

MARS® v2025.0 User Manual

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1 Product Overview

1.1 Product Description

Introduction and Product Description

Merrick Advanced Remote Sensing (MARS®) Software

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MARS® Merrick Advanced Remote Sensing Software

The **Merrick Advanced Remote Sensing (MARS®)** software suite is developed and sold by the Geomatics division of Merrick & Company, a full-service engineering firm headquartered in Greenwood Village, Colorado, USA. MARS® is a production-grade, 64-bit, multi-threaded Windows application designed to manage, visualize, process, and analyze LiDAR data. Boasting powerful visualization capabilities and unparalleled performance, MARS® is ready to support your LiDAR data processing needs! Visit our website at https://www.merrick.com/mars.

- Designed to support version 1.4 LAS files ***only*** with Point Data Record Formats 6, 7, or 8 - tools are included to up-convert the data from earlier versions, as well as to export the v1.4 data back to earlier versions if necessary. Classification descriptions conform to the latest published ***ASPRS LAS Specification 1.4 - R15*** (released July 9, 2019)
- QC Module 1222 (for Explorer QC and Production licenses only) for testing data compliance against the ***USGS Lidar Base Specification 2025 rev. A*** 1315 (June 2025), as well as all earlier versions of the specification (depending on the LAS version of the point cloud data)
- Check Point Report tool that includes 3D/Horizontal as well as Vertical accuracy testing and uses the latest ASPRS Positional Accuracy Standards (June 2024) as its basis
- Enhanced Export 658 user experience with separate and simpler interfaces for each Export Type

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- Voronoi Density Reporting 1660 tool to provide an alternative, unbiased, lidar point density testing and reporting method
- Raster QC 1651 tool (for Explorer QC and Production licenses only) to report on the format, structure, and contents of certain types of Cloud Optimized GeoTIFF raster products
- Quick Classifications 1201 64-bit tool for faster/easier batch filtering of ground, buildings, & vegetation based on LAStools algorithms (requires separate license obtained directly from ***rapidlasso GmbH***)
- One-step 64-bit Ground Filter 1036 using the 'Filter Region' tool (also based on LAStools algorithms - requires the same license mentioned above for Quick Classifications)
- Customizable Quick Access Toolbar 65 plus an optional Custom Tab 514 to gather the most-used tools and functions in one place
- Automated and manual data classification tools including batch data convert/export/extract/filter functions
- 3D coordinate transformation tools using Blue Marble Geographic's GeoCalc SDK v8.2
- WMS (Web Map Service) image support (requires an Internet connection)

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1.2 Important Notes & Disclaimers

Important Notes and Disclaimers

Merrick Advanced Remote Sensing (MARS®) Software

1. Since every version of MARS® beginning with 2018.0 requires lidar data to be in LAS v1.4, PDRF 6/7/8, all standalone tools and functions (meaning those that can be used without loading the lidar data) will test for data compliancy before any processing begins. If non-compliant data is found in the list of files to be processed, the LAS up-conversion permission window will appear. This is the same

interface that appears when loading data that does not meet the MARS® compliancy minimum requirements. For compliancy requirements and details on using this interface, see the **Add LAS Files** sub-topic in the Project/Data Preparation Tab 162 section of this help file.

2. Commercial or production use of the Quick Classifications 1201 and/or Ground Filter 1036 tools requires components of the **LAStools** software suite, as well as a separate license from ***rapidlasso GmbH***, publisher of **LAStools**. See those help topics for more details.

3. **USB key based (dongle) licensing is no longer available** due to incompatibility between a Windows 10 update released in 2019 and the Sentinel drivers required for the key to be detected. If you have a working USB key, you may continue to use it to authorize MARS®. Otherwise, please contact MARS® Technical Support 59 for alternative licensing options.

4. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** should not be used in the Description or Comments boxes of any tools or windows, nor as part of any path or file name. Unexpected results may occur.

5. *To get the most out of the MARS® software's multi-threading capabilities, please follow these general guidelines regarding the location of the data being processed. Note that testing may be necessary to achieve the best results for each particular case.*

- Network disk server
  - High speed Input/Output (I/O) – always use the maximum number of threads available
  - Medium to lower speed I/O (or unknown) - single thread (1) is recommended
- Internal drive
  - SSD (solid state drive)
    - High end level (NVMe) – always use the maximum number of threads
    - Consumer level – using multiple threads should perform better than single thread but experimenting on what maximum thread count to use for each process is encouraged
  - HDD (hard disk [spinning] drive)
    - High RPM speed (e.g., 10,000 or 15,000) – lower multi-thread count is recommended, testing is encouraged
    - Lower RPM speed (e.g., 5400 or 7200) – single thread is recommended
- External drive
  - USB 3.x (or later)
    - With a spinning drive (typical of many external drives) - single thread is recommended
    - With an SSD - using multiple threads should perform better than single thread but experimenting on what maximum thread count to use for each process is encouraged
  - USB 2.0 - single thread is strongly recommended

Note - Using temporary local disk space in the scenario where the input or output data is located on a slower disk I/O location typically speeds up throughput if the local temp space drive is a high-speed disk such as an SSD.

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6. Availability of any WMS resources included with MARS® or referenced here[1879] is subject to change without notice. None of these services is endorsed, provided, or otherwise guaranteed to be functional by Merrick & Company. Merrick neither hosts nor maintains any WMS (Web Map Service) image layer sources and is therefore not responsible for the completeness, accuracy, or frequency of updates of any WMS sources that may be accessed from within the MARS® program.

7. Some program windows and interfaces may 'hide' behind the main MARS® window, making it appear as though the interface never opened or that it closed unintentionally. This is caused by Microsoft's implementation of Visual C++ (x64), which is used in the development of MARS®.

8. Some of the screen captures in this Help File may still show the '**Add MrSID Compressed LiDAR**' button on the Project/Data Preparation Tab[162] and the '**MrSID LiDAR**' layer in the Table of Contents[67]. Beginning with MARS® version 2023.0, all support for this layer has been dropped and a new reference vector data type - ***GeoPackages*** - has been added. See the Vectors[95] layer help topic for more details.

9. Tools on the Quick Access Toolbar[65] (QAT) do not work in the Cross-Section/Profile window when it has been floated (undocked). See the MARS® Layout[61] topic for information on floating and docking program windows.

10. ***Please Note:*** Unless otherwise stated, all tools and functions that use pre-populated measurements of any kind (length, height, area, etc.) are set for projects in U.S. Feet (a.k.a. U.S. Survey Feet). Since MARS is unit-less, it is up to the user to make the necessary adjustments and conversions that are appropriate for the specific project data being used.

11. MARS® does not display, process, or analyze full waveform data (auxiliary WDP files).

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1.3 System Requirements (Operating System and Hardware)

System Requirements (Operating System and Hardware) for MARS®

Merrick Advanced Remote Sensing (MARS®) Software

Minimum System Requirements:

- Microsoft Windows 10 (64-bit), Server 2019 (64-bit), or newer 64-bit versions of Windows (both physical and virtual machines are supported). Please note that Microsoft no longer supports Windows 7, Server 2012 R2, or any operating systems released prior to these.
- Microsoft .NET Framework 4.6.2 (typically present with the above operating systems, otherwise available free from Microsoft's download site)
- Microsoft Visual C++ 2015 (or newer) Redistributable (x64) - (typically present with the above operating systems, otherwise available free from Microsoft's download site)
- 2.0 GHz 64-bit (x64) Processor, 8 GB RAM, and 10 GB available hard disk space
- SXGA (1280 x 1024) or higher-resolution graphics adapter/monitor; 256 MB of graphics memory ***(NOTE: nVidia GPU graphics adapter required for complete visual results with the QC Module)***
- Internet connection (to use WMS imagery and Google Earth[1] following)
- USB 2.0 (or later) port if using a legacy USB hardware key (dongle) for licensing – note that this licensing method is no longer offered for new licensing, and may fail to work after a Windows update
- Keyboard and 2-button mouse or compatible pointing device

Recommended System Configuration:

- Microsoft Windows 10 (64-bit), Server 2019, or newer 64-bit versions of Windows

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- 3.0 GHz or faster 64-bit (x64) multi-core Processor; Intel Core i7 or equivalent Processor preferred with at least four discrete cores (or two hyper-threaded cores)
- 12 GB or more RAM
- Solid-State hard drive (SSD) - both the system drive and any data Read/Write drives if possible
- SXGA (1280 x 1024) or higher-resolution graphics adapter/monitor; nVidia graphics adapter with at least 512 MB of graphics memory ***(NOTE: nVidia GPU graphics adapter required for complete visual results with the QC Module)***
- Internet connection (to use WMS imagery, Google Earth[1] following, and interpret some results in the QC Module)
- USB 2.0 (or later) port if using a legacy USB hardware key (dongle) for licensing – note that this licensing method is no longer offered for new licensing, and may fail to work after a Windows update
- Keyboard and 2-button mouse with scroll wheel or compatible pointing device

NOTE - 32-bit operating systems are NOT supported for **MARS® v8.0.x**, **v2017.x**, or later versions.

NOTE - Although MARS® may run in a non-Windows-based Virtual environment (such as a Windows shell within MacOS or Linux), it is not officially supported in those environments.

NOTE - In a network licensing configuration, the computer acting as license server and running Sentinel RMS License Manager can be either 64- or 32-bit Windows 10 or later (or Server versions 2016 or later) with a 2 GHz or faster processor and at least 4 GB of RAM. It can be either a physical or virtual machine.

Other Recommendations:

- Running Microsoft Windows Update is strongly recommended!
- When MARS is run on a virtual machine (VM), using a non-discrete (i.e., integrated generic) virtual display adapter will cause performance issues including program crashes.
- The graphics driver should always be updated to the latest version from the graphics card

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manufacturer's (or computer manufacturer's) website. Typically any graphics driver shipped with a computer or graphics card is not current.

- Installing as much physical RAM as possible is recommended.

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1.4 MARS® License Agreement

MARS® License Agreement

Merrick Advanced Remote Sensing (MARS®) Software

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4. Term. The term of this Agreement shall commence on the Effective Date and continue until terminated by either party in accordance with Section 10 ("Term").

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8.2 **By Licensee**. Except for claims covered by Section 8.1, Licensee agrees to indemnify and defend Merrick from and against all third party claims arising out of or related to this Agreement (including Licensee use of the Software) or by Licensee negligence, willful misconduct or breach of the terms of this Agreement.

8.3 **Indemnification Procedure**. The indemnifying party's indemnification obligations under this Section 8 are conditioned upon the indemnified party (a) giving prompt notice of the claim to the indemnifying party; (b) granting sole control of the defense or settlement of the claim or action to the indemnifying party, provided that the indemnifying party shall not enter into any settlement admitting fault on behalf of the indemnified party; and (c) providing reasonable cooperation to the indemnifying party and, at the indemnifying party's request and expense, assistance in the defense or settlement of the claim.

9. Limitation on Liability. EXCEPT FOR BREACHES OF OBLIGATIONS IN SECTIONS 5, 6, AND 8, IN NO EVENT SHALL EITHER PARTY BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, OR CONSEQUENTIAL DAMAGES OF ANY KIND OR NATURE WHATSOEVER, SUFFERED BY THE OTHER PARTY, INCLUDING, WITHOUT LIMITATION, LOST PROFITS, BUSINESS INTERRUPTIONS OR OTHER ECONOMIC LOSS ARISING OUT OF OR RELATED TO THIS AGREEMENT OR ANY USE

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10. Termination. This Agreement and the license granted herein may be terminated immediately upon written notice (a) by either party upon the material breach by the other party of any of its obligations under this Agreement, which breach has not been cured within thirty (30) days after the breaching party has received notice thereof, or (b) by Merrick if Licensee has violated Sections 1, 5, or 6 of the Agreement or if Licensee is past due on any payment of the fees under this Agreement for more than 60 days. Upon termination Licensee shall promptly return the Software to Merrick. This Agreement will terminate automatically if all or a substantial portion of the assets of the Licensee are transferred to an assignee for the benefit of creditors, to a receiver or to a trustee in bankruptcy, a proceeding is commenced by or against the Licensee for relief under bankruptcy or similar laws and such proceeding is not dismissed within sixty (60) days, or the Licensee is adjudged bankrupt. Upon termination of this Agreement, any applicable fees owed by Licensee through the date of termination shall become due and payable, and Licensee shall immediately cease using the Software and Services. Each party shall promptly return to the other all Confidential Information of the other party that it may have in its possession or control. Notwithstanding the termination of this Agreement for any reason, the rights and duties of the parties under Sections 1.3, 5, 6, 8, 9, 10, and 11 of this Agreement shall survive such termination and remain in full force and effect.

11. General Terms.

11.1 **Force Majeure.** If the performance of any obligation under this Agreement, except the making of payments, is prevented or interfered with by a Force Majeure (any act or condition whatsoever beyond the reasonable control of and not occasioned by the fault or negligence of the affected party), the party so affected shall be excused from such performance to the extent of such prevention or interference.

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11.2 **Export Control**. The Software and deliverables from the Services may be subject to United States export control regulations. Licensee shall obtain at Licensee expense all necessary licenses, permits and regulatory approvals required by any and all governmental authorities and agencies having jurisdiction over the export and re-export of software and technical data in accordance with all applicable regulations of the Office of Export Administration of the U.S. Department of Commerce and the U.S. Treasury Department Office of Foreign Asset Control.

11.3 **Dispute Resolution**. Any unresolved disputes between the parties relating to or arising from this Agreement shall be settled by arbitration in accordance with the Commercial Arbitration Rules of the American Arbitration Association (the "AAA Rules") before a single neutral and competent arbitrator selected in accordance with the AAA Rules. Such arbitration shall be held in Denver, Colorado and conducted in the English language. The cost and expense of arbitration shall be shared equally by the parties to the arbitration, regardless of which party or parties prevail. The parties agree that any breach of a party's confidentiality obligations and the license grant and restrictions set forth in this Agreement will result in irreparable injury to the other party for which there is no adequate remedy at law. Therefore, in the event of any breach or threatened breach of such obligations, the nonbreaching party will be entitled to seek equitable relief in addition to its other available legal remedies without submitting such matter to arbitration. Each party hereby irrevocably submits to the jurisdiction and venue of the state and federal courts located in Denver, Colorado for any action seeking injunctive relief hereunder.

11.4 **Miscellaneous**. The parties are independent contractors and nothing in this Agreement shall be construed to create a partnership, joint venture or employment relationship between the parties. This Agreement sets forth the entire agreement between the parties and supersedes any and all prior proposals, agreements or communications, written or oral, of the parties with respect to the subject matter hereof. This Agreement may not be modified, altered or amended, except by written instrument duly executed by both parties. No failure or delay by either party in exercising any right hereunder will operate as a waiver thereof. If either party wishes to assign or otherwise transfer this Agreement to anyone, it must obtain the other party's prior written consent (which consent shall not be unreasonably withheld), with the exception that Merrick shall be permitted to assign this Agreement without the consent of Licensee in the event of a sale, merger, or change of control of Merrick, or a purchase of substantially all the assets of Merrick related to this Agreement. This Agreement will be binding on the parties, their successors and permitted assigns. This Agreement will be construed under the laws of the State of Colorado, without regard to its conflicts of law principles. The parties hereby disclaim the application of the 1980 U.N. Convention on Contracts for the International Sale of

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Goods. The English language version of this Agreement shall be controlling in the interpretation or application of the terms of this Agreement. If any provision of this Agreement is, for any reason, held invalid or illegal in any respect by an arbitrator or a court of competent jurisdiction, such inability or illegality shall not affect the validity of this Agreement itself and there shall be substituted for the affected provision, a valid and enforceable provision which most closely approximates the intent and economic effect of the invalid provision. If such provision cannot be amended so as to be valid and enforceable, then such provision is severable from this Agreement, and the remaining provisions of this Agreement shall remain valid and enforceable.

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1.5 MARS® Functionality Matrix

MARS® Functionality Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MERRICK

MARS® Merrick Advanced Remote Sensing Software

MARS® v2025.0 Functionality Matrix

Product Feature	MARS® FreeView	MARS® Explorer Evaluation	MARS® Explorer	MARS® Explorer QC	MARS® Production
Software List Price (US Dollars)	Free*	Free for 30 days*	See current price sheet *	See current price sheet *	See current price sheet *
Project Management 26	X	X[1]	X	X	X
Data Navigation 28	X	X	X	X	X
Data Visualization 29	X	X	X	X	X
Data Generation 32		X	X	X	X
Data Export/ Extract 34		X[2]	X	X	X
Data Classification 37		X	X	X	X
3D Coordinate Conversion 44		X	X	X	X
Data QC 45		X	X	X	X

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Product Feature	MARS® FreeView	MARS® Explorer Evaluation	MARS® Explorer	MARS® Explorer QC	MARS® Production
Software List Price (US Dollars)	Free*	Free for 30 days*	See current price sheet *	See current price sheet *	See current price sheet *
Data Utilities 47	X	X	X	X	X
Tools 389		X	X	X	X
QC Module 52				X	X
Breaklines Tab 54					X

Notes:

* ***MARS® is sold, and technical support is offered, only to users in the U.S. and Canada.***

[1] ***MARS® Explorer Evaluation*** *enforces a 1 GB total LAS file size limit.*

[2] ***MARS® Explorer Evaluation*** *does not support the Extraction functions.*

MARS® Explorer QC *and* ***MARS® Production*** *support an unlimited number of threads for all Multi-Threading operations;*
MARS® Explorer *and* ***MARS® Explorer Evaluation*** *support up to four (4) threads.*

Tools and functions that are only available with a ***Production*** *or* ***Explorer QC license****, or are not available with an* ***Evaluation*** *or* ***Academic*** *license, are noted as such in this Help File.*

All prices and specifications subject to change without notice.

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1.5.1 Project Management

Product Management Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

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Project Management Functions	Description
File Tab	*This tab contains the commands that control opening, saving, and closing projects.*
New	*Launches a new project workspace for the loading of LiDAR, imagery, and GIS data.*
Open	*Opens an existing MARS® project document workspace (*.mpd).*
Save	*Saves the current project workspace as a MARS® project document file (*.mpd).*
Save As	*Saves the current MARS® project document file (*.mpd) to a new path/file name.*
Exit	*Closes current MARS® project document file (*.mpd) and the MARS® application.*
Table of Contents Window	*The Table of Contents window allows the user to manage the raster, vector, and elevation datasets currently loaded within MARS®.*
On	*This button turns on the display of the selected dataset(s).*
Off	*This button turns off the display of the selected dataset(s).*
Remove	*This button removes the selected dataset(s) from the Table of Contents and the MARS® project document workspace.*
Shift	*This tool shifts the selected LAS dataset(s) by user-defined Easting, Northing, and/or Elevation adjustments*
Zoom To	*This button zooms to the extent of the selected dataset.*
Breaklines Window	*The Breaklines window allows the various breakline features to be toggled on/off.*

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1.5.2 Data Navigation

Data Navigation Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Data Navigation Functions	Description
Basic Navigation	
2D	*Displays data in 2D (orthographic) mode (default setting).*
3D	*Displays data in 3D (perspective) mode.*
Previous View	*Returns the LAS Map View window to the last display view.*
Next View	*Jumps ahead to the next display view after using 'Previous View.'.*
Fit to View	*Zoom to extent of dataset.*
Pan	*Allows user to pan across the dataset.*
Zoom In Window	*Allows the user to define a rectangular bounding box to zoom to.*
Zoom Out Window	*Allows the user to define a rectangular bounding box to zoom out to.*

Data Navigation Functions	Description
Zoom in 25%	*Allows the user to make a one-click zoom in.*
Zoom out 25%	*Allows the user to make a one-click zoom out.*
Jump to	
Jump to X,Y	*Centers the LAS Map View window on a user-defined X,Y coordinate.*
Jump to Tile	*Centers the LAS Map View window on a user-defined tile (plus a small buffer).*
Jump to Check Point	*Centers the LAS Map View window on a user-defined check point.*
Bookmarks	
Save	*Saves a specific data extent to the project file (*.mpd).*
Visit	*Displays a previously saved bookmark (data extent).*
Delete	*Deletes a previously saved bookmark.*

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1.5.3 Data Visualization

Data Visualization Matrix

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Data Visualization Functions	Description
Data Display	
Show Scale Bars	*Display scale bars on/off.*
Show Breakline Vertices	*This tool symbolizes the vertices of all loaded breaklines and labels each with the ID number stored in the shapefile attribute table.*
LiDAR Display	
Color by Elevation	*Displays LiDAR points rendered by elevation.*
Color by Intensity	*Displays LiDAR points rendered by intensity value.*
Color by Classification	*Displays LiDAR points rendered by classification.*
Color by Return	*Displays LiDAR points rendered by return value.*
Color by Collection Scan	*Displays LiDAR points rendered by collection scan.*
Color by Ground Color	*Displays user-defined ground class(es) by RGB values and all other points by classification.*
Color by RGB	*Displays LiDAR points rendered by RGB values.*
Color by Imagery (Fusion)	*Drapes imagery over the LiDAR points.*
Blend with Intensity	*Displays LiDAR points by intensity and allows the user to blend this with elevation, classification, collection scan, return, user data, or Z Delta data.*
Color by CIR	Displays PDRF 8 LiDAR points that have NIR values in a pseudo 4-band 'image.'
Color by Hillshade	*This tool will color an elevation float grid by hillshade on the fly. This tool is only available when a float grid has been loaded into MARS® and can be*

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1.5.4 Data Generation

Data Generation Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Data Generation Functions	*Description*
Topographic Production Tools	
Options	*Allows the user to define the virtual contour parameters from the 'Contour Options' dialog.*
Area to Display	*Allows the user to define an area for virtual contour generation.*
Clear Display	*Allows the user to delete all (virtual) contours.*
Toggle On/Off	*Toggles virtual contours on/off for the LAS Map View window extent.*
DEM (Grid) Production Tools	
Options	*Allows the user to define the gridding parameters.*
Build Elevation	*Allows the user to create a virtual elevation grid.*
Build Intensity	*Allows the user to create a virtual intensity grid.*

Data Generation Functions	Description
Smooth Data	*Applies a smoothing algorithm to the gridded surface.*
Build Normals	*Allows the user to generate 'Normal' vectors for each cell.*
Clear Display	*Clears any grid from the data view.*
Profile Line Tools	
Save Profile Line to 3D Shapefile	*Allows the user to generate a 3D shapefile from a Combined Profile line in the cross-section/profile window.*
Advanced Centerline/Profiler Tools	
Draw 2D Centerline	*Allows the user to draw a 2D centerline with the loaded LiDAR data as a reference.*
Delete 2D Feature	*Allows the user to delete one or more drawn line or polygon features before saving to a shapefile.*
Save 2D Shapefile	*Allows the user to save the centerlines, polygons, and/or points created in the project to a 2D shapefile(s).*
Advanced Profiler	*This tool will create several profile lines along a centerline at an interval specified by the user.*
Polygon Creation Tools	
Draw 2D Polygon	*Allows the user to draw a 2D polygon with the loaded LiDAR data as a reference.*
Point Creation Tools	

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Data Generation Functions	Description
Draw 2D Point	*Allows the user to draw 2D points with the loaded LiDAR data as a reference.*
Tile Scheme Tools	
Create Tile Scheme	*Allows the user to create a tile scheme for use within a MARS® project document.*
Populate Statistics on Tile Scheme	*Generates statistics about LiDAR data based on the loaded tile scheme.*
Viewshed	
Define Area/ Display Options	*These tools allows the user to generate LAS viewshed grid files from the user-defined viewshed parameters. Output viewshed grid files are rendered green for visible areas and red for invisible areas of the calculated viewshed.*

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1.5.5 Data Export/Extract



MARS® v2025.0 Functionality Matrix

Data Export/ Extract Functions	Description
Data Export	*The MARS® export module allows the user to export data as a single file, based on an irregular shapefile, MBR, tile scheme shapefile, or as individual collection scans (LAS).*
	3D Image
	Contours - Shapefile
	Flightline Separation - JPEG 2000
	Flightline Separation - Tiled GeoTIFF
	Grid - Cloud Optimized GeoTIFF DEM
	Grid - Cloud Optimized GeoTIFF Intensity
	Grid - ENVI (Elevation)
	Grid - ENVI (Elevation + Classification)
	Esri ASCII Grid
	Grid - Float Grid
	Grid - IMG
	Grid - LAS
	Grid - LiDAR Raster JPEG 2000
	Grid - TIFF
	Hillshade - JPEG 2000
	LAS
	LiDAR Point Density - Float Grid
	LiDAR Spatial Distribution Verification Grid - JPEG 2000

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Data Export/ Extract Functions	Description
	PLS-CADD Code - ASCII
	PLS-CADD Code - LAS
	Shapefile
	Text Files (ASCII)
	USGS Swath Separation Image - Tiled GeoTIFF
Data Extraction	
Area by Slope	*This Extraction tool is designed to analyze the slope of the ground in any particular area. This tool may be used to determine areas meeting specific slope criteria and output polygons to a 3D shapefile. Uses include well pad sites, landing zones, and other land base applications that need to determine most logical site given user specified criteria.*
Building Polygons	*This Extraction tool is designed to place polygons around a specified class. The difference between this tool and the class polygons tool (below) is that the building tool takes into account the class and the elevation of the points, whereas the class polygon tool is only concerned with the class of the points in the extraction. This tool may be used to determine areas meeting specific criteria and output user-defined polygons to a 3D shapefile.*
Canopy Density	*This Extraction tool is designed to analyze canopy points above the ground and provide a display of the density of a vertical column. The tool does this by counting the number of returns within a user-defined voxel. The results can be used to characterize canopy density and*

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Data Export/ Extract Functions	Description
	other meaningful quantitative vegetation metrics.
Class Polygons	*This Extraction tool is designed to place polygons around any specific class in any particular area. The difference between the building polygons tool (above) and this tool is that the building tool takes into account the class and the elevation of the points, whereas the class polygon tool is only concerned with the class of the points in the extraction. This tool may be used to determine areas meeting specific class criteria and output polygons to a 3D shapefile. Uses include placing polygons around tree canopies, determining low-confidence areas, and even using return value to eliminate edge matching requirements in ortho procedures.*
Extraction Options	*This tool allows the user to set various parameters for the four (4) Data Extraction tools.*

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1.5.6 Data Classification

Data Classification Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Data Classification Functions	Description
Manual Editing	
Edit Digitized Polygon (2D)	*This tool is used to reclassify LiDAR points within a user-defined polygonal area.*
Edit Selected Polygons (2D)	*This tool is used to reclassify LiDAR points within one or more pre-selected polygons (see 'Select Polygons').*
Fast Massive Reclass	*This tool allows user-digitized polygons to be saved on-the-fly, and improves reclassification performance for large areas for both digitized and selected polygons.*
Select Polygons	*This tool allows the selection of one or more loaded polygons for the 'Edit Selected Polygons' tool to process.*
Edit Paint Brush (Small, Medium, Large)	*This tool is used to select the LiDAR points to reclassify with three (3) different sizes of the edit paint brush.*
Edit Line String (Above, Below)	*This tool is used to reclassify LiDAR points with two (2) different line string editors (only functions in Cross-Section/Profile window).*
Edit Scrape (Above, Below)	*This tool is used to reclassify LiDAR points with two(2) different line scrape editors (only functions in Cross-Section/Profile window).*
Filter Region	*This tool allows the user to define a rectangular region for filtering.*
Filtering Options	*This tool allows the user to set various parameters for each of the filters.*
Filter Digitized Polygon	*This tool allows the user to define a polygonal area for filtering.*
Filter Selected	*This tool is used to filter LiDAR points*

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Data Classification Functions	Description
Polygons	*within a pre-existing polygonal shapefile (*.shp).*
Undo	*Steps back in manual reclassification process.*
Redo	*Steps forward in manual reclassification process.*
Save cached points to disk	*Commits any edits made in RAM to disk. (currently disabled, see Options Tab 519)*
Batch Processing	*This function allows the user to batch process a LiDAR dataset using a macro script or discrete filter/extraction tool.*
Quick Classifications	*This tool allows the user to batch process ground (and, optionally, vegetation and buildings) within the currently selected tiles. Use of this filter requires a separate license that can be purchased directly from rapidlasso GmbH (https://rapidlasso.de/pricing).*
Batch Process Tiles	*This tool allows the user to filter/extract the LiDAR points within the currently selected tiles.*
Script Testing (Debugging)	*These tools allow the user to step through batch scripts to support iterative script testing and modifications.*
Batch Script Test	*This tool allows the user to define a rectangular region for script testing with the loaded macro script.*
Script Step	*This tool allows the user to step through each filter of a loaded macro script.*
Script Undo	*This tool rolls back the actions of the last step within the macro script.*

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Data Classification Functions	Description
Script Go	*This tool allows the user to proceed through the entire macro script.*
Script Stop	*This tool will stop the current script testing process while in step mode.*
Script Restart	*This tool will restart the current script testing process.*
Script Edit	*This tool will launch the edit dialog window for modifications to the current macro script.*
Filter Algorithms	
Building	*The Building filter identifies buildings by looking at voids in the ground data and analyzing the characteristics (planes, height, area, etc.) of the non-ground points in these areas.*
Change Bit Flags	*The Change Bit Flags filter allows several of the bit flags for LAS v1.4 data to be modified (from set to cleared or cleared to set), with an option to reclassify the modified points.*
Consistent Return	*The Consistent Return filter reclassifies LiDAR points based on their return value. A point is reclassified if its return value and the return values of all nearby source points match the given return value requirement.*
Ditch and Berm	*The Ditch and Berm filter classifies point to ground that may have been incorrectly classified during automated bare earth extraction routines.*
Elevation	*The Elevation filter reclassifies LiDAR points based on their absolute elevation (Z) value.*
ENVI Reclass	*The ENVI Reclass filter reclassifies LiDAR points based on an ENVI*

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Data Classification Functions	Description
	classification dataset.
Extreme High	*The Extreme High filter is intended to reclassify LiDAR points that have a uniquely different and high elevation.*
Extreme Low	*The Extreme Low filter is intended to reclassify LiDAR points that have a uniquely different and low elevation.*
Ground	*The Ground filter is a one-step tool that uses the LAStools algorithms to classify ground. Use of this filter requires a separate license that can be purchased directly from rapidlasso GmbH (https://rapidlasso.com/pricing).*
Ground Distance	*The Ground Distance filter reclassifies LiDAR points when they are within a specified ground distance of a point in the reference classification set.*
Height from Surface	*The Height From Surface filter reclassifies LiDAR points that are a specified elevation above or below a surface.*
Intensity	*This filter reclassifies LiDAR points based on the value of the intensity attribute.*
Isolated Point	*The Isolated Point filter reclasses points when there is no other point of a reference class within a user-defined spherical radius (X, Y, and Z axes)*
Max Grid	*The Max Grid filter finds the highest point of each grid cell that matches the source classification set. The filter reclassifies the maximum elevation point (one per grid cell) to the target classification.*
Median Grid	*The Median Grid filter finds the median elevation point of each grid cell that*

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Data Classification Functions	Description
	matches the source classification set. The filter reclassifies the median elevation point (one per grid cell) to the target classification.
Min Grid	*The Min Grid filter finds the lowest point of each grid cell that matches the source classification set. The filter reclassifies the minimum elevation point (one per grid cell) to the target classification.*
Model Key-point	*The Model Key-point filter creates a thinned dataset from ground (surface) points by searching for the highest and lowest points within a specified elevation tolerance in a user-defined area.*
Percolate	*The Percolate filter reclassifies LiDAR points in the source classification set that are relatively low without exceeding limits on the steepness of a surface made from the target classification.*
Plane Analysis	*The Plane Analysis filter reclassifies groupings of LiDAR points that form flat, planar surfaces.*
Reclassify	*The Reclassify filter reclassifies all LiDAR points from the source classification to the target classification.*
Return	*The Return filter reclassifies LiDAR points based upon the specified return value requirement.*
RGBNI Value	*The RGBNI Value filter reclassifies LiDAR points based on their color values (and, optionally, Intensity values) or the color values of a co-located imagery file.*
Scan Angle	*The Scan Angle Filter is made*

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Data Classification Functions	Description
	specifically for use with the 'Convert SBET to 3D Shapefile' tool. The Scan Angle filter uses an SBET file which has been converted into a 3D shapefile to reclassify certain sets of points.
Slope	*The Slope filter reclassifies source LiDAR points to a specified target class based on them falling within a user-definable range of minimum and maximum angles for the slope they occupy.*
Smart Clip	*The Smart Clip Filter will reclass points at varying angles of the Field of View while ensuring full coverage.*
Smooth Grid	*The Smooth Grid Filter builds a grid surface from the points of the source classification. LiDAR points in the source classification set are compared to this grid surface and reclassified to the target classification, if they meet the elevation difference requirements as specified by the min_diff and max_diff parameters.*
Smooth Max Grid	*The Smooth Max Grid filter builds a grid surface from the maximum elevation points of the source classification set. LiDAR points in the source classification set are compared to this grid surface and reclassified to the target classification if they meet the elevation difference requirements as specified by the min_diff and max_diff parameters.*
Smooth Min Grid	*The Smooth Min Grid filter builds a grid surface from the minimum elevation points of the source classification set. LiDAR points in the source classification set are compared to this grid surface and reclassified to the target classification if they meet the*

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Data Classification Functions	Description
	elevation difference requirements as specified by the min_diff and max_diff parameters.
Timestamp	*The Timestamp filter reclassifies LiDAR points based upon the timestamp attribute value.*
XY Distance	*The XY Distance filter reclassifies LiDAR points that are within a specific horizontal distance of a point in the reference classification set.*
XYZ Distance	*The XY Distance filter reclassifies LiDAR points that are within a specific spherical distance of a point in the reference classification set.*
Editing by Location	
LiDAR Spatial Reclass	*The LiDAR Spatial Reclass tool provides two (2) basic functions: 1.) To reclass the interior of breakline polygons contained in a shapefile and 2.) To reclass a buffer around breakline polylines contained in a shapefile.*

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1.5.7 3D Coordinate Conversion

3D Coordinate Conversion Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

3D Coordinate Transformation Functions	Description
GeoCalc	*This tool allows the user to transform LAS data to different horizontal coordinate systems and/ or horizontal and vertical datums.*
GeoEdit	*This tool allows the user to define custom coordinate systems, horizontal datums, and vertical datums.*

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1.5.8 Data QC

Data QC Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Data QC Functions	Description
Check Point Report	*This tool compares the accuracy of the remotely collected data with known points on the ground, which can help uncover data integrity issues within the dataset.*
View Error Thematically	*Displays the Z error thematically from the Check Point Report. Red represents negative error and green represents positive error.*
Cross-Section/ Profile Analysis	*The cross-section/profile tool can be used to evaluate LiDAR data for calibration (collection scan, mission alignment).*
Contour by Collection Scan Analysis	*This tool generates contour lines for each overlapping collection scan, which can help determine the overall accuracy of the collection scans in relation to each other.*
Color by Z Delta (∆)	*This tool will color the LiDAR points by the elevation difference in overlapping collection scans.*
Color by Collection Scan Separation	*This tool is useful for rapidly assessing the consistency of the LiDAR dataset's elevation and is highly useful in boresighting.*
Swipe Raster Over LiDAR Tool	*This tool allows the user to move imagery over LiDAR data for rapid viewing of alignment between LiDAR and imagery.*
Coverage Tracking Tools	*These tools create a polygon shapefile noting where the user has been in the project.*

***NOTE: Tools shown in Blue are available only with a Production license.**

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1.5.9 Data Utilities

Data Utilities Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Data Utilities Functions	Description
Measure	*Allows the user to measure between two points.*
Inspect	*Displays the LiDAR point, check point, virtual contour, or shapefile feature attributes.*
Inspect RGB(N)	*Displays the red, green, blue, and near infrared (if present) values from a pixel of imagery.*
Pick Tiles	*This tool is used to select a single tile or multiple tiles for LAS file loading, data export, or batch script processing.*
Hyperlink	*This tool allows the user to click on a point from a previously-loaded EO (Exterior Orientation) text file and view the corresponding still imagery.*
Play Video	*This tool allows playback of video data collected during data acquisition by clicking on a location in a pre-loaded point shapefile.*
Statistics by Area	*This tool allows for a quick LAS statistics display for user-*

Data Utilities Functions	Description
	defined areas.
Volumetrics	*This tool allows for cut/fill analysis comparing two surfaces, a surface to a known base elevation, or a surface to a draped/3D polygon.*
Miscellaneous Options	
Viewing	*Allows the user to invert the directional function of the mouse's scroll wheel.*
Measure Tool Snapping	*Allows the user to snap to the nearest LiDAR point at both the 'from' and 'to' ends of the Measure tool vector.*
Point Size	*Allows the user to choose the pixel size of LiDAR points displayed within the LAS Map View window.*
Default Cut Area Depth	*The default cut area depth is set to 10 units and is only used with the 'Place Profile Line' tool.*
Cut Area Movement Percentage	*The forward/back percentage is set to 75% by default.*
Cross-Section/ Profile Window Orientation	*This option allows the user to tile the cross-section/profile window either horizontally or vertically.*
Cursor Location Symbol in Main View	*This option displays a white 'X' symbol in the cut area box in the LAS Map View window corresponding to the cursor location in the Cross-Section/ Profile window.*
Editing Options	*Allows the user to use 2 or 3*

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Data Utilities Functions	Description
	digit classifications when using the keyboard accelerators in editing mode.
Panning Options	*Allows the user to set the amount of the LAS map view window that is moved during any of the shortcut key pan operations.*
Check Point Report Options	
Number of Significant Figures	*Allows the user to set the number of significant digits to be used in the Check Point Report.*
Toolbar and Tab Options	
Change Button Ordering in QAT	*Allows the user to re-order buttons on the Quick Access Toolbar.*
Customization of Custom Tab	*Allows the user to create a 'Custom' tab on the ribbon with buttons and controls from the standard tabs.*

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1.5.10 Tools

Tools Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

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Tools	Description
Tools Tab	*The Tools Tab contains several data utilities that support operational end-user requirements.*
Snapshot	*This utility creates a georeferenced TIFF image file (with TFW- TIFF world file) of the display in the LAS Map View window, which is saved to a user-defined directory.*
MARS® Task Manager	*This tool allows the user to monitor and/or end multiple MARS® processes at once.*
Class to Bit Flag	*This tool sets the v1.4-required bit flags for identified class(es) of withheld or model key-points.*
Set Overlap Bit Flag	*This tool calculates overlap areas in a folder of files and sets the bit flag to 'True' for the appropriate points.*
Clear Bit Flags	*This tool allows bit flags to be cleared (set to 'False') for Synthetic, Model Key-point, Overlap, and Withheld.*
Change Bit Flags	*This tool modifies the status of several of the bit flags that can be used with LAS v1.4 data: Synthetic, Model Key-point, Withheld, and Overlap. It can optionally reclass those points whose bit flag values have been modified, and can be limited to a single collection scan.*
Withheld Point Removal	*This tool deletes specific Withheld-flagged points from LAS swaths using the following workflow: Export tiles to Collection Scans, process these to remove and renumber specific returns/ classes, export back to tiles.*
Reference Reclass	*This tool allows the user to reclassify one set of LAS files based on the classes found in another set of LAS files by using a series of user defined parameters. This tool determines which points will be reclassed based off of the LAS point's recorded **time**.*
Reference Reclass	*This tool allows the user to reclassify one set of LAS files based on the classes found in another set of LAS files by using a series of user defined*

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***NOTE: Tools shown in Blue are available only with a Production-level license.**

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1.5.11 QC Module

QC Module Test Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

***NOTE: This module requires an Explorer QC or Production license.**

QC Module functions	Purpose / Description
USGS NGP LBS - 2024 rev. A	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification 2024 rev. A from the USGS.*
USGS NGP LBS - 2023 rev. A	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification 2023 rev. A from the USGS.*
USGS NGP LBS - 2022 rev. A	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification 2022 rev. A from the USGS.*
USGS NGP LBS - 2021 rev. A	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification 2021 rev. A from the USGS.*

QC Module functions	Purpose / Description
USGS NGP LBS - 2020 rev. A	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification 2020 rev. A from the USGS.*
USGS NGP - Version 2.1	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification Version 2.1 from the USGS.*
USGS NGP - Version 1.3	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification Version 1.3 from the USGS.*
USGS NGP - Version 1.2	*This tool provides an automated method for verifying compliance of LAS v1.4 LiDAR point cloud datasets to the Lidar Base Specification Version 1.2 from the USGS.*
USGS NGP - Version 1.0	*This tool provides an automated method for verifying compliance of LAS v1.0 - LAS v1.3 LiDAR point cloud datasets to the Lidar Base Specification Version 1.0 from the USGS.*
Raster QC Tool	*This tool provides an automated method for verifying the format, structure, and contents of certain types of raster products.*
LiDAR Workflow QC - 1 LiDAR Data Checks	*This tool provides an automated method for verifying the expected data attributes, coverage, point density, and relative accuracy of a LiDAR point cloud dataset.*
LiDAR Workflow QC - 2 LiDAR Calibration Checks	*This tool provides an automated method for verifying correct LiDAR collection system function by testing the relative accuracy and channel alignment (when applicable) of a LiDAR point cloud dataset.*

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QC Module functions	Purpose / Description
Voronoi Density Reporting	This tool tests and reports on lidar point density using the Voronoi polygon method.

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1.5.12 Breaklines Tab

Breaklines Tab Matrix

Merrick Advanced Remote Sensing (MARS®) Software

MARS® v2025.0 Functionality Matrix

Breaklines Functions	Description
Breaklines Tab	
Breakline Properties	Clicking on this button will allow the user access to the 'Breakline Properties' window. With this interface, the user can change the color and description which represent any breakline, determine which features will be displayed, insert new features, rename features, and even load an existing XML template with saved features and assigned colors and codes. The user may also search for points to use in elevation calculations, delete certain breakline classifications, and change the distance between points in a segment of a breakline.
Place Breakline	This tool allows the user to place a new breakline into a MARS® project.

Breaklines Functions	Description
Delete Breakline as Selected	*This tool allows the user to delete an entire selected breakline.*
Partial Delete	*This tool allows the user to partially delete a selected area of a breakline instead of deleting the entire breakline.*
Delete by Fence	*This tool allows the user to delete breaklines by using a fence. This tool offers several different types of fencing and the ability to delete inside or outside the user defined fence.*
Reverse Breakline Direction	*This tool allows breakline direction to be identified and (optionally) reversed.*
Check Connection to Neighbors	*This tool will give the user more information concerning how a particular breakline is connected to neighboring breaklines. This tool is capable of checking for the same Z-value in two breaklines or checking to make sure that two breaklines were compiled in the same direction. It is also capable of joining two connecting breaklines to create one continuous breakline.*
Add Vertex	*This tool allows the user to add a vertex to an existing breakline.*
Move Vertex	*This tool allows the user to move a vertex in an existing breakline.*
Delete Vertex	*This tool allows the user to delete a single vertex in an existing breakline.*
Change Elevation for All Points of Breakline	*This tool is capable of changing the elevation of an entire breakline.*

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Breaklines Functions	Description
Change Elevation of Any Vertex	*The change elevation tool is capable of changing the elevation of any combination of vertices in a breakline.*
Change Elevation (Large Increment)	*The 'Change Elevation' tool is meant to work in unison with the above mentioned elevation tool and make the compilation of breaklines easier and quicker. This tool allows the user to "step" the elevation of breakline down in large increments. By default, the 'Change Elevation (Large Increment)' button lowers the elevation of an added breakline by -0.8 units.*
Change Elevation (Small Increment)	*The 'Change Elevation' tool is meant to work in unison with the above mentioned elevation tool and make the compilation of breaklines easier and quicker. This tool allows the user to "step" the elevation of breakline down in small increments. By default, the 'Change Elevation (Small Increment)' button lowers the elevation of an added breakline by -0.2 units.*
Reassess Points for Ignored Ground Classification	*This tool will reclassify points surrounding a breakline (inside a user-specified buffer zone) to a user-definable ignored ground classification.*
Drape Polylines	*This tool allows the user to select a *.dgn file or a *.shp file containing polyline breaklines and drape the breaklines in the file to the LAS data surrounding it. This tool will add a Z-value (elevation) to the breaklines in the specified file by searching the points surrounding the line for an appropriate Z-value.*

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Breaklines Functions	Description
Drape Polygons	*This tool allows the user to select a *.dgn file or a *.shp file containing polygon breaklines and drape the breaklines in the file to the LAS data surrounding it. This tool will add a Z-value (elevation) to the breaklines in the specified file by searching the points surrounding the line for an appropriate Z-value.*
Drape Selected Breaklines	*This tool allows the user to select a specific breakline and drape it to the underlying LAS data. This tool will add a Z-value (elevation) to the selected breakline by searching the points surrounding the line for an appropriate Z-value.*
Double Hydro Tool	*This tool is meant for use on river or stream breaklines. The Double Hydro Tool allows the user to reclass all points within a virtual polygon which is created between the two parallel polylines representing the river/stream banks. It also allows the user to match the Z-value or elevation of the two parallel breaklines.*
Force Double Hydro	*This tool allows the user to load a breakline shapefile and forces all breaklines down to even intervals based off of elevation information obtained during prior collection.*
Copy Parallel	*This tool allows the user to move, copy, or copy parallel to a selected breakline.*
Change Feature Code	*This tool allows the user to change the feature code of an existing breakline.*
Check for Crossing Breaklines	*This tool will search for any crossing breaklines in a project. The resulting 'Breakline Crossing' window will notify the user of the total number of breakline crossings and allow the*

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Breaklines Functions	Description
	user to pan to each instance by use of the 'Previous' or 'Next' buttons.
Place Text	*This tool allows the user to add text to the LAS Map View window.*
Form Polygon	*This tool will allow the user to create a polygon out of polylines.*
Measure Area	*This tool, only for pre-existing loaded polygon features, displays the area of a selected polygon.*
Show Breakline Vertices	*This tool symbolizes the vertices of all loaded breaklines and labels each with the ID number stored in the shapefile attribute table.*
Show Auto Pan Edge Markers	*This tool toggles the display of the Auto-pan boundary markers that indicate the area of the LAS Map View window where an auto-pan (when enabled) will occur if the cursor is moved into it.*
Reshape Feature	*This tool allows polyline and polygon breakline features to be reshaped by 'patching in' a new section of linework rather than having to move, add, or delete one vertex at a time.*
Calculate Area	*This tool allows a temporary polygon to be digitized and displays the enclosed area in acres.*
New Feature Elevation	*This text box allows the user to enter a new breakline elevation directly on the Breaklines Tab.*
Undo Breakline	*This button will undo the most recent change to any breakline. Depending on the complexity of the change and the computer's available RAM, it may be possible to undo several changes.*
Redo Breakline	*This button will redo the most recent change which was 'undone' by use of*

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Breaklines Functions	Description
	the 'Undo' button. Depending on the complexity of the change and the computer's available RAM, it may be possible to redo several 'Undo' steps.
Save Breaklines to Shapefile(s)	*This option allows the user to save the breaklines loaded into MARS® to a shapefile(s).*

*****NOTE: The Breaklines Tab tools are only functional with a Production-level license.***

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1.6 Technical Support Information

MARS® Technical Support Information

MERRICK®
MARS® Merrick Advanced Remote Sensing Software

Technical Support - General Information

Please send all written correspondence regarding the MARS® software suite to:

MARS® Software Technical Support

Merrick & Company

8051 E. Maplewood Avenue, Suite 300

Greenwood Village, CO 80111

United States

Technical Support Hours: Monday through Friday, 9:00 AM - 5:30 PM (U.S. Mountain Time Zone)

Toll Free Telephone: +1 (800) 544-1714

Email: MARSSupport@merrick.com

Web: http://www.merrick.com/MARS

Technical Support Contacts:

✓ Mark A. Stucky - MARS® Technical Support Specialist *(United States, Canada)*

Office: +1 (303) 353-3933

E-mail: mark.stucky@merrick.com

✓ Anca Dobrinescu - MARS® Technical Support *(United States, Canada)*

Office: +1 (303) 226-9851

E-mail: anca.dobrinescu@merrick.com

Social Media

Please follow Merrick & Company for the latest MARS® product announcements, feature enhancements, and user tips!

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2 General Layout

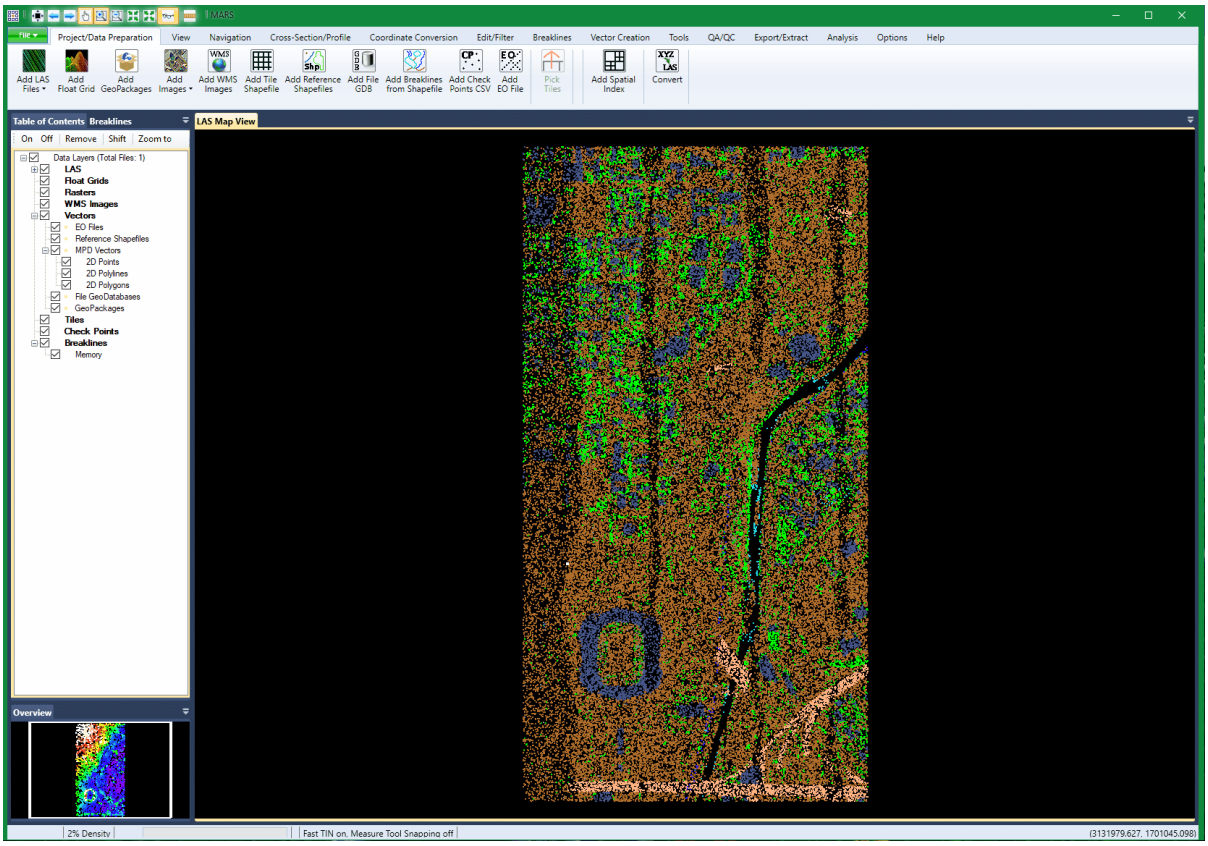
General Layout

Merrick Advanced Remote Sensing (MARS®) Software

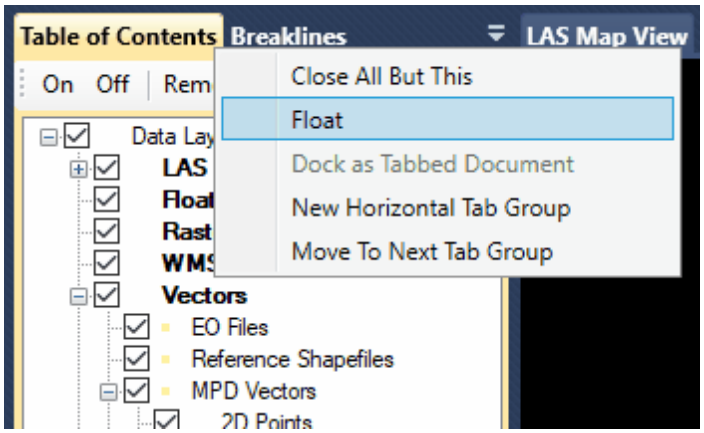
The MARS® interface consists of the following components (top-to-bottom, left-to-right): Quick Access Toolbar 65, Tabs/Ribbon 158, Table of Contents 67, Breaklines Window 142, LAS Map View Window 145, Overview Window 155, and Status Bar 158. The **Table of Contents**, **Breaklines**, and **Overview** windows can be floated (undocked) and moved to other locations including a second monitor. When in use, a Cross-Section/Profile Window 240 can share space with the LAS Map View window, or it can also be floated. The Project/Data Preparation Tab 162 is active when MARS® is first opened.

MARS® now supports drag-and-drop from Windows File Explorer for LAS files, SHP files (loaded in the Reference Shapefiles layer), CSV-format Check Points files, and supported raster formats. Files can be dropped into the LAS Map View window or the Table of Contents window.

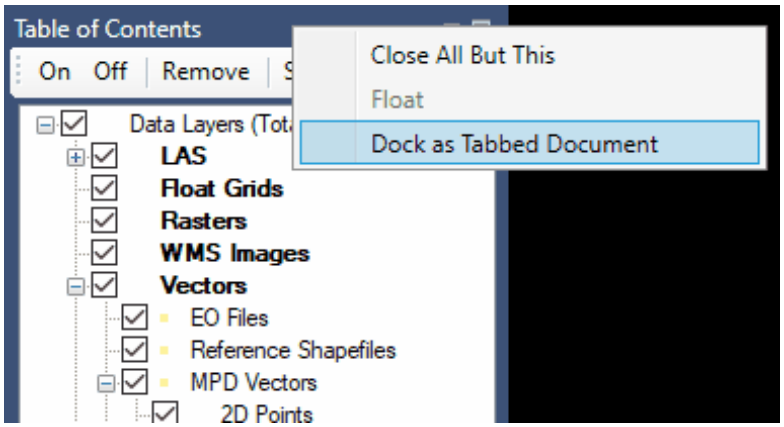
The **MARS® v2025.0** interface:



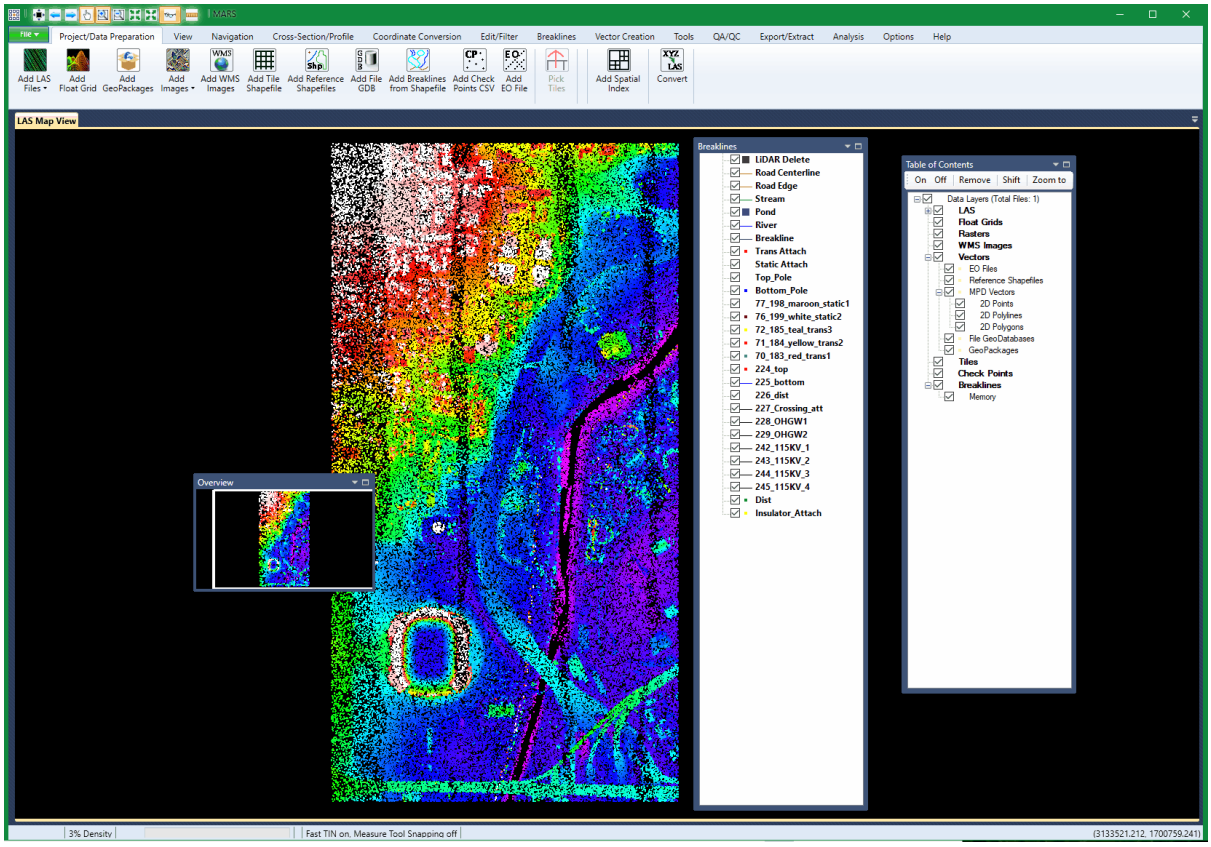
To float a window, right-click on its tab and choose 'Float'. The window may now be dragged by its title bar to a different location, including a second monitor. To return it to its docked state, right-click anywhere on the title bar and choose 'Dock as Tabbed Document'.



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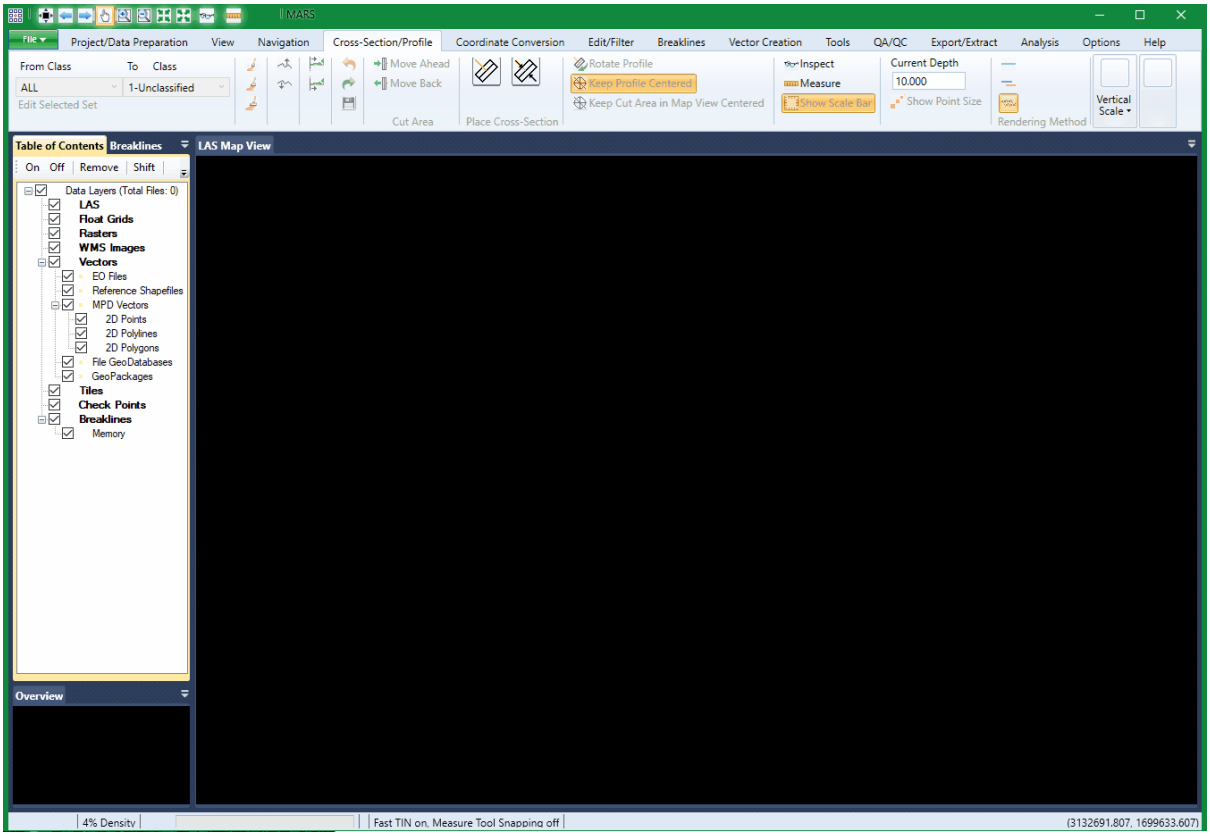
Example of windows layout when Table of Contents, Breaklines, and Overview windows are all floated:



Note that on smaller displays - especially some laptops and monitors less than 20" diagonally that have traditional 4:3 aspect ratios - the tab labels will be closer together and some tools may change their button/icon appearance. See the example below for the two tools at the far right side of the Cross-

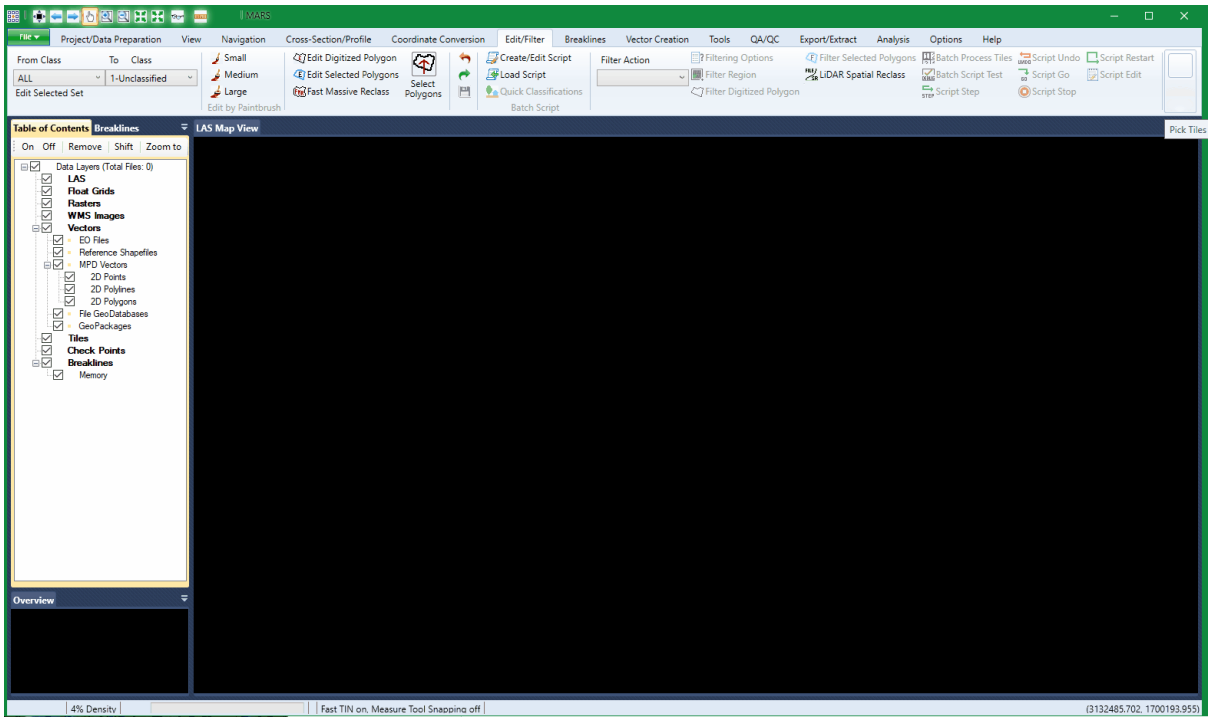
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Section/Profile tab. This is an issue with Microsoft Visual Studio and is not fixable in MARS®.



If icon and/or labeling text disappears (as in the example above), tool-tip pop-ups will be enabled when hovering over those buttons, as shown below (upper-right). Clicking an unlabeled button will present the options for that button. Always maximize the MARS® program window to allow as much space for icons as possible.

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2.1 Quick Access Toolbar

Quick Access Toolbar

Merrick Advanced Remote Sensing (MARS®) Software

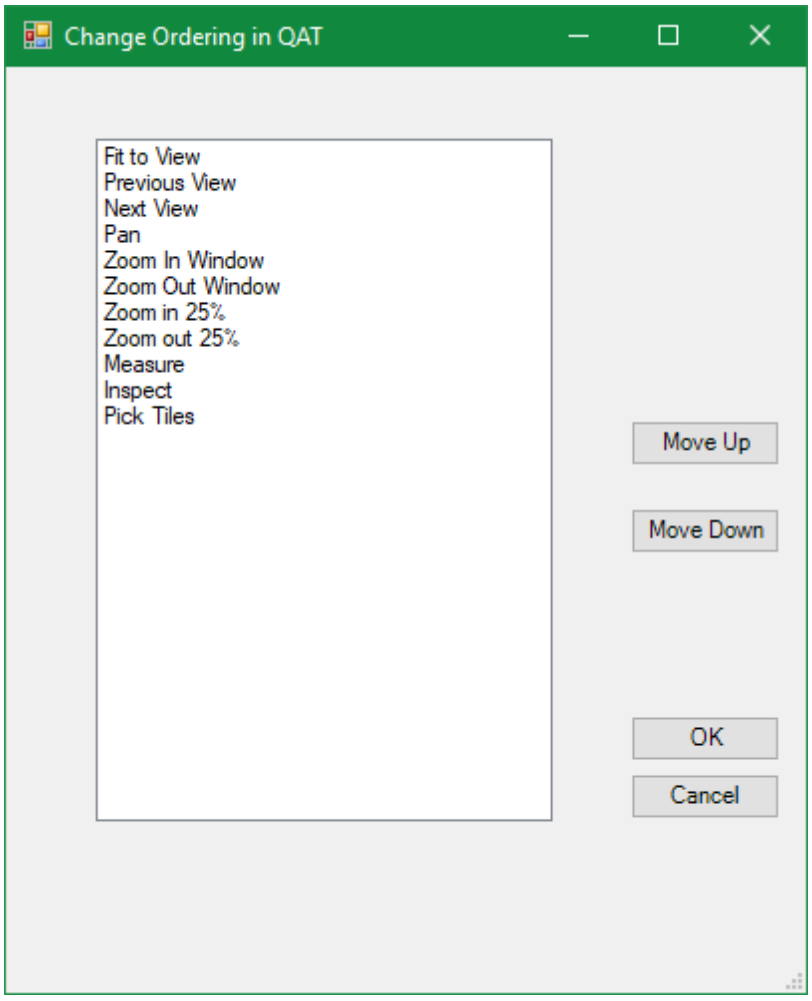
The Quick Access Toolbar:



The Quick Access Toolbar (QAT) contains commonly used tools that can be invoked without having to change tabs. When MARS® is first installed, the QAT is pre-loaded with the first eight tools from the Navigation Tab 234, the 'Inspect 943' tool, and the 'Measure 957' tool. *Most* other tools can be added - to

see if a tool is available to be added, right-click on it (in its normal tab location) and note whether 'Add to Quick Access Toolbar' is enabled. Tools that are added will initially appear at the end of the toolbar and will be immediately saved for future MARS® sessions.

To re-order the tool buttons in the QAT, click the 'Change Button Ordering in QAT' button on the Options Tab[519]. The 'Change Ordering in QAT' interface will appear, where tools may be moved up (to the left on the toolbar) or down (to the right on the toolbar) in the list of existing tools. Select the tool(s) to be re-ordered, one at a time, and click either the 'Move Up' or 'Move Down' button.



When all moves are complete, click the 'OK' button to save the positions and close the interface, or click 'Cancel' to quit without saving any changes.

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To remove a tool from the toolbar, right-click on it and choose 'Remove from Quick Access Toolbar.'

The new layout will be automatically saved for future MARS® sessions.

By default, the toolbar is located above the ribbon, but it can be moved to below the ribbon by right-clicking on any part of it and choosing 'Show Quick Access Toolbar below the Ribbon.'

Right-click and choose 'Show Quick Access Toolbar above the Ribbon' to move it back to its default location.

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2.2 Table of Contents



The 'Table of Contents' is where raster, vector, elevation datasets, and other files are managed in MARS®. The Table of Contents consists of eight (8) file type groupings - known as layers - each of which has a different functionality and contains different types of data.

➤ LAS 74 ➤ Float Grids 82 ➤ Rasters 86 ➤ WMS Images 90 ➤ Vectors 95 ➤ Tiles 121 ➤ Check Points 131 ➤ Breaklines 134

These eight layers fall under the **'Data Layers'** header which can be collapsed or expanded as needed, and which controls the visibility of all the sub-layers with a single check box. The 'Data

Layers' header has two controls available when right-clicking on it: **Projection** and **Properties**.

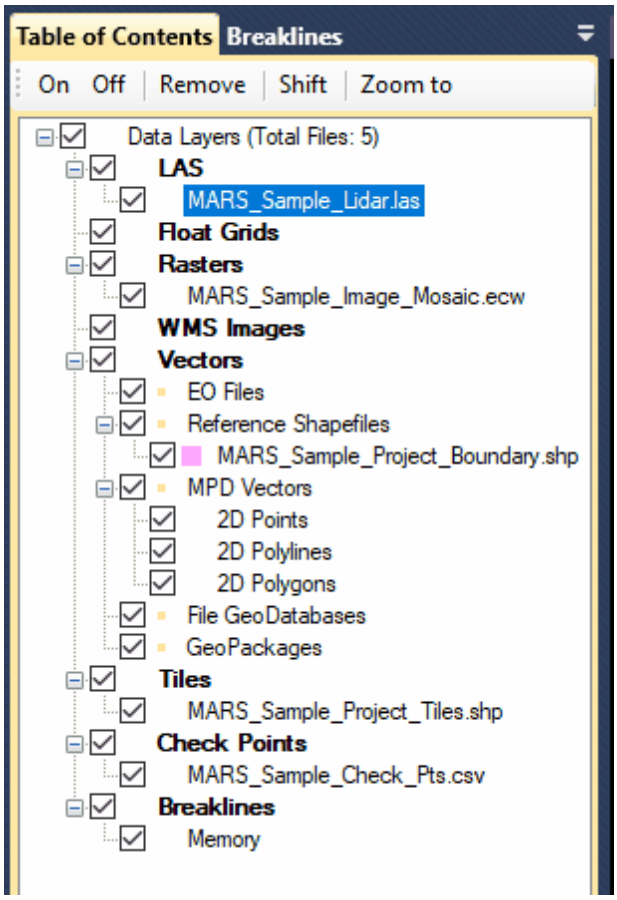
Projection - allows a coordinate reference system (CRS) to be defined for the project if the loaded data does not contain that information, or allows incorrect information to be modified so that the proper CRS is displayed for the **'Data Layers'**. *Note that modifying the CRS here does not change the actual CRS of any of the loaded data.*

Properties - displays the currently defined CRS for the loaded data, unless none exists. This information is populated from the first defined shapefile (tile or reference) or the first defined LAS file added to the Table of Contents. Defined shapefiles provide only limited CRS information, whereas an LAS file with a WKT-based CRS will fully populate the projection system information. If a defined shapefile is added first followed by a defined LAS file, the Data Layer Properties will be updated with the complete CRS information. ***NOTE that adding additional LAS files with an alternate CRS definition will NOT change what is stored in the Data Layer Properties and is not recommended in the same MARS session. MARS does not re-project data on-the-fly as it is loaded.***

MARS® supports drag-and-drop from Windows File Explorer for LAS files, SHP files (loaded in the Reference Shapefiles layer), CSV-format Check Points files, and supported raster formats. Files can be dropped into the LAS Map View window or the Table of Contents window. SHP-format (shapefile) Check Points files must be added using the 'Add Check Points Files' button on the Project/Data Preparation Tab 162 - they will be loaded as Reference Shapefiles (under the Vectors layer) if drag-and-drop is used.

Note -- The '**Vectors**' layer (expanded by default) is divided into five (5) sub-layers: EO Files, Reference Shapefiles, MPD Vectors, File GeoDatabases, and GeoPackages.

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Display colors for most reference shapefile entries and other vector types can be modified by double-clicking the display symbol between the checkbox and the entry name, or by right-clicking the entry and selecting 'Properties'.

The total number of files of all types loaded (except WMS layers and breaklines in memory) will be displayed immediately after the 'Data Layers' label at the top. The Table of Contents also offers four options at the top of the window:

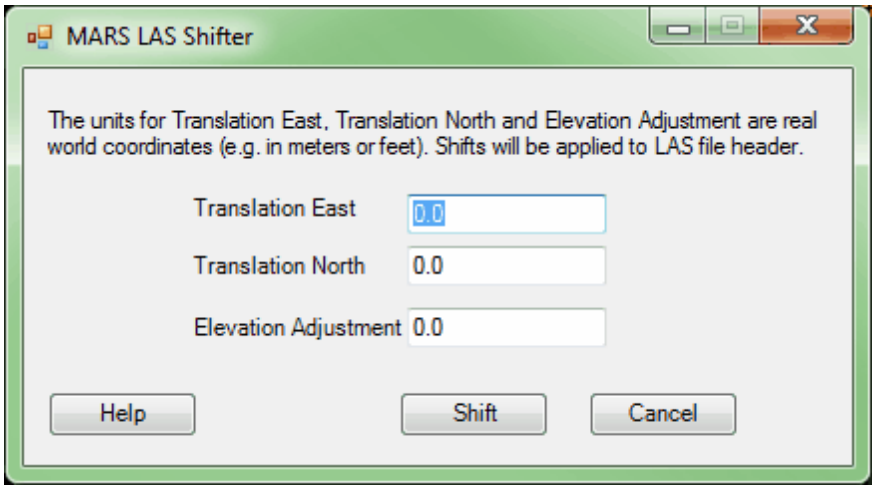
1.) On/Off: The 'On' and 'Off' buttons allow the user to turn selected file displays on or off as needed.

2.) Remove: The 'Remove' button will allow the user to remove highlighted files from MARS®. Using the **'Shift'** and **'Ctrl'** keys on the keyboard, highlight multiple files which are to be removed.

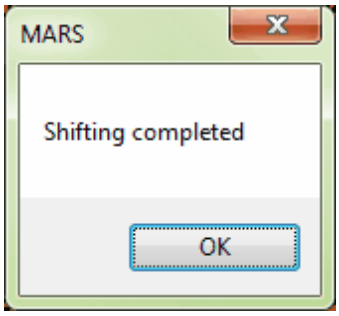
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Click the 'Remove' button and all those files chosen by the user will be removed from MARS®.

3.) Shift: The shift tool is used to shift data east (a positive shift in the Translation East text box), west (a negative shift in the Translation East text box), north (a positive shift in the Translation North text box), or south (a negative shift in the Translation North text box). The shift tool is also capable of shifting the elevation of the data by entering a positive shift value (to move data up higher) or a negative shift value (to move data down lower). In the table of contents, it is possible to select more than one LAS file at a time and apply the necessary shifts to them. Use the **'Shift'** key on the keyboard to select more than one file in a row, or use the **'Ctrl'** key on the keyboard to select several files in random order. The selected files will all have the same shifts, specified by the user in the 'MARS LAS Shifter' interface, applied to them. Shifting of LAS data produces a *.off file (one per shifted LAS file) which stores the pre-shift X, Y, and Z values read from the LAS file header. These files are created in the same folder as the LAS files that were shifted. The *.off files are used as a baseline by the 'Report LAS Shift' 570 tool to create a comma-delimited (*.csv) report that stores the total (cumulative) shift for each of the files chosen to be included in the report. **** NOTE when using the MARS LAS Shifter: If multiple shifts are applied to a single project, the effect is cumulative. Each shift is applied to the existing XYZ offset in the header.** To shift all loaded LAS files without selecting them first, use the **'XYZ Shift'** tool on the Coordinate Conversion Tab 254.



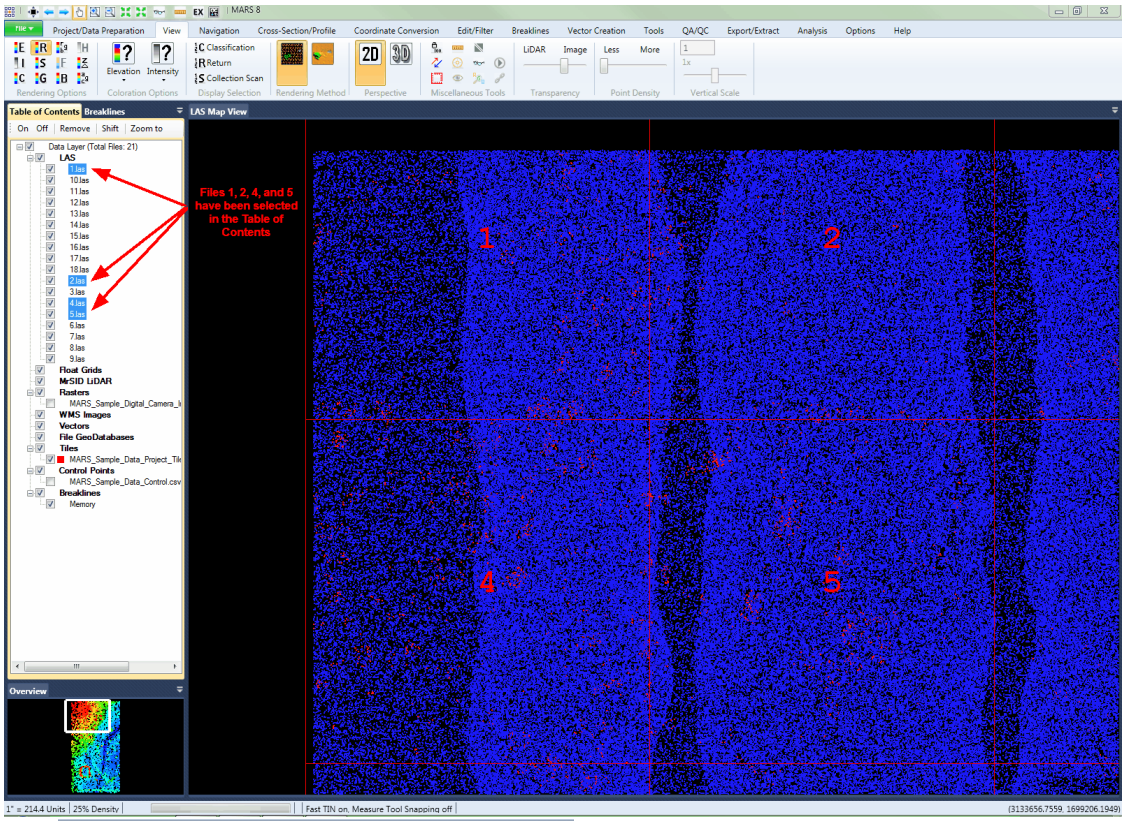
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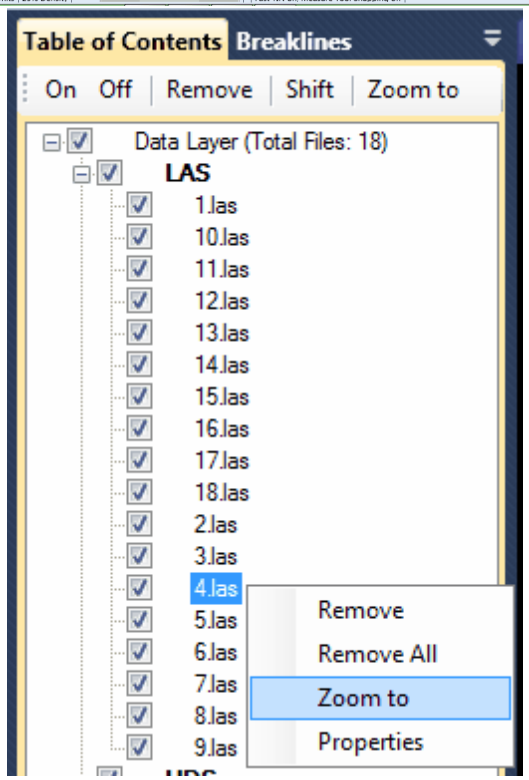


4.) Zoom To: To use this tool, data needs to be loaded into MARS®. This tool can function in two ways: it can be used to zoom to particular files inside the LAS layer, or it can be used to zoom to different layers in the Table of Contents. Select the data or layer to zoom to using the 'Shift' or 'Ctrl' keys on the keyboard to make the selections if necessary. Then click the '**Zoom to**' option at the top of the Table of Contents, and MARS® will zoom to the extent of the data or layer(s) selected. This tool will work on any dataset or file type loaded into the Table of Contents except for breaklines which have been stored to memory. It will only function in 2D (orthographic) mode and the option to '**Zoom to**' will be disabled during 3D viewing.

In the example below, the user has chosen LAS files 1, 2, 4, and 5 and clicked the 'Zoom to' button at the top of the Table of Contents. To zoom to a single LAS file, this method can be used, or the file can be right-clicked on and 'Zoom To' chosen from the context menu (below, right).

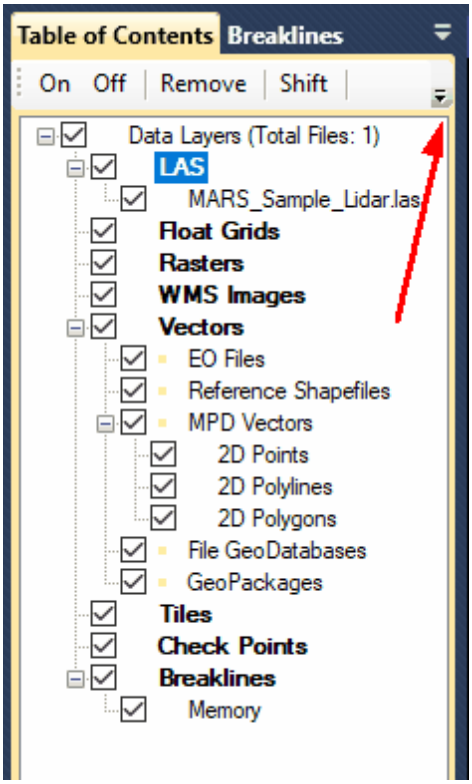
© 2000-2025 Merrick & Company

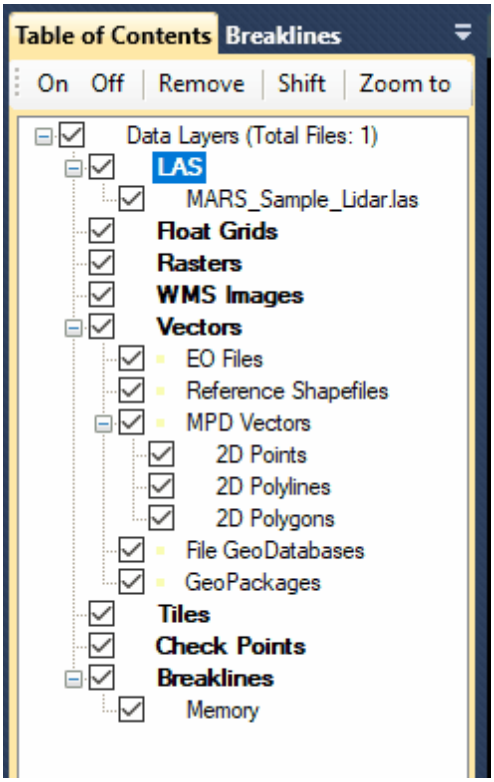




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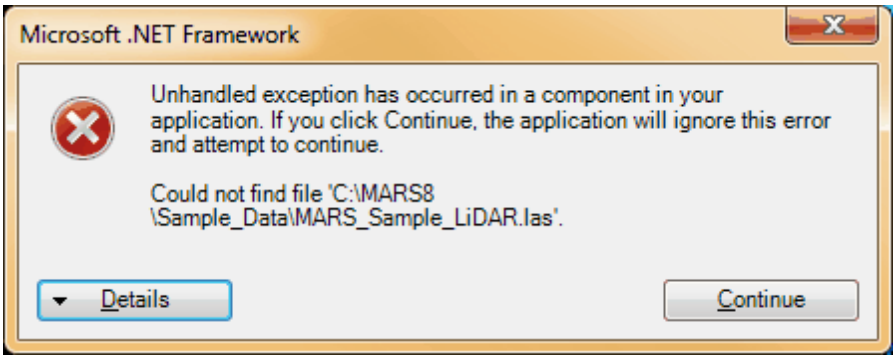
If the Table of Contents window is not set wide enough, the ‘Zoom to’ button may be hidden. Either click the drop-down arrow to the right of the 'On Off | Remove | Shift' bar to access the 'Zoom to' button, or expand the width of the Table of Contents window by dragging the right edge.

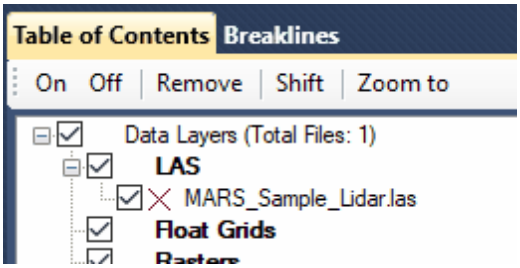




The MARS® Table of Contents will also alert the user when a loaded LAS file is no longer available for use. This scenario would occur if, for example, a file which was loaded into MARS® was deleted, moved to a different folder, or renamed while still loaded. MARS® will notify the user that the file is no longer available with the following error message. A red 'X' will also appear next to any such entries in the Table of Contents.

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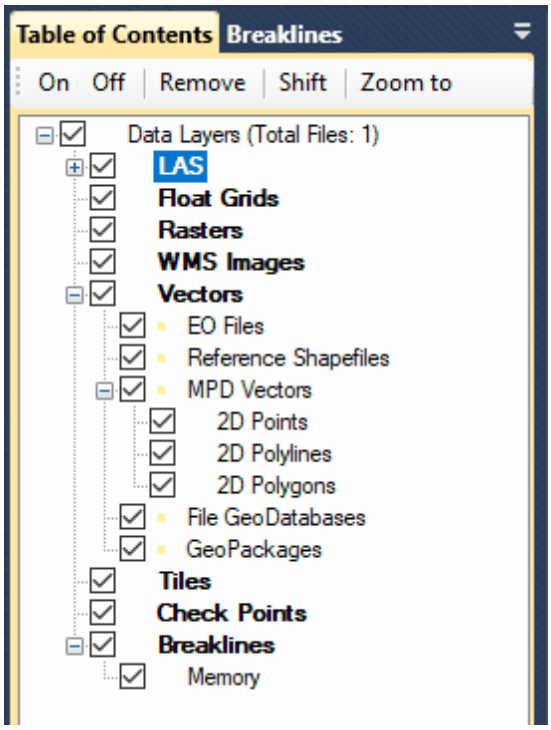


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2.2.1 LAS



➤**LAS Layer** - The 'LAS' layer shows the LAS files that are currently loaded in MARS®. It also allows the user to toggle display of files, remove files, zoom to a file, and view the properties of files. Only *.las files can be added to this layer.



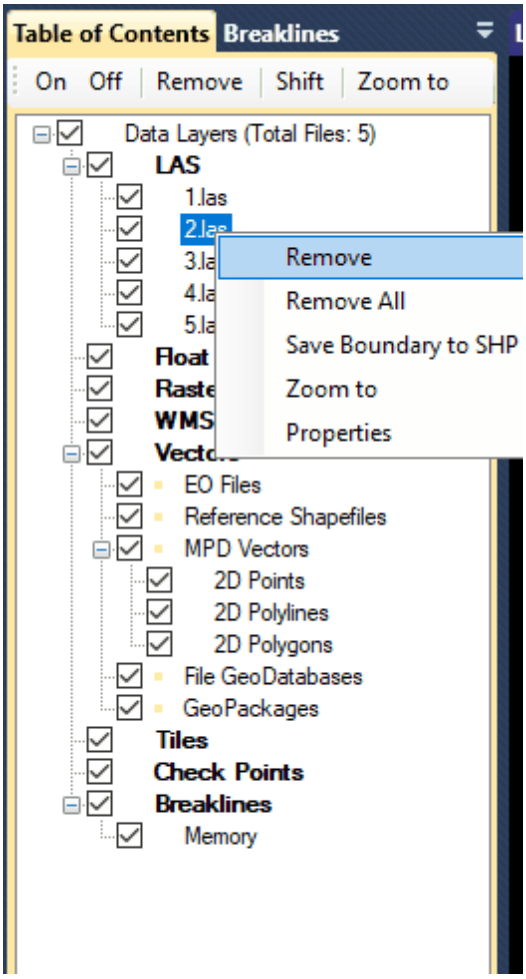
Adding LAS Files: To add an LAS file, see the 'Add LAS Files' section in the Project/Data Preparation Tab 162 topic. Note that adding files that do not meet the minimum compliancy requirements will prompt an up-conversion of those files as detailed in that same topic.

Expanding the LAS Layer: Click on the '⊞' button to expand a list of all the files loaded under the 'LAS' layer. There are three ways to turn on/off the display of the files loaded under the 'LAS' layer: 1) check/uncheck the **'LAS'** layer box, 2) check/uncheck the box next to the file(s) to be turned on/off or, 3) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'LAS'** layer box is checked to view the files loaded beneath it; if this master box is not checked 'on' the individual files will not be displayed.

Removing an LAS File: To remove a file from the LAS layer, click on the file that is to be removed to

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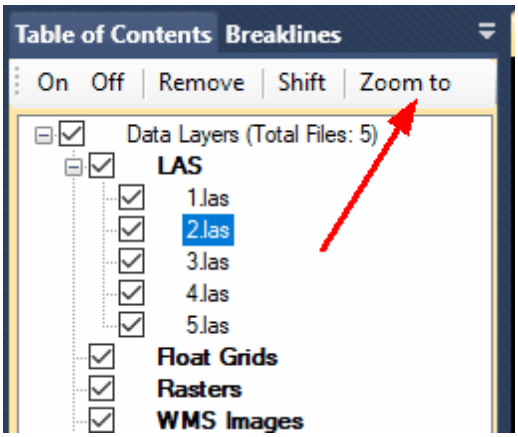
highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all LAS data, right-click and choose **'Remove All'** - all LAS data currently loaded will be unloaded. Another way to remove files from the layer is to highlight the file that needs to be removed, and click on the 'Remove' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.



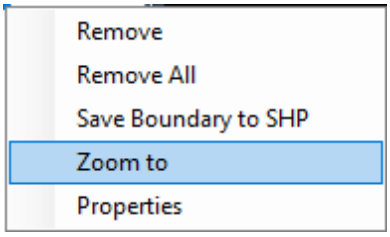
Zoom to an LAS File: There are two ways to zoom to an LAS file:

1. To zoom to a *.las file in the LAS layer, highlight the file and choose the **'Zoom to'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to highlight multiple LAS files and zoom to their combined extent.

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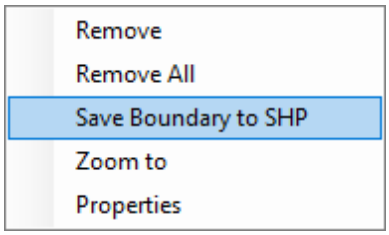


2. To zoom to a specific LAS file, highlight that file in the LAS layer and right-click. Choosing the **'Zoom to'** option will fit that particular LAS file to the LAS Map View window extent.



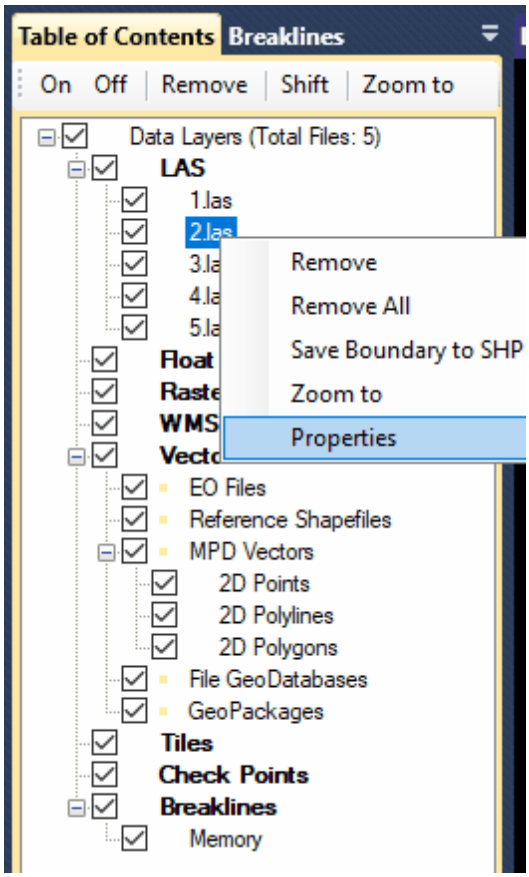
Save the Boundary of an LAS file to SHP: Whenever an LAS file is spatially indexed - e.g., by using the Add Spatial Index 907 tool, as part of Export to LAS 712 or Grid - LAS 698, when running LAS Merging 570, etc. - the XY extent is stored in the file's header. This information can be used to generate a polygon shapefile of the file's 'footprint' for analysis. Right-click on the file in the Table of Contents and choose 'Save Boundary to SHP'. The boundary shapefile will be created in the same folder where the file exists with the name 'Boundary_<*file name*>.las', and will include a PRJ file if the LAS file's Coordinate Reference System is defined.

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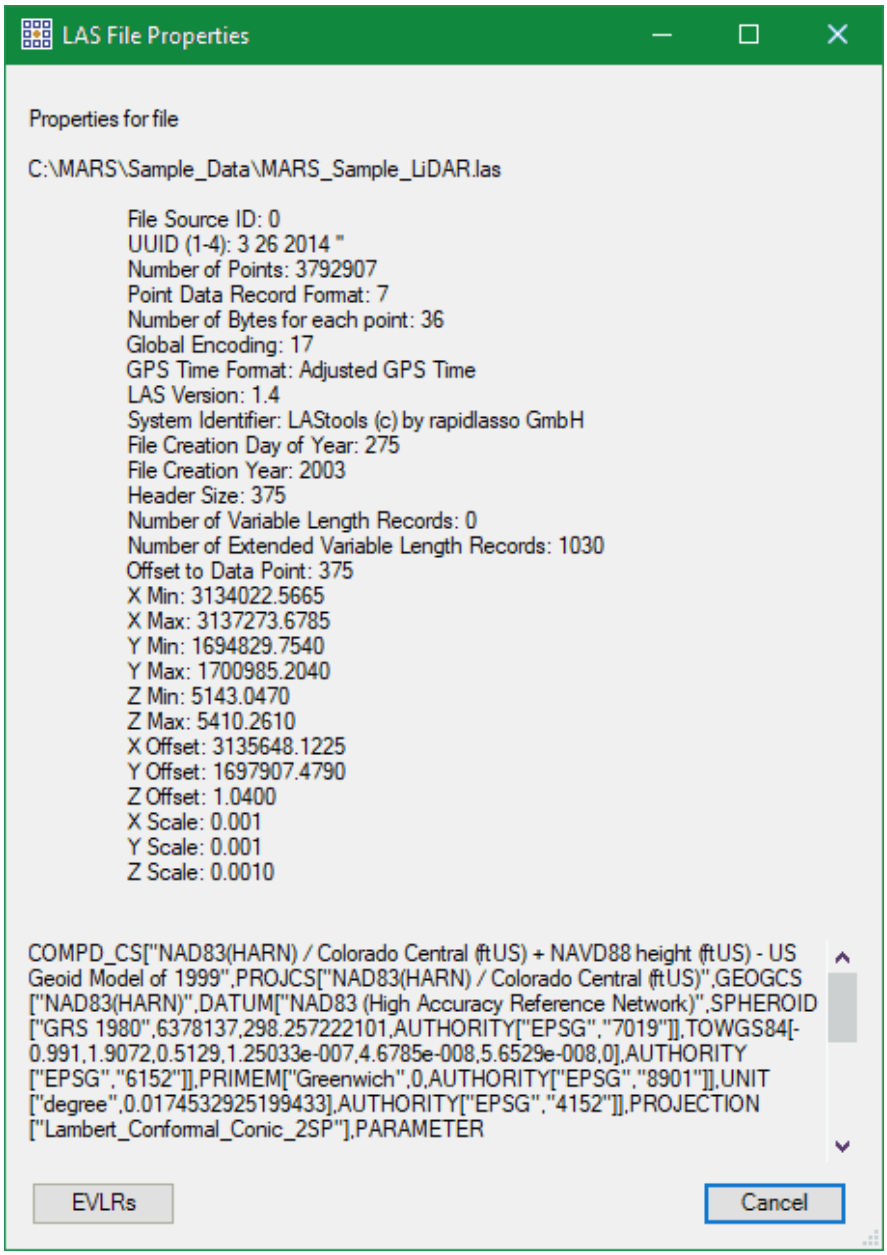


Viewing the Properties of LAS Files: To see the properties of any LAS file, first highlight (select) the file, then right-click and choose **'Properties'**. A listing of properties will be displayed for informational purposes including: the complete path and file name, File Source ID, the Number of Points, the Point Data Record Format, the Number of Bytes per point record, the GPS Time and WKT Format (Global Encoding), the LAS Version, the System Identifier, the File Creation Day (Julian Day) and Year, the Header Size, the Number of Variable Length and Extended Variable Length Records, the Offset to Data Point (the first point record), and the Min, Max, Offset, and Scale of each of the coordinates: X, Y, and Z. Coordinate reference system (CRS) data is displayed near the bottom if the file has this information defined. The 'EVLRs' button presents a scrollable list of all the Extended Variable Length Records that the file contains, showing the total record count as well as the 'user ID', 'description', 'record ID', and 'length after header' info (in that order) for each record. It is also possible to highlight, right-click, and copy data from the resulting 'LAS File Properties' window.

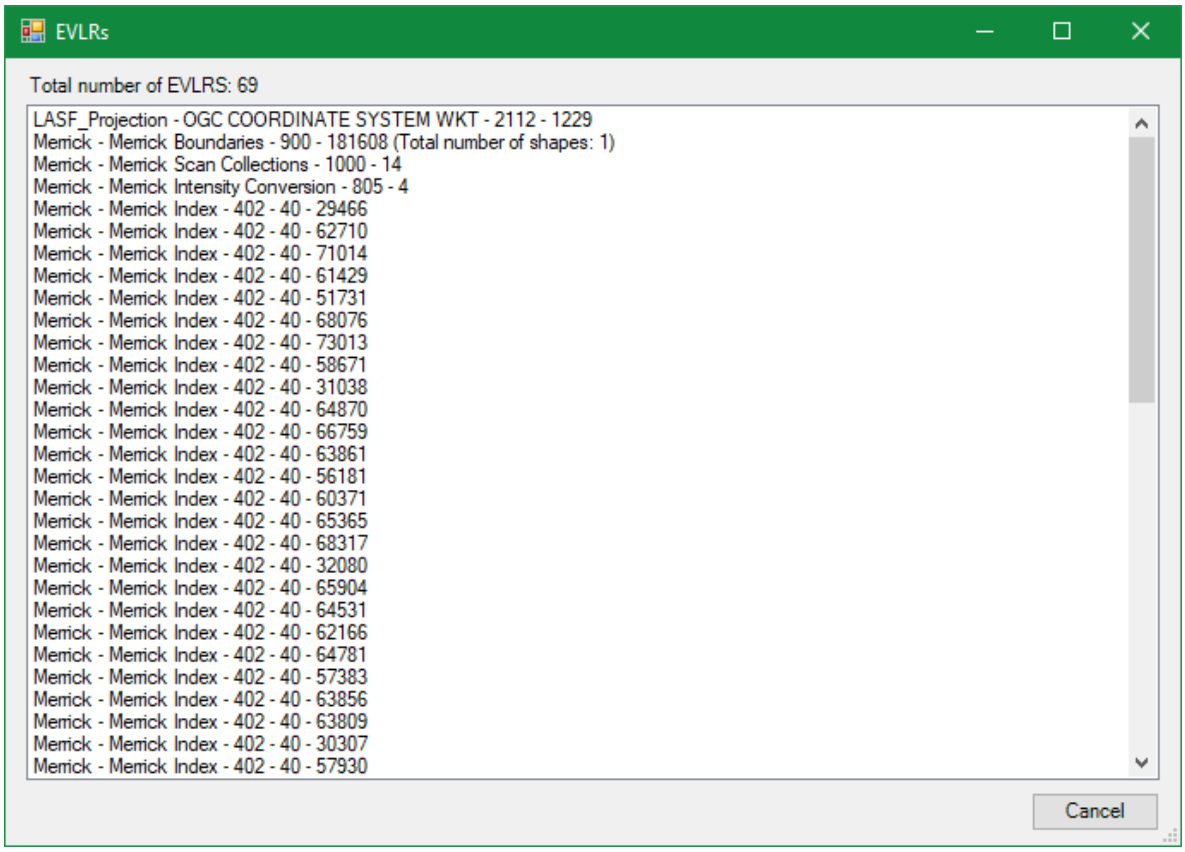
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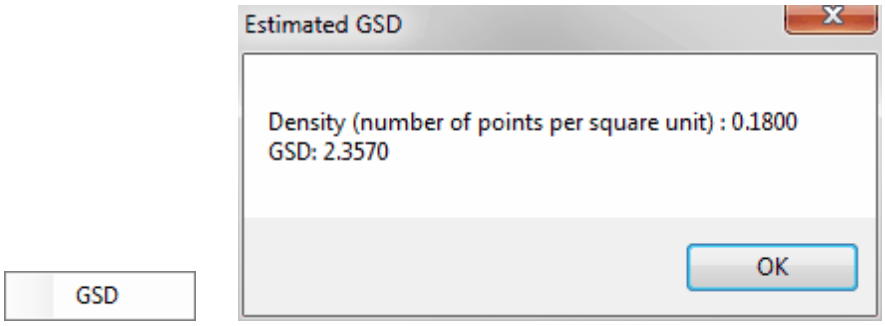
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Viewing the GSD and point density for all loaded LAS Files: To see the average GSD (ground sample distance) and average point density for all loaded LAS files, right-click on the 'LAS' layer in the Table of Contents and select 'GSD.'



The results are not an exact calculation of GSD/Density, but are based on a 20 x 20 unit sample area

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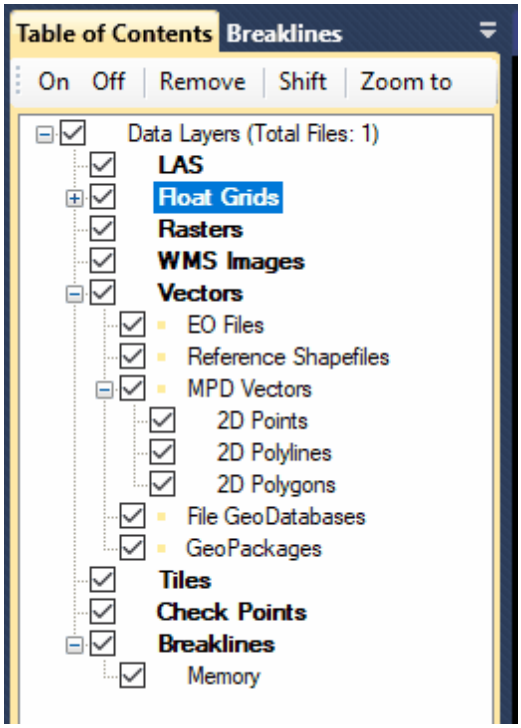
from each loaded LAS file, using all returns. If, for example, 40 LAS files are loaded, the GSD/Density values from the 40 sample areas are calculated and the median values are reported by this tool.

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2.2.2 Float Grids



➤**Float Grids Layer -** The 'Float Grids' layer shows the Float Grid files that are currently loaded in MARS®. It also allows the user to toggle display of files, remove files, zoom to a file, and view the properties of files. Only *.flt files can be added to this layer.

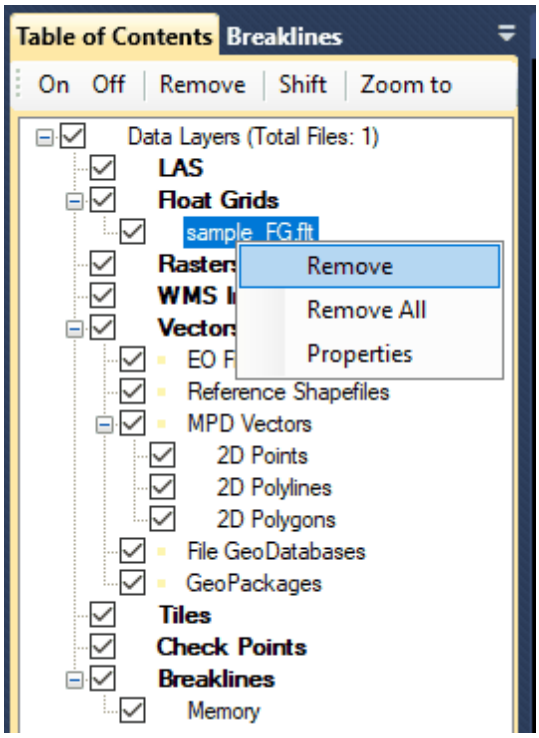


Adding Float Grid Files: To add a float grid, see the 'Add Float Grid' section in the Project/Data Preparation Tab topic.

Expanding the Float Grids Layer: Click on the '+' button to expand a list of all the files loaded under the 'Float Grids' layer. There are three ways to turn on/off the display of the files loaded under the 'Float Grids' layer: 1) check/uncheck the **'Float Grids'** layer box, 2) check/uncheck the box next to the file(s) to be turned on/off or, 3) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Float Grids'** layer box is checked to view the files loaded beneath it; if this master box is not checked 'on' the individual files will not be displayed.

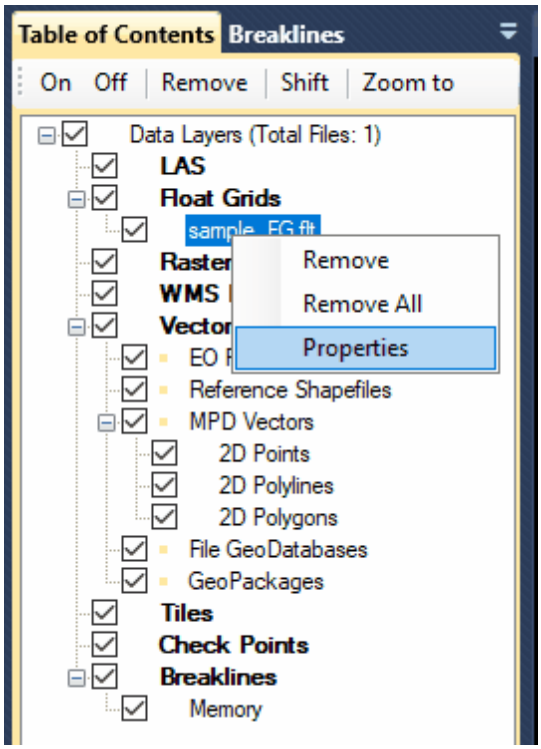
Removing a Float Grid File: To remove a file from the Float Grids layer, click on the file that is to be removed to highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all Float Grid files, right-click and choose **'Remove All'** - all Float Grid files currently loaded will be unloaded. Another way to remove files from the layer is to highlight the file that needs to be removed, and click on the 'Remove' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.

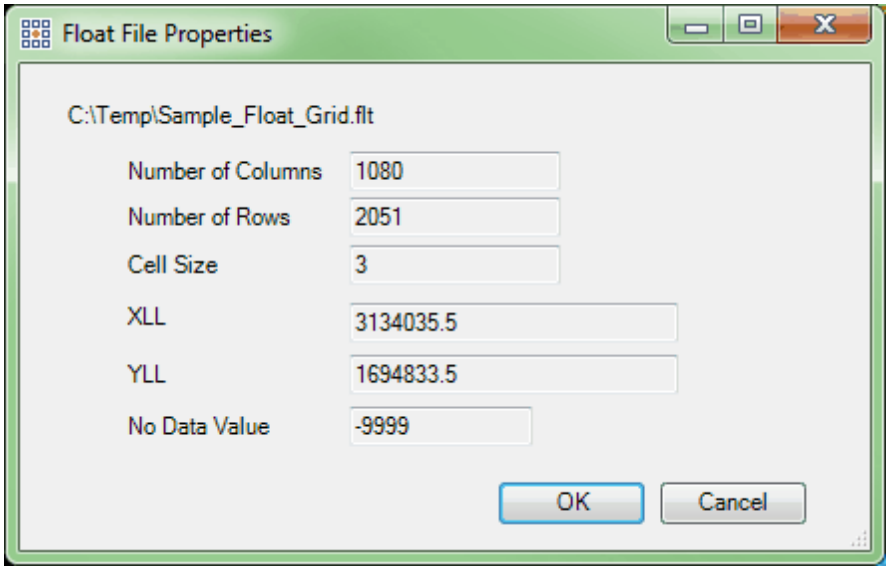
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Viewing the Properties of Float Grid Files: To see the properties of a Float Grid file, first highlight the file. Then right-click and choose **'Properties'**. The properties of the file will be displayed for informational purposes only. Information provided includes: the source of the file, the number of columns and rows, the cell size, the X and Y coordinates of the lower-left corner, and what value is used to represent NODATA cells. It is also possible to highlight, right-click, and copy data from the resulting 'Float File Properties' window.

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Zoom to a Float Grid File: To zoom to a *.flt file in the float grid layer, highlight the file and choose the **'Zoom to'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to highlight multiple files and zoom to their combined extent.

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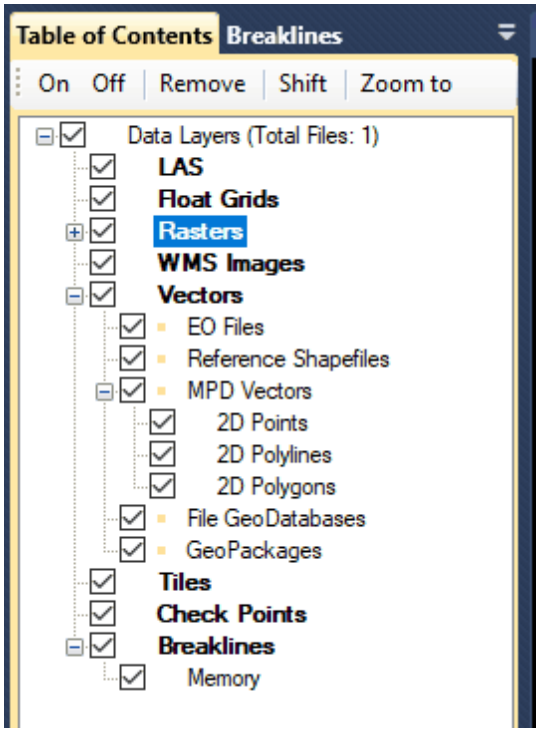
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2.2.3 Rasters (Images)

Rasters Layer

Merrick Advanced Remote Sensing (MARS®) Software

➤**Rasters Layer (for raster files and datasets)** - The 'Rasters' layer shows the Raster files that are currently loaded in MARS®. It also allows the user to toggle display of rasters, change the order of raster display, remove rasters, and view the properties of rasters. The types of raster files which may be added to this layer are: ECW (Hexagon-Intergraph), JPG, IMG (Hexagon-ERDAS), TIFF, DAT (ENVI Hyperspectral), NITF (USDoD), JP2, SID (LizardTech), and PNG files. Note that rasters are only displayed while in 2D (Orthographic) mode[234].

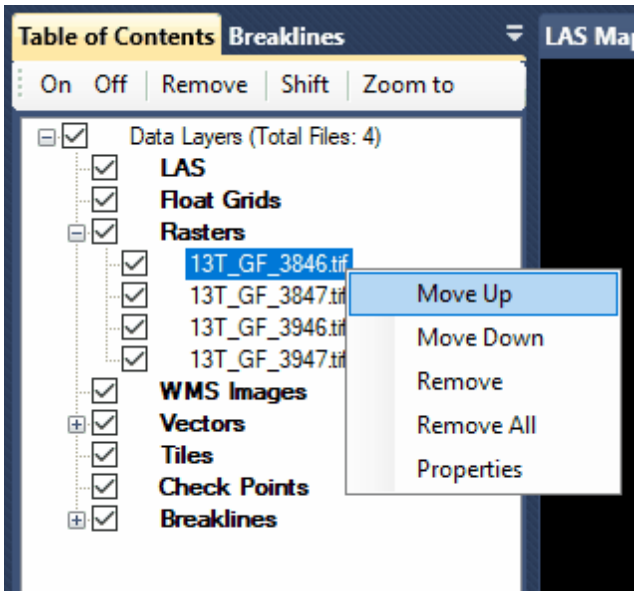


Adding Raster Files: To add a raster (image) file, see the 'Add Images' section in the Project/Data Preparation Tab 162 topic.

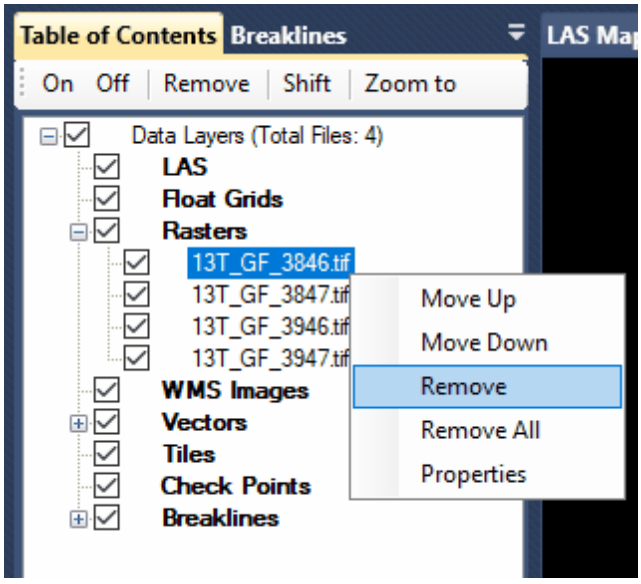
Expanding the Rasters Layer: Click on the '⊞' button to expand a list of all the raster files loaded under the 'Rasters' layer. There are three ways to turn on/off the display of the files loaded under the 'Rasters' layer: 1) check/uncheck the **'Rasters'** layer box, 2) check/uncheck the box next to the file(s) to be turned on/off or, 3) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents 67 while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Rasters'** layer box is checked to view the files loaded beneath it; if this master box is not checked 'on' the files will not be displayed.

Reordering Raster Files: When two or more raster files are loaded in the Table of Contents, individual rasters can be moved up or down in the 'Rasters' layer. This will affect the order in which they are displayed since MARS® renders the files beginning at the bottom of the list and working up. The raster listed at the top will display last, on top of all other displayed rasters. To move a raster file up or down - one position at a time - right-click on it in the 'Rasters' layer and select either 'Move Up' or 'Move Down' as appropriate.

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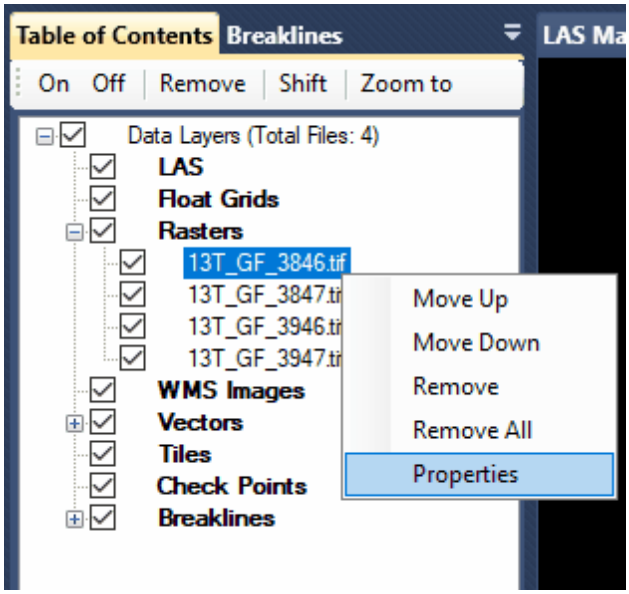


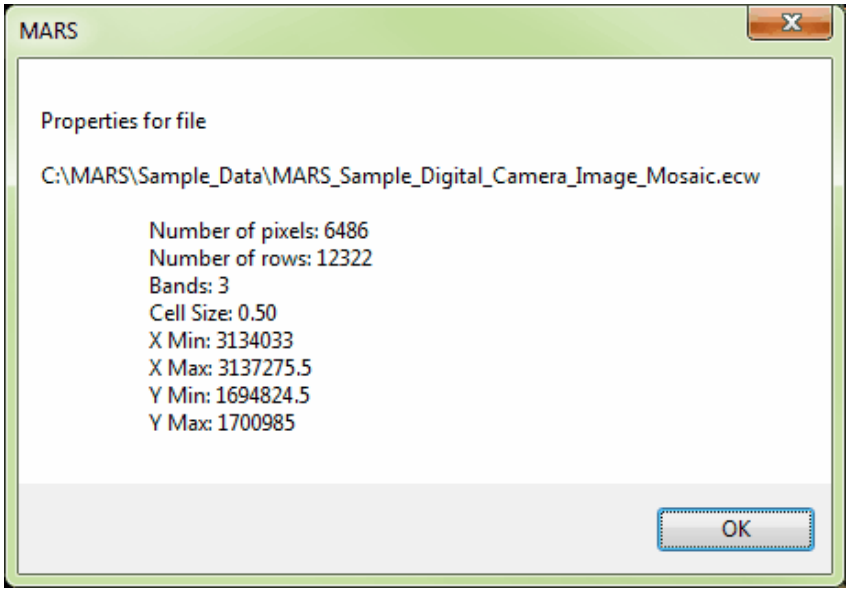
Removing a Raster File: To remove a file from the Rasters layer, click on the file that is to be removed to highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all raster files, right-click and choose **'Remove All'** - all raster files currently loaded will be unloaded. Another way to remove files from the layer is to highlight the file that needs to be removed, and click on the 'Remove' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.



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Viewing the Properties of a Raster File: To view the properties of a raster file, click on the file to highlight it. Right-click on the file and choose **'Properties'**. The window which comes up will contain information on the the source of the file, the number of pixels and rows, the number of bands, and the X and Y minimum and maximum coordinates.





Zoom to a Raster Image: To zoom to an image file in the 'Rasters' layer, highlight the file and

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choose the **'Zoom to'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to highlight multiple rasters and zoom to their combined extent.

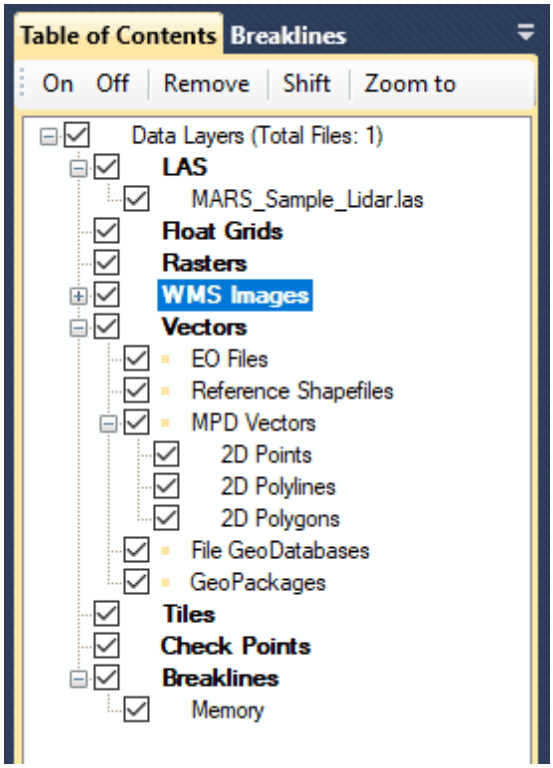
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2.2.4 WMS Images

WMS Images Layer

Merrick Advanced Remote Sensing (MARS®) Software

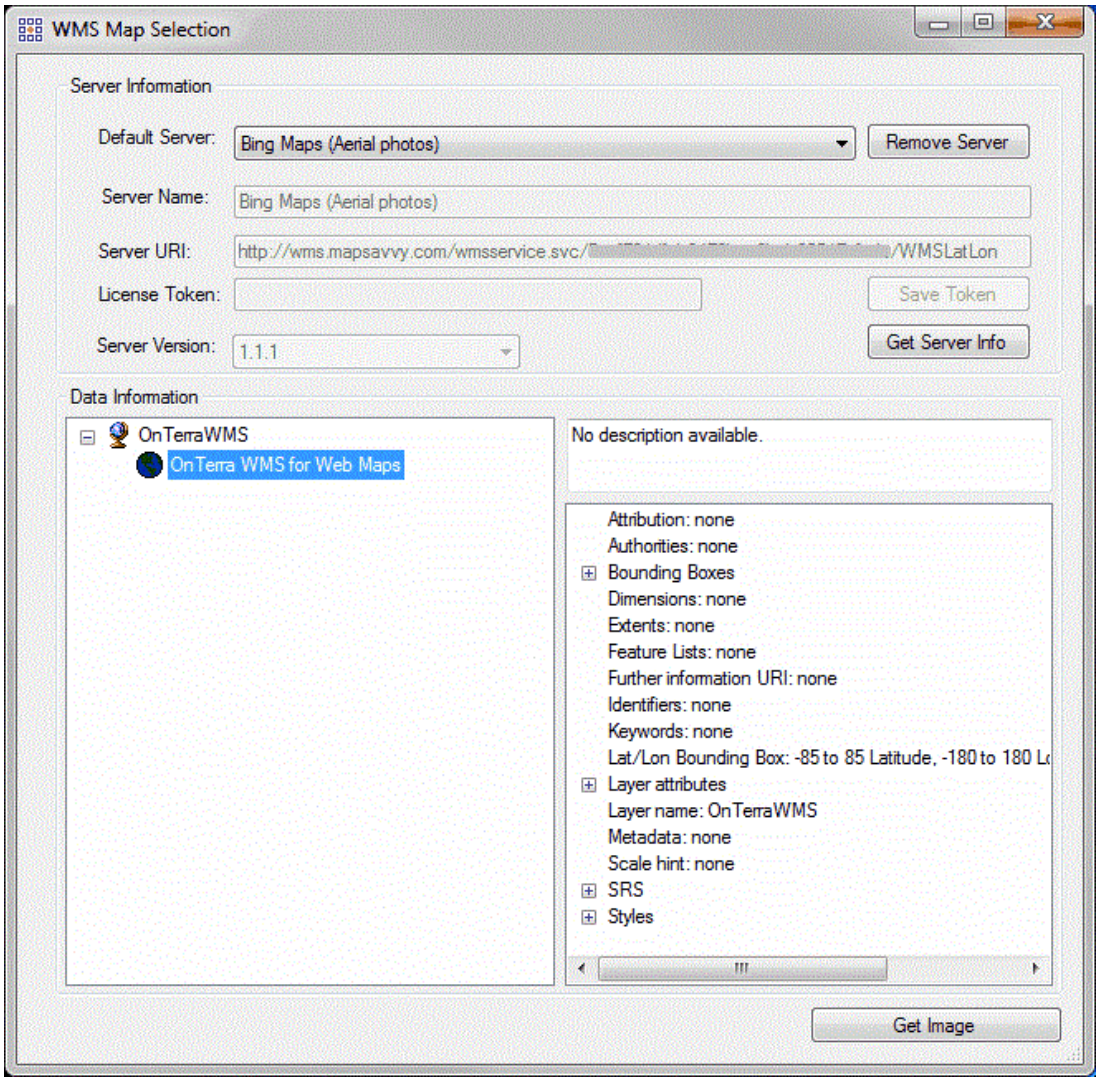
➤**WMS (Web Map Service) Images Layer (for raster layers) -** The 'WMS Images' layer shows the WMS Image layers that are currently loaded in MARS®. It also allows the user to toggle display of layers, refresh layers, and remove layers. MARS® has several pre-configured sources and allows for user input and storage of other known WMS servers[1879].



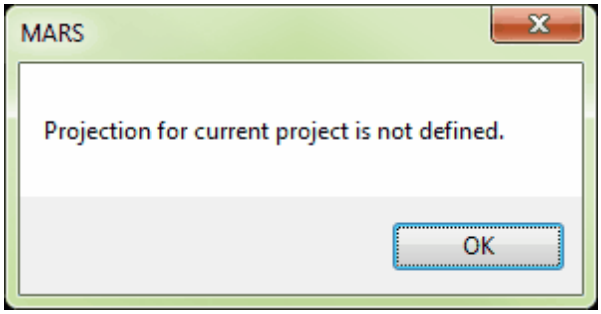
Adding WMS Raster Layers: An active Internet connection is required to use this service. To add a WMS image, see the 'Add WMS Images' section in the Project/Data Preparation Tab 162 topic and the following information.

In the 'Default Server' drop-down box, either choose a listed server or enter the URL of a known server (by choosing 'User Input'). If entering a new (non-listed) server, enter a name that is not already being used - any free-form descriptive text will work. To save a new entry for future use, click the 'Save Server Info' button before continuing. If a License Token is required for the particular server (such as for the Bing Maps layers), enter it in the box and click 'Save Token.' Saving will create an entry in the Windows Registry that will automatically load the token on future WMS calls. Next, click 'Get Server Info' to bring up the available images for the chosen server. (When choosing a 'Bing Maps' server, if no license token is listed and none is entered a pop-up with a link to obtain a token or a trial will appear.) Finally, highlight the desired image in the left pane (labeled 'Data Information') and click 'Get Image.' The image will be re-projected on the fly to match the loaded LAS or shapefile data, as long as the projection system is defined for that data. To remove an entry from the server drop-down list, choose it and click the 'Remove Server' button.

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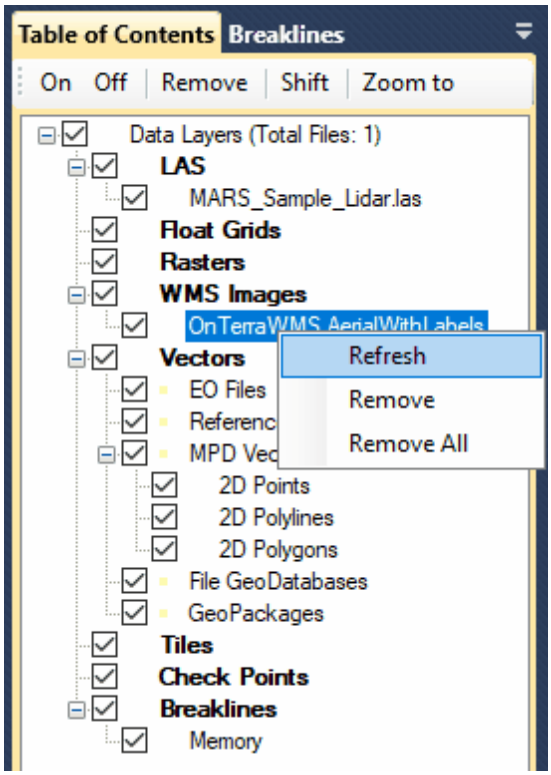
If the 'Add WMS Images' button (on the Project/Data Preparation Tab 162) is used before any projection-defined data is loaded, MARS® will return an error message indicating that projection information for the current project has not yet been defined.



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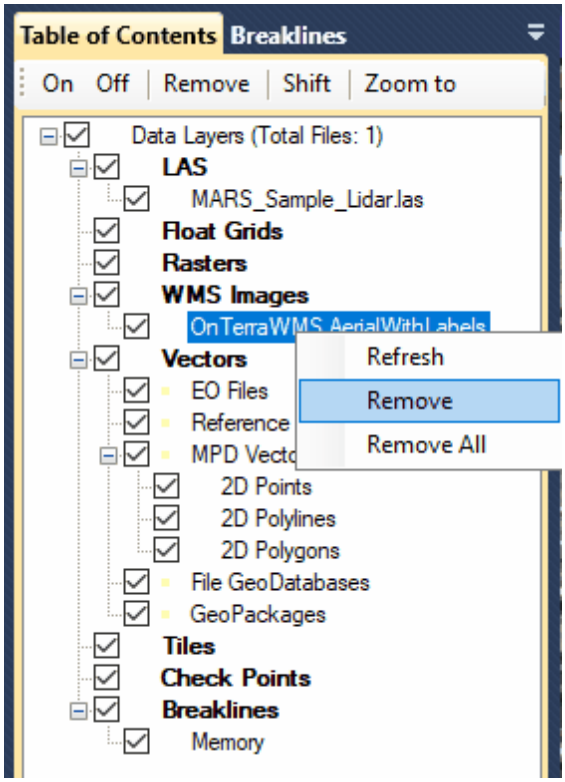
Expanding the WMS Images Layer: Click on the '⊞' button to expand a list of all the images loaded under the 'WMS Images' layer. The loaded images will appear under the layer name. There are three ways to turn on/off the display of the images loaded under the 'WMS Images' layer: 1) check/uncheck the **'WMS Images'** layer box to control all loaded images, 2) check/uncheck the box next to the individual image(s) to be turned on/off or, 3) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the desired image(s) are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard along with the mouse to select multiple images. Make sure the **'WMS Images'** layer box is checked to view the images loaded beneath it; if this master box is not checked the individual images will not be displayed.

Refreshing a WMS Image: To refresh a loaded WMS image layer, right-click on the desired entry in the Table of Contents and choose 'Refresh.' This will also force an extent update if the view window extent has changed since the image was last rendered.



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Removing a WMS Image: To remove a WMS image layer, click on the image layer that is to be removed to highlight it. Right-click on the image layer and choose **'Remove'** to remove only the highlighted image layer. To remove all WMS layers, right-click and choose **'Remove All'** - all image layers currently loaded will be unloaded. Another way to images from the layer is to highlight the image layer that needs to be removed, and click on the 'Remove' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple image layers which are to be removed.



NOTE: Availability of any WMS resources included with MARS® or referenced here[1879] is subject to change without notice. None of these services is endorsed, provided, or otherwise guaranteed to be functional by Merrick & Company. Merrick neither hosts nor maintains any

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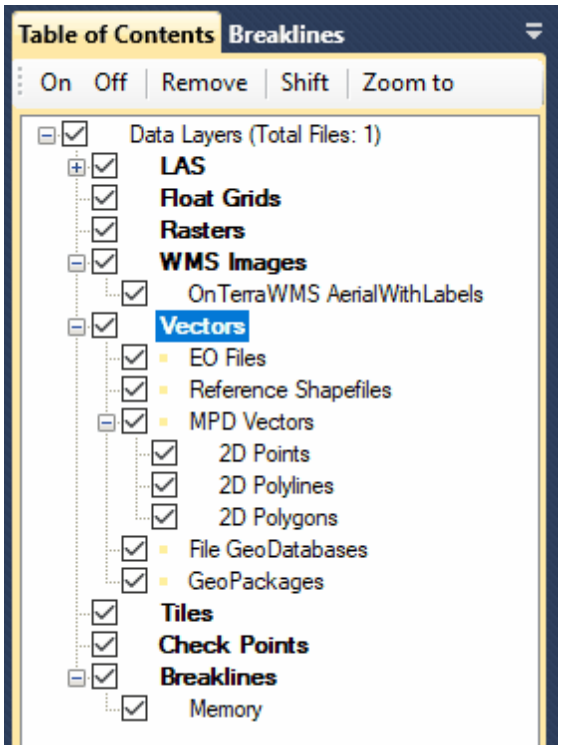
WMS (Web Map Service) image layer sources and is therefore not responsible for the completeness, accuracy, or frequency of updates of any WMS sources that may be accessed from within the MARS® program.

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2.2.5 Vectors (EOs, SHPs, GDBs, GeoPackages)



➤**Vectors Layer** - The **'Vectors'** layer shows the vector data (EO text files and/or shapefiles, reference shapefiles, MPD vectors, file geodatabases, and/or geopackages) that are currently loaded in MARS®. It also allows the user to toggle display of sub-layers/files, remove vector files, and view or change the attributes and properties of vector files. The layer can be expanded (click the '⊞' button to the left of the layer) or collapsed (click the '**-**' symbol) as needed to access the five sub-layers. Currently supported formats are EO (Exterior Orientation) text (*.txt) files or point shapefiles, Esri-compatible point, polyline, and polygon shapefiles, Esri v10.0 or later file geodatabases, and geopackages. MPD vectors are user-drawn features that can be saved in a project file (*.mpd) for later use, whether or not they have been saved as a shapefiles. Tile layout 121 and Breaklines 134 shapefiles may be loaded under the '**Reference Shapefiles**' sub-layer if they are needed only as reference data.



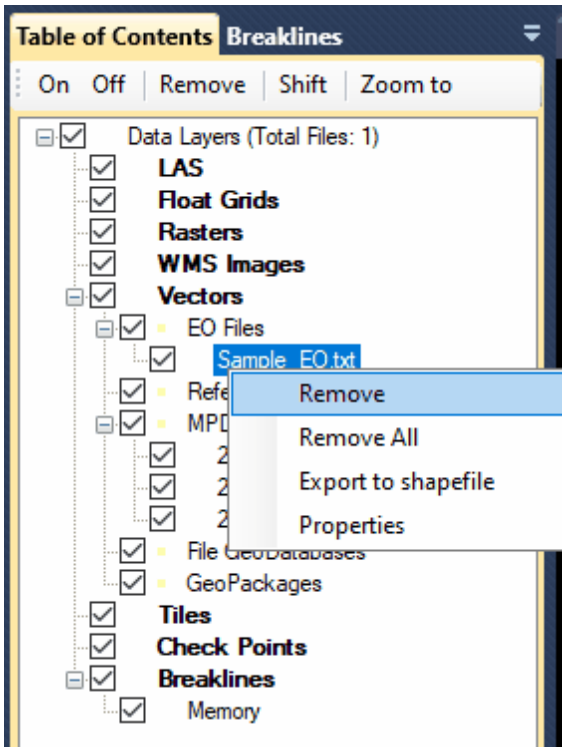
EO Files Sub-Layer

Adding an EO File: To add an EO (exterior orientation) file, see the 'Add EO File' section in the Project/Data Preparation Tab 162 topic.

Expanding the sub-layer and viewing entries: Click on the '⊞' button to expand a list of all the files loaded under the **'EO Files'** sub-layer. The loaded EO files (TXT or shapefiles) will appear under this sub-layer. There are four ways to turn on/off the display of the files loaded here: 1) check/uncheck the **'Vectors'** layer box which affects all vector types, 2) check/uncheck the **'EO Files'** sub-layer box, 3) check/uncheck the box next to the EO file(s) to be turned on/off or, 4) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Vectors'** layer box is checked to view any files in any sub-layers loaded beneath it; if this master box is not checked the files will not be displayed.

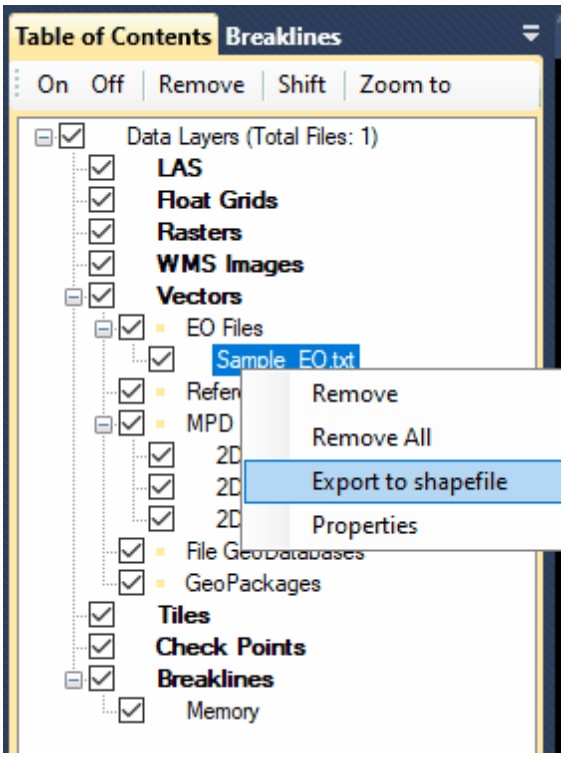
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Removing an EO File: To remove a file from the '**EO Files**' sub-layer, click on the file that is to be removed to highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all EO files, right-click and choose **'Remove All'** - all EO files currently loaded will be unloaded. Another way to remove files from the sub-layer is to highlight the file that needs to be removed, and click on the '**Remove**' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.



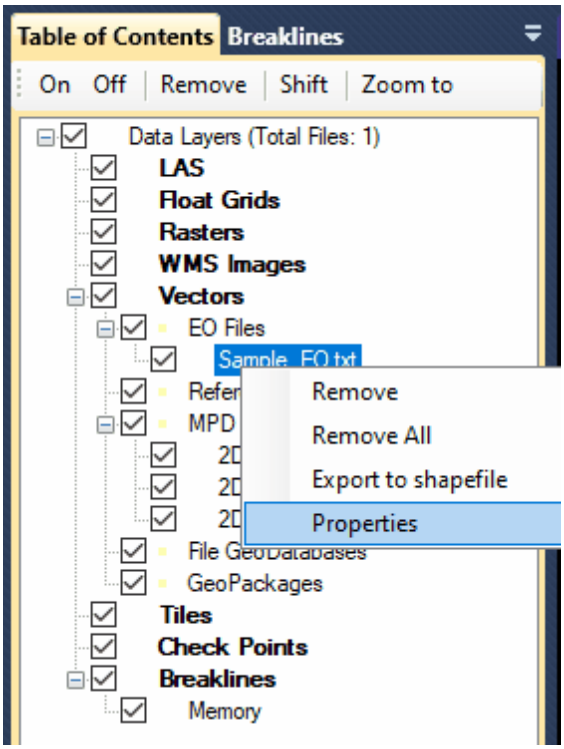
Export to Shapefile for EO Text Files: To export a loaded EO text file to an Esri-compatible point shapefile, left-click on the desired file in the Table of Contents to highlight it, then choose **'Export to shapefile'**. A 'Save As' dialog will open where the path and file name can be chosen. Click the 'Save' button to finish the export. The new shapefile can be loaded as a reference shapefile, and the attribute table may then be viewed and manipulated as described above.

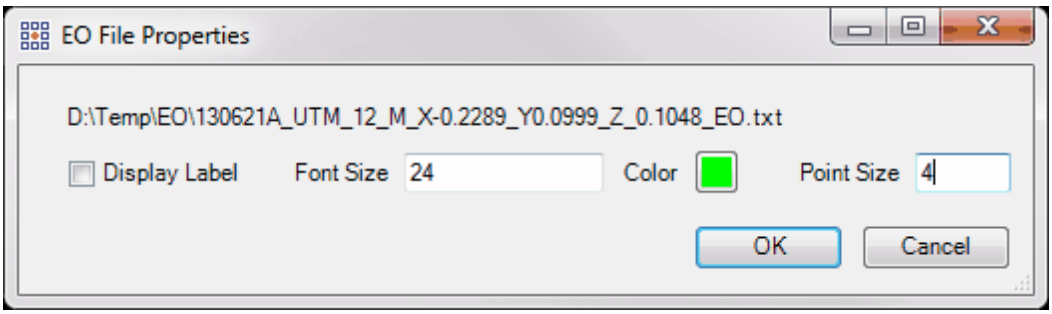
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Changing EO (Exterior Orientation) Text File Properties: To change the EO text file properties, left-click on the desired file in the Table of Contents to highlight it, then right-click and choose **'Properties'**. The full name and path of the file is displayed, and point size, point color, label display, and font size can be changed using the interface that appears.

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Zoom to an EO File: To zoom to an EO file (text or shapefile), highlight the file and choose the **'Zoom to'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to highlight multiple shapefiles and zoom to their combined extent. Select the '**EO Files**' sub-layer and choose '**Zoom to**' to zoom to the entire extent of all loaded EO files.

Reference Shapefiles Sub-Layer

Adding a Reference Shapefile: To add a reference shapefile, see the 'Add Reference Shapefiles'

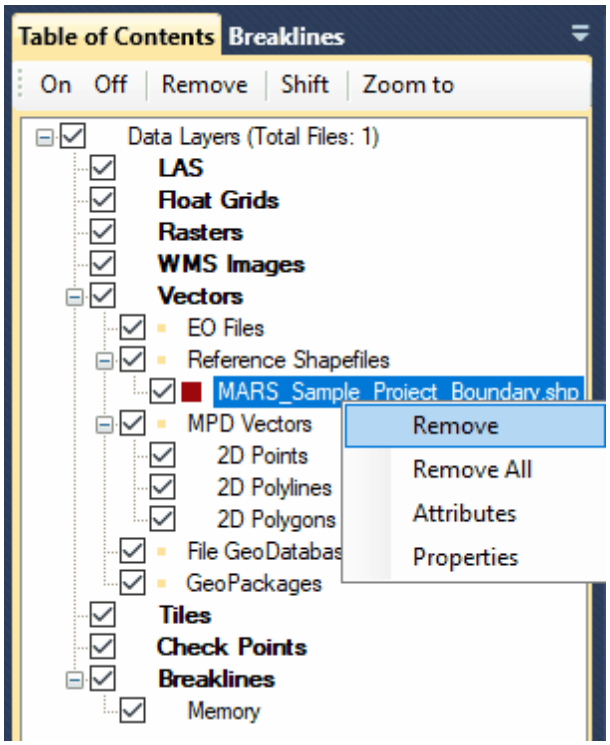
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section in the Project/Data Preparation Tab 162 topic. Display colors are assigned on a six-color repeating cycle and can be changed as described in the **Changing Reference Shapefile Display Properties** section, below 107.

Expanding the sub-layer and viewing entries: Click on the '⊞' button to expand a list of all the files loaded under the '**Reference Shapefiles**' sub-layer. The loaded shapefiles will appear under this sub-layer. There are four ways to turn on/off the display of the files loaded here: 1) check/uncheck the **'Vectors'** layer box which affects all vector types, 2) check/uncheck the 'Reference Shapefiles' sub-layer box, 3) check/uncheck the box next to the shapefile(s) to be turned on/off or, 4) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Vectors'** layer box is checked to view any files in any sub-layers loaded beneath it; if this master box is not checked the files will not be displayed.

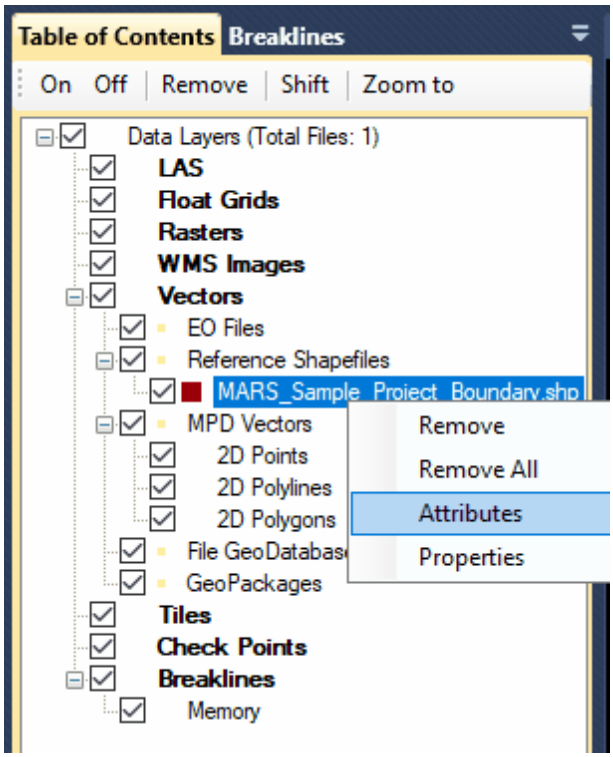
Removing a Reference Shapefile: To remove a file from the '**Reference Shapefiles**' sub-layer, click on the file that is to be removed to highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all reference shapefiles, right-click and choose **'Remove All'** - all reference shapefiles currently loaded will be unloaded. Another way to remove files from the sub-layer is to highlight the file that needs to be removed, and click on the '**Remove**' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.

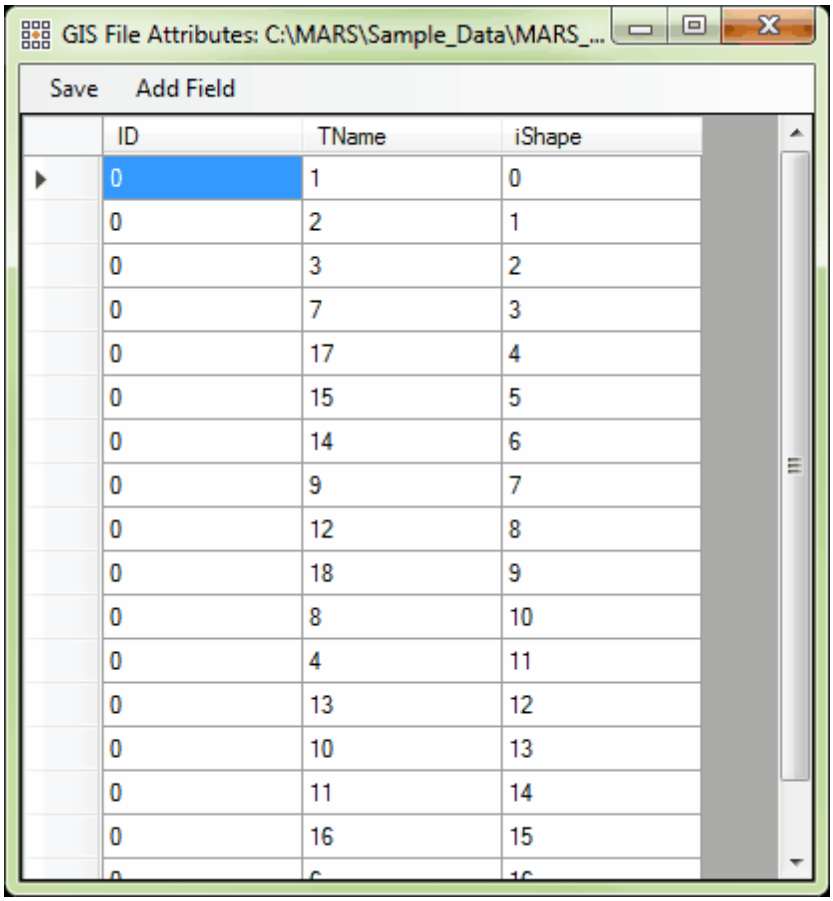
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Viewing and/or Editing Reference Shapefile Attributes: To view a reference shapefile's attribute table, click on the shapefile to highlight it. Then right-click on the shapefile and select **'Attributes'.** The attribute table and labeling fields will appear in a new window. To edit the attributes, double-click on the appropriate attribute and make the needed changes. Click on the 'Save' header to save the file. The 'iShape' field cannot be edited.

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ID	TName	iShape
0	1	0
0	2	1
0	3	2
0	7	3
0	17	4
0	15	5
0	14	6
0	9	7
0	12	8
0	18	9
0	8	10
0	4	11
0	13	12
0	10	13
0	11	14
0	16	15

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It is possible to edit the attribute table of a shapefile by adding new fields, or changing the contents of those fields. The only exception is the 'iShape' field, which cannot be edited. To add a new column or field to the attribute table, click on the 'Add Field' button at the top of the window. The 'Add Field' window will appear and the user may specify the restrictions of the new field.

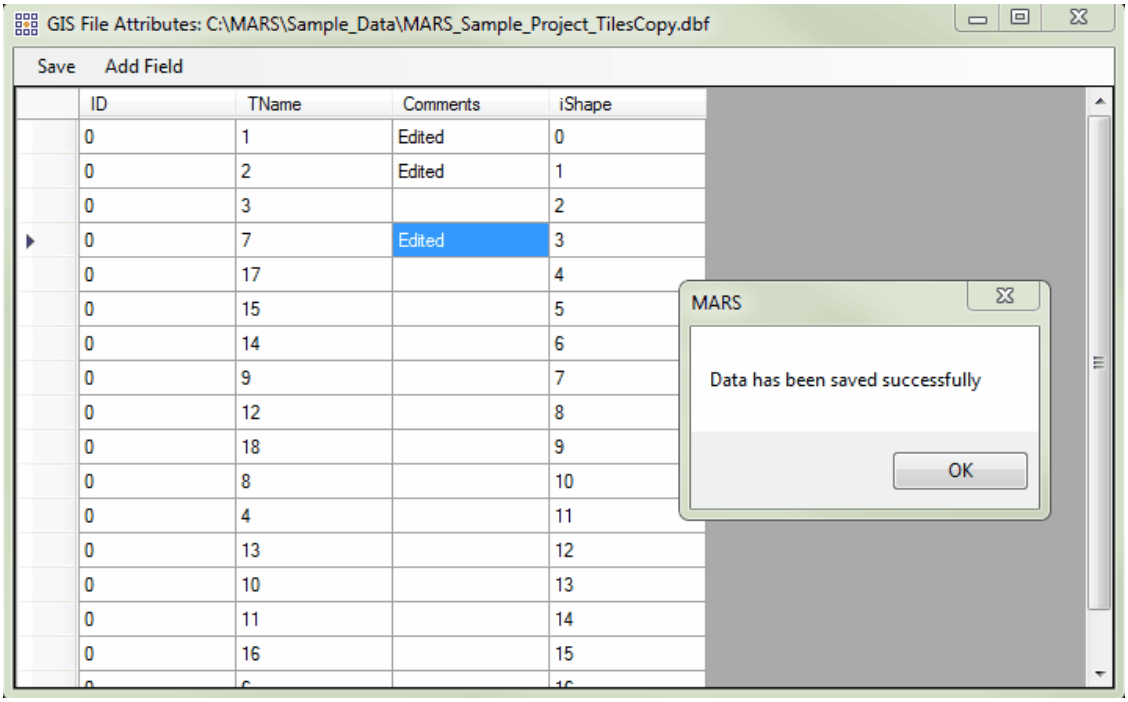
Creating a New Field:

1) First, give the new field a name in the **'Field Name'** text box. The attribute table will display up to ten (10) characters in the column heading.
2) Then define the **'Field Type'** to be used in the new column.
3) Define the **'Width'** of the column. The width defines how many characters will fit inside the defined field. For example, if the user chooses a 'Width' of twenty (20), then only twenty characters will be saved in the newly defined field. If the user is creating a 'Comments' field, the width of the new field should be larger to accommodate any needed characters for comments. If the user is creating a 'Date' field, which requires only ten characters at most, then the width may be smaller. When using the 'Logical' field type, the user-specified width does not matter, as only one character (a check mark) is used in this field.
4) In the **'Number of Decimals'** text box (only enabled for certain 'Field Type' choices) the user may specify the number of decimals which will be allowed in the newly defined field. If the user chooses '0' then all numbers entered into the newly created field will have to be integers.
5) Click the 'OK' button when finished, and then click the 'Save' button in the upper-left corner of the attribute table to make the new field permanent.

Editing a Field:

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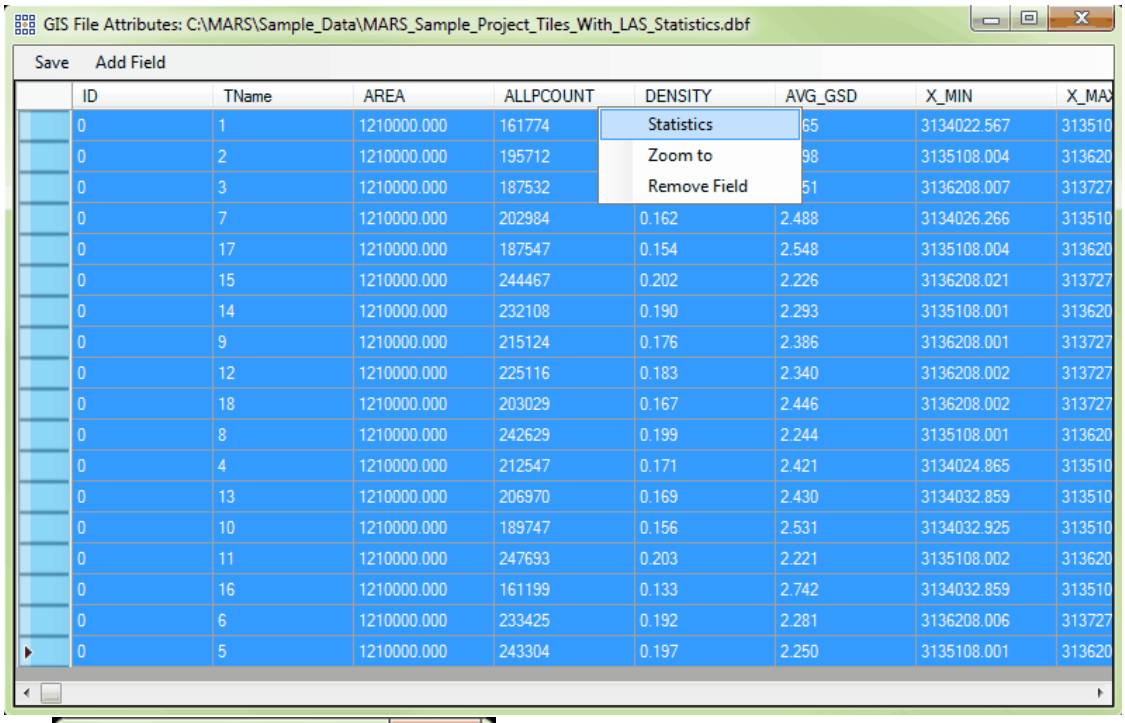
To edit any attribute information, double-click on the appropriate attribute and make the changes necessary. When finished, click on the 'Save' button in the upper-left corner to save the changed information. The user will receive a message confirming the data was saved inside the shapefile. This ability may be very useful when editing data to keep track of tiles or areas which have or have not been edited.



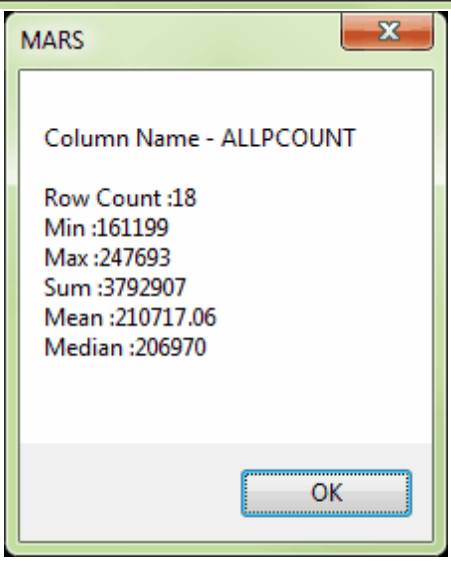
It is also possible to view the statistics of attributes in a shapefile. The user may view the statistics of a single attribute, the statistics of an entire row or column, or the statistics of an entire table. Highlight the attributes for which statistics are to be viewed, right-click and choose **'Statistics'**. The resultant table will tell the user the following statistics: the row count, minimum, maximum, sum, mean (average), and median of every attribute. To select multiple attributes for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In the example below, the user is choosing to view the statistics

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of the entire 'ALLPCOUNT' column. The resulting statistics are also shown below.



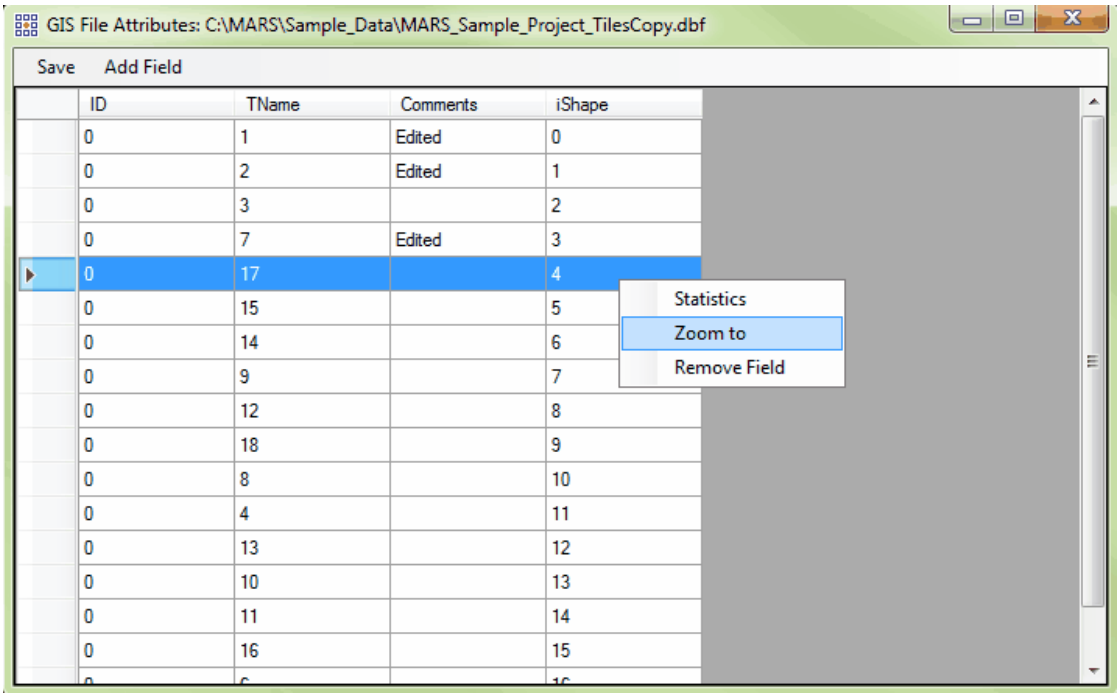
ID	TName	AREA	ALLPCOUNT	DENSITY	AVG_GSD	X_MIN	X_MAX
0	1	1210000.000	161774		65	3134022.567	313510
0	2	1210000.000	195712		98	3135108.004	313620
0	3	1210000.000	187532		51	3136208.007	313727
0	7	1210000.000	202984	0.162	2.488	3134026.266	313510
0	17	1210000.000	187547	0.154	2.548	3135108.004	313620
0	15	1210000.000	244467	0.202	2.226	3136208.021	313727
0	14	1210000.000	232108	0.190	2.293	3135108.001	313620
0	9	1210000.000	215124	0.176	2.386	3136208.001	313727
0	12	1210000.000	225116	0.183	2.340	3136208.002	313727
0	18	1210000.000	203029	0.167	2.446	3136208.002	313727
0	8	1210000.000	242629	0.199	2.244	3135108.001	313620
0	4	1210000.000	212547	0.171	2.421	3134024.865	313510
0	13	1210000.000	206970	0.169	2.430	3134032.859	313510
0	10	1210000.000	189747	0.156	2.531	3134032.925	313510
0	11	1210000.000	247693	0.203	2.221	3135108.002	313620
0	16	1210000.000	161199	0.133	2.742	3134032.859	313510
0	6	1210000.000	233425	0.192	2.281	3136208.006	313727
0	5	1210000.000	243304	0.197	2.250	3135108.001	313620



Lastly, it is possible to zoom to a particular feature (row) in an attribute table. To use this function, highlight a row and right-click anywhere on it. Right-click on the 'Zoom to' option and the highlighted feature will fit to the LAS Map View

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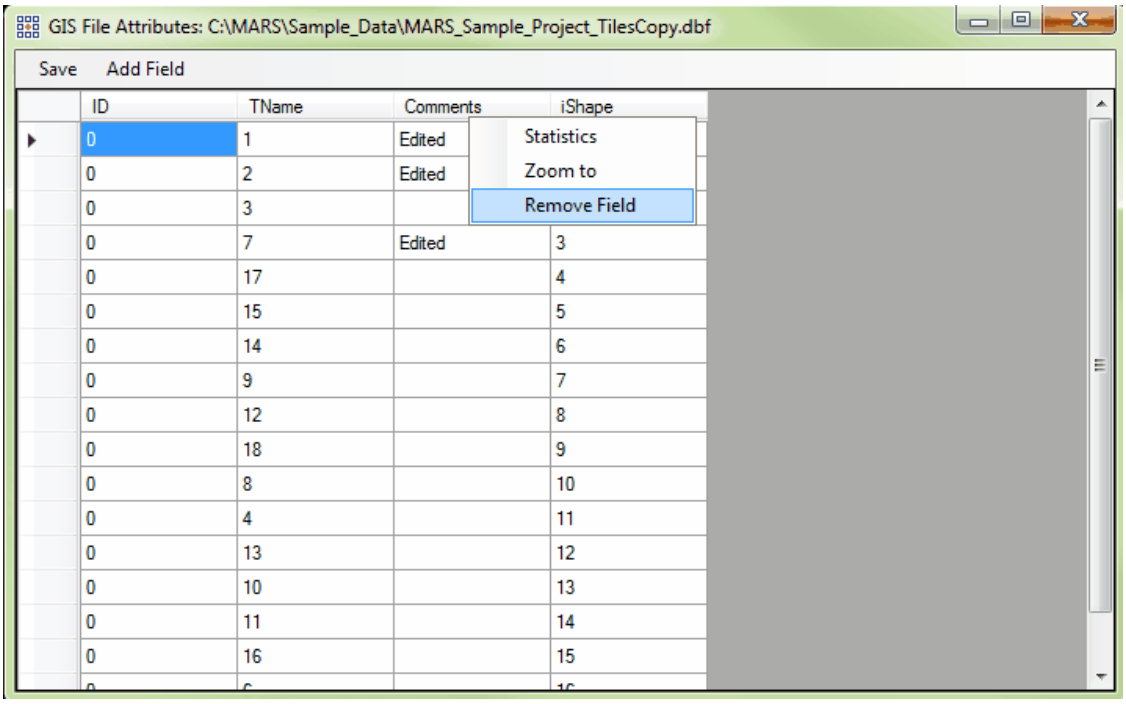
window.



Deleting a Field:

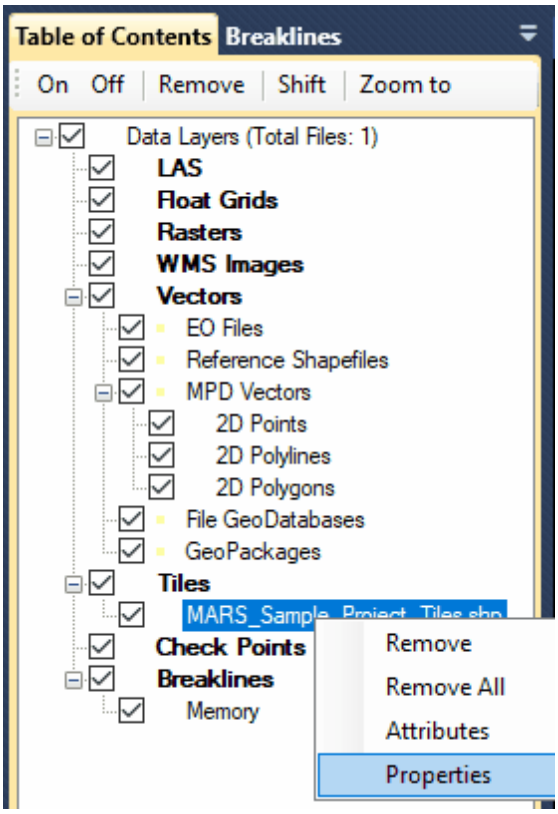
To delete an attribute field right-click on the column heading and choose 'Remove Field'. ***NOTE: the 'iShape' field should never be deleted if the shapefile is to be used in MARS® in the future.*** All information contained in this column, or attribute field, will be lost at this time. Click 'Save' in the upper-left to make this change permanent.

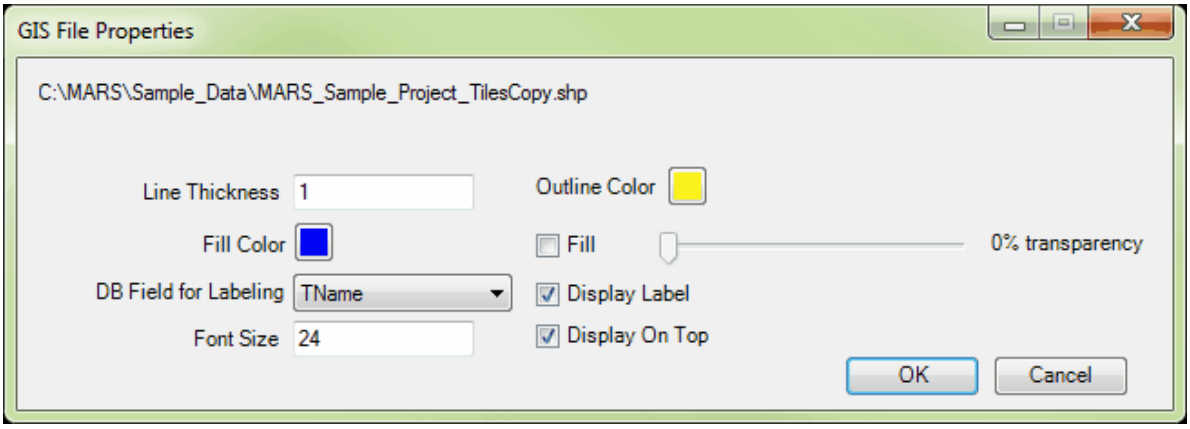
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Changing Reference Shapefile Display Properties: To change the shapefile properties, left-click on the desired file in the Table of Contents to highlight it, then right-click and choose **'Properties'**. Alternatively, toggle the 'Inspect' button on, then hold down the 'Shift' key and click on a shapefile feature to display the 'Properties' window. The full name and path of the file is displayed, and line thickness, outline and fill (if the shapefile is polygonal) colors, labeling field, and font size can be changed through the dialog that appears. To label features with an attribute value, select that attribute from the 'DB Field for Labeling' drop-down list and check the 'Display label' box. The 'Font Size' of the labels can also be set. Font color will be the same as 'Outline Color.' A transparency level can be set if 'Fill' is checked. To force the shapefile to be displayed on top of other layers, check the **'Display On Top'** box.

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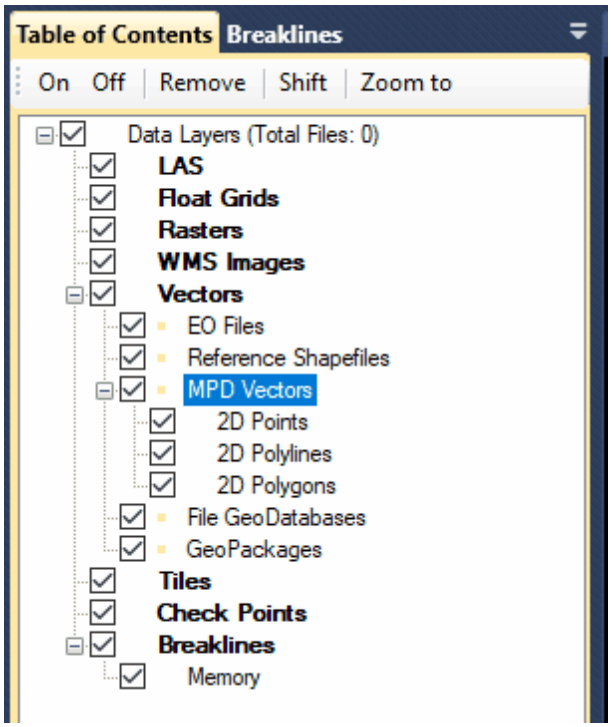


Zoom to a Reference Shapefile: To zoom to a reference shapefile, highlight the file and choose the **'Zoom to'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to zoom to multiple shapefiles at a time. Select the '**Reference Shapefiles**' sub-layer and choose '**Zoom to**' to zoom to the entire extent of all loaded reference shapefiles.

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MPD Vectors Sub-Layer

This sub-layer differs from the others under the 'Vectors' layer in that there are no separate files that hold these features - they are stored only in memory or, optionally, in an MPD (project file). There are categories for the three types of vector geometries: 2D Points, 2D Polylines, and 2D Polygons. Please see the '**Draw 2D Point**', '**Draw 2D Polygon**', and '**Draw 2D Centerline**' topics in the Vector Creation Tab 364 help section for information on drawing and storing these features.

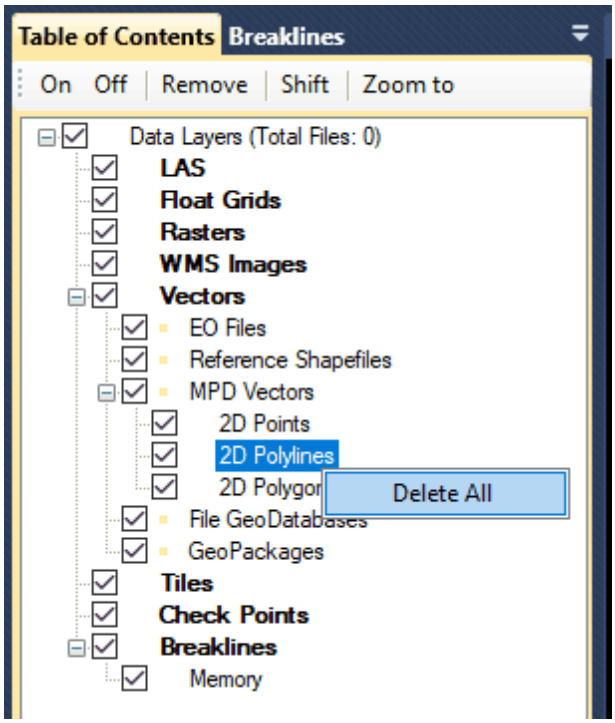


Expanding the sub-layer and viewing the geometry categories: Click on the '⊞' button to expand a list of the three geometry types available under the '**MPD Vectors**' sub-layer. There are four ways to turn on/off the display of these features: 1) check/uncheck the **'Vectors'** layer box which affects all vector types, 2) check/uncheck the '**MPD Vectors**' sub-layer box, 3) check/uncheck the box next to the geometry type(s) to be turned on/off or, 4) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the '**MPD Vectors**' sub-layer is highlighted or while the appropriate geometry

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types are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Vectors'** layer box is checked to view any files in any sub-layers loaded beneath it; if this master box is not checked the files will not be displayed.

Deleting all features from a geometry type: To delete all features from a geometry type in the '**MPD Vectors**' sub-layer, click on the geometry type to highlight it. Right-click on the geometry type and choose '**Delete All**'. Be sure to save the MPD file if this is to be a permanent deletion.



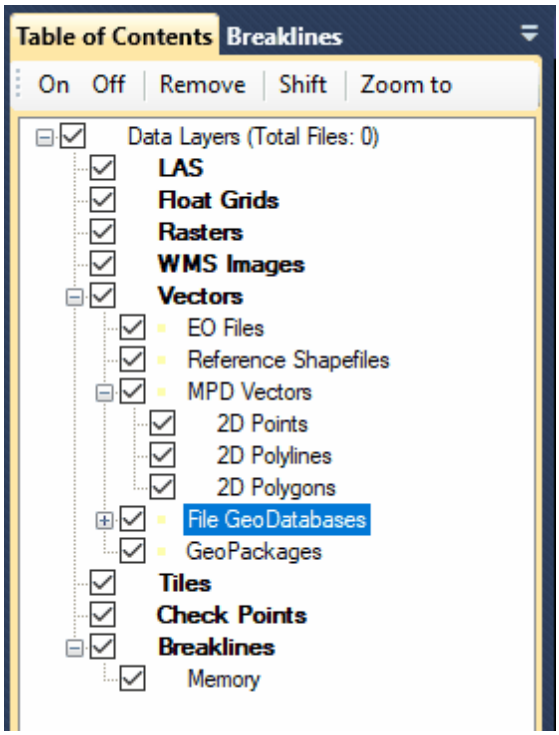
Zoom to MPD Vectors: To zoom to MPD vectors, highlight the desired geometry type and choose the '**Zoom to**' button found at the top of the Table of Contents. Select the '**MPD Vectors**' sub-layer and choose '**Zoom to**' to zoom to the entire extent of all MPD vectors of all geometry types.

File GeoDatabases Sub-Layer

The **'File GeoDatabases'** sub-layer shows the Esri File GDB data that is currently loaded in MARS®.

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It also allows the user to toggle display of multiple file GDBs along with their datasets and feature classes, remove File GDBs, view the attributes of feature classes, and view or change the properties of feature classes. Currently supported formats are v10.0 or later. Any topologies must be removed from the GDB before it can be loaded, and features must be 2D (no 'M' or 'Z' values present).

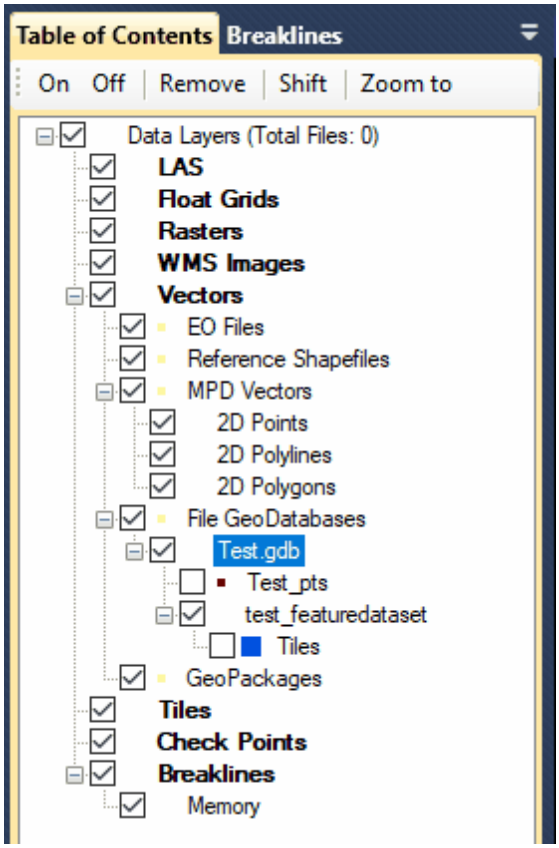


Adding a File GDB: To add a File GDB (including all datasets and feature classes within it), see the 'Add File GDB' section in the Project/Data Preparation Tab 162 topic.

Expanding the sub-layer and viewing entries: Click on the '⊞' button to expand a list of all the file GDBs loaded under the '**File GeoDatabases**' sub-layer. GDBs can be further expanded by clicking the '⊞' button next to them to reveal feature datasets and standalone feature classes. Feature datasets can be further expanded by clicking the '⊞' button next to them to reveal feature classes within the dataset. There are five ways to turn on/off the display of the entries loaded here: 1) check/uncheck the **'Vectors'** layer box which affects all vector types, 2) check/uncheck the '**File GeoDatabases**' sub-layer box to control all loaded GDBs, 3) check/uncheck the box next to the GDB

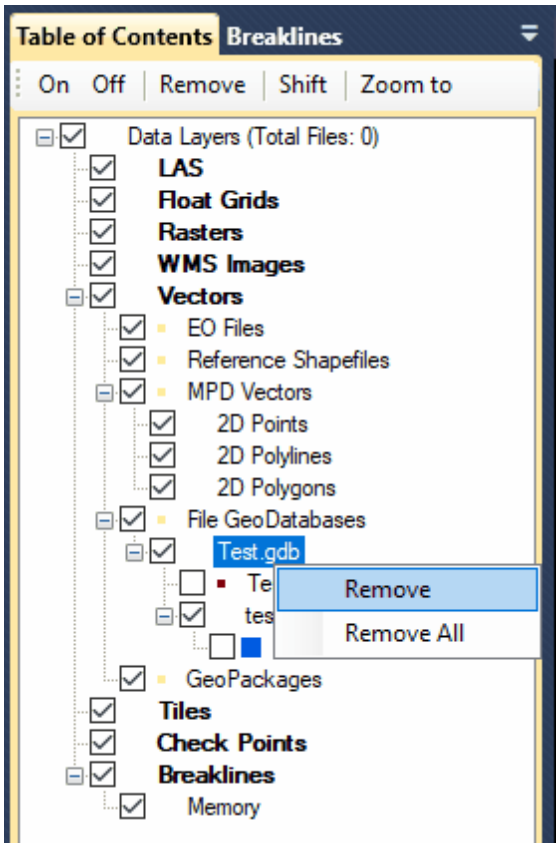
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(s) to be turned on/off, 4) check/uncheck the box next to the feature dataset(s) and/or feature class (es) to be turned on/off or, 5) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate entries are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple entries. Make sure the **'Vectors'** layer box is checked to view any files in any sub-layers loaded beneath it; if this master box is not checked the entries will not be displayed.



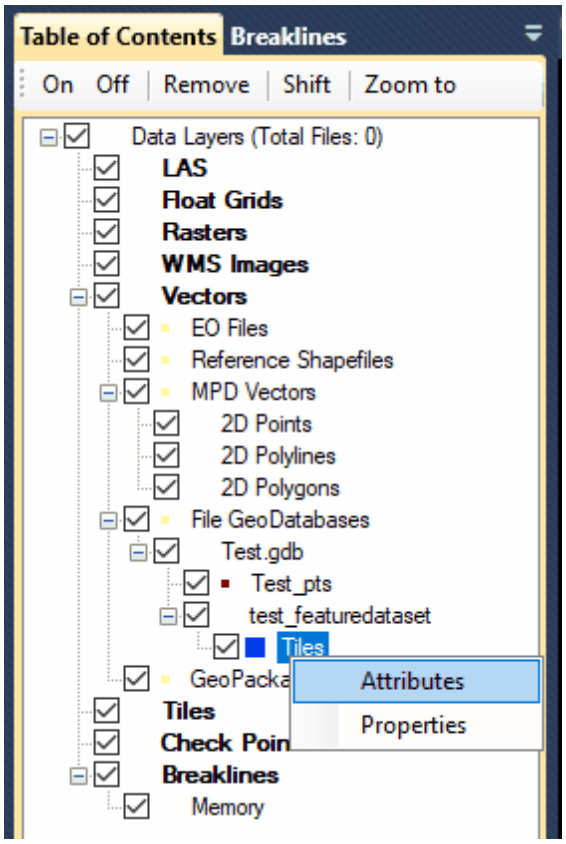
Removing a File GDB: To remove a File GeoDatabase from the project, click on the main (top-level) GDB entry to highlight it. Then right-click on the highlighted entry and select **'Remove',** or choose **'Remove All'** to empty the entire sub-layer if multiple File GDBs are loaded. Another way to remove data from the sub-layer is to highlight the entry that needs to be removed, and click on the '**Remove**' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple entries which are to be removed.

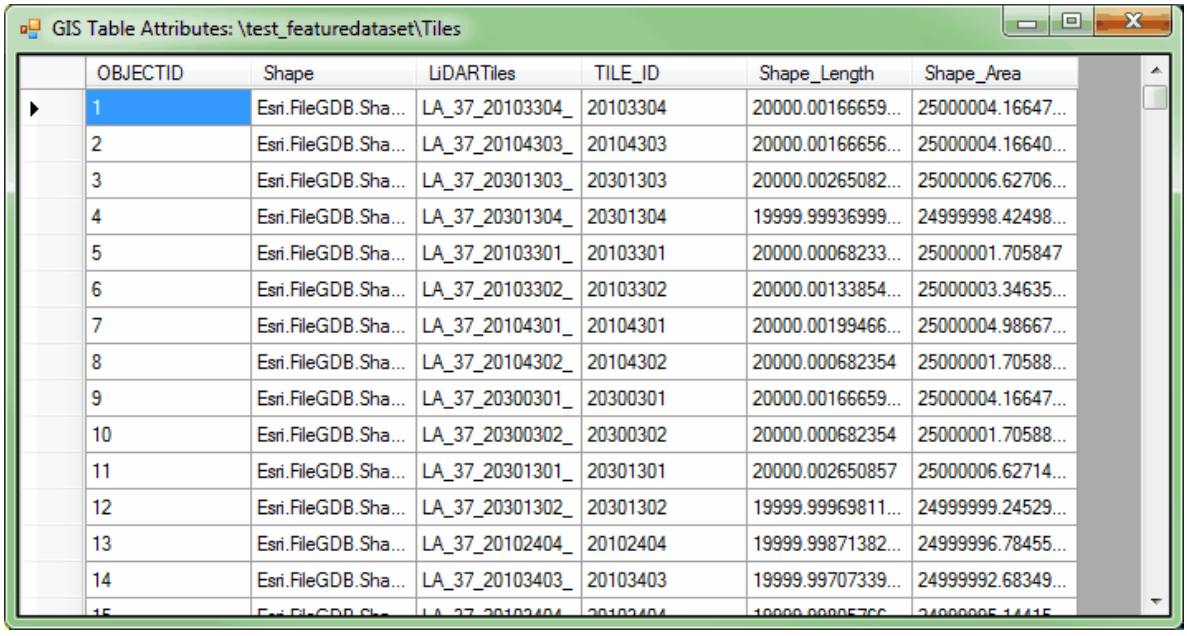
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Viewing Feature Class Attributes: To view a feature class's attribute table, click on the feature class entry to highlight it. Then right-click on the entry and select **'Attributes'.** The attribute table and labeling fields will appear in a new window. Editing of feature class attribute tables is not possible in MARS®.

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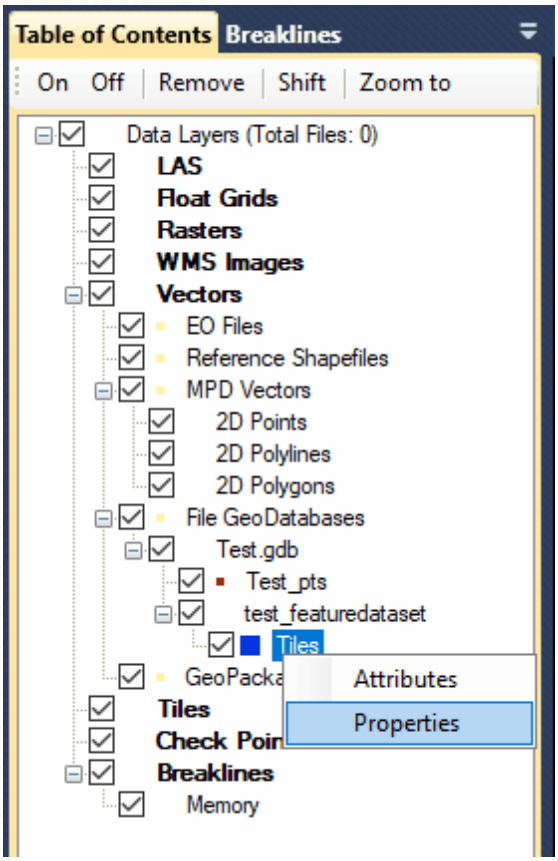


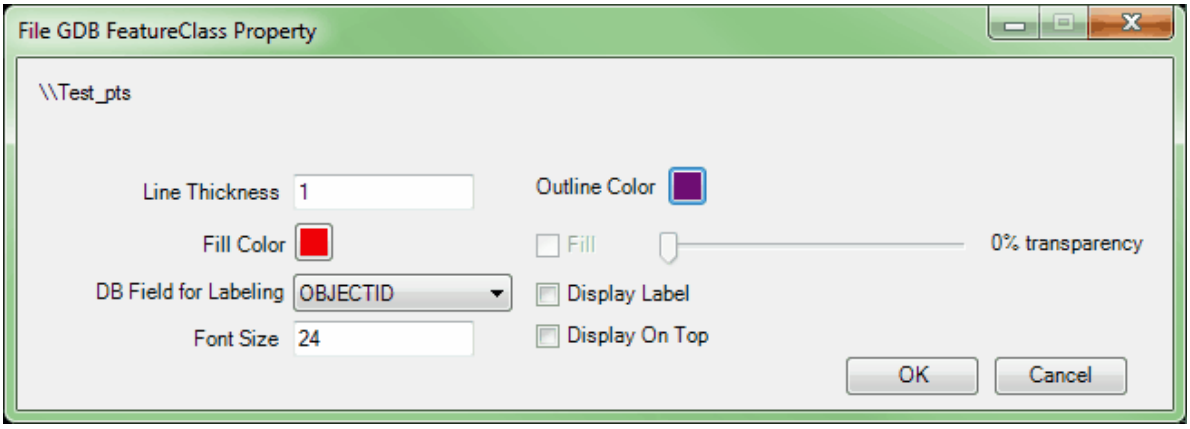
OBJECTID	Shape	LiDARTiles	TILE_ID	Shape_Length	Shape_Area
1	Esri.FileGDB.Sha...	LA_37_20103304_	20103304	20000.00166659...	25000004.16647...
2	Esri.FileGDB.Sha...	LA_37_20104303_	20104303	20000.00166656...	25000004.16640...
3	Esri.FileGDB.Sha...	LA_37_20301303_	20301303	20000.00265082...	25000006.62706...
4	Esri.FileGDB.Sha...	LA_37_20301304_	20301304	19999.99936999...	24999998.42498...
5	Esri.FileGDB.Sha...	LA_37_20103301_	20103301	20000.00068233...	25000001.705847
6	Esri.FileGDB.Sha...	LA_37_20103302_	20103302	20000.00133854...	25000003.34635...
7	Esri.FileGDB.Sha...	LA_37_20104301_	20104301	20000.00199466...	25000004.98667...
8	Esri.FileGDB.Sha...	LA_37_20104302_	20104302	20000.000682354	25000001.70588...
9	Esri.FileGDB.Sha...	LA_37_20300301_	20300301	20000.00166659...	25000004.16647...
10	Esri.FileGDB.Sha...	LA_37_20300302_	20300302	20000.000682354	25000001.70588...
11	Esri.FileGDB.Sha...	LA_37_20301301_	20301301	20000.002650857	25000006.62714...
12	Esri.FileGDB.Sha...	LA_37_20301302_	20301302	19999.99969811...	24999999.24529...
13	Esri.FileGDB.Sha...	LA_37_20102404_	20102404	19999.99871382...	24999996.78455...
14	Esri.FileGDB.Sha...	LA_37_20103403_	20103403	19999.99707339...	24999992.68349...

Changing Feature Class Display Properties: To change the properties of a feature class, left-click on the desired entry to highlight it, then right-click and select **'Properties'**. The feature class name

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and feature dataset it belongs to (if applicable) is displayed, along with several options for controlling the display of the feature class, in the interface that appears. Currently, only the 'Line Thickness' and 'Outline Color' can be set - the additional controls in the properties interface may be enabled in a future release.





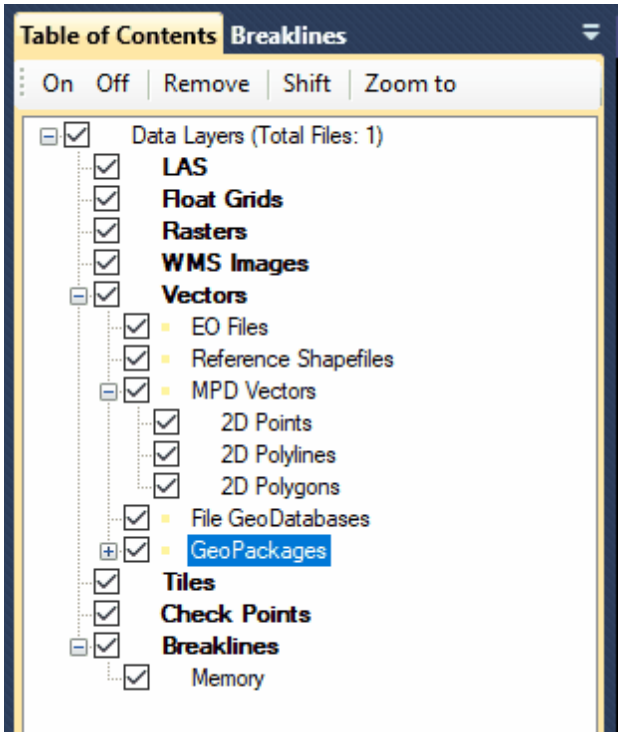
Zoom to a File GeoDatabase: To zoom to a file geodatabase, highlight the GDB and choose the

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'Zoom to' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to zoom to multiple GDBs at a time. Select the '**File GeoDatabases**' sub-layer and choose '**Zoom to**' to zoom to the entire extent of all loaded file geodatabases.

GeoPackages Sub-Layer

The **'GeoPackages'** sub-layer shows the geopackage data that is currently loaded in MARS®. It allows the user to toggle display of multiple GeoPackage layers, remove layers, view the attributes of feature classes, and view or change the properties of feature classes. The latest version of the GeoPackage standard currently supported is v1.3.1.

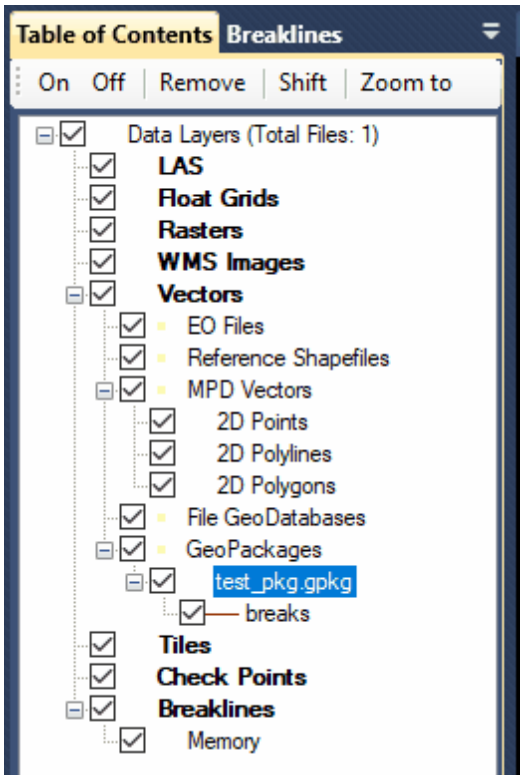


Adding a GeoPackage dataset: To add a GeoPackage dataset (including all layers within it), see the 'Add GeoPackages' section in the Project/Data Preparation Tab 162 topic.

Expanding the sub-layer and viewing entries: Click on the '⊞' button to expand a list of all the

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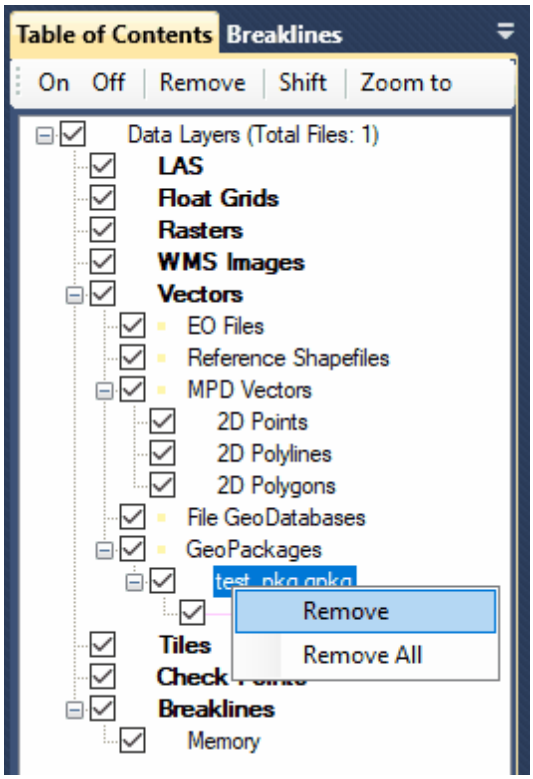
GeoPackage layers loaded under the '**GeoPackages**' sub-layer. Click on the '⊞' button to the left of a GeoPackage entry to expand a list of all the layers loaded as part of that GeoPackage. There are five ways to turn on/off the display of the entries loaded here: 1) check/uncheck the **'Vectors'** layer box which affects all vector types, 2) check/uncheck the '**GeoPackages**' sub-layer box to control all loaded GeoPackage datasets, 3) check/uncheck the box next to the individual GeoPackage(s) to be turned on/off, 4) check/uncheck the box next to the layer(s) to be turned on/off or, 5) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the appropriate entries are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple entries. Make sure the **'Vectors'** layer box is checked to view any files in any sub-layers loaded beneath it; if this master box is not checked the entries will not be displayed.



Removing GeoPackages: To remove a GeoPackage from the project, click on an entry ending in '.gpkg' immediately below the main (top-level) GeoPackages sub-layer to highlight it. Then right-click on the highlighted entry and select **'Remove',** or choose **'Remove All'** to empty all GeoPackage

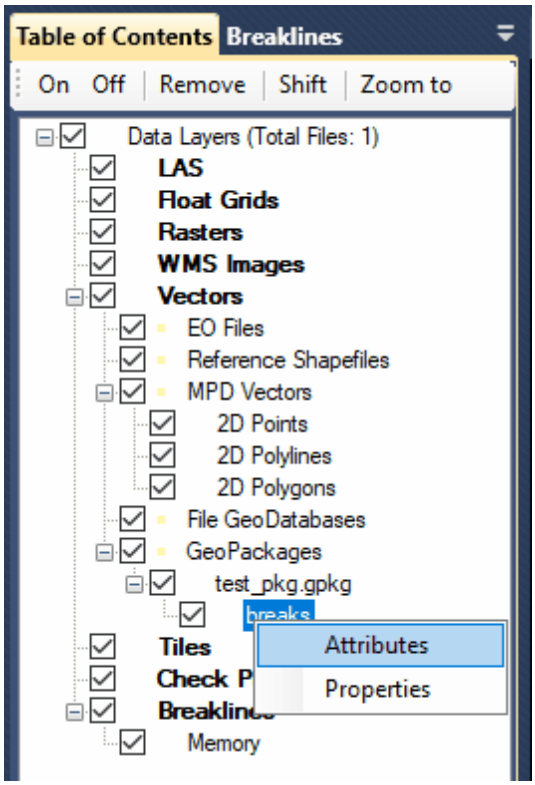
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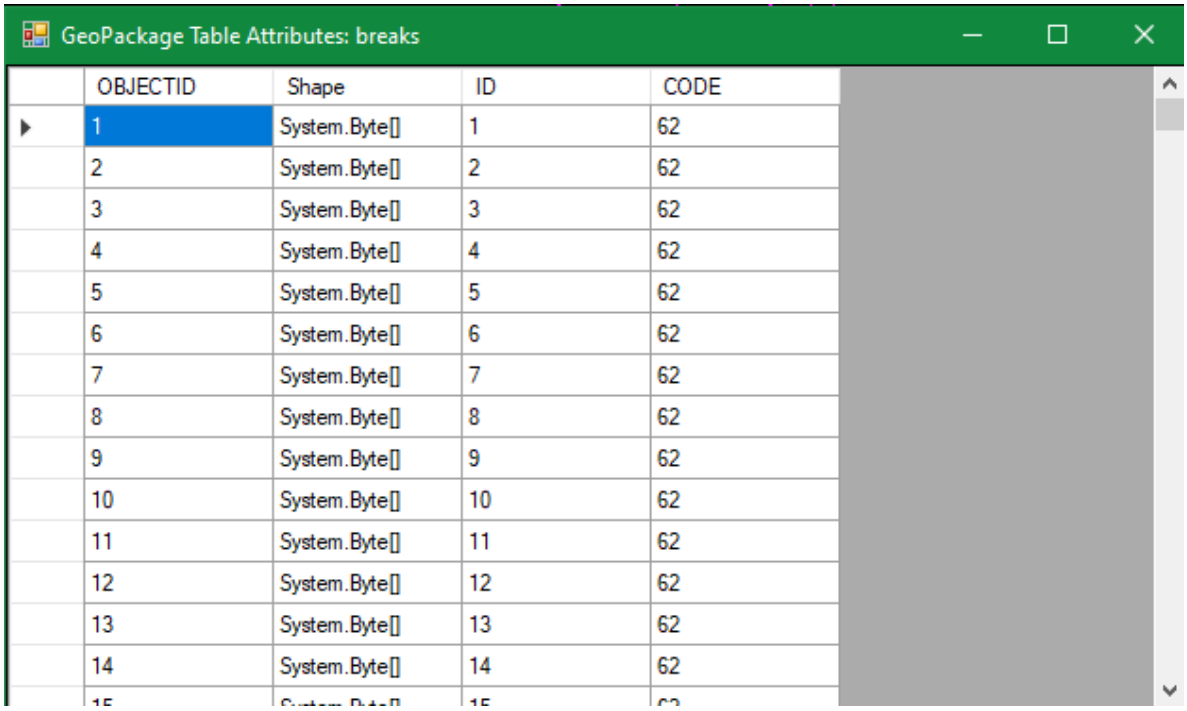
entries from the Table of Contents. Another way to remove data from the GeoPackage sub-layer is to highlight the entry that needs to be removed, and click on the '**Remove**' button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple entries which are to be removed.



Viewing GeoPackage Layer Attributes: To view a GeoPackage layer's attribute table, click on the layer entry to highlight it. Then right-click on the entry and select **'Attributes'.** The attribute table and labeling fields will appear in a new window. Editing of layer attribute tables is not possible in MARS®.

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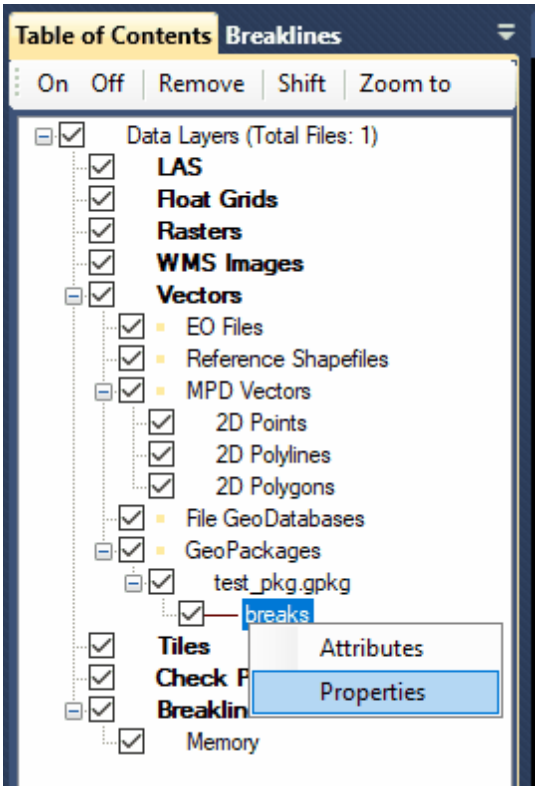


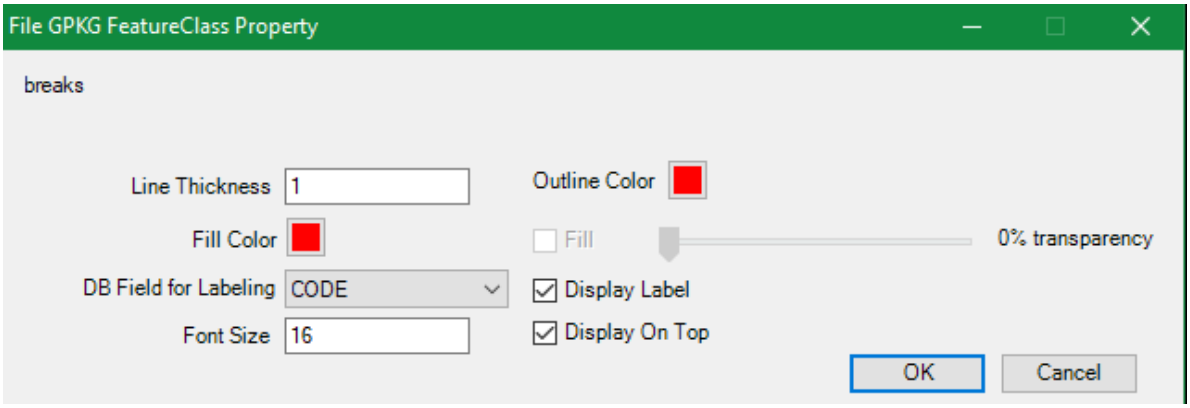
OBJECTID	Shape	ID	CODE
1	System.Byte[]	1	62
2	System.Byte[]	2	62
3	System.Byte[]	3	62
4	System.Byte[]	4	62
5	System.Byte[]	5	62
6	System.Byte[]	6	62
7	System.Byte[]	7	62
8	System.Byte[]	8	62
9	System.Byte[]	9	62
10	System.Byte[]	10	62
11	System.Byte[]	11	62
12	System.Byte[]	12	62
13	System.Byte[]	13	62
14	System.Byte[]	14	62

Changing GeoPackage Layer Display Properties: To change the properties of a GeoPackage layer, left-click on the desired entry to highlight it, then right-click and select **'Properties'**. The layer

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name is displayed, along with several options for controlling the display of the layer, in the interface that appears. Currently, the 'Line Thickness' and 'Outline Color' can be set as well as labeling options for the features in the layer. To label features with an attribute value, select that attribute from the 'DB Field for Labeling' drop-down list and check the 'Display label' box. The 'Font Size' of the labels can also be set. Font color will be the same as 'Outline Color.' The additional controls in the properties interface may be enabled in a future release.





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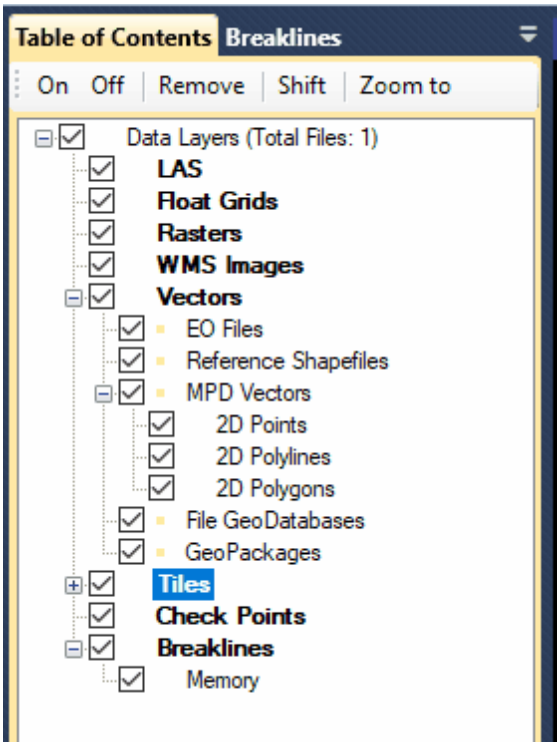
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2.2.6 Tiles (SHPs)

Tiles Layer

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➤**Tiles Layer (for polygon shapefiles or tile layouts)** - The **'Tiles'** layer allows the loading of a tile shapefile or layout into a project. It also allows the user to toggle display of the shapefile, remove the file, zoom to the file, and view or change the attributes and properties of the file. Only ONE shapefile can be added to the **'Tiles'** layer at a time, and only polygon shapefiles should be loaded in the **'Tiles'** layer. If a second tile layout is added, it will replace the current loaded one.

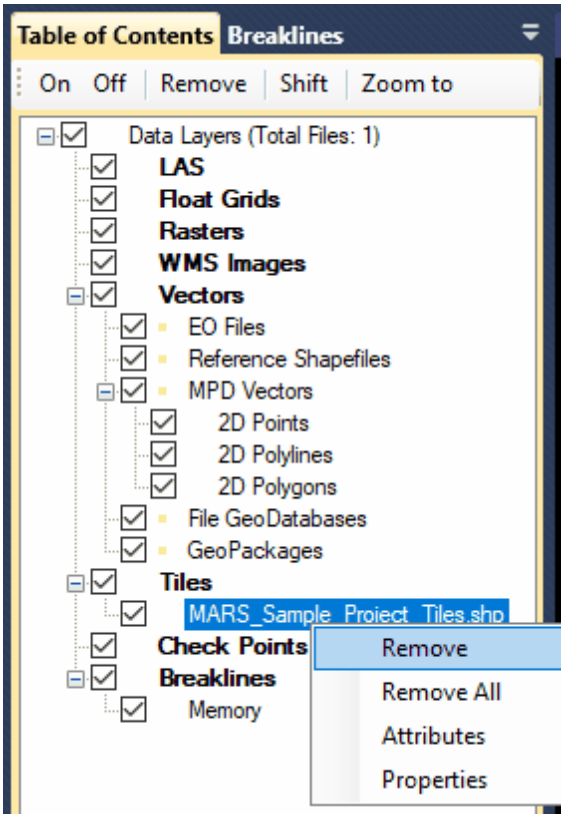


Adding a Tile Shapefile: To add a tile shapefile, see the 'Add Tile Shapefile' section in the Project/

Data Preparation Tab 162 topic.

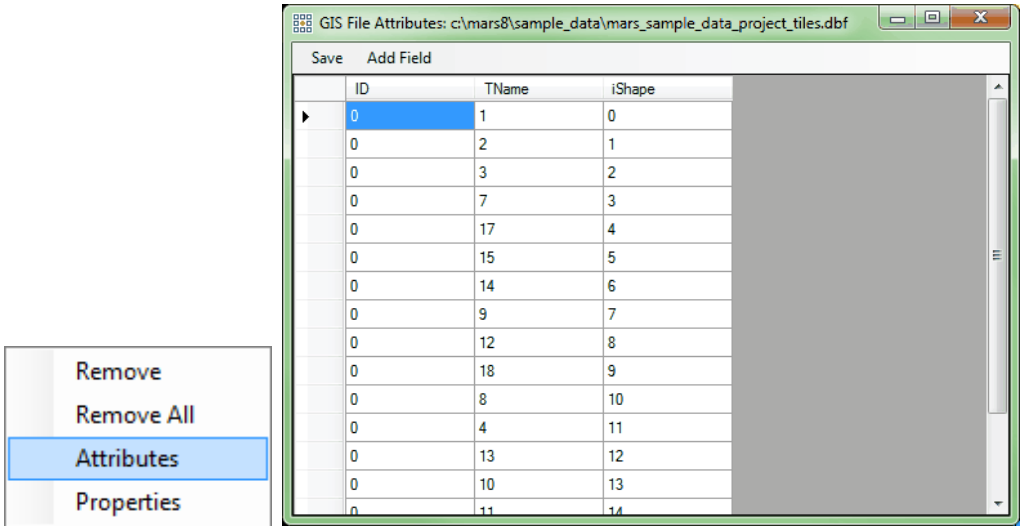
Expanding the Tiles Layer: Click on the '⊞' button to expand the 'Tiles' layer. The loaded tile shapefile will appear under this layer. There are three ways to turn on/off the display of the file loaded under the 'Tiles' layer: 1) check/uncheck the **'Tiles'** layer box, 2) check/uncheck the box next to the tile shapefile or, 3) click on the **'On'** or **'Off'** buttons at the top of the Table of Contents while the file is highlighted. Make sure the **'Tiles'** layer box is checked to view the file loaded beneath it; if this master box is not checked 'on' the file will not be displayed.

Removing the Tile File: To remove the shapefile from the Tiles layer, click on the file to highlight (select) it. Right-click on the file and choose **'Remove'**. Another way to remove the shapefile from the layer is to highlight the file and click on the **'Remove'** button found at the top of the Table of Contents.

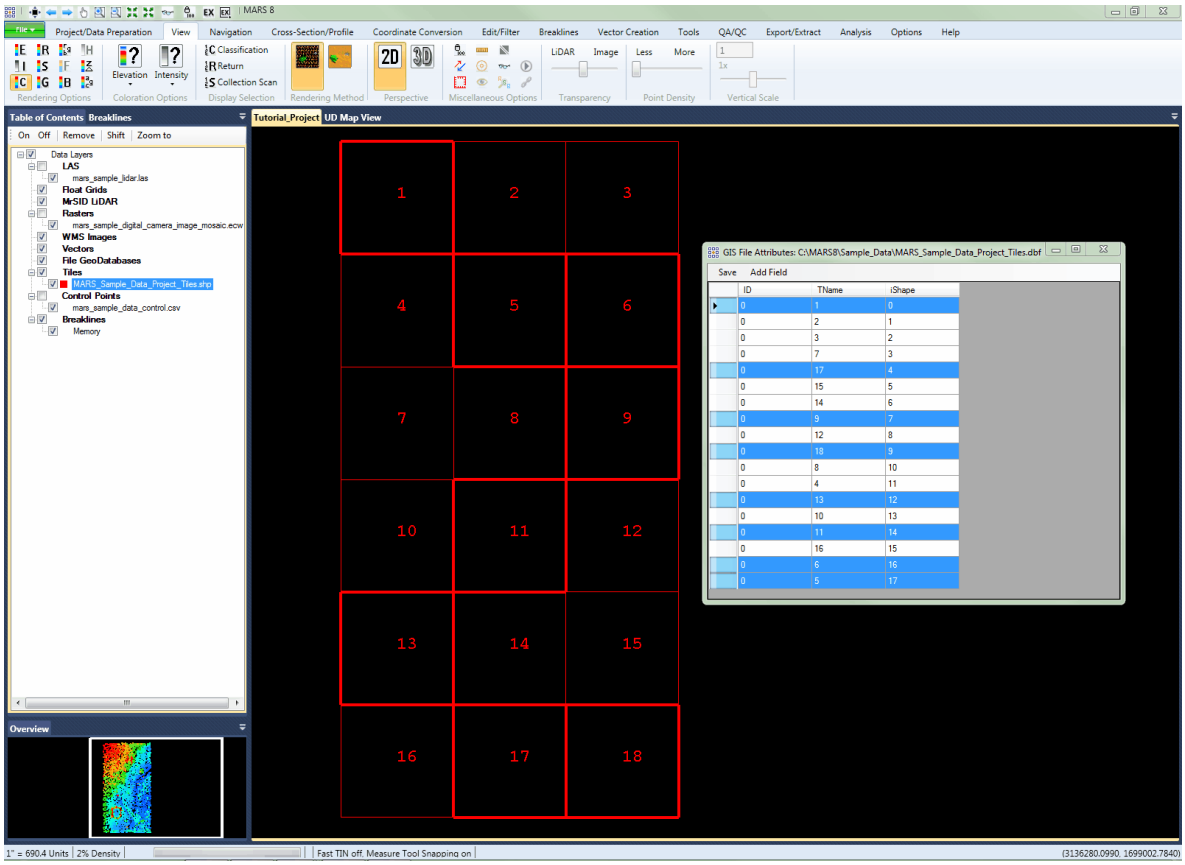


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Viewing or Editing Shapefile Attributes: To view or edit a shapefile's attribute table, click on the shapefile in the table of contents to highlight it. Then right-click on the shapefile and select **'Attributes'.** The attribute table and labeling fields will appear in a new window. It is possible to use the attribute table to select tiles or polygons from the shapefile. Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the appropriate polygons/tiles. There is a linked selection between the polygons selected and the corresponding rows (features) in the attribute table. Polygons or tiles selected using the 'Pick Tiles' utility will show up as selected, or highlighted, inside the attribute table. This linked selection also works vice versa. The user may use the 'Shift' and 'Ctrl' keys on the keyboard to select rows pertaining to specific tiles in the attribute table and those specified polygons/ tiles will be highlighted in the LAS Map View window.



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It is possible to edit the attribute table of a shapefile by adding new fields, or changing the contents of those fields. The only exception is the 'iShape' field, which cannot be edited. To add a new column or field to the attribute table, click on the 'Add Field' button at the top of the window. The 'Add Field' window will appear and the user may specify the restrictions of the new field.

Creating a New Field:

1) First, give the new field a name in the **'Field Name'** text box. The attribute table will display up to 10 characters in the column heading.
2) Then define the **'Field Type'** to be used in the new column.
3) Define the **'Width'** of the column. The width defines how many characters will fit inside the defined field. For example, if the user chooses a 'Width' of 20, then only twenty characters will be saved in the newly defined field. If the

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user is creating a 'Comments' field, the width of the new field should be larger to accommodate any needed characters for comments. If the user is creating a 'Date' field, which requires only ten characters at most, then the width may be smaller. When using the 'Logical' field type, the user-specified width does not matter, as only one character (a check mark) is used in this field.

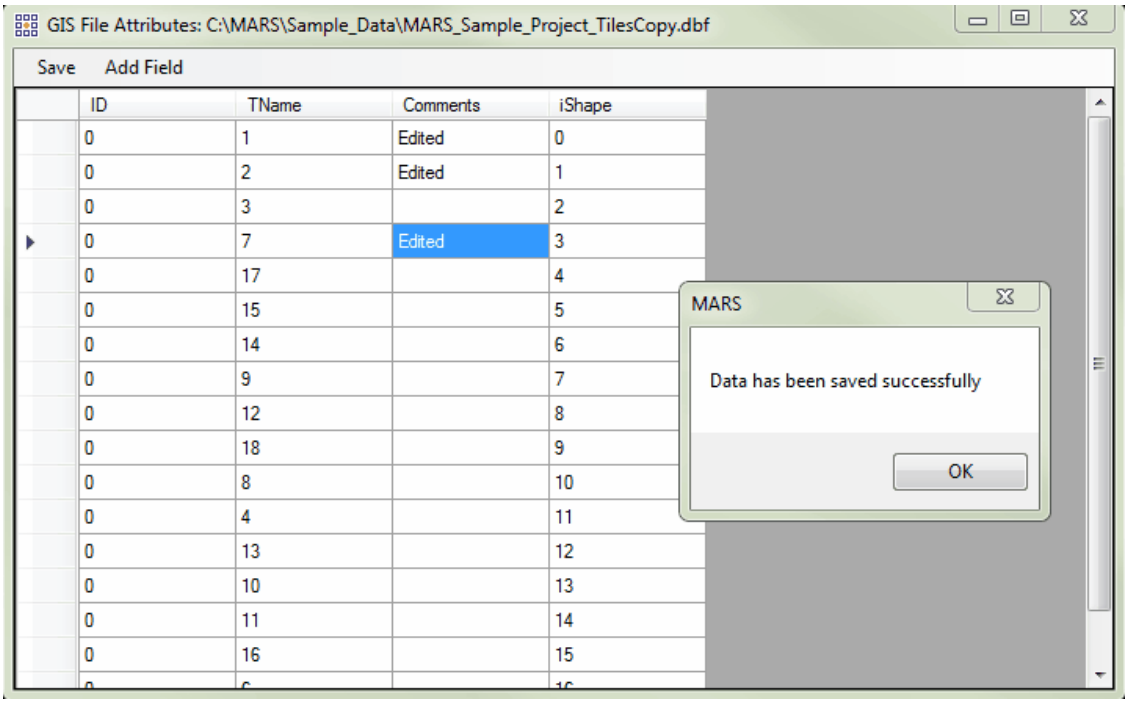
4) In the **'Number of Decimals'** text box (only enabled for certain 'Field Type' choices) the user may specify the number of decimals which will be allowed in the newly defined field. If the user chooses '0' then all numbers entered into the newly created field will have to be integers.

5) Click the 'OK' button when finished, and then click the 'Save' button in the upper-left corner of the attribute table to make the new field permanent.

Editing a Field:

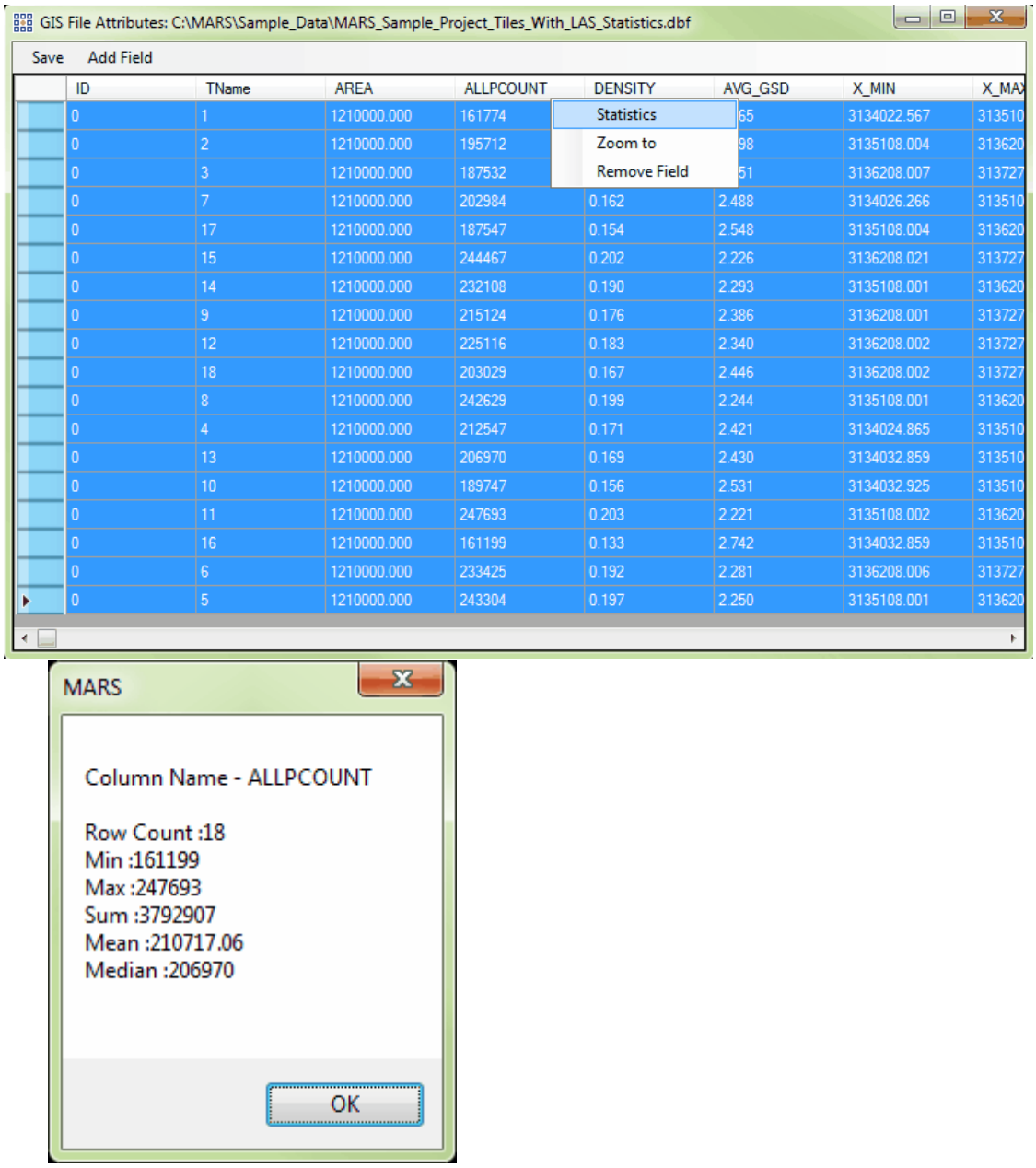
To edit any attribute information, double-click on the appropriate attribute and make the changes necessary. When finished, click on the 'Save' button in the upper-left corner to save the changed information. The user will receive a message confirming the data was saved inside the shapefile. This ability may be very useful when editing data to keep track of tiles or areas which have or have not been edited.

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It is also possible to view the statistics of attributes in a shapefile. The user may view the statistics of a single attribute, the statistics of an entire row or column, or the statistics of an entire table. Highlight the attributes of which statistics are to be viewed, right-click and choose **'Statistics'**. The resultant table will tell the user the following statistics: the row count, minimum, maximum, sum, mean (average), and median of every attribute. To select multiple attributes for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In the example below, the user is choosing to view the statistics of the entire 'ALLPCOUNT' column. The resulting statistics are also shown below.

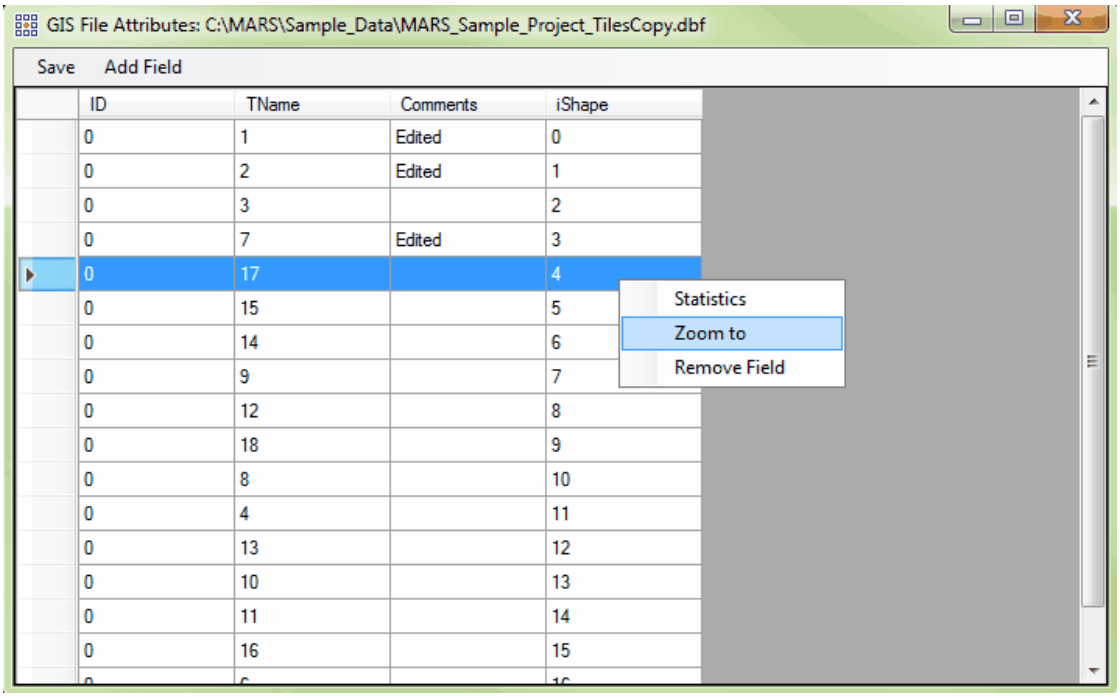
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ID	TName	AREA	ALLPCOUNT	DENSITY	AVG_GSD	X_MIN	X_MAX
0	1	1210000.000	161774		65	3134022.567	313510
0	2	1210000.000	195712		98	3135108.004	313620
0	3	1210000.000	187532		51	3136208.007	313727
0	7	1210000.000	202984	0.162	2.488	3134026.266	313510
0	17	1210000.000	187547	0.154	2.548	3135108.004	313620
0	15	1210000.000	244467	0.202	2.226	3136208.021	313727
0	14	1210000.000	232108	0.190	2.293	3135108.001	313620
0	9	1210000.000	215124	0.176	2.386	3136208.001	313727
0	12	1210000.000	225116	0.183	2.340	3136208.002	313727
0	18	1210000.000	203029	0.167	2.446	3136208.002	313727
0	8	1210000.000	242629	0.199	2.244	3135108.001	313620
0	4	1210000.000	212547	0.171	2.421	3134024.865	313510
0	13	1210000.000	206970	0.169	2.430	3134032.859	313510
0	10	1210000.000	189747	0.156	2.531	3134032.925	313510
0	11	1210000.000	247693	0.203	2.221	3135108.002	313620
0	16	1210000.000	161199	0.133	2.742	3134032.859	313510
0	6	1210000.000	233425	0.192	2.281	3136208.006	313727
0	5	1210000.000	243304	0.197	2.250	3135108.001	313620

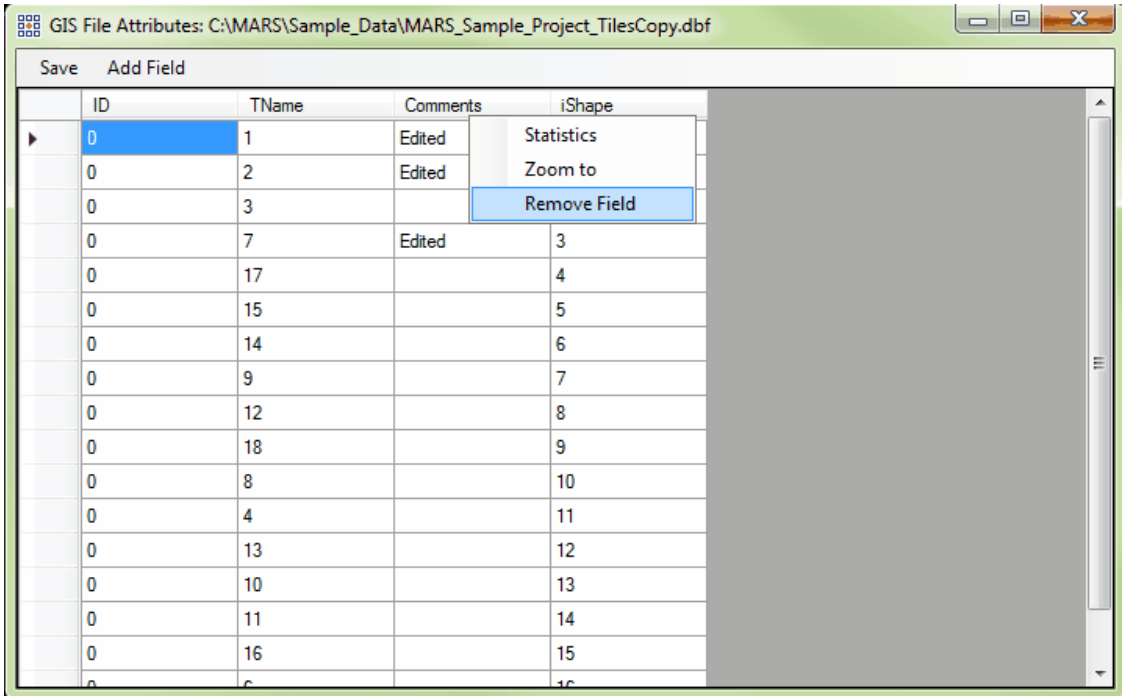
Lastly, it is possible to zoom to a particular feature (row) in an attribute table. To use this function, highlight a row and right-click anywhere on it. Right-click on the 'Zoom to' option and the highlighted feature will fit to the LAS Map View window.

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Deleting a Field:

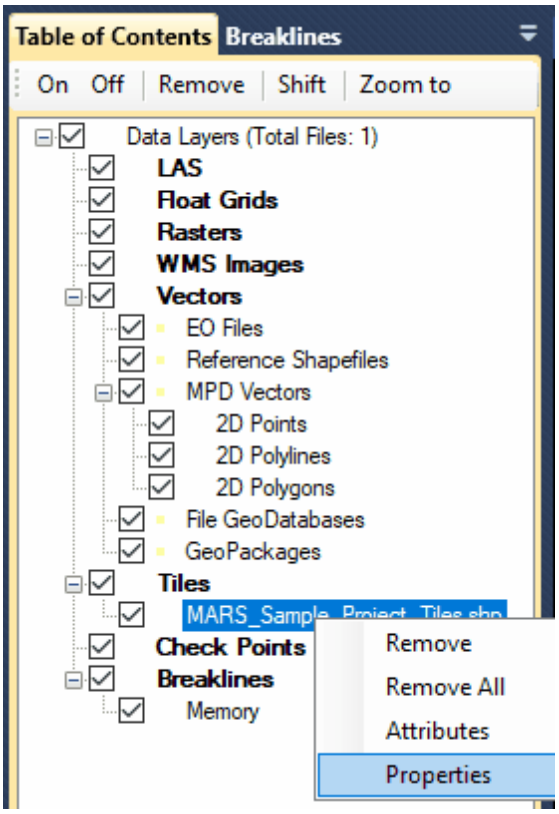
To delete an attribute field right-click on the column heading and choose 'Remove Field'. All information contained in this column, or attribute field, will be lost at this time. Click 'Save' in the upper-left to make this change permanent.

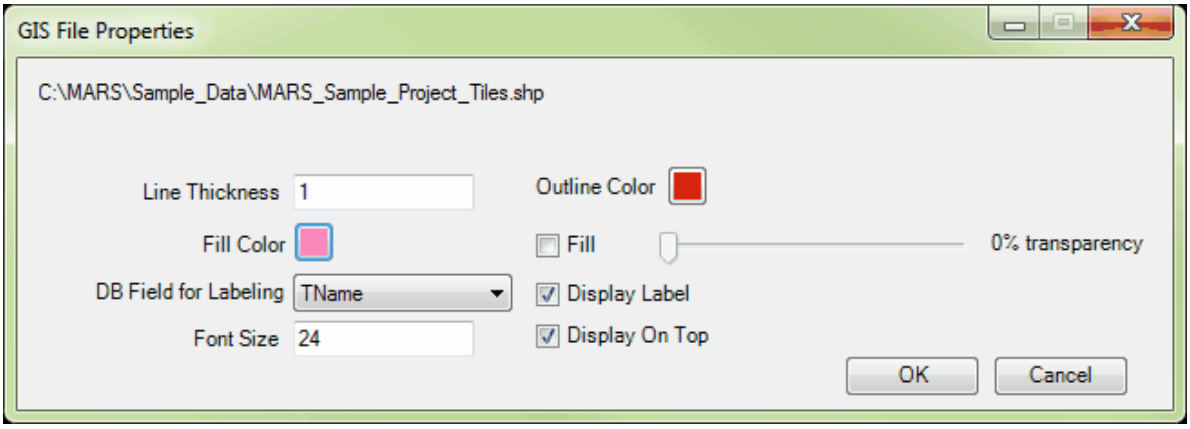


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Changing Tile Shapefile Display Properties: To change the tile shapefile properties, first expand the **'Tiles'** layer. (See the above instructions: **'Expanding the Tiles Layer'**.) Left-click on the desired file to highlight it, then right-click and choose **'Properties'**. The GIS File Properties window will display the full path and name of the tile shapefile, and allow the user to change the line thickness, the outline and fill colors, the font size of the displayed label, and the labeling field (information which comes from the shapefile's attribute table). The user may choose whether or not to display a label by checking or unchecking the box next to this option. The labeling field can be changed in the **'GIS File Properties'** window, or it can be changed inside the Table of Contents. After opening the **'Table of Contents'**, right-click on the tile shapefile in question and choose **'Properties'**. Under the **'DB Field for Labeling'** drop-down box, choose **'TName'** to show the tile names. The user's preference for the 'DB Field for Labeling' option will be stored by this tool until the MARS® application is closed. If the 'Tile Display Properties' window is re-opened, the default labeling field will reflect the most recent selection. The user may also choose to color fill the shapefile. When the 'Fill' box is checked, the transparency of the fill may be adjusted using the slider bar provided. To force the tile shapefile to display on top of other layers, check the **'Display On Top'** box.

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Zoom to the Tile Shapefile: To zoom to the extent of the *.shp file in the 'Tiles' layer, highlight the layer or the file and choose the **'Zoom to'** button found at the top of the Table of Contents. To zoom to a specific tile in the shapefile, double-click within it when the cursor is in Pan 825 mode.

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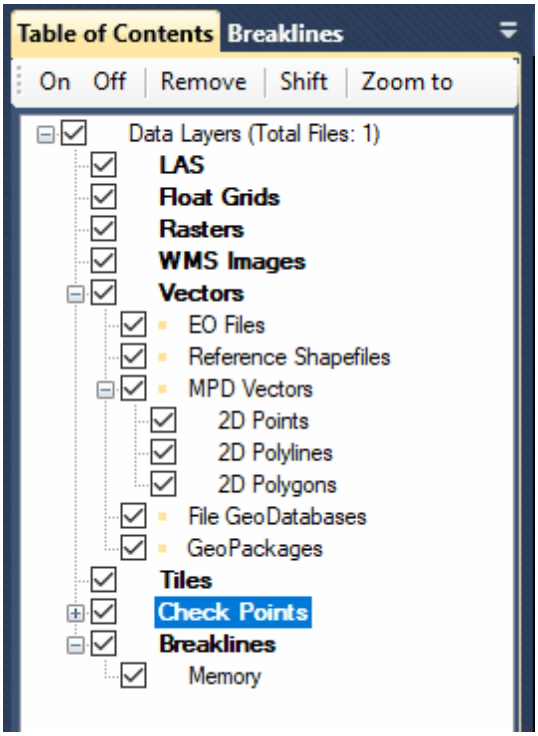
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2.2.7 Check Points (CSVs)

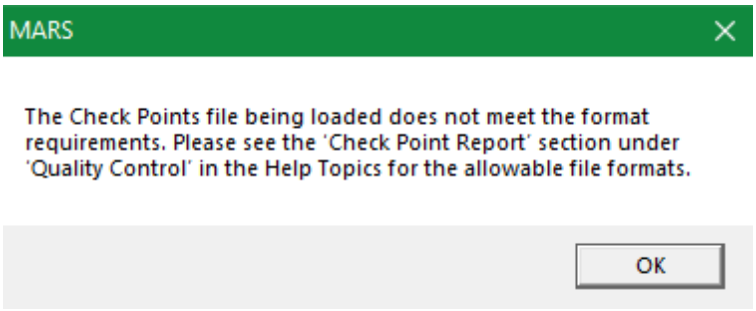
Check Points Layer

Merrick Advanced Remote Sensing (MARS®) Software

➤**Check Points Layer (for *.CSV files)** - The **'Check Points'** layer allows the loading of a check points file - in CSV format - into a project. This Table of Contents layer also allows the user to remove files, and view or change the properties of the check points. Only ONE check points file can be added into this layer at a time. If a second check points file is added, it will replace the current loaded one.



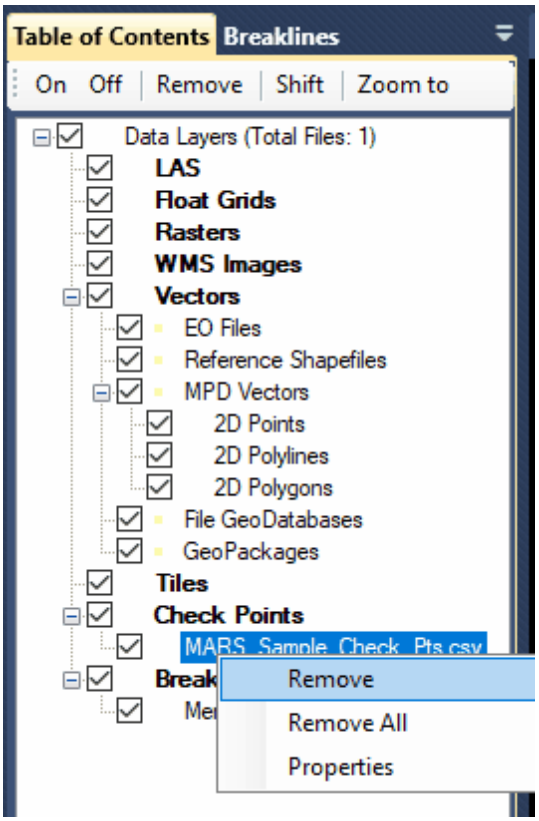
Adding a Check Points File: To add a Check Points file, see the 'Add Check Points Files' section in the Project/Data Preparation Tab 162 topic. CSV files loaded into this layer will be tested for compliance with either of the two allowable formats, 13-column 1225 or 7-column 1228. Any other detected format will cause a warning pop-up message to be displayed, as shown below.



Expanding the Check Points Layer: Click on the '⊞' button to expand the 'Check Points' layer. The loaded check points file will appear under this layer. There are three ways to turn on/off the display of the file loaded under the 'Check Points' layer: 1) check/uncheck the **'Check Points'** layer box, 2) check/uncheck the box next to the check points file or, 3) highlight (select) the file entry and use the **'On'** or **'Off'** buttons at the top of the Table of Contents. Make sure the **'Check Points'** layer box is checked to view the file loaded in the layer; if this master box is not checked 'on' the file will not be displayed.

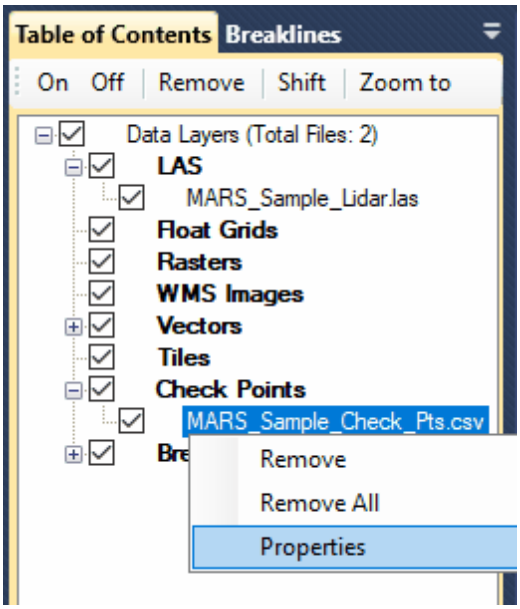
Removing the Check Points File: To remove the file from the Check Points layer, click on the file to highlight (select) it. Right-click on the file and choose **'Remove'**. Another way to remove the check points file from the layer is to highlight the file and click on the '**Remove**' button at the top of the Table of Contents.

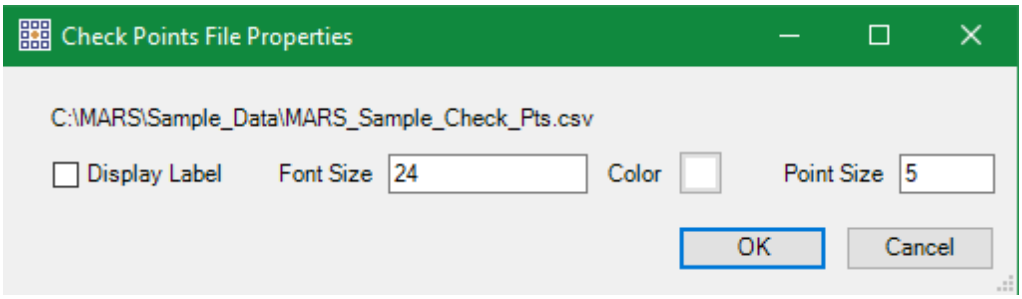
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Viewing and Changing the Properties of the Check Points File: To view or change the properties of the check points file, right-click on the file and choose '**Properties**'. The ID label of the check points can be displayed, the font size for labels can be changed, and the display color and point size can be modified.

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Zoom to the Check Points File: To zoom to the extent of the file in the 'Check Points' layer, highlight the layer or the file and click the **'Zoom to'** button at the top of the Table of Contents.

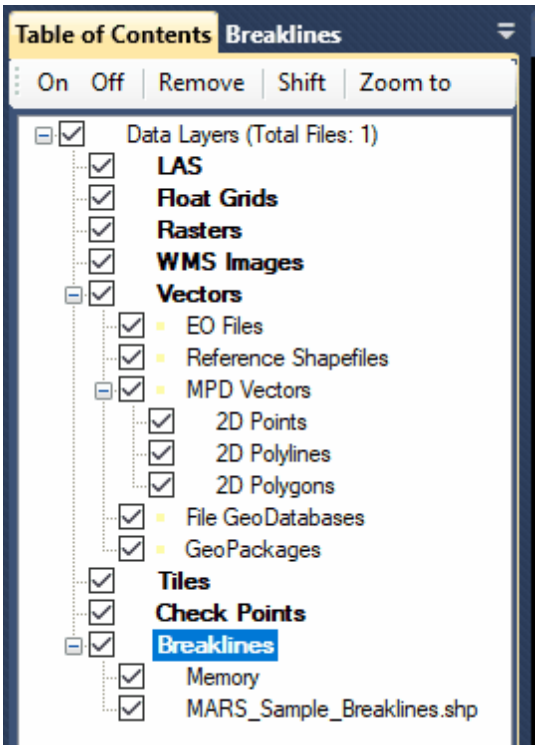
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2.2.8 Breaklines (SHPs)

Breaklines Layer

Merrick Advanced Remote Sensing (MARS®) Software

➤**Breaklines Layer (for shapefiles) -** The **'Breaklines'** layer shows the breakline shapefiles (.shp) that are currently loaded in MARS®, plus any breaklines being compiled ('Memory'). It also allows the user to remove files, view or change the attributes of the breaklines, and view or change some properties of the breaklines. The 'Memory' entry is for turning on/off the display of compiled breaklines before they are saved as a breakline shapefile. Individual breakline types (codes) can be toggled on/off using the Breaklines Window 142.



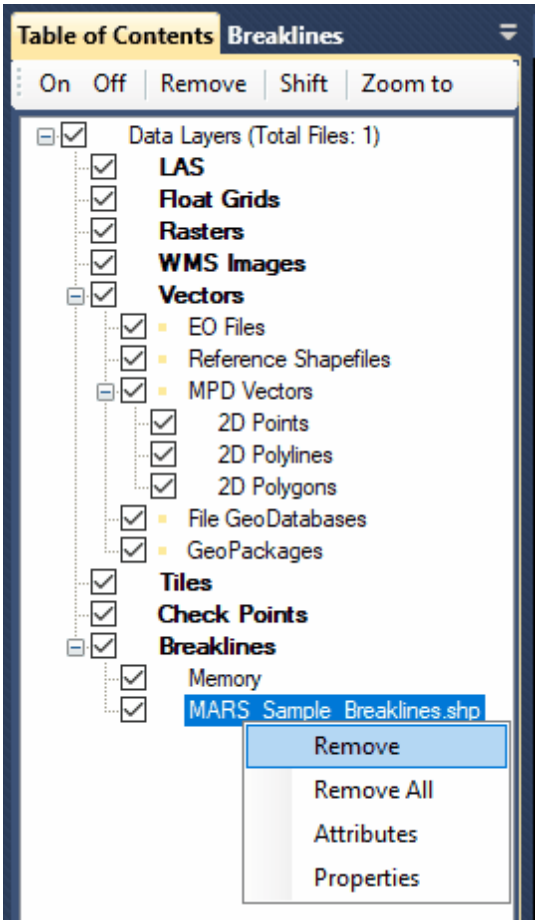
Adding Breaklines Files: To add a breaklines file, see the 'Add Breaklines from Shapefile' section in the Project/Data Preparation Tab 162 topic.

Expanding the Breaklines Layer: Click on the '⊞' button to expand a list of the files loaded under the 'Breaklines' layer. There are three ways to turn on/off the display of the file loaded under the 'Breaklines' layer: 1) check/uncheck the **'Breaklines'** layer box, 2) check/uncheck the box next to

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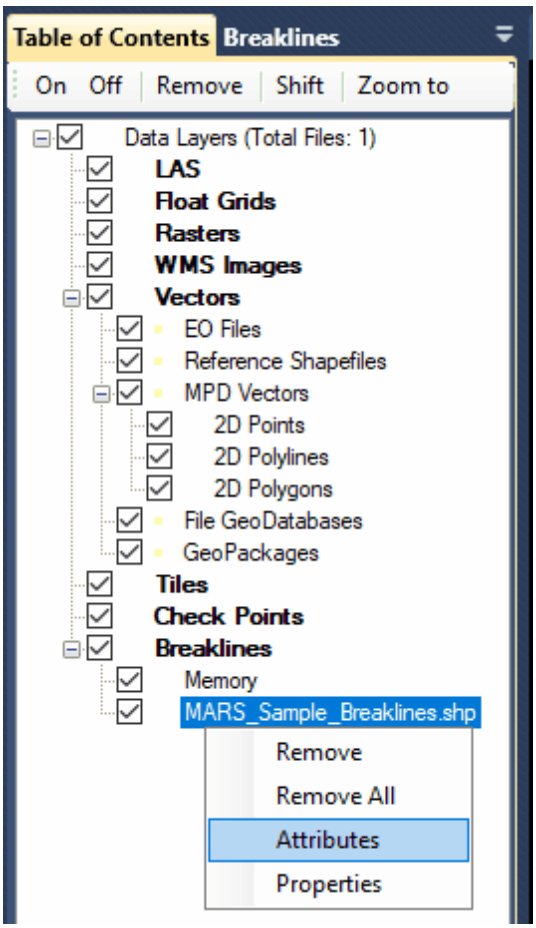
the breakline file(s) to be turned on/off or, 3) click on the 'On' or 'Off' buttons at the top of the Table of Contents while the appropriate files are highlighted. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files. Make sure the **'Breaklines'** layer box is checked to view the files loaded beneath it; if this master box is not checked 'on' the files will not be displayed.

Removing a Breakline File: To remove a file from the Breaklines layer, click on the file that is to be removed to highlight it. Right-click on the file and choose **'Remove'** to remove only the highlighted file. To remove all breaklines files, right-click and choose **'Remove All'** - all breaklines files currently loaded will be unloaded. Another way to remove data from the layer is to highlight the file that needs to be removed, and click on the **'Remove'** button found at the top of the Table of Contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to select multiple files which are to be removed.

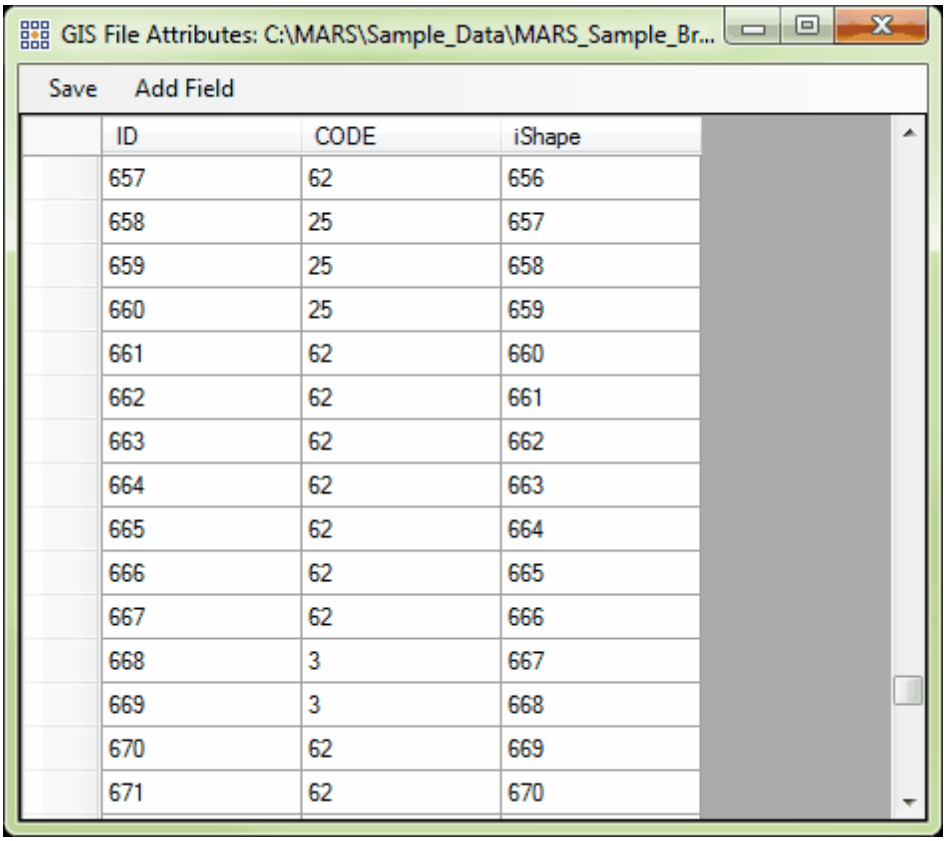


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Viewing or Editing Breakline Attributes: To view a breakline shapefile's attribute table, click on the shapefile to highlight it. Then right-click on the shapefile and select **'Attributes'**. The attribute table and labeling fields will appear in a new window. It is possible to use the attribute table to select tiles or polygons from the shapefile. Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the appropriate polygons. This useful tool can be used vice versa, polygons or tiles selected using the 'Pick Tiles' utility will show up as selected inside the respected attribute table. To edit the attributes, double-click on the appropriate attribute and make the needed changes. Click on the 'Save' button in the upper-left corner to save the file. The 'iShape' field cannot be edited.



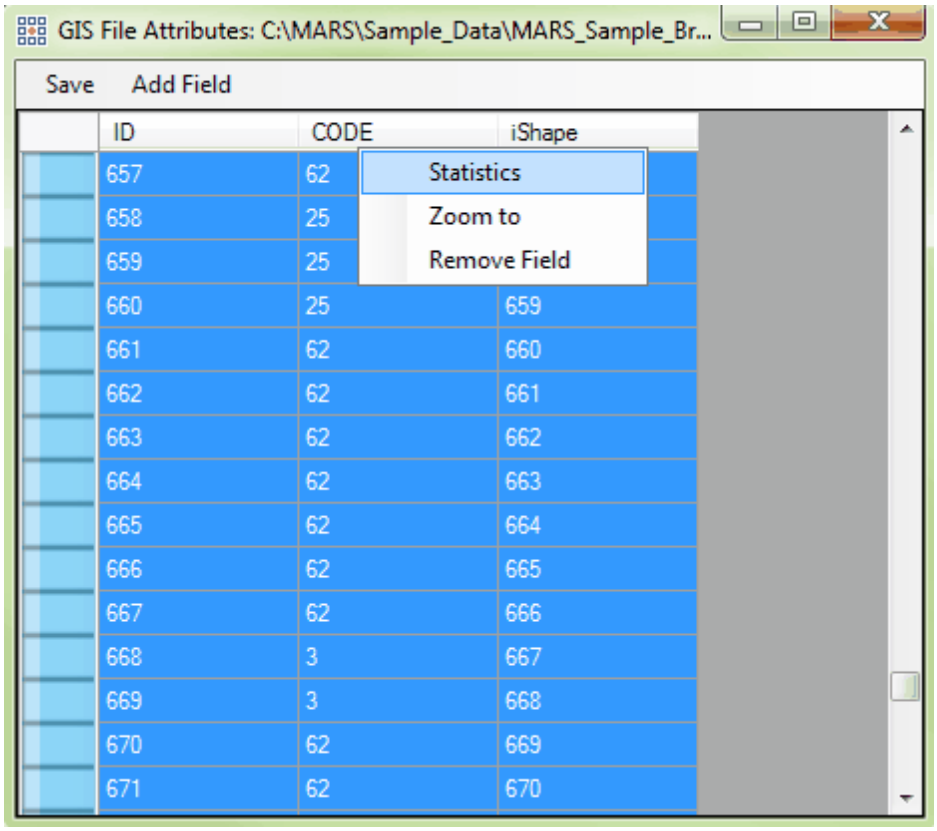
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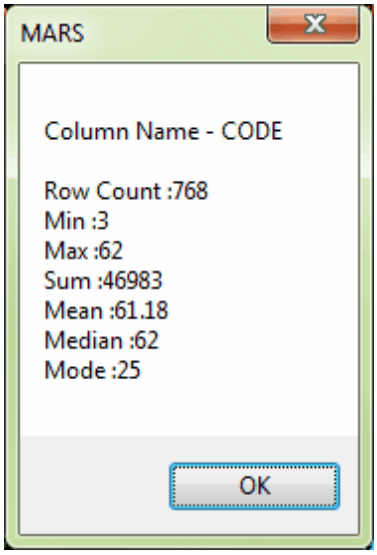


ID	CODE	iShape
657	62	656
658	25	657
659	25	658
660	25	659
661	62	660
662	62	661
663	62	662
664	62	663
665	62	664
666	62	665
667	62	666
668	3	667
669	3	668
670	62	669
671	62	670

It is also possible to view the statistics of breakline attributes in a shapefile. The user may view the statistics of a single attribute, the statistics of an entire row or column, or the statistics of an entire table. Highlight the attributes of which statistics are to be viewed, right-click and choose 'Statistics'. The resultant table will tell the user the following statistics: the row count, minimum, maximum, sum, mean (average), median, and mode of every attribute. To select multiple attributes for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In practical use, the 'CODE' field is the only useful attribute in a breakline shapefile, and the statistics that might be helpful include 'Row Count', 'Min', 'Max', and 'Mode'. In the example below, the user is choosing to view the statistics of an entire row. In the example below, the user is choosing to view the statistics of the entire 'CODE' column. An example of a resulting statistics window is also shown below.

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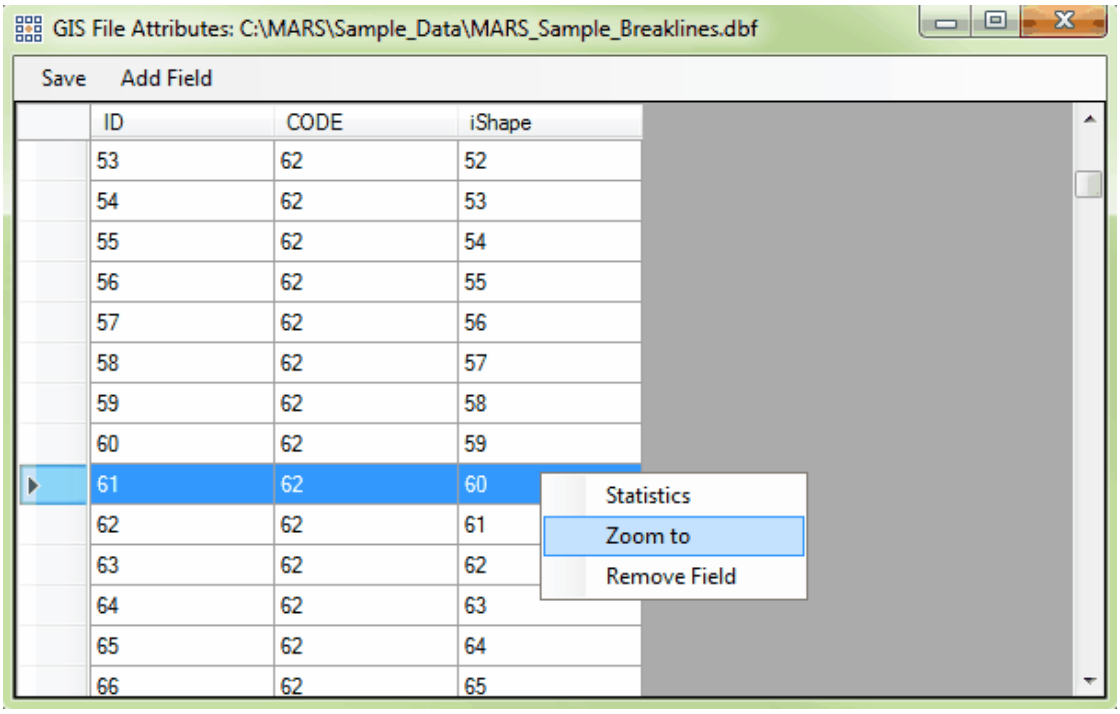




Lastly, it is possible to zoom to a particular feature (row) in an attribute table. To use this function, highlight a row and right-click anywhere on it. Right-click on the 'Zoom to' option and the highlighted feature will fit to the LAS Map View

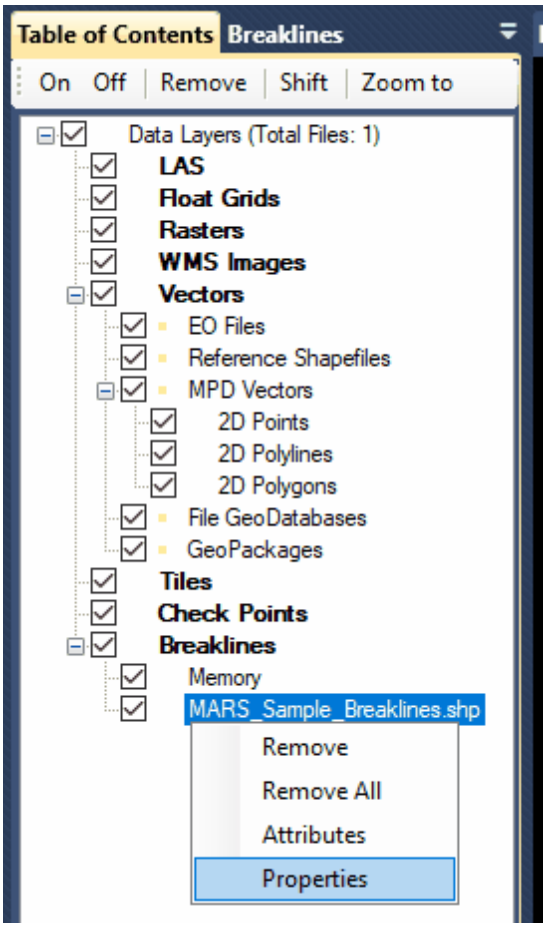
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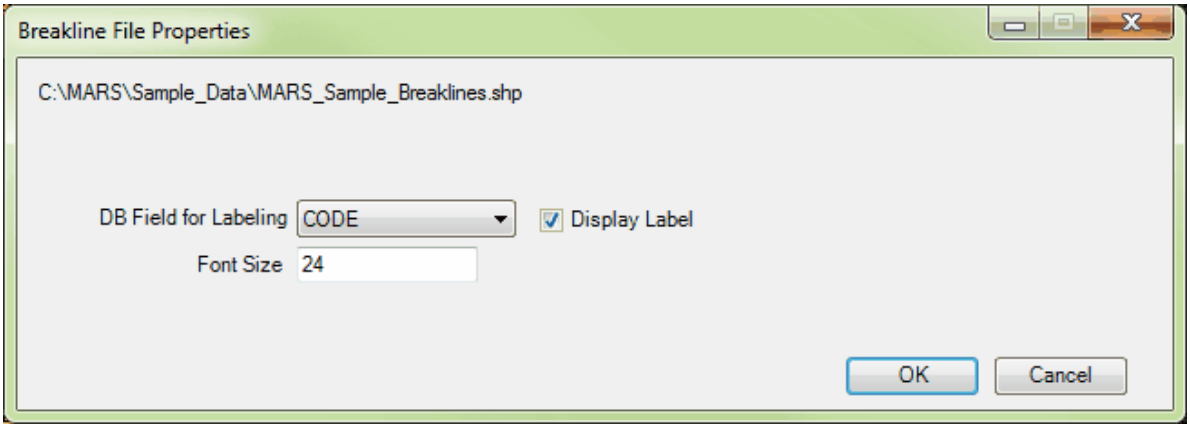
window.



Changing Shapefile Display Properties: To change the breakline shapefile feature labeling properties, left-click on the chosen file to highlight it. Then, right-click and choose **'Properties'**. The labeling field, font size, and the status of the 'Display Label' checkbox can now be changed through the dialog that appears. Other properties, such as line style, line thickness (weight), and color can be changed using the 'Breakline Properties' tool on the Breaklines Tab 298.

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Zoom to a Breakline Shapefile: To zoom to a *.shp file in the 'Breaklines' layer, highlight the file and choose the **'Zoom to'** button found at the top of the table of contents. Use the **'Shift'** and **'Ctrl'** keys on the keyboard to highlight multiple files and zoom to their combined extent. This function will not work on breaklines saved to memory.

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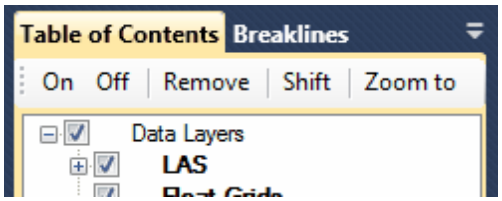
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2.3 Breaklines Window

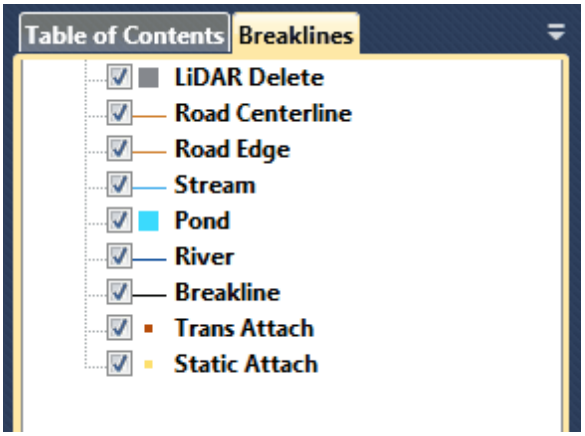
Breaklines Window

Merrick Advanced Remote Sensing (MARS®) Software

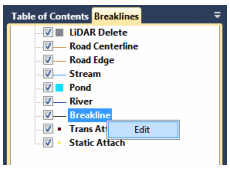
The Breaklines window allows the user to quickly and easily access control over the color, Z mode, and display of individual breakline feature types. To access the Breaklines window, choose the 'Breaklines' tab at the top of the Table of Contents 67.



After choosing the 'Breaklines' tab, a list of the breakline types (feature names) currently defined in the Breakline Properties will become available in place of the layers in the Table of Contents area. The display of individual features can be controlled by checking or unchecking the boxes.



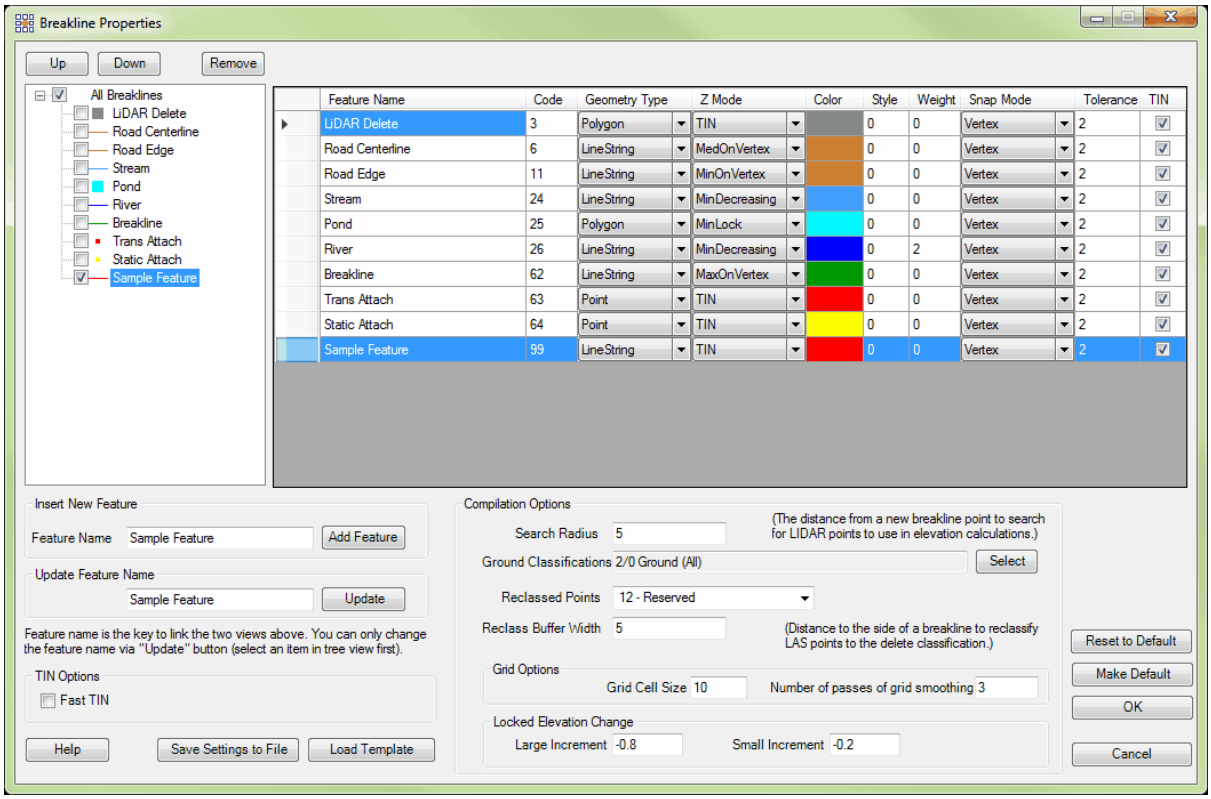
To make any changes to the breakline features listed in the window, right-click on any one of the features and choose **'Edit'**. The **'Breakline Properties'** interface will open. With this interface, the user may change the display thickness (weight) and color of the features, change, add, or delete feature names, or change the tolerance, ZMode, or style of any of the breakline features. Many other parameters are also available to be edited in this interface. Please see the 'Breakline Properties' section of the Breaklines Tab 298 topic for details.



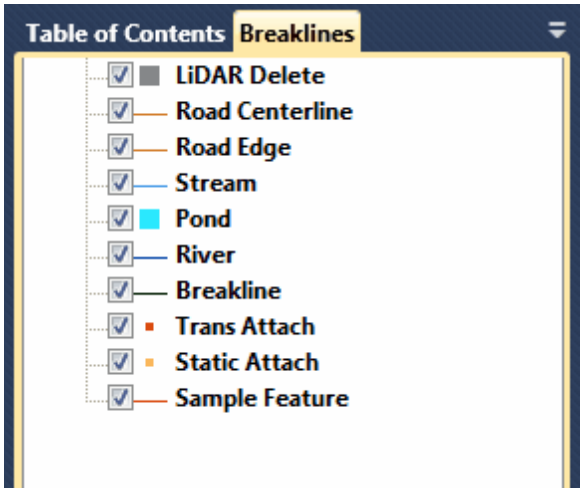
When any changes are made to the breakline features in the 'Breakline Properties' interface, the change will automatically be reflected in the Breaklines window. The example below shows the addition of a breakline feature. The corresponding screen shot then shows those changes automatically updated in the Breaklines window.

In the example below, 'Sample Feature' has been added to the breakline feature list.

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The changes made above have been reflected in the Breaklines window.



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2.4 LAS Map View Window

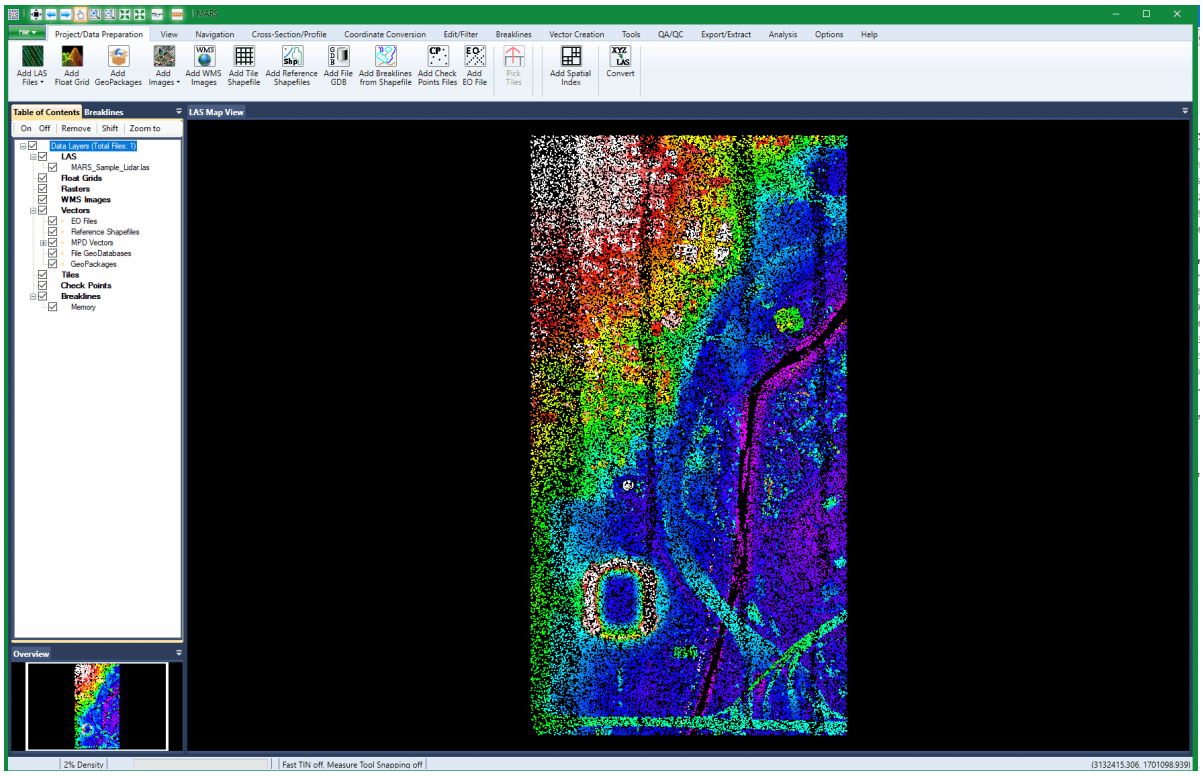
LAS Map View Window

Merrick Advanced Remote Sensing (MARS®) Software

The LAS Map View window is where all data loaded into MARS® and checked on in the Table of Contents 67 will be displayed. Its width can be re-sized by dragging the separator line between it and the Table of Contents left or right. The window is identified by a tab at its upper-left corner labeled 'LAS Map View.'

MARS® supports drag-and-drop from Windows File Explorer for LAS files, SHP files (loaded in the Reference Shapefiles layer), CSV-format Check Points files, and supported raster formats. Files can be dropped into the LAS Map View window or the Table of Contents window.

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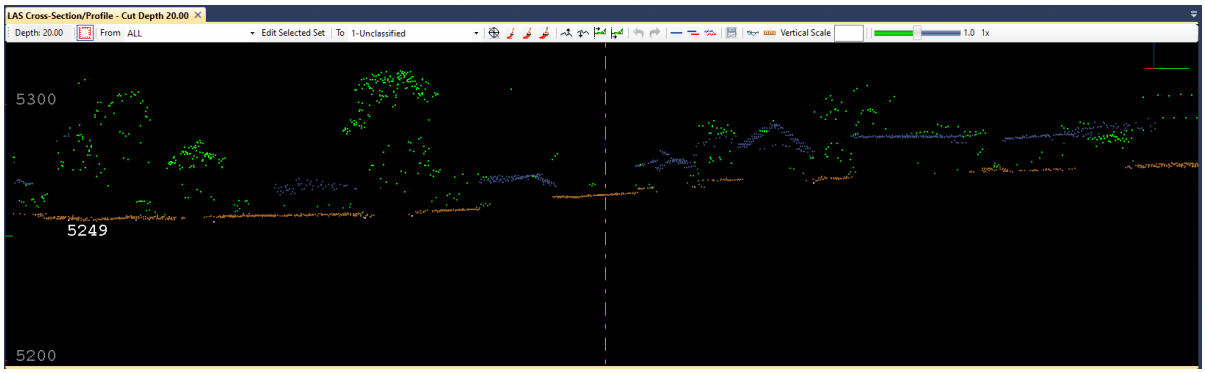
2.5 Cross-Section/Profile Window

Cross-Section/Profile Window

Merrick Advanced Remote Sensing (MARS®) Software

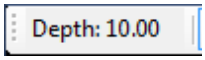
The Cross-Section/Profile window will appear any time either the 'Place Cross-Section/Profile Line' or 'Place Adjustable Cross-Section/Profile Line' tools are used. These buttons are found on the Cross-Section/Profile Tab 240. The window may be undocked by right-clicking on its tab (yellow area at upper-left of image, below) and choosing 'Float.' The window may then be dragged by its title bar to any location, including a second monitor. To re-dock, right-click on the title bar and choose 'Dock as Tabbed Document.' An optional edit toolbar can be enabled at the top of the window by checking the

'Show toolbar in cross-section window' box in the 'Miscellaneous Options' interface on the Options Tab 519. This makes it easier to access the most commonly used tools without having to keep the 'Cross-Section/Profile Tab' active.



The Edit Toolbar:





Cut Area Depth: The current cut depth will be displayed on the edit toolbar in the cross-section/profile window. This tool is for informative purposes only. To change the default depth of the 'Place Cross-Section Line' tool, go to the **'Miscellaneous Options'** interface on the Options Tab 519 and make the appropriate changes in the 'Cross-Section/Profile Window' section. To change the current depth of the cross-section/profiling tool without changing the default value, enter the new value in the text box for 'Current Depth' on the Cross-Section/Profile Tab 240 or use the shortcut key **'D'** on the keyboard.



Show Scale Bar: Toggles the display of the Elevation scale bar in the Cross-Section/Profile window on/off. The values shown (along the left side) are in the loaded data's vertical units. Clicking in the Cross-Section/Profile window will cause a label to be displayed showing the

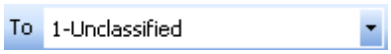
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cursor's elevation.



Source Classification: This allows the user to pick from ALL classes, a selected set of classes (see below), or any one of the 256 individual LiDAR classes to be the source class(es) for manual editing actions. During editing, the source class(es) will become re-classified to the target class.

Edit Selected Set: This function allows the user to make a selected set comprised of any combination of LiDAR classes to be used when the '- Selected -' option is chosen in the 'From Class' drop-down list.



Target Classification: This allows the user to pick from any one of the 256 individual LiDAR classes to be the target class for manual editing actions. During editing, the source class(es) will become re-classified to the target class.



Keep Profile Centered: This tool keeps data centered vertically in the cross-section/profile window by estimating a ground elevation and automatically adjusting the window to center that elevation. In steep terrain or near tall buildings this feature can produce unexpected results. To shut this off and allow the cross-section/profile to move without automatic centering, click the 'Keep Profile Centered' button to toggle it off. When the 'Keep Profile Centered' tool is not active, the cross-section/profile window can be dragged with the **'Pan'** 

tool to the user's area of interest.

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Edit Paint Small: Reclassifies points (referenced in the 'From' drop-down list) selected by the small paint brush in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the target class, press the 'Space Bar' or 'Enter' key on the keyboard. To cancel and unselect the points, right-click the mouse.



Edit Paint Medium: Reclassifies points (referenced in the 'From' drop-down list) selected by the medium paint brush in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the target class, press the 'Space Bar' or 'Enter' key on the keyboard. To cancel and unselect the points, right-click the mouse.



Edit Paint Large: Reclassifies points (referenced in the 'From' drop-down list) selected by the large paint brush in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the target class, press the 'Space Bar' or 'Enter' key on the keyboard. To cancel and unselect the points, right-click the mouse.



Edit Line String Above: Reclassifies all points (referenced in the 'From' drop-down list) above a user-drawn vector in the Cross-Section/Profile window only.



Edit Line String Below: Reclassifies all points (referenced in the 'From' drop-down list) below a user-drawn vector in the Cross-Section/Profile window only.



Edit Scrape Above: Reclassifies all points (referenced in the 'From' drop-down list) above the scrape tool cursor in the Cross-Section/Profile window only.

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 **Edit Scrape Below:** Reclassifies all points (referenced in the 'From' drop-down list) below the scrape tool cursor in the Cross-Section/Profile window only.

 **Undo/Redo:** These buttons allow the user to undo or redo manual edits made in the cross-section/profile window or the LAS Map View window.

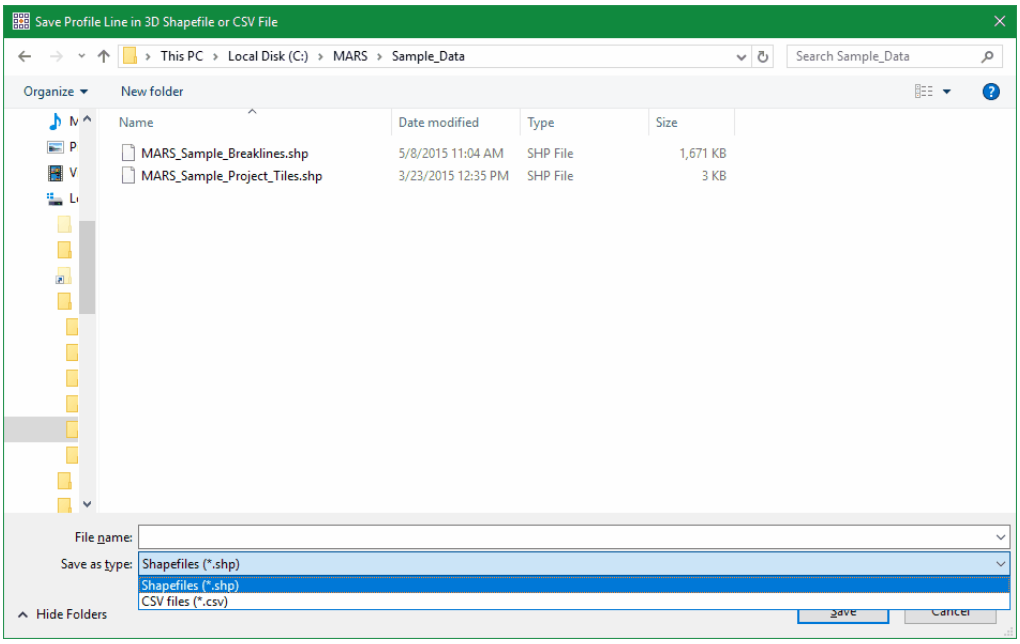
 **Profile Combined:** Displays a combined single line profile of all points for the displayed collection scans.

 **Profile by Collection Scan (not available with Evaluation license):** Displays a profile line for each displayed collection scan.

 **Cross Section:** Displays a cross-section view of the LiDAR points for the displayed collection scans.

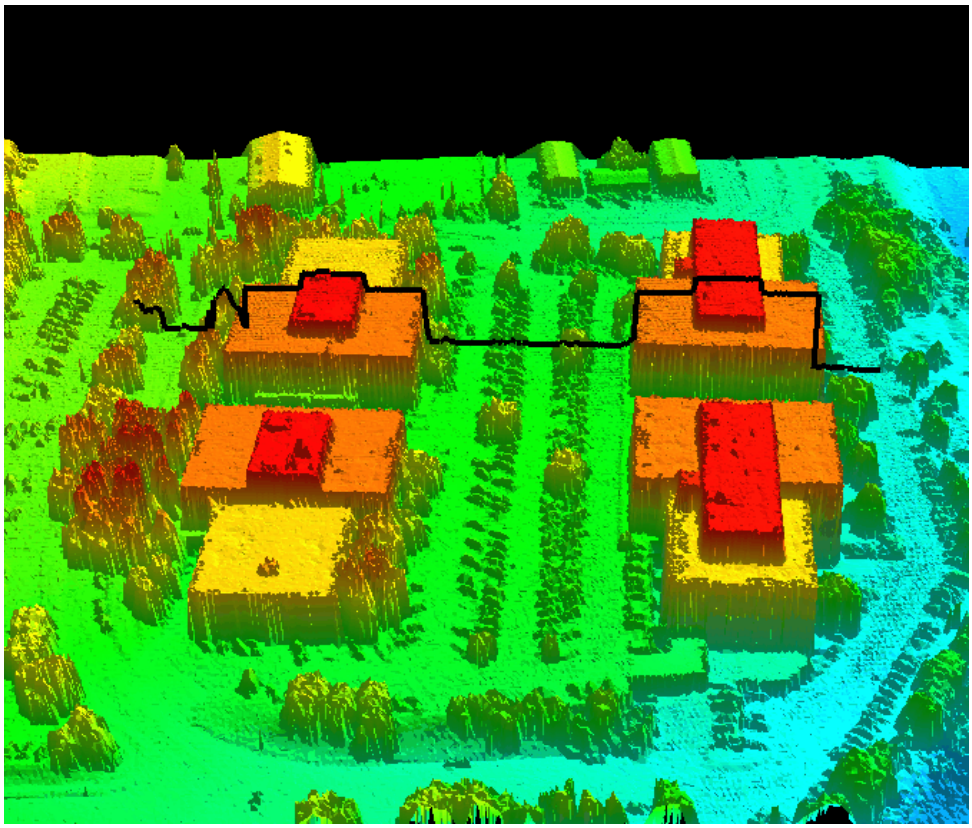
 **Save Profile Line:** This tool can create either a 3D shapefile, or a CSV file of XYZ values, for a combined profile (see above). The output file will be created from whatever profile is currently shown in the Cross-Section/Profile window. When a profile line shapefile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data. For shapefile output, the resulting shapefile can be loaded back into MARS® using the 'Add Reference Shapefiles' button on the Project/Data Preparation Tab 162, and displayed in 3D View 837. For CSV output, the resulting file of XYZ values can be opened in Excel. This tool is only available when the profile is rendered with the **'Profile Combined'** button  . For more information on the **'Profile Combined'** tool, please visit the Cross-Section/Profile Tab 240 topic.

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In the example below, the resultant 3D shapefile has been loaded into MARS® as a reference shapefile. It is shown below in 3D as the black line which profiles two of the four large buildings shown.

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 **Inspect:** This tool allows individual inspection of LiDAR points in the Cross-Section/Profile window. See the Inspect 943 tool topic for details.

 **Measure:** This tool makes measurements in the Cross-Section/Profile window based on the project's data units. See the Measure 957 tool topic for details.

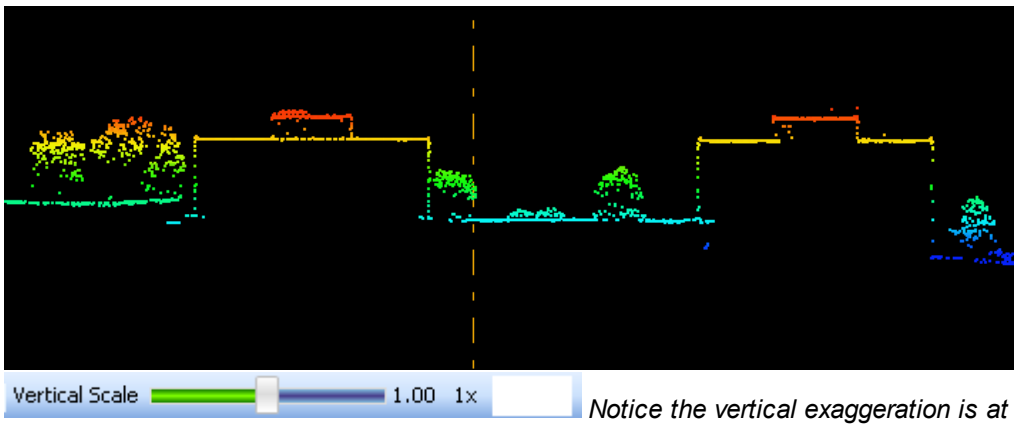


Vertical Scale Slider Bar: This vertical scale slider is only for use with cross-sections and profiles, and is synchronized with the vertical slider on the Cross-Section/Profile Tab 240. It can exaggerate or smooth the vertical data shown by

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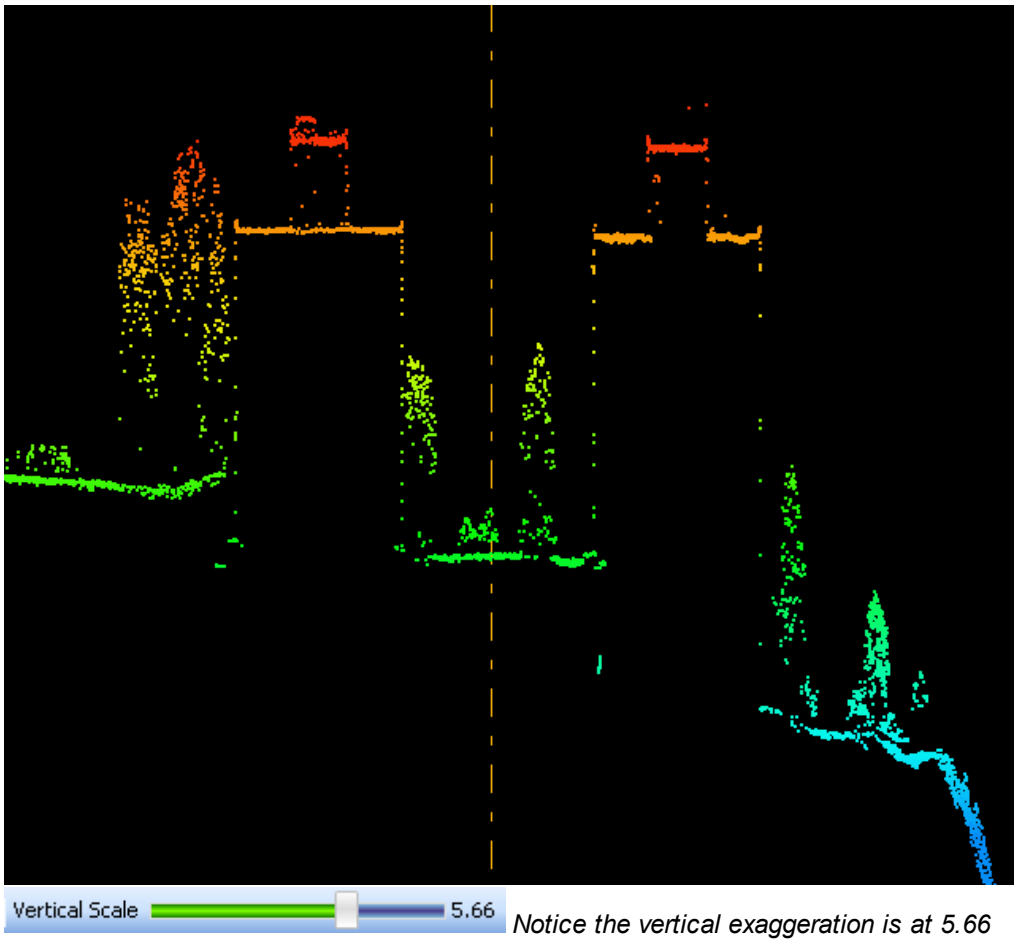
using the slider or by entering the desired scale factor in the scale text box between the label and the slider bar. The minimum value is 0.01 and the maximum is 1000. To return to the data's true scale, click the 1x button, or slide the bar until the exaggeration is shown to be 1.0 as in the example below.

See three examples of the Vertical Scale Slider working inside the Cross-Section/ Profile window below:

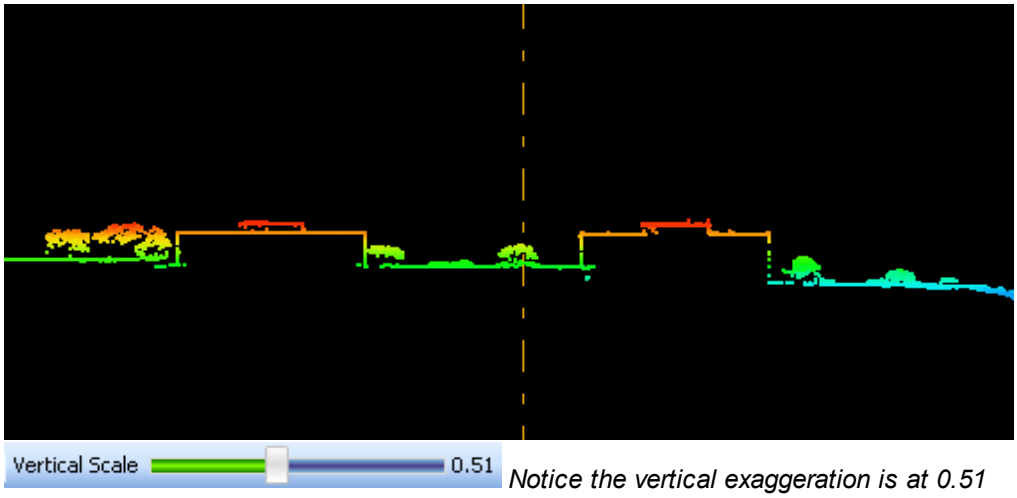


Notice the vertical exaggeration is at 1x - the true scale (1.0).

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Notice the vertical exaggeration is at 5.66 times the true scale.



Notice the vertical exaggeration is at 0.51 times the true scale.

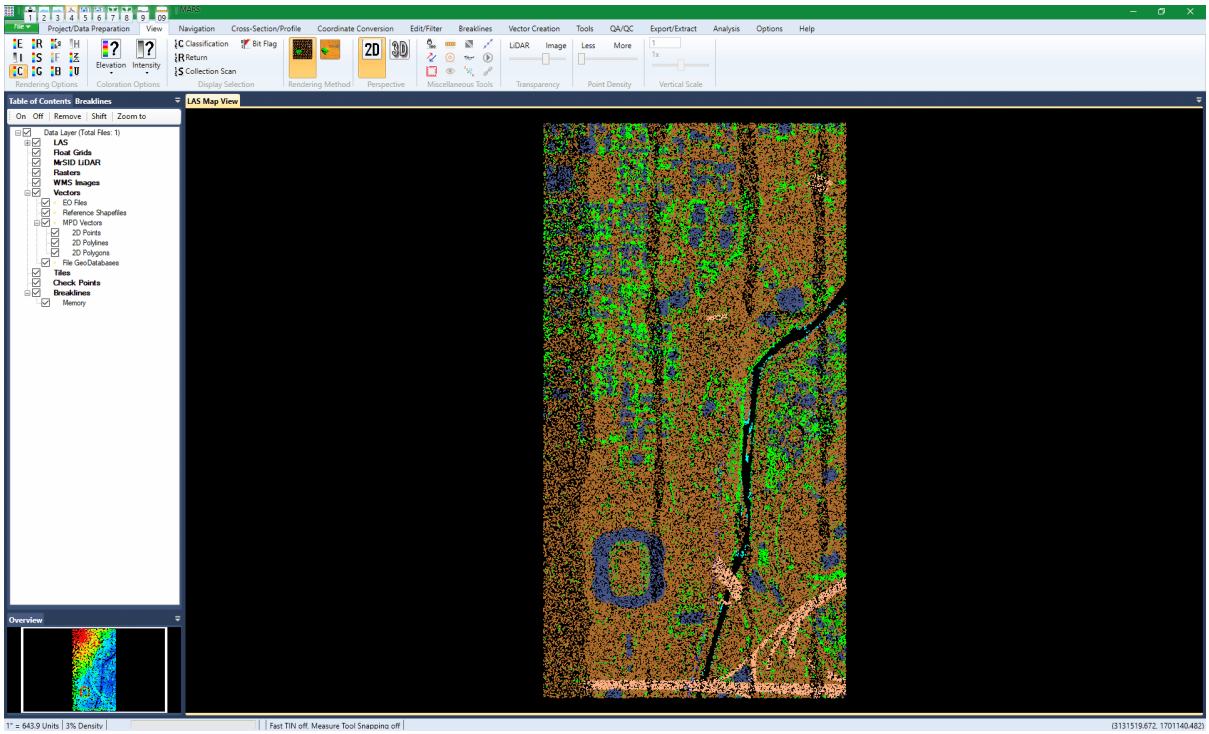
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2.6 Overview Window



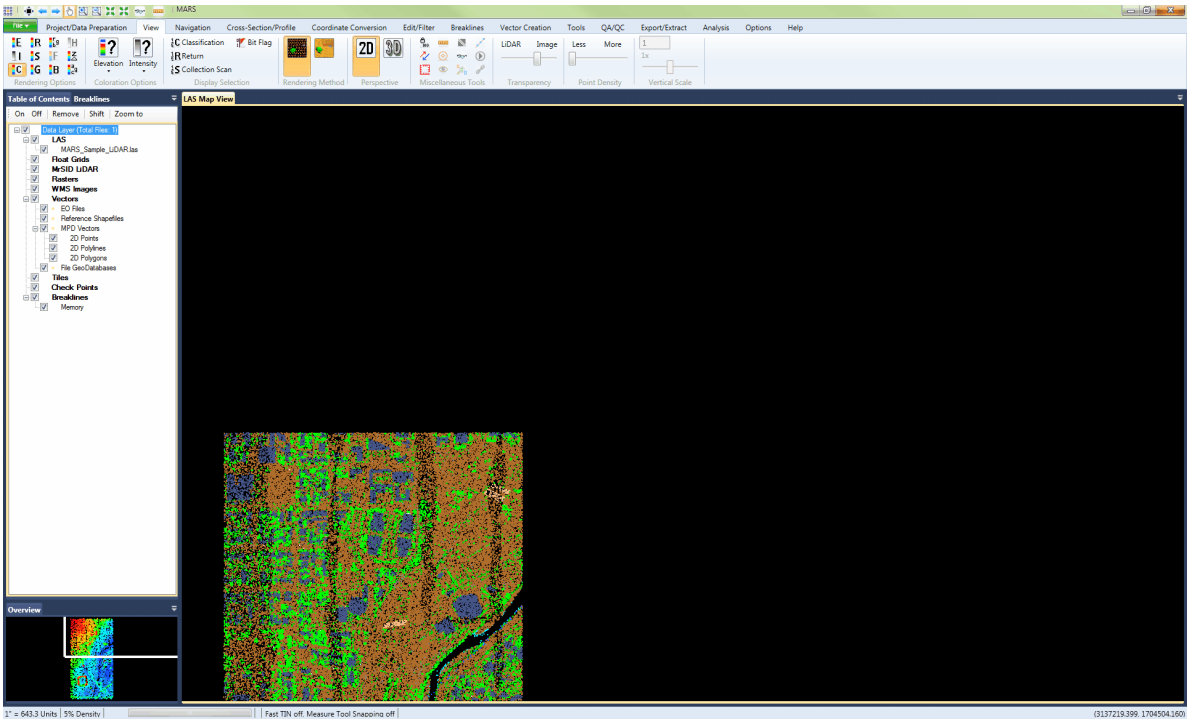
The Overview window is located in the lower-left corner of the MARS® interface (as seen below), and is identified by a tab in its upper-left corner labeled 'Overview.' It provides a locator function by superimposing a LAS Map View 145 window extent box (white color) over a snapshot of the loaded LiDAR data (rendered by elevation). It can also be used as a simple navigation tool (panning only), by left-clicking and dragging the white extent box to a new location. The LiDAR graphics can be turned off by unchecking the box labeled 'Display LiDAR graphics in Overview window' found in the 'Miscellaneous Options' interface on the Options Tab 519. The window can be re-sized vertically by dragging the separator line between it and the Table of Contents 67 window up or down. The Overview window's width will be the same as the width of the Table of Contents. Note that regardless of the Bit Flag Display Settings 841, points flagged as Withheld will not be displayed in this window.



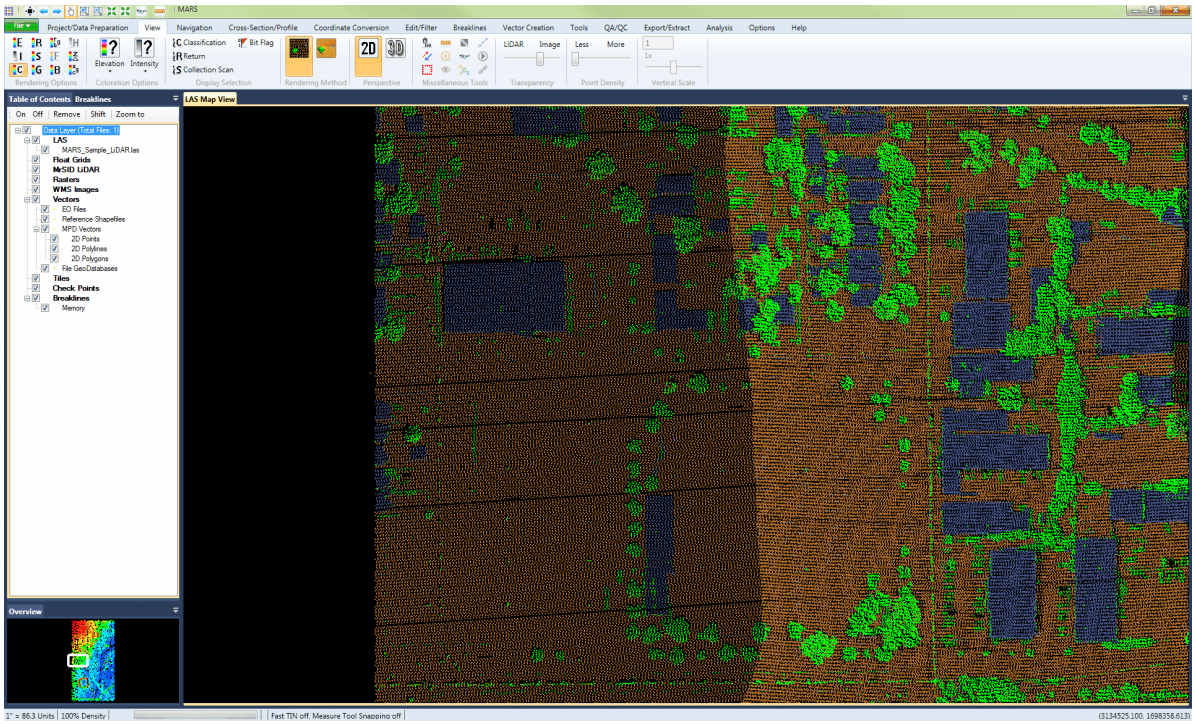
The shape and position of the LAS Map View extent box will change as the user pans, zooms in/out, pans, or forces a Fit to View822. See the examples below:

After panning to the southwest:

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After zooming in:



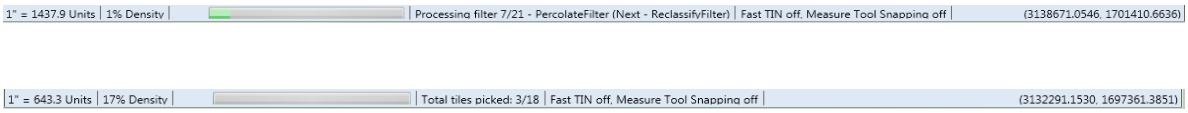
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2.7 Status Bar



The Status Bar:



The Status Bar has several sections that can display the scale of viewing extent, percentage of points (density) being displayed at a given zoom level, progress of a particular operation, the step number and description of a filter within a batch script **-- OR --** number of tiles picked out of total number of tiles, the status of 'Fast TIN' and 'Measure Tool Snapping' options, and the X and Y coordinates of the cursor location in the LAS Map View window. ***NOTE*** that the scale display (far left on the Status Bar) my not be displayed when remoting in to a computer running MARS®, depending on the type of remote display adapter being used.

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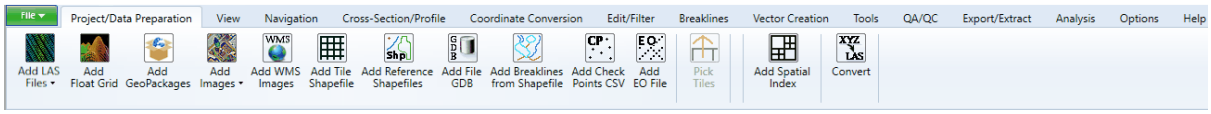
3 Tab and Ribbon Layout



Merrick Advanced Remote Sensing (MARS®) Software

Overview of the Tab layout:

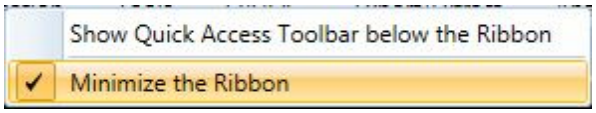
Note: The Quick Access Toolbar 65 can be located above (default position) or below the ribbon.



To minimize the ribbon and show only the tabs, right-click anywhere on it and choose 'Minimize the Ribbon.' In this mode, choosing a tab will present the ribbon temporarily until a button is clicked on it, or until clicking away from the ribbon.



To restore the ribbon back to its full size, right-click on it and choose 'Minimize the Ribbon' again.



Detailed information about the individual tabs can be found by following these links:

File 160 - Project/Data Preparation 162 - View 192 - Navigation 234 - Cross-Section/Profile 240 - Coordinate Conversion 254 - Edit/Filter 270 - Breaklines 298 - Vector Creation 364 - Tools 389 - QA/QC 458 - Export/Extract 461 - Analysis 489 - Custom 514 - Options 519 - Help 538

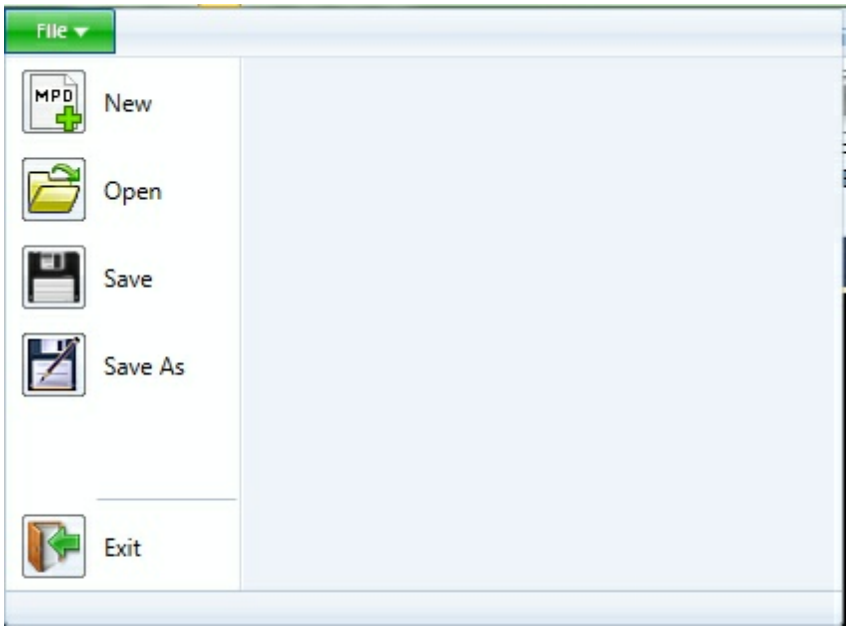
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3.1 File Tab

File Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The File Tab:



- **New:** The user can open a new MARS® document by clicking on this option. MARS® will open only one project document per application. If the user needs to have more than one MARS® project document open at a given time, an additional session of MARS® will need to be started. The hot key combination associated with starting a new MARS® document is Ctrl+N. If a MARS® project is open at the time a new document is started, MARS® will prompt the user to save the open project document before closing it and bringing up a new, empty document window.

- **Open:** The user can load an existing MARS® Project Document (*.mpd) by clicking on this option.

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The hot key combination associated with opening a MARS® project is Ctrl+O. If a MARS® project is already open at the time this command is used, MARS® will prompt the user to save the open project document before closing it and opening another one. To load data (rather than a project document), see the Project/Data Preparation Tab 162.

- **Save:** The user can save any open project as a MARS® Project Document (*.mpd) by choosing the 'Save' option or by using the hot key combination Ctrl+S. If the project has not been previously saved, the user will be prompted to give the file a name. If the file has been saved previously, choosing the 'Save' option will overwrite the original file. Projects are saved with relative paths to the loaded layers. Additional information that is stored in the .mpd includes: the current rendering method (elevation, class, intensity, etc.), the current settings for the Classification Display Settings interface (colors, descriptions, Point/TIN rendering, which classes are being displayed, etc.), the LAS Map View window extent, the 'Data Layer' properties (CRS info), the ‘From Class’ and ‘To Class’ settings on the Edit/Filter Tab 270, and any Bookmarks that were created.

- **Save As:** By choosing the 'Save As' option, the user can choose a new path and file name for the open project. Using 'Save As' avoids overwriting an original project document. Projects are saved with relative paths to the loaded layers.

- **Exit:** Choosing the 'Exit' option on the File tab will prompt the user to save changes and then close the MARS® application.

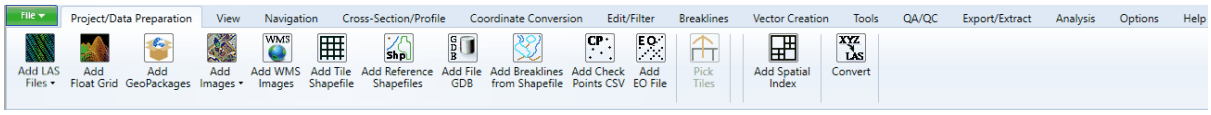
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3.2 Project/Data Preparation Tab

Project/Data Preparation Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Project/Data Preparation Tab:

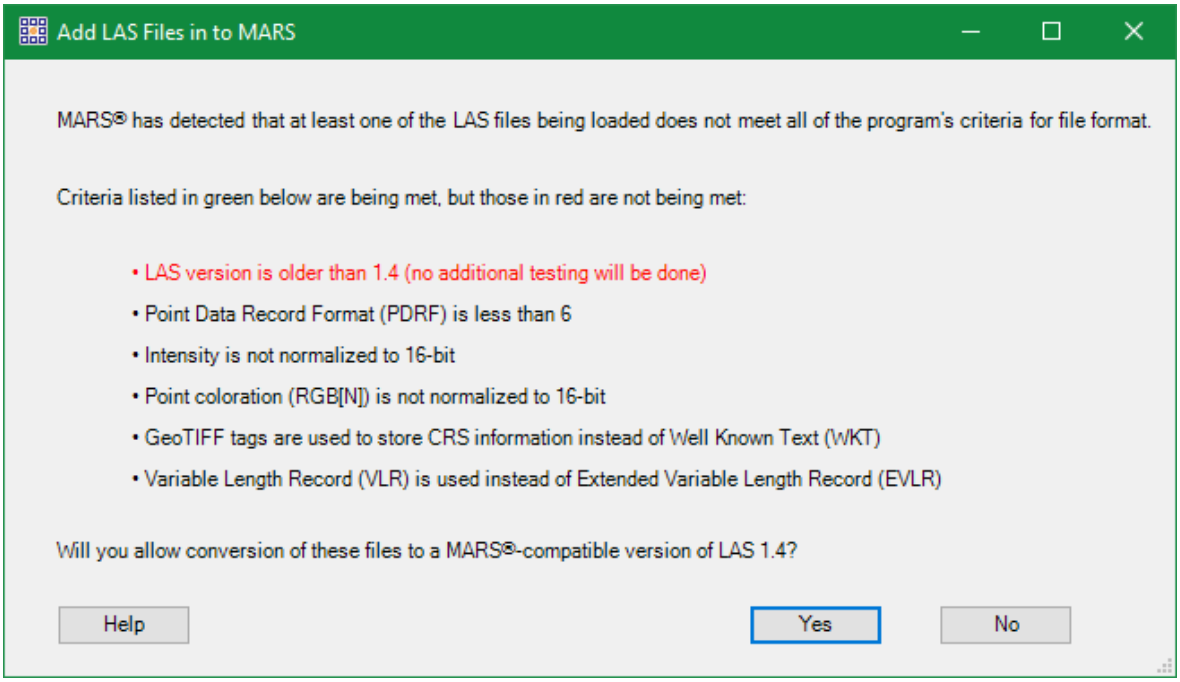


- **Add LAS Files:** Beginning with version 2018.0 of MARS®, there are minimum requirements for any LAS files being loaded in the Table of Contents, or pathed out for processing with any of the standalone tools where LAS data does not need to be loaded first. A 'permission to up-convert' prompt will appear if the LAS data does not meet these minimums. The LAS requirements are:
  - LAS version 1.4 with Point Data Record Format (PDRF) 6, 7, or 8 -- version 1.0 through 1.3 (PDRFs 0-3) will be up-converted to version 1.4, PDRF 6 or 7, depending on its current version/PDRF.
  - 16-bit (native or normalized) Intensity values -- 8-bit or 12-bit values will be normalized to 16-bit during up-conversion.
  - 16-bit (native or normalized) RGB(N) values, if the data is in PDRF 7 or 8 and these values are present in the data -- 8-bit or 12-bit values will be normalized to 16-bit during up-conversion.
  - Coordinate Reference System (CRS) info, *if present*, written as Well-Known Text (WKT) tags -- older, *readable* GeoTIFF-style CRS info will be re-written as WKT during up-conversion.
  - Extended Variable Length Record (EVLR) format for any existing variable length records -- Variable Length Records (VLRs) will be re-written as EVLRs during up-conversion.

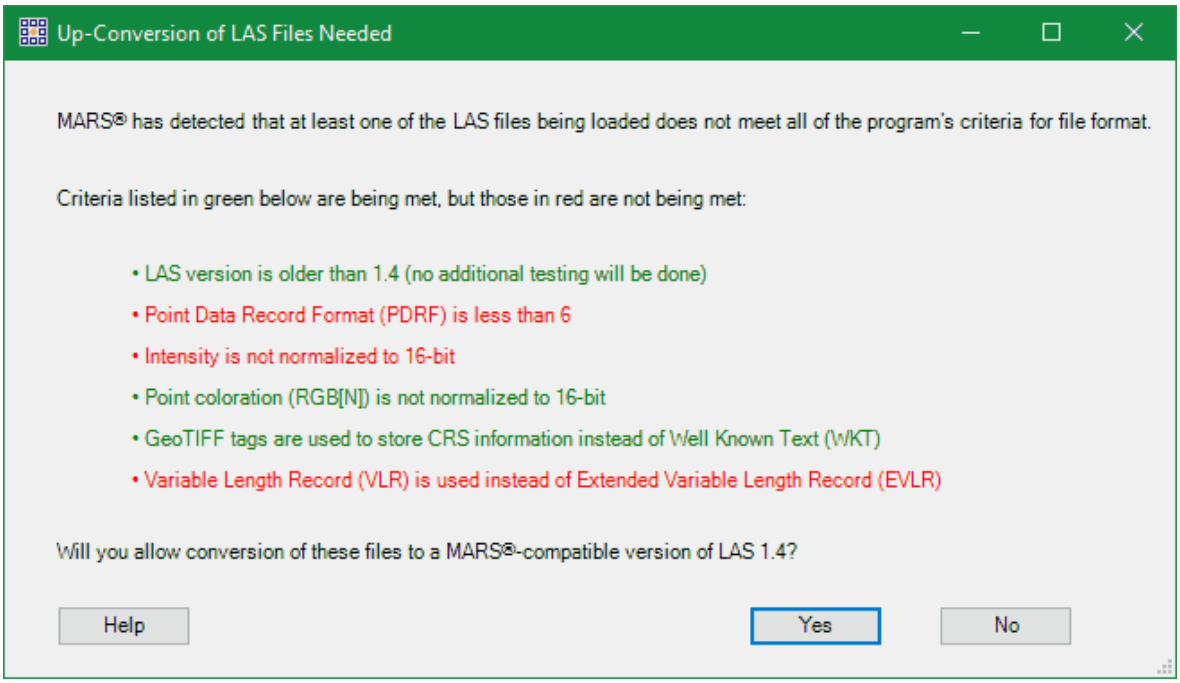
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The only exception to the minimum requirements is when running the USGS 1.0 QC Module, which can test older version (LAS v1.0 through v1.3) data.

NOTE: If any of the files to be loaded do not meet the minimum requirements for MARS® (as detailed in the example interface graphics below), a prompt will appear requesting permission to up-convert the files.



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A **'No'** answer to this prompt will close the interface without converting or adding any files, even ones that may already be fully compliant. It is expected that all files selected for loading will share the same LAS version and characteristics.

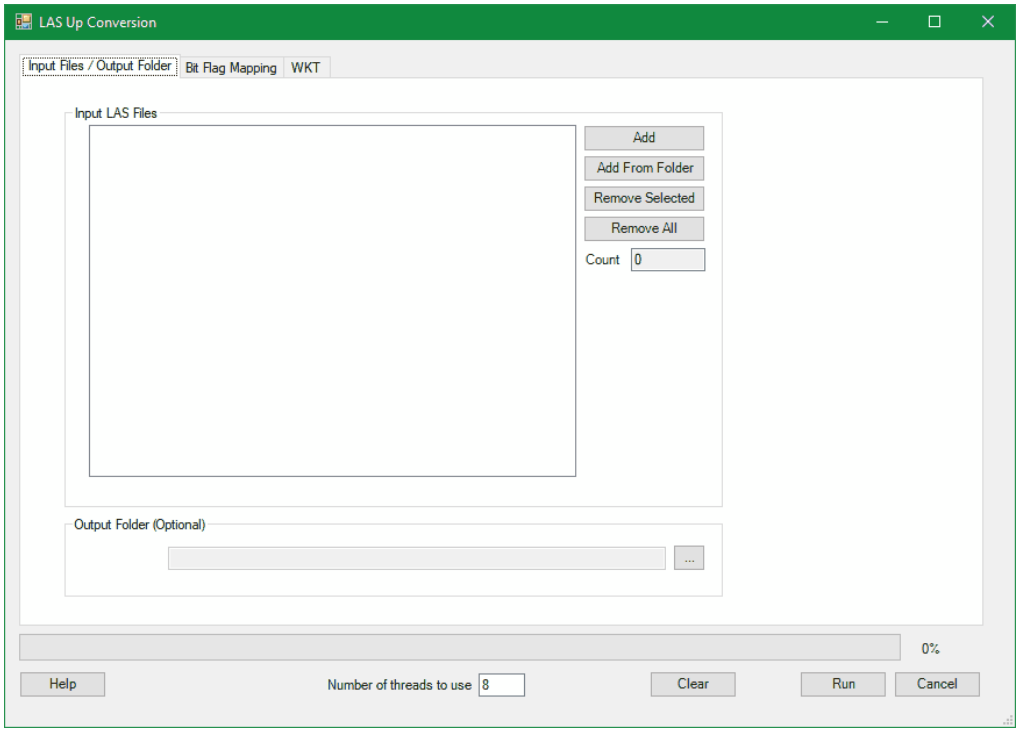
A **'Yes'** response will bring up the **LAS Up-Conversion** tool interface. This tool has several options including: 1) output to a different folder than the files currently reside in, 2) bit flag mapping to convert user-defined classes of points to any of the four changeable bit flags used in version 1.4 LAS files - **Synthetic**, **Key-point** (also referred to as Model Key-point), **Withheld**, and **Overlap**, and 3) assignment of a WKT tag for Coordinate Reference System definition. Existing bit flags (except, in some cases, the v1.4-only **Overlap** flag) can be carried over from the files being converted, or a class or classes can be specified that represented the bit flag types in older version files.

NOTE that when the **LAS Up-Conversion** interface appears as the result of running certain tools and functions that don't require LAS files to be loaded in MARS®, the particular tool will dictate whether the **Bit Flag Mapping** and/or **WKT** tabs are available. For example, when using the 'Add CRS Info'

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tool with input data that is not yet MARS®-compliant, the permission window shown above will appear when the 'Run' button is clicked. If 'Yes' is clicked, the **LAS Up-Conversion** interface that opens will not have the **WKT** tab because the coordinate reference system entry hase already been defined in the 'Add CRS Info' tool.

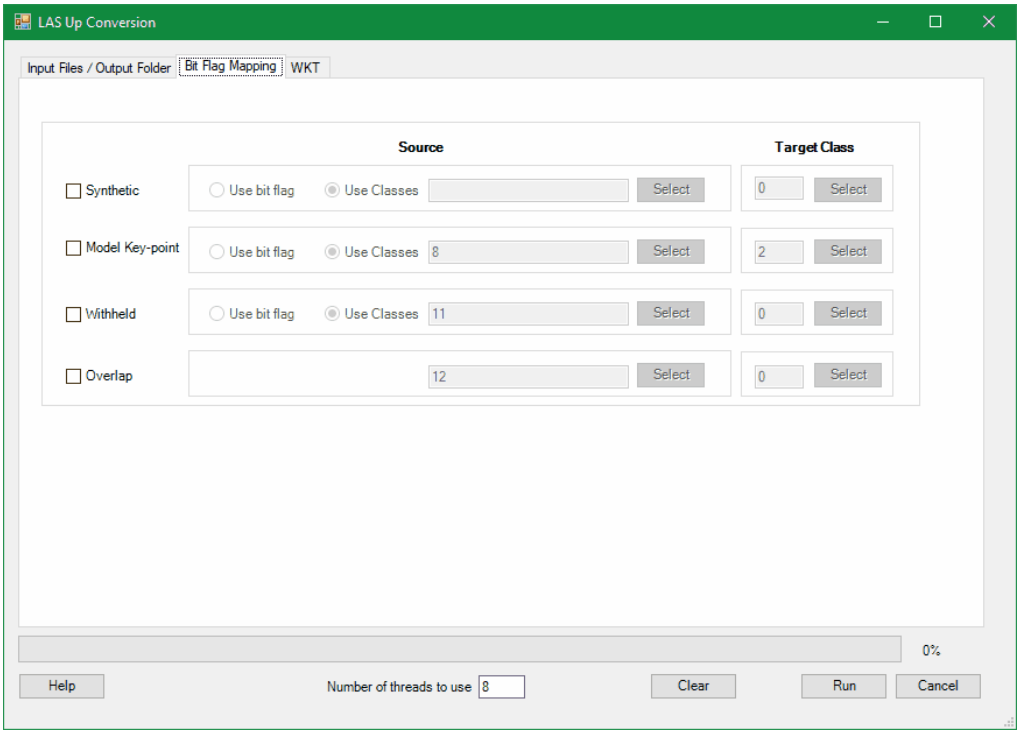
On the 'Input Files / Output Folder' tab, navigate to the files to be up-converted using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. ***The input files will be overwritten unless an Output Folder is selected.***



On the 'Bit Flag Mapping' tab, check the boxes in the left column for any bit flag types that need to exist in the up-converted files. If the existing files have bit flags set for **Synthetic** (rare), **Model Key-point**, and/or **Withheld**, select the appropriate **'Use bit flag'** radio buttons to carry over the bit flag status. Otherwise, keep the default **'Use Classes'** radio buttons selected and use the **'Select'**

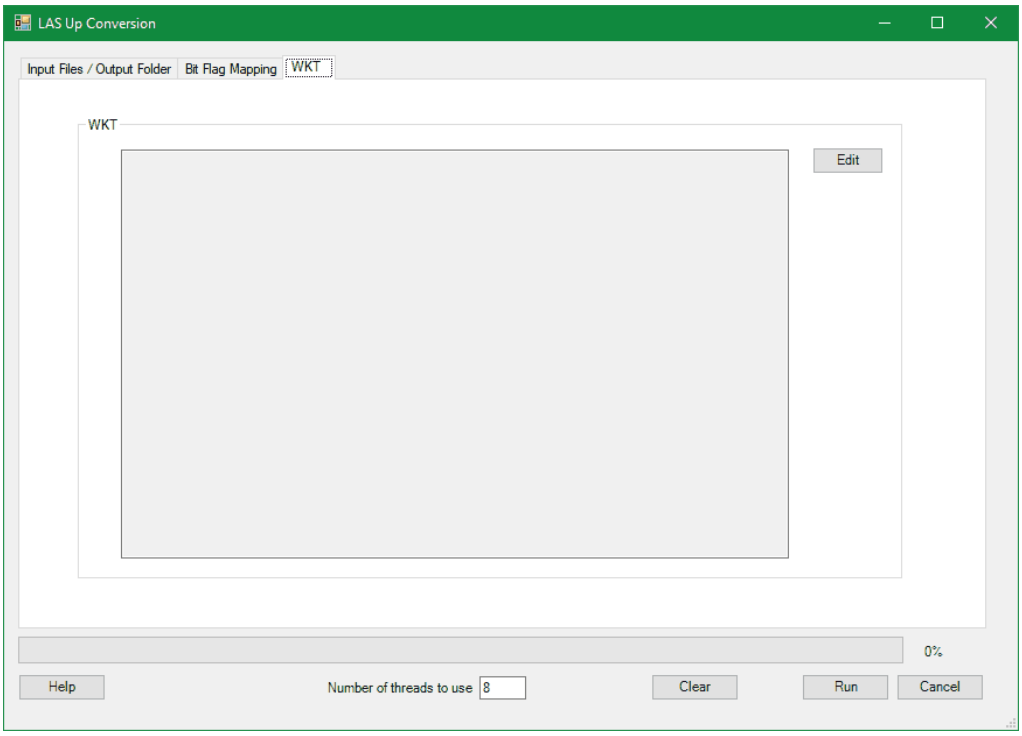
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buttons in the **'Source'** section to choose one or more classes in the existing files that are representing a bit flag type. The pre-populated **'Source'** classes were chosen as defaults because they are commonly used in LAS files older than version 1.4. Optionally, a new **'Target Class'** can be selected for the points once their bit flags are set. Class 2 is the default **'Target Class'** for **Model Key-point** since it is a sub-set of ground (which is typically stored as Class 2).



For the 'WKT' tab, any existing Coordinate Reference System information that is readable will be shown as a WKT format tag which can then be edited for correctness and/or completeness.

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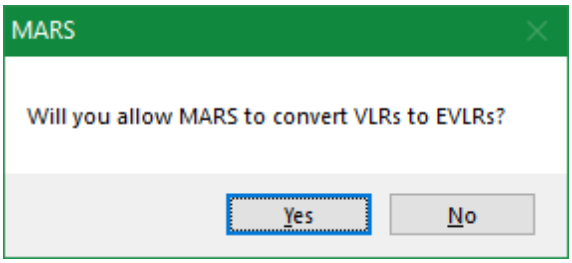
The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. When all settings have been made, click **'Run'** to start the up-conversion and load the files, or **'Cancel'** to dismiss the interface without modifying or loading any files. This tool can also be run on known non-MARS®-compliant LAS data before attempting to load it (see **'LAS Up-Conversion'** on the Tools Tab 389).

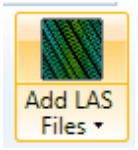
For files that do not need to be up-converted, there are four (4) tools to determine, set, and clear various bit flags found under the **'Bit Flag Settings'** drop-down on the Tools Tab 389. There is also a tool to add or edit coordinate reference system information in WKT format - see the **Add CRS Info** sub-topic in the Coordinate Conversion Tab 254 section of the help file.

LAS data that meets all the minimum requirements except the one for EVLRs will trigger a simpler up-

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conversion prompt:



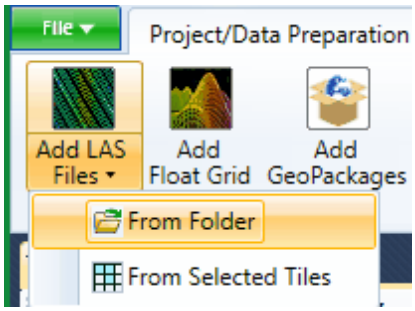
Clicking the upper-half of the button 

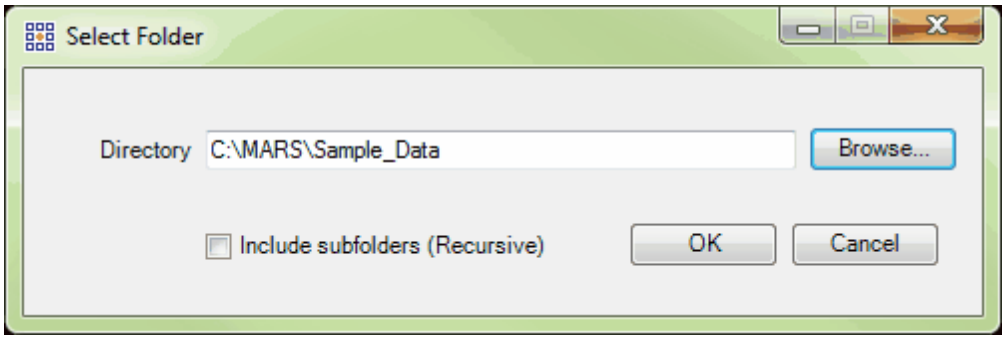
will present a standard Windows 'Open' interface to load one or more LAS files using established Windows selection methods - click, Ctrl-click, Shift-click, Ctrl-A, etc. All LAS files added will be found under the LAS 74 layer in the Table of Contents 67. The loaded LiDAR data may be viewed in either 2D View 835 mode or 3D View 837 mode in the LAS Map View window.

Note: If any of the files to be loaded do not meet the minimum requirements for MARS® (as described above 163), a prompt will appear requesting permission to up-convert the files.

- **Add LAS Files | From Folder:** Clicking the lower-half of the button and choosing the 'From Folder' option will open a window to load an entire folder of LAS files and, optionally, its sub-folders. All LAS files included in the folder(s) chosen will be loaded into MARS®. Any LAS files added will be found under the LAS 74 layer in the Table of Contents 67. The loaded LiDAR data may be viewed in either 2D View 835 mode or 3D View 837 mode in the LAS Map View window.

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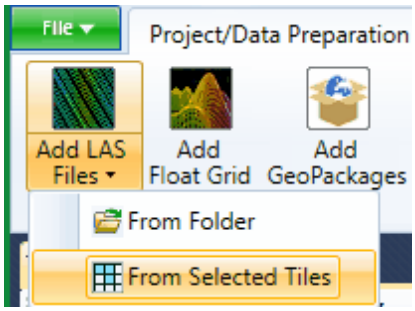


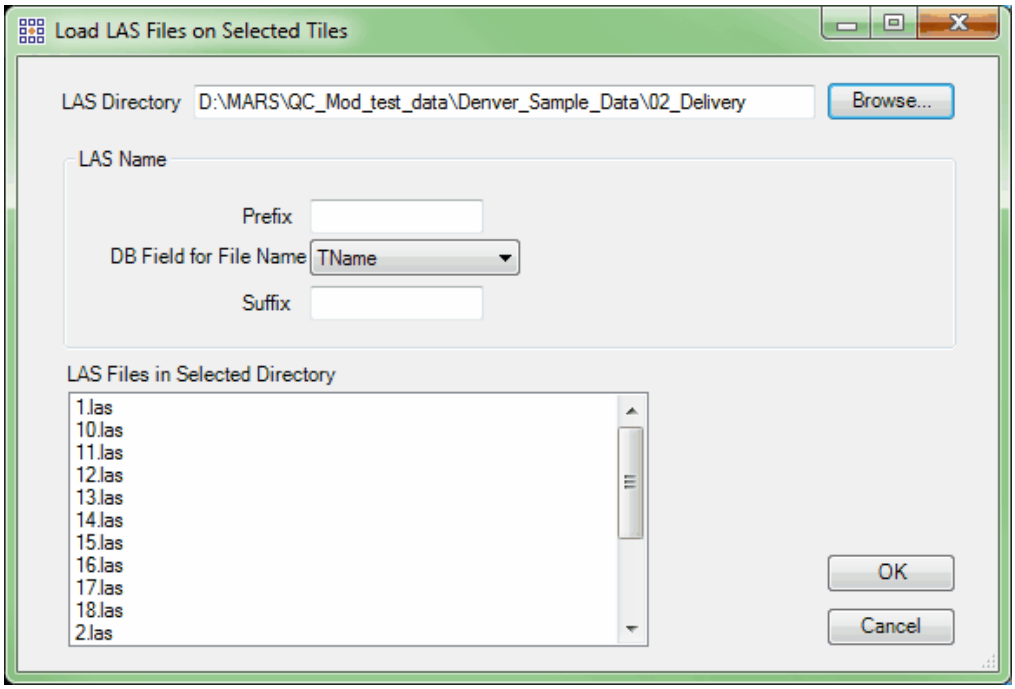


Note: If any of the files to be loaded do not meet the minimum requirements for MARS® (as described above[163]), a prompt will appear requesting permission to up-convert the files.

- **Add LAS Files | From Selected Tiles:** Clicking the lower-half of the button and choosing the 'From Selected Tiles' option will allow the user to load LAS files based on tiles selected from a loaded shapefile tile layout. Matching LAS files in the chosen directory will be loaded into MARS® and any LAS files added will be found under the LAS[74] layer in the Table of Contents[67]. For example, if tiles with 'TNAME' attribute field values of '11', '12', and '15' have been selected using the 'Pick Tiles' tool (see below), and LAS files with those names exist in the chosen LAS Directory (as shown below), then only those files will be loaded. The selection made for the 'DB Field for File Name' option will be stored by this tool until the MARS® application is closed. The loaded LiDAR data may be viewed in either 2D View[835] mode or 3D View[837] mode in the LAS Map View window.

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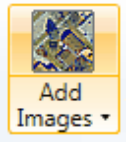


Note: If any of the files to be loaded do not meet the minimum requirements for MARS® (as described above[163]), a prompt will appear requesting permission to up-convert the files.

- **Add Float Grid:** This button will present a standard Windows 'Open' interface to load float grids (*.flt) into MARS®. Click the 'Add Float Grid' button and then navigate to the location of the float grid(s) to be loaded. Select the desired float grid(s) and choose 'Open' to load into MARS®. The loaded float grid(s) may be viewed in either 2D View[835] mode or 3D View[837] mode in the LAS Map View window. Any float grid(s) added will be found under the Float Grids[82] layer in the Table of Contents[67].

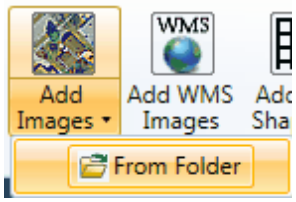
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- **Add GeoPackages:** This button will present a standard Windows 'Open' interface to load a GeoPackage file (*.gpkg) as a reference vector layer. GeoPackage is an open format for storing and transforming geospatial information (via an SQLite database) that can incorporate point, line, and polygon vector data, as well as attribute data, metadata, and tile data (rasters). At this time, metadata and tile data are not yet supported in MARS®. The most recent version of GeoPackage supported by MARS® is 1.3.1.

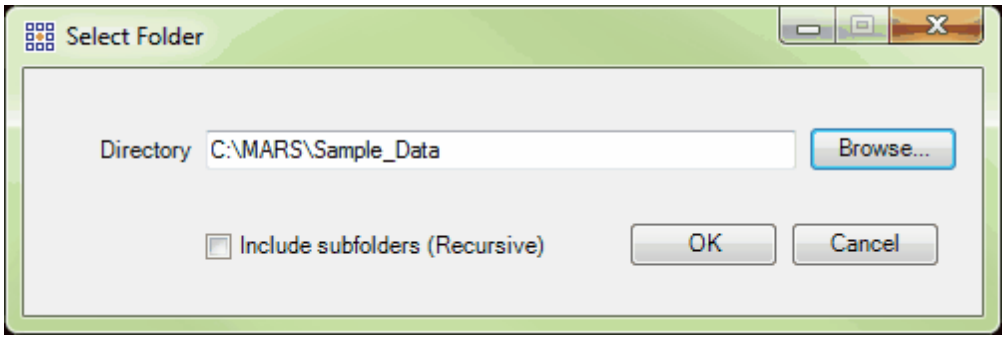
- **Add Images:** Clicking the upper-half of the button 

will present a standard Windows 'Open' interface to load any supported images (raster files) using standard Windows selection methods - click, Ctrl-click, or Shift-click. Supported raster types are: ECW (Hexagon-Intergraph), JPG, IMG (Hexagon-ERDAS), TIFF, DAT (ENVI Hyperspectral), NITF (USDoD), JP2, SID (LizardTech), and PNG. Any images added will be found under the Rasters 86 layer in the Table of Contents 67.

- **Add Images | From Folder:** Clicking the lower-half of the button and choosing 'From Folder' will open a window to load an entire folder of images and, optionally, its sub-folders. All images included in the folder(s) chosen will be loaded into MARS®. Any images added will be found under the Rasters 86 layer in the Table of Contents 67.



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- **Add WMS Images:** Clicking the 'Add WMS Images' button will open a window to load an image from a WMS server (Internet or network connection required). Any images loaded will be found under the WMS Images 90 layer in the Table of Contents 67.

  NOTE: Availability of any WMS resources included with MARS® or referenced here 1879 is subject to change without notice. None of these services is endorsed, provided, or otherwise guaranteed to be functional by Merrick & Company. Merrick neither hosts nor maintains any WMS (Web Map Service) image layer sources and is therefore not responsible for the completeness, accuracy, or frequency of updates of any WMS sources that may be accessed from within the MARS® program.

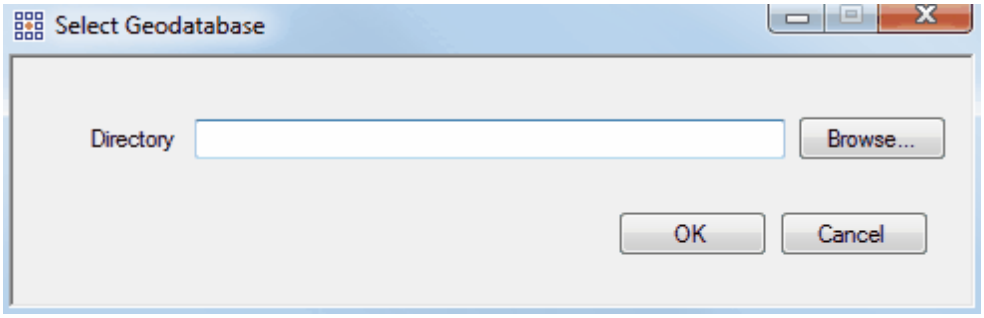
- **Add Tile Shapefile:** This button will present a standard Windows 'Open' interface to load any polygonal tile shapefile. Only Esri compatible *.shp files can be loaded as tile layouts. Any tile shapefile added will be found under the Tiles 121 layer in the Table of Contents 67, but only one tile layout can be loaded at a time (other layouts may be added as Reference Shapefiles, see below). Tools such as Jump to Tile 234 and 'Pick Tiles' (see below) will only work on shapefiles loaded under the Tiles 121 layer in the Table of Contents 67. When a shapefile is added to the 'Tiles' layer, MARS® will check and silently remove it first from the 'Reference Shapefiles' or 'Breaklines' layers *if the same path/file exists in either of those layers.*

- **Add Reference Shapefiles:** This tool will present a standard Windows 'Open' interface to load shapefiles as reference data under the 'Reference Shapefiles' sub-layer of the Vectors 95 layer in the

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Table of Contents 67. Reference shapefiles can be point, polyline, or polygon geometry. Click the 'Add Reference Shapefiles' button and then navigate to the location of the shapefile(s) to be loaded. Select the desired shapefile(s) and choose 'Open' to load into MARS®. This tool also allows the user to load breakline shapefiles, although they cannot be edited and will not modify the loaded surface or any exports when added this way. They can, however, be used as a 'target' for snapping new and existing true breakline features.

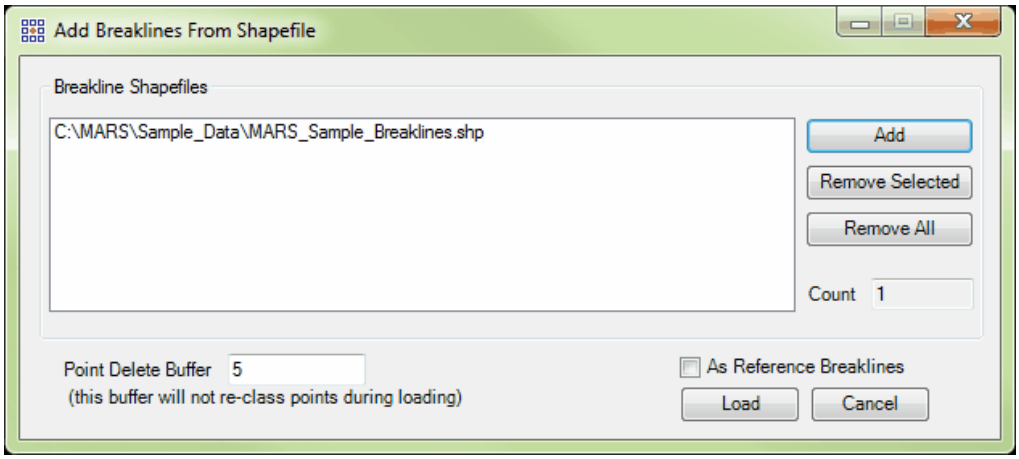
- **Add File GDB:** This tool allows the user to load Esri v10.0 or later File GeoDatabases as reference data. Any feature classes loaded will be found under the 'File GeoDatabases' sub-layer of the Vectors 95 layer in the Table of Contents 67. Personal GeoDatabases are not supported in MARS®. All Feature Classes found in the File GeoDatabase - whether inside of or outside of a Feature Dataset - will be loaded. The data is for reference only, and cannot be edited within MARS®. Features must be in 2D - no 'M' or 'Z' values present. Click the 'Add File GDB' button and then navigate to the location of the File GeoDatabase to be loaded. Select it, click 'OK', and click 'OK' again in the 'Select Geodatabase' window to finish the process.



- **Add Breaklines from Shapefile:** This tool allows the user to load breakline shapefiles into MARS® under the Breaklines 134 layer in the Table of Contents 67. The 'Add Breaklines from Shapefile' window also gives the user the option to load the breaklines as a reference breakline shapefile rather than a standard breaklines shapefile. When loaded as reference, these breaklines cannot be edited

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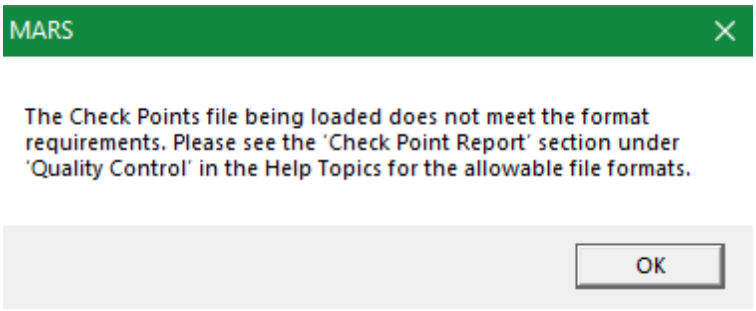
and will not affect grid and contour exports. To use this option, make sure the 'As Reference Breaklines' box is checked. The 'Point Delete Buffer' is set to '5' units by default, but may be modified for each breakline shapefile loaded. This value will be stored as a 'virtual' attribute to be honored when the 'Reassess Points for Delete Classification' tool is used (Breaklines Tab 298).



Breaklines loaded as reference files do not need the accompanying LiDAR data to be viewed in the Cross-Section/Profile window. If a breakline file is loaded as a reference file, its symbol will be shown in neon green in the Table of Contents. If the file is marked with a neon green line, this file is loaded as a *polyline* reference file. If the file is marked with a neon green box, this file is loaded as a *polygon* reference file.

- **Add Check Points CSV:** This button will present a standard Windows 'Open' interface to load a CSV-format check points file. A *.CSV file added using this option will be found under the Check Points 131 layer in the Table of Contents 67. Only one check points file can be loaded at any time. If a CSV file in a non-allowed format is being loaded, a warning pop-up message will be displayed as shown below.

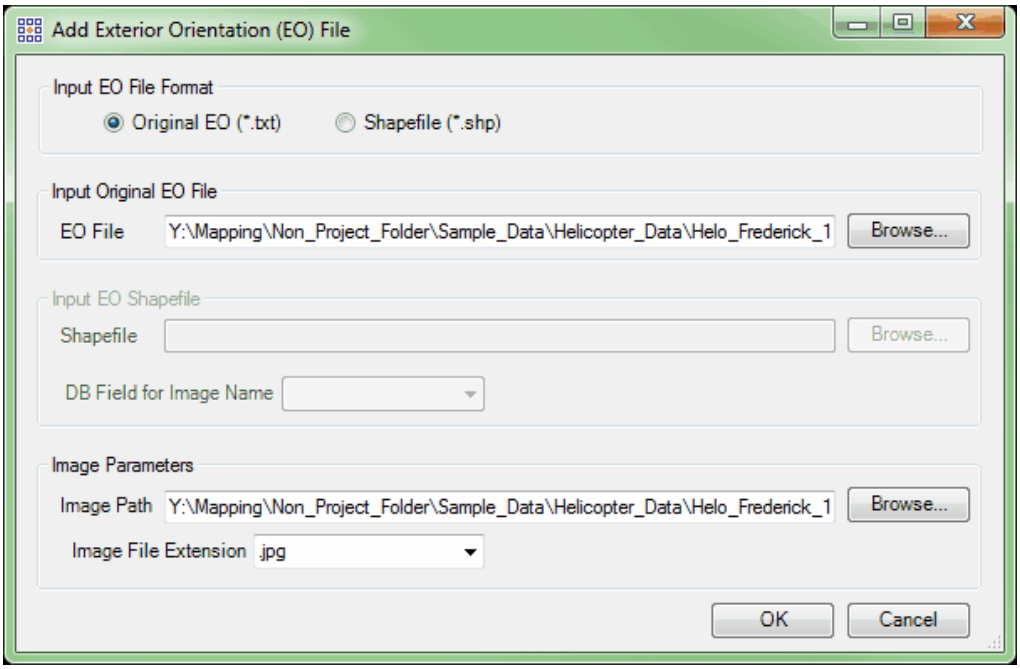
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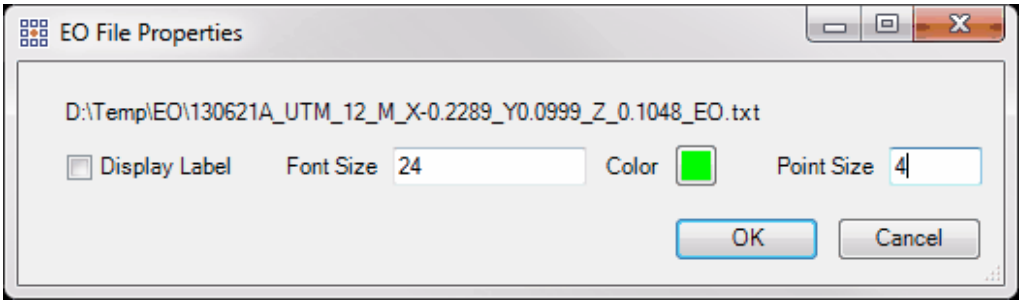
See the Check Point Report 1224 topic for a full description of the allowable file formats.

- **Add EO File:** This button allows the user to load one or more EO, or Exterior Orientation, files into MARS®. This tool adds point shapefile (*.shp) or text (*.txt) files only. Added files will appear under the 'EO Files' sub-layer of the Vectors 95 layer in the Table of Contents 67. The tool is meant for use with the Hyperlink  tool which may be found on the View Tab 192. The purpose of the 'Hyperlink' tool is to display the imagery associated with each event in the EO file(s). To use this tool, first an EO file must be loaded into MARS®. The user may add a shapefile or text file by choosing the appropriate file type in the 'Input EO File Format' section. Depending on the choice made, either the 'Input Original EO File' or the 'Input EO Shapefile' section will become available to specify the location of the desired EO file. Under the 'Image Parameters' section, navigate to the folder with the associated JPEG (*.jpg) or TIFF (*.tif) image files. Be sure to designate the image file extension type in the drop-down box next to 'Image File Extension'.

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The EO file is displayed as a 3D point shapefile (even when a TXT file is loaded) and each point, or event, in the file is associated with imagery. Because it is displayed as a shapefile, it is also possible to change the display settings of each EO file by right-clicking on the file inside the Table of Contents 67 and choosing 'Properties'. The resulting 'EO File Properties' window will allow the user to change the color and size of the point shapefile and will also allow the user to display labels.



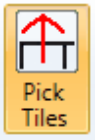
A text (*.txt) format EO file may be exported to a point shapefile by right-clicking on the entry in the Table of Contents 67 and choosing 'Export to shapefile.' In the resulting dialog box, choose the desired path and file name, then click 'Save.'

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To remove an EO file from the Table of Contents 67, right-click on it and choose 'Remove'.

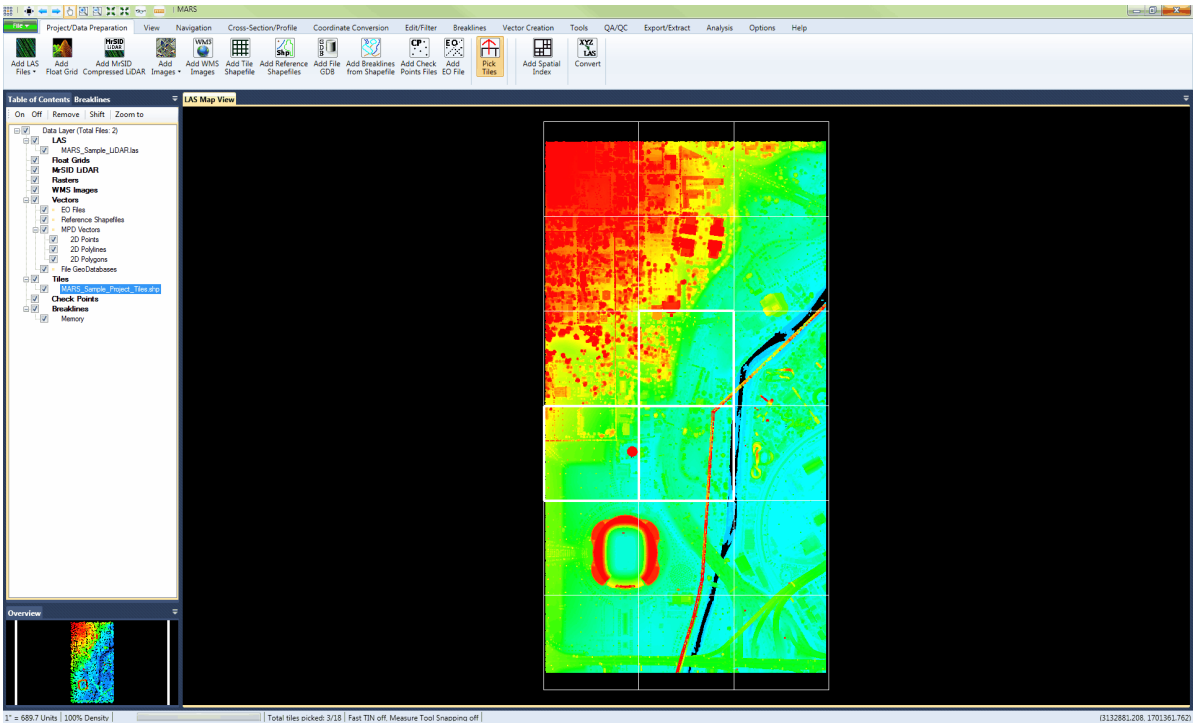
- **Pick Tiles:** This tool is used to select a single tile or multiple tiles for Project/Data Preparation 162, Export/Extract 461, or Edit/Filter 270 activities. This tool is inactive until a polygonal shapefile (ex. a tile layout) is loaded into MARS®. The 'Pick Tiles' tool will only work on data loaded as a tile shapefile. See the 'Add Tile Shapefile' section of the Project/Data Preparation Tab 162 topic for information on loading a tile layout. This tool works only in 2D View 835.

The 'Pick Tiles' tool allows the user to load a tile layout shapefile and then select a single tile or multiple tiles to be processed. The selected tiles will then appear selected in the attribute table representing the shapefile. To view the attribute file, right-click on the file in the 'Tiles' layer of the Table of Contents 67 and choose 'Attributes'. Conversely, it is possible to use the attribute table to select tiles from the shapefile. Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard to select the appropriate tile (s). The selected tile(s) will then appear selected in the LAS Map View window on the tile layout itself.

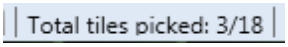
'Pick Tiles': To use the **'Pick Tiles'** tool, select the 

button. Move the cursor over tiles to be exported and left-click. Using the tool, draw a box over many tiles and they all will be selected, or use the **'Ctrl'** key on the keyboard to select single tiles without losing the ones already selected.

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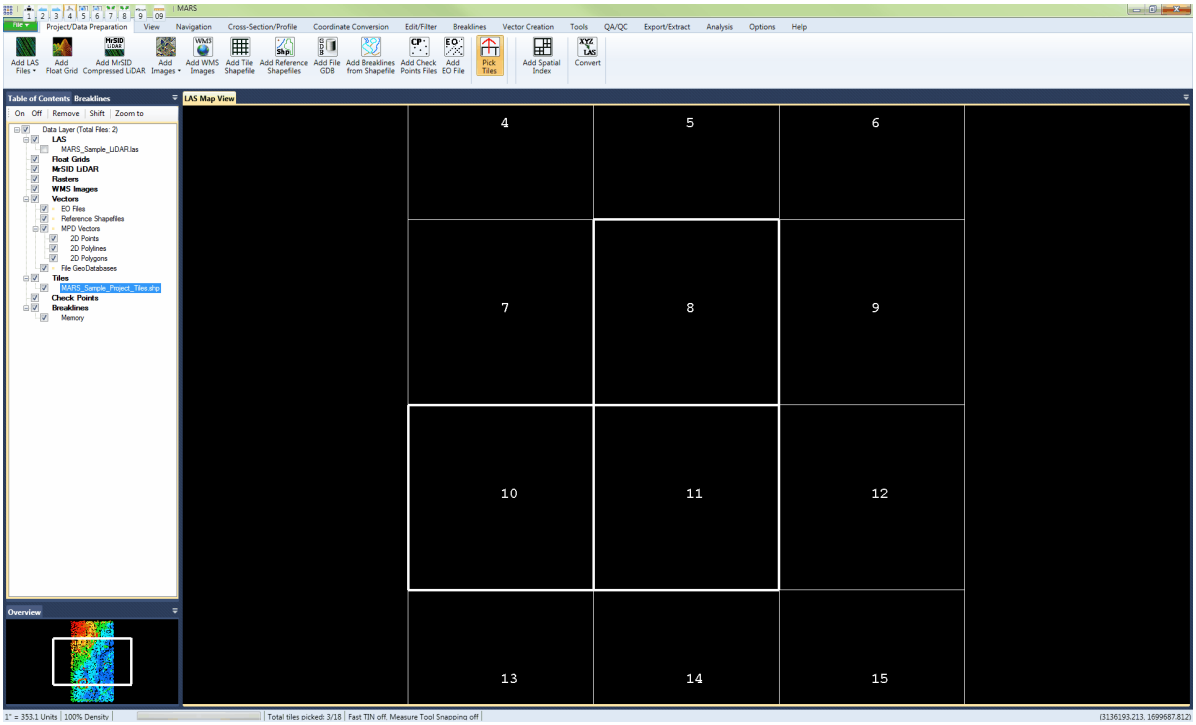
The above image shows an example of three selected tiles, which are outlined in bold. MARS® will keep a count of the tiles being chosen and the total number of tiles in the tile layout and display them as a ratio. Please see the screen shot of the Status Bar 158 below:



The following image displays the selected tiles and tile names. To see the tile name attributes, right-click on the file in the Table of Contents 67 and select 'Properties', then choose the appropriate name attribute (ex. TName) in the 'DB Field for Labeling' drop-down box. Check the box which says 'Display Label', change the 'Font Size' if desired, and click 'OK'. The labels will be displayed in the same color as the tile outlines, and the selected tiles will remain outlined in bold. The user's preference for the 'DB Field for Labeling' option will be stored by this tool until the MARS® application is closed. The field chosen will be synced with the same parameter in the 'Load LAS Files on Selected Tiles' option when adding LAS data. To read more concerning the 'Add LAS Files on Selected Tiles' option, please view the Project/Data Preparation Tab 162 topic. Once the desired tiles are selected, they can also be

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exported by clicking the **'Export'** button on the Export/Extract Tab 461.



Tile Selection Methods

- **Individual:** To select an individual tile, use the 'Pick Tiles' tool to click on the desired tile.
- **Multiple:** To select multiple tiles, depress the CTRL key and use the 'Pick Tiles' tool to choose the desired tiles.
- **Drag Box:** For large areas, use the 'Pick Tiles' tool to click and drag a box. All tiles touched by the drag box will be selected. Additional tiles can be added to the selection set by holding down the CTRL key and clicking within the desired tile(s).
- **To unselect tiles:** In some cases, it may be easier to use the drag box to select a large area of tiles and unselect the few that are not needed. To unselect tiles, make sure the 'Pick Tiles' button is active, then hold the 'Ctrl' button on the keyboard and click individually on the tiles to be unselected. To unselect all tiles, click outside of any tiles while the 'Pick Tiles' button is active.

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- **Add Spatial Index:** This tool performs a spatial index on one or more LAS files to enable MARS® to read and display the point data. It can add spatial index information, remove it, or mark any existing spatial index records as superseded. Either of the last two uses may be necessary for using the files in other software.

NOTE: ***For best stability and faster performance, LAS files that have been spatially indexed in an older version (v2019.3 or earlier) should be re-indexed using version 2020.0 or later of MARS®. This can be done quickly in two steps using the multi-threaded 'Add Spatial Index' tool - the 'Fast Remove Index' option followed by the 'Add Spatial Index' option. See the paragraph immediately before the screen shot of the tool interface for more information. Also note that issues may occur with LAS files if they are spatially indexed in a newer version of MARS® and then have their index records removed in an older version.***

Using the Add Spatial Index interface - This method will modify the LAS files when spatial index information is added, removed, or superseded.

- ✓ Navigate to the files to be processed by clicking on the 'Add' button. Files may be removed from the list by highlighting them (using standard Windows mouse/keyboard controls) and clicking on the 'Remove Selected' or 'Remove All' buttons.
- ✓ If adding spatial indexing. choose one of the 'Collection scan options':
  - **Incremental:** Assigns sequential collection scan numbers to each LAS file in the list to be spatially indexed. Using this option will overwrite any existing collection scan numbering in the LAS files. Enter the desired starting number in the 'Starting collection scan number' text box, keeping in mind that LAS version 1.4 files are limited to collection scan numbers of

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1 to 65,535. If multi-channel files are being processed, check the 'Group Multi-Channel LAS files (one number per group)' box to have the same collection scan number assigned to each file in the group. ***The tool requires that files in a multi-channel group be named identically starting with the letter 'L' except for a unique digit denoting the channel number following the mandatory letter 'C' - for example, 'L1-1-140324_A-C1_r.las and 'L1-1-140324_A-C2_r.las' - for this collection scan numbering method to work.***

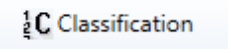
- **No Assign - Keep the collection scan number of every point:** No changes are made to collection scan numbering that may exist in the LAS files. This is the default.
- **Set all files to one collection scan number:** Assigns only one collection scan number to all listed files. This option will overwrite any existing collection scan numbering in the LAS files. Enter the desired number in the 'Starting collection scan number' text box, keeping in mind that LAS version 1.4 files are limited to collection scan numbers of 1 to 65,535.

✓ WKT: This area shows any existing WKT-based coordinate reference system definition for the added files and allows the information to be edited. Changes made here will be applied only when adding spatial indexing. See the procedure outlined in the 'Add CRS Info (to LAS Files)' topic in the Coordinate Conversion 254 section of this help file for details.

✓ Multi-Threading: The 'Add Spatial Index' tool is capable of multi-threading the indexing process. To multi-thread (which may shorten the processing time), enter the desired number of threads up to the maximum available for the computer in the text box. For best performance, there should be a minimum of eight (8) GB of RAM available (not

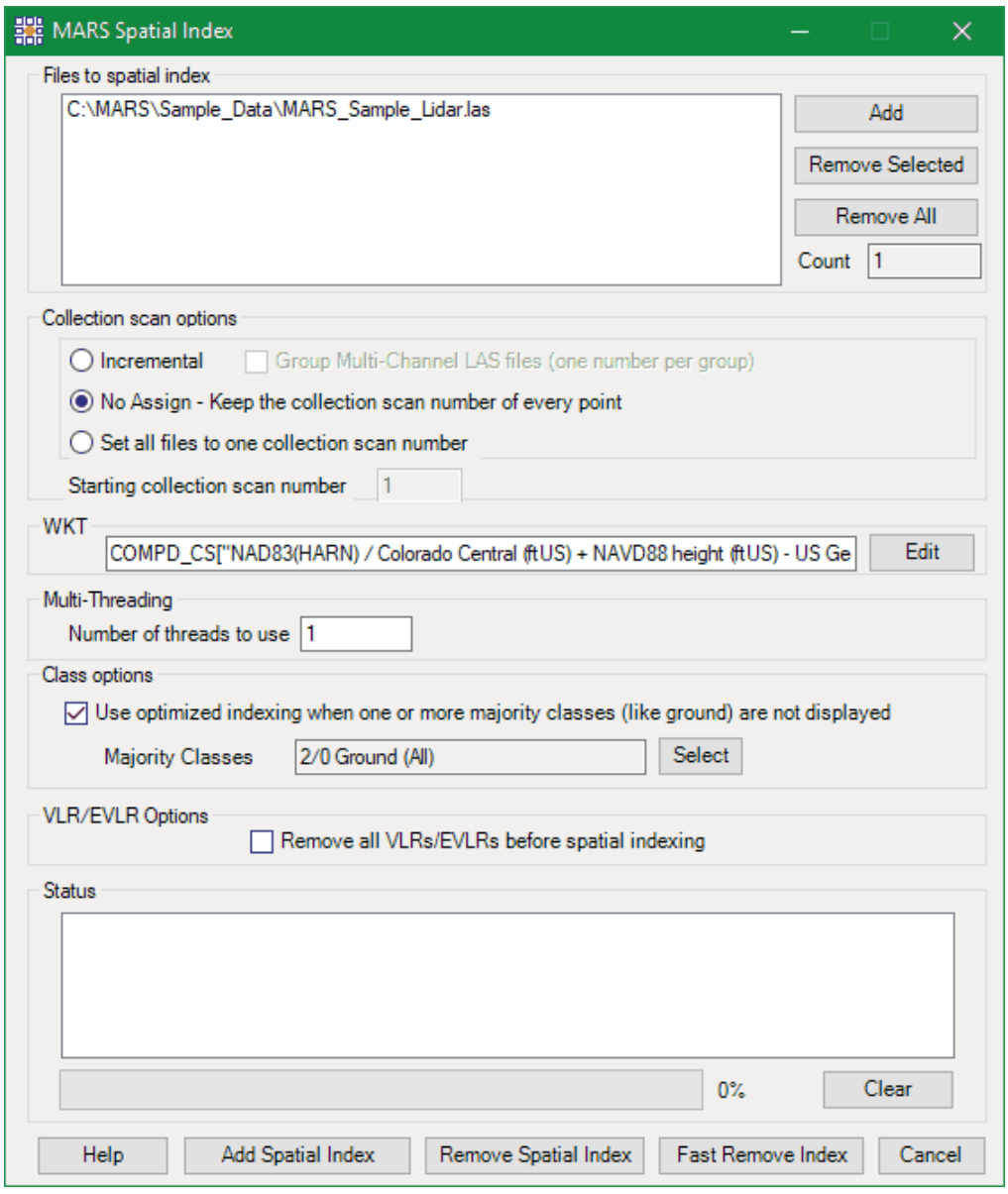
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just installed) per thread. Multi-threading the Spatial Indexing functions across a USB 2.0 connection is not recommended as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

- ✓ Class options: This option allows a second spatial index to be created based on all classes EXCEPT the one(s) listed in the 'Majority Classes' box. Click the 'Select' button to choose the desired majority classes. When one or more of the chosen classes are turned off using the Classification 192  button on the View Tab 192, performance is increased during display-related operations such as pan and zoom. In addition, a higher percentage of the available point cloud will be displayed for a given window extent. If more than one class was chosen as a majority class during 'Add Spatial Index', the performance boost will be highest when all majority classes are turned off.
- ✓ VLR/EVLR options: The 'Remove all VLRs/EVLRs before spatial indexing' option (unchecked by default) can be used to completely remove *all* Variable Length and/or Extended Variable Length Records (not just indexing records) from the LAS files listed in the 'Files to spatial index' box during the 'Add Spatial Index' process. This function works only when adding indexing, not when using the 'Remove Spatial Index' or 'Fast Remove Index' buttons.
- ✓ Note: All files will be tested for empty 'System Identifier' header fields and, if found, will have this field populated with 'OTHER' (see the LAS file specifications on the ASPRS LAS File Format website). Files with values already in place will not have this field modified.
- ✓ Click 'Add Spatial Index' to index the data, or 'Remove Spatial Index' to delete any existing spatial index records. Removal will make LAS file sizes a little smaller, but

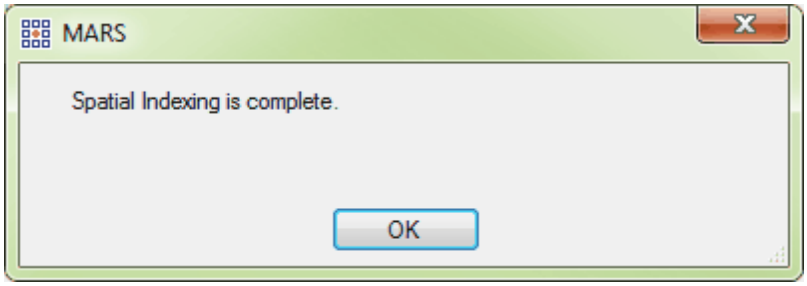
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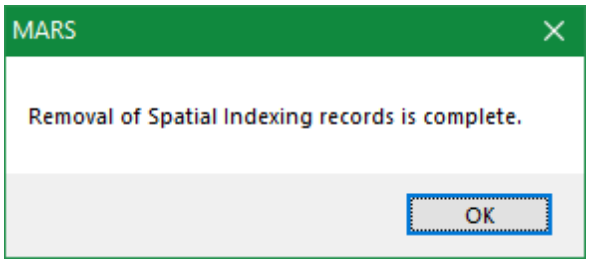
will cause the files to be unloadable in future MARS sessions unless they are re-indexed. The 'Fast Remove Index' button will mark all indexing records as superseded (ignored) without actually deleting them. As with complete removal, this makes the files unreadable in future MARS sessions unless they are re-indexed, but the re-indexing process will be much faster. Either of the removal options may be helpful in loading data into other lidar software. Neither the 'Remove Spatial Index' function nor the 'Fast Remove Index' function will make any changes to collection scan numbering.

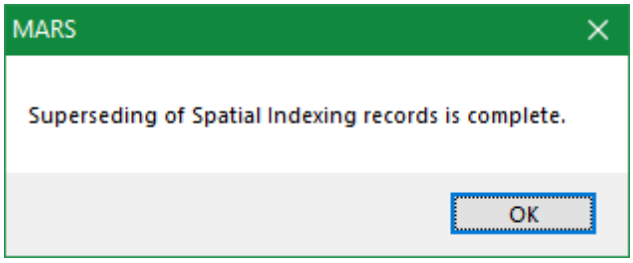


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When 'Add Spatial Index', 'Remove Spatial Index', or 'Fast Remove Index' is successfully completed, MARS® will alert the user with the following messages:







Clicking the 'Clear' button near the bottom of the interface will empty the 'Status' area so that more files can be spatially indexed.

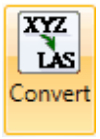
- **Convert:** This tool is used to translate elevation data files to the LAS file format, which MARS® natively supports. Specifically, MARS® is capable of converting **ASCII Text files (*.txt, *.dat, *.csv, *.xyz, *.grd), Esri ASCII Grids (*.asc), Float Grids (*.flt), and GeoTIFF Grids or TIFF Grids with world files (*.tif, *.tif/*.tfw)** to the LAS file format.

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NOTE: *When the above-listed **Grid**-based types of elevation data are converted into a version 1.4 LAS file, the resulting LiDAR points will be bit-flagged as 'Synthetic.' Converted **ASCII Text** files will have the 'Synthetic' bit flag set based on the status of the 'Treat as actual collected returns' checkbox. This box is unchecked by default.*

For more information on the LAS specification, please visit the following link at the ASPRS Online Website.

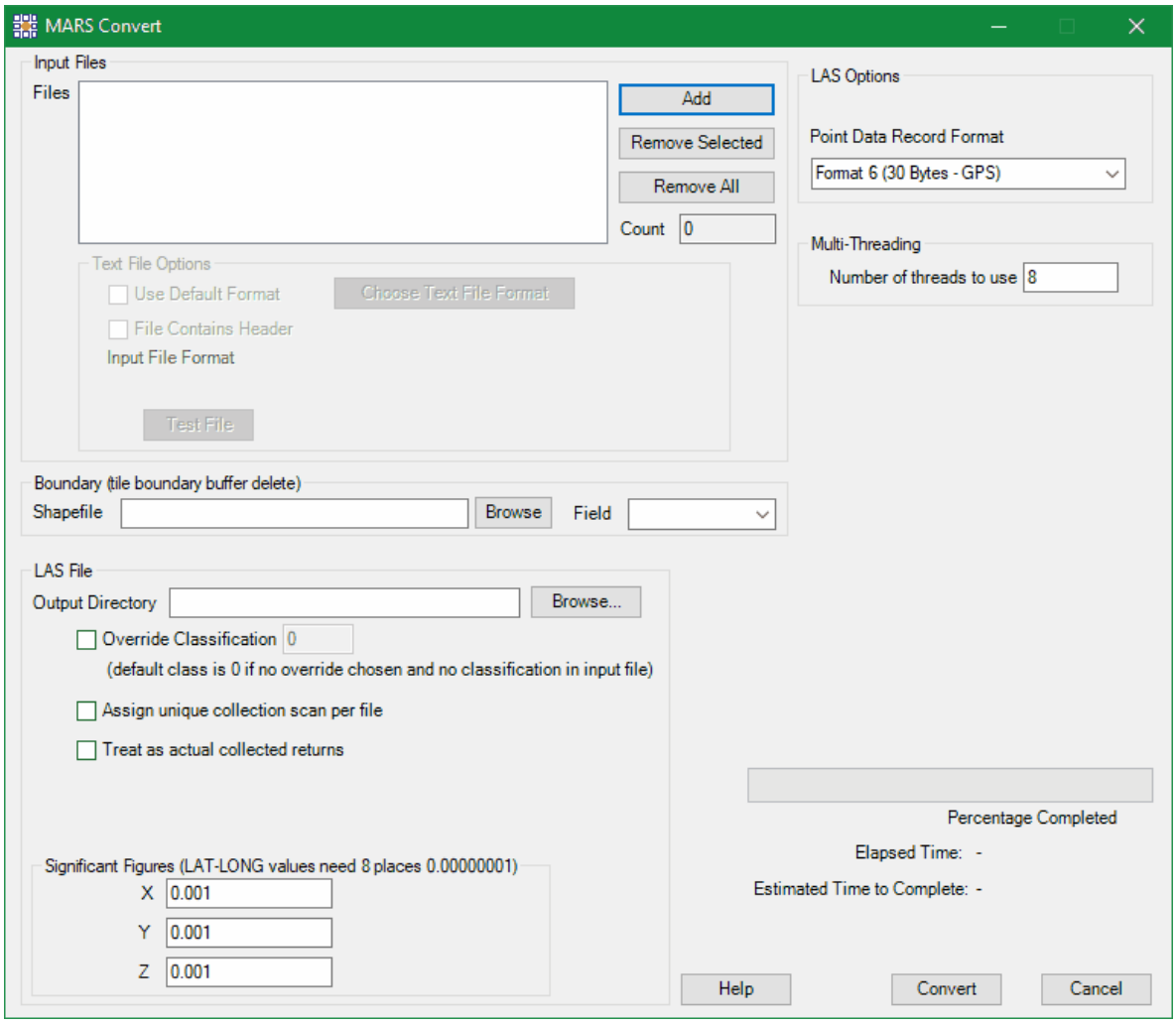
The following steps outline how to use the Convert tool:

Click the **'Convert'** button 

.

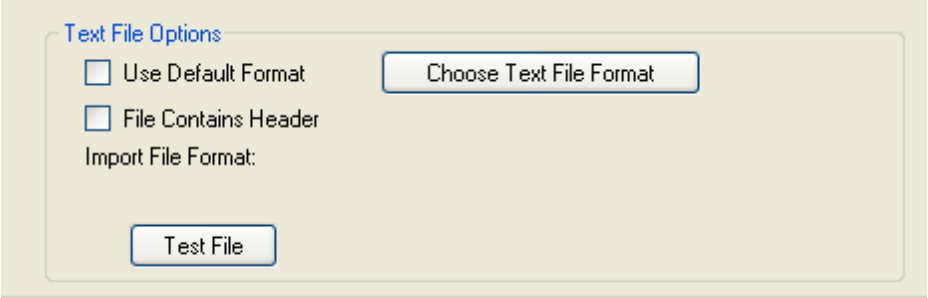
The following image shows the MARS® Convert dialog.

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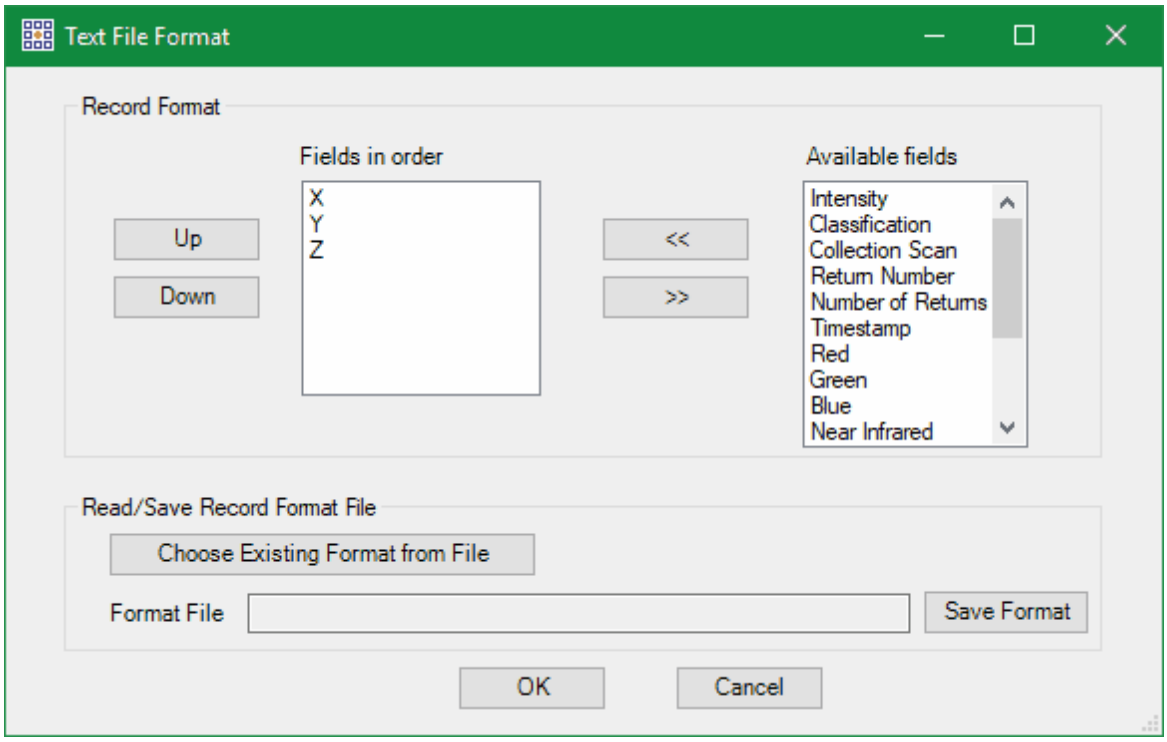
Text File Options: When either a *.txt or *.csv text file is selected to be converted, the 'Text File Options' dialog becomes available. Text files can be comma, space, or tab delimited. If the **'Use Default Format'** box is checked, the default fields will be used in the format. The default text format is XYZ with a space delimiter. If the file contains header information (i.e., a header row), select the **'File Contains Header'** check box, which causes the convert module to skip the first line of the file when creating point records.

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To further specify the format settings for the text file conversion, select the **'Choose Text File Format'** button. The X, Y, and Z fields are in the fields in order dialog box by default. If additional fields are necessary to convert the text file, the user can select the desired attributes one at a time from the right window of the dialog (Available fields) and click the **'<<'** button to add it to the file format definition in the left window. The user can also reorder the convert file format definition by selecting a field in the left window and using the **'Up'** or **'Down'** arrow buttons to match the text file format. In addition, the **'Ignore'** option from the attribute field list (left side of dialog) allows the user to disregard specific data values in the input file for translation. The **'Ignore'** field may be used as many times as necessary. If there is an existing record format file to be used on the data, select the **'Choose Existing Format from File'** button, browse to where the format file is kept, and click **'Open'**.

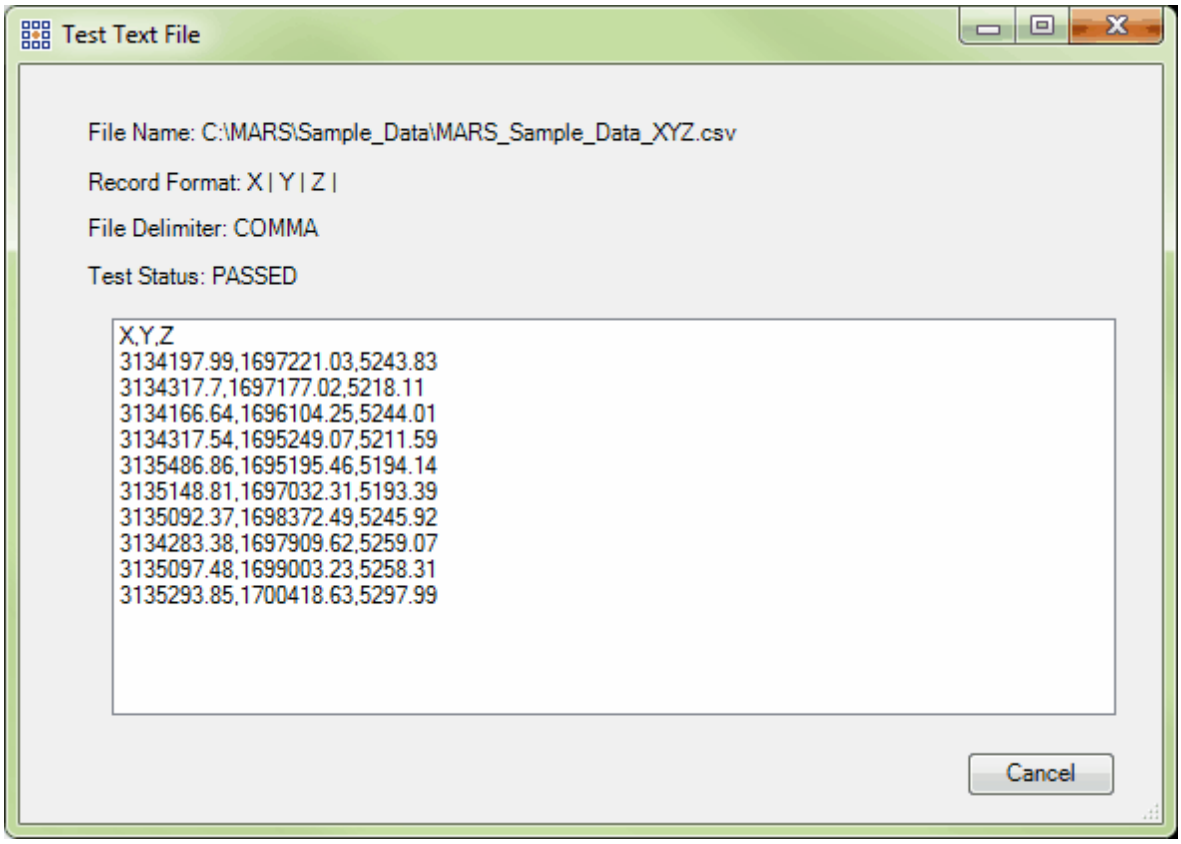
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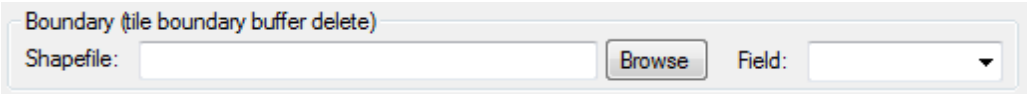
The user can bring in saved format settings ('Choose Existing Format from File'), and any unique settings described in the dialog box by the user can also be saved for use at a later time. Once the file definition to be used is complete, these values can be saved to an external file for reuse by clicking on the **'Save Format'** button. The target directory and file name for the file definition format can then be assigned. When all the dialog settings are complete, click **'OK'** to return to the previous convert window.

By using the **'Test File'** function on a selected (highlighted) file, the user can quickly verify that the inputted file format matches the actual contents of the target file. The **'Test File'** dialog is displayed to the user and provides a file status of **'PASSED'** or **'FAILED'**, and also displays the first several lines of the file for review purposes.

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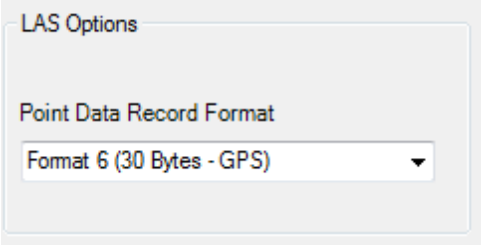


Boundary: The 'Boundary' section of the MARS® Convert module allows the user to clip the converted data with a polygon shapefile. The result of this process is that only the points within each feature in the shapefile will be converted into an LAS file. The names of the input files must **exactly** match values in the shapefile's chosen attribute field (TName in the image below). The created LAS files will have the same names as the input files.

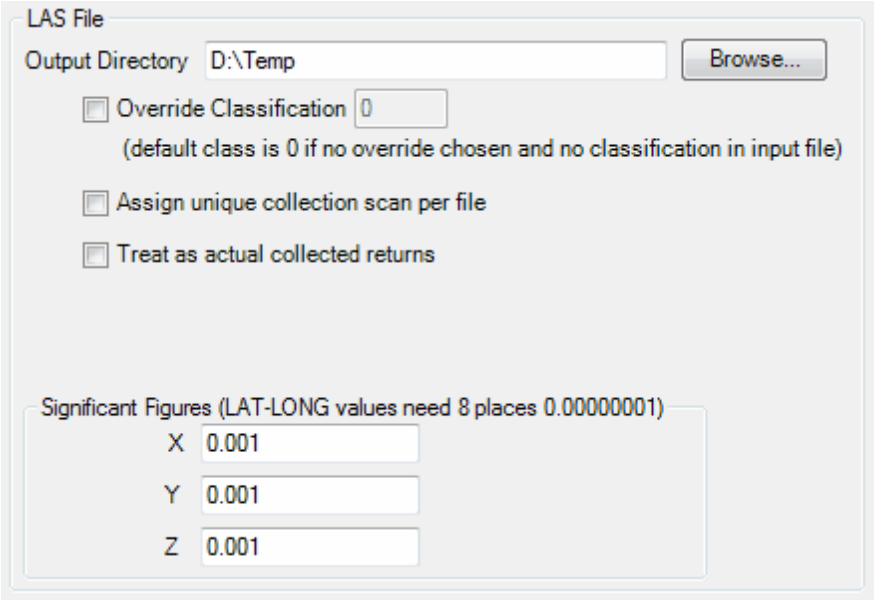


LAS Options: The 'LAS Options' section of the MARS® Convert module allows the user to create the new v1.4 LAS files using Point Data Record Formats of 6, 7, or 8 (depending on whether RGB(N) values are available in the input files).

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LAS File: The 'LAS File' section of the MARS® Convert dialog allows the user to modify the output LAS file and choose its output location.



Note: If the output directory is not specified by the user, the new LAS files will be generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the ***'Browse'*** *button and navigate to the desired directory or key in a path.*

Override Classification: The 'Override Classification' check box is used to assign a specific data classification to the converted dataset. For example, when converting "bare-earth" ASCII files to LAS, the user may choose to override the data classification to 2, which represents 'Ground (All)'. The default override classification value is 0 (zero).

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Assign unique collection scan per file: During the conversion process, the user may assign a unique collection scan number per file during LAS file creation, which is useful if each file contains only one (1) collection scan. This function is not necessary if the input files already contain collection scan information and the 'Collection Scan' field is used appropriately in the file-to-LAS mapping. This tool can also be implemented when converting TIFF files.

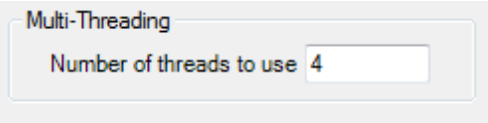
Treat as actual collected returns: This checkbox is available when converting ASCII Text files to LAS. The default is unchecked, since most text files of XYZ points do not represent actual LiDAR points. It should be checked if the coordinates in the file are known to represent actual collected returns.

Significant Figures (LAT-LONG values need 8 places 0.00000001): The 'Significant Figures' section of the Convert module should be utilized when the user is converting LAS files. The default value is set to 0.001 to retain the accuracy of any type of projected data (UTM, State Plane, etc.). In some cases where the 'X' and/or 'Y' extent of the data is very large, the tool may fail to make a valid LAS file. In this scenario, try reducing the default 'X' and/or 'Y' Significant Figures value(s) to '0.01'. This will reduce the decimal precision of the resulting data slightly, but will still provide two decimal places for the point values. If the user is converting latitude/longitude data in decimal degrees, another five decimal places (0.00000001- eight total decimal places) will need to be added to the default value to preserve the accuracy of the data.

Multi-threading: To help speed up 'Convert', multi-threading is available for this function. Enter any number of threads from 2 to the maximum number available in the text box on the right side of the interface. If '1' is entered inside this text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per

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thread.



Convert: To complete the file convert process, the user must click the **'Convert'** button after all of the necessary data convert parameters have been defined. To follow the progress of the conversion, please see the progress bar, which will display the percentage of the conversion completed, the elapsed time, and the estimated time remaining to complete.

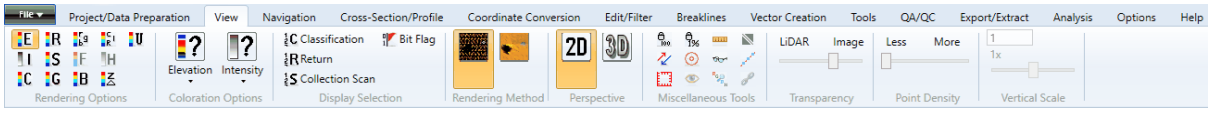
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3.3 View Tab

View Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The View Tab:



Color by Elevation: Displays LiDAR points rendered by relative elevation[878] value. (See also Elevation Repeat[881], Elevation Rescale[886], and Elevation Throughout[887])

Color by Intensity: Displays LiDAR points rendered by intensity[888] value. (See also Intensity

Gray-scale Only 895, Intensity Multi-color 896, Intensity Color Extremes 892, and Intensity Equalize 893)

 **Color by Classification:** Displays LiDAR points rendered by classification 846 value.

 **Color by Return**: Displays LiDAR points rendered by return 862 value.

 **Color by Collection Scan:** Displays LiDAR points rendered by collection scan 850 (Point Source ID value).

 **Color by Ground Color:** Displays user-defined ground class(es) by RGB values and all other points by classification. RGB values stored with the points will be used if no imagery is loaded.

 **Color by RGB :** Uses the R(ed), G(reen), B(lue) values stored for each LiDAR point to render the point cloud or TIN as a 3-band 863 pseudo-image.

Beginning with the LAS v1.2 specification, RGB values can be stored in an LAS file on a point-by-point basis. The Near Infrared (NIR) band values can also be stored beginning with LAS v1.4. When the 'Color by RGB' rendering method is used, those *visible* color values are used in the display. The data can then be viewed in 2D or 3D, and in either point cloud or TIN display. If no RGB(N) values exist within the loaded LiDAR data and imagery is available (either traditional rasters or WMS imagery), a new set of LiDAR data can be exported using the RGB(N) values from the imagery as follows:

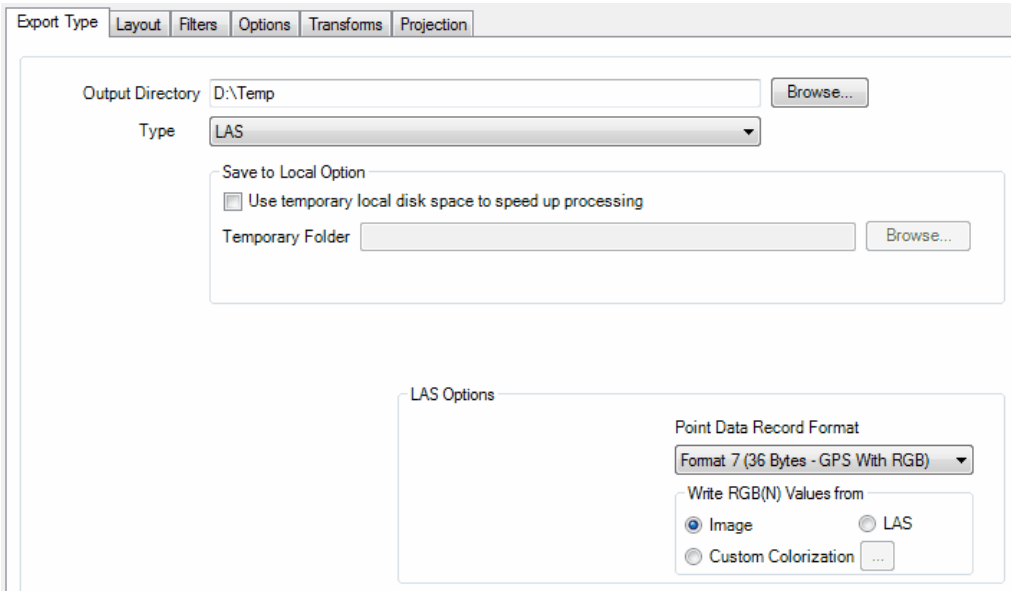
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1.) To be able to use this tool properly, first the user must have ***BOTH*** an image and an LAS file loaded into MARS®.

2.) Next, the user must export the data.

3.) See the screen shot below for the parameters needed to use the 'Color by RGB' tool.

- ✓ Designate an output directory for the LAS file.
- ✓ Make sure the 'Type' of export is 'LAS'.
- ✓ In the 'LAS Options' section, choose a 'Point Data Record Format' that can store RGB(N) values: either 7 or 8 (if the imagery is 4-band).
- ✓ In the 'Write RGB(N) Values from' section, select the button labeled **'Image'**. This option will allow the RGB(N) values of the image(s) to be stored with the exported LAS point data.
- ✓ Click on the 'Layout' tab and create a name for the exported data in the 'File' text box.
- ✓ Click **'Export'** at the bottom of the dialog box.

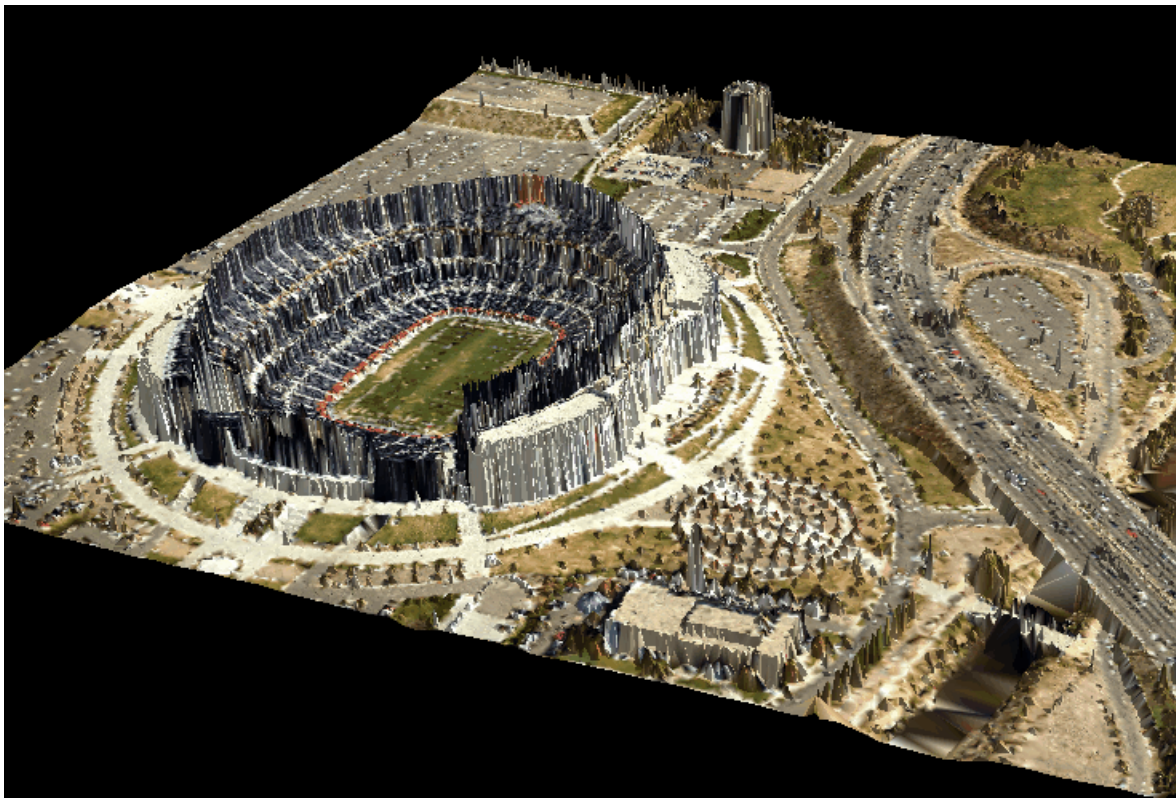


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4.) To properly view the RGB data, close the current project in MARS® and open a new, empty project, or unload the current data.

5.) Open the newly exported file by clicking the top half of the '**Add LAS Files**' button on the Project/Data Preparation Tab 162, and navigate to the output folder that was chosen for the export. Select the file and click **'Open'**.

6.) Now select the **'Color by RGB'** button and the LAS file will appear rendered by the RGB values stored for the points. To view the data more easily, click the **'TIN'** button. This data can also be viewed in 3D as shown below.



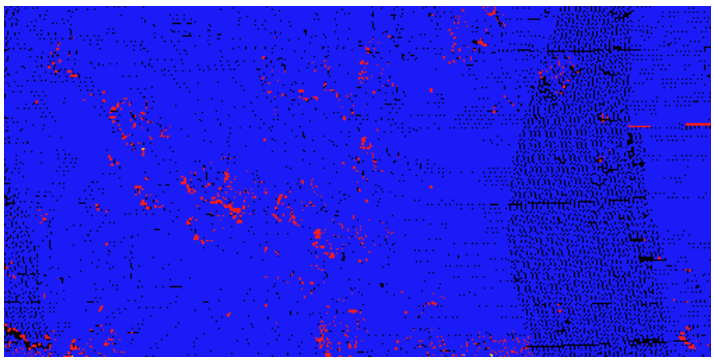
See also 'Color by CIR 845.'

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Color by Imagery (Fusion): Drapes imagery over the LiDAR points. There must be imagery loaded for this option to be enabled.

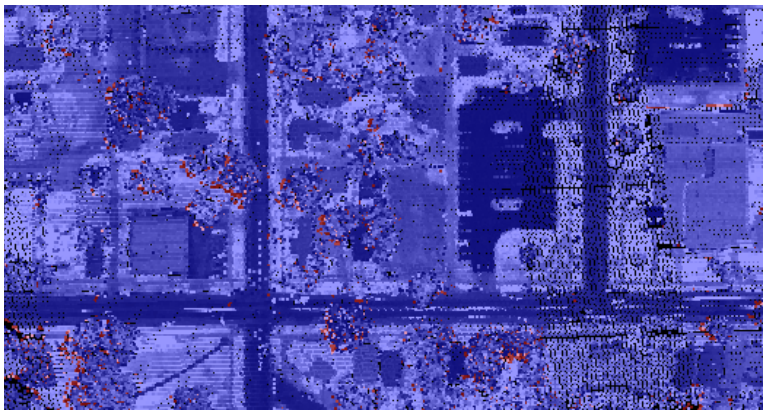
Blend with Intensity: This tool displays LiDAR points by gray-scale intensity and allows the user to blend this with other 'color by' views. Intensity may be blended with elevation, classification, return, collection scan, ground color, or user data. There is no terrain relief when viewing LiDAR data by intensity alone, but the ability to view intensity along with another rendering option may allow the data to be viewed more efficiently. Please see the examples below for further explanation.

In the example below, the LiDAR data is being viewed by return only. By viewing only the return values, it is impossible to know which characteristics in the terrain the first return (blue) and second return (red) data correspond to.



The example below is of the same area, but the 'Blend with Intensity' tool has been utilized with the return values in the LiDAR data. It is now easy to see that the first return data (blue) corresponds to areas with roads and buildings whereas the second return data (red) corresponds to areas containing trees.

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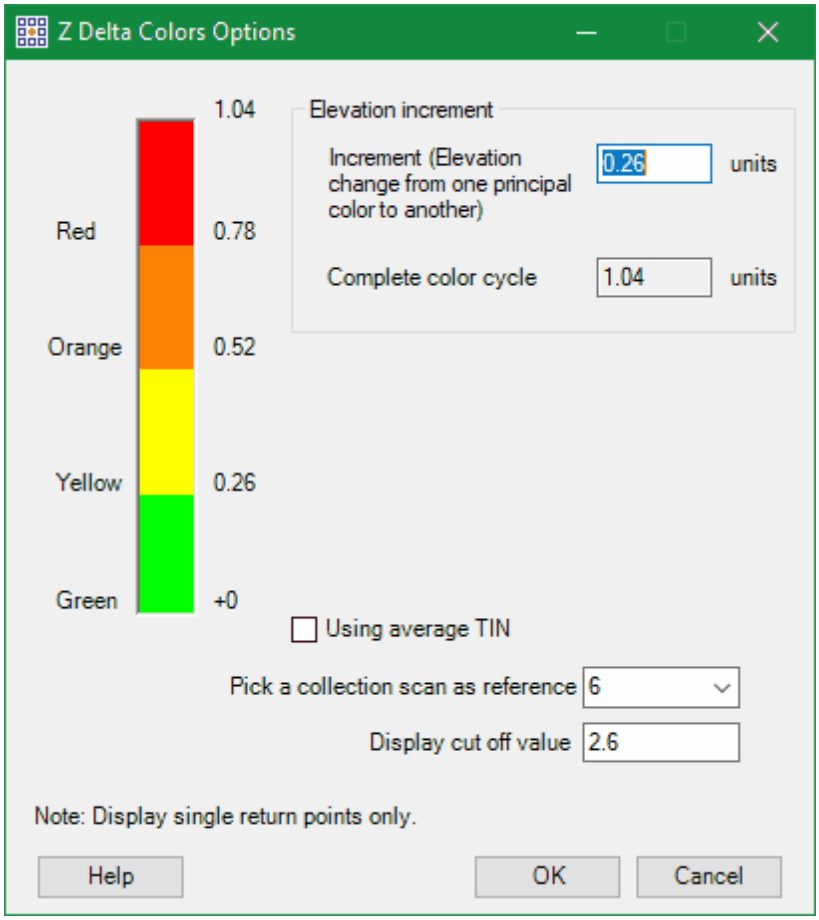
Color by CIR: Uses the R(ed), G(reen), B(lue), and N(ear Infrared) values stored for each LiDAR point to render the point cloud or TIN as a 4-band[845] pseudo-image. This option is intended for use with Point Data Record Format (PDRF) 8 point clouds that can store NIR values. See also 'Color by RGB[863].'

Color by Hillshade: This tool will color an elevation float grid by hillshade[860] on the fly and allows for user settings of sun azimuth and altitude. This tool is only available when a Float Grid (*.flt) has been loaded into MARS® and can be used in 3D (perspective) mode[837]. For more information on loading a float grid into MARS®, please see the Convert Float Grid[655] section of the MARS® Help file. To read more about the Color by Hillshade[860] tool, please select the link to this topic.

Color by Z Delta *(not available with Evaluation license)*: This tool will color the points in the LiDAR data by the vertical difference between adjacent collection scans. To see how this tool is used for QA/QC procedures, please see the Color By Z Delta Analysis[1731] section.

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Clicking the **'Color by Z Delta'** button will bring up the **'Z Delta Colors Options'** window.



✓ **Increment:** Specify here how many elevation units should be between each of the four principal colors.

✓ **Complete color cycle:** This text box will automatically update to tell the user how many total vertical units will be included in the complete color cycle (four colors).

✓ **Using average TIN:** If this check box is used, the Z-Delta will be determined using the average TIN value of all collection scans.

✓ **Pick a collection scan as reference:** This drop-down box is automatically populated with the collection scan numbers of the collection scans shown in the LAS Map View at the time the 'Color by Z Delta' button was clicked. If the user would like to have the Z-Delta be

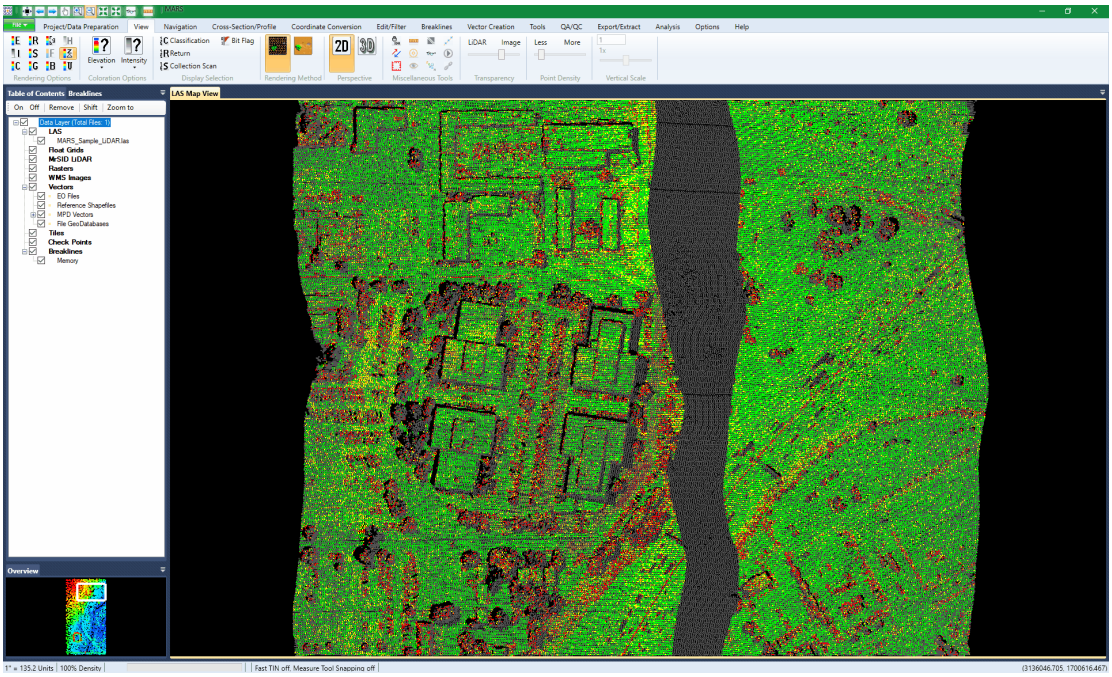
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determined for the overlap areas of collection scans adjacent to one particular collection scan, then this option should be used. Make sure the 'Using average TIN' check box is unchecked if using this option.

- ✓ **Display cut off value:** The user has the option of entering a Z-Delta value in this text box which would be considered out of the realm of possibility. For example, in one collection scan a car may have been parked beside the road when the LiDAR points were collected, causing some of the returns to be from the top of the car. In the next (adjacent) collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Color by Z Delta' tool will bring this discrepancy to the user's attention. An entry in the 'Display cut off value' text box tells the process to ignore data areas with a greater Z-Delta. By entering a value of '4' for example, the Z-Delta between a car on the side of the road vs. no car on the side of the road will be ignored and no data coloration will be applied in this area.

Example: The data in the screen shot below has been properly boresighted. The user has chosen a collection scan as a reference compared to any overlapping collection scans, and an increment of 0.15 units. The results show that most of the ground points are green - this means that the Z-Delta in these overlap areas is less than or equal to 0.15 units. The areas of yellow show a Z-Delta between 0.15 and 0.30 units, the areas of orange show a Z-Delta between 0.30 and 0.45 units, and the red areas show a Z-Delta between 0.45 and 0.60 units. These areas of yellow, orange, and red should be QC'ed carefully to make sure that the larger Z differences are explainable.

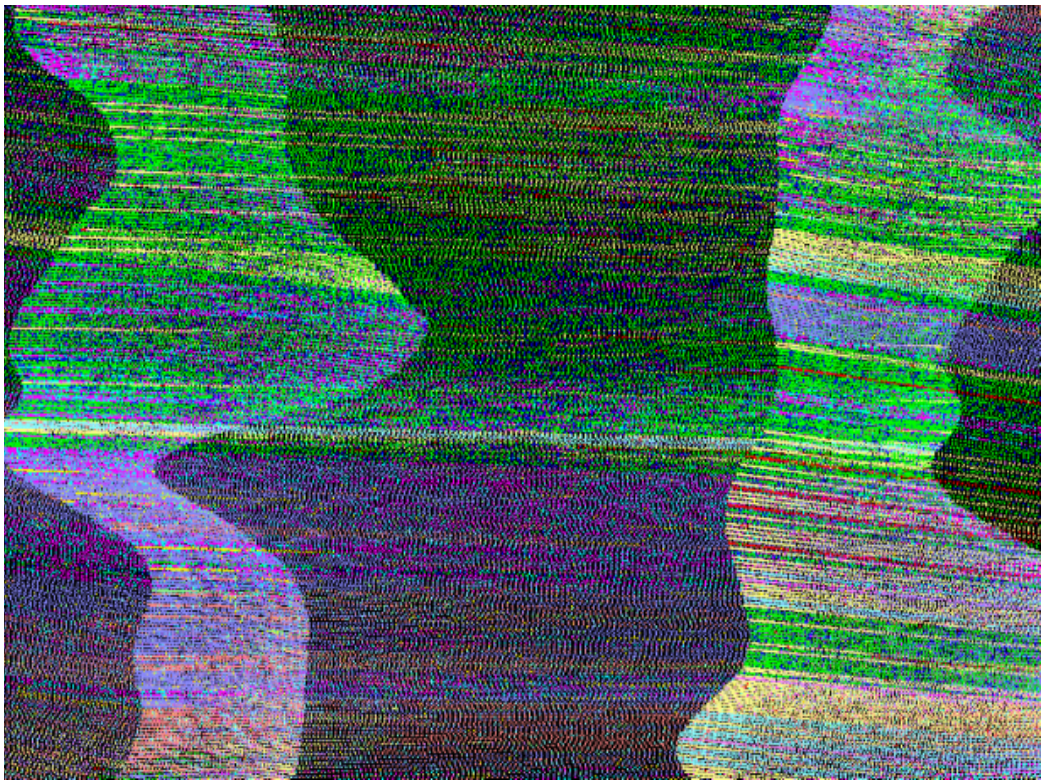
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Color by User Data: Displays LiDAR points rendered by values stored in the 1-byte 'User Data' field which can contain any type of data at the user's discretion. This field has often been used to store Auto-Gain Control values at the time the particular point in question was recorded in the system. These AGC values, specific to Leica sensors, tell the user how the system was attempting to center the intensity histogram at the time of collection.

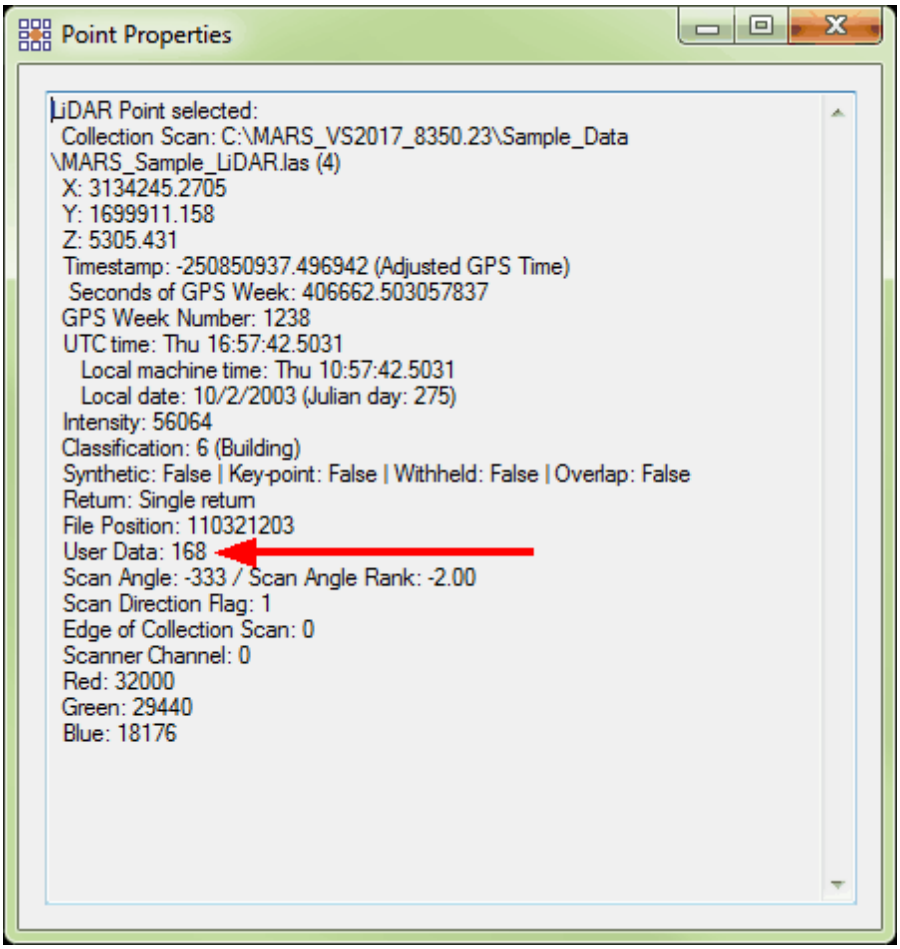
Below is an example of an area of data colored by User Data when AGC values are stored.

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The **Inspect** button  can show the user the User Data value of a particular point. Click on the **'Inspect'** button and click on the point for which information is needed. The chosen point will flash twice and then remain highlighted in white using a larger symbol size to identify itself. See more on the **Inspect** tool below in the **Miscellaneous Tools** section.

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- **Coloration Options:**



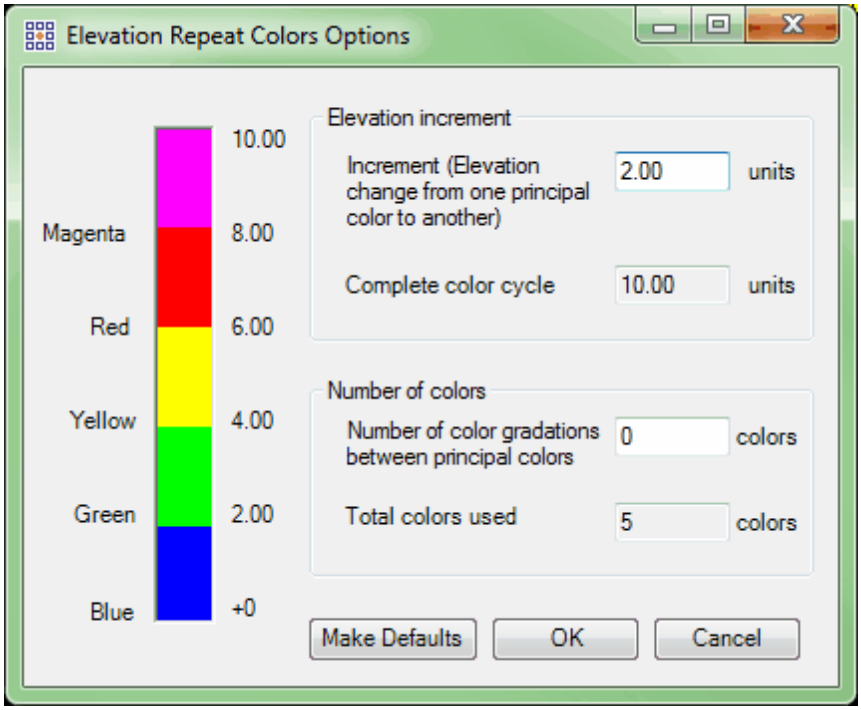
Elevation: The Color by Elevation 192 tool  displays the LiDAR points by relative elevation value. When this rendering option is used, the following **Elevation Coloration Options** are available:

  - **Rescale** (default)**:** When using this option, the elevation display will be rescaled for the current viewing extent every time the user moves around the project, zooming in

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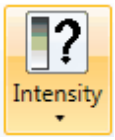
and out or panning. In other words, each window extent will have its own relative high and low elevations. Please see the Elevation Rescale 886 topic for further information.

- **Throughout:** This option uses every loaded point's elevation - visible in the current extent or not - in determining the elevation color to be assigned to each point. Please see the Elevation Throughout 887 topic for further information.
- **Repeat:** This option allows for adjustments to the color repeat cycle for different elevations in both the LAS Map View window and the Cross-Section/Profile window. Please see the screen shot below and the Elevation Repeat 881 topic for further information. The settings on this interface will be stored when an MPD is created or saved.



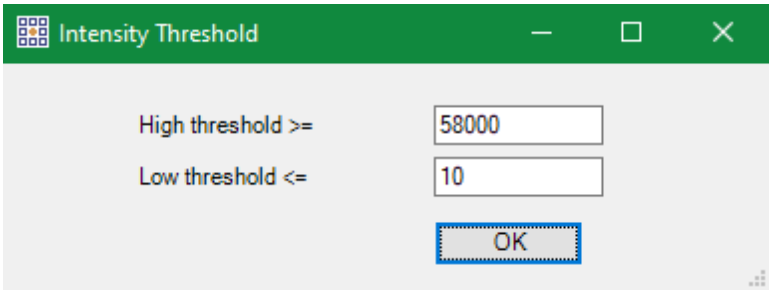
Please see the Elevation 878 rendering section for more information.

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Intensity: The Color by Intensity 192 tool  displays the LiDAR points by intensity value. When this rendering option is used, the following **Intensity Coloration Options** are available:

- **Gray-scale Only:** Gray-scale is a quantitative measure of the intensity for each return. For 16-bit data the intensity values range from 0 to 65535, where 0 represents the darkest reflections (ex. new asphalt) and 65535 represents the brightest reflections (ex. white rooftop). Please see the Gray-scale Only 895 topic for further information.
- **Multi-color:** This option displays Intensity values rendered by a color ramp, with the lowest values in magenta and the highest in white.
- **Color Extremes:** This option allows all extreme low and high intensity values to be displayed in color. When selected, a control pops up to allow the low and high thresholds to be entered. For example, if 58000 is entered as the 'High threshold' and 10 is entered as the 'Low threshold', all points with intensity values of 58000 or higher will be rendered in blue and all points with intensity values of 10 or lower will be rendered in yellow. Please see the Color Extremes 892 topic for further information.

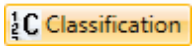


- **Equalize:** By default the intensity color display is set to 'Equalize'. Using this option, the intensity display will be equalized every time the user moves around the

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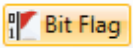
project, zooming in, or out, or viewing different areas. This tool will take the intensity ranges within the LAS Map View window and use a histogram stretch on the data so the data can be viewed more easily. Please see the Intensity Equalize topic for further information.

- **Display Selection:**



Classification: There are two different versions of the interface - one when the LAS Map View window is active, and one when the Cross-Section/Profile window is active. Settings on each will affect the display only for its corresponding window. ***Note that the interface's Class/ Description combinations are correct for LAS v1.4, Point Data Record Format (PDRF) 6 or higher per the latest ASPRS specification (1.4 - R15, dated July 9, 2019).*** Custom settings files can be made as described in the last paragraph of this topic.

The LAS Map View version of the interface allows the user to choose specific classifications for visibility and for rendering method. Check/uncheck the '**Display**' boxes for the classes to be viewed/ hidden. The shortcut buttons at the bottom of the interface offer quick settings: The '**All Classifications On/Off**' buttons will turn all classes on/off. The '**Ground (All)**' button will turn on Class 2 only and will, by default, include those ground points that are bit-flagged as Model Key-points. The '**Apply**' button will show the effect of the current settings without closing the interface. Separate Bit Flag display settings for all bit flag types can be found in the 'Bit Flag' display settings tool



(below).

Individual classes can be set for how they are displayed (as '**Point**' or '**TIN**') when the LAS Map View window is using the TIN Rendering Method (see separate topic below). For Point/TIN rendering, the individual boxes may be checked per class, or the shortcut buttons '**All Classes as Points**' and '**All**

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Classes as TINs' may be used.

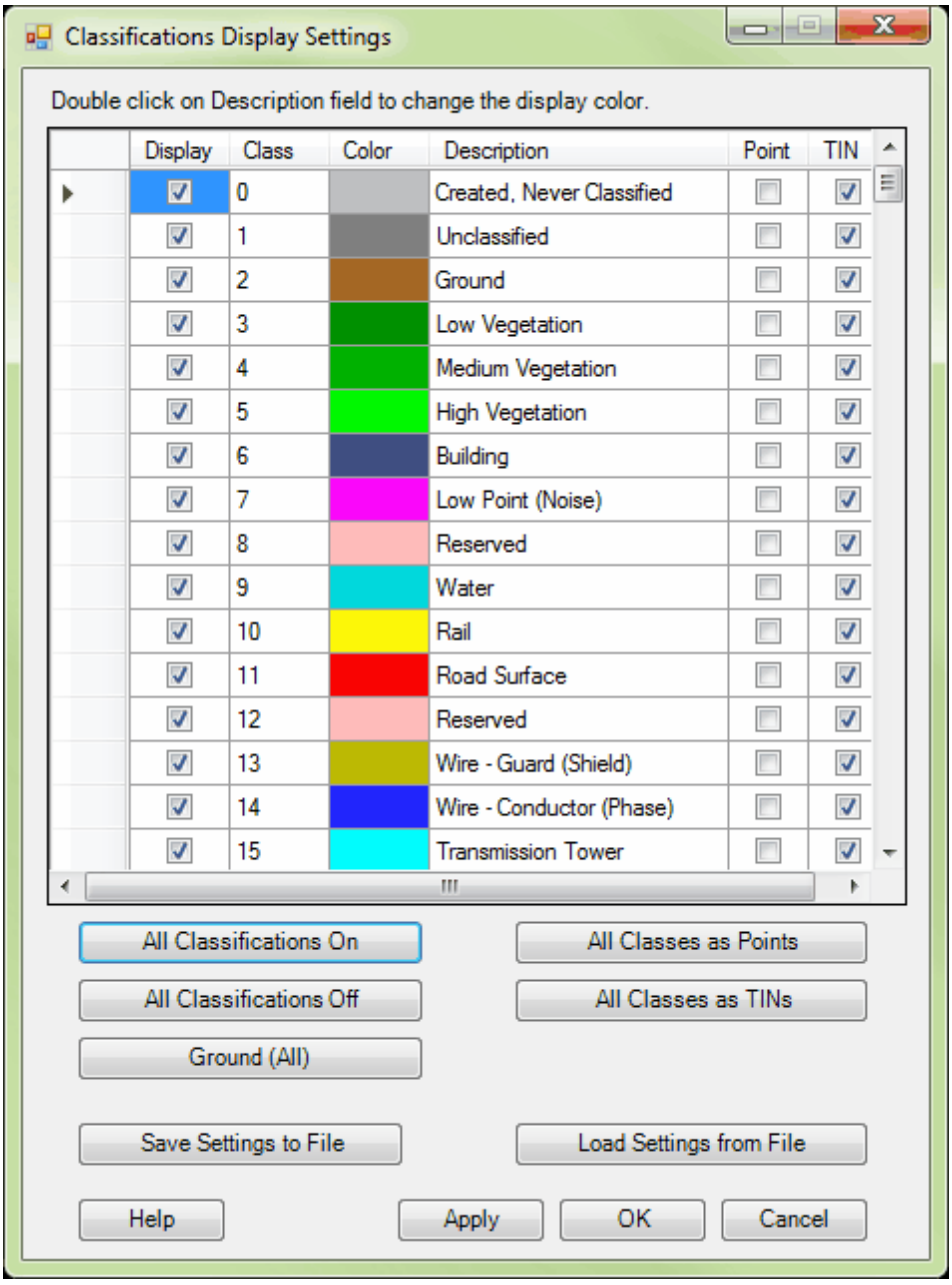
Any of the settings representing a class can be changed to make custom settings files without affecting the default values by following these instructions: For '**Display**' status, check or uncheck the boxes as desired. For '**Color**' changes, double-click on a color box - the standard Windows color dialog will appear. For '**Description**' changes, highlight the text and then click on it - a new description can then be entered. For Point/TIN rendering status, (**'Save Settings to File'** and **'Load Settings from File'**). These files can save the display status, class color and description, and Point/TIN status for each class. For more information, please see the Color by Classification 846 and the Displaying Data 1772 topics.

When the Cross-Section/Profile window is active, the interface will appear as in the screen shot below right. This version includes only the class display checkboxes and a reduced set of shortcut buttons.

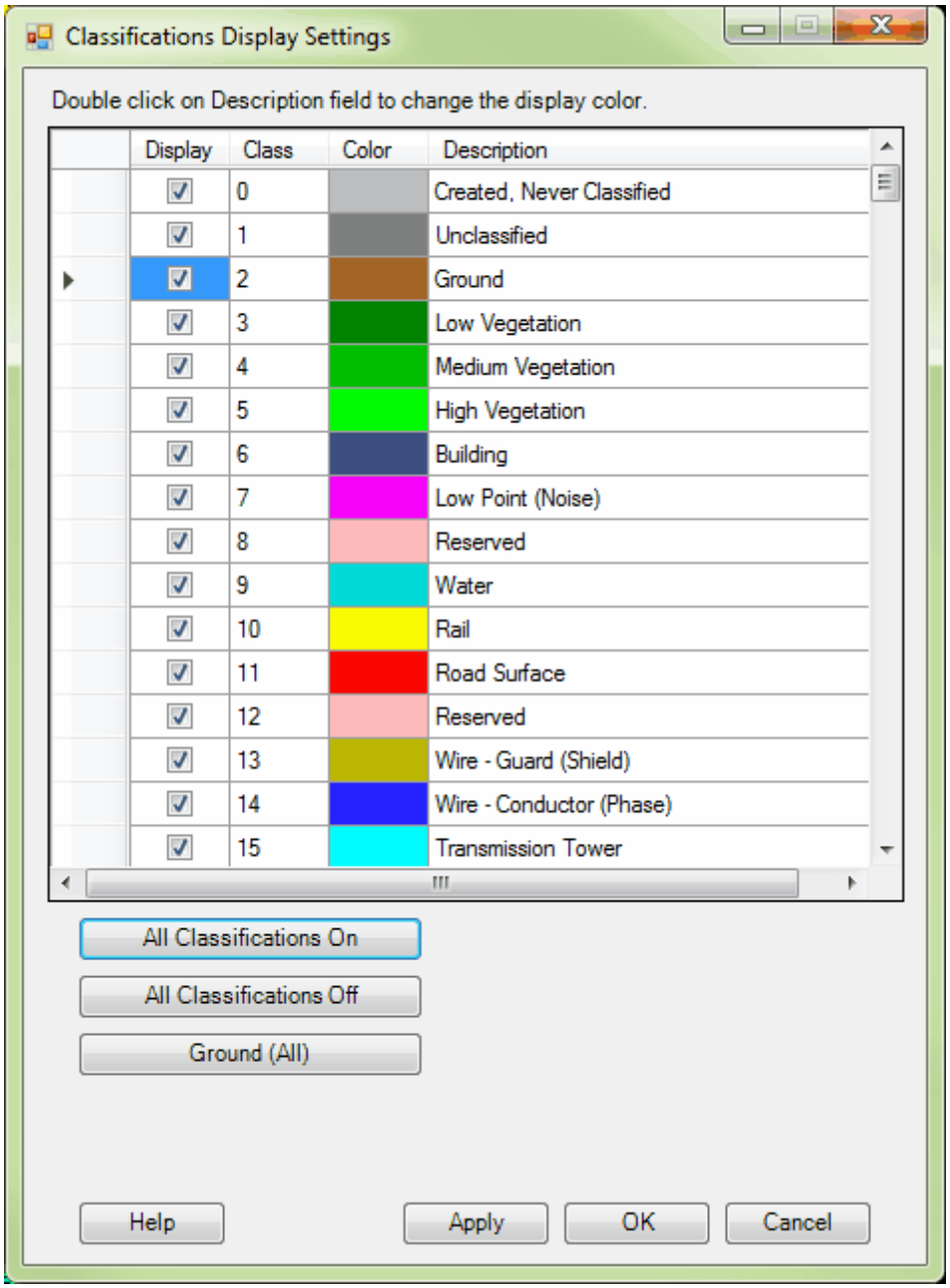
When the LAS Map View window is active

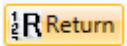
When the Cross-Section/Profile window is active

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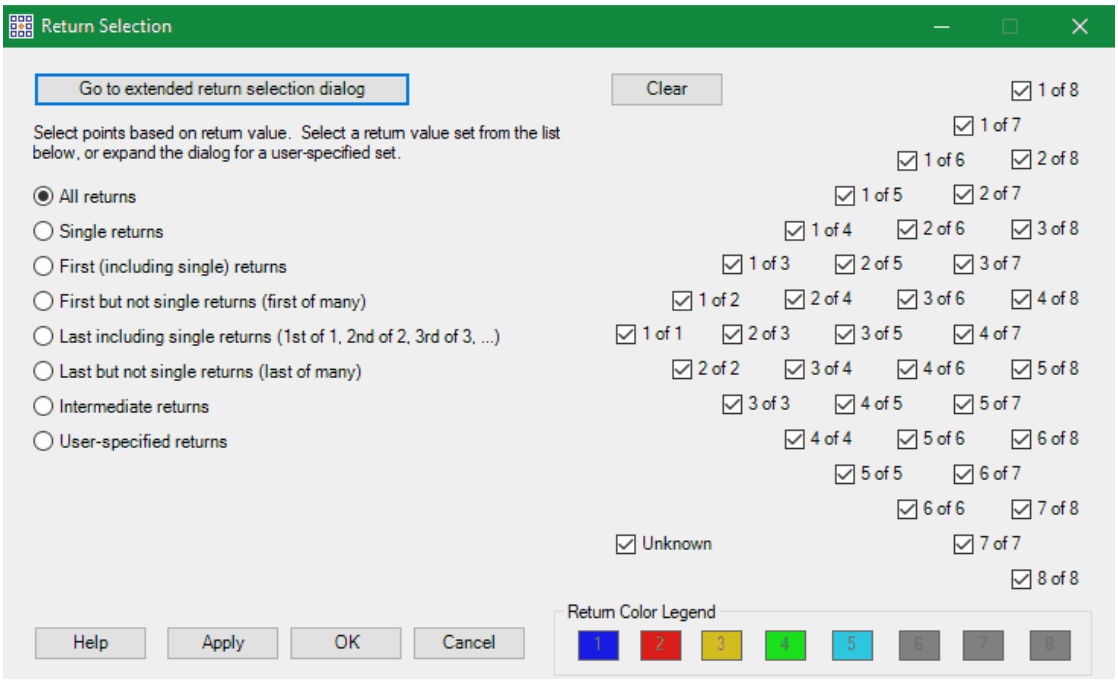




Return: This two-part interface offers the user the opportunity to choose specific returns for viewing when using the **'Color by Return'** rendering option. On the 'traditional' part of the interface (see below), check the returns which are to be viewed, and uncheck those which are not to be viewed. The short-cut radio buttons at the left side of the interface offer exclusive settings. Use these short

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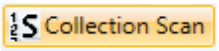
cuts to choose the returns for viewing or manually choose the returns for viewing by checking the boxes on the right side of the interface. This part of the interface handles up to eight returns, which is the current limit for most commercial LiDAR sensors. Changes cannot be made to this interface unless the loaded data has valid point family (discrete return) information. For more information, please see the data viewing by Return 862 topic and the Return Information Testing (Return Info) tool topic in the LAS Tools 570 section of this help file.



To make more granular selections up to the LAS v1.4 specification limit of 15 returns, click the button at the top labeled **'Go to extended return selection dialog'**. The interface will switch to the second part, which uses a column in the center to list the currently selected returns (see below). The same short-cut buttons are available on the left side, and their selection will affect the list shown in the column. On the right side, there are various buttons for more control of the listed (to be displayed) return values. By default, all return values are listed for display. Values may be removed by selecting them in the list, either individually or using the 'Shift' or 'Ctrl' keys while clicking to make multiple selections. Click the **'Remove Selected'** button once the selections are made to remove those

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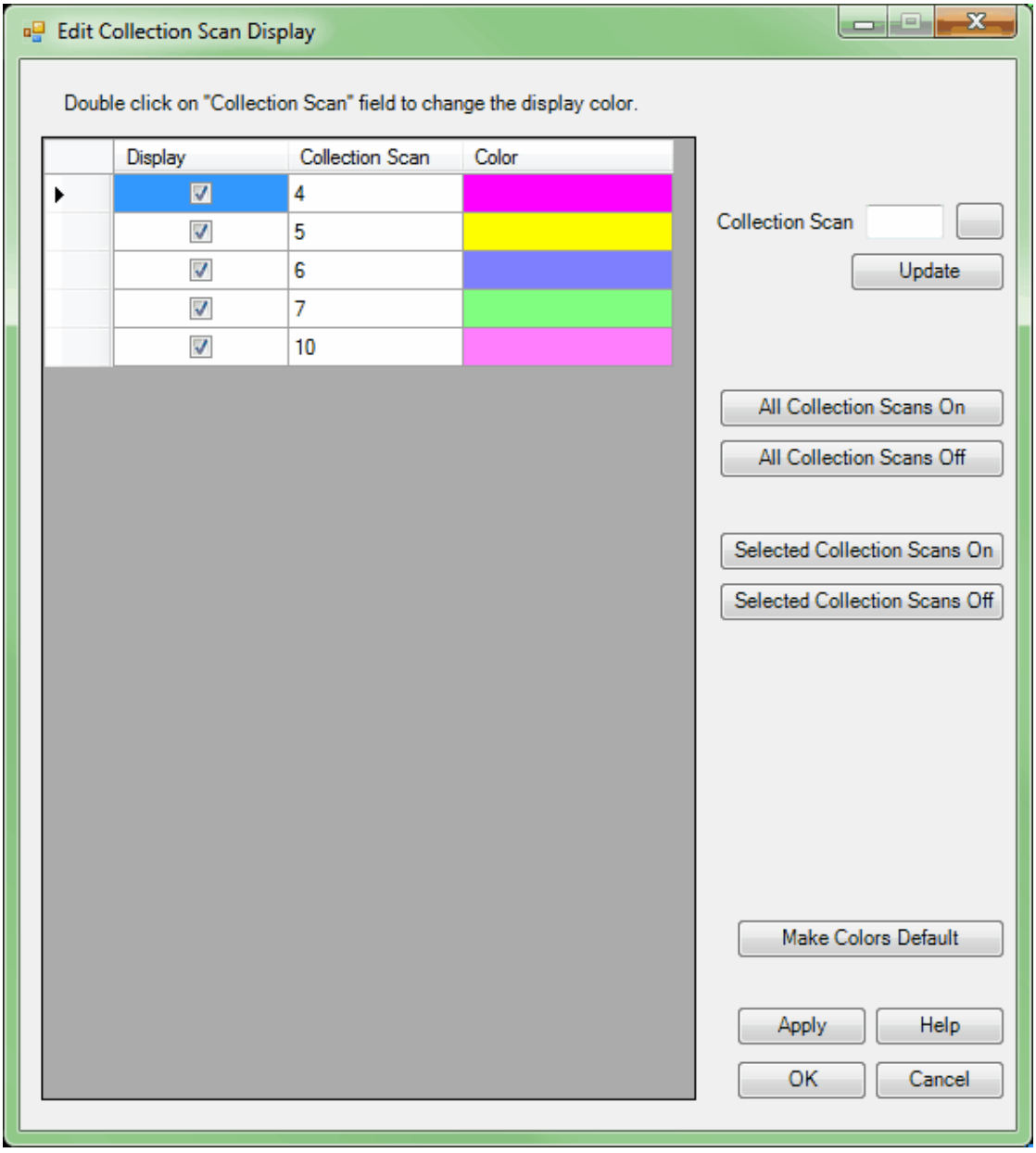
values from the list. To clear the entire list, use the **'Clear'** button. Use the **'Add Unknown'** button to add returns that don't have proper point family information - when inspected, these may appear as '0' or '1 of 0', for example, indicating a possible sensor malfunction. Entering values in the **'Return Number'** and **'Total Returns'** boxes and clicking the **'Add'** button will populate the list with just that value - second of eight (2/8) for example. All third returns can be added by entering '3' in the **'Return Number'** box and clicking **'Add All for This Return'**. To add all returns in point families consisting of nine returns, enter '9' in the **'Total Returns'** box and click **'Add All for This Total'**. With these detailed options, any and all combinations of return values can be set for display. Note that each of the two selection windows has its own independent **'OK'** and **'Clear'** buttons to confirm and remove all selections, respectively. The '**Apply**' button will show the effect of the current settings without closing the interface. To go back to the traditional interface, click the button labeled **'Go to return selection dialog for <= 8 returns'**.



Collection Scan: The 'Edit Collection Scan Display' interface allows the user to choose which collection scans are displayed and change the colors assigned to each collection scan loaded into MARS®. The settings in this interface affect the display when the 'Color by Selection Scan' and/or 'Collection Scan Direction' tools are used. Only those collection scans that are actually loaded into MARS® will appear in the interface. Enter the number of the collection scan to be edited in the 'Collection Scan' text box. Click the color button which appears to the right of the text box to bring up a color palette and change the color associated with that particular collection scan. Click on the 'Update' button to update the color change in the master list to the left side of the interface. To change which collection scans are to be displayed, check or uncheck the boxes in the 'Display' column. All collection scans can be toggled on or off using the 'All ...' buttons, and selected (highlighted) collection scans can be toggled on or off using the 'Selected ...' buttons. Clicking the 'Make Default' button will create an XML file that MARS® will read each time it is opened. The 'Apply'

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button allows changes to be made and viewed while leaving the interface open. The dialog box may be left open during pan/zoom, editing, etc. Please see the Color by Collection Scan 850 topic for more information.



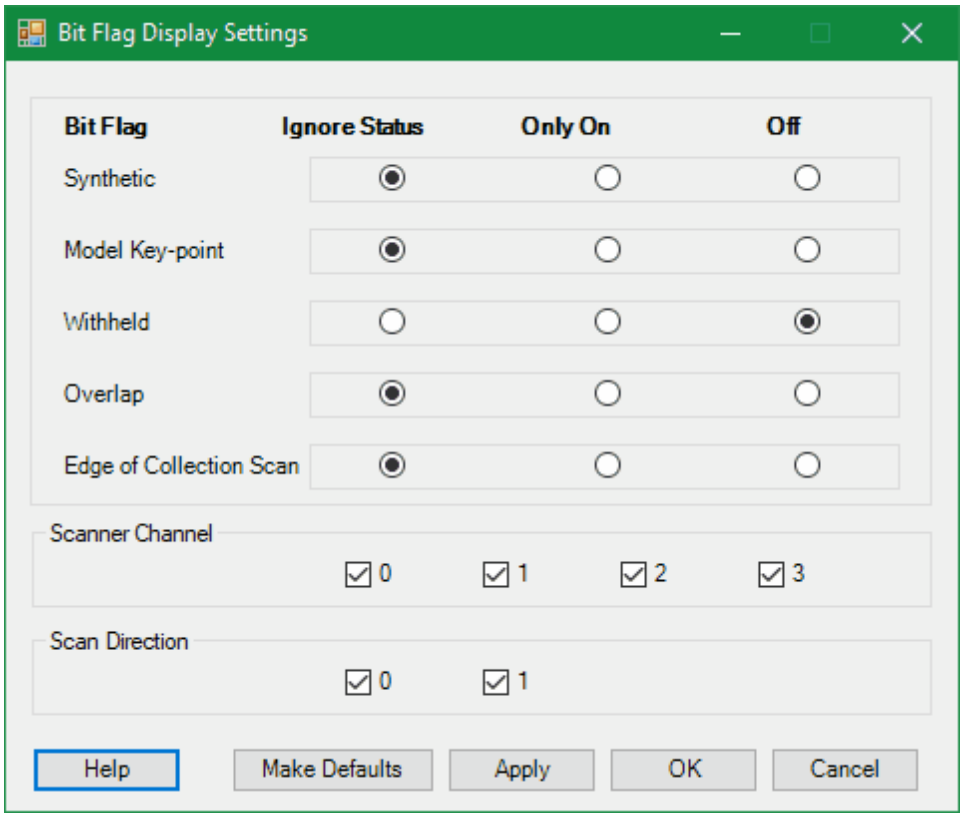
Bit Flag **Bit Flag:** The 'Bit Flag Display Settings' interface allows for LiDAR point rendering to be controlled by the point-level status of several bit flags: Synthetic, Model Key-point, Withheld, Overlap

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(also referred to as 'Overage'), Edge of Collection Scan, Scanner Channel, and Scan Direction. By default, points flagged as 'Withheld' are not displayed ('Off'). All other bit flag types are initially set to 'Ignore Status' - meaning that the points will be displayed whether or not the bit flag for that particular type is set to 'True' - or, in the case of Scanner Channel and Scan Direction, all possible values are checked on. For the upper portion of the interface, if 'Only On' is chosen only the points with that bit flag set to 'True' will be visible. If multiple bit flag types are set to 'Only On', only points with all corresponding bit flags set to 'True' will be displayed. For example, if 'Model Key-point' and 'Overlap' are both set to 'Only On', only those points with both bit flags set to 'True" will be visible. The 'Off' option is used to turn off those points that have the corresponding bit flags set to 'True'. Unlike 'Only On', however, points will be turned off when any one of the bit flags is set to 'True' for types using the 'Off' option. For example, if both 'Synthetic' and 'Overlap' are set to the 'Off' option, any points with either of those bit flags set to 'True' will be turned off. The 'Scanner Channel' and Scan Direction' settings operate independently of the other bit flag settings - they simply toggle certain channels and/or directions on or off regardless of the other bit flag settings.

Only those points that are visible will participate in the 'Rendering Method' (Point or TIN) or the 'Perspective" (2D or 3D) view. These settings can be made independently in both the LAS Map View and Cross-Section/Profile windows, except for the 'Scanner Channel' and 'Scan Direction' settings which are ignored in the Cross-Section/Profile window. To view by the new settings after making changes without closing the tool, click the 'Apply' button. To save a display configuration beyond the current MARS® session, click the 'Make Defaults' button.

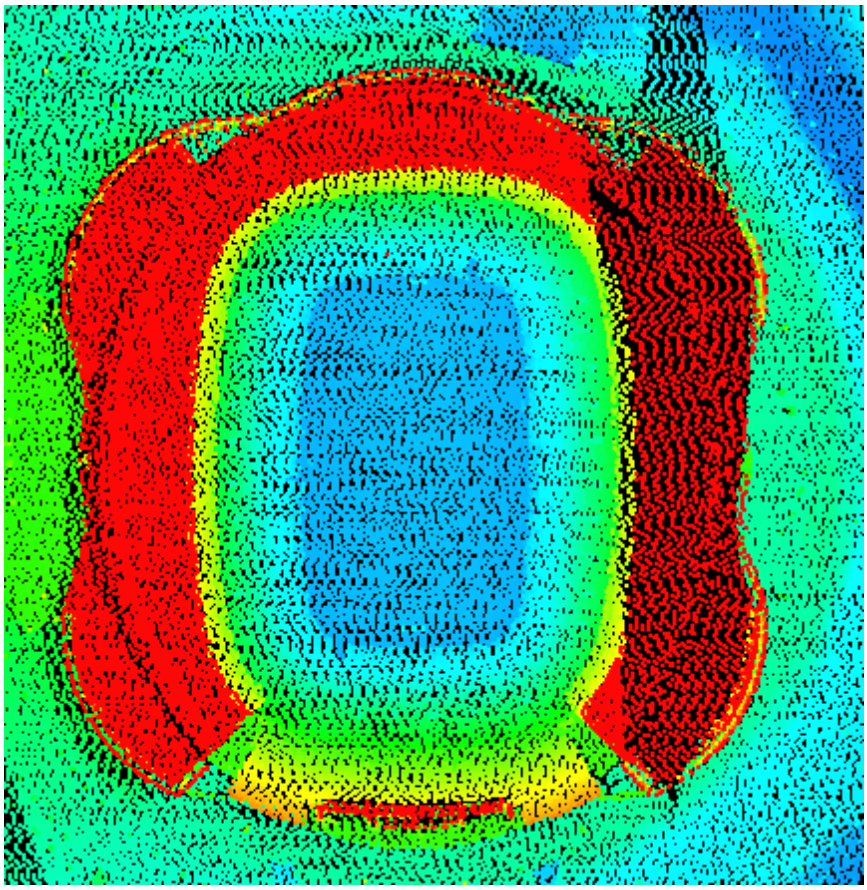
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- **Rendering Method:** Here, the user can choose how the data is rendered. There are two ways to look at data loaded into MARS®: Point rendering and TIN rendering.

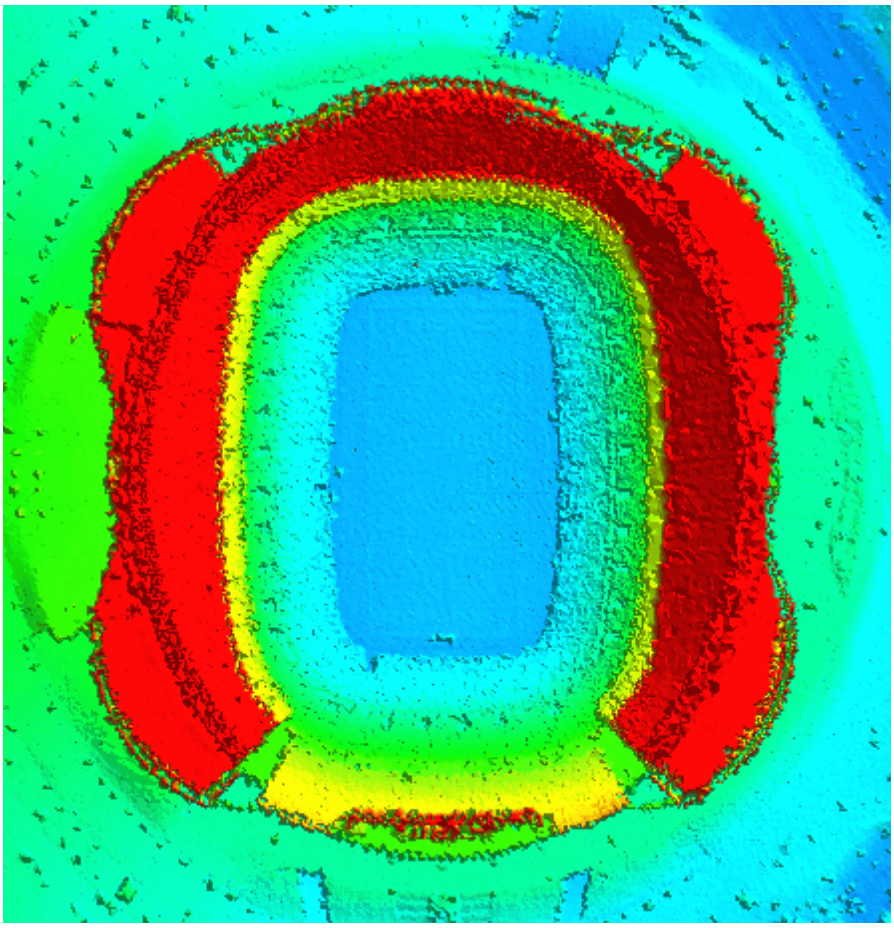
  ✓ **Points:** To view the data as points, click the 'Points' button  . The screen shot below is an example of LiDAR data rendered by Points.

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✓ **TIN:** To display LiDAR data as a TINned surface, click the 'TIN' button  . The TIN is generated on the fly and, therefore, may slow down navigation noticeably. It is recommended to switch to Points mode, as described above, before navigating around the project. Use TIN mode only at zoomed-in levels. The TIN rendering method may also be used in 3D view. The screen shot below is an example of LiDAR data rendered by TIN.

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- **Perspective:**



2D View: Displays data in 2D, or orthographic, mode (default setting). For more information on 2D navigation, see the 2D View[835] topic.

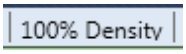


3D View: Displays data in 3D, or perspective, mode. For more information on 3D navigation, see the 3D View[837] topic.

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- **Miscellaneous Tools:**

 **Lock to view 100%:** This tool forces all points in the loaded LAS files to be displayed and is intended for hand editing purposes, when using the Flood Fill utility, and when displaying virtual contours. The density percentage on the left side of the Status Bar[158] tells the user the percentage of points which are currently being displayed.



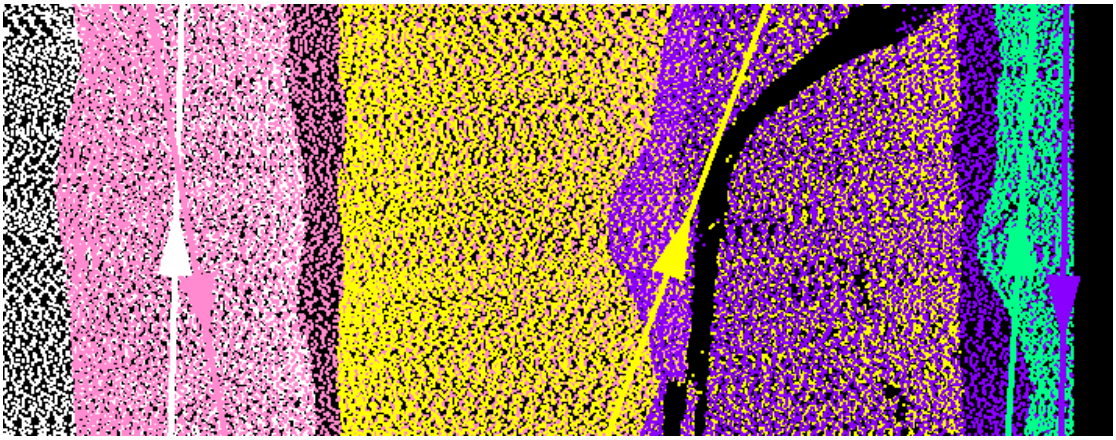
Hand editing should ONLY be done when viewing points at 100% density. It is easy for the editor to zoom in/out or lose/gain point density frequently throughout the hand editing process by maneuvering around the project, and this tool allows the editor to lock the point density of the display at 100% regardless of zoom level.

If navigation is slowed too much with this tool enabled, toggle it off, move to the desired area, and re-enable the tool. The tool will reset to the 'off' mode when all loaded LAS files are removed and must be manually toggled back on (if desired) after new data is loaded.

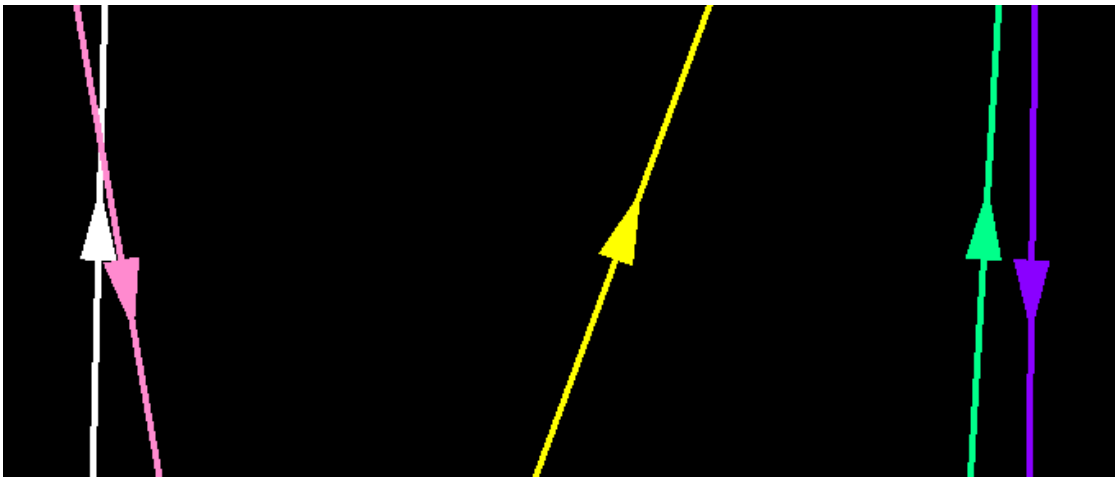
 **Collection Scan Direction:** The Collection Scan Direction tool allows the user to view the direction in which each collection scan was acquired. When the button is active (orange), the collection scan direction will be indicated with arrows pointing in the direction of acquisition. Each arrow is also color-coded to match the color of the corresponding collection scan data. See the section titled 'Display Selection - Collection Scan' earlier in this topic for information on changing collection scan colors.

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The example below shows five collection scans color-coded in white, pink, yellow, purple, and green.



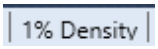
This example shows the same five color-coded collection scan direction arrows without the LiDAR data displayed.



Show Scale Bars: Toggles the display of Easting and Northing scale bars in the MARS® LAS Map View window on/off. The values shown are in the loaded data's coordinate system and units. This allows the user to gauge the horizontal distance of a project in the LAS Map View.

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 **Lock to view 1%:** This tool locks on only the 'thinned points,' the minimum set of points that can be displayed for loaded LAS files. This can speed up panning and zooming operations while the area of interest is being determined. The density percentage indicator on the left side of the Status Bar[158] shows the percentage of points which are currently being displayed.



Note that the actual percentage of points displayed may be less than 1% depending on the data loaded.

.

Line-of-Sight Display: MARS® supports the display of a source/target line-of-sight display (while in 3D perspective viewing mode only) for analysis purposes.

 **Place Target:** Allows the user to define a target location for an 'on-the-fly' line-of-sight display. With LAS data rendered in a 3D (Perspective) view, click on the 'Place Target' button and then click on a location in the data display. The data display will re-center around that point. Next, click on the 'Place Target' button (see below) and then click on a location in the data display that will be the observer's location.

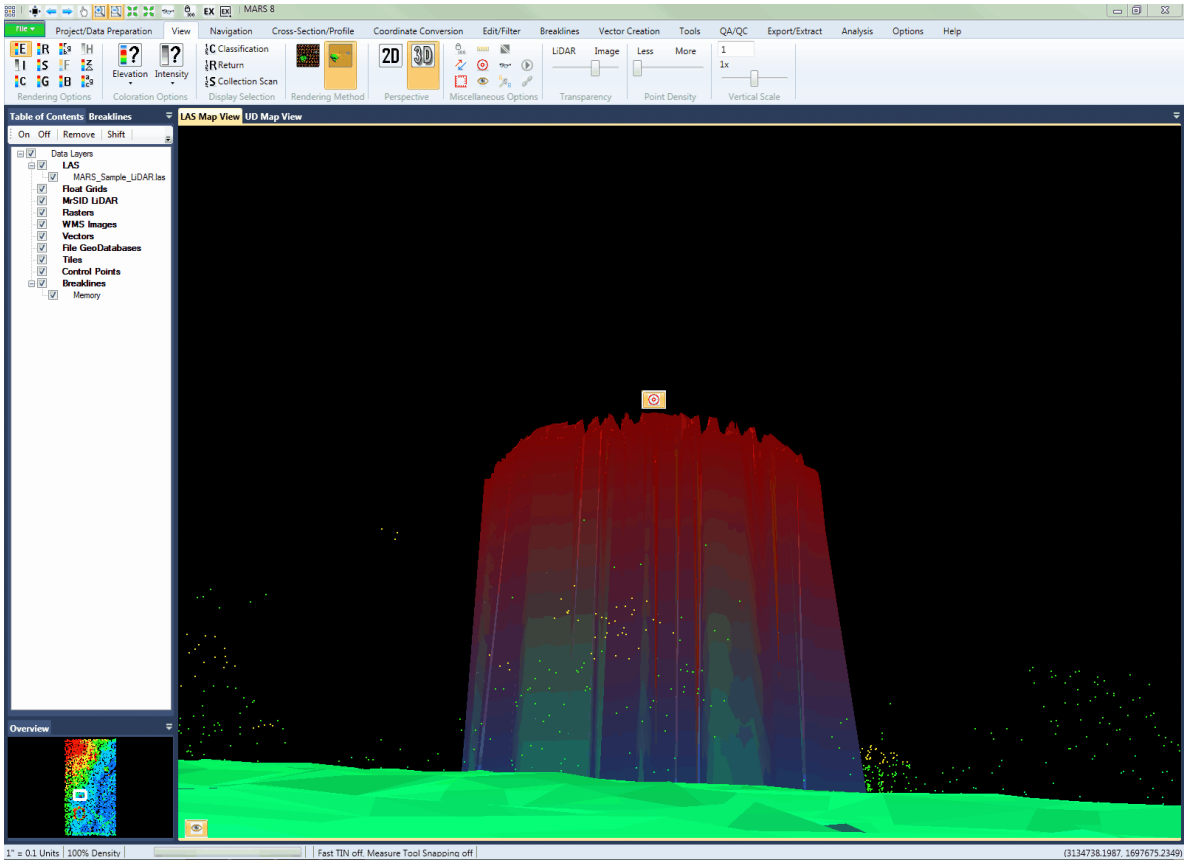
 **Place Eye:** Allows user to define a point of origin (viewer location) for an 'on-the-fly' line-of-sight display after a target location has been established (see above). With LAS data rendered in a 3D (Perspective) view and a target location already chosen, click on the 'Place Eye' button and then click on a location in the data display that will be the observer's location.

Example:

The user must select an area of interest and then change to 3D View[837] mode to use this tool. First,

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the user must define the line-of-sight target by clicking the **'Place Target'** button  on the View Tab 192 and defining a target location by clicking the mouse. The user must then define the point of origin (source) for the line-of-sight display by clicking the **'Place Eye'** button  and selecting a location by clicking the mouse. Once both locations have been defined, the LAS Map View display will update to show the view from 'eye' to 'target.'



 **Measure:** Allows for length, heading, and slope measurements, depending on whether it is used in the LAS Map View window or in an active Cross-Section/Profile window. Please see the detailed Measure 957 topic for more information.

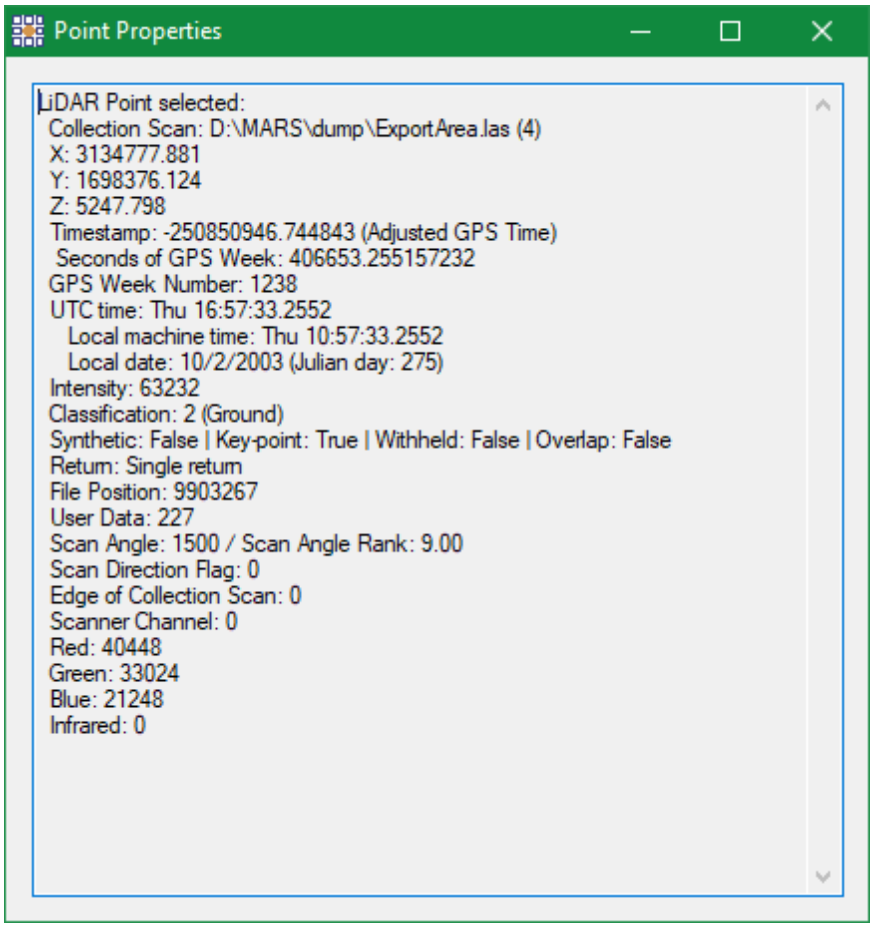
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Inspect - Click on this tool, and then click on the displayed LiDAR point that is to be inspected. The chosen point will flash twice and then remain highlighted in white with a larger symbol size to identify itself. Any number of displayed points can be inspected, one at a time. If a Cross-Section/Profile window is open, the point may be chosen in either view, and will be highlighted in both views. The one exception to this is in the Cross-Section/Profile window, the Inspect tool will identify the file name and collection scan number rather than a point when the data is viewed in Profile by Collection Scan mode.

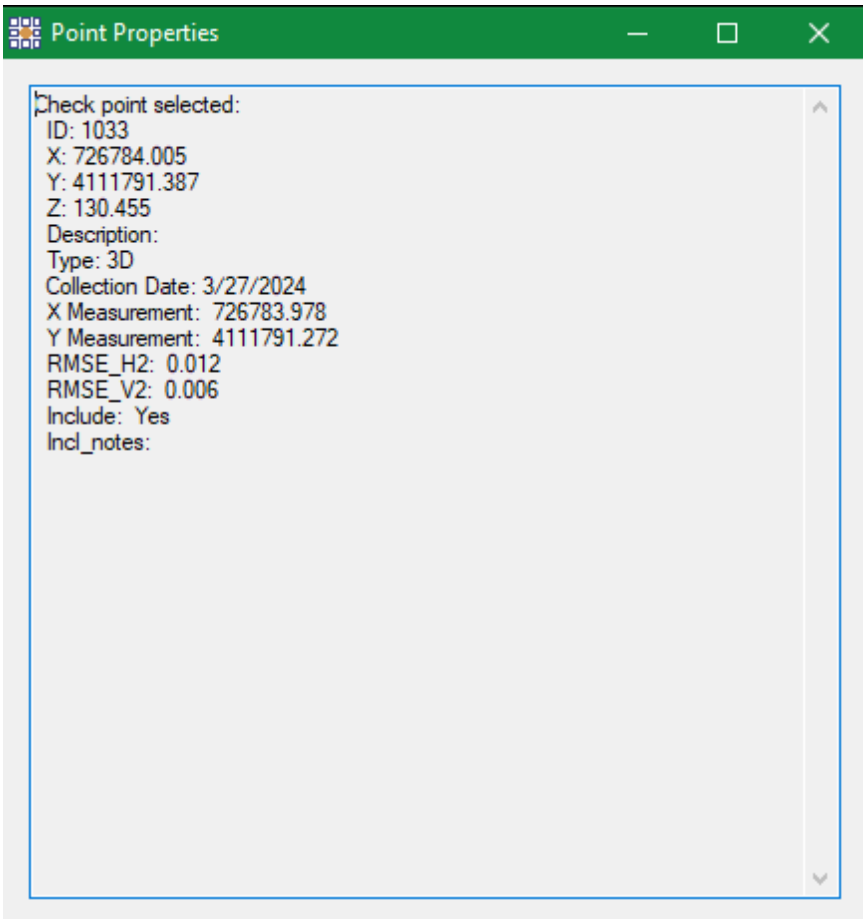
The tool displays the point's parent file path and point source ID (PSID), X, Y, and Z coordinates, timestamp (including Seconds of GPS Week, GPS Week Number, and Julian day), intensity value, classification, bit flag status, return number, user data, scan angle/scan angle rank, scan direction flag, edge of collection scan flag, scanner channel flag, and RGB(N) values (see Inspect 943 for details of these attributes). The tool works in 2D (orthographic) and Cross-Section/Profile views. Note that for LiDAR data, some fields are dependent on the data collected and the post-processing software used, as well as the LAS version and Point Data Record Format.

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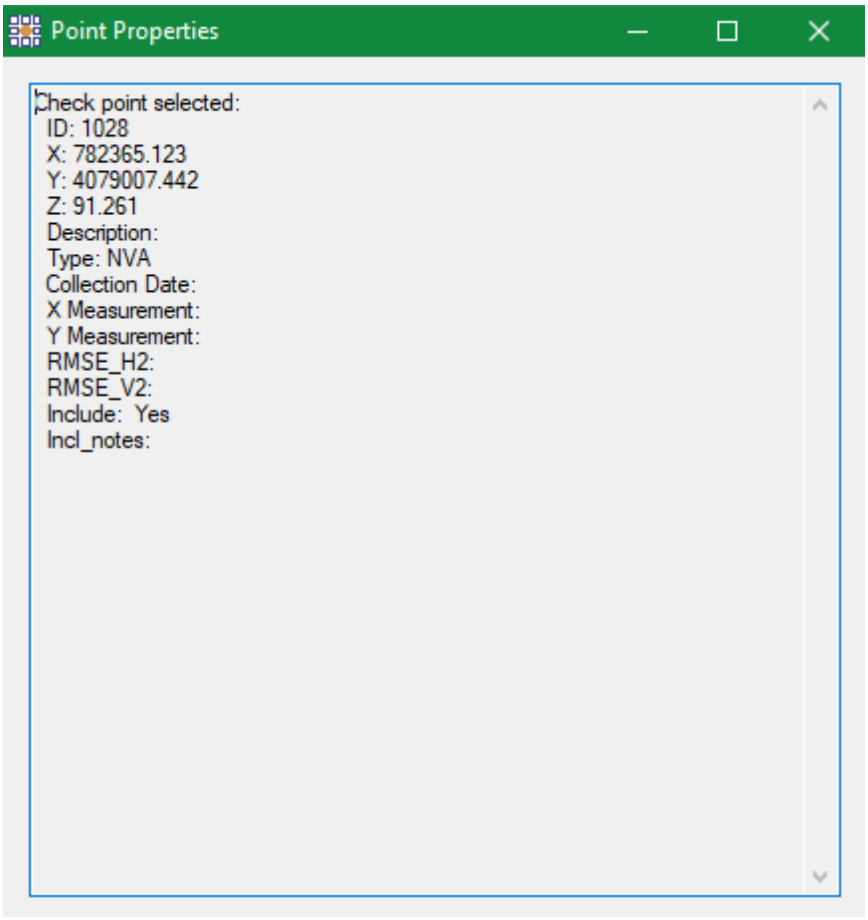
- To select a displayed check point for inspection, click on the desired check point (the LAS data may need to be turned off to avoid selecting a LiDAR point instead). For points in a full 13-column check points CSV file, the window that opens will display the point's ID, XYZ values, a description (if stored), the point's 3D / NVA / VVA type, the collection (survey) date (if stored), X Measurement (3D type only), Y Measurement (3D type only), RMSE_H2 error value, RMSE_V2 error value, Include status (if stored), and Include notes (if stored).

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For an abbreviated 7-column check points CSV, the window that opens will display the point's ID, XYZ values, the point's NVA / VVA type, Include status (if stored), and Include notes (if stored).

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- Holding down **'Ctrl'** on the keyboard and clicking on a virtual contour line, or displayed reference or breakline shapefile feature while the **'Inspect'** tool is toggled on will allow the user to inspect that feature rather than the closest LiDAR point.

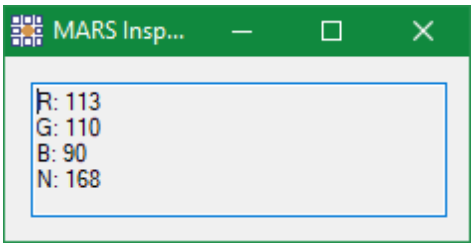
Windows copy-and-paste controls can be used in the resulting pop-up window. To unselect the **'Inspect'** tool and return the chosen feature to its original symbol and/or color, right-click the mouse. See the Inspect 943 tool topic for more details.

Inspect RGB(N) Tool: This utility allows the user to select and display the RGB(N) - Red-Green-Blue and, if present, NIR - values from the loaded imagery data. This tool is normally used to define RGB(N) values for the RGBNI Value Filter 1110. This tool will only work on RGB or RGB(N) imagery

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(not ENVI rasters) and is only available to use when imagery is loaded into MARS®.

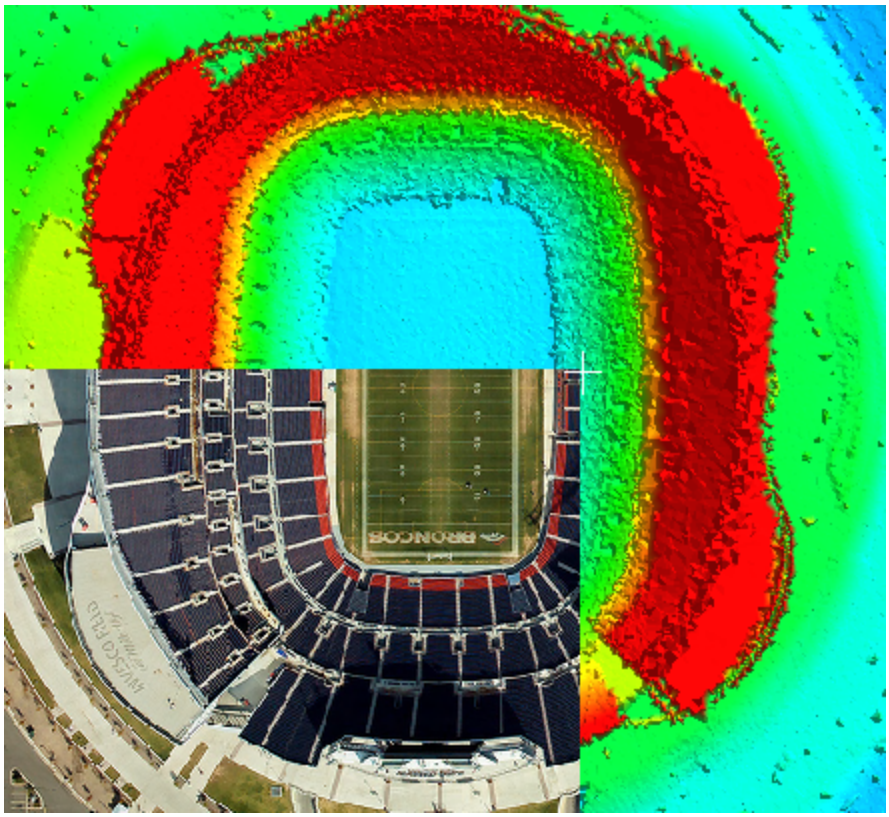
To use this tool, click in the desired location on the imagery. Once the user has selected a target, the **'Inspect RGB(N)'** dialog (see below) will be displayed, showing the RGB(N) values from the selected pixel. Additional locations can be selected without closing the pop-up. 3-band imagery will display 'N/A' for the 'N' field.



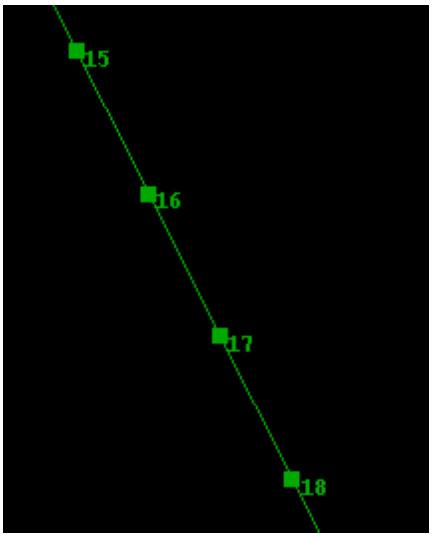
Swipe Raster Over LiDAR: This tool allows the user to move imagery over LiDAR data for rapid viewing of the alignment between the two. Both a raster image (or images) and LiDAR data must be loaded to use this tool. When checking the alignment of these two data types, it is most advantageous to have the LiDAR data in TIN mode. To use the tool, hold the Left Mouse button to swipe.

The MARS® window below shows the Swipe Raster Over LiDAR tool working between imagery and LiDAR.

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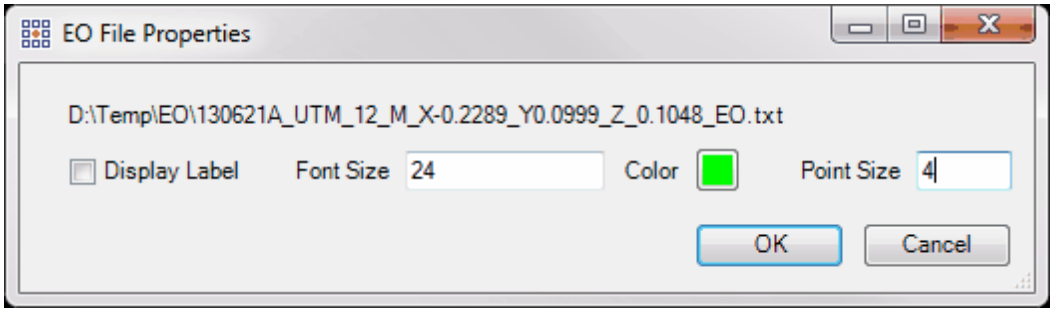
 **Show Breakline Vertices** ***(available with Production license only)*****:** This tool symbolizes the vertices for all loaded breaklines, and labels each with the ID number stored in the shapefile attribute table.



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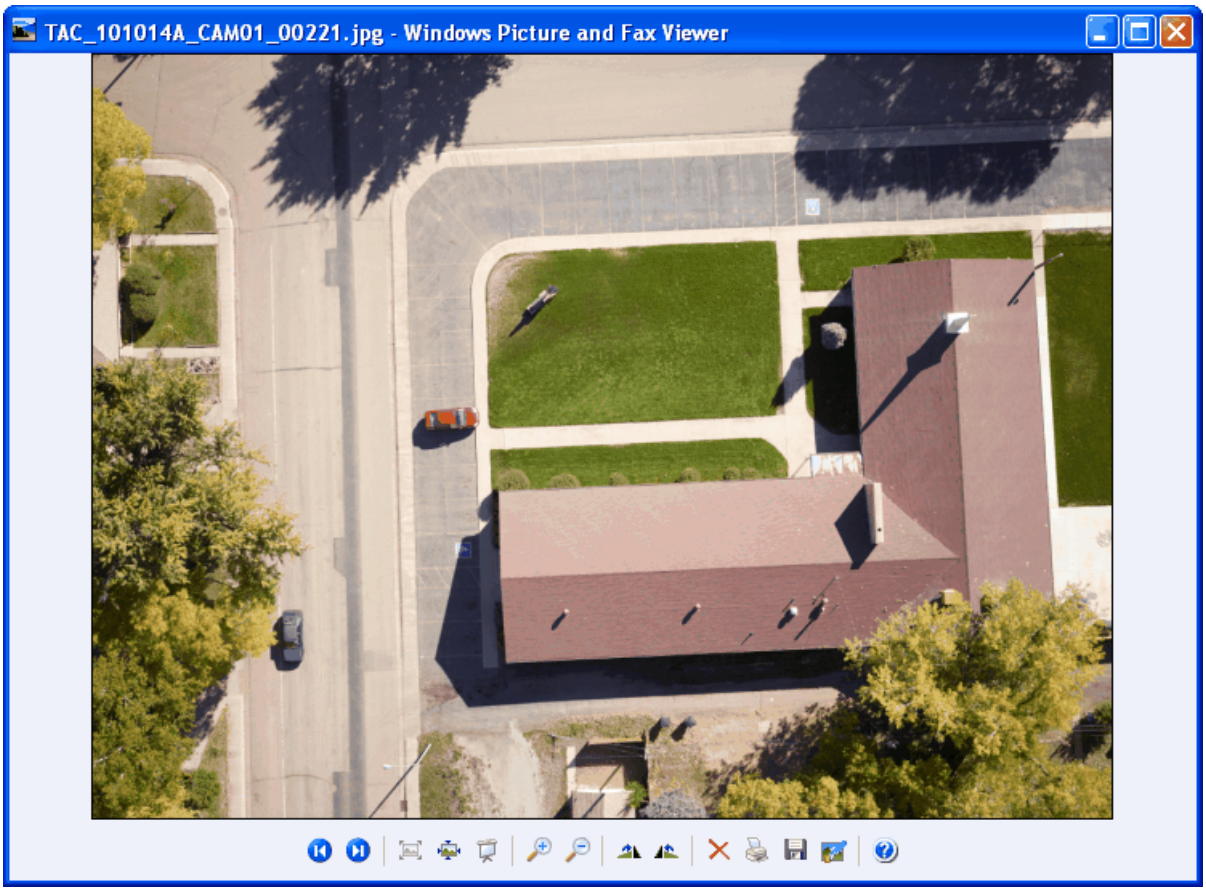


Hyperlink: The Hyperlink tool is associated with the 'Add EO File' tool which is located on the Project/Data Preparation Tab[162] tab. In order to use the Hyperlink tool, an EO file must be loaded into MARS® along with its associated imagery path. For more information concerning adding an EO file, please see the Project/Data Preparation Tab[162] topic. Once an EO file is loaded into MARS® the Hyperlink button will become enabled. The purpose of the Hyperlink tool is to provide the user with a way to display an aerial image associated with a particular EO event point. The EO file is displayed as a 3D point shapefile and each point, or event, in the EO shapefile is associated with imagery. Because it is displayed as a shapefile, it is also possible to change the display settings of an EO file by right-clicking on the file inside the Table of Contents and choosing 'Properties'. The resulting 'EO File Properties' window will allow the user to change the color and size of the point shapefile and will also allow the user to display labels.



When the user selects a point with the Hyperlink button toggled on, the associated image is then brought up in the Windows default viewing program. Below is an example of the imagery which will appear when an EO event point is selected. If the user selects a point from an EO file linked to RGB nadir imagery, this is the imagery which will be displayed. The same methodology applies for linking to CIR nadir, forward-facing, and aft-facing imagery.

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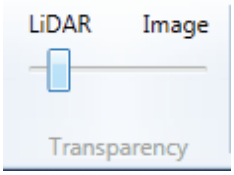
It is possible to display multiple EO files at once in MARS®. The Hyperlink tool will only display imagery with an associated EO file which is currently displayed in MARS®. For example, if the user has a separate EO file loaded for the CIR nadir, RGB nadir, forward-facing, and aft-facing imagery, it can be difficult to select the proper EO event file to bring up only one type of imagery. By using the options within the Vectors 95 layer of the Table of Contents 67 to turn off the display of EO files which are not currently needed, it is much easier to select the proper point for display. It is possible to save all loaded EO files, paths to imagery, and any raster files which may be loaded to a MARS® project file (*.mpd) for use at a later time.

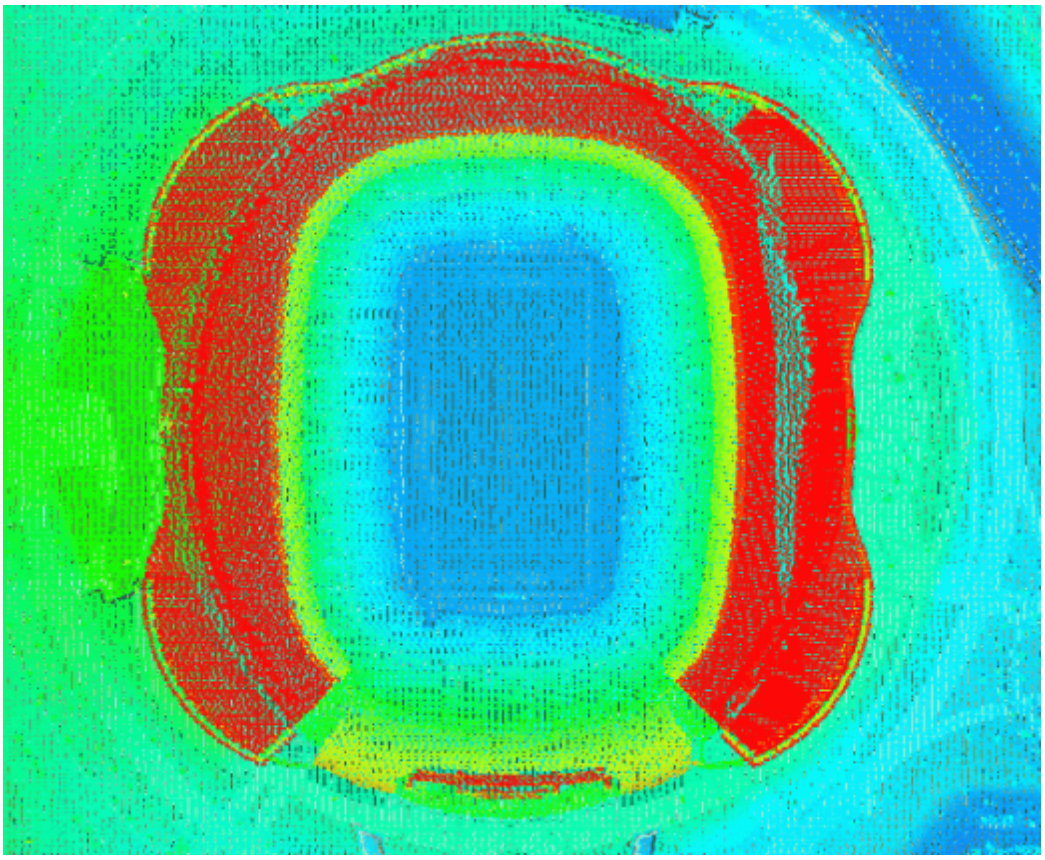
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- **LiDAR/Image Transparency slider bar:** Allows the user to adjust the transparency of the LiDAR points with respect to the imagery. This slider bar can only be used in the LAS Map View window while in 2D View[835].

See the examples below:

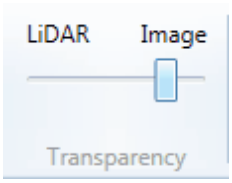
Ex: Viewing the data with LiDAR points favored over the imagery:





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Ex: Viewing the data with the imagery favored over the LiDAR points:

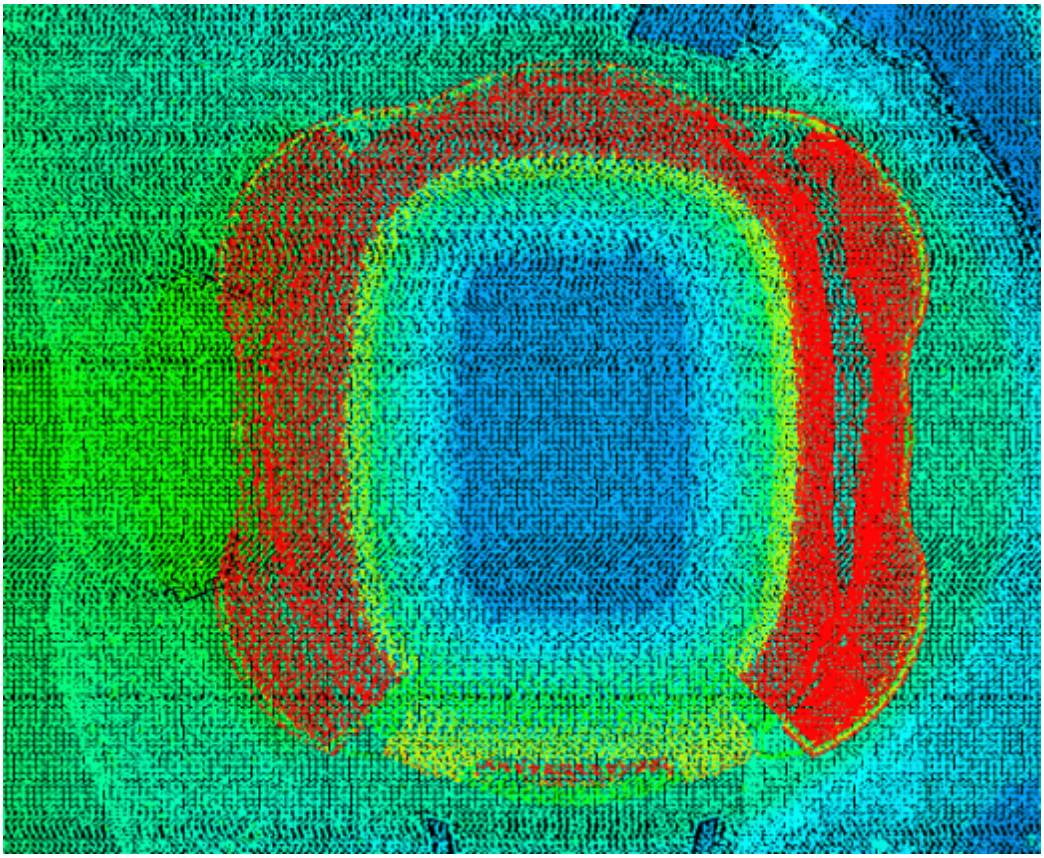


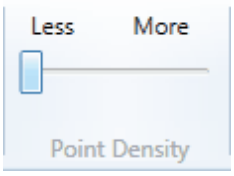


- **Point Density slider bar:** This control changes the point density in the LAS Map View window. The user must be zoomed in to at least 4% before the slider bar will work. The point density slider bar does not work inside the Cross-Section/Profile 240 window. To **TIN**  the data being viewed, the slider bar must be set to 0 (far left). If the bar is not set to 0 before the TIN button is clicked, an error window will appear.

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*Ex: Points set at 0 to allow user to **TIN***  *the data.*

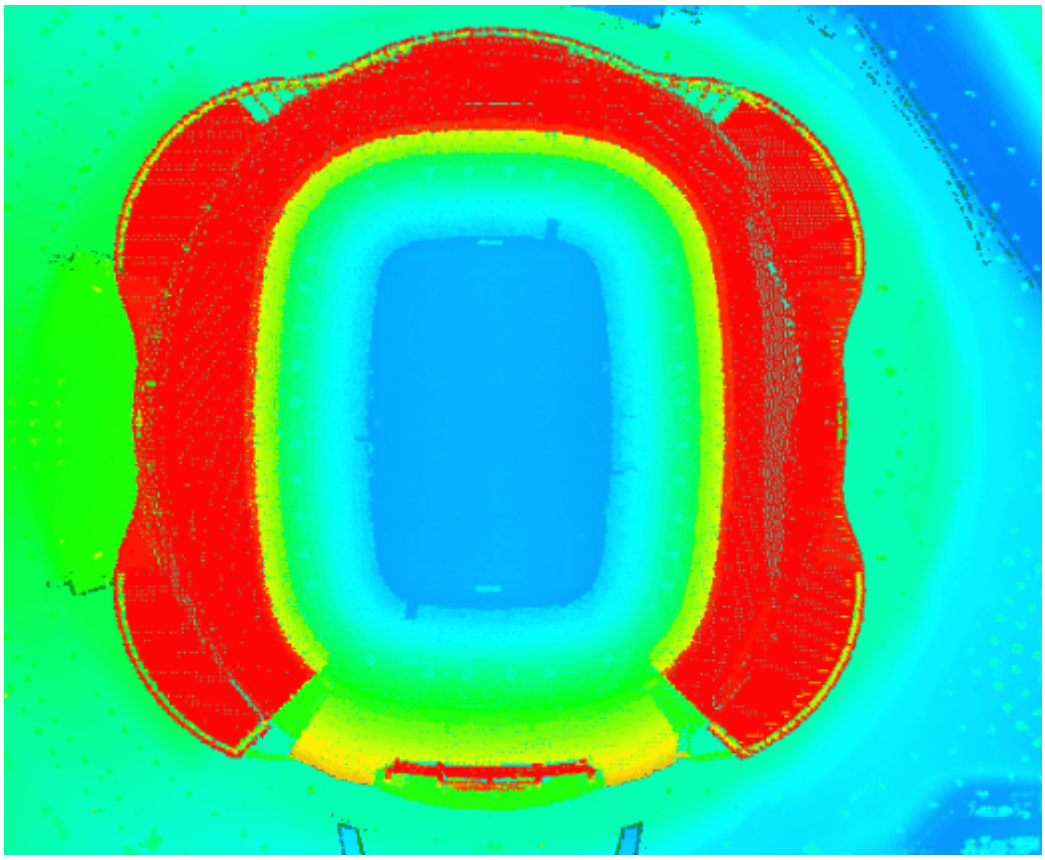


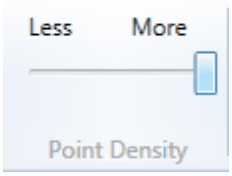


The Point Density slider bar is set at '0' (far left) in this position.

Ex: Points Set at 'More': The highest point density option

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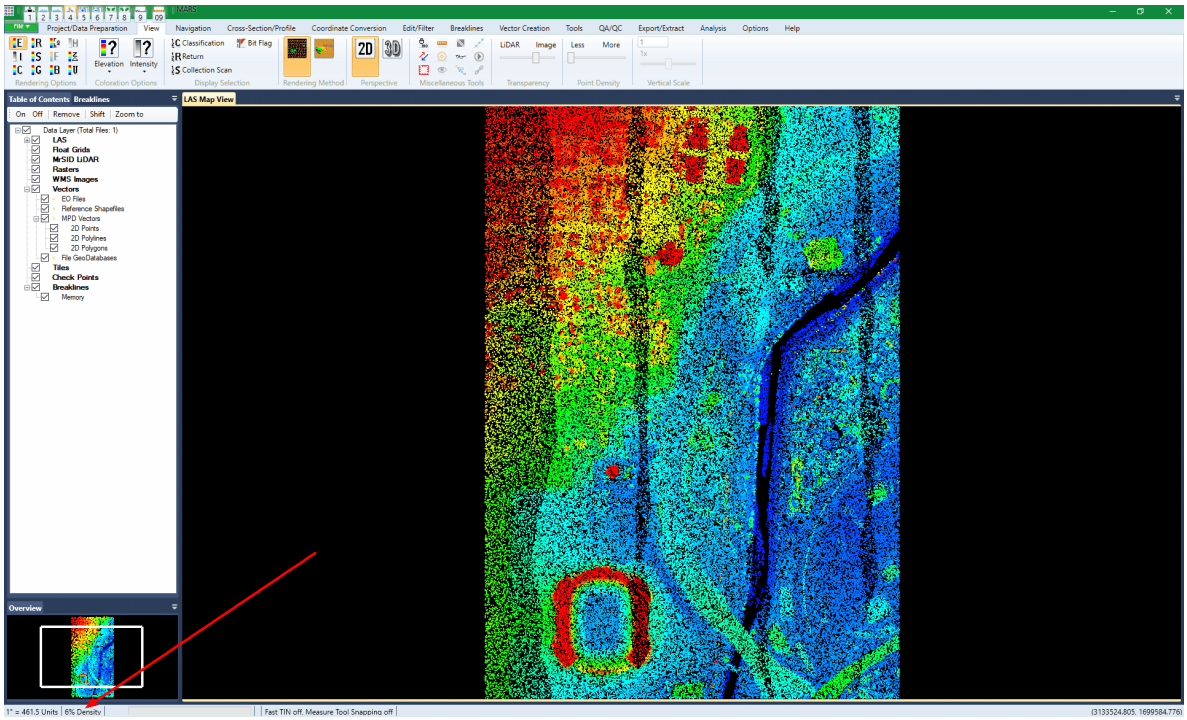
The Point Density slider bar is set at its highest point density in this position.

The percentage of points being displayed (point density) can also be found in the bottom left corner of the LAS Map View window. As the Point Density slider bar is moved left or right, this percentage will change accordingly.

In the example below, the slider bar is set to display fewer points. The percentage of points being displayed can be found on the left side of the Status Bar[158]. In this case, 6% of points are being

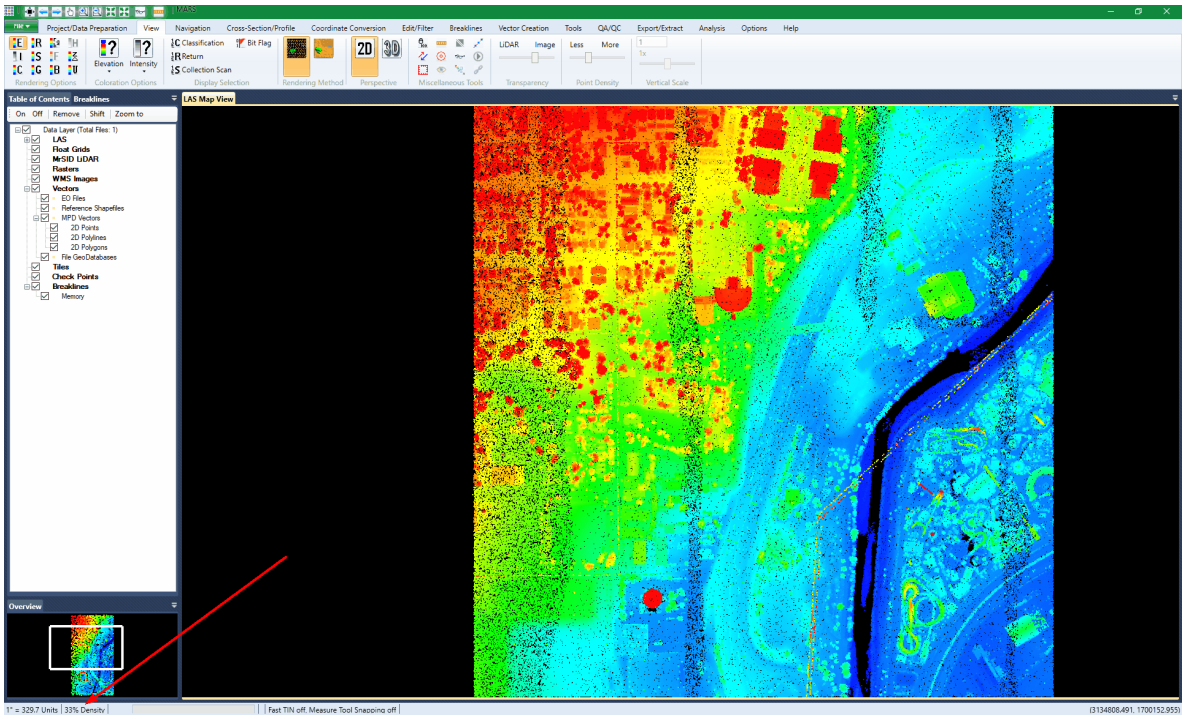
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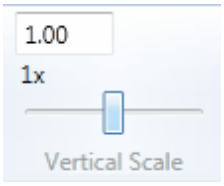
displayed.



In the example below, the slider bar is set to display more points. The percentage of points being displayed can be found on the left side of the Status Bar[158]. In this case, 33% of points are being displayed.

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- **Vertical Scale slider bar:** MARS® is capable of vertically rescaling data while in 3D View[837] mode in the LAS Map View window. Above the slider bar is a vertical scale text box that allows entry of an exact scale value. Type in the scale (relative to horizontal) at which the data is to be viewed and press 'Enter' on the keyboard. The minimum value is 0.01 and the maximum is 1000. The '**1x**' button will revert back to a 1:1 scale.

See Also

Displaying Data[1772]

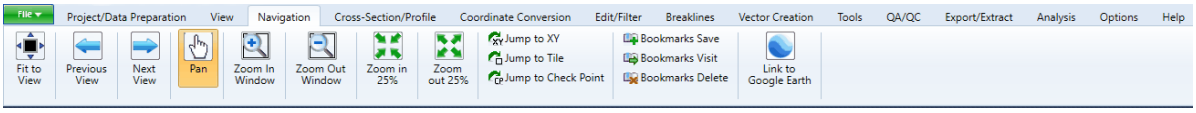
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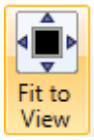
3.4 Navigation Tab

Navigation Tab Items

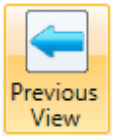
Merrick Advanced Remote Sensing (MARS®) Software

The Navigation Tab:





Fit to View: This tool will zoom out to display the project extent of all loaded data in the LAS Map View window only.



Previous View: Allows the user to return to the last display view.



Next View: Allows the user to jump to the next display view. *(Note: the user can only jump to the next display view if the previous button was used prior)*



Pan: Allows user to pan (move without zooming in/out) across the dataset. When the tool is active, click and hold the left mouse button while moving the mouse. Panning can also be done in most situations by using a push-and-hold technique with the mouse wheel and then

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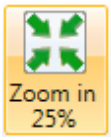
moving the mouse. See additional panning methods in the 'Miscellaneous' section of the Options Tab[519].



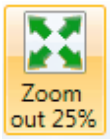
Zoom In: When active, left-click and drag the mouse to define the area that will fill the LAS Map View window. Click and hold right mouse button and pull mouse backward to zoom in. Or roll the scroll wheel on the mouse towards the computer (forward) to zoom in on the data.



Zoom Out: Click and hold right mouse button and push mouse forward to zoom out. Or roll the scroll wheel on the mouse away from the computer (backward) to zoom out on the data.



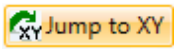
Zoom in 25%: Using this tool, the software will zoom in 25% to the center of what is displayed in the LAS Map View window.



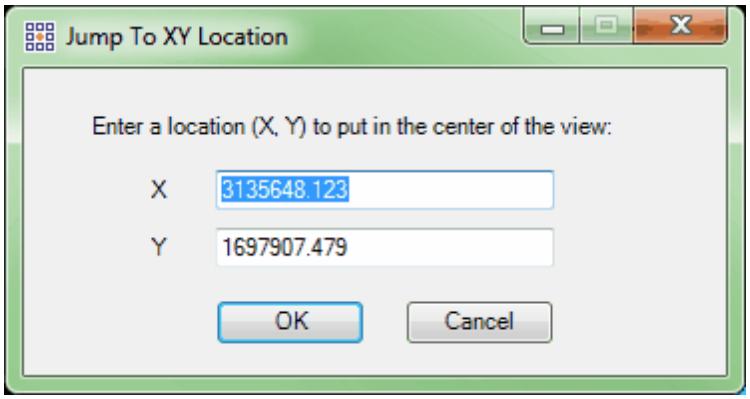
Zoom out 25%: Using this tool, the software will zoom out 25% from the center of what is displayed in the LAS Map View window.

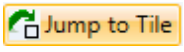
- **'Jump to' buttons:** These tools allow navigation based on a specific coordinate pair, tile (in a loaded layout), or check point ID. Each method will put the chosen value or feature in the center of the LAS Map View window. See also the Jump To[822] topic.

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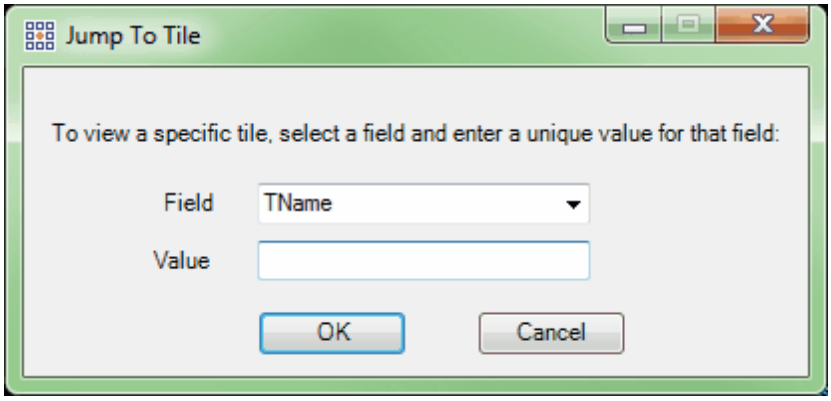


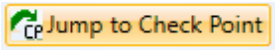
Use this tool to jump to a precise XY coordinate location, based on the Easting and Northing values of the project.





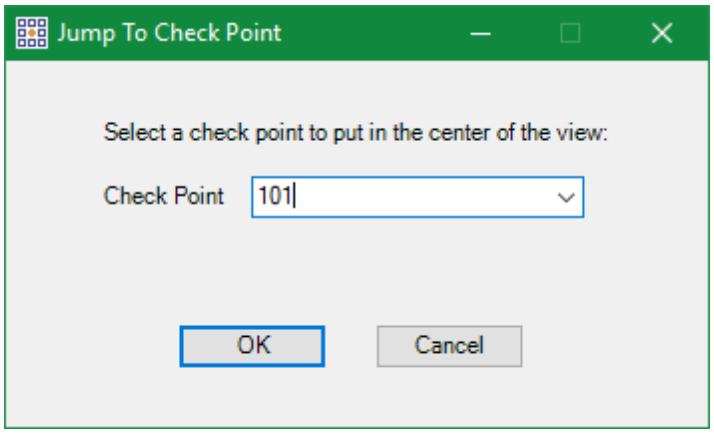
Use this tool to jump to a particular tile. There must be a tile shapefile loaded to use this tool. The user can choose to search from the ID attribute field or the TName (tile name) attribute field. The user must know the value of the TName or the ID field to use this tool.



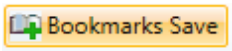


Use this tool to jump to an individual check point. There must be a check point (.csv or .shp) file loaded to use this tool. Use the drop-down box to choose a particular point from the check points available.

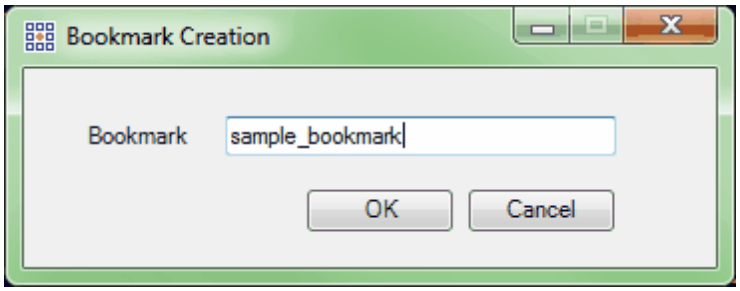
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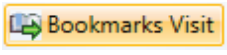


- **Bookmarks:** Bookmarks can be used to mark a certain place in the data. By saving a bookmark, the user will be able to click on the bookmark name in the future and be taken to the location in the data that the particular bookmark was placed. Bookmarks are convenient when editing to be able to pick up editing in a particular spot, to save a place where re-work needs to be done, or as a point of reference for another user. See also the Bookmarks 814 topic.



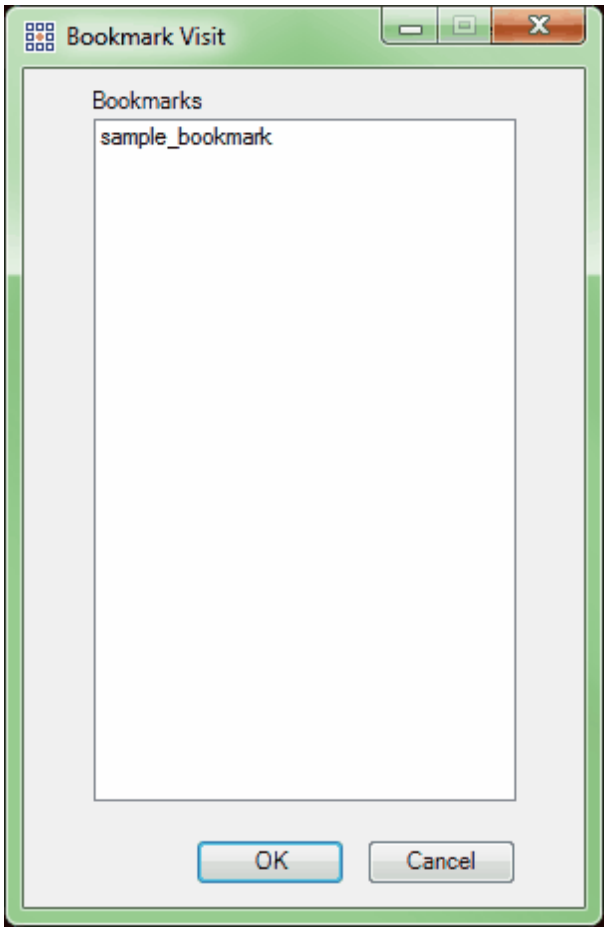
To create or save a bookmark for future reference, choose this option. The user will be shown a Bookmark Creation interface to name and save the bookmark. Click on the 'OK' button or press the 'Enter' key on the keyboard to commit the save.

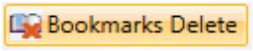




To visit a saved bookmark, use this option. A list of saved bookmarks will appear. Choose the needed bookmark and click 'OK' to view the bookmark placement.

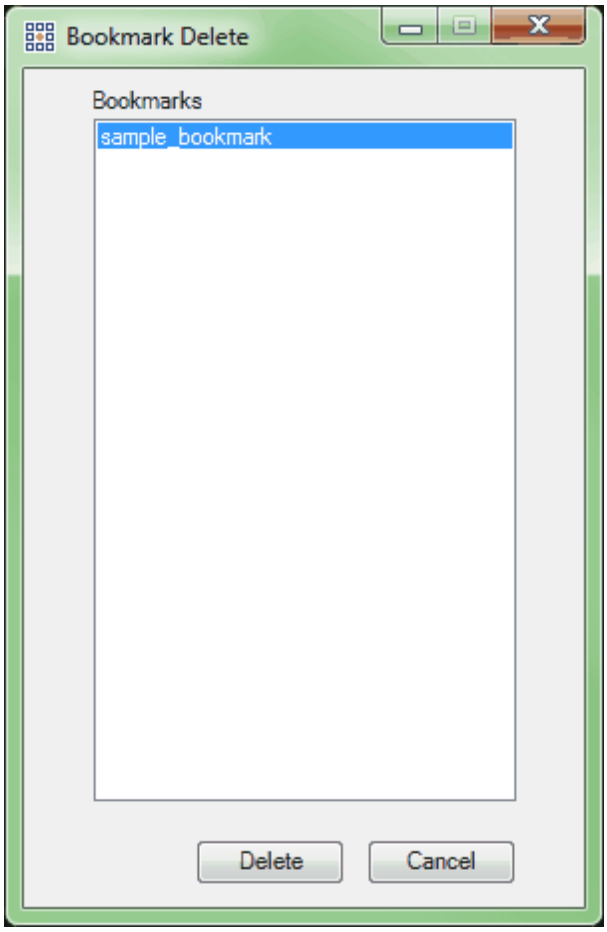
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To delete a saved bookmark, use this option. A list of all saved bookmarks will appear. Choose the bookmark to be deleted by highlighting it and choose' Delete' at the bottom of the window.

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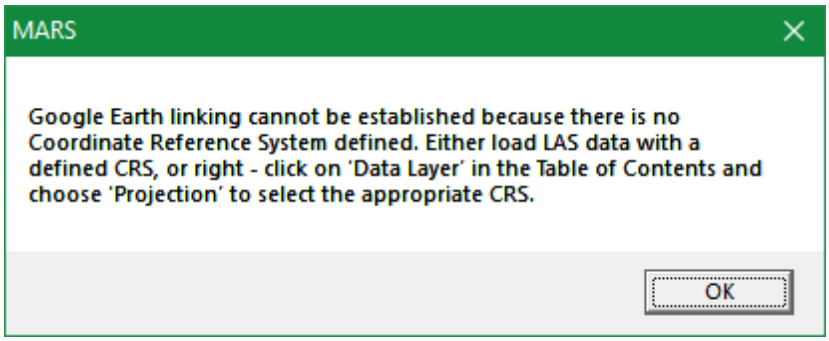




Link to Google Earth: If either Google Earth© or Google Earth Pro© is installed, it will open in a separate window and auto-navigate to the location that is displayed in the LAS Map View window.

When the tool is enabled, it will check to see if Coordinate Reference System (CRS) information is defined for either the loaded LAS data or in the 'Data Layer' properties. If not, the following message will appear:

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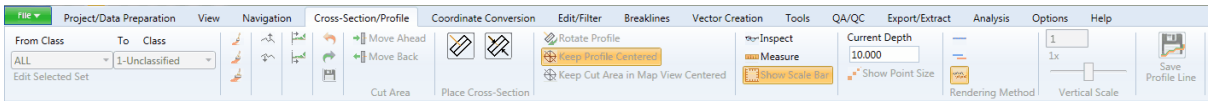
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3.5 Cross-Section/Profile Tab

Cross-Section/Profile Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Cross-Section/Profile Tab:



- **From Class drop-down list:** This allows the user to pick from ALL classes, a selected set of classes (see below), or any one of the 256 individual LiDAR classes to be the source class(es) for manual editing actions.

- **Edit Selected Set:** This function allows the user to make a selected set comprised of any

combination of LiDAR classes to be used when the '- Selected -' option is chosen in the 'From Class' drop-down list. More details about using and saving selected sets can be found in the Manually Editing LiDAR Data 1824 tutorial.

- **To Class drop-down list:** This allows the user to pick from any one of the 256 individual LiDAR classes to be the target class for manual editing actions.

- **Edit Paint Small:** This paint utility is the smallest paint tool. It reclassifies visible points (referenced in the 'From Class' drop-down list) selected in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the 'To Class' class, press the Space Bar on the keyboard. To cancel and unselect the points, right-click the mouse. More detailed information on editing in the Cross-Section/Profile window can be found in the Manually Editing LiDAR Data 1824 and Cross-Sections and Profiles 1797 topics.

- **Edit Paint Medium:** This paint utility is a medium-sized paint tool. It reclassifies visible points (referenced in the 'From Class' drop-down list) selected in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the 'To Class' class, press the Space Bar on the keyboard. To cancel and unselect the points, right-click the mouse. More detailed information on editing in the Cross-Section/Profile window can be found in the Manually Editing LiDAR Data 1824 and Cross-Sections and Profiles 1797 topics.

- **Edit Paint Large:** This paint utility is the largest paint tool. It reclassifies visible points (referenced in the 'From Class' drop-down list) selected in the Cross-Section/Profile window. Drag the cursor box over the desired points and they will turn white. To commit them to the 'To Class' class, press the Space Bar on the keyboard. To cancel and unselect the points, right-click the mouse. More detailed information on editing in the Cross-Section/Profile window can be found in the Manually Editing LiDAR

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Data[1824] and Cross-Sections and Profiles[1797] topics.

- **Edit Line String Above:** Reclassifies all visible points (referenced in the 'From Class' drop-down list) above a user-drawn vector in the Cross-Section/Profile window only.

- **Edit Line String Below:** Reclassifies all visible points (referenced in the 'From Class' drop-down list) below a user-drawn vector in the Cross-Section/Profile window only.

- **Edit Scrape Above:** Reclassifies all visible points (referenced in the 'From Class' drop-down list) above the scrape tool cursor in the Cross-Section/Profile window only.

- **Edit Scrape Below:** Reclassifies all visible points (referenced in the 'From Class' drop-down list) below the scrape tool cursor in the Cross-Section/Profile window only.

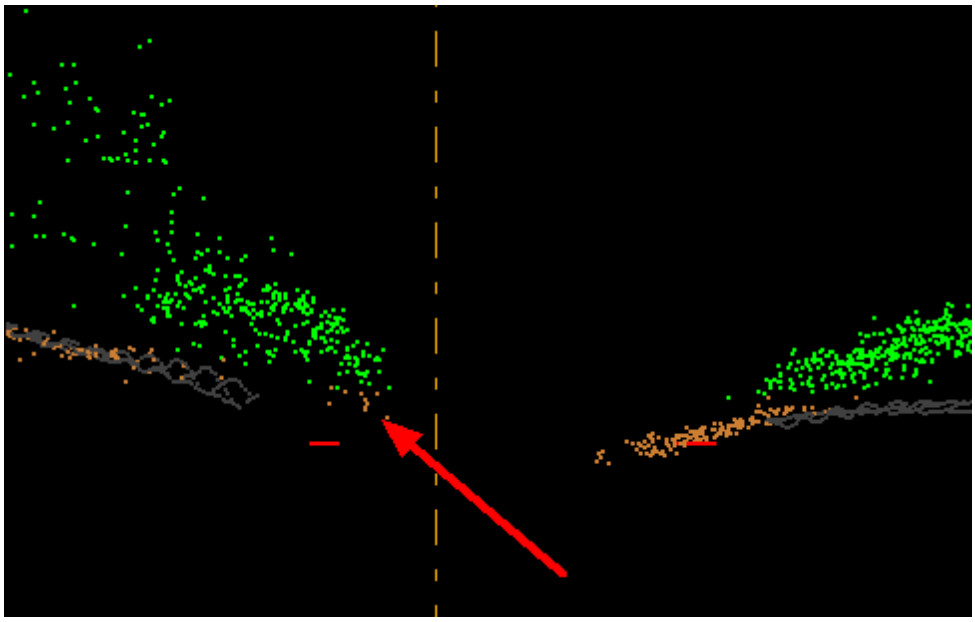
- **Undo:** This tool will undo an edit process each time it is selected. This tool is useful when an edit process is not done correctly. It can be undone and the user can attempt the edit process again.

- **Redo:** This tool will redo an edit process each time it is selected. This tool can be used only after the 'Undo' tool has been used - it will 'redo' an undone process.

Please see the examples below to see the functions of the 'Undo' and 'Redo' tools.

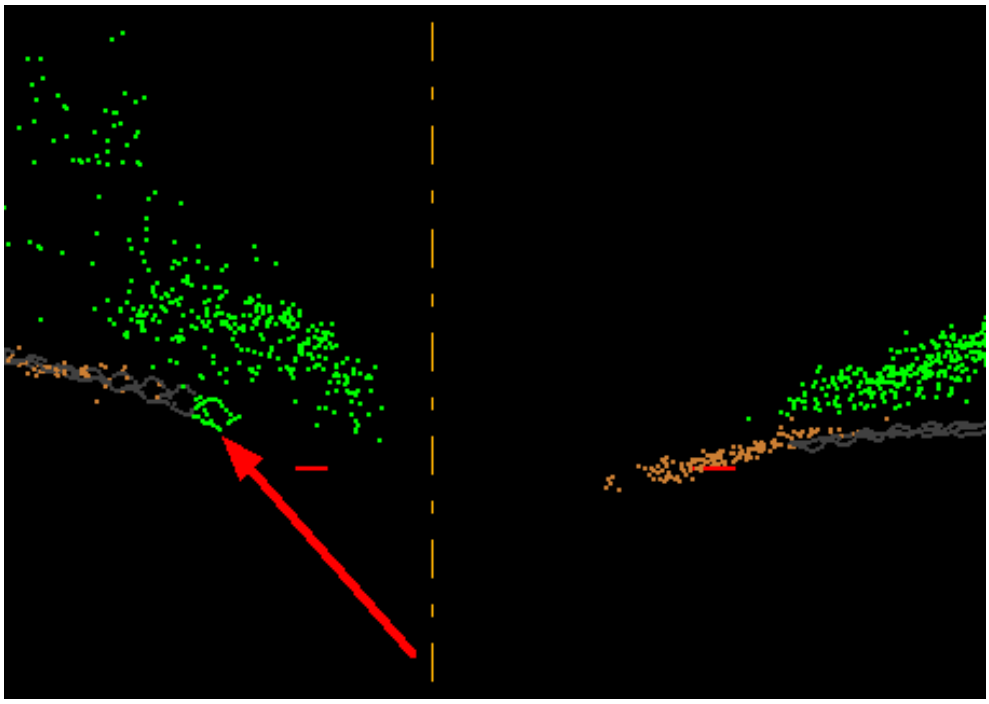
In this first example, a bit of vegetation next to a river has been incorrectly classified as ground.

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In the next example, the misclassified ground point has been changed to vegetation. However, the editor has made a mistake and has accidentally classified the ground below the vegetation as vegetation. By clicking on the ***'Undo'***  *button, this mistake is easily reversed and the point classifications that were changed to vegetation will go back to their original ground value as if the edit was never made. To reverse an 'undo' action, click on the* ***'Redo'***  *button and the edit that was made will reappear.*

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- **Save cached points to disk:** *This button is currently disabled.* Due to LAS datasets becoming increasingly larger in file size (frequently surpassing the available RAM in a computer) as well as the possibility of lost work caused by an unexpected shutdown of MARS prior to a save operation, the 'Cache points into available RAM' option has been disabled. LAS data will be read from disk and 'live' edit changes (such as hand filtering) are committed to disk as soon as they occur. Additionally, with newer, faster hard drives such as SSD, the performance difference between disk-based and RAM-based operations is constantly shrinking.

- **Move Cut Ahead:** This tool moves the cross-section box ahead as defined in the 'Forward/back percentage' setting (Options Tab 519, 'Miscellaneous' button). The cross-section/profile window display will update automatically.

- **Move Cut Back:** This tool moves the cross-section box back as defined in the 'Forward/back

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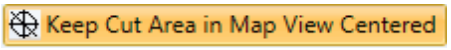
percentage' setting (Options Tab 519, 'Miscellaneous' button). The cross-section/profile window display will update automatically.

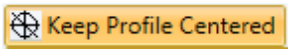
- **Place Cross-Section Line:** Creates cross-sections with a fixed cut depth. Works only in 2D View 835. The tool uses two-point compilation: to start, click once to place one side of the cross-section, click again to place the other side of the cross-section - this determines the cut depth (width). The first time either this or the 'Place Adjustable Cross-Section Line' tool is used a new Cross-Section/Profile window will automatically open. A new cross-section (replacing the previous one) may be created at any time this window is open. LiDAR point display may be turned off in the LAS Map View window without affecting the point display in the Cross-Section/Profile view by unchecking the LAS 74 layer in the Table of Contents 67. There are adjustable default settings and special controls for this tool:

    - **Default #1 -** The LAS Map View and cross-section/profile windows will tile automatically; the default is for the cross-section/profile window to appear to the right of the LAS Map View window. To change the default go to the Options Tab 519 and click the **'Miscellaneous'** button. The setting may be changed in the 'Arrange Cross-Section/Profile window' section.
    - **Default #2 -** The cross-section/profile width defaults to 10 units. To change the default go to the Options Tab 519 and click the **'Miscellaneous'** button. Entering a new value into the 'Default cut area depth' text box will change the default depth.
    - **Default #3 -** The cross-section/profile cut area can be moved forward and backward ('broomed') in the 2D View window. The default value of this movement is 75%, meaning that the forward motion will be 75% of the cross-section/profile's width, leaving a 25% overlap. This percentage can be changed by going to the Options Tab 519 and clicking the **'Miscellaneous'** button. The 'Forward/back percentage' radio

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buttons available are 25%, 50%, 75%, 90%, or 100%.

- **Cross-Section/Profile Movement #1 -** The cross-section/profile cut area can be dragged to a new location. Select and drag the cut area in the 2D View window.
- **Cross-Section/Profile Movement #2 -** For stepping the cross-section/profile cut area forward and back ('brooming'), use the **UP** ⬆ and **DOWN** ⬇ arrows. The step size movement is controlled by Default #3.
- **Cross-Section/Profile Movement #3 -** If the 2D View window is selected, the **'Keep Cut Area in Map View Centered'** 

tool will keep the Cross-Section/Profile cut area centered in the middle of the LAS Map View window. To disable this and allow the cut area to move independently from the window, click the **'Keep Cut Area in Map View Centered'** tool to toggle it off while the 2D View window is active. If the cross-section/profile window is the active window, the **'Keep Profile Centered'** 

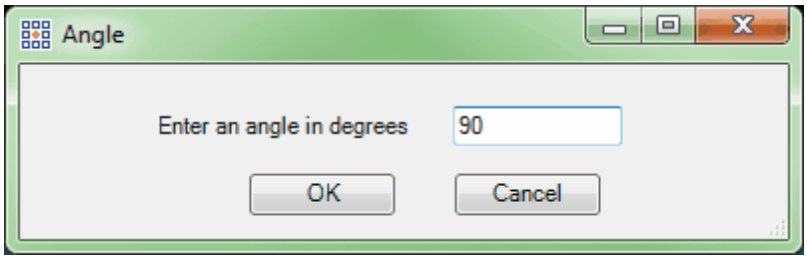
tool will try to estimate a ground elevation and automatically adjust the window to that elevation. In steep terrain or near tall buildings this feature can fail. To disable this and allow the cross-section/profile to move without automatic elevation adjustment, click the **'Keep Profile Centered'** tool to toggle it off while the cross-section/profile window is active.
- **Cross-Section/Profile Movement #4 -** The cross-section/profile cut area can be rotated in the 2D View window. The cut area will rotate around its center node. Rolling the mouse scroll wheel rotates the cross-section/profile.

- **Place Adjustable Cross-Section Line:** Creates cross-sections with an adjustable depth. Works only in 2D (orthographic) mode 835. The tool uses three-point compilation; to start, click once to place one side of the cross-section, click again to place the other side of the cross-section (width), and click a third time to set the depth of the cross-section. The first time either this or the 'Place Cross-Section

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Line' tool is used a new Cross-Section/Profile window will automatically open. A new cross-section (replacing the previous one) may be created at any time this window is open. LiDAR point display may be turned off in the LAS Map View window without affecting the point display in the Cross-Section/Profile view by unchecking the LAS 74 layer in the Table of Contents 67. The same adjustable default settings and special controls that are available for the 'Place Cross-Section Line' tool (above) are also available for this tool, except that the default cut depth setting is ignored.

- **Rotate Profile:** This tool works *only* when the cross-section/profile window is open and allows the user to rotate the cross-section/profiled area a specified number of degrees in a clockwise direction. 90 degrees is the default value, but any numerical value may be entered. Entering a negative value (ex: -90 degrees) will cause the cross-section/profile view to rotate in a counter clockwise direction. Select 'OK' to see the results in both the LAS Map View window and the cross-section/profile window. This window has a keyboard accelerator. To bring up the window below without using the button, select the letter 'R' on the keyboard when the cross-section/profile window is active.



- **Keep Profile Centered:** This tool keeps data centered vertically in the cross-section/profile window by estimating a ground elevation and automatically adjusting the window to center that elevation. In steep terrain or near tall buildings this feature can produce unexpected results. To shut this off and allow the cross-section/profile to move without automatic centering, click the 'Keep Profile Centered' button to toggle it off. When the 'Keep Profile Centered' tool is not active, the cross-section/profile

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window can be dragged with the **'Pan'** 

tool to the user's area of interest.

- **Keep Cut Area in Map View Centered:** This tool keeps the cut area box centered vertically and horizontally in the LAS Map View window. To shut this off and allow the cut area box to move independently from the window, click the 'Keep Cut Area in Map View Centered' button to toggle it off. When the 'Keep Cut Area in Map View Centered' tool is not active, the cross-section/profile window can be dragged with the **'Pan'** 

tool to the user's area of interest.

- **Inspect:** Click on this tool, and then click on the displayed LiDAR point that is to be inspected. The chosen point will flash twice and then remain highlighted in white at a larger symbol size to identify itself. Any number of displayed points can be inspected, one at a time. If a Cross-Section/Profile window is open, the point may be chosen in either view, and will be highlighted in both views. The one exception to this is in the Cross-Section/Profile window, where the Inspect tool will identify the file name and collection scan number rather than a point when the data is viewed in Profile by Collection Scan mode. The tool displays the point's parent file path and point source ID (PSID), X, Y, and Z coordinates, timestamp, intensity value, classification, bit flag status, return number, user data (often AGC values), scan angle/scan angle rank, scan direction flag, edge of collection scan flag, scanner channel flag, and RGB(N) values (see Inspect 943 for details of these attributes). The tool works in 2D (orthographic) and Cross-Section/Profile views.

  To unselect the **'Inspect'** tool and return the chosen feature to its original symbol and/or color, right-click the mouse. See the Inspect 943 tool topic for more details including other uses for this tool.

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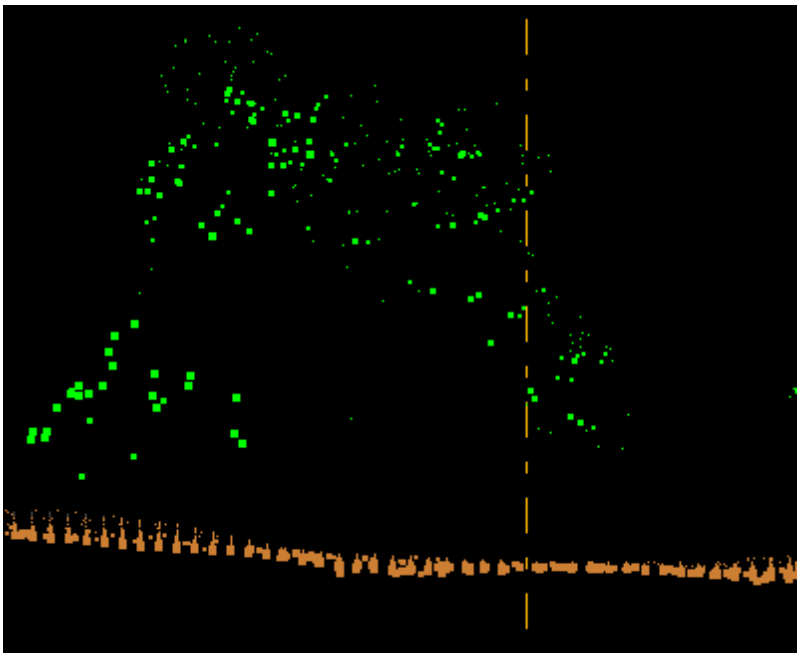
- **Measure:** Measures distance (in project units) and heading between two locations in the 2D View, or distance and slope angle (in degrees) in the Cross-Section/Profile window. Please see the detailed Measure 957 topic for more information.

- **Show Scale Bar:** Toggles the display of the Elevation scale bar in the Cross-Section/Profile window on/off. The values shown (along the left side) are in the loaded data's vertical units. Clicking in the Cross-Section/Profile window will cause a label to be displayed showing the cursor's elevation.

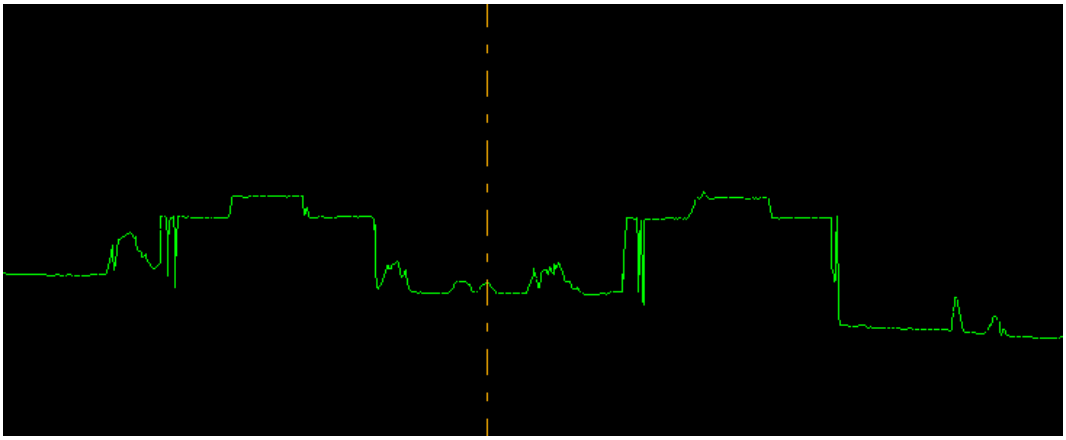
- **Current Depth:** This entry box allows the user to adjust the depth of an existing cut by typing in a new value and hitting the 'Enter" key. the current value is also shown on the Cross-Section/Profile window tab. To change the default cut depth for newly-created cross-sections using the 'Place Cross-Section Line' tool  , go to the **'Miscellaneous Options'** interface on the Options Tab 519 and make the appropriate changes in the 'Cross-Section/Profile Window' section.

- **Show Point Size:** Resizes the point display proportionally within the cross-section/profile window. When toggled on, the LiDAR points nearest to the viewer side of the cut area are slightly larger, and points on the far side are slightly smaller.

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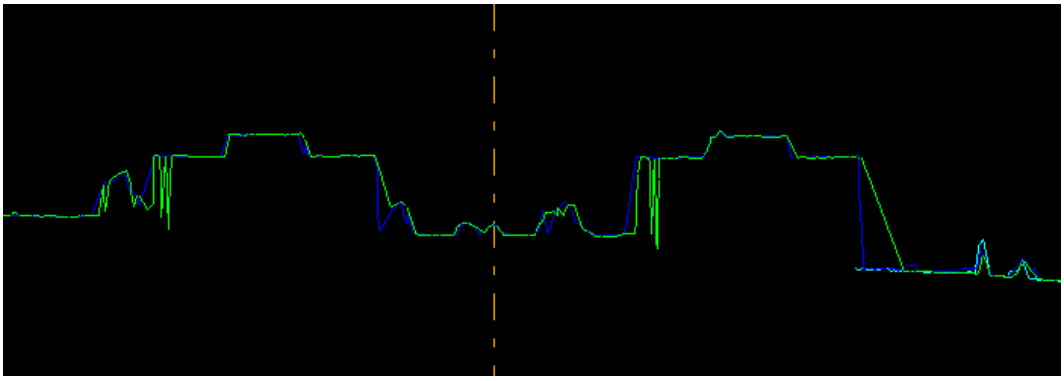
Profile Combined: Displays a combined single line profile of all points for the displayed collection scans. This 'profile combined' example is rendered by classification.



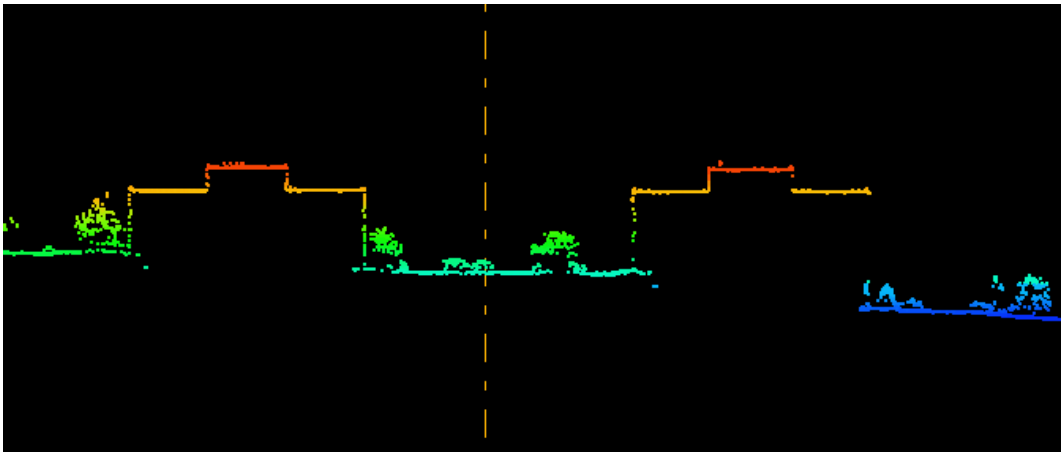
Profile by Collection Scan (not available with Evaluation license): Displays a profile line for

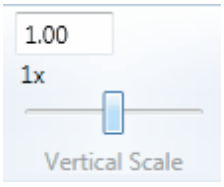
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each displayed collection scan. This profile example is rendered by collection scan color.



 **Cross Section:** Displays a cross-section view of the LiDAR points for the displayed collection scans in the cross-section/profile window. This cross-section example is rendered by elevation.



- **Vertical Scale slider bar:** 

MARS® is capable of vertically rescaling data in the Cross-Section/Profile window. Above the slider bar is a vertical scale text box that allows entry of an

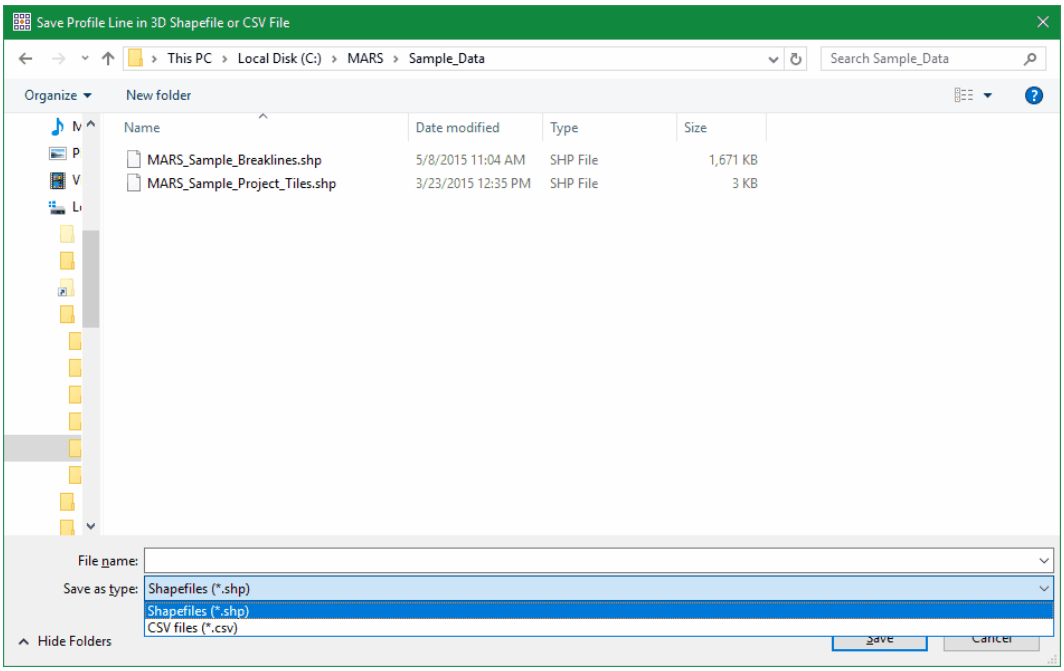
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exact scale value. Type in the scale (relative to horizontal) at which the data is to be viewed and press 'Enter' on the keyboard. The minimum value is 0.01 and the maximum is 1000. The '**1x**' button will revert back to a 1:1 scale. This slider is synchronized with the vertical scale slider on the optional Cross-Section/Profile Window 146 toolbar.

A separate vertical scale control is located on the View Tab 192 for data being displayed in 3D View 837 in the LAS Map View window.

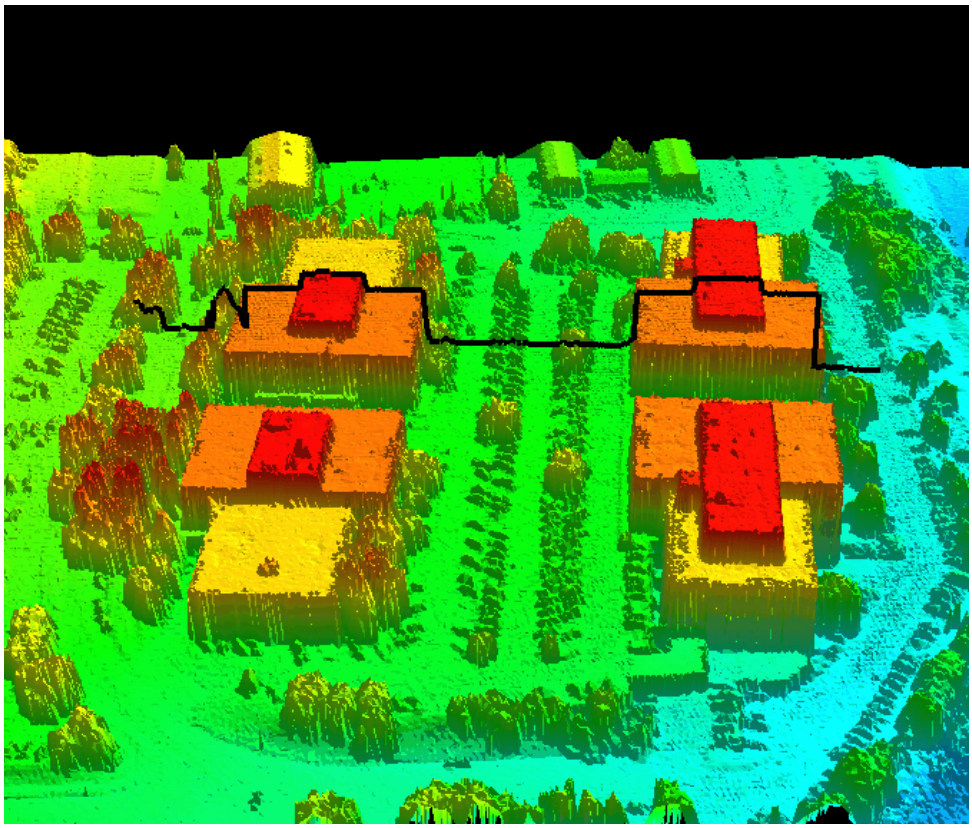
- **Save Profile Line:** This tool can create either a 3D shapefile, or a CSV file of XYZ values, for a combined profile (see above). The output file will be created from whatever profile is currently shown in the Cross-Section/Profile window. When a profile line shapefile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data. For shapefile output, the resulting shapefile can be loaded back into MARS® using the 'Add Reference Shapefiles' button on the Project/Data Preparation Tab 162, and displayed in 3D View 837. For CSV output, the resulting file of XYZ values can be opened in Excel. This tool is only available when the profile is rendered with the **'Profile Combined'** button  . For more information on the **'Profile Combined'** tool, please visit the Cross-Section/Profile Tab 240 topic.

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In the example below, the resultant 3D shapefile has been loaded into MARS® as a reference shapefile. It is shown below in 3D as the black line which profiles two of the four large buildings shown.

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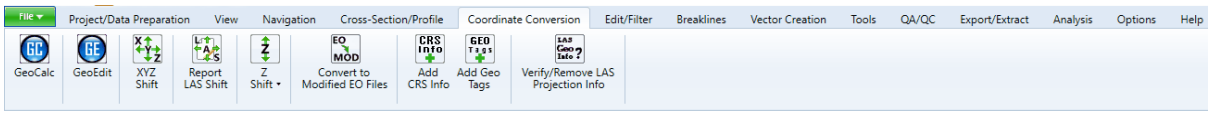
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3.6 Coordinate Conversion Tab

Coordinate Conversion Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Coordinate Conversion Tab:



For any LAS tools (including 'GeoCalc') that allow files to be pathed out without loading them in

the Table of Contents in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.

GeoCalc: This tool allows the user to transform LAS data to different horizontal coordinate systems, horizontal and/or vertical datums, height models, and units. For more information on the use of this tool, please see the GeoCalc 1748 section. This tool, as well as many other coordinate system related functions, requires that the Blue Marble Geographics shift files be installed. See Page 23 of the v2025.0 Installation and Licensing Guide for download and installation details.

GeoEdit: The GeoEdit tool allows the user to define custom coordinate systems, horizontal and vertical datums, and height models, as well as test re-projections for the expected results on a single set of 2D or 3D coordinates. For more information on the use of this tool, please see the GeoEdit 1754 section. This tool, as well as many other coordinate system related functions, requires that the Blue Marble Geographics shift files be installed. See Page 23 of the v2025.0 Installation and Licensing Guide for download and installation details.

XYZ Shift: This tool is used to shift LAS data in all loaded files in six different directions:

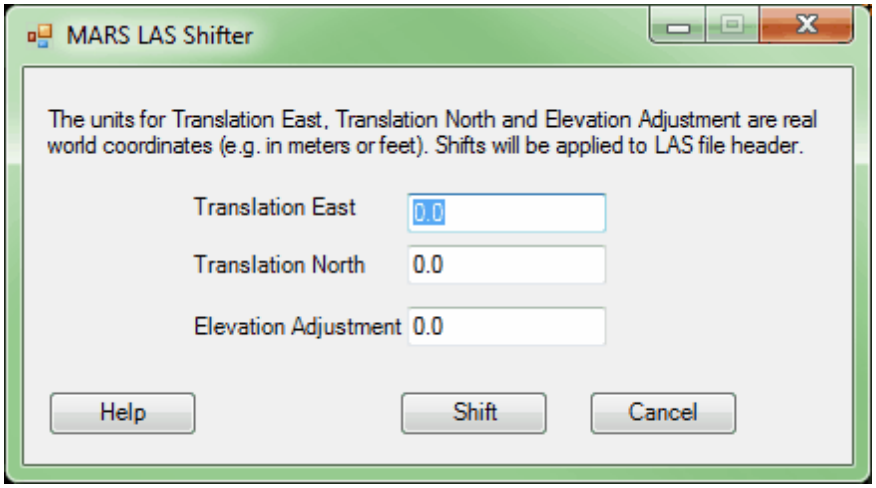
1. **East** (a positive shift in the Translation East text box)
2. **West** (a negative shift in the Translation East text box)
3. **North** (a positive shift in the Translation North text box)
4. **South** (a negative shift in the Translation North text box)
5. **Higher in Elevation** (a positive shift in the Elevation Adjustment box)
6. **Lower in Elevation** (a negative shift in the Elevation Adjustment box)

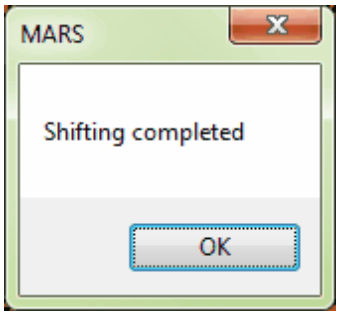
All loaded files will have the same shifts, specified by the user in the 'MARS LAS Shifter' interface, applied to them. To shift only selected (highlighted) files, use the **'Shift'** button at the top of the Table of

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Contents 67.

**** NOTE: If multiple shifts are applied to a single project, the effect is cumulative. Each shift is applied to the existing XYZ offset in the header.****



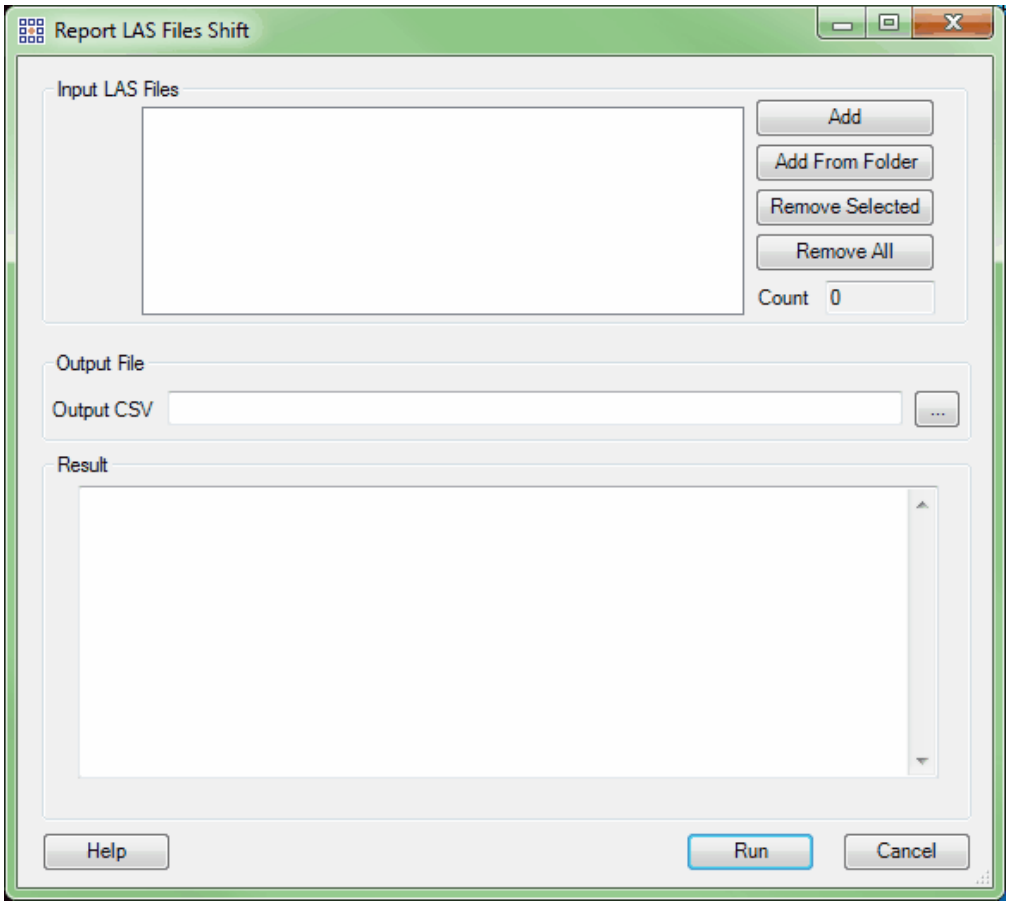


An OFF file (*.off) will be created for each file that is shifted storing the X, Y, and Z offsets that existed in the file before the shift was processed. These 'offset' files will be created with the same name and in the same folder as their corresponding LAS file(s). They are used with the **'Report LAS Shift'** tool (below) as a baseline. If the *.off files are moved, renamed, or deleted, they will be recreated the next time the MARS LAS Shifter is run, but with the then-current offsets used as baselines.

Report LAS Shift: Shifting LAS data using the Table of Contents 67 'Shift' button or the 'XYZ Shift' tool (see above) produces a *.off file (one per shifted LAS file) which stores the pre-shift X, Y, and Z offset

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values read from the LAS file header. These files are created in the same folder as the LAS files that were shifted. The *.off files are used as a baseline by the **'Report LAS Shift'** tool to create a comma-delimited (*.csv) report that stores the total (cumulative) shift for each of the files chosen to be included in the report. To use the tool, add one or more shifted LAS files using the **'Add'** button, or add an entire folder of shifted LAS files using the **'Add From Folder'** button. Choose a path and file name for the output CSV file - click on the ellipse  button, then navigate to the desired output folder and enter a filename and finish by clicking **'Save.'** To create the report, click the **'Run'** button at the bottom of the tool interface.

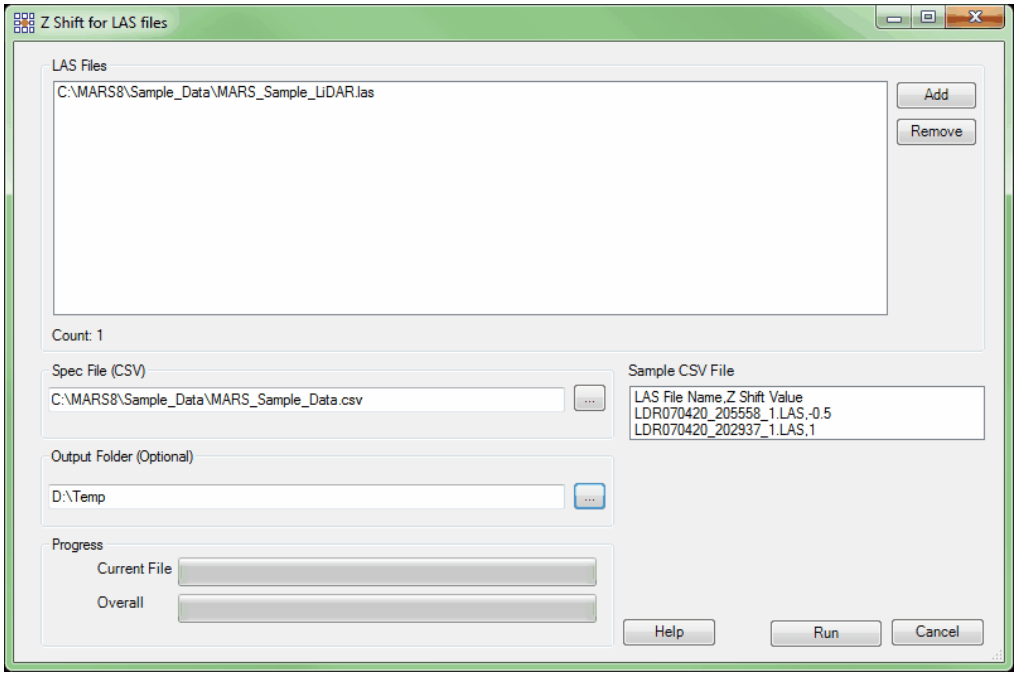


Z Shift for LAS files ***(available with Production license only):*** The 'Z Shift for LAS files' tool is

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located under the 'Z Shift' drop-down button. It will allow the user to batch shift the Z-value (level the elevation) of all LAS files in a project by use of a comma-delimited *.csv file. *This tool is meant for use **after** boresighting has been completed.* The corresponding *.csv file must include a header row (as shown in the sample below), followed by the file names of the LAS files to be shifted and the adjustment value to be made to each file. *It is important to note that the adjustment values to be made to each file need to be in the project units unique to that particular project.* A sample *.csv file may be seen inside the 'Z Shift for LAS files' interface. To use this tool, point to the LAS files by clicking on the 'Add' button in the upper-right corner and add the LAS files which need shifting. To remove single or multiple files, highlight the file or files (using standard Windows mouse/keyboard controls) to be removed and click on the 'Remove' button. Specify the corresponding *.csv file in the 'Spec File (CSV)' section and (optionally) designate an output folder. **If no Output Folder is specified, the input LAS files will be overwritten**

.

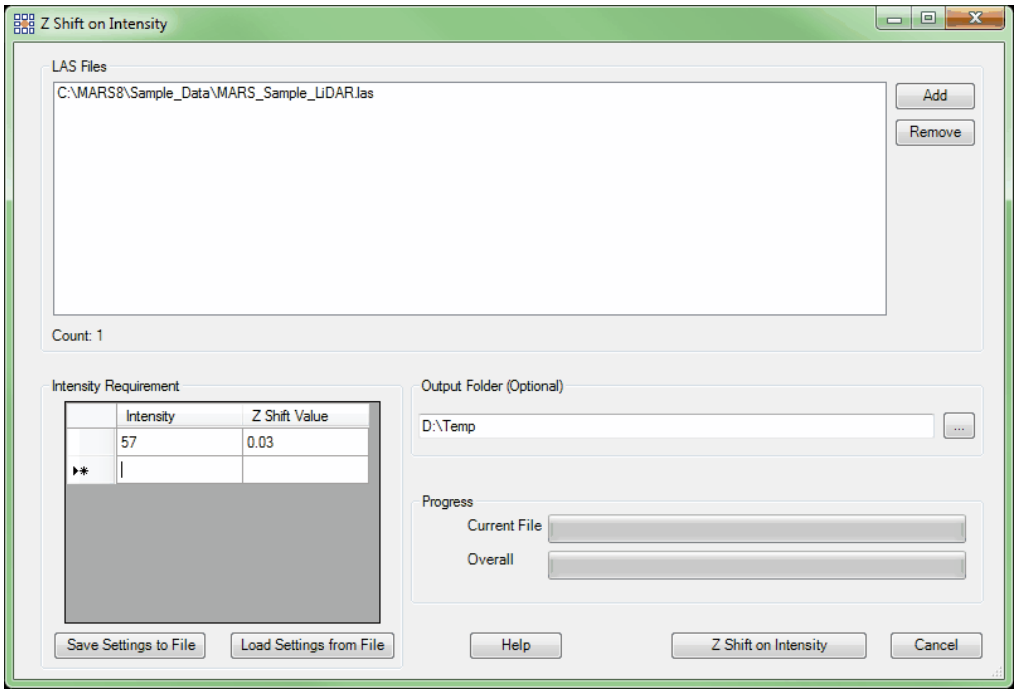


Z Shift On Intensity ***(available with Production license only):*** The 'Z Shift On Intensity' tool is located

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under the 'Z Shift' drop-down button. This tool is capable of shifting LAS data that matches a specific user defined intensity value. The ‘Z Shift Value’ (amount and direction of shifting) is also defined by the user.

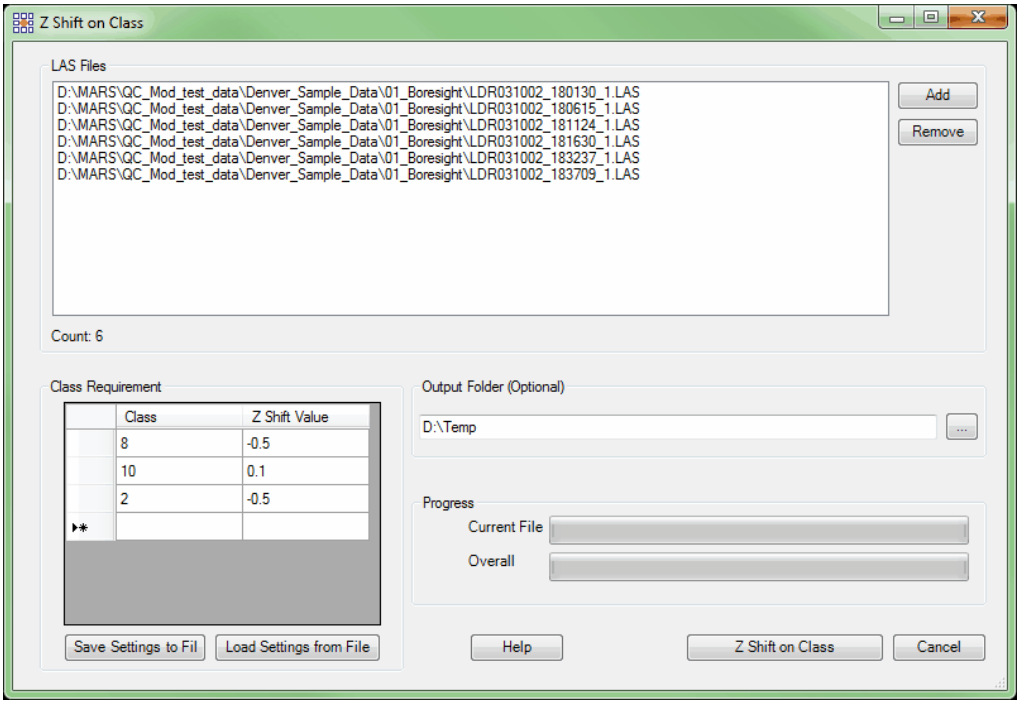
After the LAS data is added into the ‘Z Shift On Intensity’ tool, the 'Intensity Requirement' text boxes are used to specify an ‘Intensity’ value that will be used to identify which points should be shifted, and the ‘Z Shift Value’ to apply to those intensities. Multiple entries can be made in this section. An output folder can be designated and progress can be tracked in the ‘Z Shift On Intensity’ interface. **If no Output Folder is specified, the input LAS files will be overwritten**.



Z Shift On Class ***(available with Production license only)*****:** The 'Z Shift On Class' tool is located under the 'Z Shift' drop-down button. This tool is similar to the 'Z Shift On Intensity' tool, but uses classifications to determine which points will be shifted.

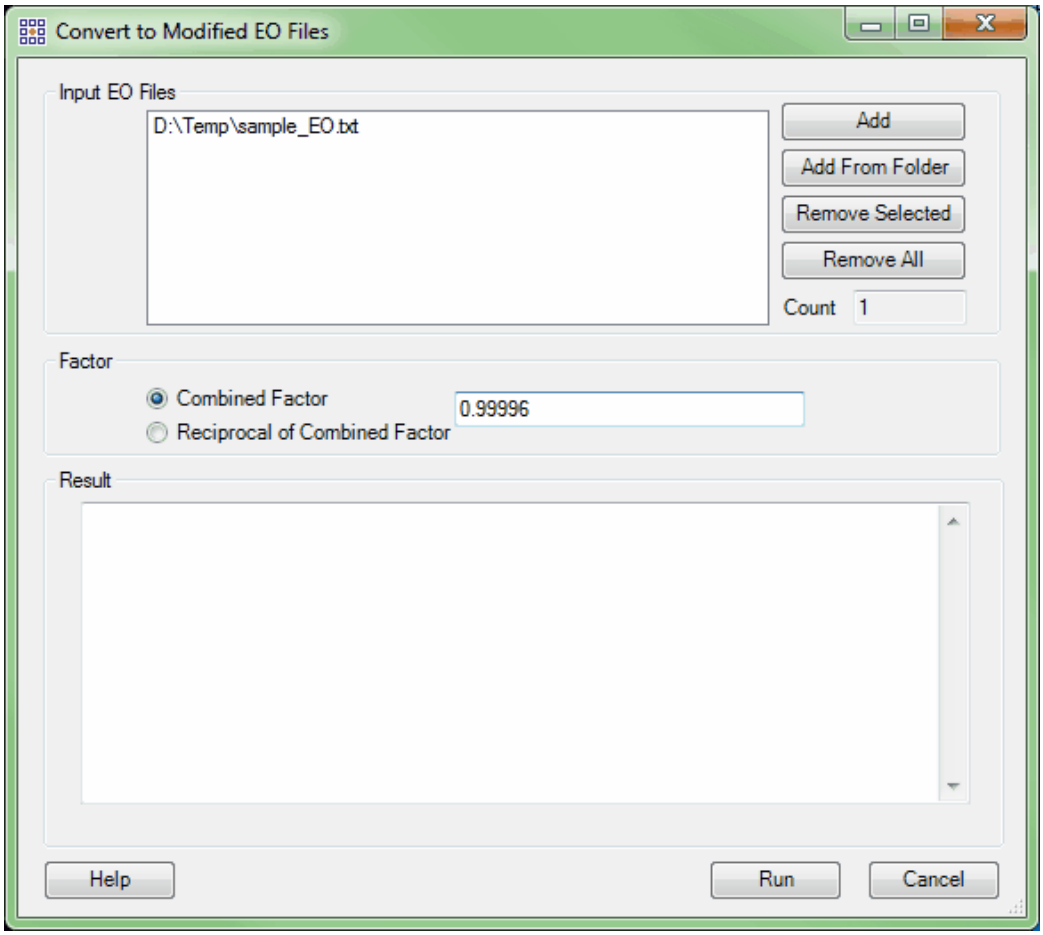
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After the LAS data is added into the ‘Z Shift On Class’ tool, the 'Class Requirement' text boxes are used to specify a ‘Class’ value that will be used to identify which points should be shifted, and the ‘Z Shift Value’ to apply to those classes. An output folder can be designated and progress can be tracked in the ‘Z Shift On Class’ interface. **If no Output Folder is specified, the input LAS files will be overwritten.**



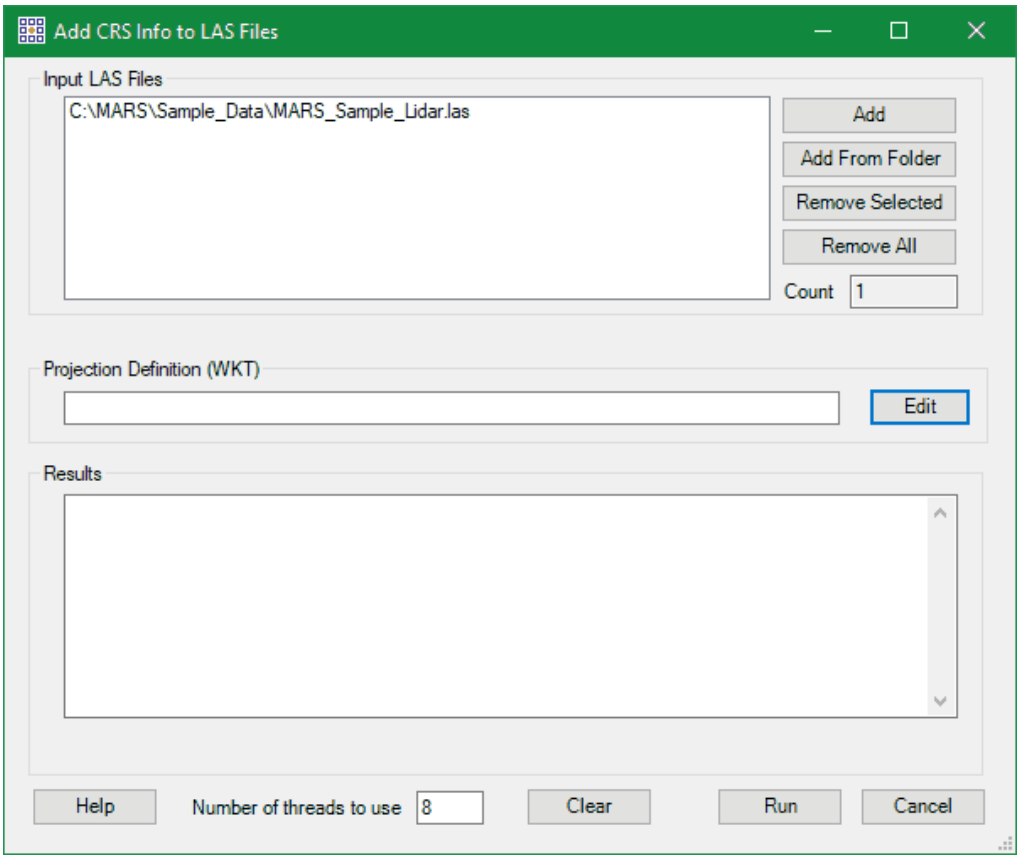
Convert to Modified EO Files: This tool allows a 'Combined Factor' or its reciprocal to be applied to one or more EO (exterior orientation) files. The EO files must be in a text (*.txt) format. To use the tool, navigate to a file or folder with the 'Add' or 'Add From Folder' buttons, then enter the 'Combined Factor' value in the text box found in the middle section of the interface. Choose the desired calculation method - either 'Combined Factor' or 'Reciprocal of Combined Factor' - and click the 'Run' button. A new file or files will be created with '_mod' appended to the original name(s), along with a log file storing the value used. These will be located in the same folder as the original file(s).

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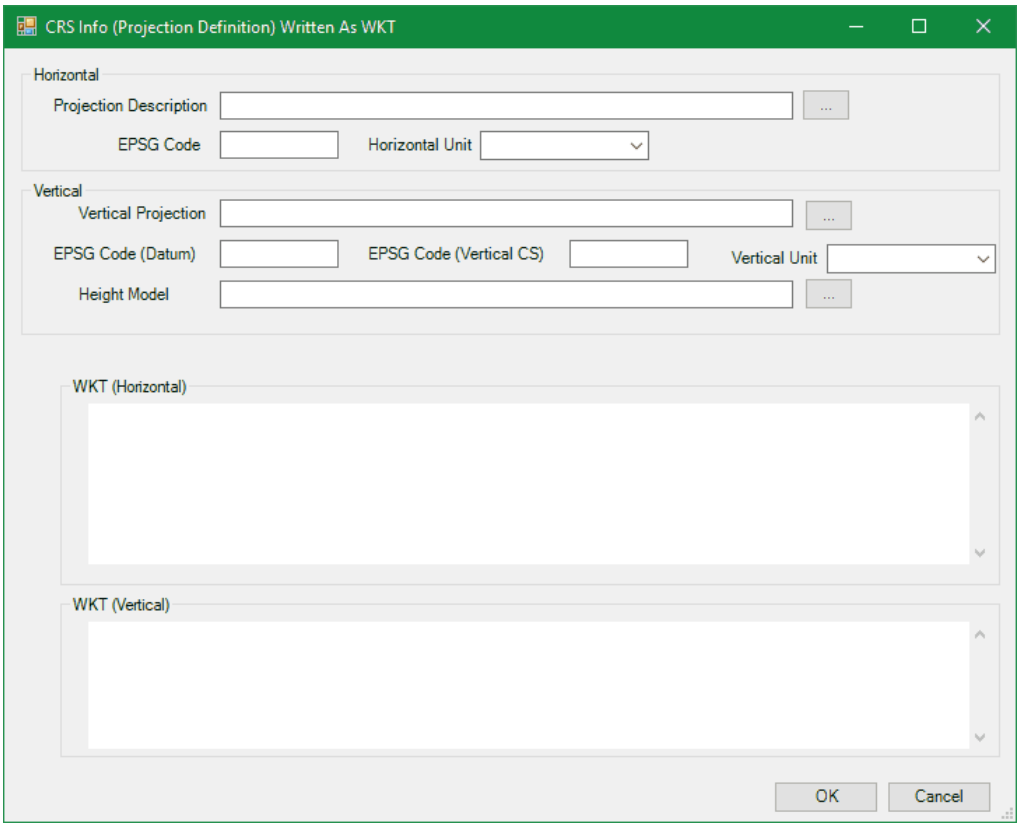
Add CRS Info (to LAS Files): This tool allows the user to add or update coordinate reference system (CRS) information in an LAS file. For LAS version 1.4 files, the tag is written as WKT (Well-Known Text) in an Extended Variable Length Record (EVLR). *Running the tool with no information entered in either the Horizontal or Vertical sections will result in any existing info being cleared.* This tool is capable of processing an entire folder of LAS files ('Add From Folder'), or the user may specify one or more individual files ('Add'). Files already added can be removed (using standard Windows mouse/keyboard controls) by using the 'Remove Selected' or 'Remove All' buttons.

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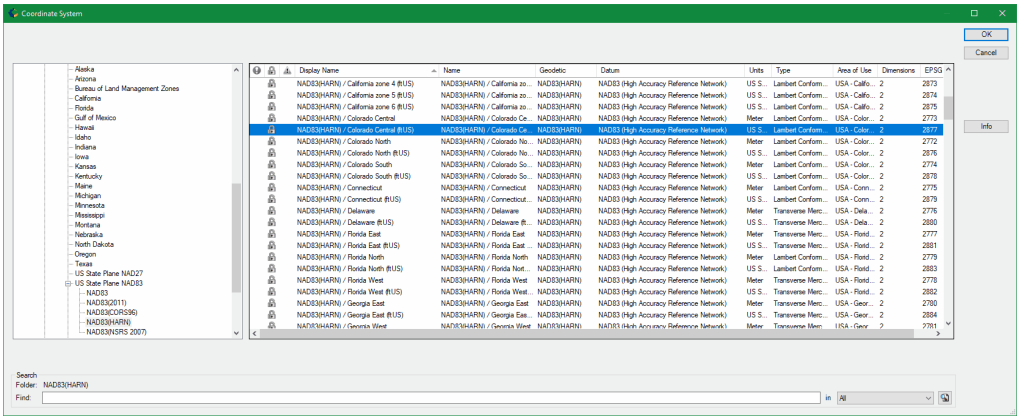


After choosing the desired file(s) or folder, select the coordinate reference system that the data is in by clicking the 'Edit' button beside the 'Projection Definition (WKT)' text box. The 'CRS Info (Projection Definition) Written as WKT' window will then appear.

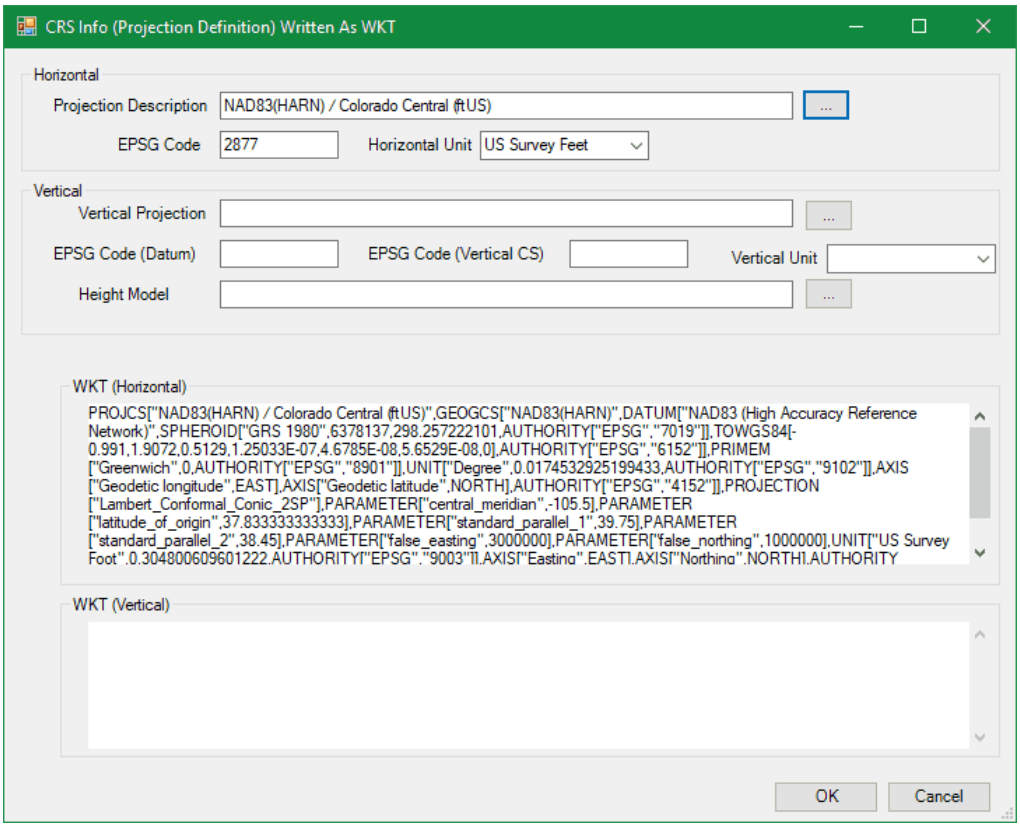
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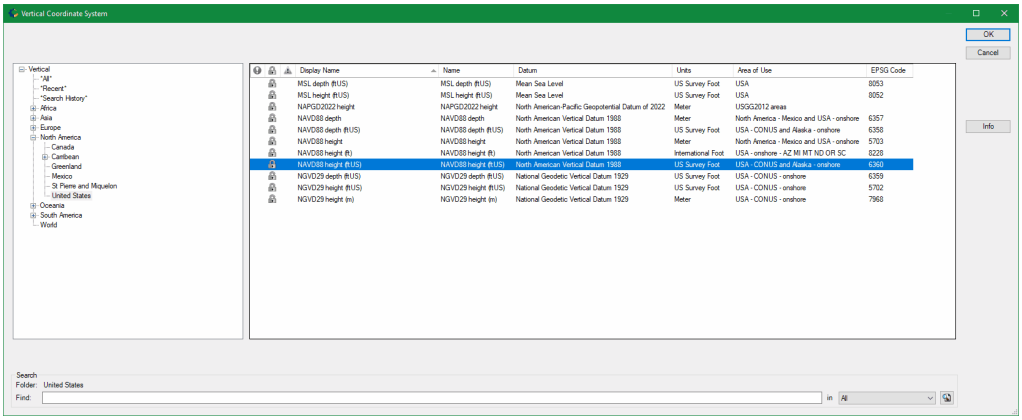
Click the browse button ('...') next to the 'Horizontal Projection Description' text box to bring up the 'Coordinate System' selection interface, and choose the horizontal coordinate system of the data. The user may either navigate to the system which defines the data and click **'OK'**, or the **'Find'** search engine at the bottom of the interface may be used to help find the desired coordinate system.



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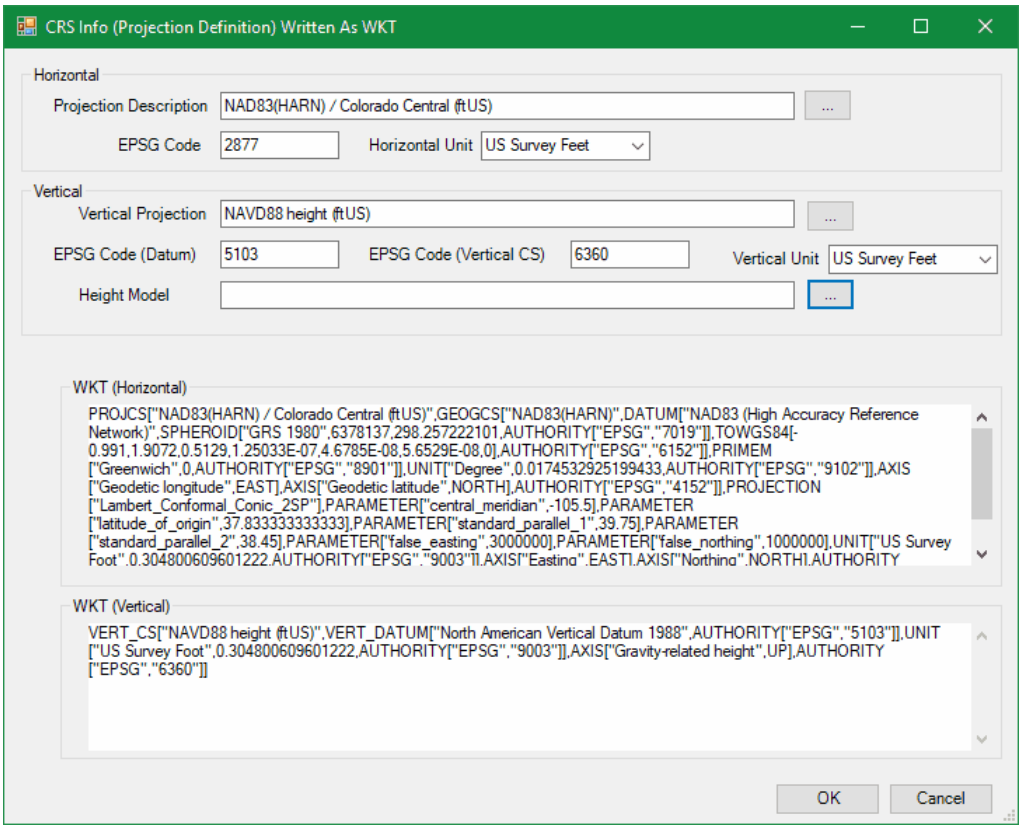


Next, click the browse button ('...') next to the 'Vertical Projection' text box to bring up the 'Vertical Coordinate System' selection interface, and choose the vertical coordinate system of the data in a similar manner.

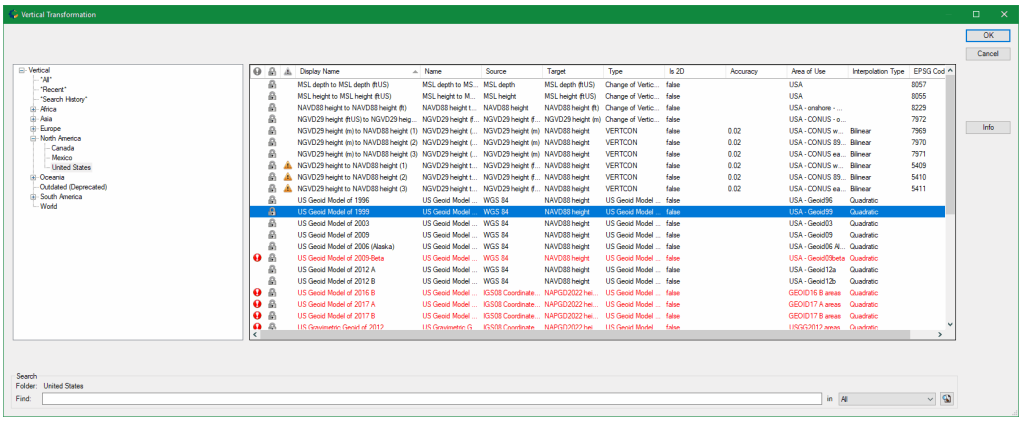


Be sure that both the 'Horizontal Unit' and 'Vertical Unit' boxes are correctly populated on the 'CRS Info (Projection Definition) Written as WKT' interface.

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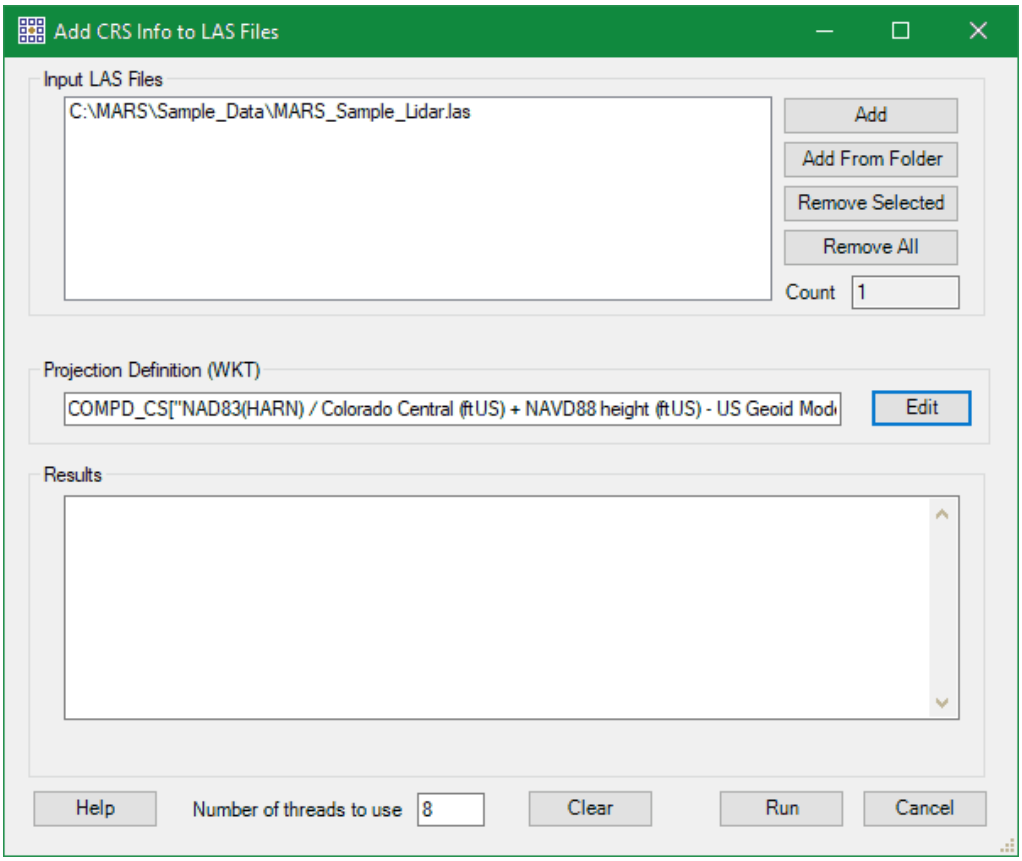


The 'Height Model', if known, can be selected by using its browse button and choosing the appropriate model from the 'Vertical Transformation' selection interface.



When all information has been entered on the 'CRS Info (Projection Definition) Written as WKT' interface, click the 'OK' button to return to the original 'Add CRS Info (to LAS Files)' tool.

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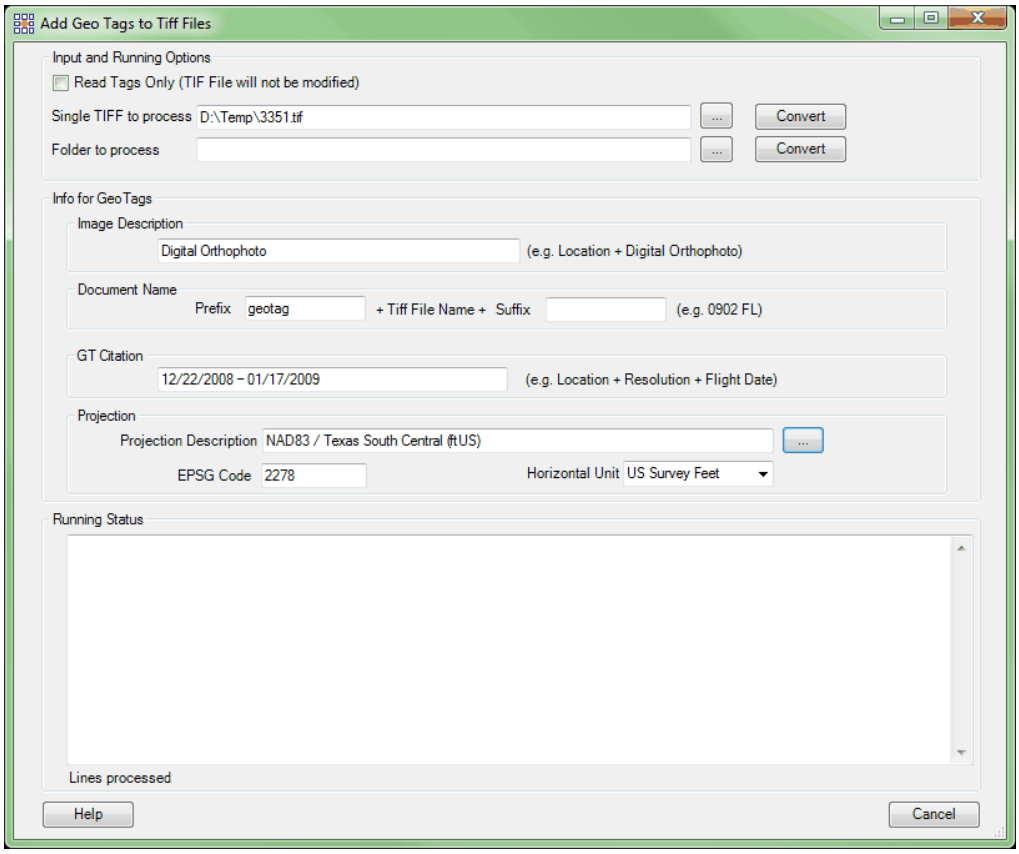
Like many other MARS® tools, this tool is capable of multi-threading to decrease processing time. The **'Number of threads to use'** text box at the bottom of the interface will automatically be populated with the maximum number of threads available on the particular computer in use. A lower number of threads can be entered as needed. A value of '1' is equivalent to single-thread processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Click on the **'Run'** button at the bottom of the interface to start the processing. The file or files that were defined will appear in the 'Results' section, and a completed message will indicate when all processing is finished. The **'Clear'** button can be used to remove **'Input LAS Files'** and **'Results'** information to prepare for additional processing.

Add Geo Tags (to Tiff Files): This tool is a GeoTiff header tool meant for use with georeferenced tiff

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files. By navigating to the *.tif file to be converted and specifying all of the needed information, the user can produce a *.tif which will function on its own without the accompanying tiff world file (*.tfw). To produce a single GeoTiff file, start by navigating to the file which is to be defined. The *.tif and accompanying *.tfw must both reside in the same folder. If only a single file is to be defined, it is easiest to use the 'Single TIFF to process' text box. If an entire folder of tiff files is to be defined, using the 'Folder to process' text box will be faster. For the folder option, navigate to the folder which contains the tiff files to be defined. As the tiff images are loaded into the interface, the 'Image Description' and 'GT Citation' sections of the interface will automatically populate. If the user wishes to add a prefix or a suffix to the tiff file name(s), these can be specified under the 'Document Name' section. Lastly, specify the projection of the tiff file in the 'Projection' section. The user may choose the projection from a list by choosing the '...' button and either navigating to or running a search for the needed projection. Once the projection has been chosen, the 'EPSG Code' will automatically populate. Make sure to choose the correct horizontal unit, and the tiff file(s) will be ready to be defined. Click the appropriate 'Convert' button at the top of the interface and the 'Running Status' section of the interface will show the progress of the tool. The new tiff file(s), with georeferenced information in the header, will be found in the same folder in which the original tiff files were found. ***The original tiff file(s) will be replaced.***

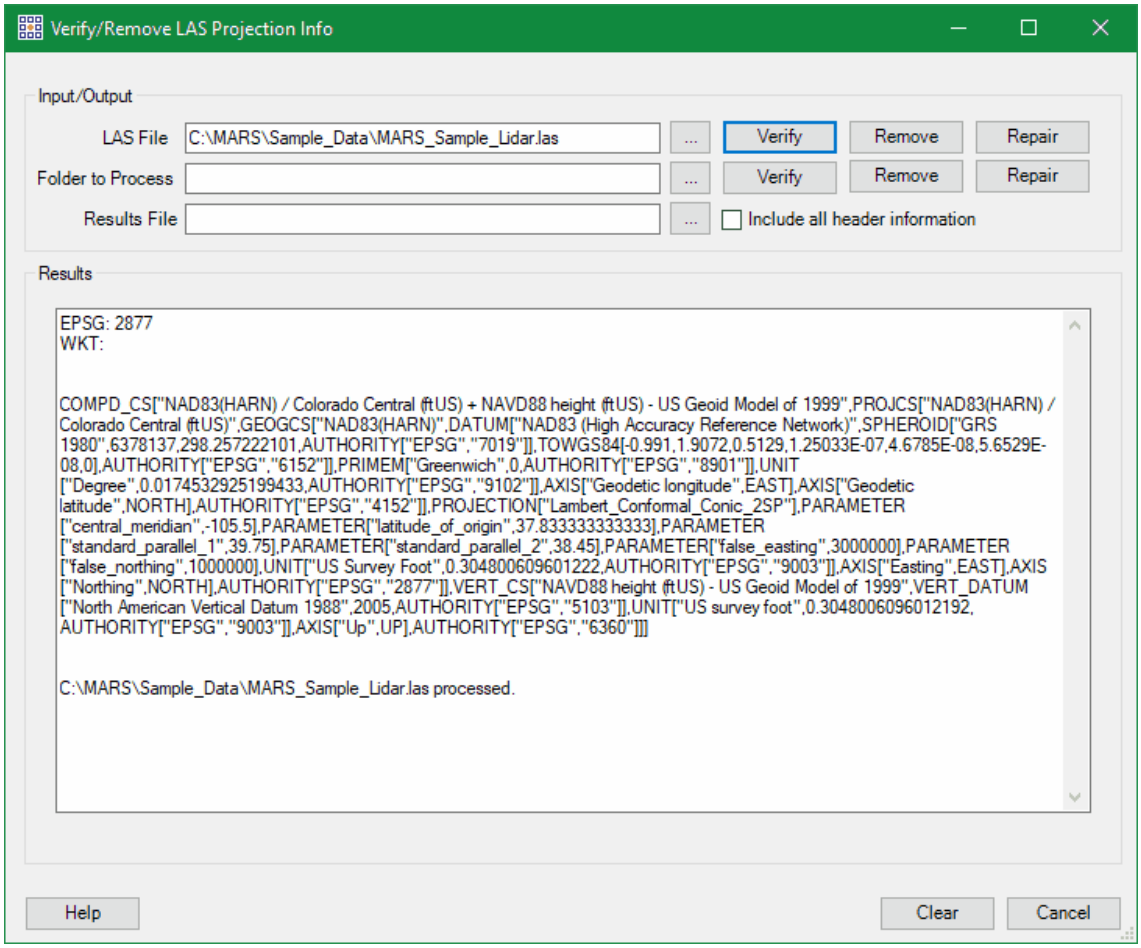
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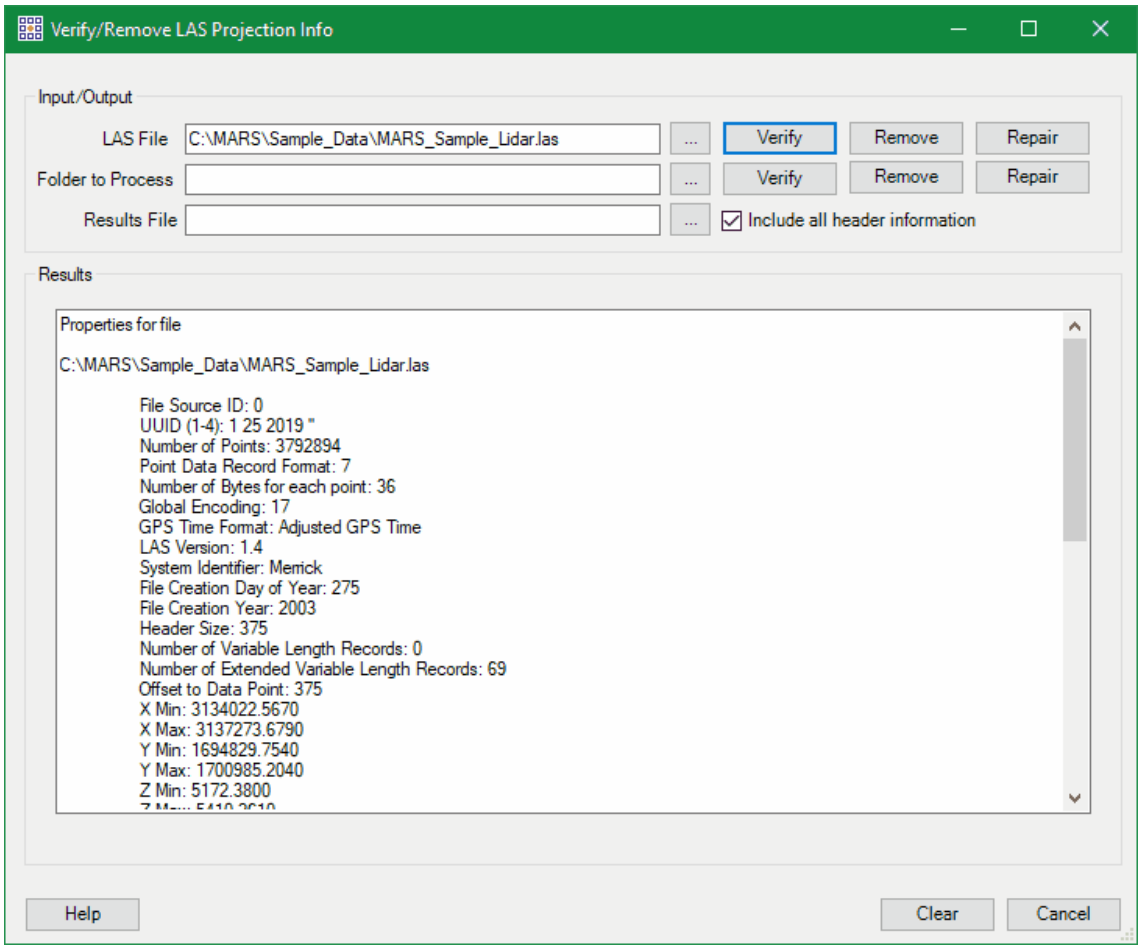
Verify/Remove LAS Projection Info: This tool allows the user to verify the projection definition (coordinate system) information for an LAS file or an entire folder of files and, optionally, save the displayed output to a Results File. The user can navigate to an individual LAS file or a folder of LAS files depending on the browse button used. Clicking on the corresponding **'Verify'** button will start the process and the results will be shown in the **'Results:'** box. If the user wishes to clear (remove) projection information from an LAS file or folder of files, click on the corresponding **'Remove'** button. The **'Repair'** button fixes certain errors in superseded WKT-based coordinate system tags in LAS v1.4 files. The function will search all EVLRs or VLRs containing superseded WKT tags and fix incorrect 'Record ID' values of '0' (zero) to the correct value of '7'. It will also fix incorrect values of the 'User ID' field - 'LAS_Spec' and 'LASF_Projection' - to the correct 'LASF_Spec' for superseded records, so that the files will be in compliance with ASPRS specifications.

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In addition, an option - '**Include all header information**' - exists that will display and, optionally, save the header contents (similar to metadata) as well as the projection information.



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The **'Clear'** button can be used to remove **'Input/Output'** and **'Results'** information to prepare for additional processing.

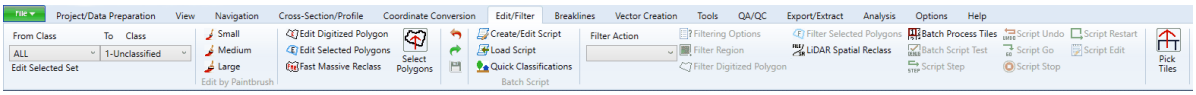
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3.7 Edit/Filter Tab

Edit/Filter Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Edit/Filter Tab:



- **From Class drop-down list:** This allows the user to pick from ALL classes, a selected set of classes (see below), or any one of the 256 individual LiDAR classes to be the source class(es) for manual editing actions.

- **Edit Selected Set:** This function allows the user to make a selected set comprised of any combination of LiDAR classes to be used when the '- Selected -' option is chosen in the 'From Class' drop-down list. More details about using and saving selected sets can be found in the Manually Editing LiDAR Data 1824 tutorial.

- **To Class drop-down list:** This allows the user to pick from any one of the 256 individual LiDAR classes to be the target class for manual editing actions.

- **Edit Paint Small:** This paint utility is the smallest paint tool. It reclassifies visible points selected by clicking or dragging the cursor box over them (in both 2D and 3D Views). To make edits in 3D the user must be either zoomed in to 100% point density or have the 'Lock to view 100%' button toggled on - the paint brush buttons will not be available otherwise. Also while in 3D, if TIN rendering is used only those classes being displayed as Points (see the Display Selection | Classification section of the View Tab 192 topic) can be edited. It is possible (but not recommended) to edit in 2D View at less than 100% point density, but some points may be missed this way. ***Changes are made immediately to the loaded data.***

- **Edit Paint Medium:** This paint utility is a medium-sized paint tool. It reclassifies visible points selected by clicking or dragging the cursor box over them (in both 2D and 3D Views). To make edits

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in 3D the user must be either zoomed in to 100% point density or have the 'Lock to view 100%' button toggled on - the paint brush buttons will not be available otherwise. Also while in 3D, if TIN rendering is used only those classes being displayed as Points (see the Display Selection | Classification section of the View Tab 192 topic) can be edited. It is possible (but not recommended) to edit in 2D View at less than 100% point density, but some points may be missed this way. ***Changes are made immediately to the loaded data.***

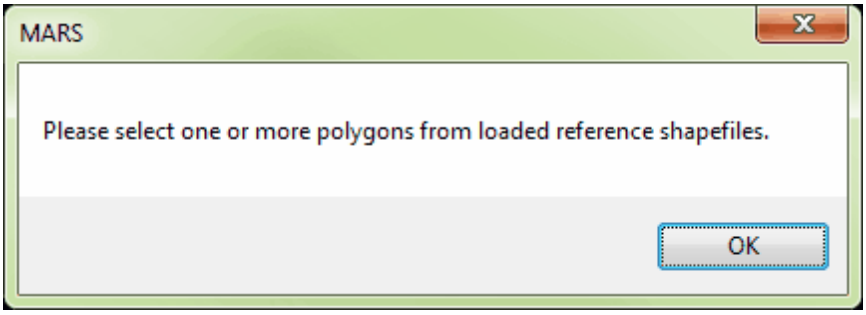
- **Edit Paint Large:** This paint utility is the largest paint tool. It reclassifies visible points selected by clicking or dragging the cursor box over them (in both 2D and 3D Views). To make edits in 3D the user must be either zoomed in to 100% point density or have the 'Lock to view 100%' button toggled on - the paint brush buttons will not be available otherwise. Also while in 3D, if TIN rendering is used only those classes being displayed as Points (see the Display Selection | Classification section of the View Tab 192 topic) can be edited. It is possible (but not recommended) to edit in 2D View at less than 100% point density, but some points may be missed this way. ***Changes are made immediately to the loaded data.***

- **Edit Digitized Polygon**: Allows the user to create a polygon in the LAS Map View window (only while in 2D View 835 mode) for reclassification of visible points. Left-click the mouse to place polygon vertices, and right-click to close the polygon and re-class the points inside, based on the settings of the 'From Class' and 'To Class' drop-downs. See the **Fast Massive Reclass** topic (below) for details on optionally saving the digitized polygon for later use. ***Changes are made to the loaded data.***

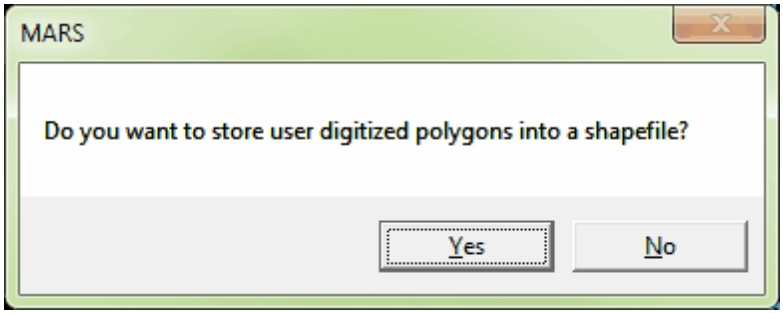
- **Edit Selected Polygons:** This tool starts the edit process for visible points within any polygon(s) selected with the 'Select Polygons' tool (see below). Before using, first render the LAS Map View data using **'Color by Classification'** by clicking the  button on the View Tab 192, or use the **'CTRL-C'** shortcut key (this will allow a visual confirmation as each selected polygon is processed). Then,

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choose a 'From' class (or classes) and a 'To' class. ***Changes are made to the loaded data.*** This option is only available for editing while in 2D View[835] mode. If the 'Edit Selected Polygons' button is clicked before any polygons have been selected, the following message will appear:

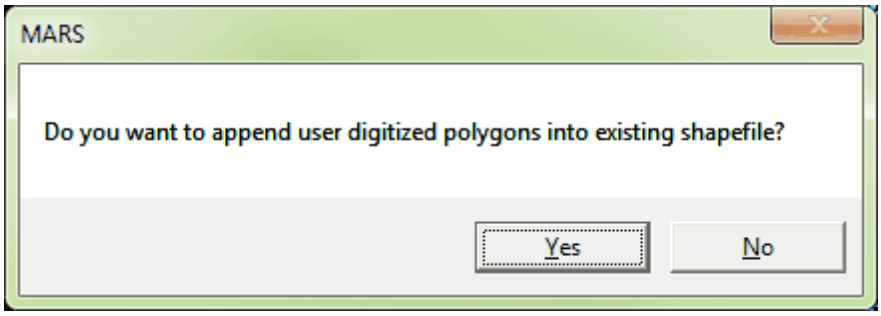


- **Fast Massive Reclass:** When this tool is toggled on (highlighted in orange), the performance of both the 'Edit Digitized Polygon' and 'Edit Selected Polygons' manual reclassification methods (see above) is improved. In addition, each time the 'Edit Digitized Polygon' tool is invoked while 'Fast Massive Reclass' is toggled on, a prompt appears asking if the polygon about to be digitized should be saved to a polygon shapefile.

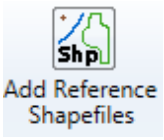


A 'No' answer will switch to the digitizing cursor and a temporary polygon can be created. A 'Yes' answer will display an additional prompt as to whether the polygon about to be digitized should be appended to an existing polygon shapefile.

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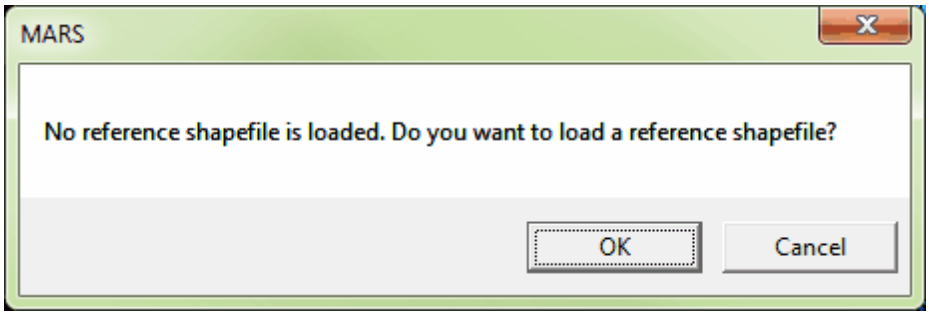


A 'Yes' answer allows the user to navigate to an existing polygon shapefile to which the new polygon feature will be added. After choosing the pre-existing shapefile, digitization can begin. A 'No' answer allows the user to path out and name a new polygon shapefile for storing the newly-created polygon after which digitization can begin.

- **Select Polygons:** Use this tool to select any pre-existing polygon(s) for visible point reclassification. A polygon shapefile must be loaded as a Reference Shapefile to use this tool. Use the **'Add Reference Shapefiles'** button 

on the Project/Data Preparation Tab 162 to load the polygons. When a shapefile is added this way, the user can reclassify points within polygons of any shape. This tool is used to select a single polygon or multiple polygons for use with the 'Edit Selected Polygons' tool (see above), and works only in 2D View 835. To use, left-click and drag the cursor over the polygon(s) to be reclassed - they will be highlighted in a thicker line weight. Additional polygons can be selected by holding down the **'Ctrl'** key on the keyboard and clicking on a polygon(s). Individual polygons can be removed from the selected set using the same **'Ctrl'** key/mouse-click combination. ***Note*** that if multiple polygon shapefiles are loaded, all polygons from all shapefiles that fall within the selection area will be selected. If this tool is used when no polygon shapefile is loaded as a Reference Shapefile, a prompt will appear allowing the user to load one.

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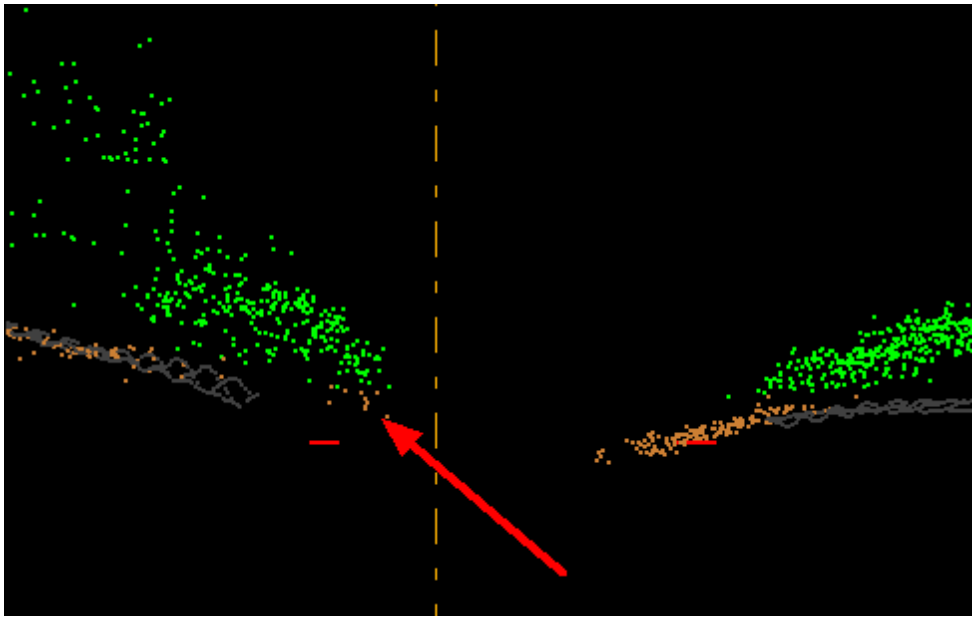


- **Undo:** This tool will undo an edit process each time it is selected. This tool is useful when an edit process is not done correctly. It can be undone and the user can attempt the edit process again.

- **Redo:** This tool will redo an edit process each time it is selected. This tool can be used only after the 'Undo' tool has been used - it will 'redo' an undone process.

Please see the examples below to see the functions of the 'Undo' and 'Redo' tools.

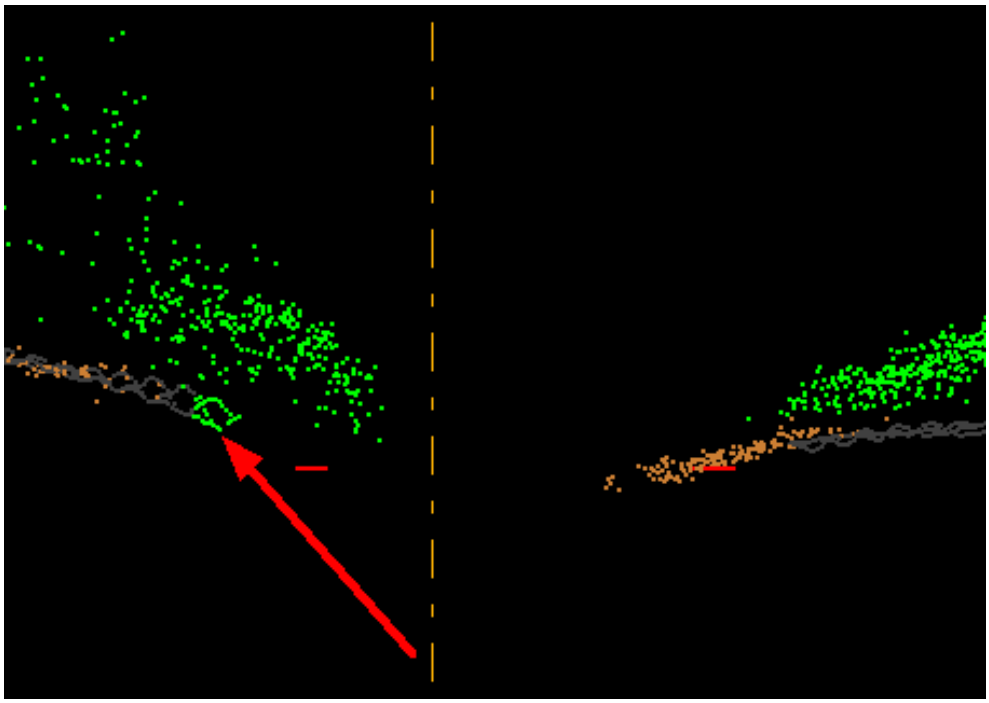
In this first example, a bit of vegetation next to a river has been incorrectly classified as ground.



In the next example, the misclassified ground point has been changed to vegetation. However, the

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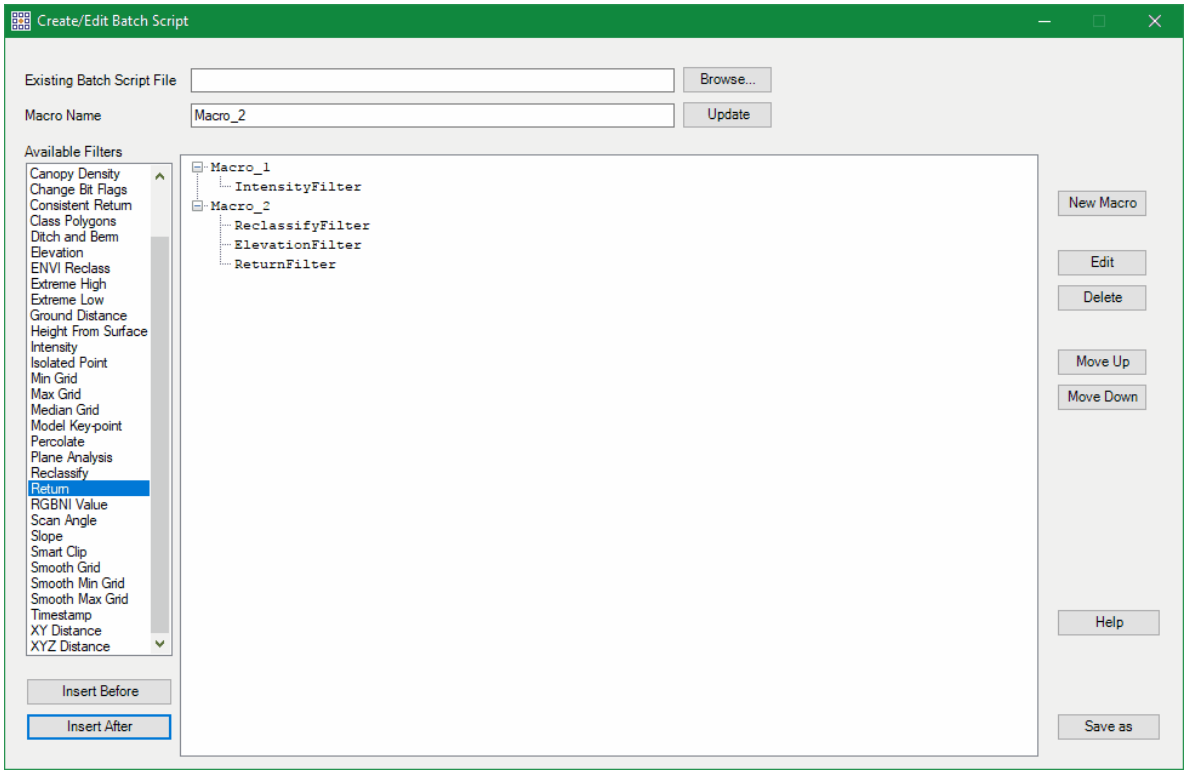
*editor has made a mistake and has accidentally classified the ground below the vegetation as vegetation. By clicking on the **'Undo'** button, this mistake is easily reversed and the point classifications that were changed to vegetation will go back to their original ground value as if the edit was never made. To reverse an 'undo' action, click on the **'Redo'** button and the edit that was made will reappear.*



- **Save cached points to disk**: *This button is currently disabled.* Due to LAS datasets becoming increasingly larger in file size (frequently surpassing the available RAM in a computer) as well as the possibility of lost work caused by an unexpected shutdown of MARS prior to a save operation, the 'Cache points into available RAM' option has been disabled. LAS data will be read from disk and 'live' edit changes (such as hand filtering) are committed to disk as soon as they occur. Additionally, with newer, faster hard drives such as SSD, the performance difference between disk-based and RAM-based operations is constantly shrinking.

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- **Create/Edit Script:** The user can create, edit, and save macros (a sequence of filters and/or extraction tools) in a batch script using this tool. The user may also add comments to each filter/extraction tool, which will be shown after the filter/extraction tool in the 'Create/Edit Batch Script' window. Note that the reserved XML characters <, >, /, %, &, ', " cannot be used in the Comments box for any filters/extraction tools.



1.) To create a batch script, first create a name for the macro which will contain the list of steps in the 'Macro Name' text box (the default name is Test, but has been changed to Macro_1 by overwriting Test and clicking the 'Update' button). Then choose the desired filter/extraction tool from the list of 'Available Filters' on the left side of the window. To learn more about the types of filters and extraction tools, please see the Filter Action 987 and Extraction Tools 1175 topics.

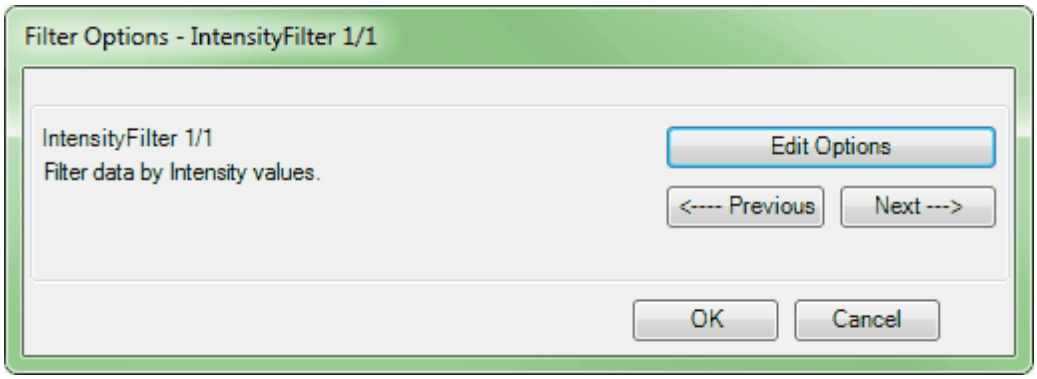
2.) After choosing the first filter/extraction tool to be added, click either 'Insert Before' or 'Insert After' to insert it into the list under the macro name in the center area of the

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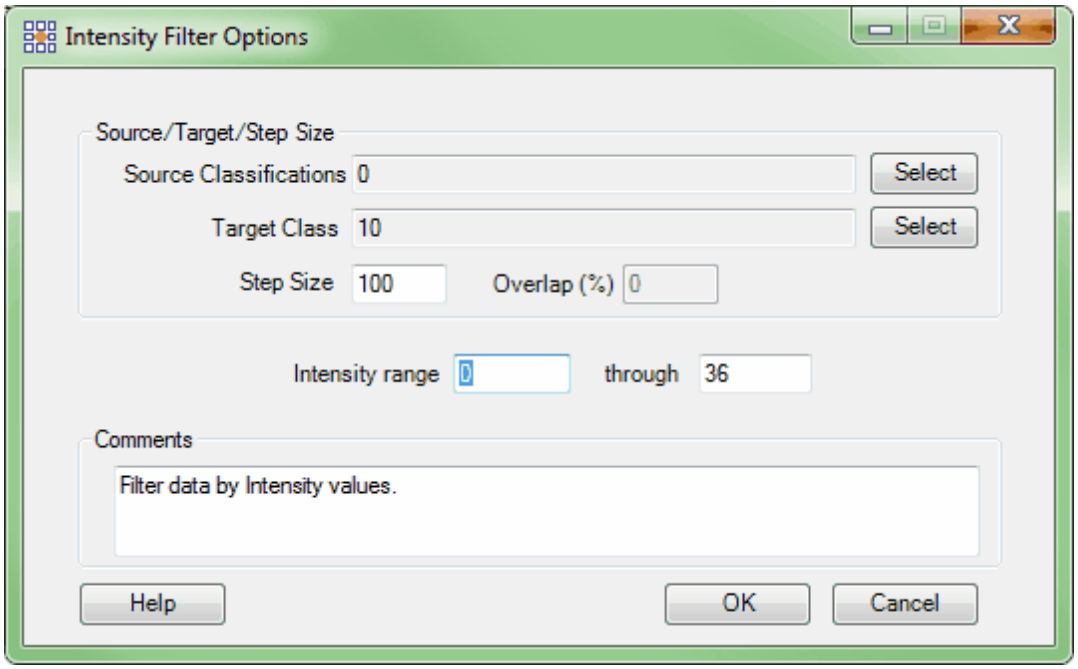
interface.

3.) Continue making a list of filters/extraction tools to complete the macro. Highlight an existing filter/extraction tool and use the 'Insert Before' or 'Insert After' buttons to place the filters/extraction tools in a particular order. If the user wishes to move one already placed into a list as a macro is being created, or move one or more in a previously-created batch script (XML) file, select the filter/extraction tool to be moved and choose either the 'Move Up' or 'Move Down' button (as appropriate) located on the right side of the window.

4.) After adding all the filters/extraction tools that will make up the macro, double-click on any entry in the list (or select an entry in the list and click the 'Edit' button on the right side of the window) to bring up the first 'Filter Options' window (below, left). Use the 'Previous' and 'Next' buttons to navigate to the filter/extraction tool whose parameters need to be set or edited, then click the 'Edit Options' button to bring up the specific 'Filter Options' interface for the chosen filter/extraction tool (below, right).



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In the screen shot above (right), the Intensity filter parameters have been brought up for editing. The user may enter comments in each filter which will then be seen in the 'Create/Edit Batch Script' interface. Note that the reserved XML characters XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box for any filters/ extraction tools. For more information on how to set the parameters of a specific filter/ extraction tool, please see the lists under the Filter Action 987 and Extraction Tools 1175 topics.

5.) Unneeded steps can be removed from a macro by selecting them (one at a time) and clicking the 'Delete' button on the right side of the window.

6.) When all the filters/extraction tools have been added and/or edited, save the batch script file by clicking on the 'Save as' button and browsing to an output folder. Now that the file (in XML format) has been saved, it can be loaded at any time for further editing or use.

7.) To create multiple macros inside a single XML script file, type a new macro name in the 'Macro Name' text box of the 'Create/Edit Batch Script' window and click on the 'New Macro' button. A new macro header (Macro_2, above) will appear in the center

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area of the window and filters may be added to this macro as described above.

- **Load Script:** If a batch script XML file has previously been created, it can be loaded into MARS® with this command. Only one XML script can be loaded at a time - a subsequent load will replace the previous XML file. Browse to the folder which contains the .xml file, choose it, and click 'Open' to load it into MARS®. Upon loading the script, all macros within it will be added to the list of available filters in the **'Filter Action'** drop-down (see next topic), with the first macro appearing automatically at the top of the list. All macros within a script can be accessed by scrolling down to the bottom of the drop-down, immediately following the list of discrete ('built-in') filters. Once a macro is selected, it can be edited by using the 'Script Edit'  button located on the Edit/Filter Tab 270. Edits made while the script file is loaded are saved immediately. If a MARS® project file (*.mpd) is created or saved with a macro from a batch script loaded, the macro will be saved in that project. See the Filter Action 987 topic for more information on how to use filters.

- **Quick Classifications:** This filtering method - written, distributed, and licensed by ***rapidlasso GmbH*** - uses algorithms and routines that are part of the **LAStools** software suite to classify ground and, optionally, high vegetation and buildings. Its use requires that at least part of the LAStools suite ('*lasground_new.exe*' and '*lasground_new64.exe*' at a minimum) be present on the local computer or in an accessible network location that can be pathed out. The minimum required version of **LAStools** for use in MARS® will contain a 'CHANGES.txt' file dated November 8, 2018, or later. The LAStools suite can be downloaded at no charge, but licensing is required to use the classification routines in a commercial, government, or production environment. *Unlicensed use in any setting may cause data corruption!* As taken from the ***rapidlasso GmbH*** website, "Note that the output of the unlicensed version can be slightly distorted after certain point limits are exceeded." Please contact ***rapidlasso GmbH*** by e-mail directly at info@rapidlasso.de for general information including questions about

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licensing and allowable use, or see the ***rapidlasso GmbH*** website for details. For pricing information, go to http://rapidlasso.de/pricing. Licenses are available for the entire **LAStools** suite, or the components needed for the 'Quick Classifications' tool can be licensed separately at a reduced cost. All licensing, pricing, and payment is handled directly between the end user and ***rapidlasso GmbH*** - Merrick & Company has no involvement at this level.

If the vegetation and building filtering option will be used:

Either two or four additional executable files (*.exe) - depending on the license status - from the **LAStools** suite must be in the path entered as in the example shown in the first graphic following the '**License Status**' table. Both '*lasclassify.exe*' and '*lasclassify64.exe*' are needed with or without a license, while '*lasheight.exe*' and '*lasheight64.exe*' are additionally required when no license is present. Remember that unlicensed use is limited (by ***rapidlasso GmbH***) to testing and/or evaluation only. A license purchased for this tool will authorize the Ground Filter 1036 tool as well.

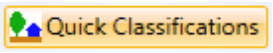
License Status:

	Licensed	Unlicensed
lasground_new.exe and ***lasground_new64.exe*** files needed:	✓	✓
lasclassify.exe and ***lasclassify64.exe*** files needed:	✓1	✓1
lasheight.exe and ***lasheight64.exe*** files needed:	N/A	✓1

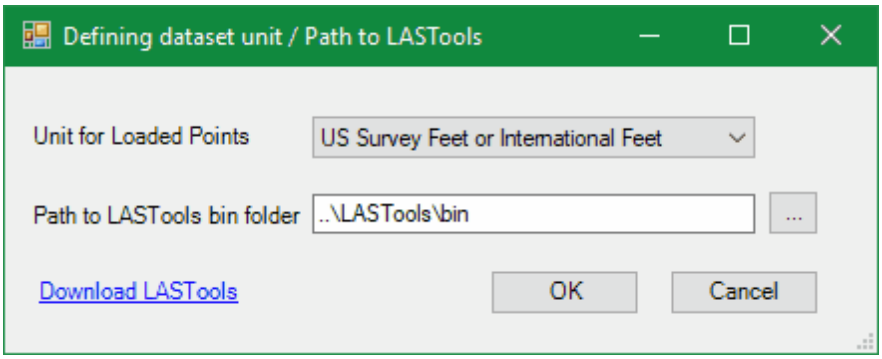
✓1 - required only if the vegetation and building filtering option is used.**License Status:**

As implemented in MARS®, 'Quick Classifications' is used to produce tiled, classified LAS files based on an existing tile layout shapefile. The tool takes unclassified or partially classified data as the input and creates tiled files with ground points and unclassified points, with an option to also classify buildings and high vegetation once ground is known. The input data will not be altered with this tool.

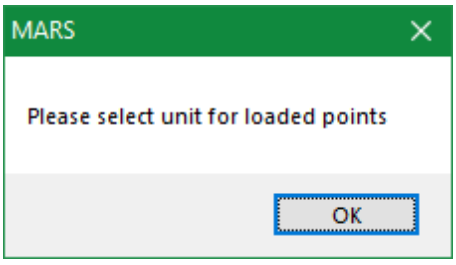
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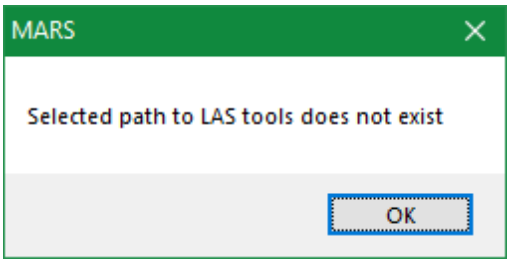
The LAS data to be re-classified must be loaded along with a polygonal tile shapefile that has the same coordinate reference system definition. Once these are loaded, click the 'Quick Classifications' button 

to get started. A window will appear where both the data units and the path to the **LAStools** executable files and the license file (if purchased) must be set. The LAStools software suite can be downloaded from a link on this interface. The minimum required version of **LAStools** for use in MARS® contains a 'CHANGES.txt' file dated November 8, 2018, or later.



The data units must be set each time the tool is used - a correct entry is critical to the operation and results of the classification routines. The path to the **LAStools** files will be stored for future use, but can be updated if the location of the files is ever changed. If the units are not selected, or the path entered to the LAStools folder does not exist, or the path entered does not contain the minimum required **LAStools** files, the following messages will appear when the 'OK' button is clicked:

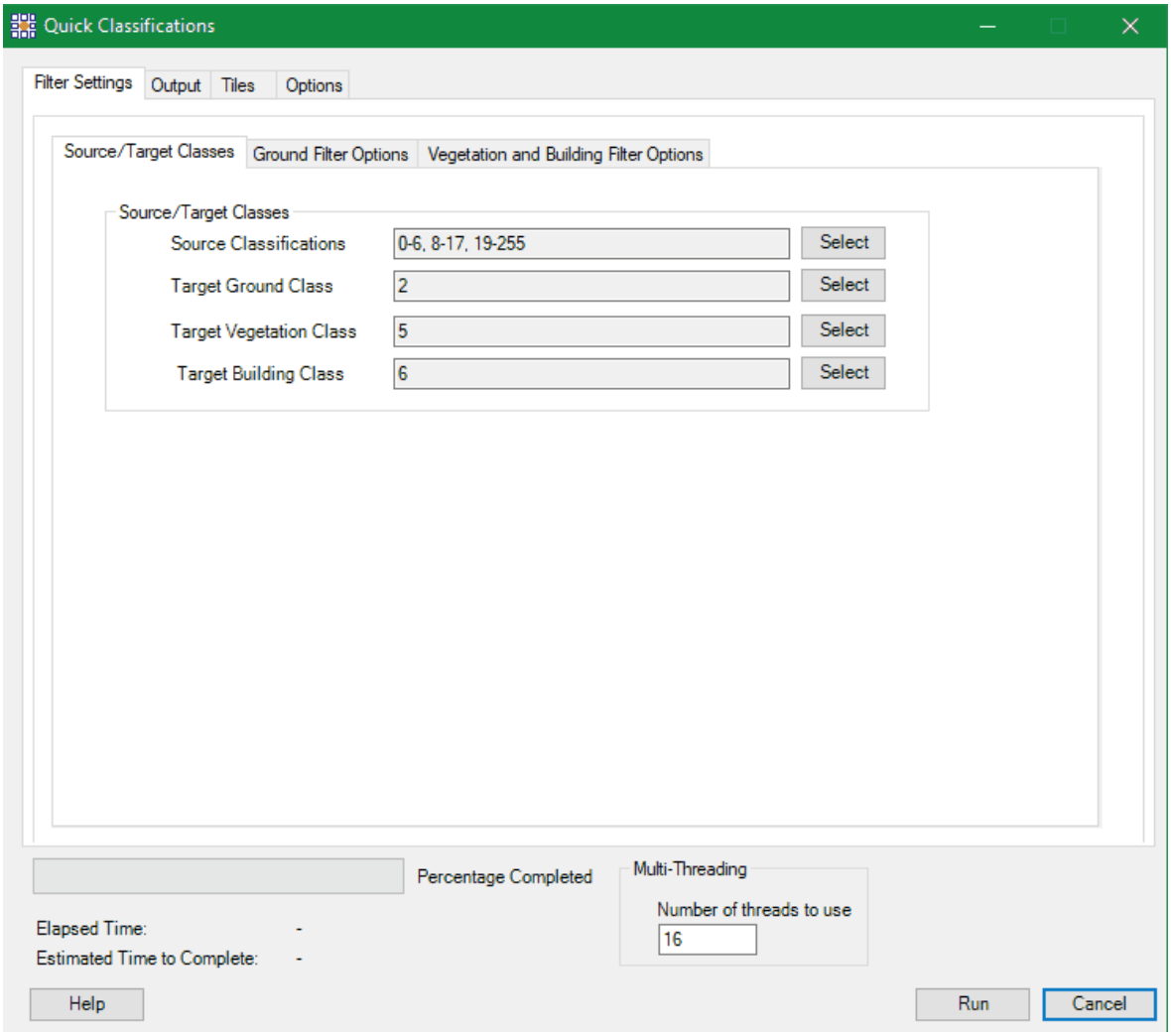




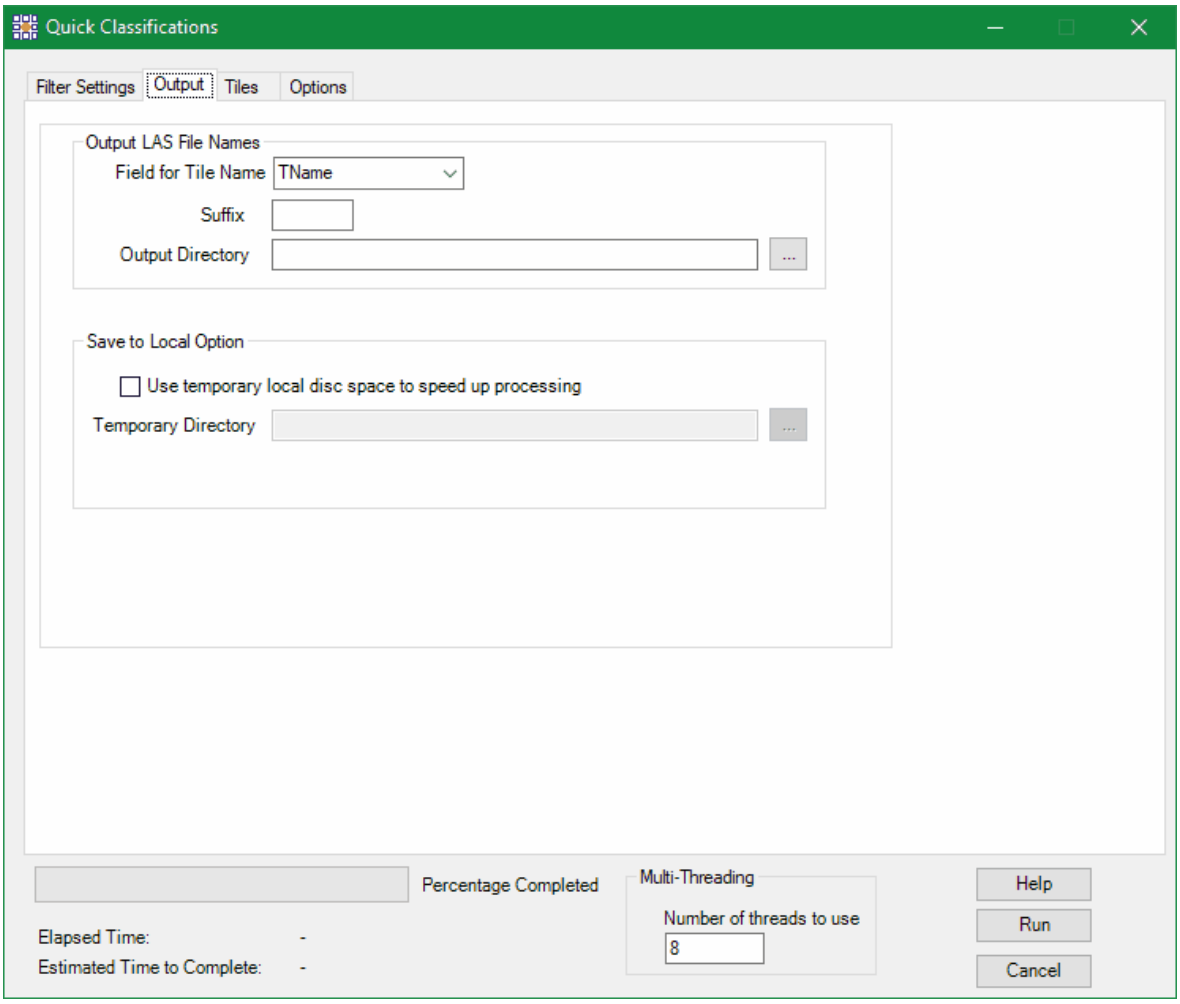
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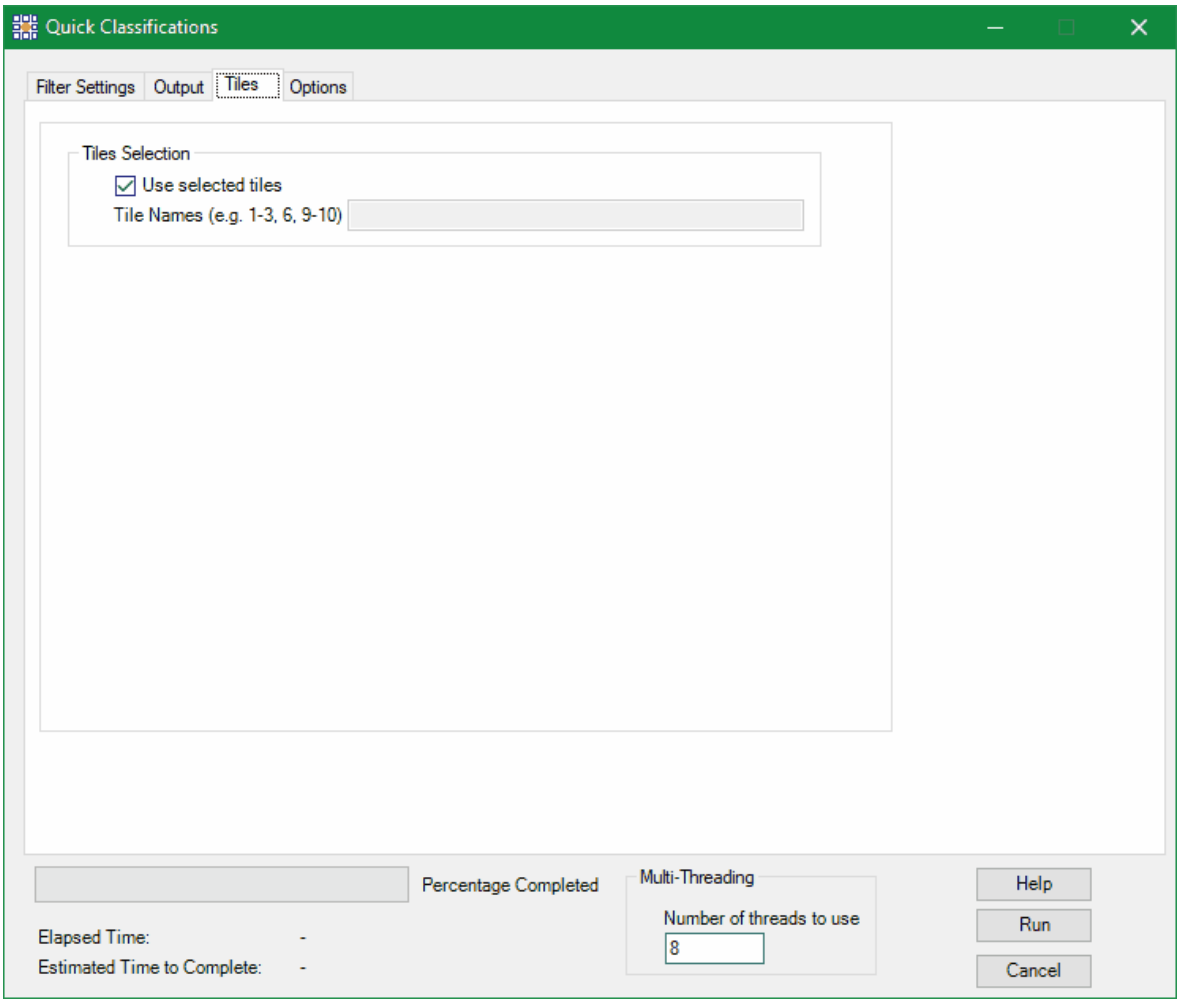
When the data units are entered and a valid **LAStools** path exists, click 'OK' to bring up the main 'Quick Classifications' interface. The interface consists of four tabs:



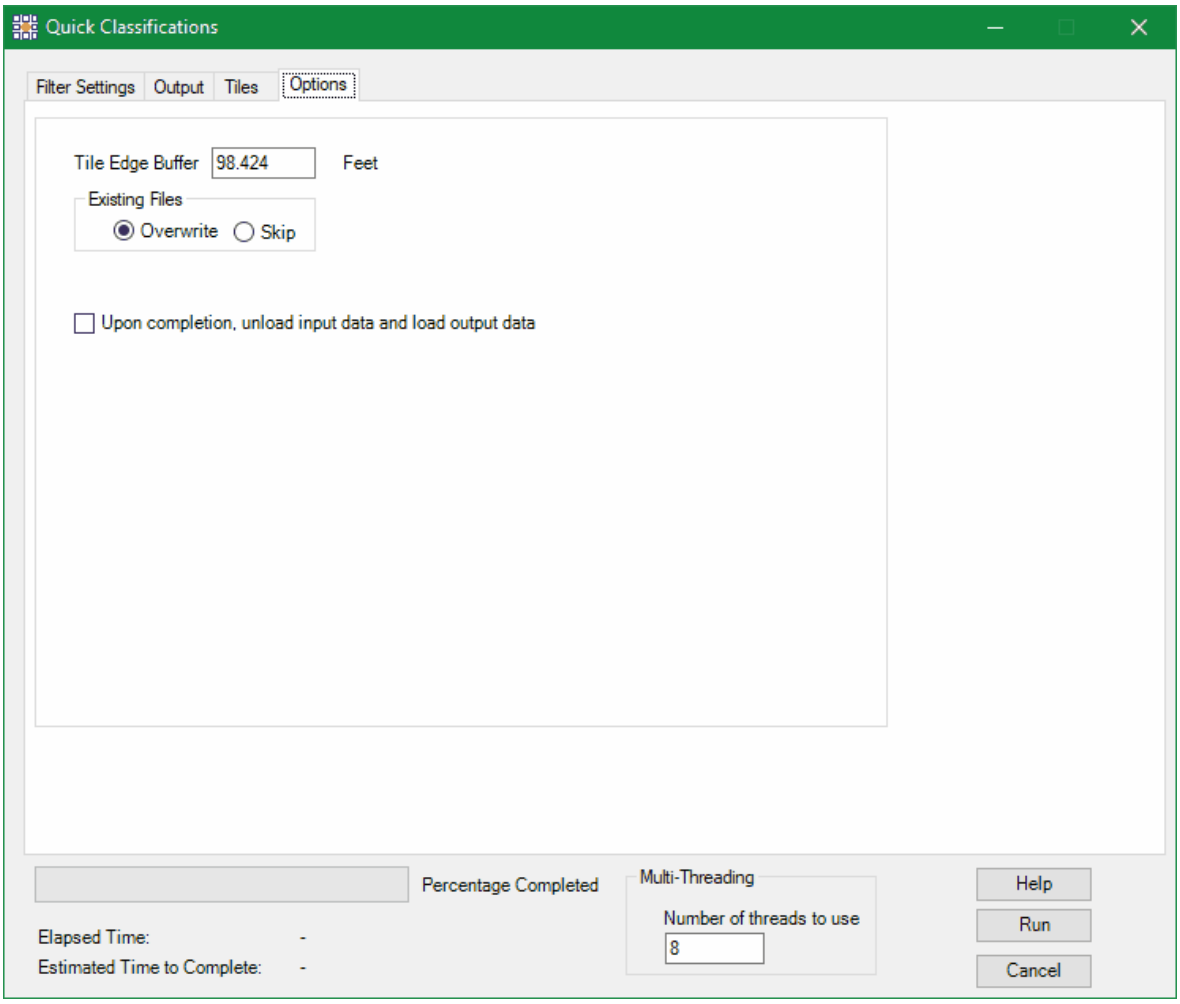
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Filter Settings tab: The Source and Target classes are selected here. By default, all 256 classes are included in the 'Source Classifications', but this can be changed by clicking the 'Select' button. Likewise, defaults are set for the 'Target Ground Class' as well as the optional 'Target Vegetation Class' and 'Target Building Class'. These are based on the ASPRS standard classes for these features, but they can be modified by clicking the appropriate 'Select' button (s). For info regarding the 'Ground Filter Options' and 'Vegetation and Building Filter Options' tabs, see below.

Output tab:

- ***Field for Tile Name:*** Select an attribute field with unique values for the output tile naming.
- ***Suffix:*** Optionally, specify a suffix to be appended to the tile name for the output files.

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NOTE: The naming convention selected will be applied to all output LAS files.

- ***Output Directory:*** Browse to select an output folder where the final processed tiled LAS files will be stored.
- ***Save to Local Option*****:** When the 'Output Directory' is a network location, temporary local disk space can be used to speed up processing. Select this option by checking the box and then specify a temporary local folder with sufficient free space. The 'Temporary Folder' specified WILL NOT be the final output folder, but rather is a local directory which can be used to speed up the processing. The output data will be moved to the 'Output Directory' when all processing is complete. ***NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***

Tiles tab:

- ***Tiles Selection*****:** The 'Use selected tiles' check box is checked on by default. Keep this box checked if the tiles which are to be processed have been selected in the tile layout. If the user would like to run 'Quick Classifications' on other (specified) tiles, enter those tile names (using the 'Field for Tile Name' attribute) into the 'Tile Names' text box separated by commas.

Options tab:

- ***Tile Edge Buffer:*** The default value, as recommended by ***rapidlasso GmbH***, is '30' when the data units have been set to 'Meters'. When 'US Survey Feet or International Feet' is set, the value is automatically converted to 98.424 units. In either case, this value can be modified. This buffer will be added during processing to improve the results, and cut back to the original tile boundary when processing is finished.
- ***Existing Files*****:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g., power failure, computer shuts down, an error occurs, etc.). When the user starts processing again, checking this button will cause the software to skip any tiles which already exist in the specified output folder. Tiles which have already been processed will not

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be run again and the software will process only those tiles which are not found in the output folder. (For this reason it is suggested that if processing stops for any reason, the user should go into the output folder and delete the last tile that was processed based on the timestamp. This tile may not be complete, but since the tile name exists in the output folder it would otherwise be skipped.) The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.

- ***Upon completion, unload input data and load output data*:** This option is self-explanatory.

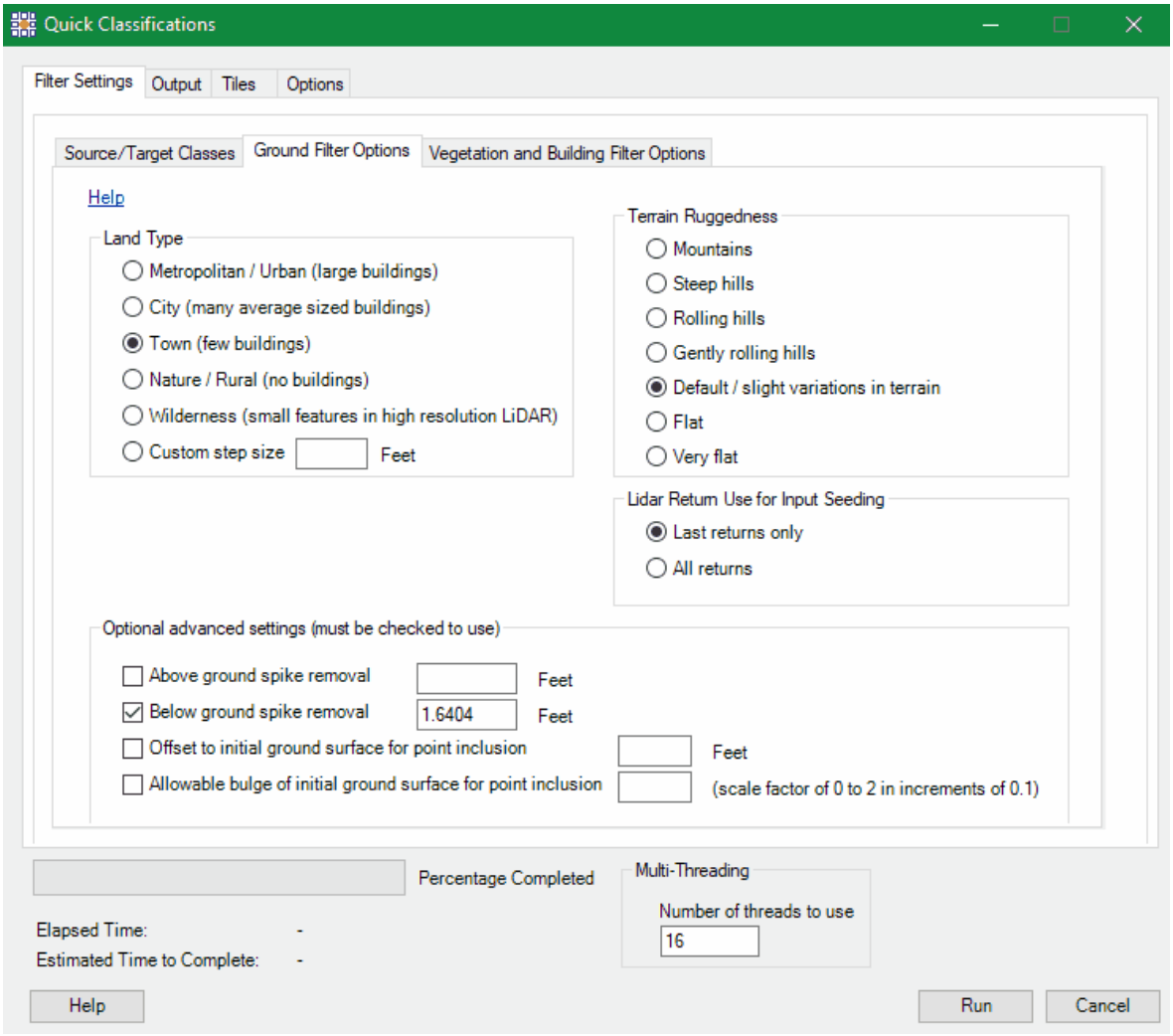
General interface options:

- ***'Multi-Threading'* section:** To help speed up processing, multi-threading is available for this tool. Enter any number of threads from 1 to the maximum number available in the text box. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

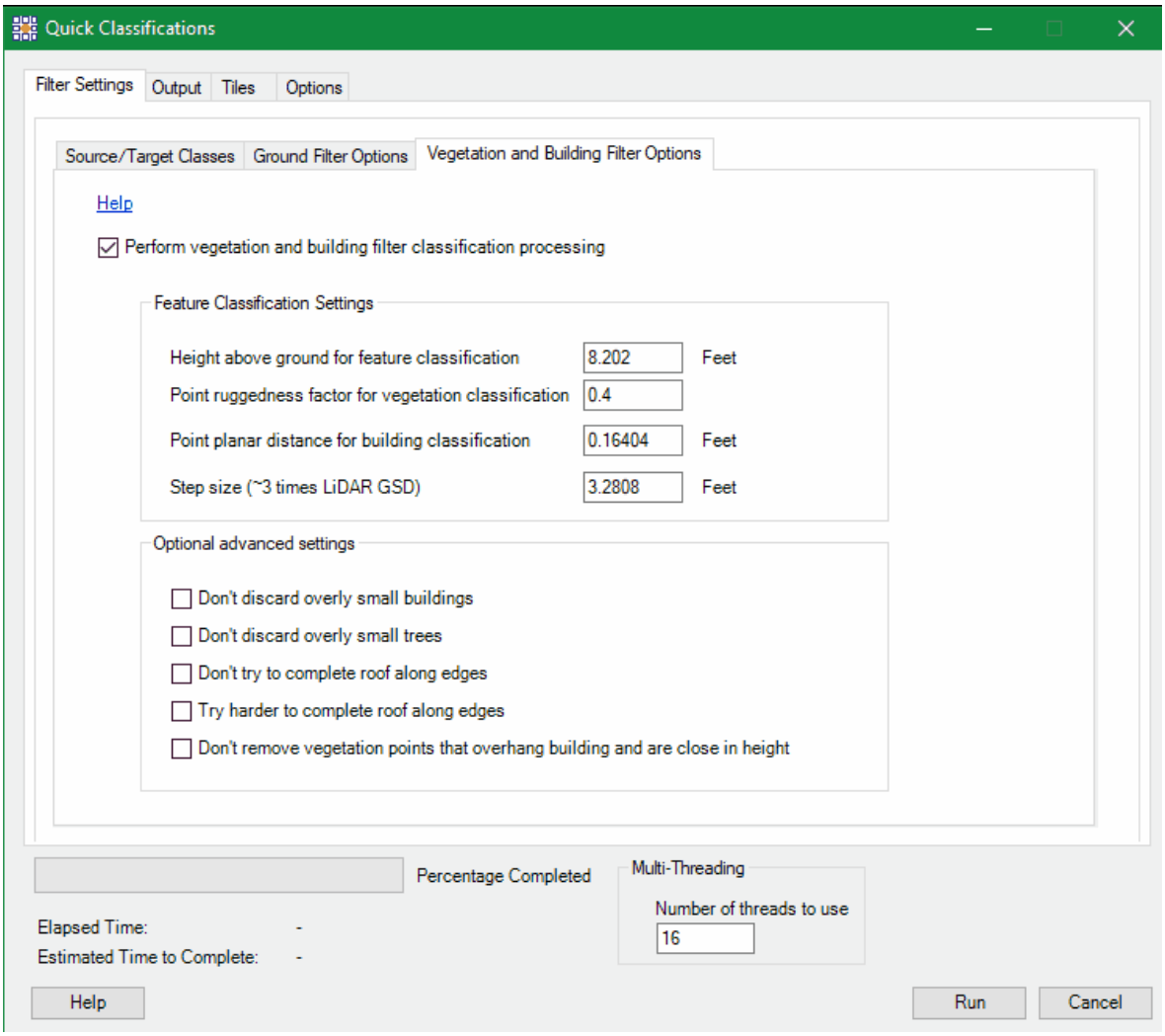
The 'Filter Settings' tab is further divided into 'Source/Target Classes' (see description and upper-left graphic, above), 'Ground Filter Options', and 'Vegetation and Building Filter Options'. By default, the 'Perform vegetation and building filter classification processing' box is checked on the "Vegetation and Building Filter Options' tab. To use this option, 'lasclassify.exe' (as described near the top of this topic) must exist in the specified LAStools path. The latter two interfaces (shown below) have 'Help' links in the upper-left corners that go directly to the **LAStools** read-me files for 'lasground' and 'lasclassify', respectively. The parameters on these tabs are explained in those read-me files, which are updated and maintained solely by ***rapidlasso GmbH***. The 'lasground' read-me file is based on an earlier (but very similar) iteration of the ground classification executable. As of the release date of this version of MARS®, **LAStools** was not yet hosting a read-me file for the '*lasground_new.exe*' executable that is used in this batch filter tool. However, it is available in the downloaded LAStools suite package as '*lasground_new_README.txt*'. All the controls and entries within the red boxes (see

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below) feed directly into the arguments of the **LAStools** executables. When all settings have been made, click the 'Run' button in the lower-right corner of the interface.

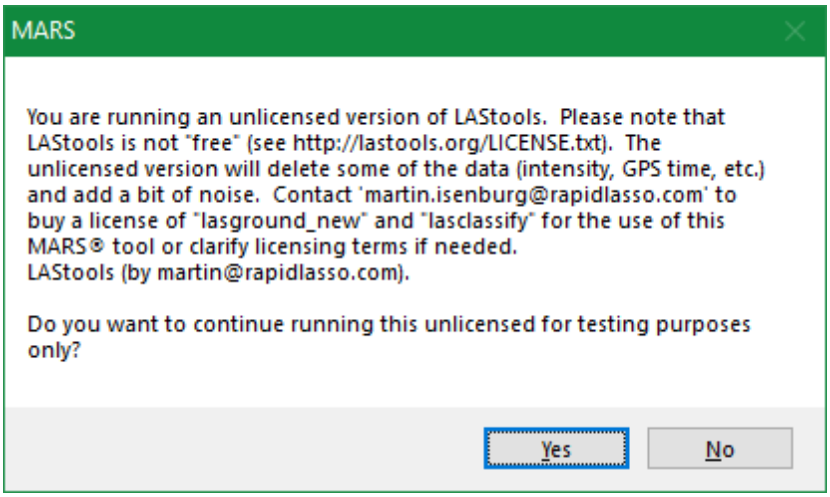


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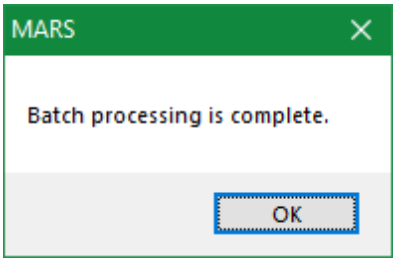


If a license for **LAStools** has not been purchased or is not present in the path to the executable files, the following warning message will appear immediately after clicking 'Run':

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The following message will appear when the 'Quick Classifications' routine is finished:



- **Filter Action Selection List:** This drop-down list contains the 31 filters included with MARS®, plus any macros within a script file loaded with the 'Load Batch Script' button (see above). Use this list to choose from the filters: Building, Change Bit Flags, Consistent Return, Ditch and Berm, Elevation, ENVI Reclass, Extreme High, Extreme Low, Ground, Ground Distance, Height from Surface, Intensity, Isolated Point, Max Grid, Median Grid, Min Grid, Model Key-point, Percolate, Plane Analysis, Reclassify, Return, RGBNI Value, Scan Angle, Slope, Smart Clip, Smooth Grid, Smooth Max Grid, Smooth Min Grid, Timestamp, XY Distance, or XYZ Distance. Detailed information about using these filters can be found in the Filter Action 987 topic and its sub-topics.

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- **Filtering Options:** Allows the user to specify the filter parameters. A unique filtering options interface will appear for each different filter. Please click on the following link(s) for more information on how to use the 'Filtering Options' dialog for the filters included with MARS®.

Filter Action Tools:

• Building 988 • Change Bit Flags 994 • Consistent Return 1001 • Ditch and Berm 1008 • Elevation 1013 • ENVI Reclass 1018 • Extreme High 1025 • Extreme Low 1030 • Ground 1036 • Ground Distance 1044 • Height from Surface 1052 • Intensity 1059 • Isolated Point 1063 • Max Grid 1068 • Median Grid 1072 • Min Grid 1077 • Model Key-point 1082 • Percolate 1087 • Plane Analysis 1095 • Reclassify 1100 • Return 1104 • RGBNI Value 1110 • Scan Angle 1118 • Slope 1126 • Smart Clip 1130 • Smooth Grid 1138 • Smooth Max Grid 1144 • Smooth Min Grid 1150 • Timestamp 1156 • XY Distance 1161 • XYZ Distance 1161 •

- **Filter Region:** Once the desired filter or macro has been chosen and the filtering options have been specified, this button initiates the processing for a selected area of the project. This tool provides the user with a ‘drag box’ to graphically define a rectangle for the desired area. The tool will remain active to allow multiple areas to be processed - right-click the mouse or use the 'Esc' key to dismiss the tool. This is the only reclassification method that can be used for the Ground Filter 1036. ***The loaded LAS data is modified with this tool.***

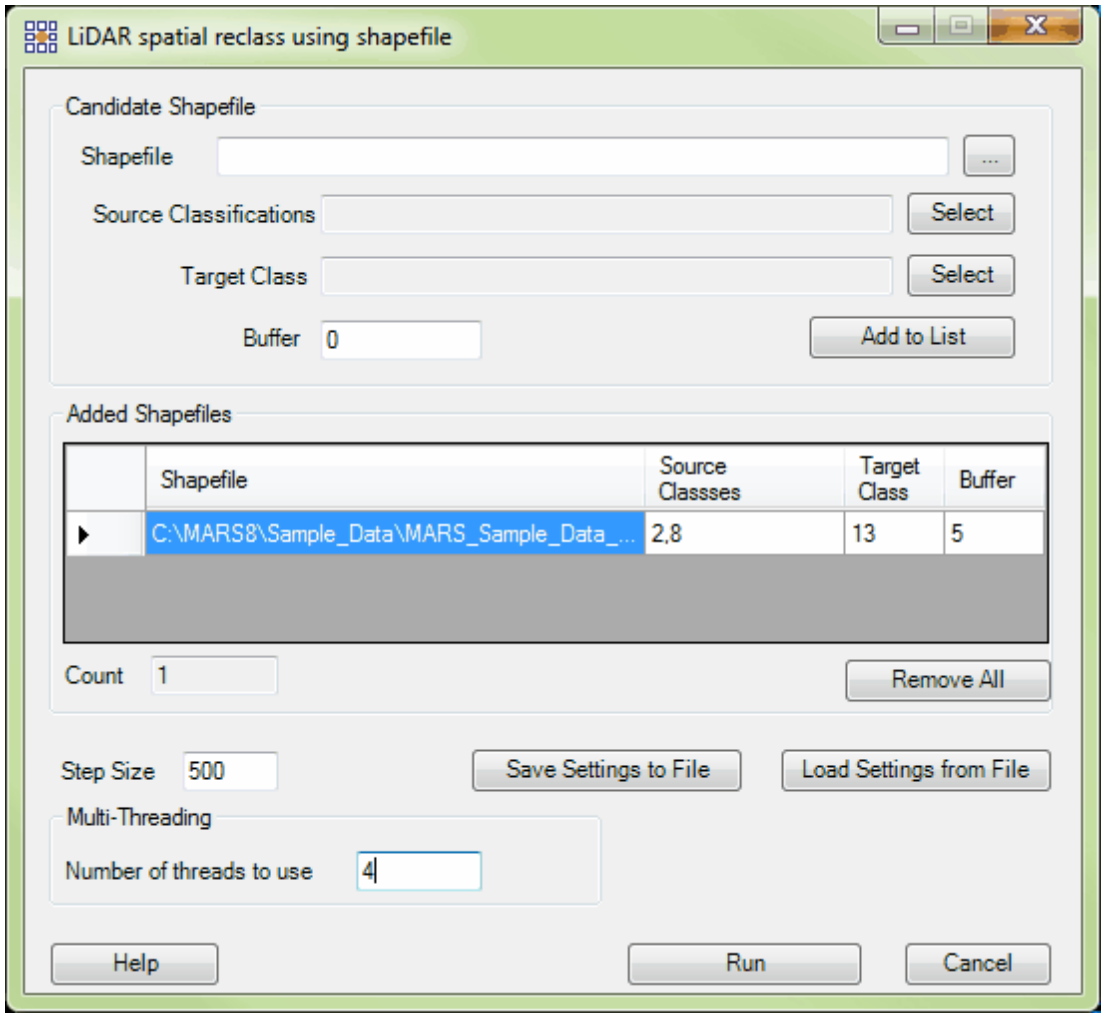
- **Filter Digitized Polygon:** Use to run a filter or macro on a user-created polygon in the LAS Map View window. Left-click to create the vertices of the polygon, and right-click to close and start the processing. Before closing the polygon, the 'Ctrl-Z' shortcut key can be used to delete the most recently placed vertex. The 'N' shortcut key allows re-use of the last polygon created. ***The loaded LAS data is modified with this tool.***

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- **Filter Selected Polygons:** Use to run a filter or macro based on the area of a pre-existing polygon (or multiple polygons) in the LAS Map View window. The polygon shapefile must be loaded as a 'Tile Shapefile' and the desired polygon(s) must first be chosen using the 'Pick Tiles' tool (see below). ***The loaded LAS data is modified with this tool.***

- **LiDAR Spatial Reclass:** The LiDAR Spatial Reclass tool provides two basic functions: 1.) To reclass the interior points of breakline polygons contained in a shapefile and, 2.) To reclass points in a buffer area around breakline polylines contained in a shapefile. For example, if the user were to select a shapefile containing polygons representing water bodies in the 'Candidate Shapefile' section of the tool, the points bounded by the polygons would be reclassed to Class 9: Water in the example below. Additionally, if a shapefile of polyline breaklines were to be used as the candidate shapefile in the LiDAR Spatial Reclass tool, the ground points within a specified buffer distance around each breakline would be reclassified to an ignored classification such as Class 20: Ignored Ground in the same example. The shapefiles specified for use in the tool do not need to be loaded into MARS® for this tool to process them. ***When run, the loaded LAS data is modified with this tool.***

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- **Shapefile:** Used to path out to the candidate shapefile(s). This will be a shapefile containing either polygon breaklines or polyline breaklines which need points to be reclassified within or around them 'Buffer'). Multiple entries may be made here (see 'Add to List', below). Either a 2D or 3D shapefile can be used.
- **Source Classifications:** The user will specify here which class(es) of points will be used to determine candidates for reclassification. This is done separately for each shapefile added.
- **Target Class:** The points chosen as the 'Source Classifications' will be reclassified to the 'Target Class' if they meet the conditions set by the 'Buffer' value (below).
- **Buffer:** This option allows the user to define a buffer area around each breakline contained in the source shapefile(s). A buffer will most often be used with a shapefile of breakline

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polylines, but may also be used with a polygon shapefile to reclass a buffer around the outside of the polygon(s). The larger the buffer around each breakline, the more data that will be reclassified. The user may determine how many units on each side of the breakline that source points will be reclassed by entering an integer into this text box. If no buffer is specified, there will be no buffer run on the data.

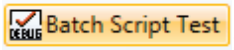
- **Add to List:** This button allows the user to add the candidate shapefile and specific parameters pertaining to that shapefile to the table in the LiDAR Spatial Reclass tool. Once a shapefile and its specifications have been entered, the 'Candidate Shapefile' section will clear allowing the user to add another shapefile and its particular parameters. If the user does not click on the 'Add to List' button to load the shapefile and settings into the interface, the tool WILL NOT process that particular shapefile.
- **'Added Shapefiles' section:** The table in this section shows the user a list of the shapefiles and the unique specifications for each that will be processed. The user may enter several different shapefiles in this area and each shapefile will be run separately (and consecutively) with its own unique, user-defined specifications. Please see the example above to view two separate shapefiles loaded to be processed with two different sets of parameters.
- **Count:** This display at the bottom of the 'Added Shapefiles' section is informational only and keeps a count of the number of files loaded into the 'Added Shapefiles' area.
- **Remove All:** The 'Remove All' button will allow the user to clear the 'Added Shapefiles' table of all shapefiles which have been added for processing.
- **Step Size:** The user may specify here how much data the tool will work on at a time. For example, a step size of 2500 causes a 2500 unit x 2500 unit area to be processed at a time. In general, the larger the step size the faster the process will run, but more available RAM is needed for larger step sizes. The tool will not function without a step size entered.
- **Save Settings to File:** This tool is capable of saving the user-defined settings to an *.xml file. To use, click the **'Save Settings to File'** button, save the file with a unique name, and a

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*.xml will be created that can be loaded for later use.

- **Load Settings from File:** If settings inside the 'LiDAR Spatial Reclass' interface have been saved previously, they can be loaded by clicking the **'Load Settings from File'** button and navigating to a saved *.xml file.
- **'Multi-threading' section:** To help speed up processing, multi-threading is available for this tool. Enter any number of threads from 1 to the maximum number available in the text box. This option requires that a tile layout (polygonal shapefile) be loaded and some (or all) tiles picked to cover the area to be processed. The Pick Tiles 960 tool can be found on the Project/ Data Preparation 162, Edit/Filter 270, or Export/Extract 461 tabs. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

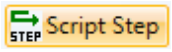
- **Batch Process Tiles:** This option (commonly known as Auto-Filter) allows the user to run a single filter or filter macro script by tile and will output the results to a new v1.4 LAS file(s). Choose the tile (s) to filter with the 'Pick Tiles' tool (see below) before clicking the 'Batch Process Tiles' button. For more information, see the Batch Filter/Extraction Processing 1212 topic.

- 

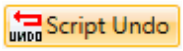
: The purpose of this and the following "Script Debug" tools is to allow the user to run through filters in a macro step by step (manually) rather than running the macro in batch process mode. This button allows a box to be dragged over a test area - filters can then be run one at a time and the user can easily distinguish the breaks between filters. This allows the user to stop processing at any point to see the effects an individual filter may have on the data as well as to edit the parameters of the filter. While debugging, the Status Bar 158 will display a short summary of the filters found in the loaded macro. The first number tells the user which filter of the total number of filters in the macro the software is running. (ex: 6/18: the software is currently processing the sixth

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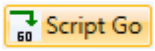
filter in a macro which has a total of 18 filters). The name of the filter currently running will be shown next to these numbers, along with the name of the next filter in the macro. This is to let the user know which filter is running if it should need to be edited or deleted from the macro. This manual method is slower than batch processing, so this method should only be used for testing. Batch processing is run in RAM, so it can run behind the scenes more quickly for high performance. See 'Load Batch Script" (above) for information on loading a macro script to use in debugging.

- 

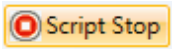
: This tool allows the user to step through each filter of a batch macro script. Clicking this button once will only run through the next single filter in the macro script.

- 

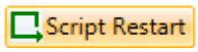
: This tool rolls back the actions of the last filter process.

- 

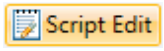
: Proceed through the macro to the end of the macro script.

- 

: Stop filtering process after clicking 'Script Debug Go'. This tool is especially useful when the user has started a large batch auto-filter and needs to stop the process of the filter without canceling the action entirely.

- 

: Restart the filtering process.

- 

: Will bring up the edit dialog window to modify the loaded macro. Changes made here will be immediately saved in the XML file.

- **Pick Tiles:** This tool is used to select a single tile or multiple tiles for batch processing functions.

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The button is disabled until a polygonal shapefile is loaded into MARS® as a tile layout. See the 'Add Tile Shapefile' section of the Project/Data Preparation Tab 162 topic for information on loading a tile layout. This tool works only in 2D View 835. To use, left-click and drag the cursor over the tiles to be exported - they will be highlighted in a thicker line weight. Additional tiles can be selected by holding down the **'Ctrl'** key on the keyboard and clicking on a tile(s). Individual tiles can be removed from the selected set using the same 'Ctrl' key/mouse combination. Selected tiles will also be highlighted in the tile shapefile's attribute table. To view the attribute table, right-click on the tile shapefile in the Table of Contents and choose **'Attributes'**. Alternatively, the attribute table can be used to select tiles - use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the desired tile(s) by row. The selected tile(s) will then appear highlighted in the LAS Map View window display.

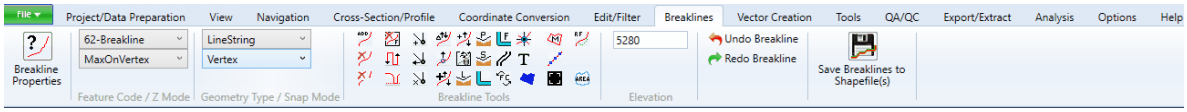
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3.8 Breaklines Tab

Breaklines Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

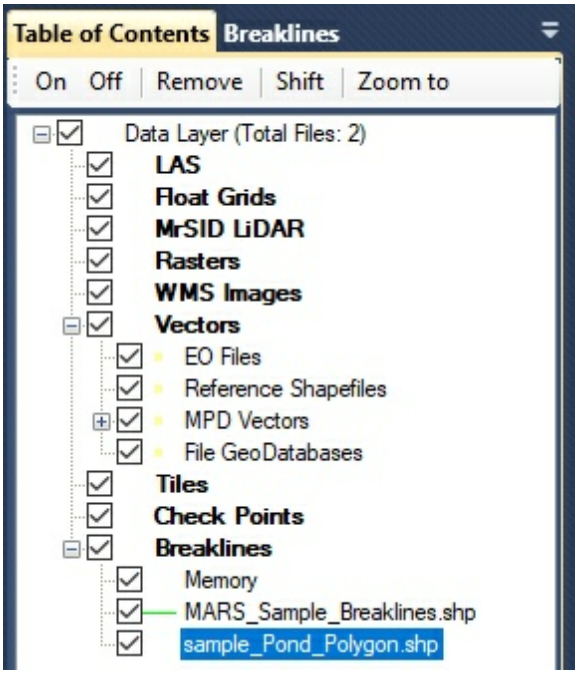
The Breaklines Tab:



All breaklines tools on this tab are available only with a Production license.

All newly created breaklines and breaklines loaded as regular (meaning editable) or reference breaklines files will be seen in both the LAS Map View 145 window and the Cross-Section/Profile 146

window. If a file is loaded in MARS® as a reference breakline file, it will be shown with a neon green symbol in the Table of Contents 134 - a line for a polyline file, and a filled square for a polygon file. There are two files loaded into the Table of Contents as seen below. The file named 'MARS_Sample_Breaklines.shp' (polyline) is shown with a neon green line next to it. This means the file is a polyline shapefile loaded as a reference breakline file (non-editable). The file loaded below it in the Table of Contents ('sample_Pond_Polygon.shp') is loaded as a regular breakline file - it is a polygonal shapefile that can be edited.

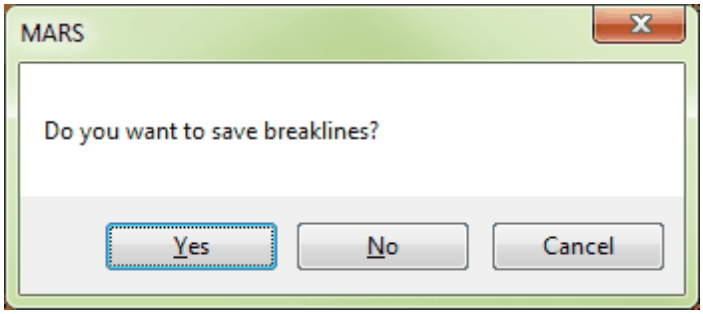


MARS® will automatically pan (by default) across the data as the user digitizes breaklines. This makes it easier to continue drawing breaklines without having to stop and move the view window to a different extent. For example, if the user is adding a breakline and moves the mouse cursor close to the right side of the LAS Map View window, MARS® will assume the user would like to continue digitizing to the right. The window will pan to the right and allow the user to continue drawing without having to end the current breakline and begin a new one. This functionality can be disabled and a

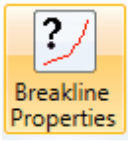
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manual pan option used as described in the Keyboard shortcuts 363 section at the bottom of this page.

If any breaklines have been added, modified, or deleted since the last save (see **Save Breaklines to Shapefile(s)** 362, below), a prompt to save will appear when closing MARS®.



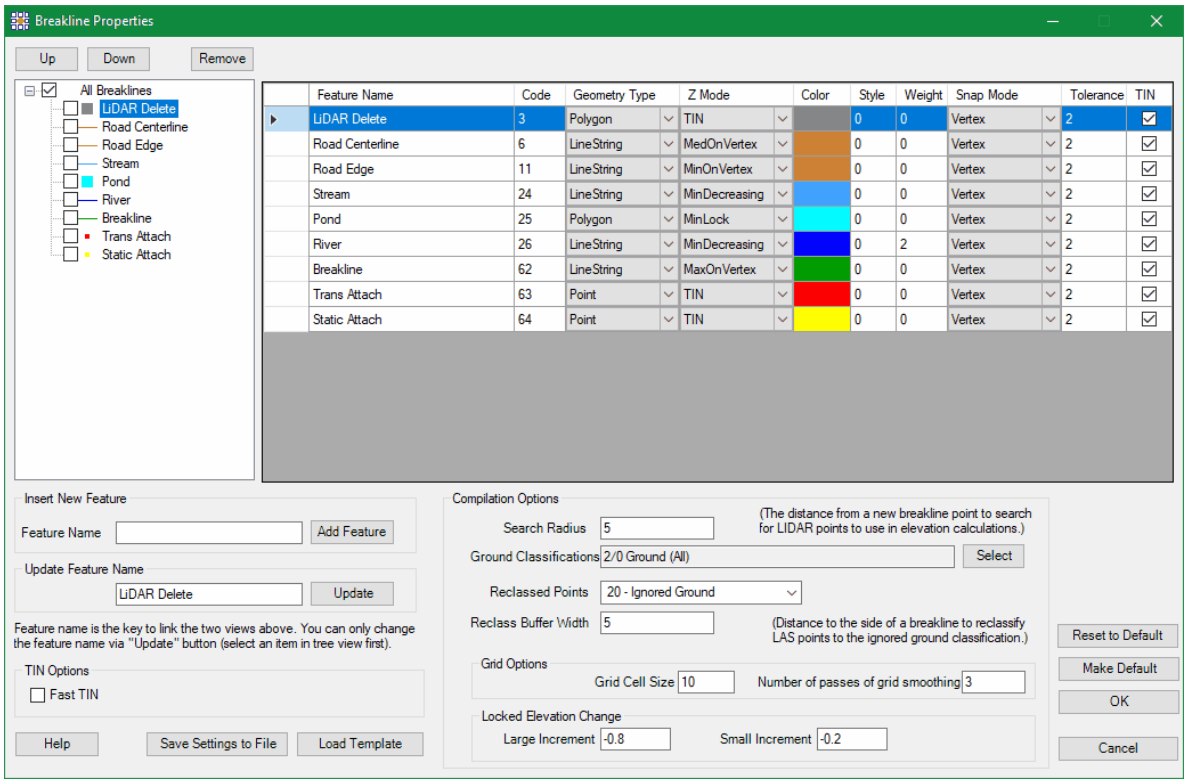
NOTE: Changes to vertex elevation values only (e.g., with tools such as 'Change Elevation for All Points of Breakline' and 'Change Elevation of Any Vertex') will not prompt a save message when opening a new project or exiting MARS®. A manual save must be done first using the 'Save Breaklines to Shapefile(s)' button (see below 362).



Breakline Properties: Any breakline shapefile which can be loaded into or created in MARS® can be edited to fit the user's needs. With this interface, the user can change the color and description which represent any breakline, change the style and weight of each feature type, determine which features will be displayed, define whether or not a particular breakline feature will affect the TIN edges, insert new features, rename features, toggle 'Fast TIN' on and off, and even load an existing XML template with saved features and assigned colors and codes. Feature labeling options can be accessed by right-clicking on a loaded breakline shapefile and choosing 'Properties 140'. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Feature Name or

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Update Feature Name fields or boxes. The compilation options are also only for use with breaklines which have been loaded into MARS®. With this section of the interface, the user can search for points to use in elevation calculations, delete certain breakline classifications, and change the distance between points in a segment of a breakline.



1.) To add a new feature, select a node under which the new feature will belong in the upper-left corner of the window, name the feature in the 'Feature Name' text box, and then click on the 'Add Feature' button to add it to the list of features. The new feature will initially be assigned the next highest unused code (which would be 65 in the example above), a Type of 'LineString', a ZMode of 'TIN', a Color of black, a Style of '0', a Weight of '0', a Snap Mode of 'Vertex', and a Tolerance of '2'. All fields can be modified as needed, but Code values cannot be duplicated. The new feature will stay present for the remainder of the current session only, unless the 'Make Default' button is clicked. Another option is to save the settings to a user-named settings file that can be called at

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any time for a specific need. This is done by clicking the 'Save Settings to File' button. Clicking the 'Load Template' button allows the user to choose a previously-saved settings file.

2.) To change the name of a feature, highlight it by selecting in the list of breakline feature names (upper-left of 'Breakline Properties' interface), and replace the existing name with the desired name in the 'Update Feature Name' text box near the lower-left corner. Click **'Update'** to apply the changes. The 'Make Default', 'Save Settings to File', and 'Load Template' functions may be used as described above (item 1).

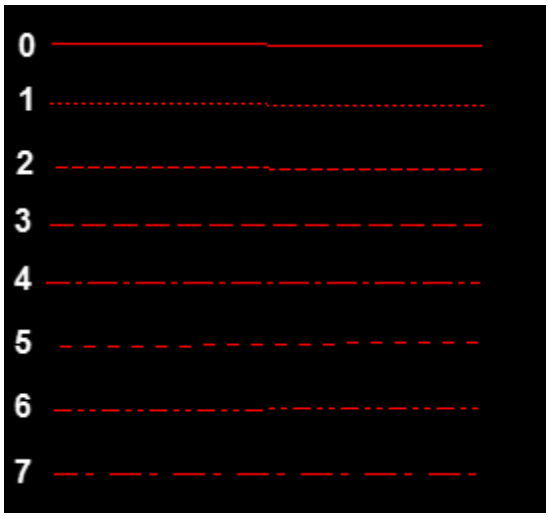
3.) To move a feature up or down in the list (in both the tree view and the detailed listing area), select it with a single click and click the 'Up' or 'Down' button at the top left. The 'Make Default', 'Save Settings to File', and 'Load Template' functions may be used as described above (item 1).

4.) To change the color of a feature, double-click on the 'Feature Name' or the 'Color' box in the upper-right section of the interface. A color palette interface will then be available to choose a new feature color. The user can choose from one of the pre-existing colors, or create a custom color by clicking the 'Define Custom Colors' button. After creating a custom color, click the **'Add to Custom Colors'** button. Make sure the box representing the custom color is selected and click '**OK'** to assign that color to the chosen feature. The 'Make Default', 'Save Settings to File', and 'Load Template' functions may be used as described above (item 1).

5.) To change the line-type (style) of a polygon or linestring feature, click in the 'Style' box for that feature and enter a value from 0 through 7. See below for samples of the

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eight available styles:



Note: Entering any number other than 0 through 7 will result in a solid (0) Style.

6.) Line thickness (weight) can be changed by clicking in the feature's 'Weight' box and entering a new integer value.

7.) The 'Tolerance' value sets the maximum snapping distance (in project units) for the beginning and/or end of a breakline being compiled to snap to an existing breakline while using the 'Nearest Point' connection option (see **Snap Mode Drop-Down** 307, below). The 'Tolerance' value only pertains to the type of breakline being compiled, not the types that it will be snapped to. The 'Shift' key must be held down when creating the first and/or last point in a breakline to force a snap.

8.) Check (default) or uncheck the boxes labeled 'TIN' to control which breakline features will have an effect on the TIN surface.

9.) Click **'OK'** to make the changes take effect for the current MARS® session only. See item 1 301, above, for details on making the changes permanent, or saving settings

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files for later use.

TIN Options: The **'Fast TIN'** option will completely disable the effect that all breakline features have on a rendered TIN surface, regardless of the 'TIN' settings described in item 8 303 in the 'Breakline Properties' section, above. When on, rendering speed during pan and zoom operations will be increased, but changes to the TIN surface caused by breaklines will not be visible. 'Fast TIN' should always be turned off (unchecked) during breakline compilation. This checkbox is synced with the shortcut key option '**Ctrl-T**'.

Compilation Options: The **'Search Radius'** option allows the user to set the distance from a new breakline point (vertex) from which to search for LiDAR points to use in breakline elevation (Z-value) calculations. The default setting is a 5 unit search radius. The **'Ground Classifications'** selection determines which class(es) will be used to find points within the 'Search Radius'. The **'Reclassed Points'** drop-down allows the user to select the target class for 'Ground Classifications' points that are within the **'Reclass Buffer Width'** (in project units) of compiled breaklines. This prevents them from being used as any part of the ground surface during subsequent processing.

Reset to Default: This button will delete any custom '**MARSBreaklineProperties.xml**' file created in the 'C:\MARS\' folder by using the '**Make Default**' button. The next time MARS® is opened, the Feature Names, Colors, and other settings will appear as they did when MARS® was first installed (see interface screen shot, above). A new default file can be created, or other saved settings files can be used as described in item 1 301, above.

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Feature Code Drop-Down: The user may choose the breakline feature code to be added when placing a new breakline in a MARS® project. The user may choose to add a breakline from the following default codes: 3- LiDAR Delete, 6- Road Centerline, 11- Road Edge, 24- Stream, 25- Pond, 26- River, and 62- Breakline. By default, the code '3- LiDAR Delete' and '25- Pond' breaklines are collected as polygons while all other codes listed are collected as polylines. Additional features may be added to this list - see item 1 301 in the 'Breakline Properties' section, above.



Z Mode Drop-Down: The user may choose the method of elevation assignment of a collected breakline with this drop-down list. There are 10 different options:

1. **Zero:** Choosing this option will lock the elevation of an entire breakline at zero.
2. **TIN:** This option will place the vertices of the newly created breakline on a virtual TIN between the two nearest LiDAR points and adopt the elevation of the TIN at each vertex's XY location.
3. **MinLock:** The MinLock option will collect the entire breakline at the lowest elevation of any LiDAR point found inside the search radius of the first breakline vertex.
4. **Lock:** Choosing the Lock option will collect the entire breakline at the user specified elevation found in the 'Enter a different elevation to use for Z value of new features' text box.
5. **MedOnVertex:** This option will place a breakline vertex at the average (or median) elevation of the LiDAR points which fall within the user-defined search radius.
6. **MinOnVertex:** This option will place a breakline point at the lowest elevation of the LiDAR points which fall within the user-defined search radius at any given breakline point. The elevation of the resulting breakline may increase or decrease in any

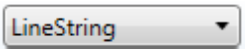
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given area of the breakline depending on the lowest available elevation found in a LiDAR point inside the search area.

7. **MinDecreasing:** The MinDecreasing option will force the newly collected breakline to decrease in elevation as it is collected. This is accomplished using the search radius specified by the user. The software will search for a LiDAR point within the specified search radius that has an elevation that is equal to or lower than the last elevation assigned to a breakline point. When a LiDAR point that is equal or lower in elevation is found within the search radius, the nearest point providing an elevation with the specifications listed above will be used to assign an elevation to the newest breakline collection point. The overall elevation of this breakline will decrease intermittently through breakline compilation and will never rise in elevation.
8. **MaxOnVertex:** This option will place a breakline point at the highest elevation of the LiDAR points which fall within the user-defined search radius.
9. **Grid:** The Grid option is most useful in areas with low penetration of ground points and is similar in function to the GridDecreasing option (below). The Grid option will find an elevation to be assigned to a breakline by using a search radius as defined by the user and a virtual grid. The elevation chosen to be assigned to each breakline point will come from an average of the points inside the search radius. The elevation of the most recent breakline point collected will also help determine the elevation of the next point. The virtual grid will be used to find LiDAR points with similar elevations and create a gently sloping breakline in an area of low penetration of ground points. Without this grid, the user may witness a 'stair stepping' effect in which the breakline elevation from one point to the next will drop or rise in elevation quickly. With the use of a virtual grid, this effect is minimized and gently sloping breaklines may be created.
10. **GridDecreasing:** This option is most useful in areas with low penetration of ground

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points and is similar in function to the MinDecreasing option. The GridDecreasing option will force the newly collected breakline to decrease in elevation as it is collected. This is accomplished using the search radius specified by the user and a virtual grid. Using the search radius, the software will search for a LiDAR point within the specified area that has an elevation that is equal to or lower than the last elevation assigned to a breakline point. When a LiDAR point that is equal or lower in elevation is found within the search radius, the nearest point providing an elevation with the specifications listed above will be used to assign an elevation to the newest breakline collection point. A virtual grid will be made when collecting each breakline point to assist in creating a more correct breakline with a gradually decreasing elevation. Without this grid use in areas of low penetration, the user may see a 'stair-stepping' effect in which the breakline drops in elevation suddenly. This is due to a low penetration of ground points for the breakline to assign an elevation from. The virtual grid will help keep this 'stair-stepping' effect from occurring and will allow the breaklines to decrease in elevation in a more gradual manner.



Geometry Type Drop-Down: Determines the geometry of breakline features. This drop-down allows the user to choose from a linestring breakline (which does not need to be connected to anything at either end), a polygon breakline (which must form an enclosed polygon), or a break point.



Snap Mode Drop-Down: The user may choose the breakline connection point option which will be applied when choosing to snap a new breakline to an existing breakline. The user may choose from the following codes and their purposes: the 'StartEndVertex' option will snap the

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breakline which is being compiled to the nearest start or end point of another breakline. The 'Vertex' option will snap the breakline which is being compiled to the nearest vertex - start, end, or intermediate - of another breakline. The 'NearestPoint' option will snap the breakline which is being compiled to the nearest location of an existing breakline, but only if within the tolerance value set in the 'Breakline Properties' options (see item 7 303, above) and only if the 'Shift' key is held down while the first and/or last point of the breakline is compiled. Lastly, the 'MidPoint' option will snap the breakline which is being compiled to the nearest mid-point between two breakline points.



Place Breakline: This tool allows the user to place a new breakline into a MARS® project.

When the tool is activated, the breakline will be added to the project with the specifications of the feature code drop-down options which are chosen. For example, if the 'Stream', 'MinDecreasing', and 'LineString' options are chosen in the feature code drop-downs, then the resulting breakline will be added to the project with these specifications. To use, left-click where the breakline is to start. Hold down the 'Shift' key before left-clicking to force the starting vertex to snap to the nearest existing breakline, based on the 'Snap Mode' option set in the 'Breakline Properties' interface (see above) for the pre-existing breakline feature. Continue left-clicking along the path that the breakline is to follow. To create a three-point arc within a breakline, left-click where the arc section is to begin and then press the '**A**' key on the keyboard. The next left-click will place the center of the arc and the following left-click will finish the arc. Additional 'normal' vertices can then be placed by left-clicking. During compilation, '**Ctrl-Z**' can be used to back up one vertex at a time. When the breakline is complete, right-click to end it. If the '**Shift**' key is held down for the last vertex, the new breakline will snap to the nearest existing breakline as described above. At this time, the breakline will turn the color assigned to it.

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MARS® offers an auto-pan option when collecting breaklines. This feature will automatically pan across data in the user-defined direction when the cursor is placed close to one edge of the LAS Map View window. To turn auto-pan off and manually pan across the data, press the '**B**' key on the keyboard. To toggle the auto-pan feature back on, press the '**B**' key on the keyboard a second time. An indicator on the LAS Map View window Status Bar shows whether the Auto Pan function is enabled. Holding the **'Alt'** key down while in collection mode will allow the user to pan across the data when auto-pan is turned off. The cursor will temporarily turn from collection tool to pan tool while the **'Alt'** key is pressed. Alternatively, pressing and holding the scroll wheel button on most mice while moving the mouse will perform a panning operation, with compilation paused until the button is released.

 **Delete Breakline as Selected:** This tool allows the user to delete an entire selected breakline. To use this tool, first select the breakline to be deleted by left-clicking on it. When the breakline is selected, it will change to the selected features color. Left-click anywhere in the project to delete the breakline. To deselect a selected breakline, right-click anywhere in the project.

 **Partial Delete:** This tool allows the user to partially delete a selected segment of a breakline instead of deleting the entire breakline. To use, click on the breakline which will be partially deleted. The selected breakline will change to the selected features color. Left-click on the location in which the partial delete is to start and hold the left mouse button down, dragging the cursor to the location where the partial delete is to end. A white line from the cursor will enable the user to see which areas of the breakline are being selected for deletion and the breakline will disappear in that area. Please see

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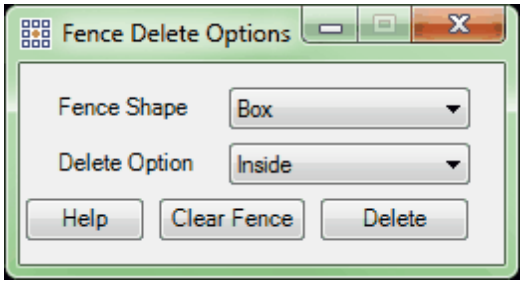
the example of a partial delete on a stream line below. The green line represents a stream breakline, and the white line represents the area of the stream breakline which is being selected for deletion.



 **Delete by Fence:** This tool allows the user to delete breaklines by using a fence. This tool offers several different types of fencing and the ability to delete inside or outside the user defined fence. To use this tool, first select the 'Delete by fence' button. The 'Fence Delete Options' interface will then become available. The user may choose which fence shape will work best for their purpose (either a box shape or an irregular shaped fence), and the user may also choose from several delete options such as inside, inside with overlap, inside clip, outside, outside with overlap, or outside clip. The 'Box' fence shape is a drag-box which can be positioned around the breaklines in question. The 'Irregular

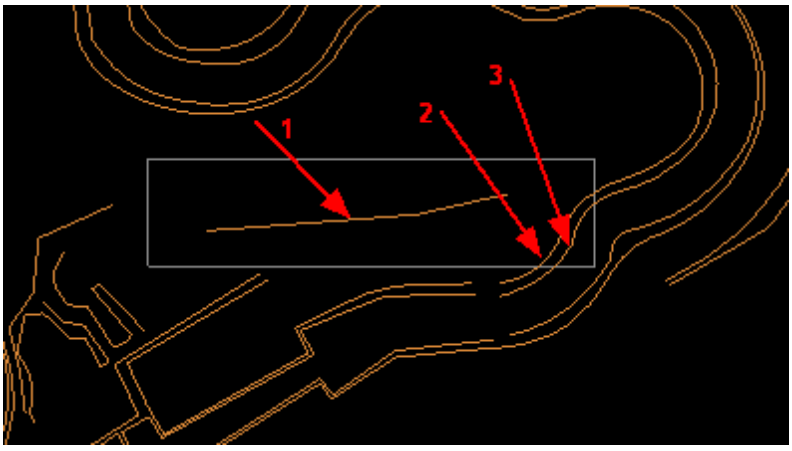
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Shape' fence shape option allows the user to create a polygon of any shape by left-clicking around the area in question, then using a right mouse click to close the fence. Once a fence is in place, the user may choose a delete option as listed below. The tool can be re-used by clicking the 'Clear Fence' button after a deletion, and drawing a new fence.

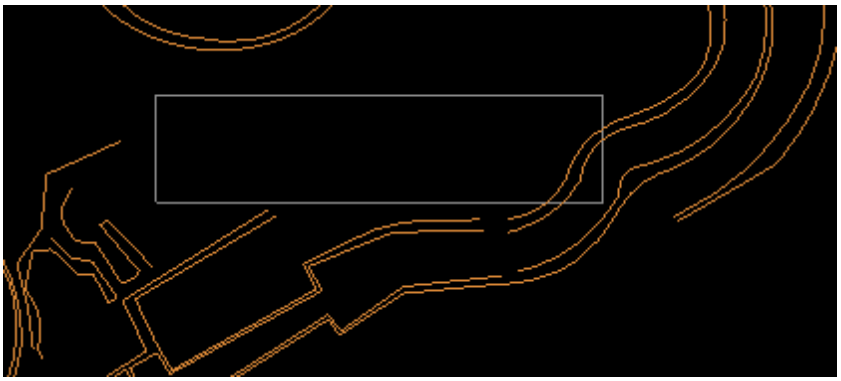


Inside: This option will only delete breaklines which are completely contained within the user defined fence. This option will NOT delete any breaklines which are outside the fence or partially contained by the fence.

Example: In the example below, Breakline #1, which is completely contained inside the user defined box, will be deleted. Breaklines # 2 & 3 will NOT be deleted because they are only partially contained in the box.

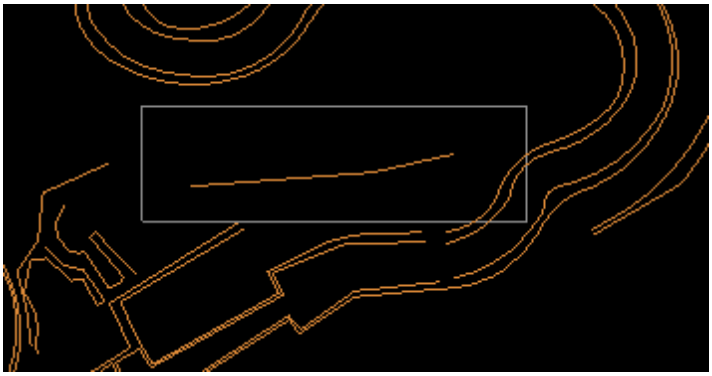


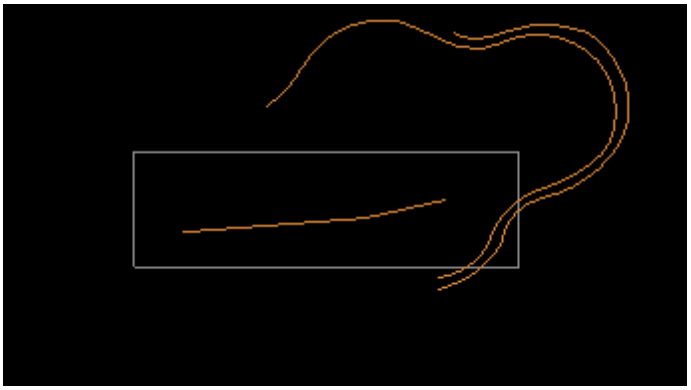
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Outside: This option will only delete breaklines which are completely outside the user defined fence. This option will NOT delete any breaklines which are inside the fence or partially contained by the fence.

Example: The 3 breaklines which are either completely or partially enclosed by the user defined fence will NOT be deleted.

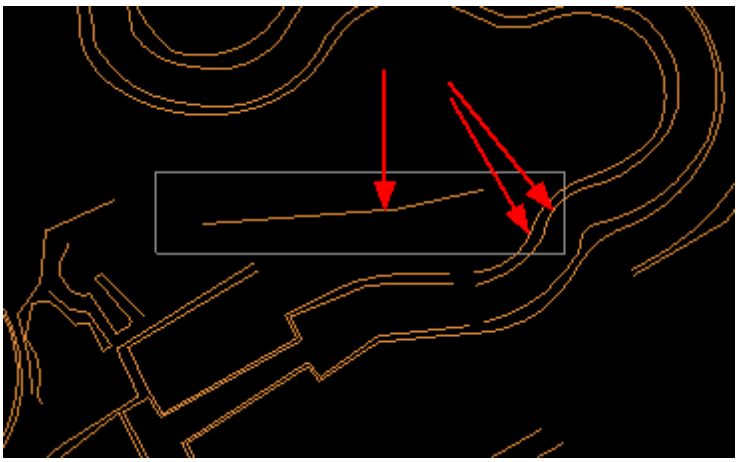




Inside with Overlap: This option will delete all breaklines which are completely inside the user defined box and will also delete any breaklines (in their entirety) which are only partially contained in the user defined box.

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Example: The tool will delete 3 breaklines as seen in the case below. It will delete the breakline which is entirely contained by the user defined box, but it will also delete the 2 other breaklines which are only partially contained in the user defined box. All 3 breaklines are deleted in their entirety as seen in the second example.

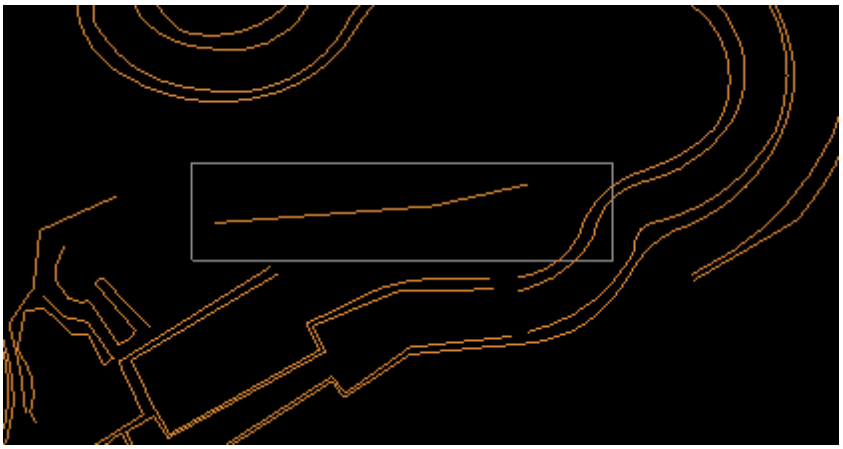


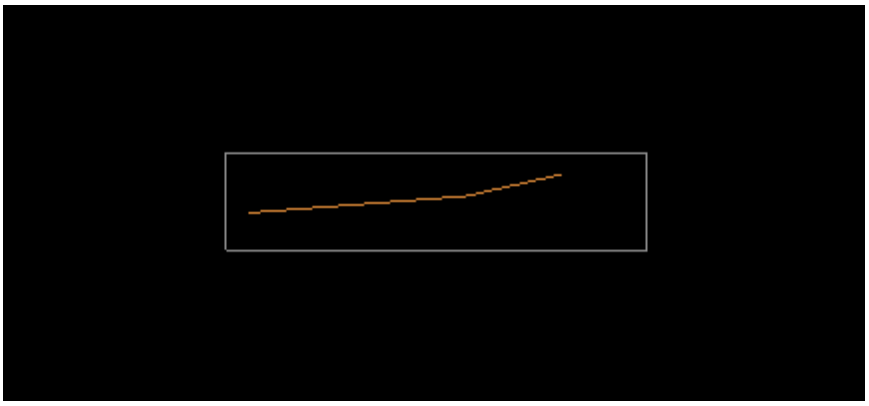


Outside with Overlap: This option will delete all breaklines except those completely contained by the user defined box. Any breaklines which are only partially contained within the user defined box WILL also be deleted.

Example: In the example below, the only breakline which will remain after the use of this tool is the breakline which is completely contained by the user defined box. Breaklines which are only partially contained in the box will also be deleted.

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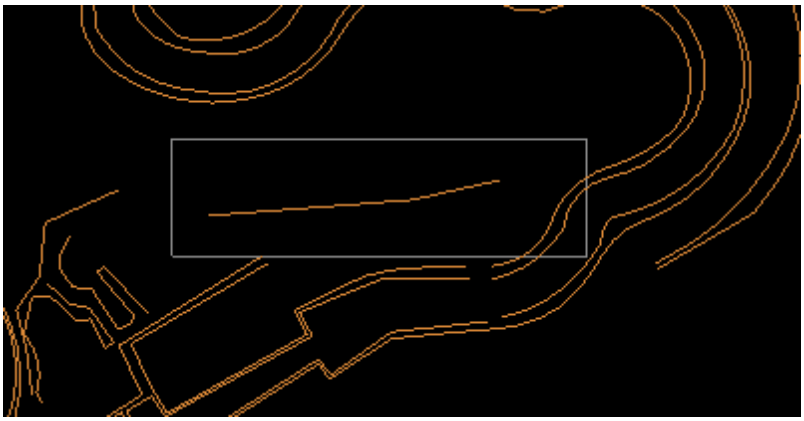


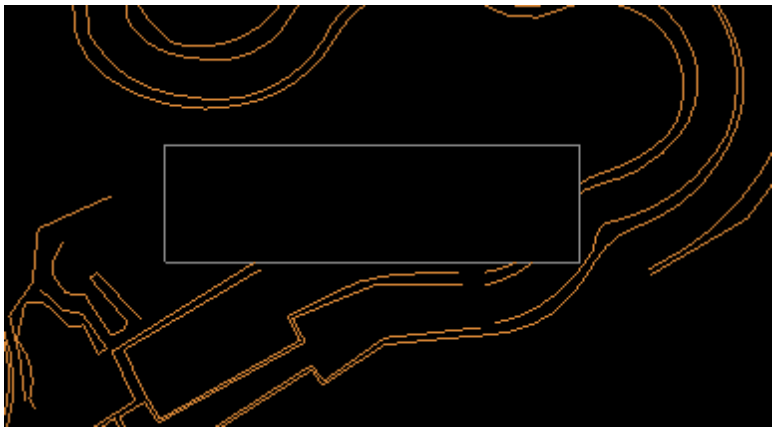


Inside Clip: This option allows the user to delete only EXACTLY what is found inside the user defined box. This may include clipping breaklines which are only partially included in the user defined area.

Example: This tool will delete exactly what is contained inside the user defined box. In this case, it has deleted a breakline which was completely enclosed inside the user defined area, but it has also made two small partial deletes to two breaklines which were also enclosed in the user defined area.

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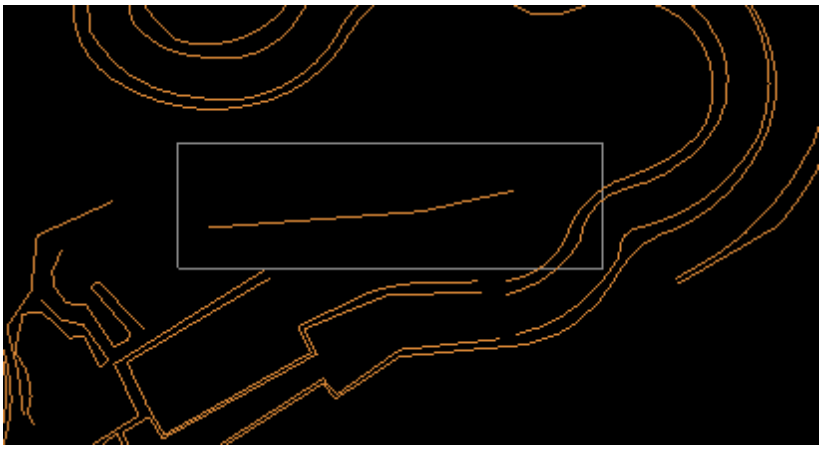


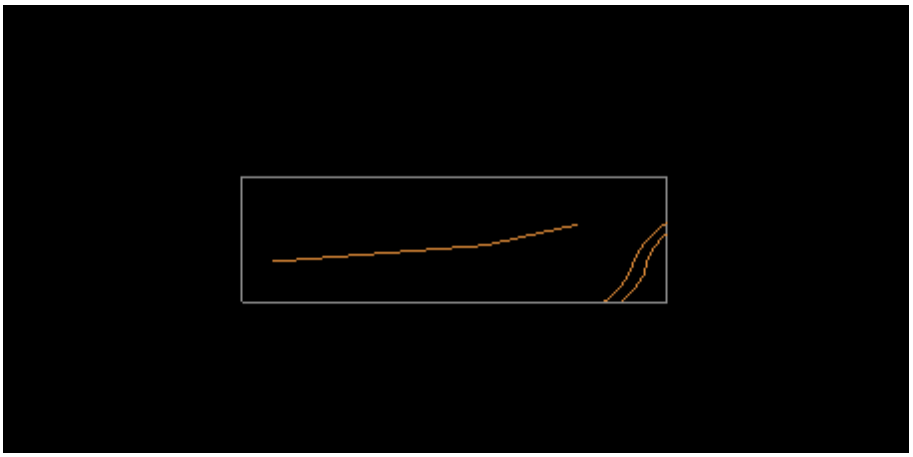


Outside Clip: This option allows the user to keep only EXACTLY what is found inside the user defined box. Everything outside the box will be deleted. This may include clipping breaklines which are only partially included in the user defined area.

Example: This tool will delete everything that is NOT contained inside the user defined box. In this case, it has deleted every breakline which was completely outside the user defined area, but it has also made clips to two breaklines which were enclosed in the user defined area.

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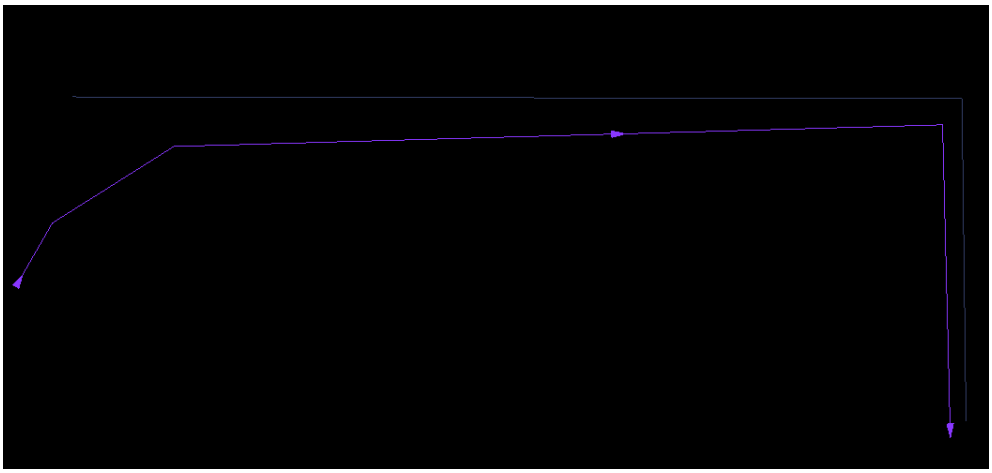




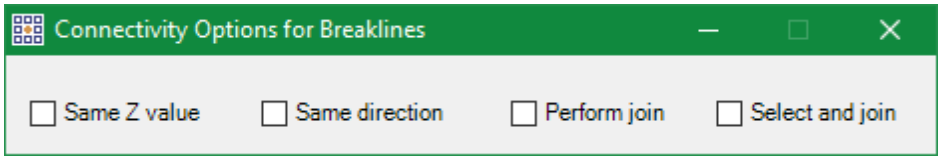


Reverse Breakline Direction: This tool is used to identify, and (optionally) reverse, the direction of loaded breaklines. After clicking on the button, left-click the mouse to choose a breakline to inspect. The selected feature will change to the selected features color and display directional arrows indicating the 'from' and 'to' ends. If no change is needed, right-click the mouse to dismiss the selected breakline. Otherwise, a second left-click anywhere in the LAS Map View window will reverse the line direction. Subsequent left-clicks will continue to alternate the direction until the selected breakline is dismissed by right-clicking. The button will remain active and another breakline may then be selected.

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Check Connections to Neighbors: This tool provides information concerning how a particular breakline is connected to neighboring breaklines. The connections (nodes) that are tested must have only two breakline segments snapped together at each location. The user may choose which specific types of connections the tool should look for by checking or unchecking the options available in the interface - the tool is capable of checking for the same Z-value in two or more connected breaklines, or checking to make sure that two or more connected breaklines were compiled in the same direction. It is also capable of joining multiple connected breaklines to create one continuous breakline. This tool is particularly useful in areas which were compiled by different editors. The breaklines in each area may be joined and breaklines which cross through the editors' areas may be checked for the same elevation and compilation direction.



Same Z value: This option will check for two neighboring, *connected* breaklines that have the same elevation, or Z-value. This tool will not work with breaklines

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which have not been snapped together and connected. To use this tool, make sure the 'Same Z Value' option is selected. Click on one of the two breaklines which are being checked for elevation. Then click on the second breakline to be checked for the same Z-value. If it is possible to highlight both breaklines simultaneously, then the Z-value is the same in both breaklines. If both breaklines will not become selected, or highlighted, at the same time then the Z-values differ.

Same direction: This tool will check for two neighboring, *connected* breaklines that have the same compilation direction. This tool will not work with breaklines which have not been snapped together and connected. To use this tool, make sure the 'Same Direction' option is selected. Click on one of the two breaklines which are being checked for compilation direction. Then click on the second breakline to be checked for the same compilation direction. If it is possible to highlight both breaklines simultaneously then the compilation direction is the same in both breaklines. If both breaklines will not become selected, or highlighted, at the same time then the compilation directions differ. The user may view compilation direction by noting the direction of the arrows on selected breaklines. The direction of the arrows indicate the compilation direction.

Perform join: This tool will join all *connected* breaklines. The tool will not work with breaklines which have not been snapped together. To use this tool, make sure the 'Perform Join' option is selected. Click on one of the breaklines which is to be joined together with its snapped neighbors. The breakline the user selects *first* will override the connected breaklines' elevations and/or compilation directions if any of the values differ. Then click again near the first breakline to confirm the join - the connected breaklines will be joined at this time. Clicking once more will select the single, newly joined breakline, showing the user it is

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now one breakline rather than multiple separate segments. To cancel the joining operation, press the 'Esc' key before performing the confirmation click.

Select and join: This tool will join user-selected *connected* breaklines (i.e., dissolve them into one continuous breakline). The tool will not work with breaklines which have not been snapped together. To use this tool, first make sure the 'Select and join' option is selected. Click on one of the breaklines which is to be joined together with one or more of its snapped neighbor(s). The breakline the user selects *first* will override the additional chosen breaklines' elevations and/or compilation directions if any of the values differ. Then click on the additional breakline(s) to be joined - one at a time - until the desired set of breaklines is selected. Hold down the 'Shift' key and left-click anywhere in the main MARS® window to perform the join. To cancel the joining operation, press the 'Esc' key before completing the 'Shift' key/left-click operation.

This tool operates in 11 different ways depending on the options chosen at the time of use:

1. Using the '**Same Z value**' option only: Used alone, this option will highlight connected breaklines of the same Z-value regardless of compilation direction. No joining is performed.
2. Using the '**Same direction**' option only: Used alone, this option will highlight connected breaklines of the same compilation direction regardless of Z-value. The user may view compilation direction by noting the arrows on the connected breaklines. No joining is performed.
3. Using the '**Perform join**' option only: Used alone, this option will join all connected breakline segments regardless of Z-values or compilation direction. The user may choose which elevation/compilation direction will override the

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others in the final, joined breakline by selecting the breakline segment with the desired elevation/compilation direction FIRST when joining the connected breaklines.

4. Using the '**Select and join**' option only: Used alone, this option will join selected breakline segments that are connected regardless of Z-values or compilation direction. The user may choose which elevation/compilation direction will override the others in the final, joined breakline by selecting the breakline segment with the desired elevation/compilation direction FIRST when joining the connected breaklines.
5. Using the '**Same Z value**' and '**Same direction**' options together: Used together, this combination highlights all connected breaklines which have the same Z-values and the same compilation direction. The user may view compilation direction by noting the arrows on the connected breaklines.
6. Using the '**Perform join**' and '**Same Z value**' options together: Used together, this combination joins all connected breakline segments only if they have the same Z-values. The breakline selected FIRST will determine the compilation direction of the final joined breakline.
7. Using the '**Perform join**' and '**Same direction**' options together: Used together, this combination joins all connected breakline segments only if they have the same compilation direction. The user may view compilation direction by noting the arrows on the connected breaklines. The breakline selected FIRST will determine the Z-value of the final joined breakline.
8. Using the '**Perform join**', '**Same Z value**', and '**Same direction**' options together: Used together, this combination joins all connected breakline segments only if they have the same Z-values and the same compilation direction. The user may view compilation direction by noting the arrows on the

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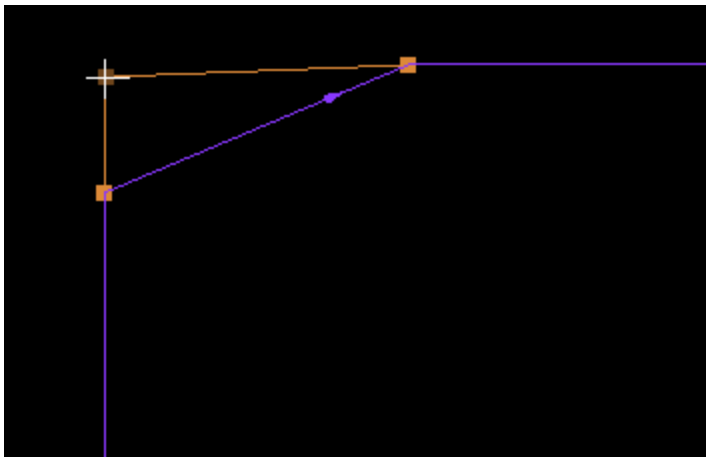
connected breaklines. The breakline selected FIRST will determine the Z-value and compilation direction of the final joined breakline.

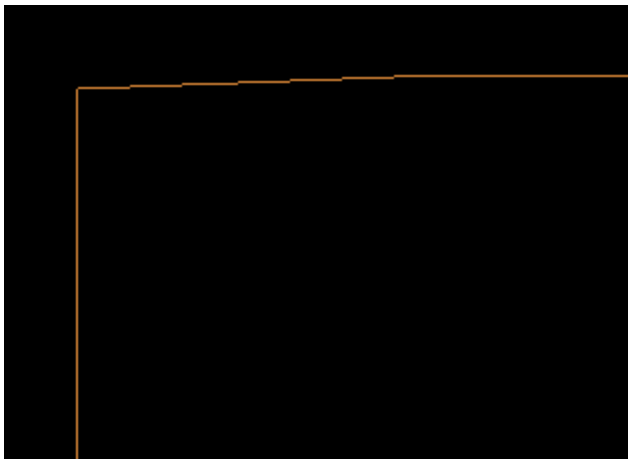
9. Using the '**Select and join**' and '**Same Z value**' options together: Used together, this combination joins user-selected connected breakline segments only if they have the same Z-values. The breakline selected FIRST will determine the compilation direction of the final joined breakline.
10. Using the '**Select and join**' and '**Same direction**' options together: Used together, this combination joins user-selected connected breakline segments only if they have the same compilation direction. The user may view compilation direction by noting the arrows on the connected breaklines. The breakline selected FIRST will determine the Z-value of the final joined breakline.
11. Using the '**Select and join**', '**Same Z value**', and '**Same direction**' options together: Used together, this combination joins user-selected connected breakline segments only if they have the same Z-values and the same compilation direction. The user may view compilation direction by noting the arrows on the connected breaklines. The breakline selected FIRST will determine the Z-value and compilation direction of the final joined breakline.



Add Vertex: This option allows the user to add a vertex to an existing breakline. To use this tool, select the 'Add Vertex' button, then left-click on the breakline in the area in which a new vertex needs to be added. The cursor will then drag the new vertex as it is moved. When the cursor is in the desired location, left-click again to add the vertex.

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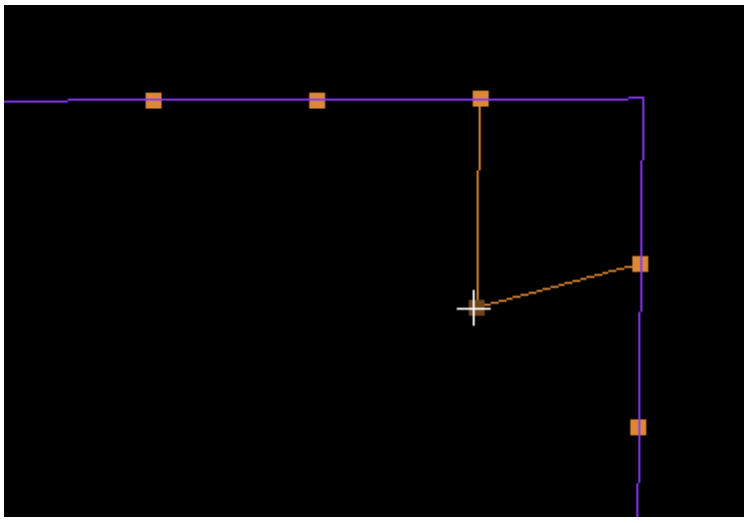


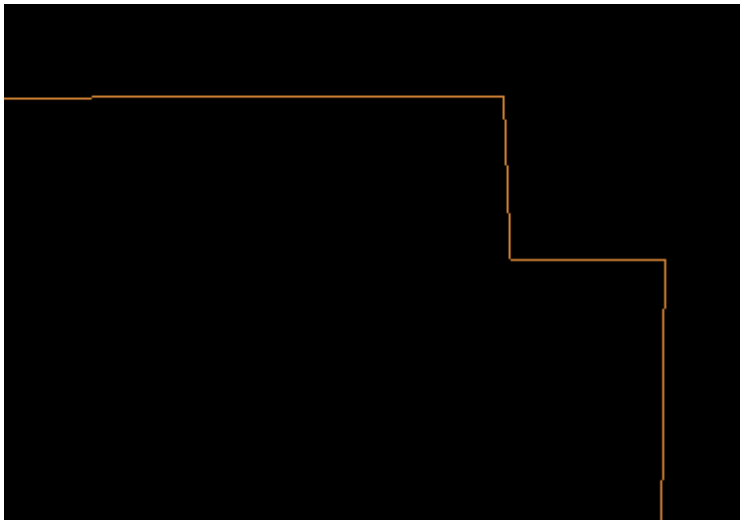




Move Vertex: This option allows the user to re-locate a vertex in an existing breakline. After selecting the vertex to be moved by left-clicking on it, the breakline in which the vertex exists will change to the selected features color and every vertex in that breakline will be highlighted. The vertex selected for re-location will be connected to the cursor. Please see the screen shots below as an example. To move the selected vertex, left-click and place the vertex in the desired area. To deselect the vertex, right-click anywhere in the project.

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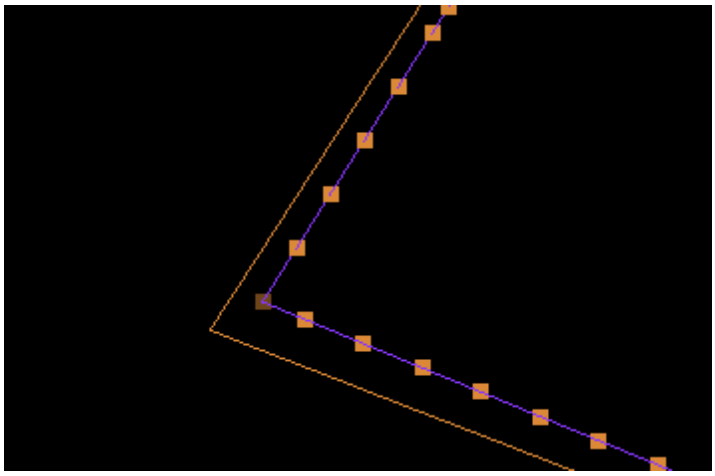


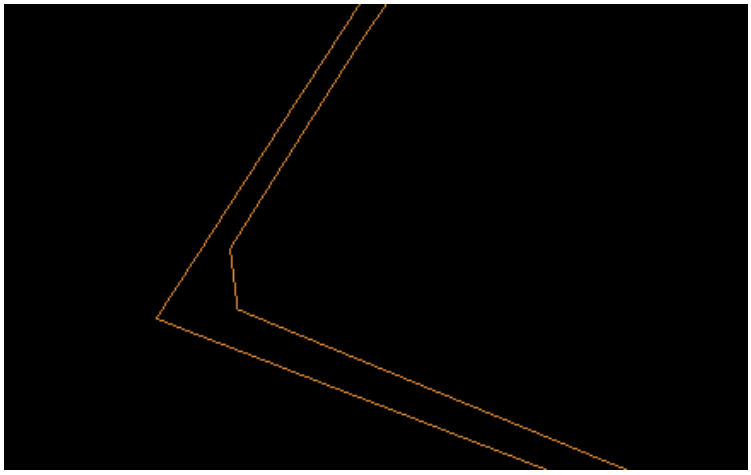


Delete Vertex: This tool allows the user to delete a single vertex in an existing breakline. After selecting the vertex to be deleted by left-clicking on it, the breakline in which the vertex exists will change to the selected features color and every vertex in that breakline will be highlighted. The vertex selected for deletion will be highlighted in a contrasting color. Please see the screen shots below as an example. To delete the selected vertex, left-click anywhere else in the project. To deselect the vertex, right-click anywhere else in the project.

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In the first example below, the breakline containing the selected vertex is highlighted purple. Every vertex in the breakline is highlighted in orange, and the single vertex selected for deletion is shown in brown. Left-clicking in the project area deletes the chosen vertex (in the corner of the breakline), as shown in the second screen shot.

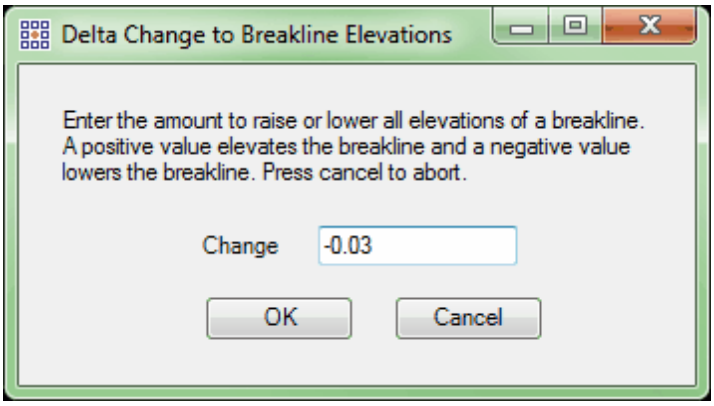




Change Elevation for All Points of Breakline: This tool is capable of changing the elevation of an entire breakline. To use this tool, click on the breakline which will have its elevation changed. The breakline will change to the selected features color when selected. Left-click once more to bring up the 'Delta Change to Breakline Elevations' window. Enter the change in elevation to be applied in the 'Change' text box. A negative value will lower the selected breakline and a positive value will raise the

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selected breakline.



Change Elevation of Any Vertex: This change elevation tool is capable of changing the elevation of any vertices of an existing breakline. With this tool, the user may change the elevation of an entire breakline, sections above or below a selected vertex, or within a selected range of vertices. The tool is also capable of viewing the X, Y, and Z coordinates of each vertex in a selected breakline. To use this tool, select the button, then left-click on the desired breakline. After the breakline has been selected and is highlighted, left-click in any other area to bring up the 'Breakline Elevation Edit' window. The vertex closest to the original selection point (first left-click) will appear in red on the breakline and its corresponding row will be highlighted in the table. The selected vertex's Z-value is listed in the 'Elevation' box near the top. At the very top of the table, the number of the selected vertex and the total number of vertices in the breakline are shown. The direction that the breakline was compiled is shown with a white arrow in the display.

Once open, the 'Breakline Elevation Edit' window will allow the user to make elevation changes. In example **A.)** below, the Z-value of the entire breakline is '5186.7'. The user wishes to change the Z-value of every vertex from ID 15 up to ID 1 in the table, inclusive. Select/highlight the vertex ID number '15' - that vertex changes to red in the display.

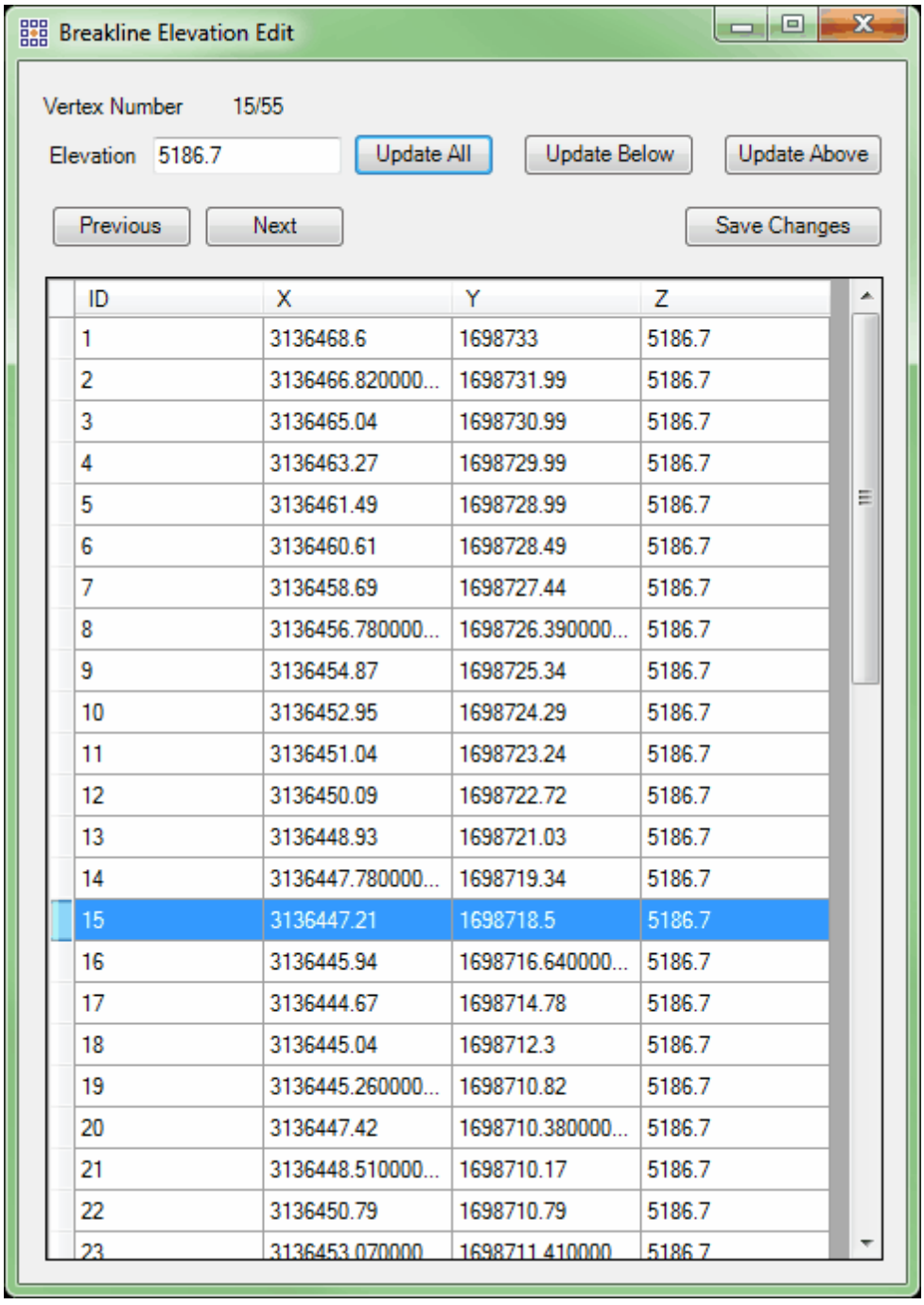
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Enter the desired elevation value into the 'Elevation' text box - '5201.3' in this example - then click the 'Update Above' button. The results are shown in example **B.)**. The elevation of every vertex numbered from 15 to the top of the list (Above) has been changed to the desired elevation of 5201.3 units. The 'Breakline Elevation Edit' window is capable of updating every vertex Above or Below the selected vertex ID, updating every vertex in a breakline with the same elevation ('Update All'), or updating a selected range of vertices. To select a range, use the 'Shift' or 'Ctrl' keys while clicking in the far-left column with the mouse (standard Windows selection procedures), or drag a box through the left column to include the vertices to be changed. Once the range is selected, enter a new value in the 'Elevation' text box and click 'Update Selection' as shown in example **C.)**. In addition, the elevation of a single vertex can be changed by clicking in the 'Z' cell for that vertex and entering a new value directly in that cell. The 'Previous' and 'Next' buttons can be used to select and highlight the row above or below (respectively) the current selection and the corresponding vertex in the display will change to red. To save the changes which are currently shown in the 'Breakline Elevation Edit' window, click the 'Save Changes' button before exiting the interface.

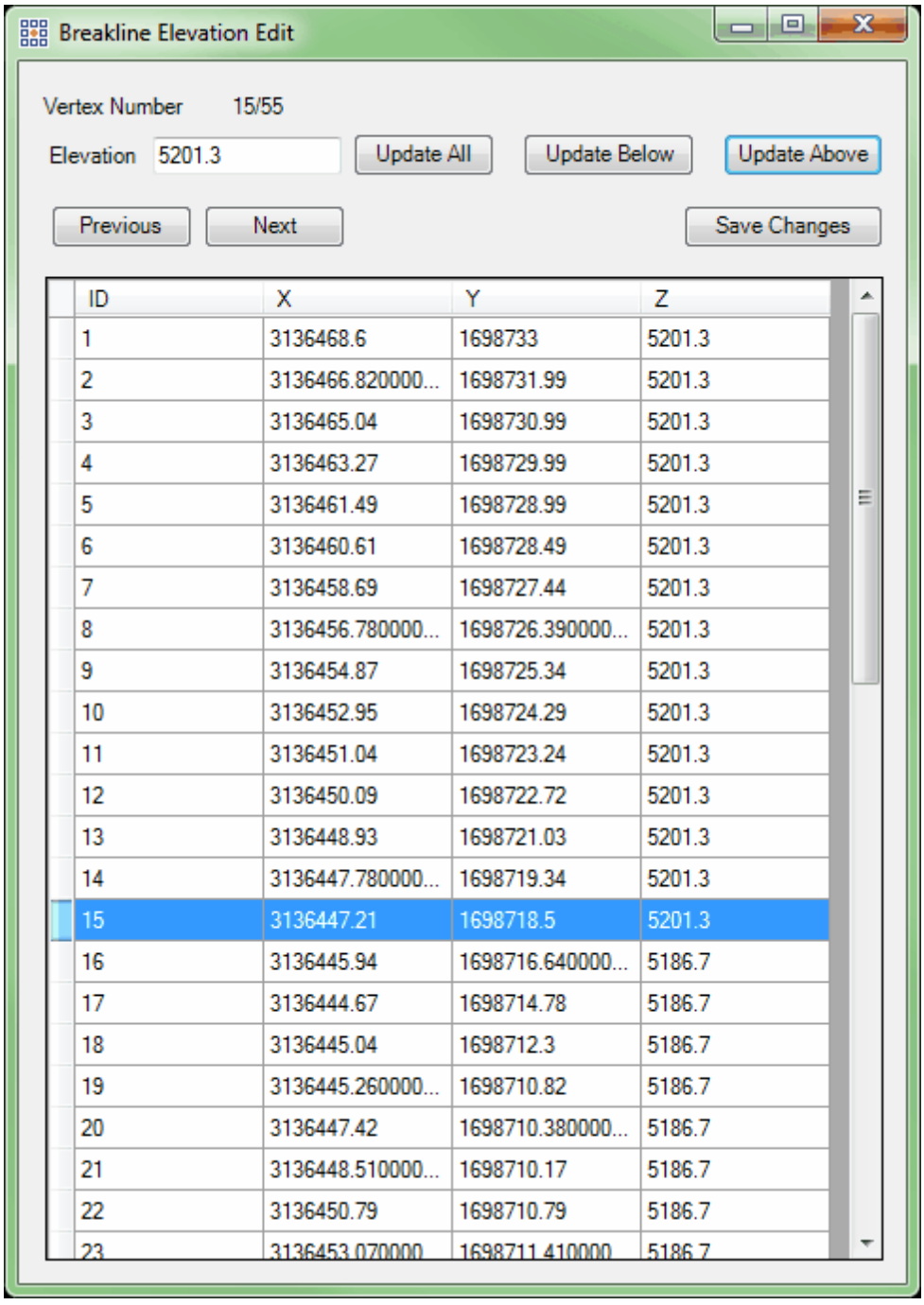
A.)

B.)

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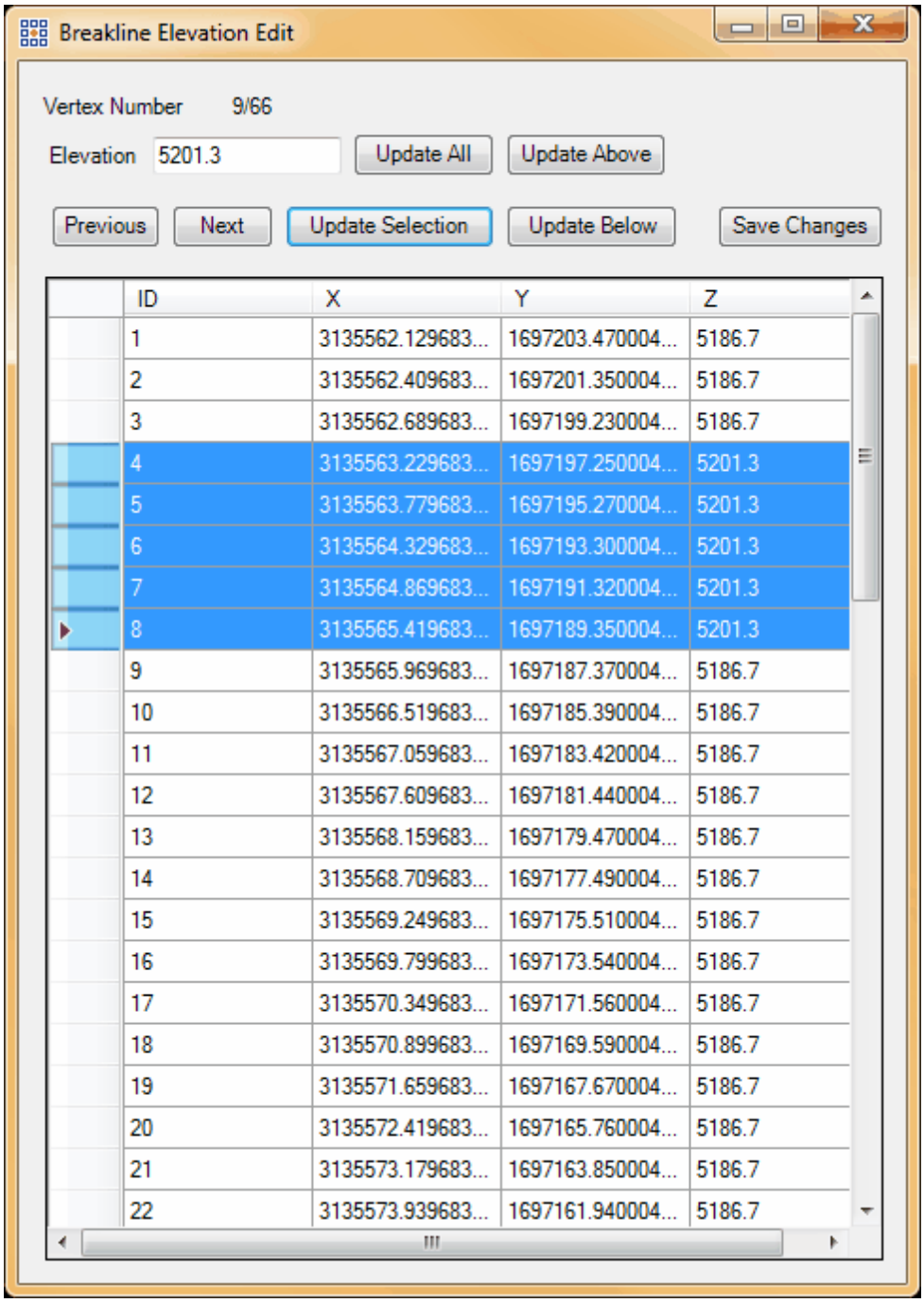


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C.)

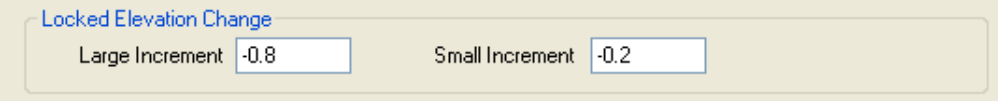
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Change Elevation (Large Increment): The 'Change Elevation' tool is meant to work in unison with the 'Elevation' tool and make the compilation of breaklines easier and quicker. This tool allows the user to “step” the elevation of breakline up or down in large

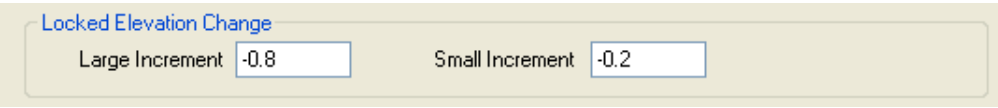
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increments. By default, the 'Change Elevation (Large Increment)' button lowers the elevation of an added breakline by -0.8 units. The user may change this default value by opening the 'Breakline Properties' window and entering the desired unit change in the 'Locked Elevation Change' area as seen below. Values can be positive or negative.





Change Elevation (Small Increment): This tool works exactly like the Large Increment tool (above), but with a different (smaller) increment value. By default, the 'Change Elevation (Small Increment)' button lowers the elevation of an added breakline by -0.2 units. The user may change this default value by opening the 'Breakline Properties' window and entering the desired unit change in the 'Locked Elevation Change' area as seen below. Values can be positive or negative.



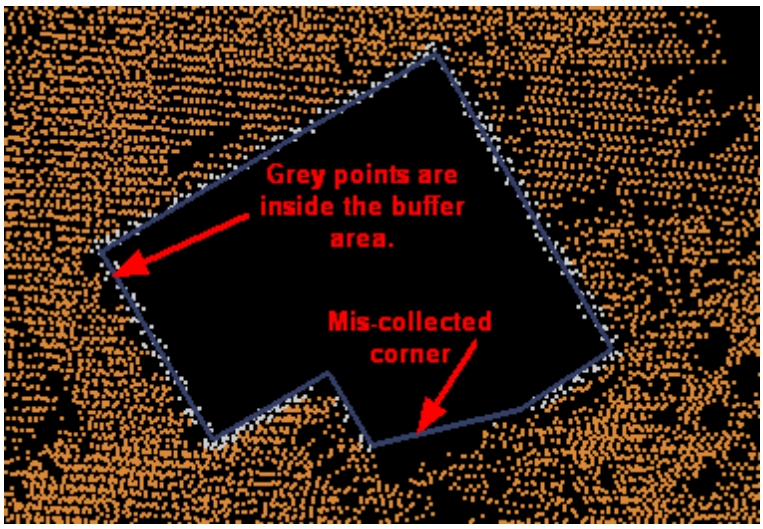


Reassess Points for Ignored Ground Classification: This tool will reclassify points surrounding a modified breakline, or where a breakline was deleted (inside a user-specified drag-box).

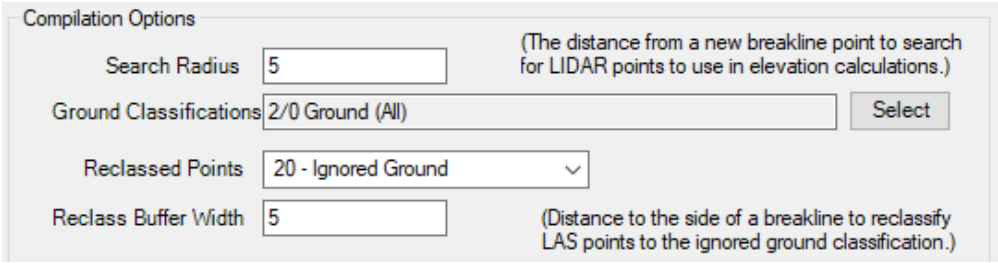
1.) Create or locate the breakline (or former breakline area) on which this tool will be used. In the example below, a breakline has been created around a building, but has one corner of the building accidentally omitted. When the collection of the misshapen breakline was complete, the points which were inside the user-defined buffer around the breakline were reclassified from Class 2: Ground (All) (shown in orange) to Class

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20: Ignored Ground (light gray in this example).

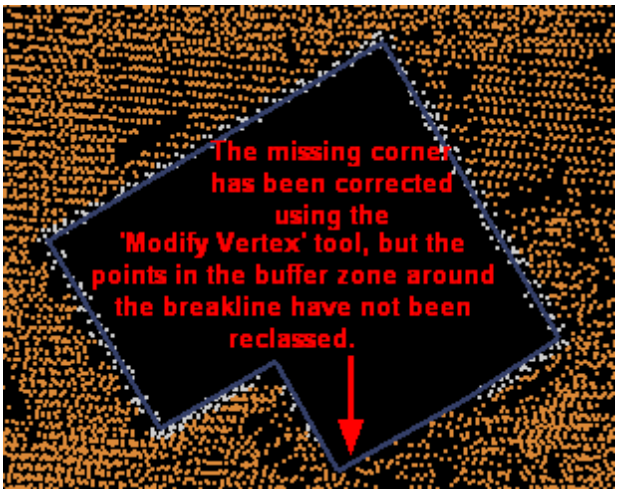


The specifications which decide the buffer width, points to be reclassed, and ground classification to use in the reclass are made inside the 'Compilation Options' section of the 'Breakline Properties' interface. The settings in the interface shown below are set to reclass any point from Class 2 to Class 20 within a 5 unit buffer around the specified breakline during compilation. The results of these settings may be seen in the image above.

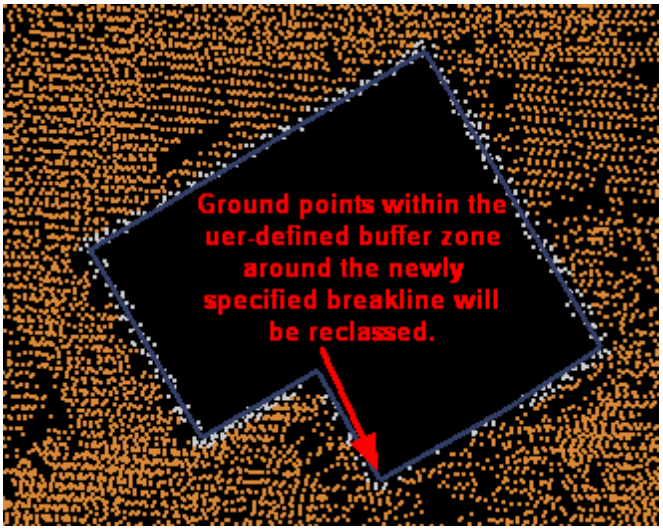


2.) The misshapen breakline is then corrected by using the 'Modify Vertex' tool  . Once the vertex has been moved, the breakline is now correctly drawn. However, the buffer zone around the new corner of the breakline has not yet been reclassified.

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3.) To reclass the buffer zone around the modified breakline, click on the 'Reassess Points for Ignored Ground Classification' tool . Left-click and drag a box over the area which has been modified. This tool will classify the new buffer zone around the modified breakline. When this tool is used, the buffer zone that is honored is based on the 'Point Delete Buffer' value entered when the breakline shapefile was loaded (see the 'Add Breaklines from Shapefile' topic in the Project/Data Preparation Tab 162 section of this Help File).



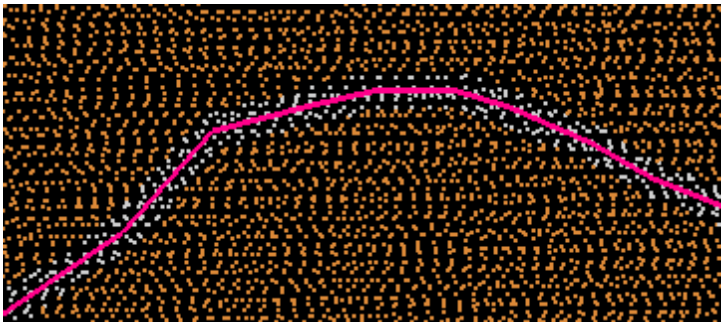
If the buffer zone has previously reclassed points which should be returned to their

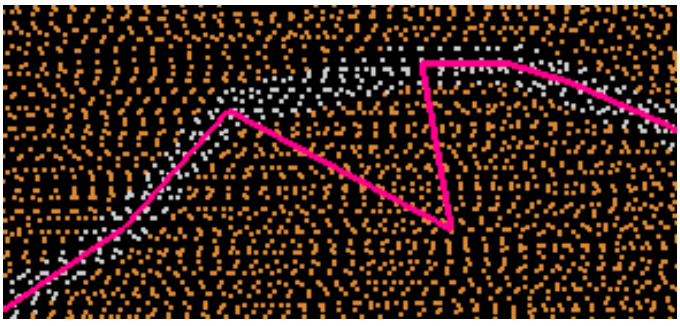
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original value after a modification of a breakline, these points will also be corrected. **a.)** In the example below (left), a breakline has reclassed all ground points within a buffer zone surrounding it to Class 20: Ignored Ground (light gray in this example). **b.)** The user then modifies a vertex of the breakline (middle). The points which were reclassed in the buffer zone based on the original breakline shape are no longer correctly classified. **c.)** Points around the newly modified breakline need to be reassessed using the 'Reassess Points for Ignored Ground Classification' tool (as in step **3.**, above). This tool will not only reclass the points within the new buffer area (below, right) surrounding the modified breakline to Class 20, but will also return the previously reclassed buffer points from Class 20 back to their original ground class (orange). Note that modified breaklines will not have their vertex elevation values changed automatically with this tool. It will be necessary to drape those breaklines that were modified using the 'Drape Selected Breaklines' tool.

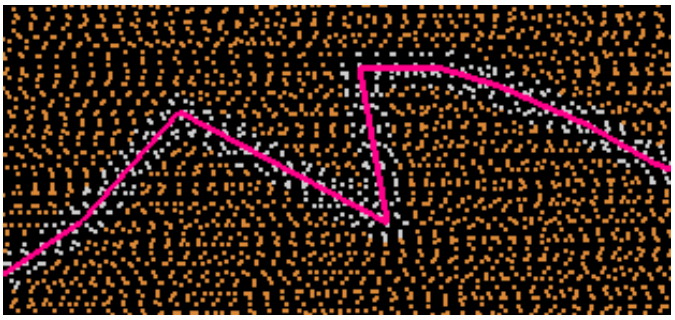
a.) **b.)**

c.)





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Drape Polylines: This tool allows the user to select a *.dgn file or a *.shp file containing polyline breaklines and drape those breaklines to the LAS data surrounding it. This tool will add a Z-value (elevation) to the breaklines in the specified file by searching the points surrounding the line for an appropriate Z-value. If the shapefile or DGN file indicated only contains stream or river breaklines, this tool will also has the option of enforcing the downhill stream rule if the user chooses.

- **Enforcing stream rule (downhill):** By checking this option, the tool will force the selected breakline to flow downhill. This option is useful when draping the 'Stream' feature code.
- **Reference Classes:** The user may choose one class or multiple classes to act as a reference. The draping tool will search the area surrounding the selected breakline (the specified search radius) for this specified class only. Only this class will be used in finding an appropriate Z-value for draping the selected breakline.
- **'Input' section:** The user may choose which type of input file will be used to drape polylines. The user may choose from either a 'DGN' or a 'Shapefile' input type. Either type of file should contain polyline breaklines. If the user chooses a DGN input type, select the 'DGN' radio button and the 'Input DGN File' browse box will become available (see example **a.**, below). If the user chooses a shapefile input type, select the 'Shapefile' radio button and the 'Input Shapefile' browse box will become available (see example **b.**, below). Browse to the appropriate input file and move on to the 'Output' section of the interface.
- **'Output' section:** The 'Output' section will also change options based on the user's choice

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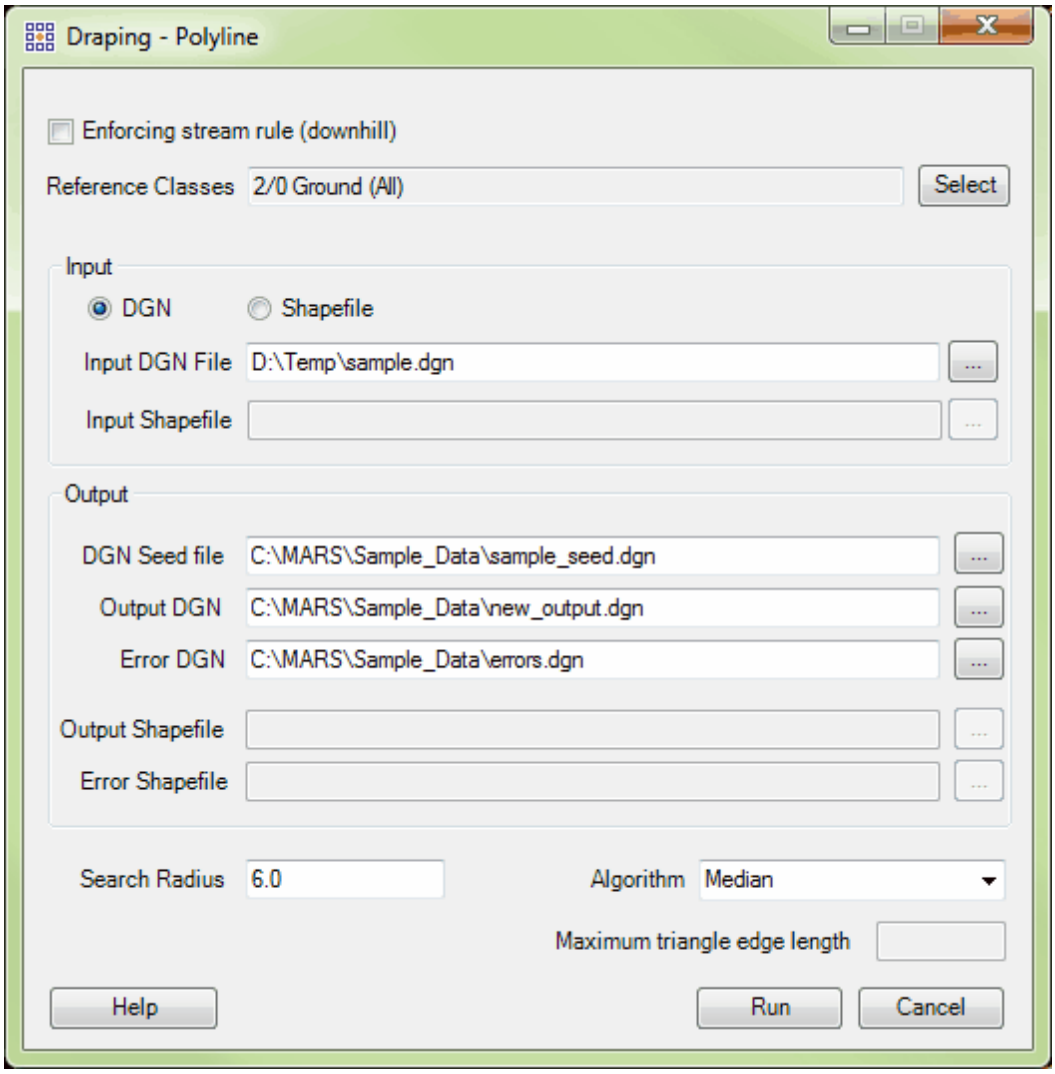
between 'DGN' and 'Shapefile' in the 'Input' section. If the user chooses a DGN file as the input file, the first three options available in the 'Output' section will become available. The user must specify a 'DGN Seed File', the 'Output DGN' location and name, and a name for the 'Error DGN' file which will be created. This error file will be created if draping of any polyline is not possible. A DGN will be created marking the location of each error (see example **a.**, below). If the user chooses a shapefile as the input file, the last two options available in the 'Output' section will become available. The user must specify an 'Output Shapefile' name and location and a name for the 'Error Shapefile' which will be created. Similar to the 'Error DGN' file, this error file will be created if draping of any polyline is not possible. A shapefile will be created marking the location of each error (see example **b.**, below).

- **Search Radius:** The user may specify the size of the search radius (in project units), or area surrounding each breakline, in which the tool will look for appropriate Z-values in the reference class specified. Please see the reference to 'search radius' in the above explanation of 'Reference Classes'.
- **Algorithm:** The user may select an algorithm to search for surrounding Z-values which will be used to assign an elevation to the selected breakline. Choose from: Median, Average, Min, Max, and TIN.
- **Maximum triangle edge length:** This text box is only available when the user chooses the 'TIN' option as the algorithm to search by. When 'TIN' is the selected algorithm, the user may then specify the maximum triangle edge length which will be allowed in the search.

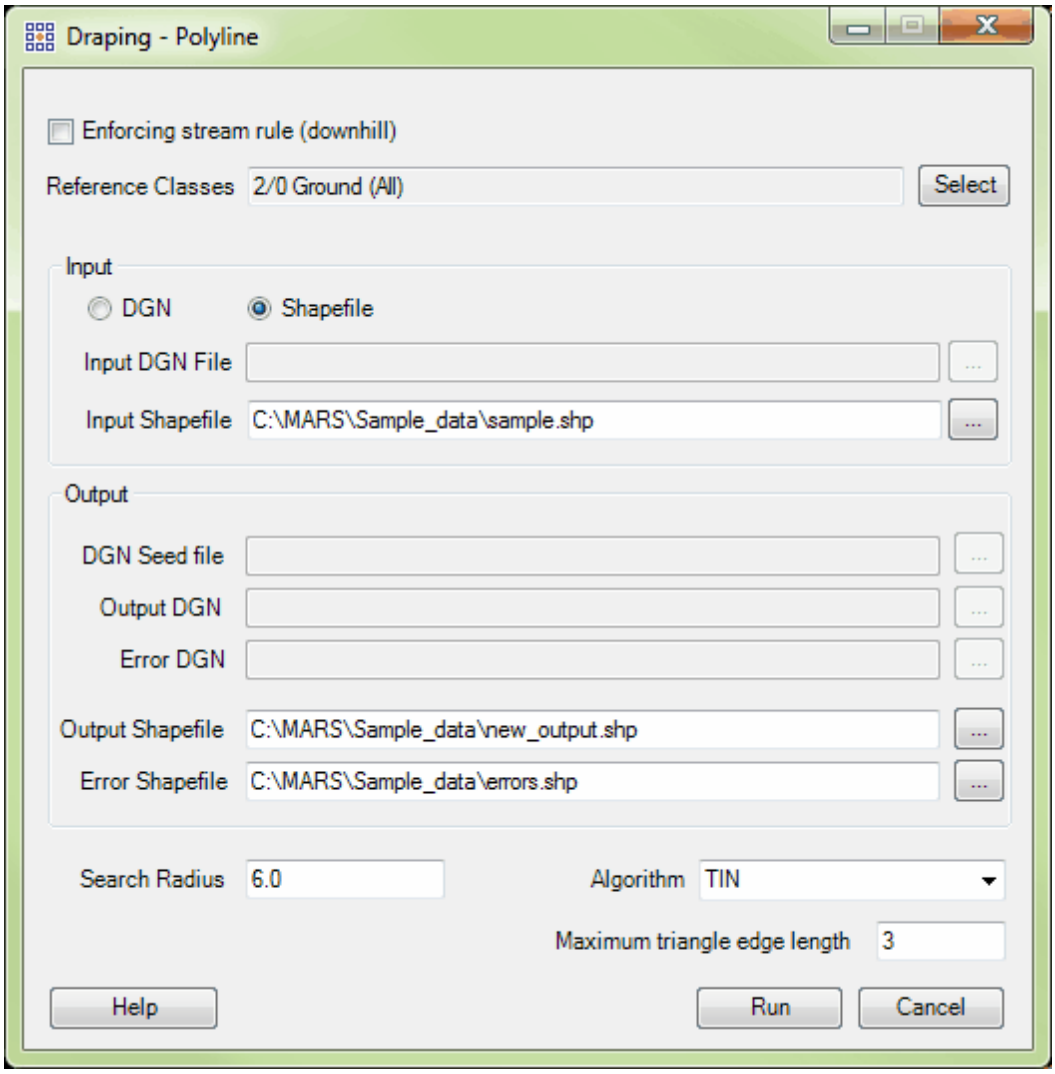
a. *Options available if the user chooses a DGN as the input file type:*

b. *Options available if the user chooses a shapefile as the input file type:*

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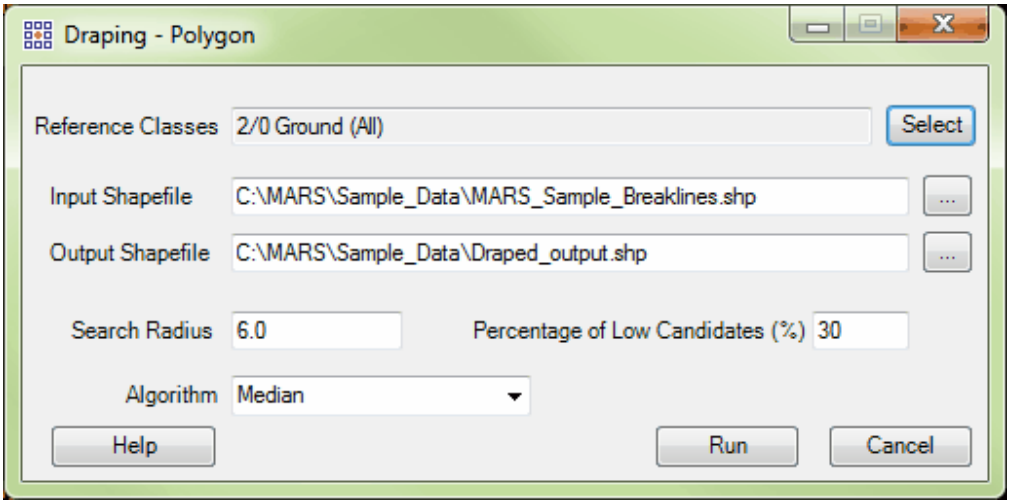
Drape Polygons: This tool allows the user to select a *.shp file containing polygon breaklines and drape those breaklines to the LAS data surrounding it. This tool will add a Z-value to the breaklines in the specified file by searching the points surrounding the line for an appropriate Z-value. This tool also allows the user to choose the percentage of the lowest points found within the search radius which will be included in determining the Z-value of the draped breakline.

- **Reference Classes:** The user may choose one class or multiple classes to act as a

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reference. The draping tool will search the area surrounding the selected breakline (the specified search radius) for these specified classes only. Only these classes will be used in finding an appropriate Z-value for draping the selected breakline.

- **Input Shapefile:** Select the ellipsis **'...'** button and use the following window to navigate to the desired input shapefile containing breakline polygons to be draped.
- **Output Shapefile:** Select the ellipsis **'...'** button and use the following window to navigate to the desired output folder where the newly created, draped breakline shapefile will be placed. Also give the new output shapefile a name.
- **Search Radius:** The user may specify the size of the search radius (in project units), or area surrounding each breakline, in which the tool will look for appropriate Z-values in the reference class(es) specified. Please see the reference to 'search radius' in the above explanation of 'Reference Classes'.
- **Percentage of Low Candidates (%):** This option allows the user to choose what percentage of the lowest points (in the specified reference classes) surrounding the polygon will be used in determining a Z-value for the selected breakline.
- **Algorithm:** Draping can be based on a Median, Average, Min, or Max Z-value using the previous two parameters.



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Drape Selected Breaklines: This tool allows the user to select a specific breakline or set of breaklines and drape to the surrounding LAS data. The tool will add Z-values to the selected breakline(s) by searching the surrounding points for appropriate elevations. This tool is capable of performing a drape on a single, selected breakline or on multiple breaklines at a time. Results are rounded to three (3) decimal places, regardless of the project's vertical units.

- **'Feature Code Change' section:** To change the feature code of the selected breaklines, check the **'Change feature code'** box. When checked, the **'Change code to:'** drop-down box will become available and the user may choose which feature code to change the breaklines to.

'Common Options' section

- **Reference Classes:** The user may choose one class or multiple classes to act as a reference. The draping tool will search the area surrounding the selected breaklines (the specified search radius) for the specified classes only. Only these classes will be used in finding appropriate Z-values, or elevations, for the selected breaklines.
- **Search Radius:** The user may specify the size of the search radius, or area surrounding the selected breaklines, in which the tool will look for appropriate Z-values in the reference classes specified. Please see the reference to 'search radius' in the above explanation of 'Reference Classes'.
- **Algorithm:** The user may select an algorithm to search for surrounding Z-values which will be used to assign elevations to the selected breaklines. Available choices are: Median, Average, Min, Max, and TIN.
- **Maximum triangle edge length:** This text box is only available when the user chooses the 'TIN' option as the search algorithm. If 'TIN' is selected, the user may then specify the maximum triangle edge length which will be allowed in the search.

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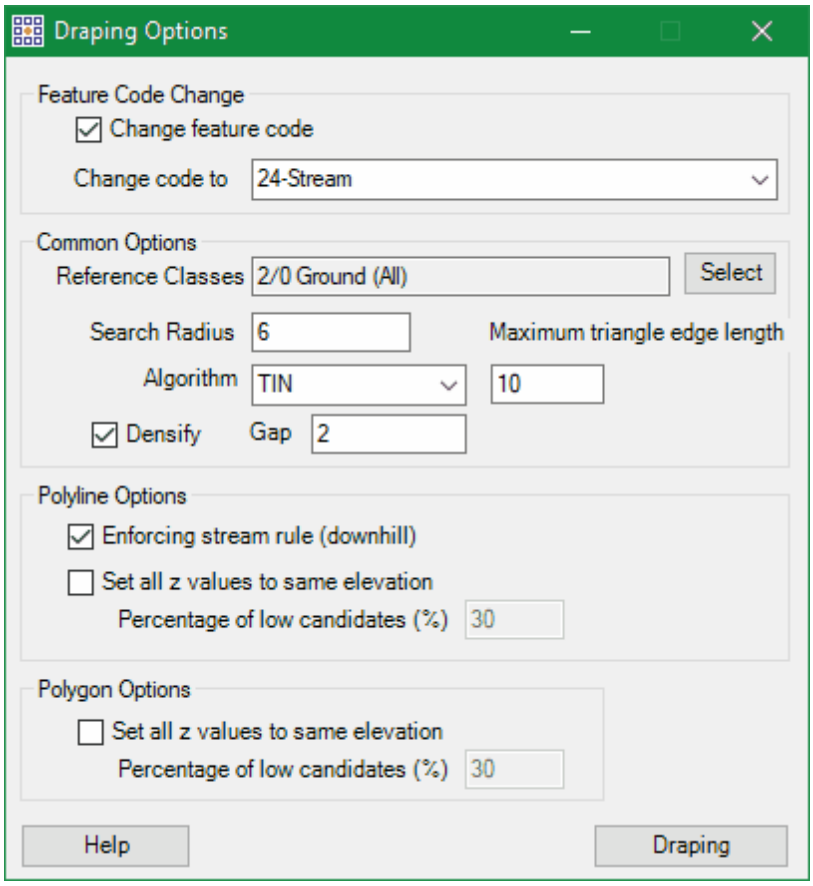
- **Densify:** This option will allow the user to densify the selected breaklines by adding more points to them.
- **Gap:** This option is only available when the 'Densify' option is chosen. The user may specify how much more dense to make the selected breaklines. For example, if the user enters a value of '2' into the 'Gap' text box, the tool will make sure that a point exists at every 2 units along the breaklines.

'Polyline Options' section (only for use with polyline breaklines)

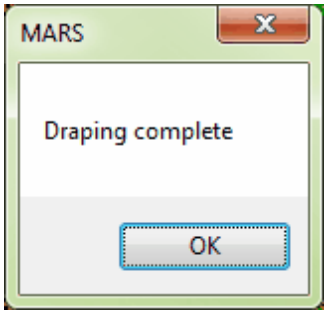
- **Enforcing stream rule (downhill):** By checking this option (on by default), the tool will force the selected breaklines to flow downhill. This option is particularly useful when draping the 'Stream' feature code.
- **Set all z values to same elevation:** By checking this option, every point in the selected breaklines will be set to the same Z-value, and the 'Percentage of low candidates (%)' option will become available. This option allows the user to choose what percentage of the lowest points (in the specified reference classes) surrounding the polylines will be used in determining Z-values for the selected breaklines.

- **'Polygon Options' section:** This section of options is only for use with polygonal breaklines (e.g., ponds or lakes). By checking the 'Set all z values to the same elevation' check box, every point in the selected breaklines will be set to the same Z-value, and the 'Percentage of low candidates (%)' option will become available. This option allows the user to choose what percentage of the lowest points (in the specified reference classes) surrounding the polygons will be used in determining Z-values for the selected breaklines.

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When all parameters are set, click the 'Draping' button to start the processing.

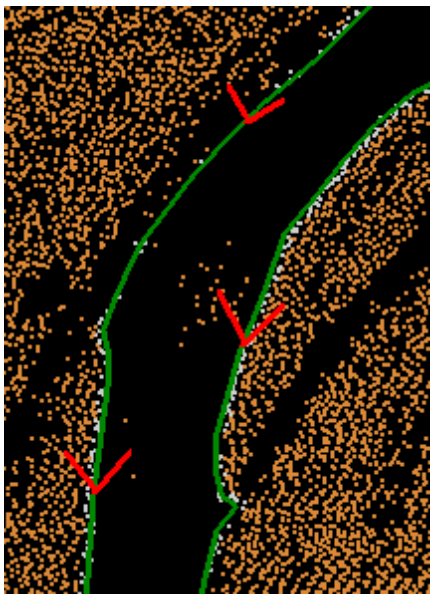


Double Hydro Tool: This tool is meant for use on rivers or double-line streams. In order to use this tool, the user must have already collected breaklines along each edge of a river or

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stream, and these breaklines must have been compiled in the same direction. The Double Hydro Tool allows the user to reclass all points within a virtual polygon (which is created between the two parallel polylines representing the water's edge). It also allows the user to match the Z-value of the two breaklines representing the edges of the river or stream. To use this tool:

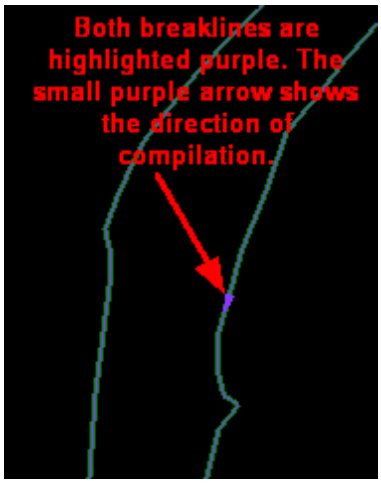
1. Compile breaklines along the edge of a stream or river. Make sure the breaklines are both compiled in the same direction or the Double Hydro Tool will not function. In the example below, the breaklines collected have both been collected in the direction the red arrows are pointing. Stream and river breaklines should be compiled in the direction of decreasing elevation (direction of water flow). This is why the 'MinDecreasing' feature collection type is used. Also, the breaklines in this example have reclassed the ground in a small buffer around each line to Class 20 - Ignored Ground, which is colored light gray in this example (see step **4a** for more information on changing the class of reclassed points).



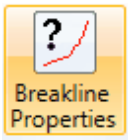
2. Next click on the 'Double Hydro Tool' button.

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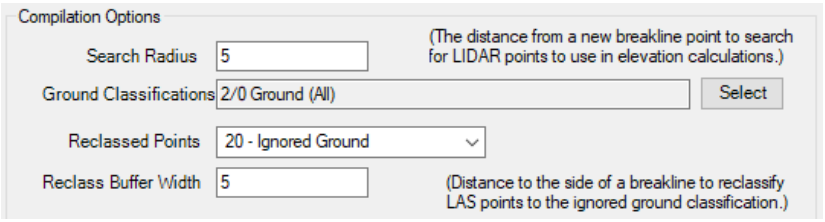
3. Click once on each breakline following the river or stream's edge. Both breaklines will change to the selected features color. Also, small arrows will show the direction of compilation for each breakline. In the example shown below, the LAS points have been turned off for easier viewing.



4. Now that the two breaklines which will serve as a boundary for the Double Hydro Tool have been selected, make a third mouse click inside the LAS Map View window to activate the tool. At this time, the tool will create a virtual polygon and reclassify the points inside the polygon.

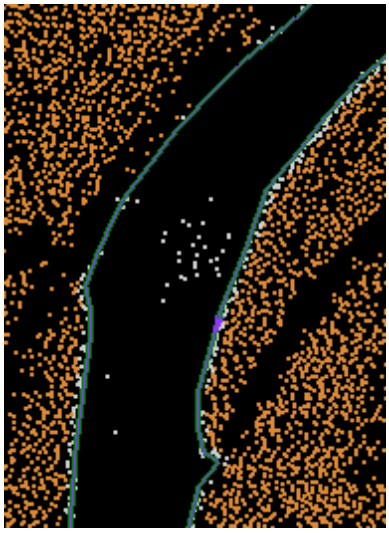
a.) The user may select the class to which the points are reclassed by selecting the 'Breakline Properties' 

button. Inside this interface, the user may choose the class which the points inside the virtual polygon will be reclassed to.



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b.) The points on the river (inside the virtual polygon) in this example have been reclassed to Class 20 - Ignored Ground.

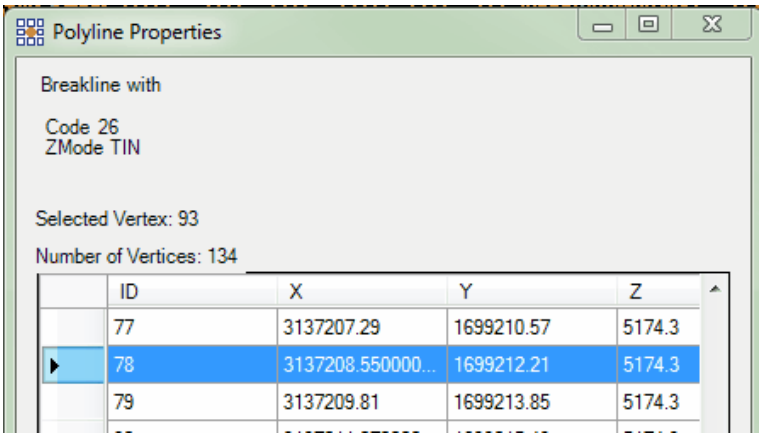


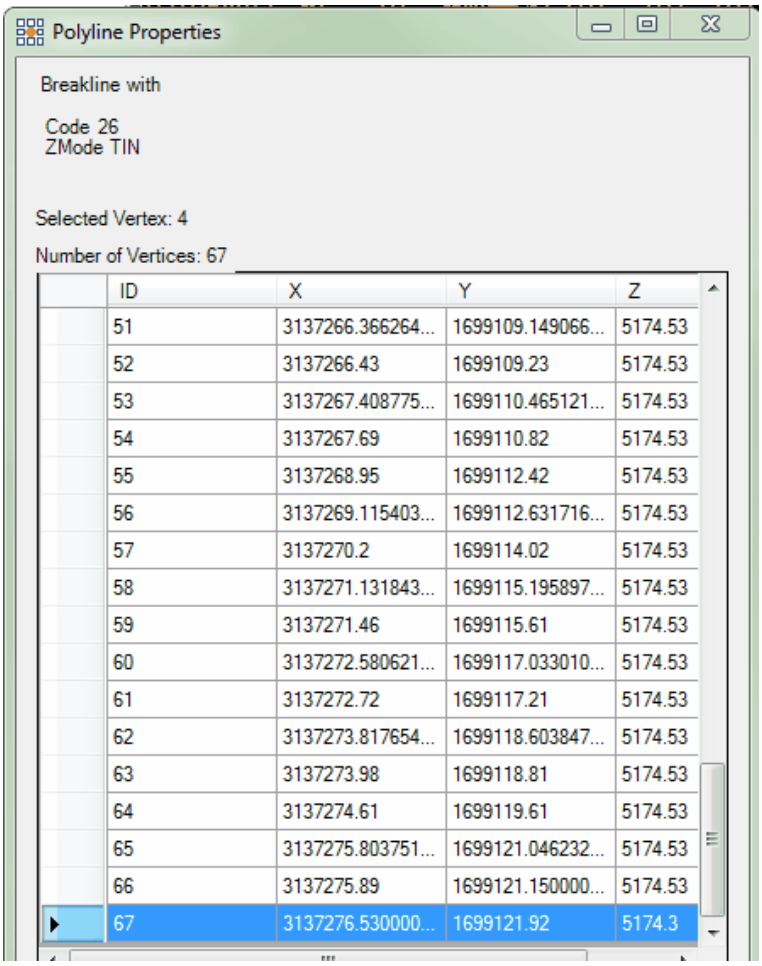
c.) As well as reclassing the points to the interior of the breaklines selected, the Double Hydro Tool will make sure the elevations of the two selected breaklines match at vertices which are perpendicular to one another. The elevation of the left-hand breakline will always be used to override the breakline elevation of the right-hand breakline. The user may check to make sure the breaklines match by using the Inspect tool  . Click on the 'Inspect' button, hold down the **'Ctrl'** key on the keyboard, and click on the breakline in question. The polyline properties of the two separate breaklines may be seen below. Vertices 30 (ex. 1) and 15 (ex. 2) are perpendicular to each other in the breakline examples shown above. The Z-value of both breaklines at perpendicular vertices is the same.

1.)

2.)

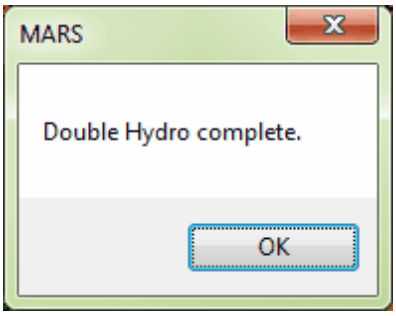
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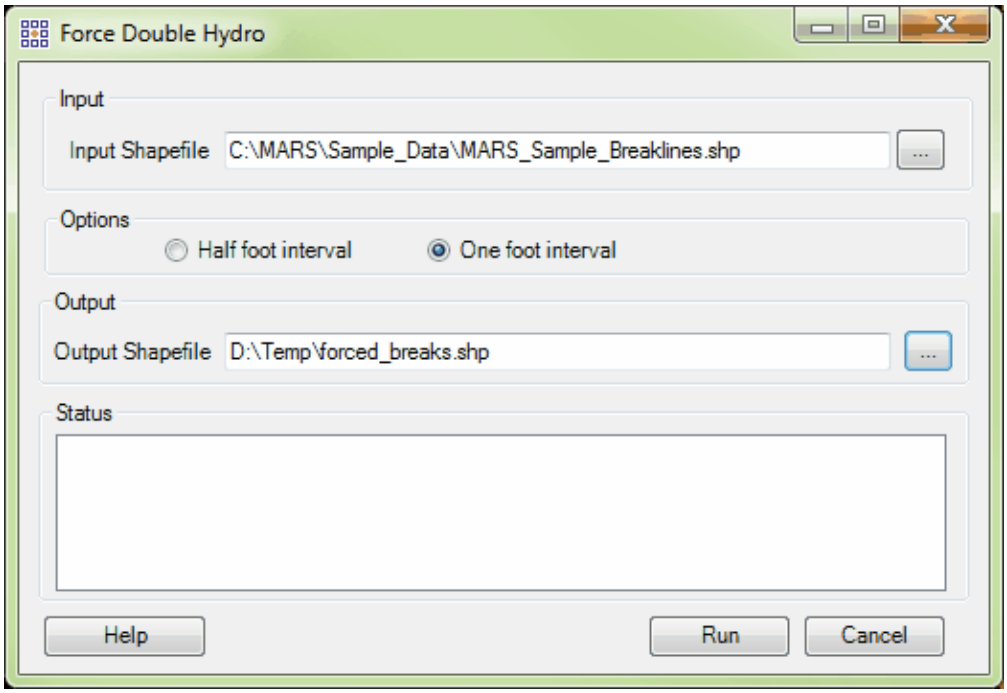


5. When the Double Hydro tool is finished, a prompt will appear.

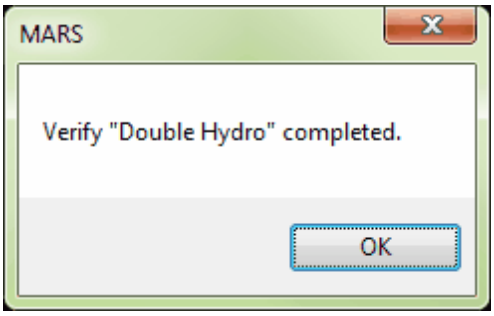
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Force Double Hydro: This option allows the user to load a breakline shapefile and forces all breaklines down to even intervals based off of elevation information obtained during prior collection. The user may choose to force breaklines down to half-foot or one foot intervals. To use this tool, specify an input shapefile, or breaklines shapefile. Next, specify the folder in which the output file should be placed and name the new shapefile. This tool will create a status, or summary, when finished processing and alert the user with a window prompt.



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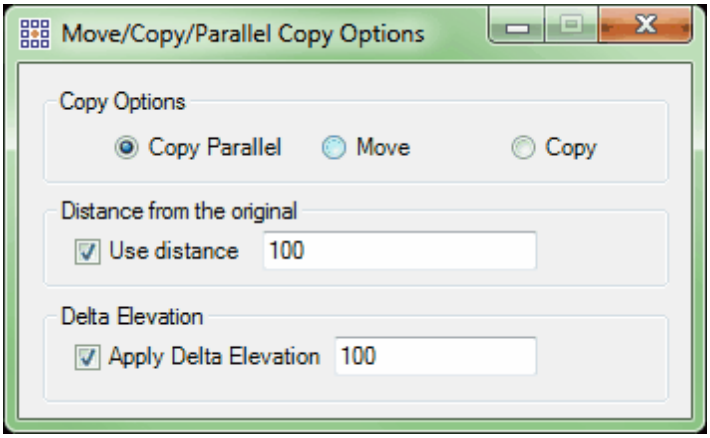


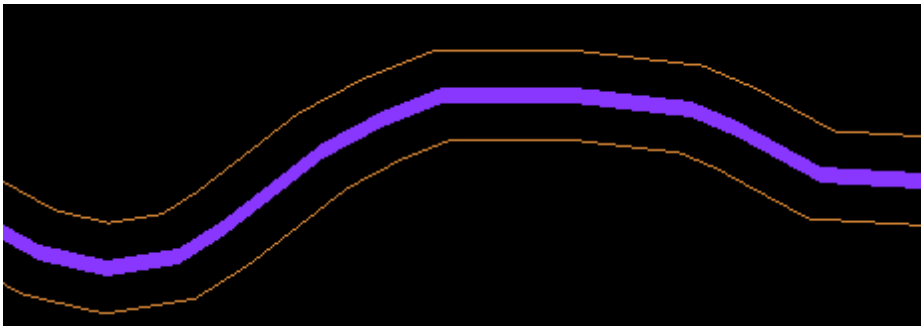
Copy Parallel: The 'Copy Parallel' tool allows the user to move, copy, or copy a breakline exactly parallel to an existing breakline. To use this tool, click on the 'Copy Parallel' button. At this time, the 'Move/Copy/Parallel Copy Options' window will appear. The user may choose which action they want performed: move, copy, or parallel copy, on an existing breakline. When using the 'Copy Parallel' option, the user may also choose to use the 'Distance from the original' option by checking the box called 'Use distance' and entering a distance in units into the text box. The newly created breakline will be copied the specified distance from the original breakline if this option is chosen. Another available option to the user when the 'Copy Parallel option is chosen is the 'Delta Elevation' option. The user may choose this option by placing a check mark in the box named 'Apply Delta Elevation'. This option allows the user to give the newly created breakline(s) a separate elevation from the original breakline. Enter the change in elevation for the new breakline into the text box available. For example, if the user would like the new breakline to be created exactly 50 units lower than the original breakline, then -50 should be entered into the 'Apply Delta Elevation' text box. To raise the elevation of the newly created breakline above that of the original breakline, enter a positive unit change. Once the parameters of the window have been set, left-click near the existing breakline. This breakline will appear as bold and in the color currently set

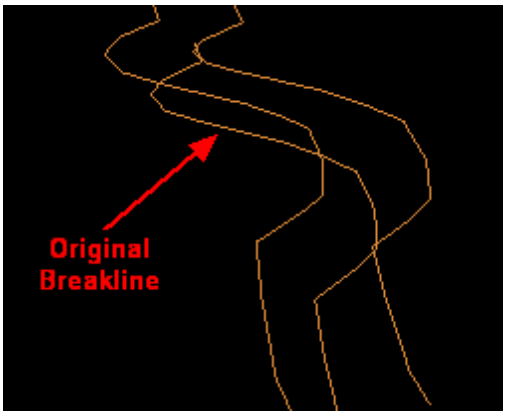
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for selected features. Left-click again to either move, copy, or copy parallel the selected breakline.

Example: Create a new breakline 100 units away from and parallel to the original breakline (shown in bold purple and in the center), and 100 units higher than the original breakline on both sides of the original.

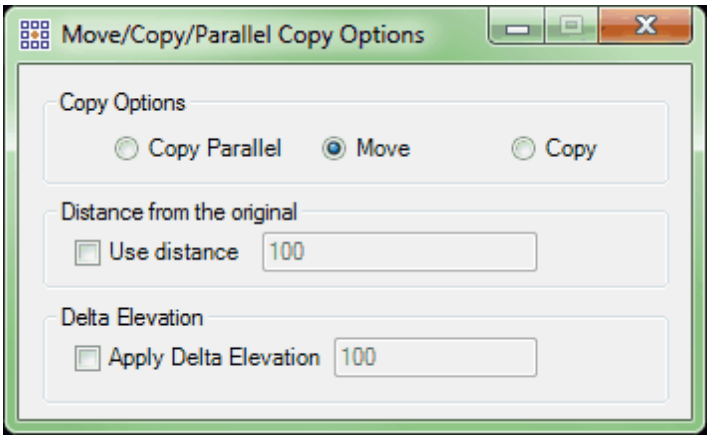


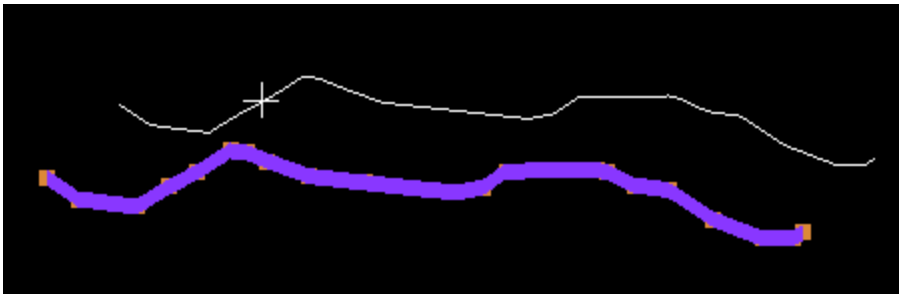




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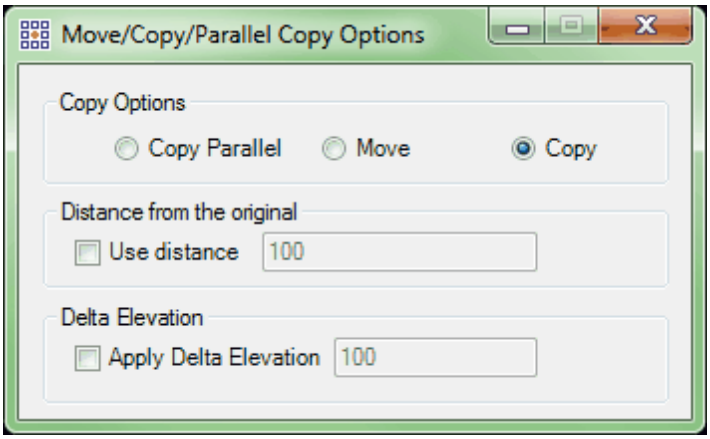
Example: To move a breakline, choose 'Move' in the 'Move/Copy/Parallel Copy Options' window and click on the breakline to be moved. The original placement of the breakline is shown in bold purple, and the cursor and white breakline show the placement of the breakline as it is being moved.

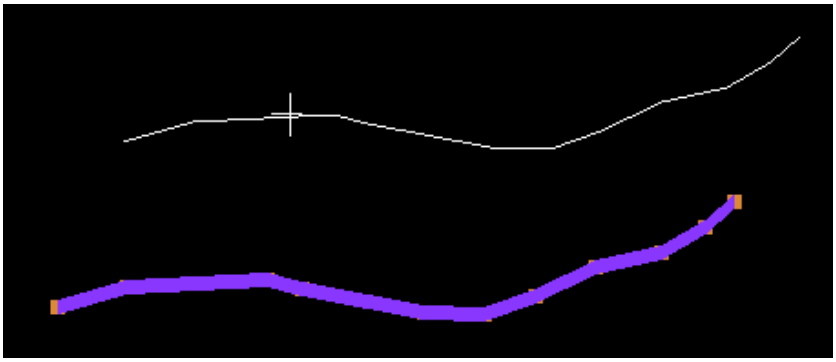


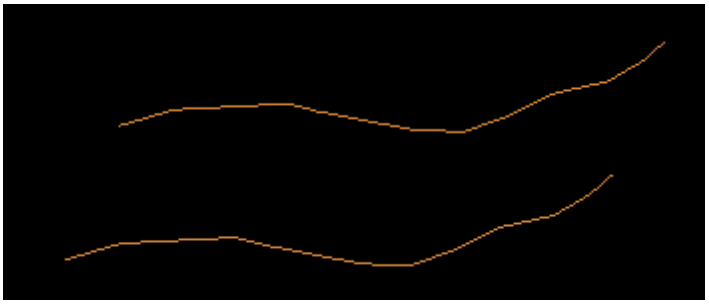


Example: To copy a breakline choose the 'Copy' option. This option is similar to the 'Move' option, but keeps the original breakline (shown in bold purple). The placement of the copy breakline appears in white and attached to the cursor for positioning.

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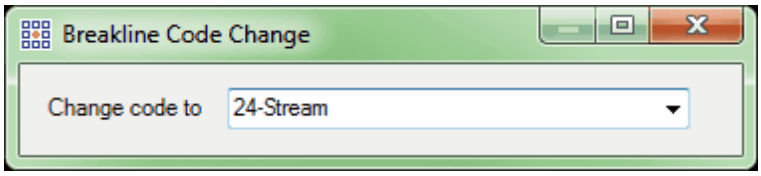




Change Feature Code: This tool allows the user to change the feature code of an existing breakline. When this tool is selected, the 'Breakline Code Change' window will appear. Click on the breakline which is to have its code changed to highlight it, and then select the desired feature code from the drop-down list contained in the 'Breakline Code Change' window. Left-click anywhere in the project to set the change, and the breakline color will change to reflect the new feature code. Exit the interface to deactivate the

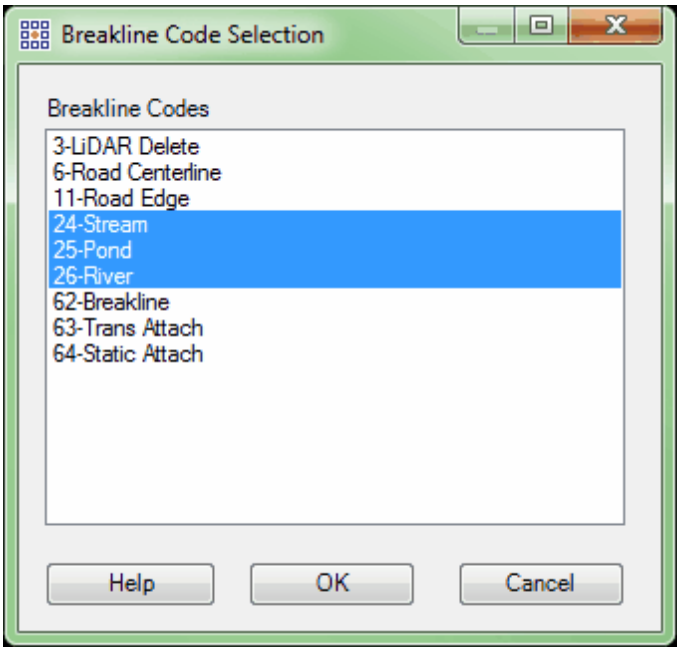
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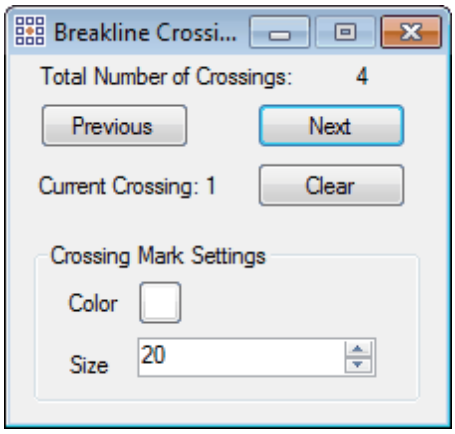
tool.

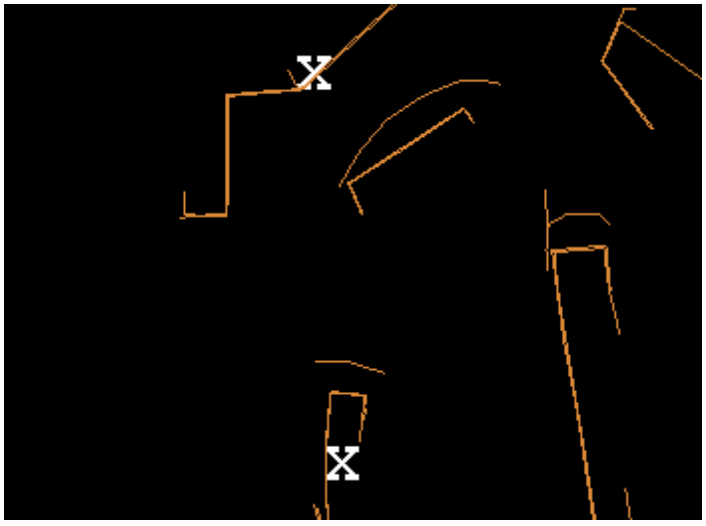


Check for Crossing Breaklines: This tool will search for any crossing breaklines in a project. The user will be prompted to choose the code or codes that will participate in the crossing check (the 'Ctrl' and 'Shift' keys can be used in selecting codes). Breaklines loaded as 'Reference Breaklines' will also be included in the crossing check. The software will only recognize crossings in which the Z-value of both lines does NOT match. If the Z-value of both breaklines is the same or if the breakline points have been snapped together the crossing will be considered an intersection and will not be counted. The resulting 'Breakline Crossing' window will notify the user of the total number of breakline crossings and allow the user to pan to each instance by use of the 'Previous' or 'Next' buttons. The crossing locations will be marked with an **X**. The 'Breakline Crossing' window also allows the user to choose the color and size of the **X** markers. The user may choose from a set of pre-defined colors or create a unique color from a palette. The font size of the **X** markers can range from 1 to 30. The 'Clear' button allows the user to clear the number of recorded crossings and the **X** markers shown in the LAS Map View window display. In the 'Breakline Crossing' window seen below, the user has chosen to view the 1st crossing found out of 4 total crossings.

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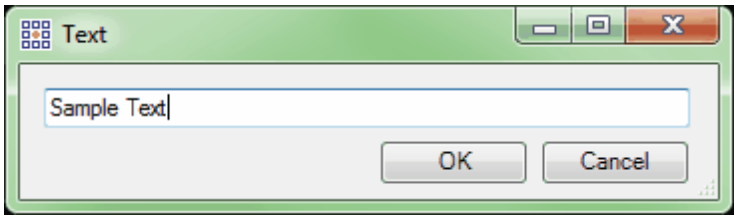


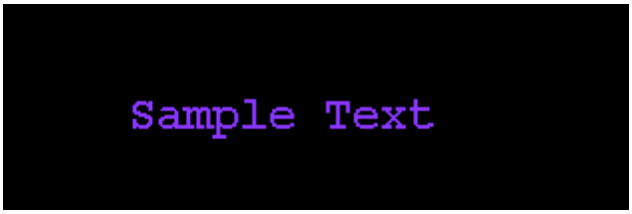




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Place Text: This tool allows the user to add text to the LAS Map View window. To use this tool, click on the 'Place Text' button, then left-click in the LAS Map View window where the text should appear. At this time, a 'Text' window will appear. Enter the desired text into the window and choose the 'OK' button to place the text in the project. Choosing 'Cancel' will cancel the place text action.

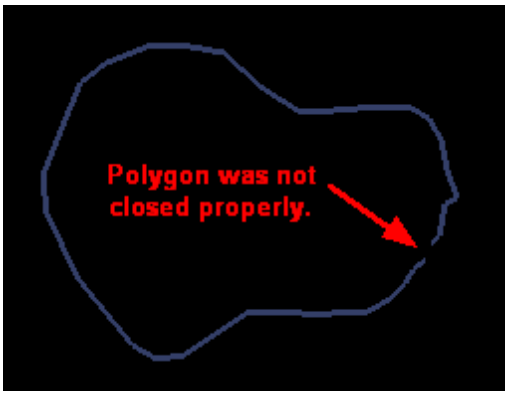




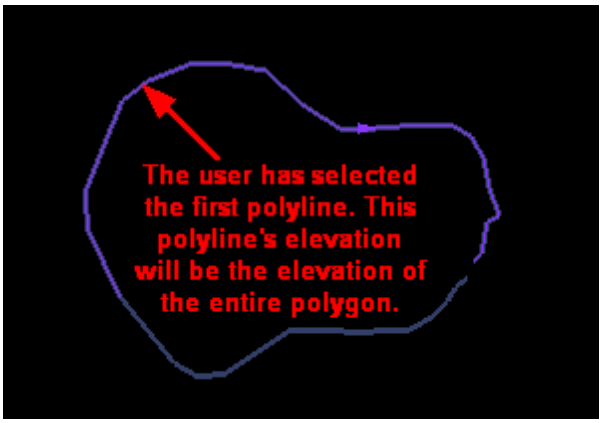
Form Polygon: The 'Form Polygon' tool will allow the user to create a polygon out of polylines. The tool will take two or more polylines and connect them, forming a single enclosed polygon. In the example below, the user has created two polylines and has failed to completely close them to create a polygon. To close the polygon using this tool, follow the directions below:

1. Select the **'Form Polygon'** button to close the polygon.

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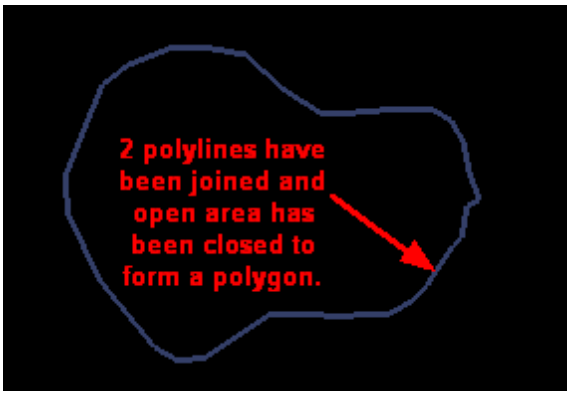


2. Select the first polyline by left-clicking on it. This first polyline selected should be the polyline with the most correct elevation. The elevation gathered from the first polyline will be transferred to the second polyline selected to create a polygon with a single elevation.

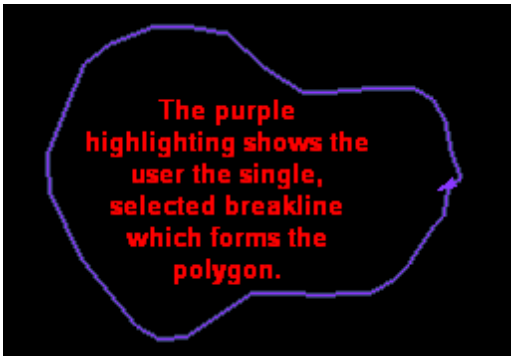


3. Left-click on the second polyline which is to be connected with the first to create the new polygon. There should be no selected polylines after this step because the polylines have now been joined in a polygon. Note that the area in which the polygon was not closed previously is now closed.

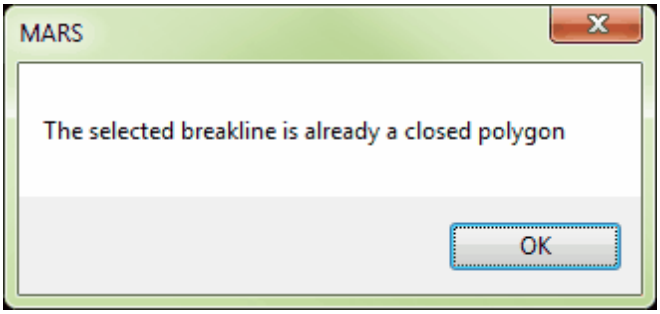
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4. Another left mouse click inside the newly formed polygon shows the user that there is only a single, uninterrupted breakline forming the polygon.



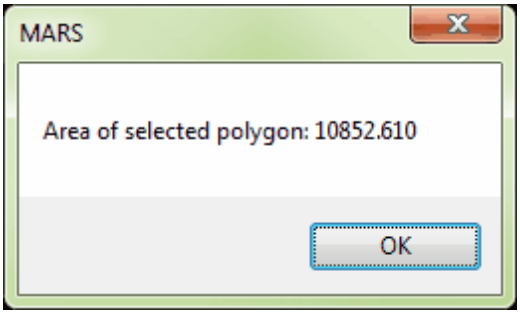
If the user attempts to use the 'Form Polygon' tool on a polygon which is already closed, the following prompt will appear:



Measure Area: This tool works only with pre-existing loaded polygon features. To use, click on

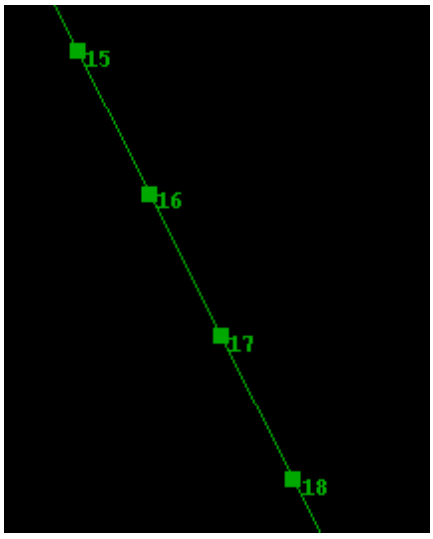
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the 'Measure Area' button and then left-click inside the appropriate polygon area. Left-click once more anywhere in the LAS Map View window to see the resulting window which will display the area of the selected polygon.





Show Breakline Vertices: This tool symbolizes the vertices for all loaded breaklines, and labels each with the ID number stored in the shapefile attribute table. Best practice is to zoom in on the area of interest before enabling this tool - it can take a significant amount of time to render if hundreds or thousands of breaklines are visible in the LAS Map View extent.



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Show Auto Pan Edge Markers: This tool toggles the display of the Auto-pan boundary markers that indicate the area of the LAS Map View window where an auto-pan (when enabled) will be done if the cursor is moved into it during breakline compilation. Auto-pan is active by default during breakline compilation as well as when creating 2D polygons and centerlines (polylines) using the 'Draw' tools on the Vector Creation 364 tab. See the Keyboard Accelerators 1880 section for info on the '**B**' key used to toggle auto panning on/off.



Reshape Feature: This tool allows existing polyline and polygon breakline features to be reshaped by 'patching in' a new section of linework rather than having to move, add, or delete one vertex at a time or re-compile the entire breakline. To use this tool, click once on the breakline to be reshaped to highlight it. It will temporarily be displayed in white with a thicker than normal line weight and an arrowhead to indicate the direction in which it was compiled. If the wrong breakline is accidentally selected, use the 'Esc' key to unselect it and exit the tool. Restart the tool and re-select the desired breakline.

- For polyline breaklines: Once the breakline has been selected, left-click once near the part of the breakline that will be reshaped to begin the patch, then cross the line with the mouse cursor and begin clicking in each location where a new vertex will be added in the reshape patch. Finish compiling the new linework by crossing back over the original breakline, left-clicking to add a final vertex and then right-clicking to end the reshaping. Only the section of the breakline between the crossing locations will be kept for the new line shape. The edited

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breakline will return to its original color and line weight and the tool will remain active for another breakline to be selected. Use the 'Esc' key to exit the tool. At this time, the Reassess Points for Ignored Ground Classification 330 tool can be used to set ground points within the Breakline Properties 'Reclass Buffer Width' value to the ignored ground class (see the Compilation Options 304 section, above). The 'Reassess ...' tool will also reclassify ignored ground points back to ground (Class 2) for points that are no longer within the 'Reclass Buffer Width' distance.

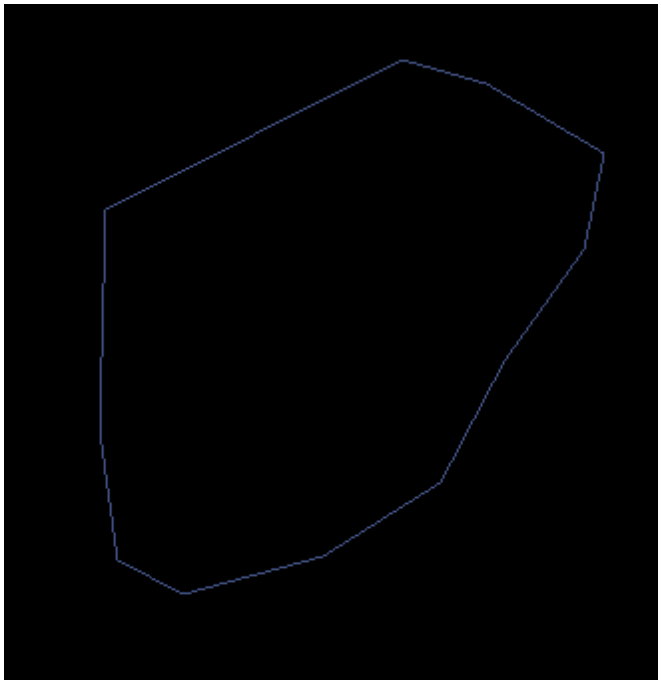
NOTE that any reshaped polylines will need to be re-draped to ground (see the Drape Selected Breaklines 339 tool, above).

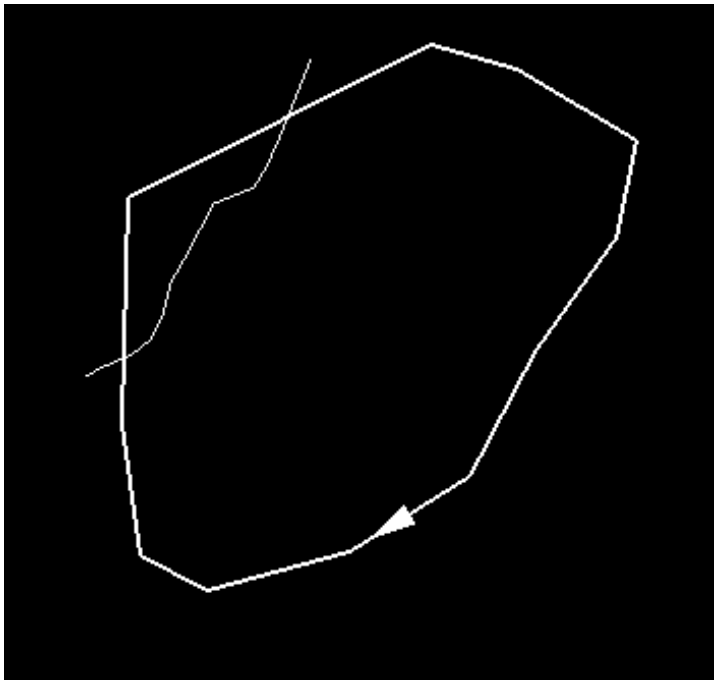
- For polygon breaklines: Once the breakline has been selected, left-click once near the part of the breakline that will be reshaped to begin the patch, then cross the line with the mouse cursor and begin clicking in each location where a new vertex will be added in the reshape patch. The patch can be started either inside or outside of the polygon, but must finish on the same side as the starting location (first vertex). Finish compiling the new linework by left-clicking to add a final vertex and then right-clicking to end the reshaping. The edited breakline will return to its original color and line weight and the tool will remain active for another breakline to be selected. Use the 'Esc' key to exit the tool. At this time, the Reassess Points for Ignored Ground Classification 330 tool can be used to set ground points within the Breakline Properties 'Reclass Buffer Width' value to the ignored ground class (see the Compilation Options 304 section, above). The 'Reassess ...' tool will also reclassify ignored ground points back to ground (Class 2) for points that are no longer within the 'Reclass Buffer Width' distance.

  NOTE that only the longest original piece of the reshaped polygon will be

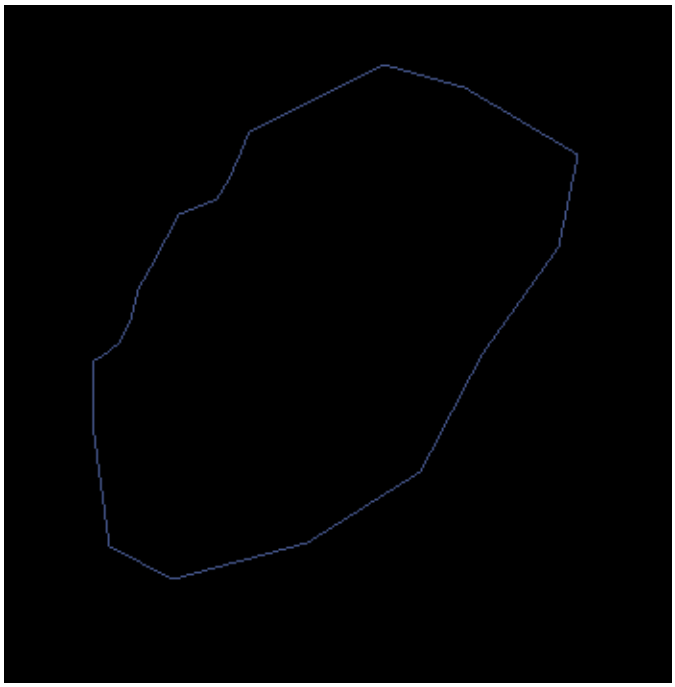
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kept. For example:





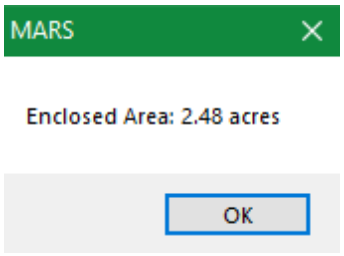
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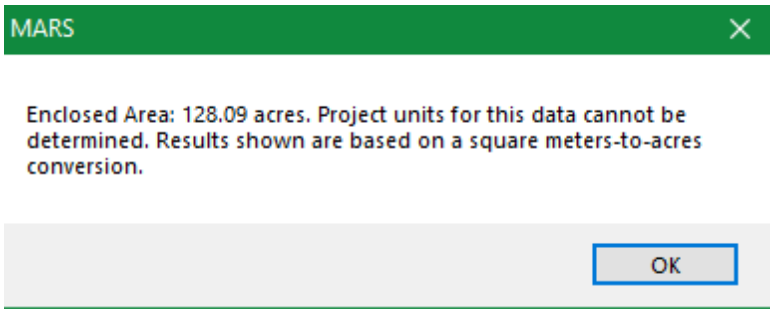
Calculate Area: This tool allows a temporary polygon to be digitized and displays the enclosed area in acres. To ensure that the correct project units-to-acres conversion is applied, the Data Layers 67 properties must be populated with a full Coordinate Reference System (CRS) using the Well Known Text (WKT) format that is part of a fully compliant LAS v1.4, PDRF 6+ file. This can be done by loading one or more LAS files that contain this information. If the Data Layer is not fully defined, acreage measurements will be based on the conversion from horizontal units of meters. If a measurement based on feet is needed and the Data Layer info cannot be set, a manual conversion will be required. For reference, one acre is equal to 43,560 $USft^2$ or approximately 4047 m^2.

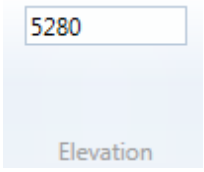
To use, left-click with the mouse to add vertices to the polygon being created. Right-click to complete the drawing and the area pop-up will appear.

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When the horizontal units are unknown, the following pop-up will appear:





Elevation: This text box allows the user to enter a new breakline elevation directly into the Breaklines Toolbar. Access directly to the toolbar makes compiling breaklines quicker and easier with fewer steps. The user can click in the text box named 'Elevation' and type in the desired elevation followed by the 'Enter' key, or use the two 'Locked Elevation Change' tools (see above) to make incremental adjustments to the displayed elevation. Every new breakline placed using a 'Z Mode' drop-down value of 'Lock' (see above) will have this elevation assigned to it.



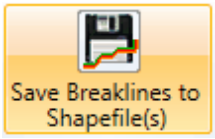
Undo Breakline: This button will undo the most recent change to any breakline. Depending on the complexity of the change and the computer's available RAM, it may be possible to

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undo several changes.

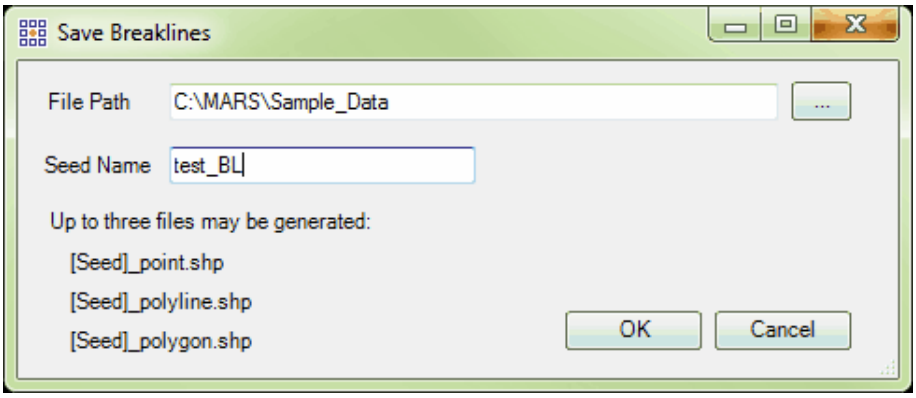


Redo Breakline: This button will redo the most recent change which was 'undone' by use of the 'Undo' button. Depending on the complexity of the change and the computer's available RAM, it may be possible to redo several 'Undo' steps.



Save Breaklines to Shapefile(s): This button allows the user to save the breaklines compiled or modified in MARS® to one or more shapefiles, depending on the changes made. Click on the 'Save Breaklines to Shapefile(s)' button and the 'Save Breaklines' window will appear. Navigate to the folder to which the shapefile(s) should be output and choose a seed name for the shapefile(s). Click 'OK' when the appropriate selections have been made. A shapefile will be saved with the user-supplied name and '_polyline' appended to that name for any breaklines compiled as polylines (e.g., along retaining walls). For any polygonal breaklines (e.g., pond/lake shorelines), '_polygon' will be appended to the name for that saved shapefile. For any break points, '_point' will be appended to the name for that saved shapefile. For any saved shapefiles, a *.prj (projection definition file) is also created if the projection information is known for the source LAS data. If the specified name for the new file already exists in the defined folder, a prompt will appear warning the user that the “Files already exist, are you sure you want to overwrite?”.

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When the 'Save Breaklines to Shapefile(s)' button is used and two or more regular (not reference) breaklines files are loaded in the Table of Contents 134, a prompt will appear:

"There is more than one breakline file loaded. Do you want to save all loaded breaklines into one file?"

Clicking '**No**' will close the prompt and do nothing. Any breaklines other than the set being edited can then be removed before clicking the 'Save Breaklines to Shapefile(s)' button again. If **'Yes'** is clicked, the 'Save Breaklines' dialog will open as shown above.

Keyboard shortcuts which apply to breakline compilation:

1. The **'Esc'** key: Using the 'Esc' key will exit the user from any tool or dialog window which is opened or activated from the breaklines tab.
2. The **'Shift'** key: The 'Shift' key will allow the user to snap a breakline which is currently being compiled to another breakline. To use this tool, the user must hold the 'Shift' key down while clicking the mouse in the near vicinity of the desired snap point. The user may specify which point the new breakline should snap to by using the 'Snap Mode' drop-down list on the breaklines tab. The user may choose to have the newest breakline snap to 'StartEndVertex', 'Vertex', 'NearestPoint', or 'MidPoint'. If either 'NearestPoint' or 'MidPoint' are chosen, a vertex will be created in the existing breakline upon snapping

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completion.

3. The **'Ctrl'** key: The 'Ctrl' key shortcut allows the user to copy or “borrow” a Z-value from an existing breakline and use this Z-value as the beginning of a new breakline. To do this, the user must hold down the ‘Ctrl’ key while using the mouse to left-click on the breakline which has the desired Z-value. Then, while still holding the ‘Ctrl’ key down, left-click the mouse where the new breakline is to begin. At this time the compilation of a new breakline will continue with the “borrowed” Z-value.
4. The **'B'** key: Toggle on/off the auto-pan mode that is triggered during breakline compilation when the cursor nears the edge of the LAS Map View window.
5. The **'V'** key: Toggle on/off the auto-pan edge markers.
6. The **'Alt'** key: Holding the 'Alt' key down while in breakline compilation mode allows the user to pan across the data when auto-pan is toggled off. The cursor will temporarily change from the compilation symbol (cross-hair) to a pan symbol (hand) when the left mouse button is clicked and dragged. Release the 'Alt' key to resume compilation.
7. The **'Ctrl-B'** key: Toggle display of breaklines on/off.
8. The **'Ctrl-M'** key: Allow display of only the ground point classification (2) and the ignored ground classification (20).
9. The **'Ctrl-T'** key: Toggle Fast TIN on/off.
10. The **'Ctrl-Z'** key: Undo the last vertex drawn when placing a breakline.
11. The **'Shift-B'** key: Quick save of breaklines without confirmation (when path/name has previously been established).

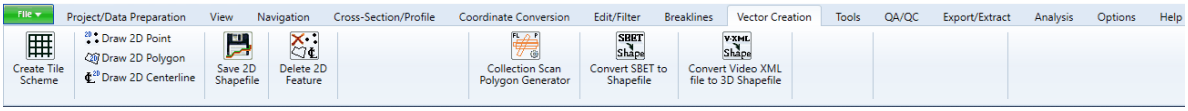
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3.9 Vector Creation Tab

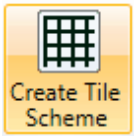
Vector Creation Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Vector Creation Tab:

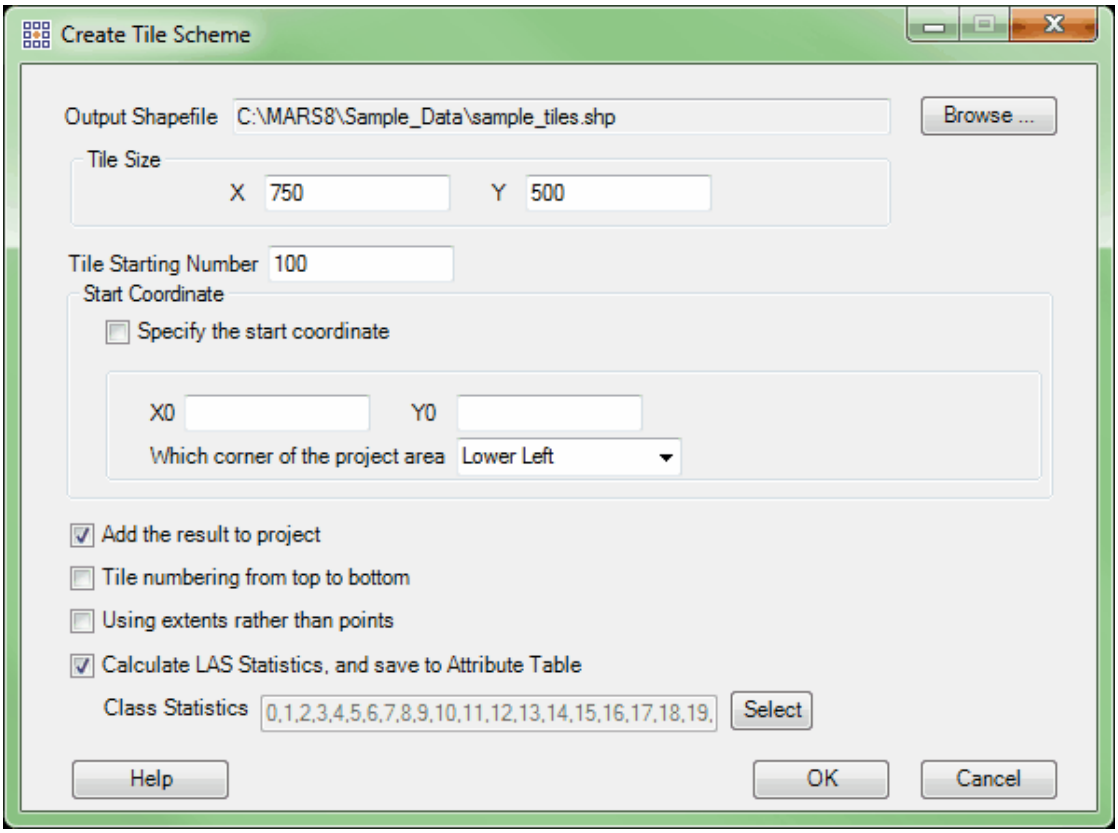


For any LAS tools (including 'Collection Scan Polygon Generator') that allow files to be pathed out without loading them in the Table of Contents in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.



Create Tile Scheme: This option allows the user to create a unique tile layout. The newly created tile layout will be found under the 'Tiles' 121 layer in the Table of Contents where only one shapefile can be loaded at a time. If a tile shapefile is already loaded under the 'Tiles' layer, it will be removed and the new tile layout will be loaded in its place automatically.

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- ✓ **Output Shapefile:** Click the 'Browse' button to designate an output folder and name for the tile shapefile being created. Once this is completed, click 'Save'. When a tile shapefile is generated, a *.prj (projection definition file) is created if the projection information is known for the source LAS data.
- ✓ **Tile Size:** Specify an X and Y length for the sides of each tile. A larger number in either text box will denote a larger tile.
- ✓ **Tile Starting Number:** Choose a number for the Tile Name labeling to start at. The tiles will be named upward from the number specified (for example, if 100 is the starting number, tiles numbered 101, 102, 103, 104... will follow).
- ✓ **Start Coordinate:** If the user would like to specify the coordinate at which the tile layout should start, check the 'Specify the start coordinate' check box. The X and Y coordinates may be specified in the text boxes following this option. After specifying

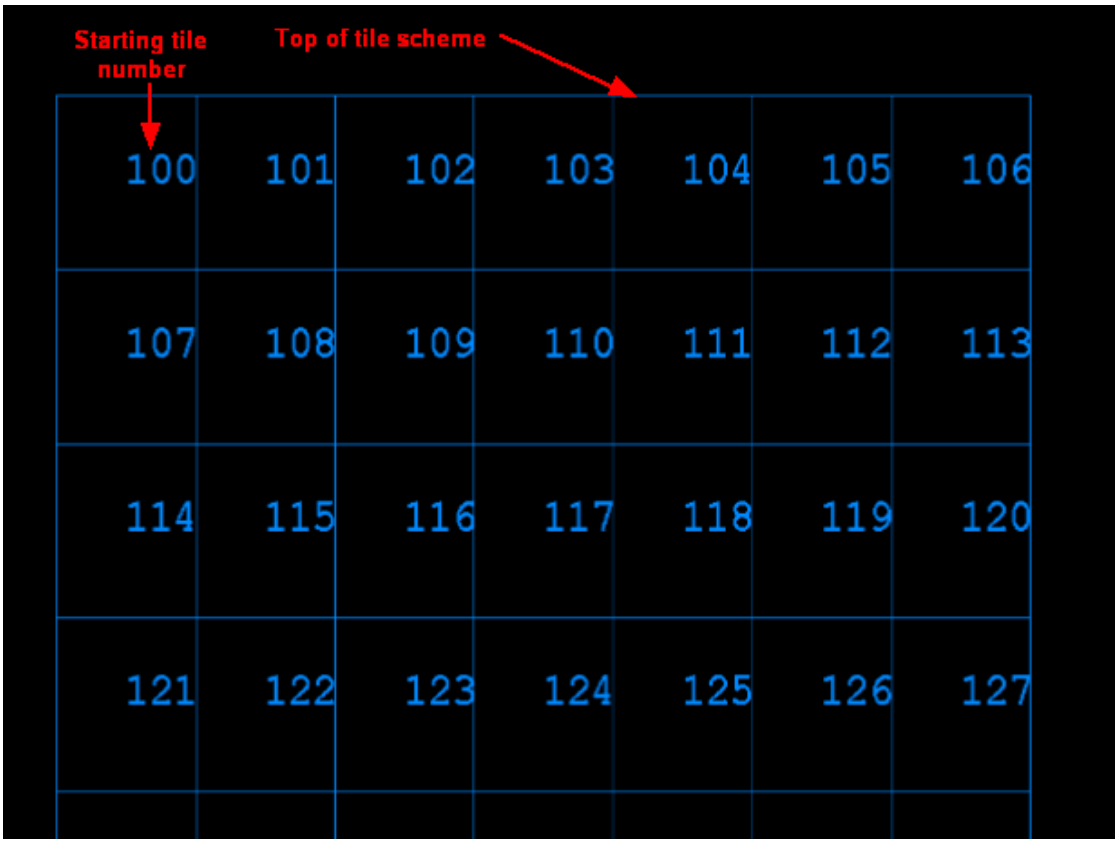
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the coordinates, the user may further define which corner of the created tile layout that the coordinates will represent. The user may choose from: Lower Left, Upper Left, Upper Right, Lower Right.

- ✓ **Add the Result to Project:** Checking this box option will load the new tile layout to the project after it is created. If a tile shapefile is already loaded into MARS® under the 'Tiles' tab and this option is checked, the shapefile already in MARS® will be removed and the new tile shapefile will take its place under the 'Tiles' tab. If this box is left unchecked, the new shapefile will not be loaded into MARS® upon creation, but it can be found in the output folder.
- ✓ **Tile numbering from top to bottom:** If this box is checked, the tiles will be labeled starting at the top left tile of the tiling layout and count upward, labeling tiles from left to right. When the end of the row is reached, the labeling will continue on the second row from the top on the left most tile and continue from left to right. If this box is left unchecked, tile labeling will begin in the bottom right tile in the tiling layout. Tiles will be labeled counting upward from left to right. When the end of the row is reached, labeling will continue in the second row from the bottom in the left most tile and count upward from the left end tile to the right end tile. See the screen shots below for visual examples.

EX: The following is an example of tile labeling with the 'Tile numbering from top to bottom' option chosen.

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EX: The following is an example of tile labeling without the 'Tile numbering from top to bottom' option chosen.

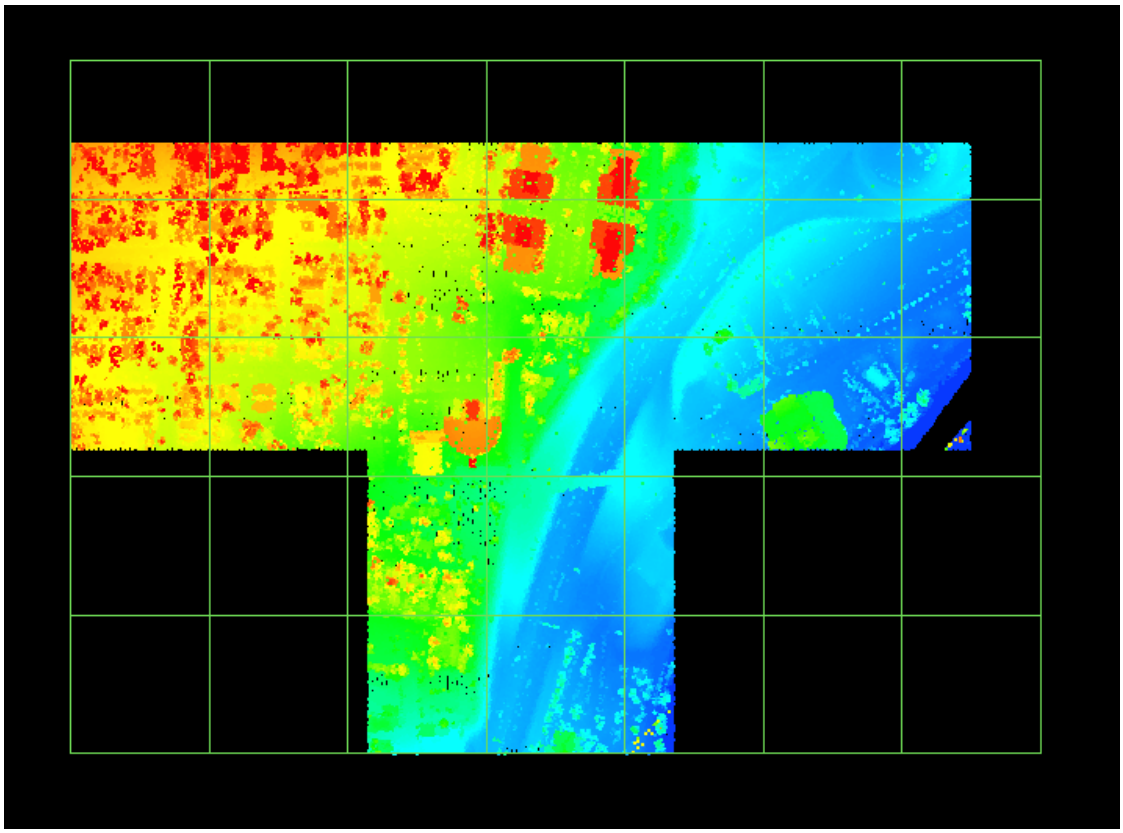
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✓ **Use extents rather than points:** Checking this option will produce an MBR rectangular tile layout that incorporates the extents of the data. In this case, some tiles in the tile layout that is produced may be empty tiles. To create a tile layout which only creates tiles which carry data, uncheck this option.

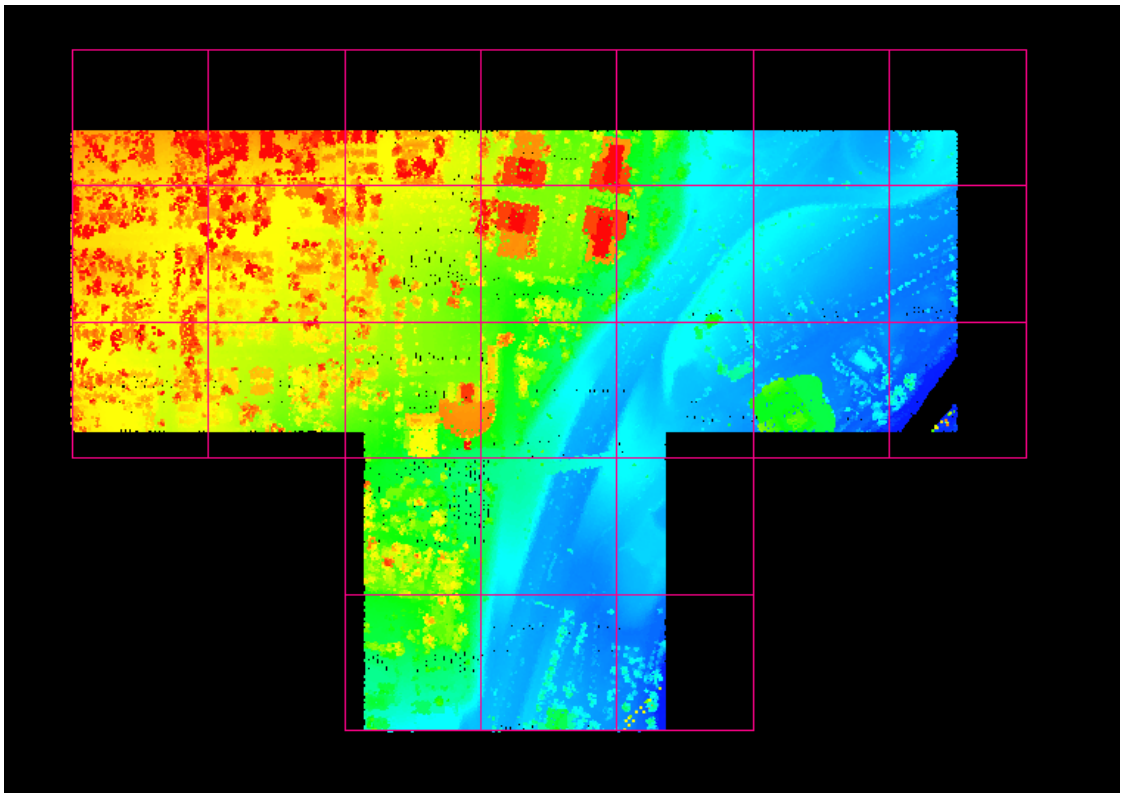
Ex. Tile layout created with the 'Use extents rather than points' option checked. Some empty tiles are produced to make the tiling layout rectangular.

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Ex. Tile layout created with the 'Use extents rather than points' option unchecked. Empty tiles are avoided and the tiling layout is produced based on LiDAR points instead of the data extents.

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✓ **Calculate LAS Statistics, and save to Attribute Table:** This option allows the user to create statistics for each LAS tile. By choosing this option, the user will make the 'Class Statistics' option available - the classes to be included in the statistics can then be selected. This option will populate the following statistics in the output tile shapefile attribute table:

ID: A uniquely generated ID number for each tile created.

TName: The TName is a uniquely-generated tile name with a starting number specified by the user.

AREA: The area in square project units of a particular tile.

ALLPCOUNT: A count of the total number of points within a particular tile.

DENSITY: The point density in points per square unit (using first

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returns only).

AVG_GSD: The average GSD (ground sample distance).

X_MIN: The x axis (easting) minimum within a particular tile.

X_MAX: The x axis (easting) maximum within a particular tile.

Y_MIN: The y axis (northing) minimum within a particular tile.

Y_MAX: The y axis (northing) maximum within a particular tile.

Z_MIN: The z axis (elevation) minimum within a particular tile.

Z_MAX: The z axis (elevation) maximum within a particular tile.

Z_DELTA: The difference between Z_MAX and Z_MIN within a particular tile.

COLL_SCAN: A listing of the different collection scan numbers which overlay a particular tile.

GPS_MIN: The GPS time (timestamp) minimum found within a particular tile.

GPS_MAX: The GPS time (timestamp) maximum found within a particular tile.

MIN_INT, MAX_INT, MEAN_INT, MED_INT, and **MODE_INT:** Various intensity value statistics.

RETURN_0: The number of 'other' returns found within a particular tile (returns that are missing or have incorrect point family info).

RETURN_1 through **RETURN_15:** The number of first returns through fifteenth returns (listed in individual attribute fields) found within a particular tile.

SYNTHETIC: The number of points bit-flagged as 'Synthetic' found within a particular tile.

MKP: The number of points bit-flagged as 'Model Key-point' found

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within a particular tile.

WITHHELD: The number of points bit-flagged as 'Withheld' found within a particular tile.

OVERLAP: The number of points bit-flagged as 'Overlap' found within a particular tile.

Class0 through **Class255:** The number of points in each class (listed in individual attribute fields) is recorded per tile.

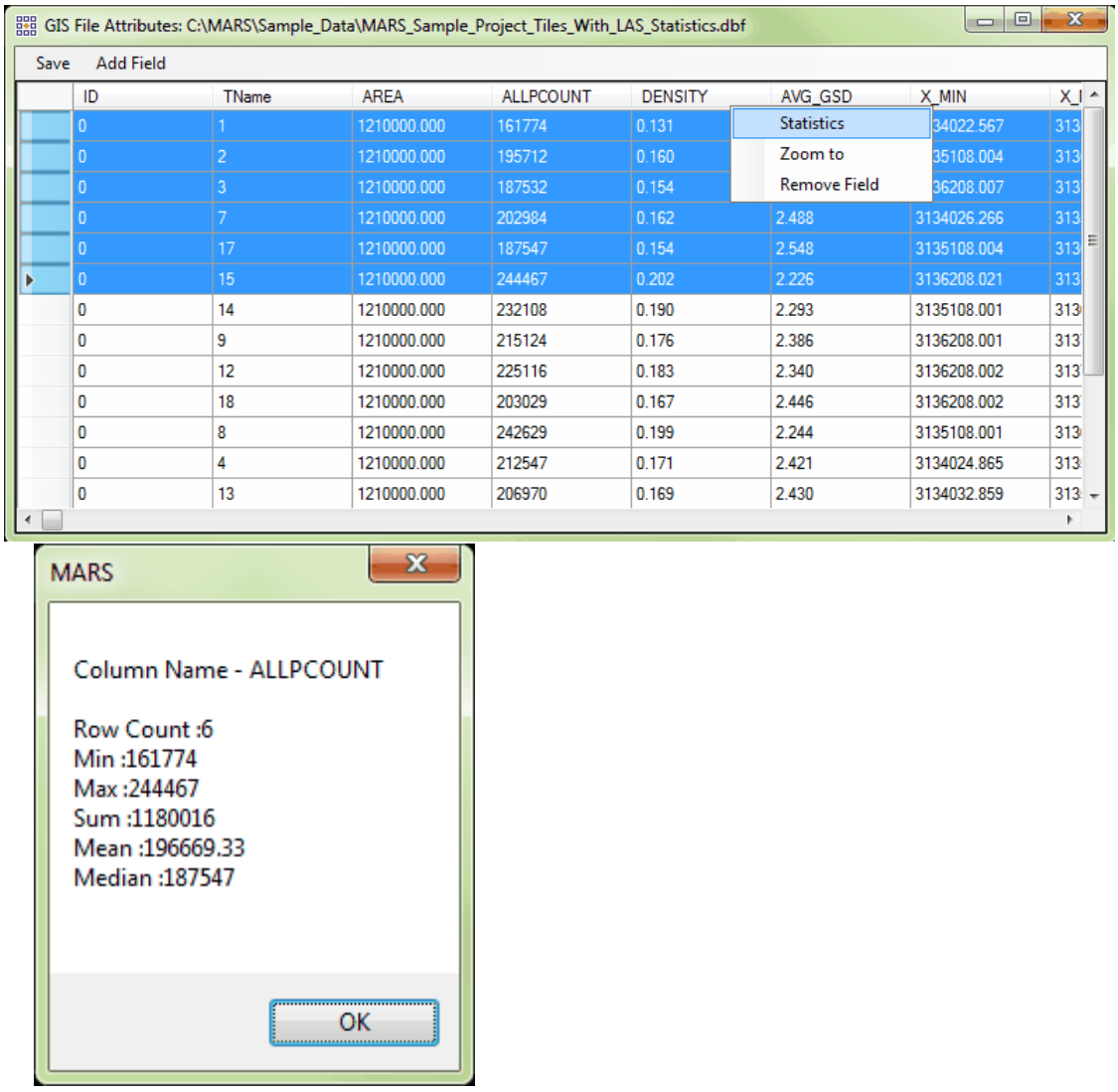
ClassWH0 through **ClassWH255**: The number of Withheld bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

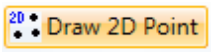
iShape: A MARS®-specific value that is not relevant for the user.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>' fields that are zeroed out for every tile will be omitted from the final attribute table to simplify analysis.

It is also possible to view the statistics of attributes in a shapefile. The user may view the statistics of a single attribute, the statistics of an entire row or column, or the statistics of an entire table. Highlight the attributes of which statistics are to be viewed, right-click and choose 'Statistics'. The resultant table will tell the user the following statistics: the row count, minimum, maximum, sum, mean (average), median, and mode of every attribute. To select multiple attributes for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In the example below, the user is choosing to view the statistics of six rows of data for the 'ALLPCOUNT' field. The resulting statistics are also shown below.

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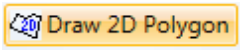




Draw 2D Point: Allows the user to create 2D points using the loaded LiDAR, vector, and/or image data as a reference. Multiple points can be created after the tool has been clicked - use a right-click, press the 'Esc' key, or choose another tool button to dismiss the tool. The keyboard shortcut '**Ctrl-Z**' can be used to 'undo' placed points. The points are created in memory, but will be stored in a project file (MPD) when a new one is created or a loaded one is saved. To save the points created with this tool as a shapefile, use the '**Save 2D Shapefile**'

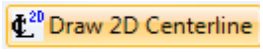
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button (see below).



Draw 2D Polygon: Allows the user to draw a 2D polygon using the loaded LiDAR, vector, and/or image data as a reference. Multiple polygons can be created be clicking the tool before drawing each one. The keyboard shortcut '**Ctrl-Z**' can be used to 'undo' placed vertices. Polygons are created in memory, but will be stored in a project file (MPD) when a new one is created or a loaded one is saved. To save the polygons created with this tool as a shapefile, use the '**Save 2D Shapefile**' button (see below).

- When drawing with the 'Draw 2D Polygon' tool, MARS® is equipped with an **auto-pan** feature to aid in drawing a large polygon that exceeds the window extent.
- To turn off the auto-pan feature, select the **'B'** quick key on the keyboard. To toggle auto-pan back on, select this key again.
- To pan while auto-pan mode is turned off, hold down the **'Alt'** key on the keyboard which will temporarily turn the cursor from collection mode to pan mode and allow the user to move the data across the display to a new location.



Draw 2D Centerline: Allows the user to draw a 2D centerline (polyline) using the loaded LiDAR, vector, and/or image data as a reference. Multiple polylines can be created be clicking the tool before drawing each one. The keyboard shortcut '**Ctrl-Z**' can be used to 'undo' placed vertices. Polylines are created in memory, but will be stored in a project file (MPD) when a new one is created or a loaded one is saved. To save the polylines created with this tool as a shapefile, use the '**Save 2D Shapefile**' button (see below).

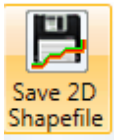
- When drawing with the 'Draw 2D Centerline' tool, MARS® is equipped with an **auto-pan** feature to aid in drawing a long polyline that exceeds the window extent.
- To turn off the auto-pan feature, select the **'B'** quick key on the keyboard. To toggle

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auto-pan back on, select this key again.

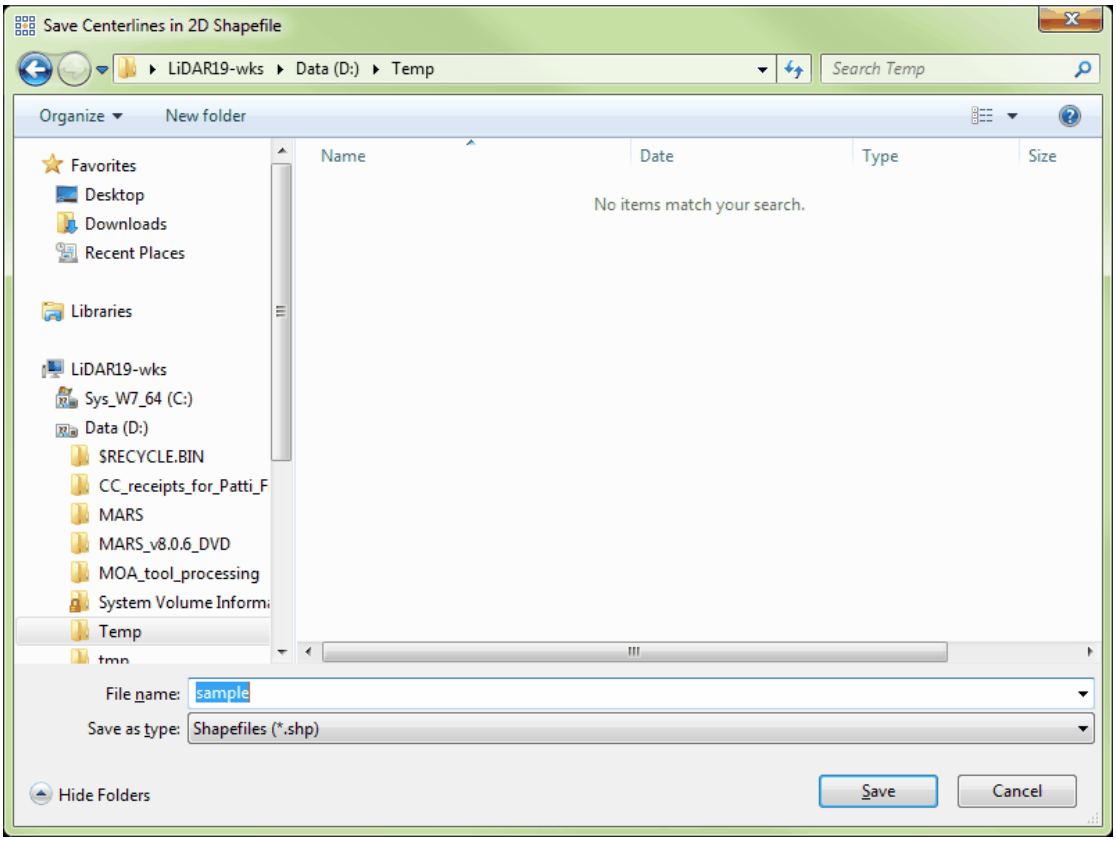
- To pan while auto-pan mode is turned off, hold down the **'Alt'** key on the keyboard which will temporarily turn the cursor from collection mode to pan mode and allow the user to move the data across the display to a new location.

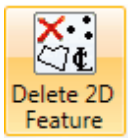
Please see the Vectors 95 topic under the Table of Contents 67 section for more information on storing vectors in an MPD.



Save 2D Shapefile: Allows the user to save the points, polygons, and centerlines created in the project to 2D shapefiles - one file per geometry type. Navigate to the folder in which each shapefile is to be saved, and click the 'Save' button once the new shapefile has been named. When the shapefile is saved, a *.prj (projection definition file) is created if the projection information is known for the loaded LAS data. Once the point, polygon, or centerline data has been saved as shapefiles, it will be unloaded from MARS®. To reload any newly saved shapefile (s), click the **'Add Reference Shapefiles'** button on the Project/Data Preparation Tab 162 and the shapefile(s) can be loaded as vector data to MARS® for further use.

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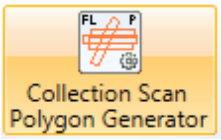




Delete 2D Feature: Allows the user to delete drawn 2D Point, Polygon, and/or Centerline features before they are saved in an MPD or to a shapefile. Features can also be deleted from a loaded MPD. After clicking the tool, left-click once on a feature to highlight it (it will change to the selected features color), then left-click again to delete it. While highlighted, right-clicking will de-select it.

More information about editing shapefiles can be found in the 'Show Shapefiles' section of the Displaying Data tutorial.

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Collection Scan Polygon Generator: This tool creates a polygonal shapefile based on LAS collection scan (swath) extents. Each collection scan file will result in one polygon feature in the final, merged shapefile.

Input and Running Options:

Navigate to a folder containing the LAS files to be used in generating swath footprint polygons by clicking the browse button to the right of the **'Folder to process'** entry box.

'Perform full statistics': When this box is checked (default), full statistics per collection scan will be calculated on the classes which are specified in the **'Class Statistics'** section. Choose classes by clicking on the **'Select'** button.Attribute fields will be added to each swath record to hold these values. By default, all classes are used.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>' fields that are zeroed out for every swath record will be omitted from the final attribute table to simplify analysis.

When using the 'Perform full statistics' option, either the 'TIN' or 'Grid' algorithm can be used for edge detection:

'TIN': With this option, the edges of the polygonal shapefile(s) will be created based on the edge of the virtual TIN which is created. MARS® will use 3 points to create a TIN and the edges of the TIN will determine

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the extents of the polygonal shapefile.

'Grid': With this option, the edges of the polygonal shapefile(s) will be created based on the edges of a virtual grid (created in RAM) to cover the input data. A cell size is entered - the default is 3 (3 ground units by 3 ground units). The cell size should be greater than or equal to the ground sample distance (GSD) of the input data. MARS® looks for points within the virtual grid cells and establishes the edges of the collection scan data by determining whether or not points exist in a cell. When points are no longer located, the edge of the collection scan is confirmed.

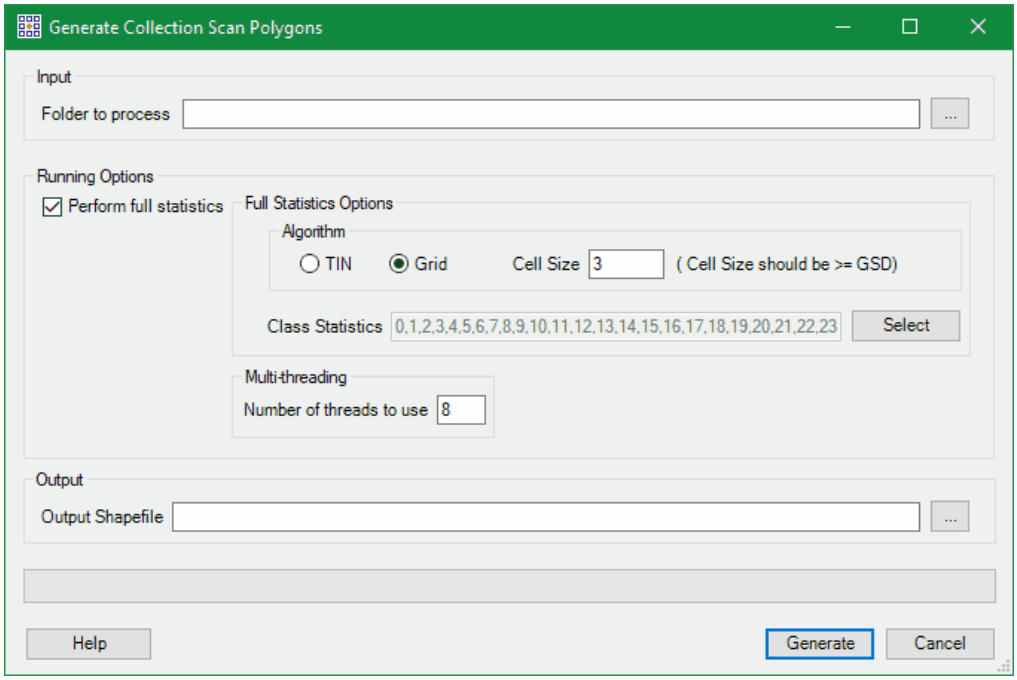
This tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

For the **'Output Shapefile'**, navigate to the folder in which the newly generated shapefile should be stored and give it a name. When all settings have been made, click the **'Generate'** button and the progress bar will display the processing status. A completion message will appear when the process has finished.

The newly created shapefile may then be brought back into MARS® as a reference Shapefile. Right-click on the shapefile in the Table of Contents and choose 'Attributes' to view a table specific to that shapefile. At a minimum, the attribute table will have a 'FILENAME' field with the name of the LAS file(s) processed, and a 'COLL_SCAN' field with the Point Source ID listed that created each attribute table record. If the **'Perform full statistics'** option was checked on for processing, the fields stored in the resulting shapefile will be similar to those

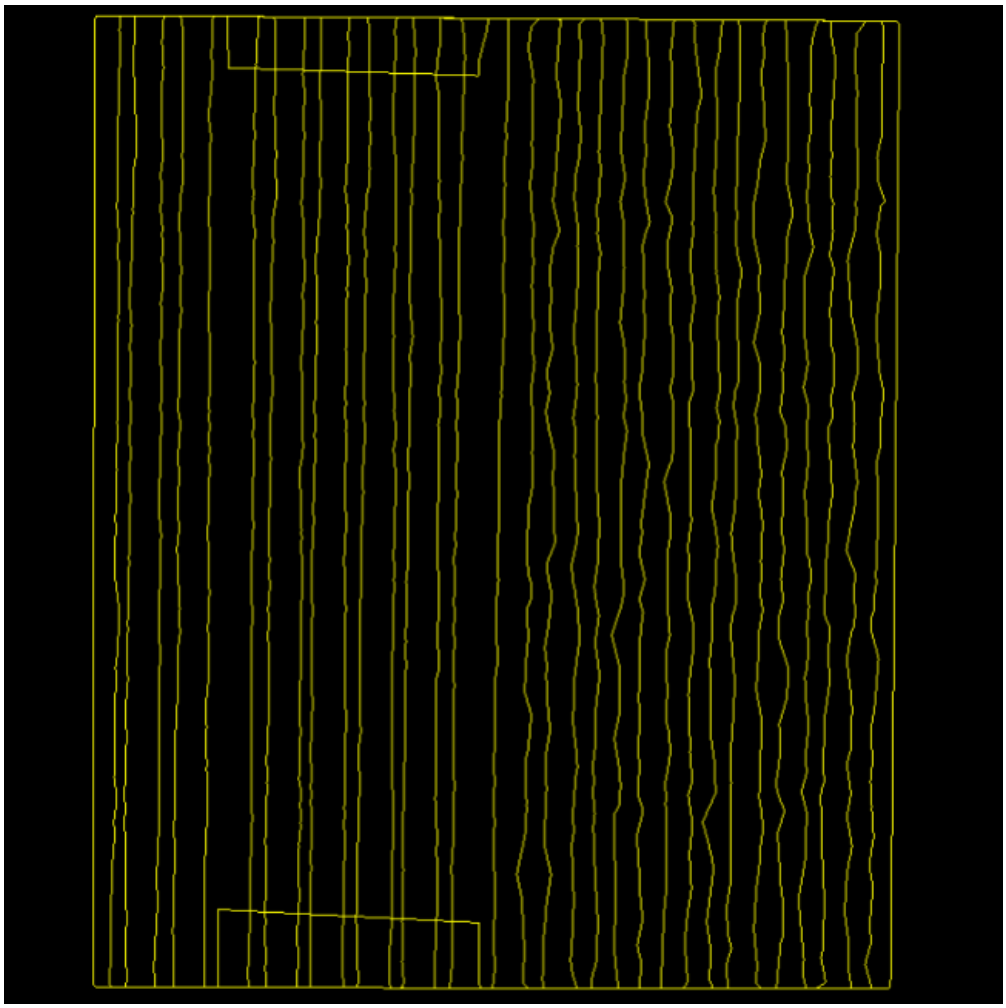
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listed in the **Create Tile Scheme** topic at the top of this help section (when the 'Calculate LAS Statistics' option is checked), except that ‘TName’ is replaced by ‘FILENAME’ to indicate the collection scans processed.



Below is an example result loaded as a Reference Shapefile into MARS®. The shapefile outlines each of the collection scans contained in the LAS files chosen. This can be a useful tool in checking the overlap between collection scans and making sure there are no gaps in the data.

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Convert SBET to Shapefile: This tool is used to convert a raw SBET, or **S**moothed **B**est **E**stimate of **T**rajectory file, into a point shapefile. This is often the final step in a typical workflow - computing the tightly integrated position and orientation solution using the correction observations, the raw GPS, and inertial data extracted from the project. The data is processed in both the forward and backward directions in order to produce the optimal solution, smoothing the effect of GPS outages and other aberrations in the data. This results in the best possible position and orientation solution for a

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given data set, usually maintaining centimetric accuracy for significantly more time and at longer distances than would be possible with traditional GPS processing. The output from this process is referred to as an SBET. The 'Convert SBET to Shapefile' tool will create a 3D shapefile (including a *.prj - projection definition file) from an SBET file, giving the user the ability to visualize the SBET overlaid on top of LiDAR data. This tool requires some previous knowledge of geodesy. Among many purposes, the 'Convert SBET to Shapefile' tool can be used to see how centered in the scan the SBET is, and the resultant shapefile can be used in the Scan Angle Filter[1118].

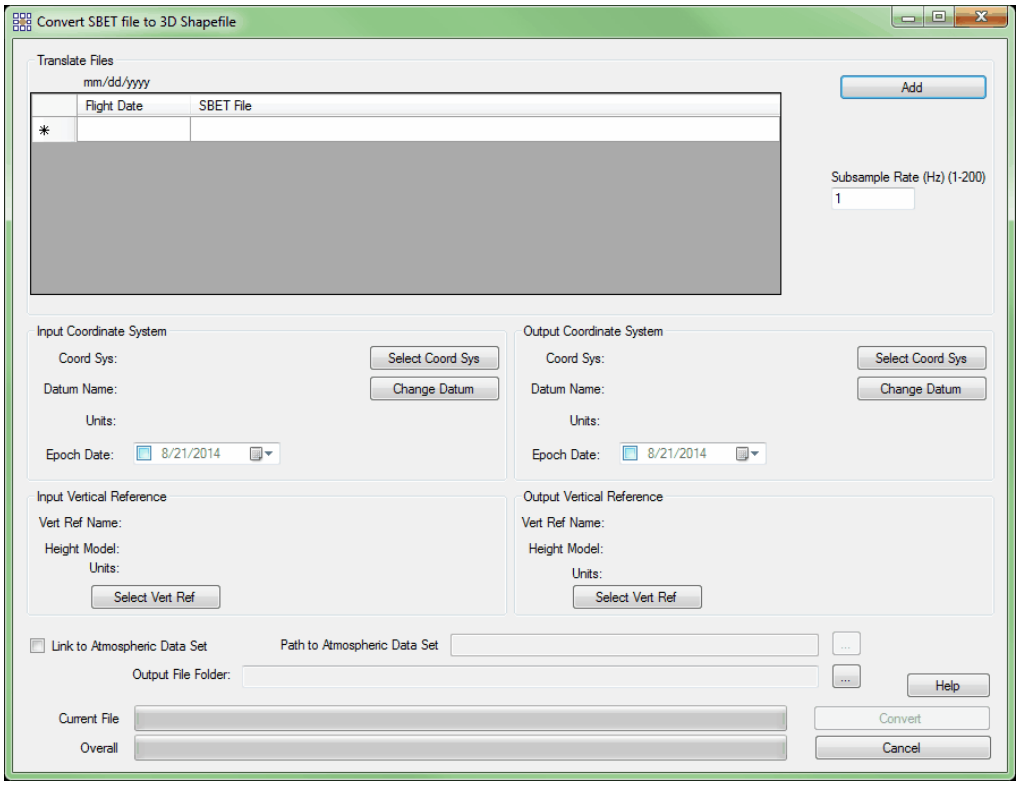
- ***'Translate Files'* section:** The user will load the SBET (*.out) file into this text box by choosing the **'Add'** button and navigating to the location of the SBET file to be converted. To remove an SBET file in this section, highlight it by clicking at the far left of the row and press 'Delete' on the keyboard.
- **Subsample Rate (Hz) (1-200):** The Subsample Rate allows the user to choose how much data from the SBET will be converted and displayed in MARS®. The user may choose any subsample rate from 1 to 200 and enter the chosen rate into the text box provided. For example, if the user chooses a subsample rate of 1, MARS® will use 1 sample of the total samples taken in one second to create the 3D shapefile. If a flight was 3 hours long, then 10,800 samples (1 per second) will be used to create the 3D shapefile of the SBET. The higher the subsample rate the more accurate the 3D shapefile representing the SBET will be, but the longer it will take to convert the file. Higher rates may also cause "Out of Memory" errors depending on the computer. A subsample rate of 1 (the default value) is detailed enough for most purposes.
- ***'Input Coordinate System'* section:** The Input Coordinate System is the horizontal reference that the SBET was created in. The user will need to enter the proper Geodetic system, with Lat/Long in degrees, which was used to create the SBET in this section. Examples include NAD83(NSRS2007) and NAD83(2011).
- ***'Input Vertical Reference'* section:** The user will need to enter the vertical references

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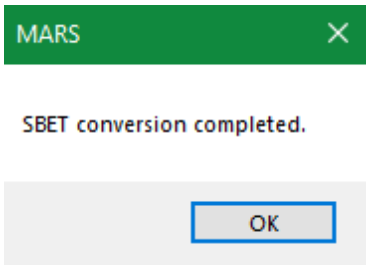
used to create the SBET in this section of the interface. This includes the vertical reference name, the height model, and the units in which the SBET was processed. Typical *.out SBET files are in Ellipsoidal Height meters.

- ***'Output Coordinate System'* section**: The Output Coordinate System, in most cases, will be the horizontal reference that the corresponding LiDAR data is in. In most cases the user will want to view the 3D shapefile created from the SBET over the matching LiDAR data. In order to do this the shapefile will need to be created with the same vertical and horizontal coordinate systems as the LiDAR data. The user will need to enter the coordinate system, datum, units, and epoch date of the related LiDAR data.
- ***'Output Vertical Reference'* section:** The user will need to enter the vertical references that the corresponding LiDAR data is in. In most cases the user will want to view the 3D shapefile created from the SBET over the matching LiDAR data. In order to do this the shapefile will need to be created with the same vertical and horizontal coordinate systems as the LiDAR data. The user will need to enter the vertical reference name, the height model, and the units of the related LiDAR data.
- **Link to Atmospheric Data Set:** When checked, allows the user to set the path to related meteorological data by clicking the ellipse  button to the right of the 'Path to Atmospheric Data Set' text box and navigating to the desired folder.
- **Output File Folder:** Navigate or key in the path to the folder which is to be the destination of the newly created 3D shapefile. The output file (or 3D shapefile created from the SBET) will be given same name as the SBET file loaded into the 'Translate Files' section, but will have the file extension *.shp.

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Once all the data has been entered into the 'Convert SBET File to 3D Shapefile' interface, the user may click on the 'Convert' button. There can be a substantial amount of wait time while MARS® reads the file and begins converting it. Once conversion has started, the user may watch the progress of the current file as well as the overall (total number of files to be converted) progress on the progress bars at the bottom of the interface. When the process is complete a prompt window, as seen below, will appear.

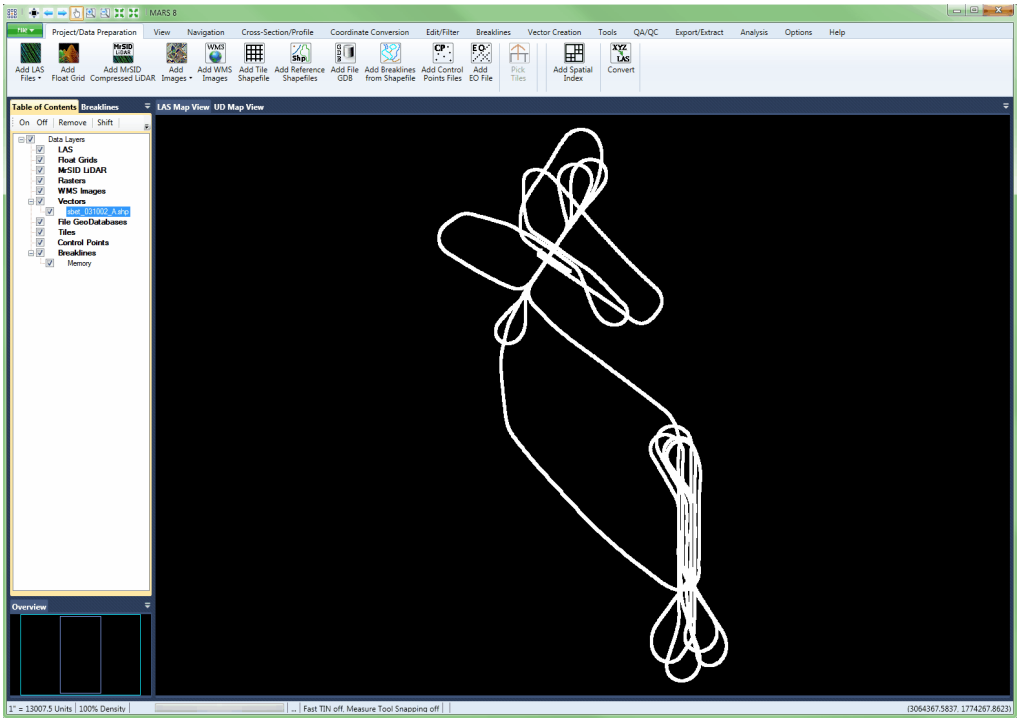


At this time, the user may add the newly converted 3D shapefile to MARS®. Do this by going

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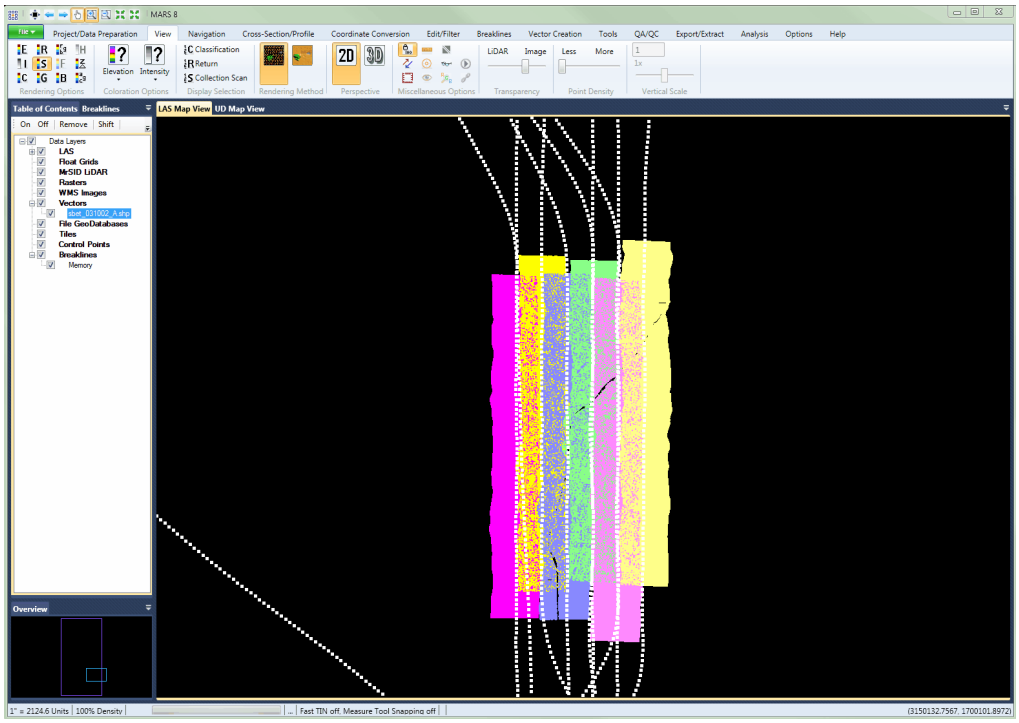
to the Project/Data Preparation Tab 162 and clicking the **'Add Reference Shapefiles'** button. Navigate to the output folder which was specified in the 'Convert SBET to 3D Shapefile' interface and select the *.shp file which matches the name of the SBET used to create it. Open this file.

In this example, an SBET has been used to create a shapefile and has been loaded into MARS®. The SBET shapefile represents the path of the plane in space and time as it flew a particular project. The shapefile is being viewed in 2D.



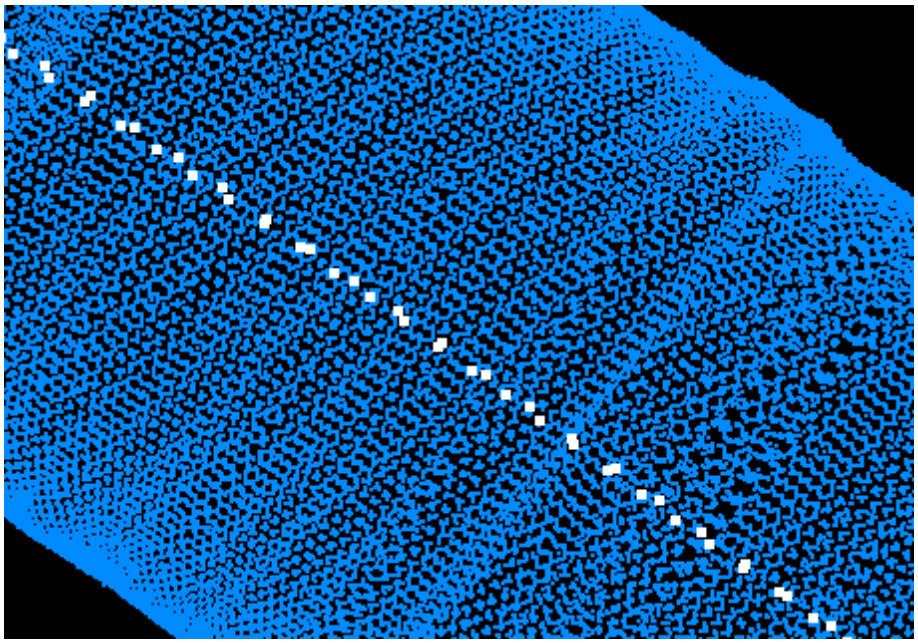
In this example, the corresponding LiDAR data has also been loaded into MARS® and is colored by collection scan. The SBET shapefile can be viewed layered over the LiDAR data.

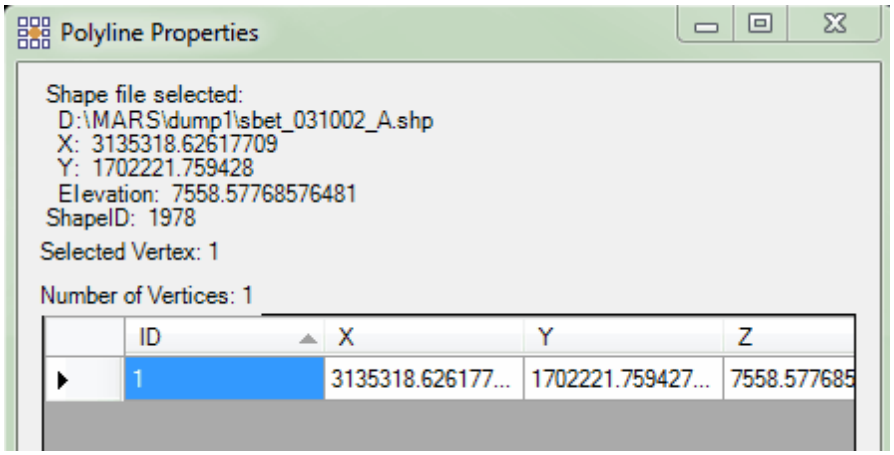
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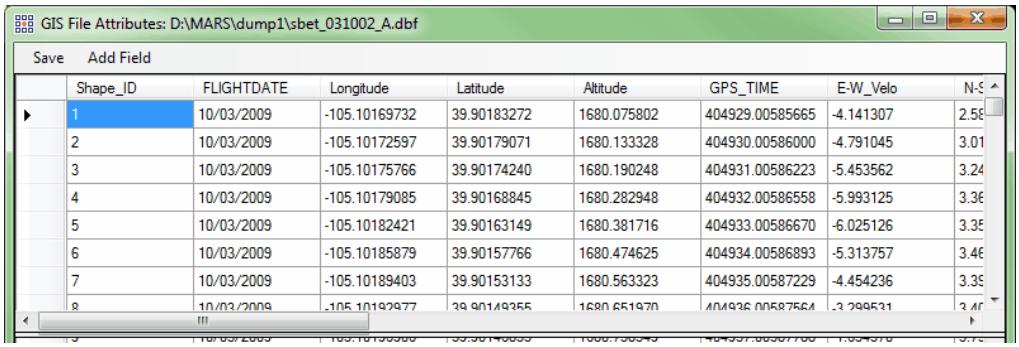
In the example below, the 3D shapefile representing the SBET file is shown in white. It may be difficult to select the white shapefile points for inspection among the LiDAR data. To select the 3D shapefile (SBET) or any other reference file among LiDAR data with the Inspect 943 tool, hold the **'Ctrl'** key on the keyboard while using the **'Inspect'** tool. This instructs MARS® to select any nearby feature, *other than a LiDAR point,* for inspection. It is possible to copy from the properties window resulting from use of the **'Inspect'** tool.

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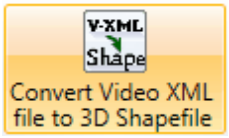




Right-click on the shapefile entry in the Table of Contents and choose 'Attributes" to see the entire table of values.



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Convert Video XML file to 3D Shapefile (not available with Academic or Evaluation license): The 'Convert Video XML file to 3D Shapefile' tool will convert any XML coordinates video file to a 3D shapefile. A projection definition (*.prj) will be created if the projection system is known for the video data.

1. To use this tool, add *.xml files by choosing the 'Add' button. The specified files will appear in the 'Translate Files' area and may be removed (using standard Windows mouse/keyboard controls) by highlighting and clicking on the 'Remove' button.

2. Define the desired output video file type by choosing *.mts, *.wmv, *.avi, or *.mpg from the drop-down under 'Video File Extension'.

3. Specify the input coordinate systems including both horizontal and vertical references.

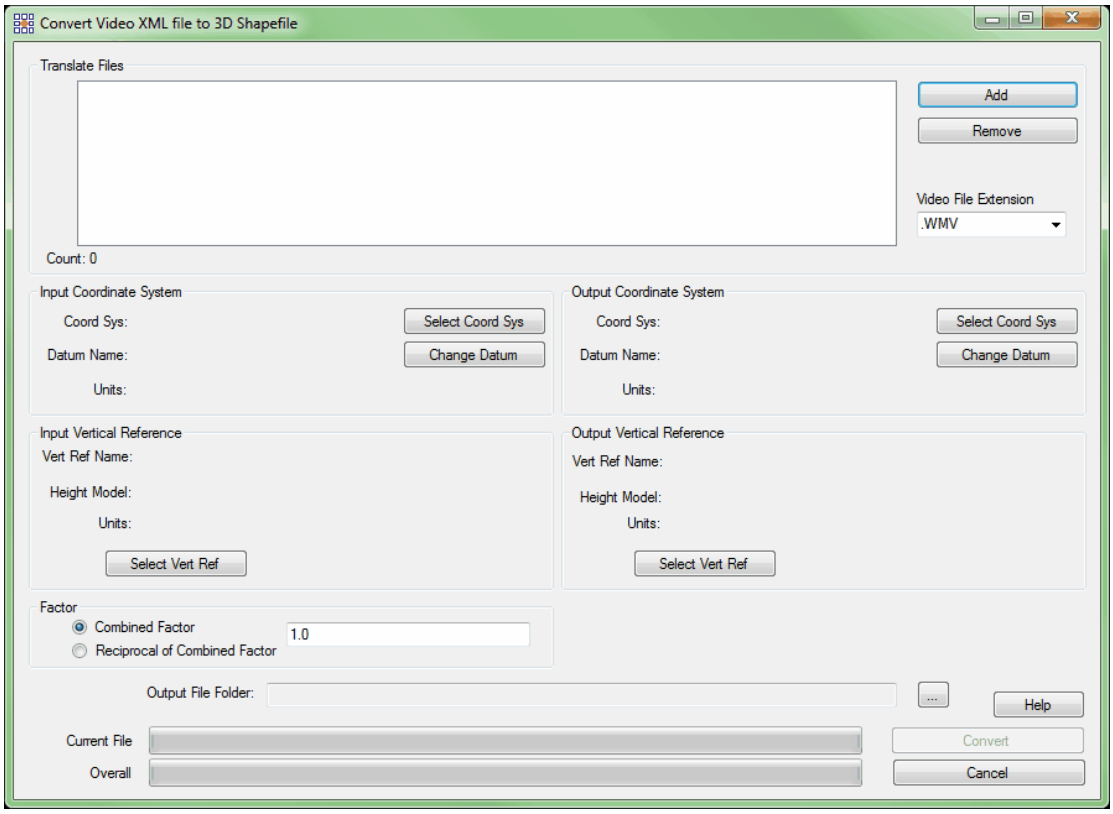
4. Define the output coordinate systems including both horizontal and vertical references.

5. Enter a 'Combined Factor' or 'Reciprocal of Combined Factor' if required for the particular coordinate conversion.

6. Choose the output folder where the new shapefile will be created.

7. Click the 'Convert' button to start the process.

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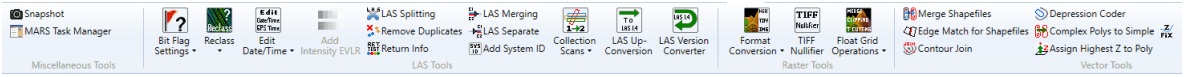
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3.10 Tools Tab

Tools Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Tools Tab:



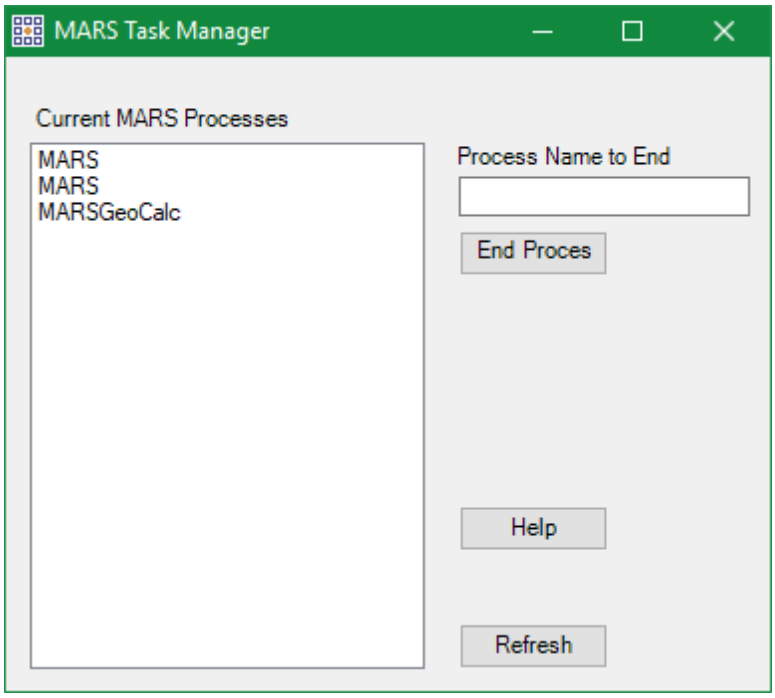
For any LAS tools that allow files to be pathed out without loading them in the Table of Contents

in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/ Data Preparation Tab 162 topic.

Snapshot: This utility creates a screen capture of the display in the LAS Map View window, which is saved to a user-defined folder. Format options include: georeferenced TIFF (with TFW world file), georeferenced JPEG (with JGW world file), BMP, GIF, PNG, or WMF. This tool works while in 2D View 835 or 3D View 837. **'Snapshot'** is also a quick way to determine what graphics card is installed in the computer. To see more information about the Snapshot utility, see the Snapshot 970 section of this Help manual.

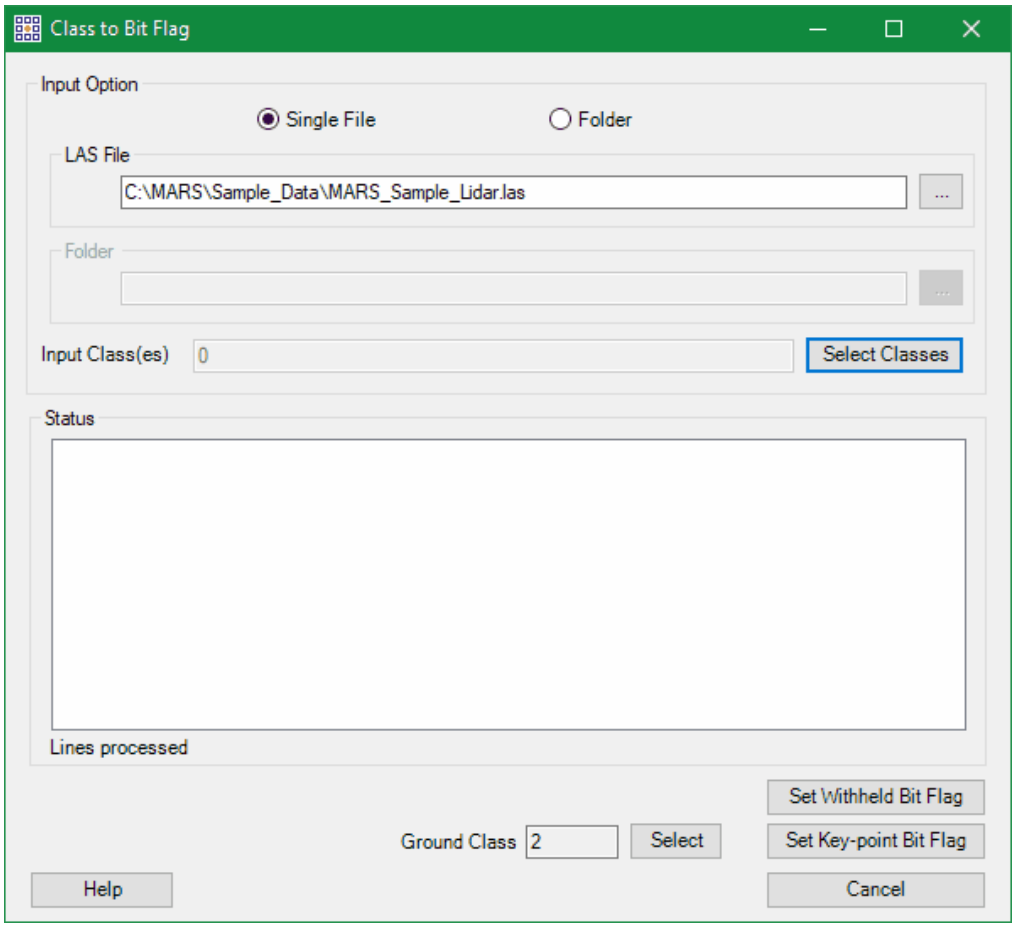
MARS® Task Manager: The task manager will allow the user to monitor and/or end multiple MARS® processes at once. To end a process, highlight it and it will appear in the 'Process Name to End' text box. Click on the 'End Process' button to end the chosen process. The session (instance) of MARS® that is running the Task Manager cannot be ended. The 'Refresh' button allows the user to refresh the 'MARS® Task Manager' without closing and re-opening the tool - ending a process will cause an automatic refresh.

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Class to Bit Flag: This tool, found under the **'Bit Flag Settings'** drop-down, sets the bit flag for Withheld points or Key-points (a.k.a. Model Key-points) that are in unique classes, in compliance with LAS version 1.4 specifications. For example, if a dataset has withheld points in Class 0 (Created, Never Classified), those points must have the withheld bit flag set to 'True'. In this case, navigate to the file or folder to be processed, set the **'Input Class(es)'** to Class 0, and click the **'Set Withheld Bit Flag'** button. For key-points, the process is very similar except that a final **'Ground Class'** must also be set. For this case, set the **'Input Class(es)'** to Class 8 (or other class holding *only* key-points) and choose the desired **'Ground Class'** that the key-points will be re-classed to after they have their key-point bit flag set to 'True'. Since ground is typically Class 2, that is the default, although another class can be selected. Withheld points and key-points should be in separate classes, so it will be necessary to run the tool once for each bit flag setting. The tool can be run on a single file or an entire folder of files.

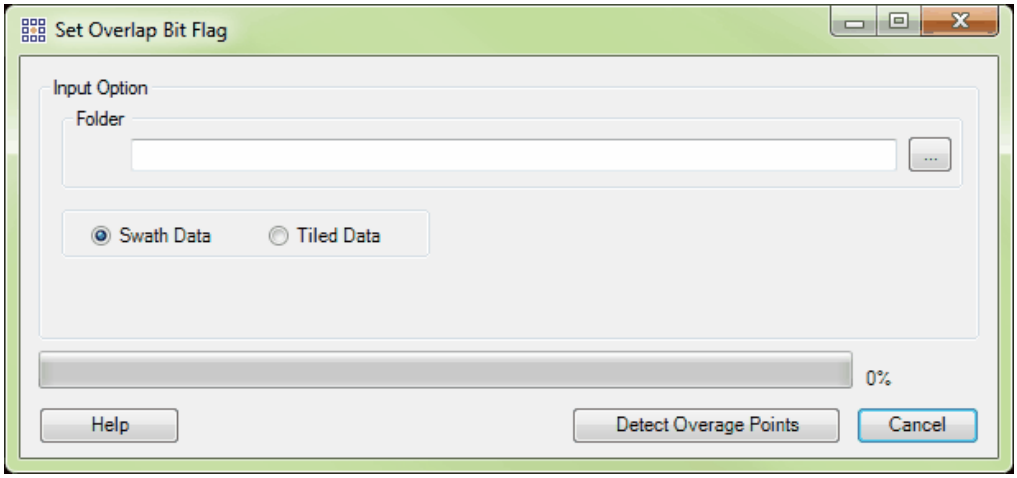
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Set Overlap Bit Flag: This tool, found under the **'Bit Flag Settings'** drop-down, analyzes the overlapping (overage) areas of a folder of swath (collection scan) or tiled files and sets the Overlap bit flag to 'True' for those points that fall within the overage area for each file. ***This flag is specified by ASPRS only for LAS v1.4 files.*** Only those points in a collection scan that are farthest from the single-coverage part of the scan and within the overlapping area (between collection scans) will be flagged. Points flagged as 'Overlap' in one collection scan will never share space with points flagged in any other collection scan. Even though a bit flag status of 'True' signifies these points as 'Overlap' per the ASPRS specification, note that the USGS refers to them as 'Overage' points in its NGP Lidar Base Specification 2.1 published in October 2019.

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Navigate to the folder containing the files to be processed by using the browse button ( ) in the **'Input Option | Folder'** section. Choose the appropriate data type - **'Swath'** (the default) or **'Tiled'**. **'Swath Data'** assumes only one collection scan per file, and **'Tiled Data'** assumes the files contain data from one or more collection scans (swaths) per tiled file. Individual multi-channel swath files must be merged into a single swath containing all points from all channels before processing (see the LAS Merging 570 tool). When the settings have been made, click the **'Detect Overage Points'** button to start the processing. ***This tool overwrites the original files.***



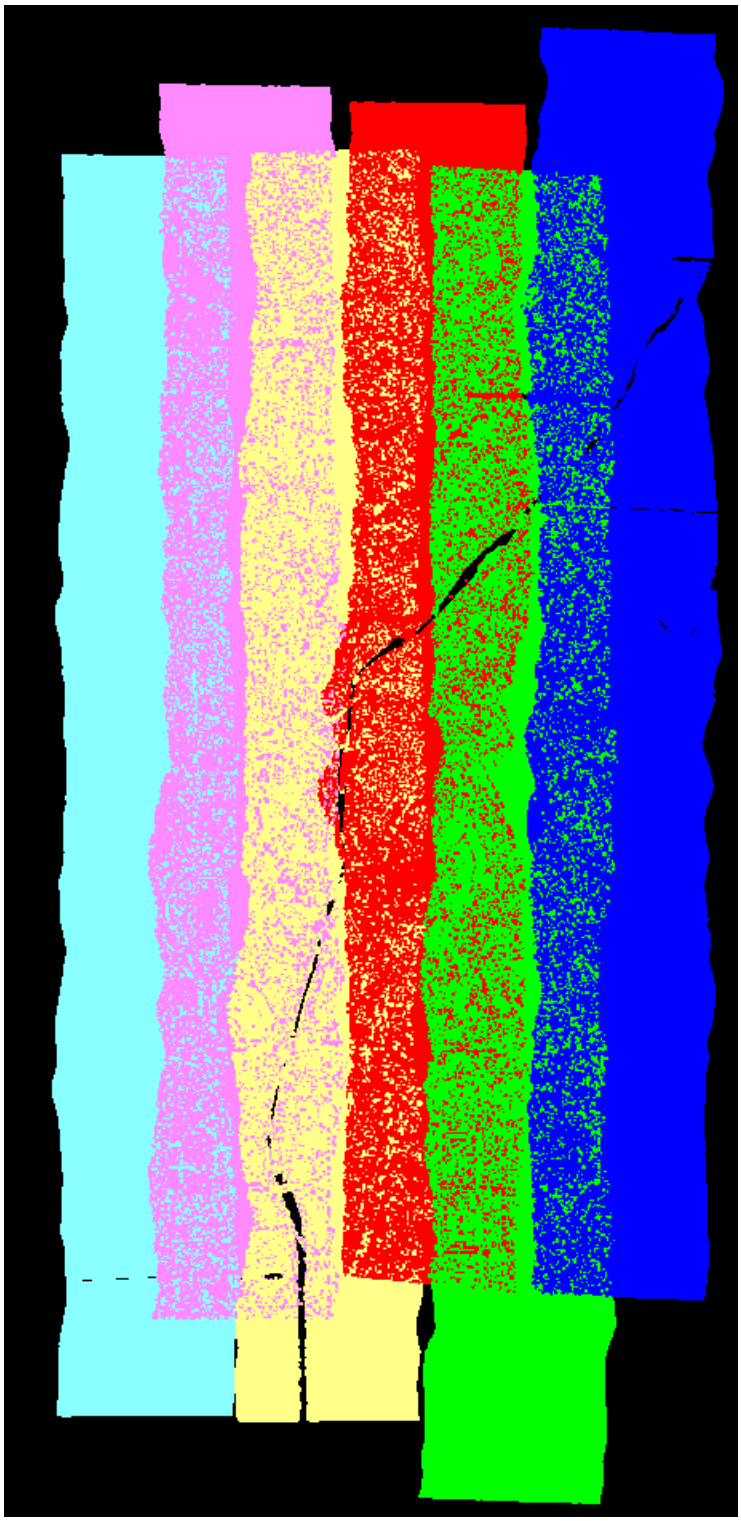
The following screen shots show examples of the **'Set Overlap Bit Flag'** results on Swath Data:

All points displayed

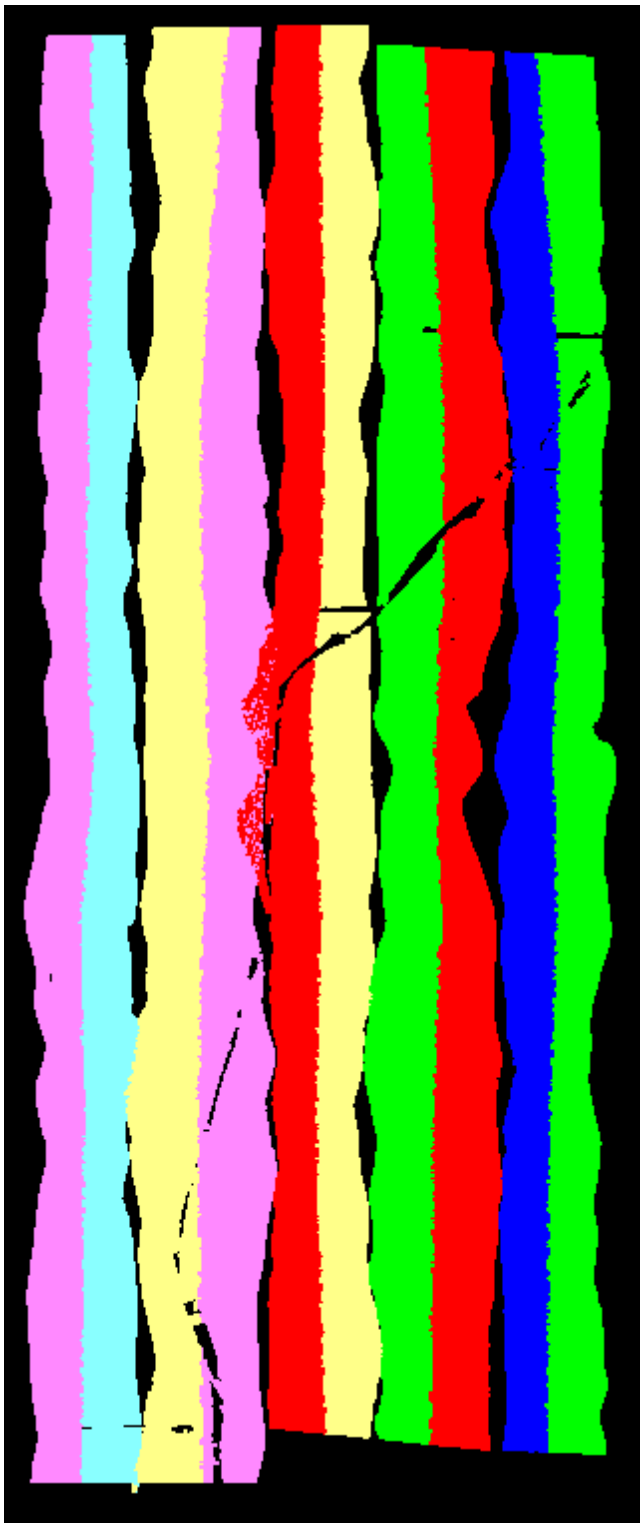
Overlap flagged points (only) displayed

Overlap flagged points turned off

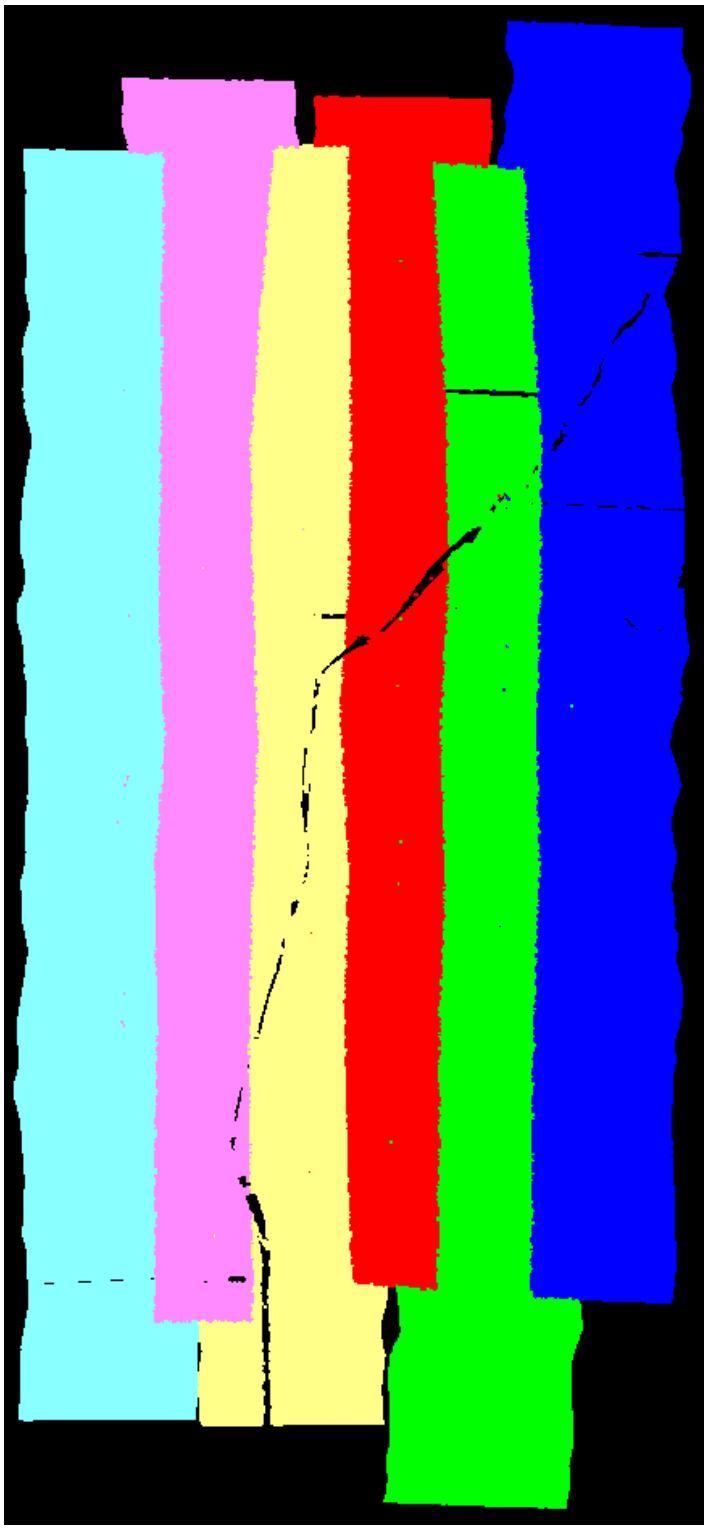
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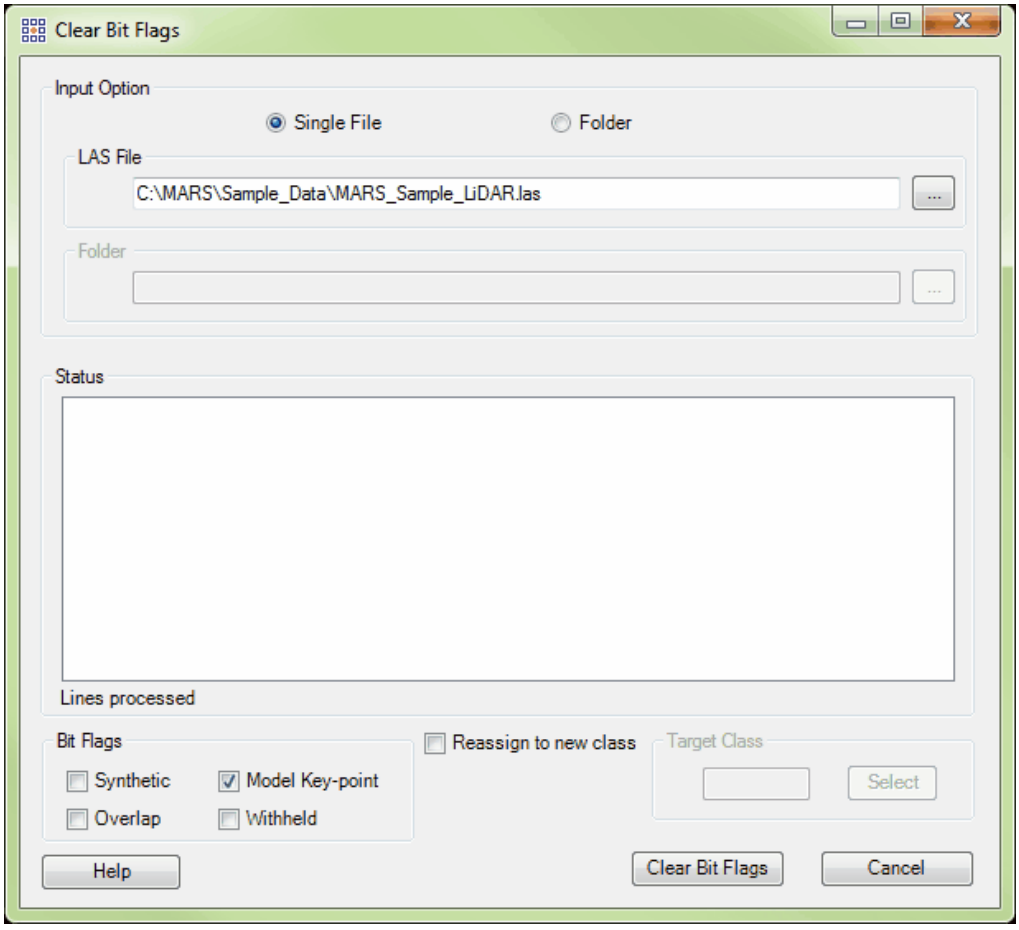


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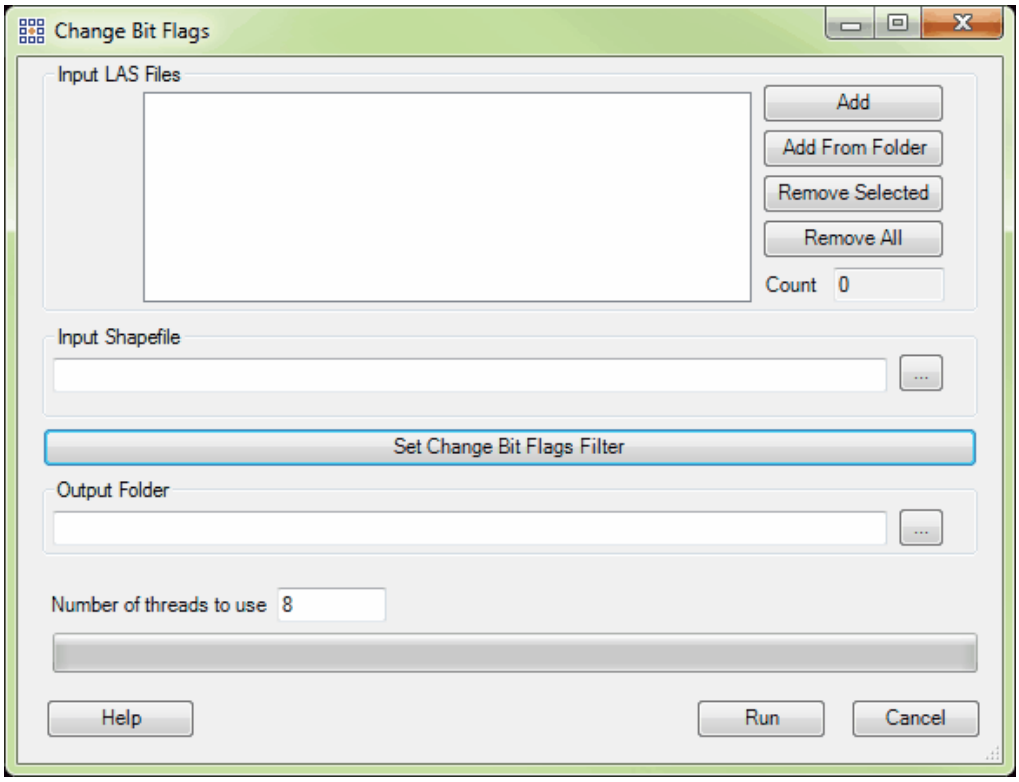
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Clear Bit Flags: This tool, found under the **'Bit Flag Settings'** drop-down, allows any of the bit flags that are not set by the LiDAR sensor to be cleared (set to 'False'). The tool can be run on a single file or an entire folder of files. Navigate to the file or folder by choosing the appropriate radio button and using the browse button to the right of the entry box that is enabled. Check the boxes for the flag(s) to be cleared and click the 'Clear Bit Flags' button. Optionally, the cleared points can be reassigned to a new Target Class to keep them separate from previously non-flagged points in the same original class. *Note that if more than one category of bit flag is checked and the reassign option is used, all the cleared points from any classes will be assigned to the Target Class.* To avoid this, run the tool separately for each category of bit flag and select a unique target Class each time. The **'Status'** area will display the files that have been processed. ***This tool overwrites the original files.***



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Change Bit Flags: This tool, found under the **'Bit Flag Settings'** drop-down, modifies the status (set/on or clear/off) of several of the bit flags that can be used with LAS v1.4 data: Synthetic, Model Key-point, Withheld, and Overlap. It can optionally reclass those points whose bit flag values have been modified, and can be (optionally) limited to a single specified collection scan. The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Navigate to the files to be modified using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. In the 'Input Shapefile' section, browse to a pre-existing polygon shapefile containing one or more polygons - these polygons will be used to define the area to be processed. The 'Set Change Bit Flags Filter' button will open the options interface where the specific parameters of the tool can be set - see the Change Bit Flags Filter 994 help topic for details on these settings. Choose an 'Output Folder' where the modified files will be stored, and then click the 'Run' button.



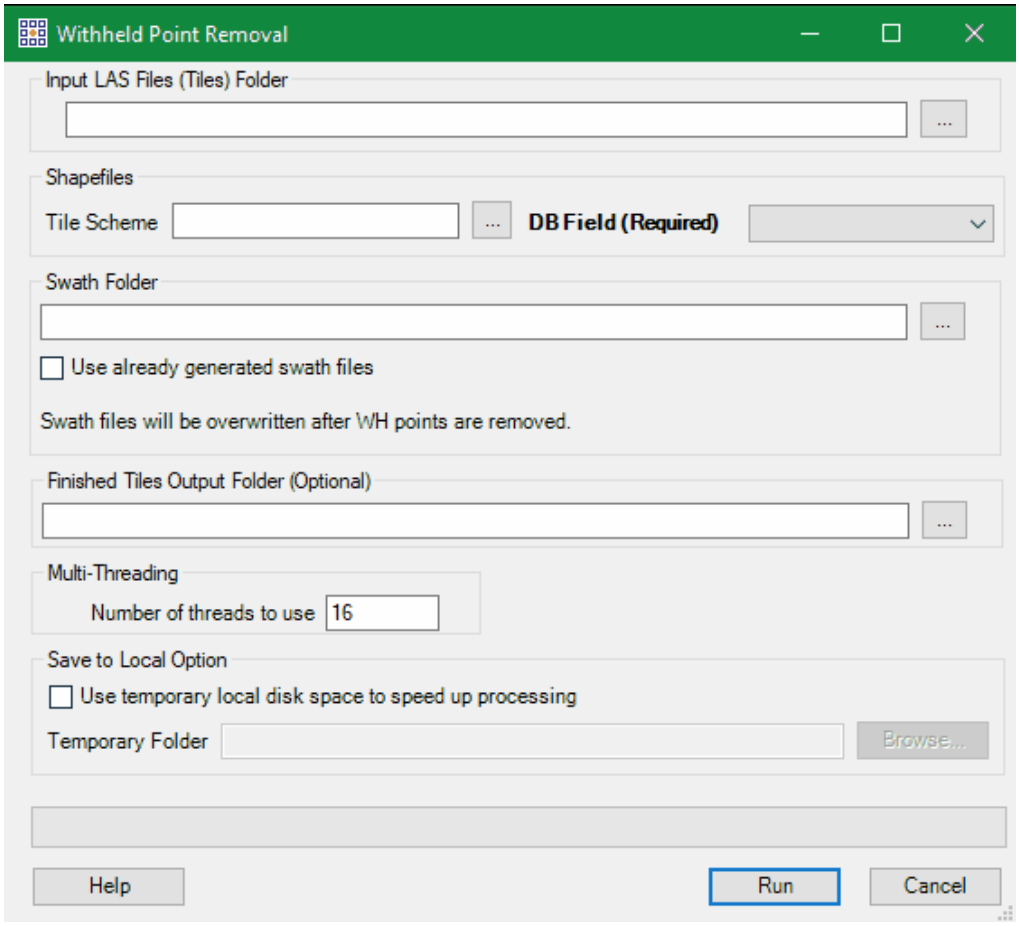
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Withheld Point Removal: This tool, found under the **'Bit Flag Settings'** drop-down, permanently removes specific points flagged as Withheld in the input LAS files and renumbers the remaining point family returns accordingly. The workflow is: input tiled or existing swath data --> export to swaths (if tiled input) --> Withheld point deletion --> Export to final tiled files. The tool uses two rules for determining candidate points to be deleted: ***1)*** Withheld-flagged points in any class that are either a single return or the first return of many in a point family and; ***2)*** Withheld points that are in Class 7 Low Point (Noise) and are the second of two returns in a point family. When Withheld-flagged points are deleted, any remaining points in the same point family will have their return numbers modified so as not to break the return numbering protocol. For the first case above, if a first of three returns point (1 of 3) is selected for deletion, the second return in that point family is renumbered as '1 of 2' and the third return is renumbered as '2 of 2'. In the second case above, when a Class 7 second of two returns point (2 of 2) is selected for deletion, the remaining first return in that point family is renumbered as '1 of 1' (single return). Note that if the input data is not classified, only the first rule will be applicable.

To use the tool, navigate to a folder containing tiled, classified LAS files using the browse control to the right of the 'Input LAS Files (Tiles) Folder' box. If available, pre-existing swaths can be pathed out in the 'Swath Folder' box to save the time of exporting tiles to swaths. In this situation, there is no need to path out tiled data in the 'Input LAS Files (Tiles) Folder,' but be sure to check the 'Use already generated swath files' box so the exporting to swaths step is skipped. Navigate to the tile layout shapefile that is geolocated with the input (tiled or swath) data using the 'Tile Scheme' control and select a unique-value attribute (e.g., 'Tilename') to be used for naming the finished output tiles. Choose a 'Swath Folder' that will hold the exported swaths produced from the input tile files, or is already storing the existing swaths to be used. During processing, these swaths will be overwritten by the new filtered swaths after the Withheld points are removed. Finally, an optional 'Finished Tiles Output Folder' can be selected to hold

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the final tiled files made from the filtered swaths. If no entry is made here, the input tiled files ('Input LAS Files (Tiles) Folder') will be overwritten with the final results.



The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Click the 'Run' button at the bottom of the interface to begin the processing. The progress bar near the bottom will track the processing, followed by a completion message.

Reference Reclass ***(available with Production license only):*** This tool, found under the 'Reclass' drop-down, allows the user to reclassify one set of LAS files (the 'Unclassified' input files) based on the classes found in another set of LAS files (the 'Classified' input files), by using a series of user-defined

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parameters found in the LAS files. In addition to reclassification, any existing bit flags (Synthetic, Model Key-point, Withheld, and/or Overlap) will be carried over to the output as well. The tool determines possible candidate points to be reclassed based on the LAS points' recorded ***time*** and other optional attributes. Because this tool finds possible matches based on their recorded time, the two folders of input files ('Classified' and 'Unclassified) must contain files in the same time format (e.g., GPS Week Time or Adjusted GPS Time). See the **'GPS Time Conversion'** topic in this section for a description of the tool that can convert between the two time storage methods.

Classified: Browse to a folder containing LAS files that have one or more classifications in each file. Like features must have like classes in all files - i.e., buildings must be classed the same in all files if the building class will be used as a Reference Class. Only those classes listed as Reference Classes will be used to identify possible candidate points in the Unclassified files for reclassification in the final Output. In the example below, classes 20 and 15 are being used from the Classified files. The Classified files are usually in a tile layout form, but other files can be used.

Unclassified: Browse to a folder containing one or more LAS files that will be used as a source of points for the final Output file. The points in the Source Classes entered in the interface - 5 and 6 in the example below - will be matched to points of the Reference Classes entered from the Classified files to create the candidate points. Those that match the values for the boxes checked at the bottom of the interface will be copied to the Output file and assigned the Target Class (12 and 10 in the example below). These files are usually in collection scan form, but other files can be used.

Output: Browse to an output folder or key in the desired path to store the results of this LAS classification reassignment. This selection choice is optional - if the user does not choose an Output folder, the Unclassified input data is

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overwritten with the newly reclassified data based on this reference reclass function.

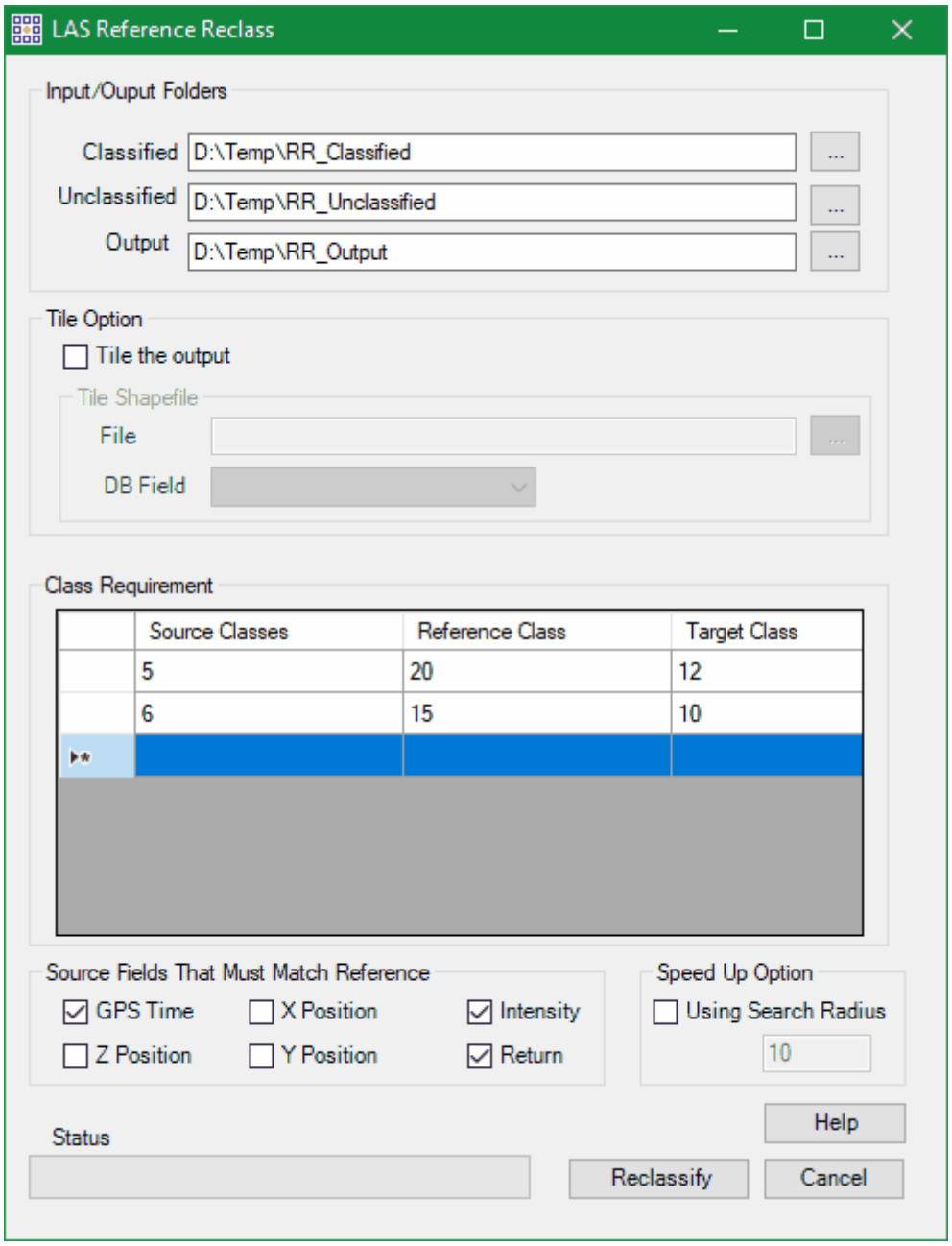
Tile Option: Optionally, the Output data can be tiled upon completion based on a user-selected polygon shapefile tile layout. The 'DB Field' chosen will be used to name the Output LAS files.

Class Requirement: In this section, the user specifies a Source Class, Reference Class, and Target Class for the specific classification sets to be used in the reclassification. Click on the appropriate box, and enter the class to be used.

Source Fields That Must Match Reference: This area of the interface allows the user to force a match of the values present in the Classified files to those in the Unclassified files in determining candidate points to be reclassed during processing.

Speed Up Option: When checked with a value entered in project units, this setting improves performance by limiting the pool of possible candidate points to be matched.

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Click the 'Reclassify' button to begin the processing.

Reference Reclass - Closest Distance ***(available with Production license only):*** This tool, found under the 'Reclass' drop-down, is similar to the Reference Reclass tool (see above). It allows the

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user to reclassify one set of LAS files (the 'Unclassified' input files) based on the classes found in another set of LAS files (the 'Classified' input files), by using a series of user-defined parameters found in the LAS files. In addition to reclassification, any existing bit flags (Synthetic, Model Key-point, Withheld, and/or Overlap) will be carried over to the output as well. The tool determines which points will be reclassed based on the LAS point's recorded ***time and position***. This is a special version of the Reference Reclass Tool: (1) Time will be used to determine possible candidate points, and (2) X, Y, Z will be used to determine the closest candidate point. This tool can process LAS data when the two inputs are in different time formats (e.g., GPS Week Time and Adjusted GPS Time) because it also takes into account the position of an LAS point.

Classified: Browse to a folder which contains LAS files that have one or more classifications in each file. These files are usually in a tile layout form, but other files can be used.

Unclassified: Browse to a folder which contains one or more files that have all points classified as a single default value. These files are usually in collection scan form, but other files can be used.

Output: Browse to an output folder or key in the desired path to store the results of this LAS classification reassignment. This selection choice is optional - if the user does not choose an output folder, the unclassified input data is overwritten with the newly classified data based on this reference reclass function.

Tile Option: Optionally, the data can be tiled upon completion based on a user-selected polygon shapefile tile layout. The 'DB Field' chosen will be used to name the output LAS files.

Class Requirement: This option is currently hard-coded to use every classification existing in the 'Classified' data to reclass points in the 'Unclassified' data.

Source Fields That Must Match Reference: This area of the interface gives the user the ability to use the values offered from the Classified to the Unclassified LAS

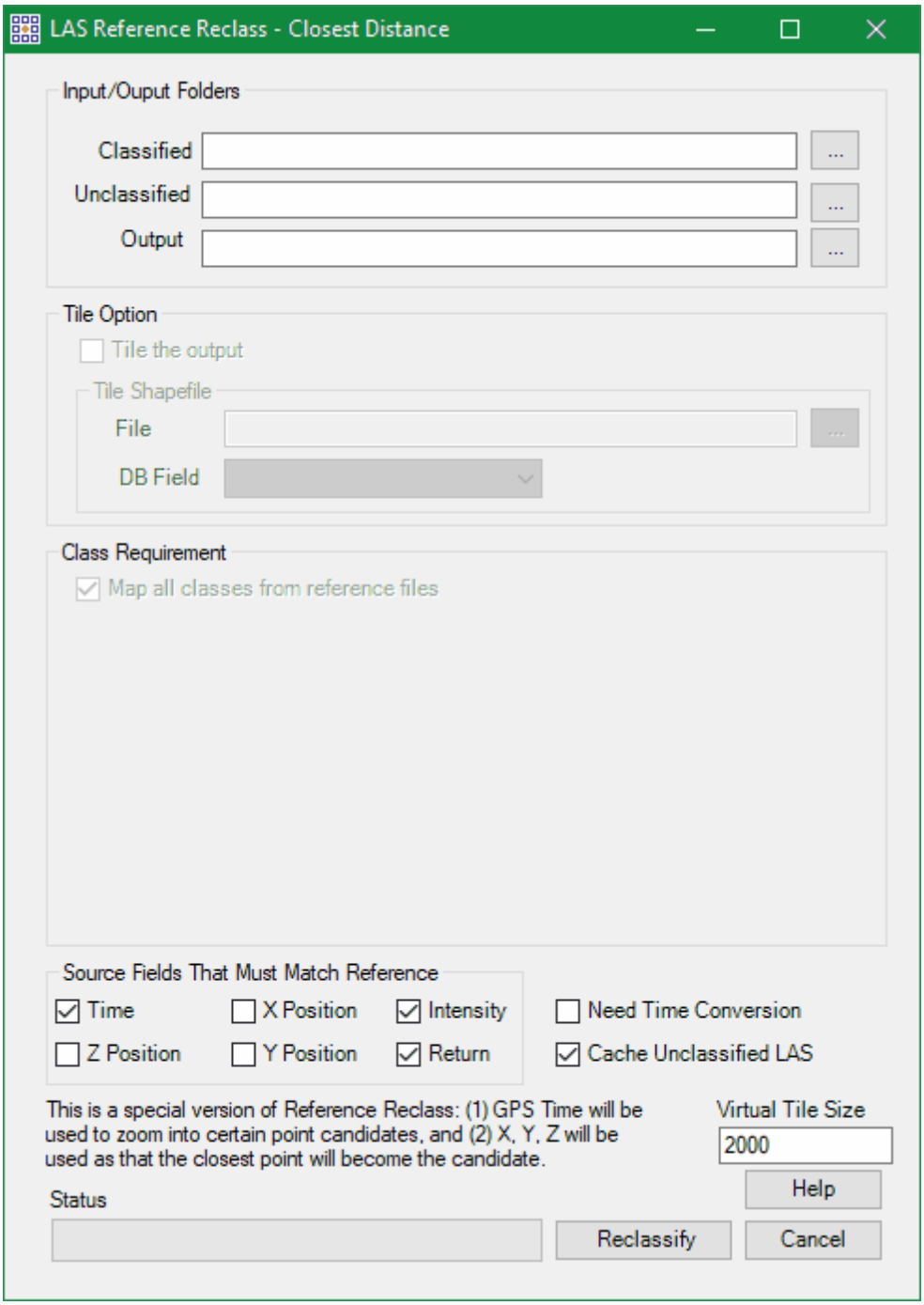
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files as a reference.

Cache Unclassified LAS: Checking this option will cache all of the points specified in the 'Unclassified' input path to RAM per file, if there is sufficient available RAM to do so. This will make the tool process more quickly than it would working from two separate locations (specified by the 'Classified' and 'Unclassified' input paths) on a network.

Virtual Tile Size: The virtual tile size sets the size of the area which the tool will process at any one time. Computers with more RAM can process larger areas resulting in a shorter time to completion.

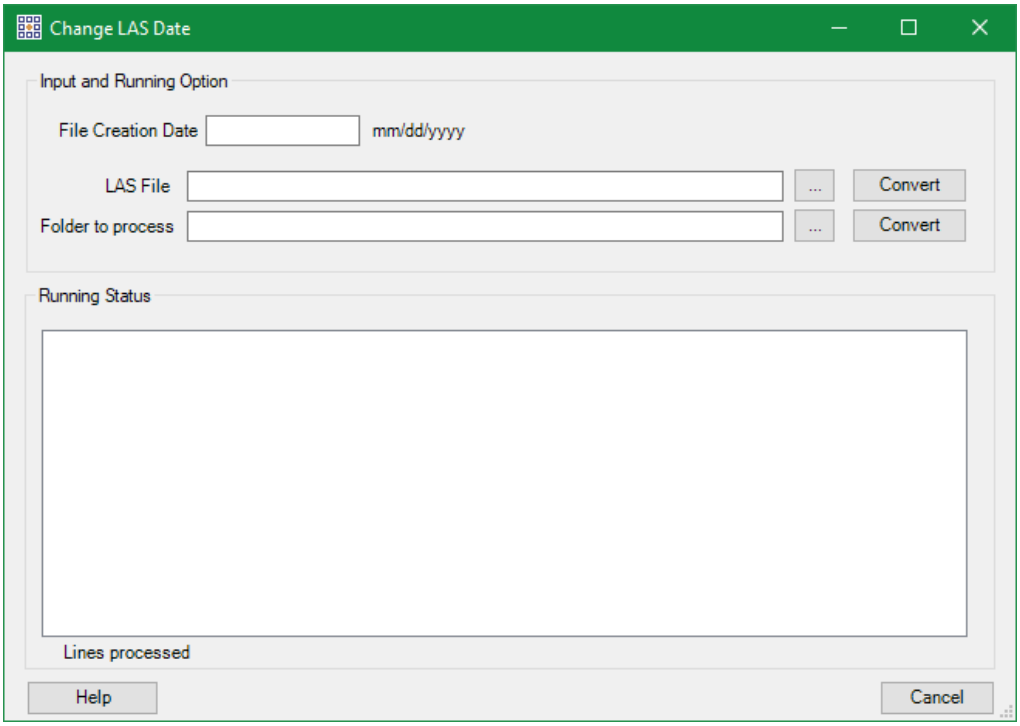
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Click the 'Reclassify' button to begin the processing.

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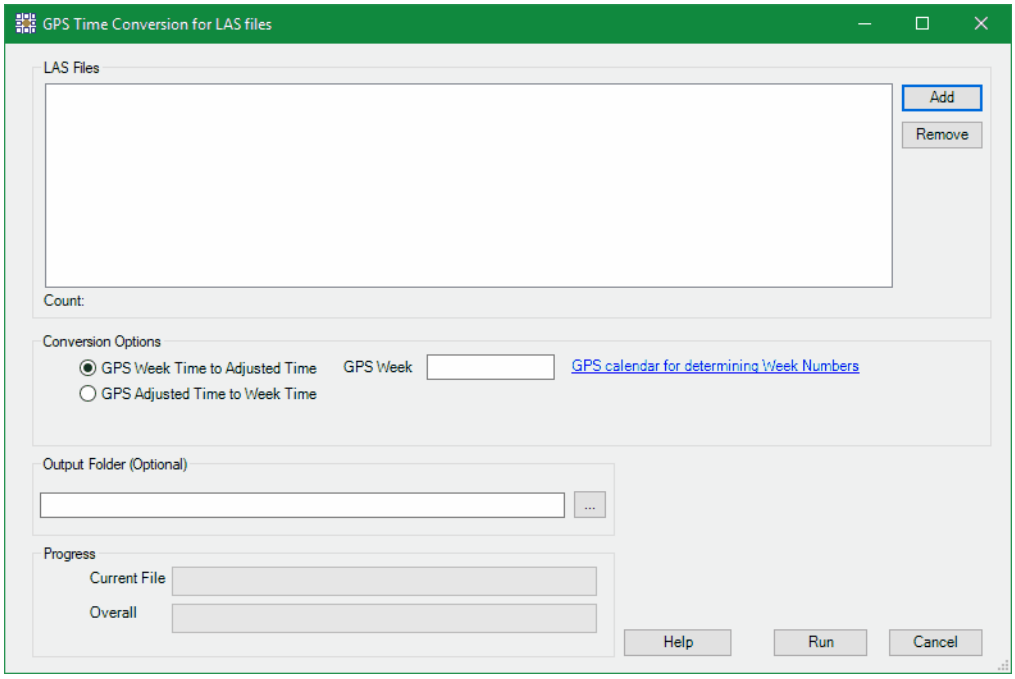
Change LAS Date ***(available with Production license only):*** This tool, found under the 'Edit Date/Time' drop-down, allows the user to alter the Julian Day and Year as stored in an LAS file's header and displayed in the file's properties. To use the tool, enter a date in the 'File Creation Date' text box (format must be mm/dd/yyyy). Navigate to either a single file or a folder of files using the ellipse button, then click 'Convert.'



GPS Time Conversion: This tool, found under the 'Edit Date/Time' drop-down, allows the user to convert how time is stored in LAS files from GPS Week Time to GPS Adjusted Time (when the GPS Week number is known) and vice versa. An output folder may be optionally defined to create a new set of files; otherwise the input files will be overwritten. Navigate to the desired file(s) using the 'Add' button. Individual files can be cleared from the list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove' button. The link provided on the interface can help in determining the correct GPS Week number. A valid value between 1 and 2600 (inclusive)

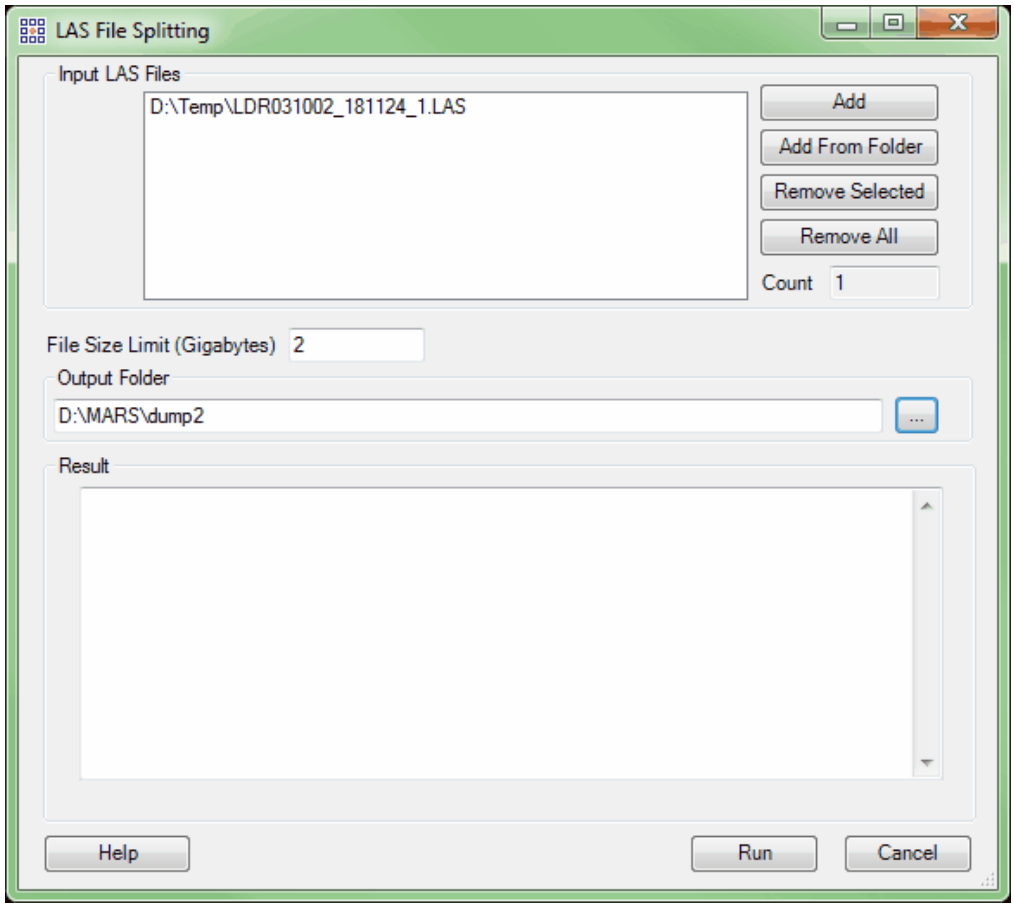
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must be entered before the 'GPS Week Time to Adjusted Time' option can be used.



LAS Splitting: This tool splits LAS files into multiple, smaller files based on a user-specified size limit. Navigate to the desired file(s) using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the list by highlighting the appropriate file or files (using standard Windows mouse/ keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. The default size limit is 2 GB per file, but any value can be entered in the 'File Size Limit (Gigabytes)' text box. After choosing an 'Output Folder,' click 'Run' to start the process. Files that are split will have '-a', '-b', etc. (as necessary) appended to the original file name and the new files will be placed in the output folder. The original input file(s) will remain unchanged. All files that are made from a single original file will maintain that parent's Point Source ID (PSID) value.

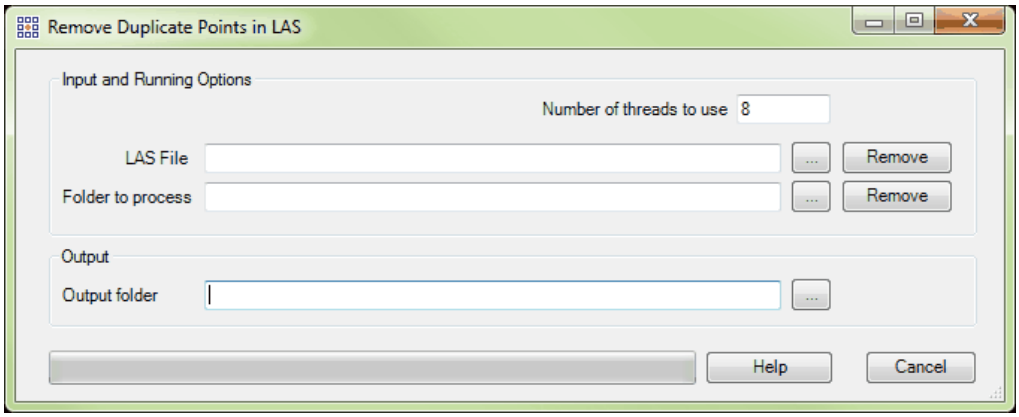
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Remove Duplicates in LAS ***(available with Production license only):*** This tool will remove duplicate LAS points in a dataset based on X, Y, Z, coordinates and timestamp. The tool can be run on a single LAS file or an entire folder of files, and can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Navigate to the input file or folder to be processed, and choose an output folder. Duplicate weeding will be based on exactly matching X, Y, Z, and timestamp values. In addition to the new cleaned files, separate files of only the removed points will be created in a 'Duplicates' sub-folder of the chosen output folder. They will have the original file name with '_dup' appended to the end. Data must be spatially indexed before it can be processed with this tool - a prompt will appear if the data

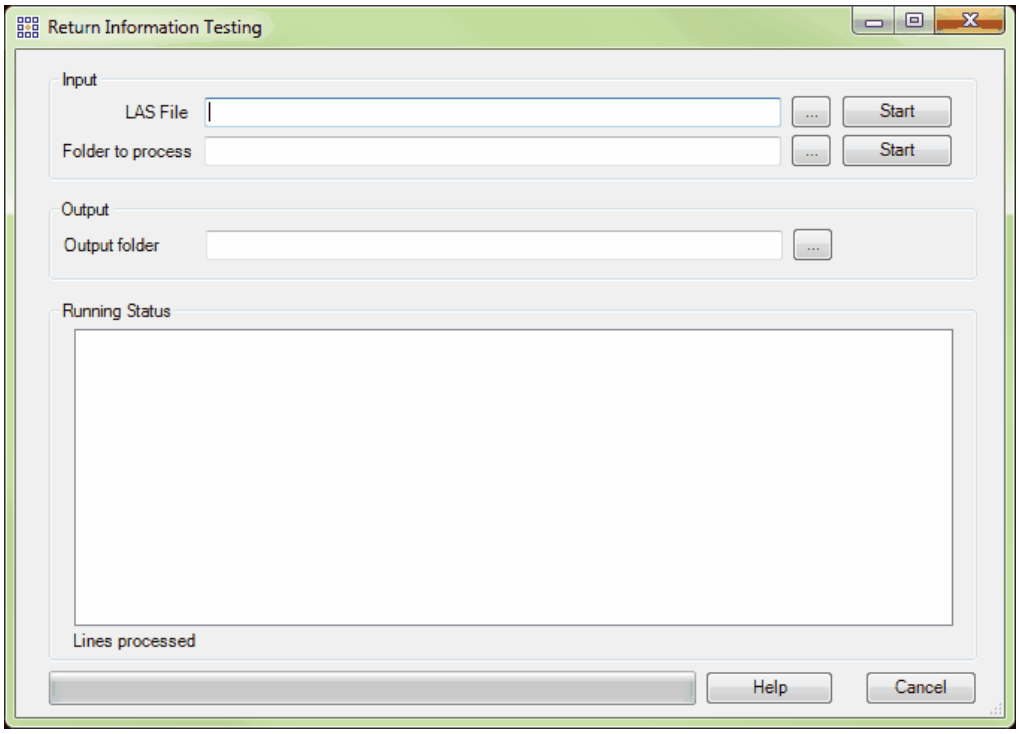
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does not yet have spatial index records.



Return Information Testing: This tool will test all points of all input files for proper return (point family) information. It should be used anytime a point family error message appears while displaying, filtering, or exporting LAS data; or while running tests C-2 or DPH-1 of the USGS 2.1 1525, 1.3 1559, or 1.2 1592 QC Modules, or tests 1.1 or 2.9 of the USGS 1.0 QC Module 1622. The tool can be run on a single LAS file or an entire folder of files. Navigate to the input file or folder to be processed, and also choose an output folder. Input files are not modified in any way during testing. Click the appropriate "Start" button depending on the input method chosen. During processing, separate LAS files will be created in the output folder. They will have the original file name with '*Valid_*' and/or '*Invalid_*' as a prefix, as appropriate. For example, if file '123456.las' contains some points with invalid return information, both a 'Vaild_123456.las' and 'Invalid_123456.las' file will be generated in the output folder. If **all** points in a given file have valid return information, only the '*Valid_*' version of the file will be generated. Likewise, if **all** points in a given file have invalid return information, only the '*Invalid_*' version of the file will be generated. Note that invalid return information cannot be changed once the data is collected and the original 'raw' LAS file is created.

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LAS Merging ***(not available with Evaluation license):*** This tool merges individual channel LAS v1.4 files (typically made from a multi-channel LiDAR sensor's collection) into a single swath (collection scan) LAS file. For example, the separate channel 1 and 2 files produced by Teledyne Optech's LMS post-processing software from data collected by that company's Pegasus sensor can be merged into a single LAS file containing all returns from the two channels. Other sensors can produce up to four individual channel files, typically numbered 0, 1, 2, and 3. The individual files must follow a naming convention in order to be grouped together – following a leading alpha character, the same number or numbers must exist before the next instance of either an alpha character or a separator ('-' or '_'). There must also be unique channel indicators at the end of each file name in a group to be merged, such as '-C0' and '-C1', or '_C1' and '_C2'. Examples of file naming that produces a properly merged output file include:

'L3-1-123456-C1.las' and 'L3-1-123456-C2.las' -- the merged output file will be named

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‘L3_M.las’ (the final 'M' means merged)

‘L42B-1-123456_C0.las’ and ‘L42B-1-123456_C1.las’ -- the merged output file will be named ‘L42_M.las’

'S456-4-789-C0.las', 'S456-4-789-C1.las', 'S456-4-789-C2.las', and 'S456-4-789-C3.las' -- the merged output file will be named 'S456_M.las'

‘3A-1-123456-C1.las’ and ‘3A-1-123456-C2.las’ -- the merged output file will be named '3_M.las'

'L45-1-K-333444-C0.las' and 'L45-1-K-333444-C1.las' -- the merged output file will be named 'L45_M.las'

Examples of file naming that will result in improperly merged output files include:

‘L3-1-123456-C1.las’ and ‘L4-1-123456-C2.las’ -- the result will be copies of one or both of the input files

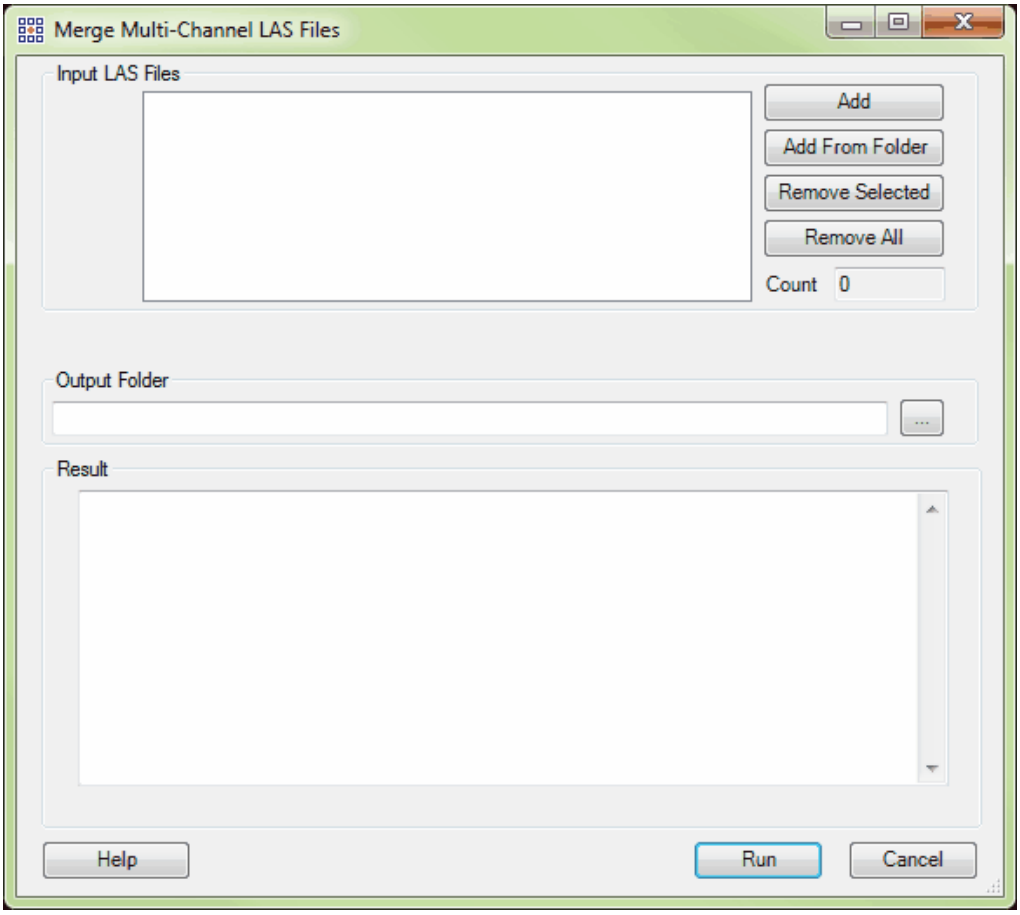
'8B-1-M-987654-C1.las' and '9B-1-M-987654-C2.las' -- the result will be copies of one or both of the input files

Proper file naming is critical to a successful merge! Each set of individual channel files to be merged must begin with a naming scheme that is unique to that set.

Once the files to be merged have been properly named, navigate to the folder containing them using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Choose an 'Output Folder' where the merged files will be stored and then click the 'Run' button. The status of each swath merge will be shown in the 'Result' area. The File Source ID

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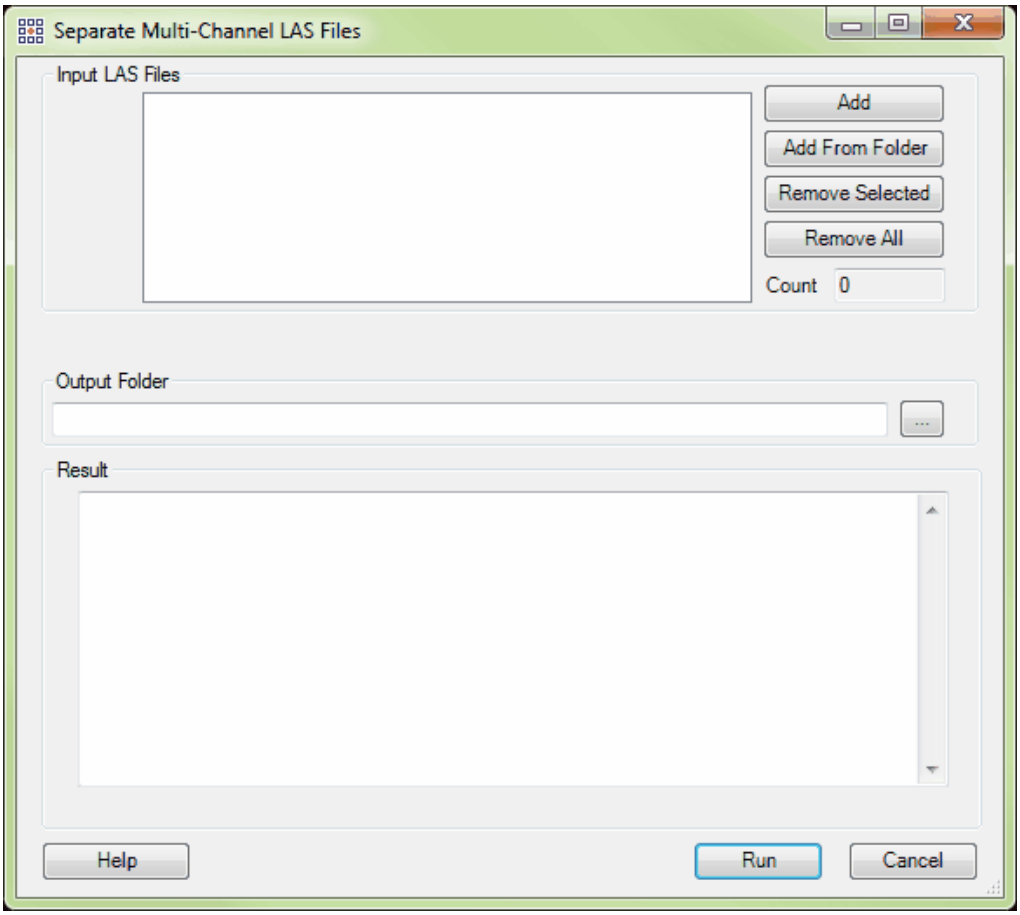
assigned to each final merged file will be taken from the first individual file of the group as listed in the 'Input LAS Files' box of the tool's interface.



LAS Separate ***(not available with Evaluation license):*** This tool separates merged multi-channel LAS v1.4 files into separate individual channel files, one file for each scanner channel value found in the original merged file. ***The Scanner Channel bit flag values must be present in the original merged file for this tool to work - possible bit flag values are 0, 1, 2, and 3.*** For example, a file containing points from both channels of a dual-channel system (stored as Scanner Channel bit flag values 0 and 1) will be separated into a channel 0-only file and a channel 1-only file. In this example, if the original merged file is named 'L3-123456-M1.las', the new individual channel files will be named 'L3-123456-M1-

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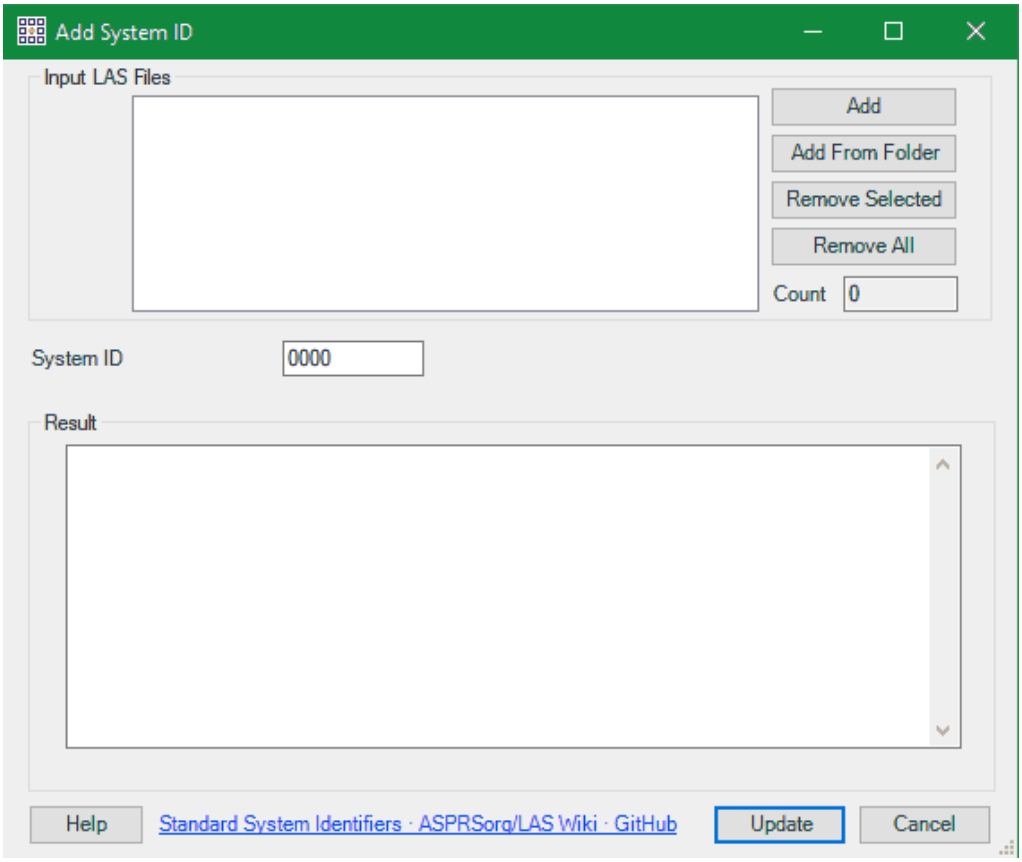
C0.las' and 'L3-123456-M1-C1.las'. Navigate to the files to be separated using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Choose an 'Output Folder' where the individual channel files will be stored and then click the 'Run' button. The status of each file separation will be shown in the 'Result' area. The File Source IDs assigned to each individual channel file will be the same as the ID from the original merged file.



Add System ID: This tool allows the System Identifier field in the Public Header Block of LAS files to be populated or edited. Note that 'System Identifier' is sometimes referred to as 'System ID', 'Sys ID', or

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'SysID'. Per the ASPRS LAS v1.4 specification, there are several entries that are valid for this field, and it can hold up to 32 bytes (characters) of information. A link at the bottom of the interface leads to a list of currently accepted System Identifiers and provides instructions for requesting additions to the list. MARS® defaults to '0000', but this can be changed as needed in the tool's interface. If a value is already present in the file header(s), it will be silently overwritten by the tool. This tool will not allow complete removal of existing entries. To use, navigate to the files to be populated/edited using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Click the 'Update' button to begin processing. The status of the updated files will be shown in the 'Result' area.



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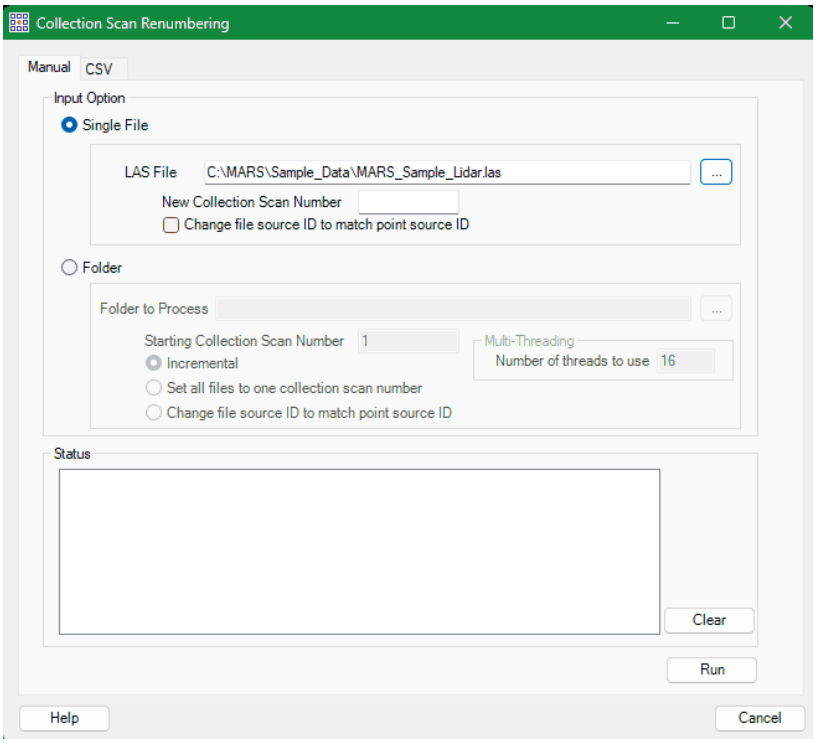
Collection Scan Renumbering: This tool, found on the Tools Tab[389] under the 'Collection Scans' drop-down, is designed for use with original collection scans (swath files), and allows the collection scan number stored with each LiDAR point to be changed using one of several methods.

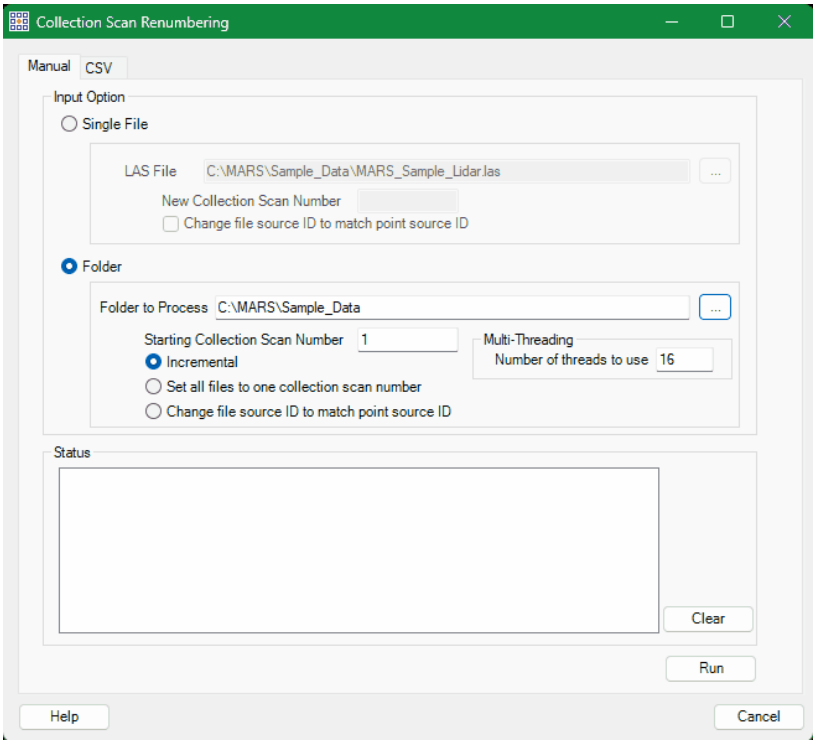
On the 'Manual' tab, a new number can be assigned on a file-by-file basis (first row, below), sequential numbers can be assigned to a folder of files by specifying a non-zero starting number in the 'Starting collection scan number' text box (second row, left), and the same number can be assigned to all swaths in the folder (second row, middle). An additional method reads existing Point Source IDs and sets the File Source ID numbers to match (second row, right). In 'Manual - Folder' mode, the tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

On the 'CSV' tab, a CSV file with multiple mapped changes can be read in for an entire folder of LAS files (third row, below). When the CSV file option is used, it must be formatted as two columns: the first is a listing of the original collection scan numbers (one per row), and the second column lists the new desired collection scan numbers. For example, 5 might become 105, 6 might become 106, etc. A header row is optional and will be ignored during processing. File Source IDs will be changed to match the new collection scan numbering for each file. Original values (first column) of zero (0) will not be changed.

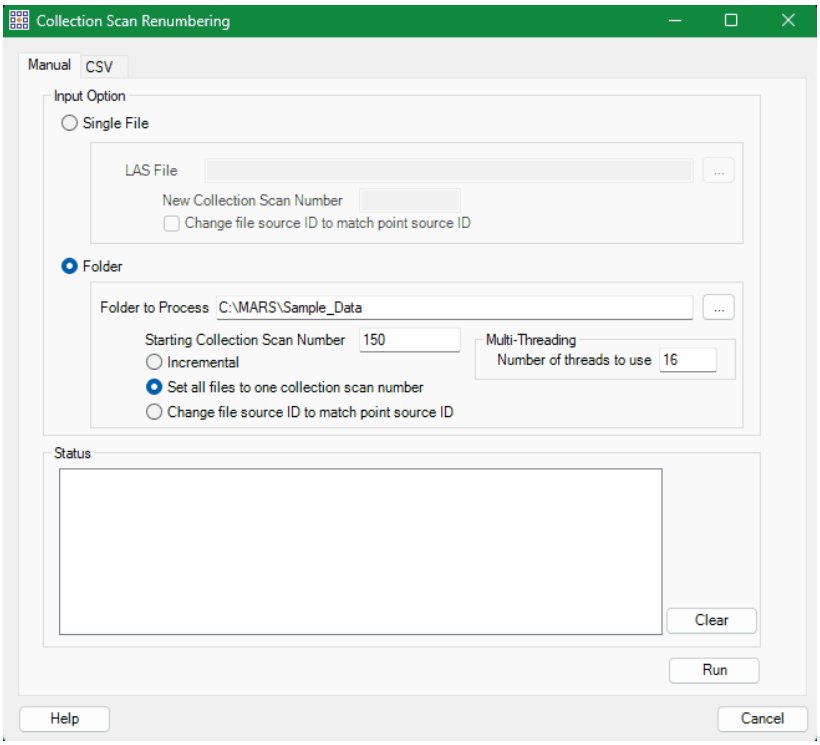
Please note that LAS version 1.4 files are limited to collection scan numbers of 1 to 65535. For 'Incremental' renumbering, be sure to use a starting value that will not cause any of the files to be given values higher than 65535.

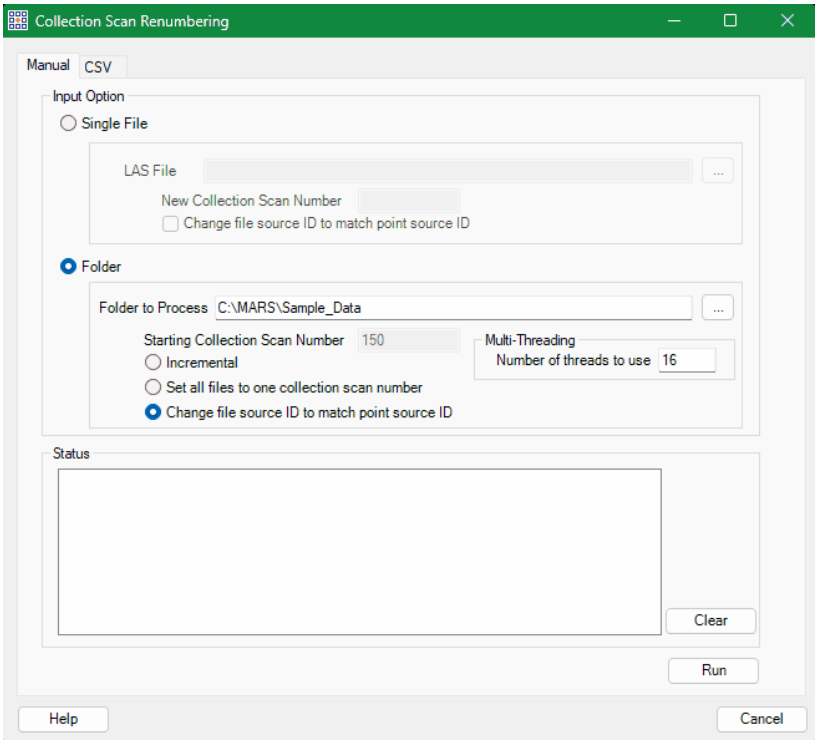
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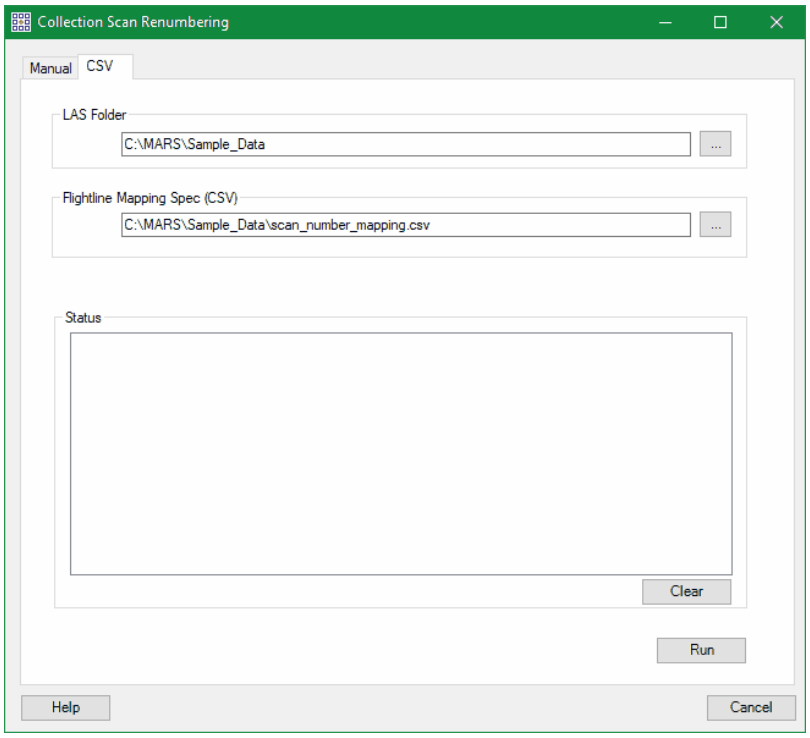


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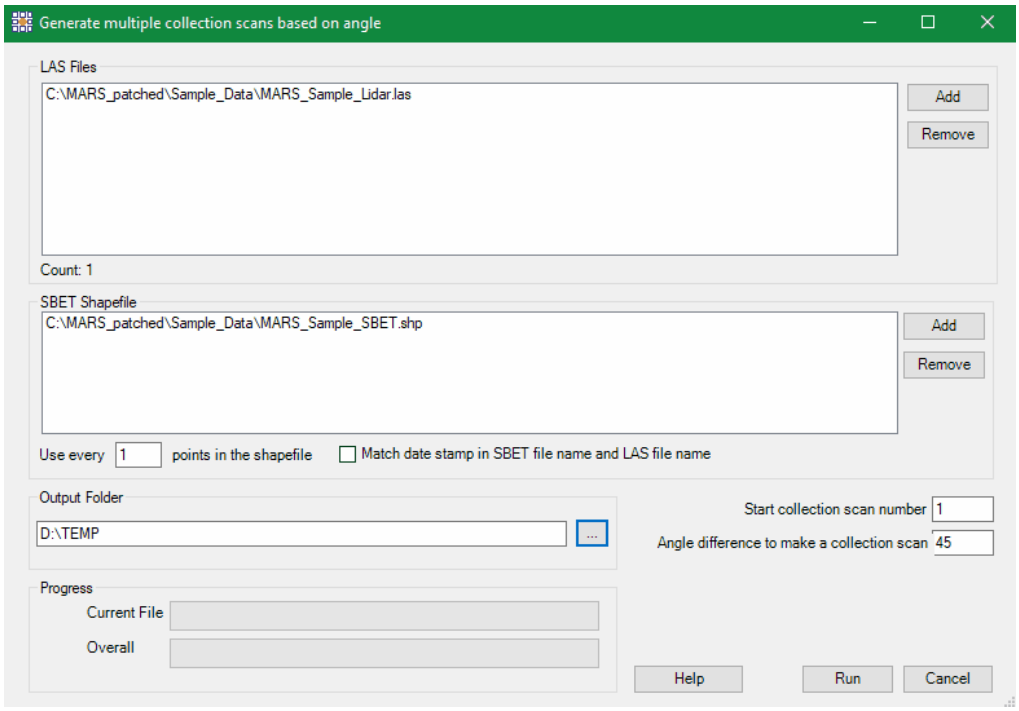


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Single Collection Scan to Multiple ***(available with Production license only):*** This tool, found under the 'Collection Scans' drop-down, will split a single collection scan into multiple, smaller collection scans at locations indicated by deviations in the flight heading, or angle, which is user defined. Having multiple, smaller collection scans rather than a single larger scan may help in boresighting as well as measuring height differences in overlapping collection scans.

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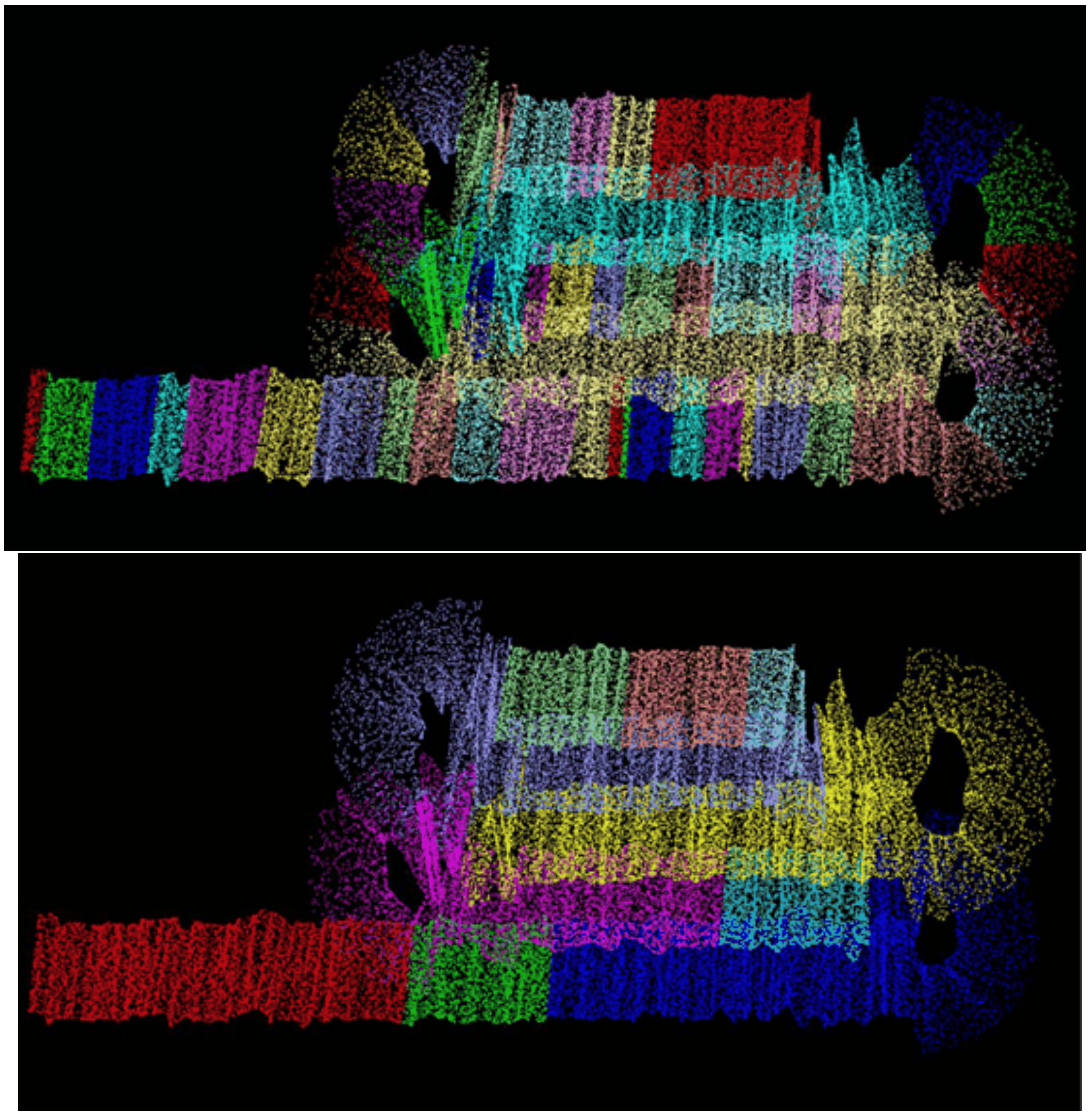
1. To use this tool, first add the LAS collection scan data to be split up. After adding the scans, individual files can be removed from the list by selecting them (using standard Windows mouse/keyboard controls) and clicking the 'Remove' button to the right of the 'LAS Files' section.

2. Next, add the SBET shapefile which is associated with the loaded LAS file(s). Only one SBET shapefile can be loaded per run.

3. Specify the sampling rate used to determine flight path angle changes by entering an integer into the 'Use every __ points in the shapefile' text box. This feature of the tool allows the user to reduce the sampling rate of (or thin out) the heading data from the SBET file by allowing the user to define a time range. By default, data points are usually one second apart.

The examples shown below compare a 1 second sampling rate (left) and 30 second sampling rate (right).

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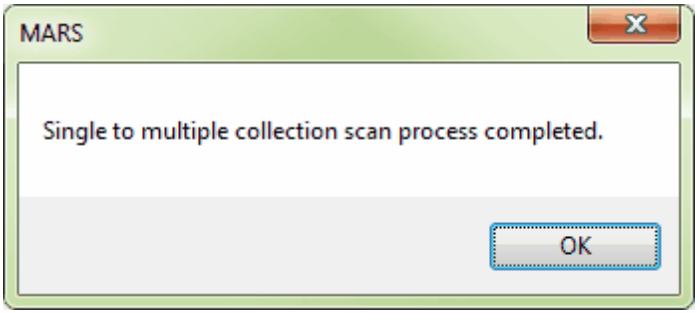


4. The 'Match date stamp in SBET file name and LAS file name' option (checked by default) improves performance by matching the SBET with only those LAS files that are named with the same mission identifier. Other missions' LAS files that may have been included in the 'LAS Files' box will be ignored to save time. A specific naming convention must be used for this option: the SBET must have a six-digit date stamp in the 6th through the 11th positions of the file name, and the LAS file(s) must have the exact same six-digit date stamp in the 1st through 6th position of the file name(s). For example, an SBET named 'Proj_210401_East.shp'

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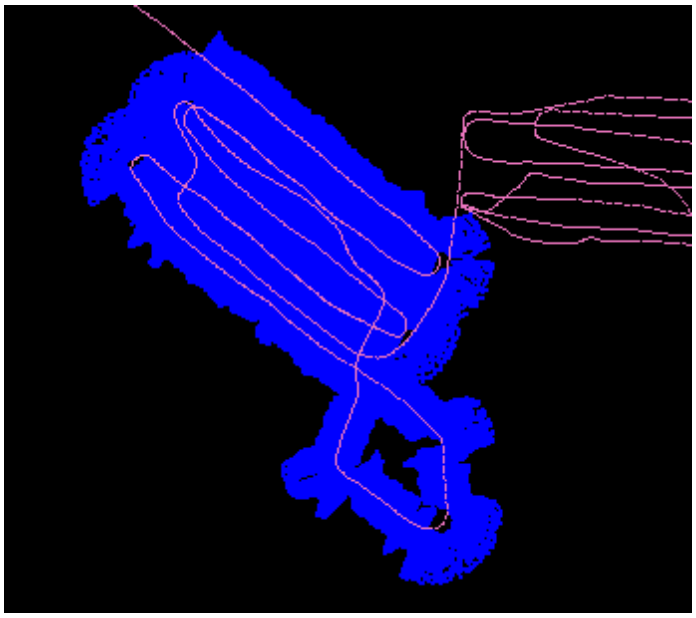
would match up with LAS filenames such as '210401_L100.las' and '210401_L101.las'. That same SBET would not match up with an LAS file named '040121_L100.las' or '20210401_L100.las', and no splitting would be performed.

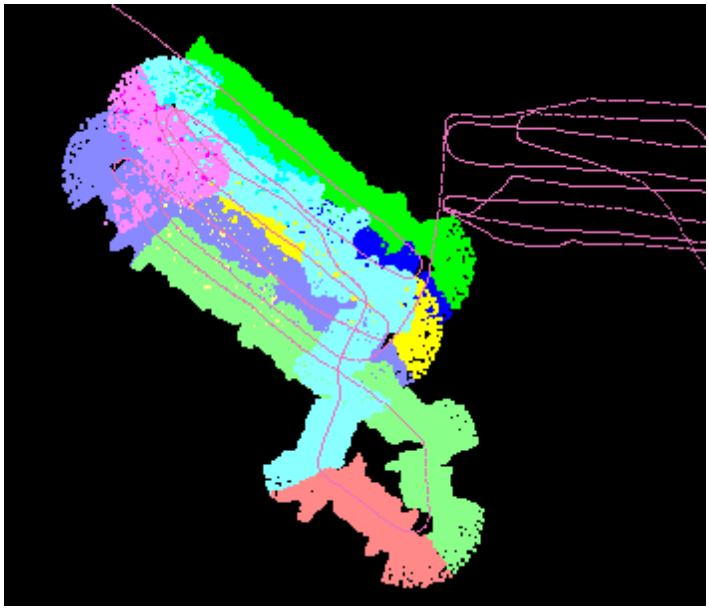
5. Define an output folder for the newly-generated collection scans.
6. Choose a starting collection scan number for the new collection scans which will be produced.
7. Choose an angle at which collection scans will be separated. Whenever the angle specified here is found in the original, single collection scan, the process will generate a new collection scan.
8. When all specifications have been made, click the 'Run' button.
9. When the process is complete the user will be notified with a prompt as seen here:



In the first example shown below the LAS data is shown colored by collection scan. There is only a single, long collection scan loaded. The SBET shapefile is shown as the pink point shapefile. In the second example, the collection scan shown previously has been converted to multiple collection scans with the collection scan angle specified for separation at 90 degrees. The new data below is also colored by collection scan.

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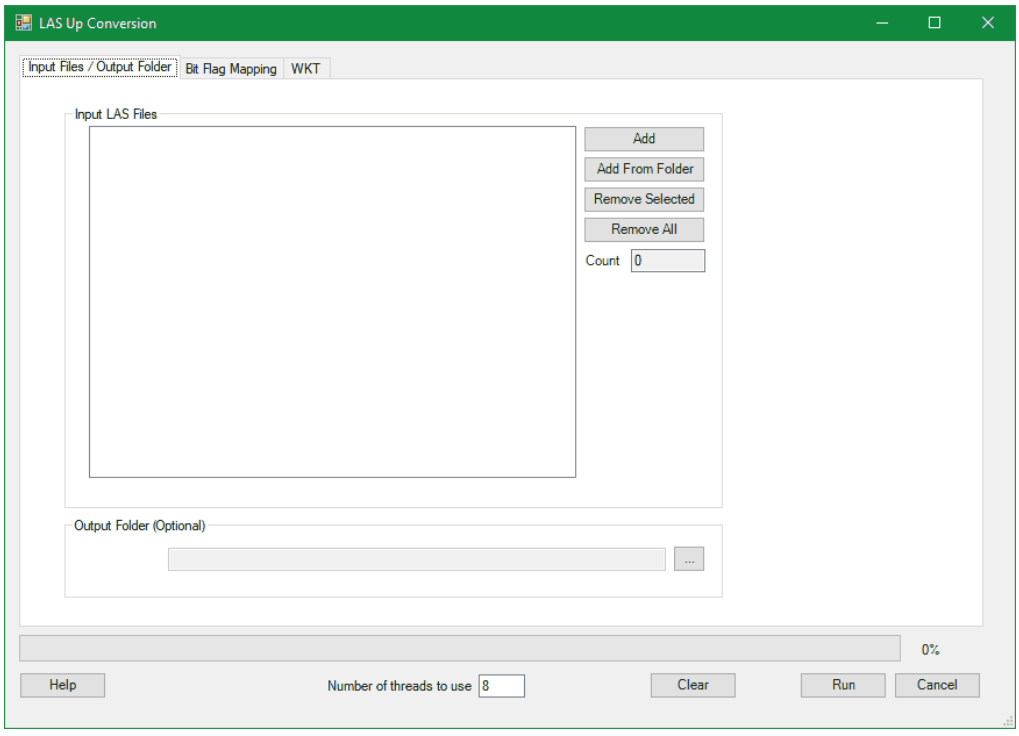
LAS Up-Conversion: This tool allows batch conversion of pre-LAS v1.4 files, or version 1.4 files with the following characteristics: a legacy Point Data Record Format of 0-5, less than 16-bit Intensity values, less than 16-bit RGB(N) values (if present), GeoTIFF tags containing Coordinate Reference System info, and/or presence of Variable Length Records. It is the same tool that appears when loading

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LAS files that are not compliant with this version of MARS® (if **'Yes'** is chosen in response to the up-conversion prompt).

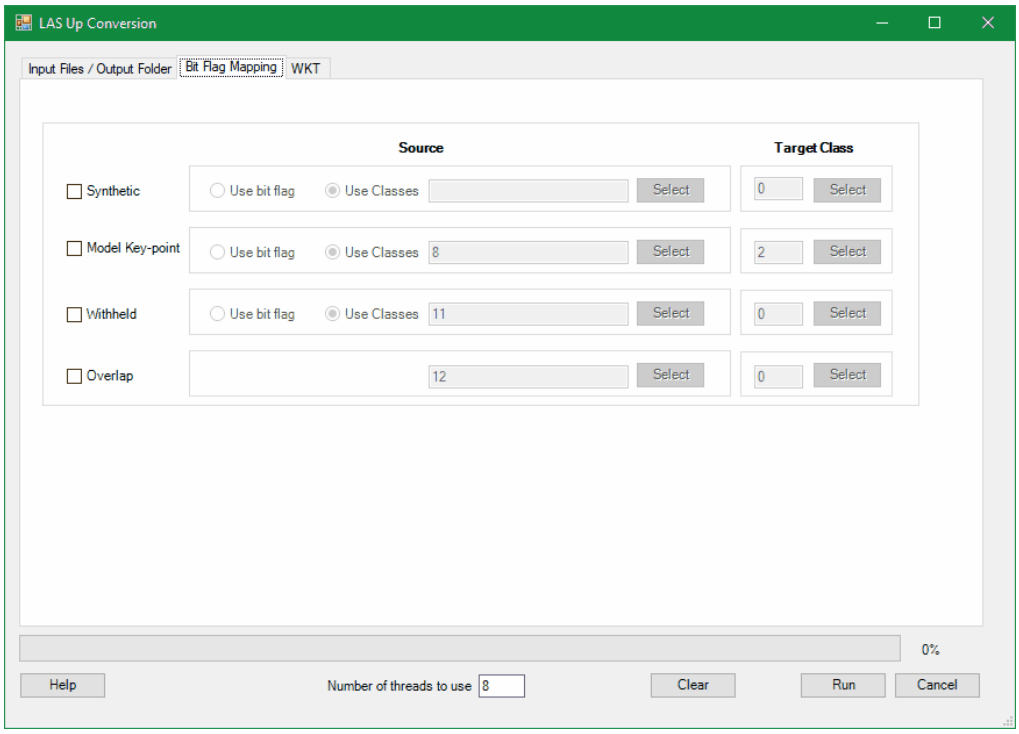
This tool has several options including: 1) output to a different folder than the files currently reside in, 2) bit flag mapping to convert user-defined classes of points to any of the four changeable bit flags used in version 1.4 LAS files - **Synthetic**, **Key-point** (also referred to as Model Key-point), **Withheld**, and **Overlap**, and 3) assignment of a WKT tag for Coordinate Reference System definition. Existing bit flags (except, in some cases, the v1.4-only **Overlap** type) can be carried over from the files being converted, or a class or classes can be specified that represented the bit flag types in older version files.

On the 'Input Files / Output Folder' tab, navigate to the files to be up-converted using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. ***The input files will be overwritten unless an output folder is selected.***



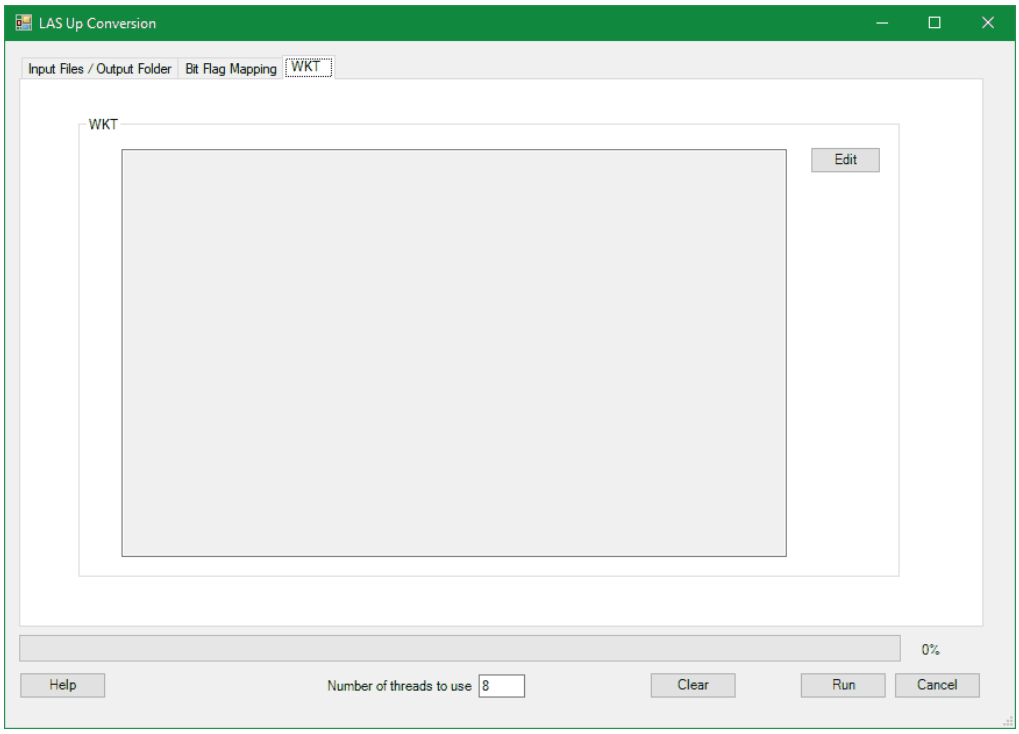
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On the 'Bit Flag Mapping' tab, check the boxes in the left column for any bit flag types that need to exist in the up-converted files. If the existing files have bit flags set for **Synthetic** (rare), **Model Key-point**, and/or **Withheld**, select the appropriate **'Use bit flag'** radio buttons to carry over the bit flag status. Otherwise, keep the default **'Use Classes'** radio buttons selected and use the **'Select'** buttons in the **'Source'** section to choose one or more classes in the existing files that are representing a bit flag type. The pre-populated **'Source'** classes were chosen as defaults because they are commonly used in LAS files older than version 1.4. Optionally, a new **'Target Class'** can be selected for the points once their bit flags are set. Class 2 is the default **'Target Class'** for **Model Key-point** since it is a sub-set of ground (which is typically stored as Class 2).



For the 'WKT' tab, any existing Coordinate Reference System information that is readable will be shown as a WKT format tag which can then be edited for correctness and/or completeness.

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The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. When all settings have been made, click **'Run'** to start the up-conversion and load the files, or **'Cancel'** to dismiss the interface without modifying or loading any files.

LAS Version Converter: This tool allows batch back-conversion (export) of LAS files to older versions (or version 1.4 with legacy Point Data Record Formats). Some loss of information is unavoidable when converting data back to older versions and/or lower PDRF values, depending on the specific version/PDRF of the resulting files. See the LAS File Specifications 1879 topic for details.

This tool has several options including: **1)** LAS version to be created, **2)** how existing bit flags will be stored (as is, or converted to classes) and, **3)** conversion of Adjusted GPS Time to GPS Seconds of the Week.

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For option 1, PDRF values for the output are determined by the 'Target LAS Version' chosen, as well as whether the input LAS v1.4 files are PDRF 6, 7, or 8. The following table lists the possibilities:

PDRF 6 -- if back-converted to LAS v1.0, LAS v1.1, LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 1.

PDRF 7 -- if back-converted to LAS v1.0 or LAS v1.1, resulting PDRF will be 1. These LAS versions cannot store point-level RGB values.

PDRF 7 -- if back-converted to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 3.

PDRF 8 -- if back-converted to LAS v1.0 or LAS v1.1, resulting PDRF will be 1. These LAS versions cannot store point-level RGB or near-infrared (NIR) values.

PDRF 8 -- if back-converted to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 3. These LAS versions and legacy PDRFs cannot store point-level near-infrared (NIR) values.

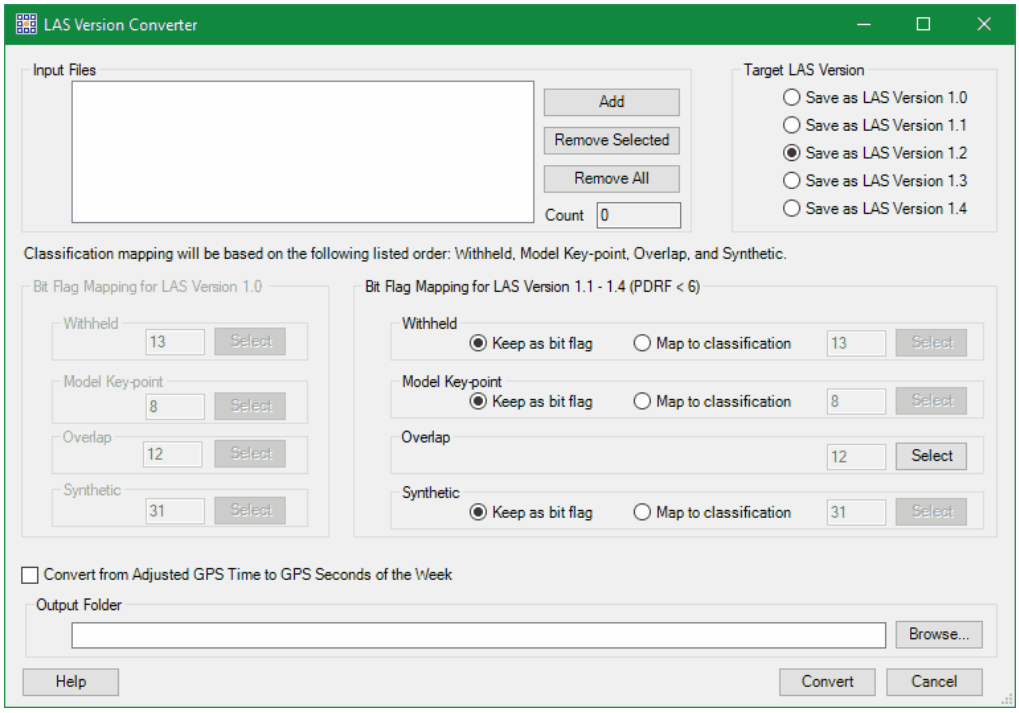
For option 2, mapping of existing bit flags to the output files depends on the 'Target LAS Version' selected. In LAS v1.0, there is no provision for bit flag storage as such, so unique classes must be used to represent bit flag values that the user wants to save. The default classification values shown in the tool interface can be changed as needed. In LAS v1.1 through LAS v1.4 (PDRF < 6), it is possible to keep the bit flag status of all but the 'Overlap' bit flag. Optionally, the user can map those bit flags to unique classes in the output files by selecting the corresponding radio button(s) and either accepting the default classes or changing them as needed. Any existing 'Overlap' bit flags must be converted to a unique class for all back-conversion scenarios.

For option 3, back-conversion to LAS v1.0 or LAS v1.1 requires timestamps to be stored as GPS Seconds of the Week - therefore, that option will be checked on and disabled. Back-conversion to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6) allows the timestamps to be *optionally* converted to GPS Seconds of the Week. Note, however, that this time storage method does not maintain the actual collection date.

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When converting back to LAS v1.4 (PDRF < 6), any existing CRS info record (in WKT format) will remain in an EVLR and all spatial indexing records will be written to VLRs. When converting back to LAS v1.0 through v1.3, ***all*** EVLRs will be written as VLRs.

In the 'Input Files' section, navigate to the files to be back-converted using the 'Add' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button.



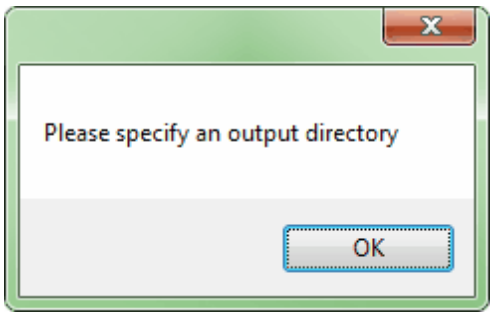
This tool requires the use of an 'Output Folder' - the input files cannot be overwritten. When all settings have been made, click **'Convert'** to start the back-conversion, or **'Cancel'** to dismiss the interface without creating any new files.

Float Grid to Hillshade: This tool, found under the 'Format Conversion' drop-down, allows the user

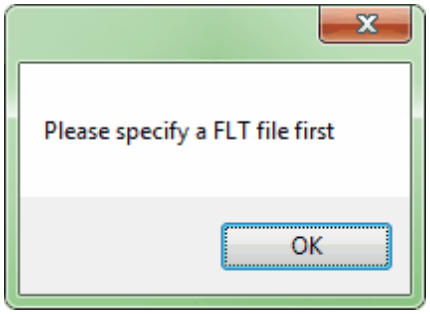
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to create a hillshade image or raster from a gridded, elevation float grid (*.flt). This tool inputs a float grid and is capable of outputting a JPEG 2000 file, BMP file, IMG file, or float grid file. It is important to understand that the output file created by this tool is an image or raster. It is meant to display quickly, similar to the performance of a compressed .ecw file. Because this tool creates an image file, the resulting file may only be viewed in 2D (orthographic) view and CANNOT be seen in 3D.

- **Output folder:** Click on the **'...'** button and navigate to or key in an output folder for the finished image or raster product. There must be an output folder specified to use this tool. If an output folder is not designated, the following prompt will appear:



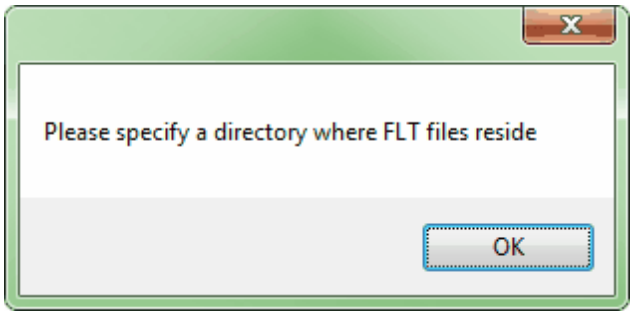
- **FLT File:** By clicking on the corresponding **'...'** button, the user may navigate to a single input *.flt file. This is the file that will be used to create an image or raster. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'FLT File' is not specified and the user attempts to click on the corresponding **'Convert'** button, the following prompt will appear:



- **Folder to Process:** By clicking on the corresponding **'...'** button, the user may navigate to a folder. Every *.flt file inside the specified folder will be converted to an

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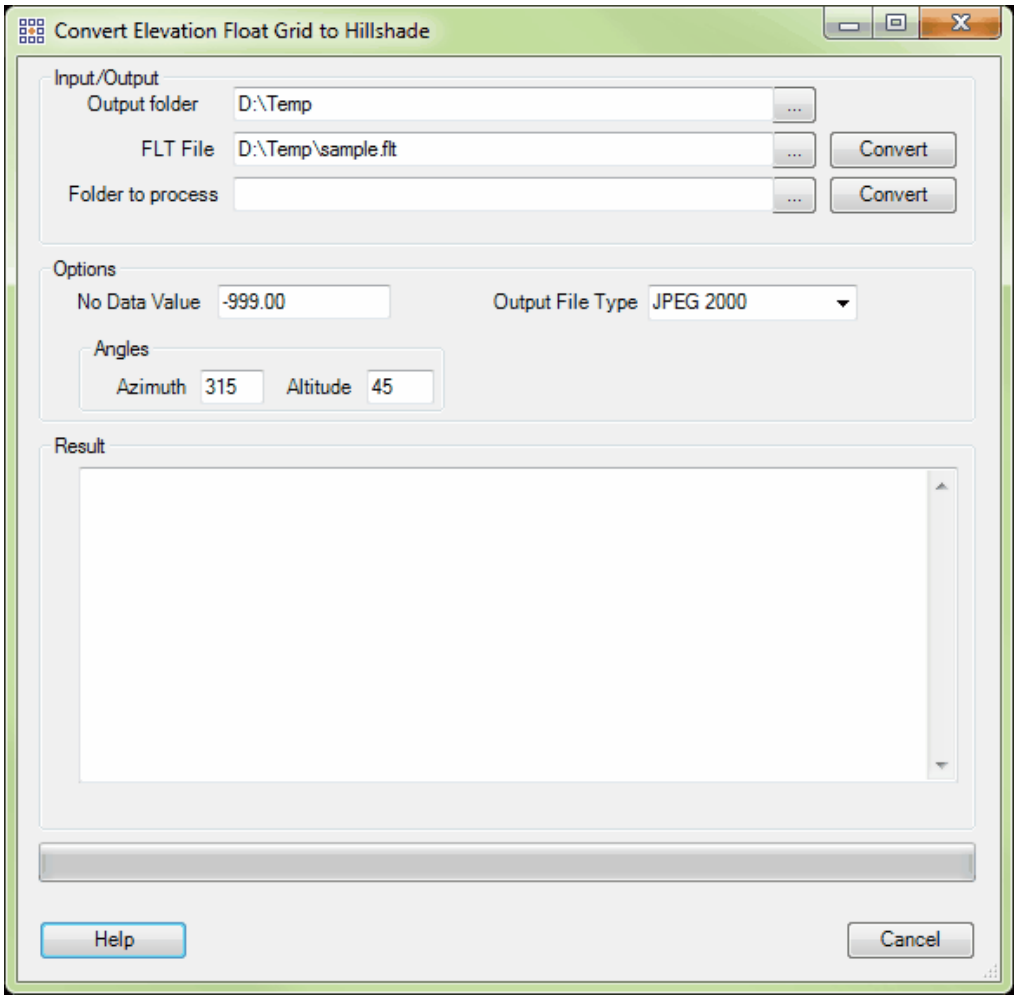
image or raster if this option is chosen. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'Folder to Process' is not specified and the user attempts to click on the corresponding '**Convert'** button, the following prompt will appear:



- **No Data Value:** If there is a data void in the data set (no information within the cell), a 'No Data' value is assigned. Cells with null values will be given a default value of -999.00 unless otherwise specified. Enter an integer in the text box for the No Data Value if another value is preferred. *Note: Water does not reflect LiDAR points, so water should be considered a No Data area.*
- **Output File Type:** The user may specify here which type of product the tool should output. The user may choose from outputting a JPEG 2000 file, float grid, IMG file, or BMP file. Click on the drop-down to display the choices.
- **Angles:** Allows the user to specify the sun azimuth and altitude to achieve the desired shading effect.
- **Result:** The 'Result' text box will show the user the processing of the tool. When the file has been converted, the result text box will display that the specified *.flt file(s) were processed.

The example below shows the 'Convert Elevation Float Grid to Hillshade' window:

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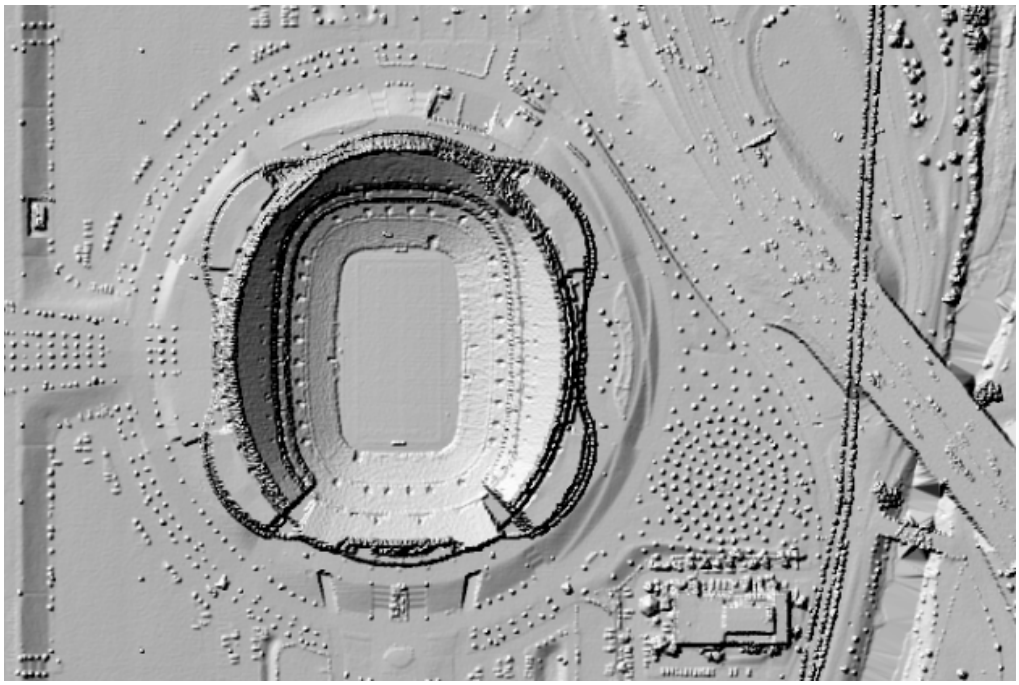


After the conversion has taken place, go to the output directory which was specified and load the resulting image or raster file into MARS®. The file will be renamed with the same name as the float grid file which was the input *.flt along with '_Hillshade' appended to the end of the file name. For example, the 'sample.flt' file which was the input *.flt in the example above was output as a JPEG 2000 file and named 'sample_Hillshade.jp2'. Load the newly converted file to MARS® to view it.

Below is a sample of the newly created 'sample_Hillshade' JPEG 2000 file. Because the resulting file is an image file, panning and moving around the data is much quicker than

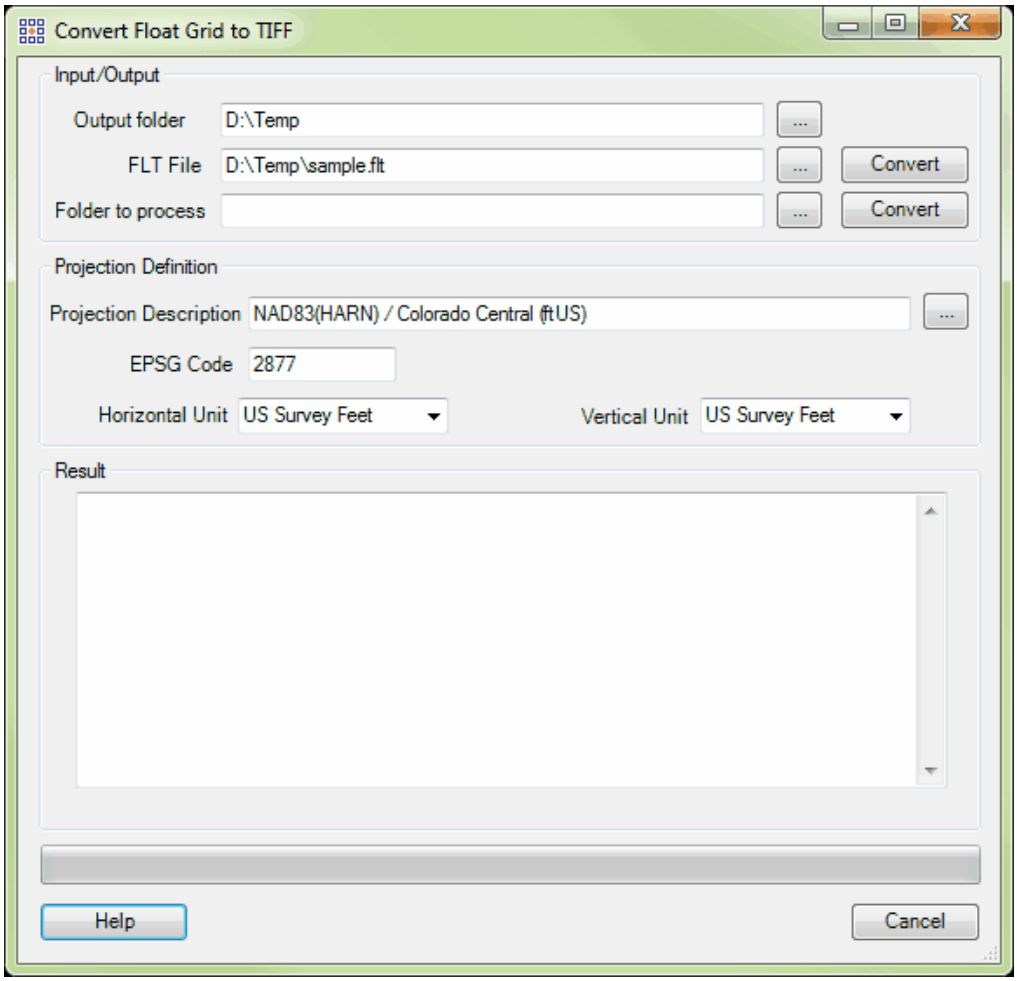
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using the corresponding float grid with hillshade created 'on the fly'.



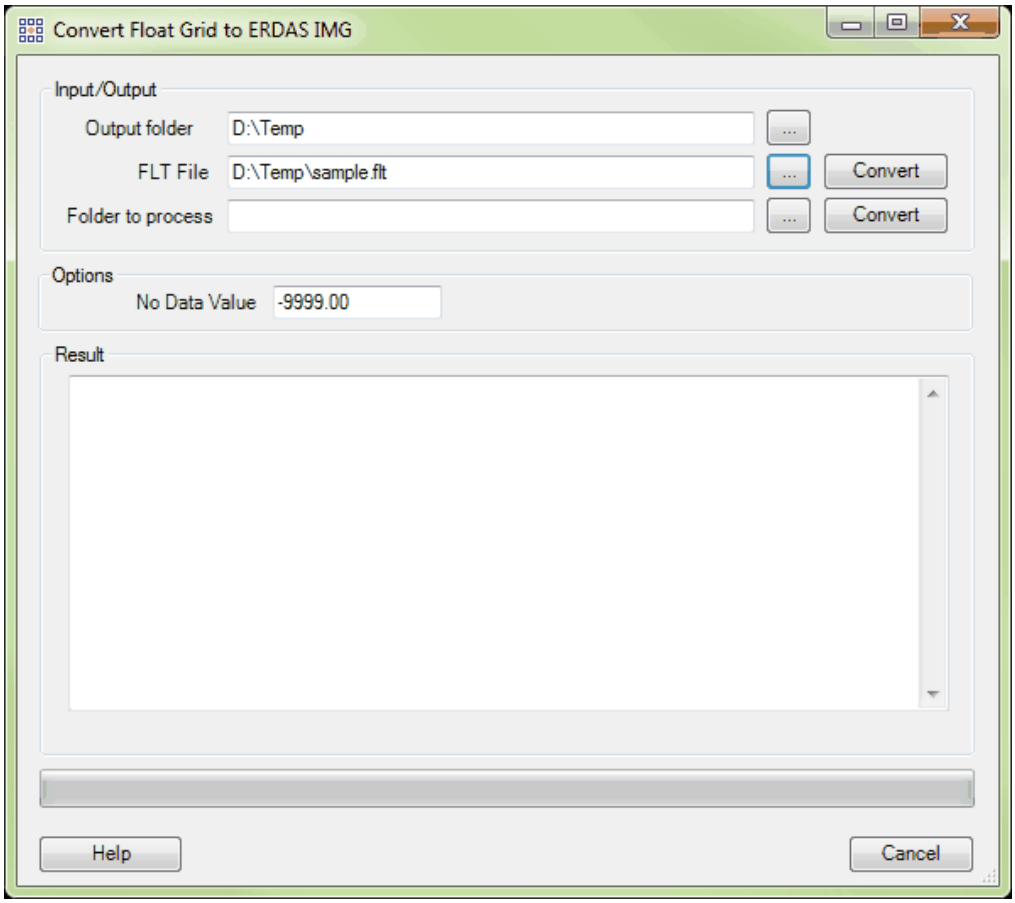
Float Grid to TIFF ***(available with Production license only):*** This tool, found under the 'Format Conversion' drop-down, will convert an existing Float Grid or folder of Float Grids to the GeoTIFF format. To use, choose a Float Grid file or folder using the appropriate browse button and browse to or key in an 'Output Folder.' Please note that the source *.FLT and *.HDR files must be in the same folder. Projection definition information may (optionally) be applied to the new TIFF(s) by selecting the horizontal system name (the browse button will bring up the GeoCalc 1748 interface where a selection can be made) and entering the Horizontal and Vertical Units from the drop-down boxes. Click the appropriate 'Convert' button to begin the process.

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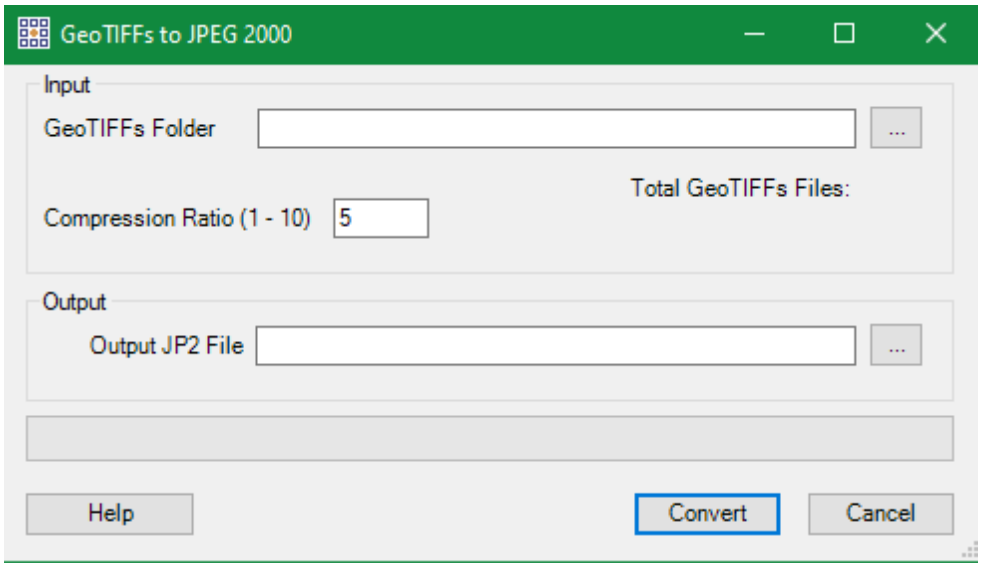
Float Grid to IMG ***(available with Production license only):*** This tool, found under the 'Format Conversion' drop-down, converts a Float Grid (*.flt) to an ERDAS Imagine compatible IMG file. The conversion can be done by file or folder, and the No Data Value can be specified by the user.

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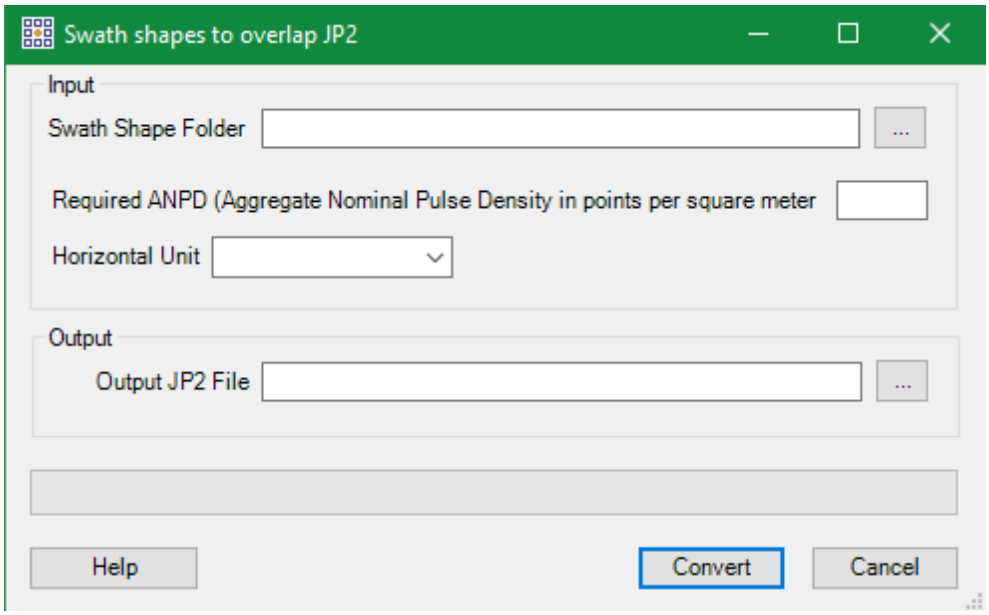
GeoTIFFS to JPEG 2000: This tool, found under the 'Format Conversion' drop-down, combines a folder of GeoTIFF rasters into a single JPEG 2000 raster (JP2) with a user-specified name and output folder location. Regardless of the input format of the GeoTIFFs, the output raster will be a 3-band (RGB), 8-bit file. The tool is, therefore, not appropriate for merging floating point rasters such as DEMs into a single JP2 raster containing elevation values in the cells. The compression ratio can be modified to find the best balance of quality and file size. The default compression value is '5' on a scale of 1 (lowest compression, highest quality) to 10 (highest compression, lowest quality). An assumption is made that all input GeoTIFFs are in the same coordinate system and have the same cell sizes.

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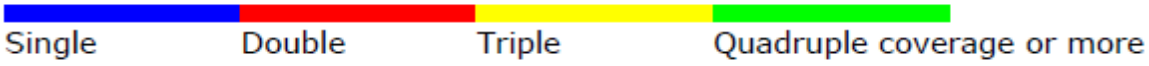


Swath shapes to overlap JP2: This tool, found under the 'Format Conversion' drop-down, converts a folder of swath footprint shapefiles into a JPEG 2000 raster to allow faster and more complete coverage checking. Browse to and select the folder containing the swath footprint shapefiles (these must be polygons), and select the output file name and location. The 'Required ANPD' (Aggregate Nominal Pulse Density) must be input, and the 'Horizontal Units' (e.g., Meters or US Survey Feet) must be selected from the drop-down list to ensure the proper cell size is used in the raster creation.

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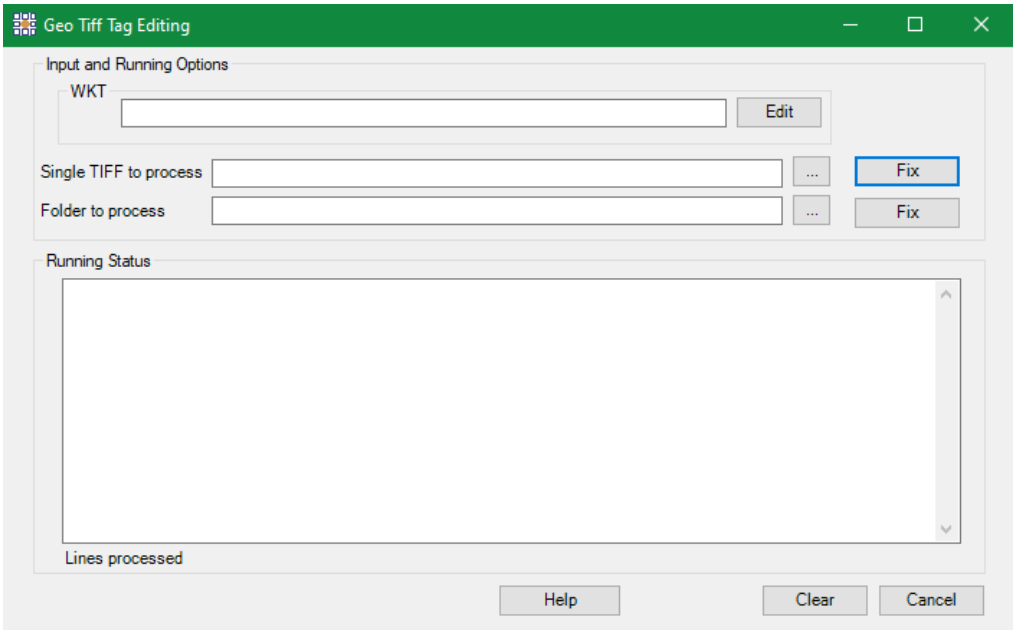


The output raster uses the same color coding as the 'Flight Line Overlap' raster in test DC10.1 of the Lidar Data Checks 1677 tool:



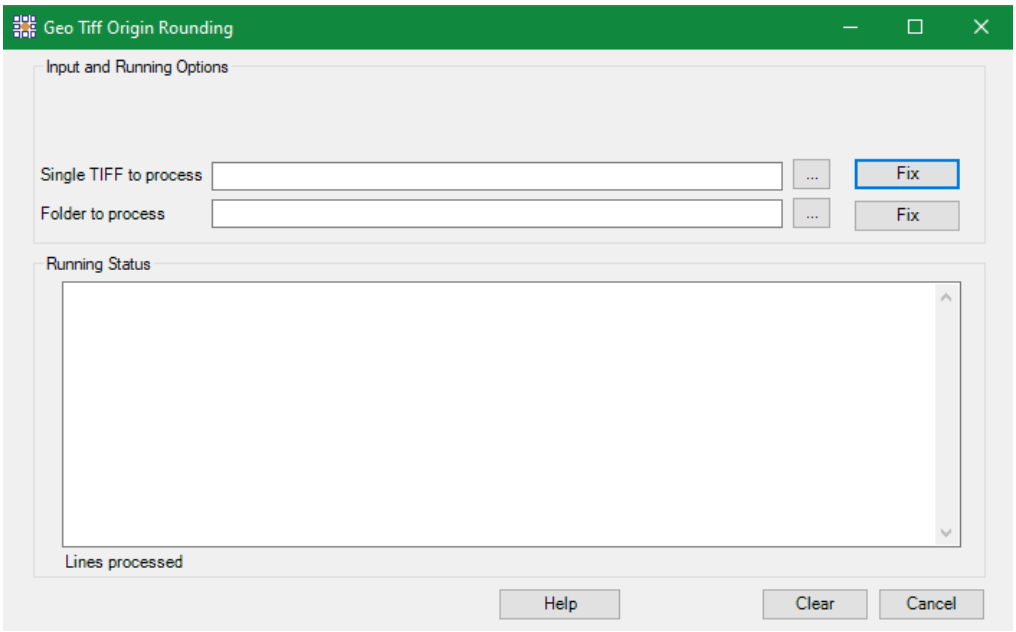
TIFF Tag Editing ***(available with Production license only):*** This tool, found under the 'Format Conversion' drop-down, creates a CRS (coordinate reference system) tag for TIFF files, or replaces an incorrect or incomplete tag. Click on the 'Edit' button to the right of the 'WKT' entry box to open a CRS selection window. Make the appropriate selections in the 'Horizontal' and 'Vertical' entry boxes in the top half of that window and click 'OK' (see the *'Add CRS Info (to LAS Files)'* topic in the Coordinate Conversion Tab 254 help section for details). Then browse to the TIFF ('Single TIFF to process') or TIFFs ('Folder to process') that need their tags edited and click the corresponding 'Fix' button. The 'Clear' button can be clicked to remove the results from the 'Running Status' box if another operation needs to be done. There is no output folder for this tool - the input TIFF or TIFFs are silently overwritten with the new versions.

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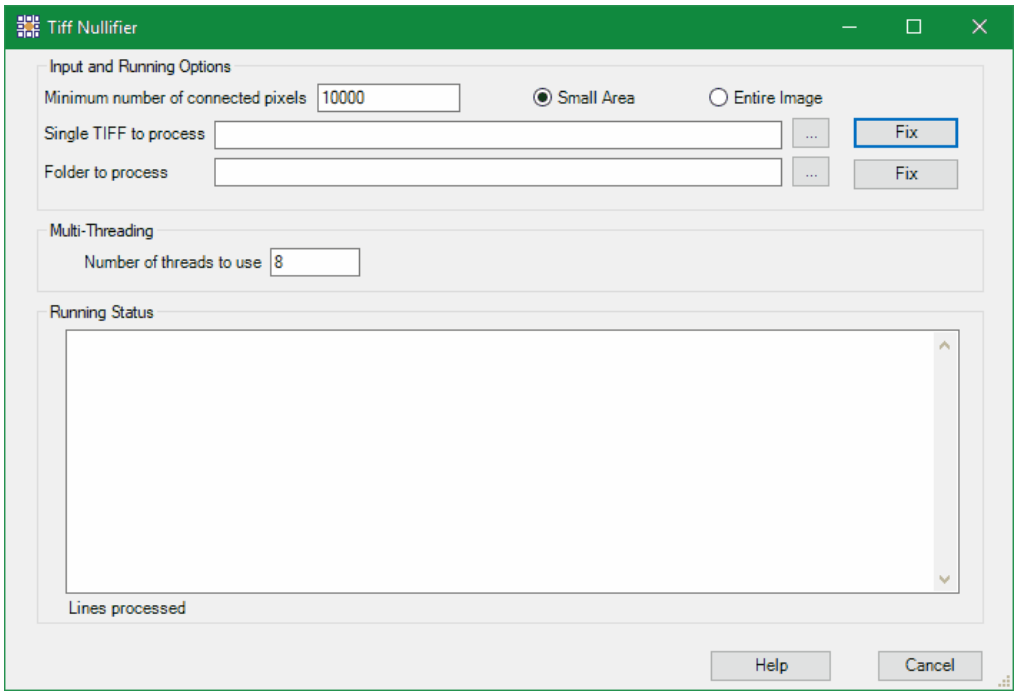
TIFF Origin Rounding ***(available with Production license only):*** This tool, found under the 'Format Conversion' drop-down, rounds off raster extent values to three decimal places, allowing for better edge-matching with adjacent rasters and better agreement with tile boundary coordinates. Browse to the TIFF ('Single TIFF to process') or TIFFs ('Folder to process') that need rounding and click the corresponding 'Fix' button. The 'Clear' button can be clicked to remove the results from the 'Running Status' box if another operation needs to be done. There is no output folder for this tool - the input TIFF or TIFFs are silently overwritten with the new versions.

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Tiff Nullifier ***(available with Production license only):*** This tool finds clusters of connected pixels with cell values of 1,1,1in one or more 3-Band (RGB) TIFF images, and re-writes those values to 0,0,0. The minimum number of connected pixels can be set, along with the search area parameters. When 'Small Area' is selected, the tool will be expecting only a single area to be modified, and the process will terminate after locating and re-writing that area. If 'Entire Image' is selected, the tool will search the entire TIFF for areas meeting the minimum cluster size before stopping. This tool will benefit from Multi-Threading when the 'Folder to process' option is used. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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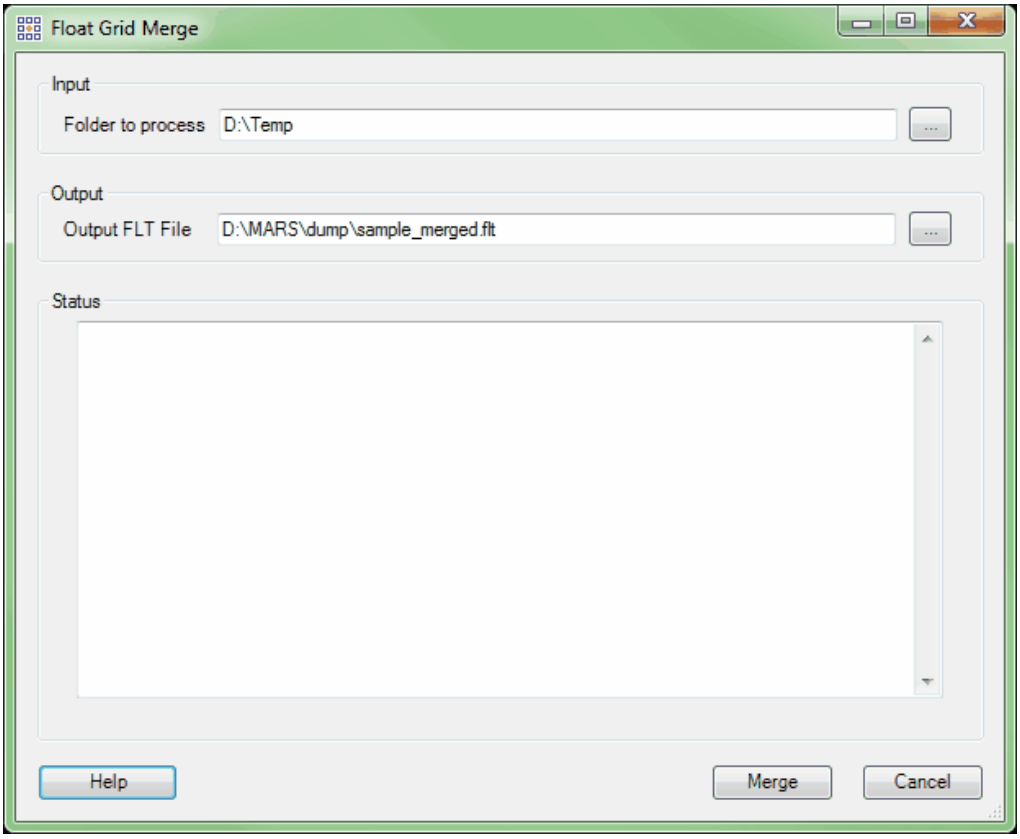
Float Grid Merge: The 'Float Grid Merge' tool, found under the 'Float Grid Operations' drop-down, allows the user to combine multiple float grids into a single file. The files being merged inside this tool do not need to be loaded into MARS® prior to being merged. To use this tool:

1. Place the singular float grids which will be combined to create the merged float grid into the same folder.
2. Specify this folder in the '**Input: Folder to process**' text box. The user may navigate to the folder by clicking the '**...**' button.
3. Next, specify the output folder and name the new float grid file. Clicking on the '...' button will allow the user to navigate to the designated output folder where the merged float grid will be placed after creation, or the path may be keyed in. The user must also name the new, merged file here. In the example below, the user has named this file 'Merged'.

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4. Click the **'Merge'** button to begin the process. The progress of the tool (by file) may be monitored in the bottom window of the interface.

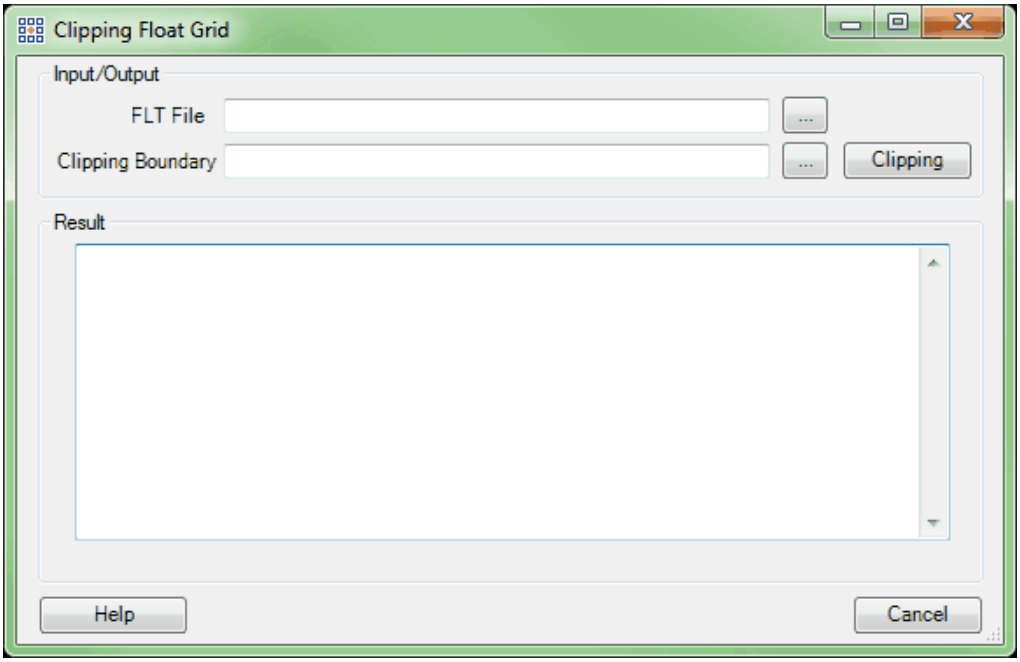
To view the result, the user must add the newly created float grid file by clicking the **'Add Float Grid'** button on the Project/Data Preparation Tab[162] and choosing the merged float grid file.



Float Grid Clipping: This tool, found under the 'Float Grid Operations' drop-down, allows a Float Grid to be clipped to the extents of a polygon shapefile. To use, click on the ellipse button to the right of the 'FLT File' text box and navigate to the Float Grid file to be clipped. Then choose the polygon shapefile to be used as a clipping boundary by clicking the ellipse button to the right of the 'Clipping Boundary' text box. Click on the 'Clipping' button to begin the process. A message will appear in the

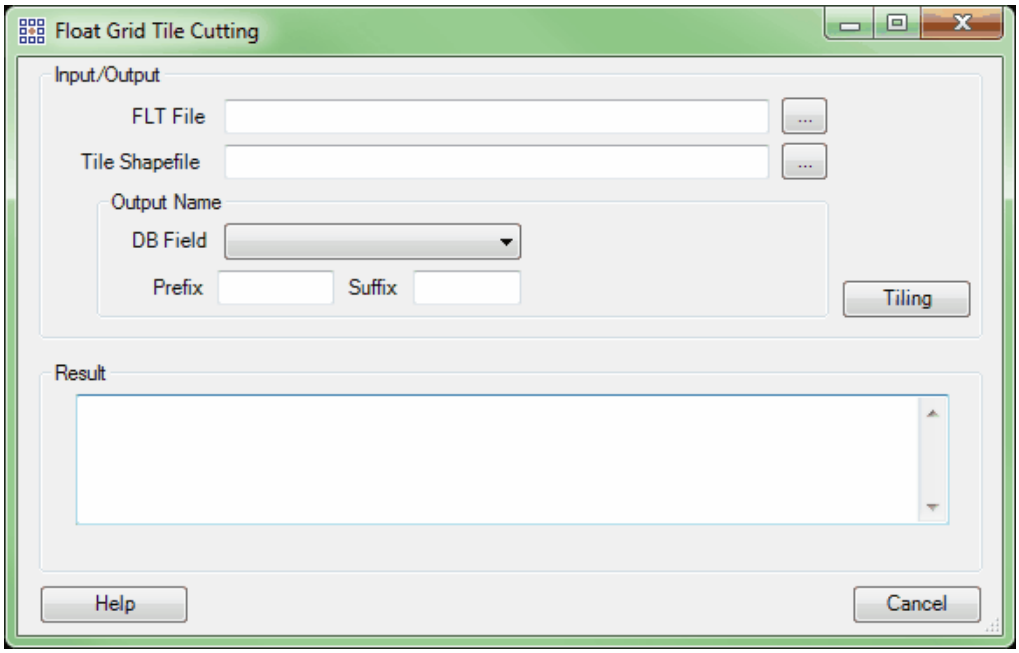
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'Result' box when the clipping is complete. ***NOTE: The existing file will be overwritten with the new result and only that grid data within the polygon(s) of the shapefile will be kept.***



Float Grid Tile Cutting: This tool, found under the 'Float Grid Operations' drop-down, allows a Float Grid to be cut into individual areas based on a tile layout shapefile. To use, click on the ellipse button to the right of the 'FLT File' text box and navigate to the Float Grid file to be tiled out. Next, click on the ellipse button to the right of the 'Tile Shapefile' text box and navigate to the tile layout. All polygons in the tile shapefile will be used to cut the original Float Grid into individual areas. Choose a unique-value attribute field ('DB Field') that will be used to name the output Float Grids. Optionally, a 'Prefix' and/or 'Suffix' can be added to further define the new grid names. Click on the 'Tiling' button to begin the process. A message will appear in the 'Result' box when the tiling is complete. The new tile-based Float Grids will be output in the same folder as the original Float Grid, and the original will not be altered in any way.

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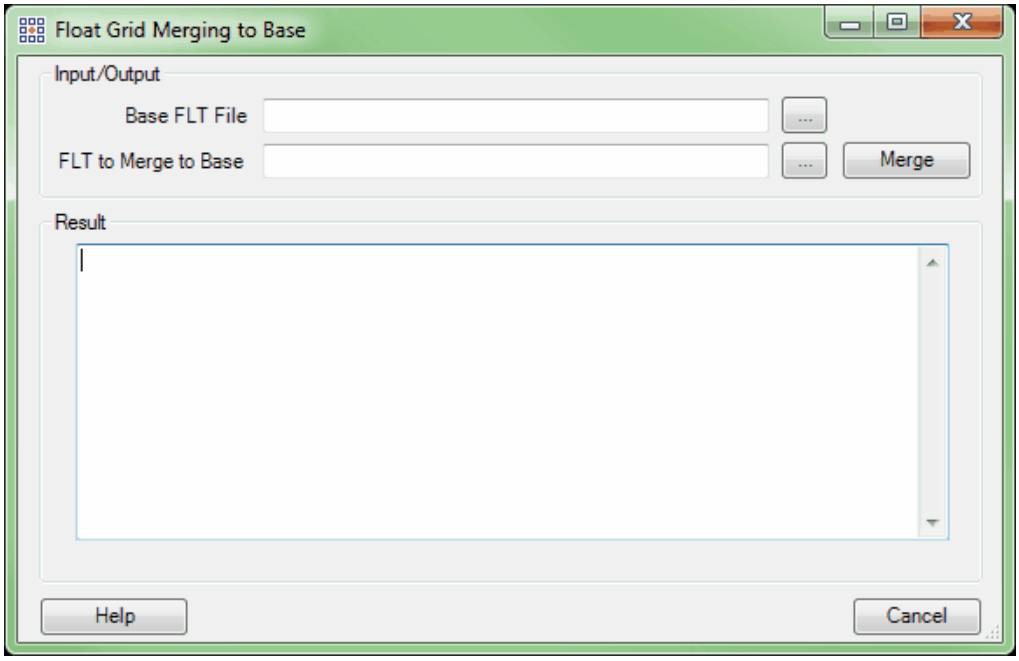


Float Grid Merge to Base: This tool, found under the 'Float Grid Operations' drop-down, can be used to replace a re-processed area of an existing Float Grid with corrected grid data. It is particularly useful when only a small portion of a large area single-file Float Grid needs to be replaced, and can save a considerable amount of time over re-exporting the entire project area. A typical workflow would be as follows: 1. After identifying a mis-classified area of a Float Grid, use a tile layout shapefile to determine which tile or tiles are affected. 2. Create a new tile shapefile with those tiles deleted. 3. Use the 'Float Grid Clipping' tool (above) to make a new Float Grid using the new tile shapefile as the Clipping Boundary - this will eliminate the bad area(s) from the original Float Grid. 4. Re-classify the LAS data as needed and export a Float Grid using only the tiles that encompass the modified area(s) - this export will be used as the 'patch.'

To use this tool, click on the ellipse button to the right of the 'Base FLT File' text box and navigate to the Float Grid that needs to be patched. Next, click on the ellipse button to the right of the 'FLT to Merge to Base' text box and navigate to the new Float Grid data that will be used to fill the void in the base grid. Click the 'Merge' button to begin the process. A

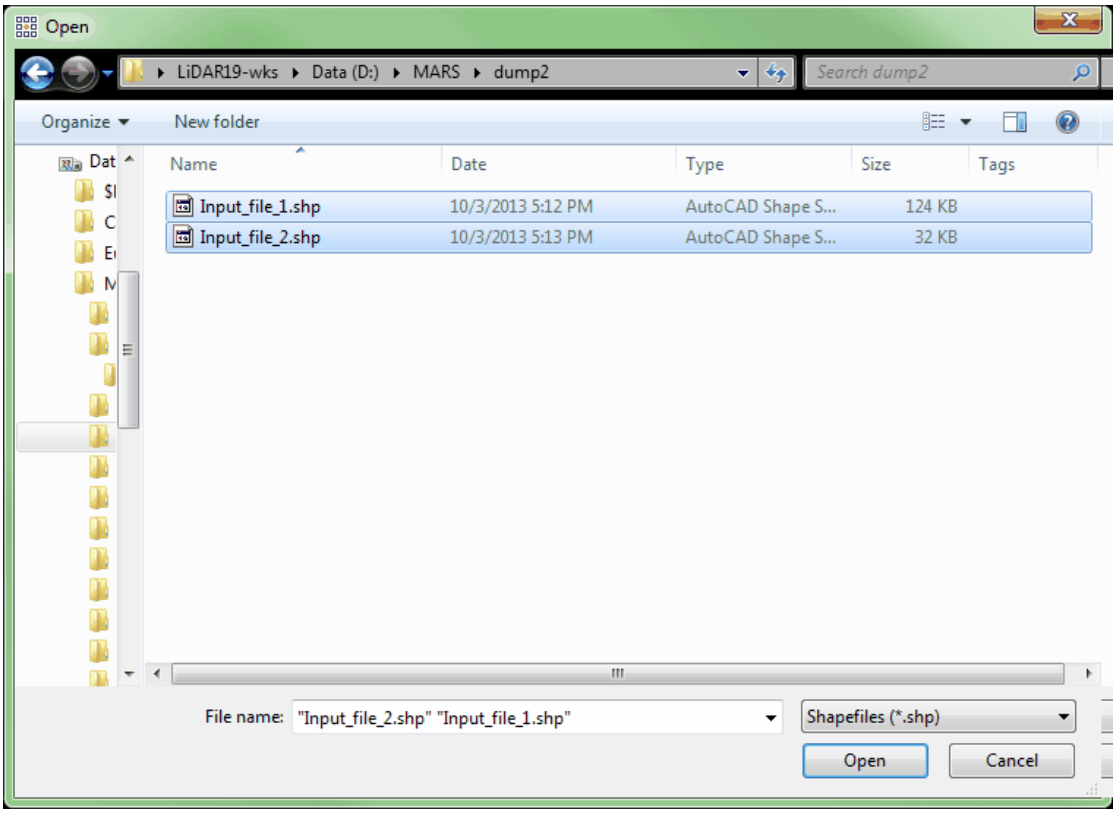
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message will appear in the 'Result' box when the merge is complete. ***NOTE: The existing base Float Grid will be overwritten by the new merged grid data.***

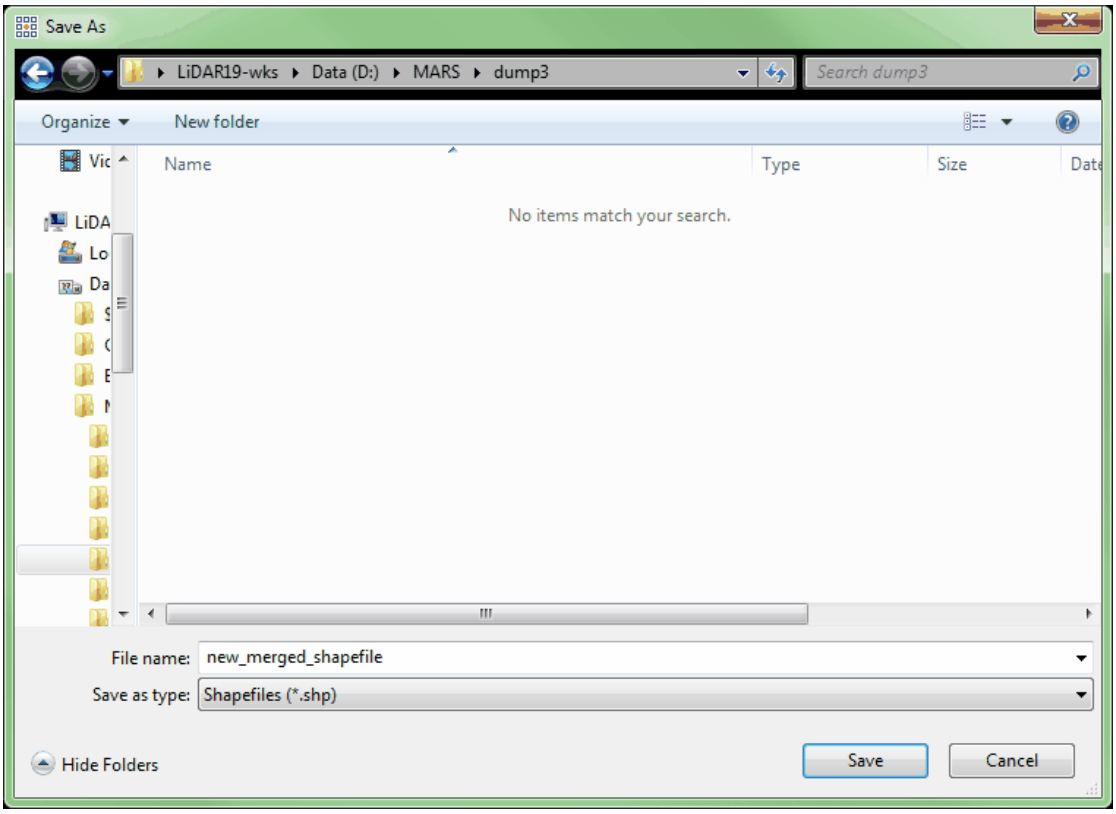


Merge Shapefiles ***(available with Production license only):*** This tool creates a new merged shapefile from two or more input shapefiles. All input files ***must*** be of the same geometry type (i.e., point, polyline, or polygon), and must reside in the same folder. After clicking on the tool, the 'Open' dialog box appears. Navigate to the folder where the shapefiles to be merged are located, then choose two or more shapefiles by using the left mouse button with 'Ctrl' or 'Shift' (standard Windows selection methods). Click 'Open' and the dialog box will change to a 'Save As' box. Enter an output folder and file name for the new merged shapefile and click 'Save.' A pop-up message will indicate when the tool has completed processing. If the input data has defined projection, then a PRJ file with that projection information will be created for the merged shapefile. The newly created shapefile can now be loaded into MARS® as a Reference Shapefile (or Tile Shapefile, as appropriate).

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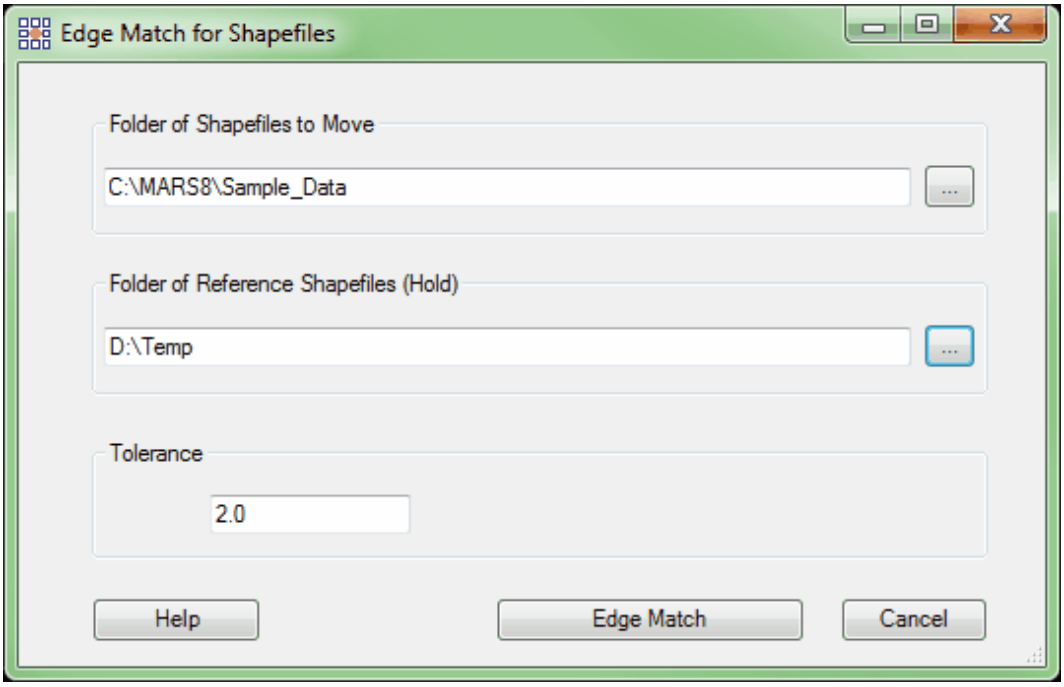
Edge Match for Shapefiles ***(available with Production license only):*** This tool allows the user to match the endpoints of shapefile contour lines in two (2) separate folders. Because the tool will only match contours with the exact same elevation, it is important that both shapefiles contain an elevation attribute field labeled 'ELV'. This attribute field must contain the elevations of each contour line.

- **Folder of Shapefiles to Move:** Navigate to the folder which contains the shapefiles of contour lines which are to be moved in the edge match process. The contour lines in these shapefiles will be moved to match the endpoints of the contour lines in the Reference Shapefiles folder. The contour lines will only be moved horizontally according to the tolerance the user defines. The elevation of the contour lines will not be changed in the edge match process. For this reason, the shapefiles ***must*** have an attribute field labeled 'ELV' which contains the elevations of every contour line in each shapefile. Only contour lines which are within the tolerance defined and which match

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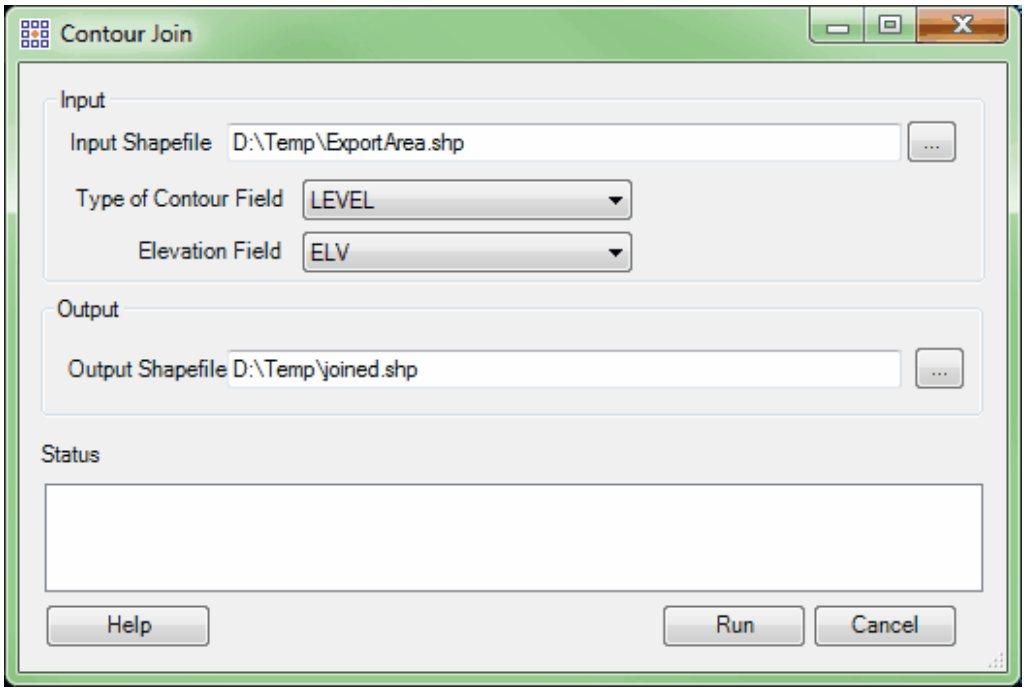
the exact elevation of the reference shapefiles' contour lines will be moved.

- **Folder of Reference Shapefiles (Hold):** Navigate to the folder which contains the shapefiles of reference contour lines to be used. The reference shapefile contour lines ***will not*** be moved during the edge match process. The reference shapefile contour lines will be used to measure the tolerance as defined below, and contour lines in the 'Shapefiles to Move' set will be moved to match these contour lines. The reference shapefiles ***must*** have an attribute field labeled 'ELV' which contains the elevations of every contour line in each shapefile.
- **Tolerance:** Enter a number (in project units) here to set a maximum search radius for finding matching-elevation contour lines in the 'Move' and 'Hold' folders. In the example below, the tolerance is set at 2.0 units. If a contour line endpoint with a matching elevation is found within 2.0 horizontal units of the contour line endpoint in a reference shapefile, the endpoint will be snapped to the endpoint of the reference shapefile contour.

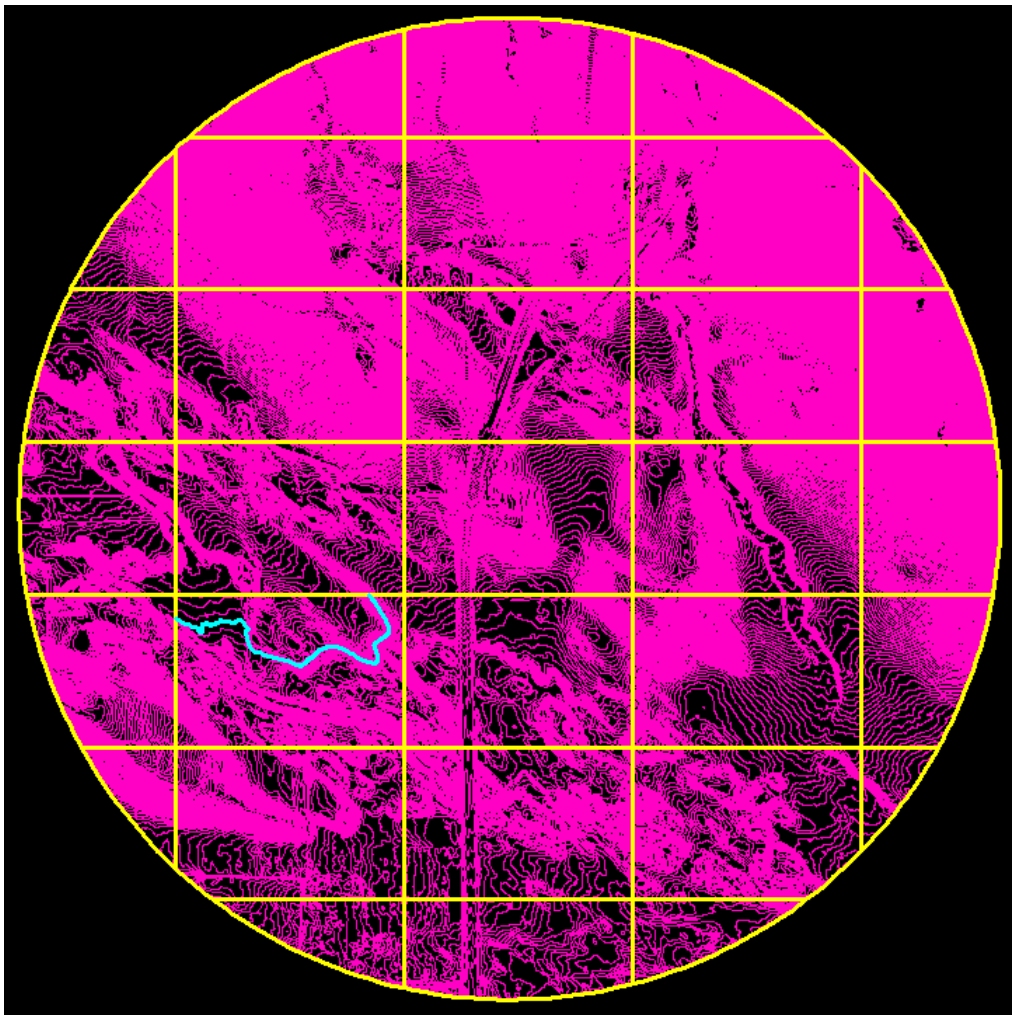


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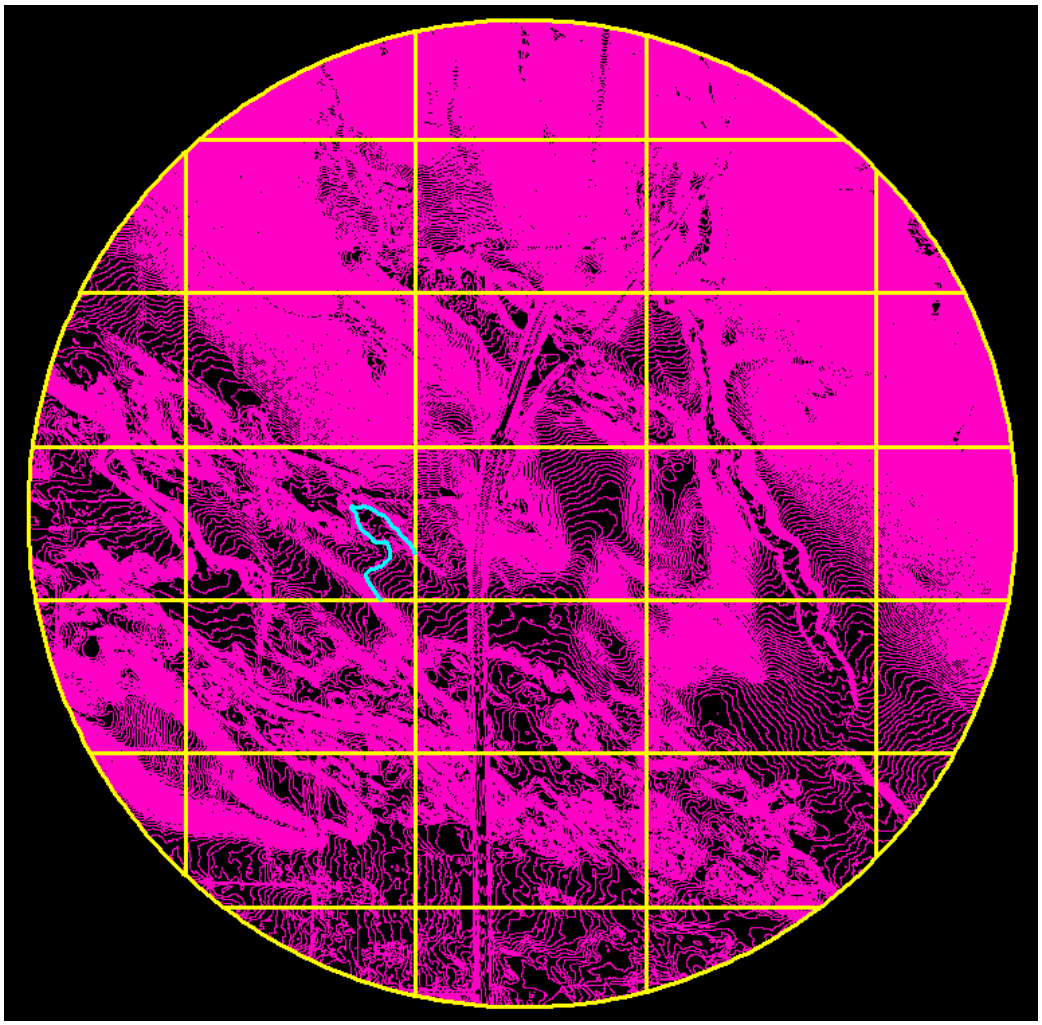
Contour Join: This tool allows the user to join several different contour features into one continuous contour. For example, the screen shots below show a single contour line which was broken apart into several different features (or separate contour lines) by tile. This line, which represents only one contour, is now several contour lines. The contour line breaks into separate contour lines at every tile boundary.



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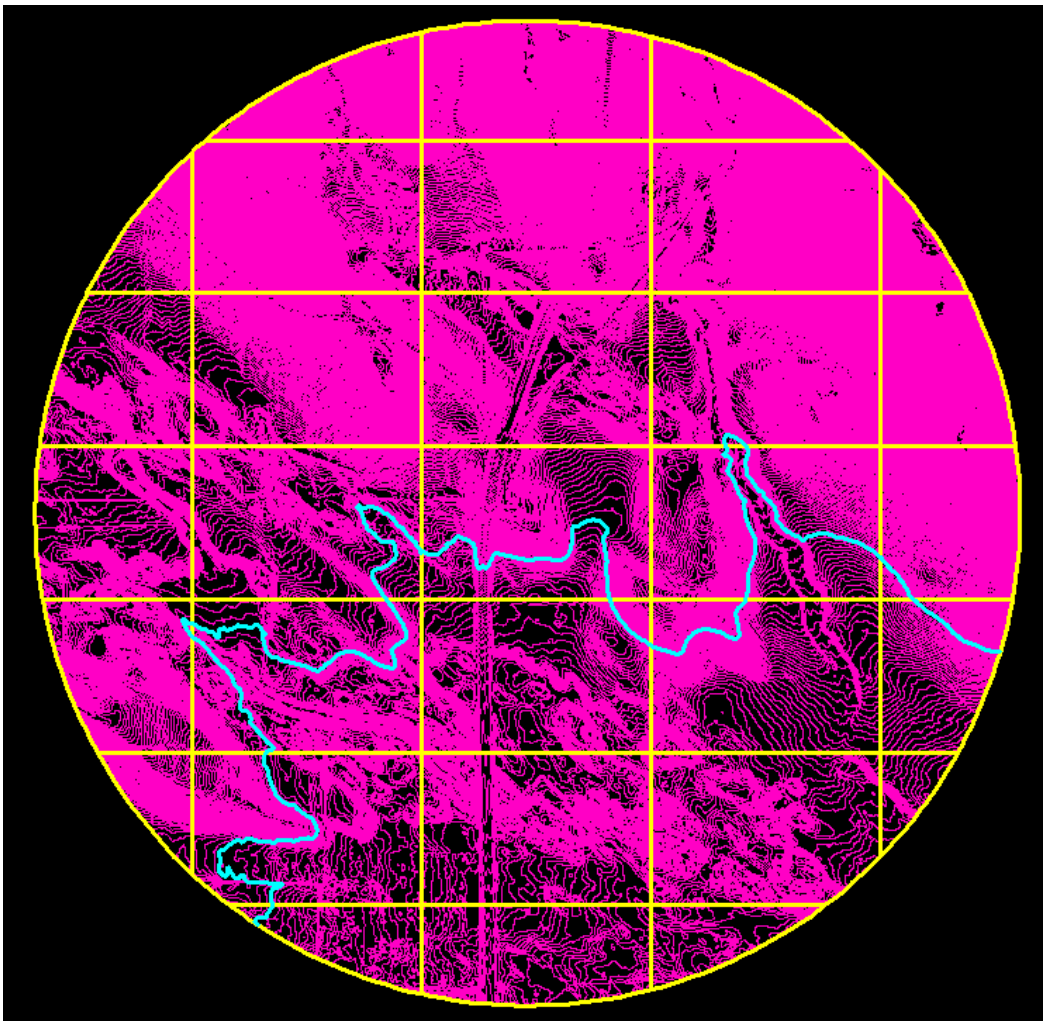


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In the example below, the 'Contour Join' tool has been run on the same contours as shown above. The contour which was cut at the edges of each tile now runs continuously for its entire length until the project boundary.

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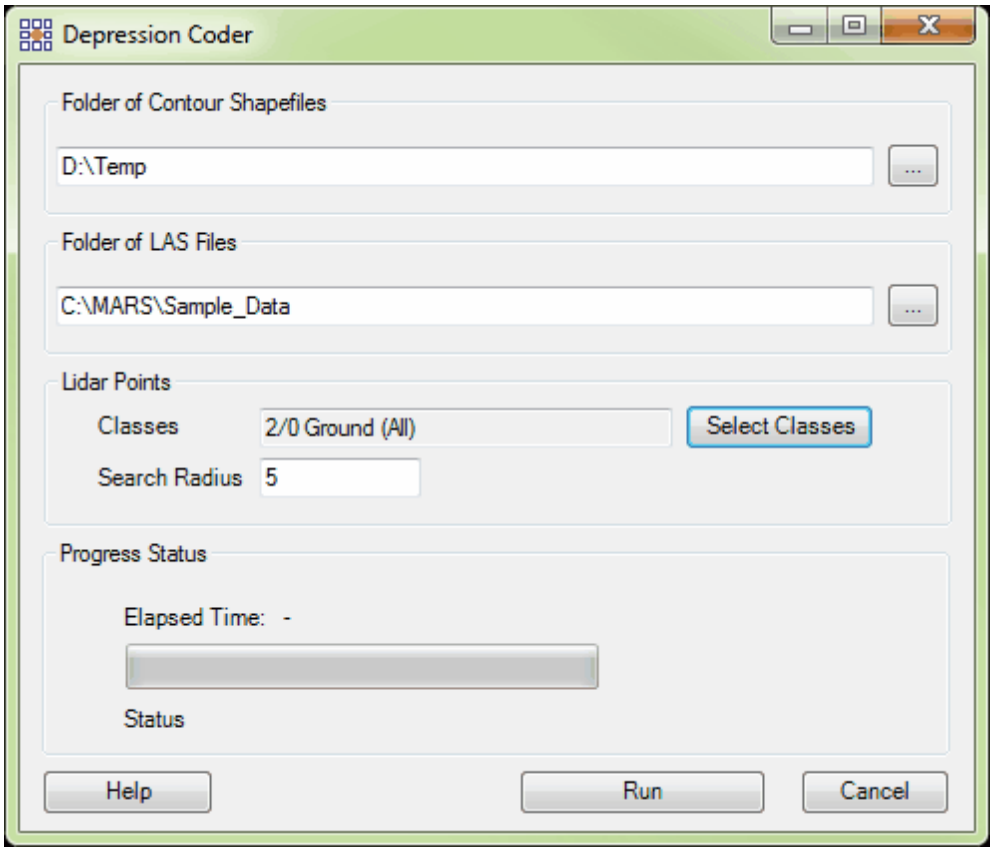
Depression Coder ***(available with Production license only):*** The 'Depression Coder' tool allows the user to find depression contours and label them as such in a newly-generated contour shapefile's attribute table. This tool is meant for use over an entire project-wide area, preferably using a single, merged shapefile of contours. This makes the processing more accurate by allowing the tool to locate large depressions spread over several tiles which would have otherwise been missed if processing was done over a smaller area or run by tile. The tool searches through the data looking for closed contours which form 'polygons', indicating a depression or rise in the earth's surface.

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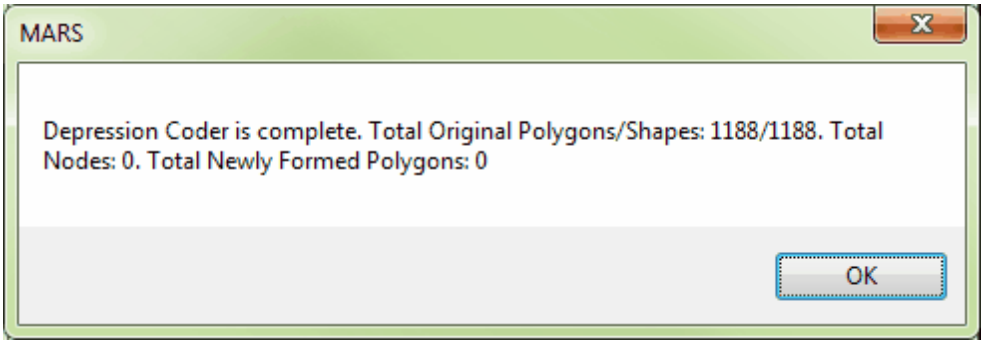
To use, navigate to the folder containing the contour shapefiles for the entire project in the **'Folder of Contour Shapefiles'** text box. Navigate to the folder containing the accompanying LAS data for the entire project in the **'Folder of LAS Files'** text box. Ideally, use the same LAS data that the contours were generated from. The 'Depression Coder' tool will not make any changes to the LAS data. The LAS information is only used as a reference to help find depression contours and ignore rising contours. For example, contours generated over a dry lake bed (depression contours) are very similar in appearance to contours created over a large hill (rising contours) when viewing only the linework and not the elevation values. Since the LAS data contains elevation information (Z-values) for each point, it will help in assessing whether the closed contours are depression or rising contours. This is done by specifying the class (or classes) that contain ground points and setting a 'Search Radius' value that is equal to (or slightly larger than) the cell size used in making the original contours or the gridded surface they were generated from. This radius is the distance inside each closed contour that the tool will search for ground points. If points are found with lower elevation values, the contour will be labeled a depression. When all the necessary entries to the 'Depression Coder' interface have been made, click the 'Run' button. The progress of the tool may be monitored via the status bar. A new shapefile containing the depression-coded contours will be created in the **'Folder of Contour Shapefiles'**, with '_Processed' appended to the input shapefile's name.

Please see the Contours Tab 806 for information on expected level attribute values for proper operation of this tool. Depressions will be given a value one number higher than non-depression contours. For example, if Index contours are level 50 and Intermediate contours are level 51, then their depression equivalents will be assigned levels 52 and 53, respectively.

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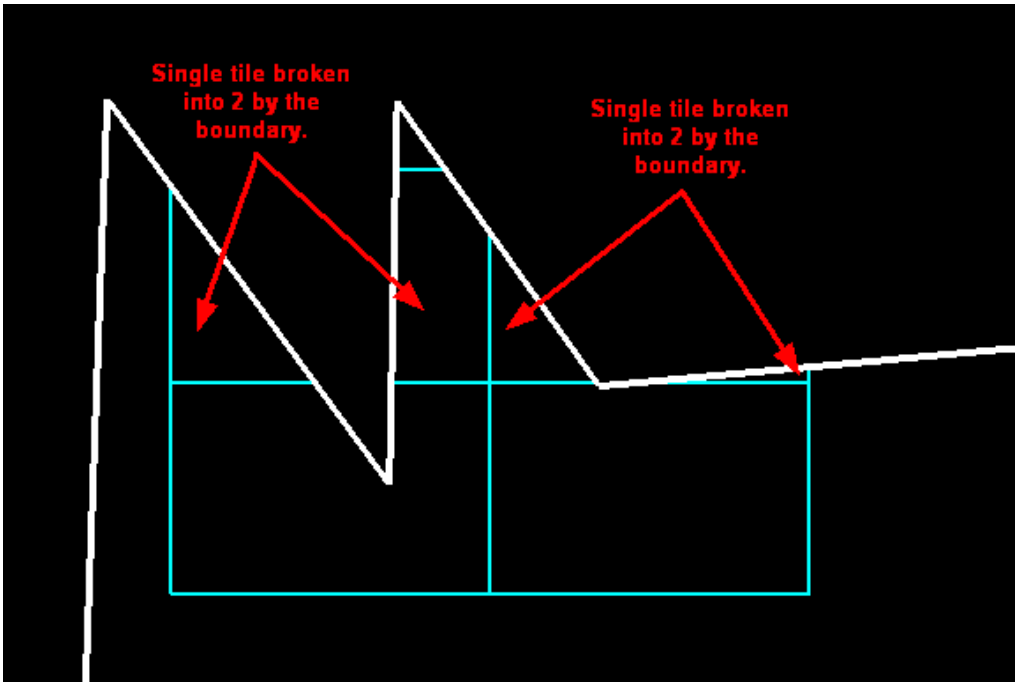
When the 'Depression Coder' tool has completed its task, the user will receive a prompt reporting the total original polygons, nodes, and newly formed polygons.



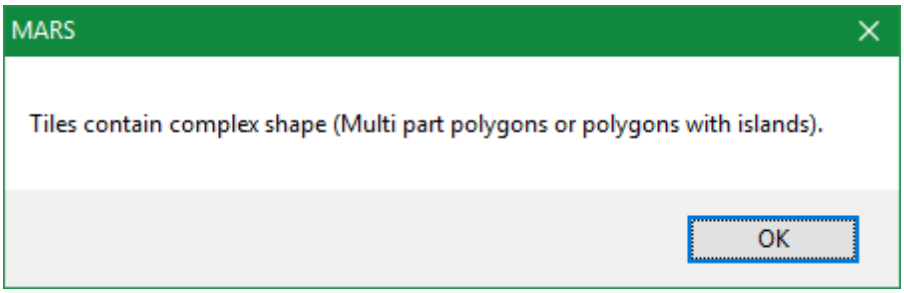
Complex Polys to Simple ***(available with Production license only):*** This tool allows the user to create separate files (simple polygons) from a multiple file (complex polygon) shapefile. This tool may be useful when the user wishes to export data by tile clipped to a boundary. If this boundary separates a

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particular tile into multiple parts, the user may end up with duplicate tile numbers. Duplicate tile numbers often may cause overwriting of needed data. The example below shows a boundary (in white) which cuts the two (2) indicated tiles in the tile shapefile (in blue) into multiple parts.



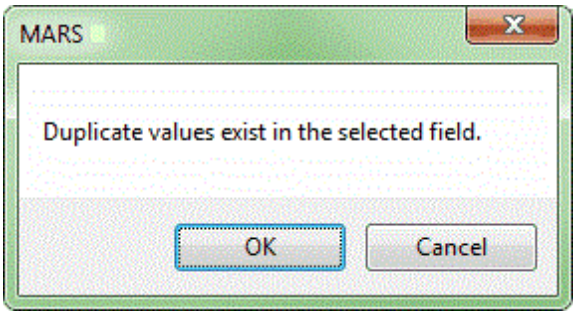
If the user loads a tile shapefile (similar to the one above in blue) that contains complex polygons, MARS® will notify the user. *This prompt will ONLY appear when the user is loading the complex shapefile AS A TILE SHAPEFILE, not* as a reference shapefile. This window appears only for information and as a suggestion to apply the 'Complex Polys to Simple' tool to avoid lost or overwritten data. If a complex shapefile (a shapefile containing multi-part polygons) has been loaded as a tile shapefile the following prompt will appear:



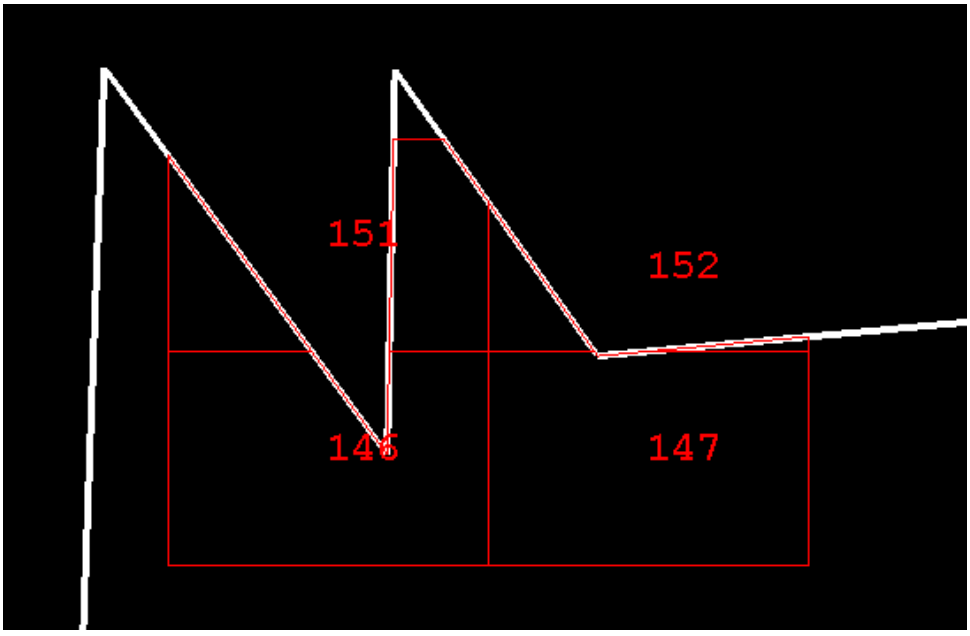
The file loaded must be a complex shapefile for this tool to work. If the user loads a tile shapefile which has been 'exploded' (separating multi-part features into single part features)

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then MARS® will not be able to recognize a single tile in multi-parts but only recognize two individual tiles. For this reason, any tile shapefile containing complex polygons must not be exploded for the 'Polygons From Complex to Simple' tool to work. If the file is 'exploded', a warning message will show upon export, but this file will no longer be functional in the 'Polygons From Complex to Simple' tool.

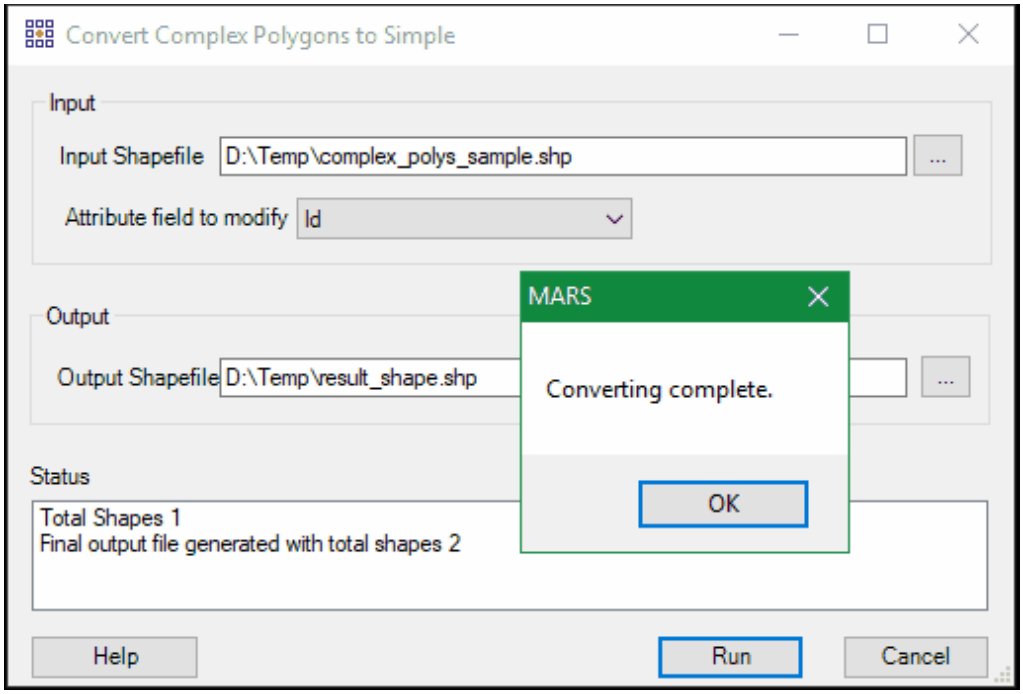


In the example below, MARS® is recognizing a tile shapefile which is complex. Tiles 151 and 152 have been cut into multiple parts by a boundary. A prompt was received when this shapefile was loaded. If the user were to export the data by tile at this point in time MARS® would export the data in one part of tile 151 then overwrite that data with the data in the other part of tile 151. The same would happen with tile 152. Thus, the user would lose some data in each tile causing gaps. To avoid this situation, use the 'Complex Polys to Simple' tool.



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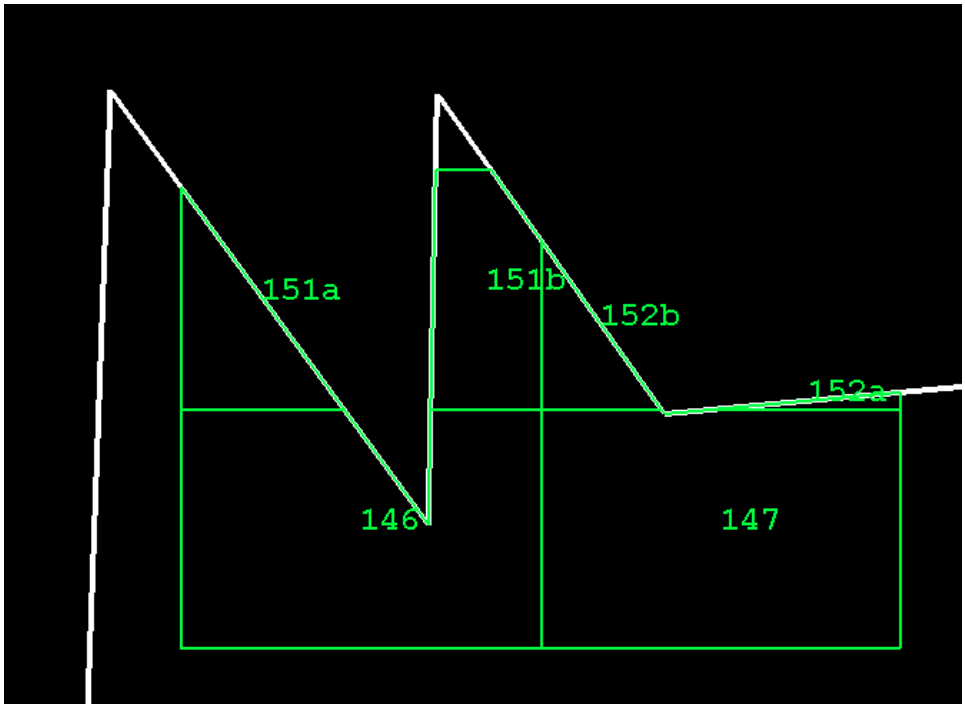
The Input Shapefile should be the complex shapefile which contains multi-part tiles. The user may choose the Attribute Field to Modify from the drop-down box. This list is created based on the attributes which are currently found in the attribute table for that particular shapefile. In most cases the user will be choosing 'TName' or the tile name of the attribute ('ET_ID' in this example). The output shapefile will be the simple polygon shapefile created. Navigate to a location for the new file and name the new file. Choose 'Run' to start processing. When processing is complete a prompt will notify the user. The Status box will give the user a short summary on the number of polygons found in the shapefile and how many new tiles it created. In the example below, the tool found one polygon (tile) and it was complex. Thus, the final output shapefile contains two polygons (tiles).



The new, simple polygon shapefile has distinguished between the multiple parts of a single tile. In order to avoid any overwritten data, the tiles have been named using an a, b, c... sequence. This way, each multiple part of a tile is perceived as a unique set of data and will

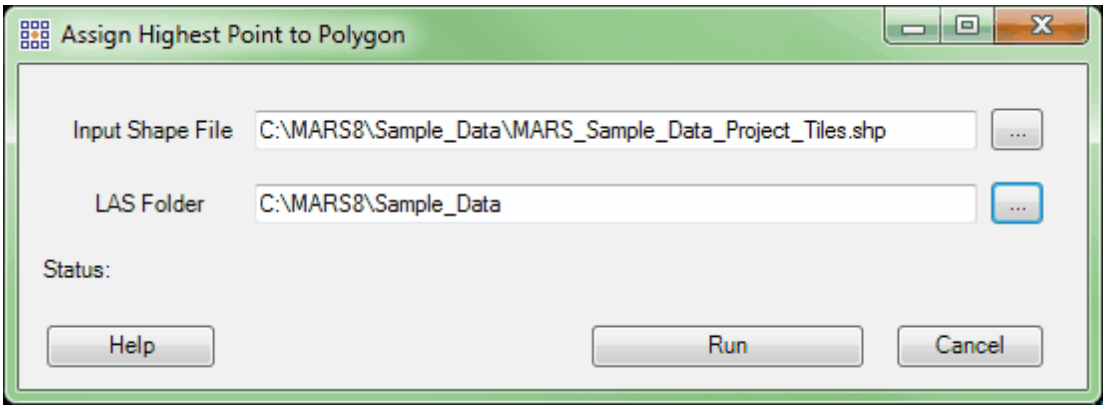
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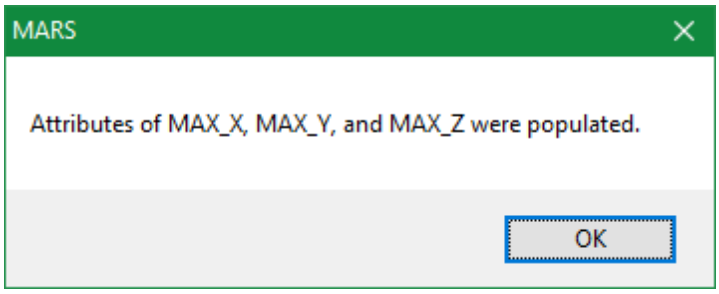
not be overwritten or replaced. The tiles previously named 151 and 152 are now named 151a, 151b, 152a, and 152 b. An example may be viewed below:

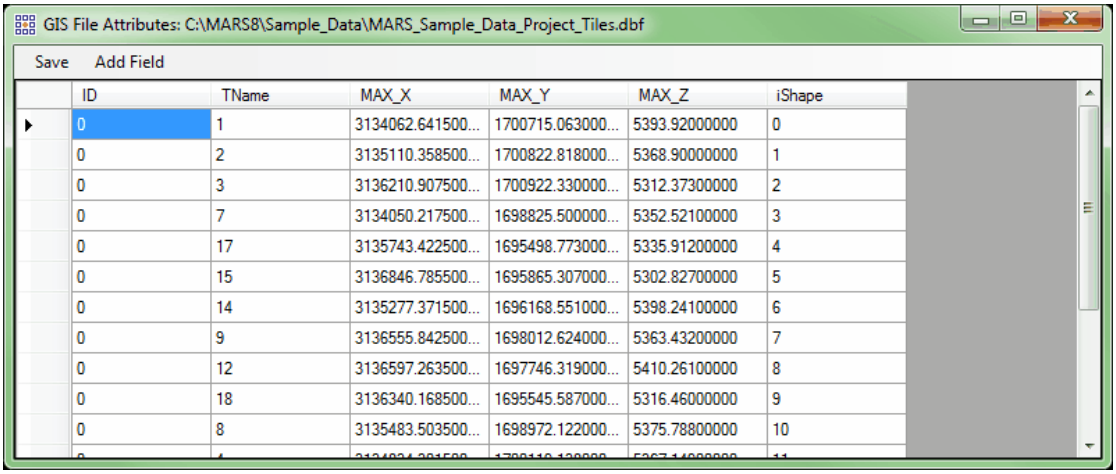


Assign Highest Z to Poly: This tool assigns X, Y, and Z values to all polygons in a polygon shapefile based on the values of the underlying LiDAR point within each polygon that has the highest Z-value(elevation). The shapefile must already have three fields defined as follows: Field Names - **MAX_X**, **MAX_Y**, and **MAX_Z**, all with the parameters Data Type - **Double**, Precision - **18**, and Scale - **8**. When the completed shapefile is loaded into MARS®, the new fields will be populated as shown in the example table (below).

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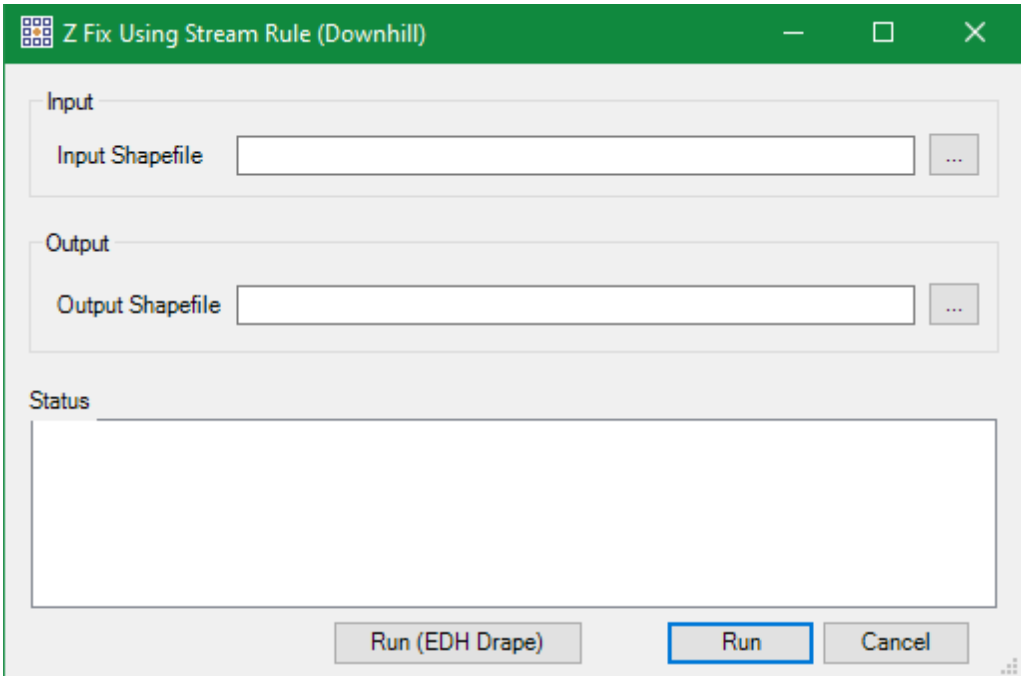


ID	TName	MAX_X	MAX_Y	MAX_Z	iShape
0	1	3134062.641500...	1700715.063000...	5393.92000000	0
0	2	3135110.358500...	1700822.818000...	5368.90000000	1
0	3	3136210.907500...	1700922.330000...	5312.37300000	2
0	7	3134050.217500...	1698825.500000...	5352.52100000	3
0	17	3135743.422500...	1695498.773000...	5335.91200000	4
0	15	3136846.785500...	1695865.307000...	5302.82700000	5
0	14	3135277.371500...	1696168.551000...	5398.24100000	6
0	9	3136555.842500...	1698012.624000...	5363.43200000	7
0	12	3136597.263500...	1697746.319000...	5410.26100000	8
0	18	3136340.168500...	1695545.587000...	5316.46000000	9
0	8	3135483.503500...	1698972.122000...	5375.78800000	10

Z Fix Using Stream Rule (***available with Production license only*****:** This tool will test and fix (if necessary) a 3D breakline shapefile to maintain monotonicity. In a hydrography context, monotonicity is the principle that elevations (Z-values) must decrease, or at least stay flat, as a breakline goes from uphill to downhill.

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No data needs to be loaded to use the tool. Path out the 3D breakline shapefile to be tested in the 'Input' section and the new (corrected) output shapefile in the 'Output' section. Then choose either the '**Run**' button (Z-values rounded to three decimal places) or the '**Run (EDH Drape)**' button (no rounding done) to start the tool. If a Z-value is detected that is higher than the previous uphill value, that previous value is copied to the 'bad' vertex. When the input shapefile has polyline geometry but contains both unclosed and closed features, two output files will be generated -- **<*name*>.shp** and **<*name*>_Polygon.shp**. The original input shapefile is never altered with this tool.

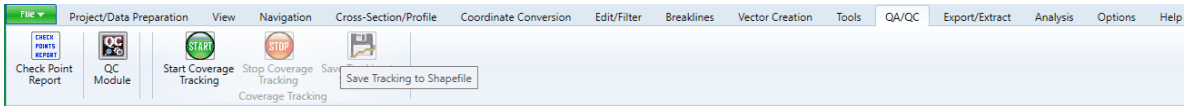


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3.11 QA/QC Tab

QA/QC Tab Items

The QA/QC Tab:



Check Point Report: Please see the Check Point Report 1224 topic for information on using this tool.

QC Module (*available with Explorer QC or Production license only*): Please see the USGS 2025 rev. A QC Module 1315, USGS 2024 rev. A QC Module 1351, USGS 2023 rev. A QC Module 1386, USGS 2022 rev. A QC Module 1421, USGS 2021 rev. A QC Module 1455, USGS 2020 rev. A QC Module 1490, USGS 2.1 QC Module 1525, USGS 1.3 QC Module 1559, USGS 1.2 QC Module 1592, USGS 1.0 QC Module 1622, Raster QC 1651, Voronoi Density Reporting 1660, LiDAR Workflow QC - 1 LiDAR Data Checks 1677, and LiDAR Workflow QC - 2 LiDAR Calibration Checks 1698 topics for information on using the various tools found in the QC Module.

Coverage Tracking Tools (*available with Production license only*):

The Coverage Tracking function makes a polygon shapefile noting where the user has been in the project. This helps to document which areas of a project have editing coverage. For example, when going into coverage check, the user would be able to distinguish what areas have been checked versus not checked. These tools work like a recorder in that the user is capable of starting recording, leaving the tool running while performing coverage checks to record movement, and then stopping recording. The user can also save the recorded data for later use.

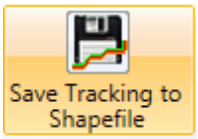
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Start Coverage Tracking: Use this tool when coverage checking, editing, or during any other activity where it is useful for the user to track movements across the project. Clicking the 'Start Recording' button will start the process of recording the user's movements across the data.



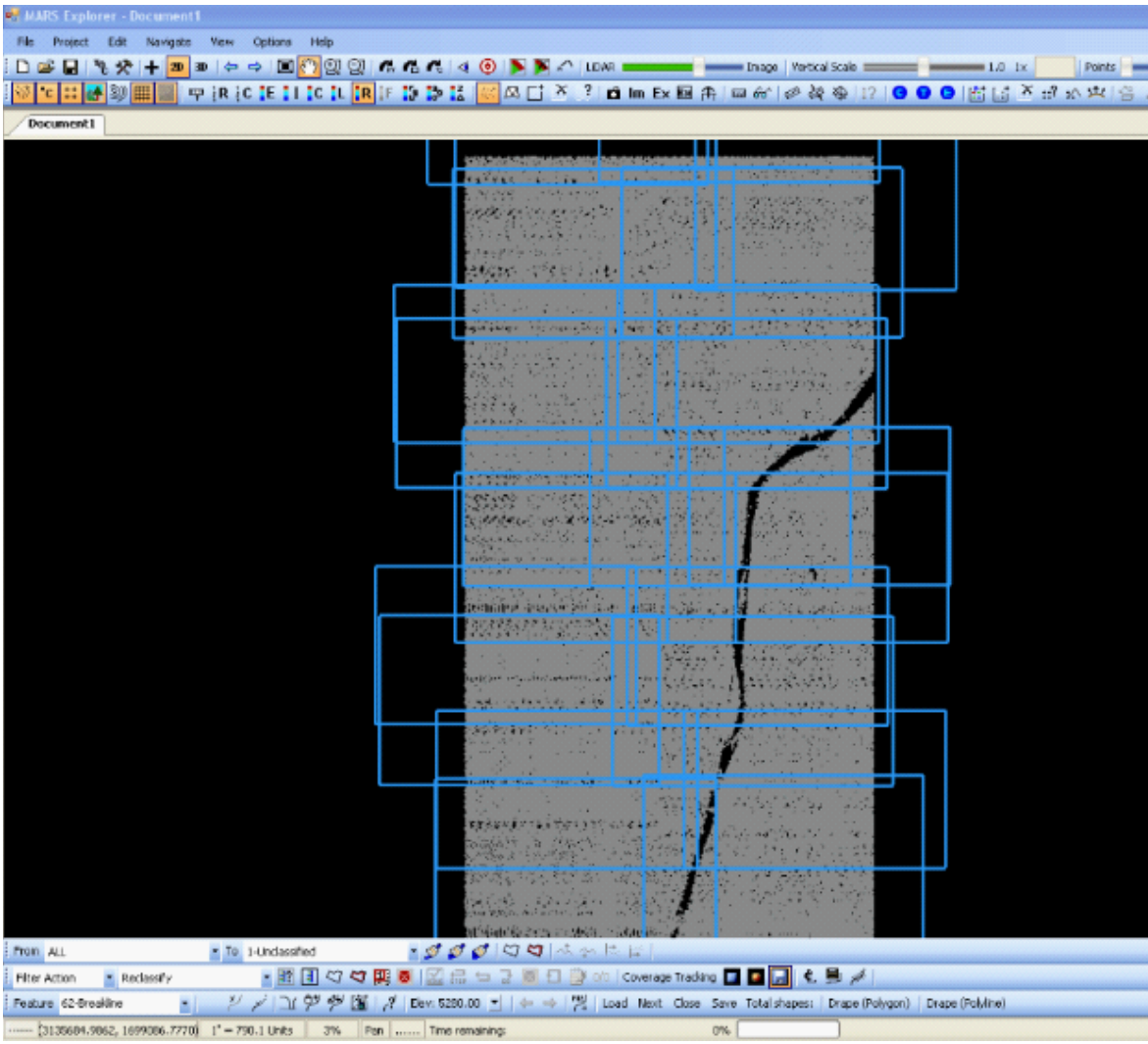
Stop Coverage Tracking: Select this button to stop the recording process. At this time, the user's movements across a project will no longer be noted in the shapefile created when the tracking path is saved.



Save Tracking to Shapefile: When the user has started and stopped a recording tracking the movements across a project, the recording can then be saved as a polygon shapefile. When a tracking shapefile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data. This shapefile will show the areas in which the user has visited. This can be useful in double checking that a project area has been fully examined. .

Ex: Each rectangle represents an area of the LAS Map View window and the data that was viewed inside that area. With this coverage checking tool, it is easy to see that all of the data below has been viewed and no area was left unchecked.

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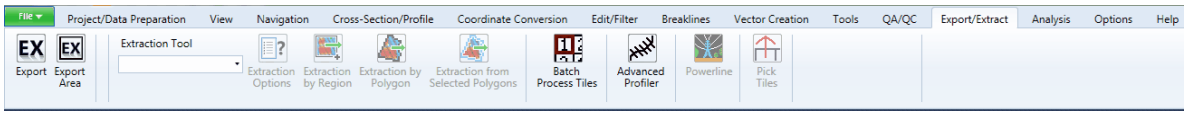
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3.12 Export/Extract Tab

Export/Extract Tab Items

Merrick Advanced Remote Sensing (MARS®) Software

The Export/Extract Tab:



For any LAS tools that allow files to be pathed out without loading them in the Table of Contents in MARS® (including 'Export' when the 'Export without loading LAS files into Map View' option is used), an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.



Export: Opens the export type drop-down list with 'LAS' as the default export type. The available export types are listed in item '**1.**' below. For more information on the different types of exports, please review the Data Export 658 topic and sub-topics.

When a type is selected and the 'OK' button is clicked, a dedicated window opens that controls all parameters and formatting options for that export type. All interfaces share several tools and functions in common: 'Save Settings to File', 'Load Settings from File', a progress bar, a display of 'Elapsed Time' and 'Estimated Time to Complete', buttons for 'Help', 'Export', and 'Cancel', and an option labeled 'Only Displayed Files Will Be Exported'. Please note that all loaded data will be exported unless the 'Only Displayed Files Will Be Exported' box is checked. ***This option is not available when the 'Export without loading LAS files into Map View' option is checked on the*** Options Tab 780 ***(see the Export Options 780 topic for details).*** Also, most export types have a 'Multi-Threading' control to improve performance by using the processing computer's resources more efficiently.

1. **Export Types:**

   - ✓ **3D Image**: This option exports a specially-colorized 'hybrid' LAS file - a mix of high-density gridded data to represent ground and non-gridded data to represent above

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ground features.

- ✓ **Contours - Shapefile**: This option exports contours in an Esri-compatible shapefile (*.shp) format.
- ✓ **Flightline Separation - JPEG 2000**: This option exports a JPEG 2000 (*.jp2) raster depicting collection scan (flightline) separation Z difference values using a color ramp.
- ✓ **Flightline Separation - Tiled GeoTIFF**: This option exports GeoTIFF rasters based on selected tiles from a loaded tile layout, depicting collection scan (flightline) separation Z difference values using a color ramp.
- ✓ **Grid - Cloud Optimized GeoTIFF DEM**: This option exports an elevation raster in GeoTIFF format with internally stored CRS (coordinate reference system) information for both horizontal and vertical. This GeoTIFF is recognized by GDAL as cloud-optimized to improve streaming performance.
- ✓ **Grid - Cloud Optimized GeoTIFF Intensity**: This option exports an intensity-based raster in GeoTIFF format with internally stored CRS (coordinate reference system) information for horizontal. This GeoTIFF is recognized by GDAL as cloud-optimized to improve streaming performance.
- ✓ **Grid - ENVI Elev**: This option exports an interpolated ENVI elevation grid (*.dat, *.hdr, and auxiliary *.xml).
- ✓ **Grid - ENVI Elev/Class**: This option exports an interpolated ENVI elevation grid (*.dat, *.hdr, and auxiliary *.xml) and a classification grid (*.dat and *.hdr).
- ✓ **Grid - Esri ASCII Grid**: This option exports an interpolated Esri ASCII elevation or intensity grid (*.asc) containing cell values in a row and column array; its auxiliary reference file (*.hdr) contains the number of rows and columns, x and y lower-left corner coordinates, the grid cell size, and the no-data value.
- ✓ **Grid - Float Grid**: This option exports an elevation or intensity float grid (*.flt with auxiliary *.hdr)) based on gridding specifications set up on the 'Grid' tab.

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- ✓ **Grid - IMG**: This option exports an ERDAS-compatible elevation or intensity grid (*.img).
- ✓ **Grid - LAS**: This option exports data to an interpolated, evenly spaced gridded LAS file (PDRF 6 only) with all points flagged as 'Synthetic'.
- ✓ **Grid - LiDAR Raster JPEG 2000**: This option exports a JPEG 2000 (*.jp2) raster of the LiDAR points colored by Class, Intensity, Elevation, or RGB values.
- ✓ **Grid - TIFF**: This option exports data to an interpolated, evenly spaced elevation or intensity gridded file, either in a GeoTiff (*.tif) format or as a TIFF format with an auxiliary World File (*.tif and *.tfw).
- ✓ **Hillshade - JPEG 2000**: This option exports a JPEG 2000 (*.jp2) raster with user-selectable sun azimuth and angle.
- ✓ **LAS**: **The s**tandardized LiDAR binary format containing: X, Y, Z, intensity, classification, collection scan, timestamp, and return information, as well as other fields.
- ✓ **LiDAR Point Density - Float Grid**: This option exports a float grid with the raster cells colored by relative point density, using the same color scheme as 'Color by Elevation' rendering on the View Tab 192.
- ✓ **LiDAR Spatial Distribution Verification GRID - JPEG 2000**: This option exports a JPEG 2000 (*.jp2) raster using a two-color display for QC.
- ✓ **PLS-CADD Code - ASCII**: This option exports PLS-CADD compatible delimited (CSV) files.
- ✓ **PLS-CADD Code - LAS**: This option exports LAS files for each class (or group of classes) that relate to a particular PLS-CADD feature code.
- ✓ **Shapefile**: This option exports LAS data to a point shapefile (.shp). The settings on the 'Layout' tab can select attribute fields to populate from the point records.
- ✓ **Text - ASCII**: The settings on the 'Layout' tab can select fields and delimiters for the output. ASCII text has grid output options.

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- ✓ **USGS Swath Separation Image - Tiled GeoTIFF**: This option exports GeoTIFF rasters based on selected tiles from a loaded tile layout, depicting collection scan (flightline) separation Z difference values with an intensity image background, using pre-determined settings that adhere to the latest USGS NGP LiDAR Base Specification.

2. **Output tab** - The 'Output Directory' path is set here for all export types. Use the **'Browse'** button or key in the desired path to set the path for the exported files. Most types also have an option for using temporary local disk space to speed up exports that are being written to a network drive. Some types have additional settings on this tab that are detailed in that help topic for that type in the Data Export 658 section.

3. **Layout tab** - Contains tools for formatting, naming, tiling, and clipping the export data.

   Format Section: There are seven different format types for controlling the shape (Layout) of the exported data. Not all are available (or visible) for all export types.

   - ✓ **Single File** - Exports all currently loaded data as a single output file. No tile layout is used, even if one is loaded. Choose this layout type if tiled export is not needed but, instead, one single file is required. This layout type is most commonly used when exporting a grid-based product.
   - ✓ **All Tiles using MBR** - Exports all currently loaded data by creating a minimum bounding rectangle for each tile in the loaded shapefile tile layout. Choose this layout type to export all tiles found in the loaded shapefile tile layout in the fastest manner possible. This layout type will determine the minimum bounding rectangle of each tile - for example, if the loaded tile layout consists of circles, the output data would be in the shape of a square circumscribed about each circle. Often, township/ range shapefiles are used as tiles. These are usually slanted in orientation and could

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take more time to process as an export tile layout. If having overlapping exported data is not a concern, choose this MBR format to speed up the export.

- ✓ **Single File From Selected Tiles** - Exports a single file (LAS and shape) from one or more selected input tiles. *This export layout is available only with the **'LAS'** and **'Shapefile'** export types.*
- ✓ **Selected Tile(s)** - Exports one or more tiles that are pre-selected in the MARS® window from a loaded tile shapefile, using the Pick Tiles 960 tool. Use this option if only some (not all) tiles from a loaded tile layout are to be exported, or if the tile shape is non-rectangular and the exact tile shape is needed.
- ✓ **User-defined Box** - Exports only the data within a user defined (dragged) box using the Export Area 658 tool.
- ✓ **By Collection Scan** - Exports the loaded data by actual collection scans that are defined internally in the LAS file(s). Available only for the **'LAS'** and **'Text - ASCII'** export types.
- ✓ **By Collection Scan From User-defined Box** - Exports from the loaded data by actual collection scans that are defined internally in the LAS file(s), when the 'Export Area' tool is used. Available only for the **'LAS'** and **'Text - ASCII'** export types.

'**File Name**' Section:

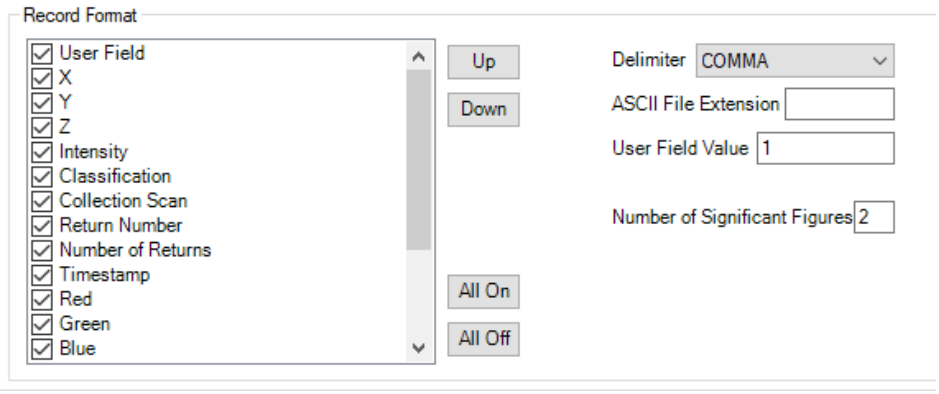
- ✓ **File -** If a user-defined area is being exported, enter a specific file name in this box. Not enabled when the Layout type is either 'By Collection Scan' or 'By Collection Scan From User-defined Box'.
- ✓ **Prefix** - Add an optional alphanumeric prefix to each file being exported.
- ✓ **Suffix** - Add an optional alphanumeric suffix to each file being exported.
- ✓ **Existing Files** - 'Overwrite' will replace all files in the output directory, while 'Skip' will ignore those with the exact same name that already exist in the output directory.

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'Tile Shapefile' Section: This will be enabled if either the 'All Tiles using MBR' or 'All Tiles' export layout is selected. Use the **'Browse'** button to select the shapefile if one is not already referenced in the project's .mpd file. Once the shapefile is referenced, choose the **'DB Field'** in the drop-down menu that contains the tile naming attribute. When a tile layout is loaded and one or more tiles are picked, the loaded layout will automatically appear with the option to choose the **'DB Field'** as above.

'Clipping' Section: This option allows only the data within a bounding polygon to be exported. Check the **'Clipping Data'** box and then select the **'Browse'** button to navigate to the boundary shapefile. Buffer settings on the 'Options' tab (see item 5., below) do not apply to a clipping boundary. ***NOTE*** that this option is disabled when the 'Export Area' tool has been used to initiate the export process.

'Record Format' Section: The **'Record Format'** section of the 'Layout' tab is only visible when the 'PLS-CADD Code - ASCII,' 'Shapefile,' or 'Text - ASCII' export types are selected.



Choose how the text document or attribute table is to be exported by making specifications in this area.

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Record Format: Select the fields or attributes which are to be included in export. If an attribute field is unchecked, it will not be included in export. By default, all fields are selected.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: The options are: SPACE, TAB, and COMMA (the default) to be used to separate fields in the output text file.

ASCII File Extension: The user may choose the file extension with which the text file is output. For example, the user may choose to export out a *.csv or a *.txt file. Enter the desired extension into the available text box.

User Field Value: This text box is valid only when the user has selected the 'User Field' attribute for inclusion. A value entered here will be applied to all records in the export. The default value is 1.

Number of Significant Figures: Specifies how many significant figures are used in the X, Y, and Z values during export. The default setting is 2, but values of 1 to 16 can be entered.

4. Filters tab 774 - Select the classifications, returns, collection scans, and/or bit flag status being used for export by checking the box next to 'Using classification set', 'Using return set', and/or 'Using collection scans', and by checking/unchecking the 'Include' boxes for the various bit flags. Note that collection scans can be selected/unselected only for the **'Flightline Separation - JPEG 2000'** and **'LAS'** export types. Next, click on the 'Select ...' buttons one at a time as needed to make the selections. Individual interfaces, similar to

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those used for filtering what is visible in the LAS Map View window (see View Tab[192]), will allow for control over exactly what is included in export. Due to the hybrid nature of the **'3D Image'** export type, there are two class selection sections. Note that certain export types will default to pre-selected return sets and the inclusion/exclusion of bit-flagged points that are appropriate for that type. Bit flag options allow for inclusion of Synthetic, Withheld, Overlap, and Edge of Collection Scan (each controllable individually), with an overall option to export only bit-flagged points for the selected categories.

5. **Options tab**[780] **-** Add a buffer to the exported data by checking the 'Use Buffer' box and by typing an integer value into the 'Buffer Size' text box. If the 'Buffer Size' text box = 0 or the 'Use Buffer' box is not checked, then no buffer will be exported. Any buffer set on this tab will be ignored when a clipping boundary is used (see the 'Clipping' Section in item 3. above). Also, a checkbox is available to force loading of the newly exported data (for most types) back into the current project. In addition, an option exists here to export data by pathing out to it rather than loading it into the LAS Map View.

6. **Transforms tab**[782] - This tab is visible only for the **'Contours - Shapefile'**, **'LAS'**, and **'Text - ASCII'** export types. Transforms the exported data by multiplying/dividing (Multiplier) and/or adding/subtracting (Shift) by a user-definable amount. Enabled by checking the box(es) - 'X Transform', 'Y Transform', or 'Z Transform' - for the coordinate(s) to be transformed and entering the desired vale(s). If only a Multiplier or a Shift is to be performed for any or all coordinates, leave the other entry box empty. If both a Multiplier and a Shift are to be performed, make entries in both boxes. For both, the order of operations is Multiplier first, then Shift.

7. **Grid tab**[783] - The 'Grid' tab is visible if any of the following export types are selected: 3D

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Image, Flightline Separation - JPEG 2000, Flightline Separation - Tiled GeoTIFF, Grid - Cloud Optimized GeoTIFF DEM, Grid - Cloud Optimized GeoTIFF Intensity, Grid - ENVI Elev, Grid - ENVI Elev/Class, Grid - Esri ASCII Grid, Grid - Float Grid, Grid - IMG, Grid - LAS, Grid - LiDAR Raster JPEG 2000, Grid - TIFF, Hillshade - JPEG 2000, LiDAR Point Density - Float Grid, LiDAR Spatial Distribution Verification GRID - JPEG 2000, and USGS Swath Separation Image - Tiled GeoTIFF.

- ✓ **Cell Size**: Enter an integer for the spacing of the export grid data.
- ✓ **Grid Smoothing Count**: Runs a Gaussian filter over the grid after initial values have been determined. Increasing the smoothing count will increase the number of passes the filter will perform.
- ✓ **NODATA Value**: If the data is void in the data set (no information within the cell), a NODATA value is assigned. Enter an integer in the text box for the NODATA value.
- ✓ **Auto Calculate Virtual Tile Size**: Used to optimize internal ('virtual') processing of manageable data sizes in RAM, based on Point Density or Ground Sample Distance (GSD), horizontal units (i.e., feet or meters), available RAM, and the number of threads to be used during the export. The function can be disabled and manually set in the 'Virtual Tile Size' box.
- ✓ **Grid Type**: Select 'Elevation' for a grid comprised of Z-value data or 'Intensity' for a grid derived from LiDAR intensity returns. The 'Color by Collection Scan Separation', 'LiDAR Spatial Distribution Density Verification', and 'Color By for LiDAR Raster' grid types are automatically selected when the corresponding export types are used.
- ✓ **Data Type**: MARS® is capable of 32-bit Float, 32-bit Signed Integer, 16-bit Unsigned Integer, and 8-bit Unsigned Integer formats for export, depending on the Grid Type being exported. 'Float 32' is the only option for the 'Elevation' Grid Type. 'Unsigned 16' is the default for the 'Intensity' Grid Type (*exception:* when the export type is **'Grid - Cloud Optimized GeoTIFF Intensity'**, the 'Data Type' defaults to 'Unsigned

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8'). 'Int 32' is the only option available for **'Flightline Separation - JPEG 2000'** exports (which use the 'Color by Collection Scan Separation' Grid Type), and the **'LiDAR Spatial Distribution Verification GRID - JPEG 2000'** Grid Type.

- ✓ **Lower Left (LL) Coordinate Shift**: When checked, forces the coordinates of the lower-left origin of an exported Float Grid to be a value that is evenly divisible by the chosen **Cell Size** (see above).
- ✓ **Algorithm**: Initial grid values can be calculated using 'Closest Point to Cell Centroid', 'Grid from TIN', 'Min Point of Cell,' 'Max Point of Cell,' or 'Median Point of Cell', depending on the grid type being exported.
- ✓ **Fill Gap**: Depending on the export type, the user has the option on how (or whether) to fill voids which are found in the LiDAR data. Both the 'Fast Fill' and 'TINned Surface Fill' options are used to prevent NODATA values. If the 'Fast Fill' radio button is selected, MARS® will use horizontal 'striping' from the last known elevation value of the input class points (see Filters tab 774) for each row of cells in the void area. The 'TINned Surface Fill' option aids in hydro-flattening by spanning across data voids to find points in the input classes. These points are used to create a flat TIN across the void. The 'Maximum distance to fill' option sets a maximum distance (in project units) for spanning a void when either of the fill options is selected. For the 'TINned Surface Fill' option, an additional value called 'Internal Buffer Size for TINned Surface' should be set to mitigate tinning errors across Virtual Tiles (see Auto Calculate Virtual Tile Size sub-topic, above). NODATA values will exist beyond this distance.
- ✓ **Input Data Type (Auto boundary algorithm)**: The boundary of the LiDAR data will be automatically detected and a NODATA value will be assigned to the raster cells that fall outside the boundary. The detection methods vary depending on whether the input LAS data is in 'Swath' or 'Tile' (the default) format. Swath data is assumed to have only one Point Source ID (PSID), also called collection scan number, per file,

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and adjacent swaths will overlap each other. Tile data may have one or more PSIDs per file, and adjacent tiles will not have any overlap. Note that there may be overlap *within* a tile, as when two or more swaths fall within a tile's boundary. The correct choice of input type is important in avoiding gaps in the exported grids within the project area.

8. **Contours tab** - The 'Contours' tab is visible only when selecting the **'Contours-Shapefile'** export type.
   - ✓ **Algorithm / 'TIN'**: Builds a grid for generating contours from the TIN.
   - ✓ **Algorithm / 'Grid'**: Generates the contours directly from a grid. The grid cell size can be specified and the number of passes of the Gaussian smoothing filter can also be specified.
   - ✓ **Algorithm / 'Use Max TIN Edge Length'**: Sets a maximum TIN triangle leg length that will be allowed in TIN creation. Gaps in the TIN that this setting may cause will not have contours generated for them.
   - ✓ **Contour Interval**: How often a contour is generated (i.e., a value of '2' would create contours every 2 vertical units).
   - ✓ **Minimum Contour Length**: For projects in feet, enter 25 as a good starting point. For metric projects, start with a value of 7. This minimum will be honored when the 'Perform cleanup' box is checked in the 'Line Cleanup' section (see below).
   - ✓ **Index Contour**: Select the indexing required for the project. Index contours appear in the LAS Map View as thicker, or bolder, contour lines to for easier identification.
   - ✓ **Shapefile Format**: Choose either the 2D or 3D radio button to control the structure of the output contours.
   - ✓ **Line Cleanup**: When 'Perform cleanup' is checked, moves incomplete or topologically incorrect contours lines to a 'Removed' folder in the output directory.

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These can later be merged back into the main shapefile. 'Clean tolerance' (similar to fuzzy tolerance in GIS programs) and 'Edge-tie tolerance' (for edge-matching across tile boundaries) can also be set. When checked, does not generate and export contours less than the 'Minimum Contour Length' (see above).

- ✓ **DGN/Shapefile Attributes**: Allows the level, group, and color attribute values of Normal (Intermediate) and Index contours to be set to facilitate conversion to either of those CAD formats.
- ✓ **Edge-tie directory of existing shapefile**: This option uses an existing folder containing contour shapefiles for edge-matching purposes. This folder *cannot* be the same as the output folder - if a different folder is not specified, a warning message will be displayed. The existing contours *MUST* contain an 'Elv' attribute field with the elevation values populated for each contour. This allows the program to 'edge-tie' each contour line being exported to equal-elevation contours in previously-created shapefiles.

9. **Projection tab** 811 **-** The 'Projection' tab is visible only when selecting the '3D Image', 'Grid - Cloud Optimized GeoTIFF DEM', 'Grid - Cloud Optimized GeoTIFF Intensity', 'Grid - IMG', 'Grid - LAS', 'Grid - TIFF', or 'LAS' export types. See the procedure outlined in the 'Add CRS Info (to LAS Files)' topic in the Coordinate Conversion 254 section of this help file for more details.
   - ✓ **Projection Description -** This text box will describe the projection to be used. Click on the browse button ('...') next to the text box to choose the needed projection if it is not already populated.
   - ✓ **EPSG Code -** Each horizontal projection system is identified by a unique EPSG Code. If the EPSG code of the particular projection to be used is known, it may be entered here. If the code is not known, this text box will be automatically populated

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when choosing a projection description through the 'Select Coordinate System from Datasource'. For more information on the Projection 811 tab, please see the associated section of the help topics.

- ✓ **Horizontal Unit -** Choose the horizontal units to be exported in Meters, US Survey Feet, International Feet, or Degrees with this drop-down box.
- ✓ **Vertical Projection -** This text box will describe the vertical projection to be used. Click on the **'...'** button next to the text box to browse to the needed projection.
- ✓ **EPSG Code (Datum) -** Each vertical datum is identified by a unique EPSG Code. If the EPSG code of the particular datum to be used is known, it may be entered here. If the code is not known, this text box will be automatically populated when choosing a datum through the 'Select Vertical Coordinate System from Datasource'. For more information on the Projection 811 tab, please see the associated section of the help topics.
- ✓ **EPSG Code (Vertical CS) -** Each vertical projection system is identified by a unique EPSG Code. If the EPSG code of the particular projection to be used is known, it may be entered here. If the code is not known, this text box will be automatically populated when choosing a projection description through the 'Select Vertical Coordinate System from Datasource'. The code for Vertical CS will typically determine the **'EPSG Code (Datum)'** described above. For more information on the Projection 811 tab, please see the associated section of the help topics.
- ✓ **Vertical Unit -** Choose the vertical units to be exported in Meters, US Survey Feet, or International Feet with this drop-down box.
- ✓ **Height Model -** Choose the appropriate height model (e.g., US Geoid of 2018) to be used as part of the vertical definition when the projection info is written as WKT (Well-Known Text) for LAS version 1.4 exports.
- ✓ **WKT (Horizontal) -** This box shows the horizontal projection info as it will be stored in WKT format when exporting to LAS version 1.4. Changes made to the 'Horizontal'

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section in the top half of the tab will be carried down to the WKT (Horizontal) box. All other LAS version exports will disable this box and write a GeoTIFF tag from the information provided at the top.

✓ **WKT (Vertical) -** This box shows the vertical projection info as it will be stored in WKT format when exporting to LAS version 1.4. Changes made to the 'Vertical' section in the top half of the tab will be carried down to the WKT (Vertical) box. All other LAS version exports will disable this box and write a GeoTIFF tag from the information provided at the top.



Export Area: Exports data within a user-defined area. After clicking the 'Export Area' button, drag a box to surround the area to be exported. Once the area is chosen, the MARS® Export Type Selection drop-down list will appear. Select an export type and the interface will open, just as it does when using the 'Export' 

button. However, with this method the 'Format' selected on the 'Layout' tab will be 'User-defined Box' by default. Note that the 'Clipping' option on the 'Layout Tab' of the export interface will be disabled for all export types when using 'Export Area.' For more information on the different types of exports, please review the Data Export 658 topic and sub-topics.

Extraction Tool Selection List *(not available with Evaluation license)*: This drop-down list contains the four extraction tools included with MARS® - Area by Slope 1177, Building Polygons 1182, Canopy Density 1188, and Class Polygons 1196. Detailed information about using these tools can be found in the Extraction Tools 1175 topic and its sub-topics.

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Extraction Options ***(not available with Evaluation license)*:** Allows the user to specify the filter parameters. A unique filtering options interface will appear for each different filter. Please click on the following link(s) for more information on how to use the 'Extraction Options' dialog for the extraction tools included with MARS®.

Extraction by Region ***(not available with Evaluation license)*:** Once the desired extraction tool has been chosen and the extraction options have been specified, this button initiates the processing for a selected area of the project. This tool provides the user with a 'drag box' to graphically define a rectangle for the desired area. The tool will remain active to allow multiple areas to be processed - right-click the mouse to dismiss the tool.

The loaded LAS data is immediately modified with this tool if the 'Reclass Interior Points' option is checked ('Area by Slope' and 'Building Polygons' extraction tools only).

Extraction by Polygon ***(not available with Evaluation license)*:** Use to run an extraction tool on a user-created polygon in the LAS Map View window. Left-click to create the vertices of the polygon, and right-click to close and start the processing.

The loaded LAS data is immediately modified with this tool if the 'Reclass Interior Points' option is checked ('Area by Slope' and 'Building Polygons' extraction tools only).

Extraction from Selected Polygons ***(not available with Evaluation license)*:** Use to run an extraction tool based on the area of a pre-existing polygon (or multiple polygons) in the LAS Map View window. The polygon shapefile must be loaded as a 'Tile Shapefile' and the desired polygon(s) must first be chosen using the 'Pick Tiles' tool. The result will be one shapefile appended together from all the polygons that were selected.

The loaded LAS data is immediately modified with this tool if the 'Reclass Interior Points' option is checked ('Area by Slope' and 'Building Polygons' extraction tools only).

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NOTE: When using this option with the 'Canopy Density' extraction tool, only one polygon can be selected before beginning the processing. The result will be a raster-based *.DAT file that can be used with ENVI or ArcGIS.

 **Batch Process Tiles:** This option (commonly known as Auto-Filter) allows the user to run a single extraction tool by tile and will output the results to feature-bounding shapefiles and (optionally) new LAS files. Choose the tile(s) to extract from with the 'Pick Tiles' tool before clicking the 'Batch Process Tiles' button. For more information, see the Batch Filter/Extraction Processing 1212 and the Extraction Tools 1175 topics.

 **Advanced Profiler:** This tool will create equally-spaced profile lines along a centerline at an interval specified by the user. This tool will perform on any polyline shapefile loaded into MARS ®. There are three ways to use this tool: **1)** Using and showing only the centerline with *no profile lines*, **2)** using and showing *both* the centerline and profile lines, and **3)** using and showing only the profile lines with *no centerline*.

Parameters:

- **Centerline Shapefile:** Click 'Browse' to navigate to the centerline file to be used. This centerline file may be any polyline shapefile (.shp); for example - a road centerline, a stream centerline, or a river centerline.
- **Source Classifications:** Choose the 'Select' button to define which classifications will be used when creating the profile lines. To create an advanced profile line based on the ground surface, choose only those classes that represent the ground - typically Class 2 (Ground).

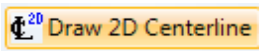
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Keep in mind that ground may exist in other classes, depending on the project data.

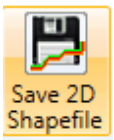
- **Interval along the Centerline:** The interval between profile lines (lines perpendicular to the original centerline shapefile) can be defined by the user here. A larger number indicates more space (horizontal units) between profile lines.
- **Profile Distance from the Centerline:** The user may specify the distance the profile line (which is perpendicular to the centerline) will extend from the centerline on both the right and left sides.
- **Draping Algorithm:** The user may choose to show and create the advanced profile by TIN or Grid. Using the Grid option allows the user to further define the grid cell size and to apply a Gaussian smoothing mechanism to the grid if need be.
- **Save Draped Centerline:** Checking this option will save the draped centerline as well as the perpendicular profiles which lie along that line. When this option is not checked, MARS® saves only the profiles perpendicular to the centerline and not the draped centerline itself.
- **Cut Depth:** This is the total width of the buffer (in project units) used to check for LiDAR points around the profile lines. Smaller values will speed processing and allow for longer input centerlines, but accuracy may suffer if there are not enough points in the Source Classifications in this buffer area.
- **Output Options:** Choose the output type - 'Save As Shapefile' for a 3D shapefile, 'Save As CSV' for a file of XYZ values that can be opened in Excel, or 'Save As DXF (2D Cross Section and Centerline)' for engineering use in a CAD program. Use the 'Browse' button to the right of the 'Output Shapefile', 'Output CSV file', or 'Output DXF File' text box and navigate to the output folder the advanced centerline shapefile, CSV file, or DXF file should be saved in. Name the new file, and click 'Save'. For the 'DXF' option, make the appropriate entries in the 'Number of Columns', 'X Step', 'Z Step', 'Vertical Exaggeration', and 'Beginning Station Number' text boxes. The effect of these five parameters can be seen in the examples at the bottom of this page.

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Using the Advanced Profiler tool:

1) First use the **'Draw 2D Centerline'** tool to create a 2D shapefile centerline line along an area which is to be profiled. Do this by selecting the **'Draw 2D Centerline'** 

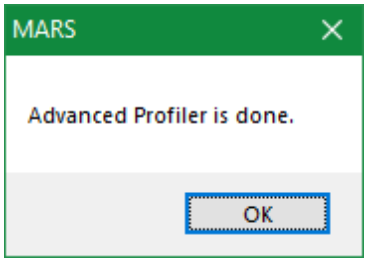
button and then left-clicking along an area. Right-click to end the centerline. In the examples below, the 2D centerline was drawn along a river.

2) To save this 2D centerline for use in the Advanced Profiler tool, click on the **'Save 2D Shapefile'** 

button. At this time, the 2D centerline just created will be unloaded from MARS®, but will be saved in the output folder which was specified by the user.

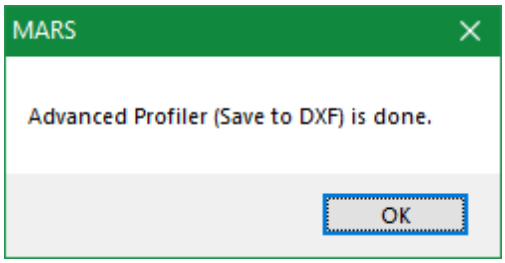
3) Click on the **'Advanced Profiler'**  button to bring up the 'Advanced Profiler' dialog. The parameters inside the interface are described above. Choose the particular settings which are needed and click **'OK'** when finished. When an advanced profile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data, and if the output type is Shapefile. Please see the bottom of this section for more information on the three (3) different uses of this tool.

4) When the advanced profile has been created, the user will be notified with one of the following pop-up messages (depending on the output type):



for shapefile or CSV **-- or --**

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for DXF

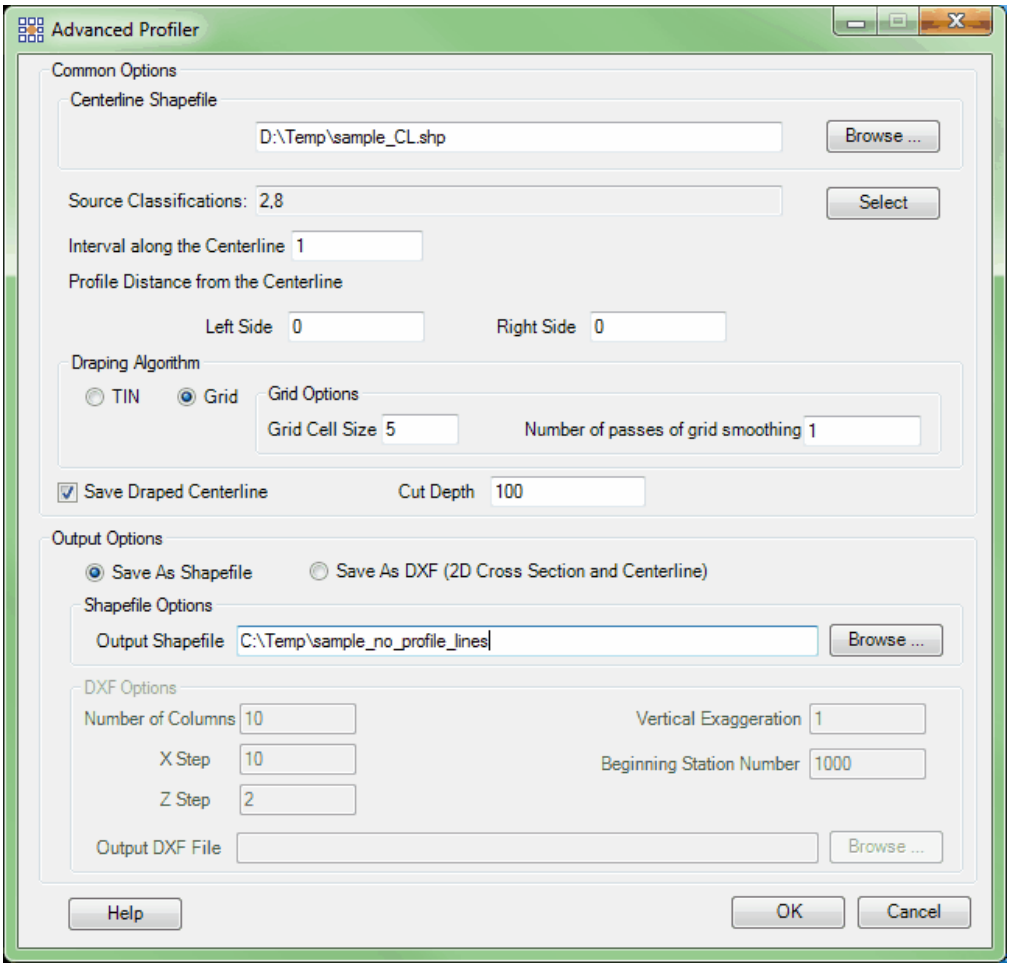
5) The advanced profiler has now created a 3D shapefile, CSV file of XYZ values, or 2D DXF file and stored it in the folder, and with the name, designated by the user. To load a newly created shapefile in MARS®, click the **'Add Reference Shapefiles'** button on the Project/ Data Preparation Tab[162]. The shapefile will appear in the Table of Contents under the 'Vectors' layer, and can be viewed in either 2D or 3D. To open the CSV file, use Excel or a text editor. To view the output of the 2D DXF file option, load the file in any CAD or GIS program that can read DXF files.

6) To remove a loaded shapefile from MARS®, right-click on the file in the Table of Contents and choose 'Remove'.

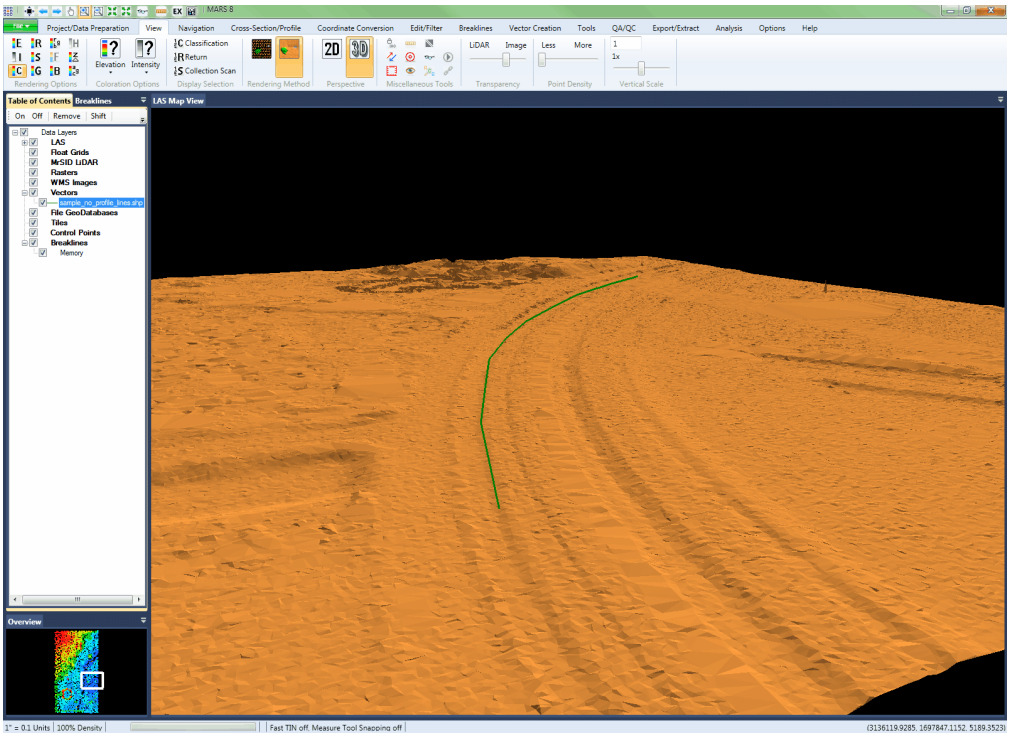
The three uses of the Advanced Profiler tool:

1) Below is an example of the advanced profiler being used in 3D and showing only the centerline with *no profile lines*. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings are to enter a '0' in both the 'Left Side' and 'Right Side' text boxes. This tells MARS® to create profile lines with a length of '0' (zero), which would create no profile lines at all. Make sure the 'Save Draped Centerline' option *is chosen* to create the 3D centerline shapefile.

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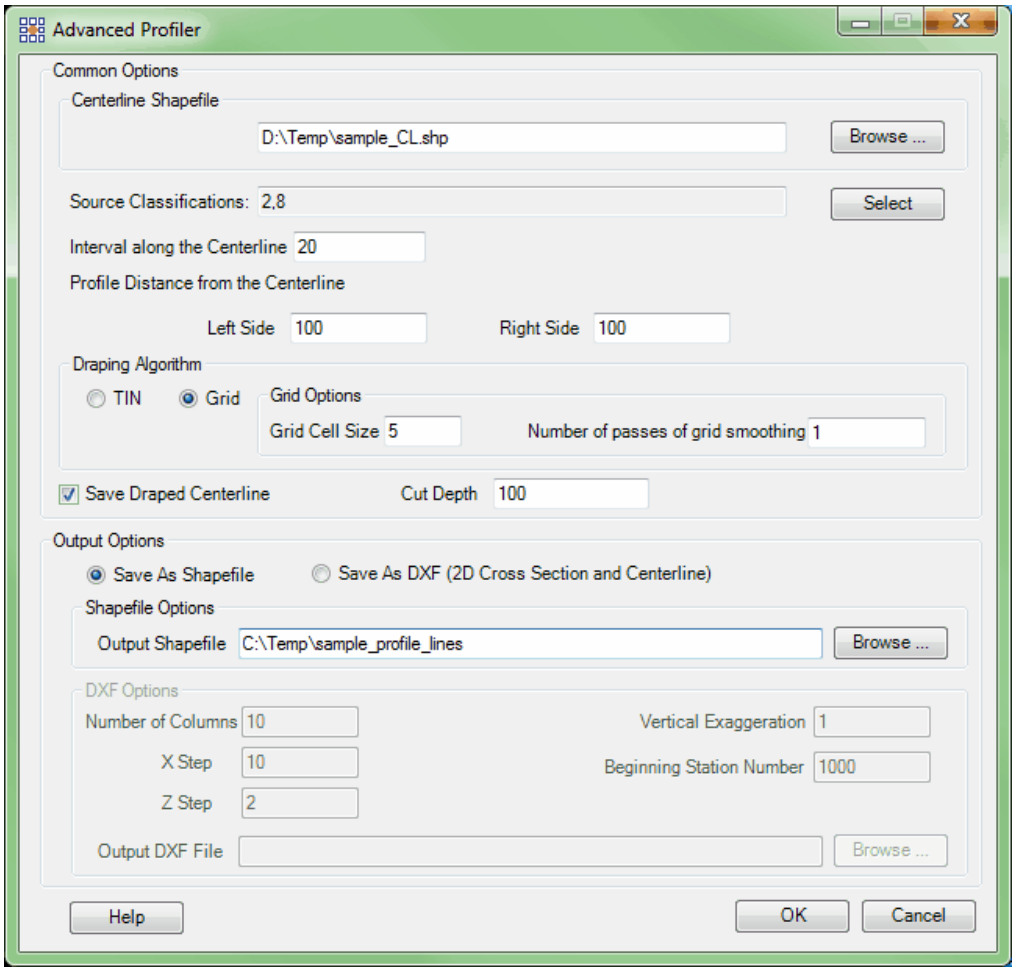


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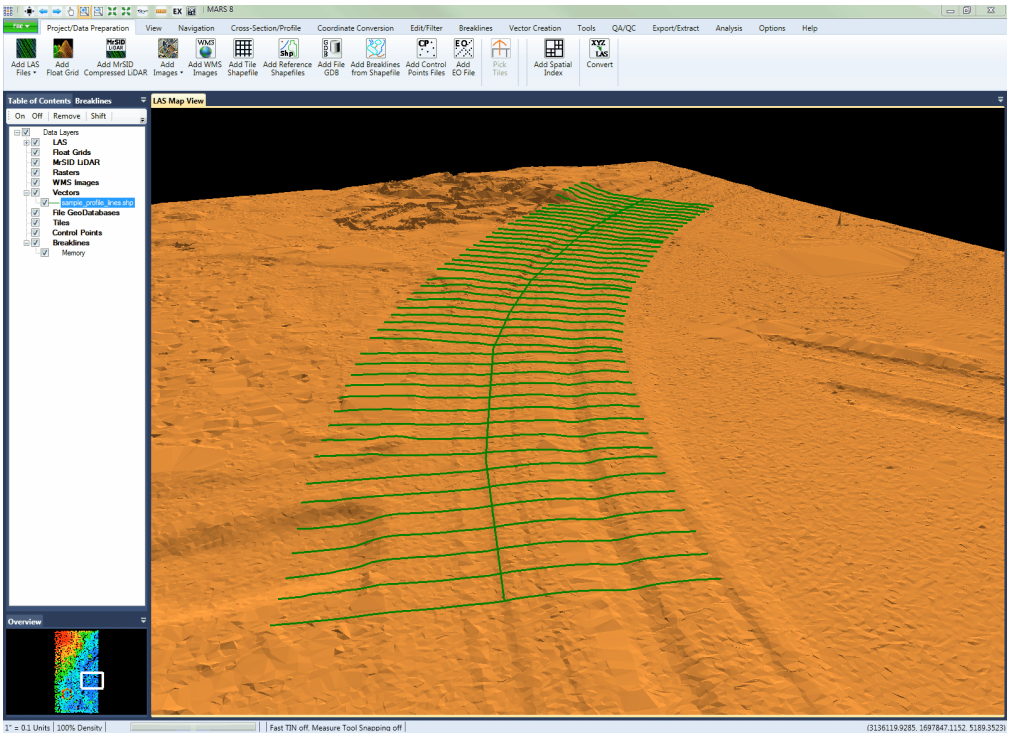


2) Below is an example of the advanced profiler being used in 3D and showing ***both*** a centerline and the profile lines associated with it. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings in this case are to enter an integer in both the 'Left Side' and 'Right Side' text boxes and in the 'Interval Along the Centerline' text box. This will create the profile lines perpendicular to the centerline. Make sure the 'Save Draped Centerline' option ***is chosen*** to also create the 3D centerline.

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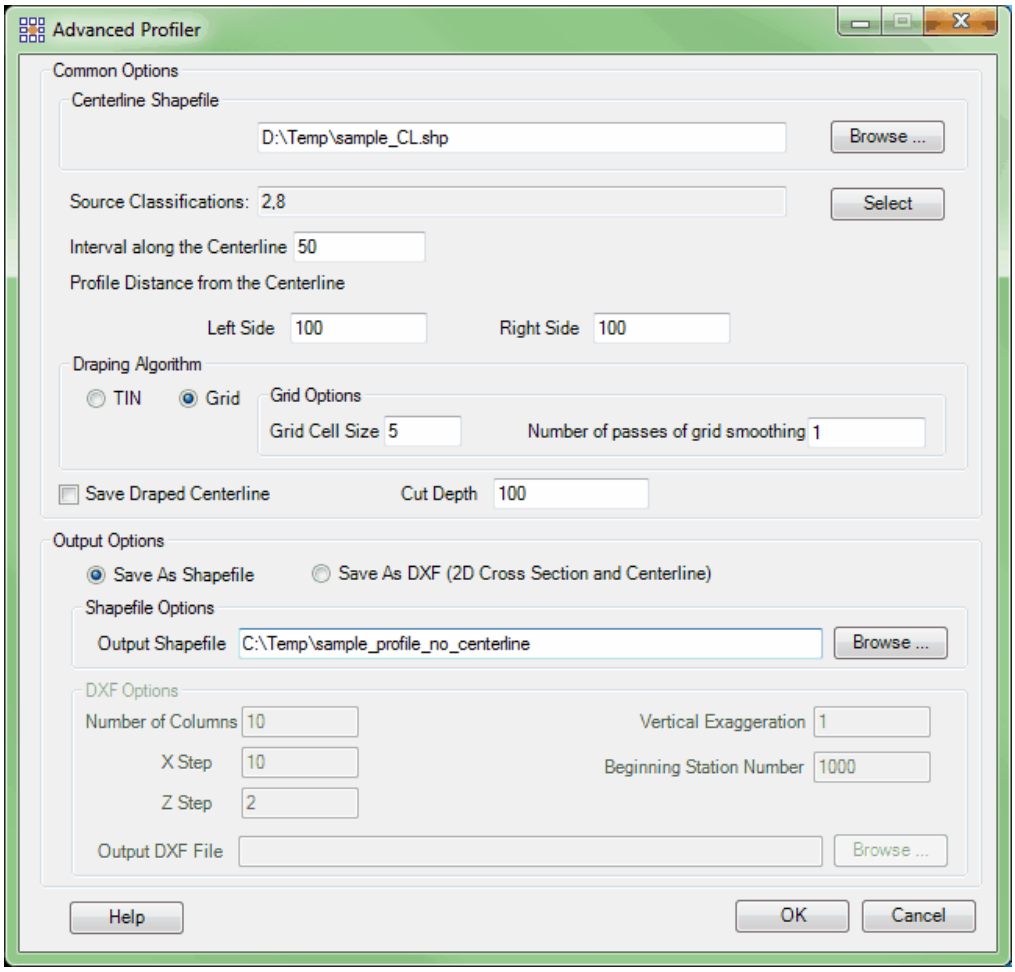


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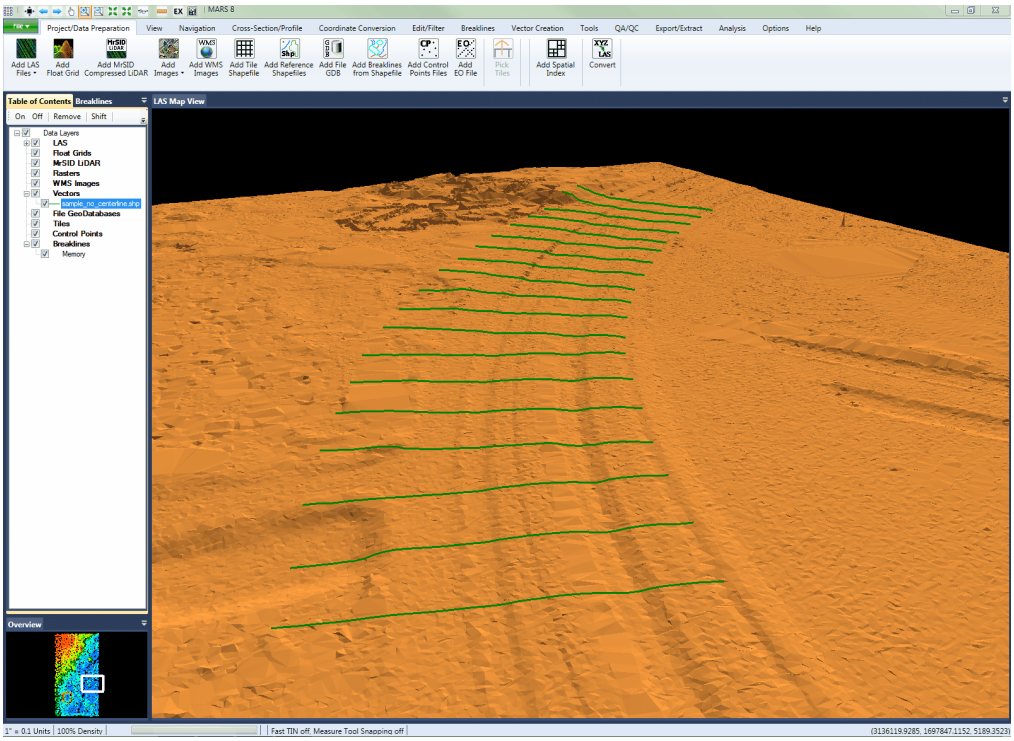


3) Below is an example of the advanced profiler tool being used in 3D and showing only the profile lines with *no centerline*. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings in this example are to enter an integer in both the 'Left Side' and 'Right Side' text boxes and in the 'Interval Along the Centerline' text box. This will create profile lines. Make sure the 'Save Draped Centerline' option is *unchecked* so a 3D centerline will *not* be created.

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CSV Output:

The table excerpt below shows the formatting of the CSV file output. The first column is the feature number, then X, Y, and Z in the last column. Feature number is based on start to end of the centerline used to generate the profile info. For example, if only the centerline is saved (example 1 of **'The three uses of the Advanced Profiler tool:'** topic, above), the feature number will be the same for all XYZ values of the centerline. If both the centerline and the transects (profile lines) are saved (example 2, above), the transects will be numbered from the beginning of the centerline to its end (as it was compiled) and the final feature number will be the centerline itself. If only the transects are saved (example 3, above), they will be numbered from the beginning of the centerline to its end as mentioned above.

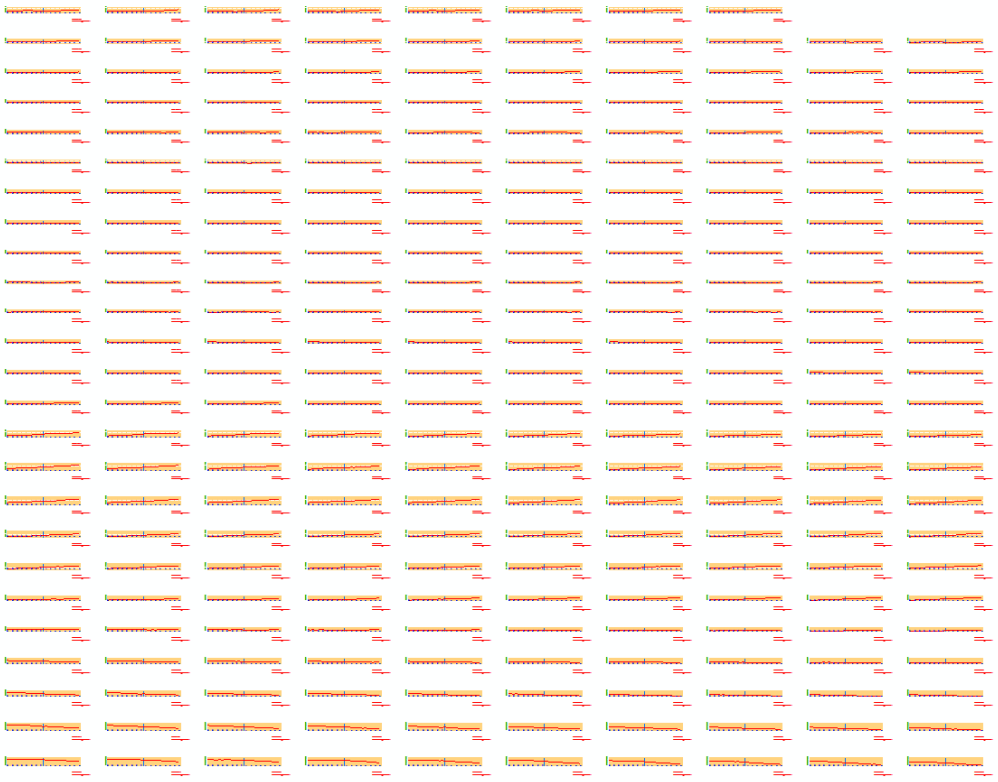
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	A	B	C	D	E
59	1	3134971.709	1697563.599	5215.602	
60	1	3134973.081	1697560.931	5214.856	
61	1	3134974.453	1697558.264	5214.469	
62	1	3134975.825	1697555.596	5214.294	
63	1	3134977.197	1697552.928	5213.974	
64	1	3134978.569	1697550.26	5213.974	
65	1	3134979.941	1697547.592	5213.758	
66	1	3134981.314	1697544.924	5213.705	
67	1	3134982.686	1697542.256	5213.392	
68	2	3134918.809	1697732.056	5230.824	
69	2	3134920.181	1697729.388	5229.692	
70	2	3134921.553	1697726.72	5229.02	
71	2	3134922.925	1697724.052	5229.042	
72	2	3134924.297	1697721.384	5228.855	
73	2	3134925.669	1697718.717	5228.742	

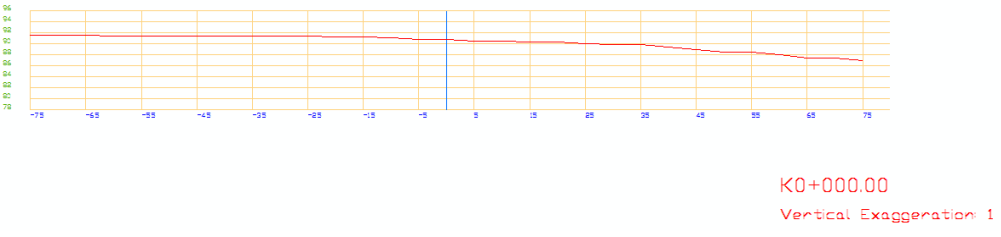
DXF Output:

Below are examples of the output when the 'Save As DXF' option is chosen. The first image shows the complete DXF with the profiles drawn at every 10 feet along the centerline ('Interval Along the Centerline' setting), starting in the lower left corner and proceeding to the right. Note the ten columns of profiles as per the 'Number of Columns' setting in the interface.

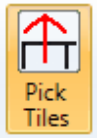
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A detail view of one profile from the above DXF is shown below. As per the parameters in the interface, the 'X Step' is 10 units (vertical tan-colored lines with blue annotation), the 'Z Step' is 2 units (horizontal tan-colored lines with green annotation), and the 'Vertical Exaggeration' is set to 1 (one vertical unit per one horizontal unit). The blue vertical line represents the position of the centerline, and the 'Left Side' and 'Right Side' values in the interface are set to 75 units. The red line shows the actual elevations of the profile line at this particular station (K0+000.00 units along the centerline - this is the beginning of the centerline where the first profile was created). The 'Beginning Station Number' can be set as needed, and the calculated values will be shown in the lower-right of each profile.



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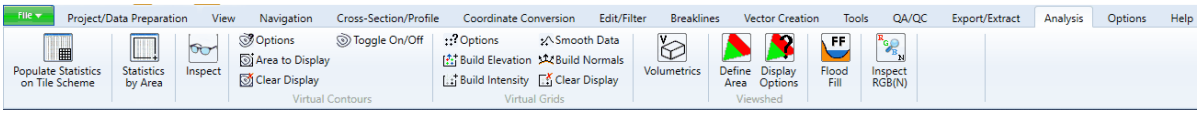
Pick Tiles: This tool is used to select a single tile or multiple tiles for export or batch processing functions. The button is disabled until a polygonal shapefile is loaded into MARS® as a tile layout. See the 'Add Tile Shapefile' section of the Project/Data Preparation Tab 162 topic for information on loading a tile layout. This tool works only in 2D View 835. To use, left-click and drag the cursor over the tiles to be exported - they will be highlighted in a thicker line weight. Additional tiles can be selected by holding down the **'Ctrl'** key on the keyboard and clicking on a tile(s). Individual tiles can be removed from the selected set using the same 'Ctrl' key/mouse combination. Selected tiles will also be highlighted in the tile shapefile's attribute table. To view the attribute table, right-click on the tile shapefile in the Table of Contents and choose **'Attributes'**. Alternatively, the attribute table can be used to select tiles - use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the desired tile(s) by row. The selected tile(s) will then appear highlighted in the LAS Map View window display.

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3.13 Analysis Tab



The Analysis Tab:

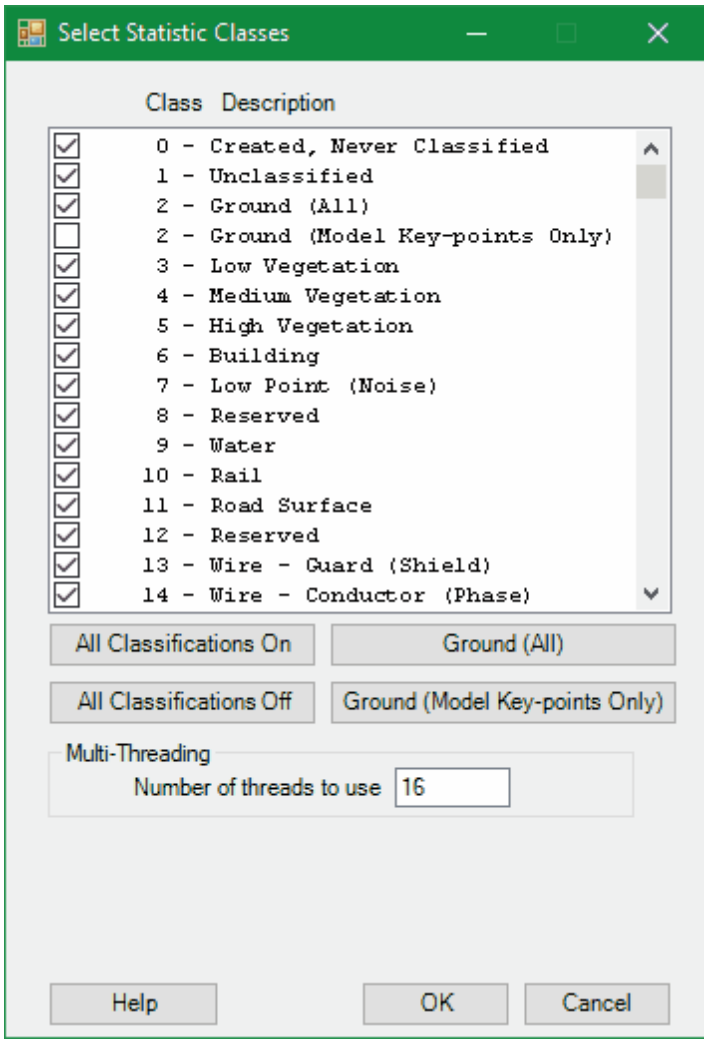


For any LAS tools that allow files to be pathed out without loading them in the Table of Contents in MARS® (including 'Volumetrics'), an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.

Populate Statistics on Tile Scheme: To use this tool, the user must already have lidar data and a matching tile layout loaded in MARS®. Another way to populate statistics on a tile layout is to have the statistics generated at the same time a tile layout is generated. To populate statistics in this way, please see the Create Tile Scheme 928 topic.

This tool will create a new shapefile in the same folder as the input tile layout, and it will contain newly calculated attribute fields for statistics including first returns, tile area, average GSD (ground sample distance), point density (points per square unit), and many more. An interface will appear where the classes to be included in the statistics calculations can be selected. Multi-threading is also available to shorten the processing time. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Clicking 'OK' will start the process, and the status can be tracked with the progress bar at the left side of the Status Bar 158.

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When the processing is complete, a pop-up window will appear showing the complete path and file name of the new tile layout (with statistics included). The new shapefile will have the same name as the original shapefile, except that appended onto the end of the file name will be "…_With_LAS_Statistics". When the new tile shapefile is generated, a *.prj (projection definition file) will be created if the projection information is known for the source LAS data. The original shapefile will not be overwritten. Once the user has run the 'Populate Statistics on Tile Scheme' tool, the newly created shapefile will need to be loaded into MARS® - it is not loaded automatically.

The following statistics will be generated for each tile layout when the 'Populate Statistics on Tile

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Scheme' tool is used, and they may be viewed in the attribute table of the resulting tile shapefile:

ID: A uniquely generated ID number for each tile.

TName: A uniquely created tile name (or number) used for many program functions.

AREA: The area in square project units of a particular tile.

ALLPCOUNT: A count of the total number of points within a particular tile.

DENSITY: The point density in points per square unit (using first returns only).

AVG_GSD: The average GSD (ground sample distance).

X_MIN: The x axis (easting) minimum within a particular tile.

X_MAX: The x axis (easting) maximum within a particular tile.

Y_MIN: The y axis (northing) minimum within a particular tile.

Y_MAX: The y axis (northing) maximum within a particular tile.

Z_MIN: The z axis (elevation) minimum within a particular tile.

Z_MAX: The z axis (elevation) maximum within a particular tile.

Z_DELTA: The difference between Z_MAX and Z_MIN within a particular tile.

COLL_SCAN: A listing of the different collection scan numbers which overlay a particular tile.

GPS_MIN: The GPS time (timestamp) minimum found within a particular tile.

GPS_MAX: The GPS time (timestamp) maximum found within a particular tile.

MIN_INT, **MAX_INT**, **MEAN_INT**, **MED_INT**, and **MODE_INT:** Various intensity value statistics.

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RETURN_0: The number of 'other' returns found within a particular tile (returns that are missing or have incorrect point family info).

RETURN_1 through **RETURN_15:** The number of first returns through fifteenth returns (listed in individual attribute fields) found within a particular tile.

SYNTHETIC: The number of points bit-flagged as 'Synthetic' found within a particular tile.

MKP: The number of points bit-flagged as 'Model Key-point' found within a particular tile.

WITHHELD: The number of points bit-flagged as 'Withheld' found within a particular tile.

OVERLAP: The number of points bit-flagged as 'Overlap' found within a particular tile.

Class0 through **Class255:** The number of points in each class (listed in individual attribute fields) is recorded per tile.

ClassWH0 through **ClassWH255**: The number of Withheld bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

ClassMK0 through **ClassMK255**: The number of Model Key-Point bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

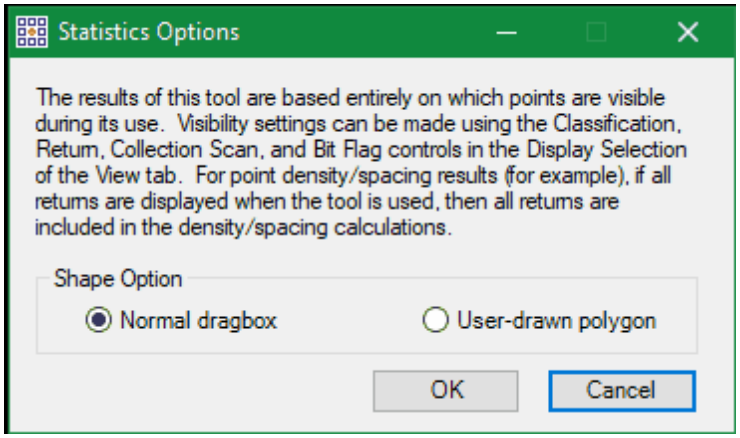
iShape: A MARS®-specific value that is not relevant for the user.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>' fields that are zeroed out for every tile will be omitted from the final attribute table to simplify analysis.

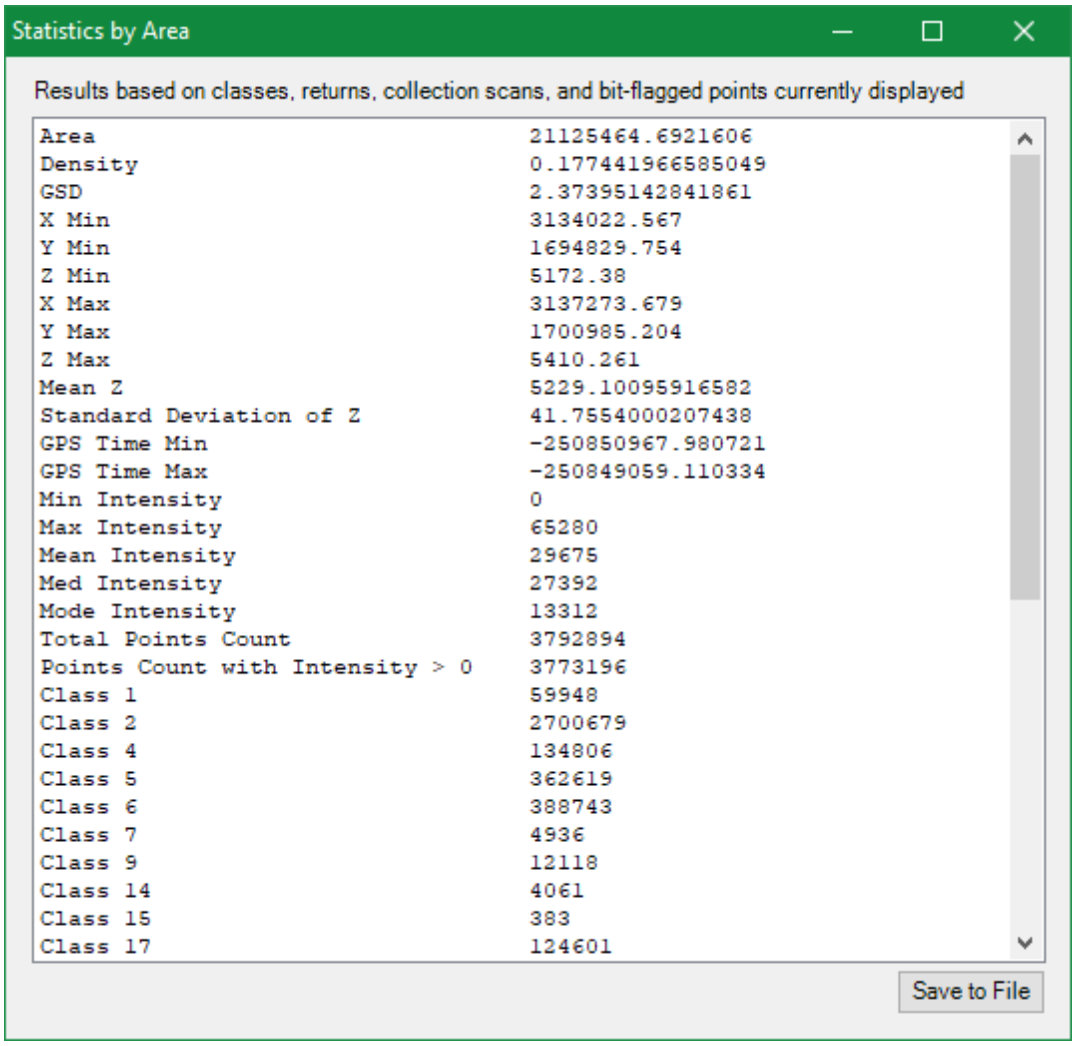
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Please see the Populate Statistics on Tile Scheme topic for additional information.

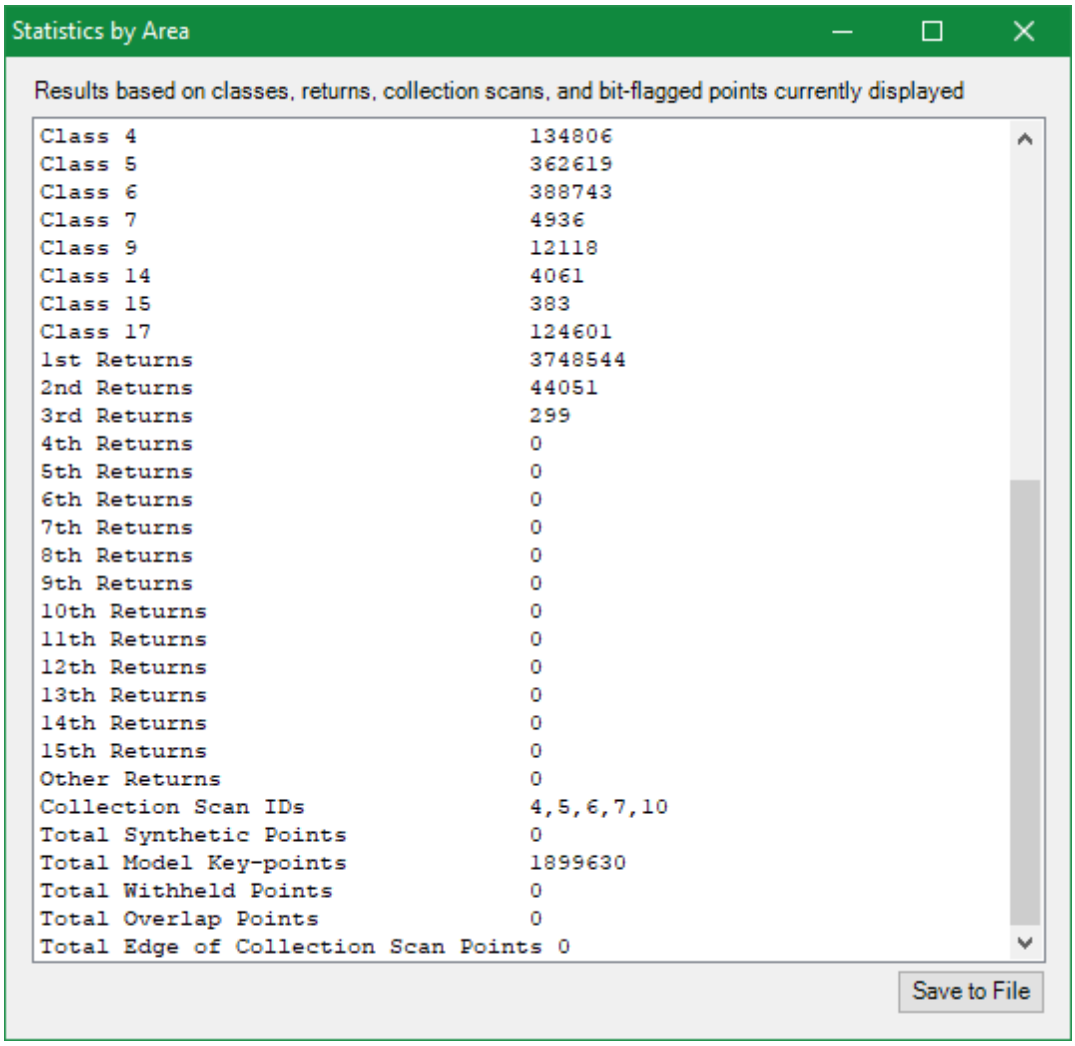
Statistics by Area: This tool allows the user to drag a box or create a user-drawn polygon over an area of LAS data to display statistics for that area. To use 'Normal dragbox' mode, left-click for a starting location, drag the mouse to define the opposite corner, and release the mouse button to define the area. For 'User-drawn polygon' mode, left-click to create the vertices of the polygon, and right-click to close from the last vertex placed back to the starting vertex. The results, which include most of the categories found in a full statistical analysis (see Populate Statistics on Tile Scheme), appear in a scrollable pop-up window with an option for saving to a text file. All results and statistics compiled are limited to only those classes, returns, collection scans, and bit flag types that are displayed at the time the area of interest is defined. To check multiple areas, close the results window and drag or draw a new area. To switch between the drag-box and user-drawn polygon methods, close the results window and click on the tool button to be prompted for the desired method. The tool remains active until dismissed by pressing the 'Esc' key on the keyboard, so multiple areas can easily be checked and the results saved if desired.



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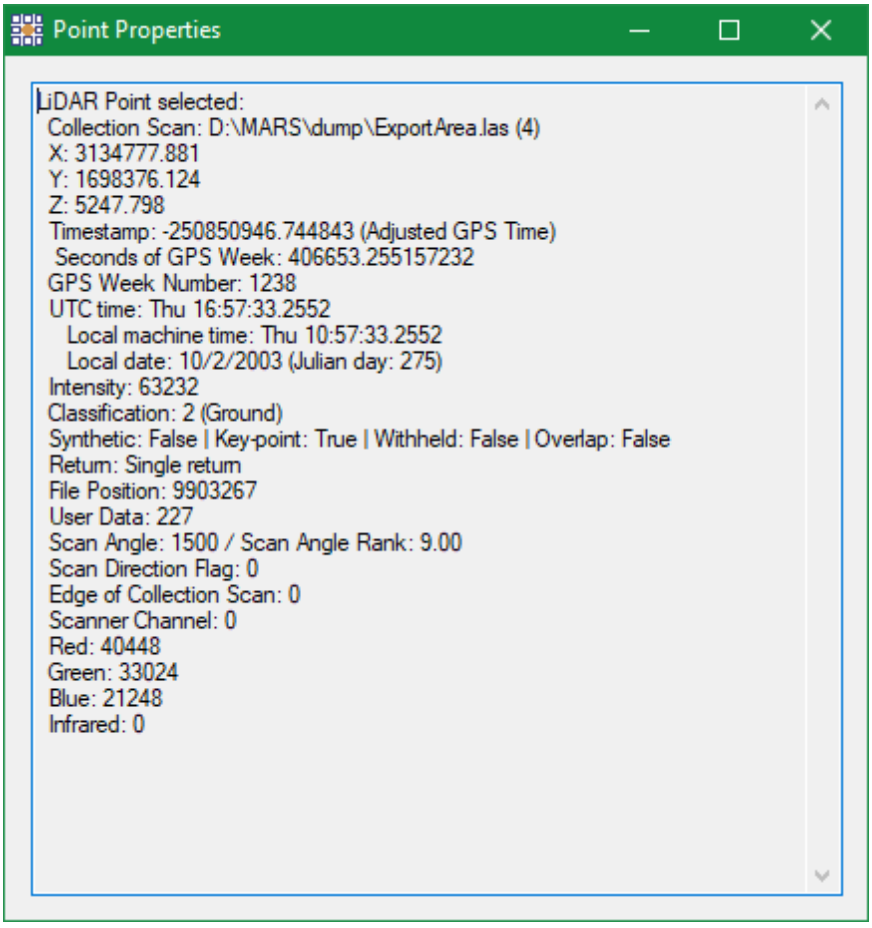
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Inspect: Click on this tool, and then click on the displayed LiDAR point that is to be inspected. The chosen point will flash twice and then remain highlighted in white at a larger symbol size to identify itself. Any number of displayed points can be inspected, one at a time. If a Cross-Section/ Profile window is open, the point may be chosen in either view, and will be highlighted in both views. The one exception to this is in the Cross-Section/Profile window, the Inspect tool will identify the file name and collection scan number rather than a point when the data is viewed in Profile by Collection Scan mode.

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The tool displays the point's parent file path and point source ID (PSID), X, Y, and Z coordinates, timestamp (including Seconds of GPS Week, GPS Week Number, and Julian day), intensity value, classification, bit flag status, return number, user data (often AGC values), scan angle/scan angle rank, scan direction flag, edge of collection scan flag, scanner channel flag, and RGB(N) values (see Inspect 943 for details of these attributes). The tool works in 2D (orthographic) and Cross-Section/Profile views. Note that for LiDAR data, some fields are dependent on the data collected and the post-processing software used, as well as the LAS version and Point Data Record Format.



To select a displayed check point for inspection, click on the desired check point (the LAS data

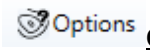
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may need to be turned off to avoid selecting a LiDAR point instead). The window that opens will display the point's ID, XYZ values and (if stored), a description, the point's NVA / VVA type, and the survey date of the point.

Holding down **'Ctrl'** on the keyboard and clicking on a virtual contour line, or displayed reference or breakline shapefile feature while the **'Inspect'** tool is toggled on will allow the user to inspect that feature rather than the closest LiDAR point.

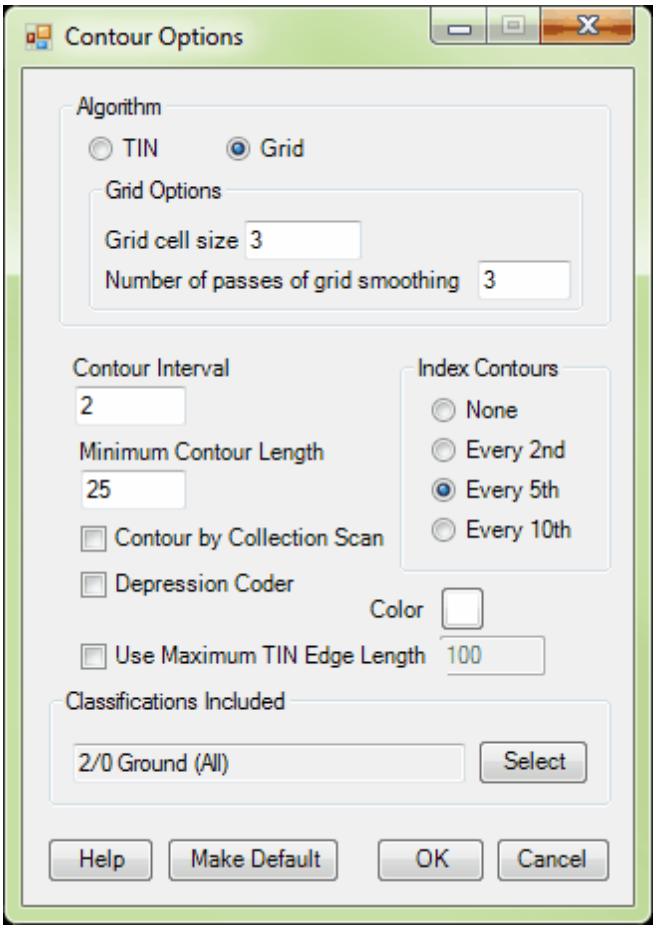
Windows copy-and-paste controls can be used in the resulting pop-up window. To unselect the **'Inspect'** tool and return the chosen feature to its original symbol and/or color, right-click the mouse. See the Inspect 943 tool topic for more details.

Virtual Contours: Contours can be created 'on the fly' for quick visual analysis, but only when the LAS Map View window is displaying point density of 100%. To see the current point density, check the left side of the Status Bar 158. 100% density can be achieved by either zooming in or by using the 'Lock to view 100%' tool on the View Tab 192.

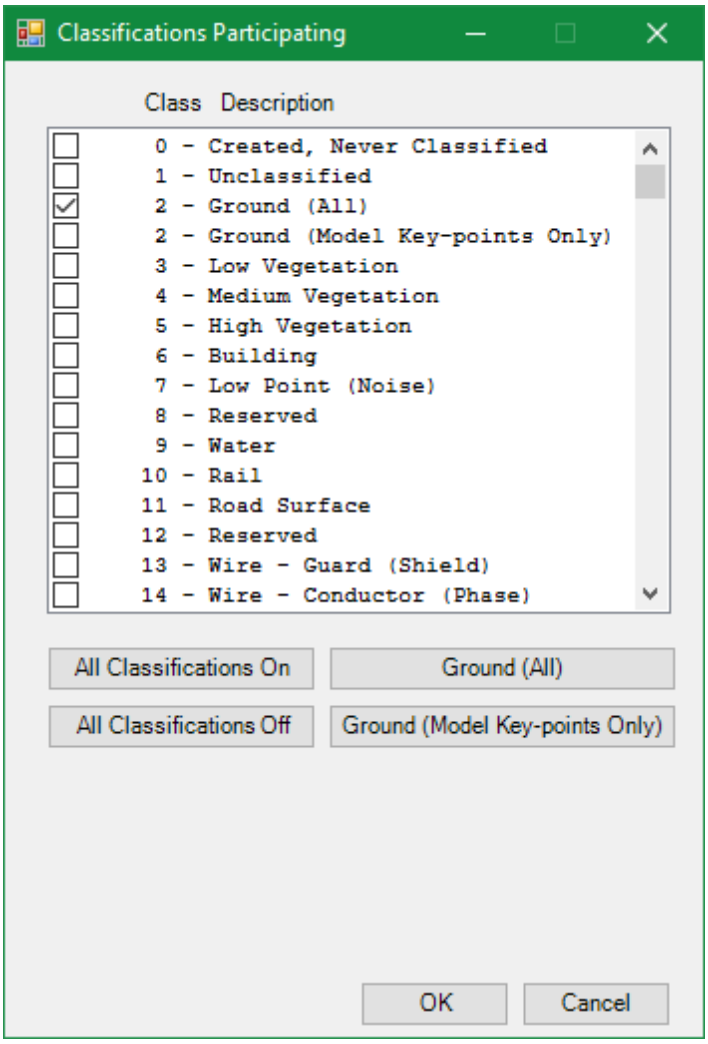


Options: This button allows the user to set the default contour settings. Enter the desired settings in the 'Contour Options' window. After the desired settings have been entered, (optionally) select the 'Make Default' button to save the settings as the future default settings. Please click the following link for a tutorial on contour generation: Viewing and Generating Contours 1806

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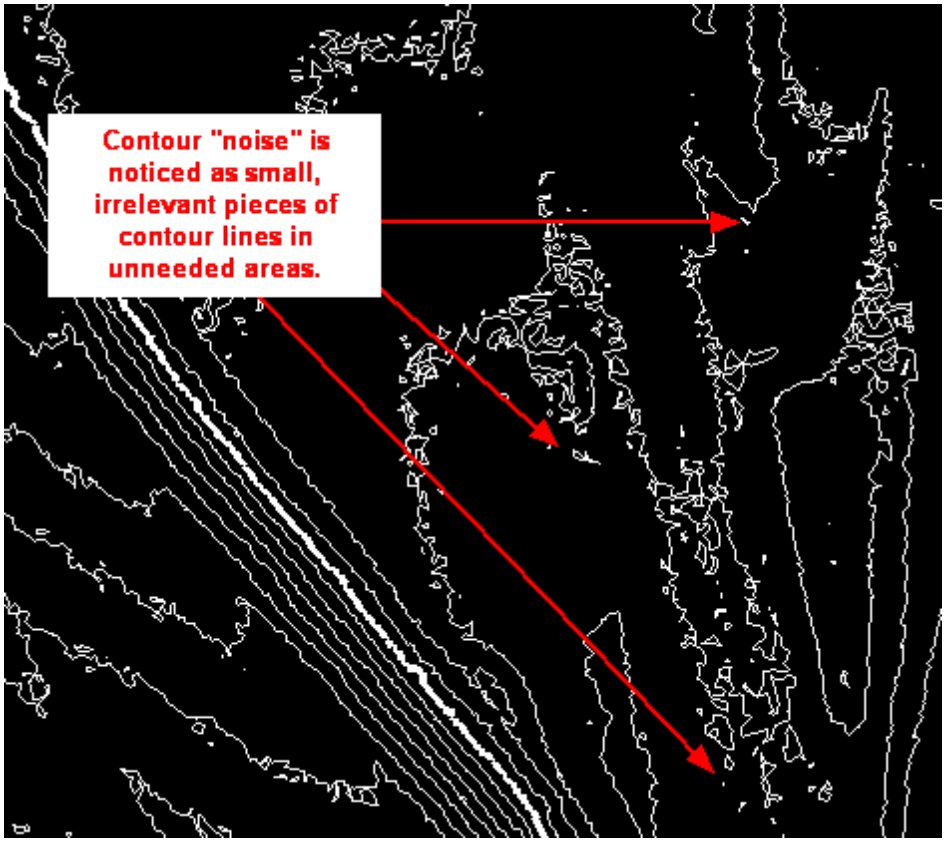
✓ **Algorithm:** The user has the option to use a virtual, RAM based smooth grid to create contours, or can create contours that are TIN-based. When using the grid option, the grid cell size and the number of Gaussian grid smoothing passes can be specified. The option to create a virtual grid inside this MARS® function allows the user to create a smooth grid file which, in turn, will create aesthetically pleasing smooth contour lines. The RAM based, virtual grid also allows for quicker production.

✓ **Contour Interval:** Choose the unit value of the interval between contour lines. For example, a value of 2 will place contour lines every 2 units. Units can be measured in meters, feet or be left unspecified.

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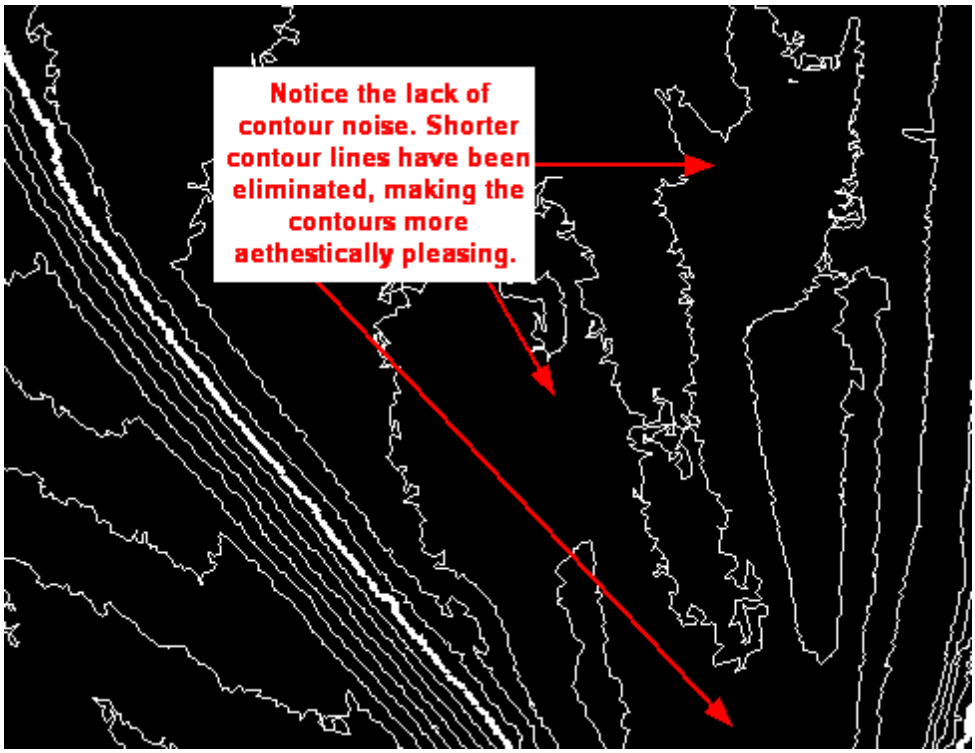
✓ **Minimum Contour Length:** Set a minimum contour length for contour generation. Longer contour lengths can minimize noise in the contour data. Shorter contour lengths, while more accurate, can show contours where there is noise in the LiDAR data.

Ex: Minimum contour length set to show very short contours. Notice the 'noise' in the contour data. Here the minimum contour length is set to 1.



Ex: Minimum contour length set to show only longer length contours. Notice the reduction in noise in the contour data. Here the minimum contour length is set to 200.

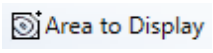
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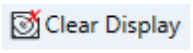
- ✓ **Contour by Collection Scan *(not available with Evaluation license)*:** Checking this box will display each individual contour line color coded by collection scan.
- ✓ **Depression Coder:** This box should be checked when the user would like to uniquely symbolize contours on depressions (areas where water cannot escape) in the data surface.
- ✓ **Color:** The user may click on the colored box and a color palate will appear. Choose a color from the pre-made palate, or design a custom color for display in the 'Define Custom Colors' area. The color selected here will be the color in which contours will be displayed. The default setting is white.
- ✓ **Use Maximum TIN Edge Length:** The maximum TIN edge length to be used in creating/ viewing contours may be specified by the user here.
- ✓ **Index Contours:** An index contour is marked by the thickness of the contour line. This makes it easier for the user to see the change in elevation by contour line. With this option, the user can choose to mark the index contours every 2nd, 5th, or 10th index contour line or not mark index contours at all.

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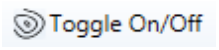
- ✓ **Classifications Included:** Choose the classifications to be included in the contour generation by clicking the 'Select' button. Classes whose box is checked will be included in the generation of contours. Use the 'All Classifications On', 'All Classifications Off', 'Ground (All)', or 'Ground (Model Key-points Only)' buttons to simplify the selection of the desired classes.
- ✓ **Make Default:** This option will allow the user to save the settings in the 'Contour Options' window for future use. The settings will be saved as shown to be used as the future default settings.



'Area to Display': Allows the user to draw a box to define the area to be contoured.



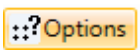
'Clear Display': Click to remove contour lines from the LAS Map View display. Another way to toggle contours on/off within the visible extent is to press 'C' on the keyboard.



'Toggle On/Off': This button toggles the contour lines on and off. Another way to toggle contours on/off within the visible extent is to press 'C' on the keyboard. Contours can only be viewed when the area for contour generation has been zoomed into at 100% density. Any area larger than this is too large for 'on the fly' contour generation. To see the density percentage, see the left side of the Status Bar 158.

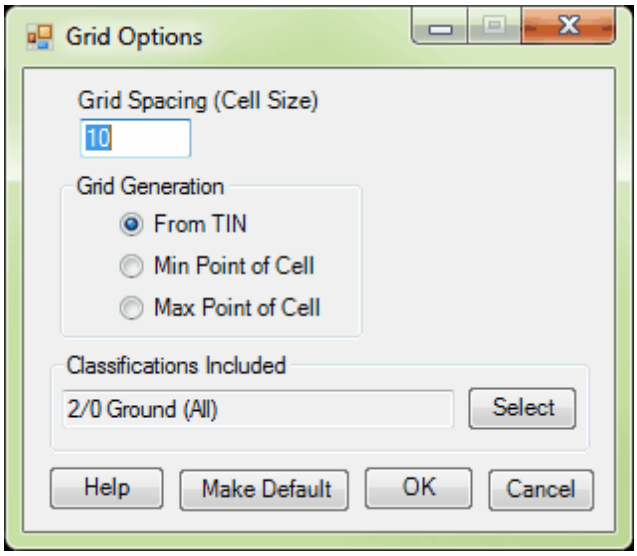
See the Displaying Contours 871 topic for more information.

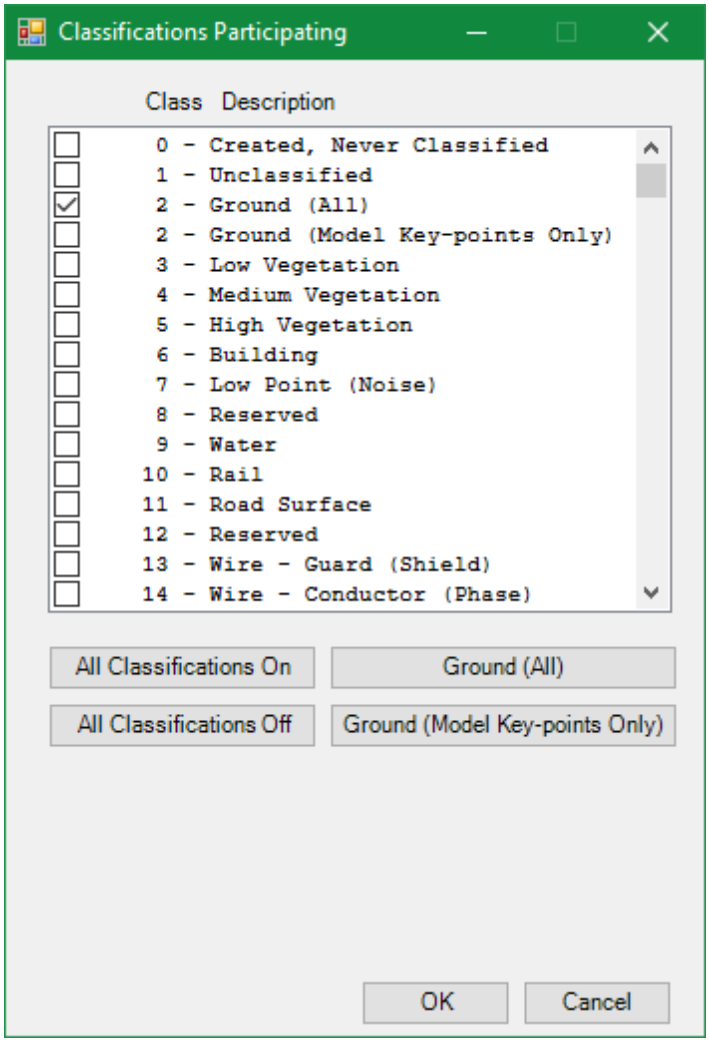
Virtual Grids:



'Options': Allows the user to define the gridding parameters.

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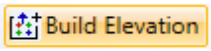


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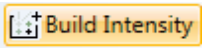
Grid Spacing: This will be the cell size for each cell in the gridded area.

Grid Generation: The user can specify here whether the grid should be built from a virtual TIN, from the minimum Z point of each cell, or from the maximum Z point of each cell.

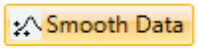
Classifications Included: Click the 'Select' button to choose which classifications will be included in the grid generation. Typically, only ground classes are used.



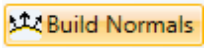
'Build Elevation': Allows the user to create an elevation grid.



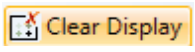
'Build Intensity': Allows the user to create an intensity grid.



'Smooth Data': Applies a smoothing algorithm to the gridded surface.



'Build Normals': Allows the user to generate normal vectors for each cell. Also known as a surface normal, a normal vector is a three-dimensional vector which is perpendicular to the surface.



'Clear Display': Clears any virtual grid from the LAS Map View window.

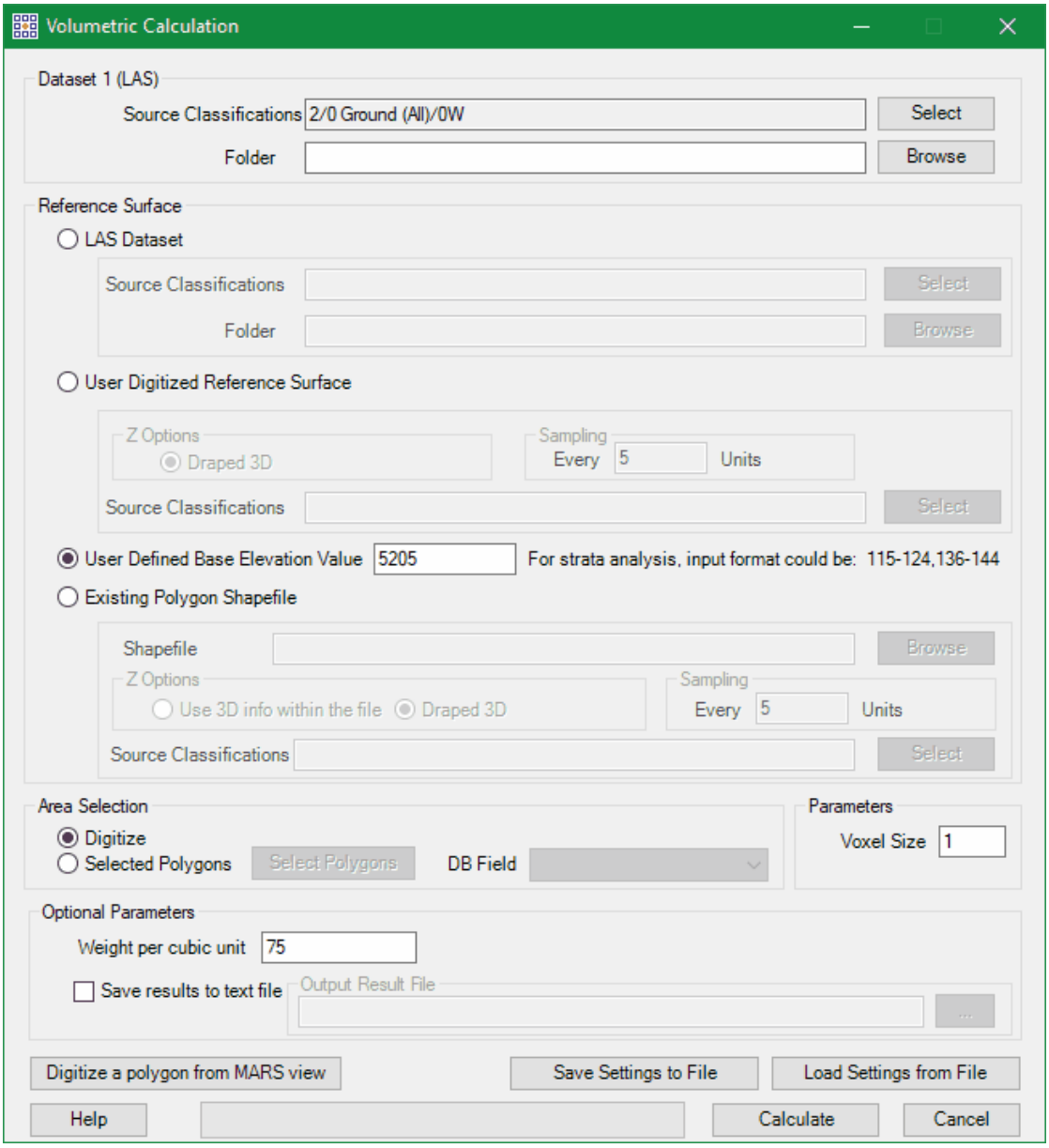
See the Displaying Grids 875 topic for more information.

Volumetrics: This tool performs cut-and-fill analysis on a LiDAR dataset using various user-defined surfaces or values for reference. It is designed to be used on datasets where ground has been classified

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separately from other points.

See the Volumetrics 980 topic for more information.



Viewshed Grid generation: Viewsheds are available for use with LAS data and MrSID Compressed LiDAR data while in 2D mode only.

Define Area: Create a viewshed by clicking on the **'Viewshed - Define Area'** button. Left-click

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inside the LAS Map View window (2D view only) where the viewshed is to start. While holding the left button, drag the mouse to the place where the viewshed is to end and release. The Viewshed options window will appear and give the user the ability to change the properties of the viewshed and, optionally, to save it. By checking the **'Field of View'** box, the user can switch the field of view from **'Azimuth'** (if the box remains unchecked) to **'Degrees'** and **'Direction'** (if the box is checked). The user can specify a radius, grid cell size, and can even specify an invisible or visible output file name to save. The Viewshed tool displays a 2-color grid to indicate the visibility of the user-defined field of view. Once generated, the viewshed may be viewed in 2D or 3D. The red areas of the viewshed represent areas which the 'viewer' would not be able to see from the starting point that was defined. The green areas represent areas which the 'viewer' would be able to see from the starting point that was defined. This color-coded display helps the user to understand where elevation changes, trees, or buildings may be. This tool is commonly used for security purposes, but can also be applied to land development and urban visualization activities. ***Note that the maximum distance (radius) that can be generated depends on available RAM, density of LAS data, field of view, and grid cell size.***

Parameters

- **Field Of View:** When checked, enables manual entry of the **'Degrees'** and **'Direction'** of the desired field of view.
- **Degrees:** Enabled when **'Field Of View'** is checked. This value defines the angular width of the area to be studied. Valid values are 1 - 360.
- **Direction:** Enabled when **'Field Of View'** is checked. This value represents the azimuth of the viewshed centerline in degrees. The width of the view (**'Degrees'**) will be centered around this vector. It is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **Azimuth Start:** Enabled when **'Field Of View'** is unchecked. This is the starting value for the

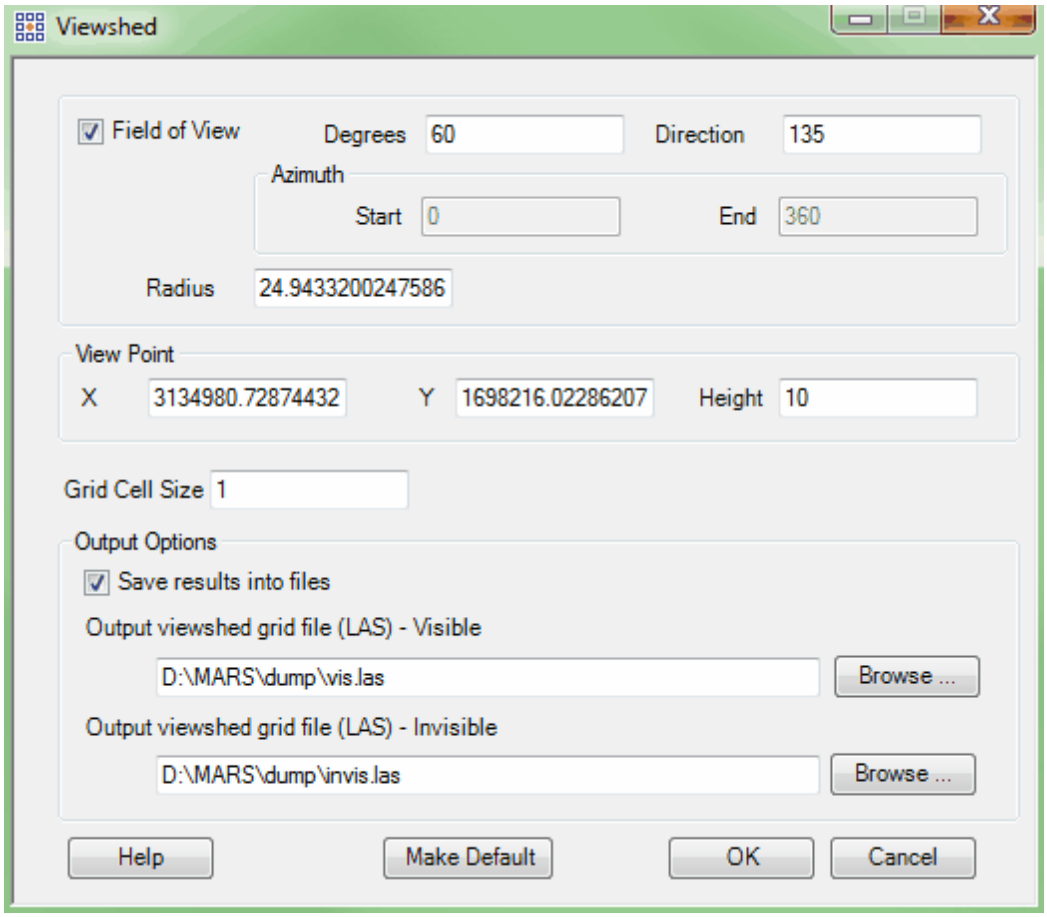
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horizontal component of the user-defined viewshed direction. Valid values range from 0 – 360, with 0 as the default value.

- **Azimuth End:** Enabled when **'Field Of View'** is unchecked. This is the ending value for the horizontal component of the user-defined viewshed direction. Valid values range from 0 – 360, with 360 as the default value.
- **Radius:** This value represents the radius length of the viewshed. This value is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **View Point X & Y:** These values represent the XY origin of the defined viewshed. This value is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **View Point Height:** The height value above the surface for the XY origin. A higher value will allow the 'viewer' to see more area within the viewshed.
- **Grid Cell Size:** This value represents the grid cell size of the displayed viewshed grid and the saved grids (both visible and invisible).
- **Save results into files:** When checked, allows the user to save the results of the viewshed analysis as LAS grids.
- **Output Viewshed Grid File:** This parameter allows the user to specify where the output files will be written.

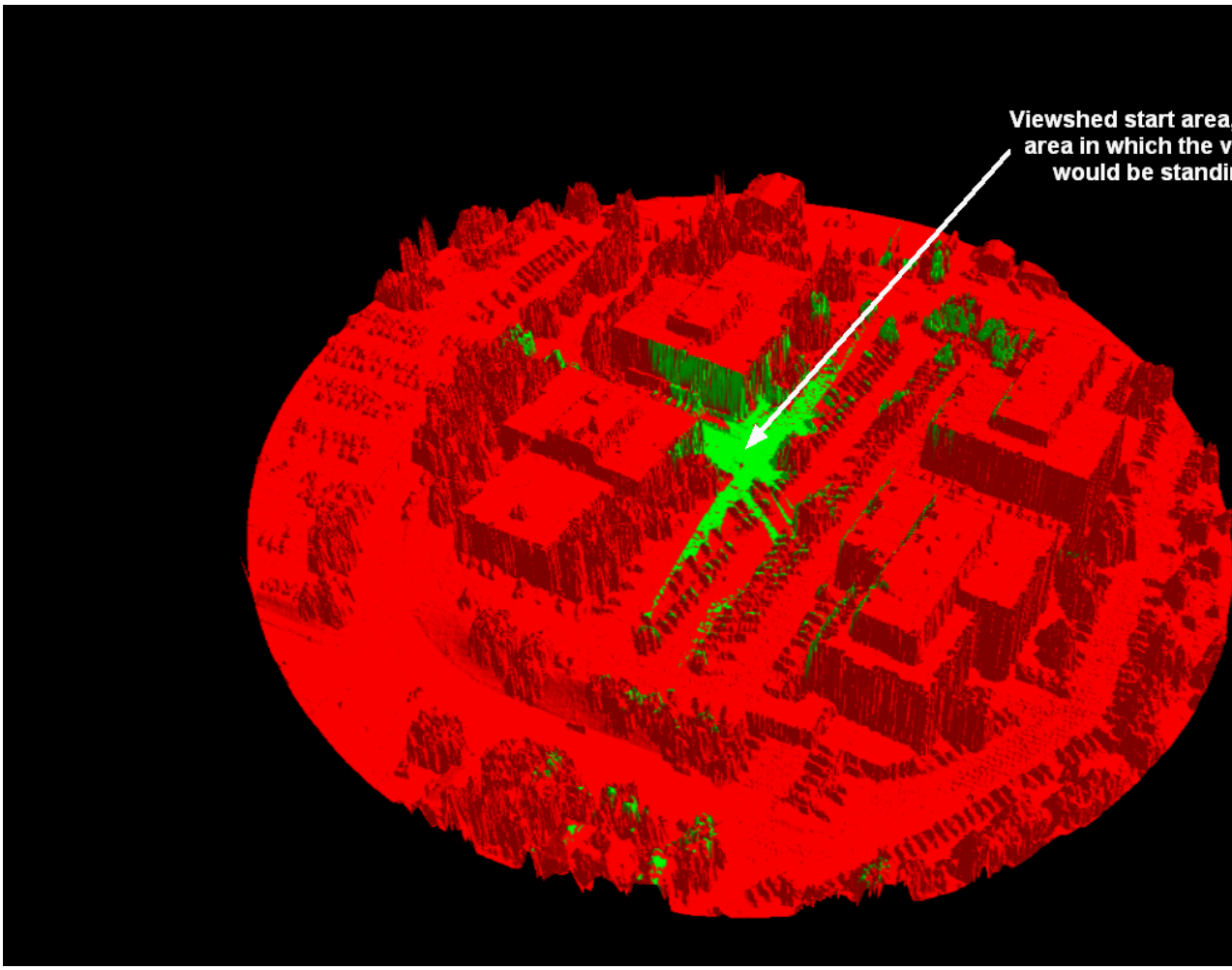
Viewshed Options Dialog:

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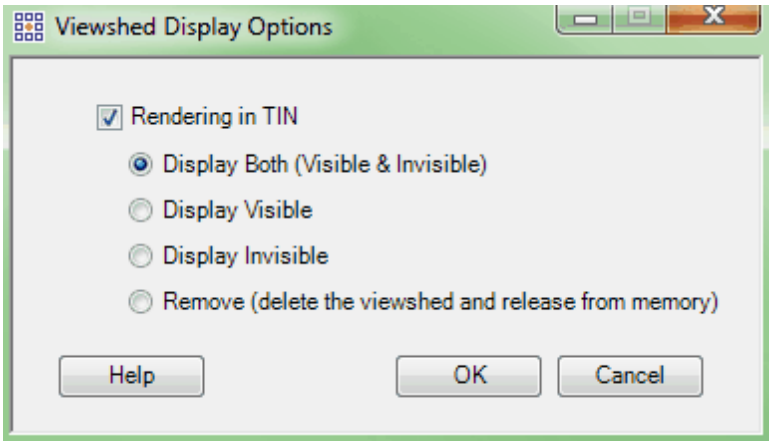
In the Viewshed display below, the data which would be visible to the viewer if standing in the area defined as the center of the viewshed is colored green. The areas which would be invisible to the viewer if standing in the center of the viewshed are represented by red. The display shown below is in 3D and is rendered in TIN.

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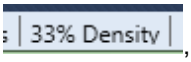


Display Options: By clicking the **'Viewshed - Display Options'** button, the user has the option of displaying both visible and invisible data, only visible data, only invisible data, and viewing any of the data choices by TIN rendering. The user can also remove the viewshed grid completely and release it from memory. In the Viewshed display, the data which would be *visible* to the viewer if standing in the area defined as the center of the viewshed is colored green. The areas which would be *invisible* to the viewer if standing in the center of the viewshed are represented by red.

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Flood Fill: This tool creates a virtual flood fill graphic that allows the user to view areas of the loaded LAS data which would be inundated during a flood. To use this tool, click on the 'Flood Fill' button and the 'Flood Fill' dialog box will appear. The user may specify the water elevation (MSL) to analyze by entering a value in the 'Elevation' text box or by using the 'Elevation' slider to simulate different flood levels. The user may also choose the color and transparency of the flood fill graphic. When all the selections have been made or when changing any of the parameters, click 'Display' to see the results. If the data is not already being rendered in TIN mode, the tool will change to, and stay in, that mode. The density of the LiDAR data currently being displayed, as shown on the left side of the Status Bar158



, will affect the accuracy of the TIN and, therefore, the flood fill. To obtain the most accurate results, the data should be viewed at 100% density. In 2D viewing mode, imagery may be used to aid in the flood analysis, but will be temporarily toggled off when switching to 3D viewing mode.

It is also possible to save the flood fill shoreline to a 3D shapefile. Check this option and choose a shapefile path and name to create a 3D shapefile, then click 'Save.' To dismiss the flood fill graphic, click 'Cancel' in the dialog box.

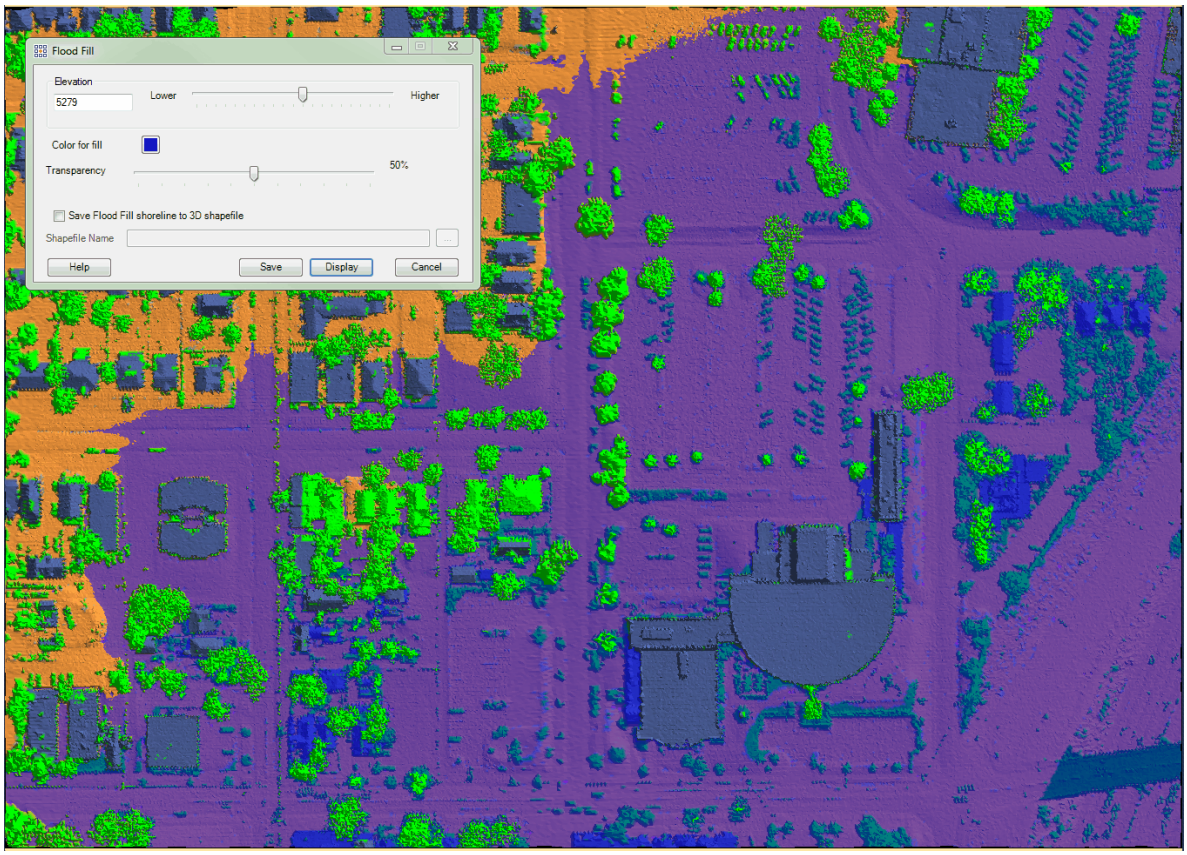
The examples below show the difference in flooding effects that can be expected at different water

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surface elevations. The top example is flooding up to an elevation of 5264 feet. The bottom example shows flooding up to 5279 feet.



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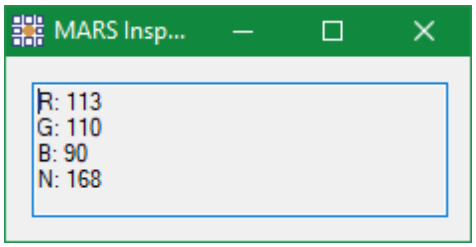
Another example of the Flood Fill tool in a 3D view:



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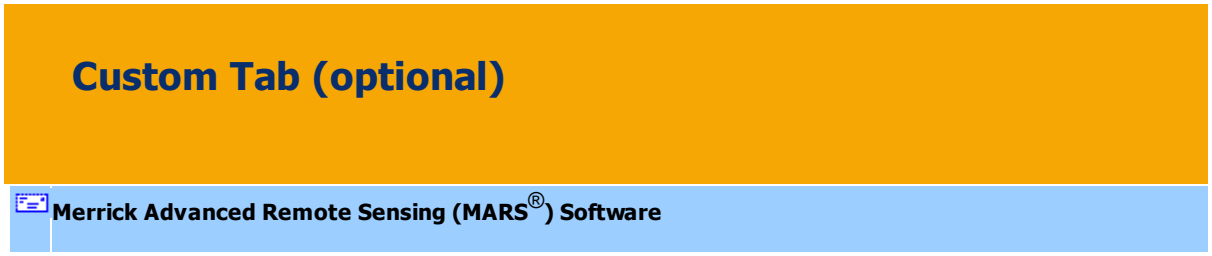
Inspect RGB(N): This utility allows the user to select and display the RGB(N) - Red-Green-Blue and, if present, NIR - values from the loaded imagery data. This tool is normally used to define RGB(N) values for the RGBNI Value Filter. This tool will only work on RGB or RGB(N) imagery (not ENVI rasters) and is only available to use when imagery is loaded into MARS®.

To use this tool, click in the desired location on the imagery. Once the user has selected a target, the **'Inspect RGB(N)'** dialog (see below) will be displayed, showing the RGB values from the selected pixel. Additional locations can be selected without closing the pop-up. 3-band imagery will display 'N/A' for the 'N' field.

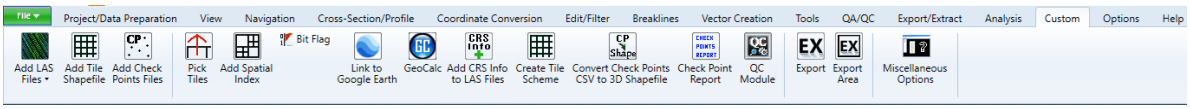


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3.14 Custom Tab (optional)



The Custom Tab:

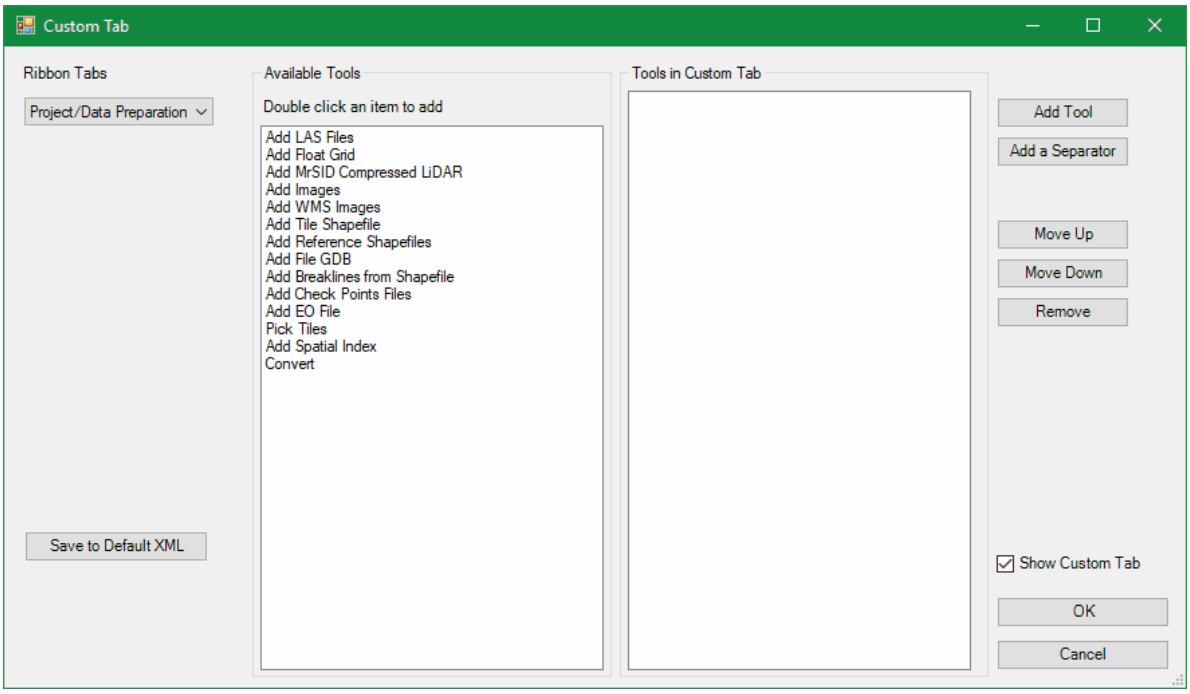


The Custom Tab is an optional component of the ribbon that can be added if desired. This tab can contain almost any tool that is found on any of the standard tabs that are part of the ribbon - the screen shot above is just one example of a possible Custom Tab. The collection of tools can be customized individually for any computer, and the XML file that contains the layout of tools can be shared with other computers. The tool buttons can be placed in any order along the tab and can be added, deleted, or moved at any time. Unlike the Quick Access Toolbar 65 (QAT), the buttons placed on the Custom Tab look identical to their versions on the standard tabs, with any accompanying text labels retained.

Initial creation of the tab requires that at least one tool from the pre-existing tabs be added. Only those tools that are enabled for the license level being used will be available to be added to the Custom Tab.

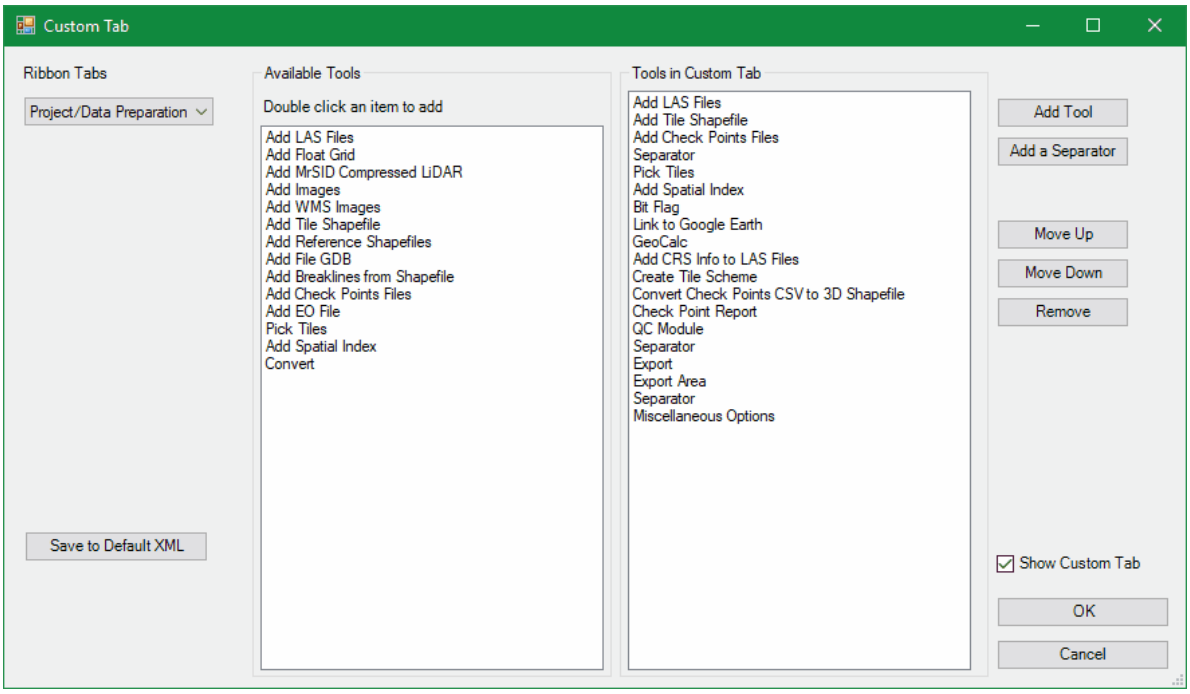
To create or edit the Custom Tab, begin by clicking the 'Customization of Custom Tab' button on the Options Tab 519. If no 'MARSCustomTab.xml' file exists in the MARS® installation folder (C:\MARS\ by default), the column named 'Tools in Custom Tab' on the interface will initially be empty.

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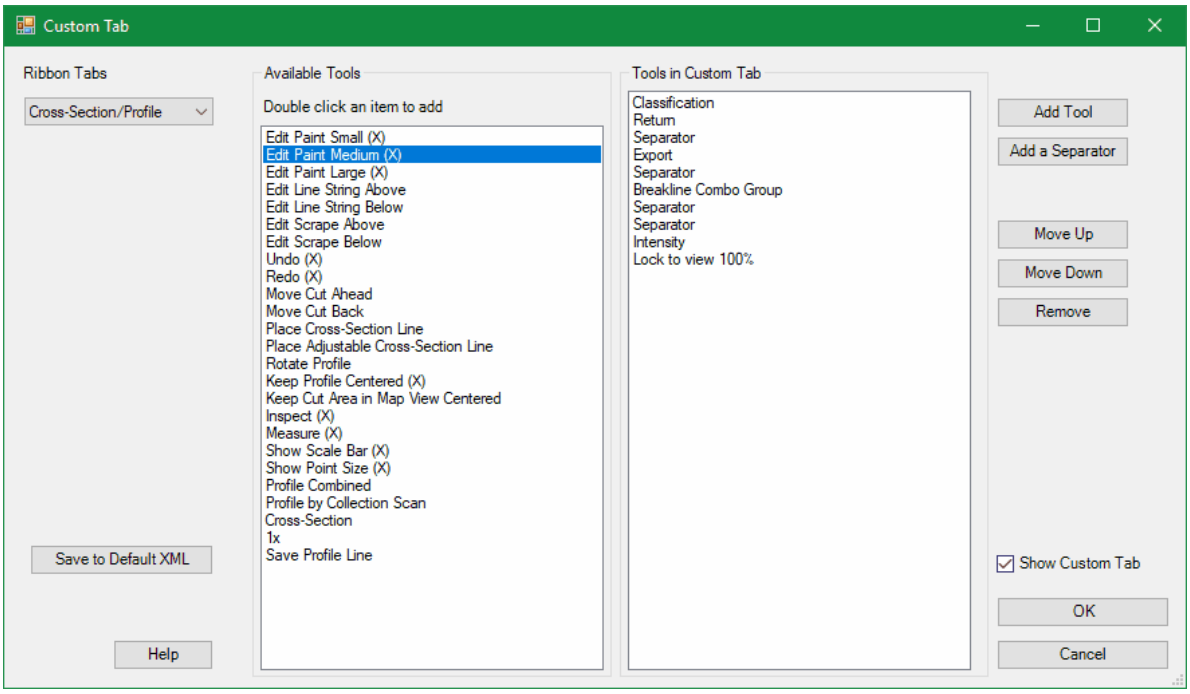
In the upper-left of the interface, choose the tab (from the 'Ribbon Tabs' drop-down list) that contains a tool to be added. Either double-click or select and click the 'Add Tool' button at the upper-right to place the tool in the 'Tools in Custom Tab' column. Continue adding tools from the various tabs until finished. The order of the tools can be modified by selecting any tool and using the 'Move Up' or 'Move Down' buttons to the right of the list. 'Move Up' will move a tool to the left on the Custom Tab, and 'Move Down' will move it to the right. Separators (vertical bars, as seen in the example at the top of this page) can be added and moved as needed. There is no limit to the number of Separators that can be added, but each tool can be placed on the Custom Tab only once.

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When the drop-down list is set to 'Cross-Section/Profile', many of the available tools are listed with an '(X)' after the tool name. These are variations of tools with the same name found on other tabs and can be added even if the identically-named tool from another tab has already been added. For example, both the 'Edit Paint Medium (X)' tool from the 'Cross-Section/Profile' tab and the 'Edit Paint Medium' tool from the 'Edit/Filter' tab can be added to the Custom Tab and exist at the same time. The '(X)' version of the tool allows reclassification in the Cross-Section/Profile window only, while the other version allows reclassification in either the LAS Map View or Cross-Section/Profile window.

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When all tools and separators have been placed, click the 'Save to Default XML' button to create an XML file in the installation folder that will be read each time MARS® is opened. After saving, the Custom Tab will be added between the 'Analysis' and 'Options' tabs, and it will become the active tab. The tools on it are duplicates of those same tools on the standard tabs, and will function the same way.

To make changes to an existing 'Custom Tab' design, click the 'Customization of Custom Tab' button on the Options Tab[519] and add or move tools as previously described. Tools and Separators can be removed from the 'Custom Tab' by selecting them (one at a time) from the 'Tools in Custom Tab' column and clicking the 'Remove' button to the right of the list. Click the 'Save to Default XML' button to write any changes to the XML file, otherwise those changes will be in effect for the current MARS® session only.

To hide the 'Custom Tab', uncheck the box labeled 'Show Custom Tab'. To permanently remove the

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tab from the ribbon layout, delete the 'MARSCustomTab.xml' file from the installation folder - it can be re-created at any time by following the instructions above.

An XML file of 'Custom Tab' settings can be shared with other MARS®-installed computers by copying and pasting it into the installation folder. If a computer with a lower license level (e.g., Explorer) uses an XML file copied from a higher license level computer (e.g., Production), only those tools that are enabled for the lower license level will be available. Conversely, if an XML file from a computer running an Explorer license is copied to a computer running Production (for example), Production-level tools may then be added to the 'Custom Tab'.

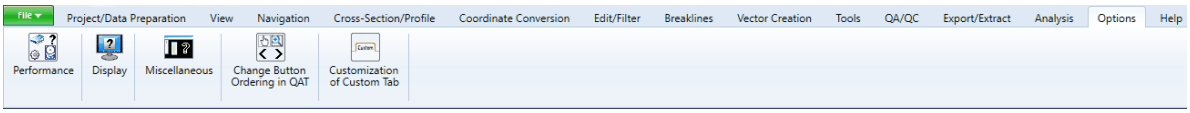
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3.15 Options Tab

Options Tab Items

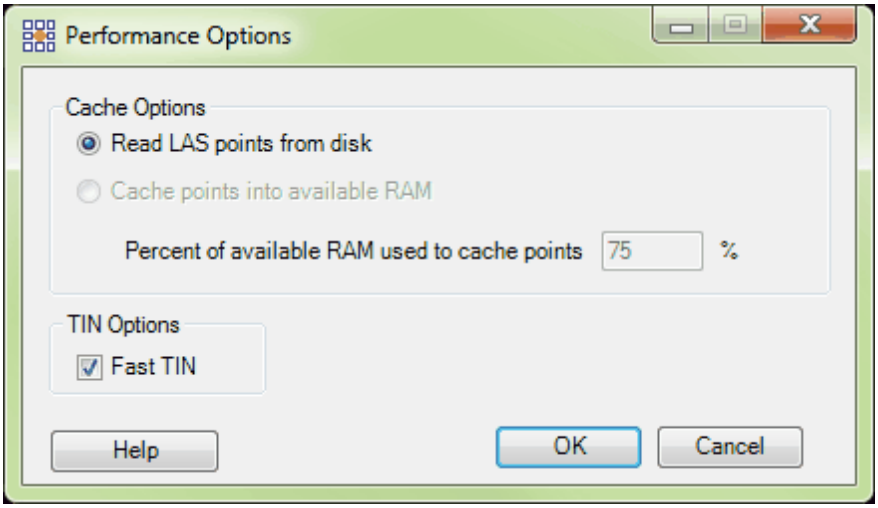
Merrick Advanced Remote Sensing (MARS®) Software

The Options Tab:



- **Performance:** Due to LAS datasets becoming increasingly larger in file size (frequently surpassing the available RAM in a computer) as well as the possibility of lost work caused by an unexpected shutdown of MARS prior to a save operation, the 'Cache points into available RAM' option has been disabled. LAS data will be read from disk and 'live' edit changes (such as hand filtering) are

committed to disk as soon as they occur. Additionally, with newer, faster hard drives such as SSD, the performance difference between disk-based and RAM-based operations is constantly shrinking.



Read LAS points from disk: Allows practically unlimited amounts of LAS data (tested beyond 1 Terabyte) to be loaded by reading the points directly from disk - either a local (internal or external) disk, or a network drive location. Changes made to the LAS files are automatically saved.

Fast TIN: This option allows the user to improve the display performance of MARS® over small areas of data when panning and zooming with TIN rendering enabled. It is intended for use in hand filtering. *This tool will speed up the display performance of point data only and is intended for hand filtering purposes. Breaklines will NOT be respected while the 'Fast TIN' option is selected and it should NOT be used during breakline editing.* The shortcut key combination for toggling Fast TIN is 'Ctrl-T.'

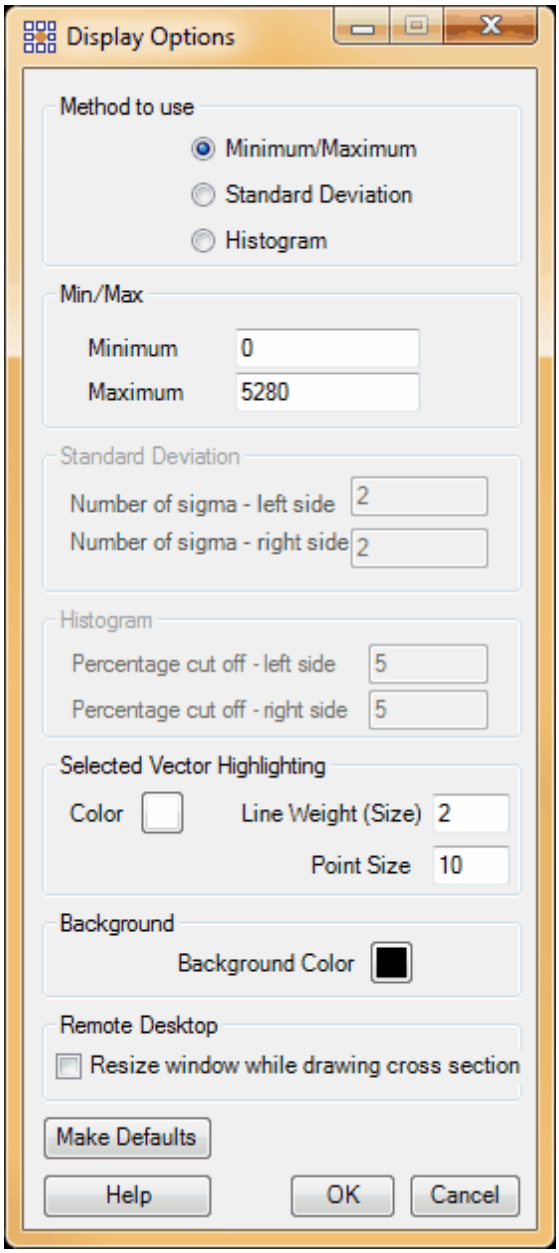
- **Display:** The upper portion of the 'Display Options' interface is meant for use with LiDAR data and the Color by Elevation tool, and allows users to choose custom display options which best fit their needs. This interface may be used to prevent color skewing, which may occur when a small quantity of point values do not match values which are popular among the majority of points being displayed.

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The display options allow the user to apply histogram clipping and stretching, as well as standard deviation stretching so that the resulting display is the most correct. If the user wishes to make any of the custom settings the new default settings, choose the 'Make Defaults' button and these custom settings will be saved and available to the user the next time the 'Display Options' window is opened, even if the MARS® application is closed. There are three methods available to the user:

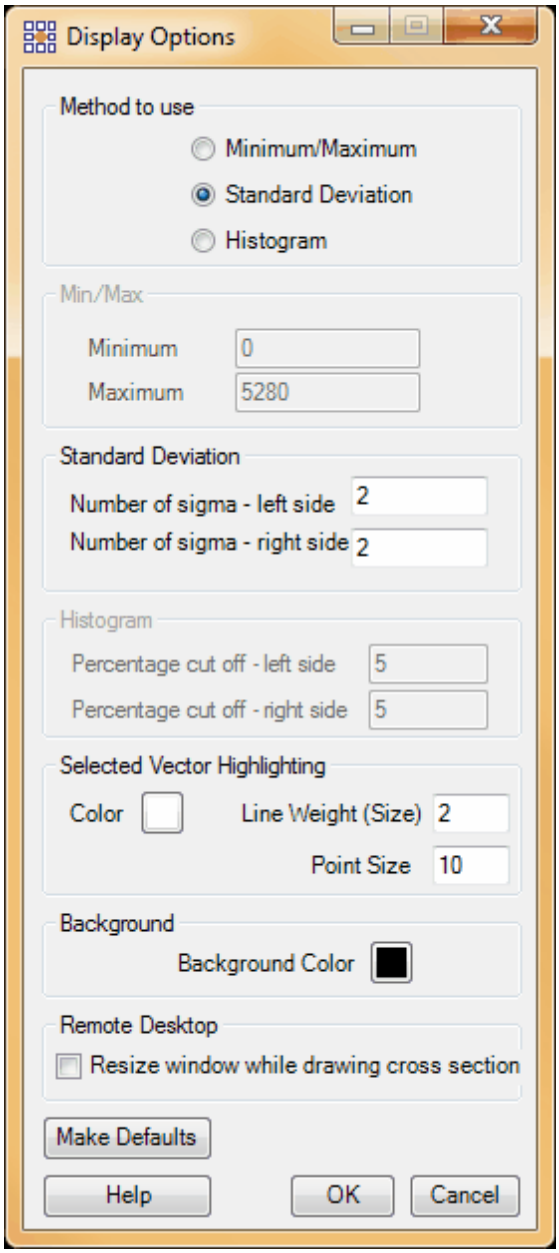
- ✓ **Minimum/ Maximum:** With this option, the user may specify a minimum and maximum color range stretch for a histogram.

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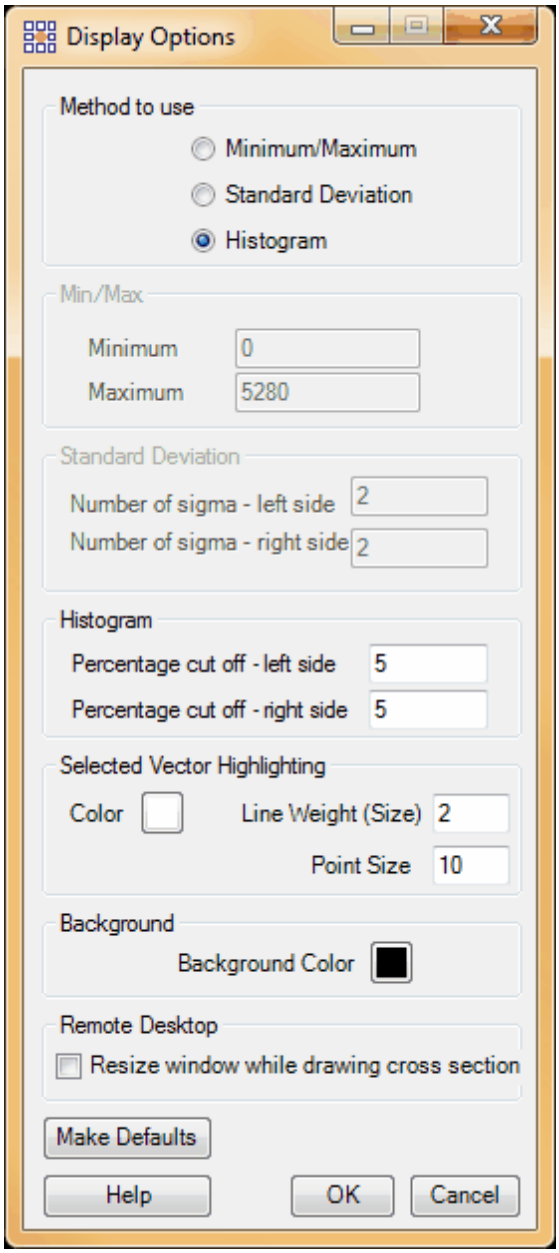
✓ **Standard Deviation:** With this option, the user may specify a number of sigmas to include in the display for both the left and right hand sides of a standard bell curve for a standard deviation stretch.

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✓ **Histogram:** With this option, the user may specify a percentage cut off for both the left and right hand sides of a histogram clip.

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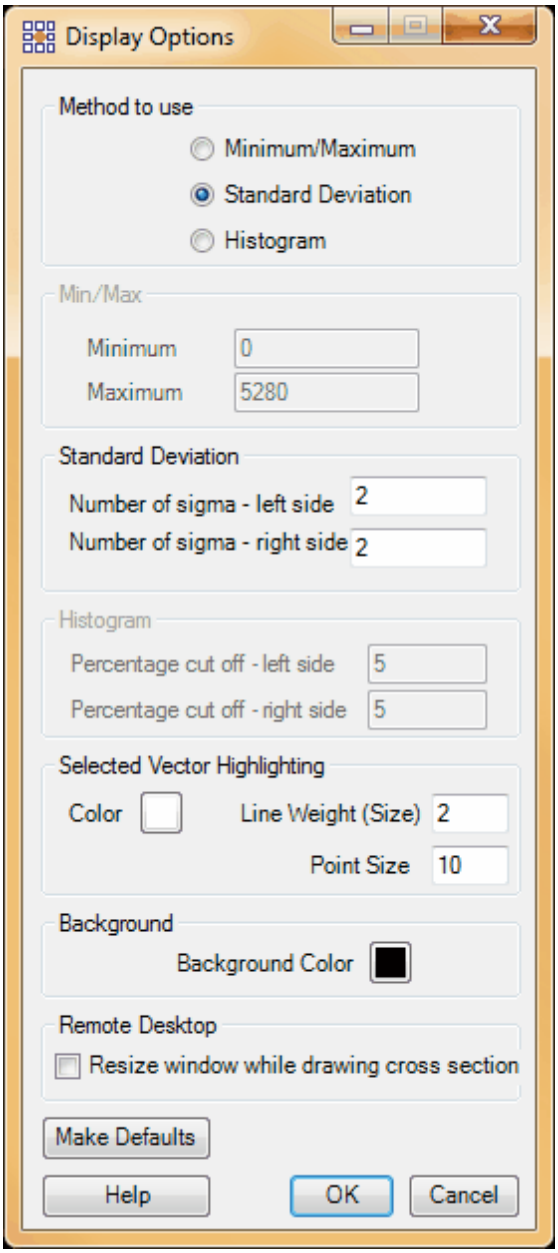
Additionally, there are options in the lower portion of the interface to change the color and line weight (or point size) of selected features (e.g., for inspection), the background color of the LAS Map View and Cross-Section windows, and to force a program window resize to improve the user experience when drawing cross-sections/profiles across a Remote Desktop Connection (when checked, this will correct incomplete data displays that may occur with some RDC/hardware configurations). Also, entering a new integer value in the 'Line Weight (Size)' box will change the display of selected

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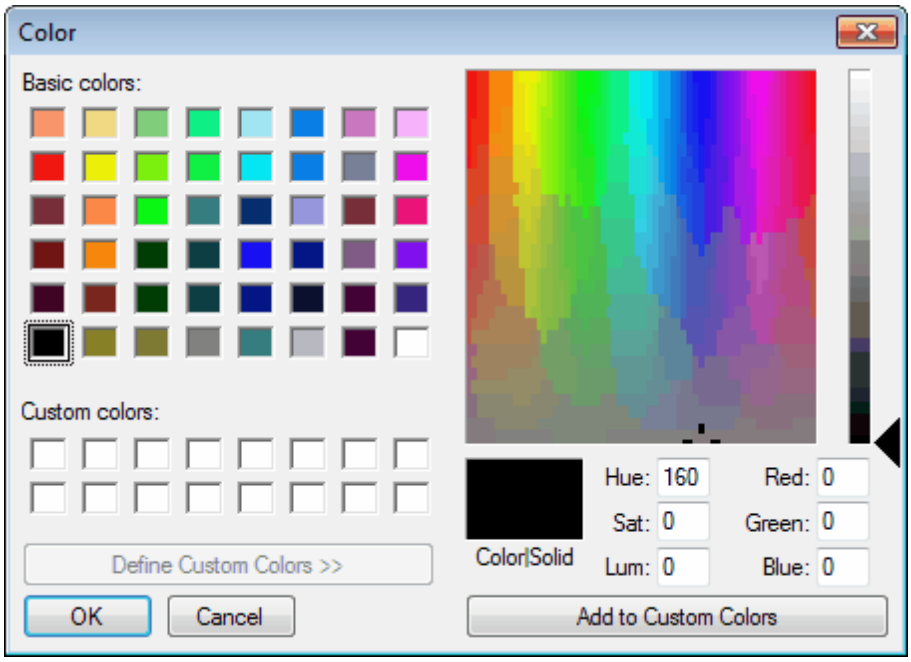
polyline and polygon features, and the 'Point Size' setting will control the size of selected point features. Features that will not be affected by the 'Selected Vector Highlighting' settings include polygon shapefiles loaded as tile layouts, and breaklines selected by the 'Add Vertex', 'Move Vertex', or 'Delete Vertex' tools on the Breaklines Tab 298 (color is honored for these tools but not line weight, so that vertices can be more easily seen). Click on the symbolized 'Color' or 'Background Color' buttons to bring up the Windows color palette to make changes.

Any changes can be made 'permanent' by clicking on the 'Make Defaults' button.

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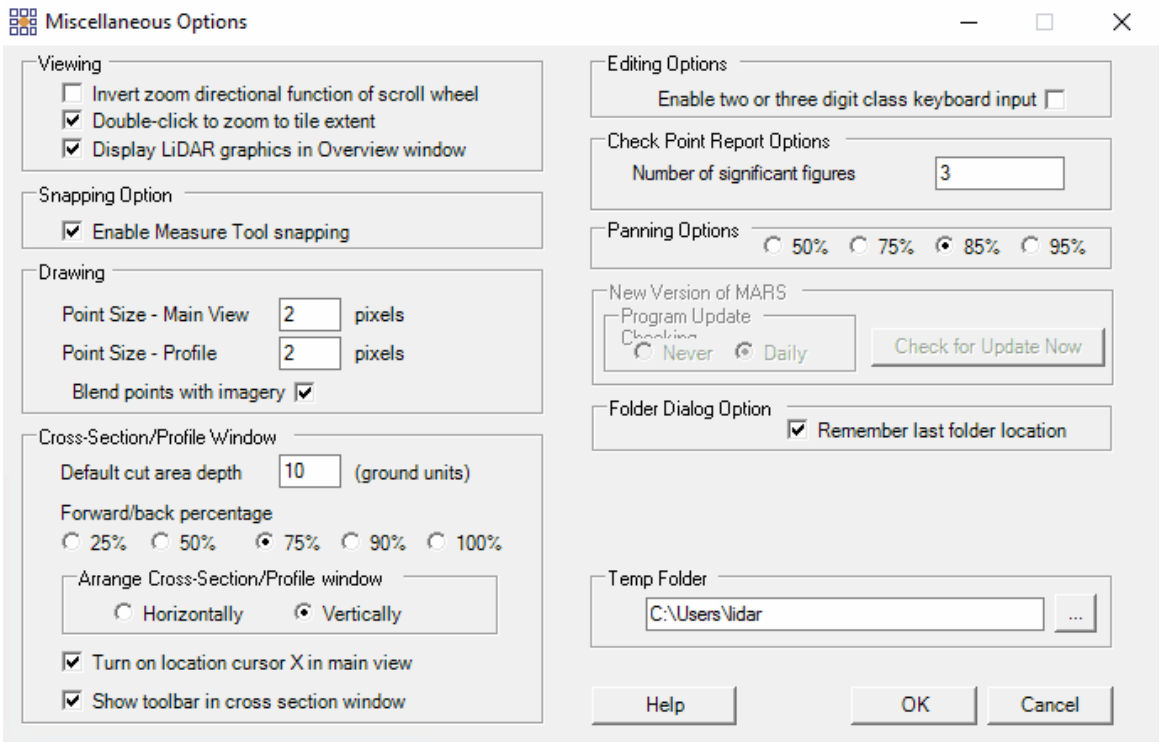


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- **Miscellaneous:** These settings control display and tool options, including inverting the directional function of the scroll wheel, LiDAR point size, Cross-Section/Profile window depth and overlap, and many more.

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✓ **Viewing:** The **'Invert zoom directional function of scroll wheel'** option allows the user to choose the zoom direction which is associated with the scroll wheel. Default settings (when this option is unchecked) are to zoom in when the mouse wheel is rolled away from the user and out when the mouse wheel is rolled toward the user. To invert these settings (zooming in when the mouse wheel is rolled toward the user, and out when the mouse wheel is rolled away from the user), please check the 'Invert zoom directional function of scroll wheel' box. The options to double-click within a tile boundary to zoom in to that tile's extent, and displaying LiDAR data in the Overview window[155] are also set here.

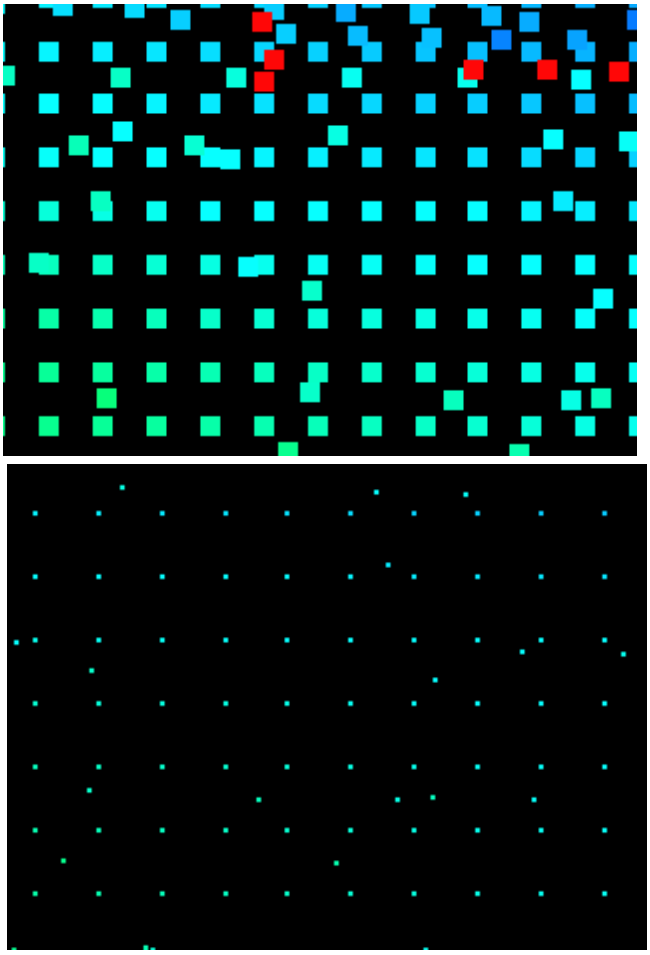
✓ **Snapping Option:** This option (enabled by default) allows the user to snap to the nearest LiDAR point at both the 'from' and 'to' ends of the Measure[957] tool vector. The current status of the function is displayed on the Status Bar[158].

✓ **Drawing:** Choose the pixel size that the points will be viewed at in the LAS Map View and in

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the Cross-Section/Profile view. The default setting for both windows is 2.

Ex: In the example below the pixel size has been changed to 10. *Ex: In the example below the pixel size is on the default setting of 2.*

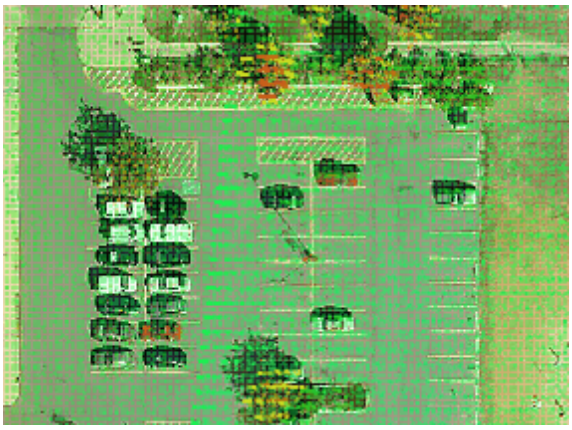


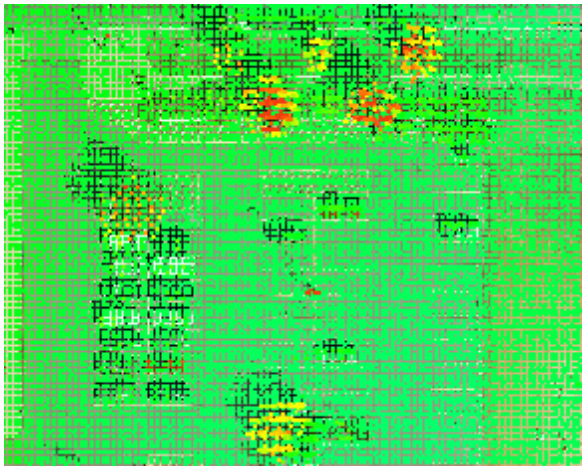
The **'Blend Points with imagery'** option (on by default) keeps a balanced mix between LiDAR points and any loaded imagery, especially when zoomed out, so the user can easily see both. If this option is unchecked, the LiDAR becomes more dominant as the display is zoomed out, and imagery becomes difficult to see.

Ex: In the example below the 'Blend Points with imagery' option is checked on.

Ex: In the example below, the 'Blend Points with imagery' option is unchecked.

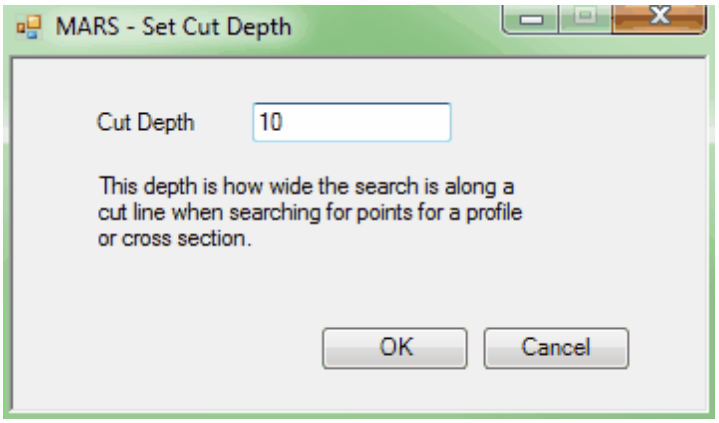
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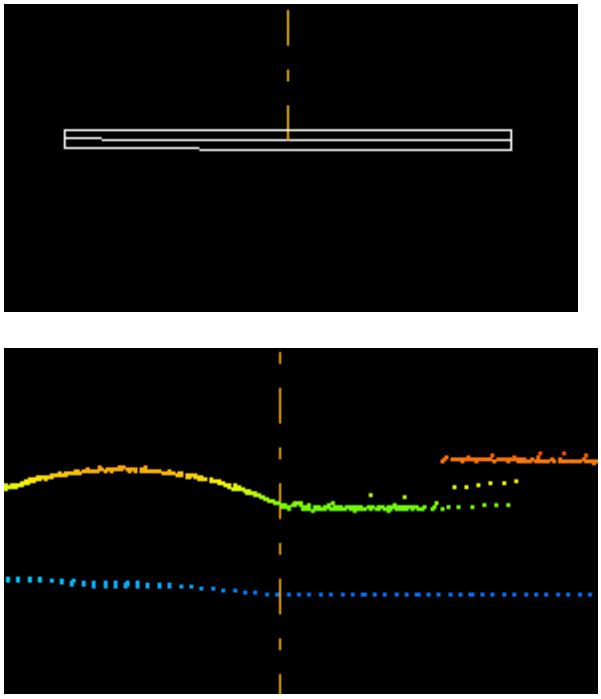
✓ **Cross-Section/Profile Window:** The **'Default cut area depth'** (set to 10 ground units by default) is used with the **'Place Cross-Section Line'**  tool. Increasing the cut depth will increase the number of points the cross-section/profiling tool shows in the cross-section/ profile window and vice versa. To change the current depth of the cross-section/profile window but not the default value, enter a new value in the 'Current Depth' text box on the Cross-Section/Profile Tab[240], or use the shortcut key **'D'** on the keyboard to open a cut depth settings window.

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The current cut depth will also be displayed on the Cross-Section/Profile window tab and the optional Cross-Section/Profile window[146] Edit Toolbar.

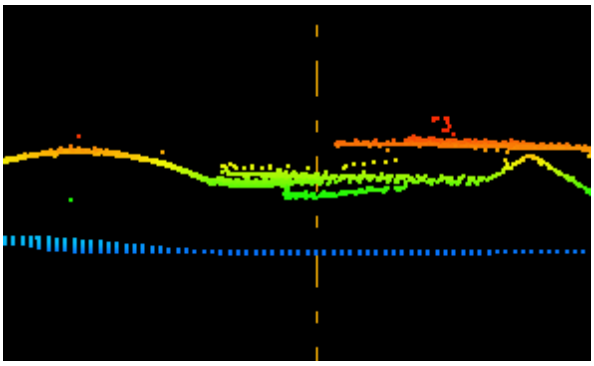
Ex. In the screen shot below, the cut depth is set at 10. Notice the density of points in the cross-section/profile window (right) as well as the size of the cut area box (left).



Ex: In the example below the cut depth has been increased to 50. Notice the increase in visible points in the cross-section/profile window (right).

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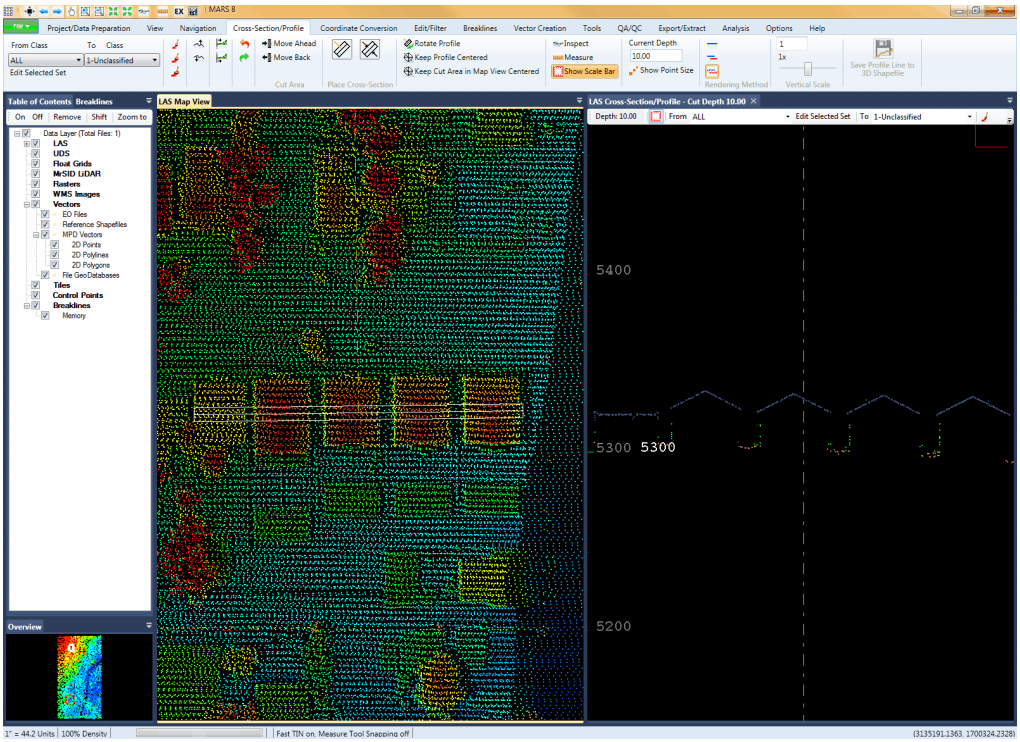


The **'Forward/back percentage'** (set to 75% by default) determines the amount of movement (and therefore, overlap) of the cut depth box. When using either of the cross-section/profiling tools **('Place Cross-Section Line'**  or **'Place Adjustable Cross-Section Line'** ) it is possible to use the arrow keys on the keyboard (⬆ and ⬇) to move the cross-section/profiling line forward and backward for a slightly different view of the data.

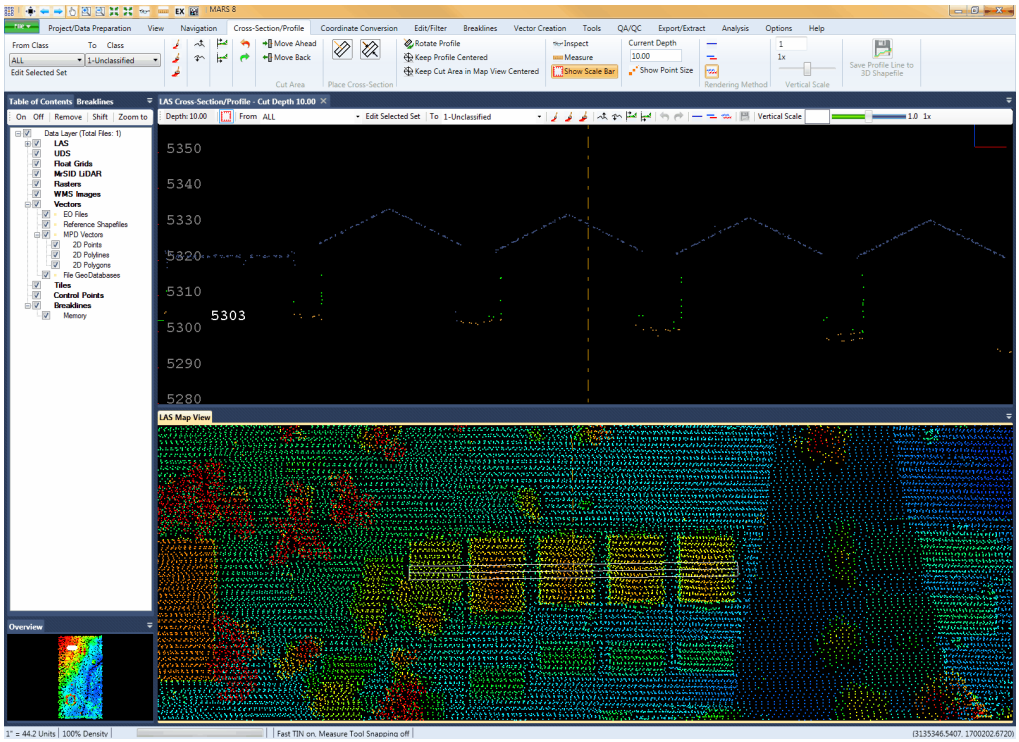
The **'Arrange Cross-Section/Profile Window'** option allows the user to arrange the cross-section/profile window either horizontally or vertically in reference to the LAS Map View window.

Ex. Cross-Section/Profile window arranged vertically.

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Ex. Cross-Section/Profile window arranged horizontally.



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The **'Turn on location cursor X in main view'** option displays a white 'X' symbol in the cut area box in the LAS Map View window. This can be helpful in relating the cursor location in the Cross-Section/Profile window to the data in the LAS Map View. If the cursor is moved out of the Cross-Section/Profile window the 'X' will stop moving, but will begin again at the correct location when the cursor re-enters the window.

The **'Show toolbar in cross-section window'** checkbox controls a supplemental toolbar of the most commonly used editing functions while in a Cross-Section/Profile window[146]. When on, the toolbar is docked at the top edge of the window so it is always convenient regardless of the arrangement of the Cross-Section/Profile window.

✓ **Editing Options:** The **'Enable two or three digit class keyboard input'** option allows the user to enter 2- or 3-digit classes when using the keyboard accelerators in editing. If LiDAR data contains classes with 2 or 3 digits, this option can be useful during editing. Enter the 2- or 3-digit class, choose 'Enter' on the keyboard, and the points highlighted will be changed to the classification entered by the user. It is also possible to enter one digit classes while the 'Enable two or three digit class keyboard input' option is chosen. Highlight the points to have their classification changed, press the keyboard number representing the one digit class, and then choose 'Enter' on the keyboard. The points will then be reclassified. When the **'Enable two or three digit class keyboard input'** option is NOT chosen, points selected cannot be reclassified to a 2- or 3-digit classes because as soon as one number is entered (representing a one digit class) the points are automatically reclassified *without* hitting the 'Enter' key. For example, the user can select certain LiDAR points needing to be reclassified and choose '15' in interest of reclassifying the points to class 15. Without the **'Enable two or three digit class keyboard input'** option chosen, the points selected will be reclassified to

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class 1 because this was the first key chosen to reclassify data. To reclass selected LiDAR points to a class with 2 or 3 digits using the keyboard accelerators, choose the 'Enable two or three digit class keyboard input' option, select the points to be reclassified, enter the class number, and choose 'Enter' on the keyboard.

✓ **Check Point Report Options:**

Number of Significant Figures: The user can set the number of significant figures to be used in the check point report. To learn more about the check point report and its settings, please visit the Check Point Report 1224 section. In addition, it controls the number of significant figures that are used in reporting for the USGS 2.1 QC Module 1525, USGS 1.3 QC Module 1559, USGS 1.2 QC Module 1592, LiDAR Data Checks 1677, and LiDAR Calibration Checks 1698. This value also affects the coordinate display shown in the lower-right corner of the LAS Map View window.

✓ **Panning Options:** When using the 'Ctrl-⬆', 'Ctrl-⬇', 'Ctrl-⬅', or 'Ctrl-➡' shortcut keys 1880, the amount of movement is determined by the radio button selected - '50%', '75%', '85%' (default setting), or '95%'. For example, when 85% is selected, using the 'Ctrl-⬅' shortcut key will pan to the left with 85% of the window extent now displaying a new area and the remaining 15% showing part of the previous extent.

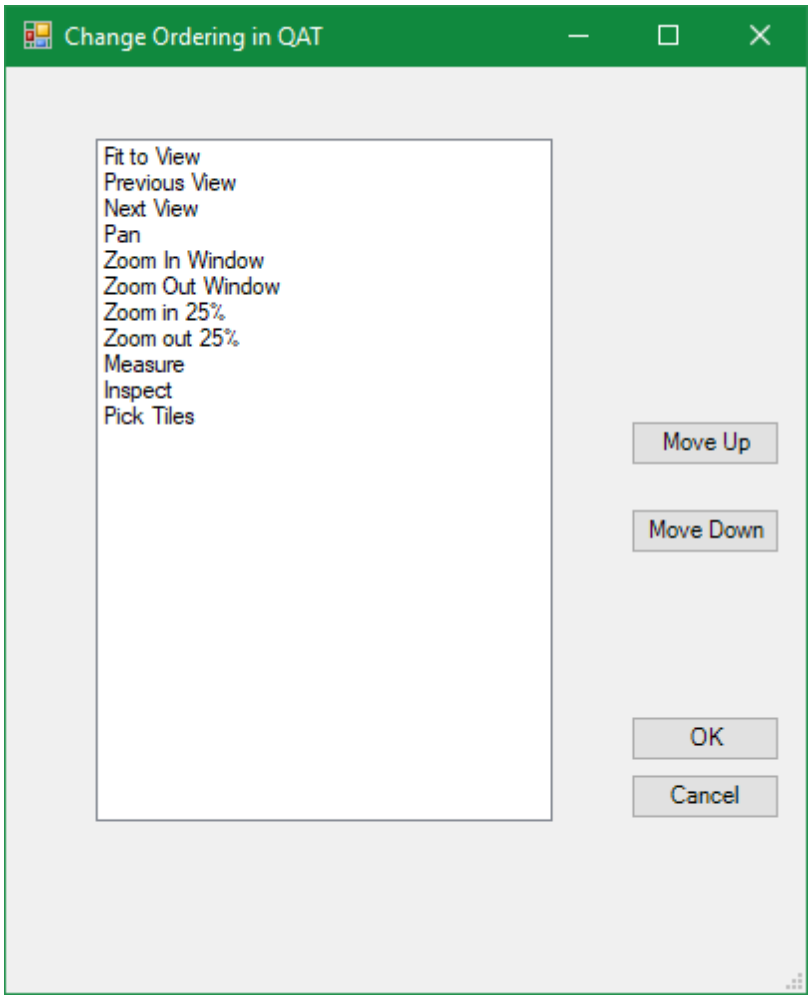
✓ **Folder Dialog Option:**

Remember last folder location: Allows last folder used to be stored within a MARS® session when a standard Microsoft Windows 'Open', 'Save', or 'Save As' dialog is not being used. Examples are: when using the 'Add From Folder' or 'Folder to process' option for input on many tools and functions, and when pointing to a folder to add LAS files, images, or an Esri File GDB.

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✓ **Temp Folder:** The location of the internal working folder used for various processes and session logs. If possible, this should be the internal local drive with the most free space.

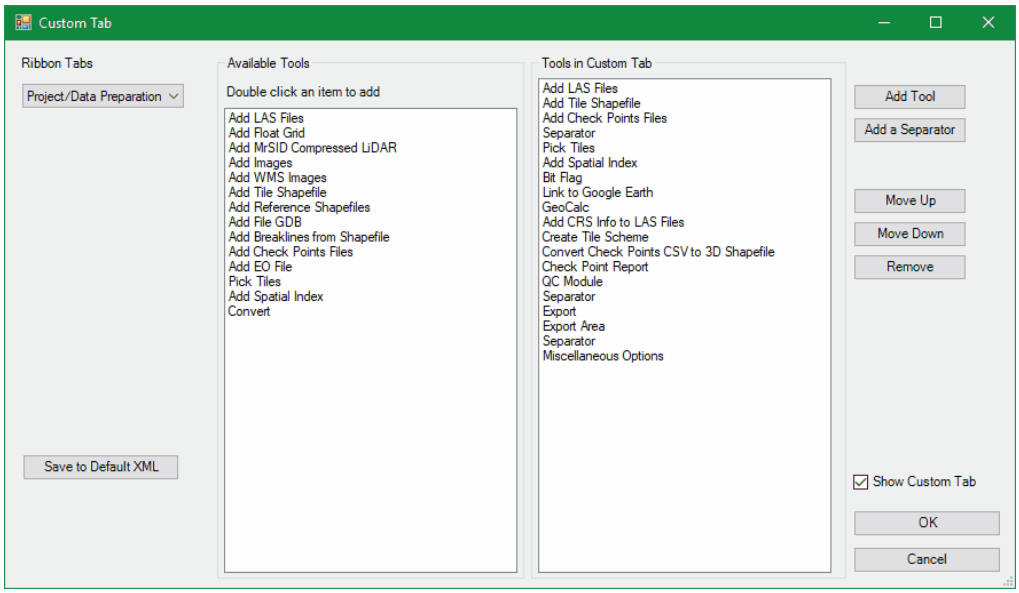
- **Change Button Ordering in QAT:** To re-order the tool buttons in the QAT, click the 'Change Button Ordering in QAT' button. The 'Change Ordering in QAT' interface will appear, where tools may be moved up (to the left on the toolbar) or down (to the right on the toolbar) in the list of existing tools. Select the tool(s) to be re-ordered, one at a time, and click either the 'Move Up' or 'Move Down' button.



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When all re-ordering is complete, click the 'OK' button to save the positions and close the interface, or click 'Cancel' to quit without saving any changes.

- **Customization of Custom Tab:** An optional Custom Tab can be created and populated with many of the most commonly used tools and functions. On the customization interface, the drop-down at the far left lists all standard tabs on the ribbon, except 'File' and 'Help'. Choose the tab from which a tool is to be added, and the list of 'Available Tools' for that tab will appear. Select a tool from that list and click the 'Add Tool' button to place it in the 'Tools in Custom Tab' list. Continue to create the custom list one-by-one, choosing any available tool from any selected tab in any order. Separators may be added to give a 'grouped' appearance to the final tab layout. Any tool or separator in the 'Tools in Custom Tab' list can be moved up (to the left on the tab) or down (to the right on the tab) to create the desired layout. There is no limit to the number of separators that may be added, but each tool can be placed only once on the Custom Tab.



When all the selections and/or re-ordering are complete, click the 'OK' button to save and close the interface. If no Custom Tab has been previously created, it will be generated between the 'Analysis' tab and the 'Options' tab. Click 'Cancel' to quit without saving any changes.

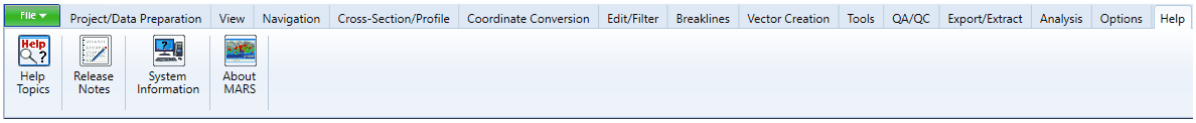
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3.16 Help Tab



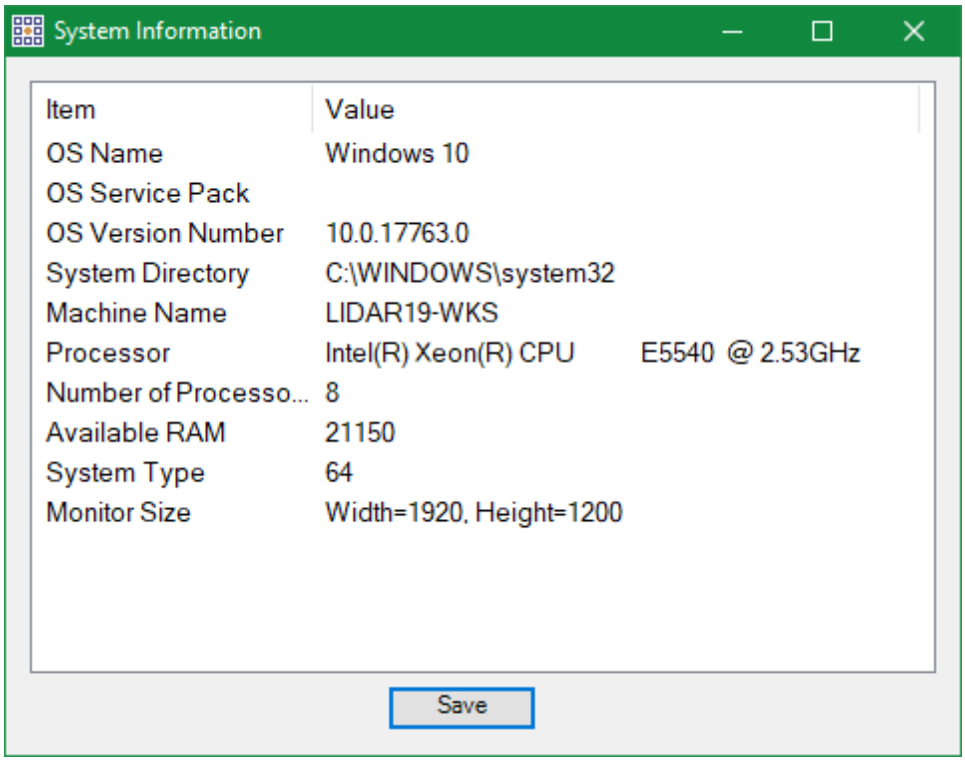
The Help Tab:



- **Help Topics:** The help file is a hyper-linked document of how-to guides, reference material, and tutorials. To see the help topics, use the **'Help Topics'** button on the Help tab, or use the hot-key **'F1'**.

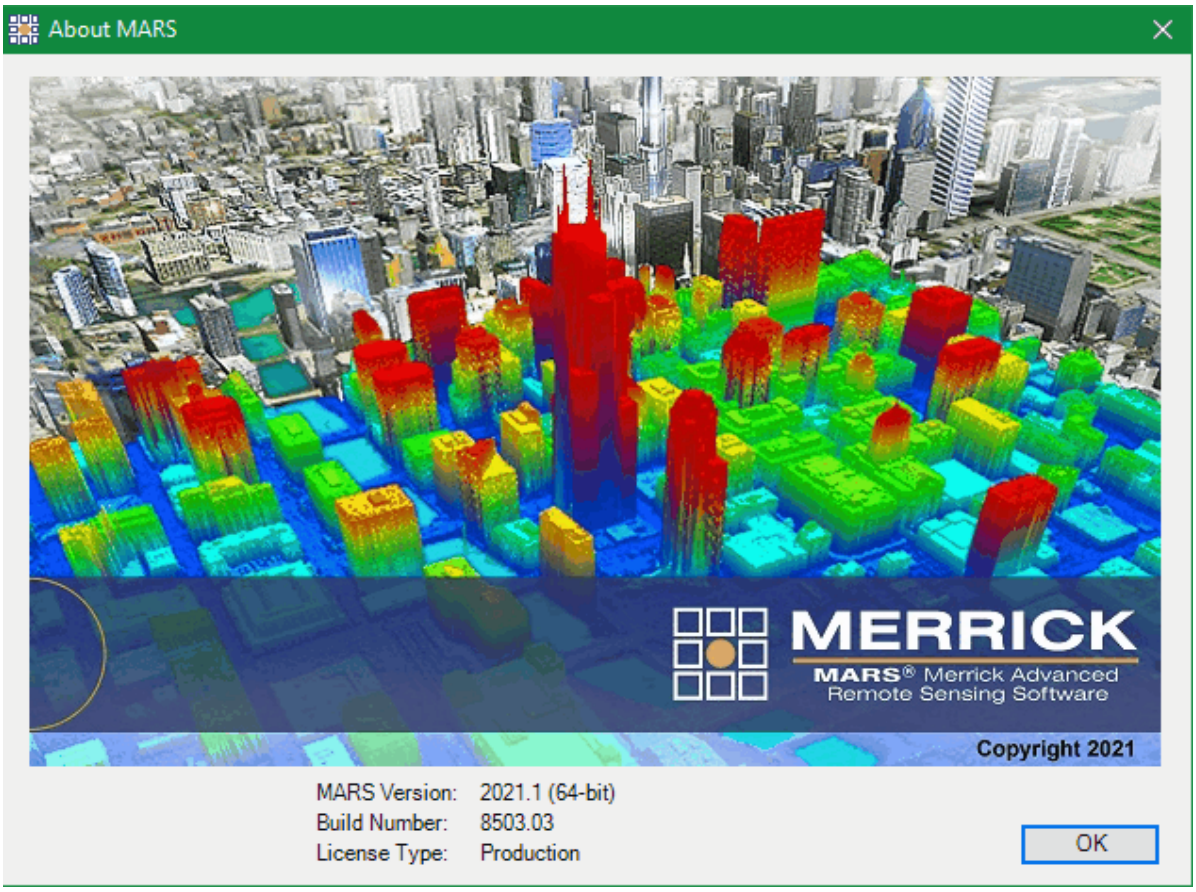
- **Release Notes:** Opens the Release Notes PDF, which details changes and fixes since the previous version was released. This document is also available from the MARS program group in Windows.

- **System Information:** Displays a pop-up with various details about the user's computer environment. The information can be saved to a text file, and may be requested by MARS® Tech Support. Note that even if the 'OS Name' value is listed as 'unknown', the OS Version Number will still report correctly.



- **About MARS:** Displays information concerning the Version number, platform (64-bit), Build Number, and License Type. See the screen shot below as an example (MARS Version and Build Number may vary):

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4 Tools and Functions

Tools and Functions

Merrick Advanced Remote Sensing (MARS®) Software

Note: Please see individual Tools Tab 389 help topics for details on which tools are only available with a Production license.

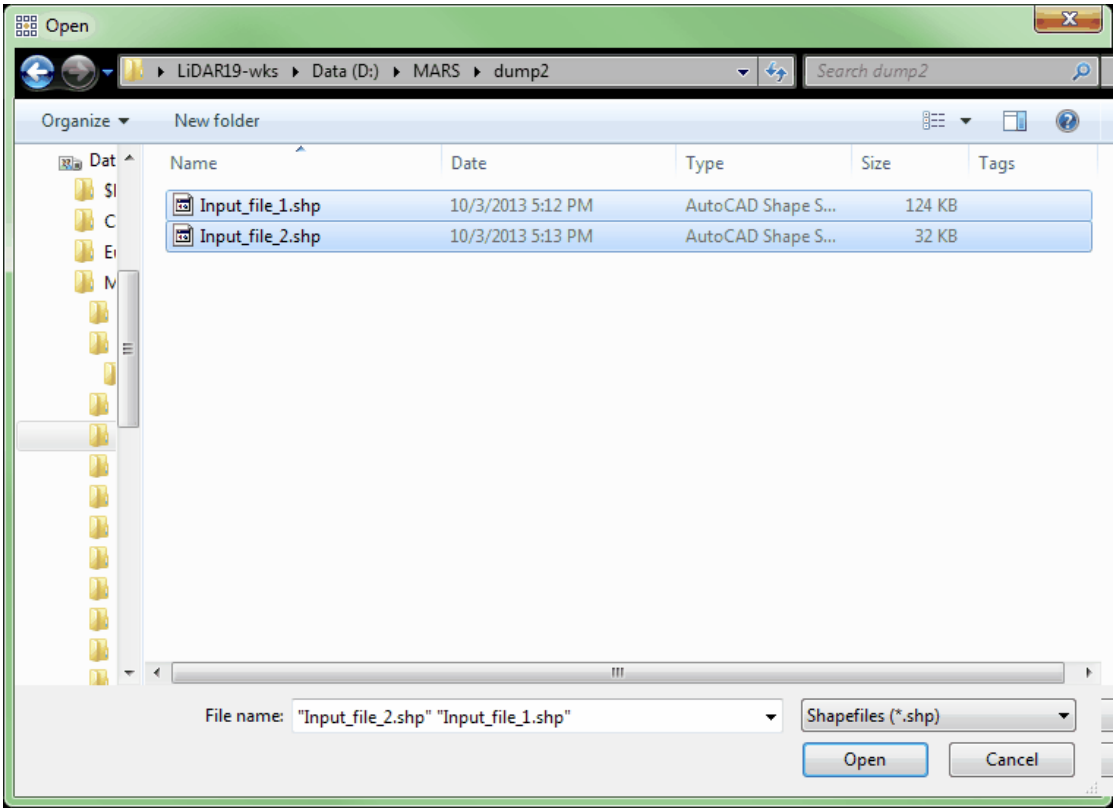
For any LAS tools that allow files to be pathed out without loading them in the Table of Contents in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/ Data Preparation Tab 162 topic.

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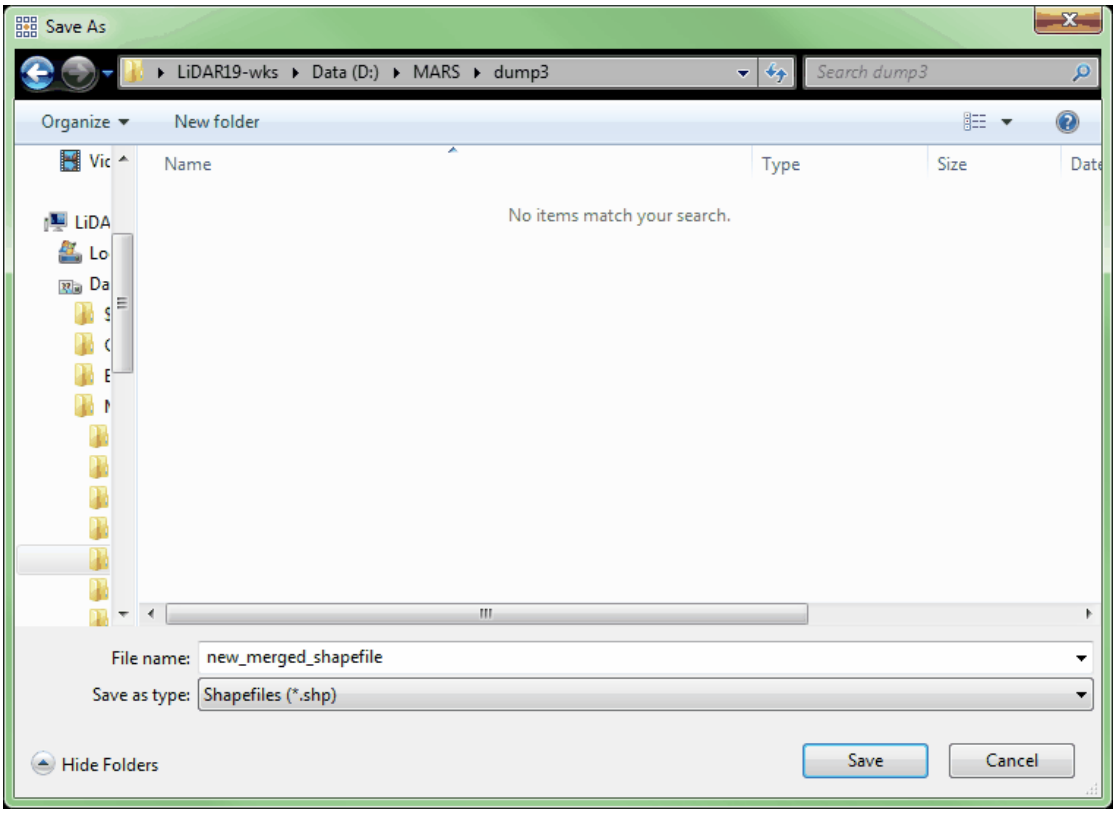
4.1 Vector Tools



- ***Merge Shapefiles*** ***(available with Production license only):*** This tool, found on the Tools Tab 389, creates a new merged shapefile from two or more input shapefiles. All input files ***must*** be of the same geometry type (i.e., point, polyline, or polygon), and must reside in the same folder. After clicking on the tool, the 'Open' dialog box appears. Navigate to the folder where the shapefiles to be merged are located, then choose two or more shapefiles by using the left mouse button with 'Ctrl' or 'Shift' (standard Windows selection methods). Now click 'Open' and the dialog box will change to a 'Save As' box. Enter an output folder and file name for the new merged shapefile and click 'Save.' A pop-up message will indicate when the tool has completed processing. If the input data has defined projection, then a PRJ file with that projection information will be created for the merged shapefile. The newly created shapefile can now be loaded into MARS® as a Reference Shapefile (or Tile Shapefile, as appropriate).



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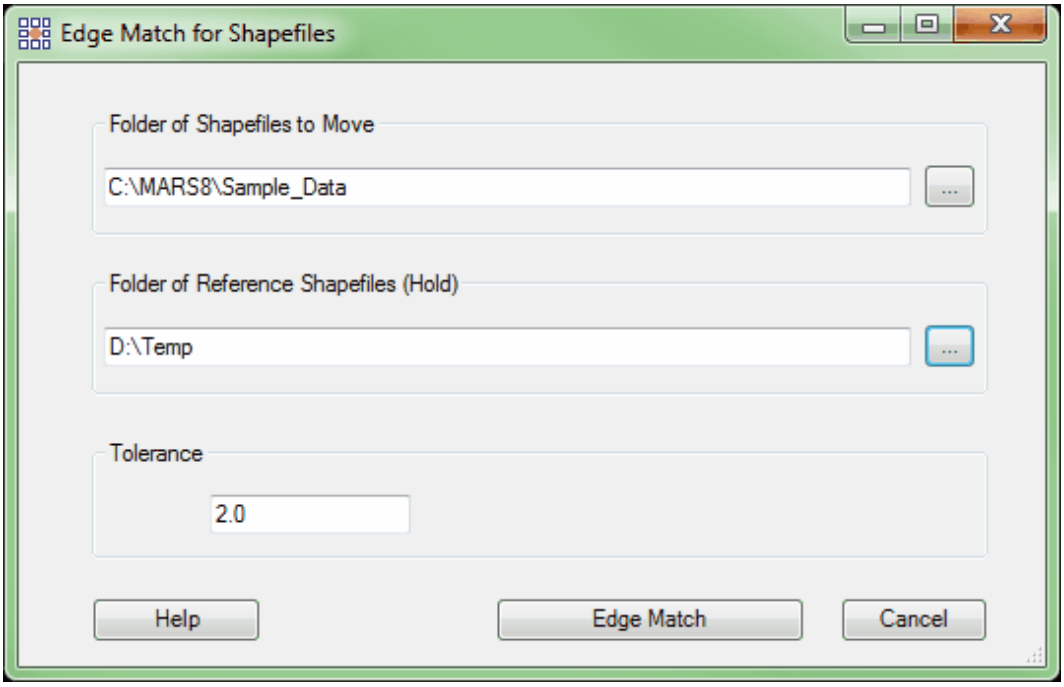


- ***Edge Match for Shapefiles*** ***(available with Production license only):*** This tool, found on the Tools Tab[389], allows the user to match the endpoints of shapefile contour lines in two (2) separate folders. Because the tool will only match contours with the exact same elevation, it is important that both shapefiles contain an elevation attribute field labeled 'ELV'. This attribute field must contain the elevations of each contour line.
    - **Folder of Shapefiles to Move:** Navigate to the folder which contains the shapefiles of contour lines which are to be moved in the edge match process. The contour lines in these shapefiles will be moved to match the endpoints of the contour lines in the Reference Shapefiles folder. The contour lines will only be moved horizontally according to the tolerance the user defines. The elevation of the contour lines will not be changed in the edge match process. For this reason, the shapefiles ***must*** have an attribute field labeled 'ELV' which contains the elevations of every contour line in each

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shapefile. Only contour lines which are within the tolerance defined and which match the exact elevation of the reference shapefiles' contour lines will be moved.

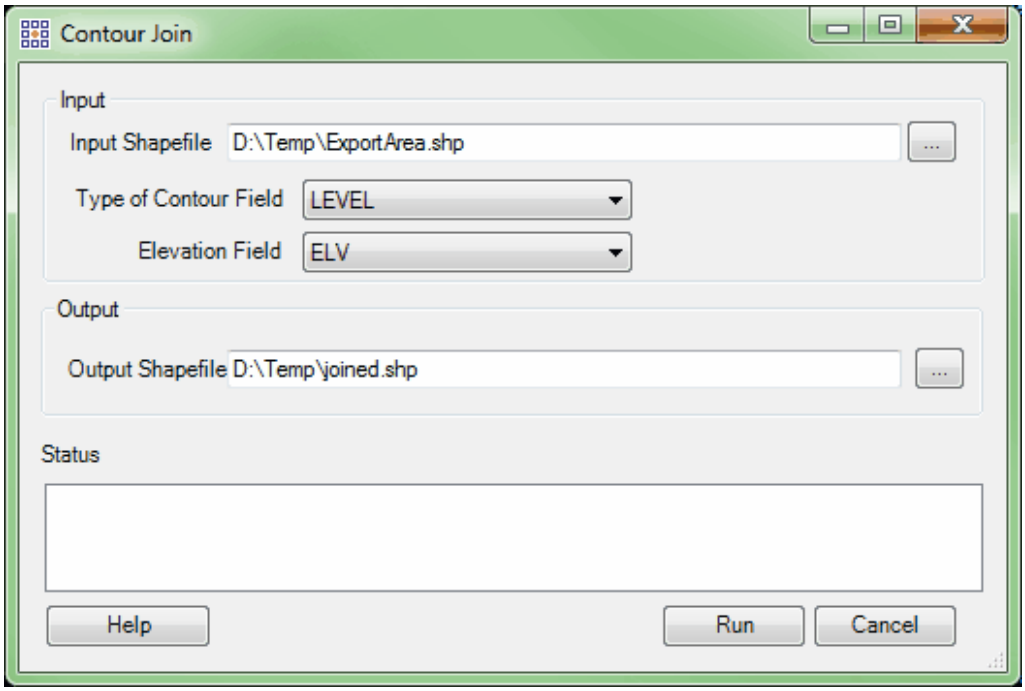
- **Folder of Reference Shapefiles (Hold):** Navigate to the folder which contains the shapefiles of reference contour lines to be used. The reference shapefile contour lines ***will not*** be moved during the edge match process. The reference shapefile contour lines will be used to measure the tolerance as defined below, and contour lines in the 'Shapefiles to Move' set will be moved to match these contour lines. The reference shapefiles ***must*** have an attribute field labeled 'ELV' which contains the elevations of every contour line in each shapefile.
- **Tolerance:** Enter a number (in project units) here to set a maximum search radius for finding matching-elevation contour lines in the 'Move' and 'Hold' folders. In the example below, the tolerance is set at 2.0 units. If a contour line endpoint with a matching elevation is found within 2.0 horizontal units of the contour line endpoint in a reference shapefile, the endpoint will be snapped to the endpoint of the reference shapefile contour.



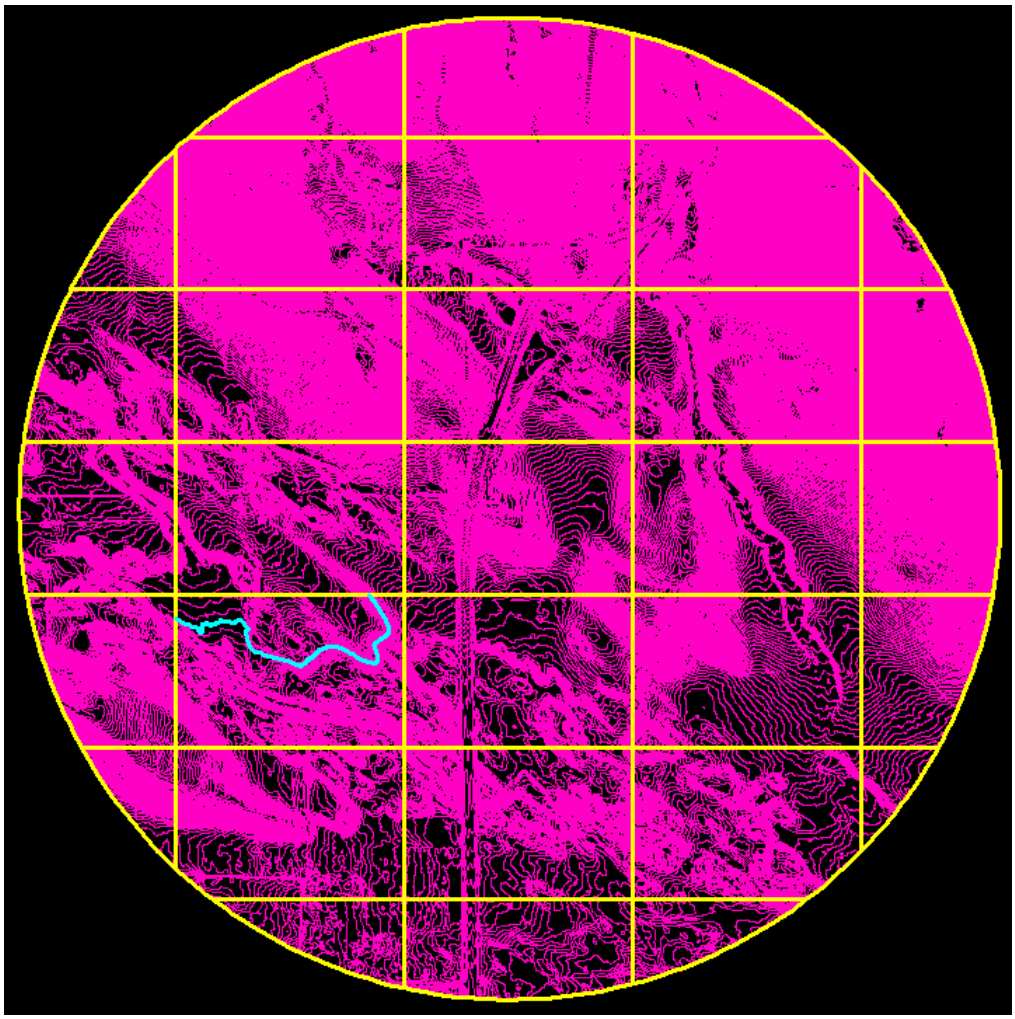
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- ***Contour Join:*** This tool, found on the Tools Tab[389], allows the user to join several different contour features into one continuous contour.

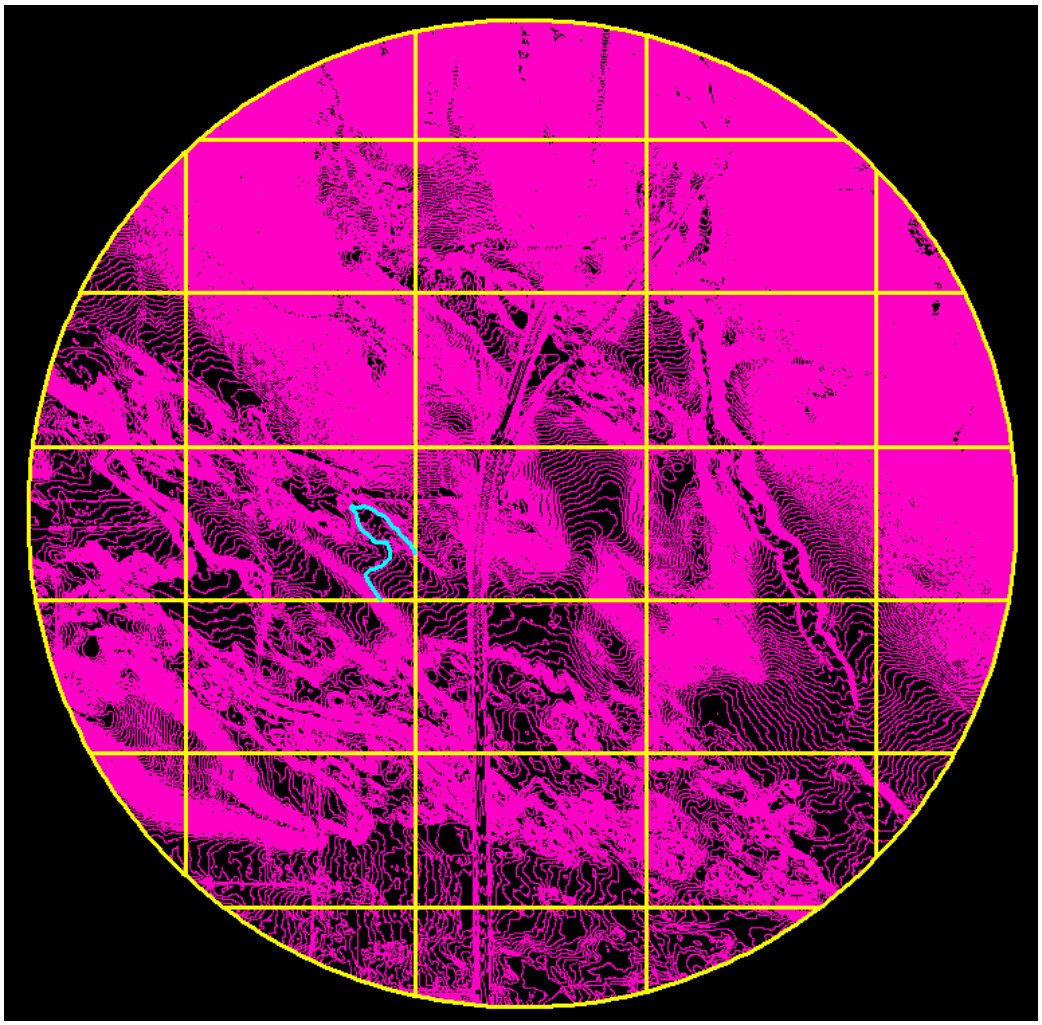
  For example, the screen shots below show a single contour line which was broken apart into several different features (or separate contour lines) by tile. This line, which represents only one contour, is now several contour lines. The contour line breaks into separate contour lines at every tile boundary.



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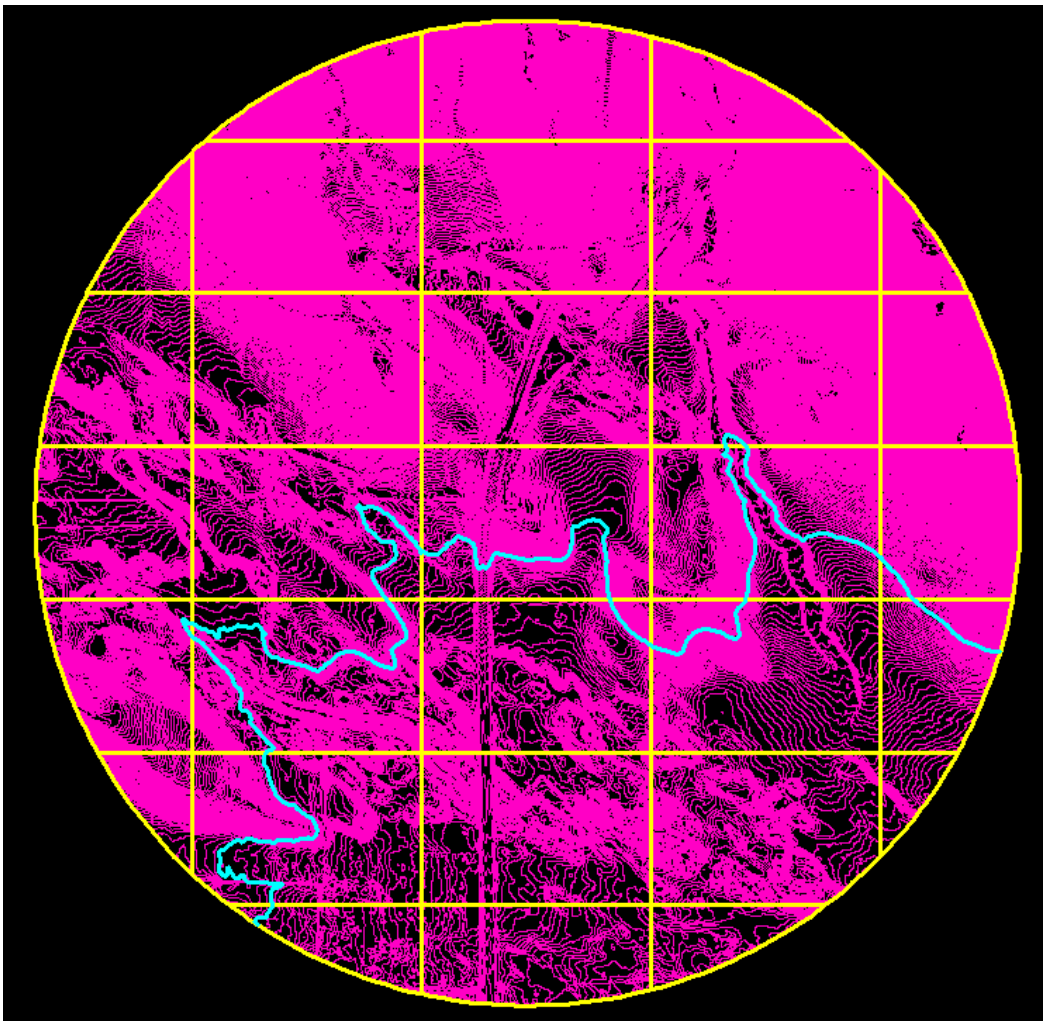


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In the example below, the 'Contour Join' tool has been run on the same contours as shown above. The contour which was cut at the edges of each tile now runs unobstructed for its entire length until the project boundary.

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- ***Depression Coder*** ***(available with Production license only):*** The 'Depression Coder' tool, found on the Tools Tab[389], allows the user to find depression contours and label them as such in a newly-generated contour shapefile's attribute table. This tool is meant for use over an entire project-wide area, preferably using a single, merged shapefile of contours. This makes the processing more accurate by allowing the tool to locate large depressions spread over several tiles which would have otherwise been missed if processing was done over a smaller area or run by tile. The tool searches through the data looking for closed contours

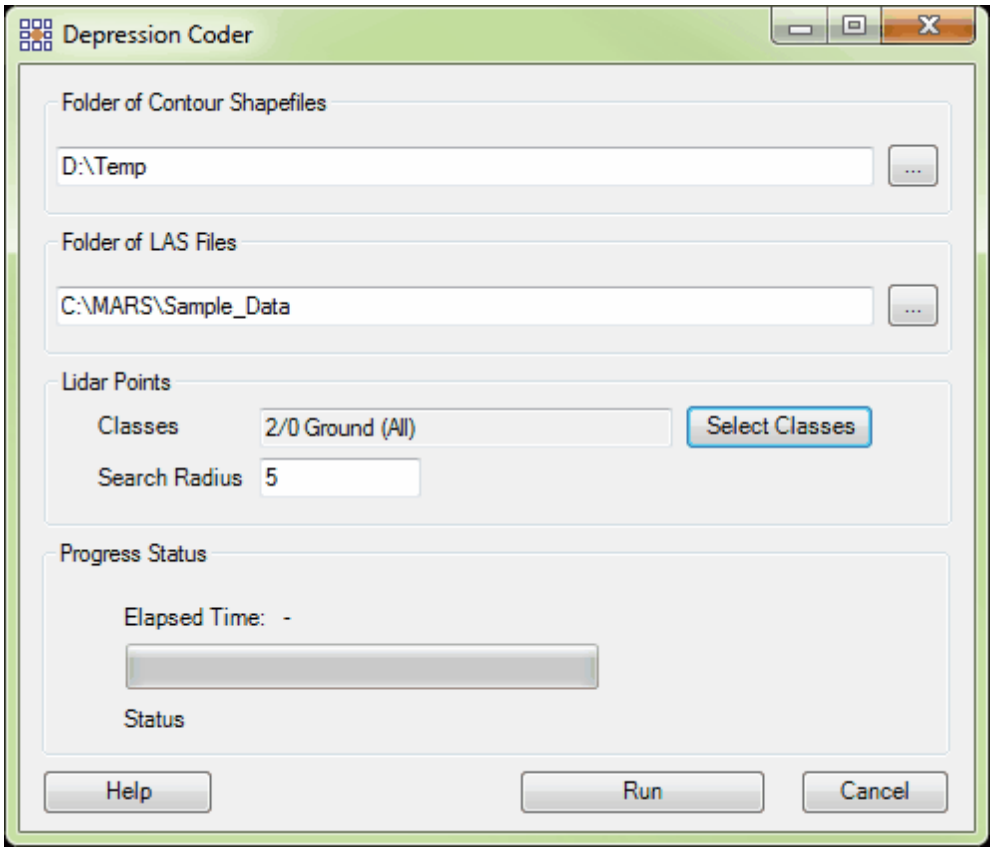
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which form 'polygons', indicating a depression or rise in the earth's surface.

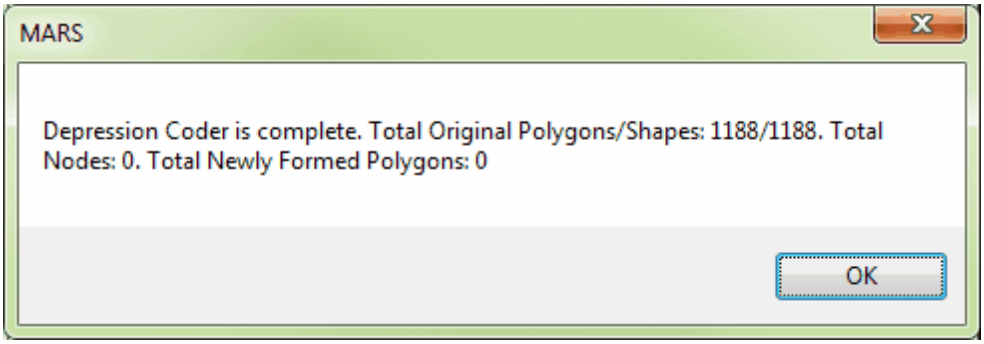
To use, navigate to the folder containing the contour shapefiles for the entire project in the **'Folder of Contour Shapefiles'** text box. Navigate to the folder containing the accompanying LAS data for the entire project in the **'Folder of LAS Files'** text box. Ideally, use the same LAS data that the contours were generated from. The 'Depression Coder' tool will not make any changes to the LAS data. The LAS information is only used as a reference to help find depression contours and ignore rising contours. For example, contours generated over a dry lake bed (depression contours) are very similar in appearance to contours created over a large hill (rising contours) when viewing only the linework and not the elevation values. Since the LAS data contains elevation information (Z-values) for each point, it will help in assessing whether the closed contours are depression or rising contours. This is done by specifying the class (or classes) that contain ground points and setting a 'Search Radius' value that is equal to (or slightly larger than) the cell size used in making the original contours or the gridded surface they were generated from. This radius is the distance inside each closed contour that the tool will search for ground points. If points are found with lower elevation values, the contour will be labeled a depression. When all the necessary entries to the 'Depression Coder' interface have been made, click the 'Run' button. The progress of the tool may be monitored via the status bar. A new shapefile containing the depression-coded contours will be created in the **'Folder of Contour Shapefiles'**, with '_Processed' appended to the input shapefile's name.

Please see the Contours Tab 806 for information on expected level attribute values for proper operation of this tool. Depressions will be given a value one number higher than non-depression contours. For example, if Index contours are level 50 and Intermediate contours are level 51, then their depression equivalents will be assigned levels 52 and 53, respectively.

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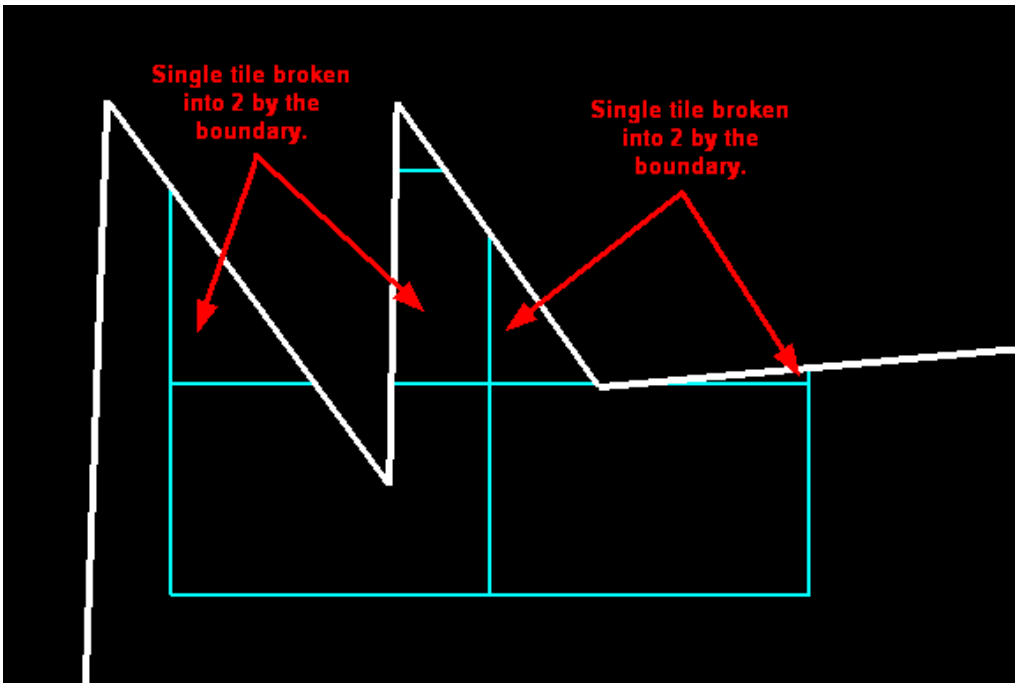
When the 'Depression Coder' tool has completed its task, the user will receive a prompt reporting the total original polygons, nodes, and newly formed polygons.



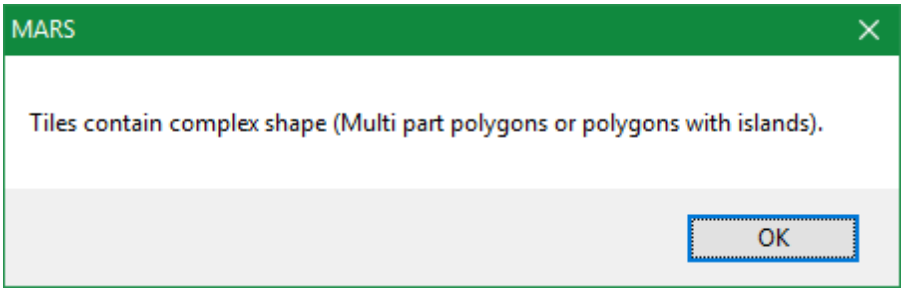
- ***Complex Polys to Simple*** ***(available with Production license only):*** This tool, found on the Tools Tab[389], allows the user to create separate files (simple polygons) from a multiple file (complex polygon) shapefile. This tool may be useful when the user wishes to export data

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by tile clipped to a boundary. If this boundary separates a particular tile into multiple parts, the user may end up with duplicate tile numbers. Duplicate tile numbers often may cause overwriting of needed data. The example below shows a boundary (in white) which cuts the two (2) indicated tiles in the tile shapefile (in blue) into multiple parts.

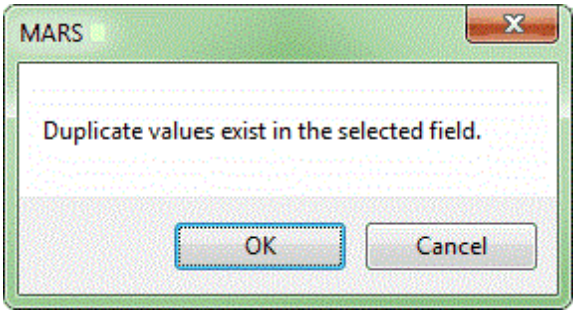


If the user loads a tile shapefile (similar to the one above in blue) that contains complex polygons, MARS® will notify the user. *This prompt will ONLY appear when the user is loading the complex shapefile AS A TILE SHAPEFILE.* If the shapefile is loaded as a reference shapefile, the user will not receive a prompt. This window appears only for the user's knowledge and as a suggestion to apply the 'Polygons from Complex to Simple' tool to avoid lost or overwritten data. If a complex shapefile (a shapefile containing multi-part polygons) has been loaded as a tile shapefile the following prompt will appear:



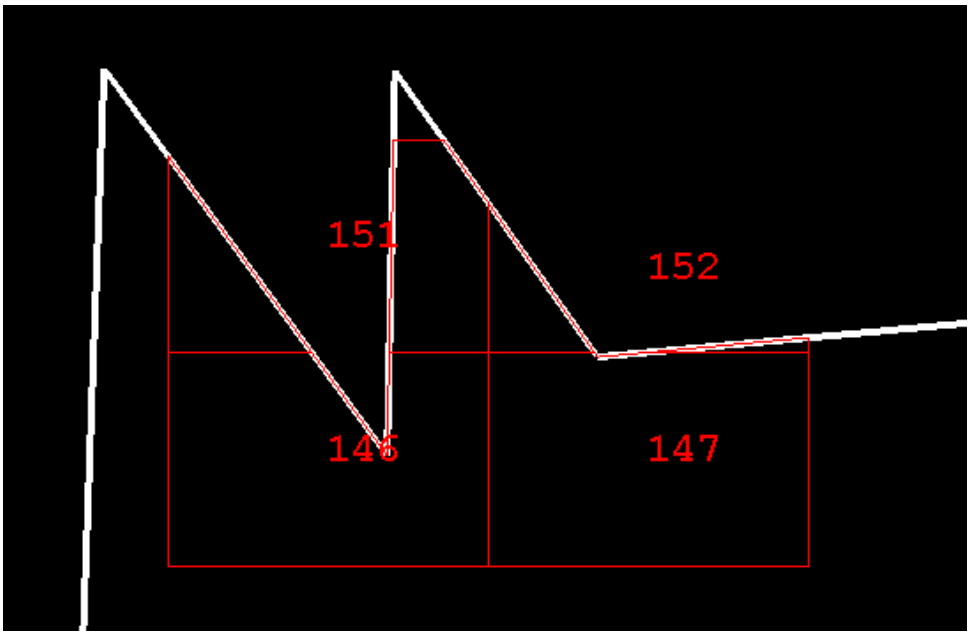
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The file loaded must be a complex shapefile for this tool to work. If the user loads a tile shapefile which has been 'exploded' (separating multi-part features into single part features) then MARS® will not be able to recognize a single tile in multi-parts but only recognize two (2) individual tiles. For this reason, any tile shapefile containing complex polygons must not be exploded for the 'Polygons From Complex to Simple' tool to work. If the file is 'exploded', a warning message will show upon export, but this file will no longer be functional in the 'Polygons From Complex to Simple' tool.



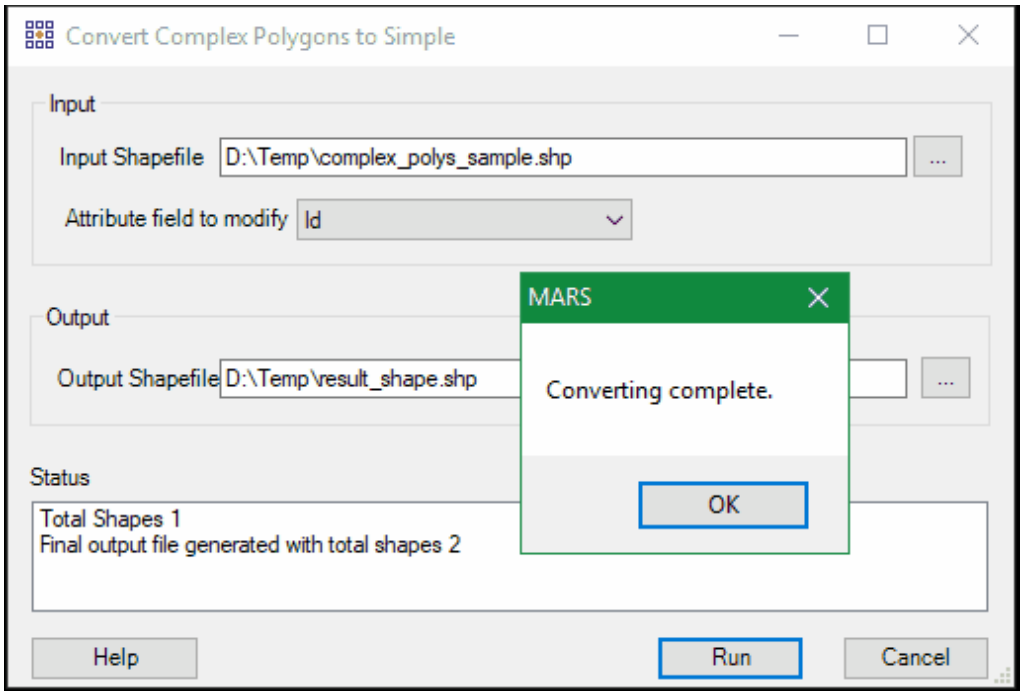
In the example below, MARS® is recognizing a tile shapefile which is complex. Tiles 151 and 152 have been cut into multiple parts by a boundary. A prompt was received when this shapefile was loaded. If the user were to export the data by tile at this point in time MARS® would export the data in one part of tile 151 then overwrite that data with the data in the other part of tile 151. The same would happen with tile 152. Thus, the user would lose some data in each tile causing gaps. To avoid this situation, use the 'Polygons From Complex to Simple' tool.

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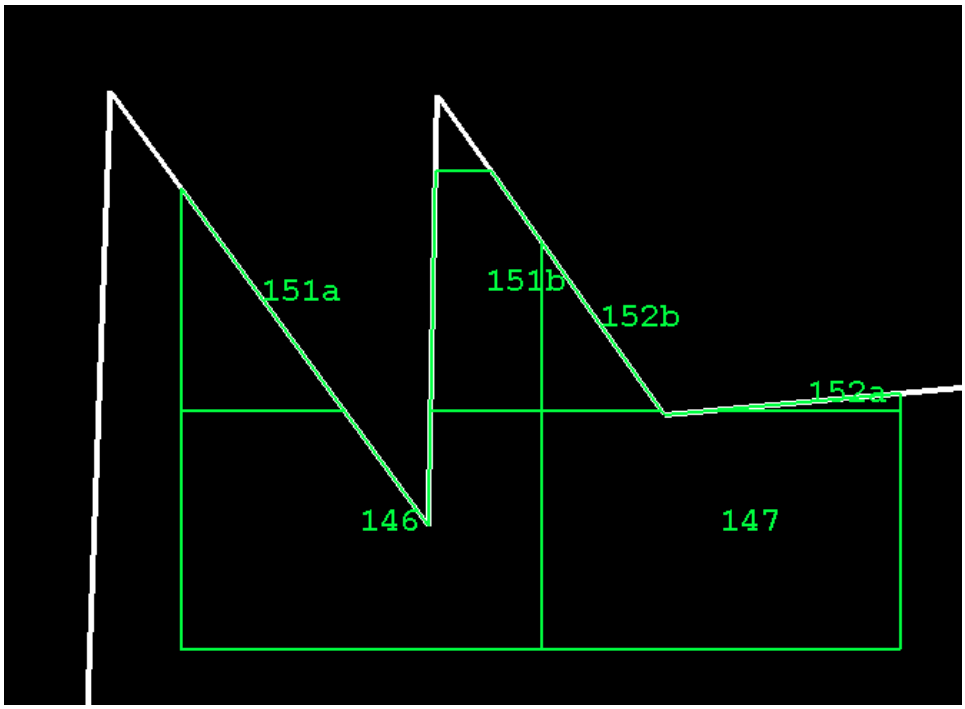
The Input Shapefile should be the complex shapefile which contains multi-part tiles. The user may choose the Attribute Field to Modify from the drop-down box. This list is created based on the attributes which are currently found in the attribute table for that particular shapefile. In most cases the user will be choosing 'TName' or the tile name of the attribute. The output shapefile will be the simple polygon shapefile created. Navigate to a location for the new file and name the new file. Choose 'Run' to start processing. When processing is complete a prompt will notify the user. The Status box will give the user a short summary on the number of polygons found in the shapefile and how many new tiles it created. In the example below, the tool found four (4) polygons or tiles of which two (2) were complex. Thus, the final output shapefile contains six (6) polygons or six (6) separate tiles.

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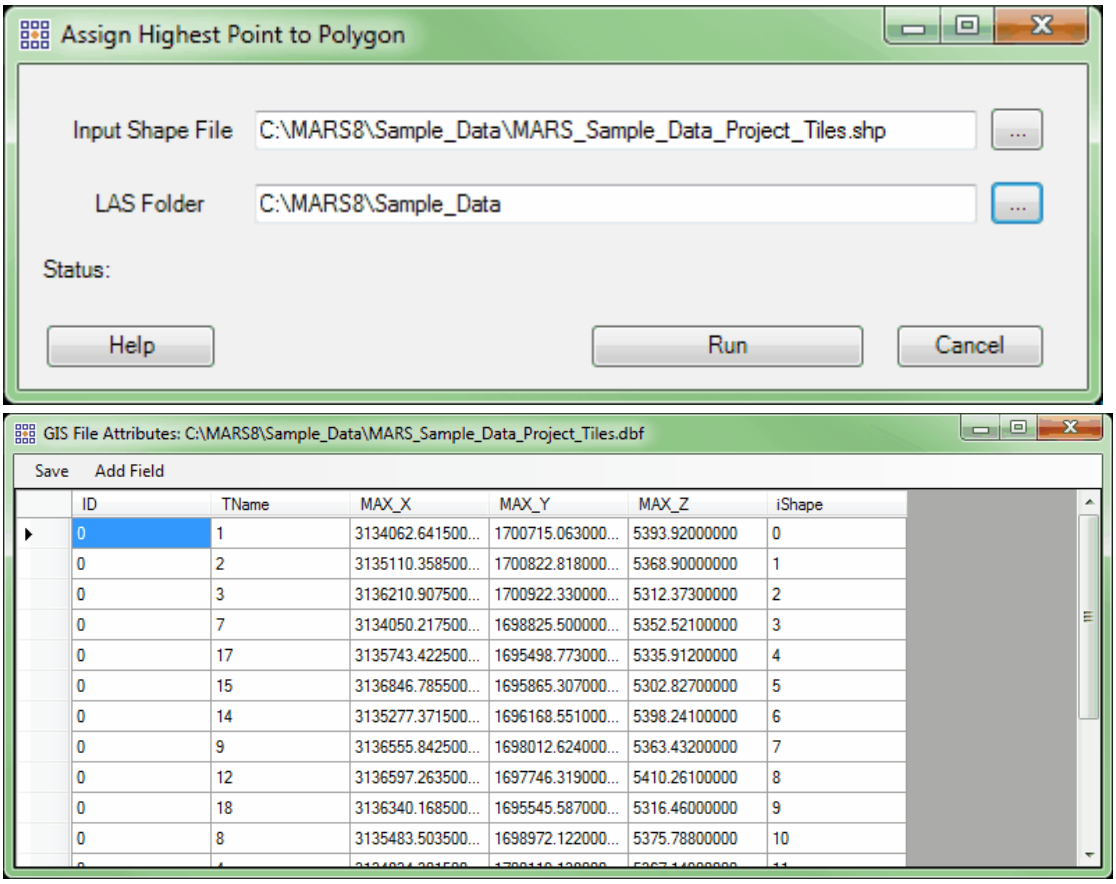
The new, simple polygon shapefile has distinguished between the multiple parts of a single tile. In order to avoid any overwritten data, the tiles have been named using an a, b, c... sequence. This way, each multiple part of a tile is perceived as a unique set of data and will not be overwritten or replaced. The tiles previously named 151 and 152 are now named 151a, 151b, 152a, and 152 b. An example may be viewed below:

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- ***Assign Highest Z to Poly:*** This tool, found on the Tools Tab[389], assigns X, Y, and Z values to all polygons in a polygon shapefile based on the values of the underlying LiDAR point within each polygon that has the highest Z-value (elevation). The shapefile must already have three fields defined as follows: Field Names - **MAX_X**, **MAX_Y**, and **MAX_Z**, all with the parameters Data Type - **Double**, Precision - **18**, and Scale - **8**. When the completed shapefile is loaded into MARS® , the new fields will be populated as shown in the example table (below).

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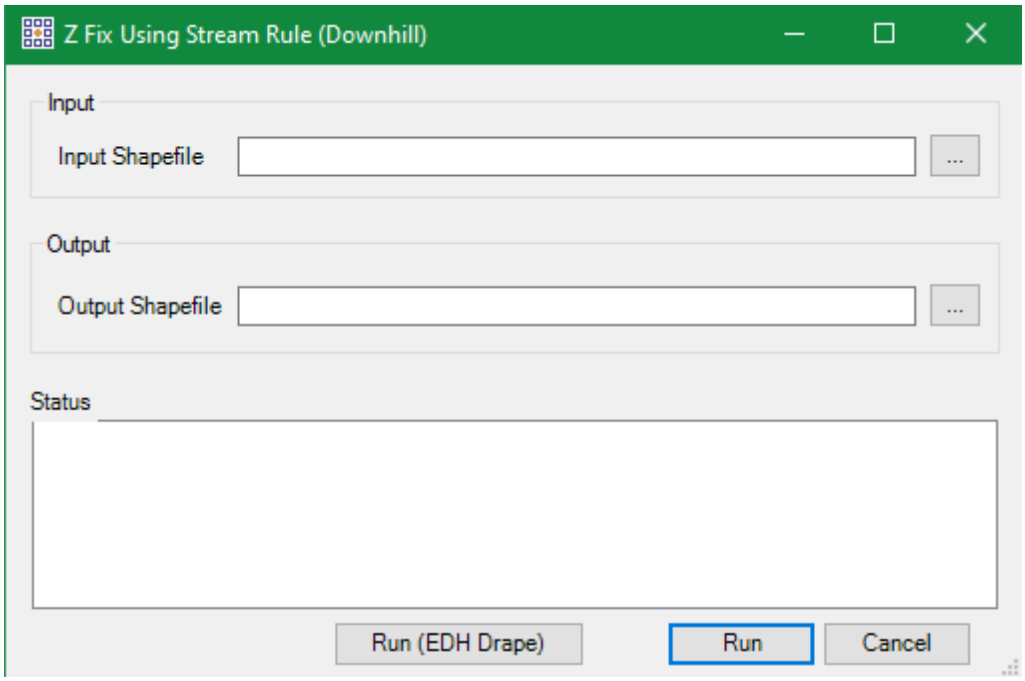
ID	TName	MAX_X	MAX_Y	MAX_Z	iShape
0	1	3134062.641500...	1700715.063000...	5393.92000000	0
0	2	3135110.358500...	1700822.818000...	5368.90000000	1
0	3	3136210.907500...	1700922.330000...	5312.37300000	2
0	7	3134050.217500...	1698825.500000...	5352.52100000	3
0	17	3135743.422500...	1695498.773000...	5335.91200000	4
0	15	3136846.785500...	1695865.307000...	5302.82700000	5
0	14	3135277.371500...	1696168.551000...	5398.24100000	6
0	9	3136555.842500...	1698012.624000...	5363.43200000	7
0	12	3136597.263500...	1697746.319000...	5410.26100000	8
0	18	3136340.168500...	1695545.587000...	5316.46000000	9
0	8	3135483.503500...	1698972.122000...	5375.78800000	10

- ***Z Fix Using Stream Rule*** ***(available with Production license only):*** This tool, found on the Tools Tab[389], will test and fix (if necessary) a 3D breakline shapefile to maintain monotonicity. In a hydrography context, monotonicity is the principle that elevations (Z-values) must decrease, or at least stay flat, as a breakline goes from uphill to downhill.

  No data needs to be loaded to use the tool. Path out the 3D breakline shapefile to be tested in the 'Input' section and the new (corrected) output shapefile in the 'Output' section. Then choose either the '**Run**' button (Z-values rounded to three decimal places) or the '**Run (EDH Drape)**' button (no rounding done) to start the tool. If a Z-value is detected that is higher than the previous uphill value, that previous value is copied to the 'bad' vertex. When the input

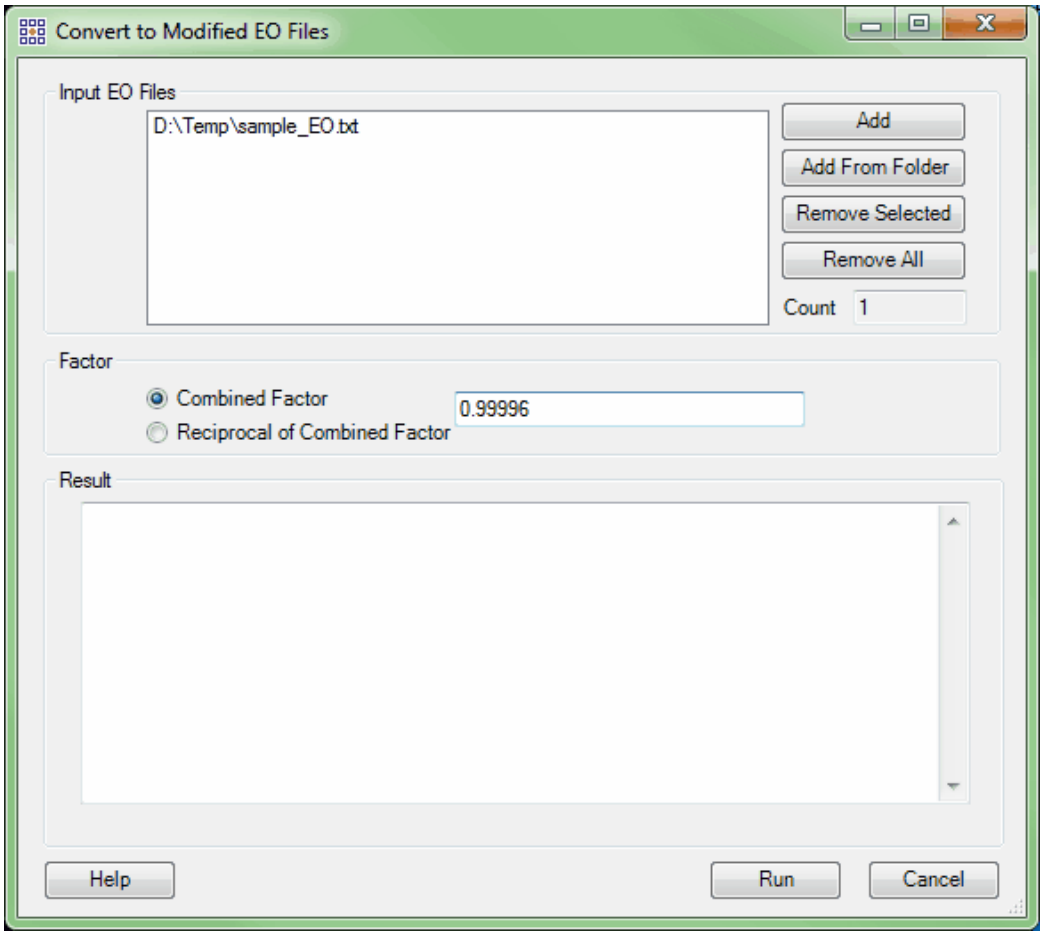
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shapefile has polyline geometry but contains both unclosed and closed features, two output files will be generated -- **<*name*>.shp** and **<*name*>_Polygon.shp**. The original input shapefile is never altered with this tool.



- ***Convert to Modified EO Files:*** This tool, found on the Coordinate Conversion Tab[254], allows a 'Combined Factor' or its reciprocal to be applied to one or more EO (exterior orientation) files. The EO files must be in a text (*.txt) format. To use the tool, navigate to a file or folder with the 'Add' or 'Add From Folder' buttons, then enter the 'Combined Factor' value in the text box found in the middle section of the interface. Choose the desired calculation method - either 'Combined Factor' or 'Reciprocal of Combined Factor' - and click the 'Run' button. A new file or files will be created with '_mod' appended to the original name(s), along with a log file storing the value used. These will be located in the same folder as the original file(s).

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- ***Collection Scan Polygon Generator:*** This tool, found on the Vector Creation Tab 364, creates a polygonal shapefile based on LAS collection scan (swath) extents. Each collection scan file will result in one polygon feature in the final, merged shapefile.

Input and Running Options:

Navigate to a folder containing the LAS files to be used in generating swath footprint polygons by clicking the browse button to the right of the **'Folder to process'** entry box.

'Perform full statistics': When this box is checked (default), full statistics per

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collection scan will be calculated on the classes which are specified in the **'Class Statistics'** section. Choose classes by clicking on the **'Select'** button. Attribute fields will be added to each swath record to hold these values. By default, all classes are used.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>' fields that are zeroed out for every swath record will be omitted from the final attribute table to simplify analysis.

When using the 'Perform full statistics' option, either the 'TIN' or 'Grid' algorithm can be used for edge detection:

'TIN': With this option, the edges of the polygonal shapefile(s) will be created based on the edge of the virtual TIN which is created. MARS® will use 3 points to create a TIN and the edges of the TIN will determine the extents of the polygonal shapefile.

'Grid': With this option, the edges of the polygonal shapefile(s) will be created based on the edges of a virtual grid (created in RAM) to cover the input data. A cell size is entered - the default is 3 (3 ground units by 3 ground units). The cell size should be greater than or equal to the ground sample distance (GSD) of the input data. MARS® looks for points within the virtual grid cells and establishes the edges of the collection scan data by determining whether or not points exist in a cell. When points are no longer located, the edge of the collection scan is confirmed.

This tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM

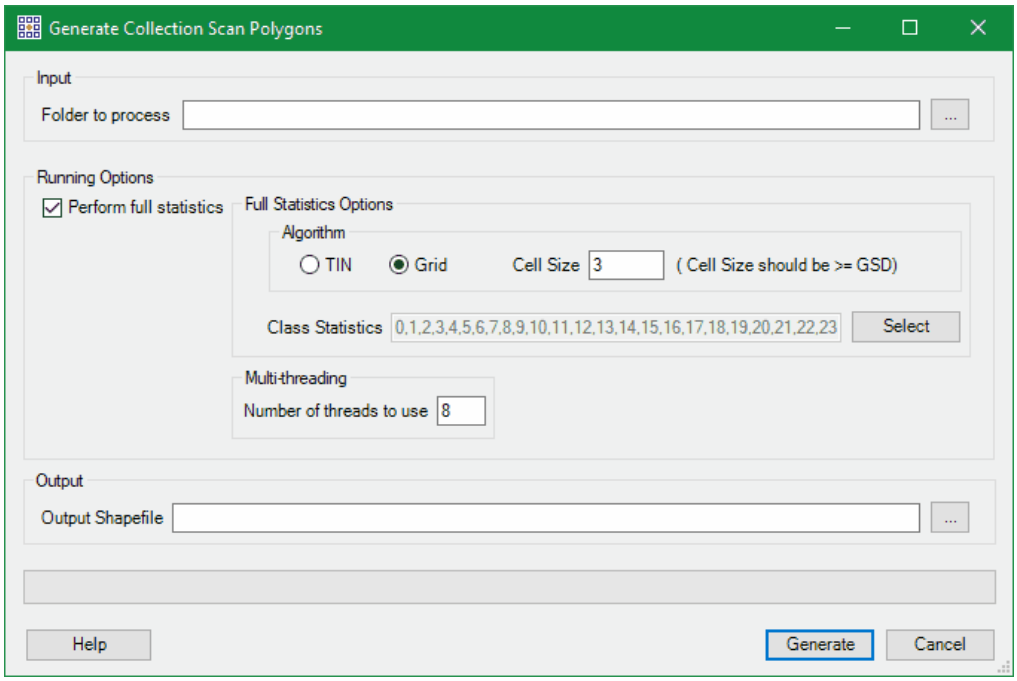
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available (not just installed) per thread.

For the **'Output Shapefile'**, navigate to the folder in which the newly generated shapefile should be stored and give it a name. When all settings have been made, click the **'Generate'** button and the progress bar will display the processing status. A completion message will appear when the process has finished.

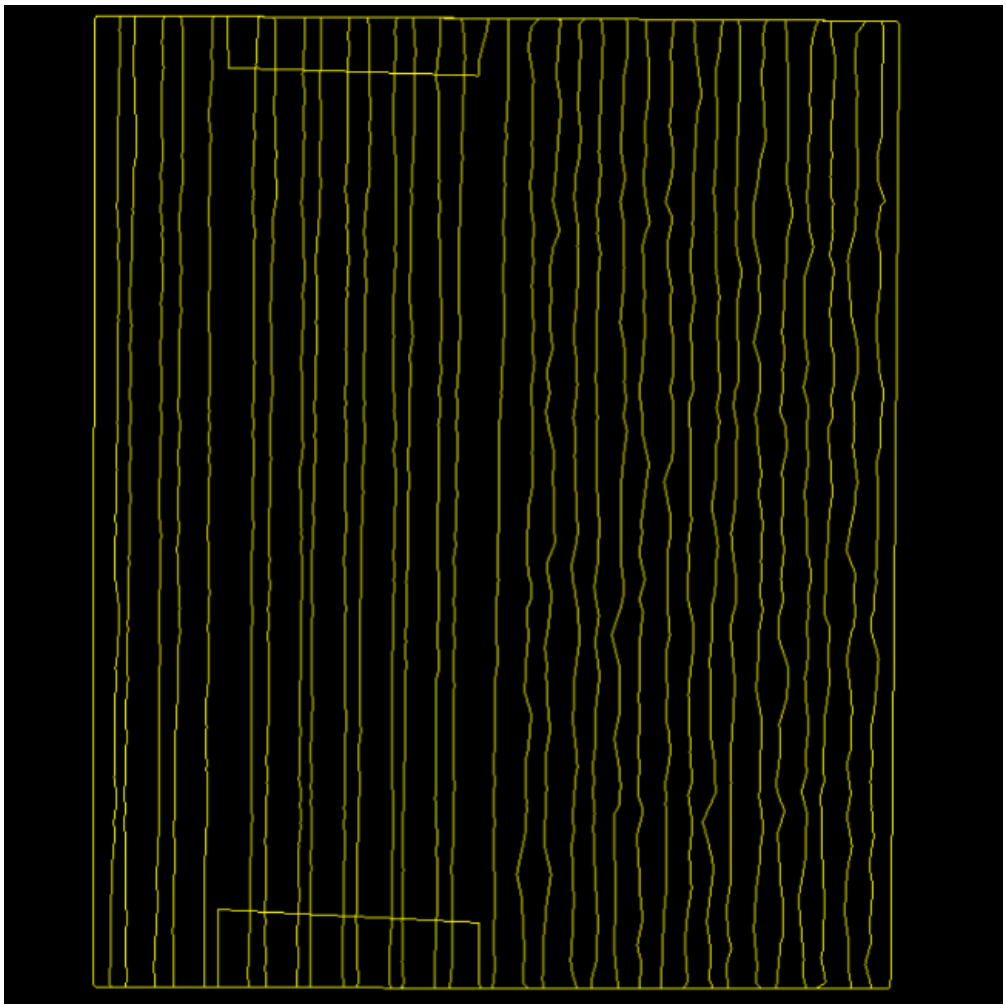
The newly created shapefile may then be brought back into MARS® as a reference Shapefile. Right-click on the shapefile in the Table of Contents and choose 'Attributes' to view a table specific to that shapefile. At a minimum, the attribute table will have a 'FILENAME' field with the name of the LAS file(s) processed, and a 'COLL_SCAN' field with the Point Source ID listed that created each attribute table record. If the **'Perform full statistics'** option was checked on for processing, the fields stored in the resulting shapefile will be similar to those listed in the **Create Tile Scheme** topic at the top of this help section (when the 'Calculate LAS Statistics' option is checked), except that ‘TName’ is replaced by ‘FILENAME’ to indicate the collection scans processed.

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Below is an example result loaded as a Reference Shapefile into MARS®. The shapefile outlines each of the collection scans contained in the LAS files chosen. This can be a useful tool in checking the overlap between collection scans and making sure there are no gaps in the data.

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- ***Convert SBET to Shapefile:*** This tool, found on the Vector Creation Tab 364, is used to convert a raw SBET, or **S**moothed **B**est **E**stimate of **T**rajectory file, into a point shapefile. This is often the final step in a typical workflow - computing the tightly integrated position and orientation solution using the correction observations, the raw GPS, and inertial data extracted from the project. The data is processed in both the forward and backward directions in order to produce the optimal solution, smoothing the effect of GPS outages and other aberrations in the data. This results in the best possible position and orientation solution for a given data set, usually maintaining centimetric accuracy for significantly more

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time and at longer distances than would be possible with traditional GPS processing. The output from this process is referred to as an SBET. The 'Convert SBET to Shapefile' tool will create a 3D shapefile (including a *.prj - projection definition file) from an SBET file, giving the user the ability to visualize the SBET overlaid on top of LiDAR data. This tool requires some previous knowledge of geodesy. Among many purposes, the 'Convert SBET to Shapefile' tool can be used to see how centered in the scan the SBET is, and the resultant shapefile can be used in the Scan Angle Filter[1118].

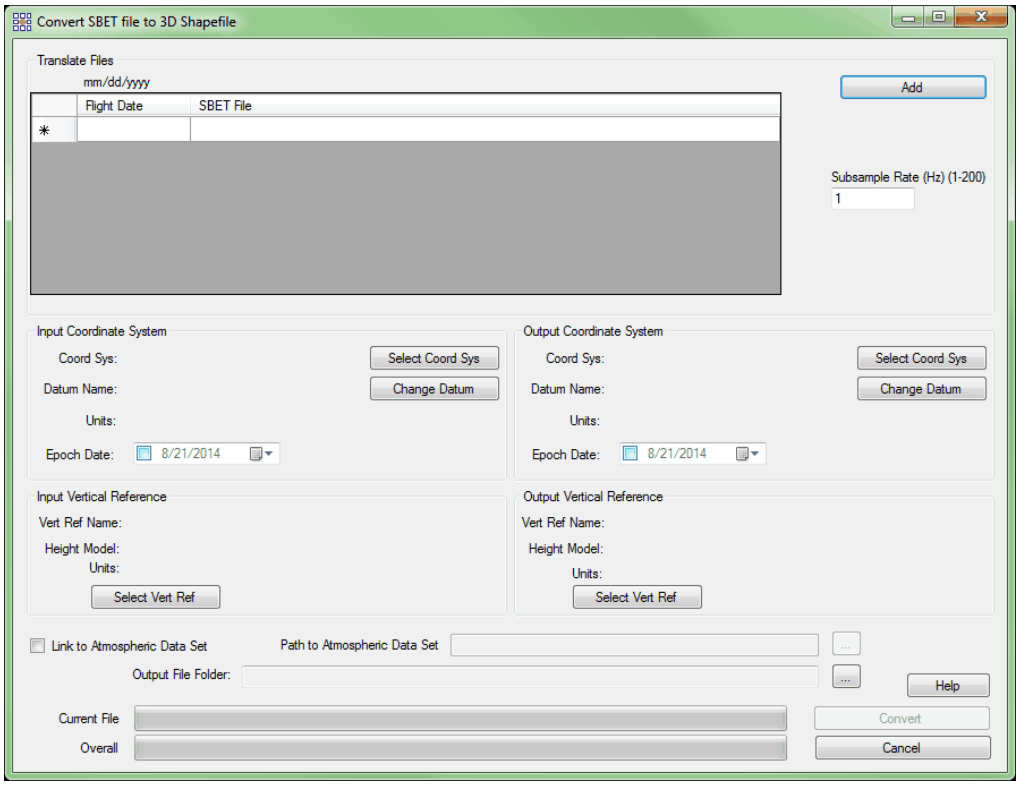
- ***'Translate Files'* section:** The user will load the SBET (*.out) file into this text box by choosing the **'Add'** button and navigating to the location of the SBET file to be converted. To remove an SBET file in this section, highlight it by clicking at the far left of the row and press 'Delete' on the keyboard.
- **Subsample Rate (Hz) (1-200):** The Subsample Rate allows the user to choose how much data from the SBET will be converted and displayed in MARS®. The user may choose any subsample rate from 1 to 200 and enter the chosen rate into the text box provided. For example, if the user chooses a subsample rate of 1, MARS® will use 1 sample of the total samples taken in one second to create the 3D shapefile. If a flight was 3 hours long, then 10,800 samples (1 per second) will be used to create the 3D shapefile of the SBET. The higher the subsample rate the more accurate the 3D shapefile representing the SBET will be, but the longer it will take to convert the file. Higher rates may also cause "Out of Memory" errors depending on the computer. A subsample rate of 1 (the default value) is detailed enough for most purposes.
- ***'Input Coordinate System'* section:** The Input Coordinate System is the horizontal reference that the SBET was created in. The user will need to enter the proper Geodetic system, with Lat/Long in degrees, which was used to create the SBET in this section. Examples include NAD83(NSRS2007) and NAD83(2011).
- ***'Input Vertical Reference'* section:** The user will need to enter the vertical references

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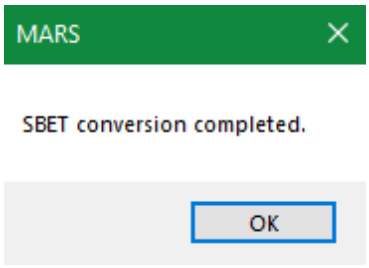
used to create the SBET in this section of the interface. This includes the vertical reference name, the height model, and the units in which the SBET was processed. Typical *.out SBET files are in Ellipsoidal Height meters.

- ***'Output Coordinate System'* section**: The Output Coordinate System, in most cases, will be the horizontal reference that the corresponding LiDAR data is in. In most cases the user will want to view the 3D shapefile created from the SBET over the matching LiDAR data. In order to do this the shapefile will need to be created with the same vertical and horizontal coordinate systems as the LiDAR data. The user will need to enter the coordinate system, datum, units, and epoch date of the related LiDAR data.
- ***'Output Vertical Reference'* section:** The user will need to enter the vertical references that the corresponding LiDAR data is in. In most cases the user will want to view the 3D shapefile created from the SBET over the matching LiDAR data. In order to do this the shapefile will need to be created with the same vertical and horizontal coordinate systems as the LiDAR data. The user will need to enter the vertical reference name, the height model, and the units of the related LiDAR data.
- **Link to Atmospheric Data Set:** When checked, allows the user to set the path to related meteorological data by clicking the ellipse  button to the right of the 'Path to Atmospheric Data Set' text box and navigating to the desired folder.
- **Output File Folder:** Navigate or key in the path to the folder which is to be the destination of the newly created 3D shapefile. The output file (or 3D shapefile created from the SBET) will be given same name as the SBET file loaded into the 'Translate Files' section, but will have the file extension *.shp.

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Once all the data has been entered into the 'Convert SBET File to 3D Shapefile' interface, the user may click on the 'Convert' button. There can be a substantial amount of wait time while MARS® reads the file and begins converting it. Once conversion has started, the user may watch the progress of the current file as well as the overall (total number of files to be converted) progress on the progress bars at the bottom of the interface. When the process is complete a prompt window, as seen below, will appear.

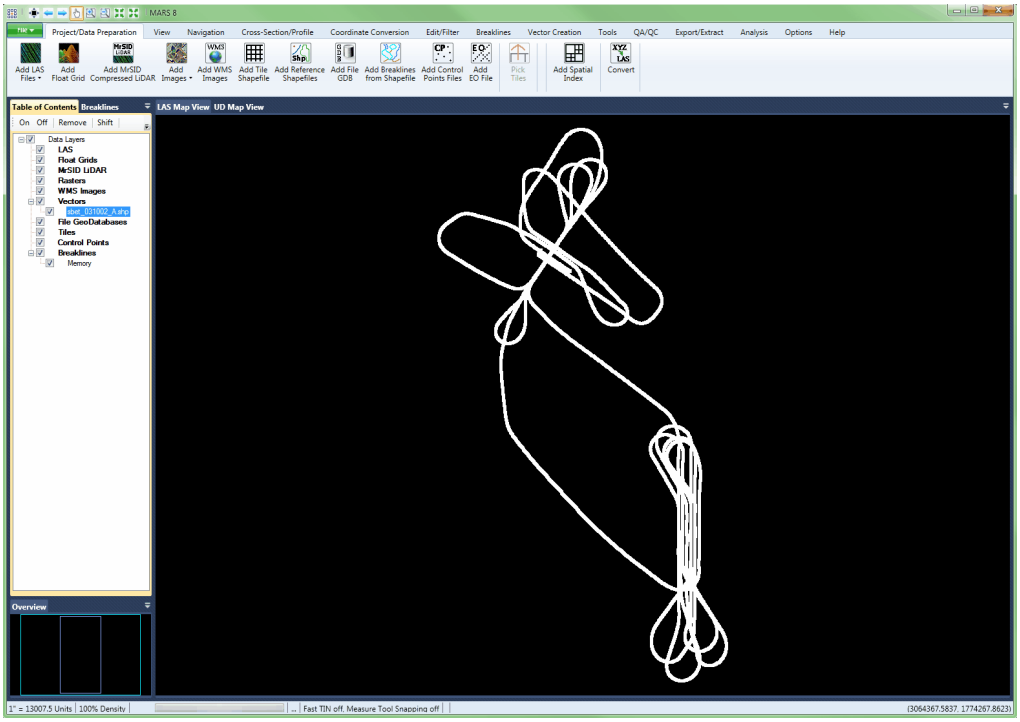


At this time, the user may now add the newly converted 3D shapefile to MARS®. Do this by going to the Project/Data Preparation Tab[162] and clicking the **'Add Reference Shapefiles'**

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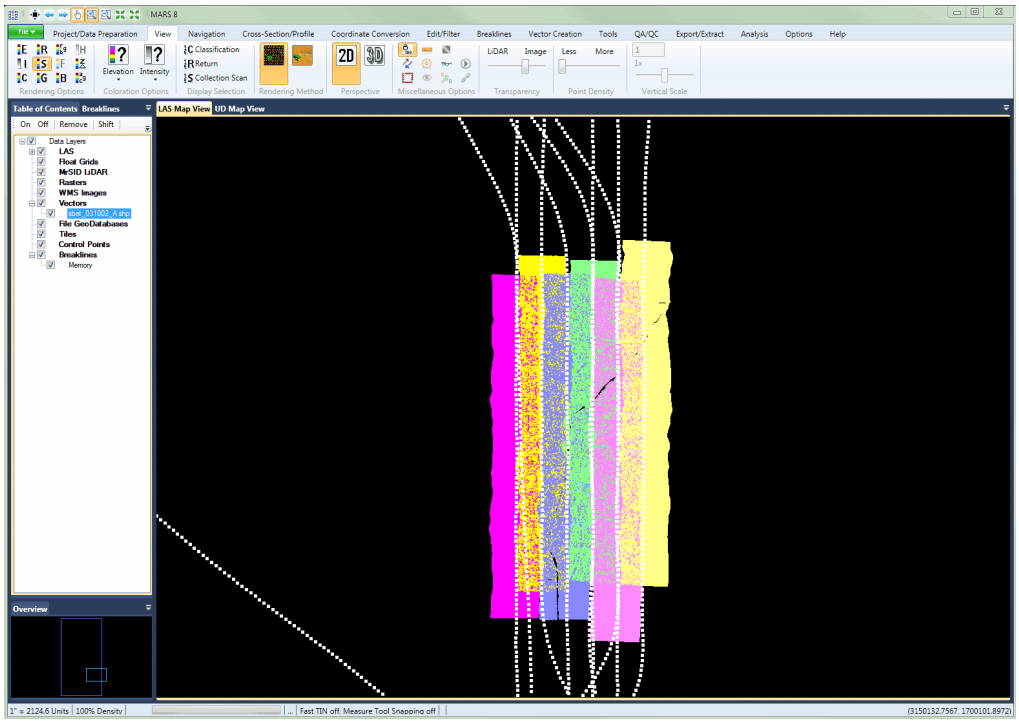
button. Navigate to the output folder which was specified in the 'Convert SBET to 3D Shapefile' interface and select the *.shp file which matches the name of the SBET used to create it. Open this file.

In this example, an SBET has been used to create a shapefile and has been loaded into MARS®. The SBET shapefile represents the path of the plane in space and time as it flew a particular project. The shapefile is being viewed in 2D.



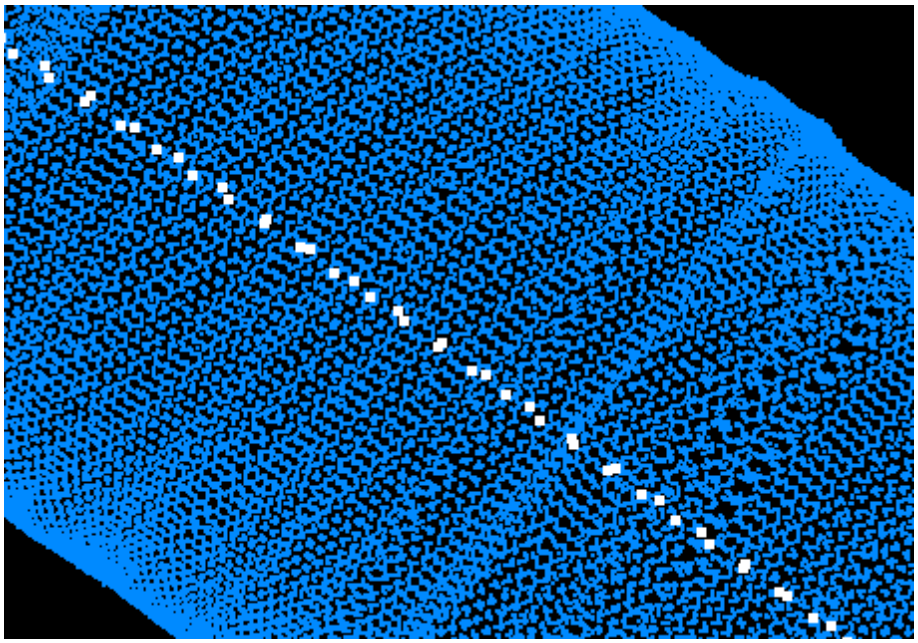
In this example, the corresponding LiDAR data has also been loaded into MARS® and is colored by collection scan. The SBET shapefile can be viewed layered over the LiDAR data.

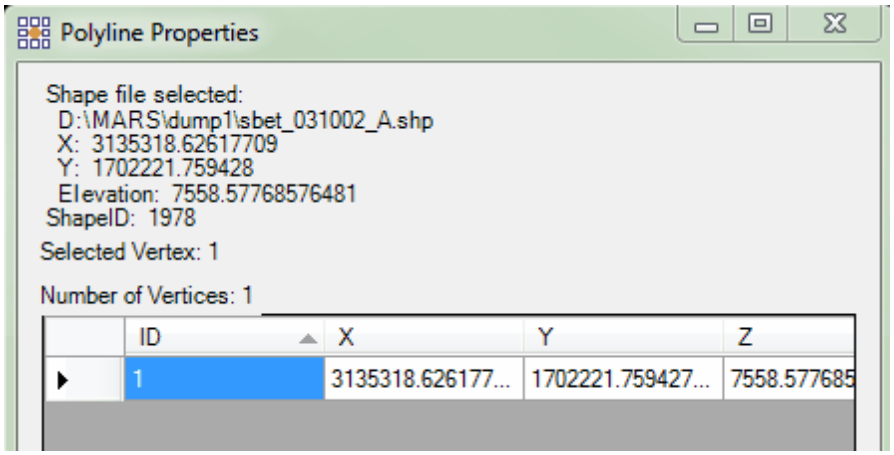
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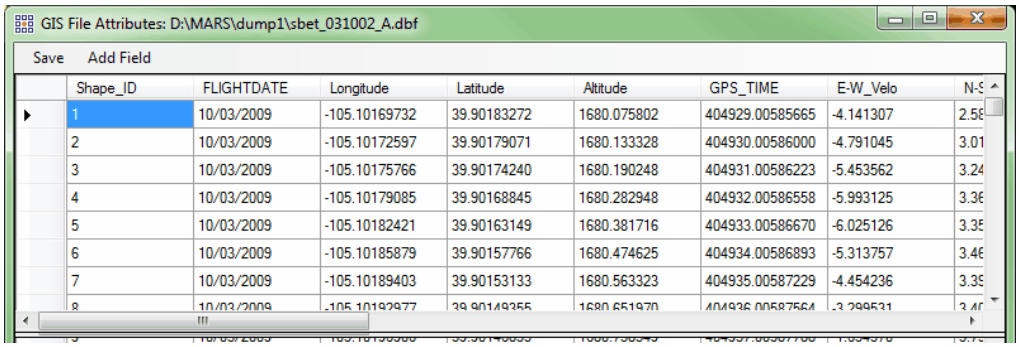
In the example below, the 3D shapefile representing the SBET file is shown in white. It may be difficult to select the white shapefile points for inspection among the LiDAR data. To select the 3D shapefile (SBET) or any other reference file among LiDAR data with the Inspect 943 tool, hold the **'Ctrl'** key on the keyboard while using the **'Inspect'** tool. This instructs MARS® to select any nearby feature, *other than a LiDAR point,* for inspection. It is possible to copy from the properties window resulting from use of the **'Inspect'** tool.

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Right-click on the shapefile entry in the Table of Contents and choose 'Attributes" to see the entire table of values.



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- ***Convert Video XML file to 3D Shapefile*** ***(not available with Academic or Evaluation license):*** This tool, found on the Vector Creation Tab[364], will convert any XML coordinates video file to a 3D shapefile. A projection definition (*.prj) will be created if the projection system is known for the video data.

1. To use this tool, add *.xml files by choosing the 'Add' button. The specified files will appear in the 'Translate Files' area and may be removed by highlighting (using standard Windows mouse/keyboard controls) and clicking on the 'Remove' button.

2. Define the desired output video file type by choosing *.mts, *.wmv, *.avi, or *.mpg from the drop-down under 'Video File Extension'.

3. Specify the input coordinate systems including both horizontal and vertical references.

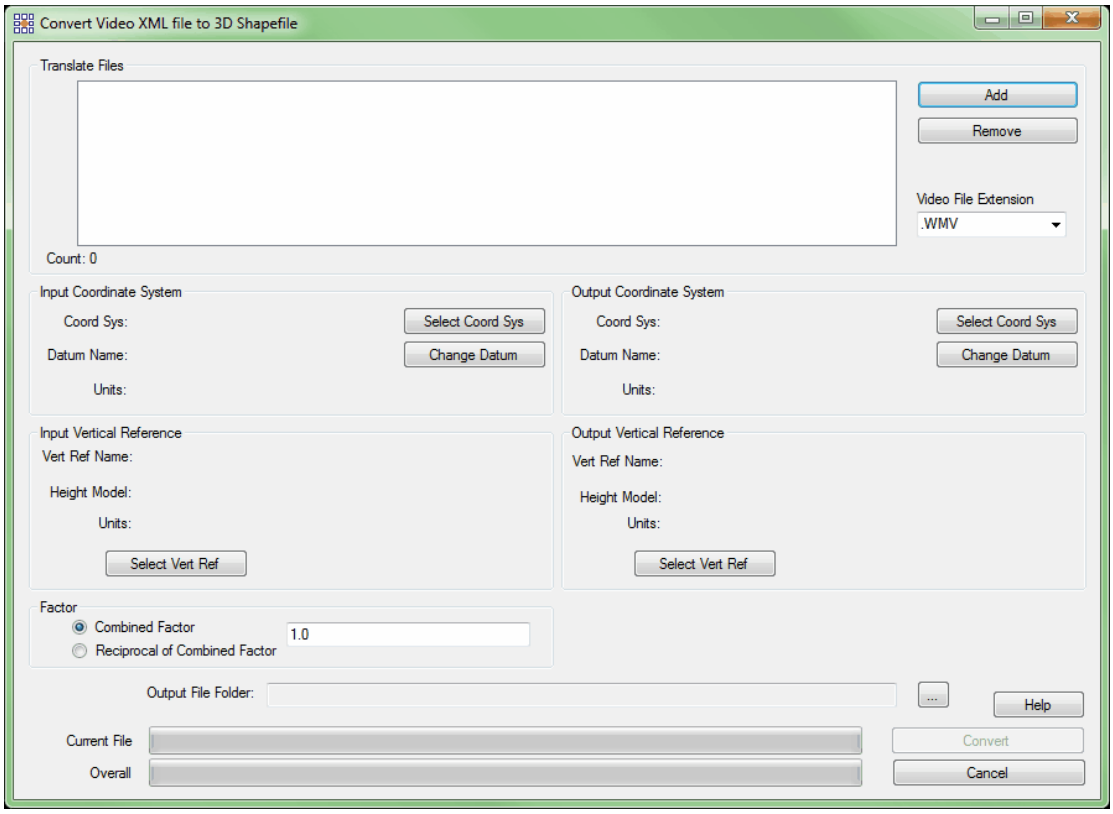
4. Define the output coordinate systems including both horizontal and vertical references.

5. Enter a 'Combined Factor' or 'Reciprocal of Combined Factor' if required for the particular coordinate conversion.

6. Choose the output folder where the new shapefile will be created.

7. Click the 'Convert' button to start the process.

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4.2 LAS Tools

LAS Tools

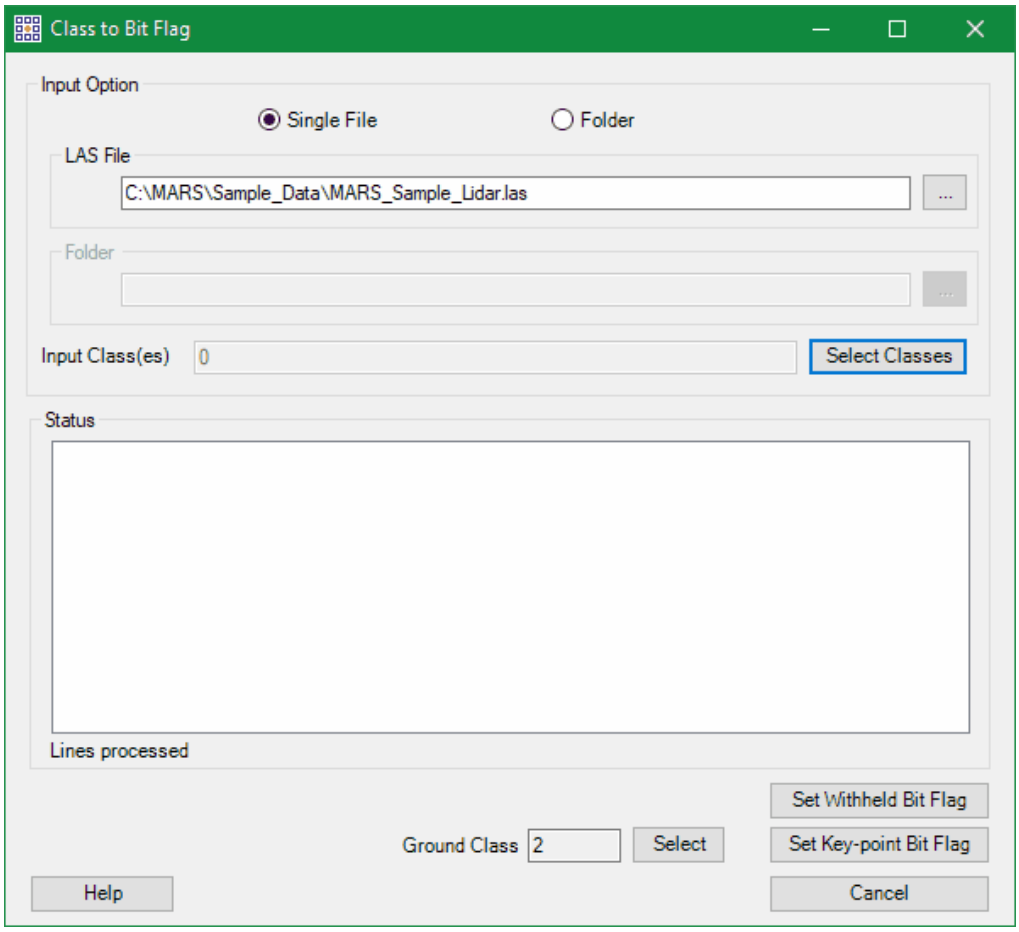
Merrick Advanced Remote Sensing (MARS®) Software

NOTE: The majority of standalone tools in MARS® (i.e., those tools that can be run without loading the LAS files in MARS®) will check the files that are pathed out in the tool's interface to ensure they are in a compatible version/format (see

the 'Add LAS Files' sub-topic in the Project/Data Preparation Tab 162 help topic). If they are not, the user will be prompted to up-convert the files before the tool can continue.

- ***Class to Bit Flag:*** This tool, found on the Tools Tab 389 under the **'Bit Flag Settings'** drop-down, sets the bit flag for Withheld points or Key-points (a.k.a. Model Key-points) that are in unique classes, in compliance with LAS version 1.4 specifications. For example, if a dataset has withheld points in Class 0 (Created, Never Classified), those points must have the withheld bit flag set to 'True'. In this case, navigate to the file or folder to be processed, set the **'Input Class(es)'** to Class 0, and click the **'Set Withheld Bit Flag'** button. For key-points, the process is very similar except that a final **'Ground Class'** must also be set. For this case, set the **'Input Class(es)'** to Class 8 (or other legacy class holding *only* key-points) and choose the desired **'Ground Class'** that the key-points will be re-classed to after they have their key-point bit flag set to 'True'. Since ground is typically Class 2, that is the default, although another class can be selected. Withheld points and key-points should be in separate classes, so it will be necessary to run the tool once for each bit flag setting. The tool can be run on a single file or an entire folder of files.

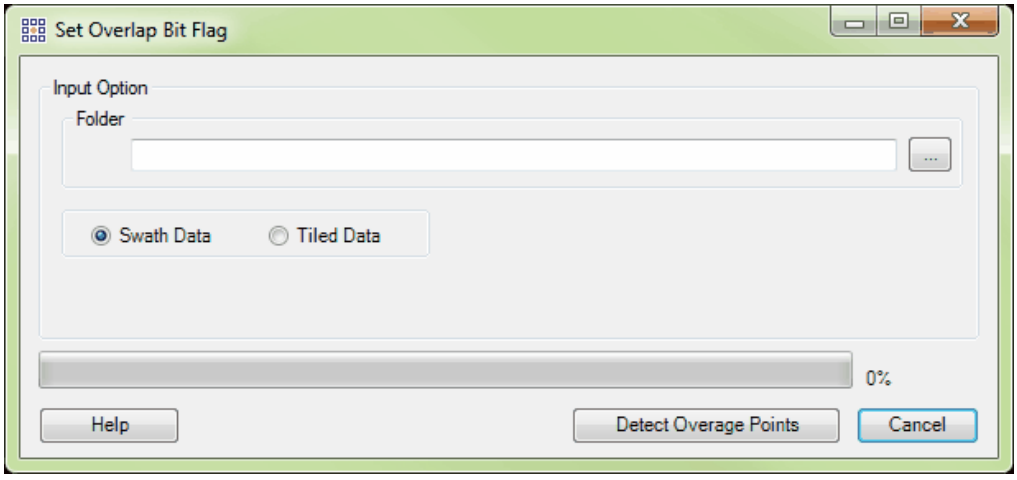
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- ***Set Overlap Bit Flag:*** This tool, found on the Tools Tab 389 under the **'Bit Flag Settings'** drop-down, analyzes the overlapping (overage) areas of a folder of swath (collection scan) or tiled files and sets the Overlap bit flag to 'True' for those points that fall within the overage area for each file. Only those points in a collection scan that are farthest from the single-coverage part of the scan and within the overlapping area (between collection scans) will be flagged. Points flagged as 'Overlap' in one collection scan will never share space with points flagged in any other collection scan. Even though a bit flag status of 'True' signifies these points as 'Overlap' per the ASPRS specification, note that the USGS refers to them as 'Overage' points in its NGP Lidar Base Specification 2.1 published in October 2019.

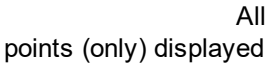
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Navigate to the folder containing the files to be processed by using the browse button () in the **'Input Option | Folder'** section. Choose the appropriate data type - **'Swath'** (the default) or **'Tiled'**. **'Swath Data'** assumes only one collection scan per file (or per set of multi-channel files), and **'Tiled Data'** assumes the files contain data from one or more collection scans (swaths) per tiled file. Individual multi-channel swath files must be merged into a single swath containing all points from all channels before processing (see the 'LAS Merging' tool, below). When the settings have been made, click the **'Detect Overage Points'** button to start the processing. ***This tool overwrites the original files.***



The following screen shots show examples of the **'Set Overlap Bit Flag'** results on Swath Data:

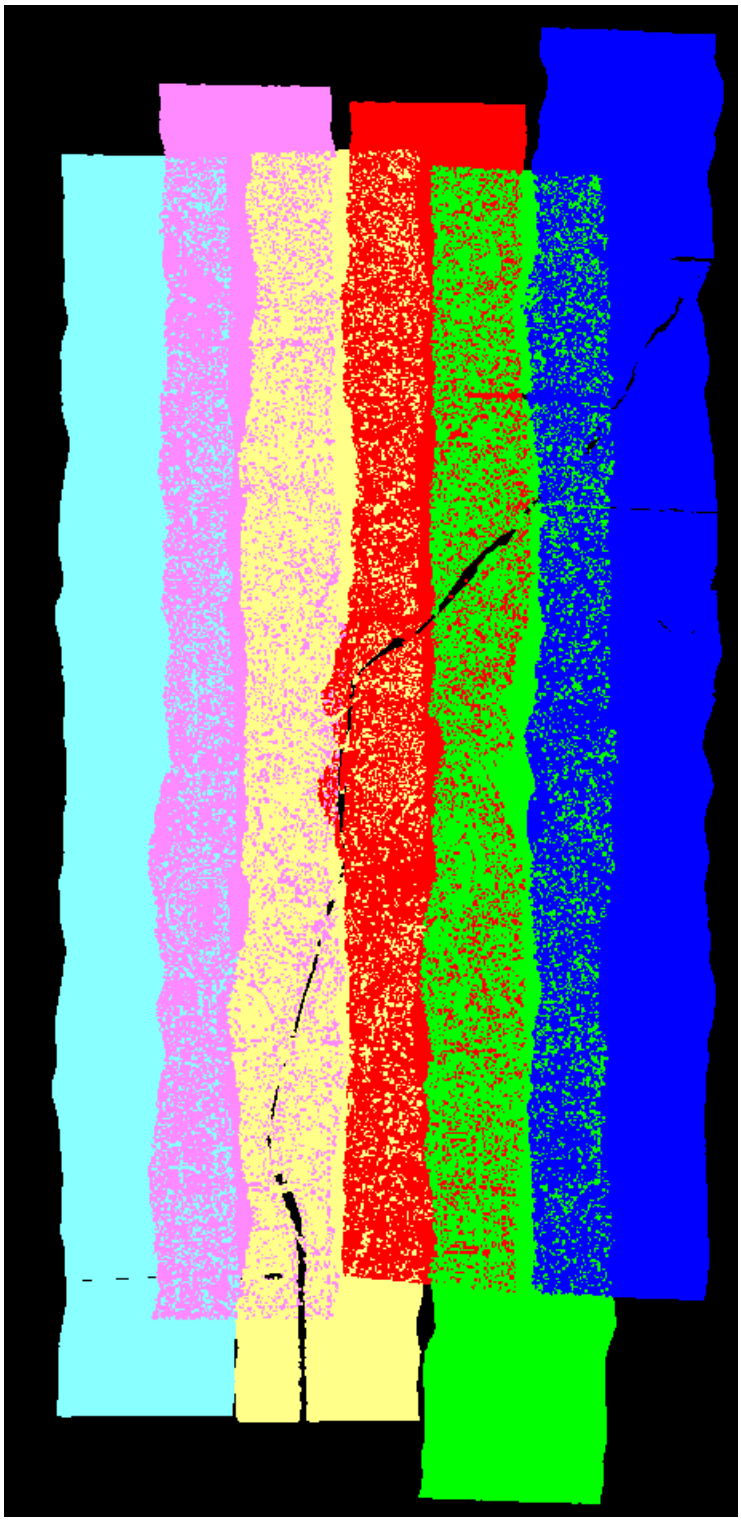
All points displayed



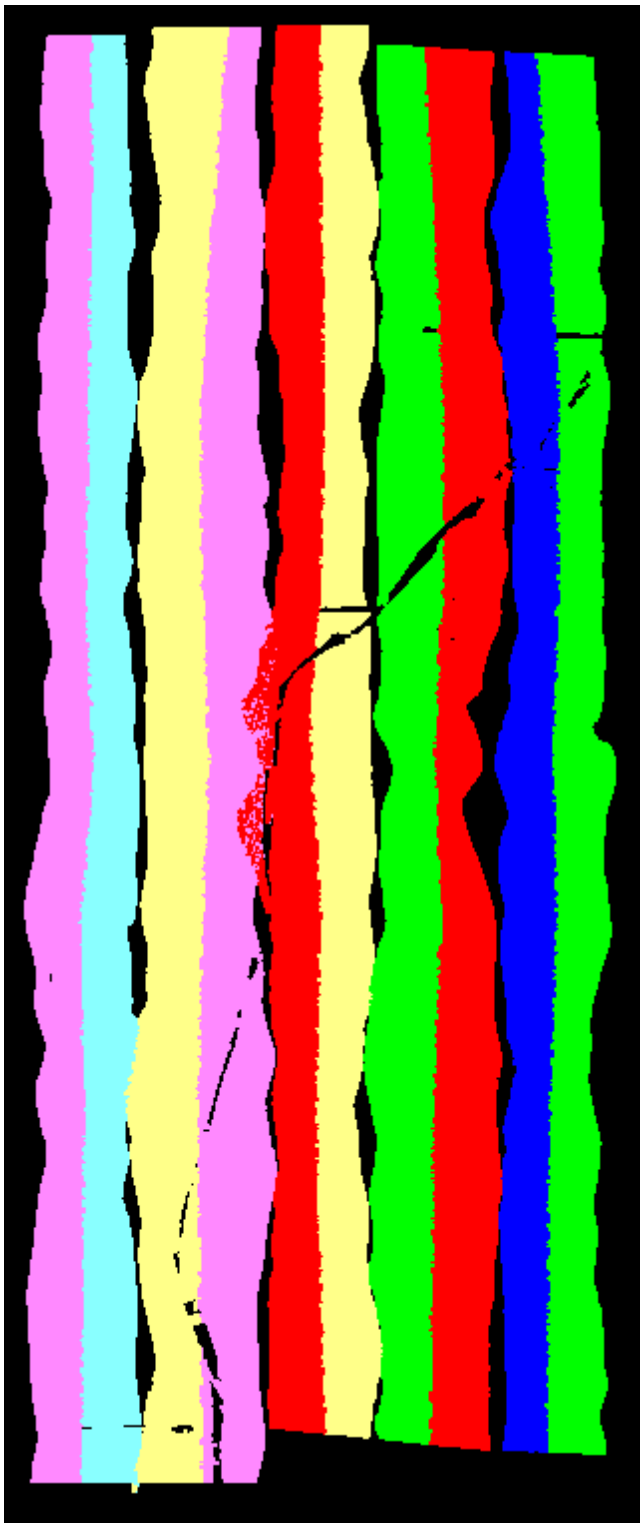
Overlap flagged points (only) displayed

Overlap flagged points turned off

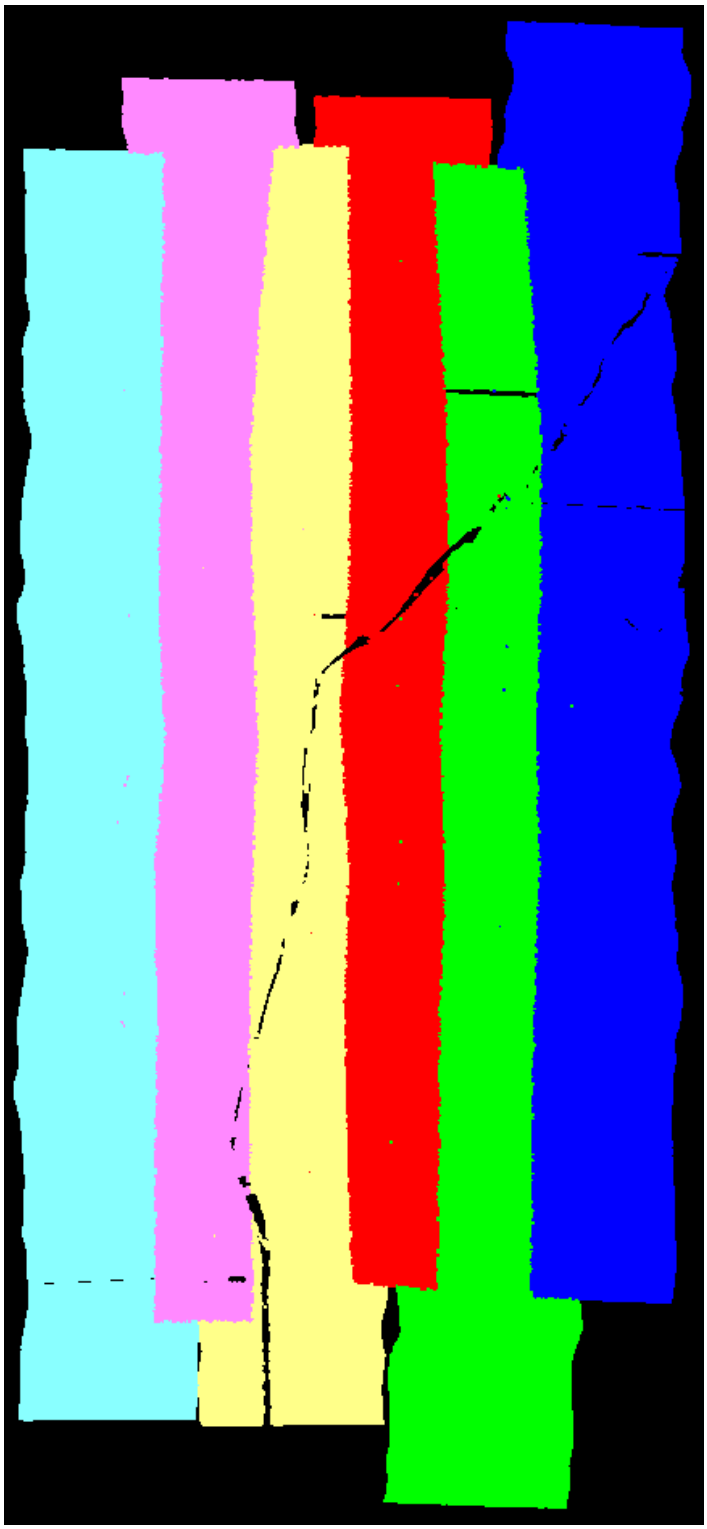
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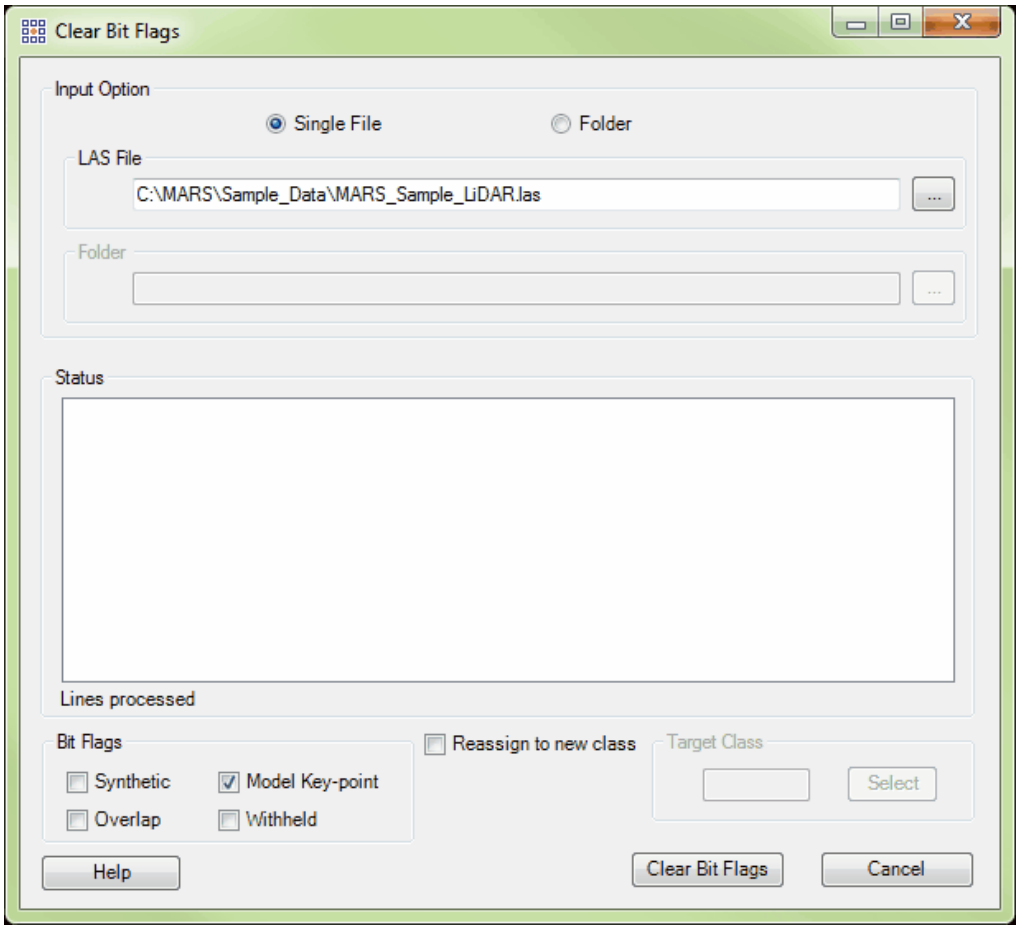


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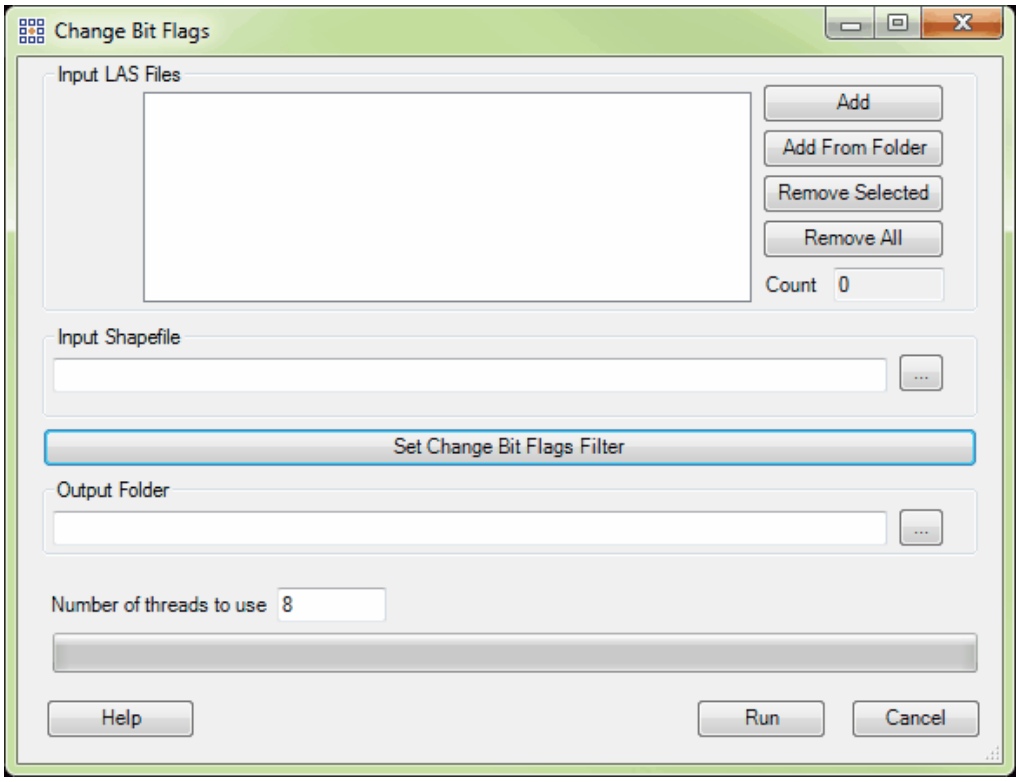
- ***Clear Bit Flags:*** This tool, found on the Tools Tab[389] under the **'Bit Flag Settings'** drop-down, allows any of the bit flags that are not set by the LiDAR sensor to be cleared (set to 'False'). The tool can be run on a single file or an entire folder of files. Navigate to the file or folder by choosing the appropriate radio button and using the browse button to the right of the entry box that is enabled. Check the boxes for the flag(s) to be cleared and click the 'Clear Bit Flags' button. Optionally, the cleared points can be reassigned to a new Target Class to keep them separate from previously non-flagged points in the same original class. *Note that if more than one category of bit flag is checked and the reassign option is used, all the cleared points from any classes will be assigned to the Target Class.* To avoid this, run the tool separately for each category of bit flag and select a unique target Class each time. The **'Status'** area will display the files that have been processed. ***This tool overwrites the original files.***



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- ***Change Bit Flags:*** This tool, found on the Tools Tab[389] under the **'Bit Flag Settings'** drop-down, modifies the status (set/on or clear/off) of several of the bit flags that are used with LAS data: Synthetic, Model Key-point, Withheld, and Overlap. It can optionally reclass those points whose bit flag values have been modified, and can be (optionally) limited to a single specified collection scan. The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Navigate to the files to be modified using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. In the 'Input Shapefile' section, browse to a pre-existing polygon shapefile containing one or more polygons - these polygons will be used to define the area to be processed. The 'Set Change Bit Flags Filter' button will open the options interface where the specific parameters of the tool can be set - see the Change Bit Flags Filter[994] help topic for details on these settings. Choose an 'Output Folder' where the modified files will be stored, and then click the 'Run' button.

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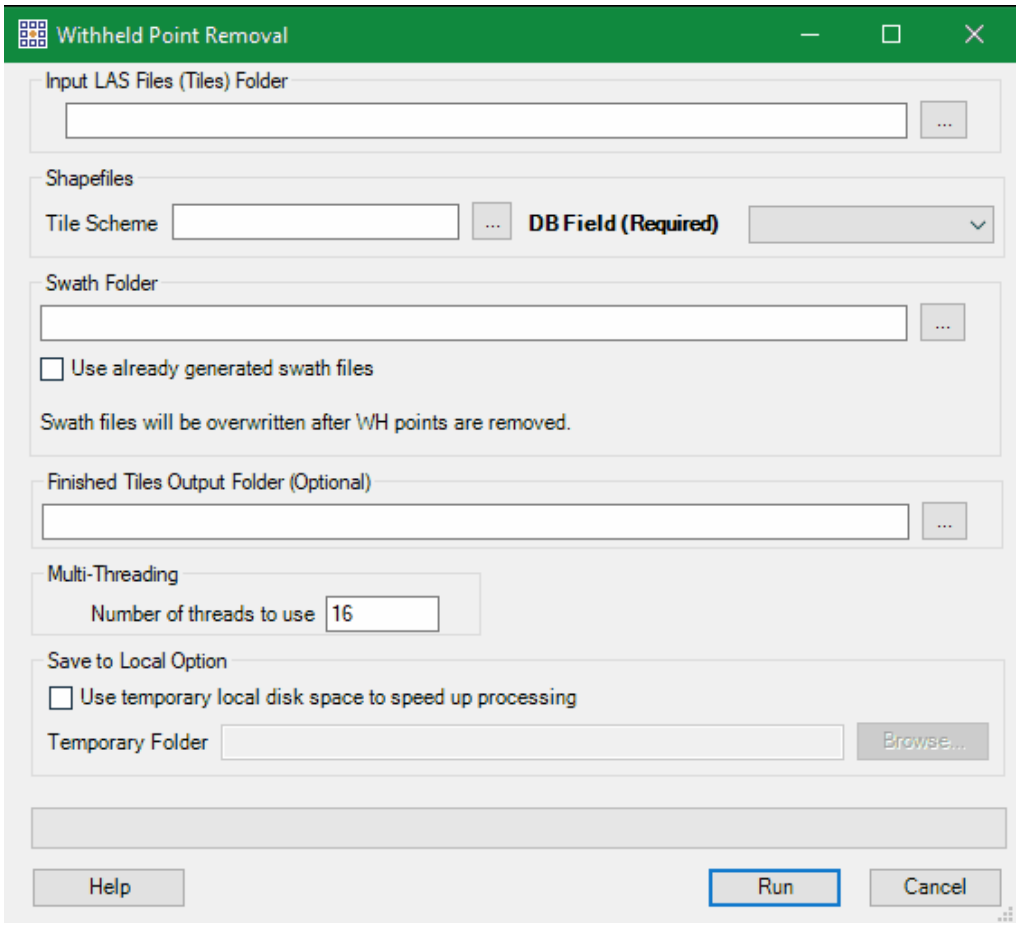
- ***Withheld Point Removal:*** This tool, found on the Tools Tab[389] under the 'Bit Flag Settings' drop-down, permanently removes specific points flagged as Withheld in the input LAS files and renumbers the remaining point family returns accordingly. The workflow is: input tiled or existing swath data --> export to swaths (if tiled input) --> Withheld point deletion --> Export to final tiled files. The tool uses two rules for determining candidate points to be deleted: ***1)*** Withheld-flagged points in any class that are either a single return or the first return of many in a point family and; ***2)*** Withheld points that are in Class 7 Low Point (Noise) and are the second of two returns in a point family. When Withheld-flagged points are deleted, any remaining points in the same point family will have their return numbers modified so as not to break the return numbering protocol. For the first case above, if a first of three returns point (1 of 3) is selected for deletion, the second return in that point family is renumbered as '1 of 2' and the third return is renumbered as '2 of 2'. In the second case above, when a Class 7 second of two returns point (2 of 2) is selected for deletion, the remaining first

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return in that point family is renumbered as '1 of 1' (single return). Note that if the input data is not classified, only the first rule will be applicable.

To use the tool, navigate to a folder containing tiled, classified LAS files using the browse control to the right of the 'Input LAS Files (Tiles) Folder' box. If available, pre-existing swaths can be pathed out in the 'Swath Folder' box to save the time of exporting tiles to swaths. In this situation, there is no need to path out tiled data in the 'Input LAS Files (Tiles) Folder,' but be sure to check the 'Use already generated swath files' box so the exporting to swaths step is skipped. Navigate to the tile layout shapefile that is geolocated with the input (tiled or swath) data using the 'Tile Scheme' control and select a unique-value attribute (e.g., 'Tilename') to be used for naming the finished output tiles. Choose a 'Swath Folder' that will hold the exported swaths produced from the input tiled files, or is already storing the existing swaths to be used. During processing, these swaths will be overwritten by the new filtered swaths after the Withheld points are removed. Finally, an optional 'Finished Tiles Output Folder' can be selected to hold the final tiled files made from the filtered swaths. If no entry is made here, the input tiled files ('Input LAS Files (Tiles) Folder') will be overwritten with the final results.

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The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Click the 'Run' button at the bottom of the interface to begin the processing. The results will be displayed in the 'Result - Withheld Point Removal per Swath' window followed by a completion message.

- ***Reference Reclass*** ***(available with Production license only):*** This tool, found on the Tools Tab 389 under the 'Reclass' drop-down, allows the user to reclassify one set of LAS files (the 'Unclassified' input files) based on the classes found in another set of LAS files (the 'Classified' input files), by using a series of user-defined parameters found in the LAS files. In addition to reclassification, any existing bit flags (Synthetic, Model Key-point, Withheld, and/or Overlap) will be carried over to the output as

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well. The tool determines possible candidate points to be reclassed based on the LAS points' recorded ***time*** and other optional attributes. Because this tool finds possible matches based on their recorded time, the two folders of input files ('Classified' and 'Unclassified) must contain files in the same time format (e.g., GPS Week Time or Adjusted GPS Time). See the **'GPS Time Conversion'** topic in this section for a description of the tool that can convert between the two time storage methods.

Classified: Browse to a folder containing LAS files that have one or more classifications in each file. Like features must have like classes in all files - i.e., buildings must be classed the same in all files if the building class will be used as a Reference Class. Only those classes listed as Reference Classes will be used to identify possible candidate points in the Unclassified files for reclassification in the final Output. In the example below, classes 20 and 15 are being used from the Classified files. The Classified files are usually in a tile layout form, but other files can be used.

Unclassified: Browse to a folder containing one or more LAS files that will be used as a source of points for the final Output file. The points in the Source Classes entered in the interface - 5 and 6 in the example below - will be matched to points of the Reference Classes entered from the Classified files to create the candidate points. Those that match the values for the boxes checked at the bottom of the interface will be copied to the Output file and assigned the Target Class (12 and 10 in the example below). These files are usually in collection scan form, but other files can be used.

Output: Browse to an output folder or key in the desired path to store the results of this LAS classification reassignment. This selection choice is optional - if the user does not choose an Output folder, the Unclassified input data is overwritten with the newly reclassified data based on this reference reclass

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function.

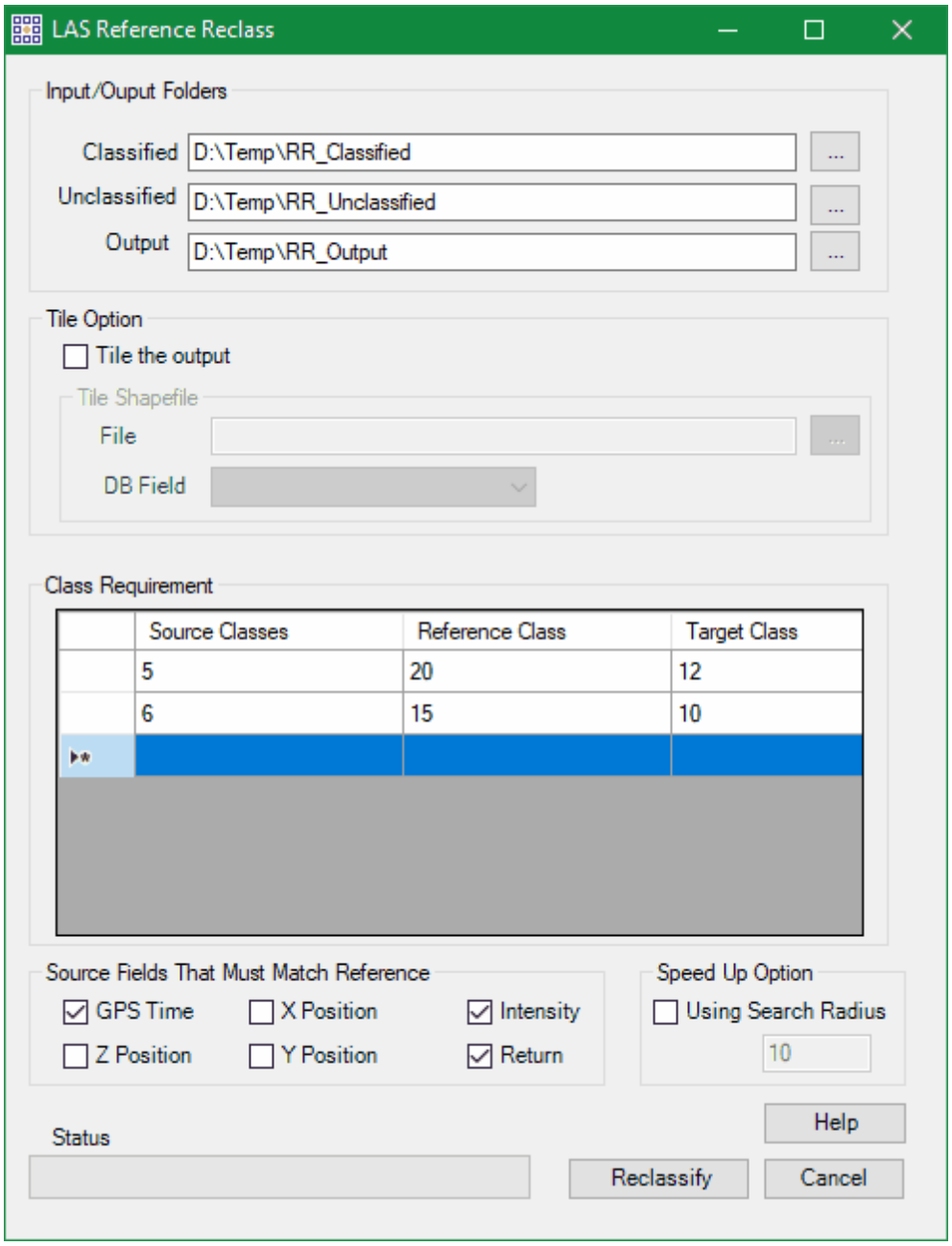
Tile Option: Optionally, the Output data can be tiled upon completion based on a user-selected polygon shapefile tile layout. The 'DB Field' chosen will be used to name the Output LAS files.

Class Requirement: In this section, the user specifies a Source Class, Reference Class, and Target Class for the specific classification sets to be used in the reclassification. Click on the appropriate box, and enter the class to be used.

Source Fields That Must Match Reference: This area of the interface allows the user to force a match of the values present in the Classified files to those in the Unclassified files in determining candidate points to be reclassed during processing.

Speed Up Option: When checked with a value entered in project units, this setting improves performance by limiting the pool of possible candidate points to be matched.

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Click the 'Reclassify' button to begin the processing.

- ***Reference Reclass - Closest Distance*** ***(available with Production license only):*** This tool, found on the Tools Tab[389] under the 'Reclass' drop-down, is similar to the Reference Reclass

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tool (see above). It allows the user to reclassify one set of LAS files (the 'Unclassified' input files) based on the classes found in another set of LAS files (the 'Classified' input files), by using a series of user-defined parameters found in the LAS files. In addition to reclassification, any existing bit flags (Synthetic, Model Key-point, Withheld, and/or Overlap) will be carried over to the output as well. The tool determines which points will be reclassed based on the LAS point's recorded ***time and position***. This is a special version of the Reference Reclass Tool: (1) Time will be used to determine possible candidate points, and (2) X, Y, Z will be used to determine the closest candidate point. This tool can process LAS data when the two inputs are in different time formats (e.g., GPS Week Time and Adjusted GPS Time) because it also takes into account the position of an LAS point.

Classified: Browse to a folder which contains LAS files that have one or more classifications in each file. These files are usually in a tile layout form, but other files can be used.

Unclassified: Browse to a folder which contains one or more files that have all points classified as a single default value. These files are usually in collection scan form, but other files can be used.

Output: Browse to an output folder or key in the desired path to store the results of this LAS classification reassignment. This selection choice is optional - if the user does not choose an output folder, the unclassified input data is overwritten with the newly classified data based on this reference reclass function.

Tile Option: Optionally, the data can be tiled upon completion based on a user-selected polygon shapefile tile layout. The 'DB Field' chosen will be used to name the output LAS files.

Class Requirement: This option is currently hard-coded to use every classification existing in the 'Classified' data to reclass points in the 'Unclassified' data.

Source Fields That Must Match Reference: This area of the interface gives the user the ability to use the values offered from the Classified to the Unclassified LAS

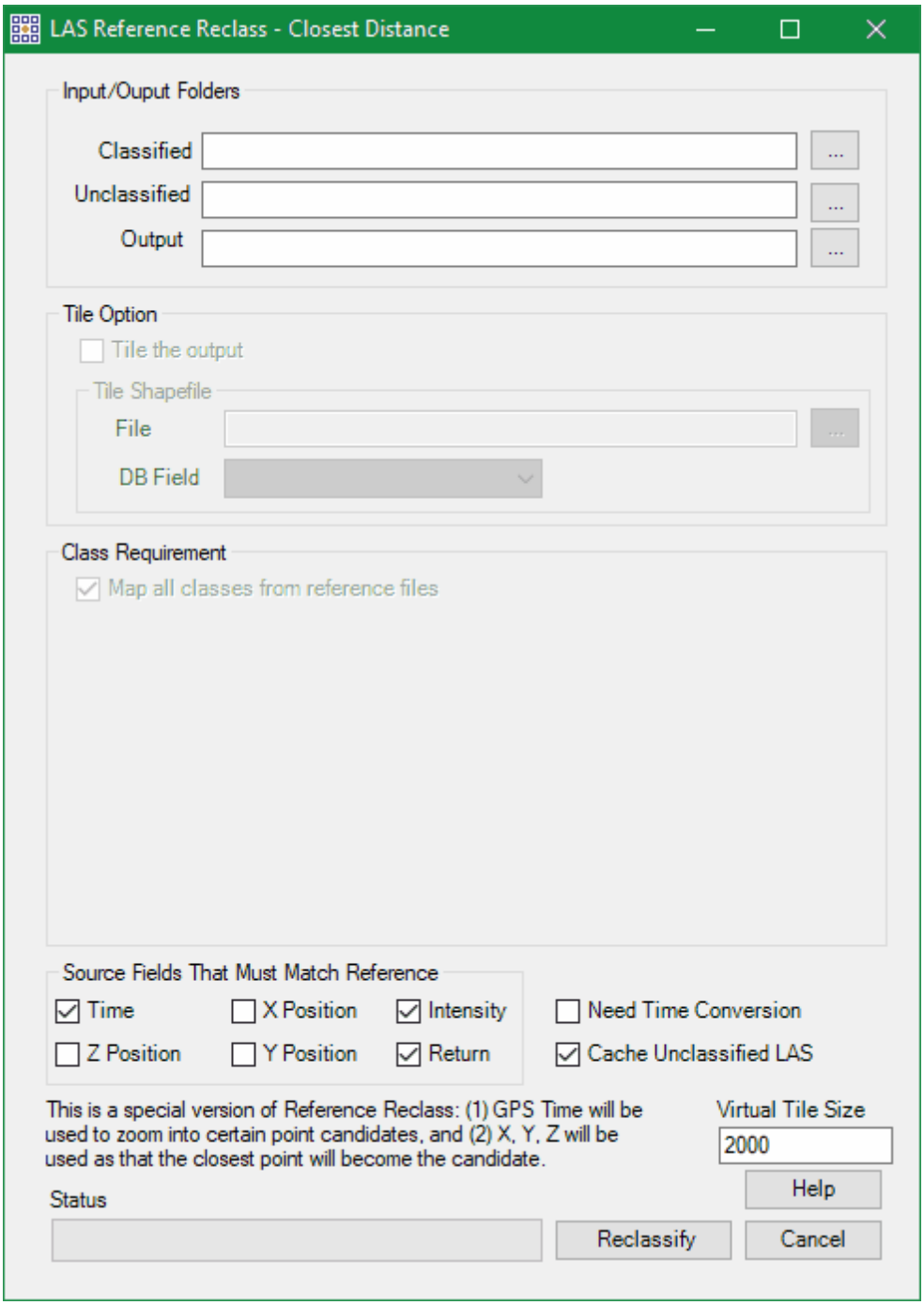
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files as a reference.

Cache Unclassified LAS: Checking this option will cache all of the points specified in the 'Unclassified' input path to RAM per file, if there is sufficient available RAM to do so. This will make the tool process more quickly than it would working from two separate locations (specified by the 'Classified' and 'Unclassified' input paths) on a network.

Virtual Tile Size: The virtual tile size sets the size of the area which the tool will process at any one time. Computers with more RAM can process larger areas resulting in a shorter time to completion.

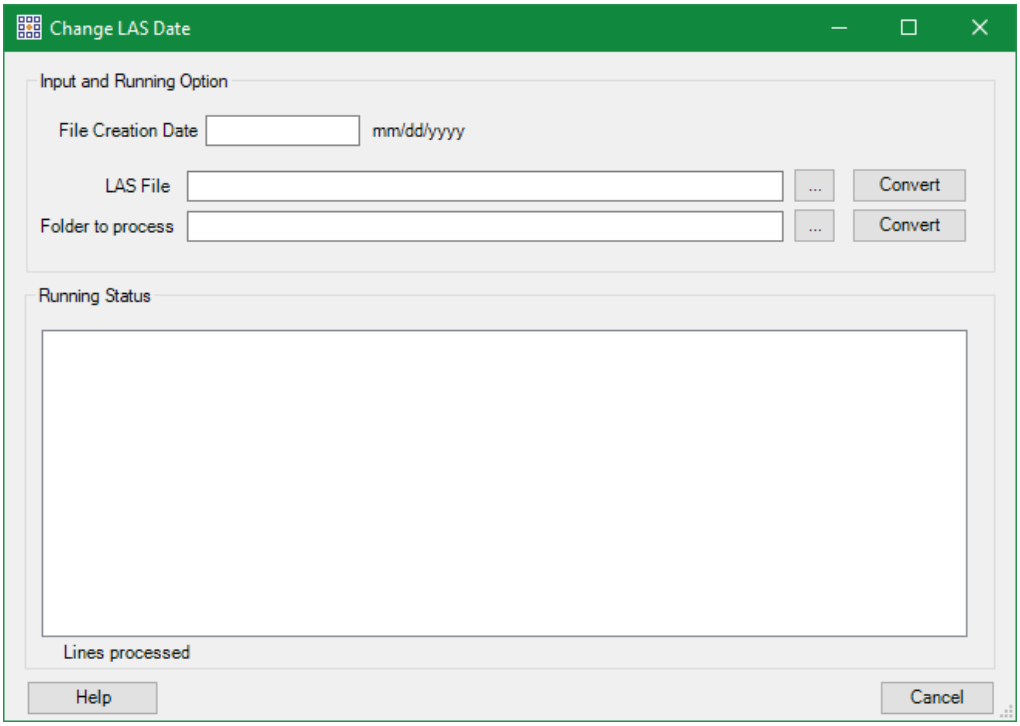
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- ***Change LAS Date*** *(**available with Production license only**)*: This tool, found on the Tools Tab

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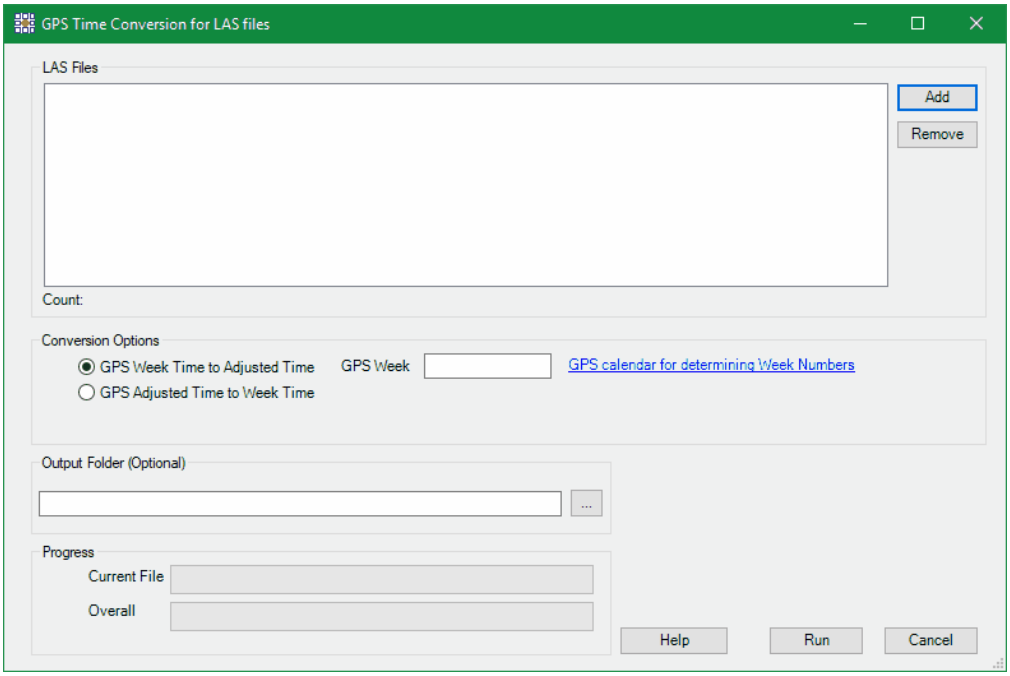
389 under the 'Edit Date/Time' drop-down, allows the user to alter the Julian Day and Year as stored in an LAS file's header and displayed in the file's properties. To use the tool, enter a date in the 'File Creation Date' text box (format must be mm/dd/yyyy). Navigate to either a single file or a folder of files using the ellipse ... button, then click 'Convert.'



- ***GPS Time Conversion:*** This tool, found on the Tools Tab 389 under the 'Edit Date/Time' drop-down, allows the user to convert how time is stored in LAS files from GPS Week Time to GPS Adjusted Time (when the GPS Week number is known) and vice versa. An output folder may be optionally defined to create a new set of files; otherwise the input files will be overwritten. Navigate to the desired file(s) using the 'Add' button. Individual files can be cleared from the list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove' button. The link provided on the interface can help in determining the correct GPS Week number. A valid value between 1 and 2600 (inclusive) must be entered before the 'GPS Week Time to Adjusted

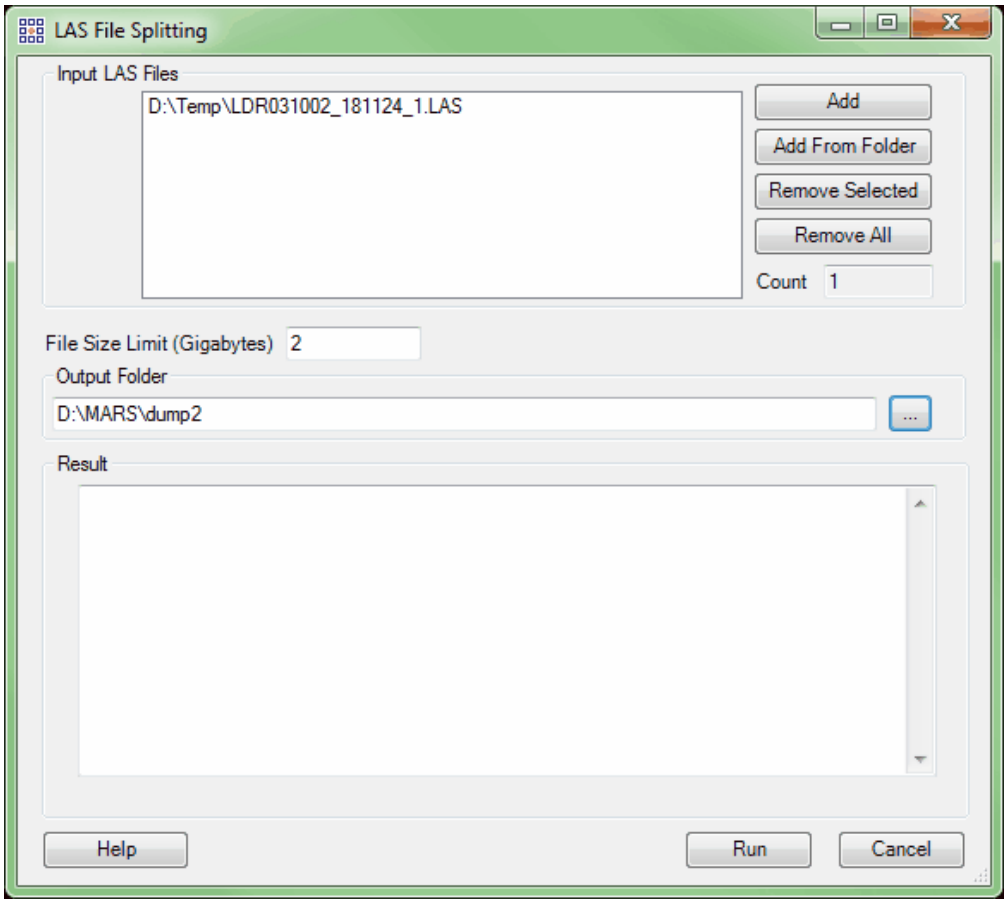
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Time' option can be used.



- ***LAS Splitting:*** This tool, found on the Tools Tab[389], splits LAS files into multiple, smaller files based on a user-specified size limit. Navigate to the desired file(s) using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. The default size limit is 2 GB per file, but any value can be entered in the 'File Size Limit (Gigabytes)' text box. After choosing an 'Output Folder,' click 'Run' to start the process. Files that are split will have '-a', '-b', etc. (as necessary) appended to the original file name and the new files will be placed in the output folder. The original input file(s) will remain unchanged. All files that are made from a single original file will maintain that parent's Point Source ID (PSID) value.

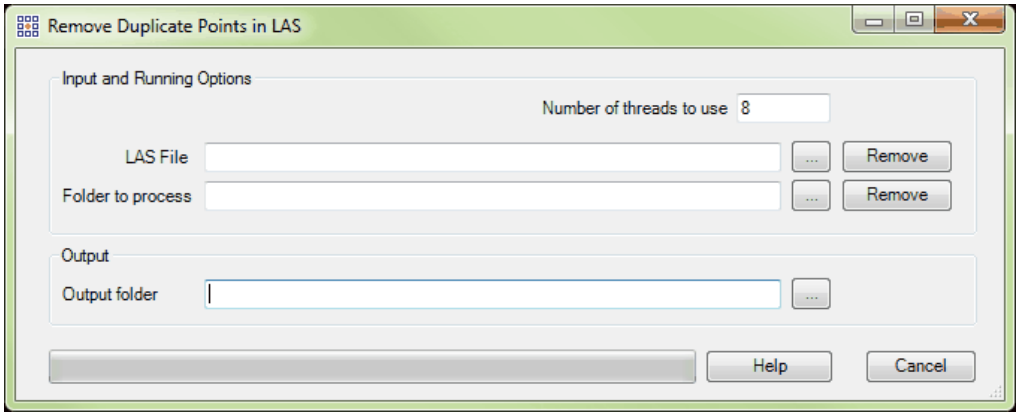
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- ***Remove Duplicates in LAS*** ***(available with Production license only):*** This tool, found on the Tools Tab[389], will remove duplicate LAS points in a dataset based on X, Y, Z, coordinates and timestamp. The tool can be run on a single LAS file or an entire folder of files, and can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Navigate to the input file or folder to be processed, and choose an output folder. Duplicate weeding will be based on exactly matching X, Y, Z, and timestamp values. In addition to the new cleaned files, separate files of only the removed points will be created in a 'Duplicates' sub-folder of the chosen output folder. They will have the original file name with '_dup' appended to the end. Data must be spatially indexed before it

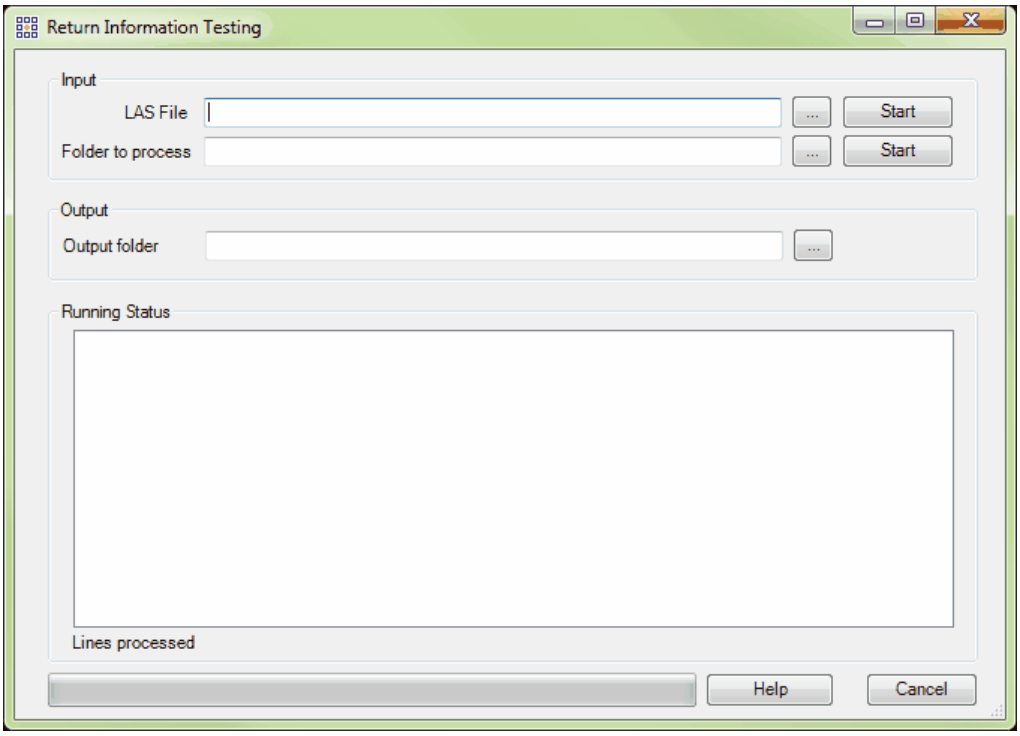
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can be processed with this tool - a prompt will appear if the data does not yet have spatial index records.



- ***Return Information Testing:*** This tool, found on the Tools Tab[389], will test all points of all input files for proper return (point family) information. It should be used anytime a point family error message appears while displaying, filtering, or exporting LAS data; or while running tests C-2 or DPH-1 of the USGS 2.1[1525], 1.3[1559] or 1.2[1592] QC Modules, or tests 1.1 or 2.9 of the USGS 1.0 QC Module[1622]. The tool can be run on a single LAS file or an entire folder of files. Navigate to the input file or folder to be processed, and also choose an output folder. Input files are not modified in any way during testing. Click the appropriate "Start" button depending on the input method chosen. During processing, separate LAS files will be created in the output folder. They will have the original file name with '*Valid_*' and/or '*Invalid_*' as a prefix, as appropriate. For example, if file '123456.las' contains some points with invalid return information, both a 'Vaild_123456.las' and 'Invalid_123456.las' file will be generated in the output folder. If **all** points in a given file have valid return information, only the '*Valid_*' version of the file will be generated. Likewise, if **all** points in a given file have invalid return information, only the '*Invalid_*' version of the file will be generated. Note that invalid return information cannot be changed once the data is collected and the original 'raw' LAS file is created.

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- ***LAS Merging*** ***(not available with Evaluation license):*** This tool, found on the Tools Tab[389], merges individual channel LAS v1.4 files (typically made from a multi-channel LiDAR sensor's collection) into a single swath (collection scan) LAS file. For example, the separate channel 1 and 2 files produced by Teledyne Optech's LMS post-processing software from data collected by that company's Pegasus sensor can be merged into a single LAS file containing all returns from the two channels. Other sensors can produce up to four individual channel files, typically numbered 0, 1, 2, and 3. The individual files must follow a naming convention in order to be grouped together – following a leading alpha character, the same number or numbers must exist before the next instance of either an alpha character or a separator ('-' or '_'). There must also be unique channel indicators at the end of each file name in a group to be merged, such as '-C0' and '-C1', or '_C1' and '_C2'. Examples of file naming that produces a properly merged output file include:

  'L3-1-123456-C1.las' and 'L3-1-123456-C2.las' -- the merged output file will be named

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‘L3_M.las’ (the final 'M' means merged)

‘L42B-1-123456_C0.las’ and ‘L42B-1-123456_C1.las’ -- the merged output file will be named ‘L42_M.las’

'S456-4-789-C0.las', 'S456-4-789-C1.las', 'S456-4-789-C2.las', and 'S456-4-789-C3.las' -- the merged output file will be named 'S456_M.las'

‘3A-1-123456-C1.las’ and ‘3A-1-123456-C2.las’ -- the merged output file will be named '3_M.las'

'L45-1-K-333444-C0.las' and 'L45-1-K-333444-C1.las' -- the merged output file will be named 'L45_M.las'

Examples of file naming that will result in improperly merged output files include:

‘L3-1-123456-C1.las’ and ‘L4-1-123456-C2.las’ -- the result will be copies of one or both of the input files

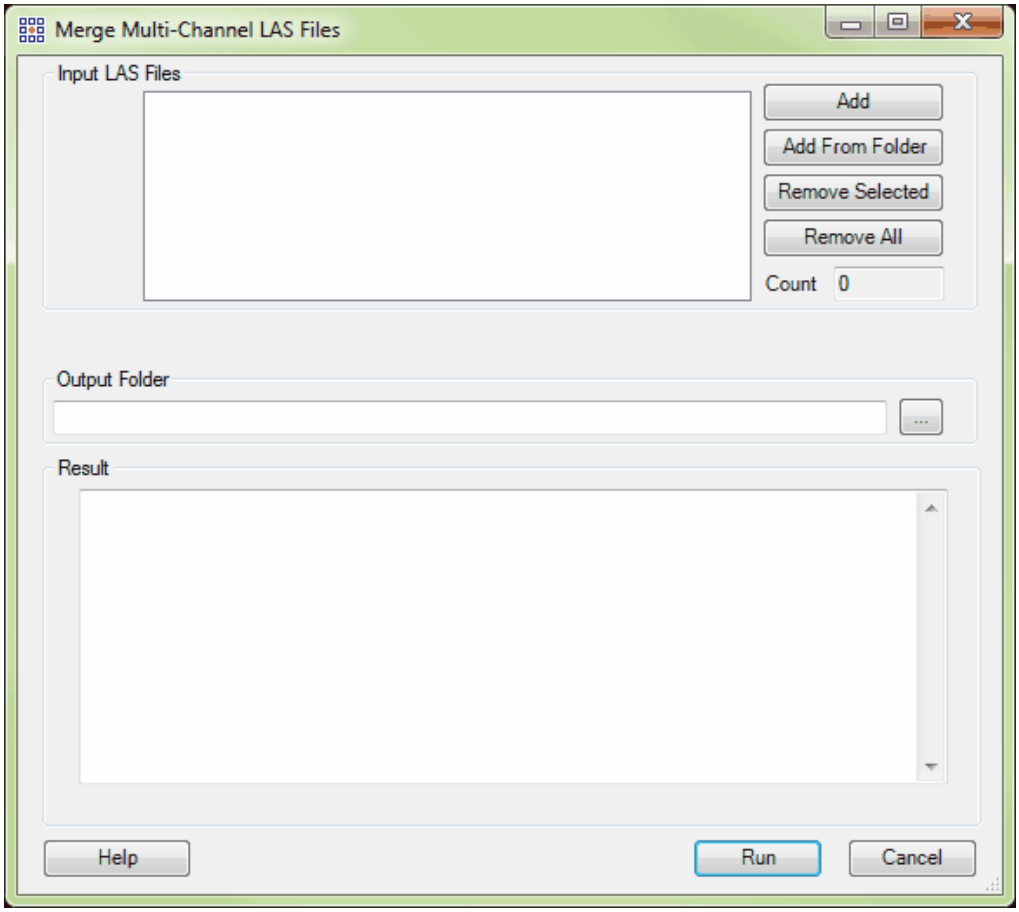
'8B-1-M-987654-C1.las' and '9B-1-M-987654-C2.las' -- the result will be copies of one or both of the input files

Proper file naming is critical to a successful merge! Each set of individual channel files to be merged must begin with a naming scheme that is unique to that set.

Once the files to be merged have been properly named, navigate to the folder containing them using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Choose an 'Output Folder' where the merged files will be stored and then click the 'Run' button. The status of each swath merge will be shown in the 'Result' area. The File Source ID

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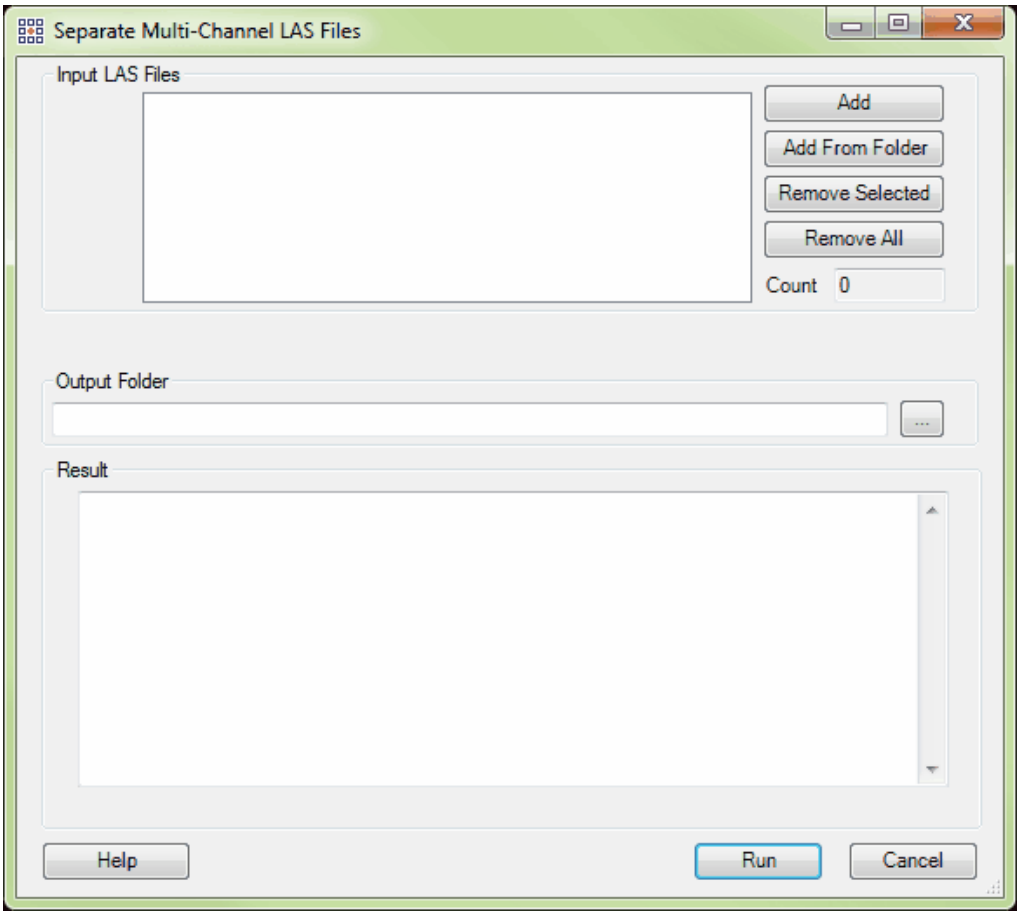
assigned to each final merged file will be taken from the first individual file of the group as listed in the 'Input LAS Files' box of the tool's interface.



- ***LAS Separate*** ***(not available with Evaluation license):*** This tool, found on the Tools Tab[389], separates merged multi-channel LAS v1.4 files into separate individual channel files, one file for each scanner channel value found in the original merged file. ***The Scanner Channel bit flag values must be present in the original merged file for this tool to work - possible bit flag values are 0, 1, 2, and 3.*** For example, a file containing points from both channels of a dual-channel system (stored as Scanner Channel bit flag values 0 and 1) will be separated into a channel 0-only file and a channel 1-only file. In this example, if the original merged file is named 'L3-123456-M1.las', the new individual channel files will be named 'L3-123456-M1-C0.las' and 'L3-123456-M1-C1.las'. Navigate to the files to

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be separated using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Choose an 'Output Folder' where the individual channel files will be stored and then click the 'Run' button. The status of each file separation will be shown in the 'Result' area. The File Source IDs assigned to each individual channel file will be the same as the ID from the original merged file.

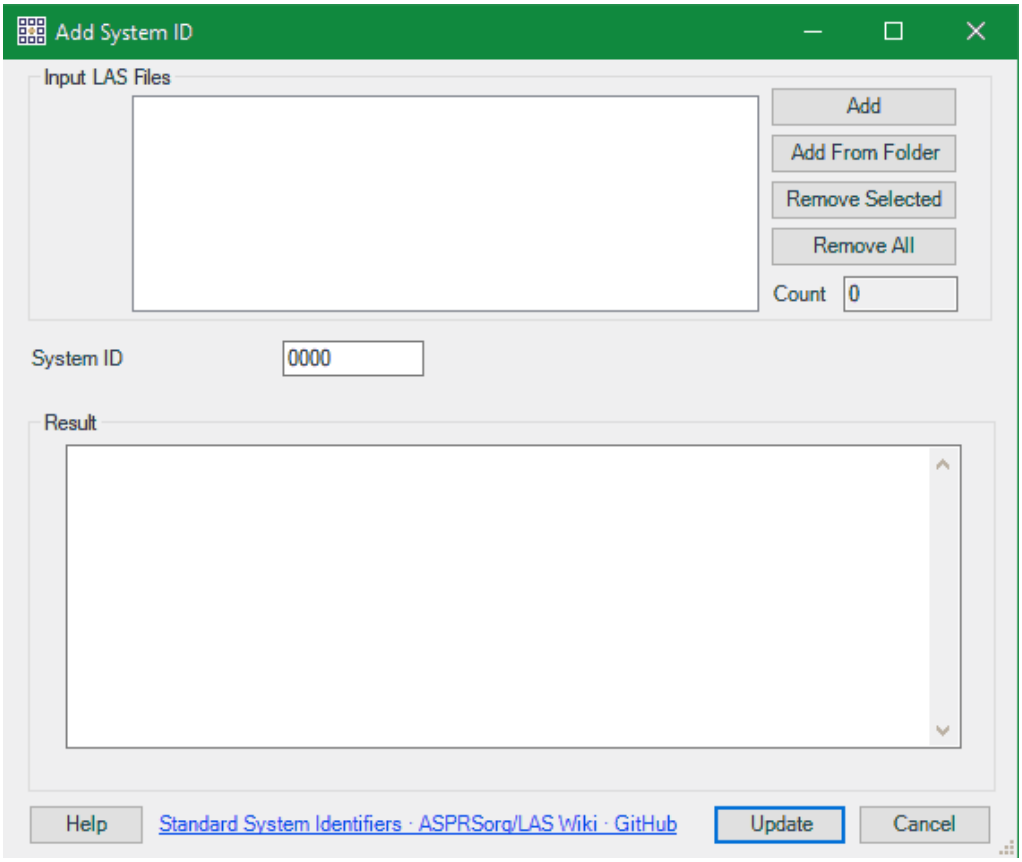


- ***Add System ID:*** This tool, found on the Tools Tab[389], allows the System Identifier field in the Public Header Block of LAS files to be populated or edited. Note that 'System Identifier' is sometimes

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referred to as 'System ID', 'Sys ID', or 'SysID'. Per the ASPRS LAS v1.4 specification, there are several entries that are valid for this field, and it can hold up to 32 bytes (characters) of information. A link at the bottom of the interface leads to a list of currently accepted System Identifiers and provides instructions for requesting additions to the list.

MARS® defaults to '0000' (unknown), but this can be changed as needed in the tool's interface. If a value is already present in the file header(s), it will be silently overwritten by the tool. This tool will not allow complete removal of existing entries. To use, navigate to the files to be populated/edited using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. Click the 'Update' button to begin processing. The status of each updated file will be shown in the 'Result' area.



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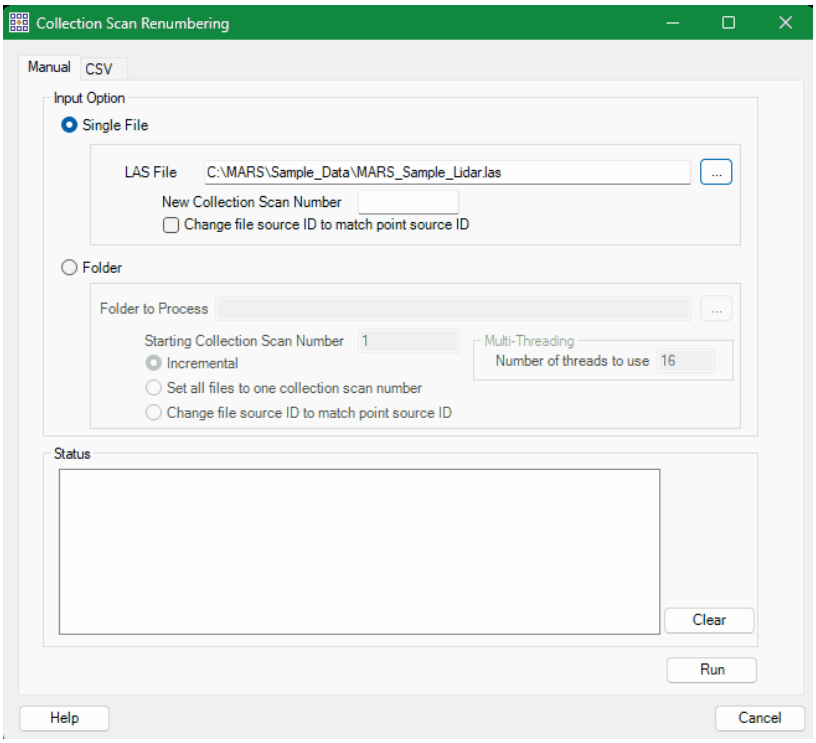
- ***Collection Scan Renumbering:*** This tool, found on the Tools Tab[389] under the 'Collection Scans' drop-down, is designed for use with original collection scans (swath files), and allows the collection scan number stored with each LiDAR point to be changed using one of several methods.

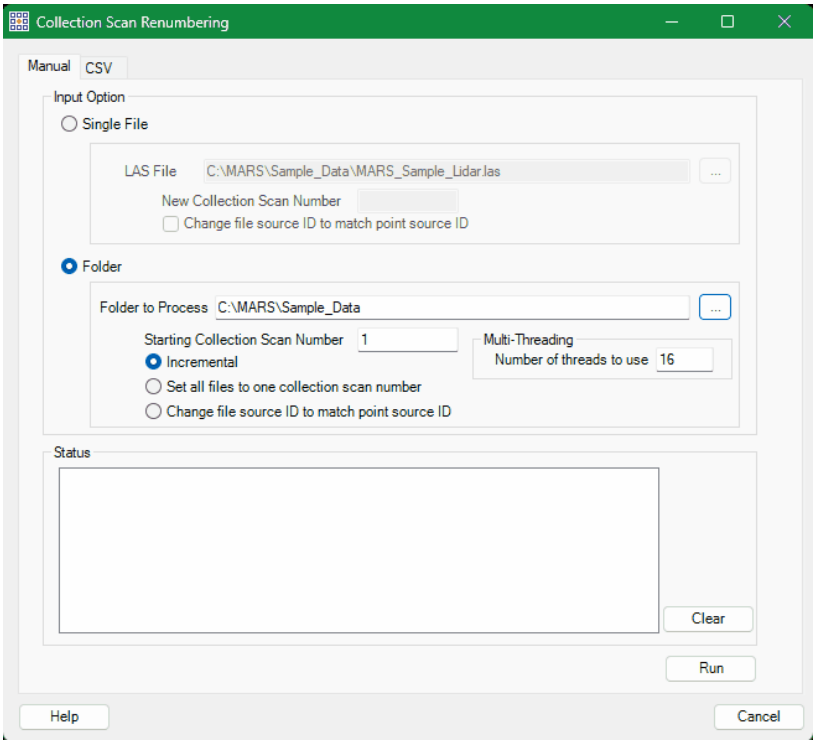
On the 'Manual' tab, a new number can be assigned on a file-by-file basis (first row, below), sequential numbers can be assigned to a folder of files by specifying a non-zero starting number in the 'Starting collection scan number' text box (second row, left), and the same number can be assigned to all swaths in the folder (second row, middle). An additional method reads existing Point Source IDs and sets the File Source ID numbers to match (second row, right). In 'Manual - Folder' mode, the tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

On the 'CSV' tab, a CSV file with multiple mapped changes can be read in for an entire folder of LAS files (third row, below). When the CSV file option is used, it must be formatted as two columns: the first is a listing of the original collection scan numbers (one per row), and the second column lists the new desired collection scan numbers. For example, 5 might become 105, 6 might become 106, etc. A header row is optional and will be ignored during processing. File Source IDs will be changed to match the new collection scan numbering for each file. Original values (first column) of zero (0) will not be changed.

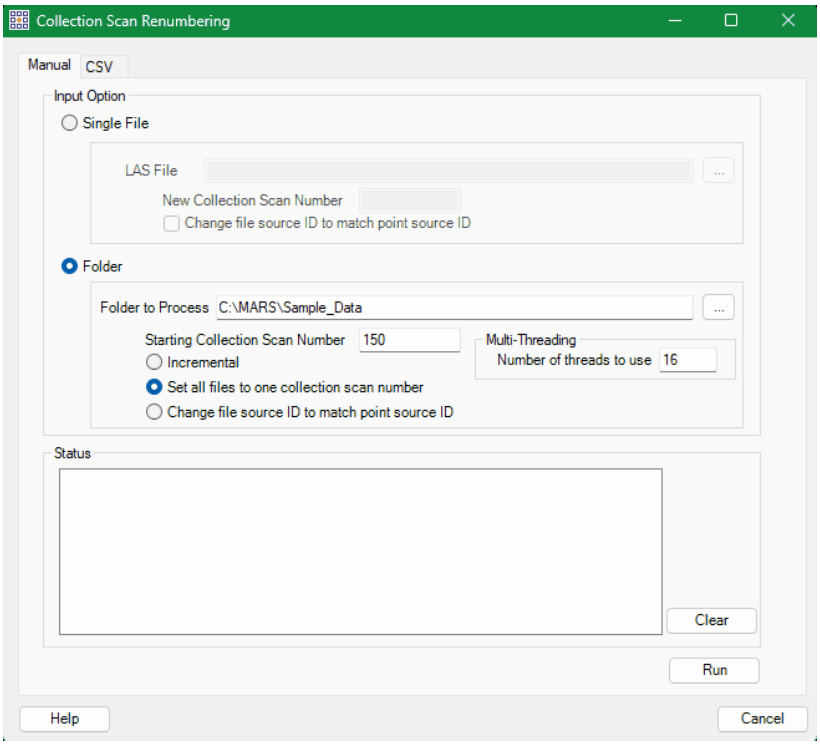
Please note that LAS version 1.4 files are limited to collection scan numbers of 1 to 65535. For 'Incremental' renumbering, be sure to use a starting value that will not cause any of the files to be given values higher than 65535.

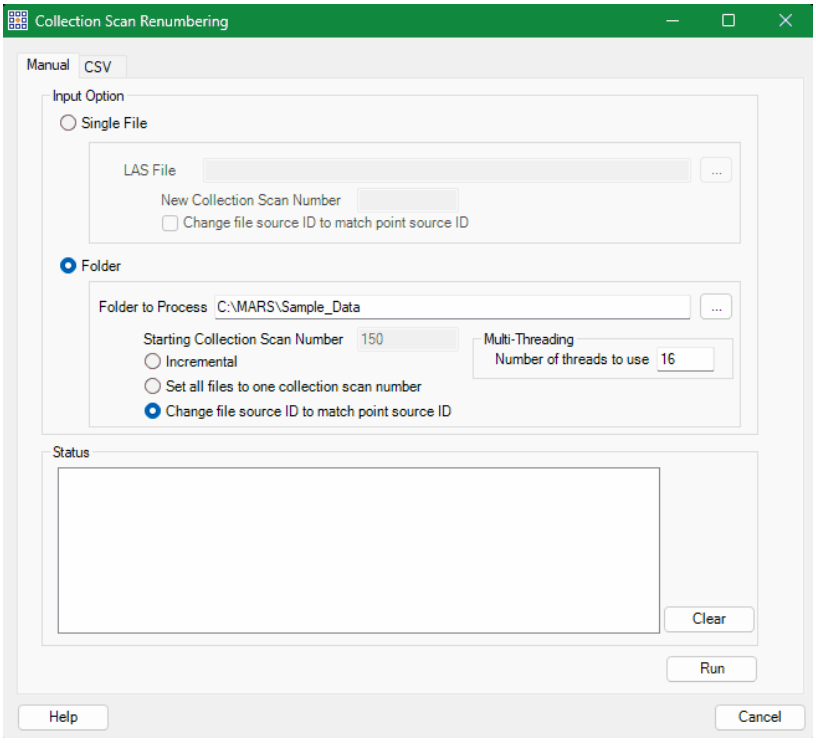
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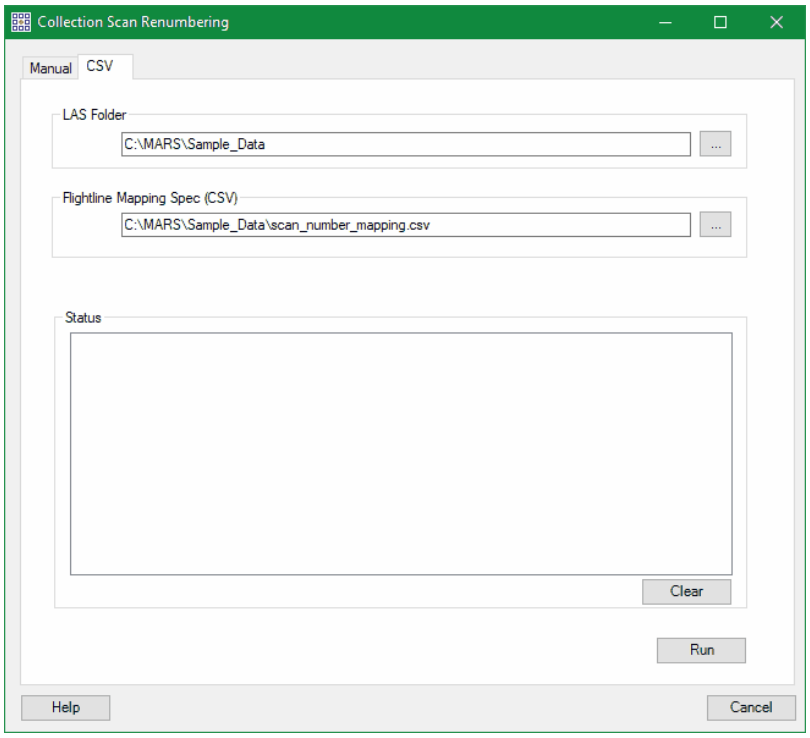


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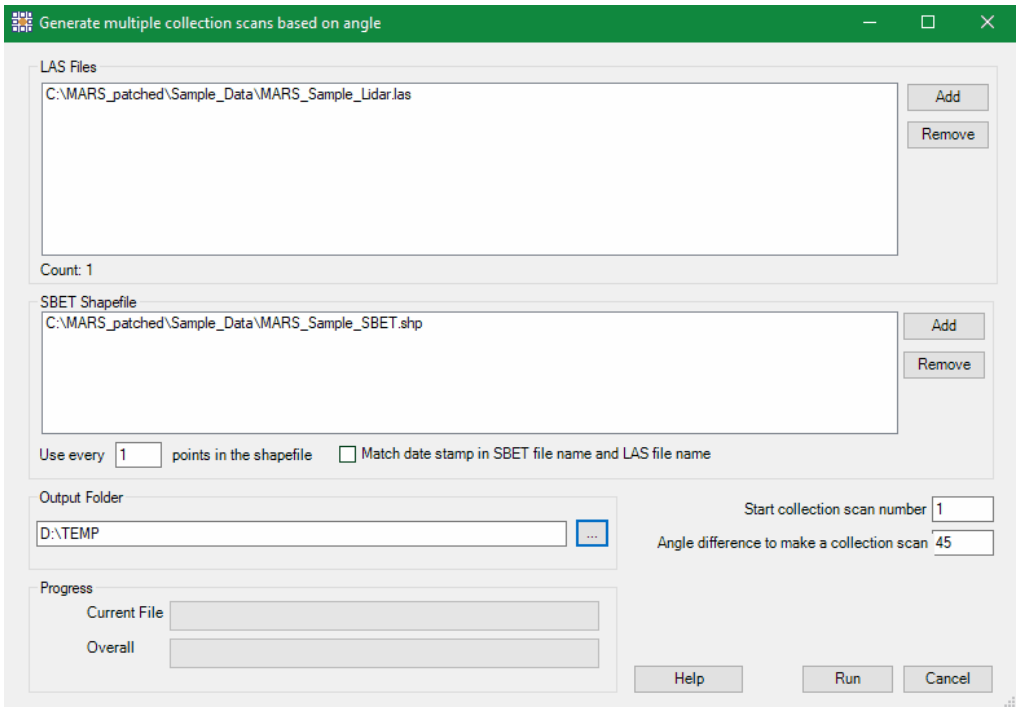


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- ***Single Collection Scan to Multiple*** ***(available with Production license only):*** This tool, found on the Tools Tab[389] under the 'Collection Scans' drop-down, will split a single collection scan into multiple, smaller collection scans in areas indicated by the flight heading, or angle, which is user defined. Having multiple, smaller collection scans versus a single, large collection scan may help in boresighting and in measuring height differentiations between collection scan overlaps.

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1. To use this tool, first load the LAS data which is the single, large collection scan by clicking the 'Add' button and navigating to the file(s).

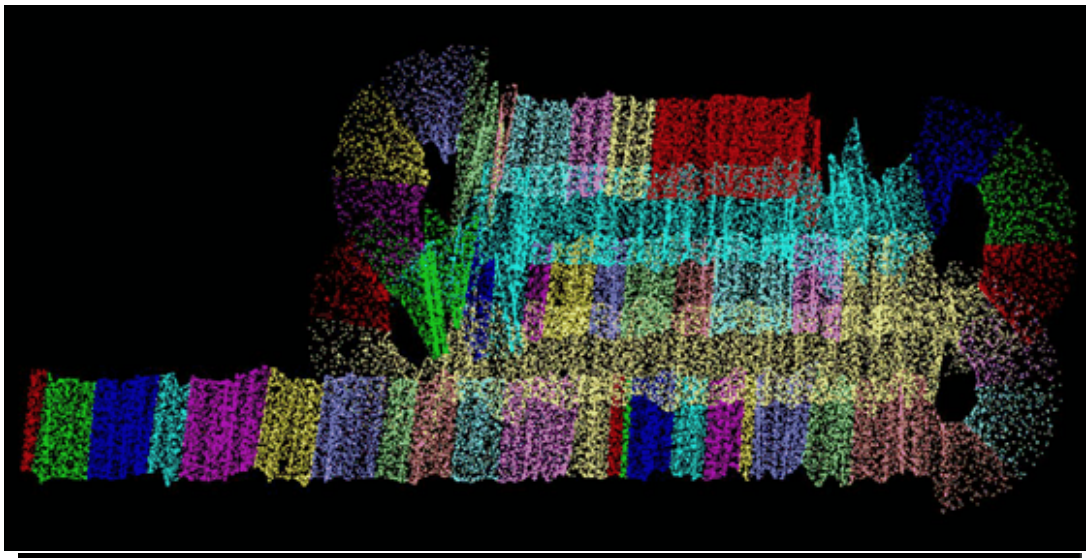
2. To remove added LAS files, select (highlight) the file or files to be removed (using standard Windows mouse/keyboard controls) and click the 'Remove' button.

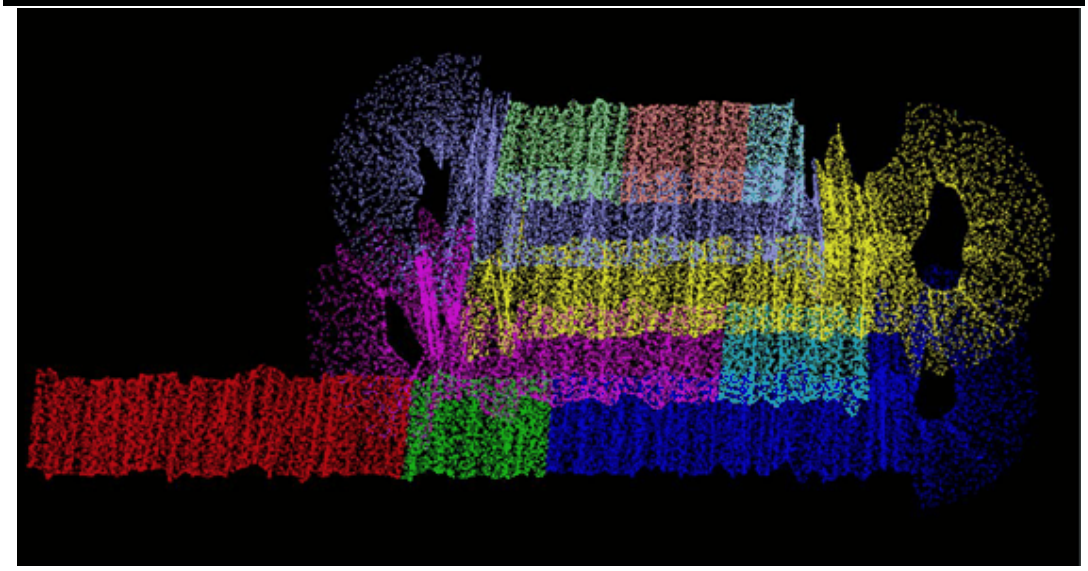
3. Next, navigate to the SBET shapefile which is associated with the loaded LAS file (s) by clicking 'Add'.

4. Specify the sampling rate at which to produce the new collection scans by entering an integer into the 'Use every __ points in the shapefile' text box. This feature of the 'Single Collection Scan to Multiple' tool allows the user to reduce the sampling rate of (or thin out) the heading data from the SBET file by allowing the user to define a time range.

The examples shown below compare a 1 second sampling rate (left) and 30 second sampling rate (right).

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5. Define an output folder for the multiple new collection scans.

6. Choose a starting collection scan number for the naming convention of the multiple new collection scans which will be produced.

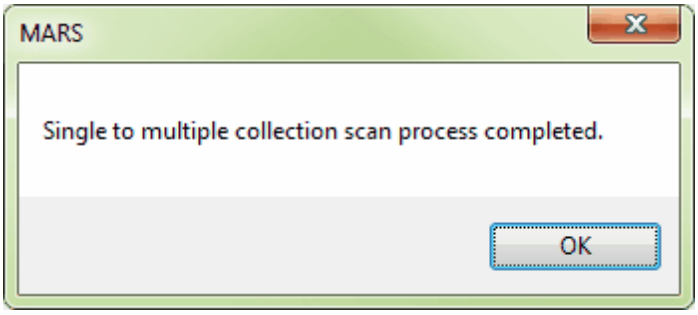
7. Choose an angle at which collection scans will be separated. Whenever the angle specified here is found in the original, single collection scan, the process will start a new collection scan.

8. When all specifications have been made, choose the 'Run' button. Multi-Threading may be used to speed up the processing. For best performance, there should

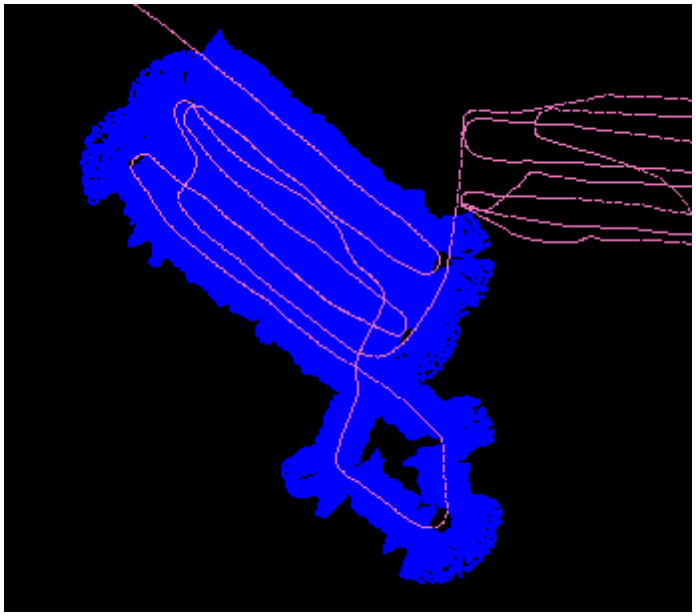
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be a minimum of eight (8) GB of RAM available (not just installed) per thread.

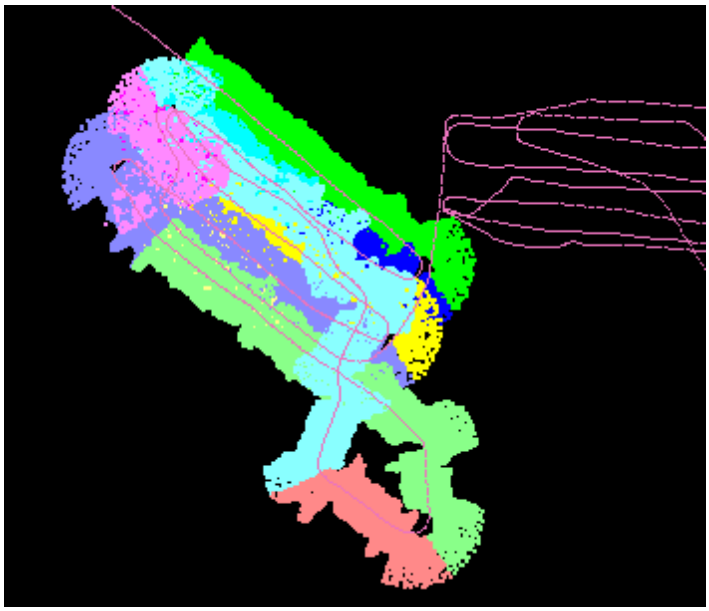
9. When the process is complete the user will be notified with a prompt as seen here:



In the first example shown below the LAS data is shown colored by collection scan. There is only a single, long collection scan loaded. The SBET shapefile is shown as the pink point shapefile. In the second example, the collection scan shown previously has been converted to multiple collection scans with the collection scan angle specified for separation at 90 degrees. The new data below is also colored by collection scan.



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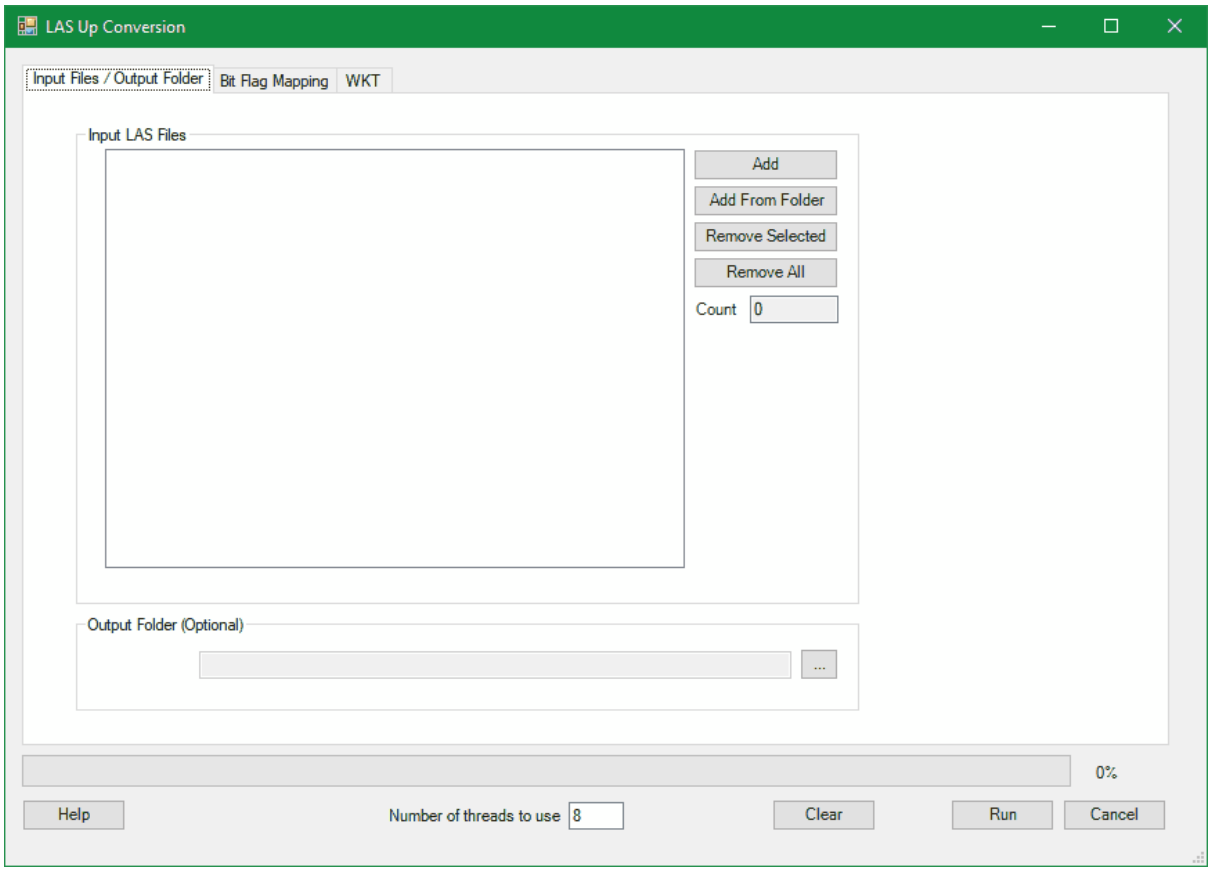


- ***LAS Up-Conversion:*** This tool, found on the Tools Tab[389], allows batch conversion of pre-LAS v1.4 files, or version 1.4 files with the following characteristics: a legacy Point Data Record Format of 0-5, less than 16-bit Intensity values, less than 16-bit RGB(N) values (if present), GeoTIFF tags containing Coordinate Reference System info, and/or presence of Variable Length Records. It is the same tool that appears when loading LAS files that are not compliant with this version of MARS® (if **'Yes'** is chosen in response to the up-conversion prompt).

  This tool has several options including: 1) output to a different folder than the files currently reside in, 2) bit flag mapping to convert user-defined classes of points to any of the four changeable bit flags used in version 1.4 LAS files - **Synthetic**, **Key-point** (also referred to as Model Key-point), **Withheld**, and **Overlap**, and 3) assignment of a WKT tag for Coordinate Reference System definition. Existing bit flags (except, in some cases, the v1.4-only **Overlap** type) can be carried over from the files being converted, or a class or classes can be specified that represented the bit flag types in older version files.

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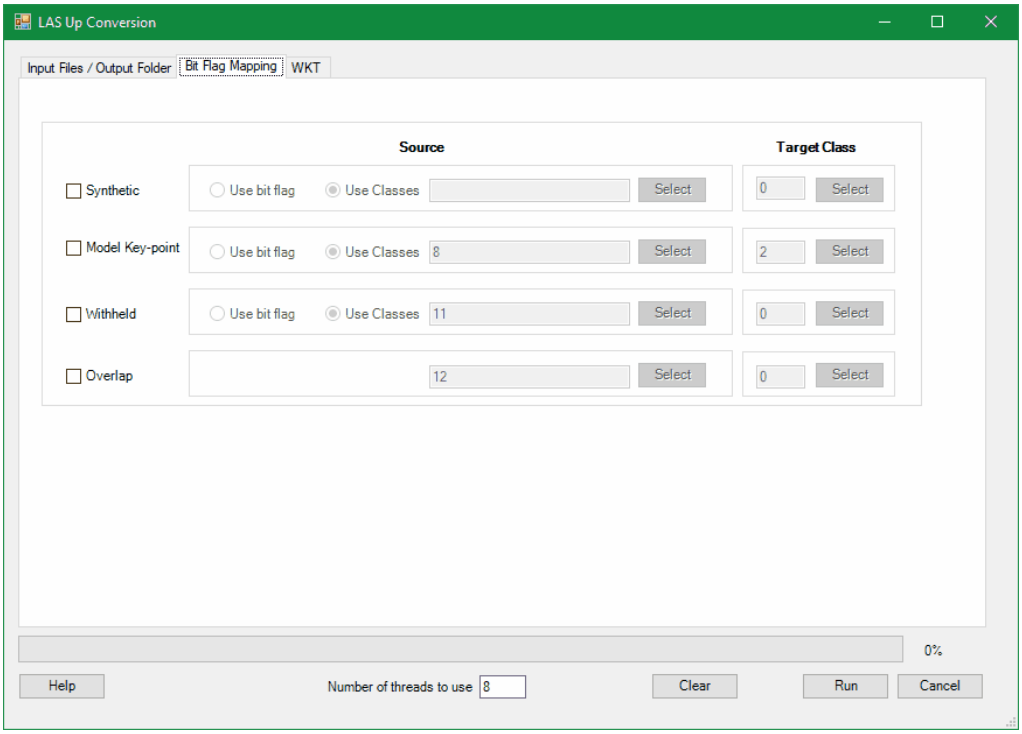
On the 'Input Files / Output Folder' tab, navigate to the files to be up-converted using either the 'Add' or 'Add From Folder' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button. ***The input files will be overwritten unless an output folder is selected.***



On the 'Bit Flag Mapping' tab, check the boxes in the left column for any bit flag types that need to exist in the up-converted files. If the existing files have bit flags set for **Synthetic** (rare), **Model Key-point**, and/or **Withheld**, select the appropriate **'Use bit flag'** radio buttons to carry over the bit flag status. Otherwise, keep the default **'Use Classes'** radio buttons selected and use the **'Select'** buttons

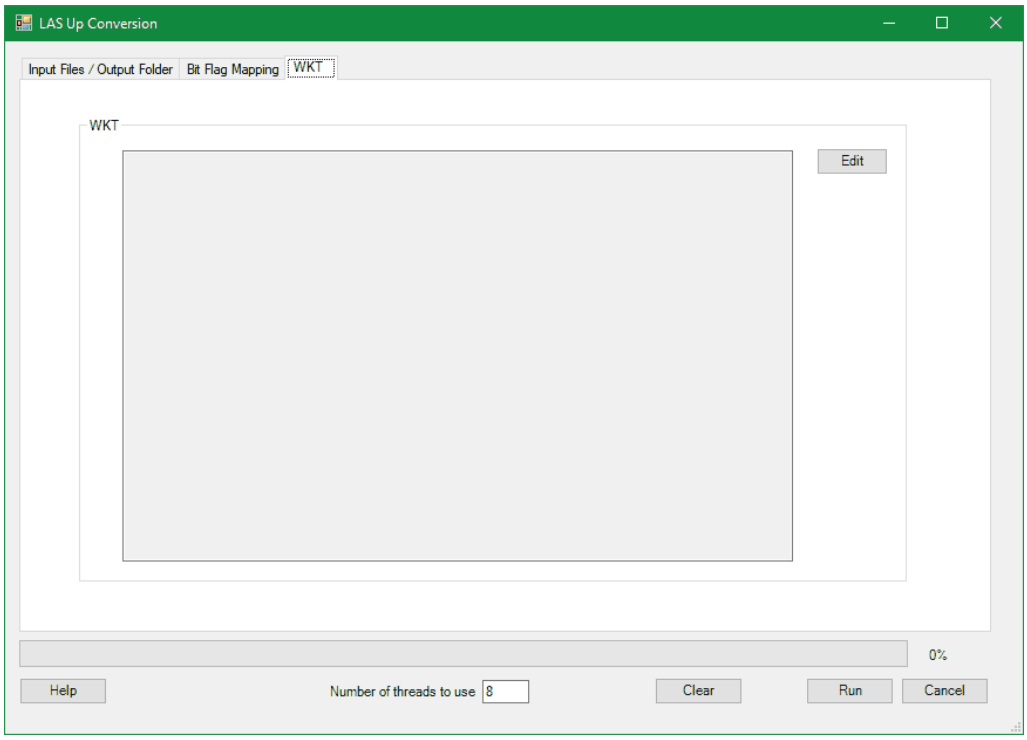
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in the **'Source'** section to choose one or more classes in the existing files that are representing a bit flag type. The pre-populated **'Source'** classes were chosen as defaults because they are commonly used in LAS files older than version 1.4. Optionally, a new **'Target Class'** can be selected for the points once their bit flags are set. Class 2 is the default **'Target Class'** for **Model Key-point** since it is a sub-set of ground (which is typically stored as Class 2).



For the 'WKT' tab, any existing Coordinate Reference System information that is readable will be shown as a WKT format tag which can then be edited for correctness and/or completeness.

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The tool can be multi-threaded ('**Number of threads to use**') for faster processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. When all settings have been made, click **'Run'** to start the up-conversion and load the files, or **'Cancel'** to dismiss the interface without modifying or loading any files.

- ***LAS Version Converter:*** This tool allows batch back-conversion (export) of LAS files to older versions (or version 1.4 with legacy Point Data Record Formats). Some loss of information is unavoidable when converting data back to older versions and/or lower PDRF values, depending on the specific version/PDRF of the resulting files. See the LAS File Specifications 1879 topic for details.

  This tool has several options including: **1)** LAS version to be created, **2)** how existing bit flags will be stored (as is, or converted to classes) and, **3)** conversion of Adjusted GPS Time to GPS Seconds of the Week.

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For option 1, PDRF values for the output are determined by the 'Target LAS Version' chosen, as well as whether the input LAS v1.4 files are PDRF 6, 7, or 8. The following table lists the possibilities:

PDRF 6 -- if back-converted to LAS v1.0, LAS v1.1, LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 1.

PDRF 7 -- if back-converted to LAS v1.0 or LAS v1.1, resulting PDRF will be 1. These LAS versions cannot store point-level RGB values.

PDRF 7 -- if back-converted to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 3.

PDRF 8 -- if back-converted to LAS v1.0 or LAS v1.1, resulting PDRF will be 1. These LAS versions cannot store point-level RGB or near-infrared (NIR) values.

PDRF 8 -- if back-converted to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6), resulting PDRF will be 3. These LAS versions and legacy PDRFs cannot store point-level near-infrared (NIR) values.

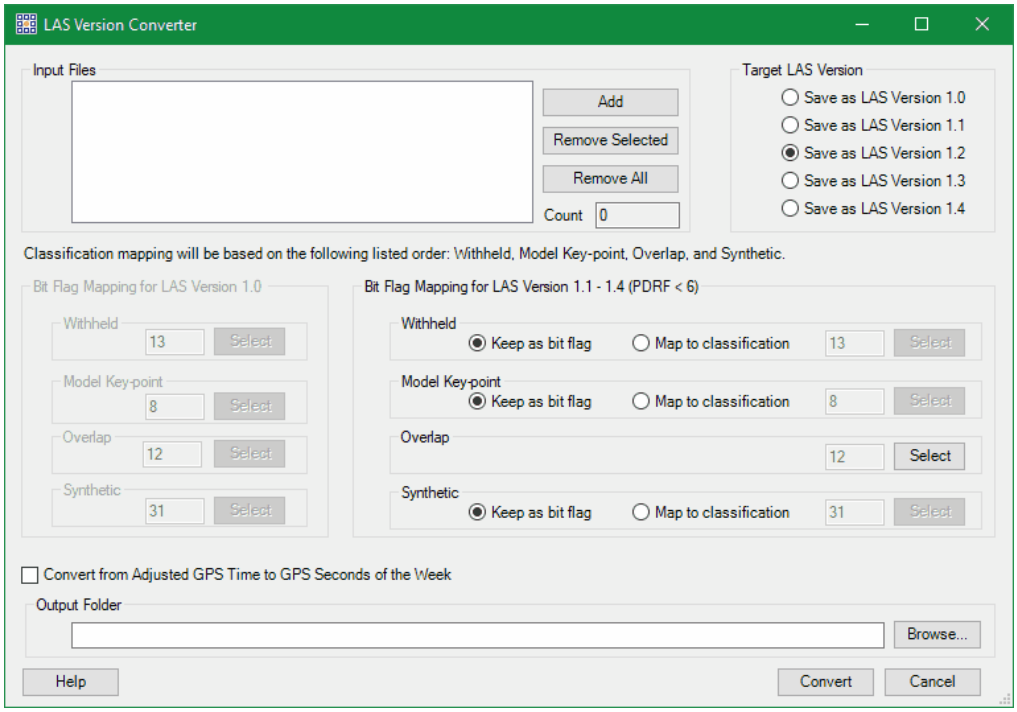
For option 2, mapping of existing bit flags to the output files depends on the 'Target LAS Version' selected. In LAS v1.0, there is no provision for bit flag storage as such, so unique classes must be used to represent bit flag values that the user wants to save. The default classification values shown in the tool interface can be changed as needed. In LAS v1.1 through LAS v1.4 (PDRF < 6), it is possible to keep the bit flag status of all but the 'Overlap' bit flag. Optionally, the user can map those bit flags to unique classes in the output files by selecting the corresponding radio button(s) and either accepting the default classes or changing them as needed. Any existing 'Overlap' bit flags must be converted to a unique class for all back-conversion scenarios.

For option 3, back-conversion to LAS v1.0 or LAS v1.1 requires timestamps to be stored as GPS Seconds of the Week - therefore, that option will be checked on and disabled. Back-conversion to LAS v1.2, LAS v1.3, or LAS v1.4 (PDRF < 6) allows the timestamps to be *optionally* converted to GPS Seconds of the Week. Note, however, that this time storage method does not maintain the actual collection date.

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When converting back to LAS v1.4 (PDRF < 6), any existing CRS info record (in WKT format) will remain in an EVLR and all spatial indexing records will be written to VLRs. When converting back to LAS v1.0 through v1.3, *all* EVLRs will be written as VLRs.

In the 'Input Files' section, navigate to the files to be back-converted using the 'Add' button. Individual files can be cleared from the input list by highlighting the appropriate file or files (using standard Windows mouse/keyboard controls) and clicking the 'Remove Selected' button, or the entire list can be cleared by clicking the 'Remove All' button.



This tool requires the use of an 'Output Folder' - the input files cannot be overwritten. When all settings have been made, click **'Convert'** to start the back-conversion, or **'Cancel'** to dismiss the interface without creating any new files.

- ***XYZ Shift:*** This tool, found on the Coordinate Conversion Tab 254, is used to shift LAS data in all

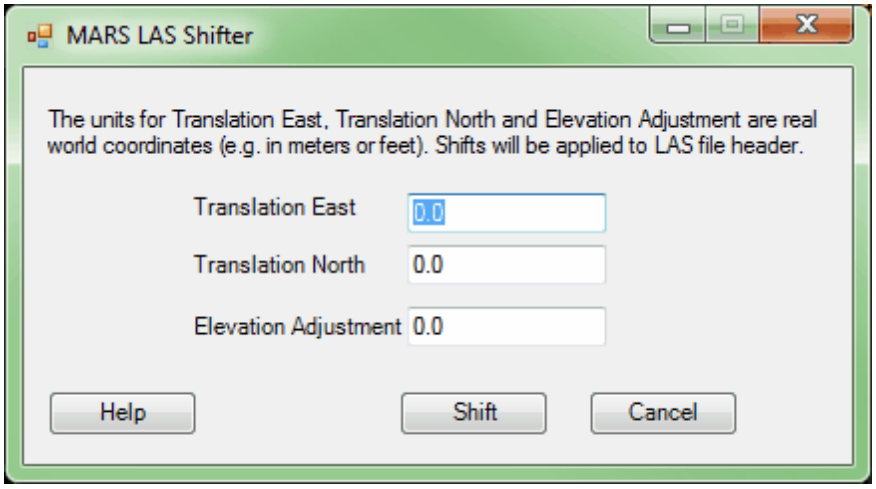
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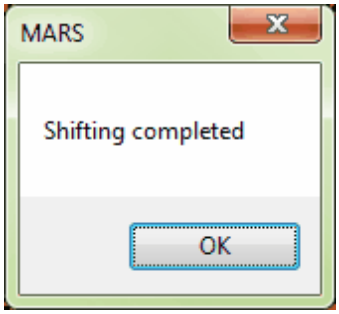
loaded files in six different directions:

1. **East** (a positive shift in the Translation East text box)
2. **West** (a negative shift in the Translation East text box)
3. **North** (a positive shift in the Translation North text box)
4. **South** (a negative shift in the Translation North text box)
5. **Higher in Elevation** (a positive shift in the Elevation Adjustment box)
6. **Lower in Elevation** (a negative shift in the Elevation Adjustment box)

All loaded files will have the same shifts, specified by the user in the 'MARS LAS Shifter' interface, applied to them.

**** NOTE: If multiple shifts are applied to a single project, the effect is cumulative. Each shift is applied to the existing XYZ offset in the header.****





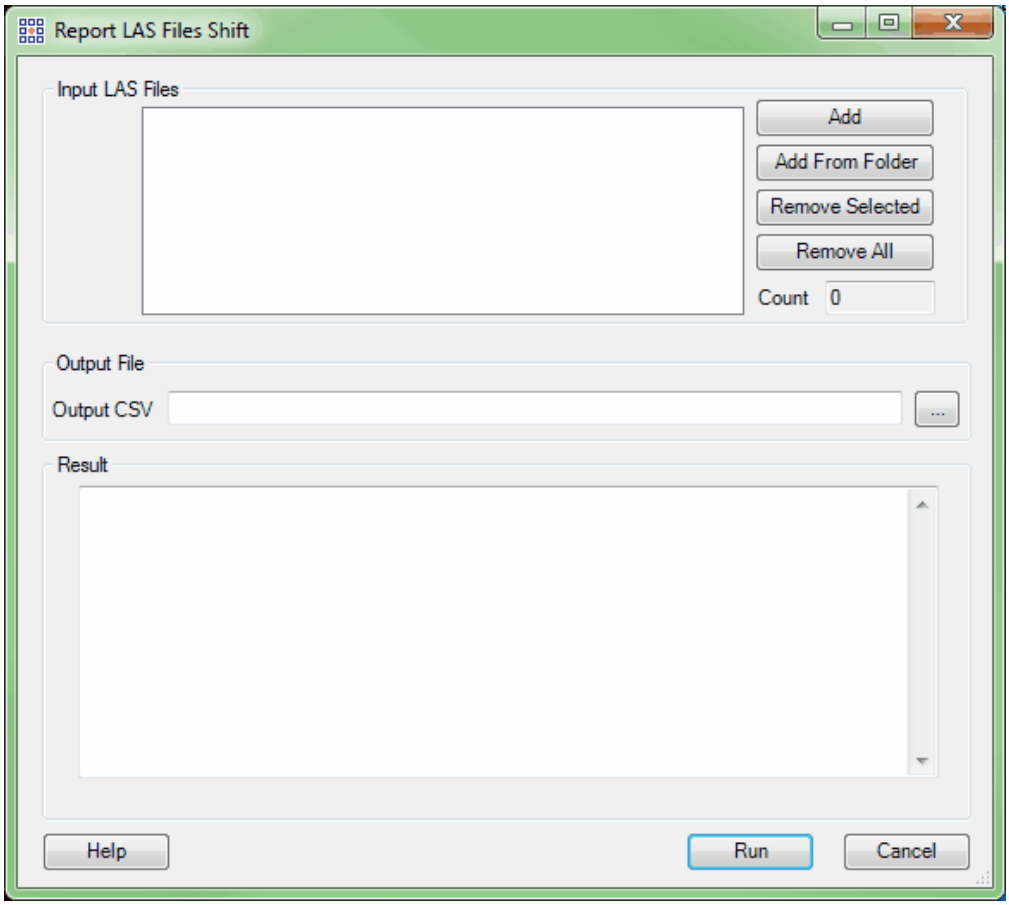
An OFF file (*.off) will be created for each file that is shifted storing the X, Y, and Z offsets that existed

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in the file before the shift was processed. These 'offset' files will be created with the same name and in the same folder as their corresponding LAS file(s). They are used with the **'Report LAS Shift'** tool (below) as a baseline. If the *.off files are moved, renamed, or deleted, they will be recreated the next time the MARS LAS Shifter is run, but with the then-current offsets used as baselines.

- ***Report LAS Shift:*** Shifting LAS data using the Table of Contents 67 'Shift' button or the 'XYZ Shift' tool on the Coordinate Conversion Tab 254 produces a *.off file (one per shifted LAS file) which stores the pre-shift X, Y, and Z offset values read from the LAS file header. These files are created in the same folder as the LAS files that were shifted. The *.off files are used as a baseline by the **'Report LAS Shift'** tool to create a comma-delimited (*.csv) report that stores the total (cumulative) shift for each of the files chosen to be included in the report. To use the tool, found on the Coordinate Conversion Tab 254, add one or more shifted LAS files using the **'Add'** button, or add an entire folder of shifted LAS files using the **'Add From Folder'** button. To remove single or multiple files, highlight the file or files to be removed or files (using standard Windows mouse/keyboard controls) and click on the 'Remove Selected' button. Choose a path and file name for the output CSV file - click on the ellipse  button, then navigate to the desired output folder and enter a filename and finish by clicking **'Save.'** To create the report, click the **'Run'** button at the bottom of the tool interface.

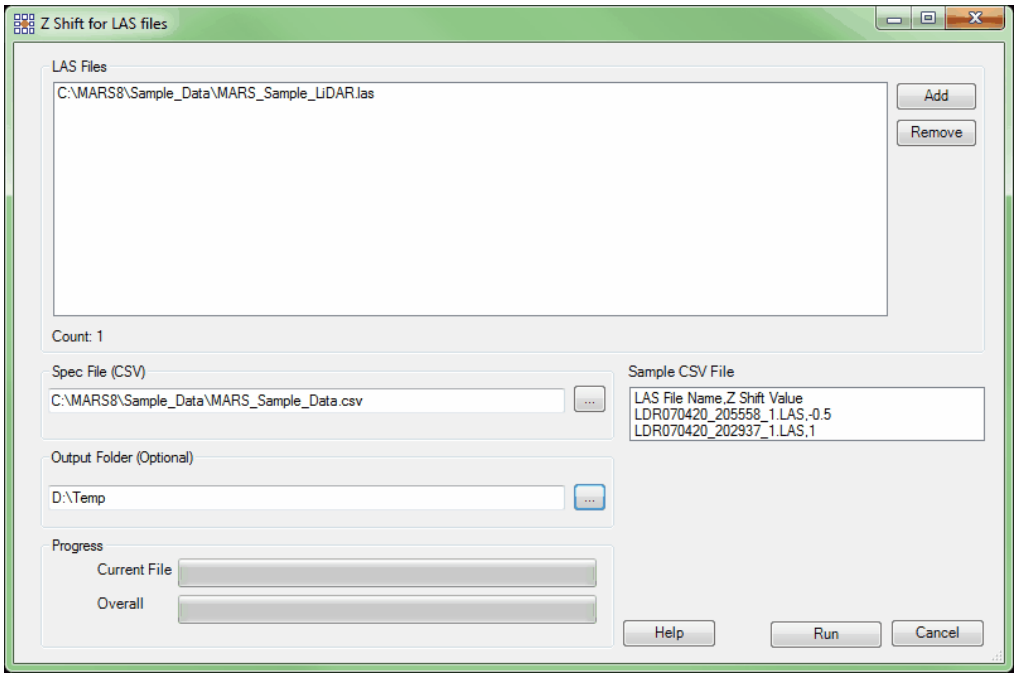
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- ***Z Shift For LAS files:*** ***(available with Production license only):*** The 'Z Shift For LAS files' tool is located on the Coordinate Conversion Tab[254] under the 'Z Shift' drop-down button. It will allow the user to batch shift the Z-value (level the elevation) of all LAS files in a project by use of a comma-delimited *.csv file. *This tool is meant for use **after** boresighting has been completed.* The corresponding *.csv file must include a header row (as shown in the sample below), followed by the file names of the LAS files to be shifted and the adjustment value to be made to each file. *It is important to note that the adjustment values to be made to each file need to be in the project units unique to that particular project.* A sample *.csv file may be seen inside the 'Z Shift For LAS files' interface. To use this tool, point to the LAS files by clicking on the 'Add' button in the upper-right corner and add the LAS files which need shifting. To remove single or multiple files, highlight the file or files to be removed

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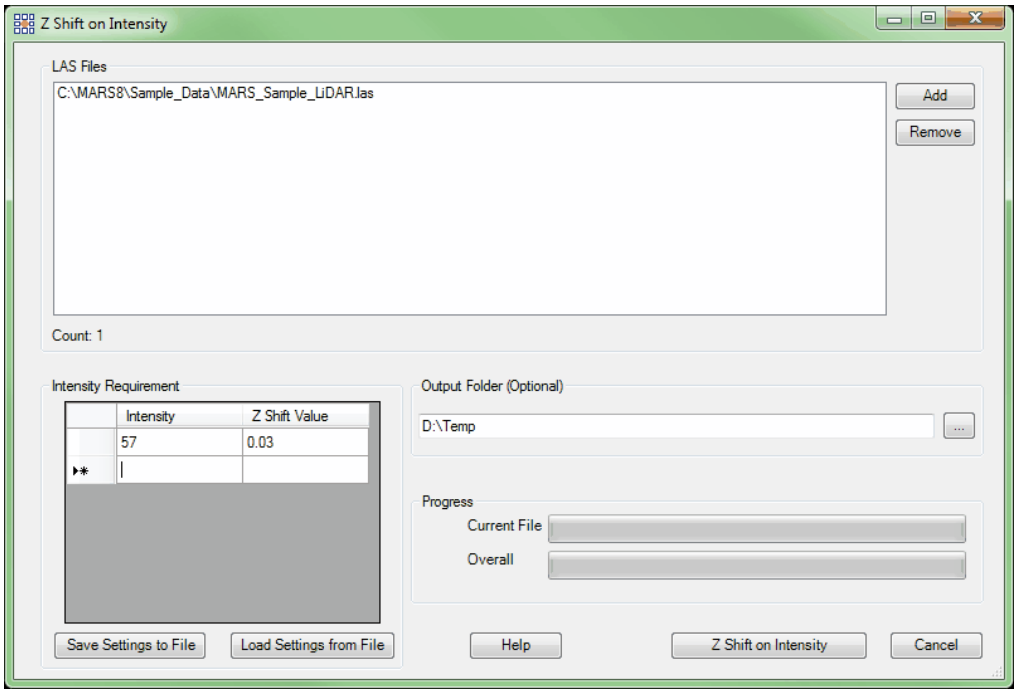
or files (using standard Windows mouse/keyboard controls) and click on the 'Remove' button. Specify the corresponding *.csv file in the 'Spec File (CSV)' section and (optionally) designate an output folder. **If no Output Folder is specified, the input LAS files will be overwritten.**



- ***Z Shift On Intensity*** ***(available with Production license only):*** The 'Z Shift On Intensity' tool is located on the Coordinate Conversion Tab 254 under the 'Z Shift' drop-down button. This tool is capable of shifting LAS data that matches a specific user defined intensity value. The 'Z Shift Value' (amount and direction of shifting) is also defined by the user.

  After the LAS data is added into the 'Z Shift On Intensity' tool, the 'Intensity Requirement' text boxes are used to specify an 'Intensity' value that will be used to identify which points should be shifted, and the 'Z Shift Value' to apply to those intensities. Multiple entries can be made in this section. An output folder can be designated and progress can be tracked in the 'Z Shift On Intensity' interface. **If no Output Folder is specified, the input LAS files will be overwritten.**

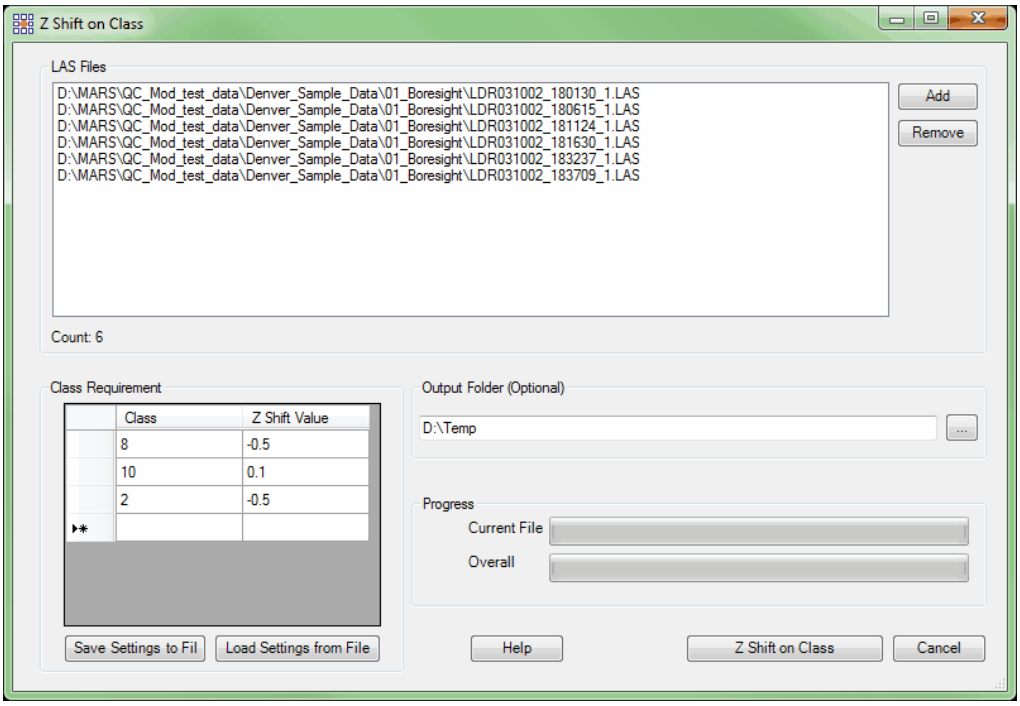
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- ***Z Shift On Class*** ***(available with Production license only):*** The 'Z Shift On Class' tool is located on the Coordinate Conversion Tab[254] under the 'Z Shift' drop-down button. This tool is similar to the 'Z Shift On Intensity' tool, but uses classifications to determine which points will be shifted.

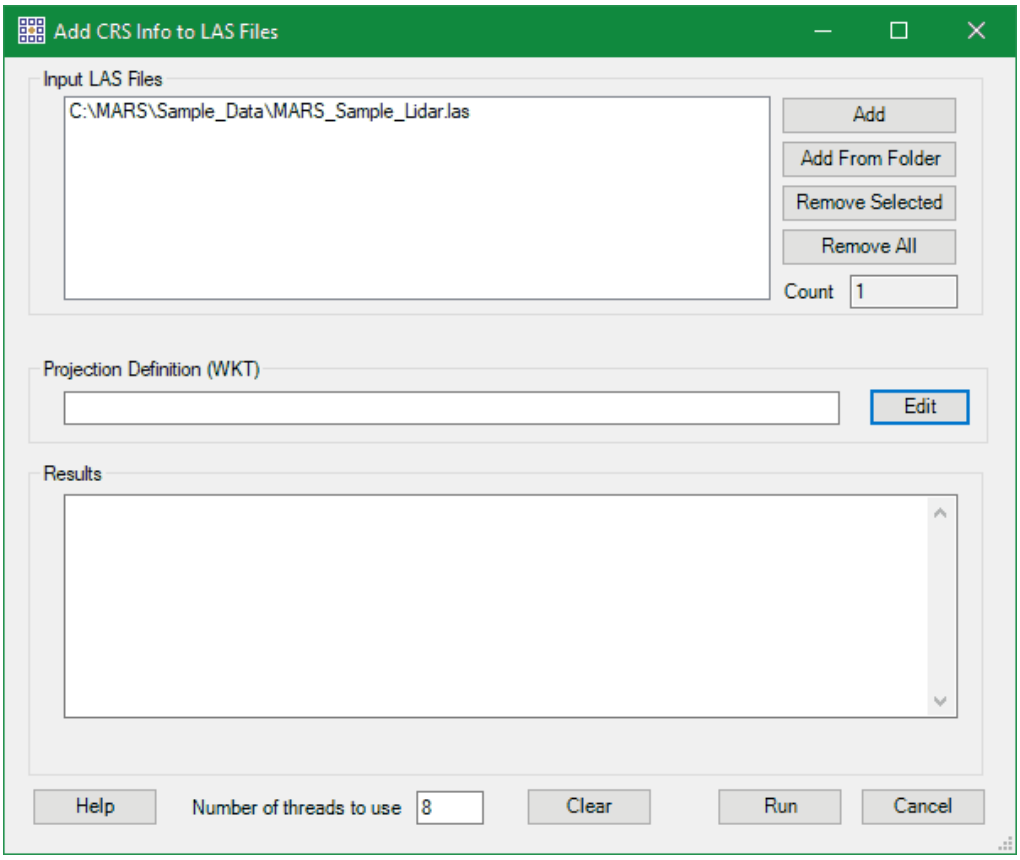
  After the LAS data is added into the 'Z Shift On Class' tool, the 'Class Requirement' text boxes are used to specify a 'Class' value that will be used to identify which points should be shifted, and the 'Z Shift Value' to apply to those classes. An output folder can be designated and progress can be tracked in the 'Z Shift On Class' interface. **If no Output Folder is specified, the input LAS files will be overwritten.**

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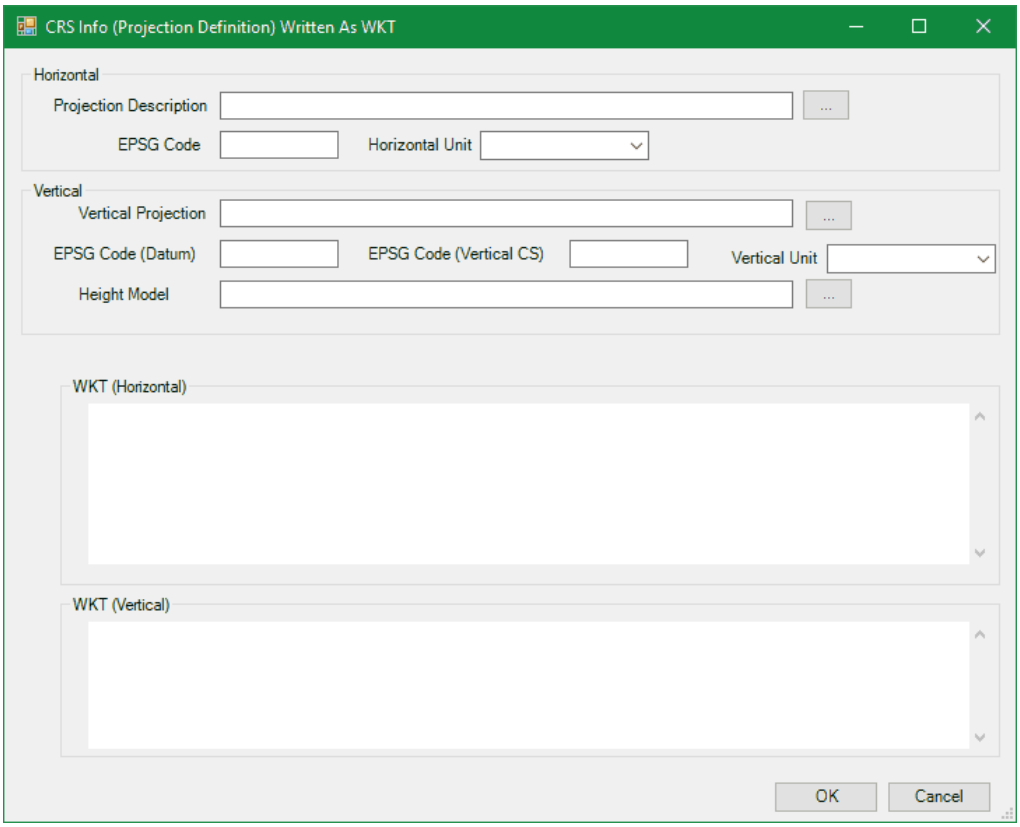
- ***Add CRS Info (to LAS Files):*** This tool, found on the Coordinate Conversion Tab[254], allows the user to add or update coordinate reference system (CRS) information in an LAS file. For LAS version 1.4 files, the tag is written as WKT (Well-Known Text) in an Extended Variable Length Record (EVLR). *Running the tool with no information entered in either the Horizontal or Vertical sections will result in any existing info being cleared.* This tool is capable of processing an entire folder of LAS files ('Add From Folder'), or the user may specify one or more individual files ('Add'). Files already added can be selected and removed (using standard Windows mouse/keyboard controls) by using the 'Remove Selected' or 'Remove All' buttons.

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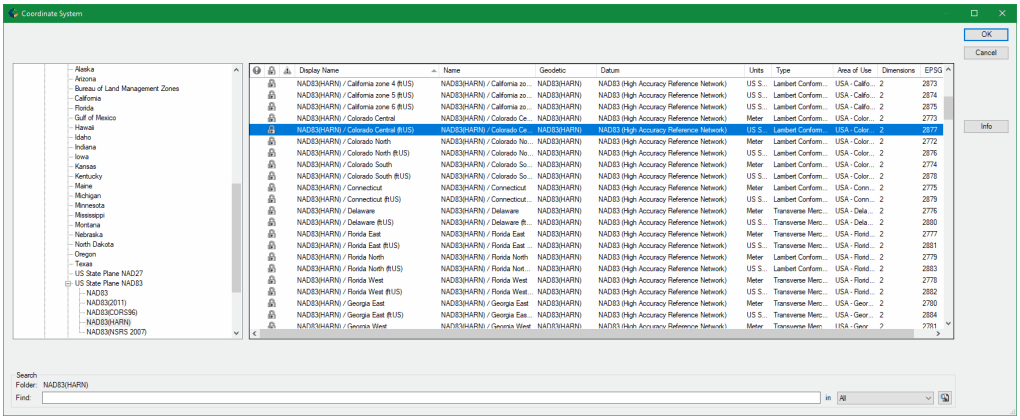


After choosing the desired file(s) or folder, select the coordinate reference system that the data is in by clicking the 'Edit' button beside the 'Projection Definition (WKT)' text box. The 'CRS Info (Projection Definition) Written as WKT' window will then appear.

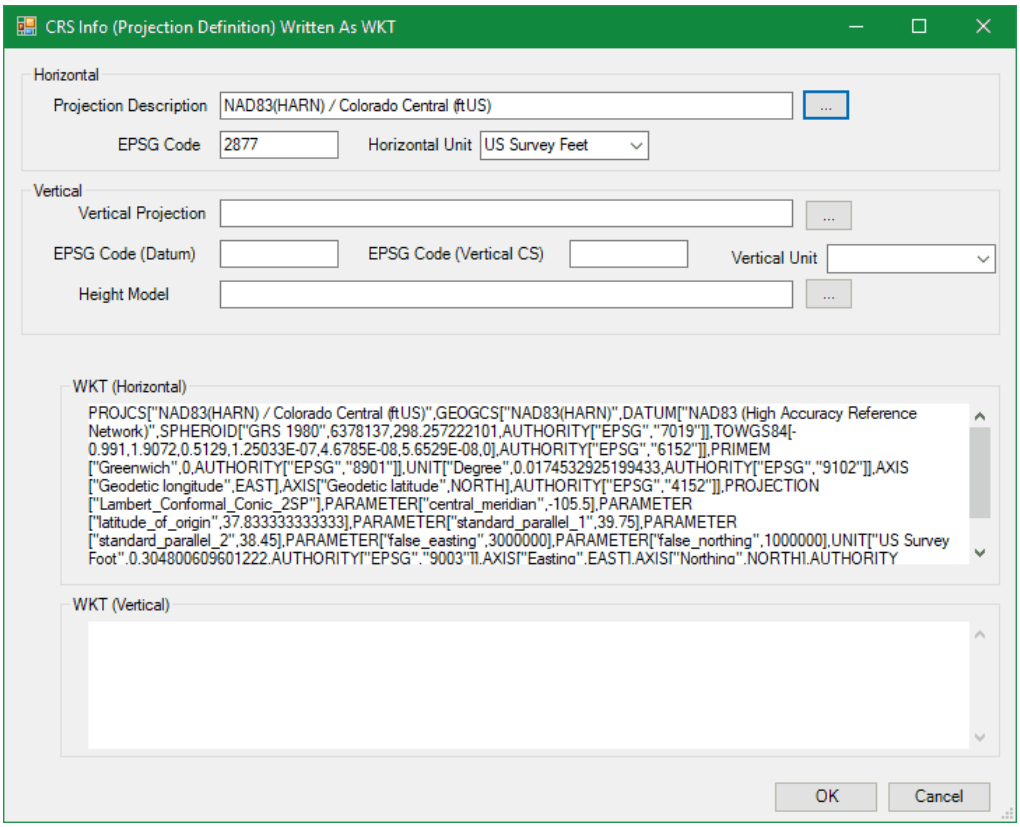
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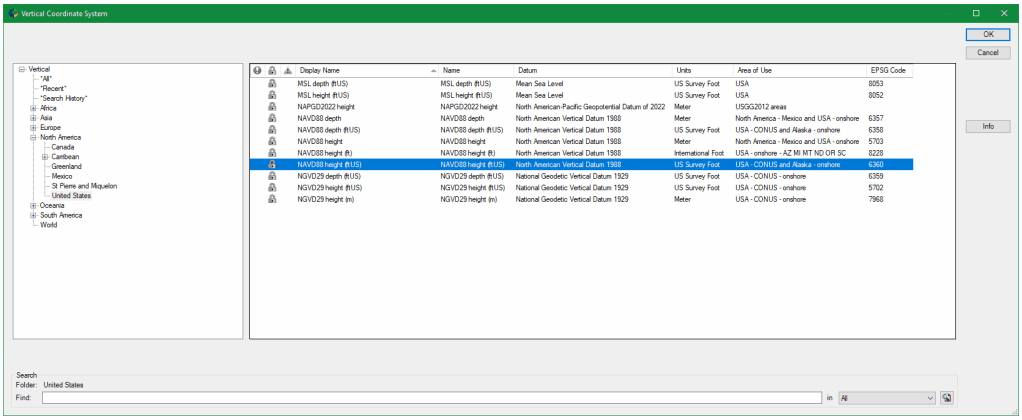
Click the browse button ('...') next to the 'Horizontal Projection Description' text box to bring up the 'Coordinate System' selection interface, and choose the horizontal coordinate system of the data. The user may either navigate to the system which defines the data and click **'OK'**, or the **'Find'** search engine at the bottom of the interface may be used to help find the desired coordinate system.



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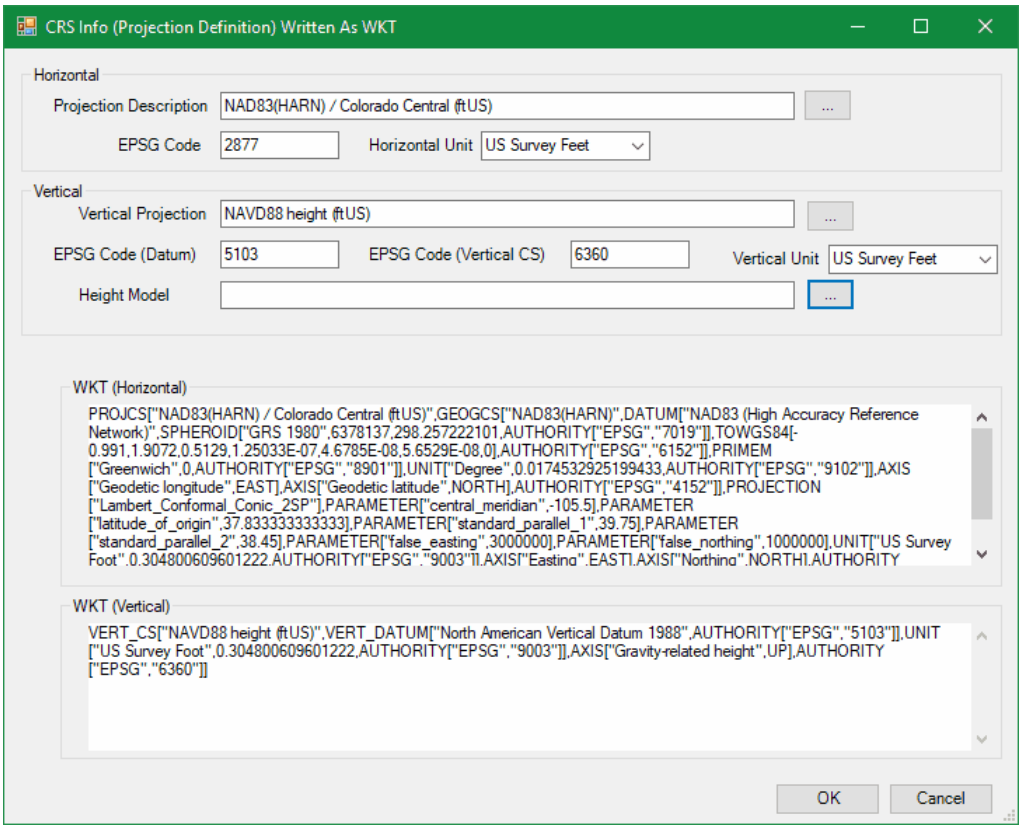


Next, click the browse button ('...') next to the 'Vertical Projection' text box to bring up the 'Vertical Coordinate System' selection interface, and choose the vertical coordinate system of the data in a similar manner.

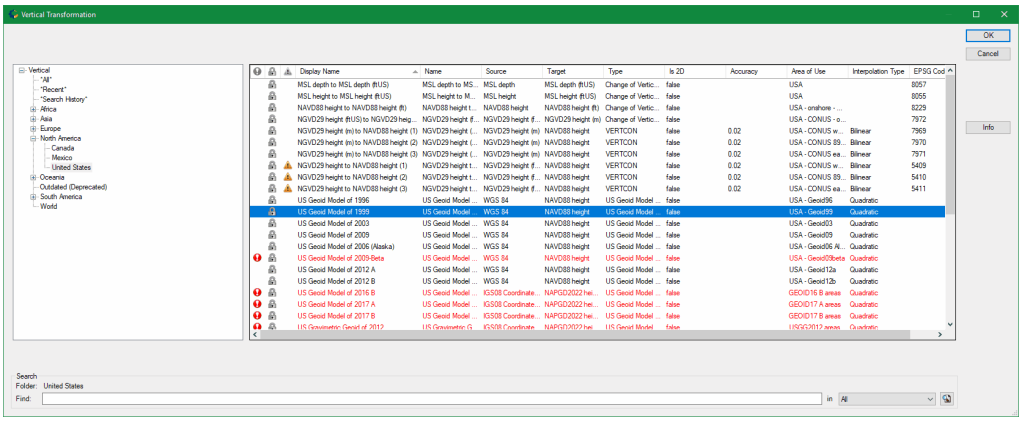


Be sure that both the 'Horizontal Unit' and 'Vertical Unit' boxes are correctly populated on the 'CRS Info (Projection Definition) Written as WKT' interface.

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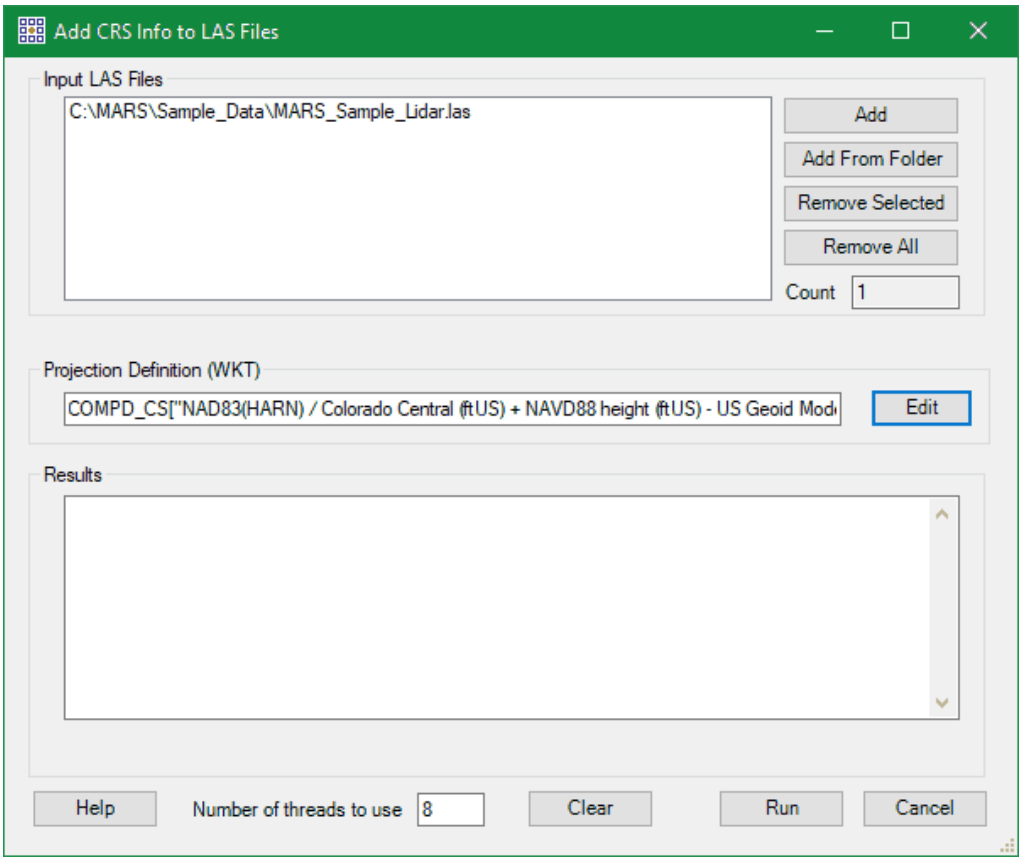


The 'Height Model', if known, can be selected by using its browse button and choosing the appropriate model from the 'Vertical Transformation' selection interface.



When all information has been entered on the 'CRS Info (Projection Definition) Written as WKT' interface, click the 'OK' button to return to the original 'Add CRS Info (to LAS Files)' tool.

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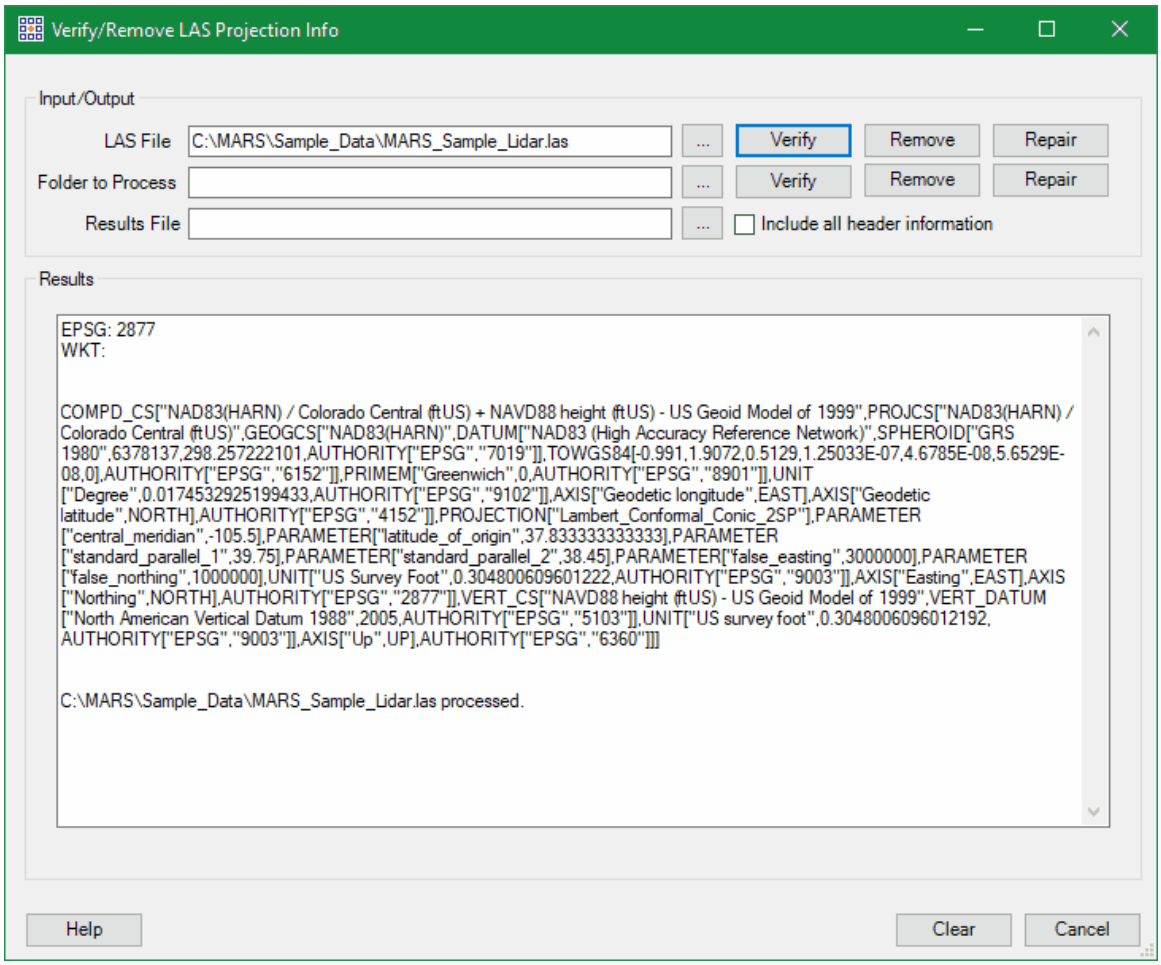
Like many other MARS® tools, this tool is capable of multi-threading to decrease processing time. The **'Number of threads to use'** text box at the bottom of the interface will automatically be populated with the maximum number of threads available on the particular computer in use. A lower number of threads can be entered as needed. A value of '1' is equivalent to single-thread processing. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Click on the **'Run'** button at the bottom of the interface to start the processing. The file or files that were defined will appear in the 'Results' section, and a completed message will indicate when all processing is finished. The **'Clear'** button can be used to remove **'Input LAS Files'** and **'Results'** information to prepare for additional processing.

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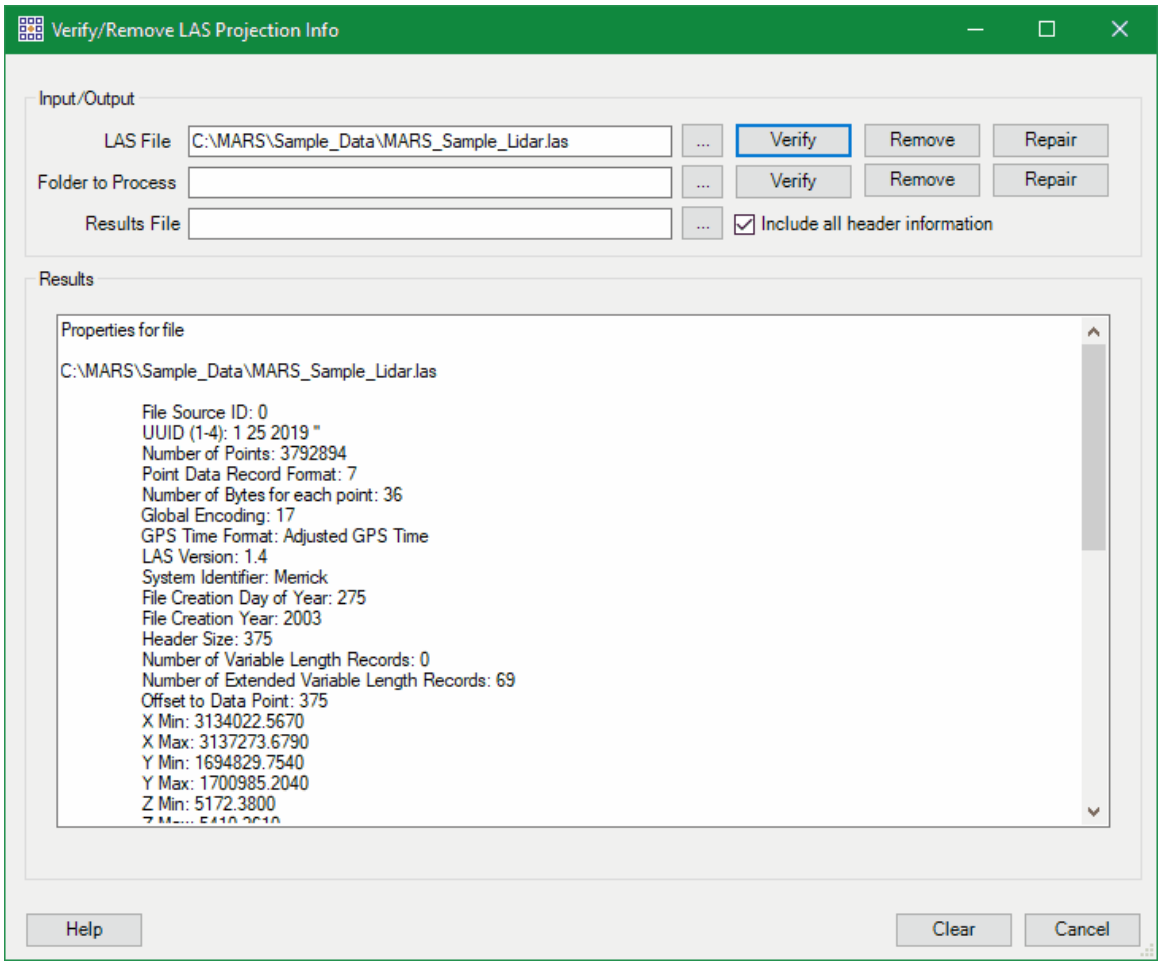
- ***Verify/Remove LAS Projection Info:*** This tool, found on the Coordinate Conversion Tab[254], allows the user to verify the projection definition (coordinate system) information for an LAS file or an entire folder of files and, optionally, save the displayed output to a Results File. The user can navigate to an individual LAS file or a folder of LAS files depending on the browse button used. Clicking on the corresponding **'Verify'** button will start the process and the results will be shown in the **'Results:'** box. If the user wishes to clear (remove) projection information from an LAS file or folder of files, click on the corresponding **'Remove'** button. The **'Repair'** button fixes certain errors in superseded WKT-based coordinate system tags in LAS v1.4 files. The function will search all EVLRs or VLRs containing superseded WKT tags and fix incorrect 'Record ID' values of '0' (zero) to the correct value of '7'. It will also fix incorrect values of the 'User ID' field - 'LAS_Spec' and 'LASF_Projection' - to the correct 'LASF_Spec' for superseded records, so that the files will be in compliance with ASPRS specifications.

  In addition, an option - '**Include all header information**' - exists that will display and, optionally, save the header contents (similar to metadata) as well as the projection information.

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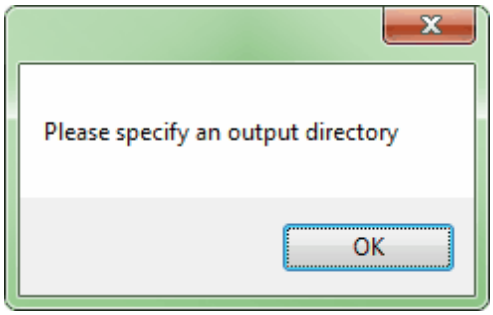
The **'Clear'** button can be used to remove **'Input/Output'** and **'Results'** information to prepare for additional processing.

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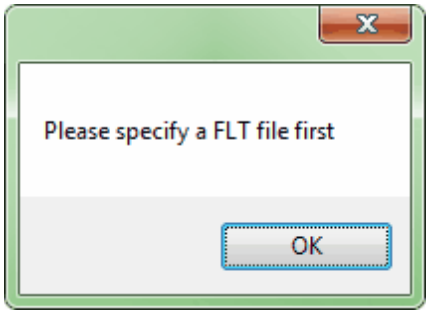
4.3 Raster Tools



- ***Float Grid to Hillshade:*** This tool, found on the Tools Tab[389] under the 'Format Conversion' drop-down, allows the user to create a hillshade image or raster from a gridded, elevation float grid (*.flt). This tool inputs a float grid and is capable of outputting a JPEG 2000 file, BMP file, IMG file, or float grid file. It is important to understand that the output file created by this tool is an image or raster. It is meant to display quickly, similar to the performance of a compressed .ecw file. Because this tool creates an image file, the resulting file may only be viewed in 2D (orthographic) view[835] and CANNOT be seen in 3D.
  - **Output folder:** Click on the **'...'** button and navigate to or key in an output folder for the finished image or raster product. There must be an output folder specified to use this tool. If an output folder is not designated, the following prompt will appear:

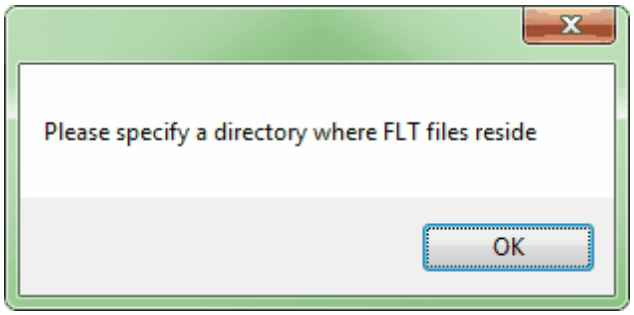


  - **FLT File:** By clicking on the corresponding **'...'** button, the user may navigate to a single input *.flt file. This is the file that will be used to create an image or raster. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'FLT File' is not specified and the user attempts to click on the corresponding '**Convert**' button, the following prompt will appear:



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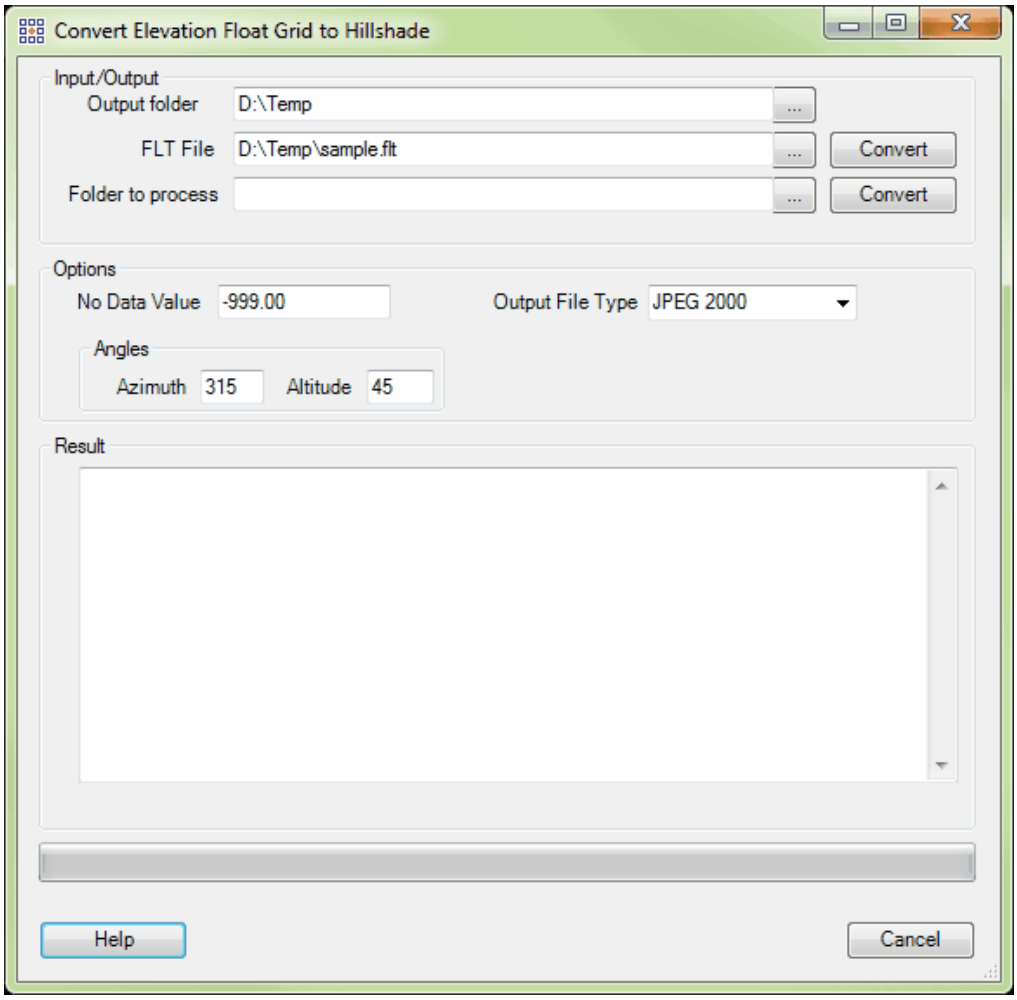
- **Folder to Process:** By clicking on the corresponding **'...'** button, the user may navigate to a folder. Every *.flt file inside the specified folder will be converted to an image or raster if this option is chosen. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'Folder to Process' is not specified and the user attempts to click on the corresponding **'Convert'** button, the following prompt will appear:



- **No Data Value:** If there is a data void in the data set (no information within the cell), a 'No Data' value is assigned. Cells with null values will be given a default value of -999.00 unless otherwise specified. Enter an integer in the text box for the No Data Value if another value is preferred. *Note: Water does not reflect LiDAR points, so water should be considered a No Data area.*
- **Output File Type:** The user may specify here which type of product the tool should output. The user may choose from outputting a JPEG 2000 file, float grid, IMG file, or BMP file. Click on the drop-down to display the choices.
- **Result:** The 'Result' text box will show the user the processing of the tool. When the file has been converted, the result text box will display that the specified *.flt file(s) were processed.

The example below shows the 'Convert Elevation Float Grid to Hillshade' window:

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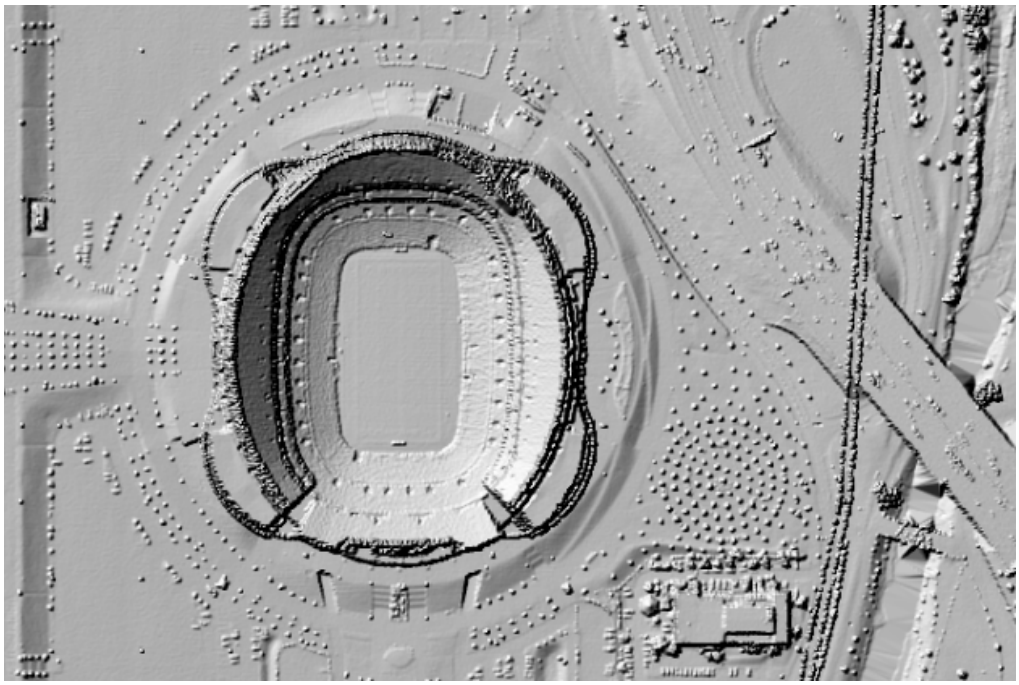


After the conversion has taken place, go to the output directory which was specified and load the resulting image or raster file into MARS®. The file will be renamed with the same name as the float grid file which was the input *.flt along with '_Hillshade' appended to the end of the file name. For example, the 'sample.flt' file which was the input *.flt in the example above was output as a JPEG 2000 file and named 'sample_Hillshade.jp2'. Load the newly converted file to MARS® to view it.

Below is a sample of the newly created 'sample_Hillshade' JPEG 2000 file. Because the resulting file is an image file, panning and moving around the data is much quicker than

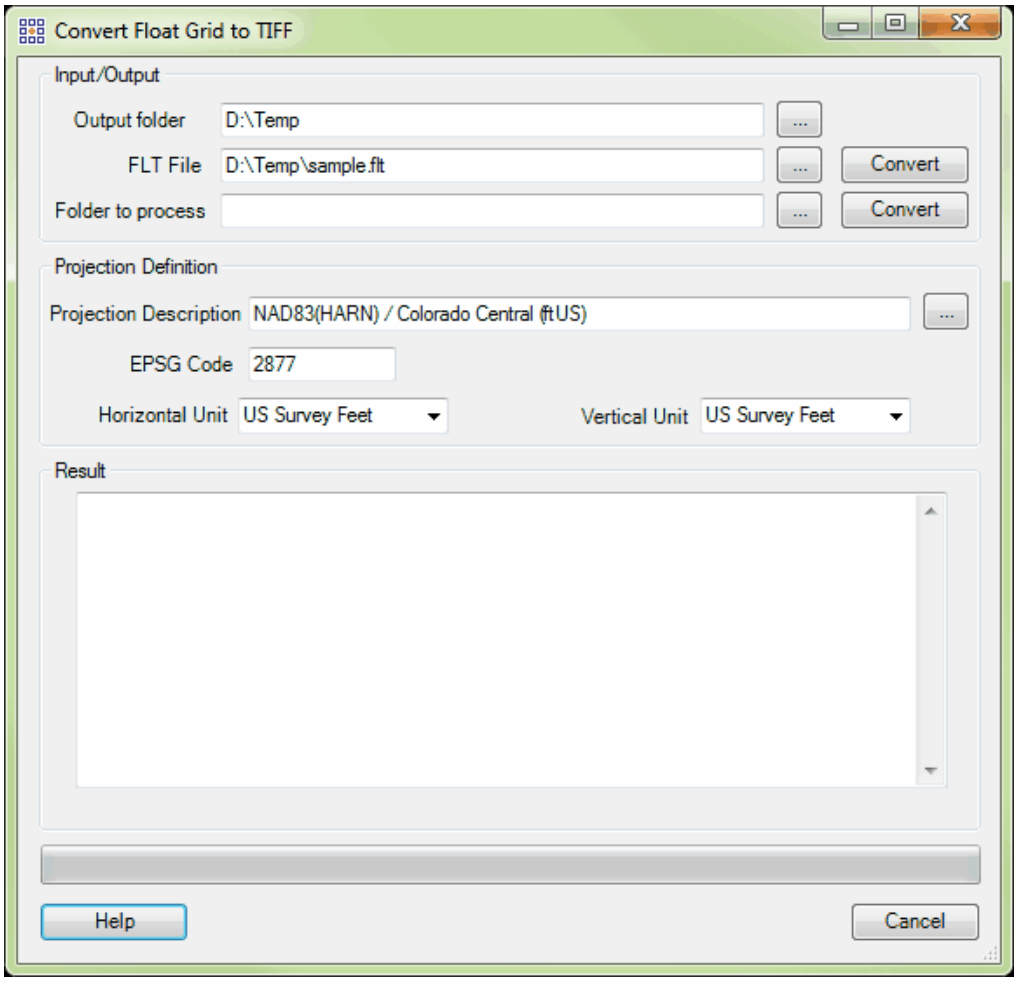
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using the corresponding float grid with hillshade created 'on the fly'.



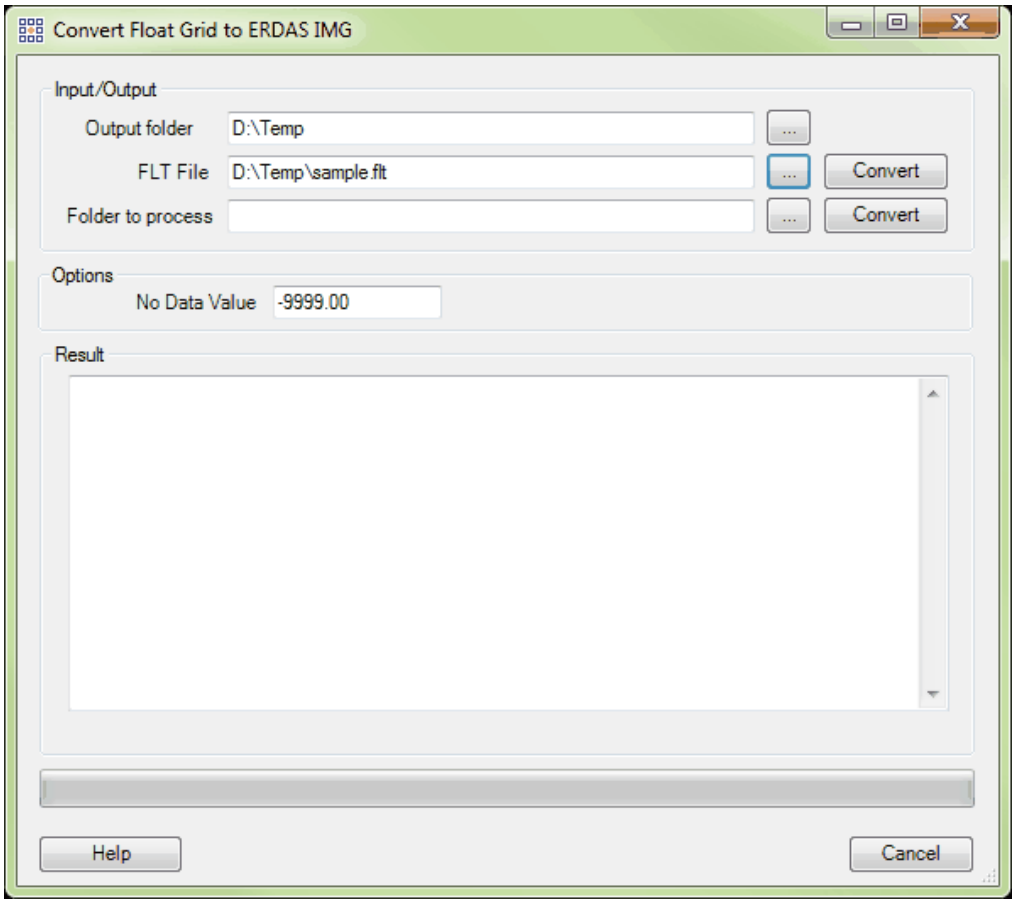
- ***Float Grid to TIFF*** ***(available with Production license only):*** This tool, found on the Tools Tab 389 under the 'Format Conversion' drop-down, will convert an existing Float Grid or folder of Float Grids to the GeoTIFF format. To use, choose a Float Grid file or folder using the appropriate browse button and select or key in an 'Output Folder.' Please note that the source *.FLT and *.HDR files must be in the same folder. Projection definition information may (optionally) be applied to the new TIFF(s) by selecting the horizontal system name (the browse button will bring up the GeoCalc 1748 interface where a selection can be made) and entering the Horizontal and Vertical Units from the drop-down boxes. Click the appropriate 'Convert' button to begin the process.

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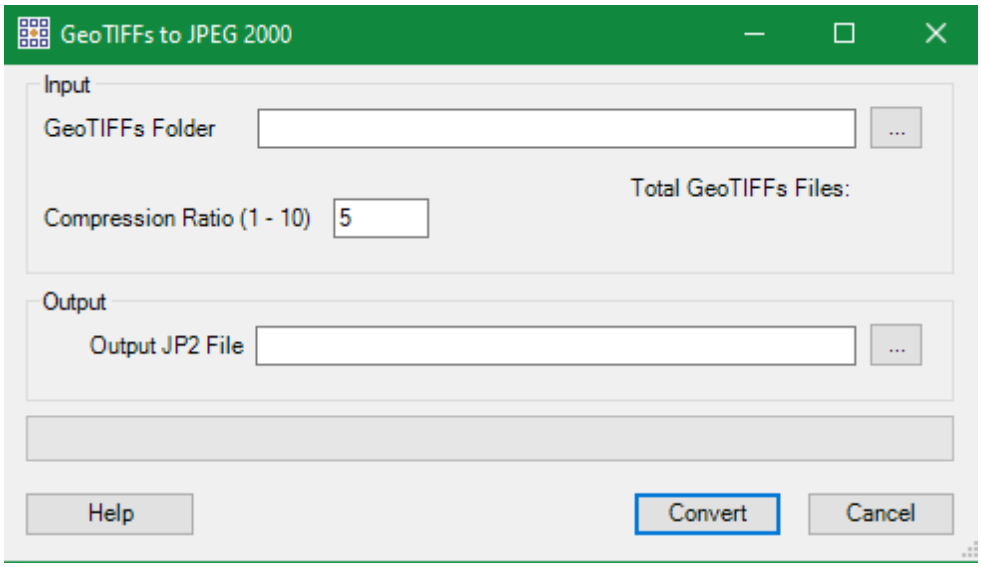
- ***Float Grid to IMG*** ***(available with Production license only):*** This tool, found on the Tools Tab 389 under the 'Format Conversion' drop-down, converts a Float Grid (*.flt) to an ERDAS Imagine compatible IMG file. The conversion can be done by file or folder, and the 'No Data Value' can be specified by the user.

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- ***GeoTIFFS to JPEG 2000:*** This tool, found on the Tools Tab[389] under the 'Format Conversion' drop-down, combines a folder of GeoTIFF rasters into a single JPEG 2000 raster (JP2) with a user-specified name and output folder location. Browse to and select the folder containing the individual GeoTIFFs, and select the output file name and location. Regardless of the input format of the GeoTIFFs, the output raster will be a 3-band (RGB), 8-bit file. The tool is, therefore, not appropriate for merging floating point rasters such as DEMs into a single JP2 raster containing elevation values in the cells. The compression ratio can be modified to find the best balance of quality and file size. The default compression value is '5' on a scale of 1 (lowest compression, highest quality) to 10 (highest compression, lowest quality). An assumption is made that all input GeoTIFFs are in the same coordinate system and have the same cell sizes.

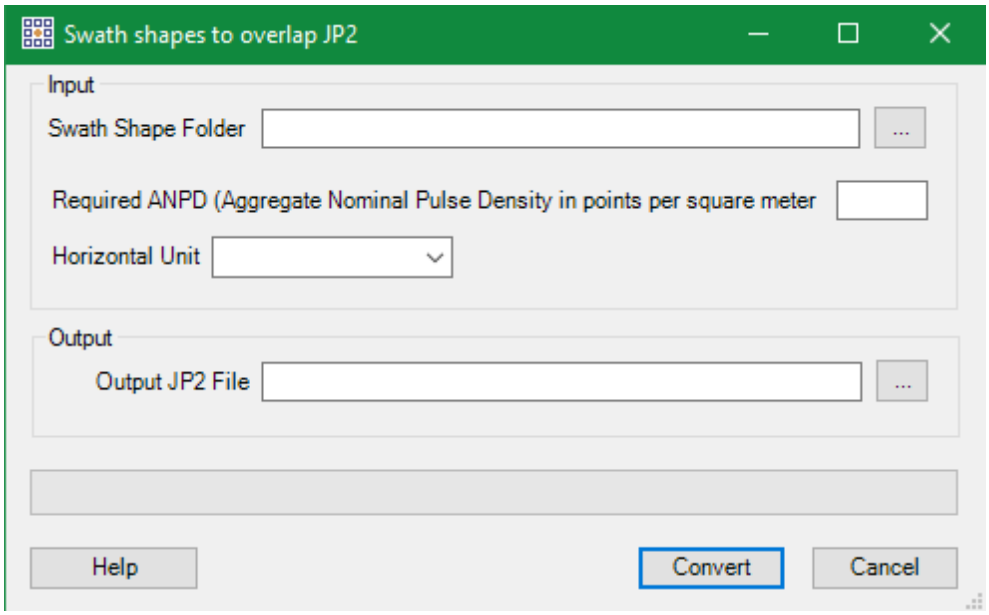
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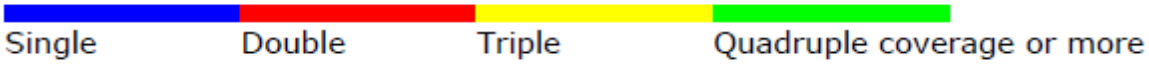
- ***Swath shapes to overlap JP2*** ***(available with Explorer QC and Production licenses only):***

  This tool, found on the Tools Tab[389] under the 'Format Conversion' drop-down, converts a folder of swath footprint shapefiles into a JPEG 2000 raster to allow faster and more complete coverage checking. Browse to and select the folder containing the swath footprint shapefiles (these must be polygons), and select the output file name and location. The 'Required ANPD' (Aggregate Nominal Pulse Density) must be input, and the 'Horizontal Units' (e.g., Meters or US Survey Feet) must be selected from the drop-down list to ensure the proper cell size is used in the raster creation.

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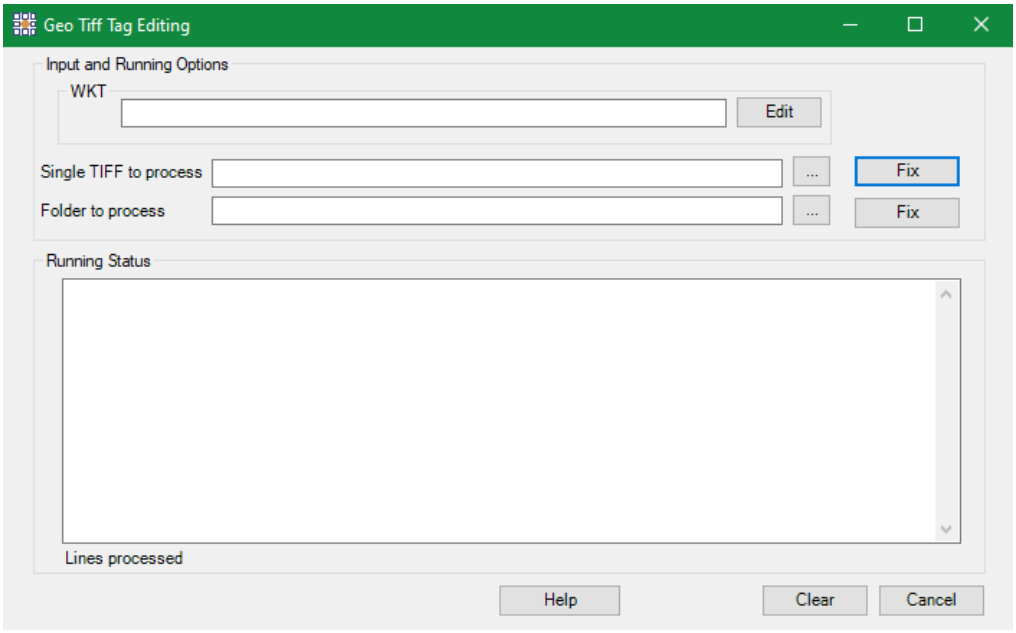


The output raster uses the same color coding as the 'Flight Line Overlap' raster in test DC10.1 of the Lidar Data Checks[1677] tool:



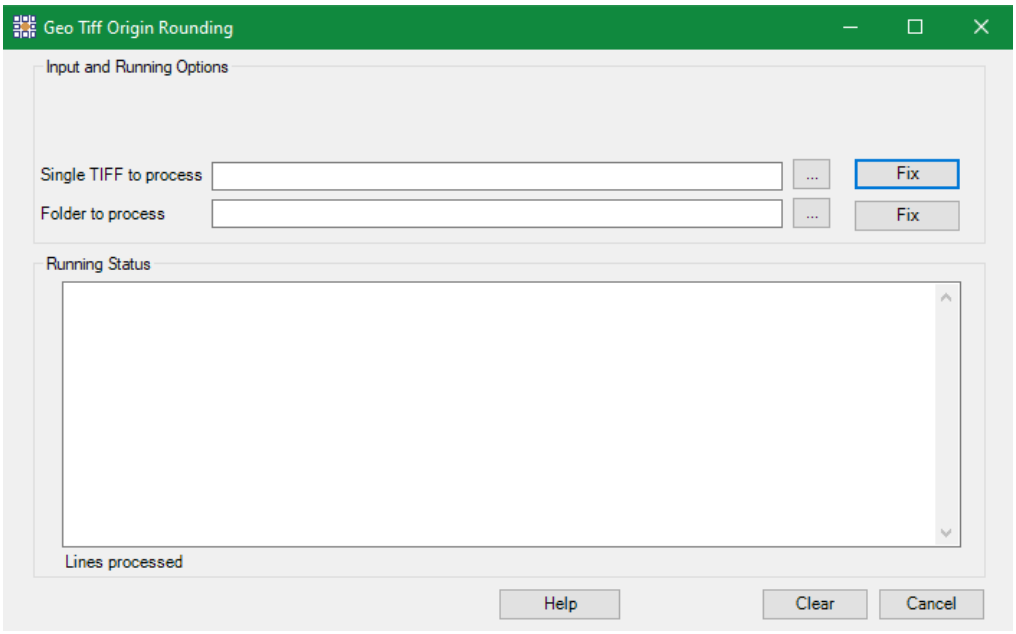
- ***TIFF Tag Editing*** ***(available with Production license only):*** This tool, found on the Tools Tab[389] under the 'Format Conversion' drop-down, creates a CRS (coordinate reference system) tag for TIFF files, or replaces an incorrect or incomplete tag. Click on the 'Edit' button to the right of the 'WKT' entry box to open a CRS selection window. Make the appropriate selections in the 'Horizontal' and 'Vertical' entry boxes in the top half of that window and click 'OK' (see the '*Add CRS Info (to LAS Files)*' topic in the Coordinate Conversion Tab[254] help section for details). Then browse to the TIFF ('Single TIFF to process') or TIFFs ('Folder to process') that need their tags edited and click the corresponding 'Fix' button. The 'Clear' button can be clicked to remove the results from the 'Running Status' box if another operation needs to be done. There is no output folder for this tool - the input TIFF or TIFFs are silently overwritten with the new versions.

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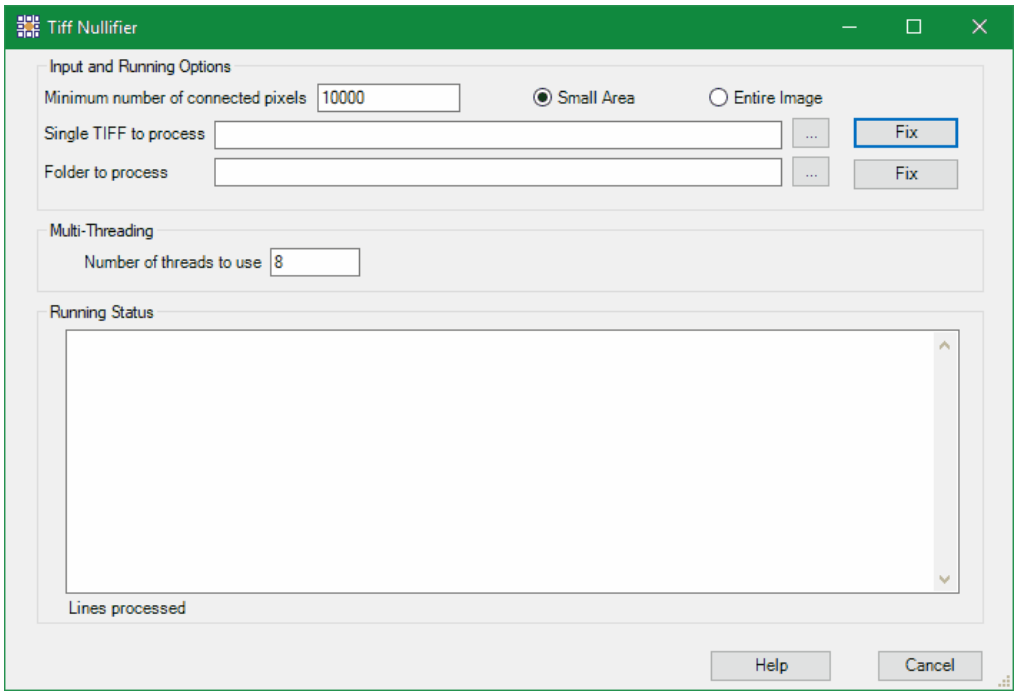
- ***TIFF Origin Rounding*** ***(available with Production license only):*** This tool, found on the Tools Tab[389] under the 'Format Conversion' drop-down, rounds off raster extent values to three decimal places, allowing for better edge-matching with adjacent rasters and better agreement with tile boundary coordinates. Browse to the TIFF ('Single TIFF to process') or TIFFs ('Folder to process') that need rounding and click the corresponding 'Fix' button. The 'Clear' button can be clicked to remove the results from the 'Running Status' box if another operation needs to be done. There is no output folder for this tool - the input TIFF or TIFFs are silently overwritten with the new versions.

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- ***TIFF Nullifier*** ***(available with Production license only):*** This tool, found on the Tools Tab[389], finds clusters of connected pixels with cell values of 1,1,1in one or more 3-Band (RGB) TIFF images, and re-writes those values to 0,0,0. The minimum number of connected pixels can be set, along with the search area parameters. When 'Small Area' is selected, the tool will be expecting only a single area to be modified, and the process will terminate after locating and re-writing that area. If 'Entire Image' is selected, the tool will search the entire TIFF for areas meeting the minimum cluster size before stopping. This tool will benefit from Multi-Threading when the 'Folder to process' option is used. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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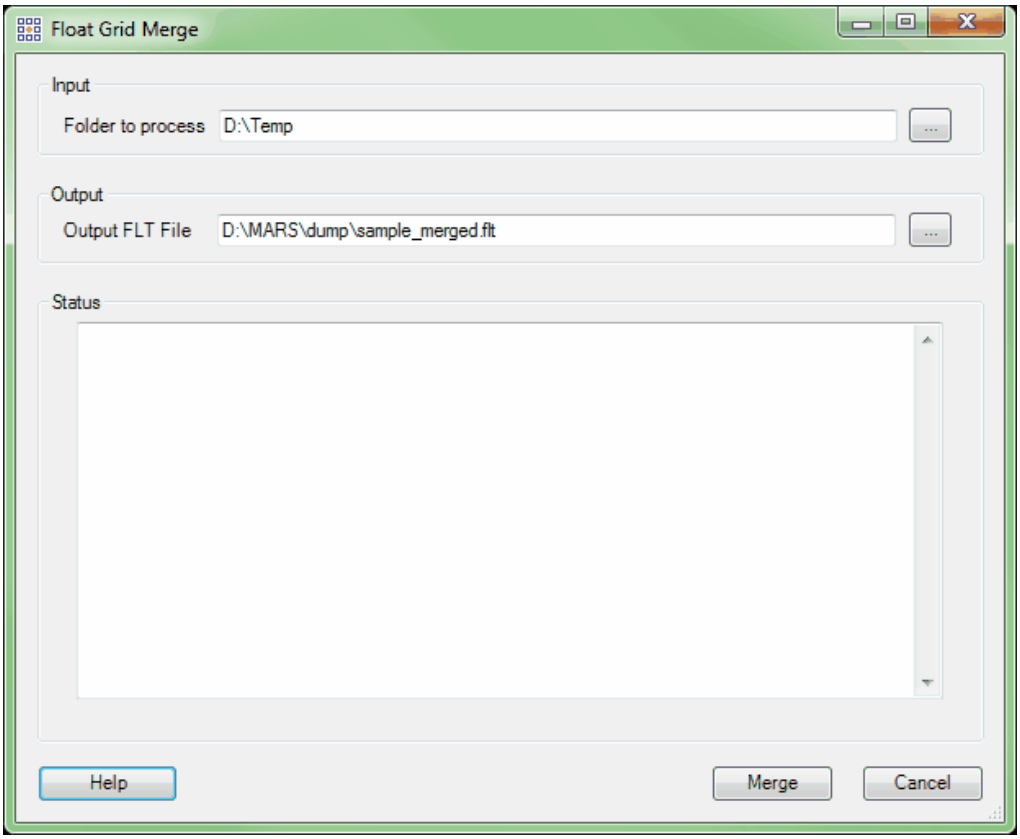


- ***Float Grid Merge:*** The 'Float Grid Merge' tool, found on the Tools Tab[389] under the 'Float Grid Operations' drop-down, allows the user to combine multiple float grids into a single file. The files being merged inside this tool do not need into be loaded to MARS® prior to being merged. To use this tool:

    1. Place the singular float grids which will be combined to create the merged float grid into the same folder.
    2. Specify this folder in the '**Input: Folder to process**' text box. The user may navigate to the folder by clicking the '**...**' button.
    3. Next, specify the output folder and name the new float grid file. Clicking on the '...' button will allow the user to navigate to the designated output folder where the merged float grid will be placed after creation. The user must also name the new, merged file here. In the example below, the user has named this file 'Merged'.
    4. Click the **'Merge'** button to begin the process. The progress of the

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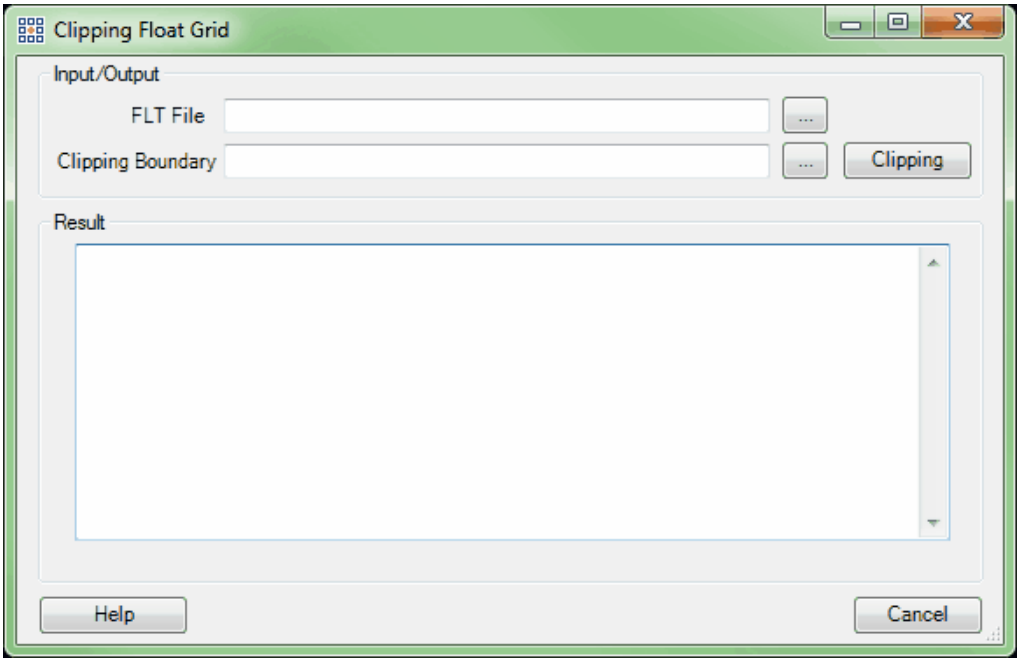
tool (by file) may be monitored in the bottom window of the interface. To view the result, the user must add the newly created float grid file by clicking the **'Add Float Grid'** button on the Project/Data Preparation Tab[162] and choosing the merged float grid file.



- ***Float Grid Clipping:*** This tool, found on the Tools Tab[389] under the 'Float Grid Operations' drop-down, allows a Float Grid to be clipped to the extents of a polygon shapefile. To use, click on the ellipse button to the right of the 'FLT File' text box and navigate to the Float Grid file to be clipped. Then choose the polygon shapefile to be used as a clipping boundary by clicking the ellipse button to the right of the 'Clipping Boundary' text box. Click on the 'Clipping' button to begin the process. A message will appear in the 'Result' box when the clipping is complete. ***NOTE: The existing file will***

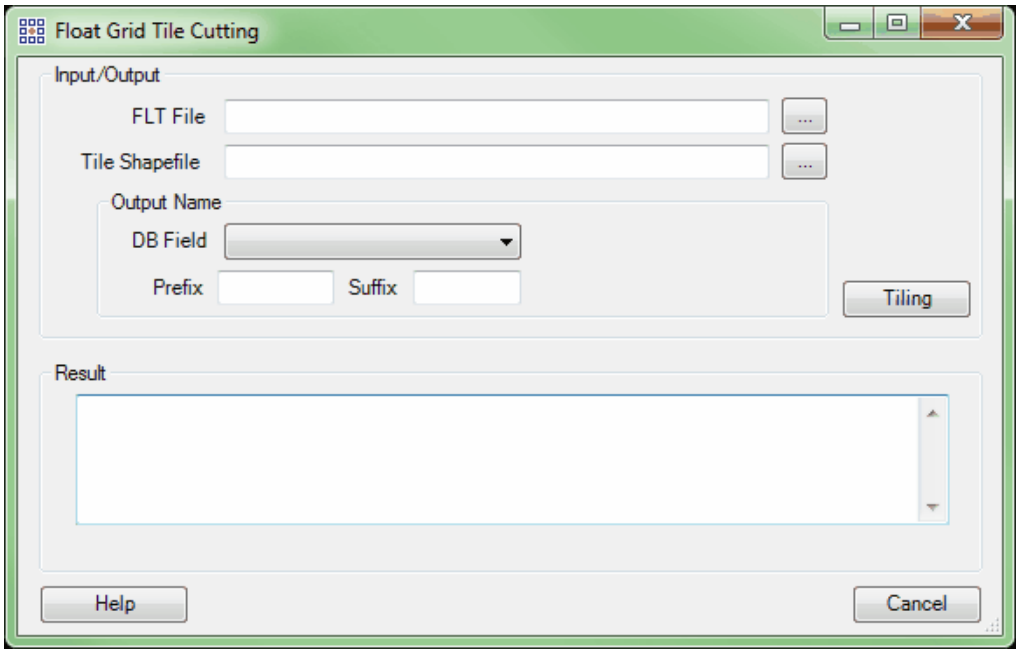
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be overwritten with the new result and only that grid data within the polygon(s) of the shapefile will be kept.



- ***Float Grid Tile Cutting:*** This tool, found on the Tools Tab[389] under the 'Float Grid Operations' drop-down, allows a Float Grid to be cut into individual areas based on a tile layout shapefile. To use, click on the ellipse button to the right of the 'FLT File' text box and navigate to the Float Grid file to be tiled out. Next, click on the ellipse button to the right of the 'Tile Shapefile' text box and navigate to the tile layout. All polygons in the tile shapefile will be used to cut the original Float Grid into individual areas. Now choose a unique-value attribute field that will be used to name the output Float Grids. Optionally, a 'Prefix' and/or 'Suffix' can be added to further define the new grid names. Click on the 'Tiling' button to begin the process. A message will appear in the 'Result' box when the tiling is complete. The new tile-based Float Grids will be output in the same folder as the original Float Grid, and the original will not be altered in any way.

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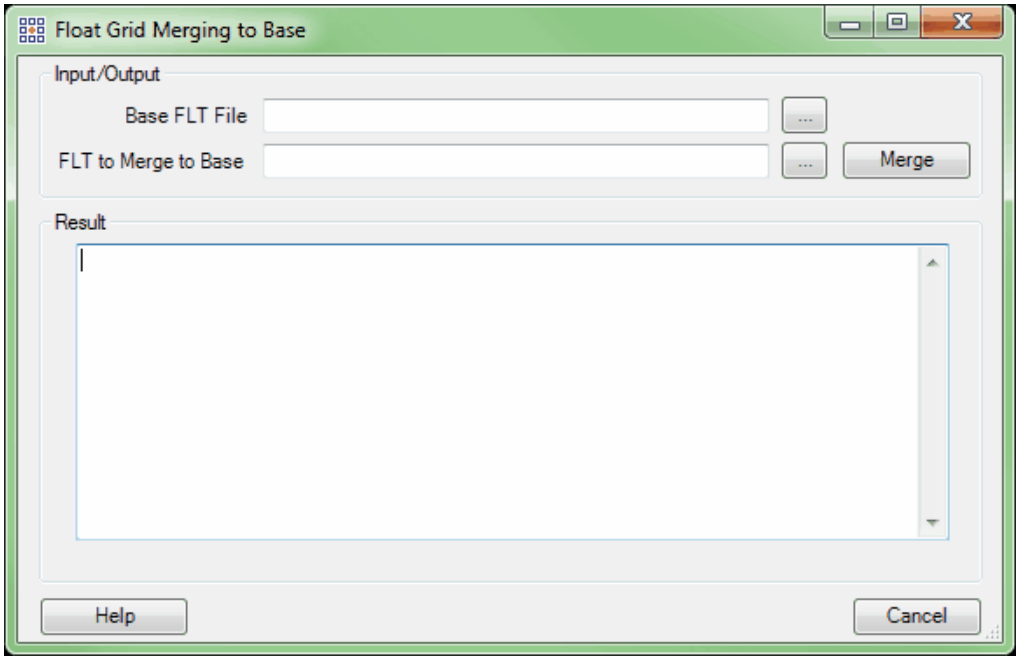


- ***Float Grid Merge to Base:*** This tool, found on the Tools Tab[389] under the 'Float Grid Operations' drop-down, can be used to replace a re-processed area of an existing Float Grid with corrected grid data. It is particularly useful when only a small portion of a large area single-file Float Grid needs to be replaced, and can save a considerable amount of time over re-exporting the entire project area. A typical workflow would be as follows: 1. After identifying a mis-classified area of a Float Grid, use a tile layout shapefile to determine which tile or tiles are affected. 2. Create a new tile shapefile with those tiles deleted. 3. Use the 'Float Grid Clipping' tool (above) to make a new Float Grid using the new tile shapefile as the Clipping Boundary - this will eliminate the bad area(s) from the original Float Grid. 4. Re-classify the LAS data as needed and export a Float Grid using only the tiles that encompass the modified area(s) - this export will be used as the 'patch.'

  To use this tool, click on the ellipse button to the right of the 'Base FLT File' text box and navigate to the Float Grid that needs to be patched. Next, click on the ellipse button to the right of the 'FLT to Merge to Base' text box and navigate to the new Float Grid data that will be used to fill the void in the base grid. Click the 'Merge' button to begin the process. A

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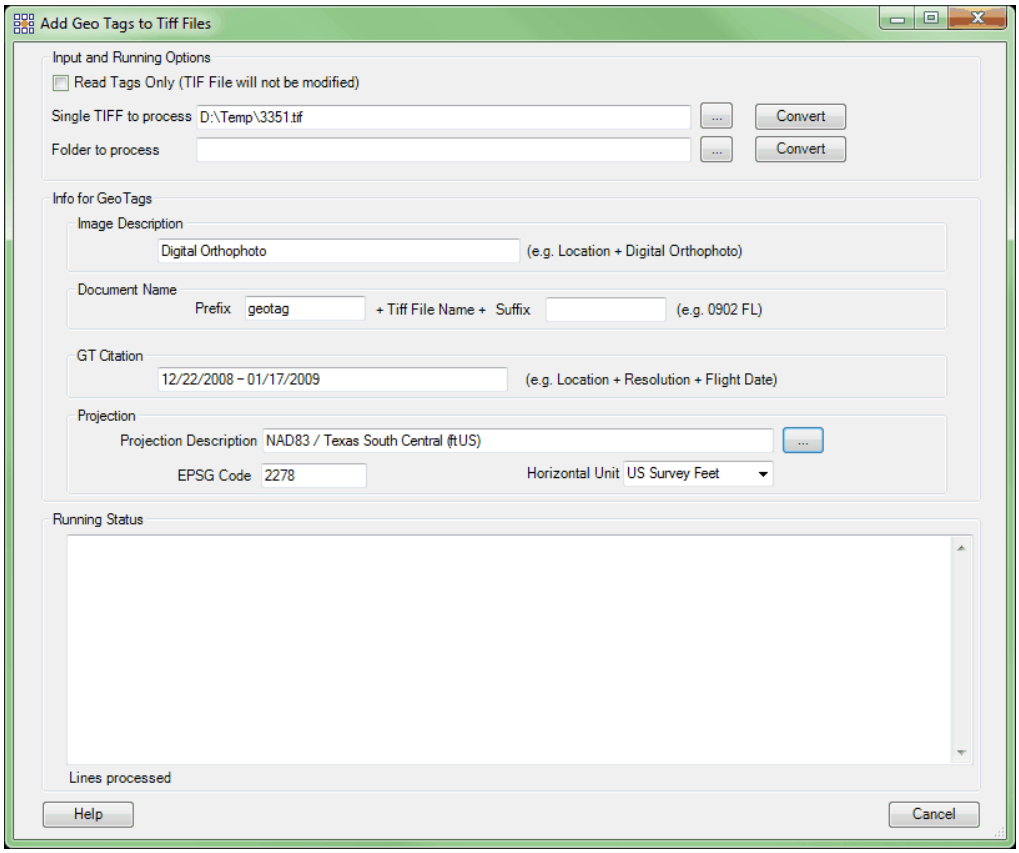
message will appear in the 'Result' box when the merge is complete. ***NOTE: The existing base Float Grid will be overwritten by the new merged grid data.***



- ***Add Geo Tags (to Tiff Files):*** This tool is a GeoTiff header tool meant for use with georeferenced tiff files. By navigating to the *.tif file to be converted and specifying all of the needed information, the user can produce a *.tif which will function on its own without the accompanying tiff world file (*.tfw). To produce a single GeoTiff file, start by navigating to the file which is to be defined. The *.tif and accompanying *.tfw must both reside in the same folder. If only a single file is to be defined, it is easiest to use the 'Single TIFF to process' text box. If an entire folder of tiff files is to be defined, using the 'Folder to process' text box will be faster. For the folder option, navigate to the folder which contains the tiff files to be defined. As the tiff images are loaded into the interface, the 'Image Description' and 'GT Citation' sections of the interface will automatically populate. If the user wishes to add a prefix or a suffix to the tiff file name(s), these can be specified under the 'Document Name' section. Lastly, specify the projection of the tiff file in the 'Projection' section. The user may

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choose the projection from a list by choosing the '...' button and either navigating to or running a search for the needed projection. Once the projection has been chosen, the 'EPSG Code' will automatically populate. Make sure to choose the correct horizontal unit, and the tiff file(s) will be ready to be defined. Click the appropriate 'Convert' button at the top of the interface and the 'Running Status' section of the interface will show the progress of the tool. The new tiff file(s), with georeferenced information in the header, will be found in the same folder in which the original tiff files were found. ***The original tiff file(s) will be replaced.***



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4.4 Data Convert

Converting Elevation Data to LAS

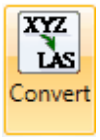
Merrick Advanced Remote Sensing (MARS®) Software

The MARS® Convert tool, found on the Project/Data Preparation Tab[162], is used to translate elevation data files to the LAS format, which MARS® natively supports. Specifically, MARS® is capable of converting **ASCII Text files (*.txt, *.dat, *.csv, *.xyz, *.grd), Esri ASCII Grids (*.asc), Float Grids (*.flt), and GeoTIFF Grids or TIFF Grids with world files (*.tif, *.tif/*.tfw)** to the LAS format.

NOTE: When the above-listed types of elevation data are converted into an LAS format 1.4 file, the resulting LiDAR points will be bit-flagged as 'Synthetic.'

For more information on the LAS specification, please visit the following link at the ASPRS Online Website.

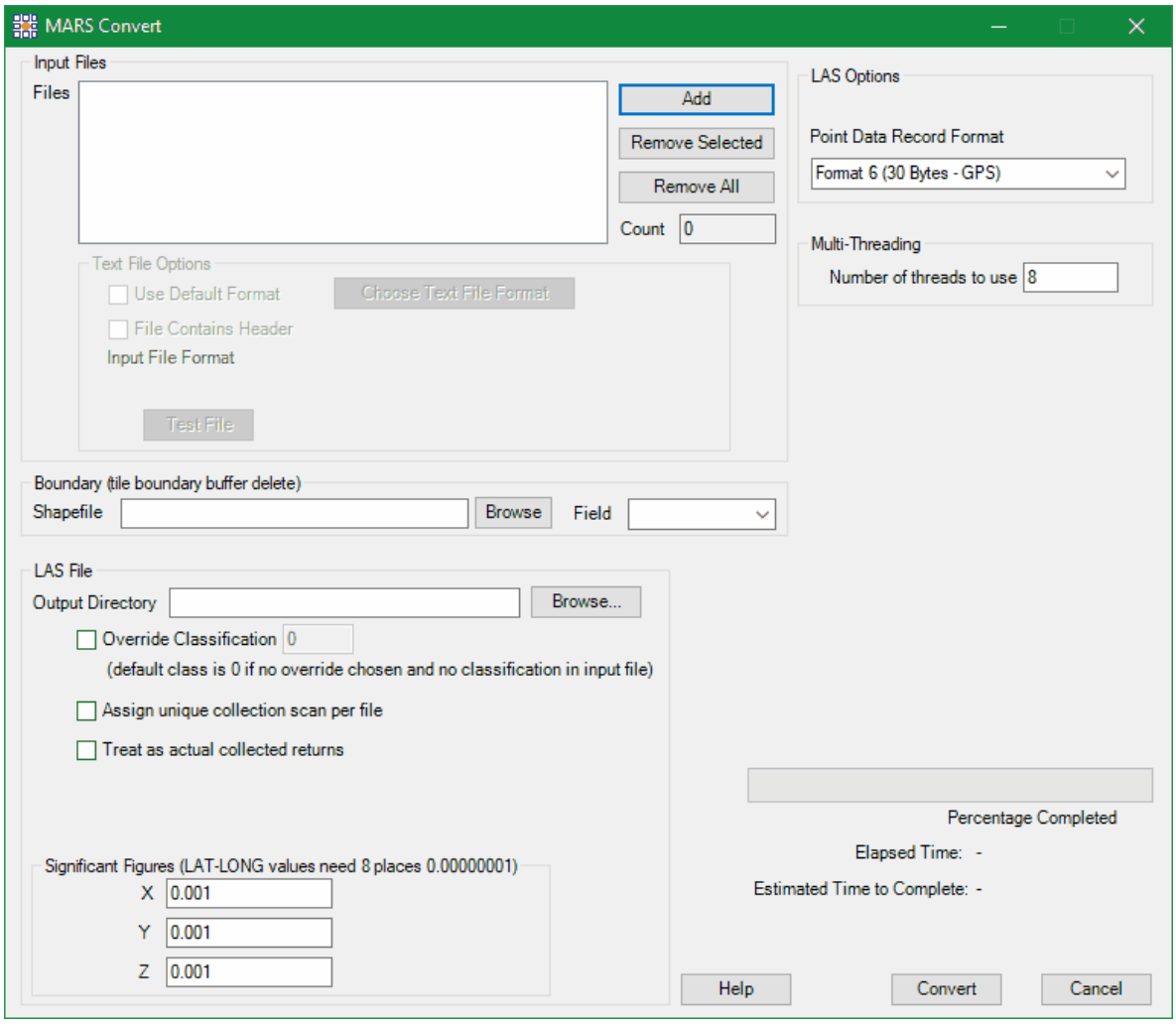
The following steps outline how to use the MARS® Convert tool:

Click the **'Convert'** button 

on the Project/Data Preparation Tab[162].

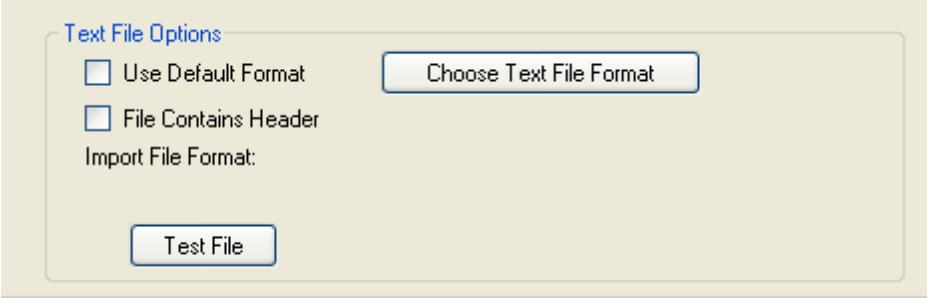
The following image shows the MARS® Convert dialog.

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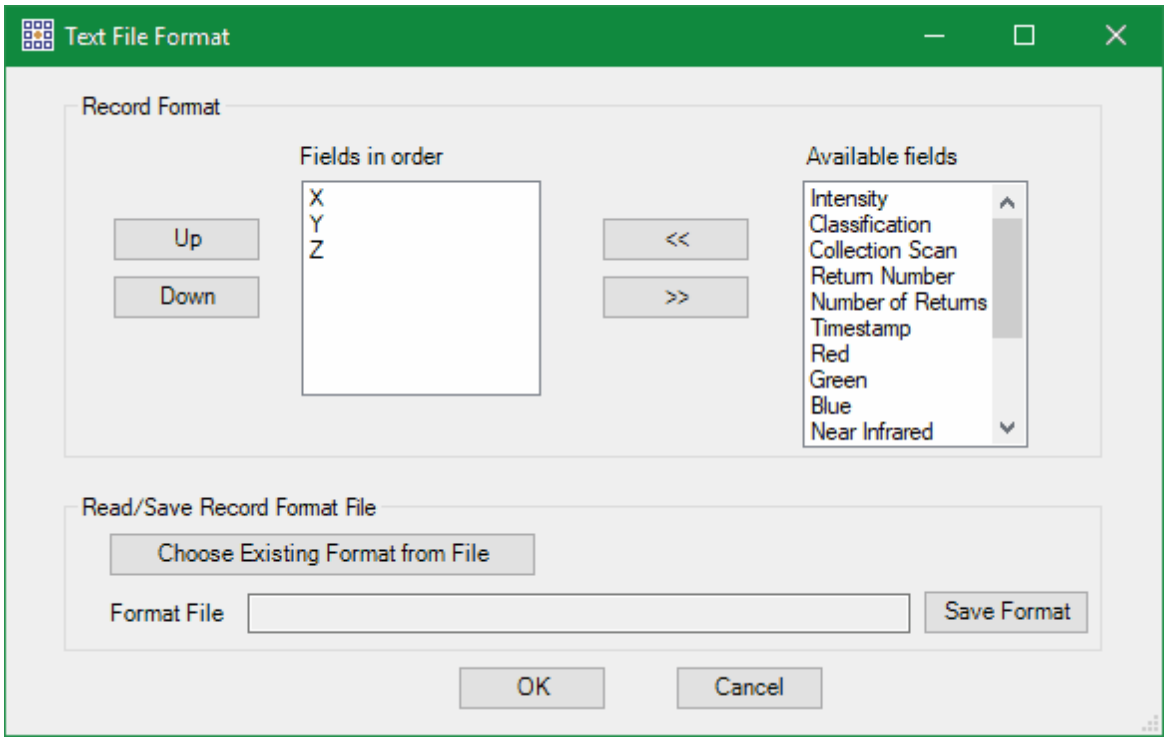
Text File Options: When either a *.txt or *.csv text file is selected to be converted, the 'Text File Options' dialog becomes available. Text files can be comma, space, or tab delimited. If the **'Use Default Format'** box is checked, the default fields will be used in the format. The default text format is XYZ with a space delimiter. If the file contains header information (i.e., a header row), select the **'File Contains Header'** check box, which causes the convert module to skip the first line of the file when creating point records.

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To further specify the format settings for the text file conversion, select the **'Choose Text File Format'** button. The X, Y, and Z fields are in the fields in order dialog box by default. If additional fields are necessary to convert the text file, the user can select the desired field from the right window of the dialog and click the **'<<'** button to add it to the file format definition in the left window. The user can also reorder the convert file format definition by selecting a field in the left window and using the **'Up'** or **'Down'** arrow buttons to match the text file format. In addition, the **'Ignore'** option from the attribute field list (left side of dialog) allows the user to disregard specific data values in the input file for translation. The **'Ignore'** field may be used as many times as necessary. If there is an existing record format file to be used on the data, select the **'Choose Existing Format from File'** button, browse to where the format file is kept, and click **'Open'**.

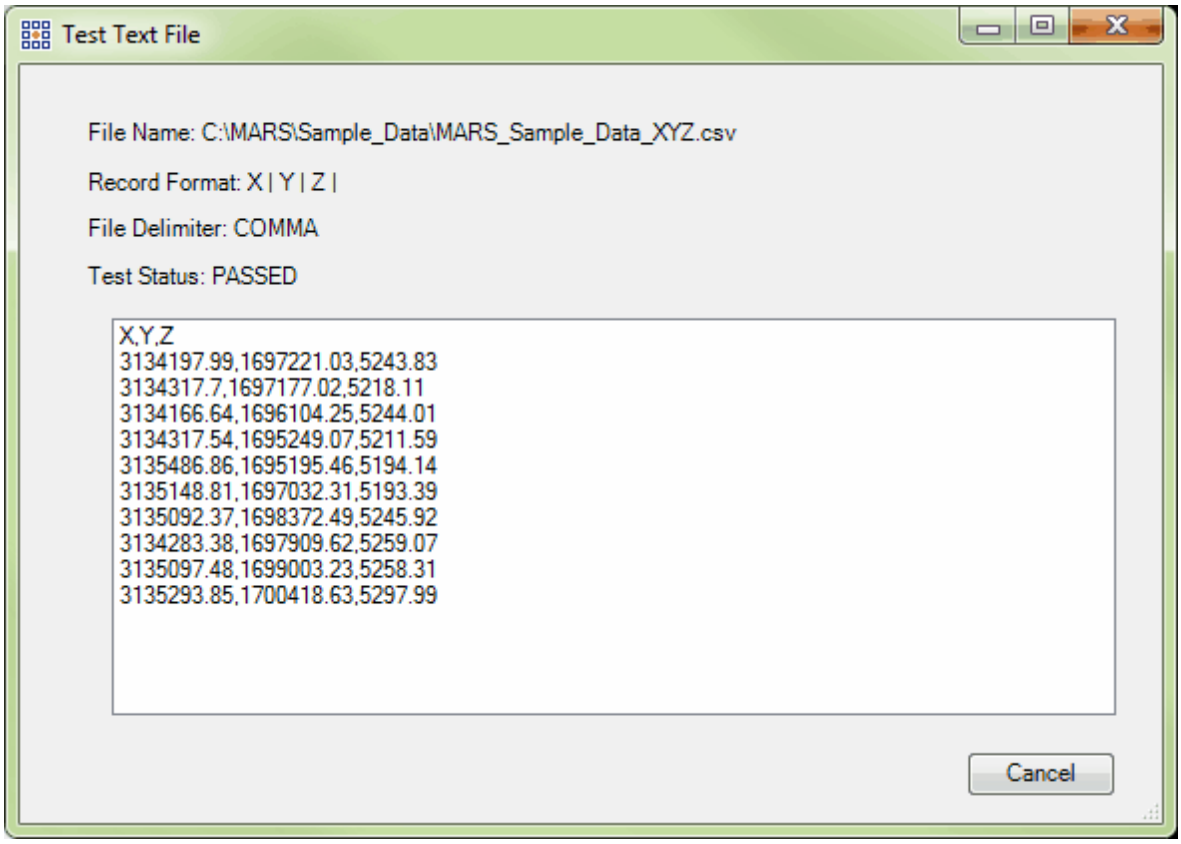
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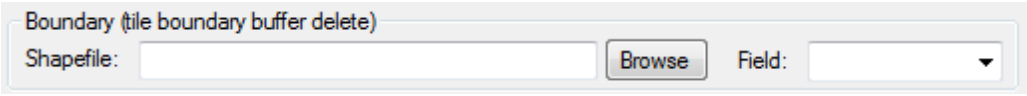
The user can bring in saved format settings ('Choose Existing Format from File'), and any unique settings described in the dialog box by the user can also be saved for use at a later time. Once the file definition to be used is complete, these values can be saved to an external file for reuse by clicking on the **'Save Format'** button. The target directory and file name for the file definition format can then be assigned. When all the dialog settings are complete, click **'OK'** to return to the previous convert window.

By using the **'Test File'** function on a selected (highlighted) file, the user can quickly verify that the inputted file format matches the actual contents of the target file. The **'Test File'** dialog is displayed to the user and provides a file status of **'PASSED'** or **'FAILED'**, and also displays the first several lines of the file for review purposes.

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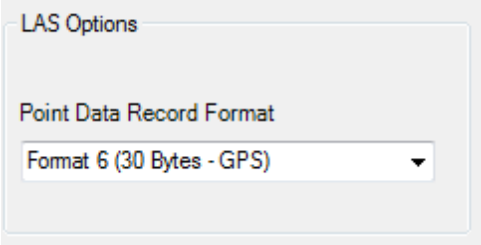


Boundary: The 'Boundary' section of the MARS® Convert module allows the user to clip the converted data with a polygon shapefile. The result of this process is that only the points within each feature in the shapefile will be converted into an LAS file. The names of the input files must **exactly** match values in the shapefile's chosen attribute field (TName in the image below). The created LAS files will have the same names as the input files.

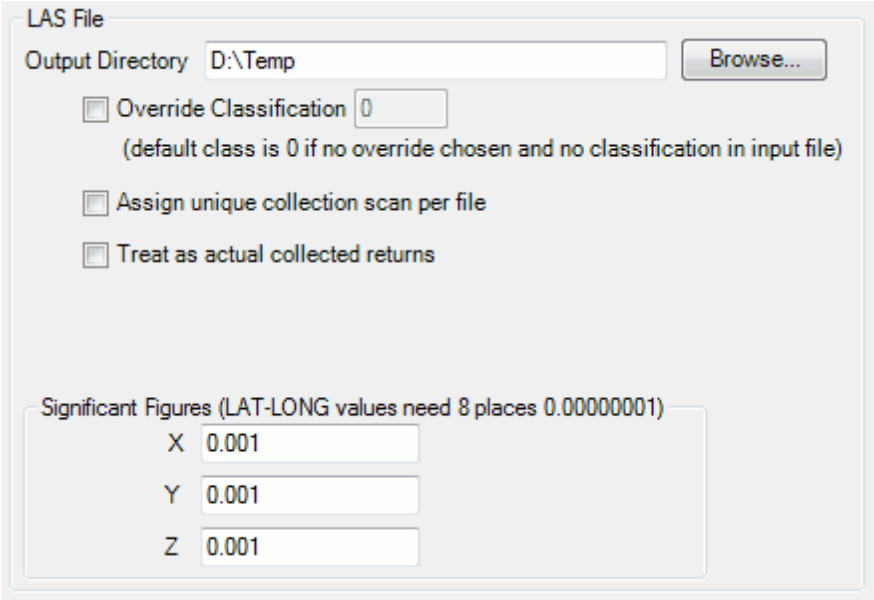


LAS Options: The 'LAS Options' section of the MARS® Convert module allows the user to create the new v1.4 LAS files using Point Data Record Formats of 6, 7, or 8 (depending on whether RGB(N) values are available in the input files).

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LAS File: The 'LAS File' section of the MARS® Convert dialog allows the user to modify the output LAS file and choose its output location.



Note: If the output directory is not specified by the user, the new LAS files will be generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the ***'Browse'*** *button and navigate to the desired directory or key in a path.*

Override Classification: The 'Override Classification' check box is used to assign a specific data classification to the converted dataset. For example, when converting "bare-earth" ASCII files to LAS, the user may choose to override the data classification to 2, which represents 'Ground (All)'. The default override classification value is 0 (zero).

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Assign unique collection scan per file: During the conversion process, the user may assign a unique collection scan number per file during LAS file creation, which is useful if each file contains only one (1) collection scan. This function is not necessary if the input files already contain collection scan information and the 'Collection Scan' field is used appropriately in the file-to-LAS mapping. This tool can also be implemented when converting TIFF files.

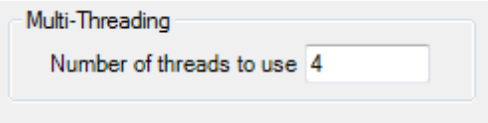
Treat as actual collected returns: This checkbox is available when converting ASCII Text files to LAS. The default is unchecked, since most text files of XYZ points do not represent actual LiDAR points. It should be checked if the coordinates in the file are known to represent actual collected returns.

Significant Figures (LAT-LONG values need 8 places 0.00000001): The 'Significant Figures' section of the Convert module should be utilized when the user is converting LAS files. The default value is set to 0.001 to retain the accuracy of any type of projected data (UTM, State Plane, etc.). In some cases where the 'X' and/or 'Y' extent of the data is very large, the tool may fail to make a valid LAS file. In this scenario, try reducing the default 'X' and/or 'Y' Significant Figures value(s) to '0.01'. This will reduce the decimal precision of the resulting data slightly, but will still provide two decimal places for the point values. If the user is converting latitude/longitude data in decimal degrees, another five decimal places (0.00000001- eight total decimal places) will need to be added to the default value to preserve the accuracy of the data.

Multi-threading: To help speed up Convert, multi-threading is available for this function. Enter any number of threads from 2 to the maximum number available in the text box on the right side of the interface. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per

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thread.



Convert: To complete the file convert process, the user must click the **'Convert'** button after all of the necessary data convert parameters have been defined. To follow the progress of the conversion, please see the Progress Bar, which will display the percentage of the conversion completed, the elapsed time, and the estimated time remaining to complete.

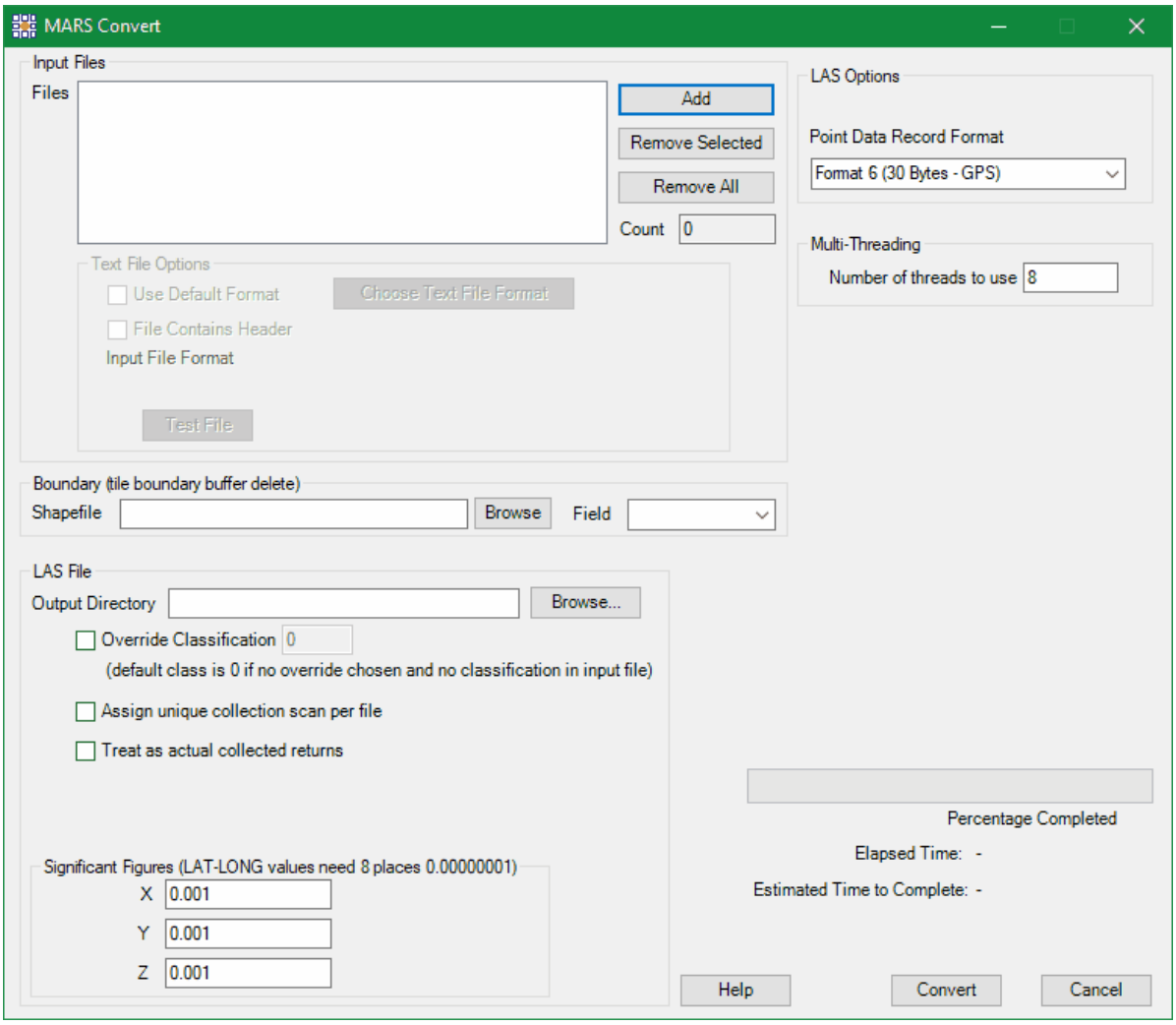
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4.4.1 Convert ASCII Text



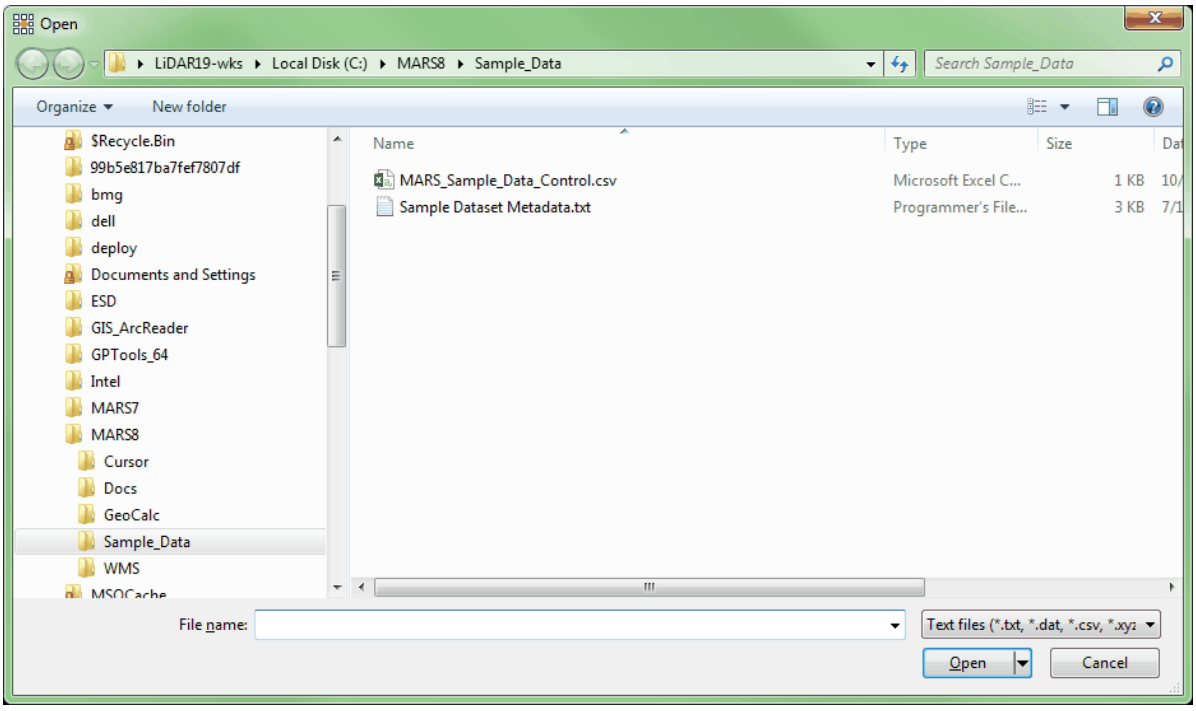
To convert an ASCII Text file to LAS for use in MARS®, open the convert dialog by clicking on the **'Convert'** 

button on the Project/Data Preparation Tab 162.



To add a file or files for conversion, click the **'Add'** button in the MARS® Convert window, which opens the following dialog:

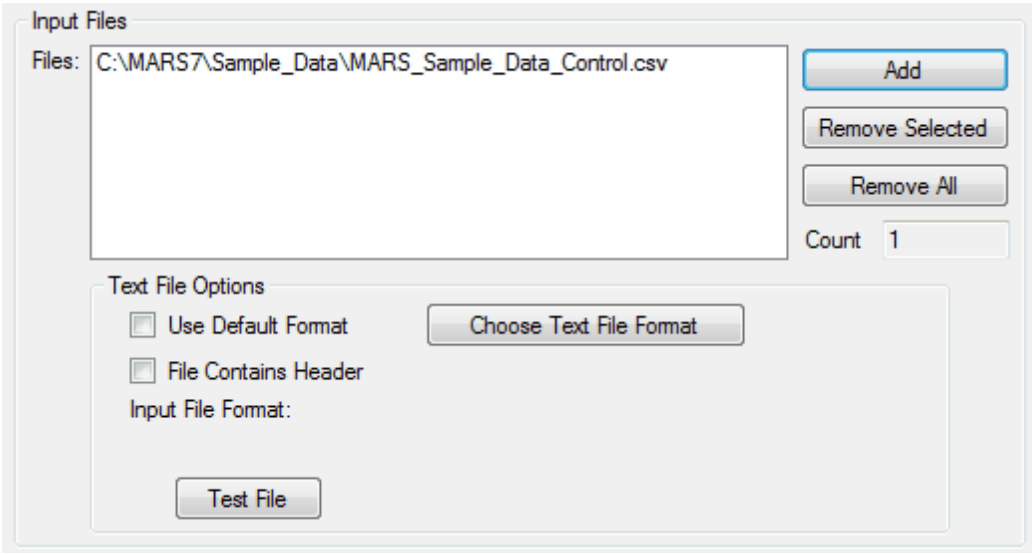
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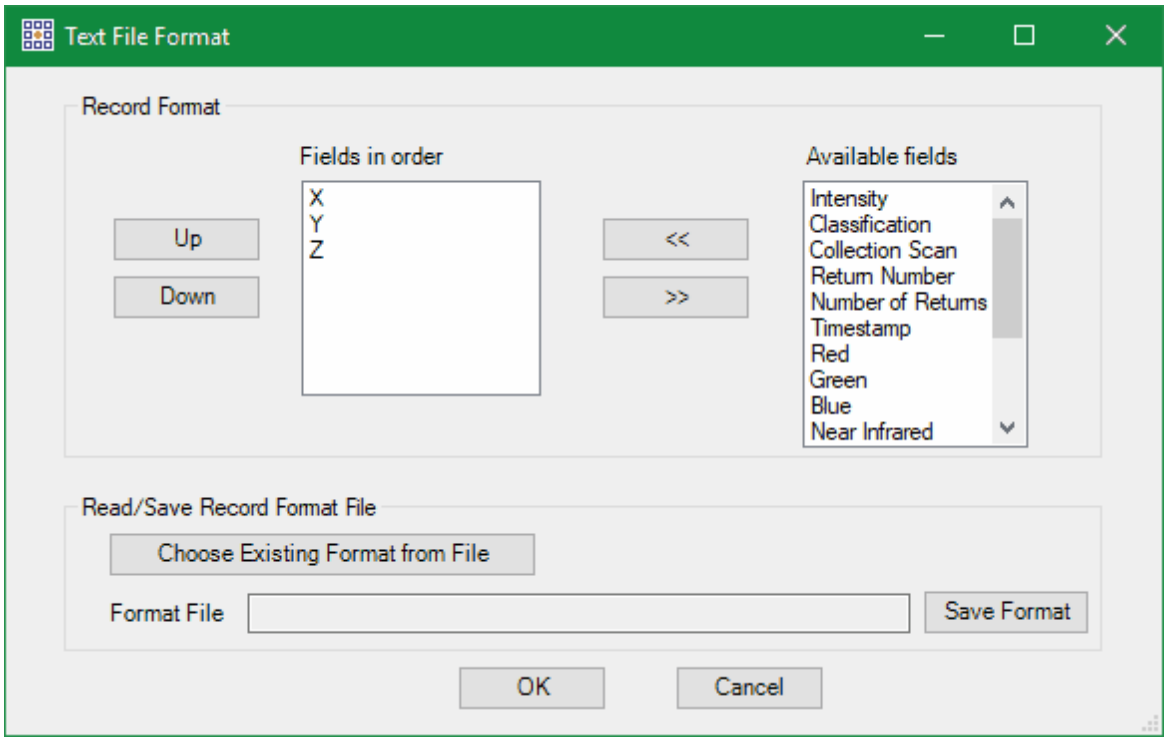
Change the file type drop-down to 'Text files (*.txt, *.dat, *.csv, *.xyz, *.grd)', navigate to the desired directory and select the file(s) to be converted into MARS®. Click the **'Open'** button to add them to the MARS® Convert dialog.

Multiple files may be added using this process, or a file or files may be selected to be removed (using standard Windows mouse/keyboard controls) by clicking the **'Remove Selected'** button or the **'Remove All'** button.

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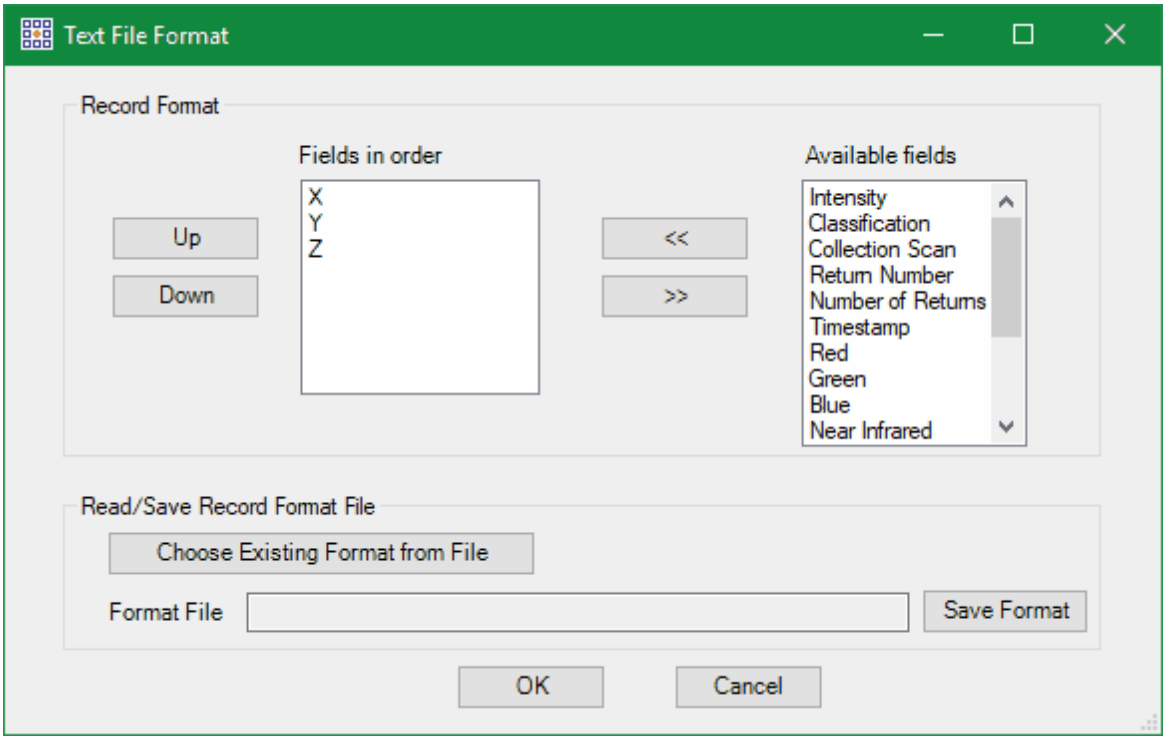
Next, the user can define the input file format by clicking on the **'Choose Text File Format'** button, which launches the 'Text File Format' dialog. The default text format is XYZ with a space delimiter.



To further specify the format settings in which the text file is to be converted, select the **'Choose Text File Format'** button. The X, Y, and Z fields are in the fields in order dialog box by default. (Checking on

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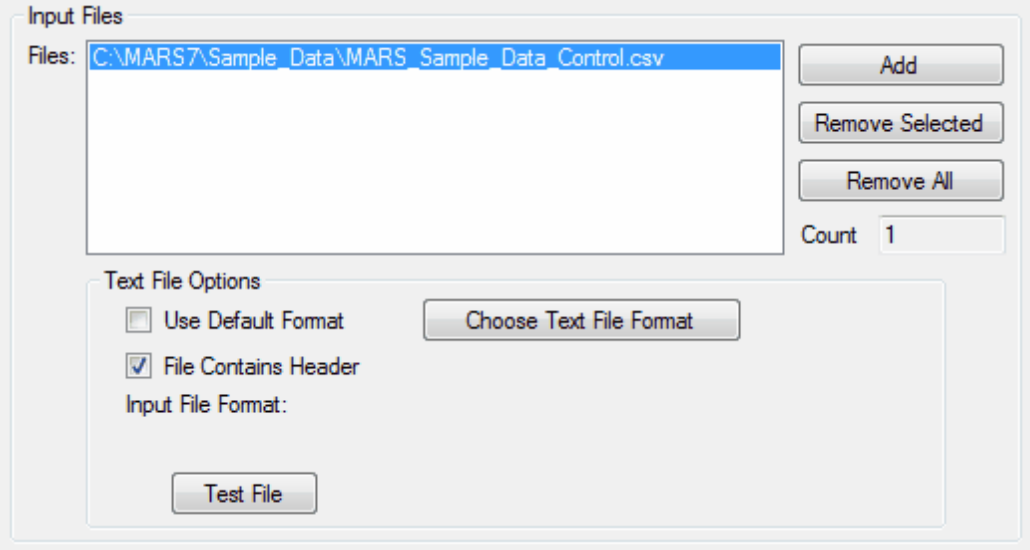
the **'Use Default Format'** box will use these default settings during conversion.) If the file contains header information, select the **'File Contains Header'** check box, which causes the convert module to skip the first line of the file. If additional fields are necessary to convert the text file, the user can select the necessary attributes one at a time from the right window (Available fields) of the dialog and click the **'<<'** button to add it to the file format definition in the left window. The user will also need to define the file delimiter, which can be a space, comma or tab. The user can also reorder the convert file format definition by selecting a field in the left window and using the **'Up'** or **'Down'** arrow buttons to match the text file format. In addition, the **'Ignore'** option from the attribute field list (left side of dialog) allows the user to disregard specific data values in the input file for translation. The 'Ignore' field may be used as many times as necessary. If there is an existing record format file to be used on the data, select the **'Choose Existing Format from File'** button, browse to where the format file is kept, and click **'Open'**.



Once the user has completed the convert file definition, these values can be saved to an external file for

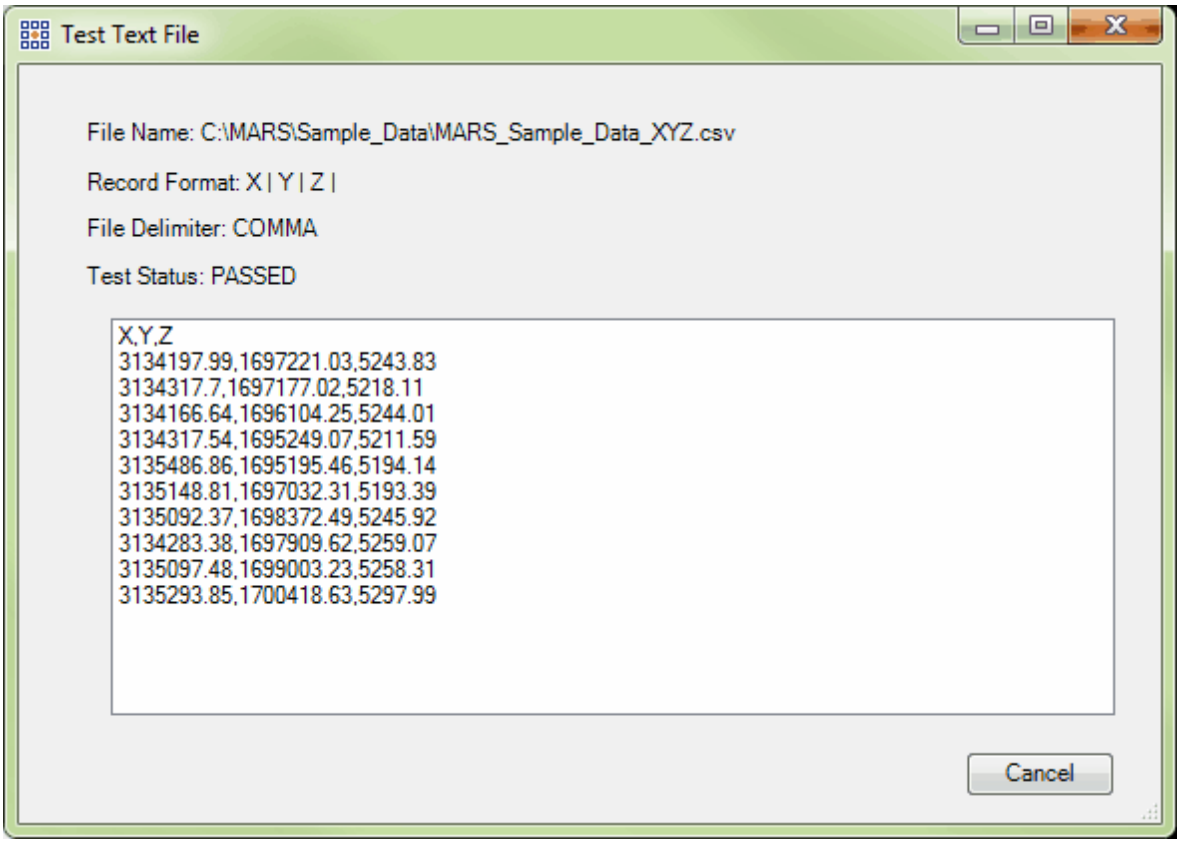
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reuse by clicking on the **'Save Format'** button. The user can define the target directory and file name for the file definition format.



By using the **'Test File'** function, the user can quickly verify that the inputted file format matches the actual contents of the target file. The 'Test File' dialog is displayed to the user and provides a file status of **'PASSED'** or **'FAILED'**, and also displays the first several lines of the file for review purposes.

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After the File has passed the 'Test File' function, review the settings in the Data Convert 640 section above and click **'Convert'** to convert the file to LAS. *(Note: If the output directory was not specified by the user, the new LAS files were generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the **'Browse'** button and navigate to or key in the desired folder.)*

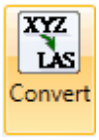
Now load the file(s) for viewing by following the procedure for the **'Add LAS Files'** button in the Project/ Data Preparation Tab 162 topic.

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4.4.2 Convert Esri ASCII Grid

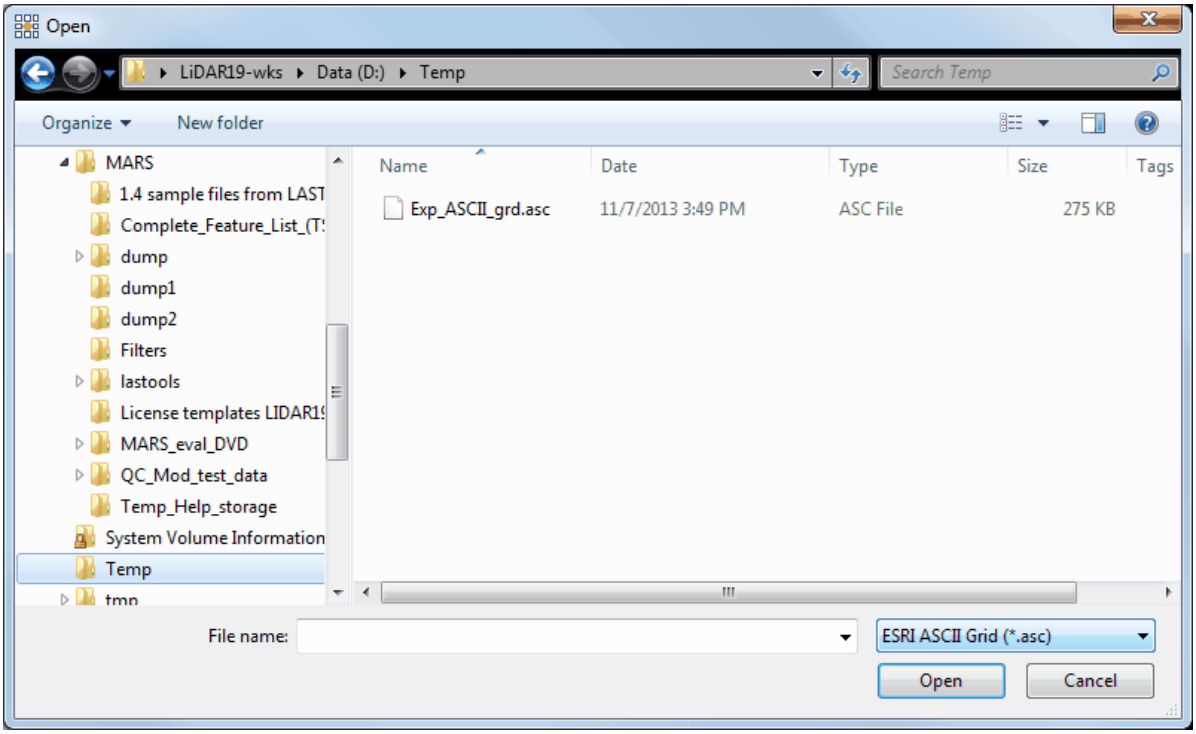
Convert Esri ASCII Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

To convert an Esri ASCII Grid file to LAS for use in MARS®, open the convert dialog by clicking on the **'Convert'** 

button on the Project/Data Preparation Tab 162.

To add a file(s) for conversion, click the **'Add'** button in the MARS® Convert window, which launches the following dialog:



Change the file type drop-down to 'Esri ASCII Grid (*.asc)', navigate to the desired directory and select the file(s) to be converted into MARS®. Click the **'Open'** button to add them to the MARS® Convert

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dialog.

The user may add multiple files and may also remove a file from the dialog by highlighting the file and clicking the **'Remove Selected'** button or the **'Remove All'** button.

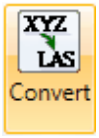
Review the settings in the Data Convert 640 section above and click **'Convert'** to convert the file(s) to LAS. *(Note: If the output directory was not specified by the user, the new LAS files were generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the '**Browse**' button and navigate to or key in the desired folder.)*

Now load the file(s) for viewing by following the procedure for the **'Add LAS Files'** button in the Project/ Data Preparation Tab 162 topic.

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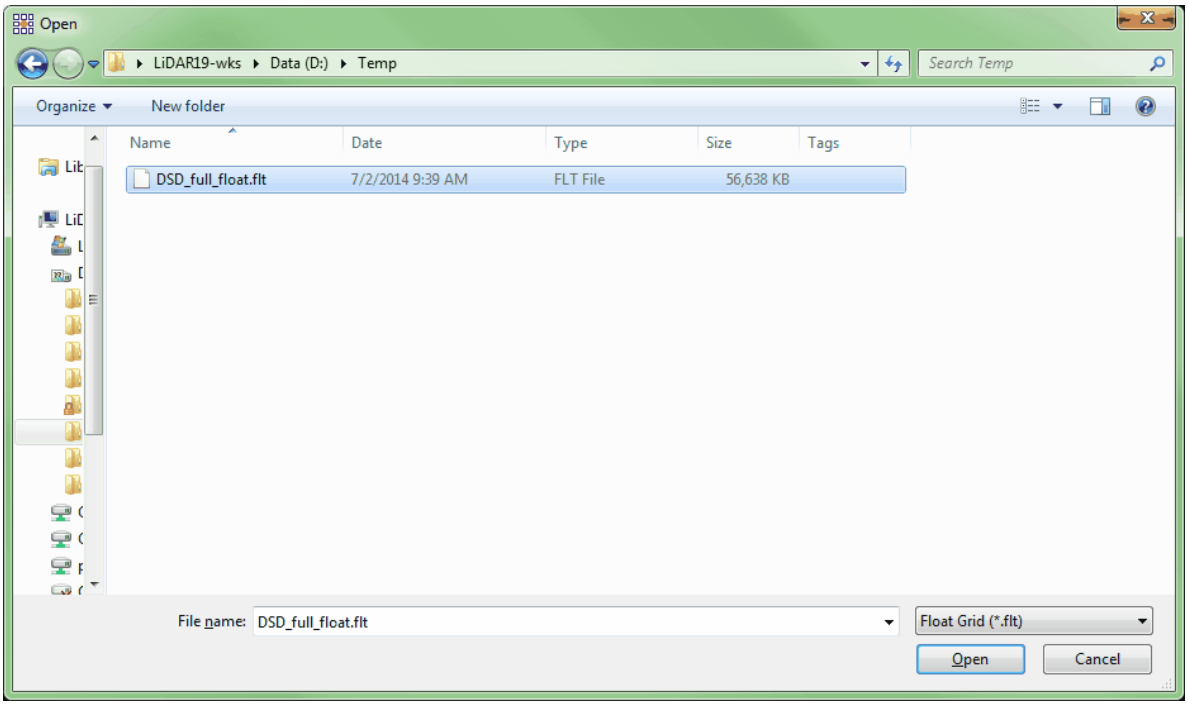
4.4.3 Convert Float Grid





To convert a Float Grid into MARS®, open the convert dialog by clicking on the **'Convert'** button on the Project/Data Preparation Tab 162.

Click on the **'Add'** button and browse to the file. Click the file type drop-down box at the bottom of the window and select 'Float Grid (*.flt)' as the file type. Click **'Open'**.



The user may add multiple files and may also remove a file(s) from the dialog by highlighting the file and clicking the **'Remove Selected'** button or the **'Remove All'** button.

Review the settings in the Data Convert 640 section above and click **'Convert'** to convert the file(s) to LAS. *(Note: If the output directory was not specified by the user, the new LAS files were generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the **'Browse'** button and navigate to or key in the desired folder.)*

Now load the file(s) for viewing by following the procedure for the **'Add LAS Files'** button in the Project/ Data Preparation Tab 162 topic.

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4.4.4 Convert TIFF Grid

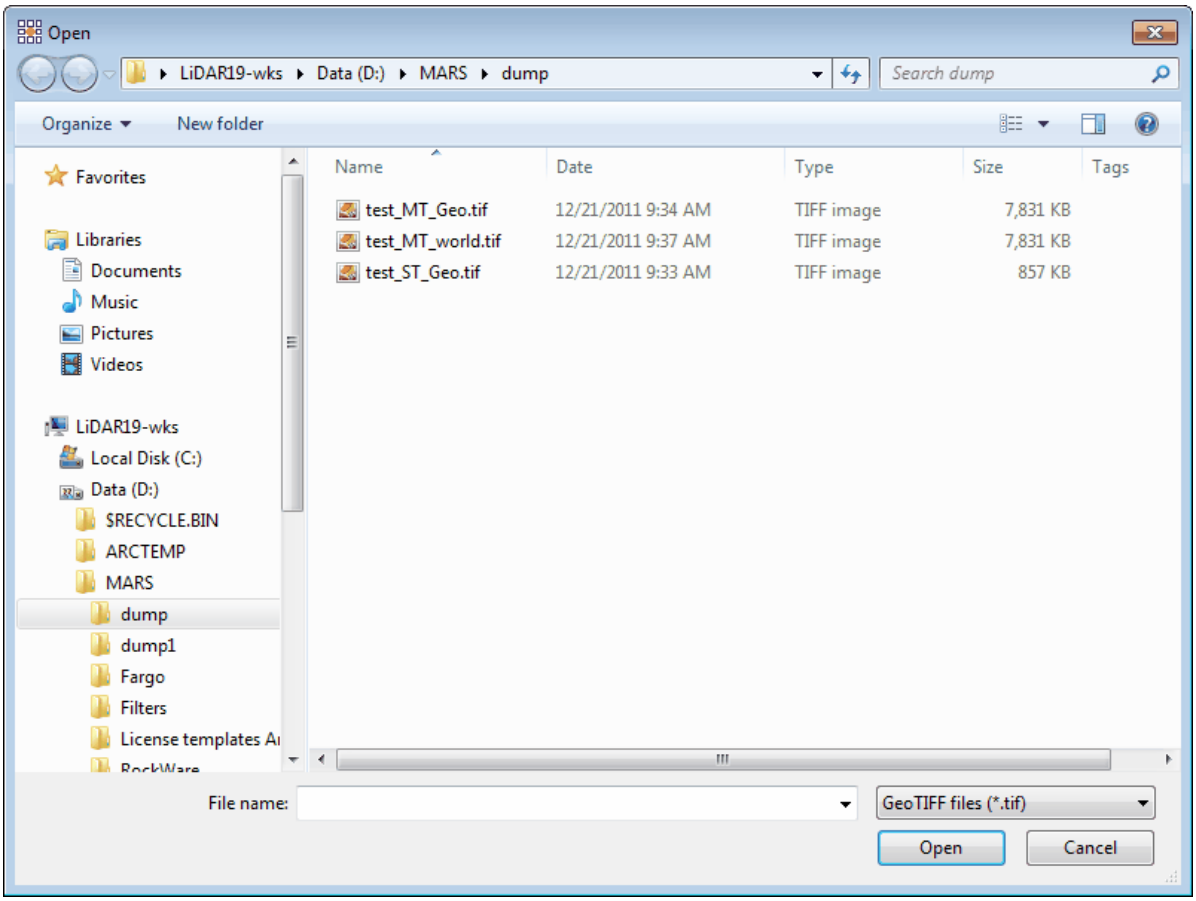
Convert TIFF Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

To convert a TIFF Grid file (GeoTIFF or TIFF with world file) to LAS for use in MARS®, open the convert dialog by clicking on the **'Convert'** 

button on the Project/Data Preparation Tab 162.

To add a file(s) for conversion, click the **'Add'** button in the MARS® Convert window, which launches the following dialog:



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Change the drop-down to 'GeoTIFF files (*.tif)', navigate to the desired directory and select the file(s) to be converted into MARS®. Click the **'Open'** button to add them to the MARS® Convert dialog.

The user may add multiple files and may also remove a file(s) from the dialog by highlighting the file and clicking the **'Remove Selected'** button or the **'Remove All'** button.

Review the settings in the Data Convert 640 section above and click **'Convert'** to convert the file(s) to LAS. *(Note: If the output directory was not specified by the user, the new LAS files were generated in the same directory as the input file location. To specify another location for the output LAS files, the user can click the **'Browse'** button and navigate to or key in the desired folder.)*

Now load the file(s) for viewing by following the procedure for the **'Add LAS Files'** button in the Project/ Data Preparation Tab 162 topic.

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4.5 Data Export



For any LAS tools that allow files to be pathed out without loading them in the Table of Contents in MARS® (including 'Export' when the 'Export without loading LAS files into Map View' option is used), an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in

the Project/Data Preparation Tab 162 topic.

'Data Export' allows the user to export **LAS, LAS Grid, 3D Image, Text (ASCII), 3D point shapefiles, Esri ASCII Grids, Float Grids (both elevation and LiDAR Point Density), Shapefile contours, PLS-CADD (both ASCII and LAS), ENVI (elevation) Grids, ENVI (elevation and classification) Grids, LiDAR Spatial Distribution Verification Grid JPEG 2000s, LiDAR Raster JPEG 2000s, Flightline Separation JPEG 2000s, Tiled Flightline Separation GeoTIFFs, Tiled Swath Separation Image GeoTIFFs, Hillshade JPEG 2000s, ERDAS IMAGINE Grids**, and various types of **TIFF Grids** from loaded or pathed-out LAS data**.** When 3D point shapefiles and 2D or 3D contour shapefiles are exported, a *.prj (projection definition file) is created if the projection information is known for the source LAS data.

All export type interfaces share several tools and functions in common: 'Save Settings to File', 'Load Settings from File', a progress bar, a display of 'Elapsed Time' and 'Estimated Time to Complete', buttons for 'Help', 'Export', and 'Cancel', and an option labeled 'Only Displayed Files Will Be Exported'. Please note that all loaded data will be exported unless the 'Only Displayed Files Will Be Exported' box is checked. ***This option is not available when the 'Export without loading LAS files into Map View' option is checked on the*** Options Tab 780 ***(see the Export Options 780 topic for details).*** Also, most export types have a 'Multi-Threading' control to improve performance by using the processing computer's resources more efficiently.

Please note: When a tile-based export is canceled by the user (by using the 'Cancel' button on the export interface), files that have been created in the output folder will be deleted based on their creation time. Anything with a creation date/time after the export was started will be removed - any pre-existing files with older date/time creation information will be left in the folder.

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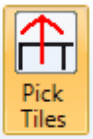
Also note that all loaded data will be exported unless the 'Only Displayed Files Will Be Exported' box at the bottom of the interface is checked. This option is not available when the 'Export without loading LAS files into Map View' option is used (see the Export Options 780 topic).

Each export type is further explained in its particular subtopic. Expand the **'Export Types'** help topic and find the type of file to be exported in the subtopics listed. Follow the instructions specific to each file type for export. While all Export Types will have 'Output 746', **'Layout',** and 'Options 780' tabs, other tabs will appear that are specific to the type of export chosen. These tabs are: Filters 774, Transforms 782, Contours 806, Grid 783, and Projection 811.

There are several ways to export data from MARS®:



'Export': The 'Export' button, found on the Export/Extract Tab 461, opens a drop-down list of export types, allowing data to be exported based on a single file (from all loaded data or selected tiles only), MBR (minimum bounding rectangle) shapefile, or selected tiles from a loaded tile layout shapefile. This export format can also be used to export separate files based on collection scan numbers (Point Source IDs) for the 'LAS' or 'Text - ASCII' export types only. ***Not every Export Type supports every Layout format, so all formats may not be visible on the Layout tab.***



'Pick Tiles': The 'Pick Tiles' button allows the user to load a tile layout shapefile and then select a single tile or multiple tiles to be exported. The selected tile(s) will then appear selected in the attribute table representing the shapefile. (To view the attribute file, right-click on the appropriate file inside the Table of Contents and choose **'Attributes'.**) Conversely, it is possible to use the attribute

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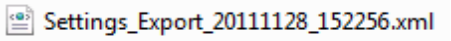
table to select tiles from the shapefile. Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the appropriate tile(s). The selected tile(s) will then appear highlighted in the LAS Map View window on the tile layout itself. (Please see the Pick Tiles 960 utility for further instructions on the use of this tool.)



'Export Area': Also found on the Export/Extract Tab 461, this tool allows a rectangular area of selected data to be exported by clicking and dragging a box (can be used only while in 2D View 835). Immediately after creating the drag box, a drop-down list of export types appears for selection. This export method also allows data to be exported to separate files based on collection scan numbers within the dragged area. (Collection scans can be exported *only* as 'LAS' or 'Text - ASCII' types.)

Note: There are system limits for 'NO DATA' areas and very large areas. Not every export type supports this method of exporting.

Every export process in MARS® will generate an XML file containing the settings used in the export. This file will be output to the same designated folder as the exported data. Each unique *.xml file name will contain the date and time of export as seen in the example below. For example, this particular export took place at 3:22:56 pm on November 28, 2011.



This file can be renamed as needed and loaded for future exports to cut down on data entry and ensure consistency between export runs. After selecting an export type to open its interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed before starting the export processing. In addition, a settings file can be created and saved for future use without actually running an export. Make all the parameter entries on the various tabs and click the 'Save Settings to File' button when

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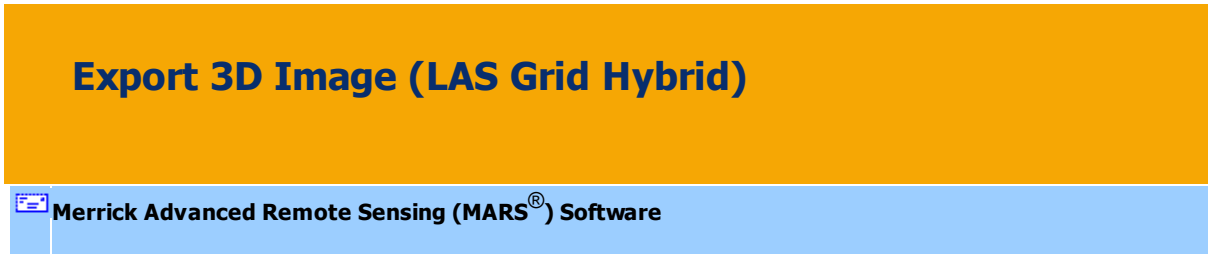
finished. Navigate to a folder to store the file as it will not be stored in the chosen 'Output Directory' automatically like it is when the export is actually run.

Please note that not all export/layout types can take advantage of multi-threading and/or temporary local disk space. In addition, not all layout formats (e.g., Single File) are supported for all export types.

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4.5.1 Export Types

4.5.1.1 3D Image



The **'3D Image'** export type is a variation of the 'Grid - LAS 698' export type that creates a specially-colorized 'hybrid' LAS file - a mix of high-density gridded data to represent ground (typically) and non-gridded data to represent above-ground features. Other classes of points such as buildings can be added to the set of classes to be output as high-density gridded points. At a minimum, the input LAS data must have ground classified separately from non-ground. The output file will have Class 2 assigned to all gridded points. Because of this, class alone can no longer be used to differentiate types of features in the final gridded points. The remaining above-ground points will retain their original classifications.

In addition to LAS data, imagery must also be loaded to use this export type. Each point in the output file has RGB values attached to it - the gridded ground data gets its RGB values from the loaded imagery, and the above ground data gets its values from Custom Colorization by classification. For

more on using Custom Colorization in export, see the LAS Export 712 topic. This export type requires that a tile layout shapefile be loaded.

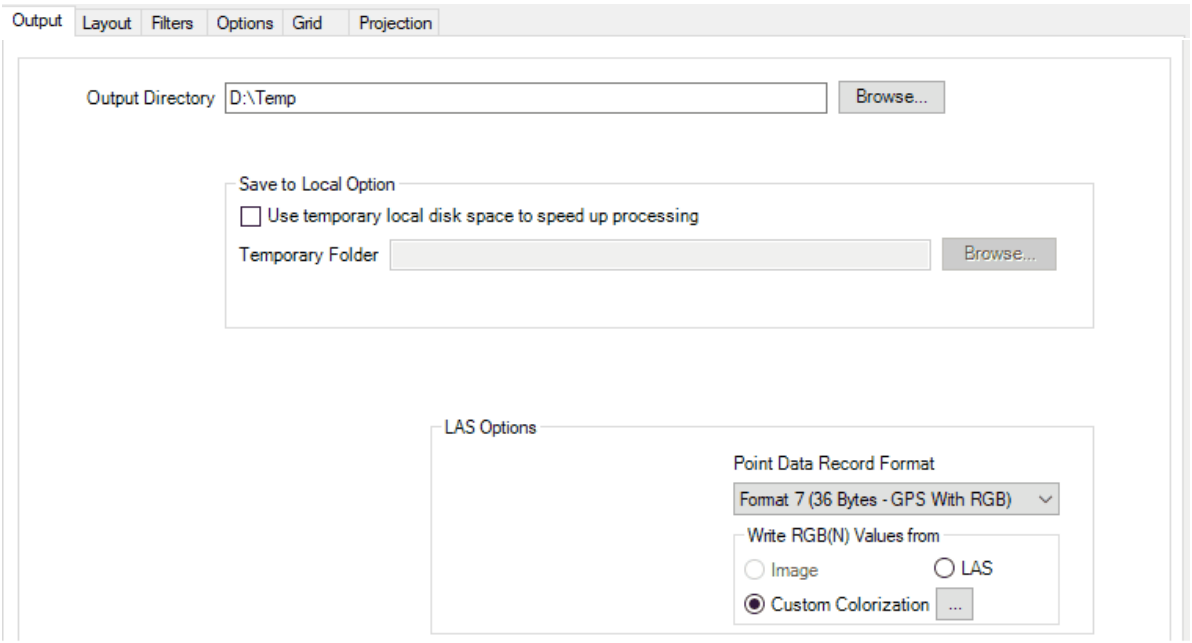
Exporting '3D Image' files: Start by clicking on the **'Export'** 

button or the **'Export Area'**



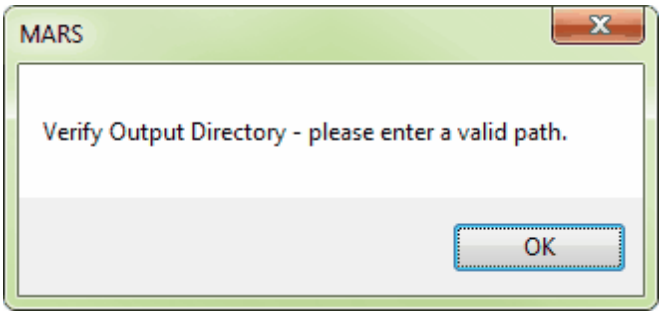
button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **3D Image** file, select it from the drop-down list. On the Output Tab 746, specify an Output Directory where the file(s) should be exported. The user may choose which Point Data Record Format - 7 or 8 - will be used, depending on whether RGB or RGB(N) values are present in the imagery.

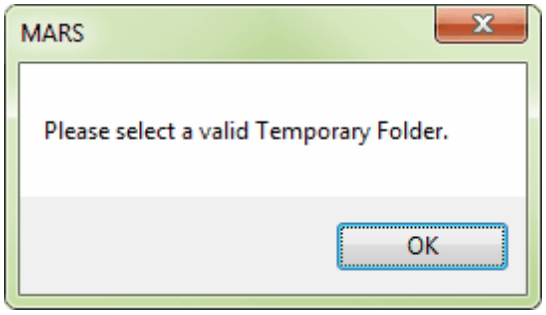


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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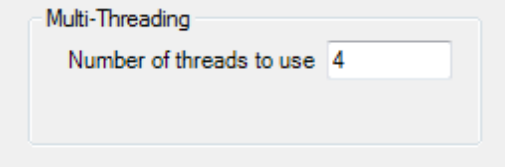
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



The Point Data Record Format will default to 7, but can be changed to 8 if desired. ****NOTE that all points in the exported '3D Image' LAS file will be bit-flagged as 'Synthetic'.**

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When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

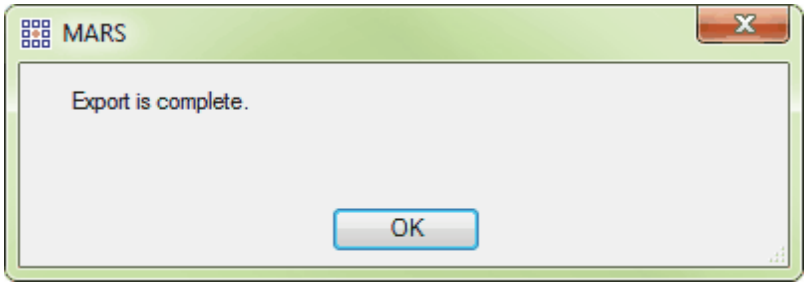


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.2 Contours - Shapefile

Export 2D/3D Contour Shapefiles

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Exporting 'Contours - Shapefile' (2D or 3D): Start by clicking on the **'Export'** 

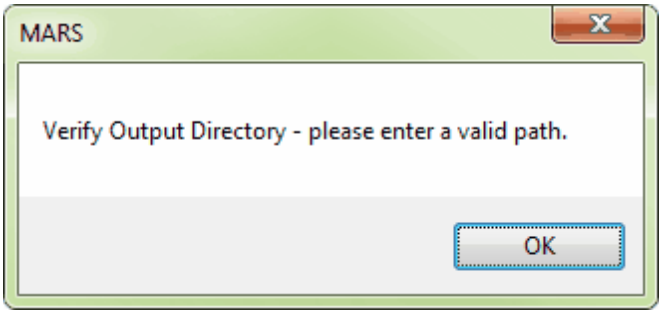
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Contours - Shapefile**, select it from the drop-down list. On the Output Tab[746], specify an Output Directory where the file(s) should be exported.

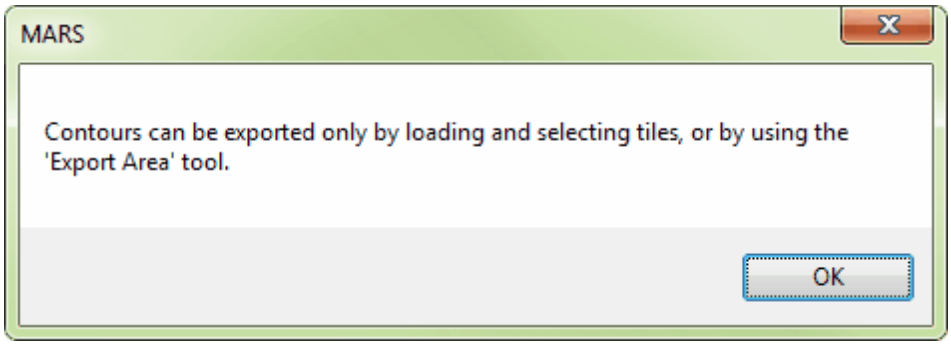


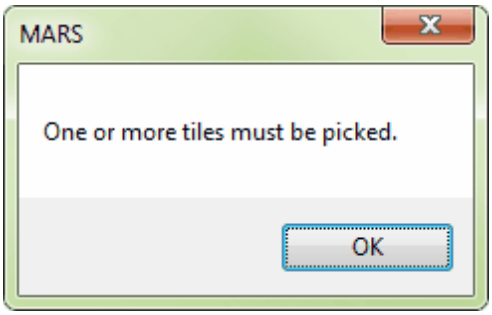
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



'Single File' Layout[747] is not available for this export type. 'Export Area[658]' 

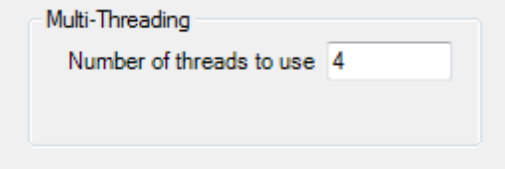
may be used to define an area, or at least one polygon (e.g., tile) must be selected for export. If an unsupported layout type is selected, or if tiles are loaded but none is selected, an error message will pop up as seen below:





When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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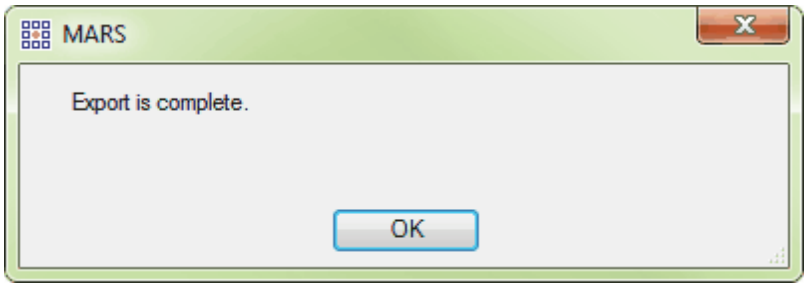


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file. When 2D or 3D contour shapefiles are exported, a *.prj (projection definition file) is created if the projection information is known for the source LAS data.

When the export is complete, the following message will appear.



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4.5.1.3 Flightline Separation - JPEG 2000

Export Flightline Separation JPEG 2000

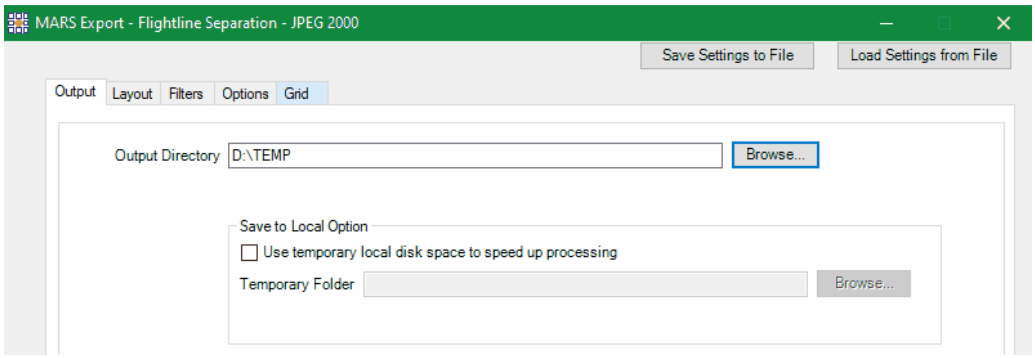
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Exporting 'Flightline Separation - JPEG 2000' files: Start by clicking on the **'Export'** 

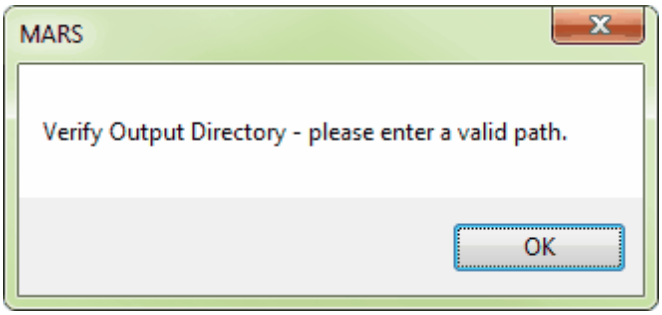
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Flightline Separation - JPEG 2000** file, select it from the drop-down list. On the Output Tab746, specify an output directory where the file(s) should be exported.



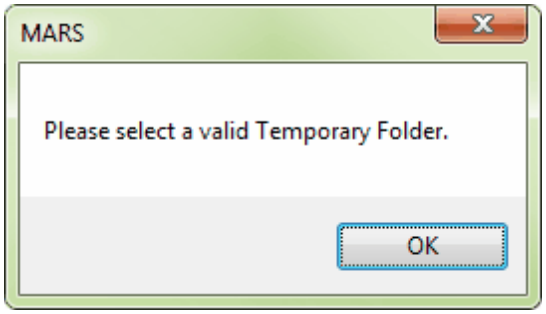
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical

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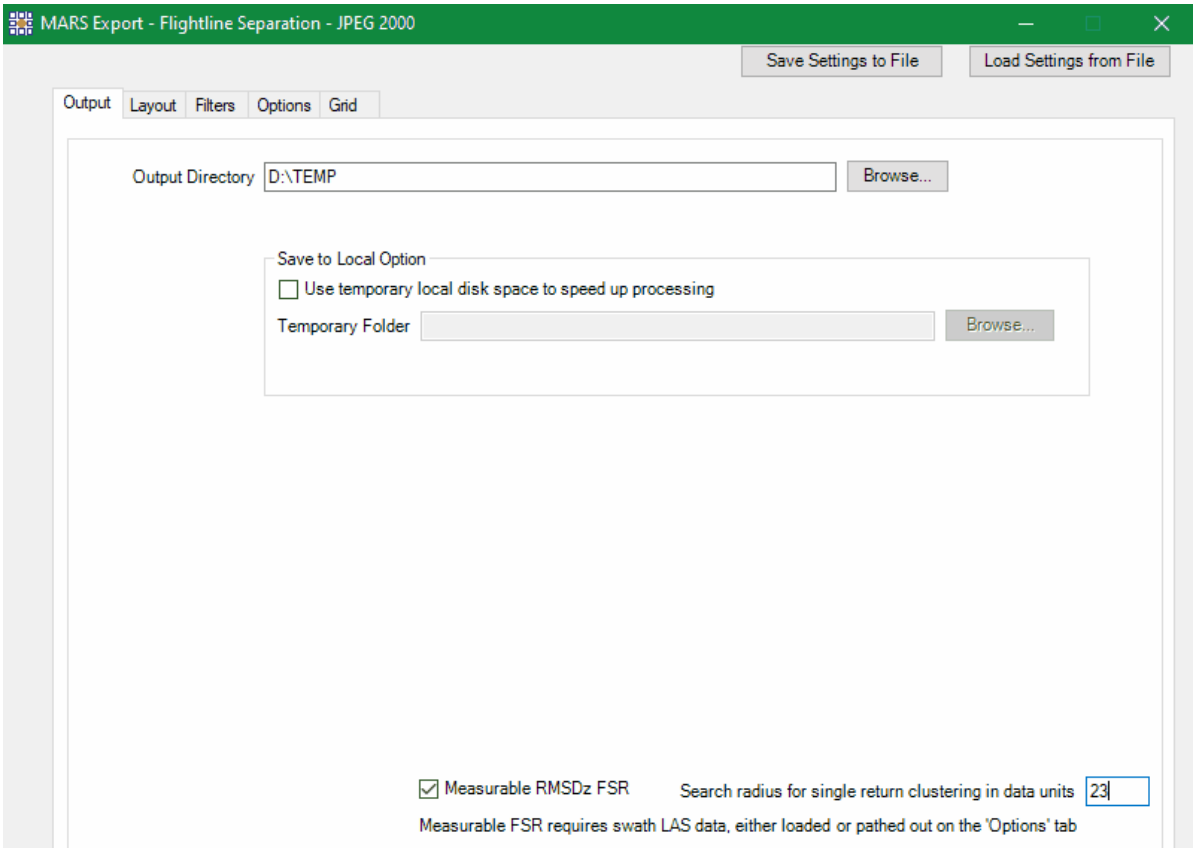
situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



An option exists for creating a Measurable RMSDz (Z difference) raster and results file for Collection Scan (flightline) Separation. This option creates a much more accurate representation of collection scan separation by limiting the results to areas away from obstructions. A results *.TXT file is created based on the RMS-derived vertical separation difference between adjacent files in overlap/sidelap areas where Single Return points are clustered at a minimum horizontal distance from other return types. This radius distance is entered manually - a value of 10 times the NPS (nominal pulse spacing) for the data being exported is a good starting point. This will ensure that the LiDAR data used for the export are in open areas, but not so far from obstructions that the number of points used is insufficient for an accurate result. In this way, the data that is tested and exported is much more likely to be ground in open areas, especially if the ‘Display cutoff value’ (see the 'Grid Type' section of the Grid Options 783

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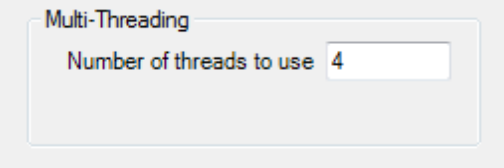
tab) is small enough to weed out non-system anomalies but large enough to ignore differences caused by targets in one collection scan not being present in an adjacent scan (a car, for example). A good starting point is 10 times the 'Elevation increment' (also explained in the 'Grid Type' section of the Grid Options 783 tab). Only the points that meet all of these criteria are used in the RMSDz calculation. See the Consistent Return Filter 1001 topic for more information on how these points are determined.



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per

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thread.

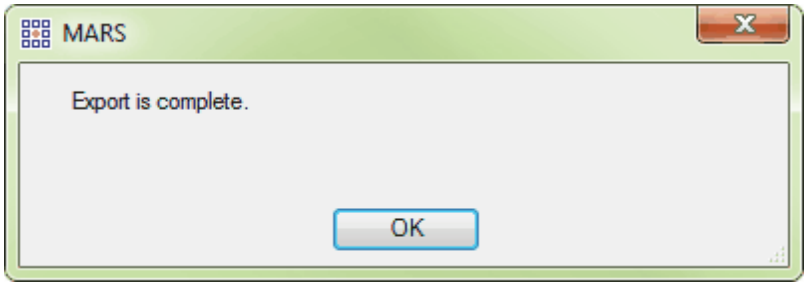


Move through the remaining tabs to continue making specifications for the export.

On the 'Filters' tab in the export dialog, the default settings of the 'Flightline Separation - JPEG 2000' export type are set to include export of the 'Last returns' only. If the 'Measurable RMSDz FSR' option is used (see above), then Single Returns are used instead. Any 'Overlap' bit-flagged points will be forced on as part of this export type as they often delineate the area to be measured. If these specifications are not sufficient for the user's export, changes can be made on the 'Filters' tab for most options. There are also options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.4 Flightline Separation - Tiled GeoTIFF

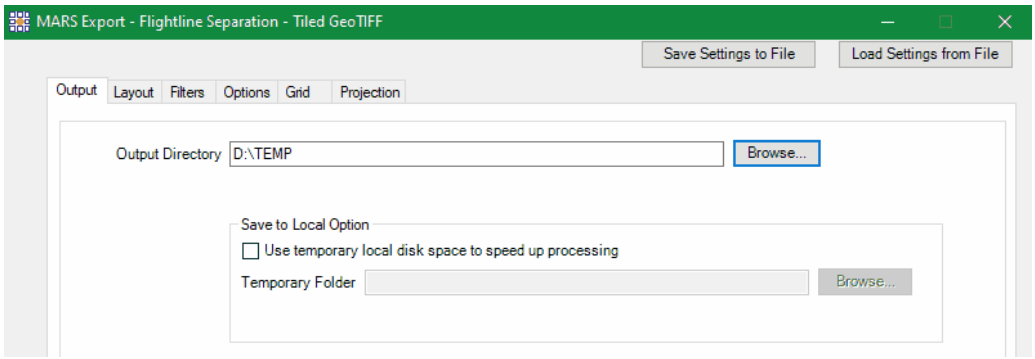
Export Flightline Separation Tiled GeoTIFFs

Merrick Advanced Remote Sensing (MARS®) Software

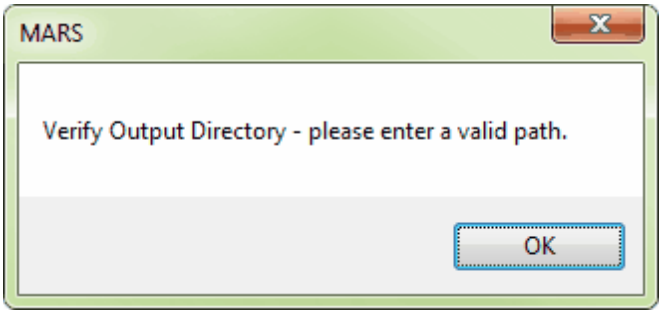
Exporting 'Flightline Separation - Tiled GeoTIFF' raster files: Start by selecting one or more tiles from a loaded tile layout shapefile, then click the **'Export'** 

button. Note that this export type works only when one or more tiles have been pre-selected using the 'Pick Tiles 960' tool.

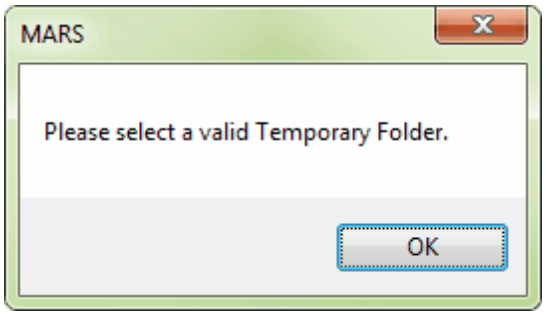
To export a **Flightline Separation - Tiled GeoTIFF** raster file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.



If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

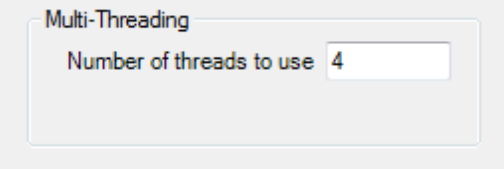


The **'Use temporary local disk space to speed up processing'** option allows the exported raster(s) to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

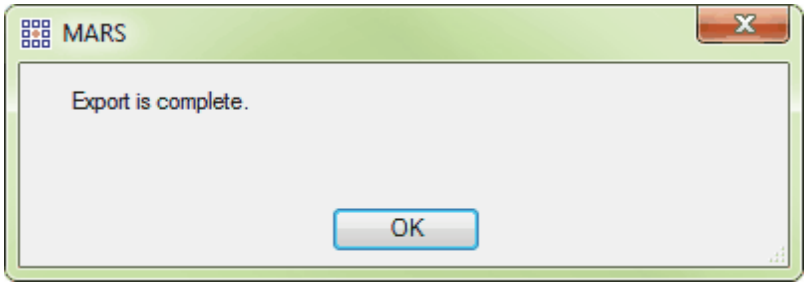
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On the 'Filters' tab in the export dialog, the default settings of the 'Flightline Separation - Tiled GeoTIFF' export type are set to include export of the 'Last returns' only. Any 'Overlap' bit-flagged points will be forced on as part of this export type as they often delineate the area to be measured. If these specifications are not sufficient for the user's export, changes can be made on the 'Filters' tab for most options. There are also options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.5 Grid - Cloud Optimized GeoTIFF DEM

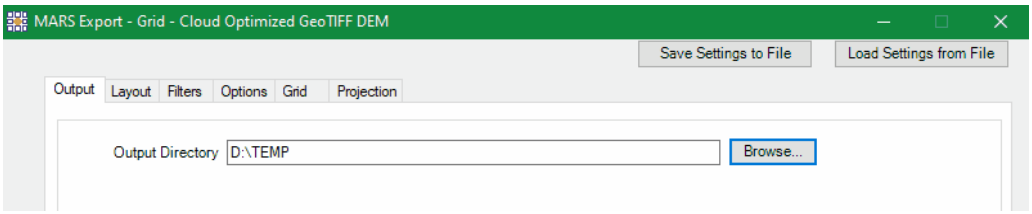
Export Cloud Optimized GeoTIFF DEM Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

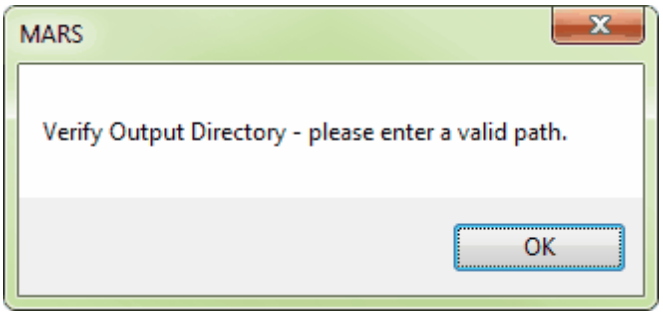
Exporting 'Grid - Cloud Optimized GeoTIFF DEM' raster files: Start by selecting one or more tiles from a loaded tile layout shapefile, then click the **'Export'** 

button.

To export a **Grid - Cloud Optimized GeoTIFF DEM** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



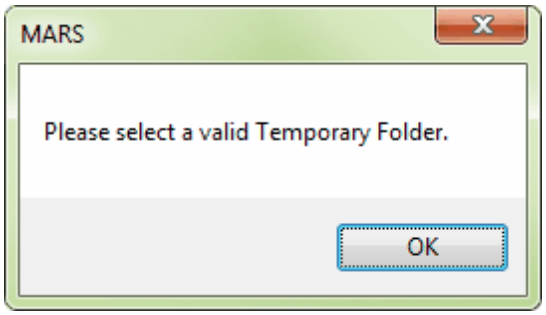
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



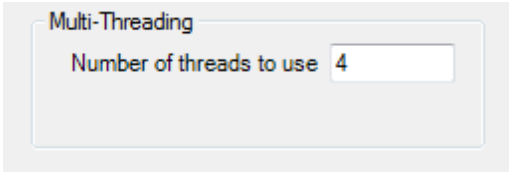
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which

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has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



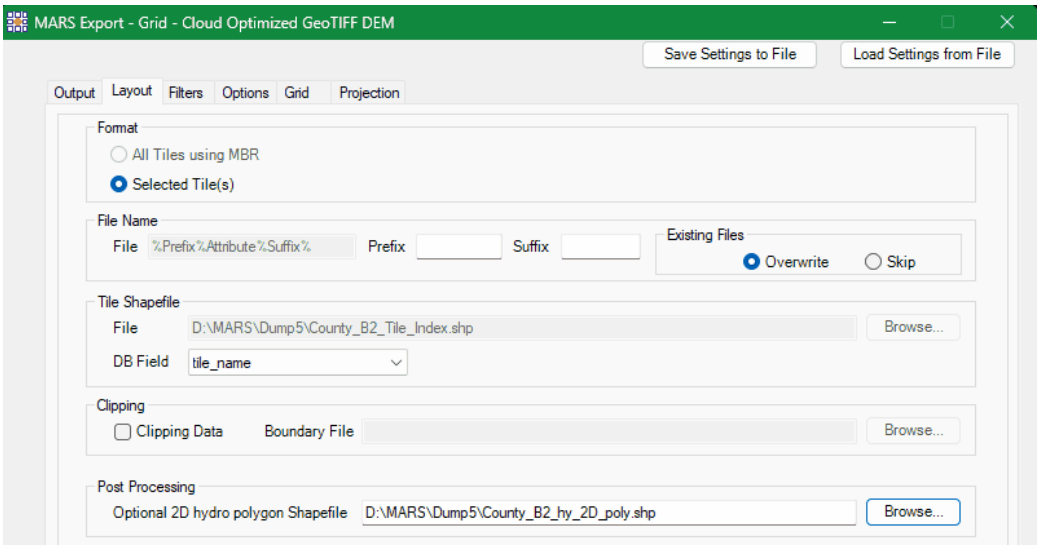
The multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



An option specific to this export and the 'Grid - Float Grid' export type is available in the 'Post

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Processing' section of the Layout tab. When using a loaded 3D polyline breakline file to define the shorelines of river polygons, a pre-existing 2D polygon shapefile of river shorelines can be added to the elevation processing *if* the vertices of the shorelines match between the 3D polylines and the 2D polygons. Browse to this 2D polygon shapefile using the 'Browse' control to the right of 'Optional 2D hydro polygon Shapefile.' The use of this shapefile will improve the elevation modeling of the river surface in the output rasters.



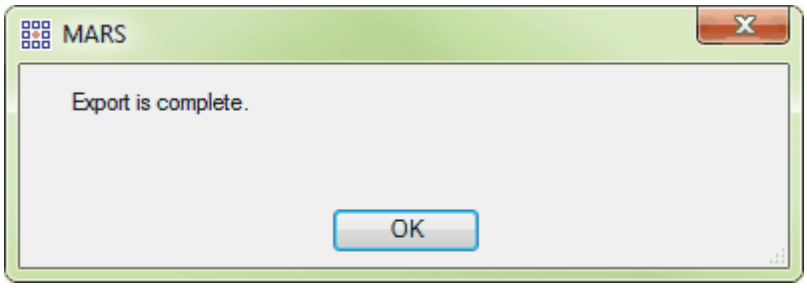
Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.

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4.5.1.6 Grid - Cloud Optimized GeoTIFF Intensity

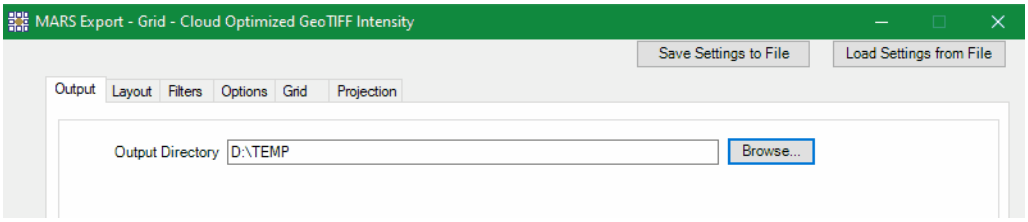
Export Cloud Optimized GeoTIFF Intensity Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

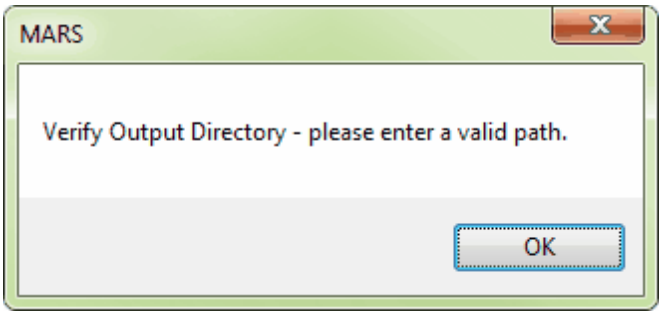
Exporting 'Grid - Cloud Optimized GeoTIFF Intensity' raster files: Start by selecting one or more tiles from a loaded tile layout shapefile, then click the **'Export'** 

button.

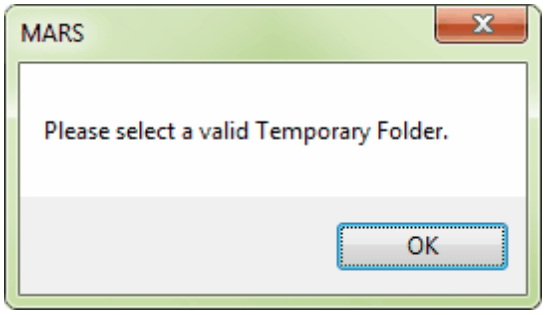
To export a **Grid - Cloud Optimized GeoTIFF Intensity** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



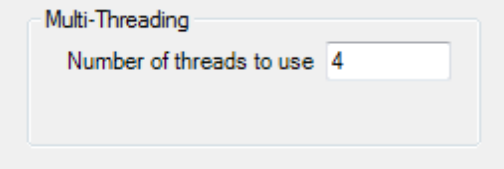
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



The multi-threading option is available for this export type. It speeds up export by using a specified

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amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

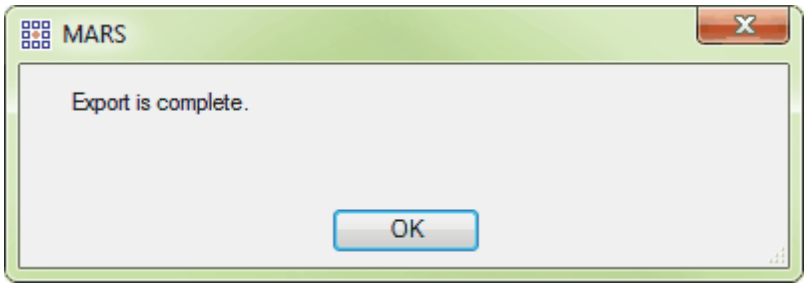


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.7 Grid - ENVI Elev

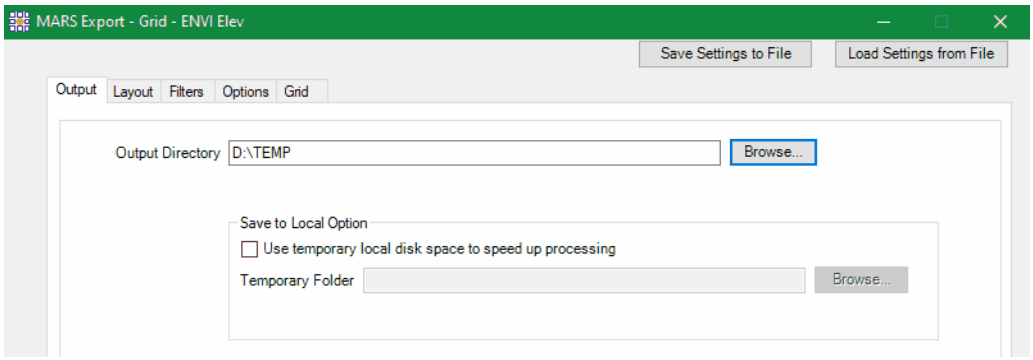
Export ENVI Elev Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

The 'Grid - ENVI Elev' export type creates a *.dat format file to be used by software that loads and interprets ENVI compatible raster data. The exported raster is an interpolated ENVI elevation grid (<*name*>.dat, <*name*>.hdr, and <*name*>.dat.aux.xml) whose cells are populated with the elevation values from the underlying lidar points. See also the Grid - ENVI Elev/Class 685 export type.

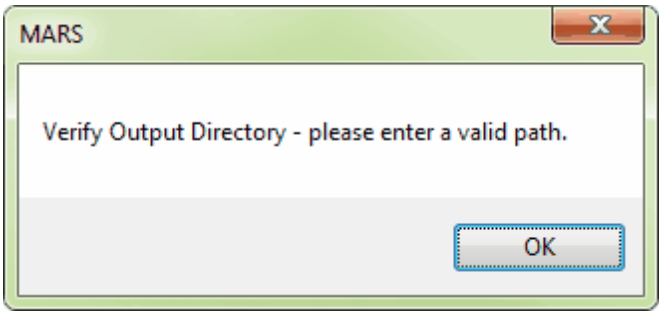
Exporting 'Grid - ENVI Elev' files: Start by clicking on the **'Export'** Export button or the **'Export Area'** Export Area button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid - ENVI Elev** file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.

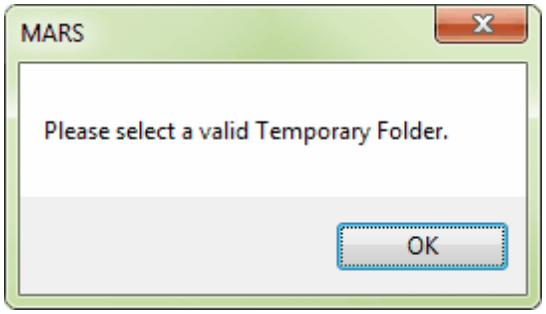


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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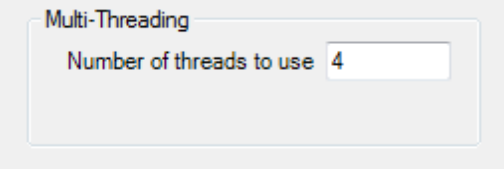
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be

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found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread

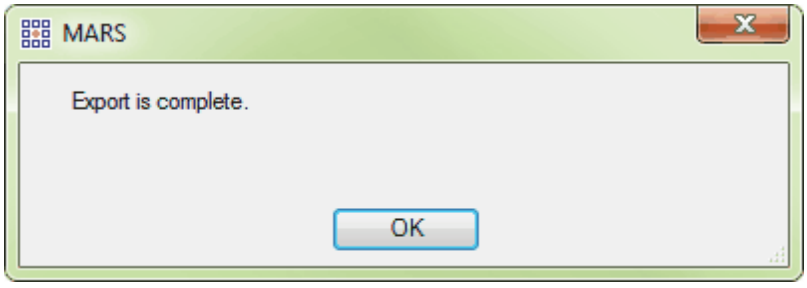


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.8 Grid - ENVI Elev/Class

Export ENVI Elev/Class Grid Files

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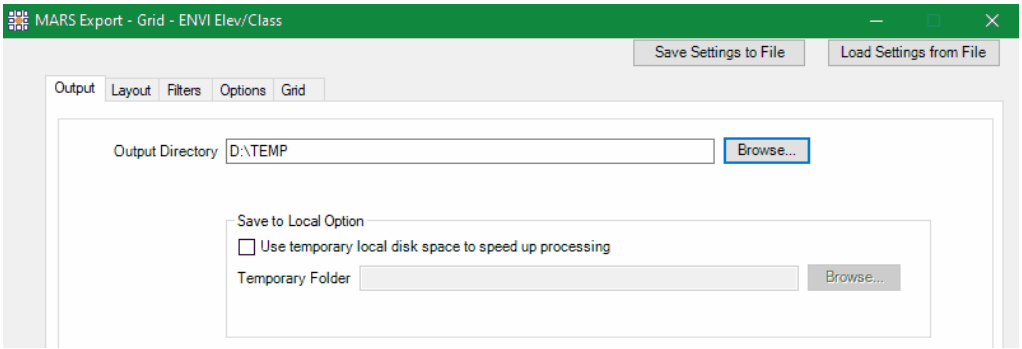
The 'Grid - ENVI Elev/Class' export type creates two (2) *.dat format files to be used by software that loads and interprets ENVI compatible raster data. The two exported files are an interpolated ENVI elevation grid (<*name*>.dat, <*name*>.hdr, and <*name*>.dat.aux.xml) whose cells are populated with elevation values of the underlying lidar points, and a classification grid (<*name*>_class.dat and <*name*>_class.hdr) whose cells are populated with the majority classification of the underlying lidar points that were included in the export. See also the Grid - ENVI Elev[682] export type.

Exporting 'Grid - ENVI Elev/Class' files: Start by clicking on the **'Export'** 

button or the **'Export Area'** 

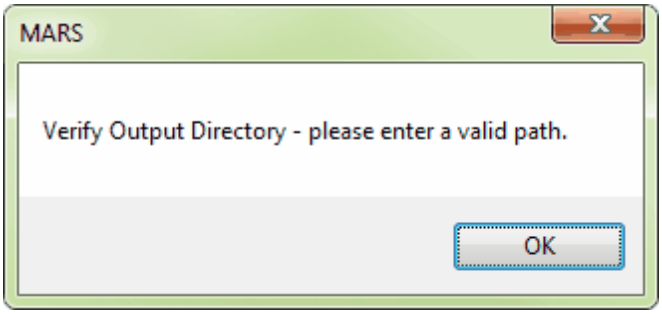
button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid - ENVI Elev/Class** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.

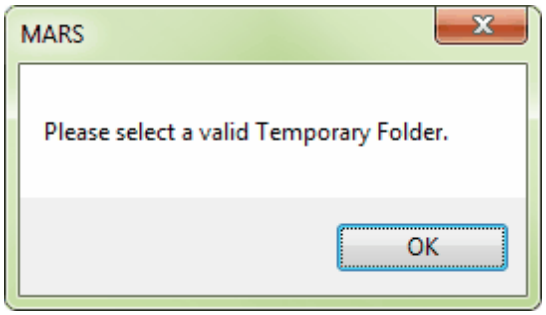


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If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

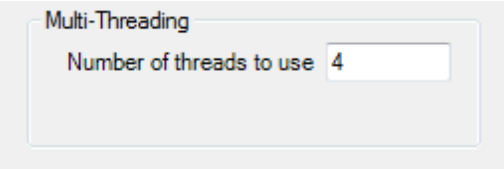


The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



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When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

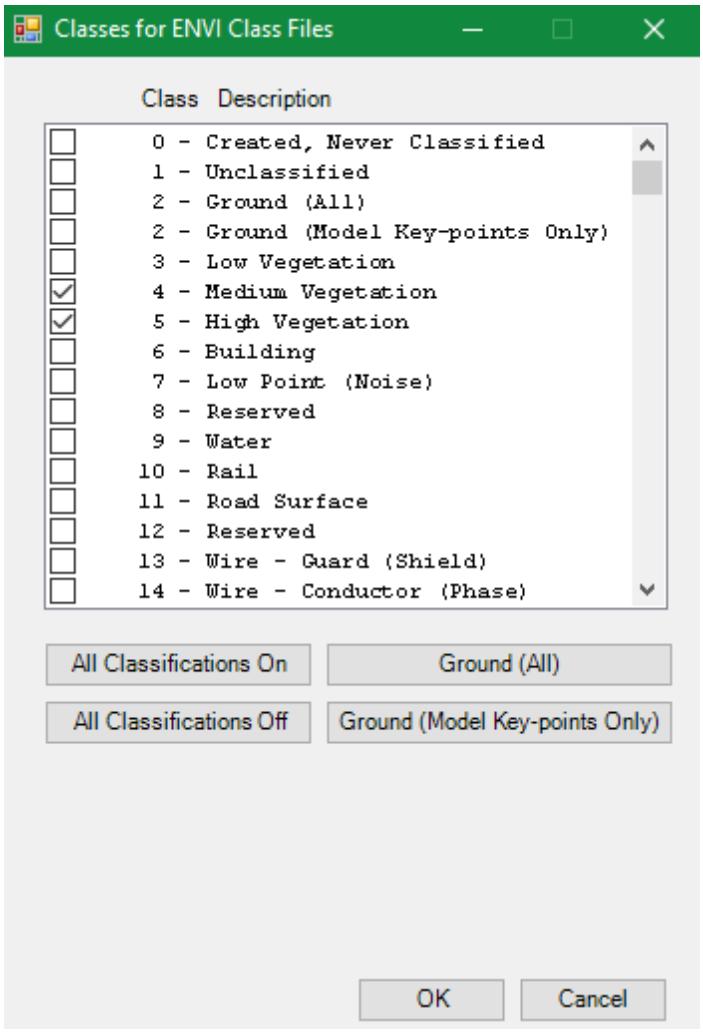


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

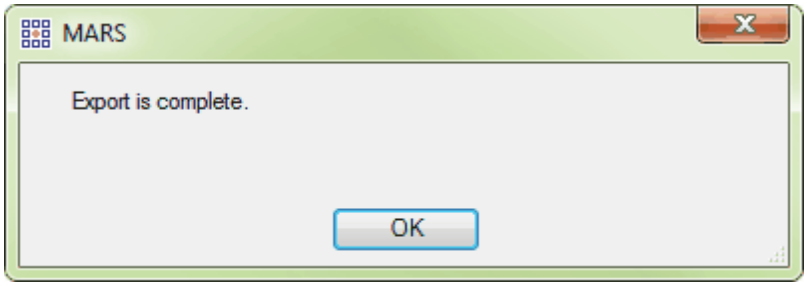
When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface. The following window will appear where the classes to be included in the classification output raster can be selected:

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Click the 'OK' button when the selection has been made to start the export process.

When the export is complete, the following message will appear.



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4.5.1.9 Grid - Esri ASCII Grid

Export Esri ASCII Grid Files

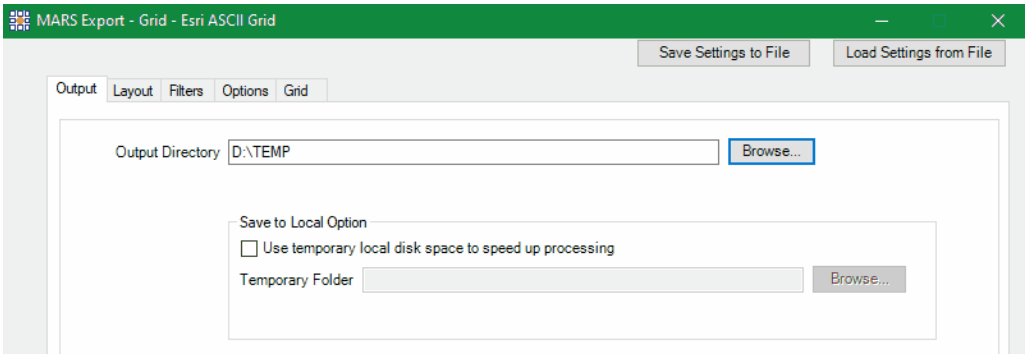
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Exporting 'Grid - Esri ASCII Grid' files: Start by clicking on the **'Export'** 

button or the **'Export Area'** 

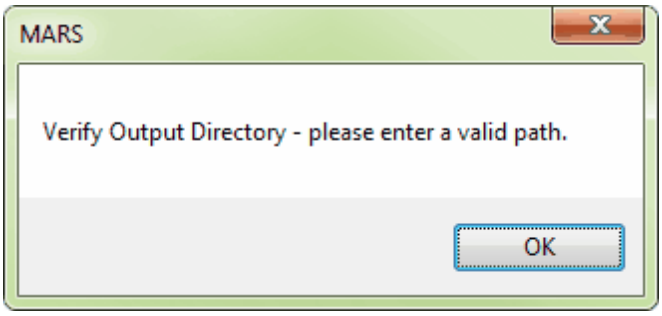
button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid - Esri ASCII Grid** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.

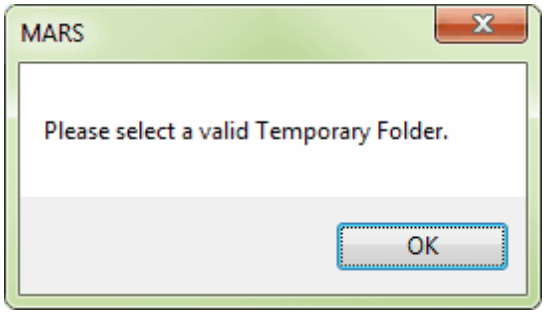


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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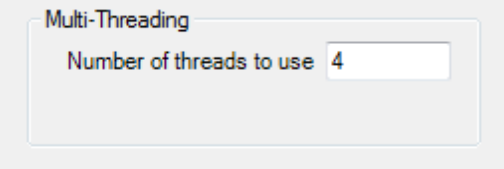
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be

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found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

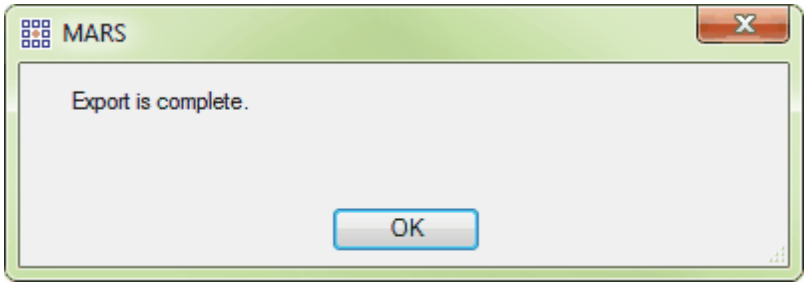


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.10 Grid - Float Grid

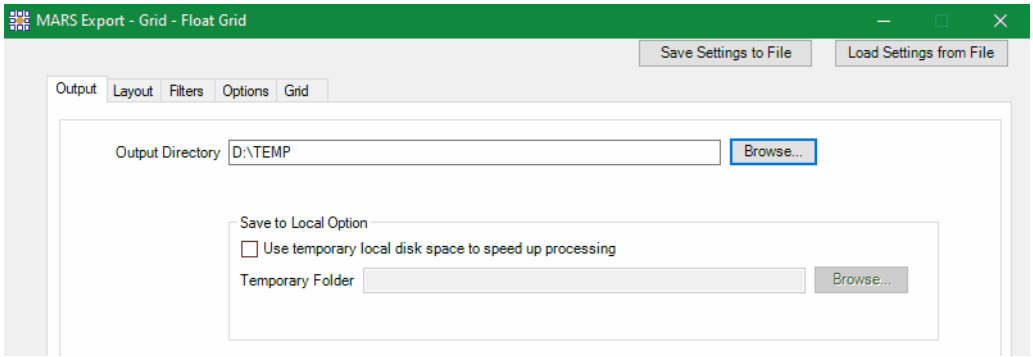


Exporting 'Grid - Float Grid' files: Start by clicking on the **'Export'** 

button or the **'Export Area'** 

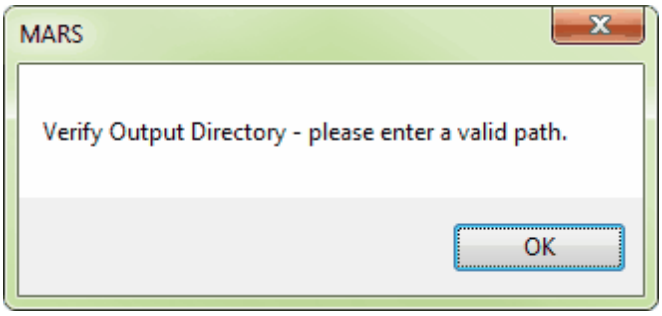
button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid - Float Grid** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.

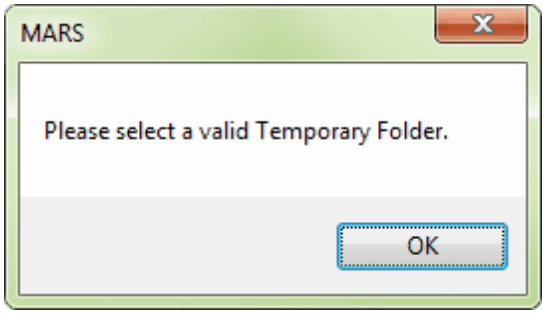


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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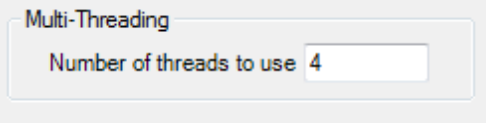
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



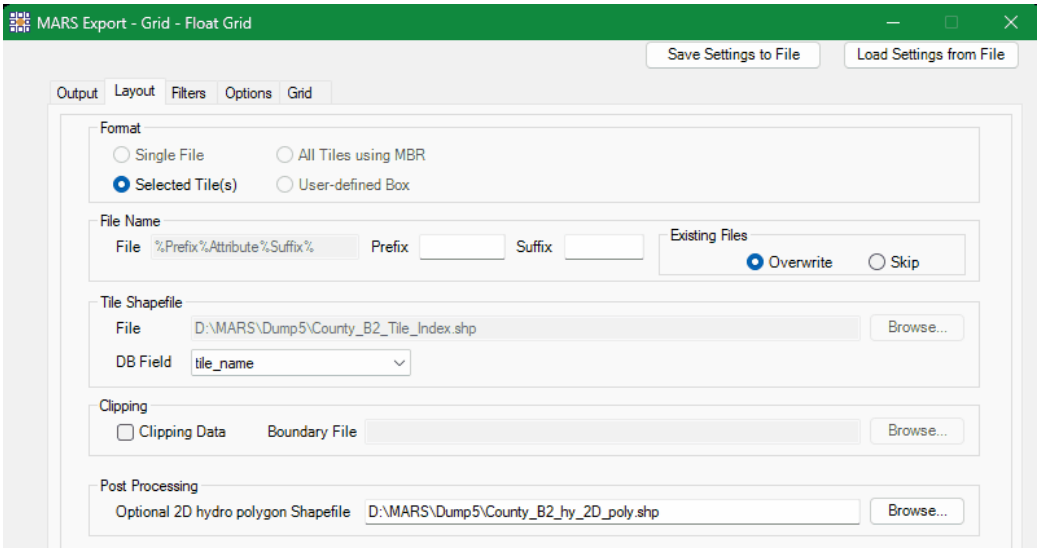
When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be

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found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



An option specific to this export and the 'Grid - Cloud Optimized GeoTIFF DEM' export type is available in the 'Post Processing' section of the Layout tab. When using a loaded 3D polyline breakline file to define the shorelines of river polygons, a pre-existing 2D polygon shapefile of river shorelines can be added to the elevation processing *if* the vertices of the shorelines match between the 3D polylines and the 2D polygons. Browse to this 2D polygon shapefile using the 'Browse' control to the right of 'Optional 2D hydro polygon Shapefile.' The use of this shapefile will improve the elevation modeling of the river surface in the output rasters.



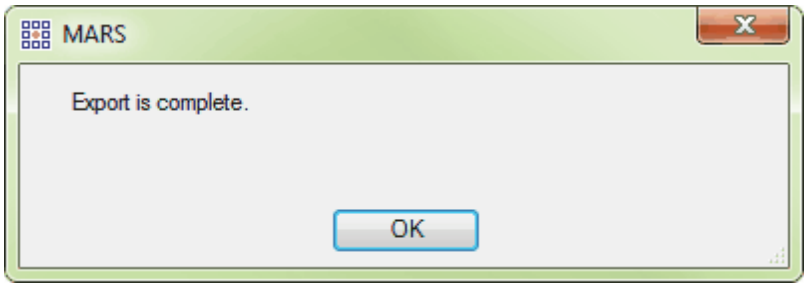
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Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear. The resulting float grid (*.flt) file may be viewed in MARS® in 3D (perspective) mode 837 as well as in 2D.



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4.5.1.11 Grid - IMG



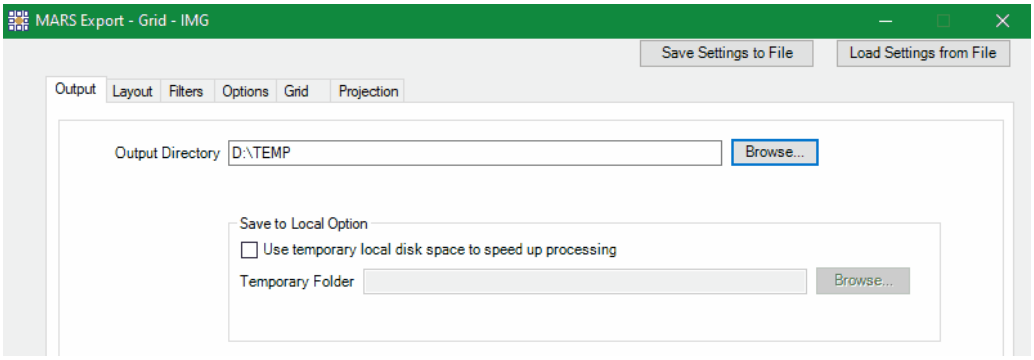
Exporting 'Grid - IMG' files: Start by clicking on the **'Export'** 

button or the **'Export Area'**

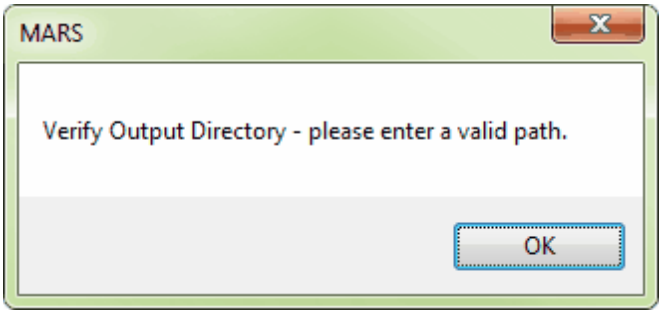


button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid - IMG** format file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



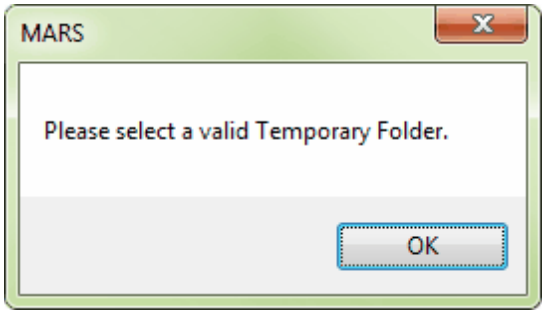
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



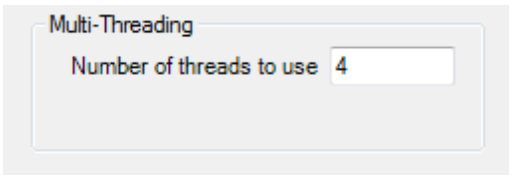
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the

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export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



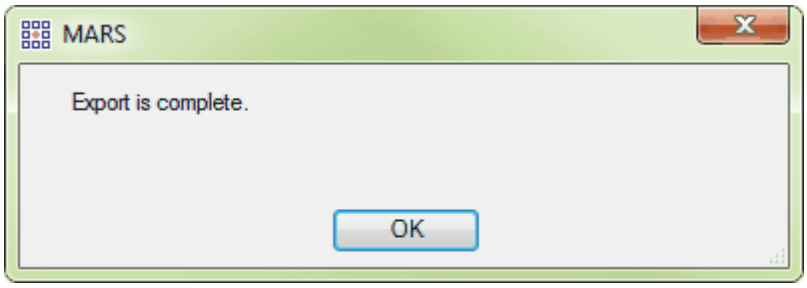
Move through the remaining tabs to continue making specifications for the export.

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There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.12 Grid - LAS

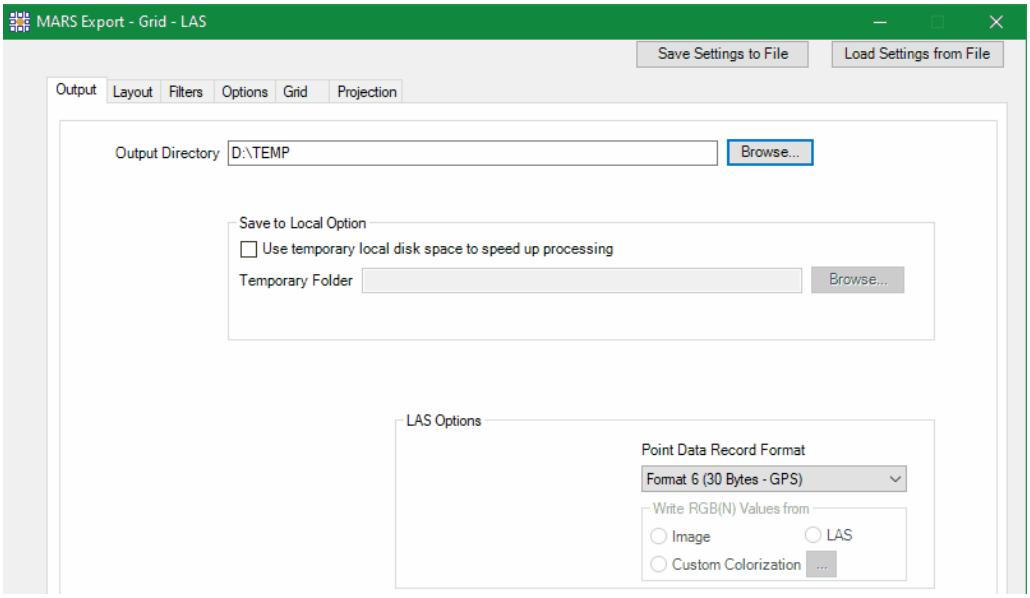


Exporting 'Grid - LAS' files: Start by clicking on the **'Export'** 

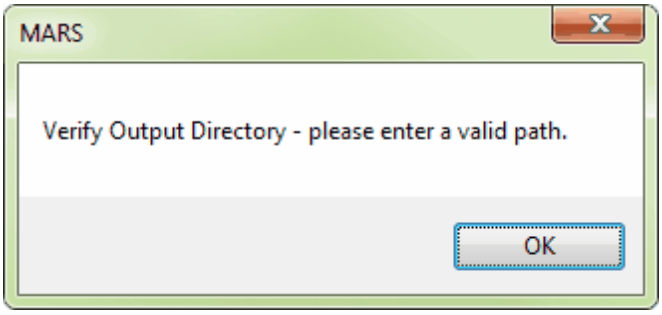
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Grid- LAS** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



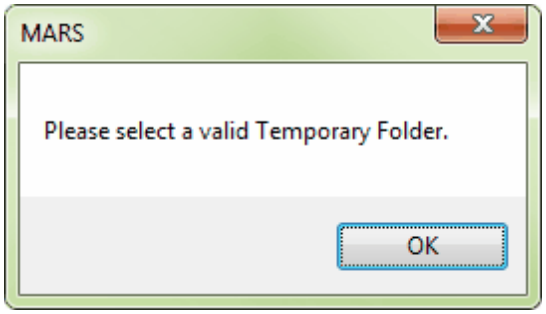
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the

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export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

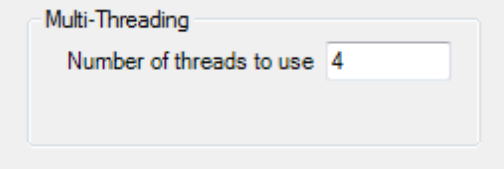


The user may choose which Point Data Record Format the output files are saved in - 6, 7, or 8 - although the default will be 6 since this type of LAS file does not typically have RGB(N) values stored in it.

****NOTE that all points in the exported LAS Grid file will be bit-flagged as 'Synthetic' and classed as 0 (zero).**

When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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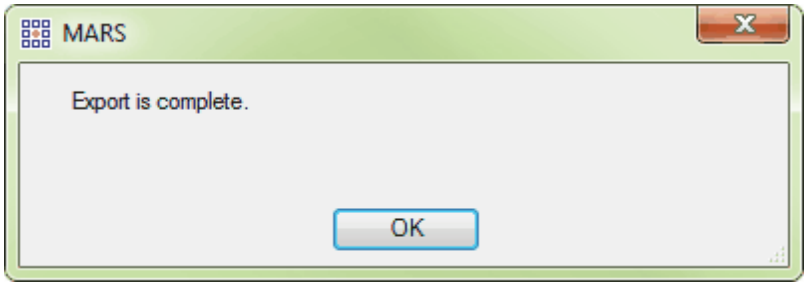


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



See also:

3D Image[662]

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4.5.1.13 Grid - LiDAR Raster JPEG 2000

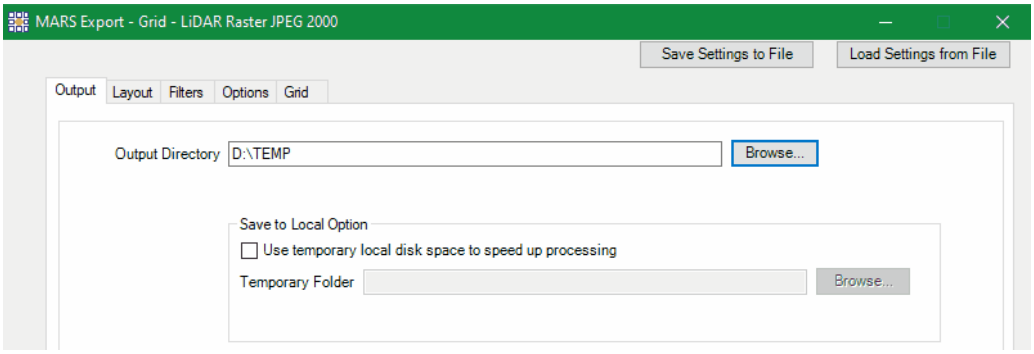
Export LiDAR Raster JPEG 2000 Files

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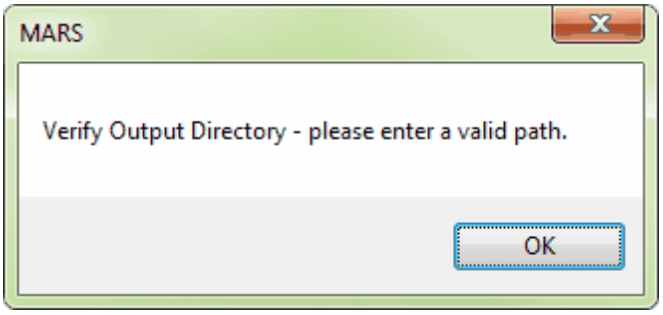
Exporting 'Grid - LiDAR Raster JPEG 2000' files: Start by clicking on the **'Export'** 

button to see the drop-down list of export types. 'Export Area' is not available for this export type.

To export a **Grid - LiDAR Raster JPEG 2000** file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.



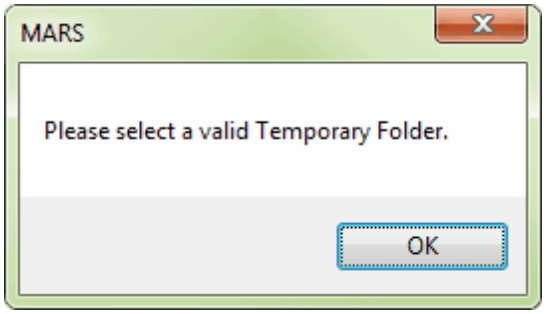
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



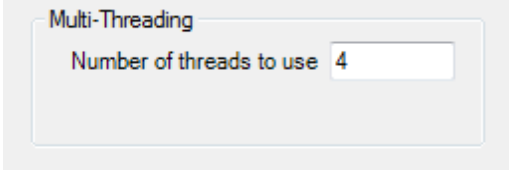
The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout

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raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



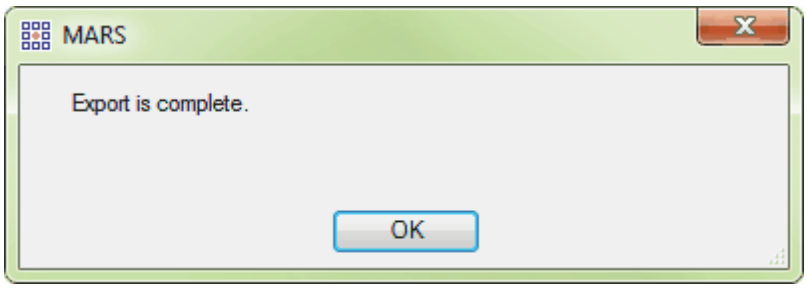
Move through the remaining tabs to continue making specifications for the export.

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There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.14 Grid - TIFF



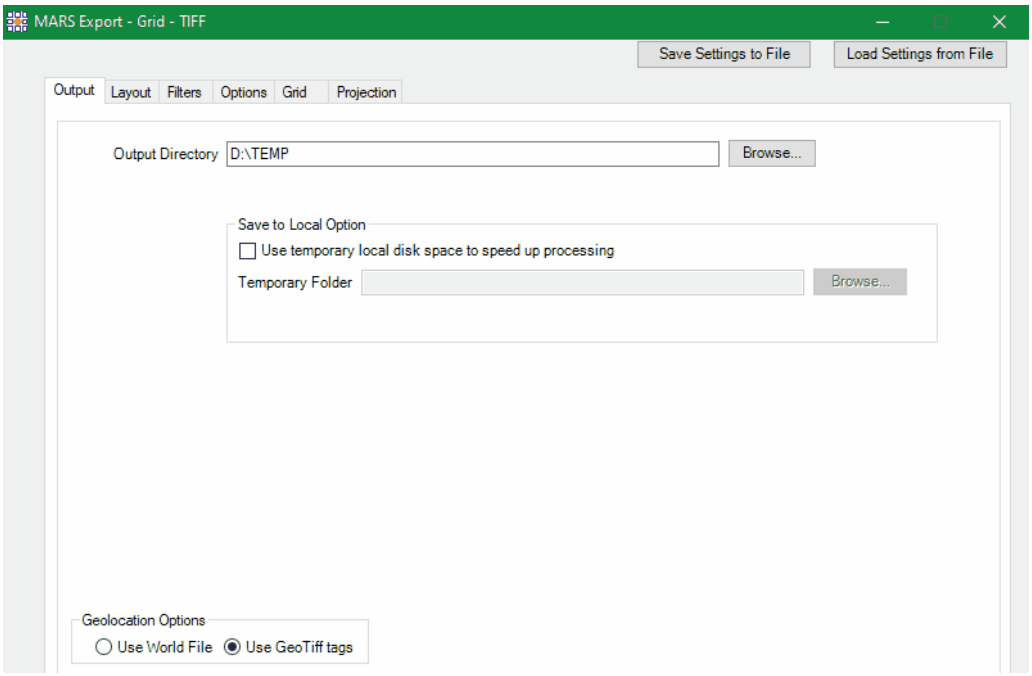
Exporting 'Grid - TIFF' files: Start by clicking on the **'Export'** 

button or the **'Export Area'** 

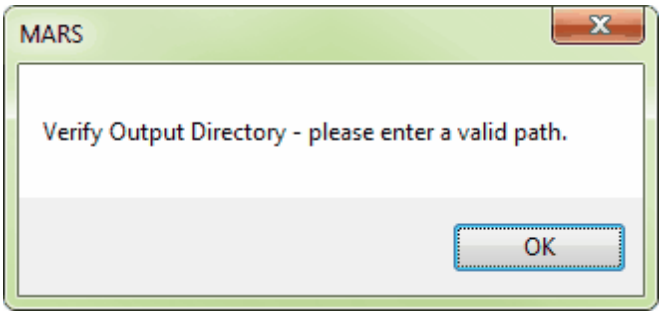
button to see the drop-down list of export types. 'Export Area' requires that a drag box be

created first before the drop-down list appears.

To export a **Grid - TIFF** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



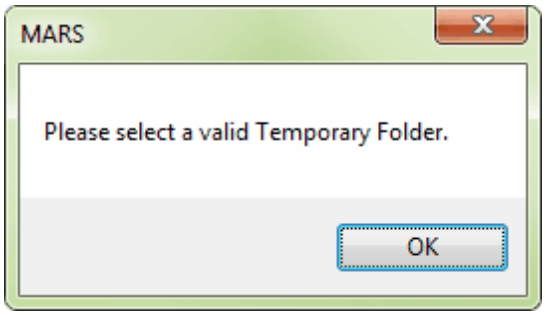
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which

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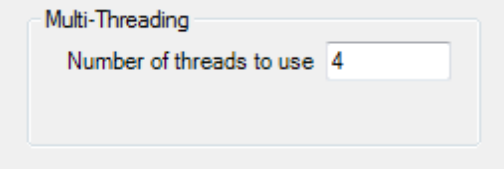
has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



There are two 'Geolocation Options' to choose from for this export type. Select either the **'Use World File'** option or the **'Use GeoTiff tags'** option. The world file option will create a *.tfw file for each exported TIFF in the Output Directory.

When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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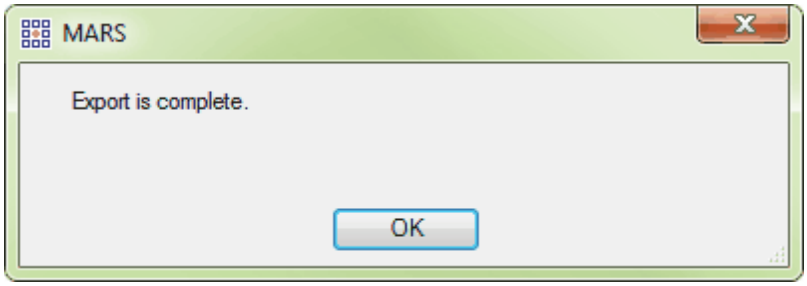


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.15 Hillshade - JPEG 2000

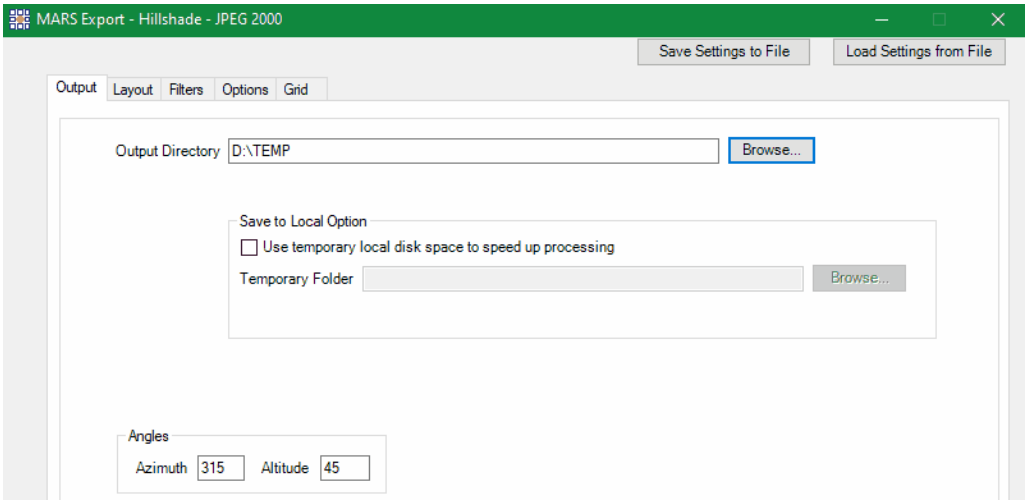


Exporting 'Hillshade - JPEG 2000' files: Start by clicking on the **'Export'** 

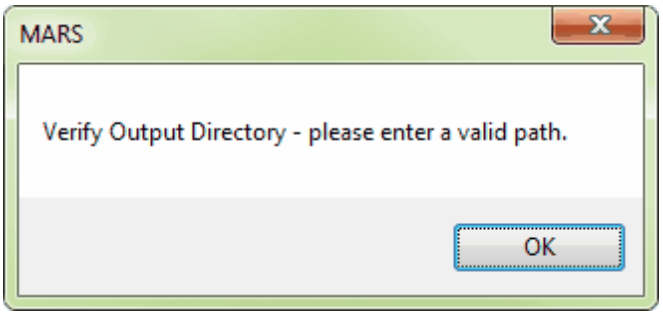
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Hillshade - JPEG 2000** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



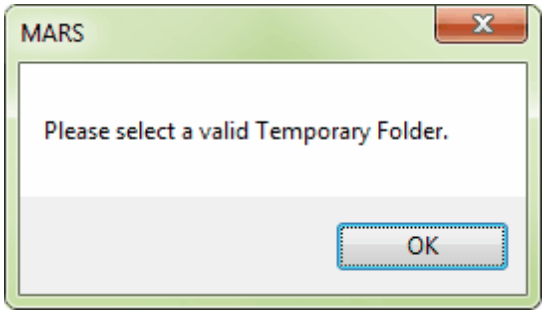
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical

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situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



On the Output tab, set the desired sun **'Azimuth'** and **'Altitude'** values. Azimuth is the direction of the sun (in degrees) - for example, an Azimuth value of 0 (zero) would mean that the sun is due north, whereas a value of 235 would represent a southwest sun. Altitude is the angle (in degrees) of the sun above the horizon. For example, an Altitude value of 0 would place the sun directly on the horizon, while a value of 90 would place it directly overhead. These values control the shading effect in the exported rasters. The default values are Azimuth 315 and Altitude 45.

Example 1 - Hillshade export with Azimuth set to 90 (east sun) and Altitude set to 65 (high sun angle).

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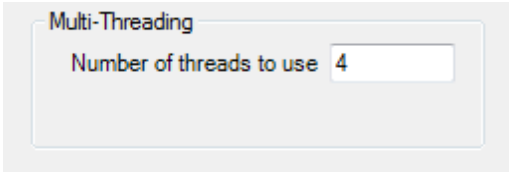


Example 2 - Hillshade export with Azimuth set to 235 (southwest sun) and Altitude set to 40 (low sun angle).

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When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



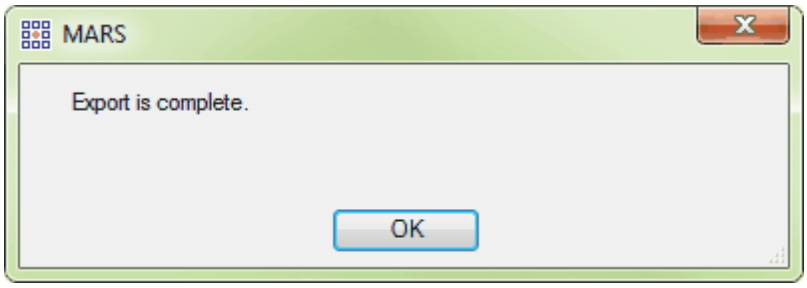
Move through the remaining tabs to continue making specifications for the export.

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There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab[774] for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.16 LAS

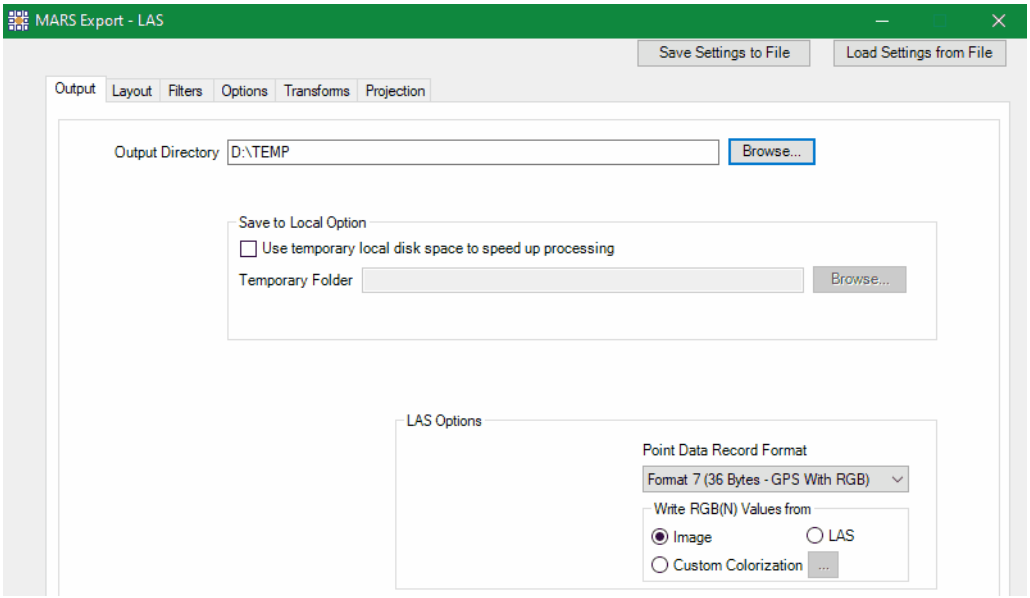


Exporting 'LAS' files: Start by clicking on the **'Export'** 

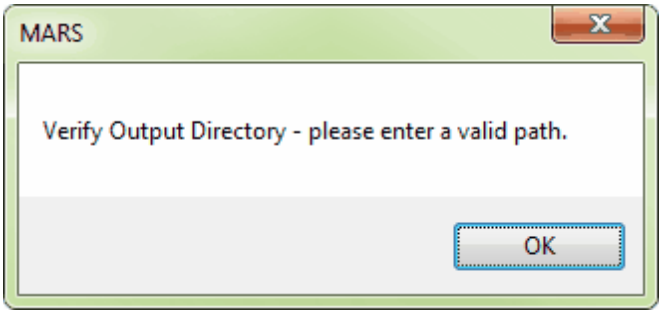
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears. This is one of two Export Types (the other is Text - ASCII[739]) that supports the By Collection Scan[768] and By Collection Scan From User-defined Box[772] layout formats.

To export an **LAS** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



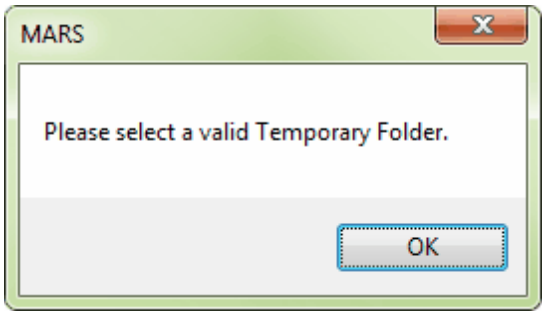
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The **'Use temporary local disk space to speed up processing'** option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space

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to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



Point Data Record Format (PDRF) 6, 7, or 8 can be selected for the exported data.

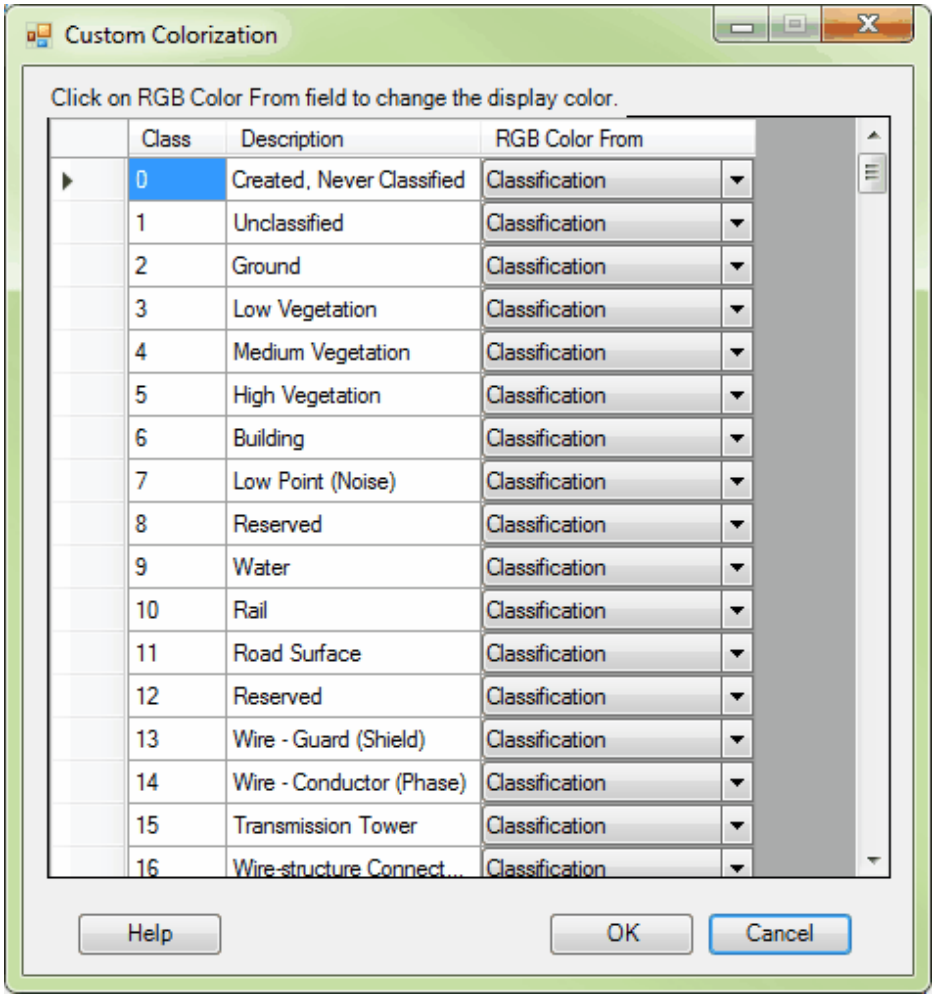
PDRF 6 stores no color values at the point level. PDRF 7 stores RGB values and PDRF 8 stores RGB (N) values at the point level. If the LAS data to be exported is either PDRF 7 or 8 and PDRF 6 is selected for the export, the exported data will no longer store any color values.

For PDRF 7, three options for 'Write RGB Values from' are enabled: 'Image', 'LAS', and 'Custom Colorization'. When choosing the 'Image' option (only available when co-located raster and LAS data are both loaded into MARS®), the image pixel RGB values will be written to the exported LAS file. Choosing the 'LAS' option allows existing RGB values to be carried over from the input data to the exported files. Choosing the 'Custom Colorization' option enables the ellipse button  which will open a selection interface. One of five methods for coloring each class of points can be selected: current classification color, intensity, class blended with intensity, RGB values from displayed images, or RGB values from the input LAS file. This allows each class in the exported LAS file to have RGB values assigned from different sources. When the newly-exported LAS file with RGB values is then

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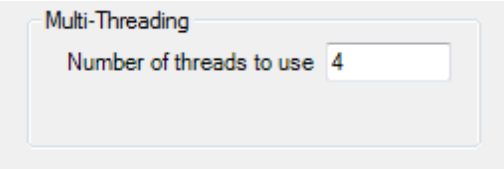
loaded into MARS®, the Color by RGB tool can be used on the data.

For PDRF 8, two options for 'Write RGB(N) Values from' are enabled: 'Image' and 'LAS' ('Custom Colorization' is disabled for this export option). When choosing the 'Image' option (only available when co-located RGBN (4-band) raster and LAS data are both loaded into MARS®), the image pixel RGBN values will be written to the exported LAS file. When the newly-exported LAS file with RGBN values is then loaded into MARS®, the Color by RGB tool can be used on the data to see the three visible color bands.



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When exporting by tiles or collection scans, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

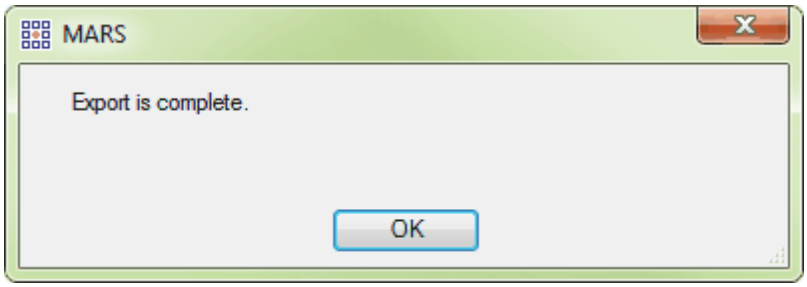


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.17 LiDAR Point Density - Float Grid

Export LiDAR Point Density - Float Grid Files

Merrick Advanced Remote Sensing (MARS®) Software

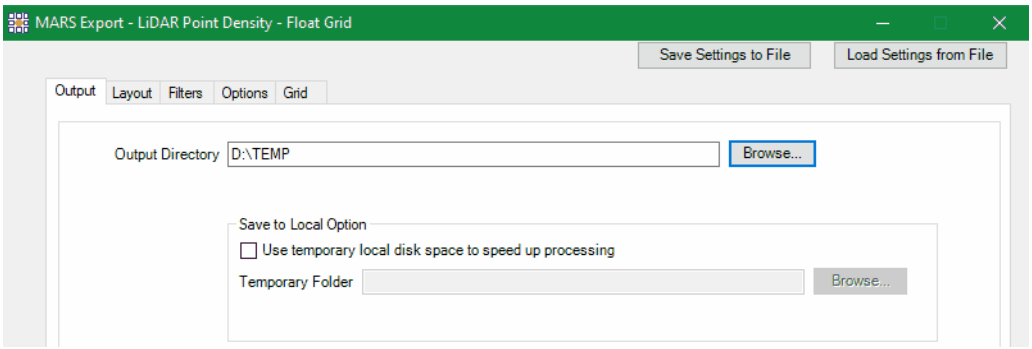
This export type creates a relative point density grid using first returns only. The result is a color-coded raster using a blue to red color ramp - deep blue cells are the least dense and red cells are the most dense. The only options on the 'Grid' tab that can be set are 'Cell Size' and 'Auto Calculate Virtual Tile Size' / 'Virtual Tile Size' (see top section of Grid 783 tab topic for explanations).

Exporting 'LiDAR Point Density - Float Grid' files: Start by clicking on the **'Export'** 

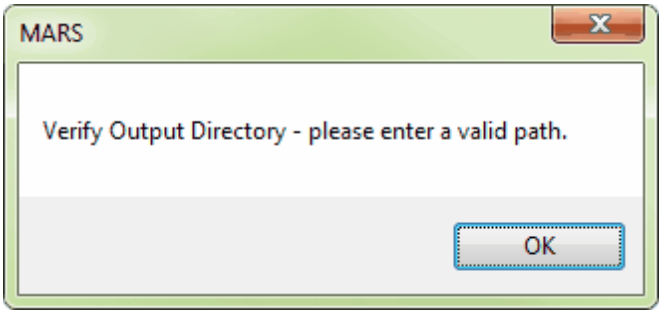
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **LiDAR Point Density - Float Grid** file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.

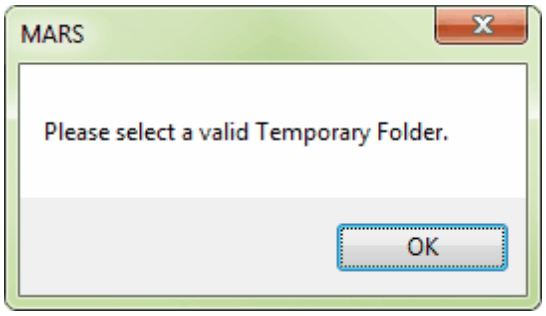


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

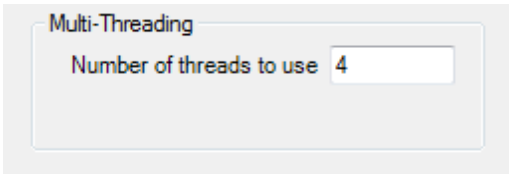


The 'Use temporary local disk space to speed up processing' option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

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When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



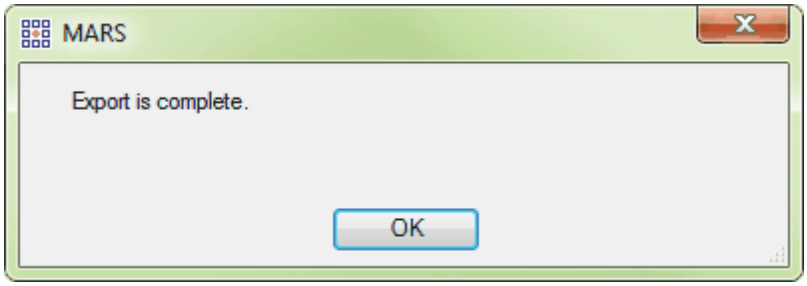
Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

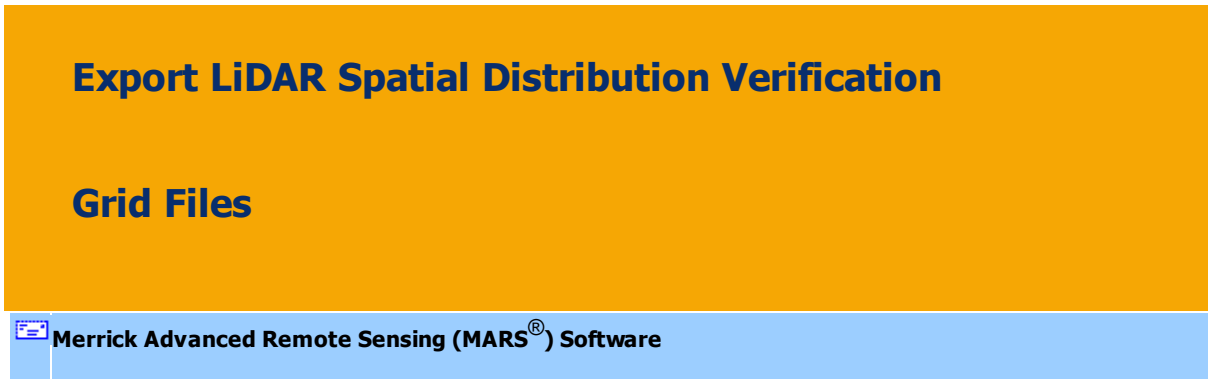
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When the export is complete, the following message will appear.



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4.5.1.18 LiDAR Spatial Distribution Verification Grid - JPEG 2000

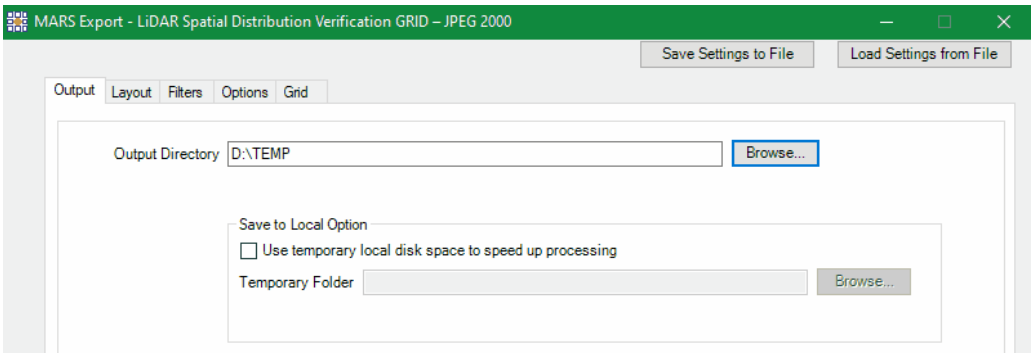


Exporting 'LiDAR Spatial Distribution Verification GRID - JPEG 2000' files: Start by clicking on the **'Export'** 

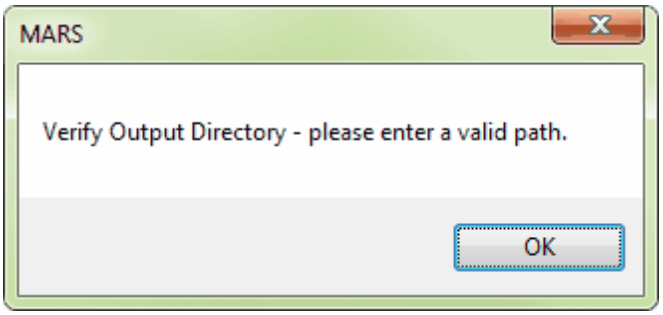
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **LiDAR Spatial Distribution Verification GRID - JPEG 2000** file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the raster file(s) and the auxiliary text file(s) should be exported.

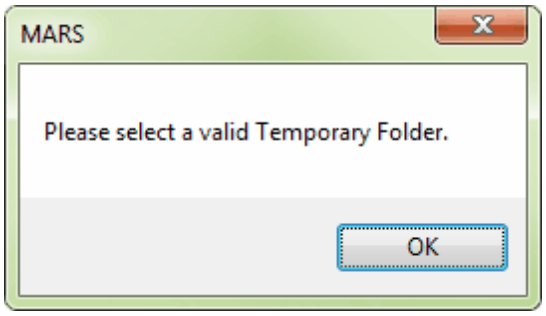


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The 'Use temporary local disk space to speed up processing' option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

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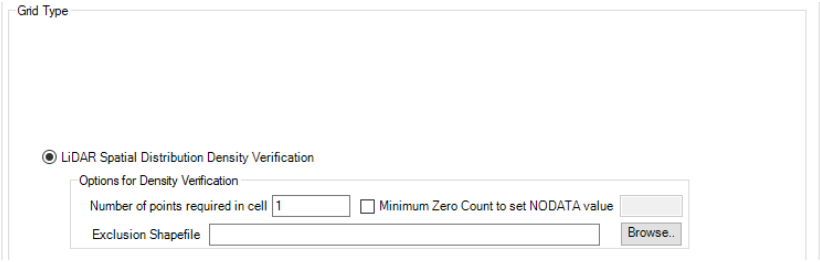
Additional details on running this export: This export type is to used create a grid that contains values representing the presence (value=1) or void (value=0) of a first (of any) return LiDAR point within any portion of a predefined grid cell size.

The **'Number of points required in cell'** text box is now enabled. The user may define the number of points required within each cell with this text box. The default number of points in a cell will remain at '1', unless the user specifies differently, to meet USGS specifications.

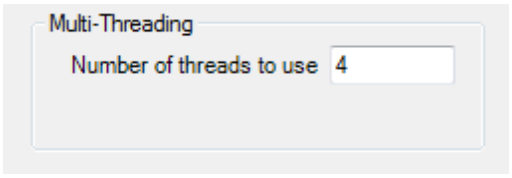
The **'Exclusion Shapefile'** option is meant for use with a polygon shapefile. A typical polygon shapefile for use with this tool will contain polygons around all water bodies which may cause the resulting output grid file to produce a '0' (zero) value. A '0' value would indicate that no LiDAR point was discovered inside that particular cell and that cell would then 'fail' the test as described above. If all the cells found inside a body of water record a '0' value, it could cause the entire project area to fall below the 90% pass rate of cells containing a value of 1 (cells which contain at least one point). Because LiDAR is absorbed by water, water should be excluded from the test results. The 'Exclusion Shapefile' option allows the user to place polygons around any water bodies which may result in a '0' value and exclude those polygons from the results. Using this parameter when producing a LiDAR Spatial Distribution Verification grid is optional.

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The **'Minimum Zero Count to set NODATA value'** option may be applied in areas where a large number of '0' value cells is anticipated, as in the case of a water body. This option implements a maximum number of contiguous '0' cells and changes the value of those '0' cells to a value of 'NULL'. This will automatically delineate large data void areas such as water bodies. This option can be used as an alternative to the 'Exclusion Shapefile' option and accomplishes the same general purpose. After checking the **'Minimum Zero Count to set NODATA value'** option, the user may enter an integer in the adjacent text box. As an example, if the user entered '3' into this text box, the process would look for three contiguous cells containing a '0' value and change all three to a 'NULL' value. The purpose of this option is to create a more accurate pass percentage if no exclusion shapefile exists.



When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



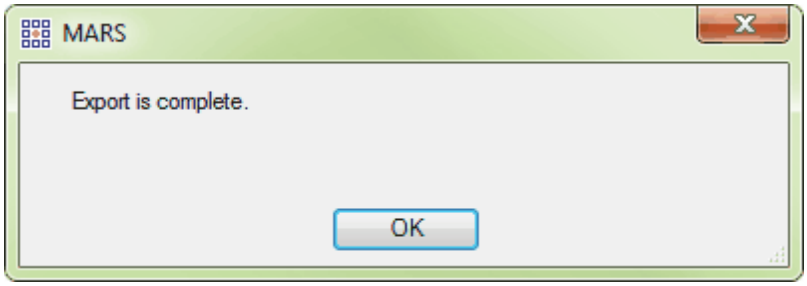
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Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

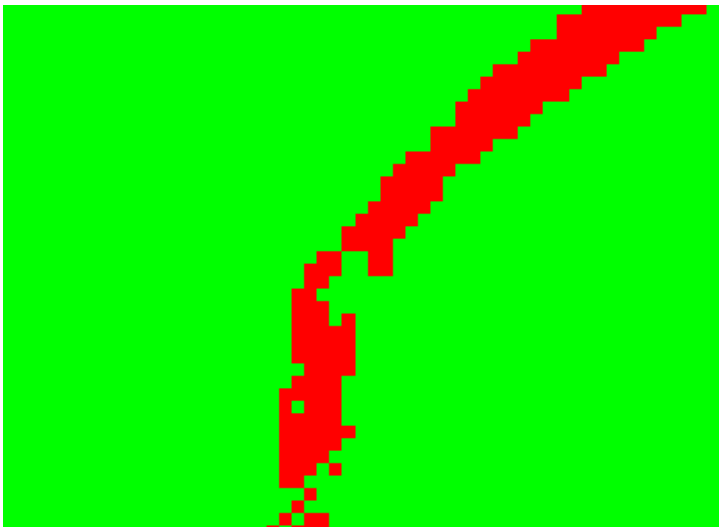
When all the parameters of the export have been set, click the **'Export'** button at the bottom of the interface to export the file.

When the export has completed successfully, a prompt, as seen below, will appear.



Below is an example result of the LiDAR Spatial Distribution Verification Grid tool. The green areas represent cells with a value of '1', meaning they have at least one LiDAR point within the cell. The red areas represent cells with a value of '0', meaning they DO NOT contain any LiDAR points. In the example below it is easy to see that there is a body of water running through this area, which is the cause of the red cells with a '0' value. If the user were to implement the 'Minimum Zero Count' option when running this tool, the areas of contiguous '0' cells (the water body) would return a 'NULL' value instead of a '0' value.

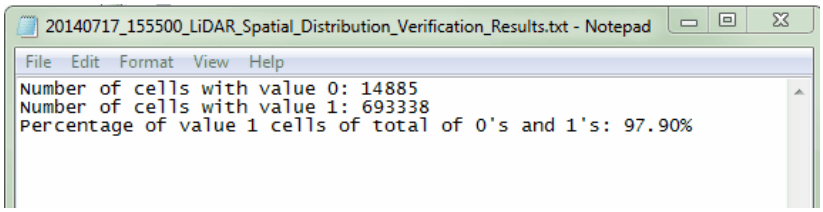
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The 'LiDAR Spatial Distribution Verification Grid' tool will also output a results text file (*.txt) every time the tool is used. This text file will be output to the same location as the JPEG 2000 (the location specified by the user in the output directory browse box). The text file will be named beginning with the date, time, and '...LiDAR_Spatial_Distribution_Verification_Results.txt'. This allows each *.txt created to be unique. For example, the file seen in the screen shot below was produced on February 2, 2011 at 2:45 pm.



The text file will contain the following information: the number of cells with a '0' value, the number of cells with a '1' value, and the number of value '1' cells as a percentage of the total number of cells. This last value will be the percentage of passing cells. This percentage needs to be 90% or above to be in compliance with the USGS specifications mentioned above. The screen shot below shows an example of the information contained in the text file.



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4.5.1.19 PLS-CADD Code - ASCII

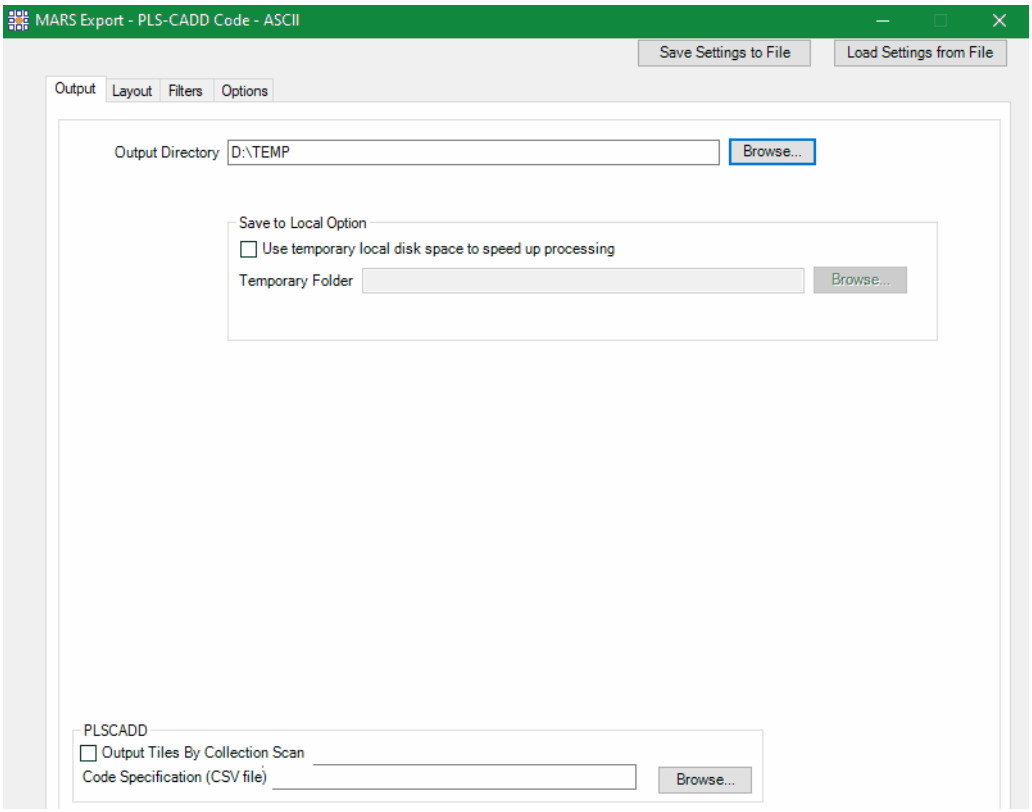


Exporting 'PLS-CADD Code - ASCII' files: Start by clicking on the **'Export'** 

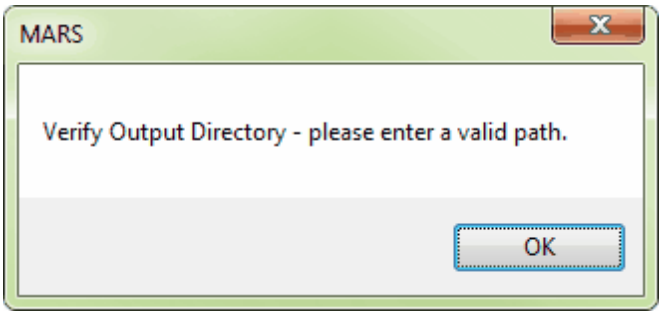
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **PLS-CADD Code - ASCII** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



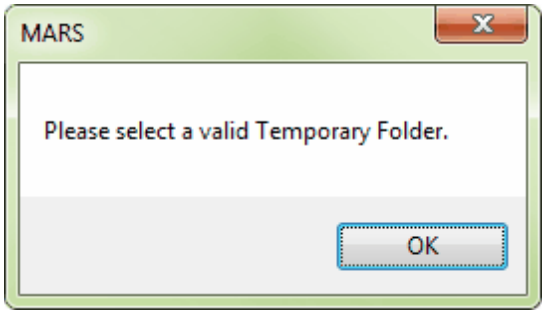
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



The 'Use temporary local disk space to speed up processing' option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the

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export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



After setting an output directory (and, optionally, a temp folder), move on to the Code Specification (CSV file) text box. A *.csv seed file MUST be used in export. Please specify a code file to be used by browsing to the appropriate directory. The PLS-CADD program's codes (often called feature codes) are related to MARS® classifications. The only way to reclass or assign multiple PLS-CADD codes to multiple different MARS® classifications is by use of a *.csv file that 'maps' certain point classes to specific feature codes. This file will specify which PLS-CADD code should be assigned which MARS® point classification(s). For example, in the CSV file below, the PLS-CADD code '100 Ground Point Thin' has been assigned the MARS® classification '2', which is typically a ground classification. If the PLS-CADD code is to be assigned to more than one MARS® classification, the classifications in column 'A' need to be separated in the CSV file by a pipe ('|') - a vertical line character created by holding down the SHIFT key while pressing the backslash ('\') key. For example, in the CSV file below, the PLS-CADD code '10000 Ground Point All' has been assigned the MARS® classifications '2 | 8' (2 and 8). Column B ('PLSCAD CODE' in this example) cannot contain any duplicate values. The 'Folder' column tells MARS® what to name the sub-folders that will be created in the output directory - almost any name can be used as long as it is unique within the output folder. Note that several

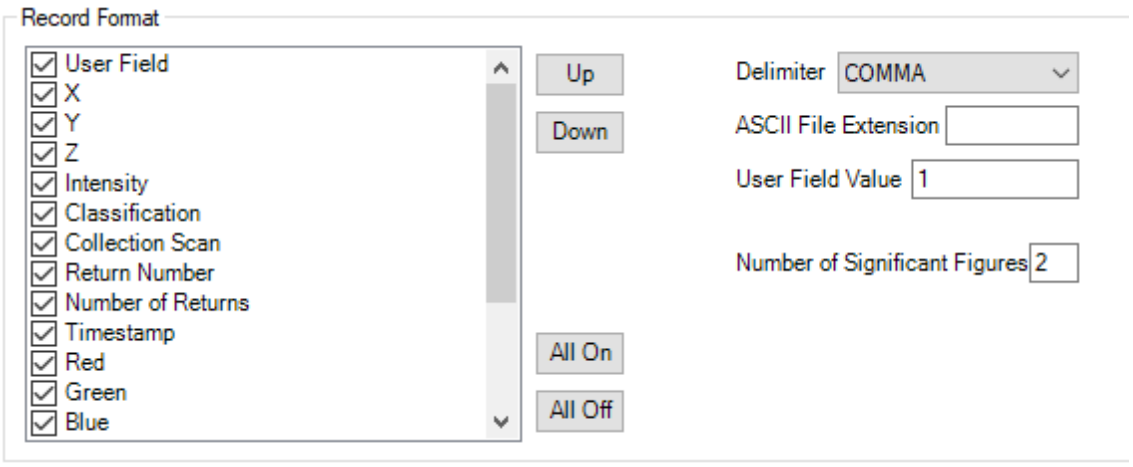
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reserved ASCII characters are not allowed as part of a folder name, and cannot be present in the 'Folder' column of the CSV file: **< > / % & ' "**. Each sub-folder will contain one (1) CSV file of the results of a particular class-to-code mapping.

	A	B	C	D
1	MARS Classification	PLSCAD CODE	Description	Folder
2	2	100	Ground Point Thin	Ground_points
3	2|8	10000	Ground Point All	Ground_all
4		101	Computed Point	
5		150	Control Point	
6	23	151	Misc. Aerial Point (overhang)	Aerial_pts
7		152	Misc. Ground Point	
8		153	Bench Mark	
9		154	USGS Control Point	
10		200	PI	
11		201	Section Corner	
12		202	Found Rebar	
13		203	Found Nail	

The **PLS-CADD Code - ASCII** export type allows tiles to be exported by collection scan. Check the box labeled 'Output Tiles By Collection Scan' to enable this option (see below). This export type uses only the 'Single File' or 'Selected Tile(s)' layout types with the 'Export' tool, or the 'User-defined Box' layout type with the 'Export Area' tool.

The **'Record Format'** section of the 'Layout' tab is available when this export type is chosen.



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Choose how the text document is to be exported by making specifications in this area.

Record Format: Choose settings in this box that are unique to the **PLS-CADD Code - ASCII** export by selecting the attributes which are to be included in export. If an attribute field is unchecked, it will not be included in the export. By default, all fields are selected.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: The options are: SPACE, TAB, and COMMA (the default) to be used to separate fields in the output text file.

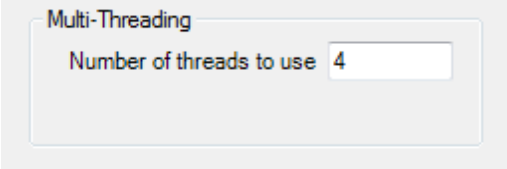
ASCII File Extension: The user may choose the file extension with which the text file is output. For example, the user may choose to export a *.csv or a *.txt file. Enter the desired extension into the entry box.

User Field Value: This text box is valid only when the user has selected the 'User Field' attribute for inclusion. A value entered here will be applied to all records in the export. The default value is 1.

Number of Significant Figures: Specifies how many significant figures are used in the X, Y, and Z values during export. The default setting is 2, but values of 1 to 16 can be entered.

When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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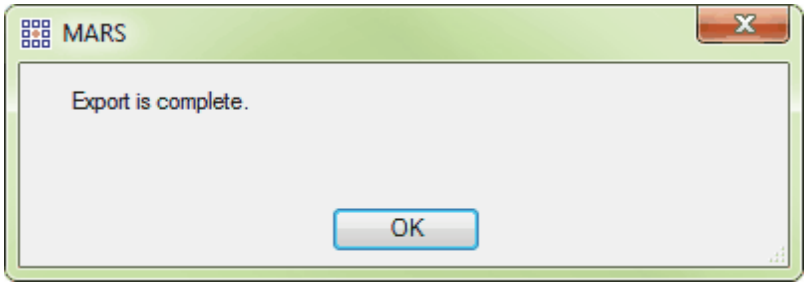


Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters on every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.20 PLS-CADD Code - LAS

Export PLS-CADD Code - LAS Files

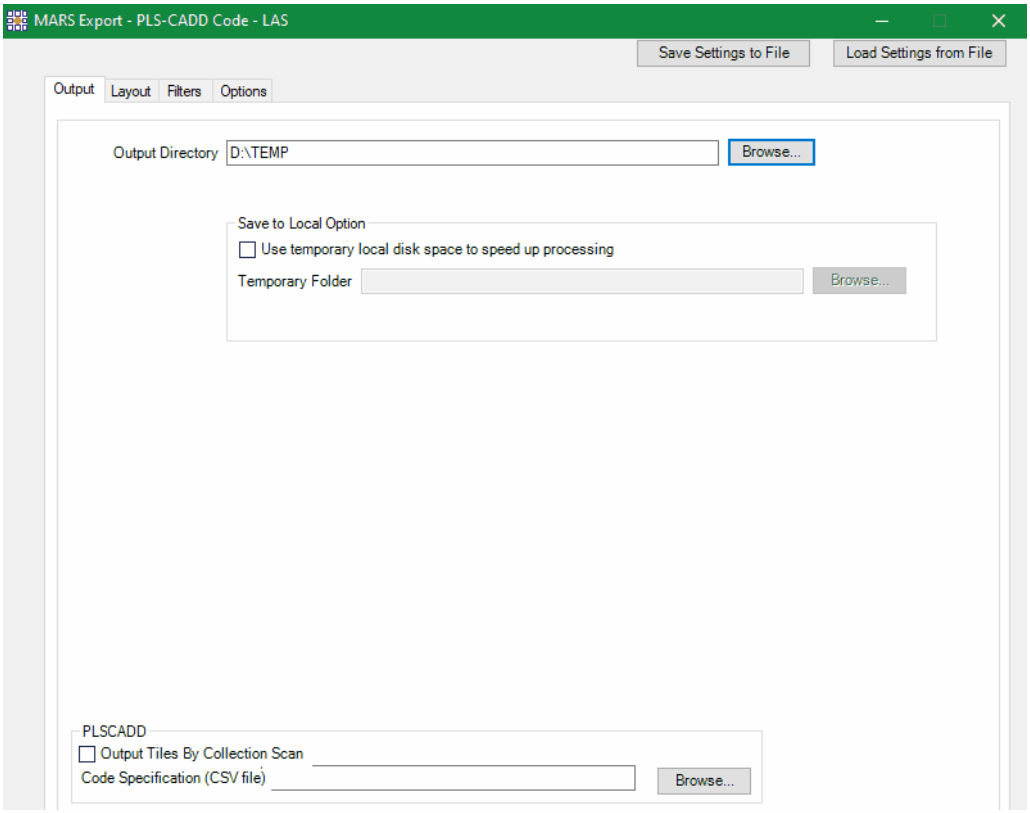
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Exporting 'PLS-CADD Code - LAS' files: Start by clicking on the **'Export'** 

button or the **'Export Area'** 

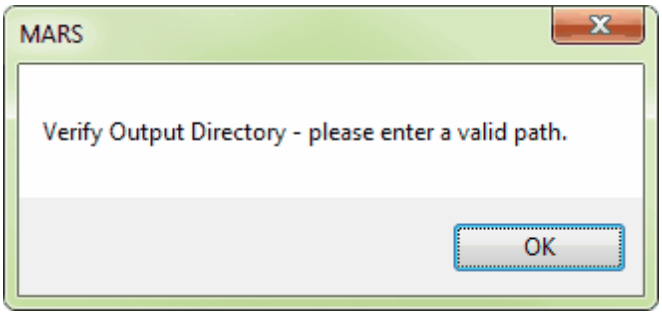
button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **PLS-CADD Code - LAS** file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported. The output folder will have subfolders created that are named by two attributes in a polygon shapefile used in the export.

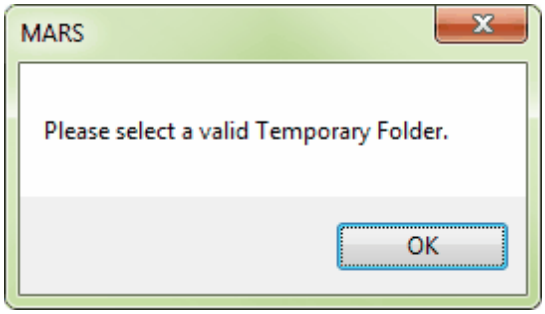


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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The 'Use temporary local disk space to speed up processing' option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



After setting an output directory (and, optionally, a temp folder), move on to the Code Specification (CSV file) text box. A *.csv seed file MUST be used in export. Please specify a code file to be used by browsing to the appropriate directory. The PLS-CADD program's codes (often called feature codes) are related to MARS® classifications. The only way to reclass or assign multiple PLS-CADD codes to

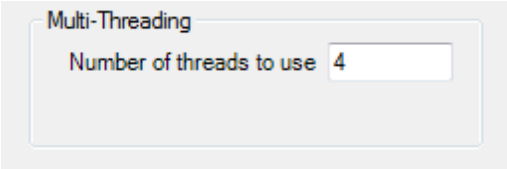
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multiple different MARS® classifications is by use of a *.csv file that 'maps' certain point classes to specific feature codes. This file will specify which PLS-CADD code should be assigned which MARS® point classification(s). For example, in the CSV file below, the PLS-CADD code '100 Ground Point Thin' has been assigned the MARS® classification '2', which is typically a ground classification. If the PLS-CADD code is to be assigned to more than one MARS® classification, the classifications in column 'A' need to be separated in the CSV file by a pipe ('|') - a vertical line character created by holding down the SHIFT key while pressing the backslash ('\') key. For example, in the CSV file below, the PLS-CADD code '10000 Ground Point All' has been assigned the MARS® classifications '2 | 8' (2 and 8). Column B ('PLSCAD CODE' in this example) cannot contain any duplicate values. The 'Folder' column tells MARS® what to name the sub-folders that will be created in the output directory - almost any name can be used as long as it is unique within the output folder. Note that several reserved ASCII characters are not allowed as part of a folder name, and cannot be present in the 'Folder' column of the CSV file: **< > / % & ' "**. Each sub-folder will contain one (1) CSV file of the results of a particular class-to-code mapping.

	A	B	C	D
1	MARS Classification	PLSCAD CODE	Description	Folder
2	2	100	Ground Point Thin	Ground_points
3	2|8	10000	Ground Point All	Ground_all
4		101	Computed Point	
5		150	Control Point	
6	23	151	Misc. Aerial Point (overhang)	Aerial_pts
7		152	Misc. Ground Point	
8		153	Bench Mark	
9		154	USGS Control Point	
10		200	PI	
11		201	Section Corner	
12		202	Found Rebar	
13		203	Found Nail	

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When exporting by tiles, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



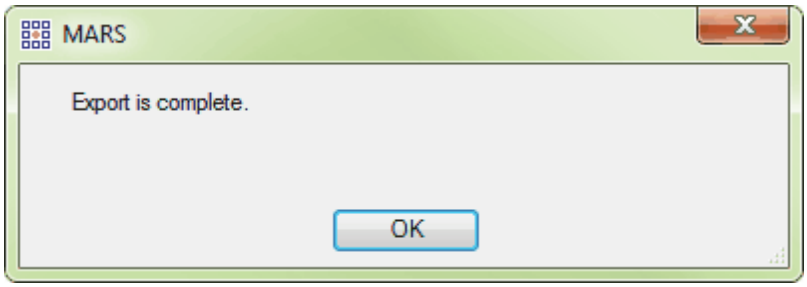
Move through the remaining tabs to continue making specifications for the export. This export type uses only the 'Selected Tile(s)' layout type with the 'Export' tool, or the 'User-defined Box' layout type with the 'Export Area' tool.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters on every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.

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4.5.1.21 Shapefile

Export Point Shapefiles

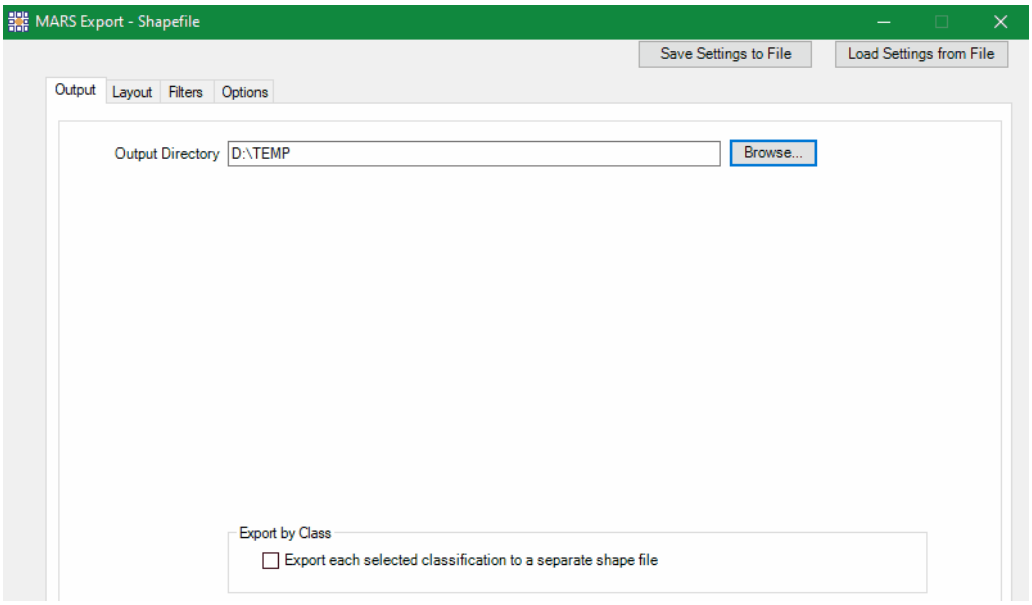
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Exporting 'Shapefile' files: Start by clicking on the **'Export'** 

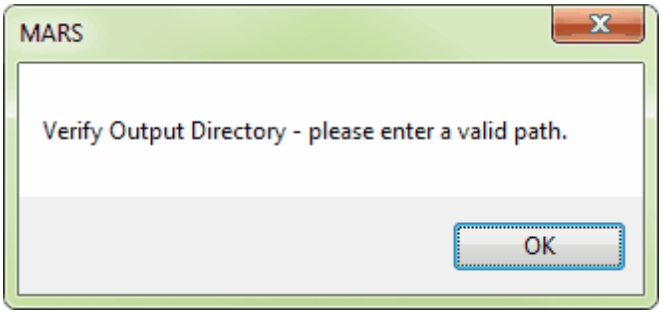
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears.

To export a **Shapefile** file (points), select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.



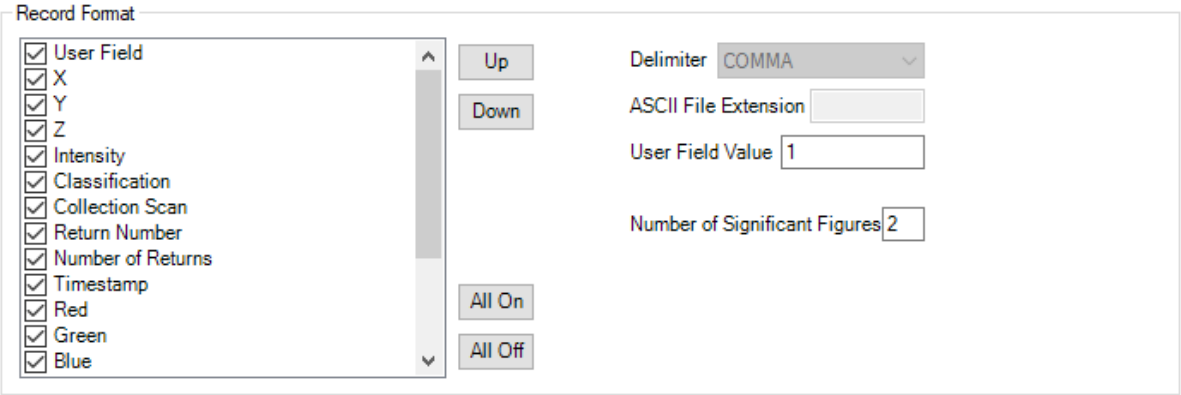
If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.



There is an option with this export type to create a separate shapefile for each selected class that exists in the loaded LAS data.

The **'Record Format'** section of the 'Layout' tab is available when this export type is chosen.

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Choose how the shapefile attribute table is to be designed by making specifications in this area.

Record Format: Choose settings in this box that are unique to the **Shapefile** export by selecting the attributes which are to be included in export. If an attribute field is unchecked, it will not be included in the export. By default, all fields are selected and will be added to the attribute table in the order listed.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: Not used for Shapefile export.

ASCII File Extension: Not used for Shapefile export.

User Field Value: Not used for Shapefile export.

Number of Significant Figures: Not used for Shapefile export.

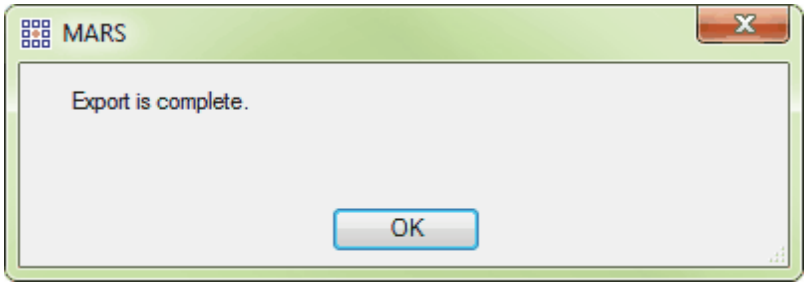
Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

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When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file. When Shapefiles are exported, a *.prj (projection definition file) is created if the projection information is defined for the source LAS data.

When the export is complete, the following message will appear.



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4.5.1.22 Text - ASCII

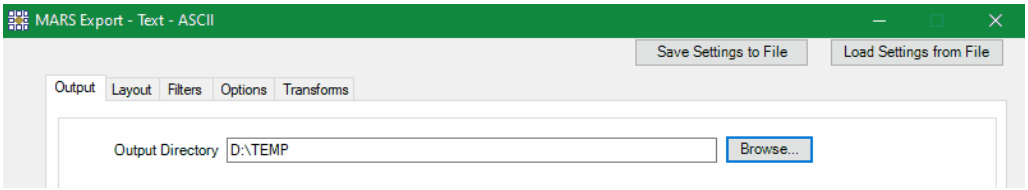


Exporting 'Text - ASCII' files: Start by clicking on the **'Export'** 

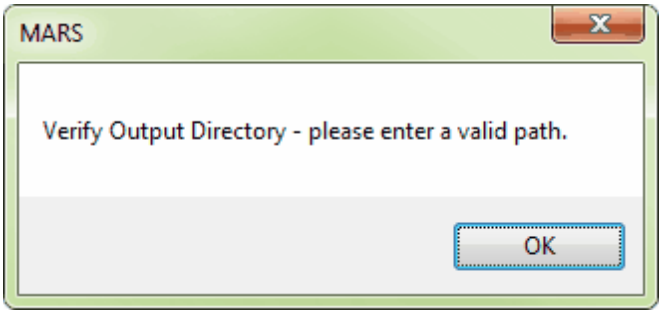
button or the **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears. This is one of two Export Types (the other is LAS 712) that supports the By Collection Scan 768 and By Collection Scan From User-defined Box 772 layout formats.

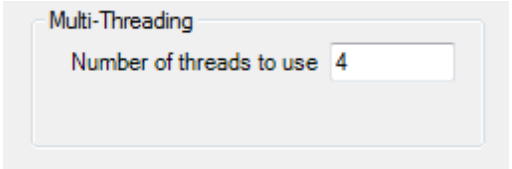
To export a **Text - ASCII** file, select it from the drop-down list. On the Output Tab[746], specify an output directory where the file(s) should be exported.



If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

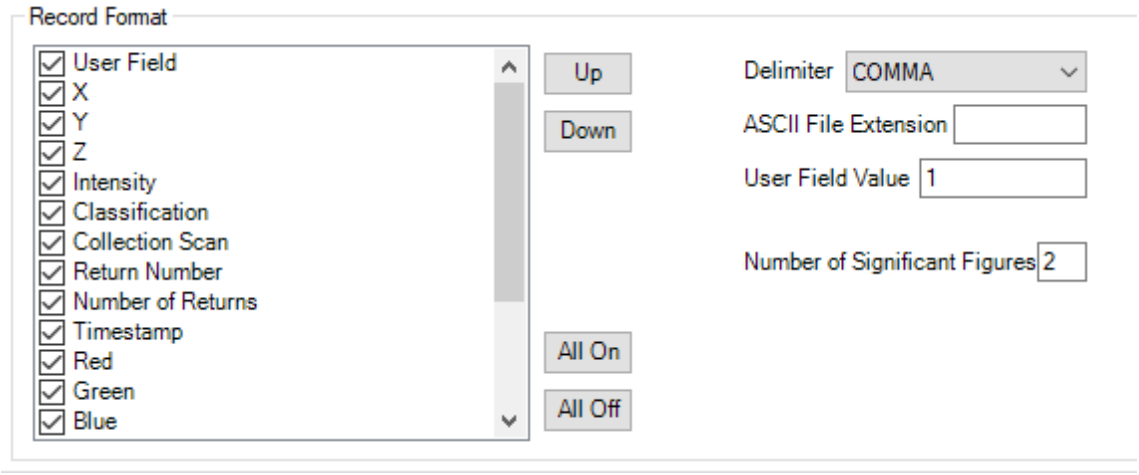


When exporting by tiles or collection scans, the multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



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The **'Record Format'** section of the 'Layout' tab is available when this export type is chosen.



Choose how the text document is to be exported by making specifications in this area.

Record Format: Choose settings in this box that are unique to the **Text - ASCII** export by selecting the attributes which are to be included in export. If an attribute field is unchecked, it will not be included in the export. By default, all fields are selected.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: The options are: SPACE, TAB, and COMMA (the default) to be used to separate fields in the output text file.

ASCII File Extension: The user may choose the file extension with which the text file is output. For example, the user may choose to export a *.csv or a *.txt file. Enter the desired extension into the entry box.

User Field Value: This text box is valid only when the user has selected the 'User Field' attribute for inclusion. A value entered here will be applied to all records in the export. The default value is 1.

Number of Significant Figures: Specifies how many significant figures are used in the X, Y, and Z

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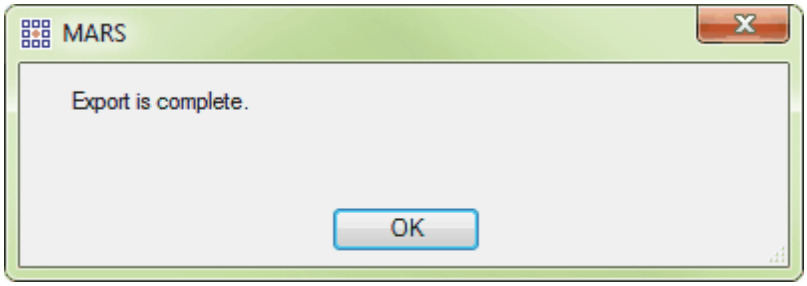
values during export. The default setting is 2, but values of 1 to 16 can be entered.

Move through the remaining tabs to continue making specifications for the export.

There are options with this export type to include/exclude specific classes, returns, collection scans, and bit-flagged points from the exported LAS file(s). Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.



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4.5.1.23 USGS Swath Separation Image - Tiled GeoTIFF

Export USGS Swath Separation Image - Tiled GeoTIFFs

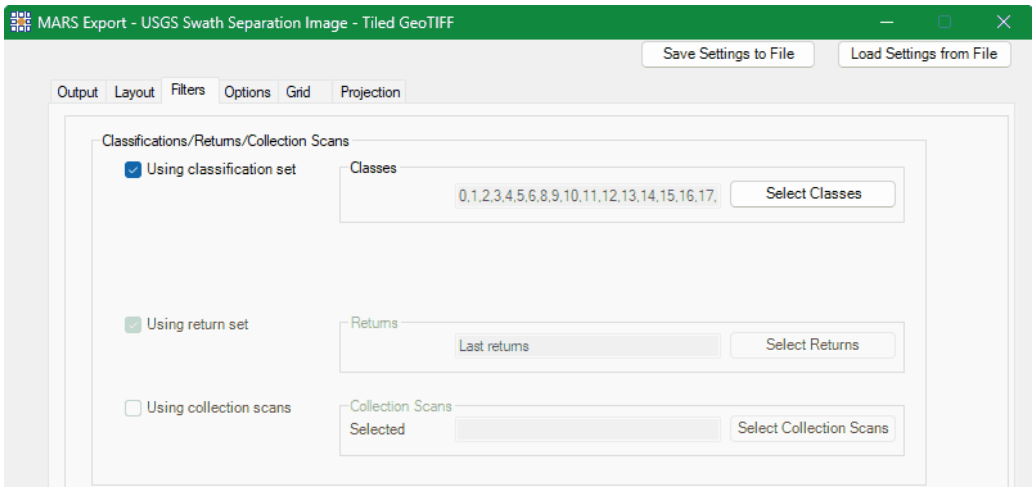
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NOTE: Swath Separation Images (SSI) are a very specific type of raster designed to meet the delivery requirements of many USGS-funded projects. As such, most of the usual export settings are 'hard-coded' and cannot be changed by the user.

Exporting 'USGS Swath Separation Image - Tiled GeoTIFF' raster files: Start by selecting one or more tiles from a loaded tile layout shapefile, then click the **'Export'** 

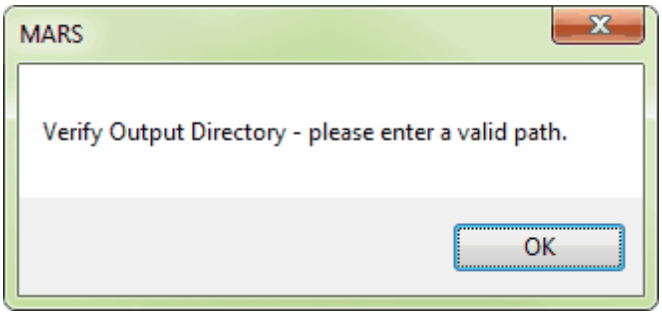
button. Note that this export type works only when one or more tiles have been pre-selected using the 'Pick Tiles 960' tool.

To export a **USGS Swath Separation Image - Tiled GeoTIFF** raster file, select it from the drop-down list. On the Output Tab 746, specify an output directory where the file(s) should be exported.

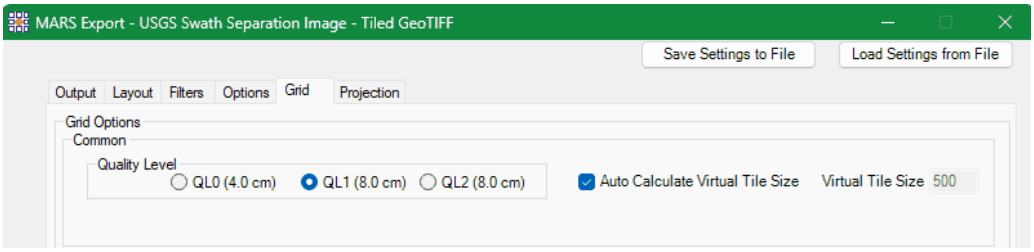


If no Output Directory is specified, a prompt will appear as seen below when trying to run the export.

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On the 'Grid' tab, select the 'Quality Level' needed for the export. This level depends on the pre-established Quality Level that must be met for a particular project.

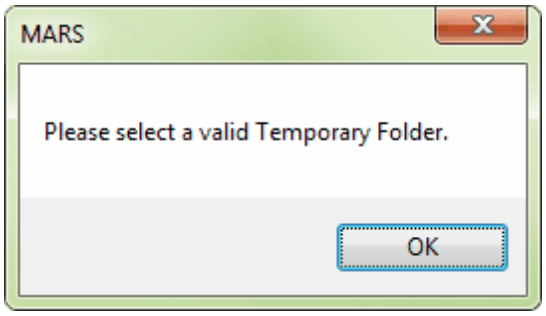


The **'Use temporary local disk space to speed up processing'** option allows the exported raster(s) to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:***

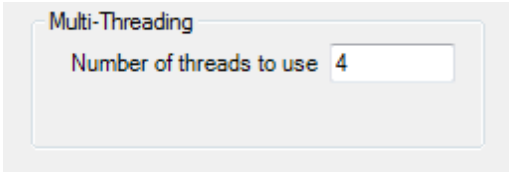
Most versions of Windows prohibit an application's output of files to the root directory of drives.

It is strongly recommended that an actual folder be used for this option.

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The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

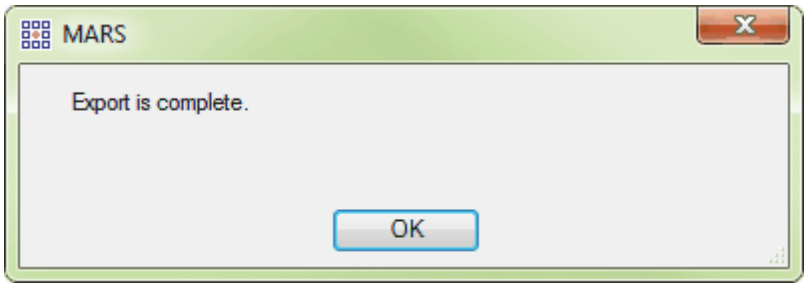


On the 'Filters' tab in the export dialog, only Classification settings can be changed - all other settings are internally set to adhere to the USGS specifications for the 'USGS Swath Separation Image - Tiled GeoTIFF' export type. Please see the Filters Tab 774 for more details.

When all of the parameters of every tab have been specified, click the **'Export'** button at the bottom of the interface to export the file.

When the export is complete, the following message will appear.

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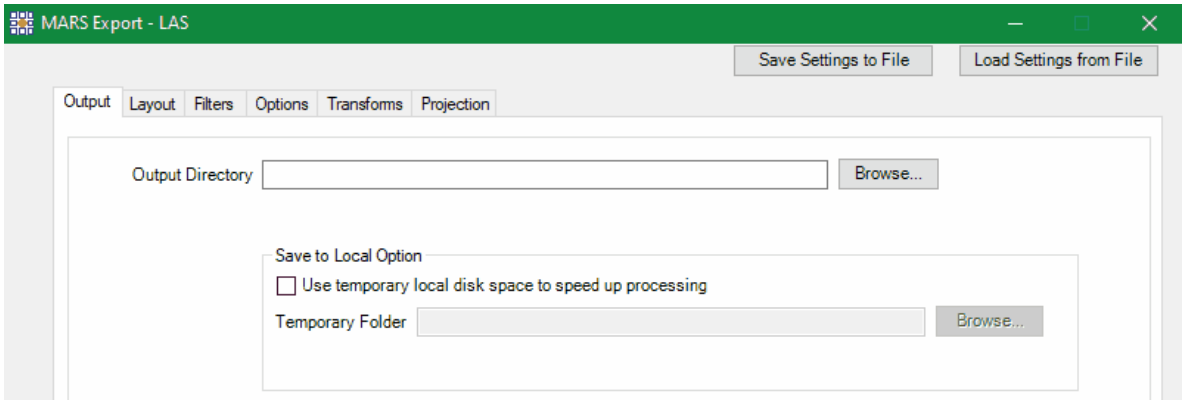
4.5.2 Output tab



The Output tab is where an **'Output Directory'** for any export type is selected. Other options for specific export types may be found on this tab as well.

Most export types include the **'Save to Local Option'** to improve performance when writing the export to a network drive (for example). Checking the **'Use temporary local disk space to speed up processing'** box allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

Several export types include additional controls and settings on this tab that are unique to the export being created. See the Data Export 658 section of the Help Topics for more information.



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4.5.3 Layout tab

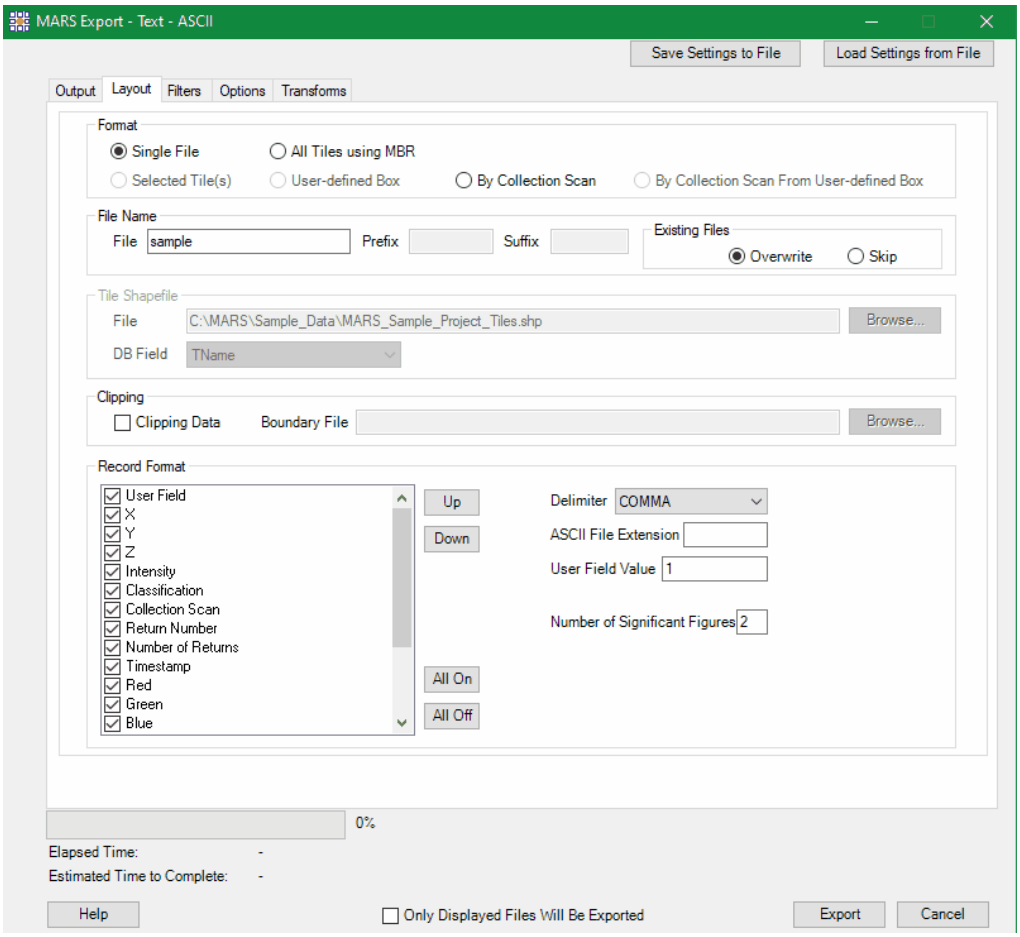
4.5.3.1 Single File



The '**Layout**' tab has many different export format options, depending on the Export Type being performed. The first option is the **'Single File'** format:

'Single File'* Export:** Exports all data loaded into MARS® as a single output file. No tile layout is used, even if one is loaded. Choose this option if tiled output is not desired, but instead, one single file is needed. This option is most commonly used with outputting a grid-based surface. ***This Layout format is not available for the 'Contours - Shapefile' export type.

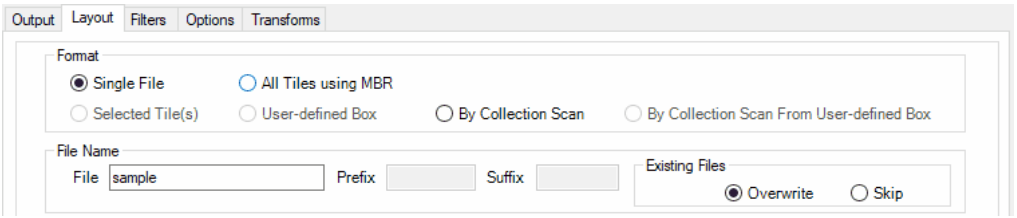
If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.



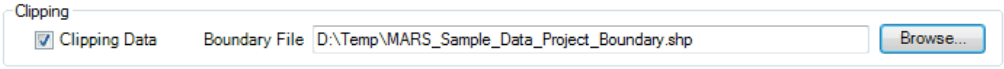
- ***'File Name'* section:** Enter a name for the exported file.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any*

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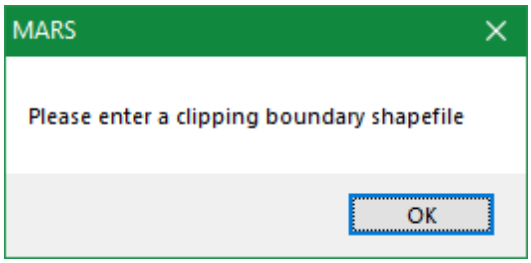
reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely. The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



- ***'Clipping'* section:** If the user would like to clip the exported file to a boundary file, check the **'Clipping Data'** check box as shown in the example below:

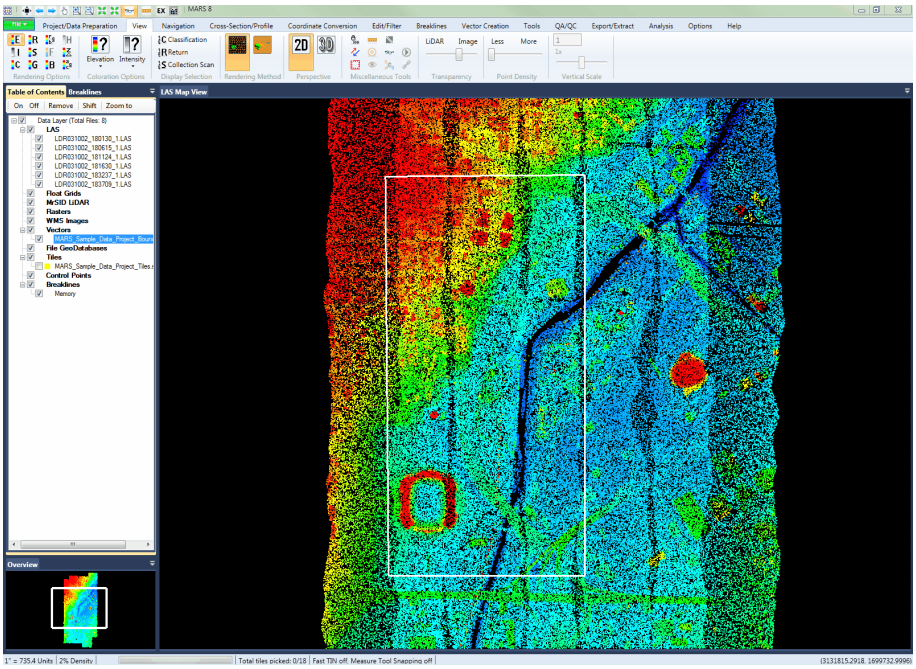


Checking this box will enable the 'Boundary File' text box, and the user can browse to the boundary file to be used in clipping. The boundary file must be a polygon shapefile. If the user checks the **'Clipping Data'** check box but does not browse to a boundary file to be used, the user will be prompted by the window seen below. Any buffer set on the 'Options' tab will be ignored when a clipping boundary is used.

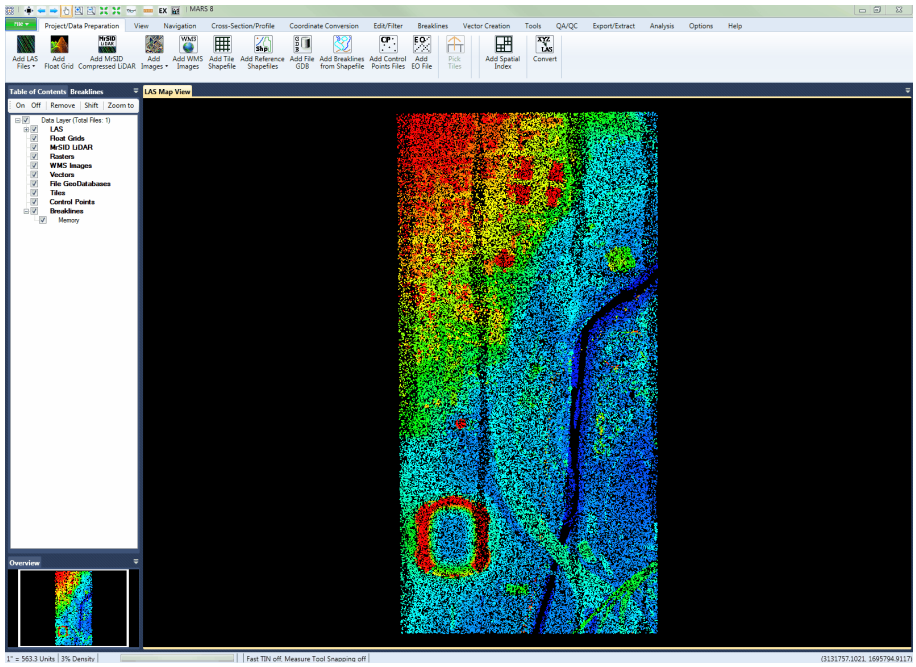


The screen shot below shows a boundary file (white) loaded into MARS® along with the sample LAS data before export.

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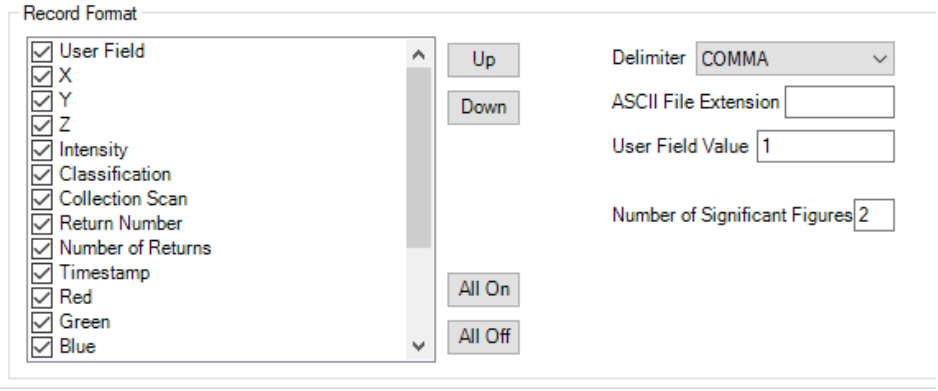


When the export is complete, the user may then load the new, clipped LAS file into MARS®. The newly exported data will be clipped to the boundary shapefile as seen below.



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- **'Record Format' Section:** Choose how the text document or attribute table is to be exported by making specifications in this area. The **'Record Format'** section of the 'Layout' tab is only visible when the 'PLS-CADD Code - ASCII,' 'Shapefile,' or 'Text - ASCII' export types are selected.



Record Format: Select the fields or attributes which are to be included in export. If an attribute field is unchecked, it will not be included in export. By default, all fields are selected.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: The options are: SPACE, TAB, and COMMA (the default) to be used to separate fields in the output text file.

ASCII File Extension: The user may choose the file extension with which the text file is output. For example, the user may choose to export out a *.csv or a *.txt file. Enter the desired extension into the available text box.

User Field Value: This text box is valid only when the user has selected the

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'User Field' attribute for inclusion. A value entered here will be applied to all records in the export. The default value is 1.

Number of Significant Figures: Specifies how many significant figures are used in the X, Y, and Z values during export. The default setting is 2, but values of 1 to 16 can be entered.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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4.5.3.2 All Tiles using MBR



The '**Layout**' tab has many different export format options, depending on the Export Type being performed. The second option is the **'All Tiles using MBR'** format:

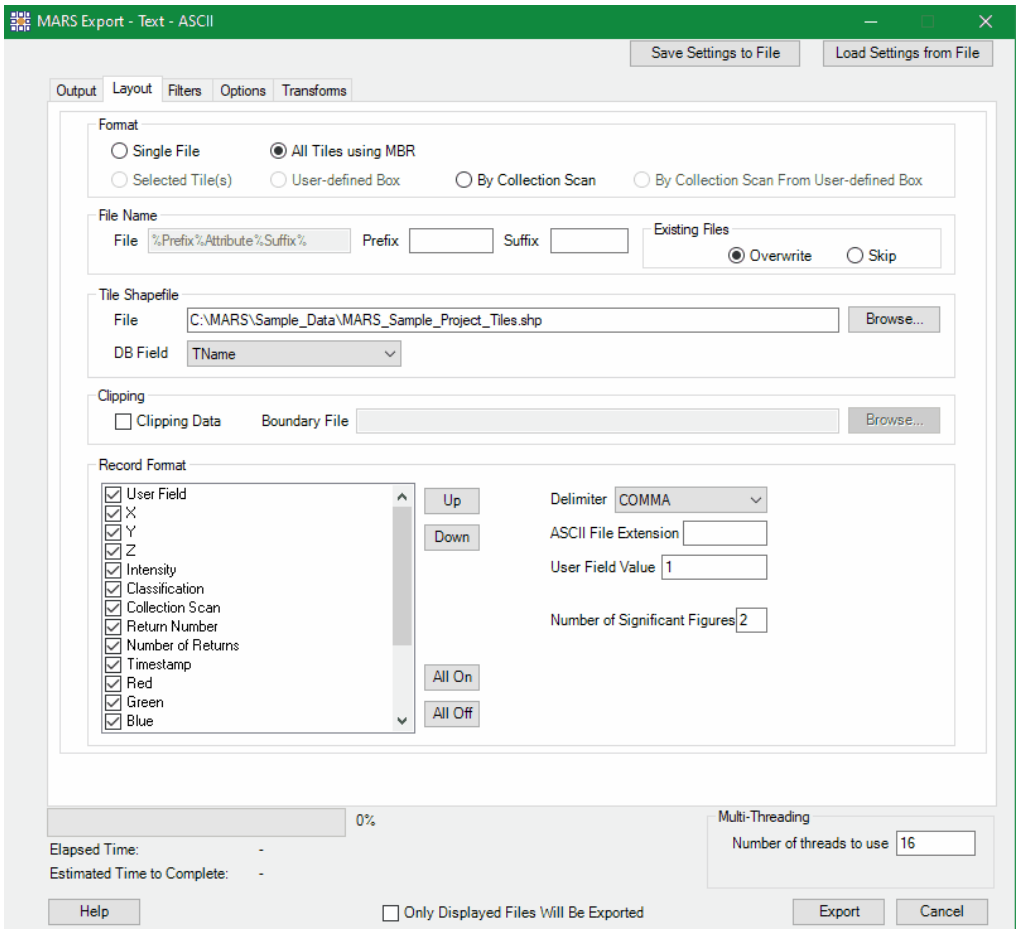
***'All Tiles using MBR'* Export:** Exports all data loaded into MARS® by creating a minimum bounding rectangle (MBR) for each tile (polygon) in the loaded shapefile tile layout. The user would choose this option if they wanted to export all of the polygons that are found in the loaded shapefile tile layout, but in the fastest manner possible. This choice determines the minimum bounding rectangle of each polygon; for example, if the user loaded a shapefile of circles as the tile layout, the output data would be square shaped. Frequently, township/range shapefiles are

used as tiles - these are often slanted from true north and could take more time to process as an export tile layout. If the user does not mind overlapping data, they may want to choose the MBR layout to speed up this export process since exporting to a slanted tile layout can be slower.

The multi-threading option is available for most export types when using the 'Selected Tile(s)' layout format. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading options can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

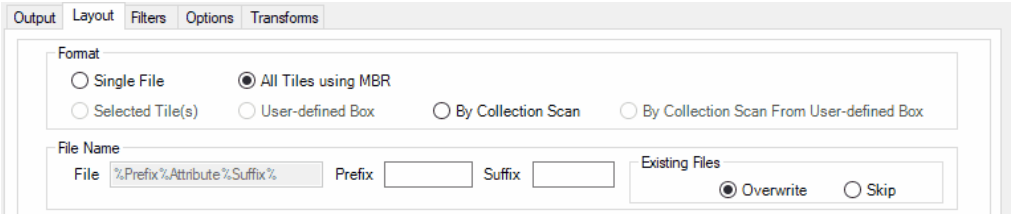
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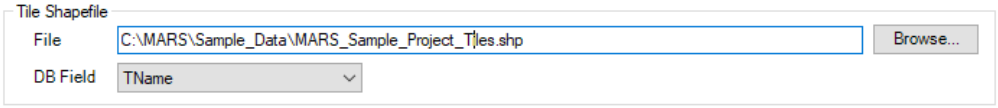
- ***'File Name'* section:** Output files will be named based on the 'DB Field' chosen in the 'Tile Shapefile' section, below. An optional 'Prefix' and/or 'Suffix' may be added to the name.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be*

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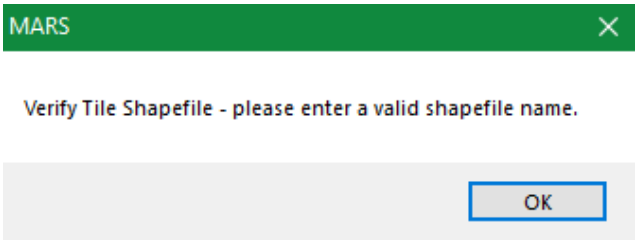
skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely. The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



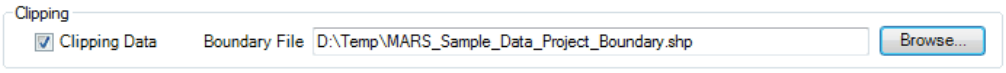
- ***'Tile Shapefile'* section:** Browse to the tile shapefile to be used for export. Use the 'DB Field' drop-down box to specify which attribute field should be used to name the tiles in the new shapefile. See the example below:



If the user attempts to export data using the 'All Tiles using MBR' format and no tile shapefile has been specified, the user will be prompted to point to a tile shapefile by a window as seen below:



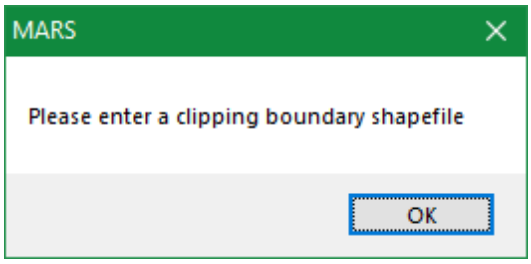
- ***'Clipping'* section:** If the user would like to clip the exported tiles to a tile boundary or irregularly shaped boundary file, check the **'Clipping Data'** check box as shown in the example below:



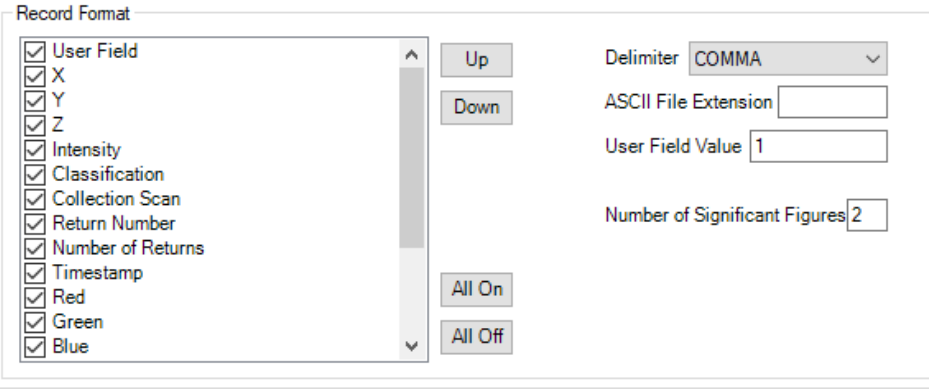
Checking this box will enable the 'Boundary File' text box, and the user can browse to

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the boundary file to be used in clipping. The boundary file must be a polygon shapefile. If the user checks the **'Clipping Data'** check box but does not browse to a boundary file to be used, the user will be prompted by the window seen below. Any buffer set on the 'Options' tab will be ignored when a clipping boundary is used.



- **'Record Format' Section:** Choose how the text document or attribute table is to be exported by making specifications in this area. The **'Record Format'** section of the 'Layout' tab is only visible when the 'PLS-CADD Code - ASCII,' 'Shapefile,' or 'Text - ASCII' export types are selected.



Record Format: Select the fields or attributes which are to be included in export. If an attribute field is unchecked, it will not be included in export. By default, all fields are selected.

Up: Moves the highlighted field higher in the list.

Down: Moves the highlighted field lower in the list.

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All On: Selects all fields for inclusion in the export.

All Off: Unselects all fields so that individual selections can more easily be made.

Delimiter: The options are: SPACE, TAB, and COMMA (the default) to be used to separate fields in the output text file.

ASCII File Extension: The user may choose the file extension with which the text file is output. For example, the user may choose to export out a *.csv or a *.txt file. Enter the desired extension into the available text box.

User Field Value: This text box is valid only when the user has selected the 'User Field' attribute for inclusion. A value entered here will be applied to all records in the export. The default value is 1.

Number of Significant Figures: Specifies how many significant figures are used in the X, Y, and Z values during export. The default setting is 2, but values of 1 to 16 can be entered.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

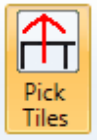
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4.5.3.3 Single File From Selected Tiles

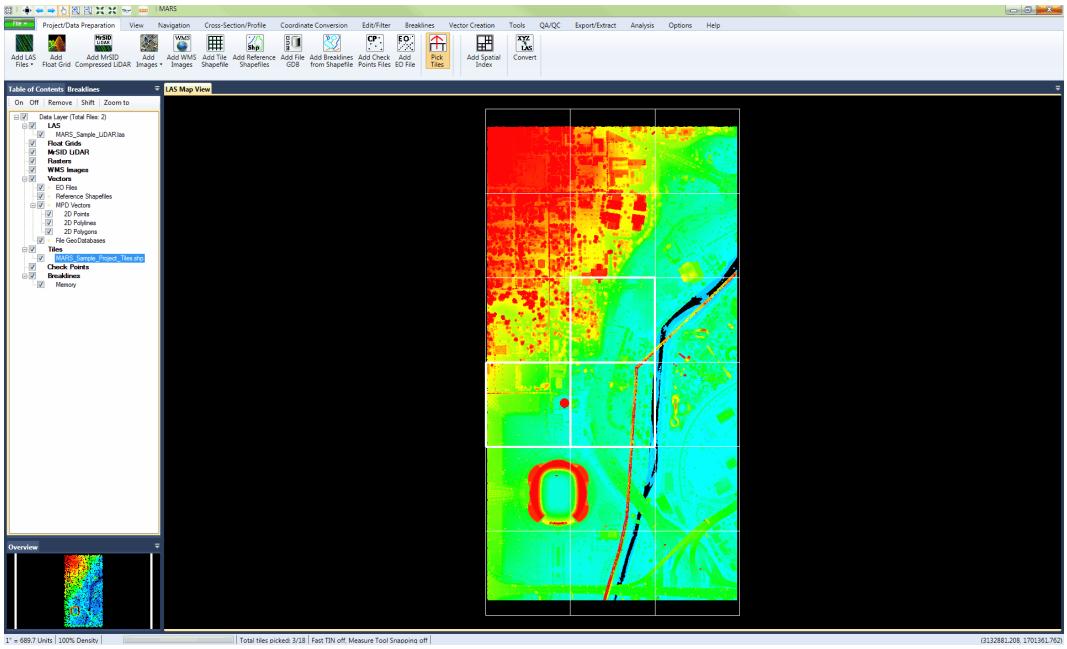


The **'Layout'** tab has many different export format options, depending on the Export Type being

performed. The third option is the **'Single File From Selected Tiles'** format:

***'Single File From Selected Tiles'* Export:** Exports a single file from selected input tiles or polygons chosen with the 'Pick Tiles' 

button. *This Layout format is only available with the 'LAS' and 'Shapefile' export types.* The user would choose this export type if they wanted to export only a single file from the selected tile(s). This export type is available when one or more tiles are selected for export using the Pick Tiles 960 tool.

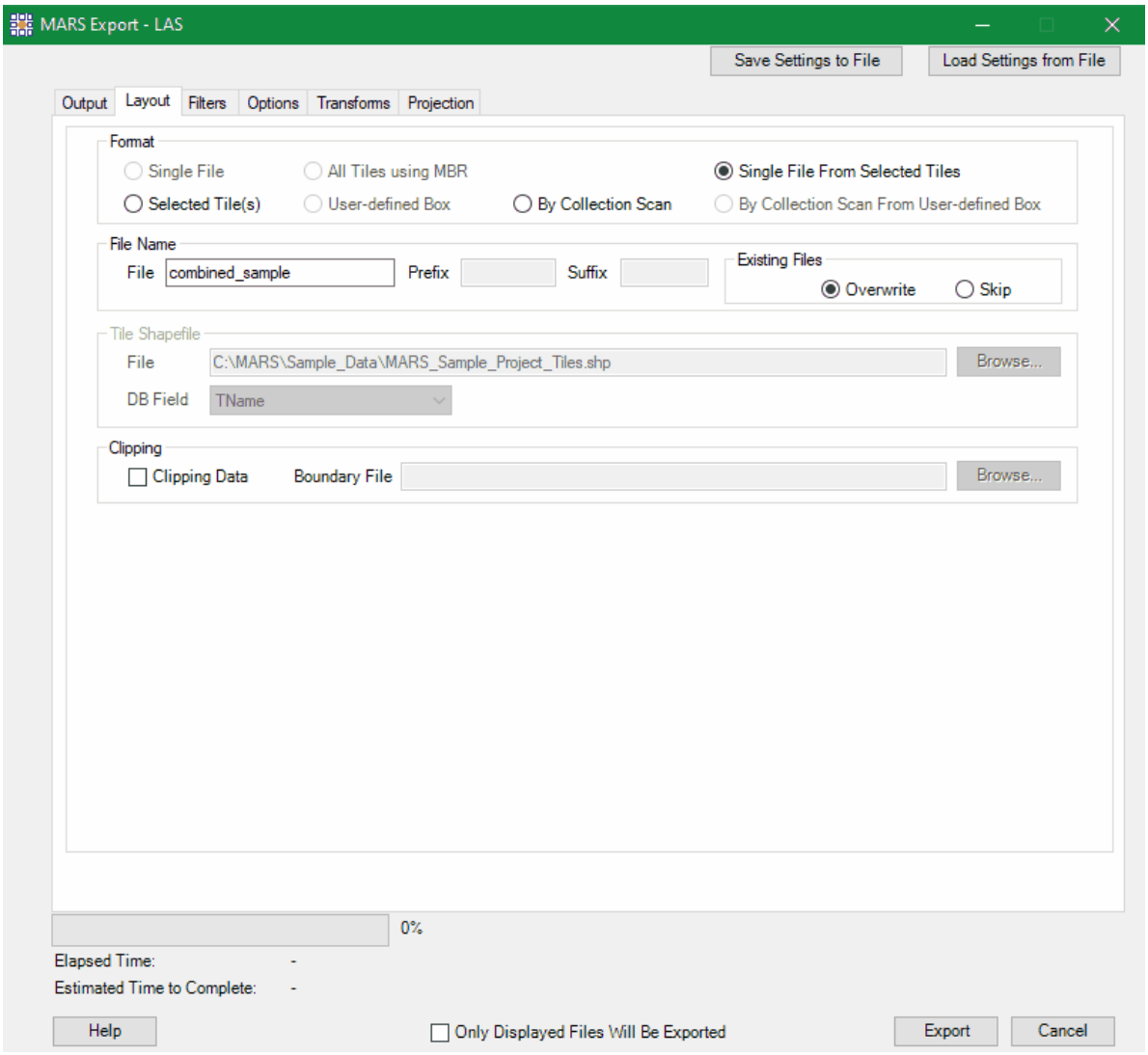


Select the 'Pick Tiles' tool as shown in the screen shot above and then click on the tile(s) to be exported. (See the Pick Tiles 960 topic for more information on how to pick a single, or multiple, tiles.)

When the tiles have been chosen, click the **'Export'** 

button and select an export type from the drop-down list that appears. Click the 'OK' button and the export interface will appear:

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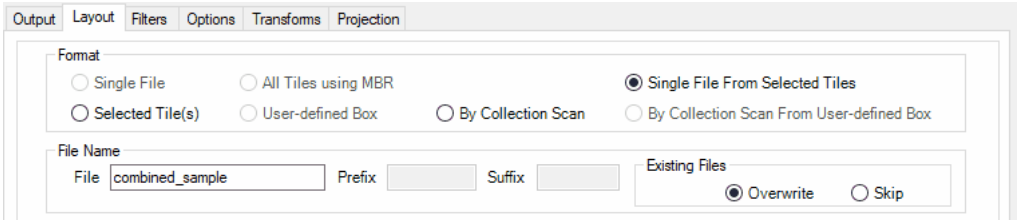
To help speed up export, use the multi-thread options found at the bottom of the export window. Note that not all export types allow multi-threaded processing. If the user chooses to multi-thread the export process, a text box will become available populated with the maximum amount of threads available for processing. Enter the number of threads to be used. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

If settings inside the export window have been previously saved, they can be loaded by clicking the

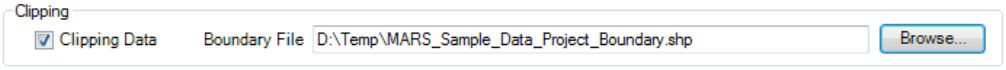
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'Load Settings from File' button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

- ***'File Name'* section:** Designate a new name for the exported file.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely.* The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



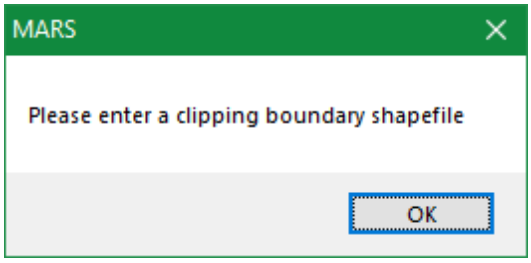
- ***'Clipping'* section:** If the user would like to clip the exported file to a boundary file, check the **'Clipping Data'** check box as shown in the example below:



Checking this box will enable the 'Boundary File' text box, and the user can browse to the boundary file to be used in clipping. The boundary file must be a polygon shapefile. If the user checks the **'Clipping Data'** check box but does not browse to a boundary

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file to be used, the user will be prompted by the window seen below. Any buffer set on the 'Options' tab will be ignored when a clipping boundary is used.



When exporting data by tile when the shapefile contains complex polygons (multi-part polygons), the **'Complex Polys to Simple'** tool may be useful. To learn more about this tool visit the Tools Tab 389 topic and see the appropriate section.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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4.5.3.4 Selected Tile(s)

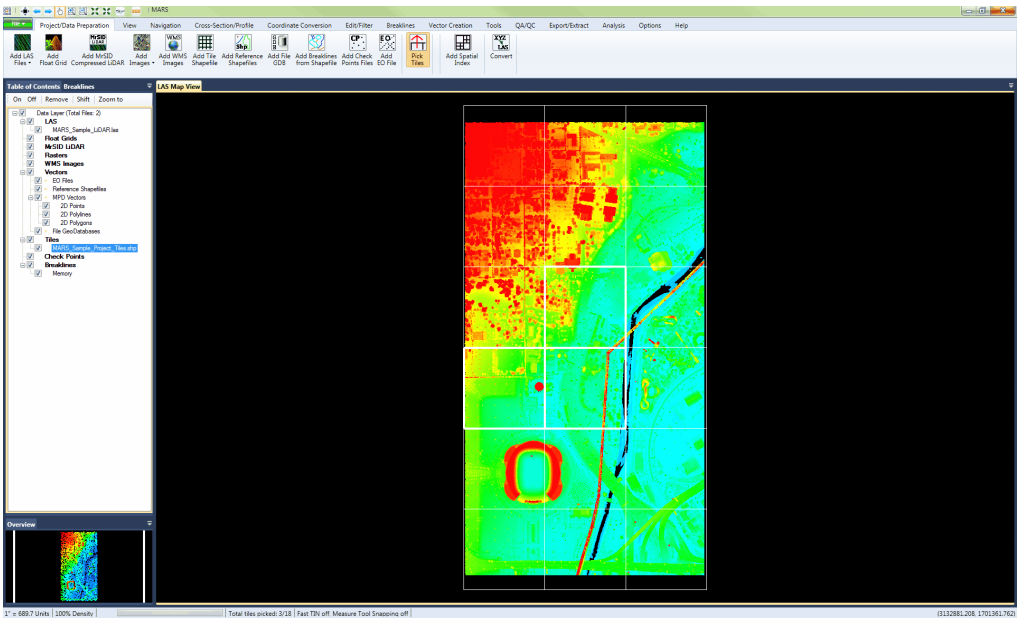


The **'Layout'** tab has many different export format options, depending on the Export Type being performed. The fourth option is the **'Selected Tile(s)'** format:

***'Selected Tile(s)'* Export:** Exports one or more tiles at a time that are preselected in the MARS® window from a loaded tile shapefile using the Pick Tiles 960 tool. A user would choose this export type if they only wanted to export some, and not all, tiles from a loaded tile layout.

To use the 'Selected Tile(s)' method of export, the user must first load a tile shapefile. Next, the tile(s) for export must be defined. The user may do this by using the **'Pick Tiles'** 

tool.

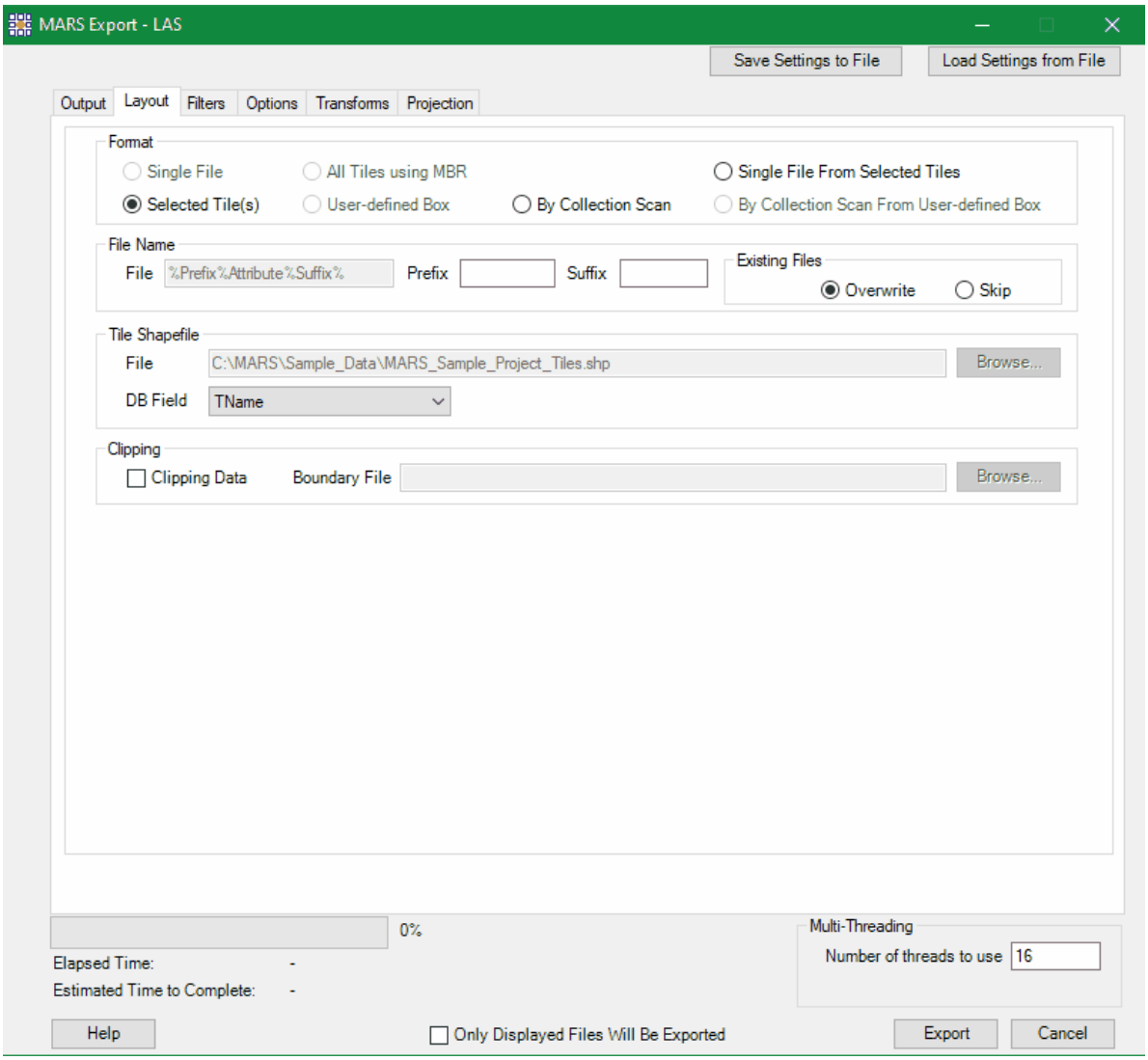


Select the 'Pick Tiles' tool as shown in the screen shot above and then click on the tile(s) to be exported. (See the Pick Tiles 960 topic for more information on how to pick a single, or multiple, tiles.)

When the tiles have been chosen, click the **'Export'** 

button and select an export type from the drop-down list that appears. Click the 'OK' button and the export interface will appear:

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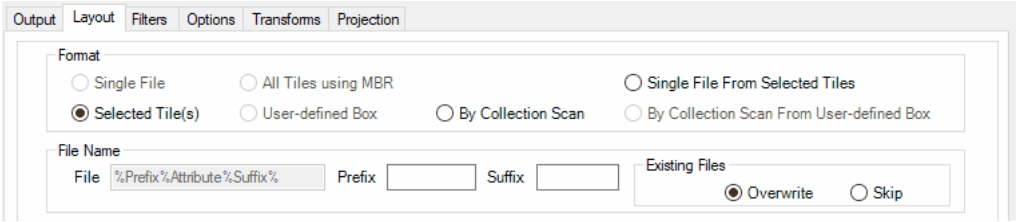


The multi-threading option is available for most export types when using the 'Selected Tile(s)' layout format. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading options can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

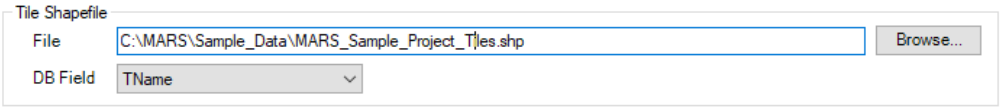
- ***'File Name'* section:** Output files will be named based on the 'DB Field' chosen in the 'Tile Shapefile' section, below. An optional 'Prefix' and/or 'Suffix' may be added to the name.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely.* The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



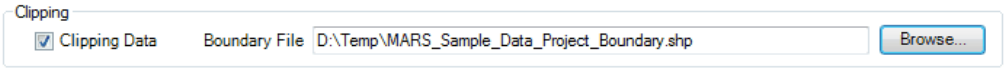
- ***'Tile Shapefile'* section:** Since a tile shapefile has to be loaded in order to select a tile for this export, the tile shapefile should be automatically populated in the 'File' text

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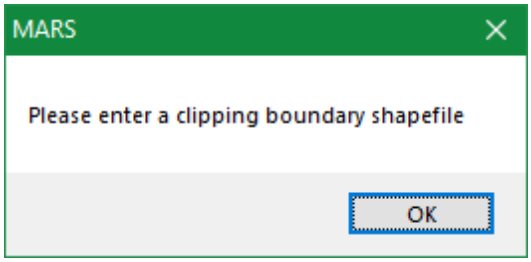
box in this section. Use the 'DB Field' drop-down box to specify which attribute field should be used to name the tiles in the new shapefile.



- ***'Clipping'* section:** If the user would like to clip the exported tiles to a boundary file, check the **'Clipping Data'** check box as shown in the example below:



Checking this box will enable the 'Boundary File' text box, and the user can browse to the boundary file to be used in clipping. The boundary file must be a polygon shapefile. If the user checks the **'Clipping Data'** check box but does not browse to a boundary file to be used, the user will be prompted by the window seen below. Any buffer set on the 'Options' tab will be ignored when a clipping boundary is used.



When exporting data by tile when the shapefile contains complex polygons (multi-part polygons), the **'Complex Polys to Simple'** tool may be useful. To learn more about this tool, visit the Tools Tab 389 topic and see the appropriate section.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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4.5.3.5 User-defined Box

User-defined Box Export

Merrick Advanced Remote Sensing (MARS®) Software

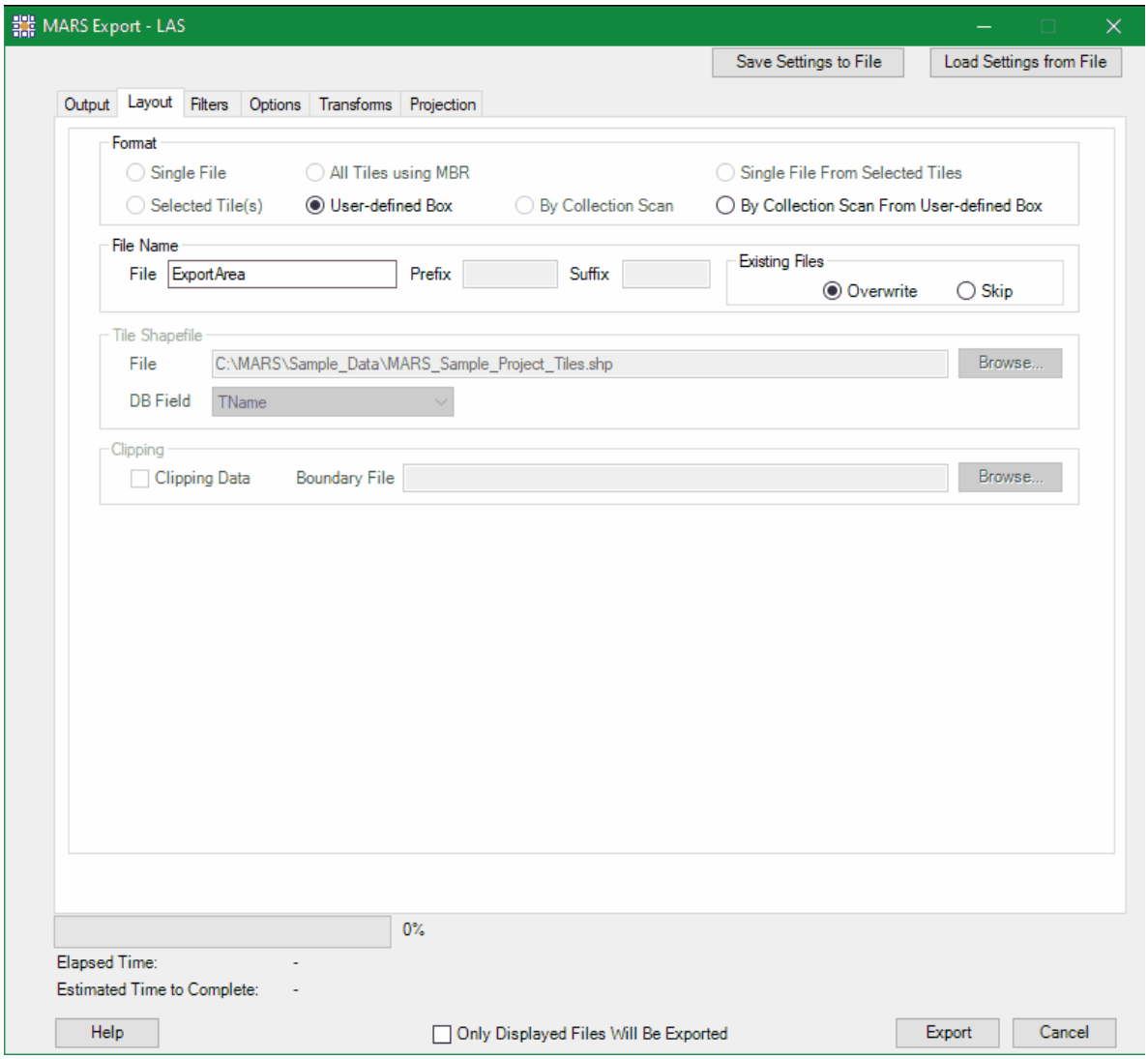
The **'Layout'** tab has many different export format options, depending on the Export Type being performed. The fifth option is the **'User-defined Box'** format (selected by default when using the Export Area tool):

***'User-defined Box'* Export:** Exports data from a user-defined rectangle using the Export Area tool. A user would choose this if they do not want to manage the exported data by a tile layout, nor do they want to export all of the loaded data as a single file, but they may have a specific area that they want exported.

To use the 'User-defined Box' method of export, the user must first define the area for export. This is done by using the **'Export Area'** 

tool.

Select the tool and drag a box over the area to be exported by left-clicking in the upper-left corner of the area and dragging a rectangular box to the lower-right corner of the area. The Export Type Selection drop-down list will appear when the mouse button is released. Select a type and click the 'OK' button to open the export interface. Notice the default Format selection on the 'Layout' tab is 'User-defined Box'.

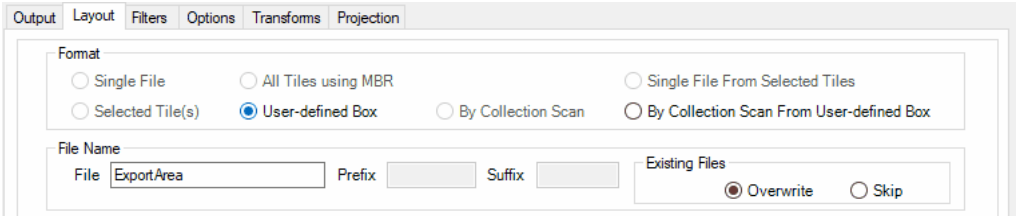


If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

- ***'File Name'* section:** Designate a new name for the exported file. The default name is 'ExportArea'.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error

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occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely.* The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



- ***'Clipping'* section:** Disabled for this Layout format for all export types.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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4.5.3.6 By Collection Scan

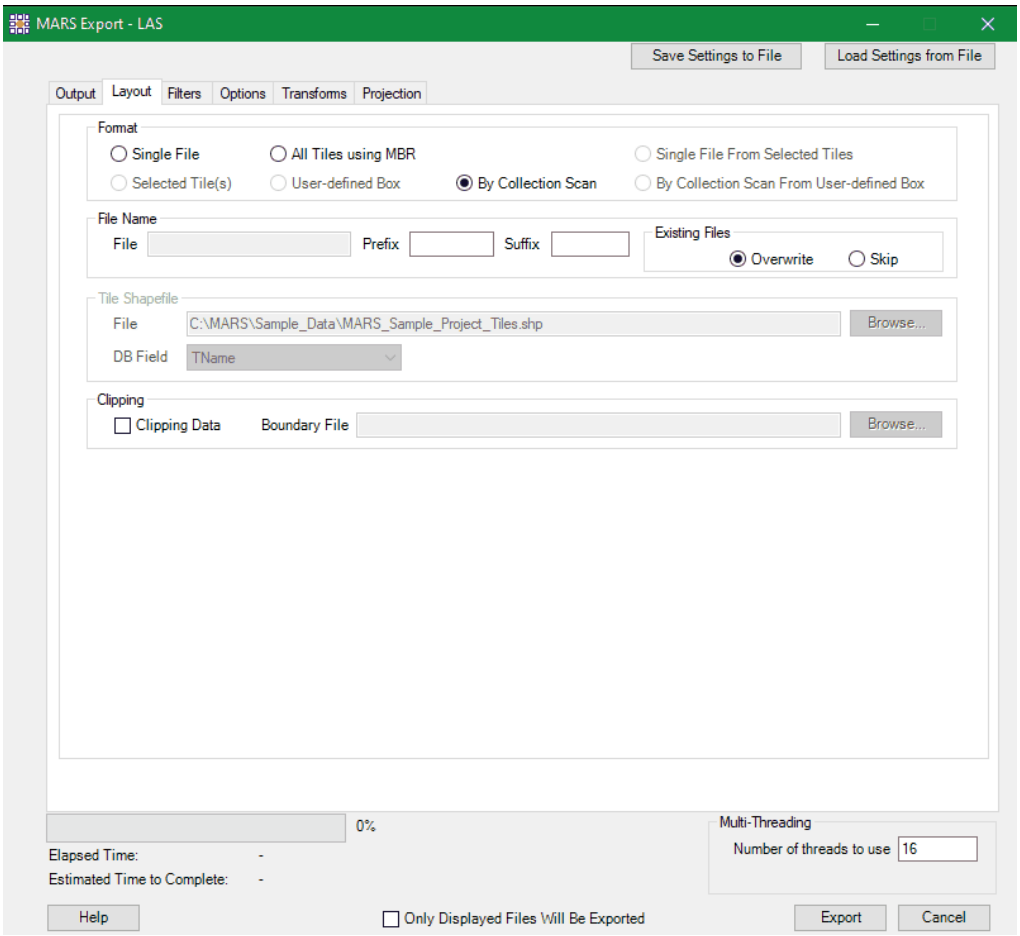


The **'Layout'** tab has many different export format options, depending on the Export Type being performed. The sixth option is the **'By Collection Scan'** format:

***'By Collection Scan'* Export:** Exports the loaded data by actual collection scans that are defined internally in the LAS file(s). The result will be one file for each collection scan number. If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

(Note: The 'By Collection Scan' Layout format is available only when the 'LAS' or 'Text - ASCII' types are chosen from the Export Type Selection drop-down list. For collection scan exports on user defined areas, see By Collection Scan From User-defined Box 772 *)*

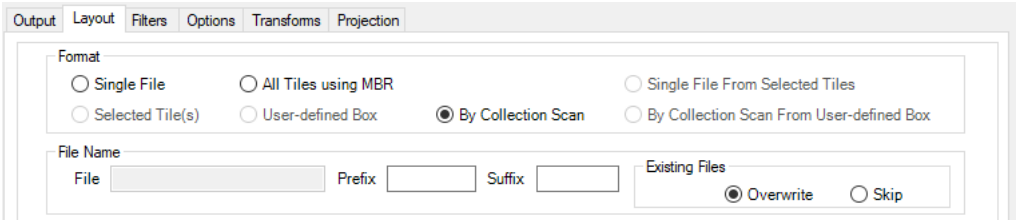
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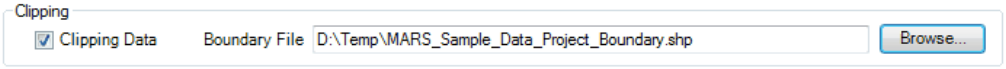
- ***'File Name'* section:** Manual entry of a File Name is disabled for this layout type. Output files will be named based on the internally-stored collection scan number with an optional Prefix and Suffix.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be*

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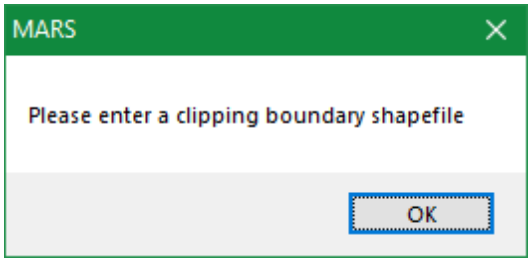
skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely. The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



- ***'Clipping'* section:** If the user would like to clip the exported files to a tile boundary or irregularly shaped boundary file, check the **'Clipping Data'** check box as shown in the example below:



Checking this box will enable the 'Boundary File' text box, and the user can browse to the boundary file to be used in clipping. The boundary file must be a polygon shapefile. If the user checks the **'Clipping Data'** check box but does not browse to a boundary file to be used, the user will be prompted by the window seen below. Any buffer set on the 'Options' tab will be ignored when a clipping boundary is used.



Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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4.5.3.7 By Collection Scan From User-defined Box

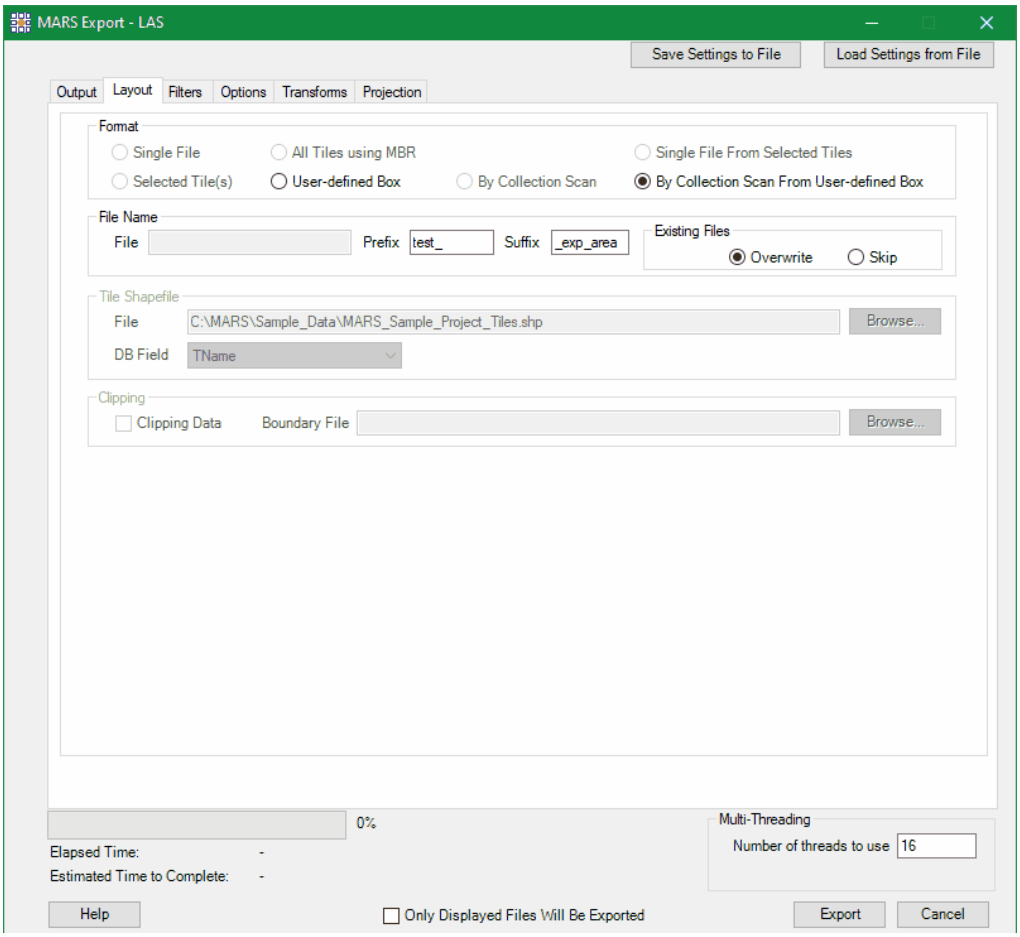


The **'Layout'** tab has many different export format options, depending on the Export Type being performed. The seventh and final option is the **'By Collection Scan From User-defined Box'** format (available only when using the Export Area[658] tool):

***'By Collection Scan From User-defined Box'* Export:** Exports the loaded data by actual collection scans that are defined internally in the LAS file(s). The result will be one file for each collection scan number in the dragged area.

If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

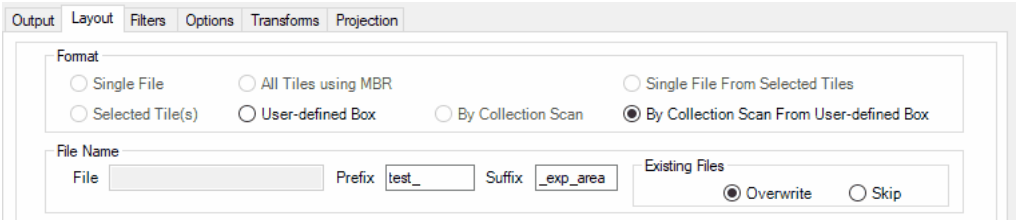
(Note: The 'By Collection Scan From User-defined Box' Layout format is available only when the 'LAS' or 'Text - ASCII' types are chosen from the Export Type Selection drop-down list. For collection scan exports from all loaded data, see By Collection Scan[768] *)*



- ***'File Name'* section:** Manual entry of a File Name is disabled for this layout type. Output files will be named based on the internally-stored collection scan number with an optional Prefix and Suffix.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g.: power goes out, computer shuts down, an error occurs, etc.). When the user starts processing again, selecting this button will cause the software to skip exporting of any files which already exist in the specified output folder. The software will pick up processing on the first file which is not found in the output folder. *For this reason it is suggested that if processing stops for any reason, the last file exported should be deleted from the output folder. This file may not have completed, but since the file name exists in the output folder it will be*

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skipped. Deleting the last file (based on date/time) ensures that it gets exported correctly and completely. The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.



- ***'Clipping'* section:** Disabled for this Layout format for all export types.

Once all the parameters in the **'Layout'** tab have been defined, move to the other tabs to further specify the export parameters. When all parameters have been set, click on the **'Export'** button to start the exporting process.

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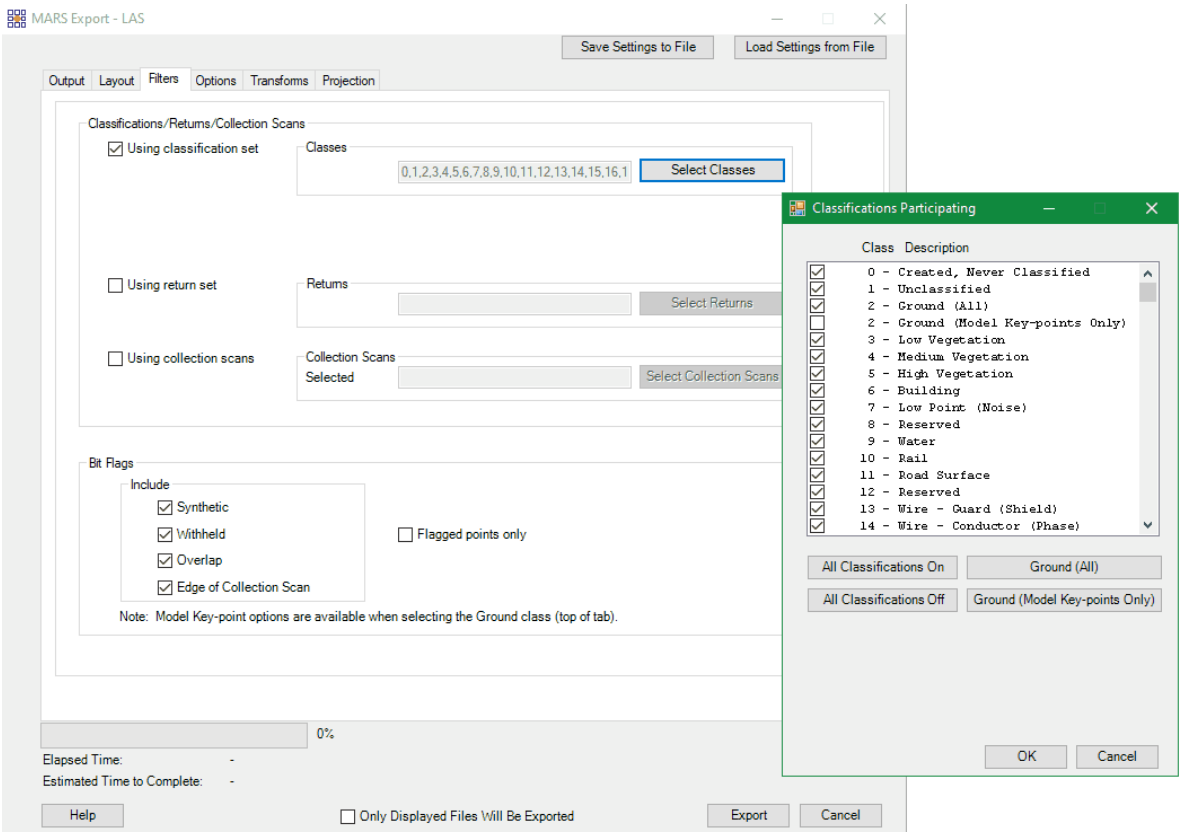
4.5.4 Filters tab



The Filters tab allows the user to specify which classes, returns, and bit-flagged points should be used in export. Many export types have specific default settings for these parameters. For the 'LAS' 712 and 'Flightline Separation - JPEG 2000' 668 export types, there is also a section to select specific collection scans to be included.

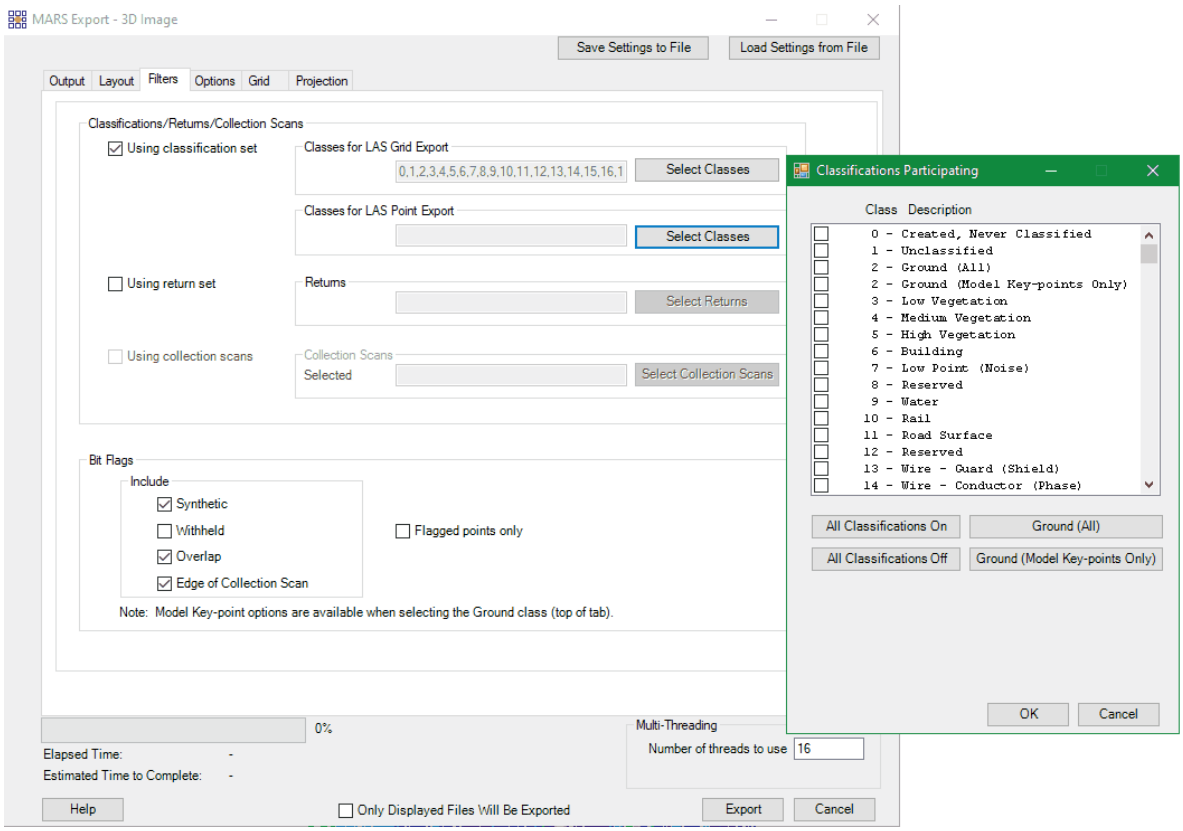
***'Filters'* tab:** Select which classes are to be included in the new file. Do this by clicking on the

'Select Classes' button. If there are specific classes to be used in the export, make sure the 'Using classification set' box is checked to include the classes chosen in export.



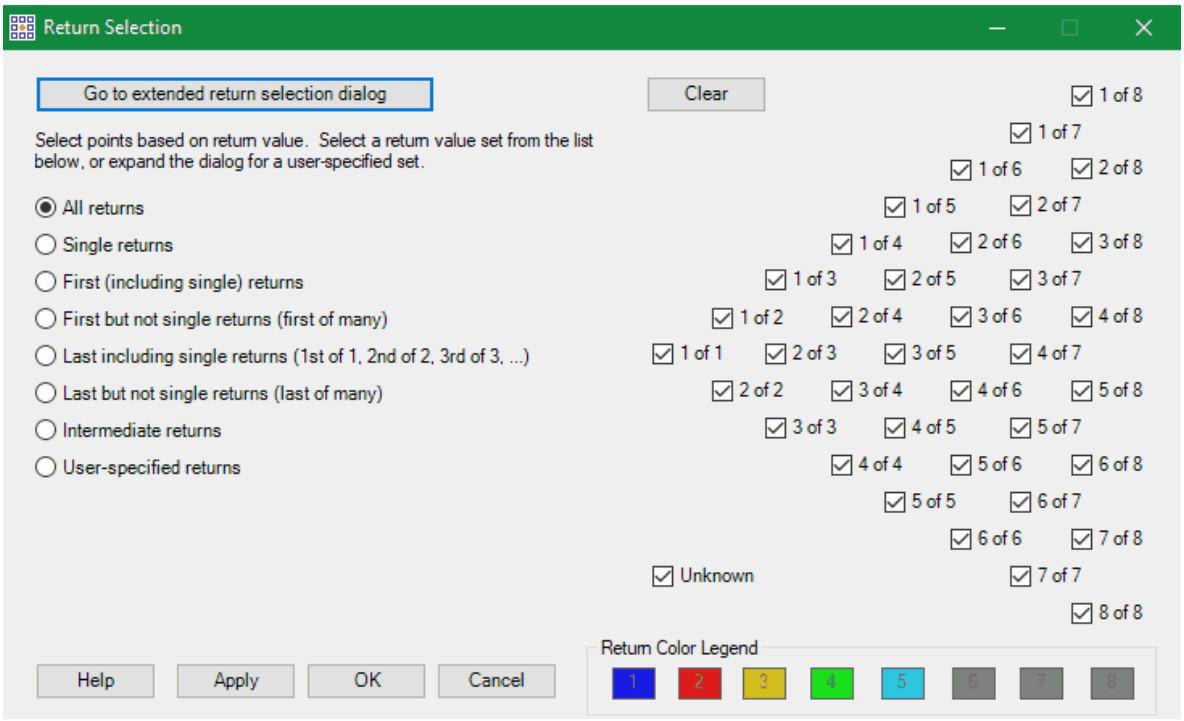
For the '3D Image 662' export type, two sets of classes can be selected - one set for ground and/or other classes that need to be represented as high-density gridded points (LAS Grid Export), and one set for any remaining above-ground classes (LAS Point Export).

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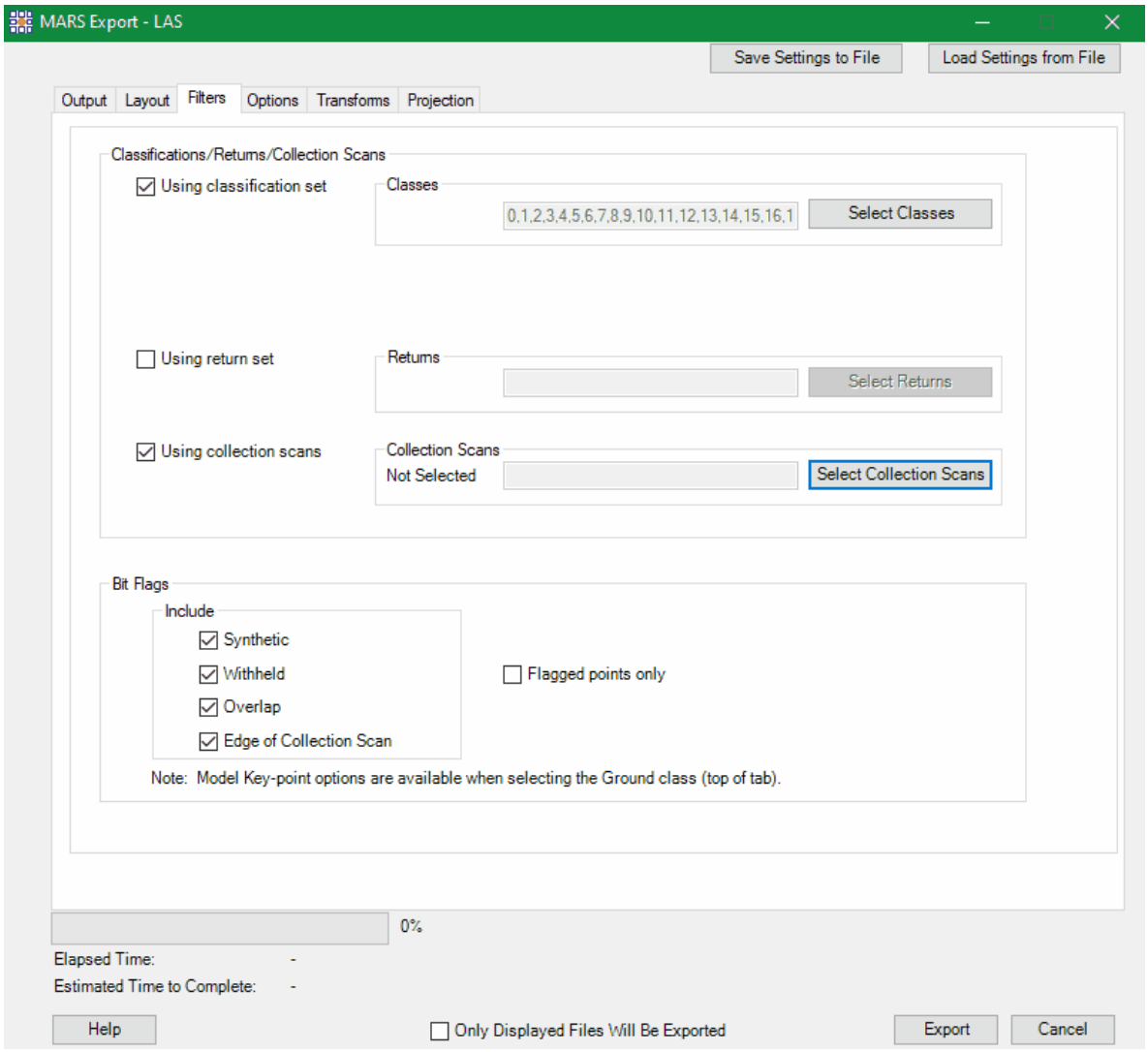
The user can select which returns will be used in the export by checking the **'Using return set'** box and clicking the **'Select Returns'** button. Some export types will have pre-selected returns set: for example, when exporting a 'Flightline Separation - JPEG 200' file returns are set to 'Last' by default (but can be modified). See the 'Display Selection: Return' section of the View Tab 192 help topic for information on making selections for this interface.

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For the **'LAS'** and **'Flightline Separation - JPEG 2000'** export types (only), the user can select which collection scans will be included in the export. See the 'Display Selection: Collection Scan' section of the View Tab 192 help topic for information on making selections for this interface.

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Finally, a 'Bit Flags' section is available to select which bit-flagged points will be included in the export. Bit flag options are Synthetic, Withheld, Overlap, and Edge of Collection Scan. An option, 'Flagged points only' exists to limit the export to only those points that have the included bit flags set to 'on'. The possible export scenarios regarding bit flags are:

1. If the 'Include' box is **unchecked**, only non-flagged points will be exported that meet the

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other criteria (class, return, and collection scan).
2. If the 'Include' box is **checked** and the 'Flagged points only' box is **unchecked**, all points that meet the other criteria will be exported regardless of bit flag status.
3. If the 'Include' box is **checked** and the 'Flagged points only' box is **checked**, only bit-flagged points will be exported that meet the other criteria (class, return, and collection scan).

Some export types have the various checkboxes pre-set, but these can be modified as needed.

If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use. Move on to the **'Options'** tab.

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4.5.5 Options tab



The **'Options'** tab has three functions:

1. It allows the user to define a buffer area around the area to be exported. The larger the buffer around the exported area the more precisely the data can be exported, but the larger the buffer the longer the export process will take. If a buffer is desired, check the 'Use Buffer' box and enter the 'Buffer Size' value (in project units) to be used. Buffer settings do not apply to a clipping boundary (if used). *Note the the 'Over Edge Buffer' option is not available for 'USGS Swath Separation Image - Tiled GeoTIFF' export type.*

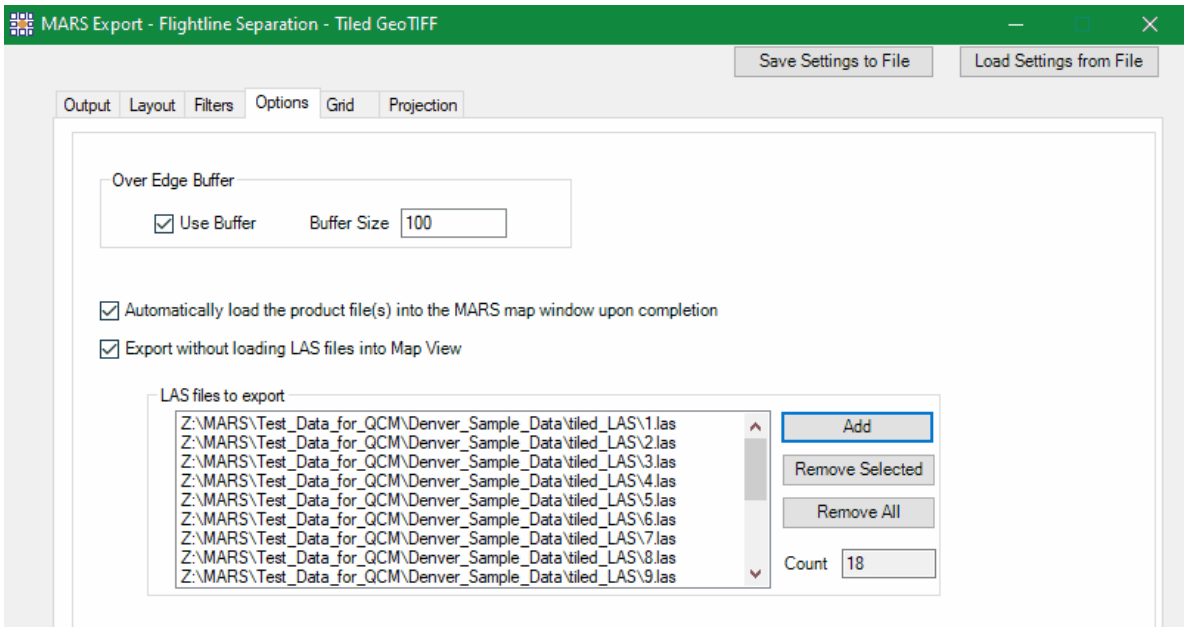
2. A checkbox allows most exported data, rasters, or vectors (shapefiles) to be automatically

loaded into the LAS Map View 145 window upon completion. The two 'PLS-CADD Code' export types as well as the 'Grid - Esri ASCII Grid' export type do not allow this option since the loading of their outputs is not supported by MARS®. The 'LAS' export type does not allow automatic loading of exported data to avoid the possibility of doubling up on loaded LAS data. In addition, the *.dat files created by the 'Grid - ENVI Elev' and 'Grid - ENVI Elev/Class' export types are not automatically loaded, but can be manually loaded as Rasters 86.

3. There is an option to export without loading the LAS data into the LAS Map View window first. A source file list can be built and modified when the 'Export without loading LAS files into Map View' box is checked. For the 'LAS' export type, tile-based exporting using this option requires that a tile layout shapefile be loaded in MARS® - this is noted on the interface as a reminder. This export option will ignore any loaded LAS files when producing the export. ***Be sure to select the desired output LAS and Point Data Record Format choices on the 'Export Type' tab as they are not read from the listed data!***

If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use. Move on to the **'Transforms'** tab if applicable.

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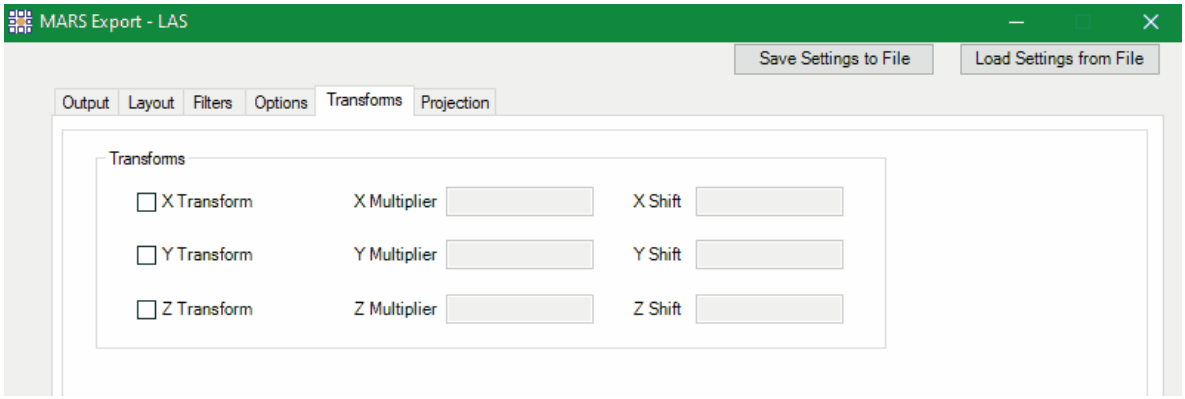
4.5.6 Transforms tab



The Transforms tab is used to apply a multiplier and/or shift to the X, Y, and/or Z coordinate values of the exported data. This tab is available only for the **'Contours - Shapefile'**, **'LAS'**, and **'Text - ASCII'** export types.

***'Transforms'* tab:** The exported data can be transformed by multiplying/dividing (Multiplier) and/or adding/subtracting (Shift) by user-definable values. The functions are enabled by checking the box(es) - 'X Transform', 'Y Transform', or 'Z Transform' - for the coordinate(s) to be transformed and entering the desired vale(s). If only a Multiplier or a Shift is to be performed for any or all coordinates, leave the other entry box empty. If both a Multiplier and a Shift are to be performed, make entries in both boxes

- the order of operations will be Multiplier first, then Shift. If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use. After moving through all the tabs in the Export window, click **'Export'** to export the data.



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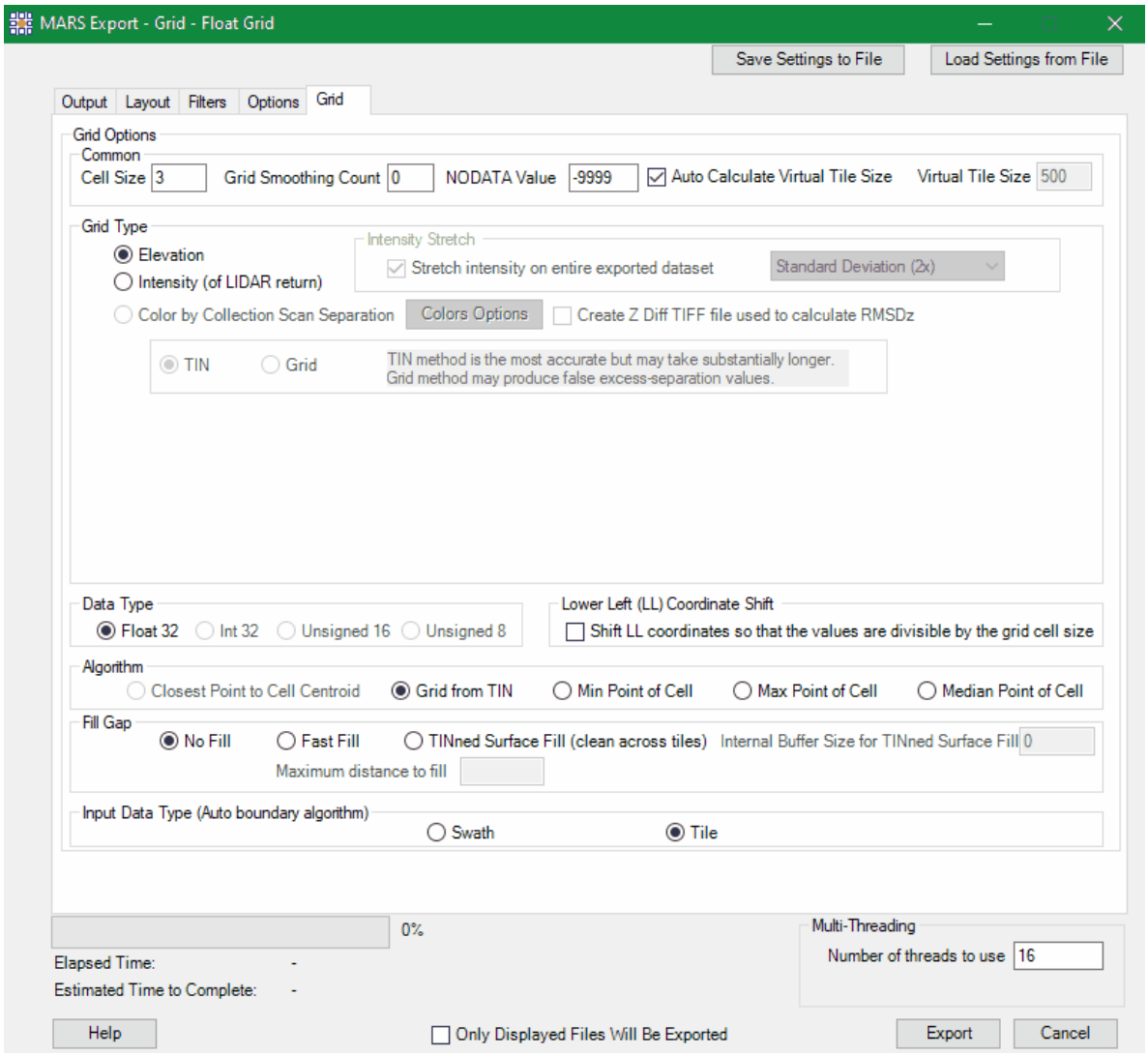
4.5.7 Grid tab



The Grid tab allows for control of the parameters relevant to grid-based exports.

***'Grid'* tab:** Enter the desired grid settings. If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use. When the options of every tab in the Export window have been

set, click the **'Export'** button at the lower-right of the interface. *Note that for the 'USGS Swath Separation Image - Tiled GeoTIFF' export type all settings other than 'Quality Level,' 'Virtual Tile Size,' 'Lower Left (LL) Coordinate Shift,' and 'Input Data Type' are internally set to adhere to the USGS LBS specification.*



- **'Cell size' -** The cell size represents the size of the grid cells produced. (EX. 3 = 3 unit grid, 10 = 10 unit grid)

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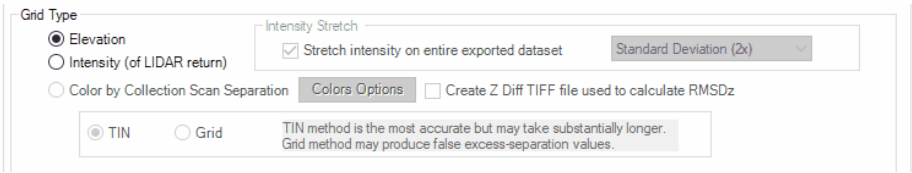
- **'Grid Smoothing Count' -** Sets a Gaussian smoothing factor. (EX. a smaller number will use less smoothing and a larger number will use more smoothing.)

- **'NODATA Value' -** Cells with null values will be given a default value of -9999 unless otherwise specified. See the Intensity 'Grid Type' section below for exceptions.

- **'Auto Calculate Virtual Tile Size' / 'Virtual Tile Size' -** Used to allow processing of manageable data sizes in RAM. A computer with less available RAM needs smaller virtual tile sizes to complete the export, whereas one with more available RAM can use larger virtual tile sizes to speed up the export . This optional tool can optimize internal processing based on average Point Density, available RAM, and the number of threads chosen to be used during the export. If unchecked, a virtual tile size (in project units) can be entered manually (virtual tile sizes *must* be evenly divisible by the cell size). Note that entering a value too large for the computer's capabilities may cause the export to hang or crash.

- **'Grid Type'-** There are five (5) basic grid types, depending on the export type selected:

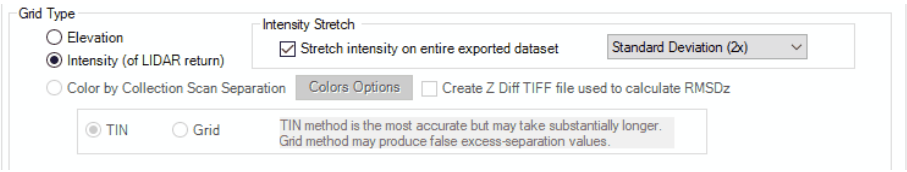
    1) **Elevation:** Populates the cell values of the grid from the LiDAR dataset's elevation values. This is the default option for most grid-based export types, and the only option when the export type is 'Grid - Cloud Optimized GeoTIFF DEM'.



    2) **Intensity (of LIDAR return):** Populates the cell values of the grid from the LiDAR dataset's intensity values. This is the only option for 'Grid Type' when **'Grid - Cloud Optimized GeoTIFF Intensity'** is selected as the export type. Typically used as an option with the

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'Grid - TIFF' and **'Grid - IMG'** export types, but can also be selected for **'Grid - Esri ASCII Grid'** and **'Grid - Float Grid'** raster exports.



There is one exclusive option associated with the Intensity Grid Type - the intensity can be stretched over an entire exported dataset area (this is the default). When enabled, a selection can be made between stretching methods: 'Standard Deviation (2x)' or 'Simple Min/Max'. In addition, the following applies to 'Grid - IMG' and 'Grid - TIFF' export types when the 'Grid Type' is Intensity:

a.) If the 'Data Type' selected is '**Unsigned 8**' and the 'Stretch intensity' box is checked, the NODATA Value will default to '255' but can be changed to '0'. If NODATA is set to

'255', cell values will be stretched between 0 and 254. If NODATA is set to '0', values will be stretched between 1 and 255.

b.) If the 'Data Type' selected is '**Unsigned 16**' and the 'Stretch intensity' box is checked, the NODATA Value will be set to '65535' and cannot be modified. Cell values will be

stretched between '0' and 65520' (the highest value that can exist when normalizing 12-bit intensity data).

3) **Color by Collection Scan Separation:** This grid type is available when either the 'Flightline Separation - JPEG 2000' or 'Flightline Separation - Tiled GeoTIFF' export type is chosen. These export types produce rasters based on the relative height (Z) differences between LiDAR data in overlapping/sidelapping areas. The overlap area differences are color coded, allowing immediate detection of relative vertical accuracy problems. The non-overlapping areas will show Intensity gridded data for reference purposes only. These export types

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are useful for rapidly assessing the consistency of the LiDAR dataset's height and can be useful in boresighting. Over hard surfaces (such as roads) the user can expect the vertical height (elevation) of points within the same 'cell' to be very similar regardless of the LiDAR collection scan from which the data originates. Differences are an indicator of a potential mission anomaly (typically a GPS/IMU problem) or a post-processing data adjustment issue. In areas such as forests or fields, where vegetation growth varies according to the time of year, understandable error may be seen. The overlaid collection scan separation coloration will have a 50% transparency set so that the output raster will still have some feature definition visibility from the background Intensity layer. For more information on these tools and to see them being used in the QA/QC process, please visit the Color By Collection Scan Separation 1718 topic.

i. *'Flightline Separation - JPEG 2000' export type:*

a) With the lidar data and tile layout shapefile loaded, click either the **'Export'** button 

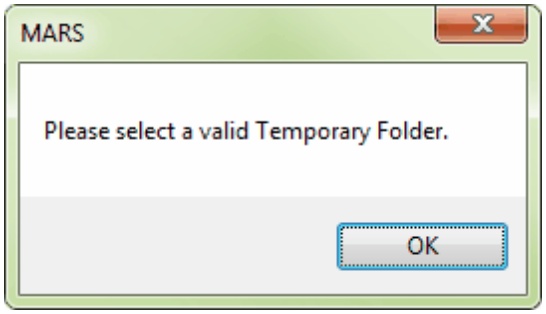
(Single File export of the entire loaded dataset), or the **'Export Area'** button 

(User-defined Box) to select the area which will be colored by collection scan separation. (For more information on the use of these tools, please see the Data Export 658 section.) Select 'Flightline Separation - JPEG 2000' from the drop-down list of export types and click the 'OK' button.

b) When the export interface opens, click on the 'Output' tab and browse to an 'Output Directory' to specify where the raster should be exported. The 'Use temporary local disk space to speed up processing' option allows the exported raster to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output

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Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



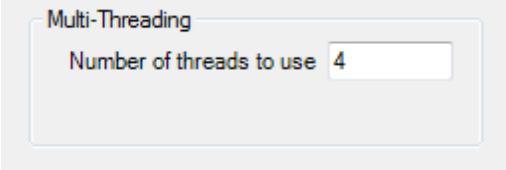
An additional option in the lower part of the 'Output' tab allows for producing a measurable vertical separation value (RMSDz) for the collection scan separation by limiting the analysis to areas of single returns. See the Flightline Separation - JPEG 2000 668 export topic for more details).

c) Select the classifications, returns, and collection scans for export on the 'Filters' tab. At least one class, return type, and collection scan must be selected for export to take place. By default, all classes and collection scans are used, but only Last Return points. If the 'Measurable RMSDz FSR' option is used (see the Flightline Separation - JPEG 2000 668 topic), then Single Returns are used

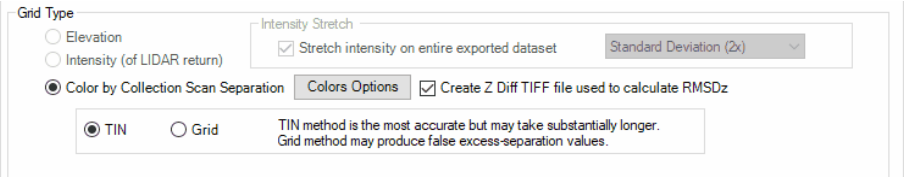
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instead. Note that 'Withheld' bit-flagged points are excluded by default from this export type.

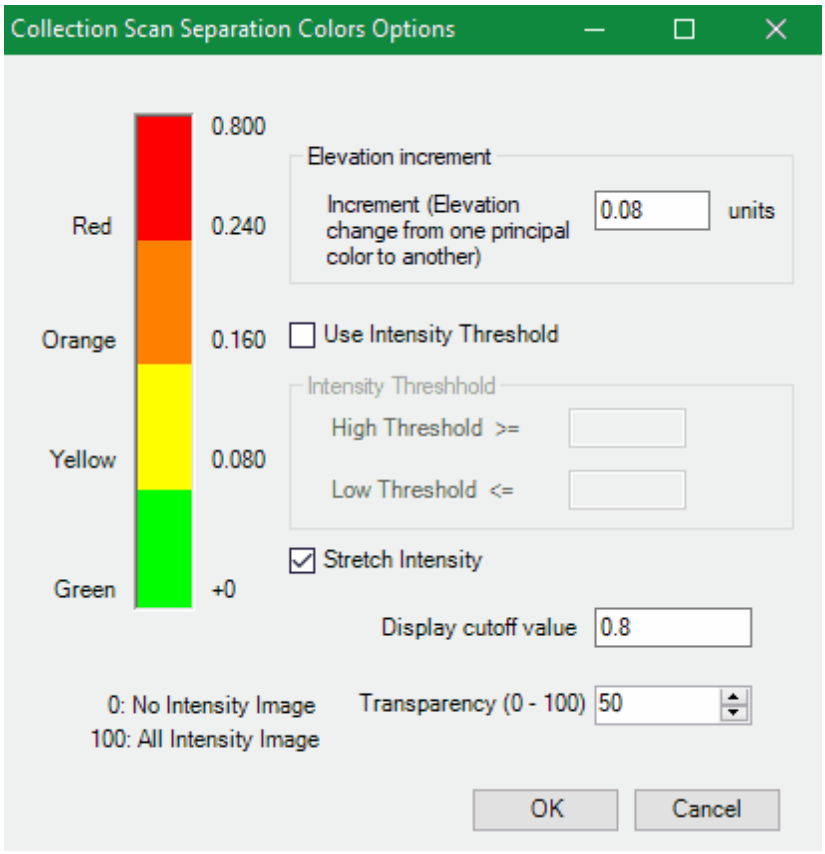
d) The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



e) There are several settings and options on the **'Grid'** tab. The user also has the option to **'Create Z Diff TIFF file used to calculate RMSD$_Z$'** by checking the labeled box. This option creates an elevation TIFF grid of the resulting RMSD$_Z$ calculation. Click on the **'Colors Options'** button to define the elevation increment and color representation options as seen in the screen shots below, then click 'OK.'



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- ✓ **Elevation increment:** Specify here how many elevation units should be between principal colors. To test against the USGS LiDAR specification (for example, less than or equal to 8cm Z difference), a value of '0.08' should be entered for projects in meters so that green raster cells would show compliance with the specification - yellow, orange, and red would not. Projects in feet should use a value of '0.26'.
- ✓ **Use Intensity Threshold:** Check this box to set high and low intensity value ranges. Pixels meeting these criteria will be rendered in magenta and blue, respectively, and will be displayed on top of collection scan separation rendered pixels.
- ✓ **Stretch Intensity:** Uncheck to disable intensity stretching for the background image of the raster.
- ✓ **Display cutoff value:** The user has the option of entering a unit value in this text box which would be considered out of the realm of possibility. For example, in one

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collection scan a car may have been present from which LiDAR returns were collected. In the next collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Display cutoff value' text box will tell the software to ignore data outside this value range. In this way entering a value of '1.0' meters, for example, the vertical discrepancy between a car versus no car will be ignored. A good starting point for this value is 10 times the '**Elevation increment**'.

- ✓ **Transparency (0-100):** The user can set the transparency of the collection scan separation coloration over the output raster. The default value is set to 50. As stated in the interface itself, a value of 0 would show no intensity image and only show the collection scan separation coloration. A value of 100 would show the intensity image only and show no collection scan separation coloration.

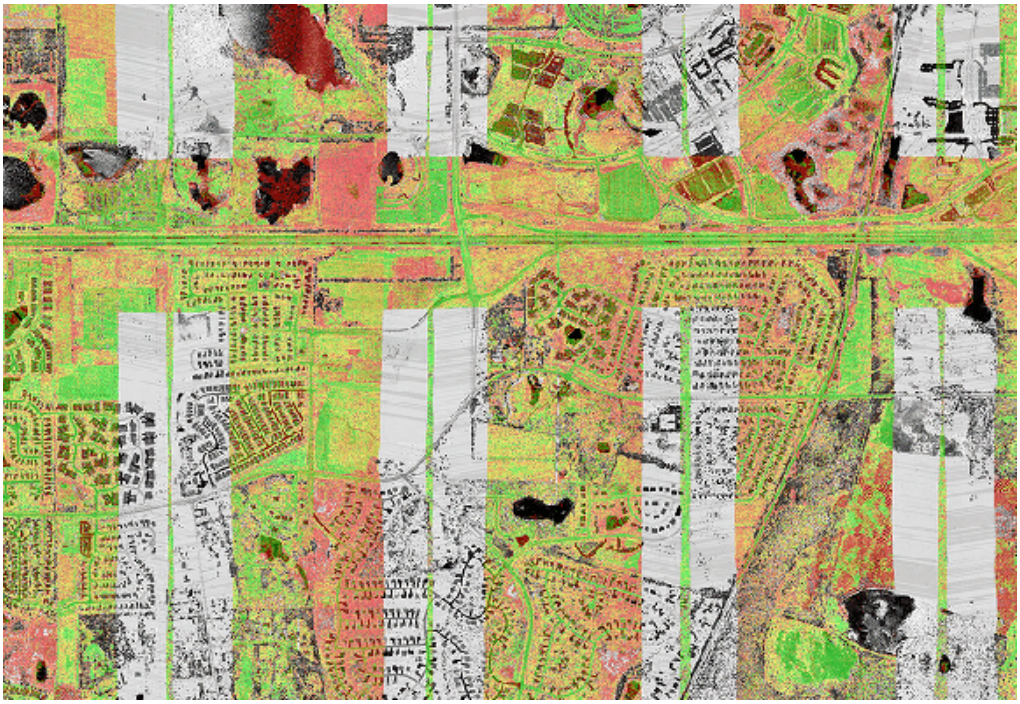
By default, a **TIN** will be created from which the final raster is made. As noted on the interface, this method is the most accurate but also the slowest. Using the **Grid** option can save time but may produce false excess-separation values depending on the area's terrain.

When all settings have been made on all tabs, click on the 'Export' button to export the data by collection scan separation.

Example: The Color by Collection Scan Separation grid type has been used on the data below which is shown as a JPEG 2000 raster image. The collection scan overlap is represented by the colored sections of data. There is a cross scan included in this example which runs East-West rather than the North-South pattern of the main

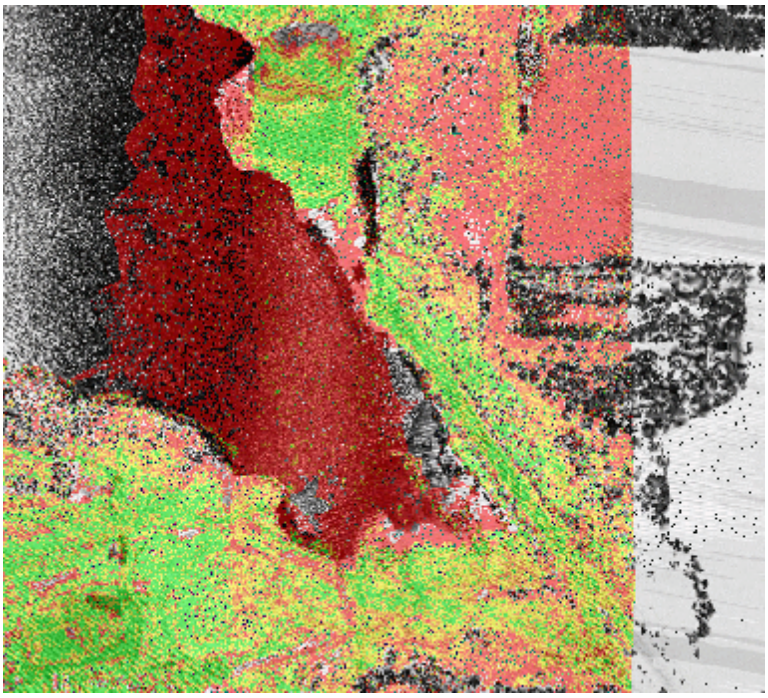
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collection scans. The areas between overlaps are shown in intensity-only (gray-scale) rendering.



Example: As defined by the user in the 'Collection Scan Separation Colors Options' window, the colors in the example below represent varying amounts of elevation (Z) difference. Green represents areas with the least amount of Z difference between the collection scans, whereas red areas indicate the largest amounts of Z difference. These red (and even orange) areas are indicators of possible problems with the GPS, IMU, or post-processing data adjustment. In this example, the Color by Collection Scan Separation tool has colored a lake red. For this particular project, the East-West cross scan was flown a month after the other collection scans and the red coloration is explained by the water level of the lake being different for each flight date. On the other hand, the road by the lake should be at the same elevation in both collection scans. The road is green, indicating that the cross scan and overlapping North-South collection scan are properly boresighted.

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There will be one raster file exported to the specified output folder unless the **'Create Z Diff TIFF file used to calculate RMSD$_Z$'** option was checked for export, in which case an elevation TIFF grid and a TXT file (with numeric results) will also be saved:

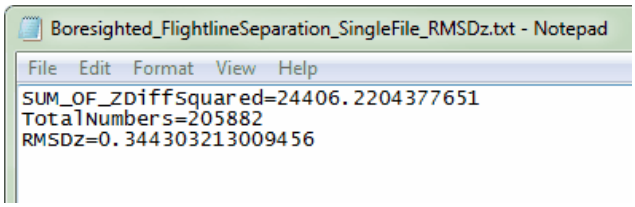
1.) A **JPEG 2000 raster image**, or *.jp2, which will allow the user to access the collection scan separation results as a raster image. The user must remember that this thematic rendering represents *values of separation* between two collection scans and is not representative of distance values. An example of a JPEG 2000 raster image may be seen above.

2.) An **Elevation TIFF Grid**, or *.tif, file which will contain the EXACT values of separation for each colored cell in the collection scan separation export (JPEG 2000, above). This file is only saved if the user has checked the **'Create Z Diff TIFF file used to calculate RMSD$_Z$'** option on the **'Grid'** export tab.

3.) A ***.txt** (or text) file, which will contain the numerical results of the collection scan separation export including the calculated RMSD$_Z$

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value. Below is a screen shot of a sample .txt file. This file is only created if the user has checked the **'Create Z Diff TIFF file used to calculate RMSD$_Z$'** option on the **'Grid'** export tab. This TXT file is always created and saved when the 'Measurable RMSDz FSR' option (on the "Export Type' tab) is used (see the Flightline Separation - JPEG 2000 668 topic).



The resulting JPEG 2000 raster file can be automatically loaded in MARS® when the export is complete if the box for that option has been checked on the Options 780 tab.

ii. *'Flightline Separation - Tiled GeoTIFF' export type:*

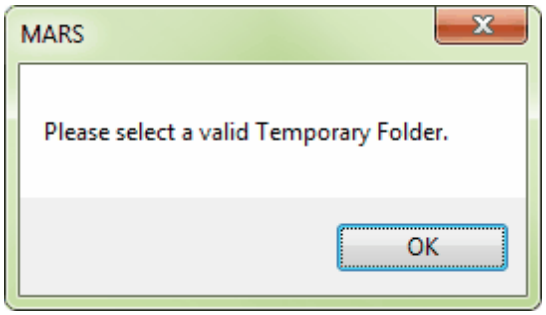
a) With the lidar data and tile layout shapefile loaded and one or more tiles selected, click the **'Export'** button 

to see the drop-down list of export types. Select 'Flightline Separation - Tiled GeoTIFF' from the drop-down list of export types and click the 'OK' button.

b) When the export interface opens, click on the 'Output' tab and browse to an 'Output Directory' to specify where the tiled raster(s) should be exported. The 'Use temporary local disk space to speed up processing' option allows the exported raster(s) to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much

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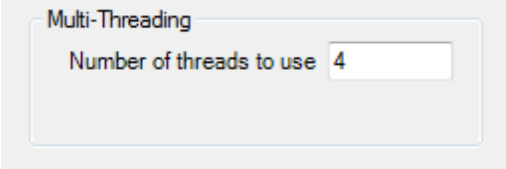
space is required and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



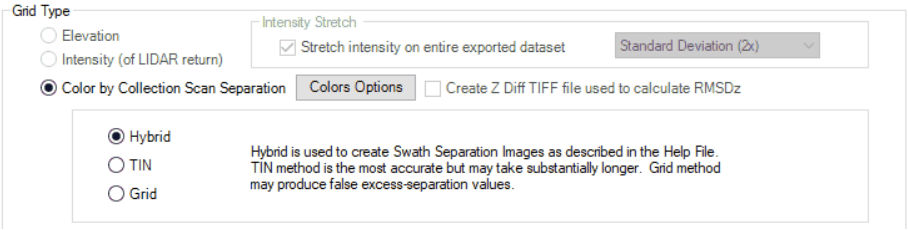
c) Select the classifications, returns, and collection scans for export on the 'Filters' tab. At least one class, return type, and collection scan must be selected for export to take place. By default, all classes and collection scans are used, but only Last Return points. Note that 'Withheld' bit-flagged points are excluded by default from this export type.

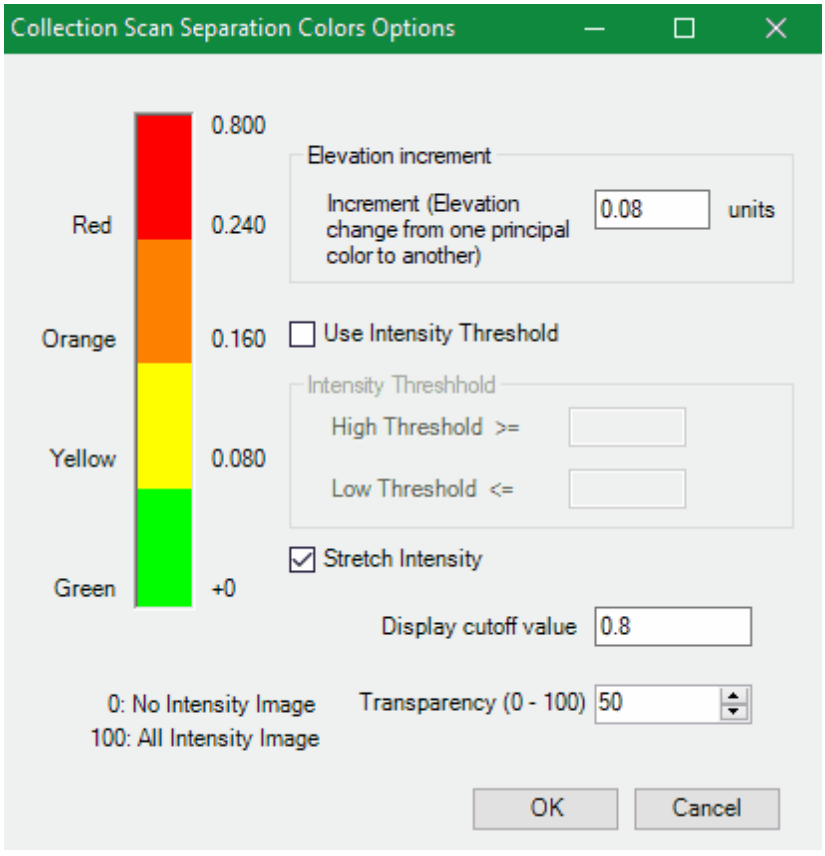
d) The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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e) There are several settings and options on the **'Grid'** tab. Click on the **'Colors Options'** button to define the elevation increment and color representation options as seen in the screen shots below, then click 'OK.'





✓ **Elevation increment:** Specify here how many elevation units should be between

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principal colors. To test against the USGS LiDAR specification (for example, less than or equal to 8cm Z difference), a value of '0.08' should be entered for projects in meters so that green raster cells would show compliance with the specification - yellow, orange, and red would not. Projects in feet should use a value of '0.26'.

- ✓ **Use Intensity Threshold:** Check this box to set high and low intensity value ranges. Pixels meeting these criteria will be rendered in magenta and blue, respectively, and will be displayed on top of collection scan separation rendered pixels.
- ✓ **Stretch Intensity:** Uncheck to disable intensity stretching for the background image of the raster.
- ✓ **Display cutoff value:** The user has the option of entering a unit value in this text box which would be considered out of the realm of possibility. For example, in one collection scan a car may have been present from which LiDAR returns were collected. In the next collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Display cutoff value' text box will tell the software to ignore data outside this value range. In this way entering a value of '1.0' meters, for example, the vertical discrepancy between a car versus no car will be ignored. A good starting point for this value is 10 times the '**Elevation increment**'.
- ✓ **Transparency (0-100):** The user can set the transparency of the collection scan separation coloration over the output raster. The default value is set to 50. As stated in the interface itself, a value of 0 would show no intensity image and only show the collection scan separation coloration. A value of 100 would show the intensity image only and show no collection scan separation coloration.

By default, a **Hybrid** of **TIN** (for ground points) and **Grid** (for non-ground points) is used

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in creating the final rasters to give the best combination of usability and speed. **TIN** and **Grid** can also be selected individually. As noted on the interface, the TIN method is generally the most accurate but also the slowest. However, it may introduce some undesirable raster artifacts if there are outlier points from a swath that are at a greater-than-normal-spacing distance from the rest of the swath they belong to. Using the **Grid** option can save time but may produce false excess-separation values depending on the area's terrain.

When all settings have been made on all tabs, click on the 'Export' button to export the data by tiled collection scan separation.

4) **LiDAR Spatial Distribution Density Verification:** This option is enabled only when the 'LiDAR Spatial Distribution Verification GRID - JPEG 2000' export type is chosen. It creates a grid containing values representing the presence (value=1) or void (value=0) of a first (of any) return LiDAR point within any portion of a predefined grid cell size. See the LiDAR Spatial Distribution Verification GRID - JPEG 2000 720 Help Topic for more details.

To use the 'LiDAR Spatial Distribution Verification GRID - JPEG 2000' export:

1) Start by loading the LAS data for the project to be analyzed. For more information on loading LAS data, please see the LAS Files 74 section of the Help Topics.
2) Select the **'Export'** 

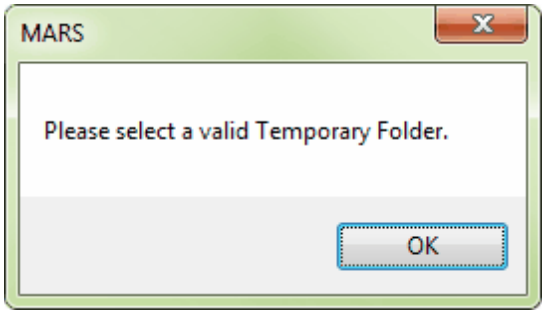
button or **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears. Select the **'LiDAR Spatial Distribution Verification GRID - JPEG 2000'** export type and click the 'OK' button.
3) When the export interface appears, specify an Output Directory. This will be the

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folder where the final JPEG 2000 (*.jp2) and auxiliary text file will be exported to when processing is complete.

4) The 'Use temporary local disk space to speed up processing' option allows the exported file to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the folder selected. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

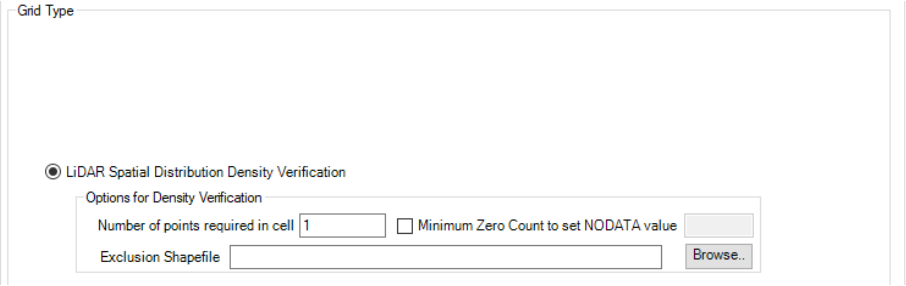


5) This export type is intended for use with either the **'Single File'** (when using the 'Export' button) or **'User-defined Box'** (when using the 'Export Area' button) layout types. On the **'Layout'** tab of export, specify a File Name for the newly created .jp2 file in the **'File'** text box.

6) The '**Grid**' tab contains a few options to control the export. The **'Number of points**

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required in cell' option sets a minimum point count required within each cell. The default value is '1' (to meet USGS specifications), but it can be changed as needed. The **'Exclusion Shapefile'** option is meant for use with a polygon shapefile. A typical polygon shapefile for this use will contain polygons around all water bodies which may cause the resulting output grid file to produce a '0' (zero) value. A '0' value would indicate that no LiDAR point was found inside that particular cell, and that cell would then 'fail' the test as described above. If all the cells found inside a body of water record a '0' value, it could cause the entire project area to fall below the 90% pass rate of cells containing a value of 1 (cells which contain at least one point). Because LiDAR is absorbed by water, water areas should be excluded from the test results. The 'Exclusion Shapefile' option allows the user to place polygons around any water bodies which may result in a '0' value and exclude those polygons from the results. Using this option when producing a LiDAR Spatial Distribution Verification Grid is optional.



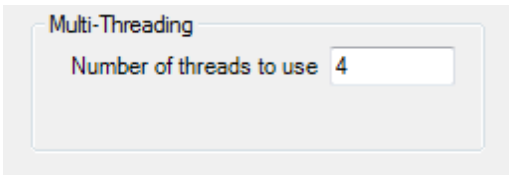
The **'Minimum Zero Count to set NODATA value'** option may be applied in areas where a large number of '0' value cells is anticipated, as in the case of a water body. This option implements a maximum number of contiguous '0' cells and changes the value of those '0' cells to a value of 'NULL'. This will automatically delineate large data void areas such as water bodies. This option can be used as an alternative to the 'Exclusion Shapefile' option and completes the same general purpose. After checking the **'Minimum Zero Count to set NODATA value'** option, the user may

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enter an integer in the adjacent text box. As an example, if the user entered '3' into this text box, the process would look for three contiguous cells containing a '0' value and change all three to a 'NULL' value. The purpose of this option is to create a more accurate pass percentage if no exclusion shapefile exists.

At the bottom of the '**Grid**' tab is the 'Auto boundary algorithm' option. The boundary of the LiDAR data will be automatically detected and a NODATA value will be assigned to the raster cells that fall outside the boundary. The detection methods vary depending on whether the input LAS data is in 'Swath' or 'Tile' (the default) format. Swath data is assumed to have only one Point Source ID (PSID), also called collection scan number, per file, and adjacent swaths will overlap each other. Tile data may have one or more PSIDs per file, and adjacent tiles will not have any overlap. Note that there may be overlap *within* a tile, as when two or more swaths fall within a tile's boundary. The correct choice of input type is important in avoiding gaps in the exported grids within the project area.

7) The multi-threading option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. The multi-threading option can be found at the lower-right corner of the export interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

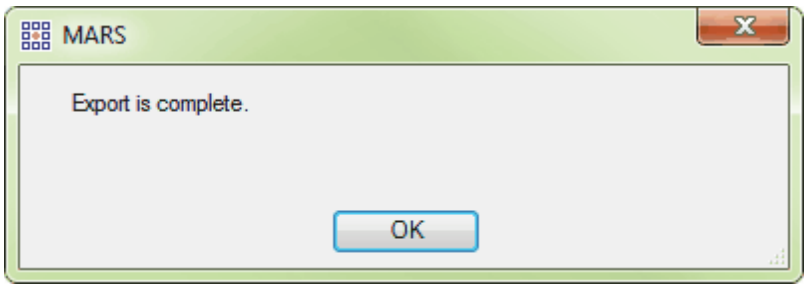


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8) If any other parameters of the export need to be set, please make those entries on the rest of the tabs located on the export interface.

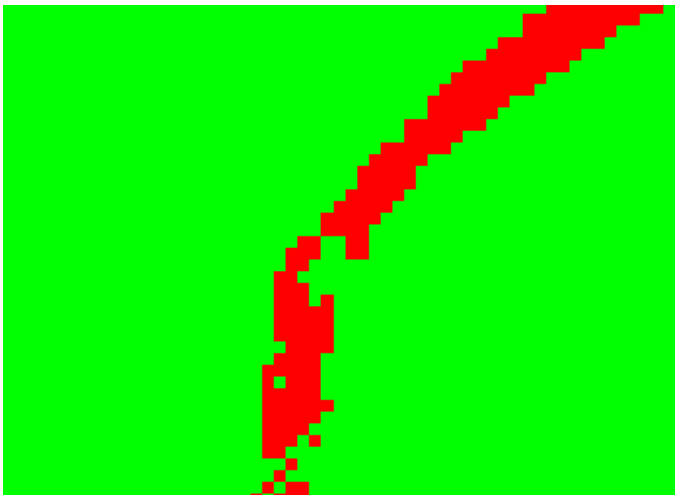
9) When all of the parameters of every tab have been specified, click the **'Export'** button to export the file.

10) When the export is complete a prompt, as seen below, will appear.

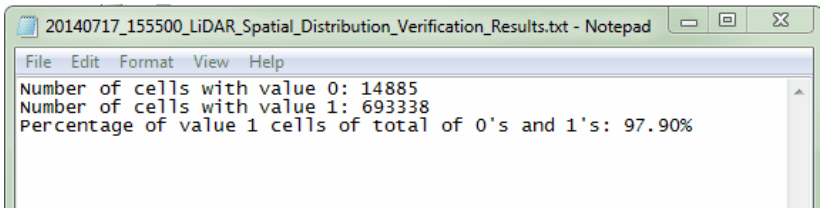


Below is an example result of the LiDAR Spatial Distribution Verification export type. The green areas represent cells with a value of '1', which have at least one LiDAR point within the cell. The red areas represent cells with a value of '0', which DO NOT contain a LiDAR point. In the example below it is easy to see that there is a body of water running through this area, which is the cause of the red cells with a '0' value. If the 'Minimum Zero Count' option was used when running this tool, the areas of contiguous '0' cells (the water body) would return a null value instead of a '0' value.

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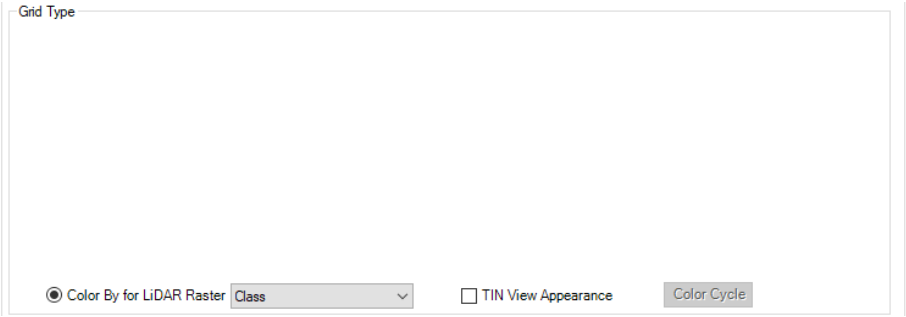


The 'LiDAR Spatial Distribution Verification' export will also output a results text file (*.txt) every time it is used. This text file will be output to the same location as the JPEG 2000 (the location specified by the user in the output directory browse box). The text file will be named beginning with the date, time, and '...LiDAR_Spatial_Distribution_Verification_Results.txt'. This allows each *.txt created to be unique. For example, the file seen in the screen shot below was produced on July 17, 2014 at 3:55 pm. The text file will contain the following information: the number of cells with a '0' value, the number of cells with a '1' value, and the number of value '1' cells as a percentage of the total number of cells. This last value will be the percentage of passing cells. This percentage needs to be 90% or above to be in compliance with the USGS specifications mentioned above. The screen shot below shows an example of the information contained in the text file.



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5) **Color By for LiDAR Raster:** This option creates a fast JPEG 2000 raster from the loaded LiDAR data. This is the only option for 'Grid Type' when the selected export type is 'Grid - LiDAR Raster JPEG 2000'. The output raster cells can be colored by Class, Intensity, Elevation - Throughout, Elevation - Repeat, or RGB values.



The appearance of the raster can be set to emulate either a Point View (default) or TIN View rendering by using the checkbox to the right of the '**Color By for LiDAR Raster**' drop-down list. This checkbox control can be used with any of the '**Color By ...**' selections except RGB. When the drop-down is set to '**Elevation - Repeat**', the '**Color Cycle**' button is enabled allowing the same control as when viewing LAS data by '**Elevation --> Repeat**'. See the Elevation Repeat 881 topic for details on controlling the display.

- **'Data Type'** - MARS® is capable of 32-bit Float, 32-bit Signed Integer, 16-bit Unsigned Integer, and 8-bit Unsigned Integer formats for export, depending on the Grid Type being exported. 'Float 32' is the only option for the 'Elevation' Grid Type. 'Unsigned 16' is the default for the 'Intensity' Grid Type (*exception:* when the export type is 'Grid - Cloud Optimized GeoTIFF Intensity', the 'Data Type' defaults to 'Unsigned 8'). 'Int 32' is the only option available for 'Flightline Separation - JPEG 2000' exports (which use the 'Color by Collection Scan Separation' Grid Type), and the 'LiDAR Spatial Distribution Verification GRID - JPEG 2000' Grid Type.

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- **'Lower Left (LL) Coordinate Shift' -** when checked, forces the coordinates of the lower-left origin of an exported Grid to be a value that is evenly divisible by the chosen Cell Size (see above).

- **Algorithm -** Depending on the export type, the user has the option on how to calculate cell values. 'Closest Point to Cell Centroid' (enabled only for the 'Intensity' Grid Type) uses the intensity value from the Lidar point closest to the cell's centroid (XY distance) to set the value for that cell; 'Grid from TIN' builds a Grid from a virtual (RAM-based) TIN, then determines each cell's value by checking the TIN at the cell center's XY value. The remaining options find the one point in the cell whose value meets the option's description and assigns that value to the cell.

- **Fill Gap -** Depending on the export type, the user has the option on how (or whether) to fill voids which are found in the LiDAR data. Both the 'Fast Fill' and 'TINned Surface Fill' options are used to prevent NODATA values. If the 'Fast Fill' radio button is selected, MARS® will use horizontal 'striping' from the last known elevation value of the input class points (see Filters tab 774) for each row of cells in the void area. The 'TINned Surface Fill' option aids in hydro-flattening by spanning across data voids to find points in the input classes. These points are used to create a flat TIN across the void. The 'Maximum distance to fill' option sets a maximum distance (in project units) for spanning a void when either of the fill options is selected. For the 'TINned Surface Fill' option, an additional value called 'Internal Buffer Size for TINned Surface' should be set to mitigate tinning errors across Virtual Tiles (see Auto Calculate Virtual Tile Size 785 sub-topic). NODATA values will exist beyond this distance.

- **Input Data Type (Auto boundary algorithm)**: The boundary of the LiDAR data will be automatically detected and a NODATA value will be assigned to the raster cells that fall outside the boundary. The detection methods vary depending on whether the input LAS data is in 'Swath' or 'Tile' (the default) format. Swath data is assumed to have only one Point Source ID (PSID), also called collection scan number, per file, and adjacent swaths will overlap each other. Tile data may have one or more PSIDs

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per file, and adjacent tiles will not have any overlap. Note that there may be overlap *within* a tile, as when two or more swaths fall within a tile's boundary. The correct choice of input type is important in avoiding gaps in the exported grids within the project area.

6)

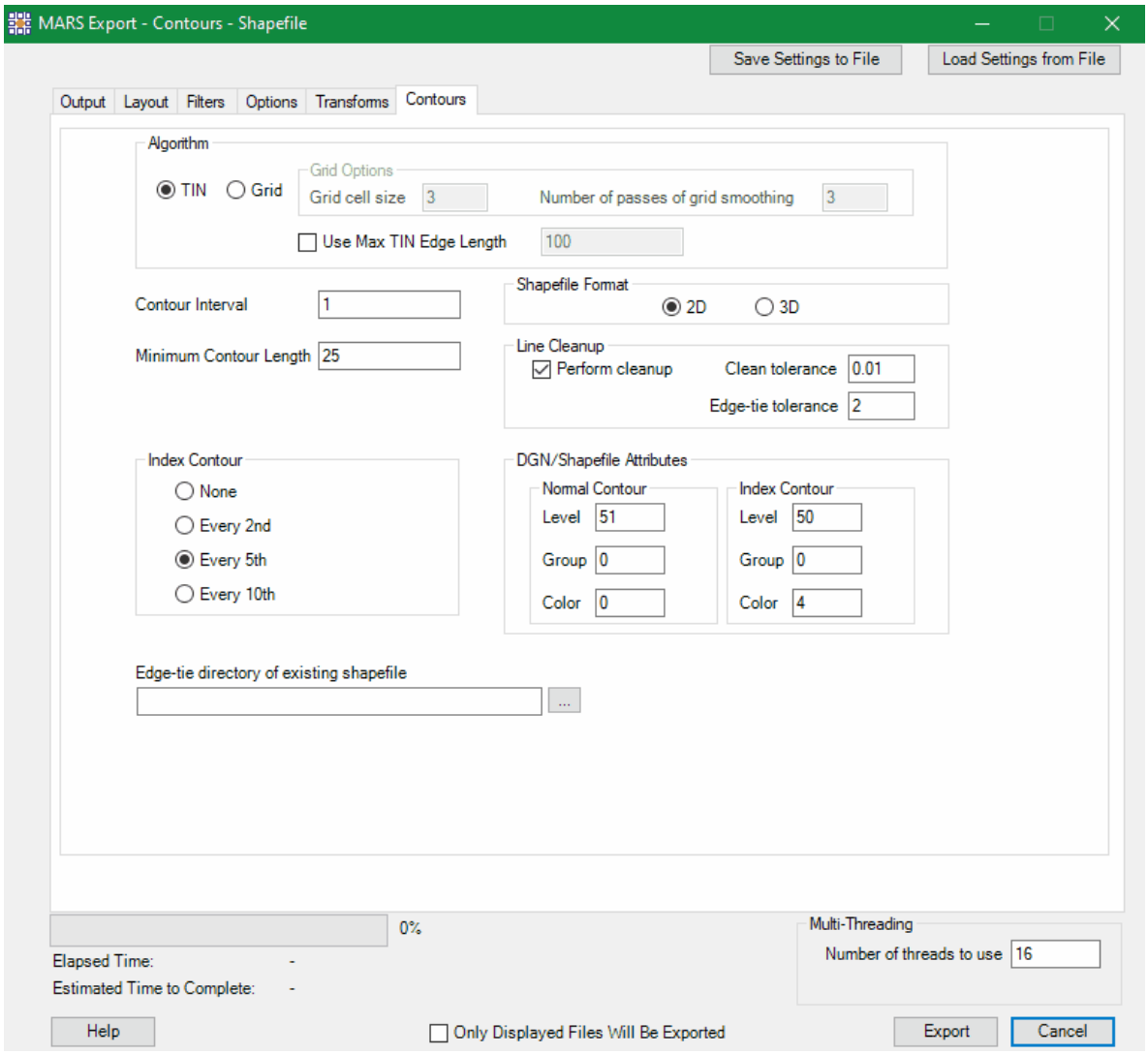
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4.5.8 Contours tab



The Contours tab allows the user to specify how exported contour shapefiles will be created and attributed.

***'Contours'* tab:** The 'Contours' tab allows the user to set the contour interval, minimum contour length, set index contours and level, group, and color for the exported contours. If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use. Please see the screen shot below followed by a description of the options available.



- **Algorithm: 'TIN' -** Builds a virtual TIN and generates the contours from that surface. This method is more exact but can create jagged looking contours.
- **Algorithm: 'Grid' -** Builds a grid from the TIN. The grid cell size can be specified and the number of passes of the Gaussian smoothing mechanism can also be specified by the user. The option to create a virtual grid inside this MARS® function allows the user to create a smooth grid file which, in turn, will create aesthetically pleasing (smooth) contour lines. The RAM-based, virtual grid also allows for quicker production.
- **Use Max TIN Edge Length:** This option is applicable to both algorithm options: 'TIN' or 'Grid'. In the

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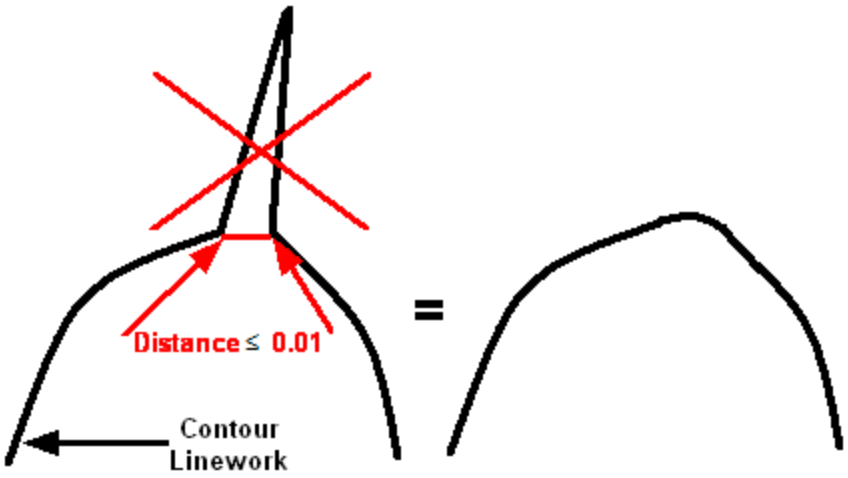
case of the 'Grid' algorithm, the software will create a TIN to assist in the creation of the grid. The maximum TIN edge length to be used in export may be specified here.

- **Contour Interval:** Choose the vertical unit value of the interval between contour lines. For example, a value of 2 will place contour lines every 2 project units of elevation.
- **Minimum Contour Length:** Set a minimum contour length for contour generation. Longer minimum contour lengths can minimize noise in the contour data. Shorter minimum contour lengths, while more accurate, can generate contours where there is noise in the LiDAR data.
- **Index Contour:** Select the indexing required for the project. Index contours appear in the LAS Map View as thicker (bolder) contour lines to allow the user to more easily visualize elevation intervals.
- **Shapefile Format: 2D or 3D -** Choose the desired format. 2D will create an elevation attribute only for each feature, while 3D will create an elevation attribute and store Z-values internally at each vertex. 3D files require approximately twice the storage space as 2D.

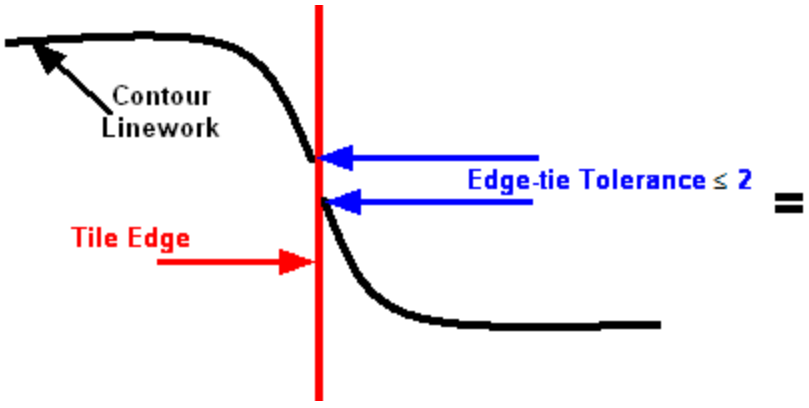
- **Line Cleanup: Perform cleanup -** This option determines whether or not MARS® will attempt to clean up unnecessary vertices (see next setting) and exclude contours from the export that have self-intersections or other topology problems. When unchecked, all generated contours will be included in the exported shapefile. When checked, contours with topology errors will be exported to a separate shapefile (using the same naming scheme as the 'good' file, but with 'removed' appended to the file name) located within a sub-folder named 'Removed.' When necessary, this folder will be created in the 'Output Directory'.
- **Line Cleanup: Clean tolerance -** The clean tolerance setting in the 'Contour' tab lets the user set the distance between vertices of contour line work which will be 'cleaned'. This tool only functions on the interior of a tile/project and will not 'clean' line work at tile/project edges. The default tolerance setting is 0.01 units. This tool will look for contour lines with vertices which are 0.01 units or less apart and connect them, cutting off unneeded line work. In the example below, the two vertices indicated are less than 0.01 units apart. Rather than keep the sharply jutting area of the contour line intact, the software will create a more aesthetically pleasing contour line by deleting

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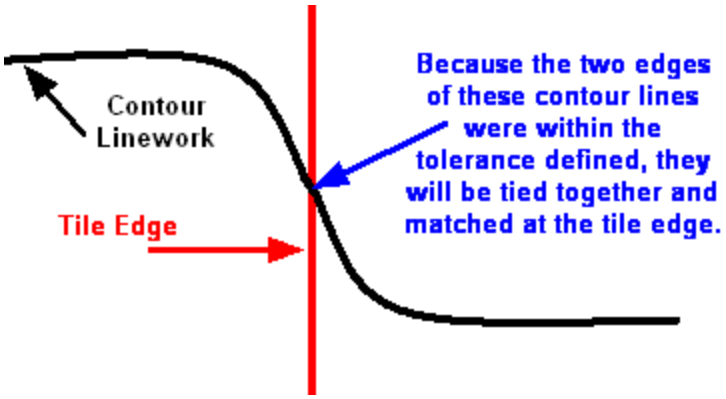
this unneeded line work. The tolerance may be set to any value but, the larger the value, the more cleaning will be done. This may result in more contours being moved to the 'Removed' sub-folder, as described in the previous setting.



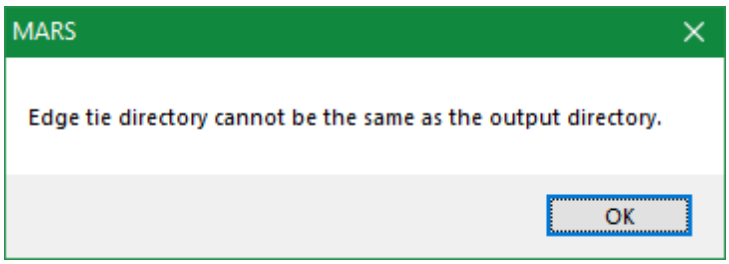
- **Line Cleanup: Edge-tie tolerance -** The edge-tie tolerance setting in the Contour tab allows the user to set the distance between ends of two contour lines which will be joined or 'tied' during export. This tool only functions on the tile edge and will not join contour lines in any other area. The default edge-tie tolerance setting is 2 units. This tool will look for contour line ends which are 2 units or less apart at the tile edge and connect them, creating one unbroken contour line. In the example below, two contours have reached the tile edge and have been cut at the tile edge. This occurs because a project is often processed by tile. Because the ends of the two contours are 2 units or less apart and occur at the tile edge, they will be joined.



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- **'DGN/Shapefile Attributes' section:** Allows the user to set the levels, groups, and colors of CAD and shapefile features. The 'level' attribute is important to the proper operation of the Depression Coder[541] tool.
- **Edge-tie directory of existing shapefile:** This option allows the user to point to an existing folder containing contour shapefiles. This folder *cannot* be the same as the output folder - if a different folder is not specified, a warning message will be displayed, as seen below. The existing contours *MUST* contain an 'Elv' attribute field with the elevation values populated for each contour. This allows the program to 'edge-tie' each contour line being exported to contours in previously-created shapefiles. Often, contours lines are cut when data is dissected into tiles. The elevation of contour lines created separately in these tiles may not match up when tiles are placed back together to create a single dataset. This option inside the contour interface creates a scenario in very few contours will be left 'dangling' or not connecting properly with the continuing contour line in another tile.



Once parameters have been set in all the export window tabs, click **'Export'** to export the data.

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4.5.9 Projection tab

Projection Options

Merrick Advanced Remote Sensing (MARS®) Software

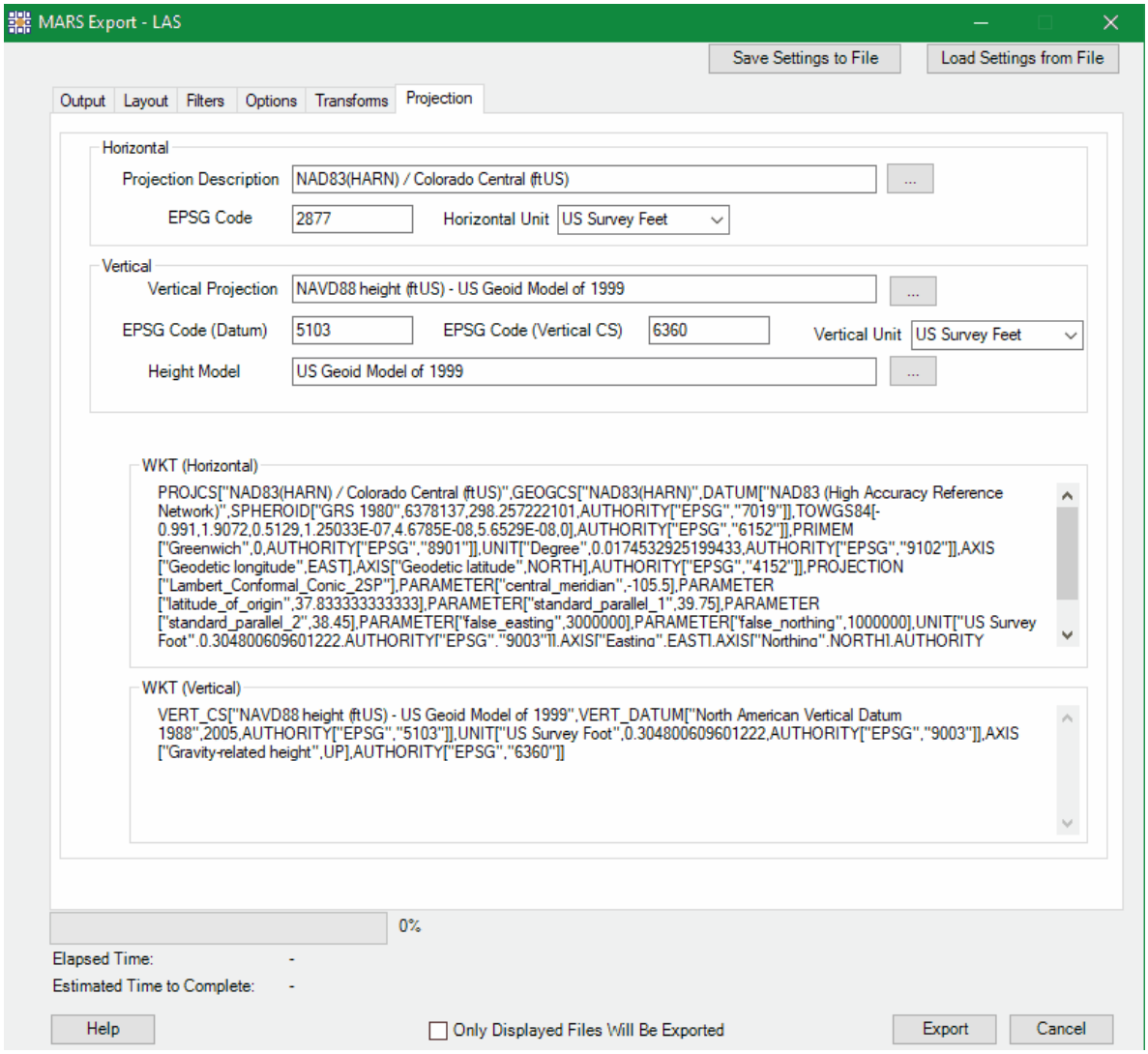
The Projection tab can be used to define the projection that the data is currently in. This tool does NOT perform any conversion or transformation. The 'Projection' tab is available only in the export interface when the 3D Image, Grid - IMG, Grid - LAS, Grid - TIFF, or LAS export types are chosen. When LiDAR data containing projection information is loaded into MARS® and one of the above-mentioned export types is chosen, the available projection information will automatically be populated in the 'Projection' tab of the export dialog.

***'Projection'* tab:** If the coordinate reference system data is not automatically entered in the 'Projection' tab, then the user may manually enter any missing or desired information for the export, including the horizontal and vertical units. To browse for coordinate system definitions, follow the procedure outlined in the 'Add CRS Info (to LAS Files)' topic in the Coordinate Conversion 254 section of this help file. When either the 'LAS' or 'Grid - LAS' export type is being used, the coordinate system tag will be written as WKT (Well-Known Text).

More information about each of the sections and settings on this tab can be found in the Export/ Extract Tab 461 help topic.

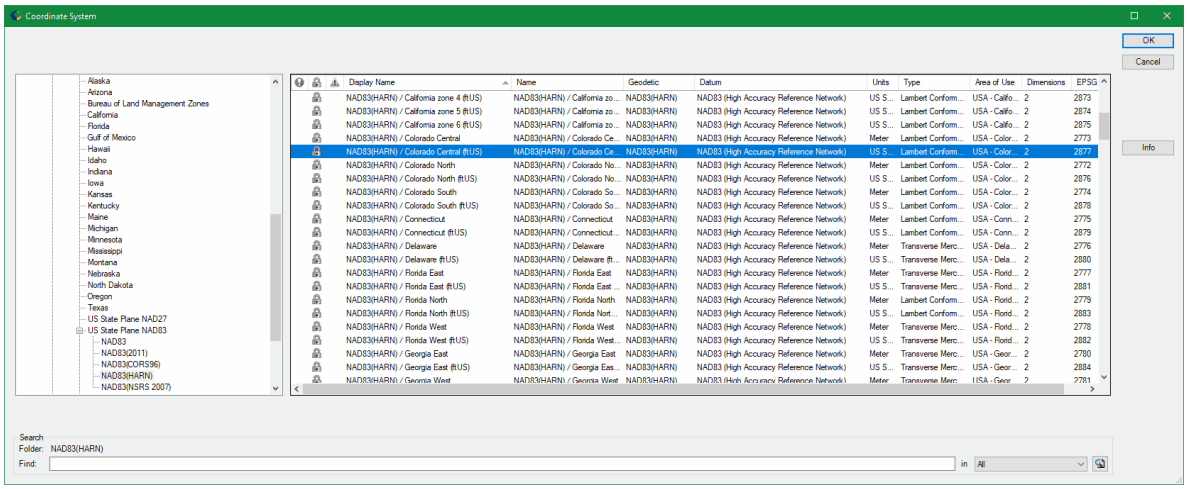
If settings inside the export window have been previously saved, they can be loaded by clicking the **'Load Settings from File'** button and navigating to the saved *.xml file. To save new settings, click the **'Save Settings to File'** button and an *.xml can be created for later use.

Projection tab when exporting to 'LAS':



The 'Coordinate System' selection window is seen below:

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When all other parameters have been set for the export, click the 'Export' button.

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4.6 Data Navigation

Data Navigation

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MARS® supports two primary navigation modes; a 2D View 835 (orthographic) and a 3D View 837 (perspective). Both modes allow for either point cloud or TIN rendering of LAS data.

Note: For fast navigation of large datasets, it is recommended that the user work in the 'Points' (point cloud) graphic display mode. Typically, the best approach is to navigate to a specific area-of-interest and then switch to the TIN mode, which will reduce the amount of processing necessary to create a surface over a very large area. Attempting to TIN large areas is very computationally 'expensive' and takes longer as TIN'ing is done on the fly by MARS®.

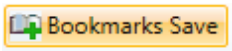
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4.6.1 Bookmarks

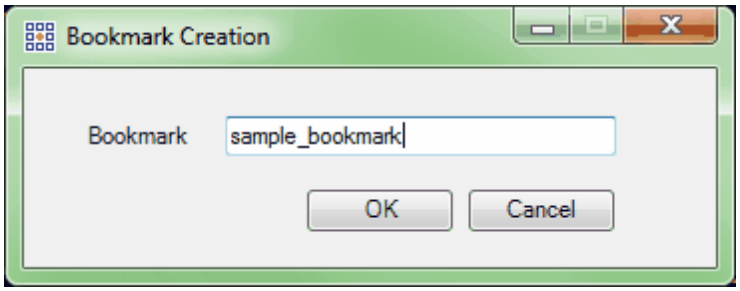
Bookmarks Functions

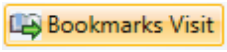
Merrick Advanced Remote Sensing (MARS®) Software

Bookmarks: Bookmarks can be used to mark a certain place in the data. The bookmark tools can be found on the Navigation Tab. By saving a bookmark, the user will be able to click on the bookmark name in the future and be taken to the location in the data that the particular bookmark was placed. Bookmarks are convenient when editing to be able to pick up editing in a particular spot, to save a place where re-work needs to be done, or as a point of reference for another user.

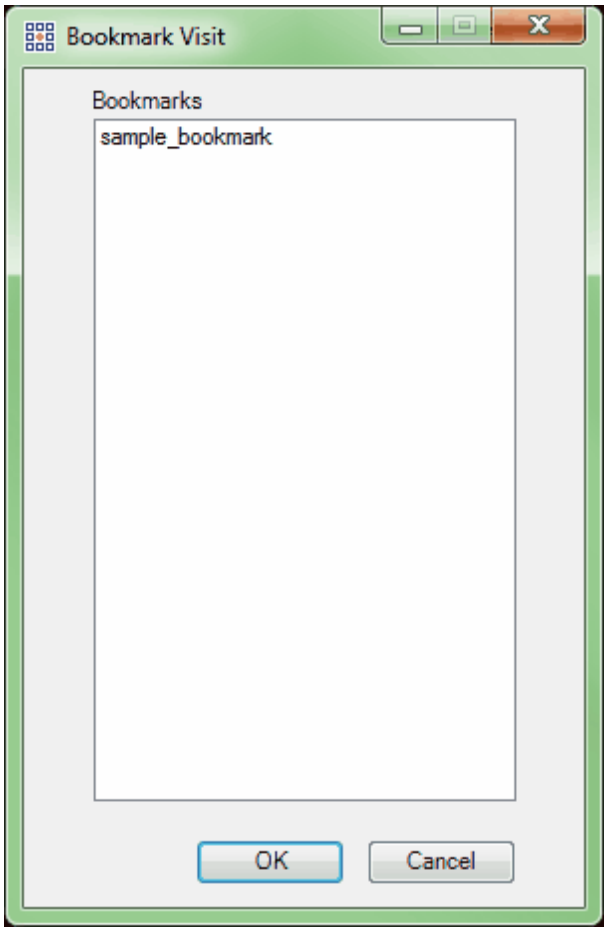


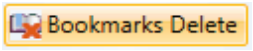
To create or save a bookmark for future reference, choose this option. The user will be shown a Bookmark Creation interface to name and save the bookmark. Click on the 'OK' button or press the 'Enter' key on the keyboard to commit the save.





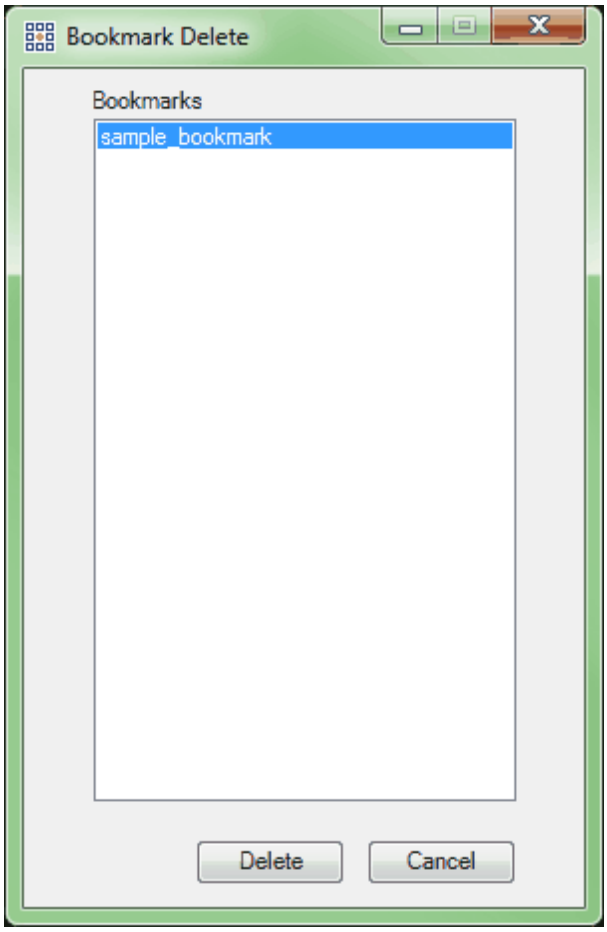
To visit a saved bookmark, use this option. A list of saved bookmarks will appear. Choose the needed bookmark and click 'OK' to view the bookmark placement.





To delete a saved bookmark, use this option. A list of all saved bookmarks will appear. Choose the bookmark to be deleted by highlighting it and choose' Delete' at the bottom of the window.

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See also:

Navigation Tab 234

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4.6.2 Cross-Section/Profile

Cross-Section/Profile View

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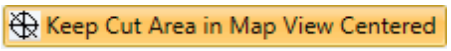
The cross-section/profile tools are most commonly used to generate cross-section data (both LiDAR and breakline data) and are also useful for evaluating data for calibration (collection scan and/or mission alignment) errors. LiDAR point display may be toggled off in the LAS Map View without affecting the point display in the Cross-Section/Profile view. Note that as the cursor is moved in the Cross-Section/Profile window, a white 'X' symbol will move in sync within the cross-section/profile box in the LAS Map View window. This aids the user in determining what areas of the data are being observed at any given time.

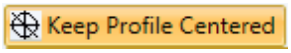
 **Place Profile Line-** Draws cross-sections with a fixed cut depth, and works only in 2D - orthographic mode. The tool uses a two-point compilation: to start, click once to place one side of the cross-section/profile, click again to place the other side of the cross-section/profile. The first time this cross-section/profile tool is used a new cross-section/profile window will open. There are adjustable default settings and special controls for this tool:

- **Default #1 -** The LAS Map View and cross-section/profile windows will tile automatically; the default is for the cross-section/profile window to appear to the right of the 2D LAS Map View window. To change the default go to the Options Tab[519] and click the **'Miscellaneous'** button. The setting may be changed in the 'Arrange Cross-Section/Profile window' section.
- **Default #2 -** The cross-section/profile width defaults to 10 units. To change the default go to the Options Tab[519] and click the **'Miscellaneous'** button. Entering a new value into the 'Default cut area depth' text box will change the default depth.
- **Default #3 -** The cross-section/profile cut area can be moved forward and backward ('broomed') in the 2D View window. The default value of this movement is 75%, meaning that the forward motion will be 75% of the cross-section/profile's width,

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leaving a 25% overlap. This percentage can be changed by going to the Options Tab 519 and clicking the **'Miscellaneous'** button. The 'Forward/back percentage' radio buttons available are 25%, 50%, 75%, 90%, or 100%.

- **Cross-Section/Profile Movement #1 -** The cross-section/profile cut area can be dragged to a new location. Select and drag the cut area in the 2D View window.
- **Cross-Section/Profile Movement #2 -** For stepping the cross-section/profile cut area forward and back ('brooming'), use the **UP** ⬆ and **DOWN** ⬇ arrows. The step size movement is controlled by Default #3.
- **Cross-Section/Profile Movement #3 -** If the 2D View window is selected, the **'Keep Cut Area in Map View Centered'** 

tool will keep the cross-section/profile cut area centered in the middle of the LAS Map View window. To disable this and allow the cut area to move independently from the window, click the **'Keep Cut Area in Map View Centered'** tool to toggle it off while the 2D View window is active. If the cross-section/profile window is the active window, the **'Keep Profile Centered'** 

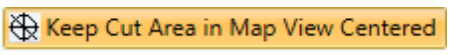
tool will try to estimate a ground elevation and automatically adjust the window to that elevation. In steep terrain or near tall buildings this feature can fail. To disable this and allow the cross-section/profile to move without automatic elevation adjustment, click the **'Keep Profile Centered'** tool to toggle it off while the cross-section/profile window is active.
- **Cross-Section/Profile Movement #4 -** The cross-section/profile cut area can be rotated in the 2D View window. The cut area will rotate around its center node. Rolling the mouse scroll wheel rotates the cross-section/profile.

 **Place Adjustable Profile Line-** Draws cross-sections *without* a fixed cut depth, and works

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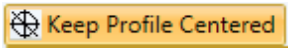
only in 2D - orthographic mode. The tool has a three-point compilation: to start, click once to place one side of the cross-section/profile, click again to place the other side of the cross-section/profile, and click a third time to set the cut depth (width) of the profile. The first time this cross-section/profile tool is used a new cross-section/profile window will open. There are adjustable default settings and special controls for this tool:

- **Default #1 -** The LAS Map View and cross-section/profile windows will tile automatically; the default is for the cross-section/profile window to appear to the right of the LAS Map View window. To change the default go to the Options Tab 519 and click the **'Miscellaneous'** button. The setting may be changed in the 'Arrange Cross-Section/Profile window' section.
- **Default #2 -** The cross-section/profile cut area can be moved forward and backward ('broomed') in the 2D View window. The default value of this movement is 75%, meaning that the forward motion will be 75% of the cross-section/profile's width, leaving a 25% overlap. This percentage can be changed by going to the Options Tab 519 and clicking the **'Miscellaneous'** button. The 'Forward/back percentage' radio buttons available are 25%, 50%, 75%, 90%, or 100%.

- **Cross-Section/Profile Movement #1 -** The cross-section/profile cut area can be dragged to a new location. Select and drag the cut area in the 2D View window.
- **Cross-Section/Profile Movement #2 -** For stepping the cross-section/profile cut area forward and back ('brooming'), use the **UP** ⬆ and **DOWN** ⬇ arrows. The step size movement is controlled by Default #2.
- **Cross-Section/Profile Movement #3 -** If the 2D View window is selected, the **'Keep Cut Area in Map View Centered'** 

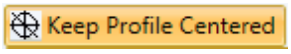
tool will keep the cross-section/profile cut area centered in the middle of the LAS Map View

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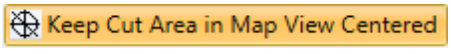
window. To disable this and allow the cut area to move independently from the window, click the **'Keep Cut Area in Map View Centered'** tool to toggle it off while the 2D View window is active. If the cross-section/profile window is the active window, the **'Keep Profile Centered'** 

tool will try to estimate a ground elevation and automatically adjust the window to that elevation. In steep terrain or near tall buildings this feature can fail. To disable this and allow the cross-section/profile to move without automatic elevation adjustment, click the **'Keep Profile Centered'** tool to toggle it off while the cross-section/profile window is active.

- **Cross-Section/Profile Movement #4 -** The cross-section/profile cut area can be rotated in the 2D View window. The cut area will rotate around its center node. Rolling the mouse scroll wheel rotates the cross-section/profile.



Keep Profile Centered - In the cross-section/profile window, the 'Keep Profile Centered' tool keeps data centered vertically in the window. If the *cross-section/profile* window is the active window, the 'Keep Profile Centered' tool will try to estimate a ground elevation and automatically adjust the window to that elevation. In steep terrain or near tall buildings this feature can fail. To shut this off and allow the cross-section/profile to move without automatic elevation adjustment, click the 'Keep Profile Centered' to toggle it off while the cross-section/profile window is active.



Keep Cut Area in Map View Centered - This tool keeps the cut area box centered vertically and horizontally in the LAS Map View window. To shut this off and allow the cut area box to move independently from the window, click the 'Keep Cut Area in Map View Centered' button to toggle it off. When the 'Keep Cut Area in Map View Centered' tool is not active, the cross-section/profile window can be dragged with the **'Pan'** 

tool to the user's area of

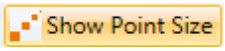
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interest.

The Cross-Section/Profile Tab 240 has several features which work with the cross-section and profiling tools. The 'Vertical Scale' slider bar, the profile by collection scan or combined, the sizes of the LiDAR points in relation to their distance from the viewer, as well as the cross-section/profile depth can all be changed.




 **Current Depth:** Allows the user to define the cut depth of the cross-section/profile window.



Show Point Size: Resizes the point display within the cross-section/profile window. When toggled on, the LiDAR points nearest to the viewer side of the cut area are relatively larger, and points on the far side are relatively smaller.

 **Profile Combined:** Displays a combined single line profile of all points.

 **Profile by Collection Scan:** Displays a separate profile line for each collection scan.

 **Cross Section:** Displays a cross-section view of the LiDAR points in the cross-section/profile window.



Vertical Scale: Allows the user to adjust the

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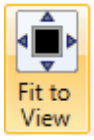
vertical scale (relative to the horizontal one) by moving the slider bar back and forth or by typing the desired scale into the scale text box. The '1x' button resets the scale to 1:1, the original or 'true' scale.

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4.6.3 Fit to View

Fit to View Function

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Fit View: Zooms out to the project's furthest extents (all loaded data). This tool, found on the Navigation Tab 234 or the Quick Access Toolbar 65, will only function in the LAS Map View window and is disabled for use in the Cross-Section/Profile window.

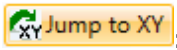
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4.6.4 Jump To

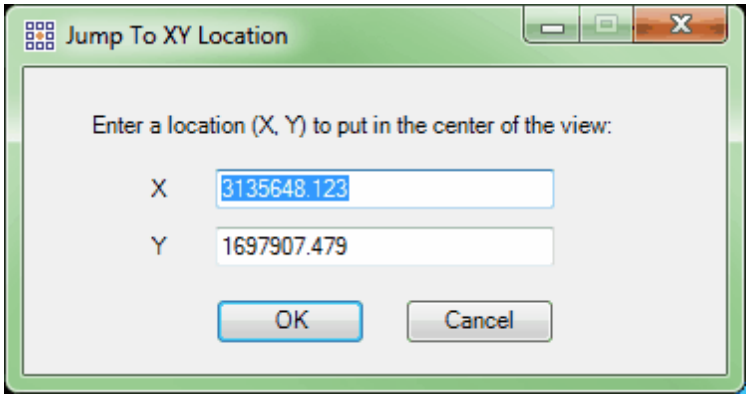
Jump To Functions

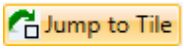
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MARS® provides three methods to quickly navigate to a specific area of interest. These buttons are found on the Navigation Tab 234:

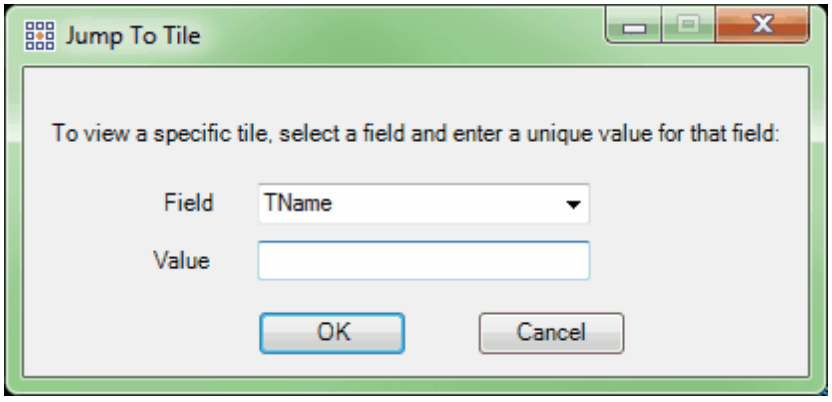


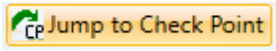
: Allows the user to navigate to a specific X, Y coordinate.





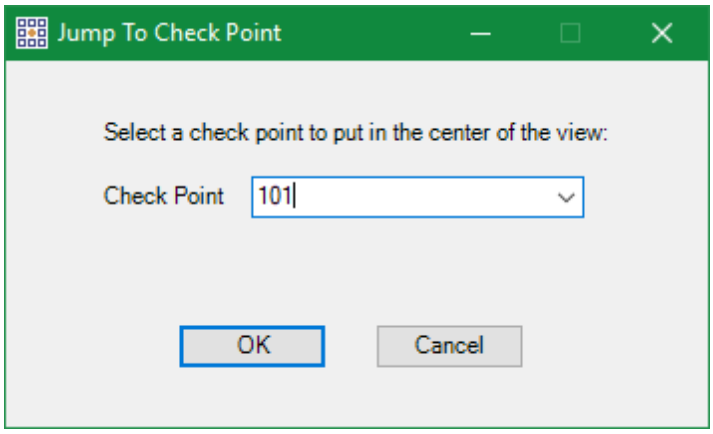
: Allows the user to navigate to the extent of a specific tile. In order to use this tool, a tile shapefile (*.shp) with a unique attribute field must be loaded into MARS®.





: Allows the user to navigate to a specific check point location. In order to use this tool, a check points file (*.csv) with an ID column must be loaded into MARS®.

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See also:

Navigation Tab 234

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4.6.5 Link to Google Earth

Link to Google Earth Function

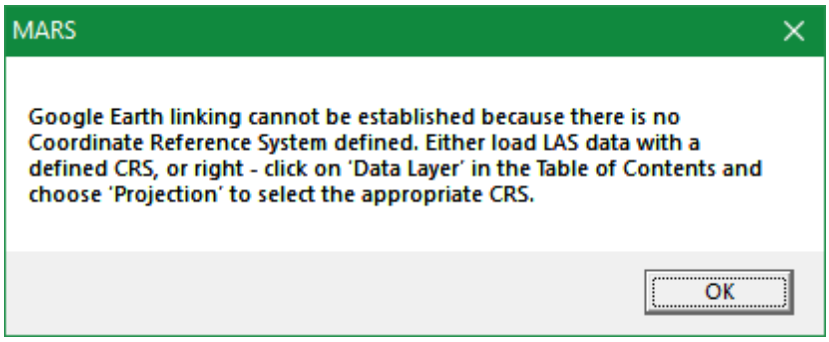
Merrick Advanced Remote Sensing (MARS®) Software



Link to Google Earth: If either Google Earth© or Google Earth Pro© is installed, it will open in a separate window and auto-navigate to the location that is displayed in the LAS Map View window.

When the tool is enabled, it will check to see if Coordinate Reference System (CRS) information is defined for either the loaded LAS data or in the 'Data Layer' properties. If not, the following message

will appear:



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4.6.6 Pan





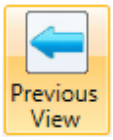
Pan: Allows the user to navigate across the loaded data and/or imagery.

To use the 'Pan' function, click the **'Pan'** button on the Navigation Tab 234 (or use the shortcut key 'Q'), then left-click and drag the mouse to navigate in any direction. Panning can also be done in most situations by using a push-and-hold technique with the mouse wheel and then moving the mouse. See additional panning methods in the 'Miscellaneous' section of the Options Tab 519.

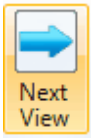
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4.6.7 Previous/Next View





Previous View: Allows the user to return to the last display view.



Next View: Allows the user to jump to the next display view. *(Note: the user can only jump to the next display view if the previous button was used prior)*

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4.6.8 Zoom In/Out



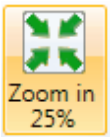
There are several ways to zoom in and out.

Zoom In:

1. **Choice #1 -** While in the 'Pan' mode (

), hold down the CTRL key and use the left mouse button to drag a rectangle. This area will now zoom in to fill the window extent.
2. **Choice #2 -** Select the 'Zoom In Window' button 

from the Navigation Tab[234] or the Quick Access Toolbar[65]. Click and hold the left mouse button to drag a rectangle. View will be zoomed to fill this area.
3. **Choice #3 -** While in the 'pan' mode (

), hold down the right mouse button and move the mouse backward. Pushing the mouse forward while holding the right mouse button down zooms out.
4. **Choice #4 -** Roll the scroll button on the mouse away from the computer (backward) to zoom in to the data.
5. **Choice #5** - If a tile shapefile is loaded, double-clicking on a tile will zoom to the extent of that tile.
6. **Choice #6** - To zoom in by a fixed amount (25%), select the '+' (plus) key on the keyboard/numeric keypad or click the 'Zoom in 25%' button 

on the Navigation Tab[234] or the Quick Access Toolbar[65].

Zoom Out:

1. **Choice #1 -** While in the 'Pan' mode (

), hold down the SHIFT key and use the left mouse

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button to drag a rectangle. View will be zoomed out from the drawn rectangle.

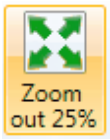
2. **Choice #2 -** Select the 'Zoom Out Window' button 

from the Navigation Tab 234 or the Quick Access Toolbar 65. Click and hold the left mouse button to drag a rectangle. View will be zoomed out from the drawn rectangle.

3. **Choice #3 -** While in the 'pan' mode (

), hold down the right mouse button and move the mouse forward. Pulling the mouse backward while holding the right mouse button down zooms in.

4. **Choice #4 -** Roll the scroll button on the mouse toward the computer (forward) to zoom out from the data.

5. **Choice #5** - To zoom out by a fixed amount (25%), select the '-' (minus) key on the keyboard/ numeric keypad or click the 'Zoom out 25%' button 

on the Navigation Tab 234 or the Quick Access Toolbar 65.

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4.7 Data Viewing



MARS® can rapidly display LiDAR datasets and supports easy navigation in 2D and 3D modes. The

following list outlines the data visualization and navigation capabilities of MARS®.

LiDAR Data Rendering

• **Color by Elevation**  : Renders LiDAR data by elevation.

• **Color by Intensity**  : Renders LiDAR data by intensity.

• **Color by Classification**  : Renders LiDAR data by data classification.

• **Color by Return**  : Renders LiDAR data by return.

• **Color by Collection Scan**  : Renders LiDAR data by collection scan.

• **Color by Ground Color**  : Renders user-defined ground class(es) by RGB values and all other points by classification. RGB values stored with the points will be used if no imagery is loaded.

• **Color by RGB**  : Uses the R(ed), G(reen), B(lue) values stored for each LiDAR point to render the point cloud or TIN as a pseudo-image.

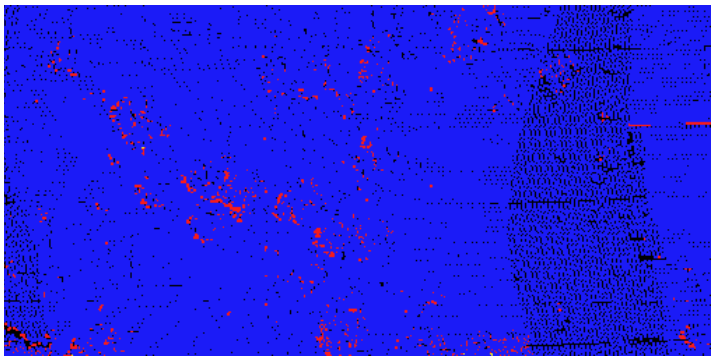
• **Color by Imagery (Fusion)**  : Fuses RGB values from Raster into the LiDAR points.

• **Blend with Intensity**  : This tool will display LiDAR points by intensity and allow the user to

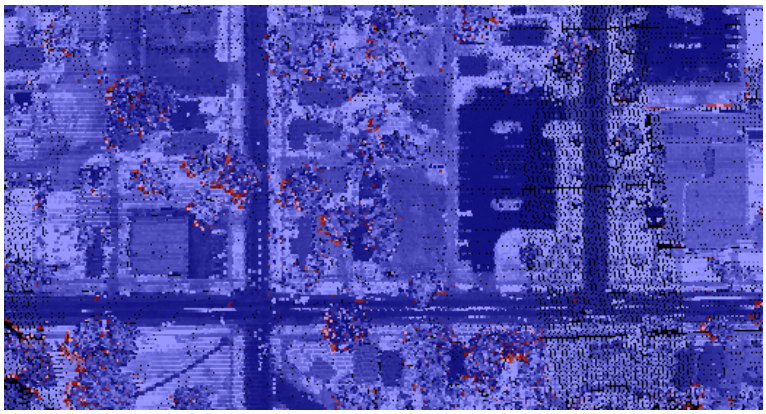
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blend these intensity images with other 'color by' views. The user may view intensity blended with elevation, classification, collection scan, return, user data, or with Z delta. There is no terrain relief when viewing LiDAR data by intensity alone, yet the ability to view intensity along with another value may allow the user to view the data more efficiently. Please see the examples below for further explanation.

In the screen shot below, the LiDAR data is being viewed by return only. By viewing only the return values, it is impossible to know which characteristic in the terrain the first return (blue) and second return (red) data corresponds to.



The screen shot below is of the same area, but the 'Blend with Intensity' tool has been utilized with the return values in the LiDAR data. It is now easy to see that the first return data (blue) corresponds to areas with roads and buildings whereas the second return data (red) corresponds to areas containing trees.



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- **Color by CIR** : Uses the R(ed), G(reen), B(lue), and N(ear Infrared) values stored for each LiDAR point to render the point cloud or TIN as a pseudo-image.

- **Color by Hillshade** : This tool will color an elevation float grid by hillshade on the fly. This tool is only available when a float grid has been loaded into MARS® and can be used in 3D in conjunction with a float grid (*.flt) file. For more information on loading a float grid into MARS®, please see the Convert Float Grid 655 section. To read more about the Color by Hillshade 860 tool, please select the link to this topic.

- **Color by Z Delta** : This tool will color the points in the LiDAR data by the vertical difference in collection scans. See the Color by Z Delta 868 topic for more details.

- **Color by User Data** : Displays LiDAR points rendered by values stored in the 1-byte 'User Data' field which can contain any type of data at the user's discretion. This field has often been used to store Auto-Gain Control values at the time the particular point in question was recorded in the system. These AGC values, specific to Leica sensors, tell the user how the system was attempting to center the intensity histogram at the time of collection.

- **Points**  : Renders the LiDAR data as points.

- **TIN**  : Renders the LiDAR data as a TIN (surface).

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2D Data Navigation

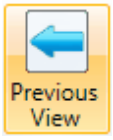
MARS® has many 2D data navigation tools. The following list outlines all of the application's 2D navigation functions:

• **Orthographic** 

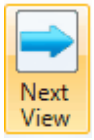
: *Orthographic* (2D) mode zoom tools and mouse controls are different than Perspective (3D) mode tools. The following tools can be used in 2D mode:

✓ **Fit to View** 

: To zoom out to the full extent of the project.

✓ **Previous View** 

: To go back to the previous zoom.

✓ **Next View** 

: To return back to the original zoom after the 'Previous View' button has been used.

✓ **Pan** 

: Can be used only while in 2D view. Click and hold the left mouse button and

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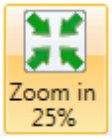
drag the display to a new location to pan across it.

✓ **Zoom In Window** 

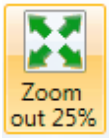
: Drag a rectangle to zoom in to the specified area.

✓ **Zoom Out Window** 

: Drag a rectangle to zoom out.

✓ **Zoom in 25%** 

: To zoom in by a factor of 25%.

✓ **Zoom out 25%** 

: To zoom out by a factor of 25%.

See Also

2D Navigation 835

3D Data Navigation

MARS® has many 3D data navigation tools also. The following list outlines all of the application's 3D navigation functions:

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• **Perspective**  : *Perspective* (3D) mode zoom tools and mouse controls are different than Orthographic (2D) mode tools. *Points may be edited while in 3D mode, and the Undo and Redo buttons on the* *Edit/Filter Tab* 270 *function in 3D editing.* Most editing should be completed in 2D mode, but if the editor is having difficulty understanding where the ground surface is, 3D mode can be a useful tool that allows the viewer to 'fly' around the data and reclass or edit specific points. **Be aware that the data must be viewed at 100% density in 2D before using the 3D application for editing.** If points are not shown at 100% density the user may possibly edit data which is not visible while viewing points at less than 100% resolution. The following tools can also be used in 3D mode:

✓ **Rotating around a central node:** First select the **'Pan'** 

button. Then click and hold the left mouse button. The data will rotate around a central node. Practice rotating the data around by sliding the mouse up and down or left and right while holding the left mouse button down.

✓ **Zooming In/Out:** First select the **'Pan'** 

button. Then click and hold the right mouse button to zoom into and away from the central node. Practice zooming with the data by sliding the mouse forward and backward while holding the right mouse button down.

✓ **Pan through/around data:** Click and hold both mouse buttons to pan through the data.

See Also

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3D Navigation 837

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4.7.1 2D View

2D View

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The 2D view is also known as 'Orthographic View'. By default, MARS® utilizes the 2D view when first loading data.

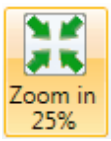
Moving in 2D:

MARS® supports several data navigation options. The user can utilize the following methods to zoom and pan, which are described below:

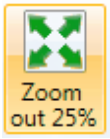
- **Zoom In/Out Window:** Click the **'Zoom In Window'** 

button or the **'Zoom Out Window'** 

button on the Navigation Tab 234 or the Quick Access Toolbar 65. Click and hold the left mouse button to drag a rectangle. The view will zoom to the defined area.

- **Zoom In/Out 25%:** Click the **'Zoom In 25%'** 

button or the **'Zoom Out 25%'**

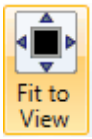


button on the Navigation Tab[234] or the Quick Access Toolbar[65].

- **Mouse Zoom:** Click and hold the right mouse button while moving the mouse backward to zoom in. Pushing the mouse forward while holding the right mouse button down will cause the display to zoom out. The user can also use the scroll button on the mouse to zoom in/out.
- **CTRL-Zoom:** Depress the CTRL key and use the left mouse button to drag a rectangle. The view will zoom to the defined area.
- **Tile Click:** If a tile shapefile is loaded into the project, the user may double-click within a tile to zoom to the extent of the desired tile.

To pan, make sure the **'Pan'** 

button is selected on the Navigation Tab[234] or the Quick Access Toolbar[65]. Click and hold the left mouse button to pan through the data.

Click the **'Fit to View'** 

button on the Navigation Tab[234] or the Quick Access Toolbar[65] to zoom to the extent of the project.

See Also:

Navigation Overview[813]

3D View[837]

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4.7.2 3D View

3D View

Merrick Advanced Remote Sensing (MARS®) Software

The 3D view is also known as 'Perspective View'. *Points may be edited while in 3D mode, and the Undo and Redo buttons on the* Edit/Filter Tab 270 *function in 3D editing.* Most editing should be completed in 2D mode or in the Cross-Section/Profile window, but if the editor is having difficulty understanding where the ground surface is, 3D mode can be a useful tool that allows the viewer to 'fly' around the data and reclass or edit specific points. **Be aware that the data must be viewed at 100% point density in 2D before using the 3D application for editing.** If points are not shown at 100% density the user may possibly edit data which is not visible while viewing points at a lower resolution.

Tutorial on 3D Navigation

1. Select the **'2D View'**  button and the **'Points'**  button.

2. Observe the resolution percentage (%) at the bottom of the window. Zoom in far enough to achieve 100% resolution.

3. TIN the data by selecting the **'TIN'**  button on the View Tab 192. To view only the LiDAR points data, proceed to the next step. To fuse the LiDAR data with loaded imagery,

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select the **'Color by Imagery (Fusion)'**  button.

4. Select the **'Place Target'**  button to pick the point of rotation within the data displayed (the nearest LiDAR point will be used). The target position may be reset at any time for a different perspective view.

5. Select the **'3D View'**  button. This will lock the current data resolution (point density), so first ensure that the displayed resolution is sufficient. *(Note: To change resolution, temporarily switch back to 2D mode.)*

6. Click and hold with the left mouse button to rotate around the data.

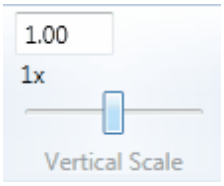
7. Click and hold with the right mouse button (forward or back) to zoom in/out.

8. Click and hold both mouse buttons to pan through the data.

9. Data will redraw at different rates depending on the amount of data displayed. The redraw operation takes the longest in the TIN graphic display.

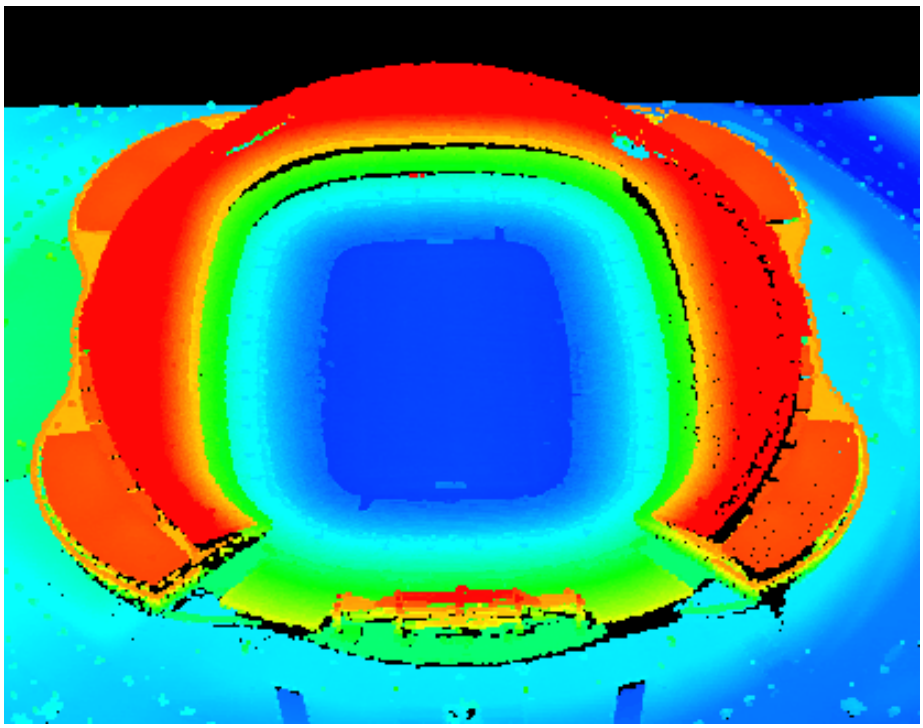
10. Select the **'Place Eye'**  button to pick a viewing location. For example, if the target location chosen with the **'Place Target'**  button is on a street below a skyscraper, select the **'Place Eye'** button and pick the top of the skyscraper. The result will be a view looking from the top of the skyscraper to the street below.

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11. MARS® is also capable of vertically rescaling data while in 3D View mode. Above the slider bar on the View Tab[192] is a vertical scale text box that allows entry of an exact scale value. Type in the scale (relative to horizontal) at which the data is to be viewed and press 'Enter' on the keyboard. The '**1x**' button will revert back to a 1:1 scale. 

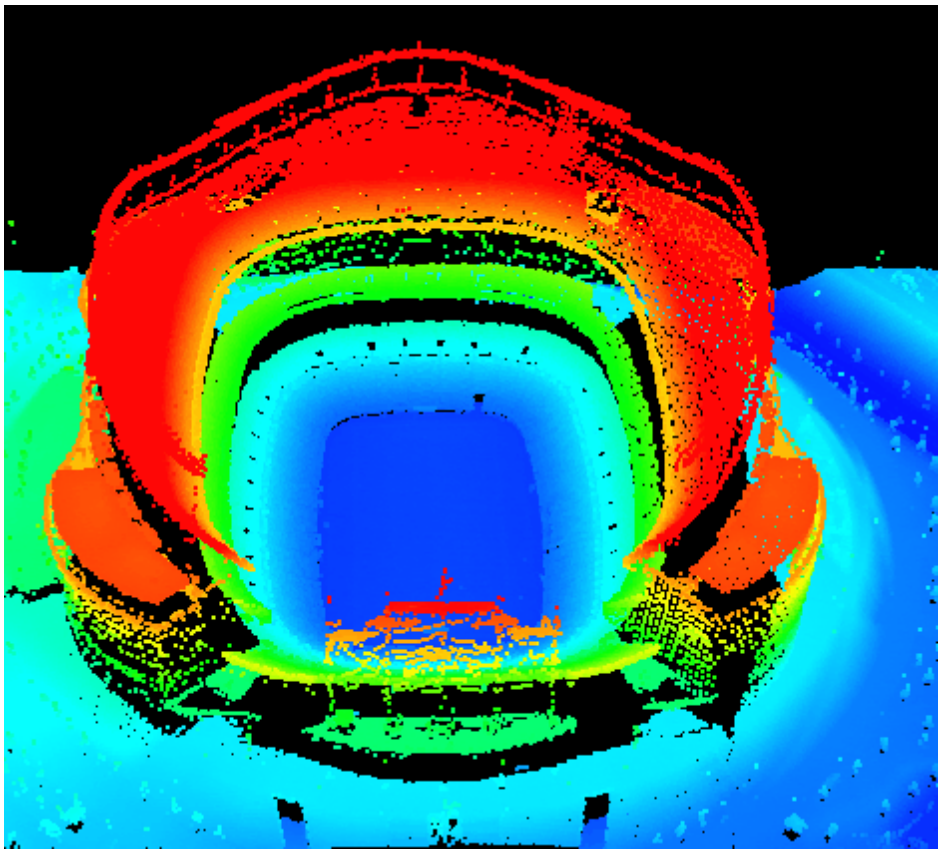
The Vertical Scale Slider inside the Cross-Section/Profile[146] window is only for use in that window and will not rescale data in the LAS Map View window.

Ex: Data scaled at 0.5



Ex: Data scaled at 2

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To return to the original or 'true' scale, either enter '1' in the scale text box, or click on the '1x' button. 

12. Select the **'Points'**  button. Select the **'2D View'** 

button and then the **'Fit to View'** 

button to return to the default display settings.

Moving in 3D:

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1. To Rotate - Click and hold the left mouse button. Moving the mouse will tilt and rotate the data around a central node. Practice tilting and rotating the data by sliding the mouse forward and back or left and right while holding the left mouse button down.

2. Zoom - Click and hold the right mouse button. Moving the mouse forward and back will zoom in and out from the central node. Practice zooming with the data by sliding the mouse forward and back while holding the right mouse button down.

3. Pan - Click and hold both mouse buttons. Moving the mouse will pan through the data.

See Also

Navigation Overview 813

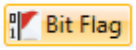
2D View 835

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4.7.3 Bit Flag Display

Bit Flag Display

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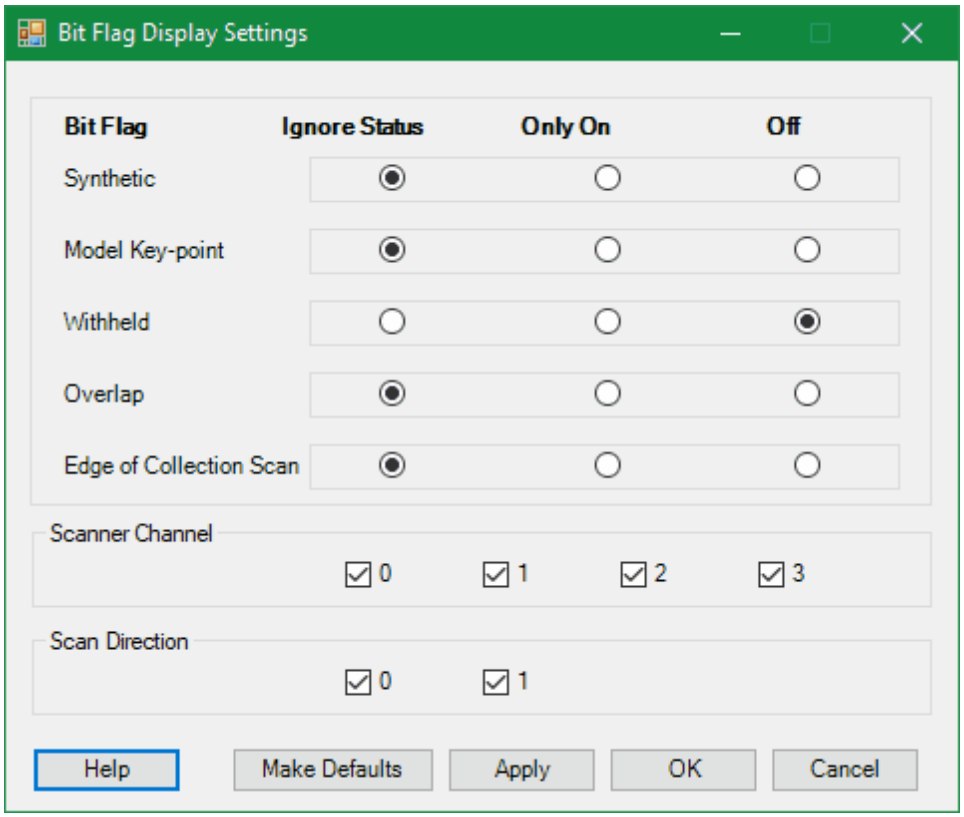
The 'Bit Flag Display Settings' tool 

, found on the View Tab 192, allows for LiDAR point rendering to be controlled by the point-level status of several bit flags: Synthetic, Model Key-point, Withheld, Overlap (also referred to as 'Overage'), Edge of Collection Scan, Scanner Channel, and Scan Direction. By default, points flagged as 'Withheld' are not displayed ('Off'). All other bit flag types are initially set to 'Ignore Status' - meaning that the points will be displayed whether or not the bit flag for

that particular type is set to 'True' - or, in the case of Scanner Channel and Scan Direction, all possible values are checked on. For the upper portion of the interface, if 'Only On' is chosen only the points with that bit flag set to 'True' will be visible. If multiple bit flag types are set to 'Only On', only points with all corresponding bit flags set to 'True' will be displayed. For example, if 'Model Key-point' and 'Overlap' are both set to 'Only On', only those points with both bit flags set to 'True" will be visible. The 'Off' option is used to turn off those points that have the corresponding bit flags set to 'True'. Unlike 'Only On', however, points will be turned off when any one of the bit flags is set to 'True' for types using the 'Off' option. For example, if both 'Synthetic' and 'Overlap' are set to the 'Off' option, any points with either of those bit flags set to 'True' will be turned off. The 'Scanner Channel' and Scan Direction' settings operate independently of the other bit flag settings - they simply toggle certain channels and/or directions on or off regardless of the other bit flag settings.

Only those points that are visible will participate in the 'Rendering Method' (Point or TIN) or the 'Perspective" (2D or 3D) view. These settings can be made independently in both the LAS Map View and Cross-Section/Profile windows, except for the 'Scanner Channel' and 'Scan Direction' settings which are ignored in the Cross-Section/Profile window. To view by the new settings without closing the tool after making changes, click the 'Apply' button. To save a display configuration beyond the current MARS® session, click the 'Make Defaults' button.

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4.7.4 Blend with Intensity

Blend with Intensity

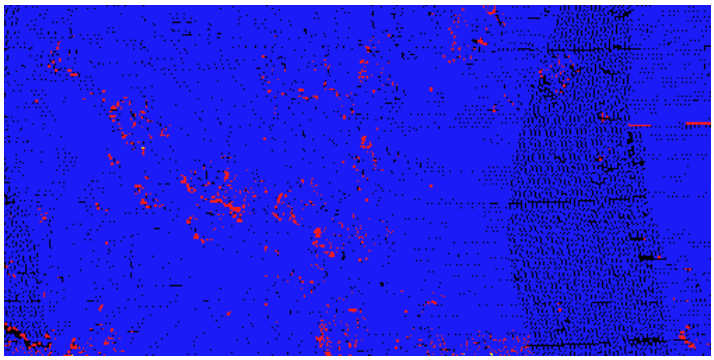
Merrick Advanced Remote Sensing (MARS®) Software

To see data colored by intensity blended with another 'color by' rendering option, click on the **'Blend with Intensity'** button on the View Tab 192.

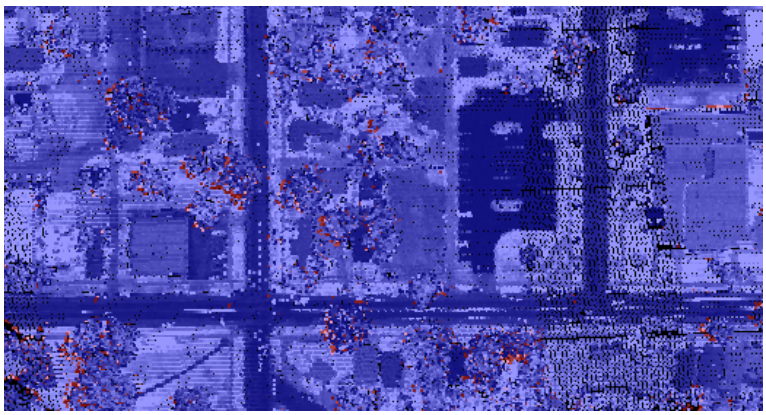
The **'Blend with Intensity'** tool displays LiDAR points by gray-scale intensity and allows the

user to blend this with other 'color by' views. Intensity may be blended with elevation, classification, return, collection scan, ground color, or user data. There is no terrain relief when viewing LiDAR data by intensity alone, but the ability to view intensity along with another rendering option may allow the data to be viewed more efficiently. Please see the examples below for further explanation.

In the example below, the LiDAR data is being viewed by return only. By viewing only the return values, it is impossible to know which characteristics in the terrain the first return (blue) and second return (red) data correspond to.



The example below is of the same area, but the 'Blend with Intensity' tool has been utilized with the return values in the LiDAR data. It is now easy to see that the first return data (blue) corresponds to areas with roads and buildings whereas the second return data (red) corresponds to areas containing trees.



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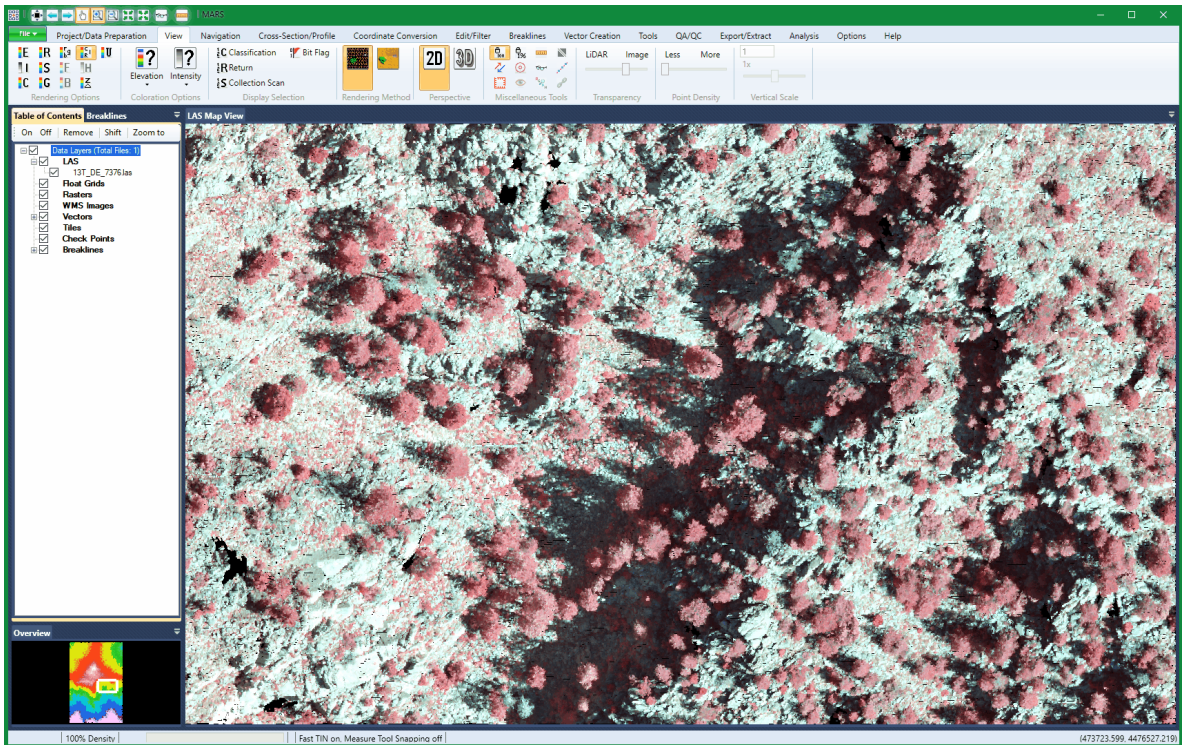
4.7.5 Color by CIR

Color by CIR (Color Infrared)

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Color by CIR: Uses the R(ed), G(reen), B(lue), and N(ear Infrared) values stored for each LiDAR point to render the point cloud or TIN as a 4-band 845 pseudo-image. This option is intended for use with Point Data Record Format (PDRF) 8 point clouds that can store NIR values.

To view the LiDAR points as a pseudo-image, click the **'Color by CIR'** button on the View Tab 192.



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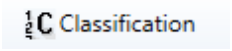
4.7.6 Color by Classification

Color by Classification

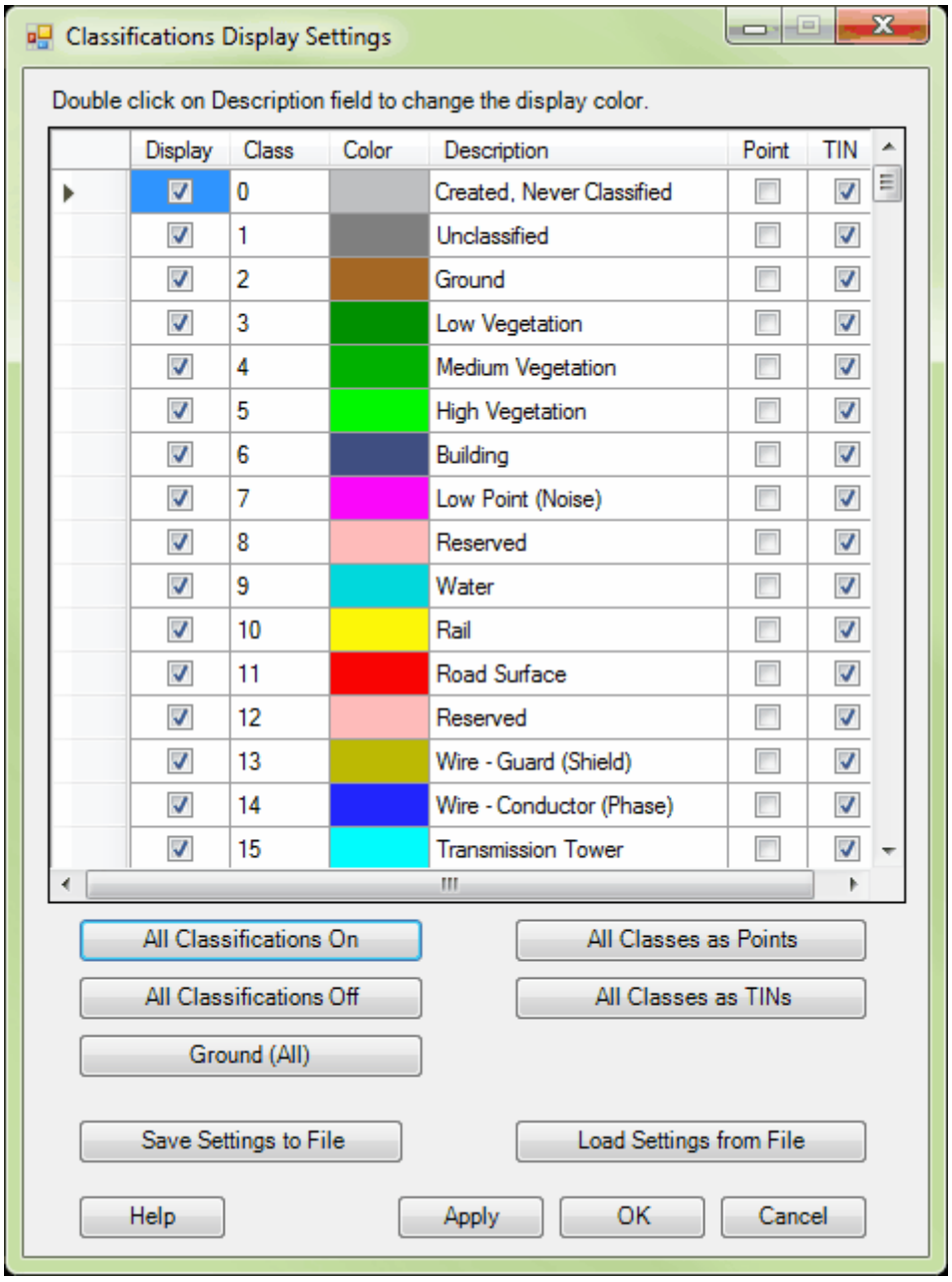
Merrick Advanced Remote Sensing (MARS®) Software

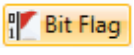
LAS files are *variable length* records that contain up to 256 different data classifications, which can be displayed in any color combination. Raw data is typically unclassified, therefore all points are displayed in a single color. Most completed projects will contain a minimum of two classes; ground (Class 2) and unclassified (Class 1). The point data may be reclassified into any of the available data classifications, which may represent various above-ground features (ex. buildings, vegetation, roads, transmission lines, etc.).

Click the **'Color by Classification'** button  on the View Tab 192 to view the points by classification. Pressing 'Ctrl-C' on the keyboard will also cause the LiDAR data to be colored by classification.

To view the list of data classifications, click the **'View Classification'** button 

on the View Tab 192. The following dialog will appear when the active window is LAS Map View. (A complete description and example of the interface when the Cross-Section/Profile window is active can be found in the **'Display Selection'** section of the View Tab 192 topic.) With this interface, the user can control settings for the display of a particular class, the color representing an individual class, and how that class will be displayed during TIN rendering.

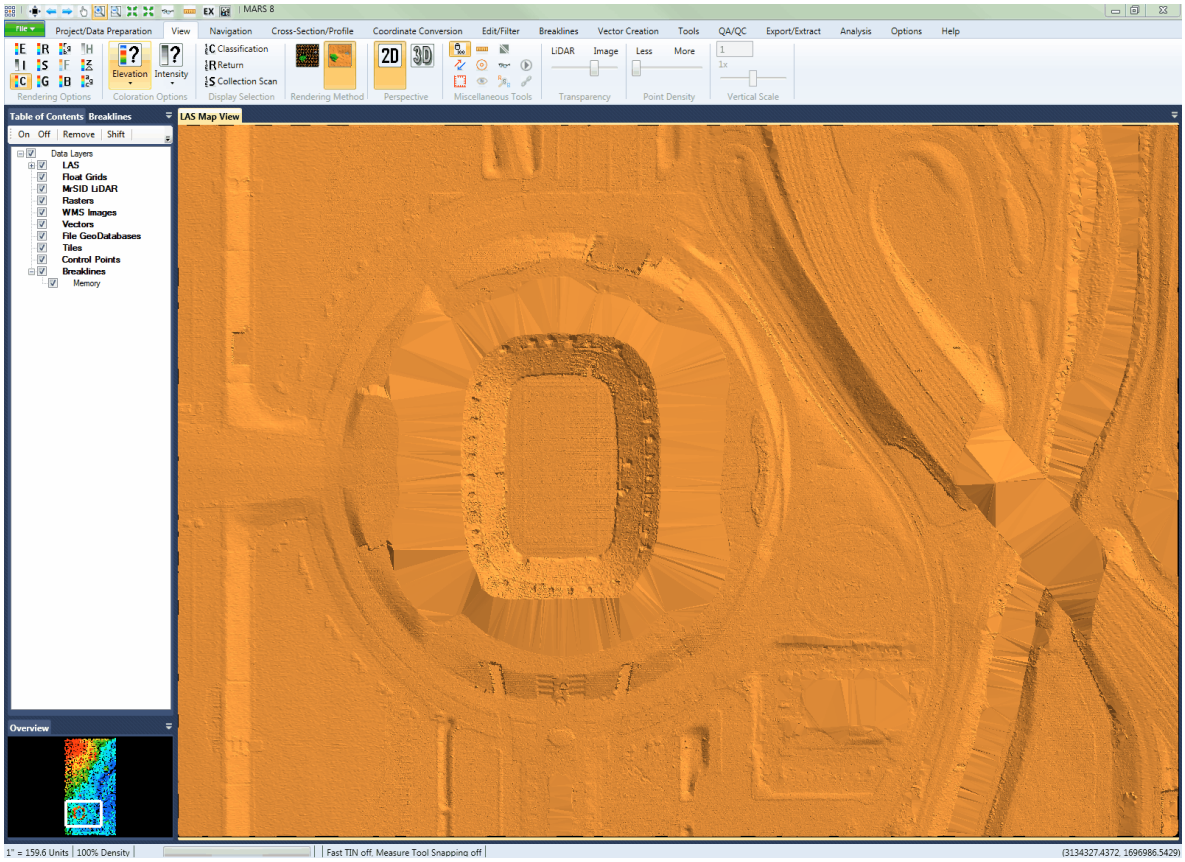


To display all ground including Model Key-points, click the **'Ground (All)'** button followed by the **'OK'** button. Note that all bit-flagged points - including Model Key-points - can be controlled for display by using the 'Bit Flag' display settings tool 

found on the View Tab 192.

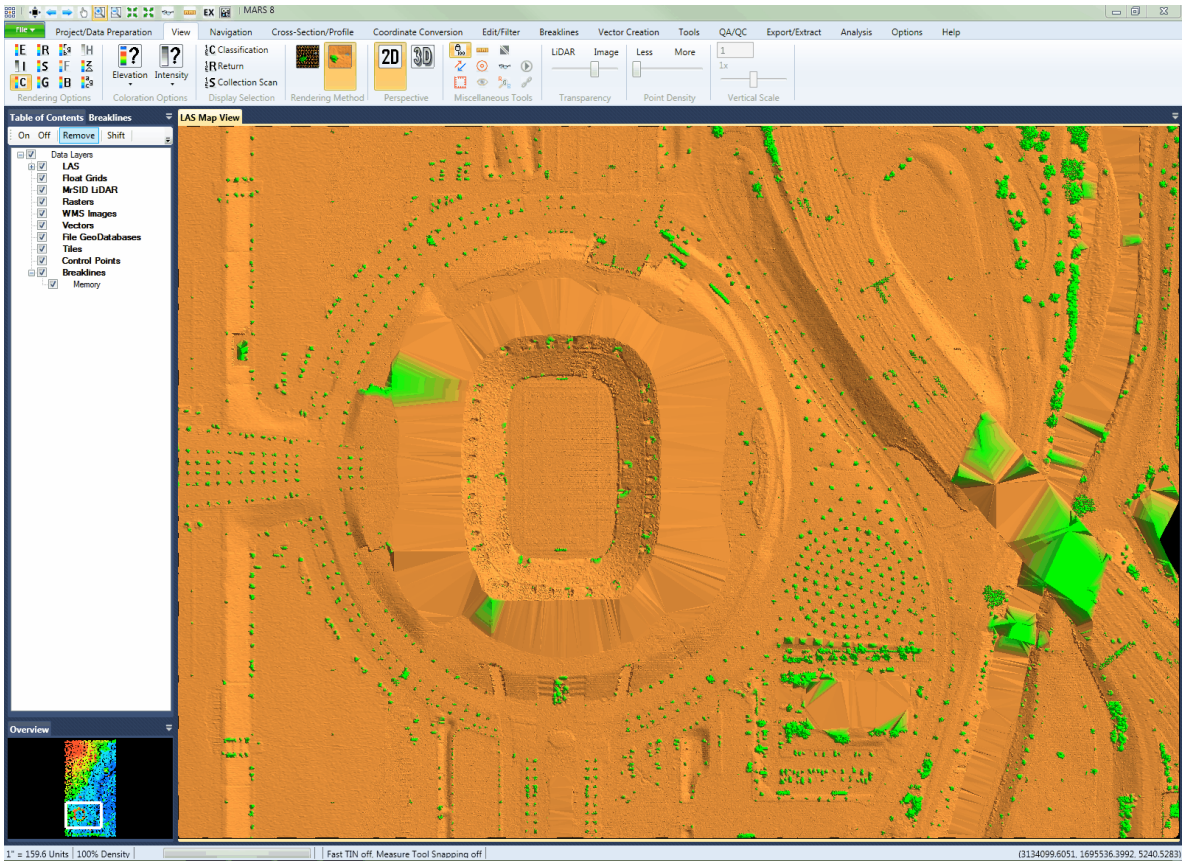
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To view the ground points as a surface model, click on the **'TIN'**  button. The bare-earth surface is displayed as follows:



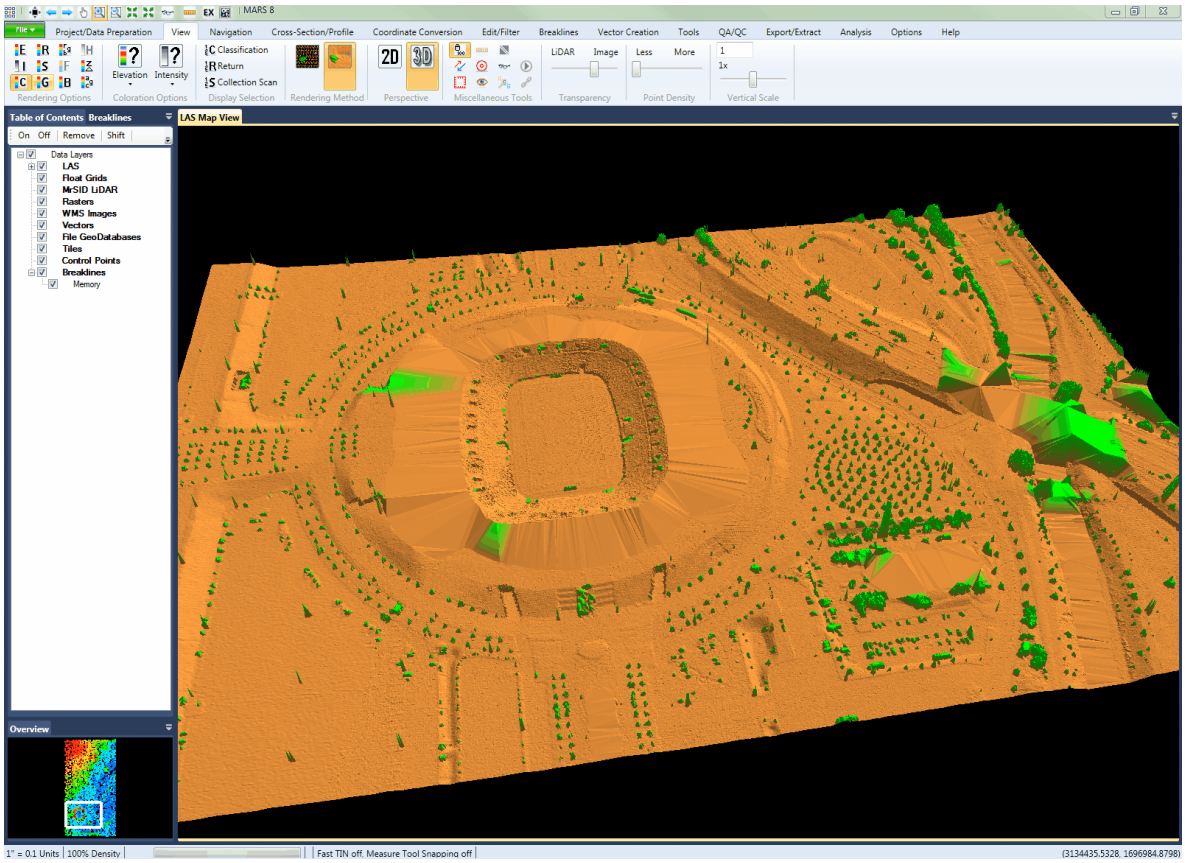
From the **'Classifications Display Settings'** dialog , click **'High Vegetation'** (Class 5) to display the canopy data points. Then click on **'OK'**. The bare-earth and canopy data classes are displayed as follows:

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To view the data in 3D mode, click the **'3D Perspective'**  button on the View Tab 192. Use the **'Pan'**  function on the Navigation Tab 234 or the Quick Access Toolbar 65 to rotate the dataset. *Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.*

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For more details on the **'Classifications Display Settings'** interface, see the **'Display Selection | Classification'** section of the View Tab 192 topic or the Displaying Data 1772 topic.

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4.7.7 Color by Collection Scan

Color by Collection Scan

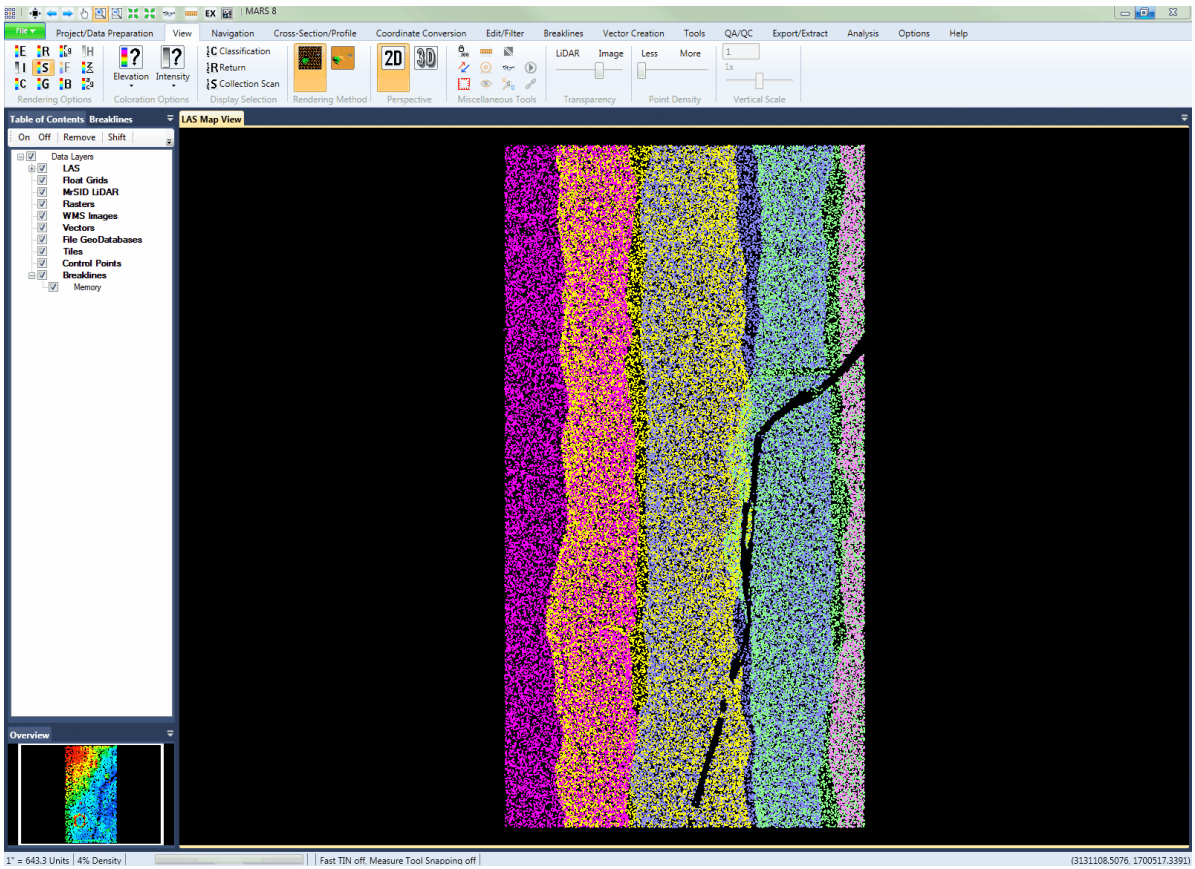
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Airborne LiDAR data is collected by flying straight, parallel lines over the intended project area. Each of these individual lines is called a 'collection scan'. LiDAR data can be viewed in MARS® by collection

scan, each uniquely colored for display purposes. Coloring the LiDAR data by collection scan allows the user to identify gaps in the collected dataset or easily see boresighting corrections that need to be made.

To view the data colored by collection scan, click the **'Color by Collection Scan'** button on the View Tab 192. Hitting Ctrl-L on the keyboard will also cause the LiDAR to be colored by collection scan.

The following image shows the LiDAR point cloud data rendered by collection scan.

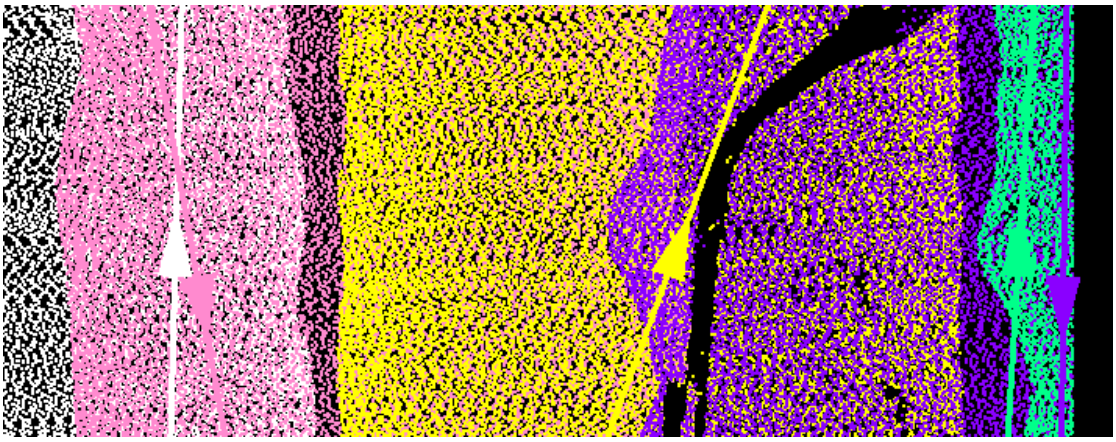


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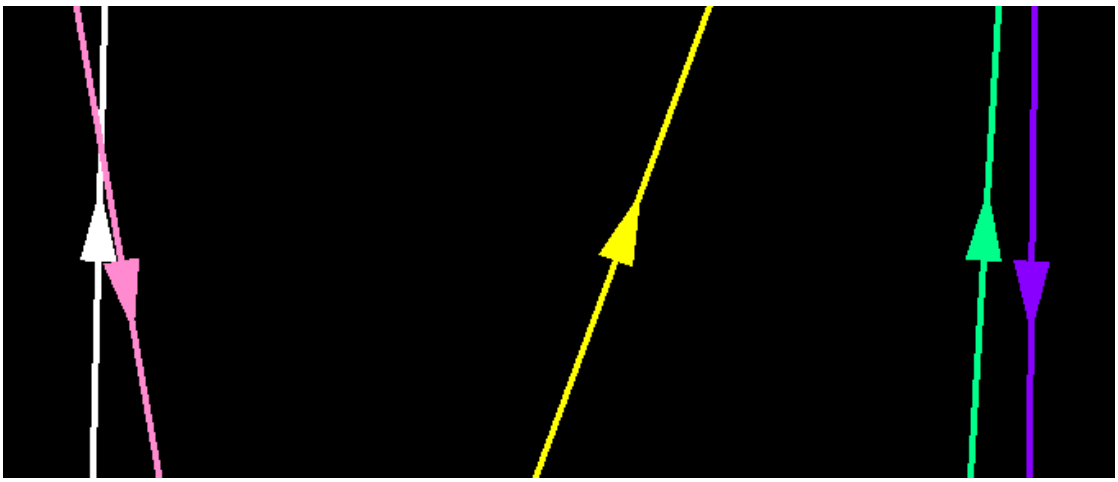


Collection Scan Direction: The Collection Scan Direction tool allows the user to view the direction in which each collection scan was acquired. To use this tool, click on the Collection Scan Direction button. When the tool is turned on, this button is orange in its display. The collection scan direction will be indicated with arrows pointing in the direction of acquisition. Each arrow is also color-coded to match the color of the corresponding collection scan data.

The example below shows five collection scans color-coded in white, pink, yellow, purple, and green.



This example shows the same five color-coded collection scan direction arrows with the LiDAR data turned off.



See Also

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'Edit Collection Scan Display' section of the View Tab[192]

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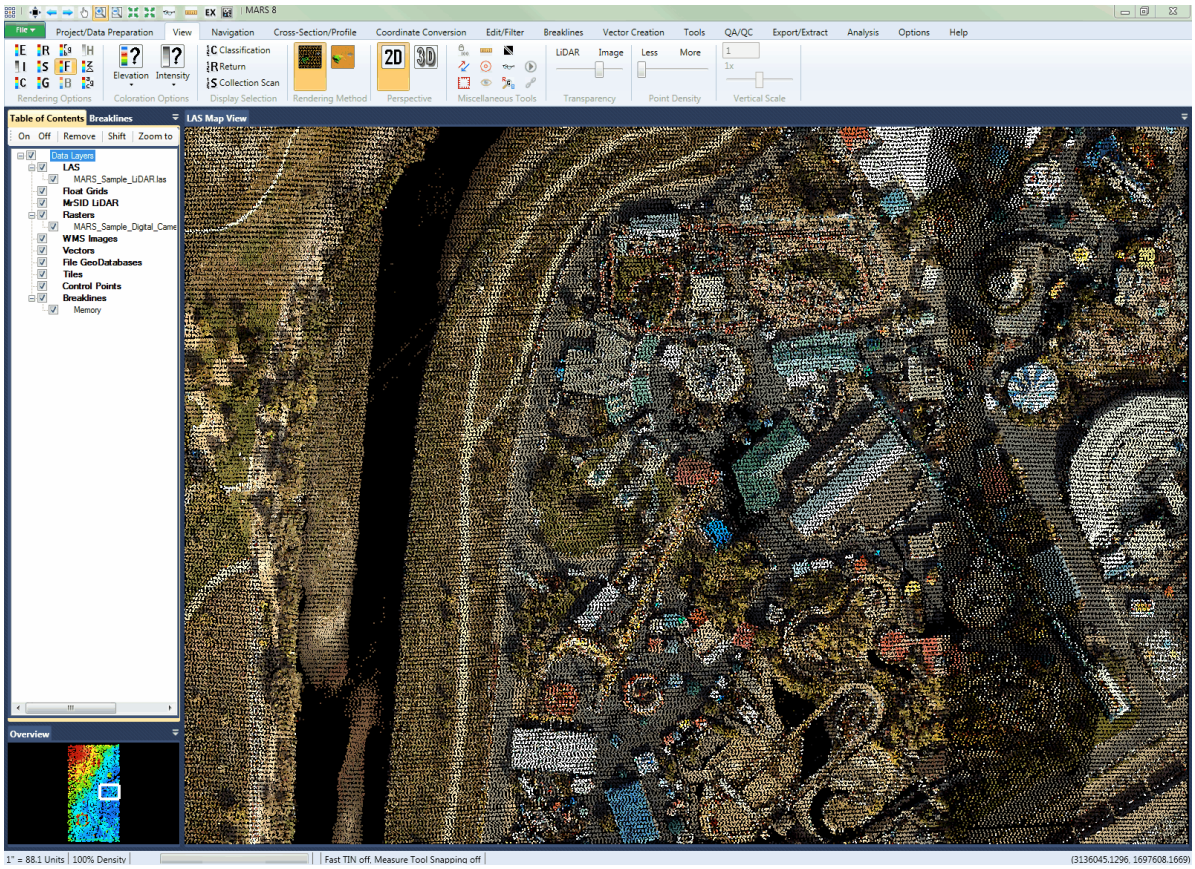
4.7.8 Color by Fusion

Color by Imagery (Fusion)

Merrick Advanced Remote Sensing (MARS®) Software

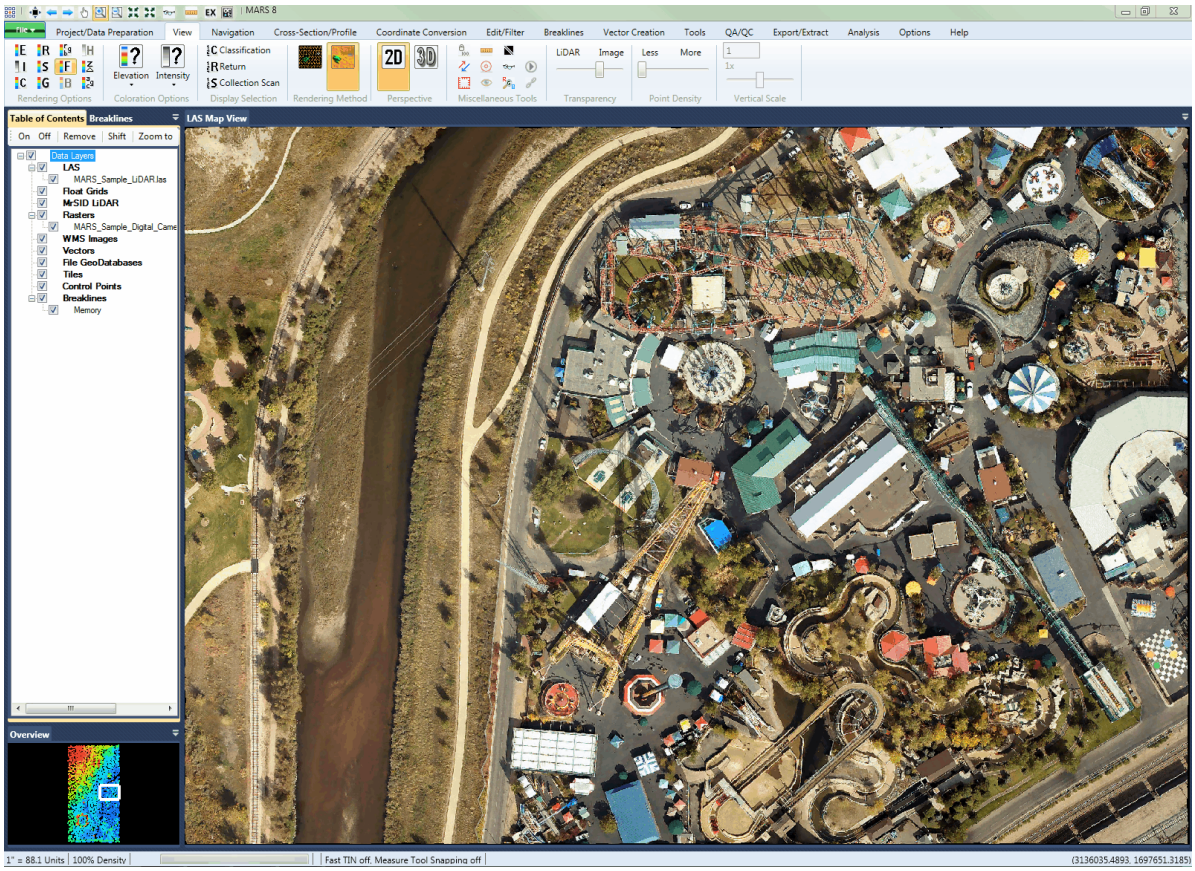
MARS® supports the fusion of LiDAR and imagery for photo-realistic display purposes. For this type of display, the RGB values from the imagery pixels are temporarily applied to the closest LiDAR point for rendering. To utilize this rendering style, click on the **'Color by Imagery (Fusion)'** button on the View Tab[192] with both LiDAR point data and imagery loaded and displayed. The user can also view the data by Fusion by pressing Ctrl-F on the keyboard. Data can only be displayed by Fusion in the LAS Map View window, not in the Cross-Section/Profile window.

The following image displays the LiDAR points fused with color digital imagery in **'Points'** mode. The darker vertical band on the right side is an area of single collection scan coverage.



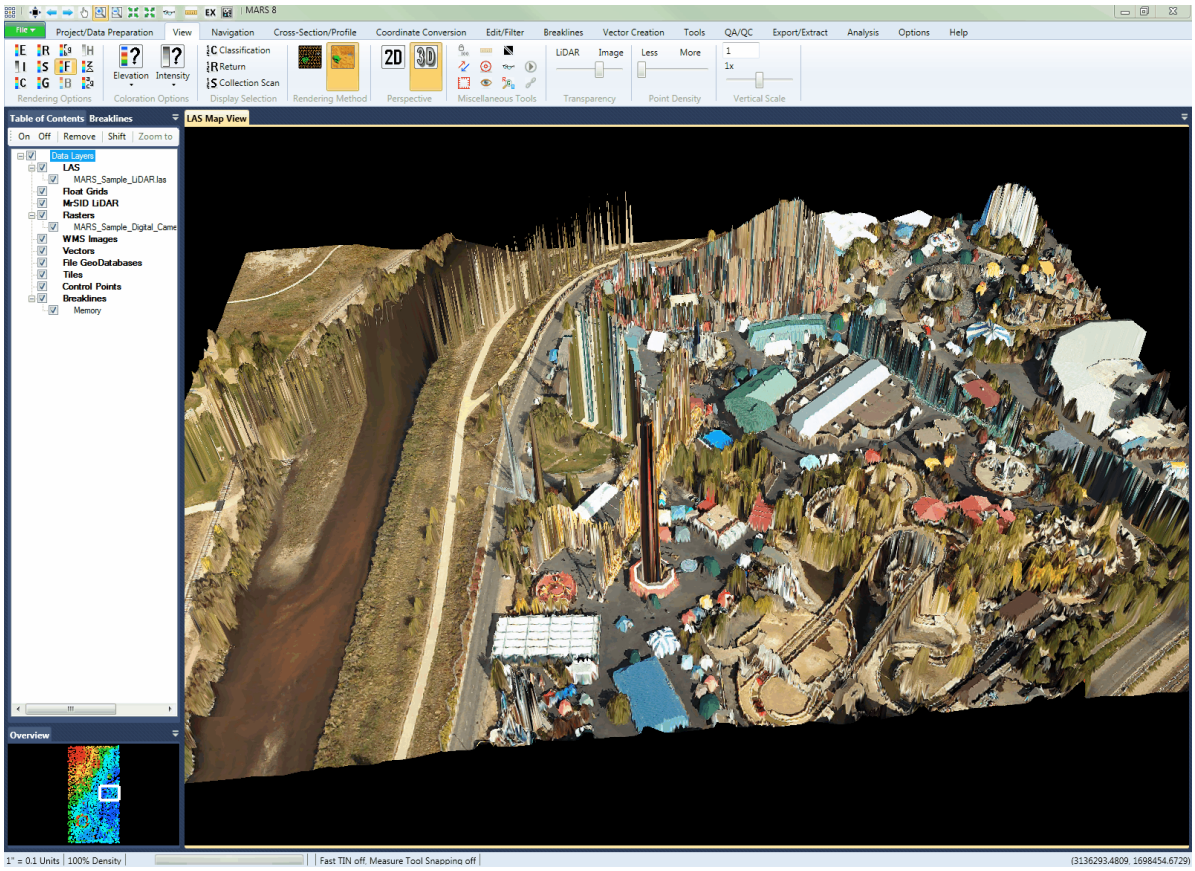
The following image displays the LiDAR points fused with color digital imagery in **'TIN'**  mode.

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The following image depicts a TINned surface rendered by Fusion in 3D (perspective) mode. To view the data in 3D mode, click the **'3D'**  button on the View Tab 192. Use the **'Pan'**  function on the Navigation Tab 234 or the Quick Access Toolbar 65 to rotate the dataset. *Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.*

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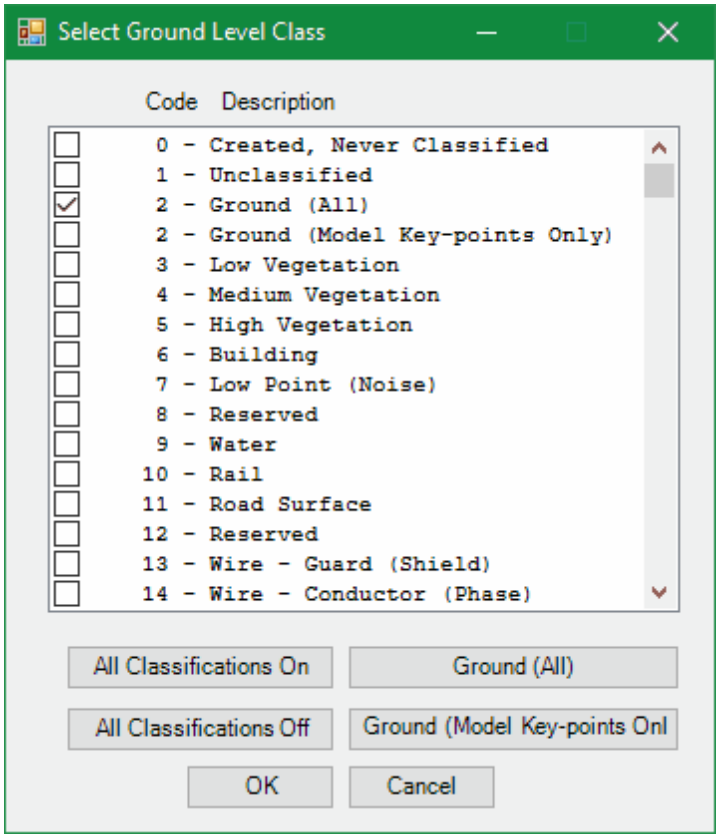
4.7.9 Color by Ground Color

Color by Ground Color

Merrick Advanced Remote Sensing (MARS®) Software

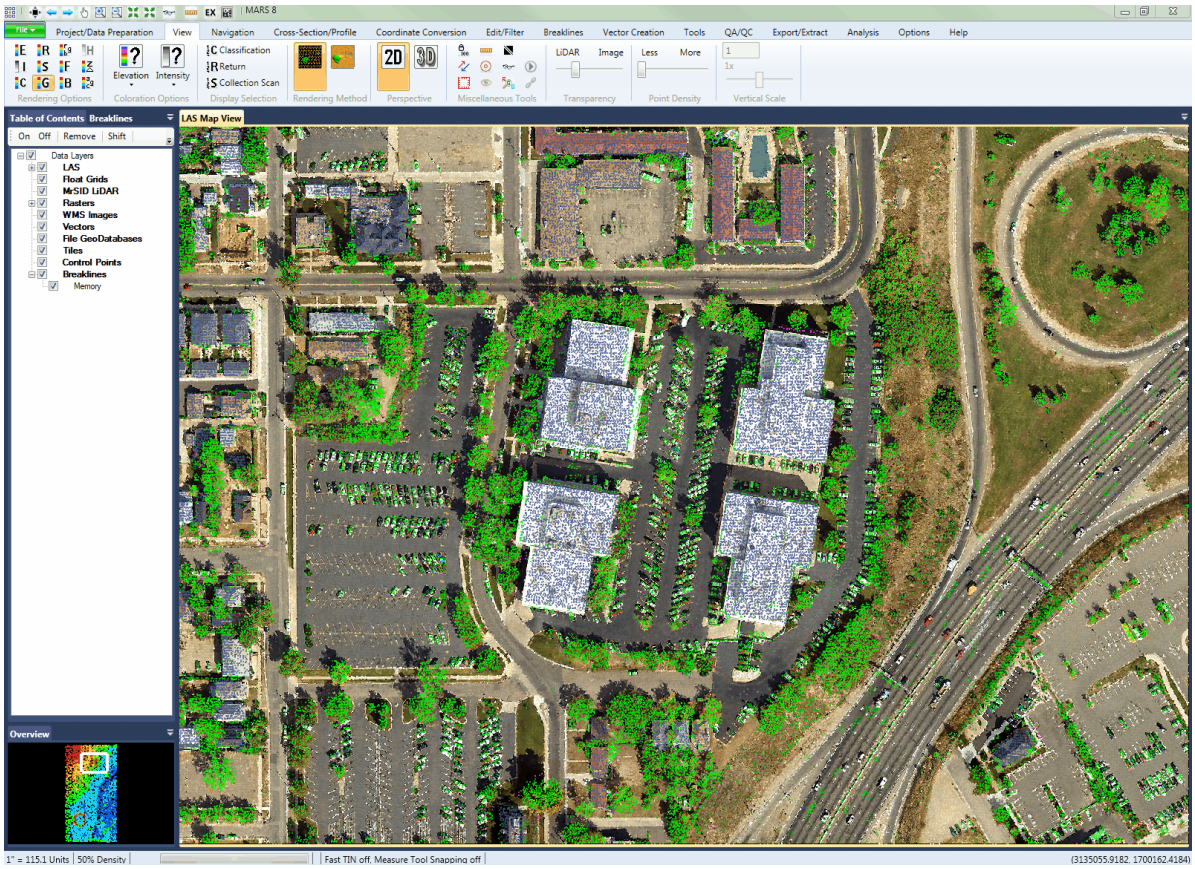
This rendering method is similar to **'Color by Imagery (Fusion)'** except that only the user-specified ground class(es) are fused with the loaded imagery or stored RGB values. For this type of display, the RGB values from the imagery are temporarily applied to the closest ground-classed LiDAR point for

rendering. If no imagery is loaded, RGB values stored with the ground-classed points will be used. To utilize this rendering style, click on the **'Color by Ground Color'**  button on the View Tab[192] with both LiDAR point data and imagery turned on. A selection interface (see below) will appear where those classes that represent ground can be selected. Data can only be displayed by Ground Color in the LAS Map View window, not in the Cross-Section/Profile window.



The following image displays the LiDAR ground-classed points fused with color digital imagery in **'Points'**  mode.

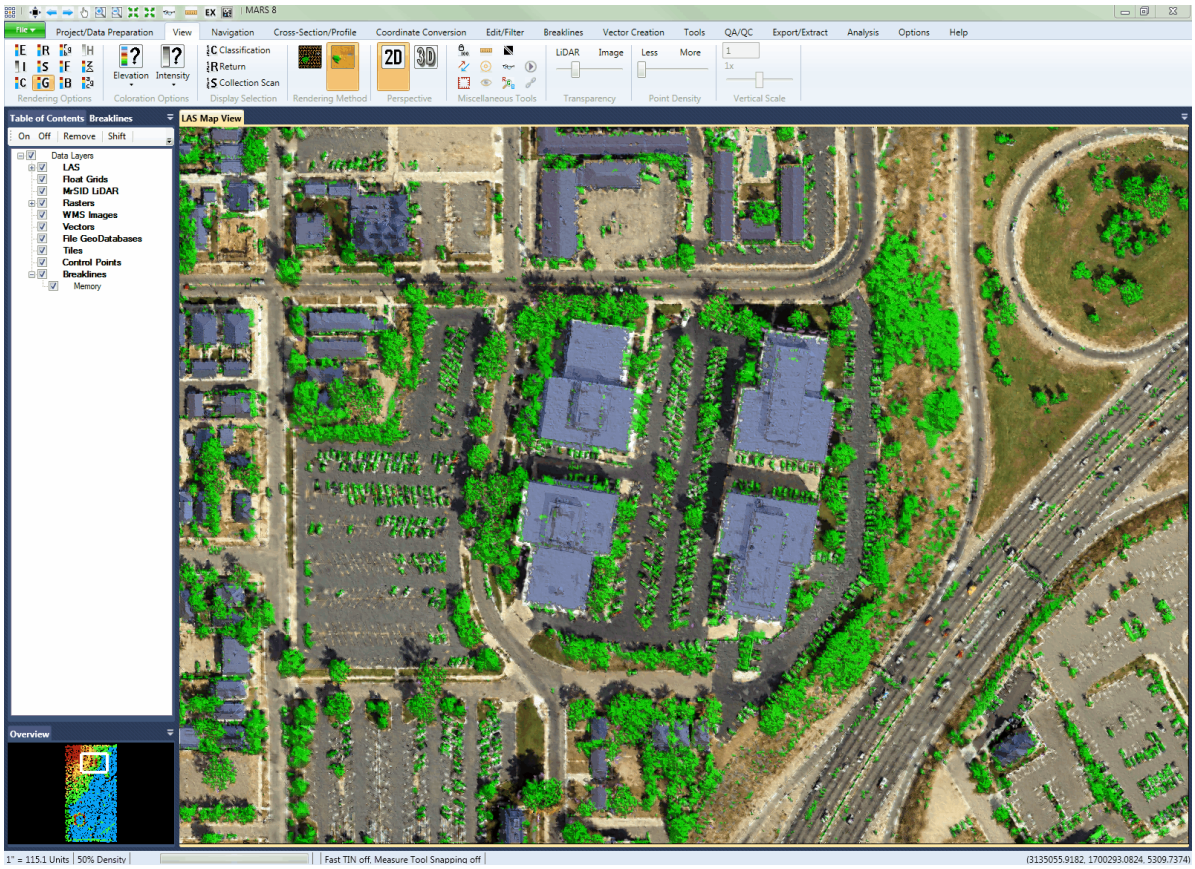
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The following image displays the LiDAR ground-classed points fused with color digital imagery in **'TIN'**

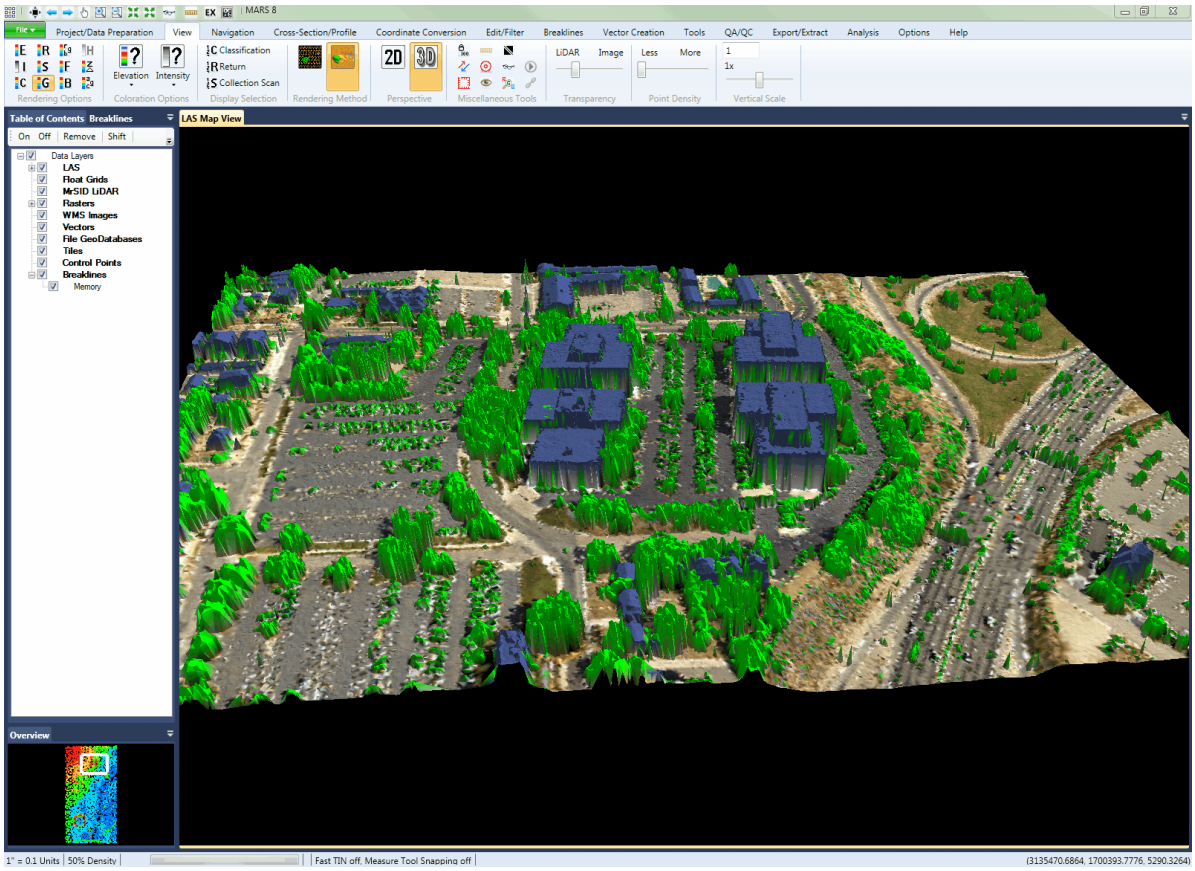
 mode.

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The following image depicts a TINned surface rendered by Ground Color in 3D (perspective) mode. To view the data in 3D mode, click the **'3D'**  button on the View Tab 192. Use the **'Pan'**  function on the Navigation Tab 234 or the Quick Access Toolbar 65 to rotate the dataset. *Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.*

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4.7.10 Color by Hillshade

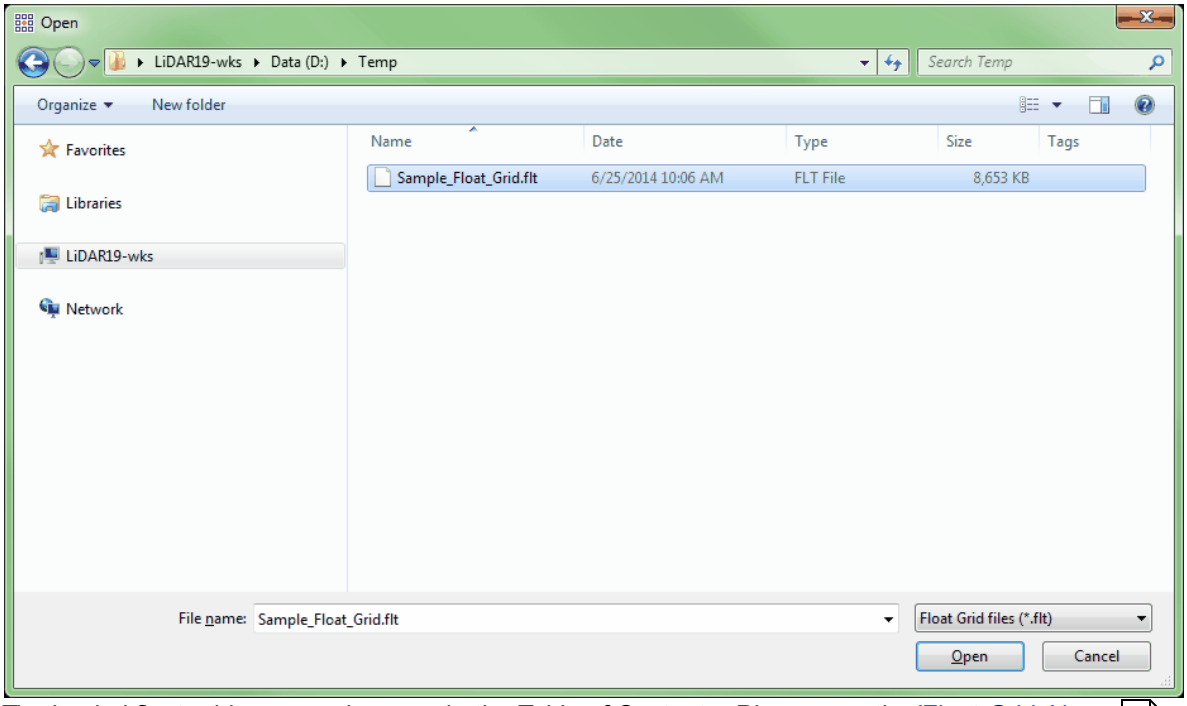
Color by Hillshade

Merrick Advanced Remote Sensing (MARS®) Software

To see data rendered as a hillshade, click on the **'Color by Hillshade'** button on the View Tab 192. This tool is enabled only when a gridded, elevation Float Grid has been loaded into MARS®.

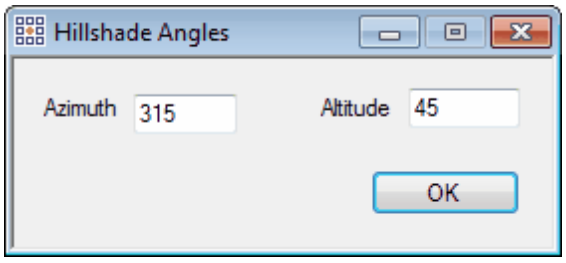
To load a Float Grid into MARS®, first select the **'Add Float Grid'** button on the Project/Data

Preparation Tab 162. Navigate to the float grid (*.flt) to be loaded and select it. Click **'Open'**.



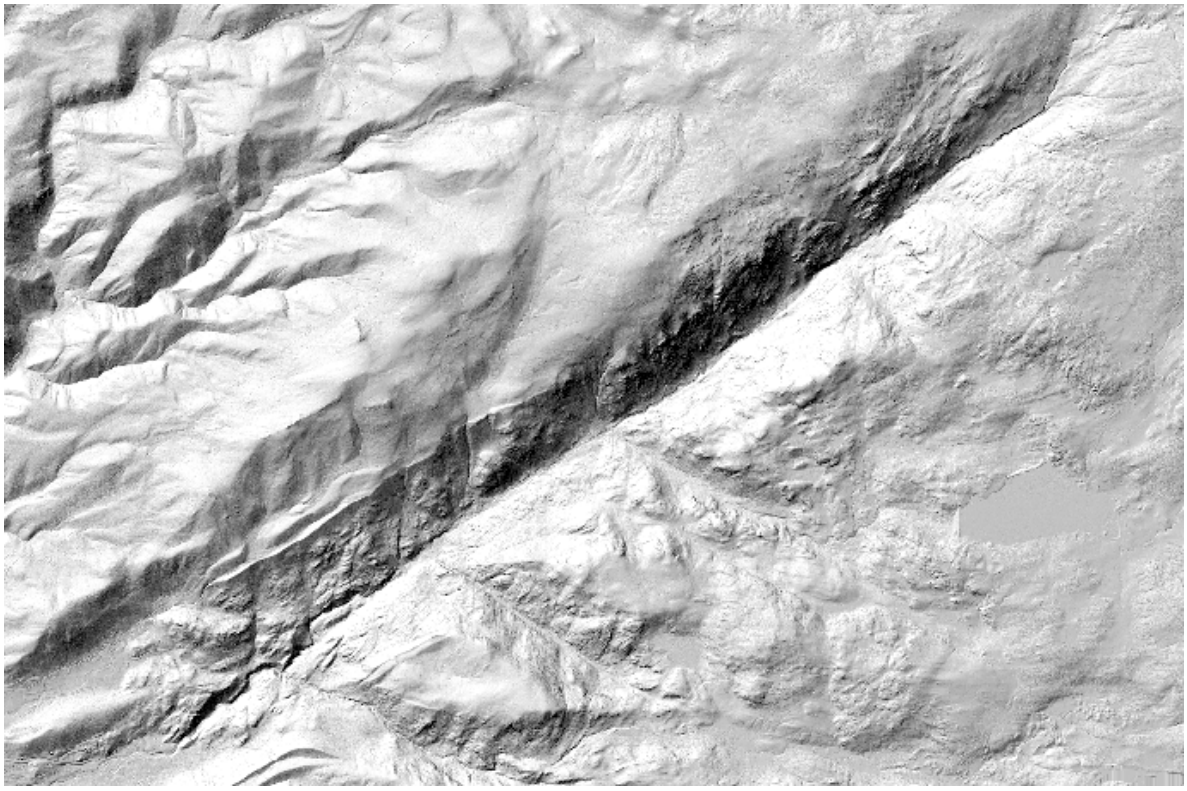
The loaded float grid can now be seen in the Table of Contents. Please see the 'Float Grids' layer 82 section for more information about using float grid files inside the table of contents.

Once a gridded, elevation float grid (*.flt) is loaded into MARS®, the 'Color by Hillshade' tool may be applied to the data. Click on the Color by Hillshade button, choose the desired sun angle settings and a hillshade will be calculated and displayed. Because the hillshade is being calculated and displayed 'on the fly,' display can sometimes be slow. The resulting display can also be viewed in 3D View 837. **Please note that loaded LAS files will not function with the Color by Hillshade tool. Only gridded, elevation float grids (*.flt) will work with this tool.**



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The example below shows a gridded, elevation float grid colored by hillshade.



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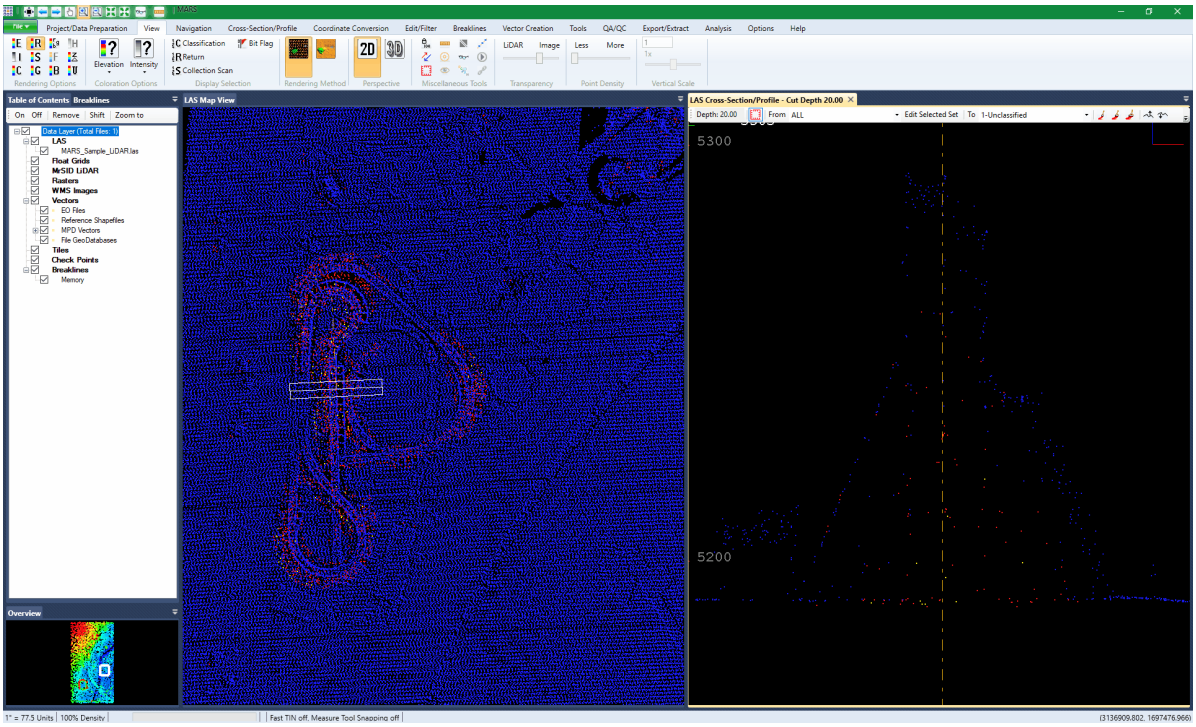
4.7.11 Color by Return

Color by Return

Merrick Advanced Remote Sensing (MARS®) Software

The LiDAR data can be viewed by its return values. The returns are colored dark blue to indicate first returns, red for second returns, yellow for third returns, and so on through all 15 possible returns (depending on the version of LAS data loaded). See the 'Display Selection: Return' section of the View Tab[192] help topic for more info and a legend of all colors used for return value rendering.

To view the LiDAR points by return value, click the **'Color by Return'** button  on the View Tab 192 . Using the 'Ctrl-R' keyboard shortcut will also cause the LiDAR to be colored by return. The following image shows LiDAR points rendered by their return value.



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4.7.12 Color by RGB

Color by RGB

Merrick Advanced Remote Sensing (MARS®) Software



Color by RGB: uses the R(ed), G(reen), B(lue) values stored for each LiDAR point to render the point cloud or TIN as a pseudo-image.

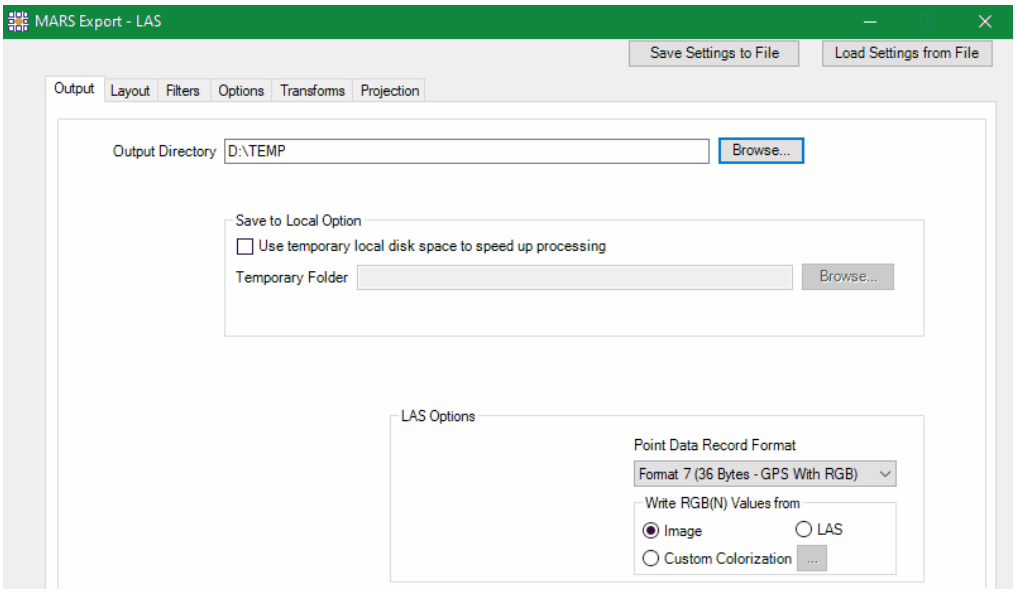
Beginning with LAS spec 1.2, RGB values can be stored in an LAS file on a point-by-point basis. The Near Infrared (NIR) band values can also be stored beginning with LAS v1.4. When the 'Color by RGB' rendering method is used, those *visible* color values are used in the display. The data can then be viewed in 2D, 3D, or cross-section/profile, and in either point cloud or TIN display. If no RGB(N) values exist within the loaded LiDAR data and imagery is available (either traditional rasters or WMS imagery), a new set of LiDAR data can be exported using the RGB (N) values from the imagery as follows:

1.) To be able to use this tool properly, first the user must have ***BOTH*** an image and an LAS file for the same area loaded into MARS®.

2.) Next, the user must export the data. See the screen shot below for the export parameters needed to use the 'Color by RGB' tool.

- ✓ Designate an output directory for the LAS file.
- ✓ Make sure the 'Type' of export is 'LAS'.
- ✓ In the 'LAS Options' section, choose a 'Point Data Record Format' that can store RGB(N) values: either 7 or 8 (if the imagery is 4-band).
- ✓ In the section labeled **'Write RGB(N) values from'** select the **'Image'** radio button for this example. This option will allow the RGB(N) values of the loaded image(s) to be stored with the exported LAS point data. The other two RGB(N) options are explained in the LAS Export 712 topic.
- ✓ Click on the 'Layout' tab and create a name for the exported data in the 'File' text box.
- ✓ Click **'Export'** at the bottom of the interface.

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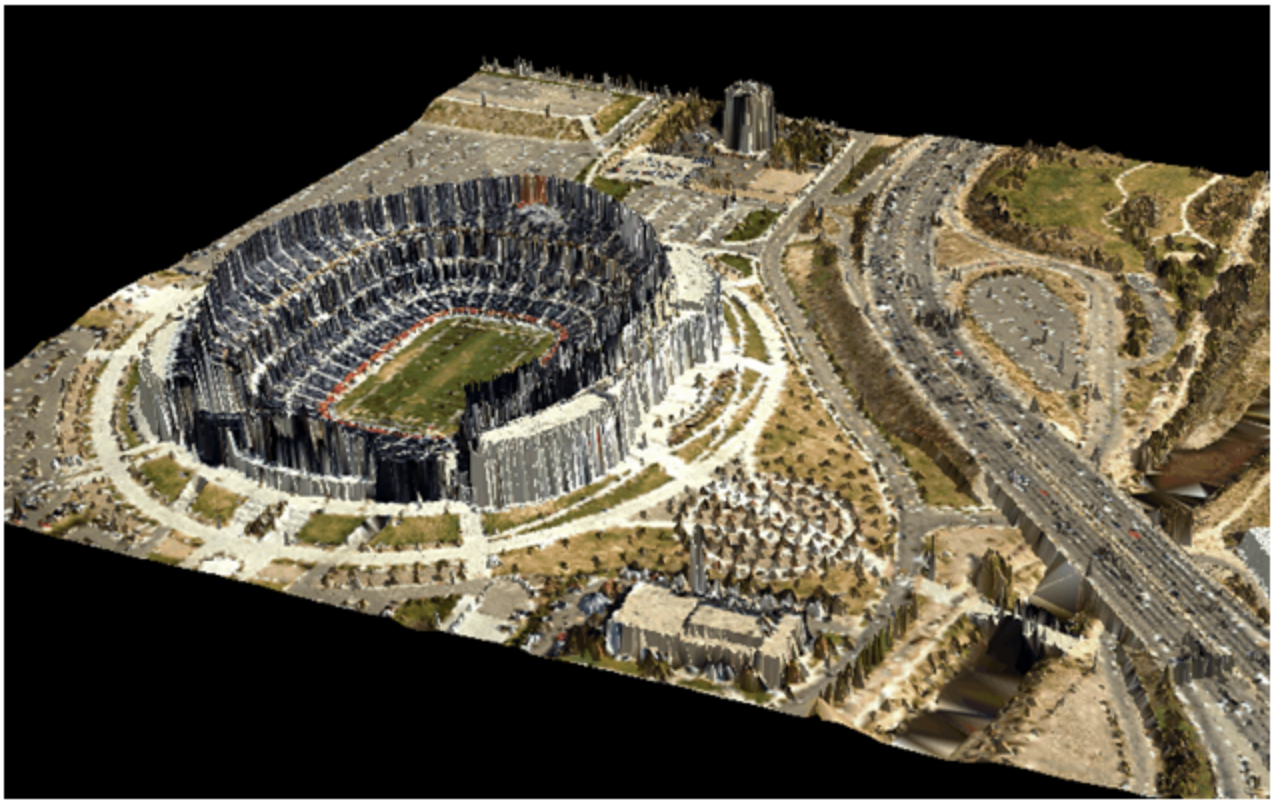


4.) To view the RGB data, close the current project in MARS® and open a new, empty project, or unload the current data.

5.) Open the newly exported file by clicking on the top half of the **'Add LAS Files'** button on the Project/Data Preparation Tab 162, and navigate to the output folder that was chosen for the export. Select the file and click **'Open'**.

6.) Now select the **'Color by RGB'** button  and the LAS file will appear rendered by the RGB values stored with the points. To view the data more easily, click the **'TIN'**  button. This data can also be viewed in 3D as shown below.

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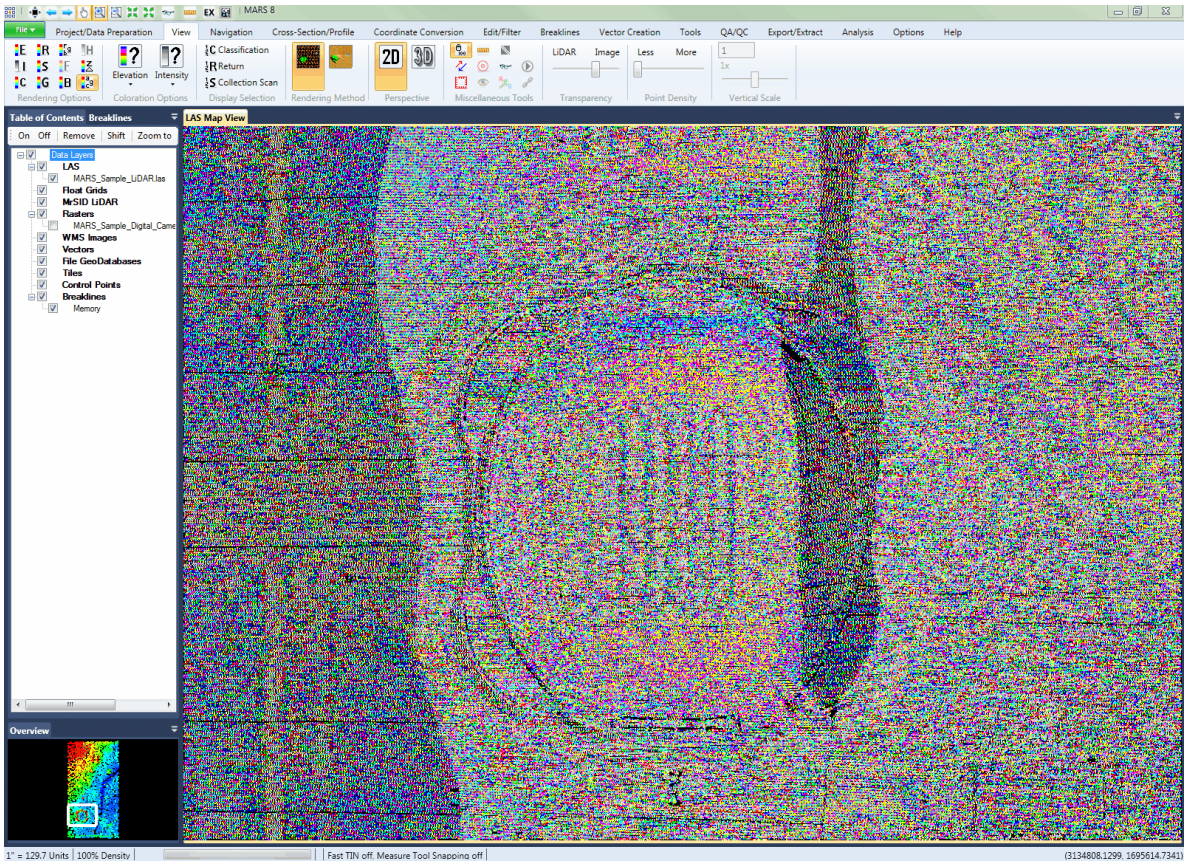
4.7.13 Color by User Data



Color by User Data: Displays LiDAR points rendered by values stored in the 1-byte 'User Data' field which can contain nearly any type of data depending on the settings of the post-processing software that created the LAS file. Among other applications, this field has been used to store Auto-Gain Control values at the time each collected point was recorded by the sensor. These AGC values, specific to Leica sensors, tell the user how the system was attempting to center the intensity

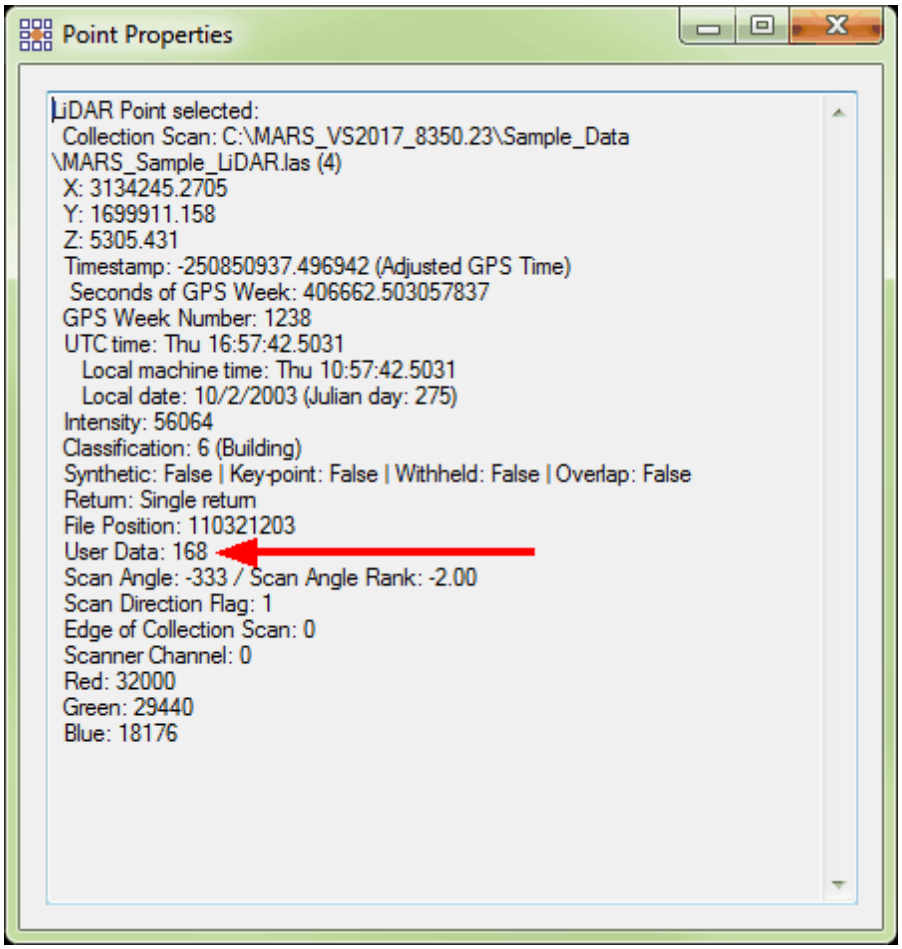
histogram at the time of collection. Another possible use is the storage of a value denoting the confidence that the post-processing software has in classifying points as noise.

Below is an example of LAS data colored by User Data when AGC values are stored.



The **Inspect** button  can show the User Data value of a particular point. Click on the Inspect button and click on the point for which information is needed. The chosen point will flash twice and then remain highlighted in white at a larger symbol size to identify itself.

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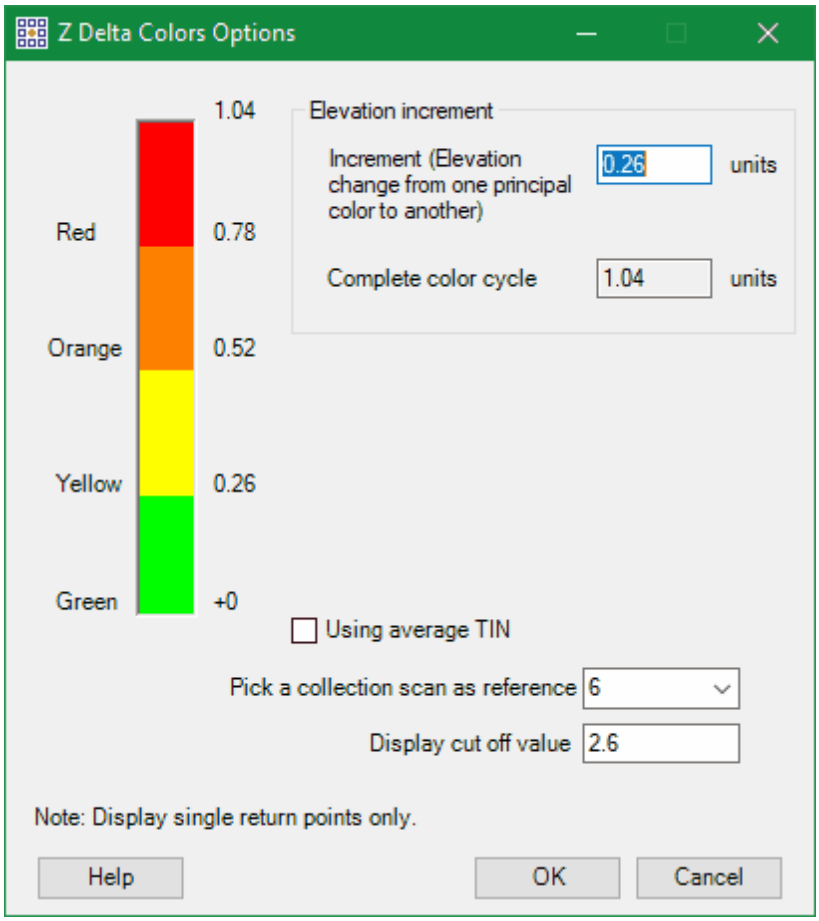
4.7.14 Color by Z Delta

Color by Z Delta

Merrick Advanced Remote Sensing (MARS®) Software

Color by Z Delta *(not available with Evaluation license)*: This tool will color the points in the LiDAR data by the vertical difference between adjacent collection scans. To see how this tool is used for QA/QC procedures, please see the Color By Z Delta Analysis 1731 section.

Clicking the **'Color by Z Delta'** button will bring up the **'Z Delta Colors Options'** window.



✓ **Increment:** Specify here how many elevation units should be between each of the four principal colors.

✓ **Complete color cycle:** This text box will automatically update to tell the user how many total vertical units will be included in the complete color cycle (four colors).

✓ **Using average TIN:** If this check box is used, the Z-Delta will be determined using the average TIN value of all collection scans.

✓ **Pick a collection scan as reference:** This drop-down box is automatically populated with the collection scan numbers of the collection scans shown in the LAS Map View at the time the 'Color by Z Delta' button was clicked. If the user would like to have the Z-Delta be determined for the overlap areas of collection scans adjacent to one particular collection scan,

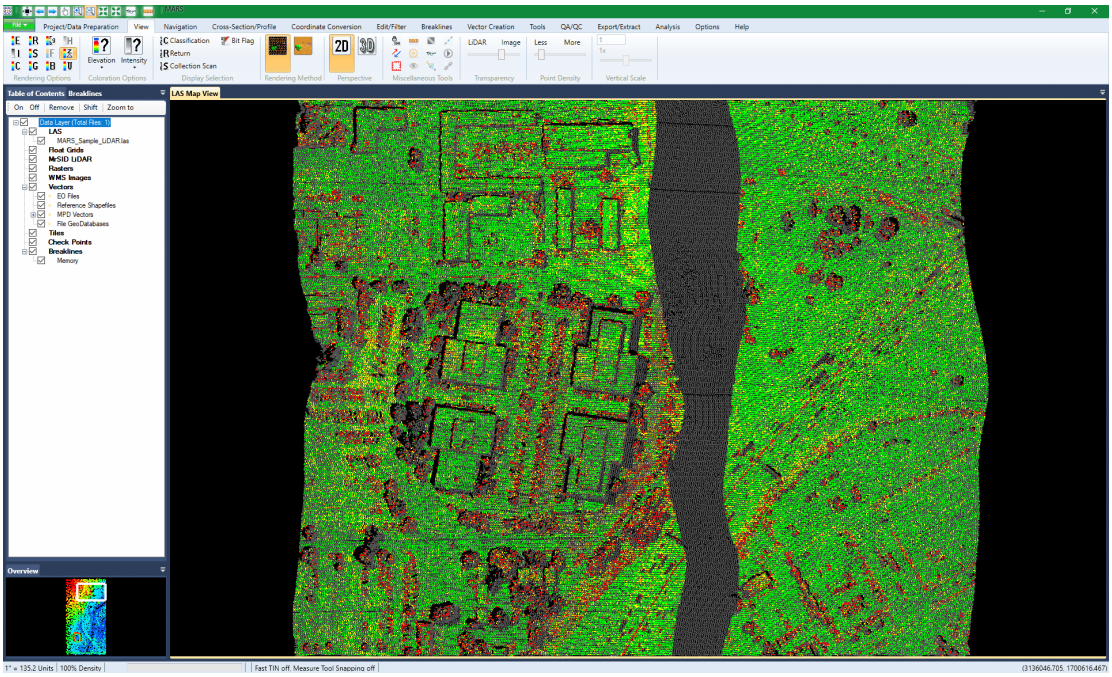
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then this option should be used. Make sure the 'Using average TIN' check box is unchecked if using this option.

- ✓ **Display cut off value:** The user has the option of entering a Z-Delta value in this text box which would be considered out of the realm of possibility. For example, in one collection scan a car may have been parked beside the road when the LiDAR points were collected, causing some of the returns to be from the top of the car. In the next (adjacent) collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Color by Z Delta' tool will bring this discrepancy to the user's attention. An entry in the 'Display cut off value' text box tells the process to ignore data areas with a greater Z-Delta. Entering a value of '4' for example, the Z-Delta between a car on the side of the road vs. no car on the side of the road will be ignored and no data coloration will be applied in this area.

Example: The data in the screen shot below has been properly boresighted. The user has chosen a collection scan as a reference compared to any overlapping collection scans, and an increment of 0.15 units. The results show that most of the ground points are green - this means that the Z-Delta in these overlap areas is less than or equal to 0.15 units. The areas of yellow show a Z-Delta between 0.15 and 0.30 units, the areas of orange show a Z-Delta between 0.30 and 0.45 units, and the red areas show a Z-Delta between 0.45 and 0.60 units. These areas of yellow, orange, and red should be QC'ed carefully to make sure that the larger Z differences are explainable.

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4.7.15 Displaying Contours

Displaying Contours

Merrick Advanced Remote Sensing (MARS®) Software

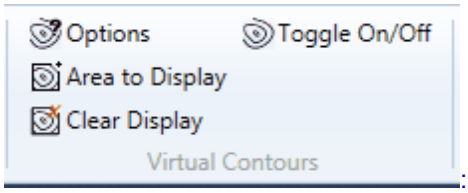
Contours can be generated for any selected viewing area that is zoomed in on the data at 100% point density. To see the density percentage, check the left side of the Status Bar 158. Contours will update dynamically with editing point classifications and will recalculate when panning or zooming in the LAS Map View window. To learn how to use this tool, see the Contouring Tutorial 1806.

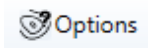
Note: This tool is only for displaying contours 'virtually'. By having the ability to contour on-the-fly this tool is useful for determining how the contours will look when they are exported. It is also used in the boresighting of LiDAR data, because the user can contour by collection scan and thus see the

misalignment between collection scans. Use this tool to visually determine the appropriate settings.

MARS® can easily export contours as shapefiles; however, contours CANNOT BE EXPORTED USING THIS TOOL. To export contours go to the Data Export 658 topic or to the Contouring Tutorial 1806 and enter the settings into the dialog to export contours. To view more about the contour options settings, please see the 'Virtual Contours Options' topic in the Analysis Tab 489 section.

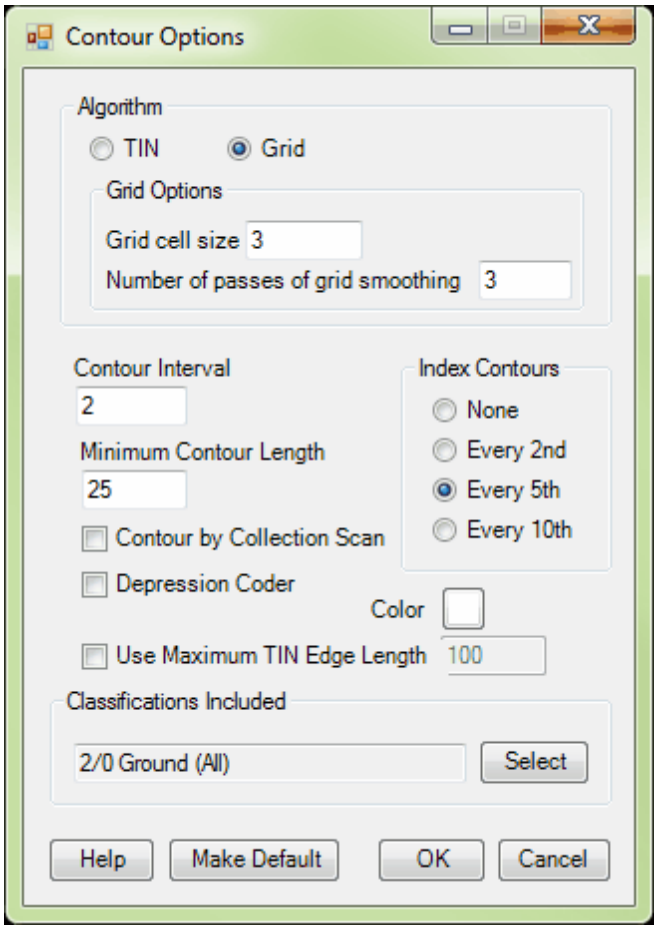
The virtual contouring tools can be found on the Analysis Tab 489





'Options': This interface is used to set the contouring options such as the contour interval, minimum contour length, index contours, and which classifications will be included in the contouring.

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To learn more about the options in this interface, please visit the 'Virtual Contours Options' topic in the Analysis Tab[489] section.

Area to Display **'Area to Display':** Allows the user to draw a box to define the area to be contoured, and is enabled only if the point density is 100%.

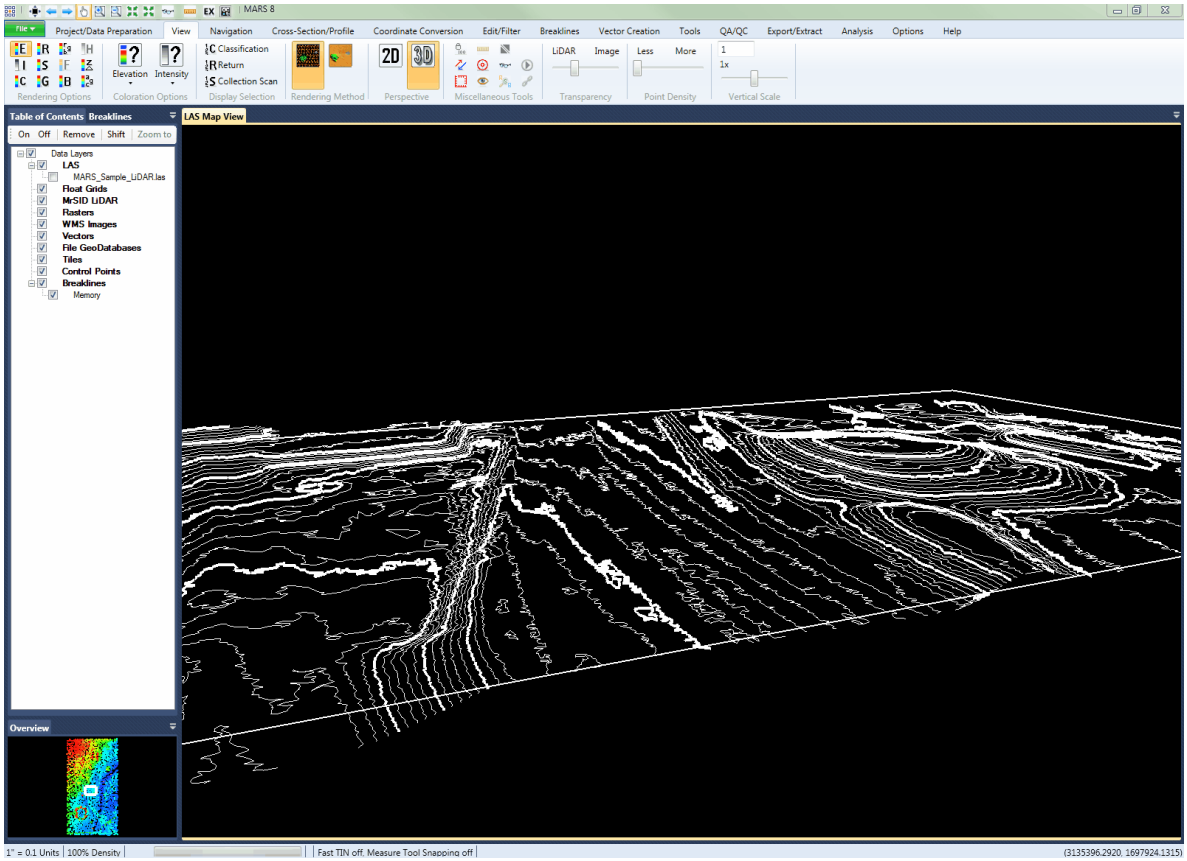
Clear Display **'Clear Display':** Click to remove contour lines from the LAS Map View display. Another way to toggle contours on/off within the visible extent is to press 'C' on the keyboard.

Toggle On/Off **'Toggle On/Off':** This button toggles the contour lines on and off. Another way to toggle contours on/off within the visible extent is to press 'C' on the keyboard. Contours can only be viewed when the area for contour generation has been zoomed into at 100% density, or by using the 'Lock to view 100%' tool on the View Tab[192]. To see the density percentage, check

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the left side of the Status Bar 158.

To view the data in 3D mode, click the **'3D Perspective'**  button on the View Tab 192. Use the **'Pan'**  function on the Navigation Tab 234 or the Quick Access Toolbar 65 to rotate the dataset. *Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.*



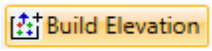
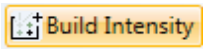
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4.7.16 Displaying Grids

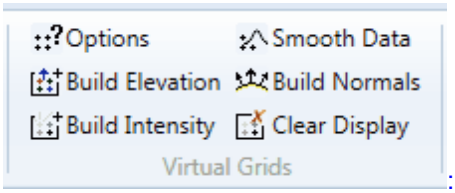
Displaying Grids

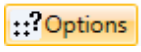
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A grid defines geographic space as an array of equally sized square cells arranged in rows and columns. The **'Build Elevation'**  tool and the **'Build Intensity'**  tool are used to 'virtually' simulate the effects of the gridding tools on elevation data in MARS®. This will not affect the loaded data or any other grids that are exported. These tools create virtual grids, so no files are being generated upon gridding an area. The purpose of these tools is for display only. The tools are used to visually derive the settings that will be applied when exporting LAS data to the various grid types. This simulation tool allows the user to define grid cell size, grid generation method, and the grid display type.

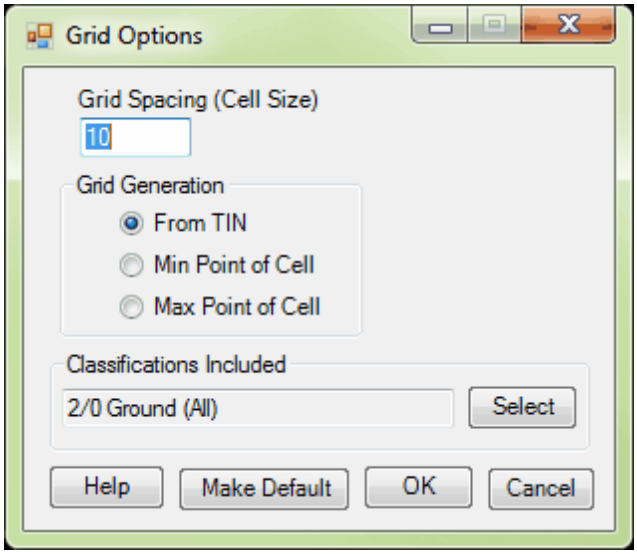
MARS® can export the following grid formats, Float Grids (FLT) 692, ASCII Grids 689, ENVI Elevation Grids 682, ENVI Elevation and Class Grids 685, and TIFF Grids 704. For more information about how to export data, please see the Data Export 658 topic.

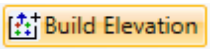
The virtual gridding tools can be found on the Analysis Tab 489:

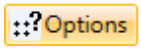


 **Options:** Allows the user to choose the size of the cells in the grid, how the grid is

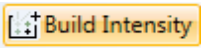
displayed, and which classifications are used to generate the grid.

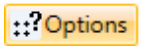




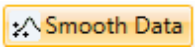
Build Elevation: Allows the user to create an elevation grid by dragging a box around the area to be gridded. This tool is meant to be used only after setting the virtual grid options with the **'Options'** 

button.

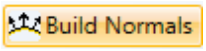


Build Intensity: Allows the user to create an intensity grid by dragging a box around the area to be gridded. This tool is meant to be used only after setting the virtual grid options with the **'Options'** 

button.

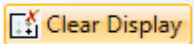


Smooth Data: Applies a smoothing algorithm to the gridded surface.



Build Normals: Generates normal vectors for each cell. Also known as a surface normal, a normal vector is a three-dimensional vector which is perpendicular to the surface.

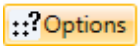
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Clear Display: Allows the user to clear any grid.

How to Display A Grid:

1.) Zoom to the area to be gridded.

2.) Click on the **'Options'** button 

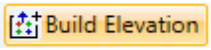
. Set the parameters of the interface for use.

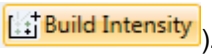
Grid Spacing: This will be the cell size for each cell in the gridded area.

Grid Generation: The user can specify here whether the grid should be built from a virtual TIN, from the min Z point of the cell, or from the max Z point of the cell.

Classifications Included: Click the 'Select' button to choose which classifications will be included in the grid generation. Typically, only ground classes are used.

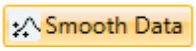
3.) Click **'OK'** to set the parameters of the grid.

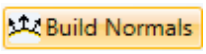
4.) Choose to build either an Elevation Grid or an Intensity Grid by setting the appropriate rendering option on the View Tab 192 ( or ), then clicking on the appropriate button on the **'Analysis'** tab (

or 

).

5.) Left-click the mouse and drag the cursor starting in the upper-left corner of the area to be gridded. Drag a box to the lower-right corner of the area and release the mouse button. The grid will be automatically generated at this time. The LiDAR data can now be turned off to see the grid better.

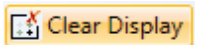
6.) If need be, use the **'Smooth Data'** 

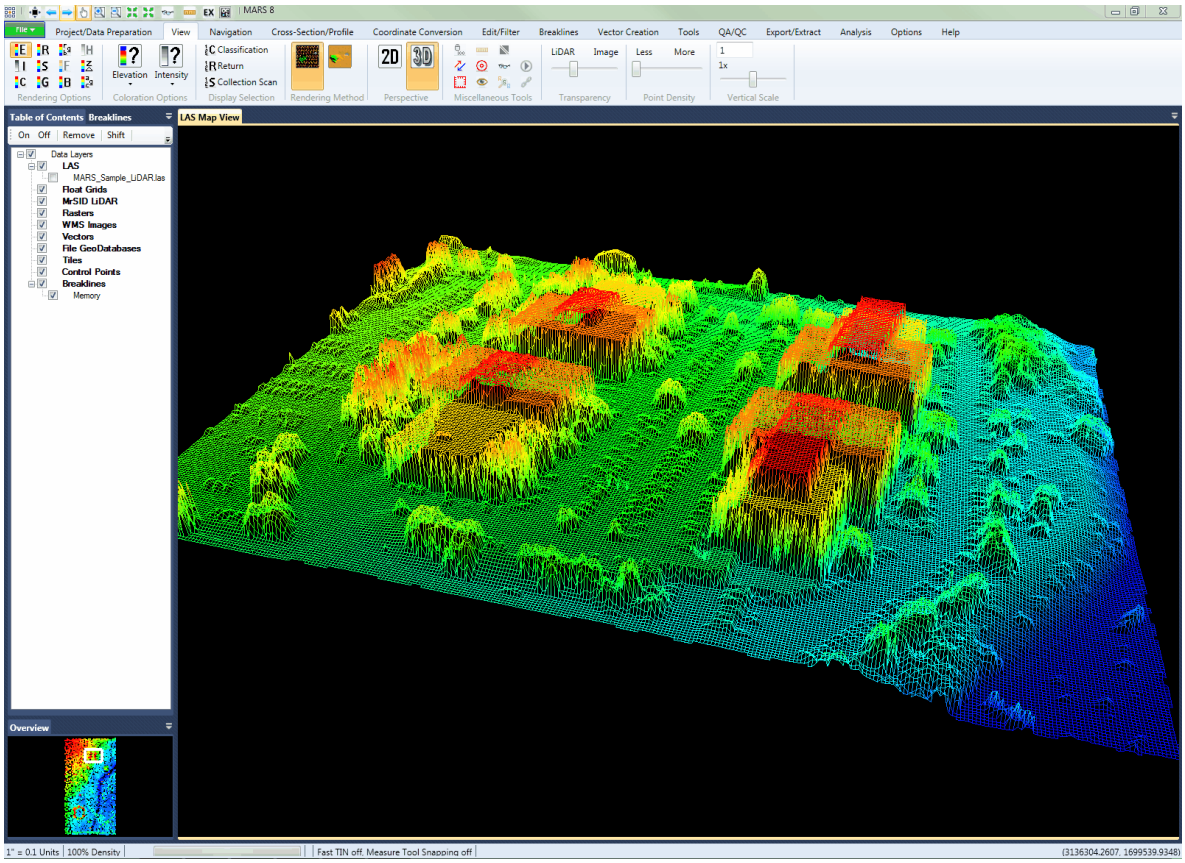
button to smooth over the gridded data, and/ or use the **'Build Normals'** 

button to generate normal vectors for each cell.

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7.) Use the **'3D'** button  to view the grid in perspective view.

8.) To remove the grid, click on the **'Clear Display'** button. 



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4.7.17 Elevation

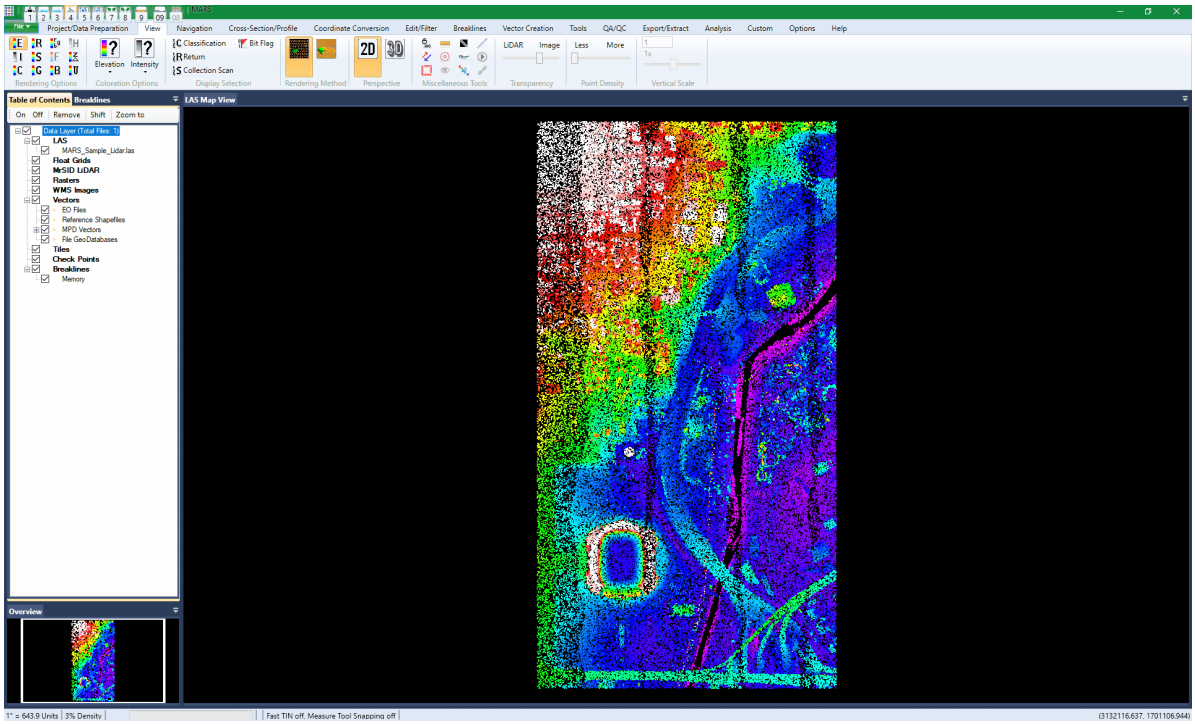
Color by Elevation

Merrick Advanced Remote Sensing (MARS®) Software

To see data colored by relative elevation, click on the **'Color by Elevation'** button on the View Tab[192], or press Ctrl-E on the keyboard.

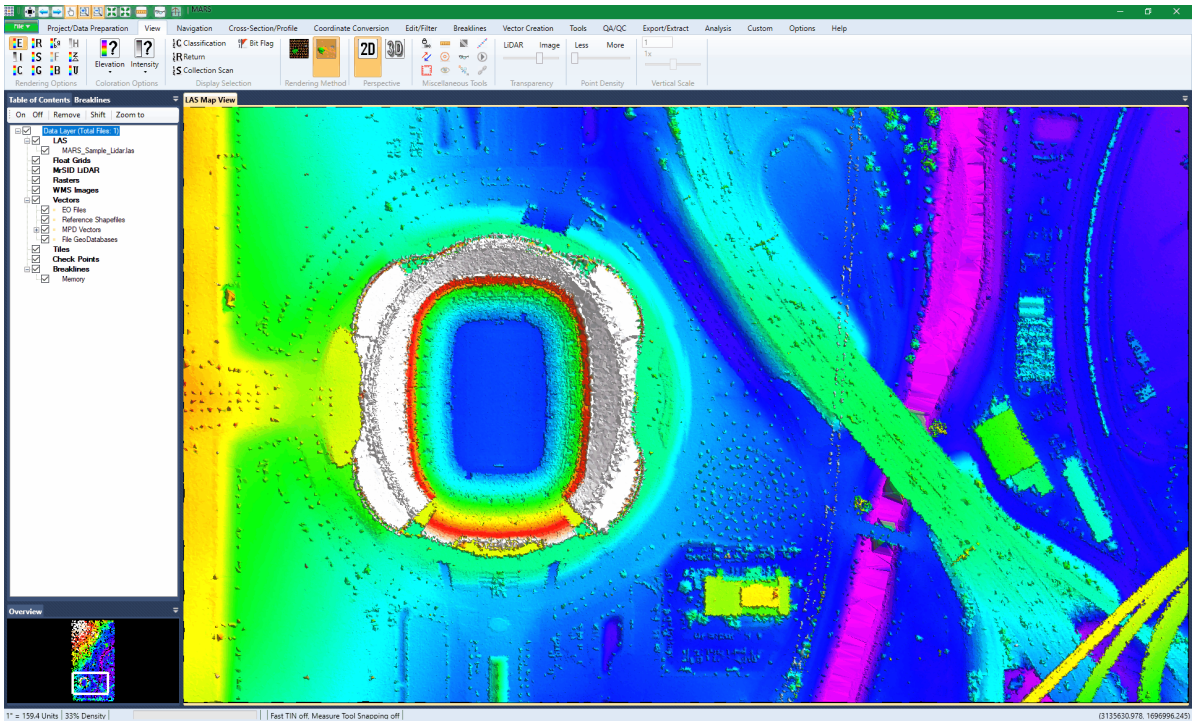
By default, MARS® displays LiDAR point data by elevation, as shown in the following image. In this rendering mode, the LiDAR data is colored based on its elevation values. In all cases, the “hotter” colors like white and red represent the higher terrain, while the lower elevations are rendered with “cooler” colors like dark blue and magenta.

The following image shows the LiDAR point cloud data rendered by relative elevation.



The following image shows a TINned surface of LiDAR data, rendered by elevation.

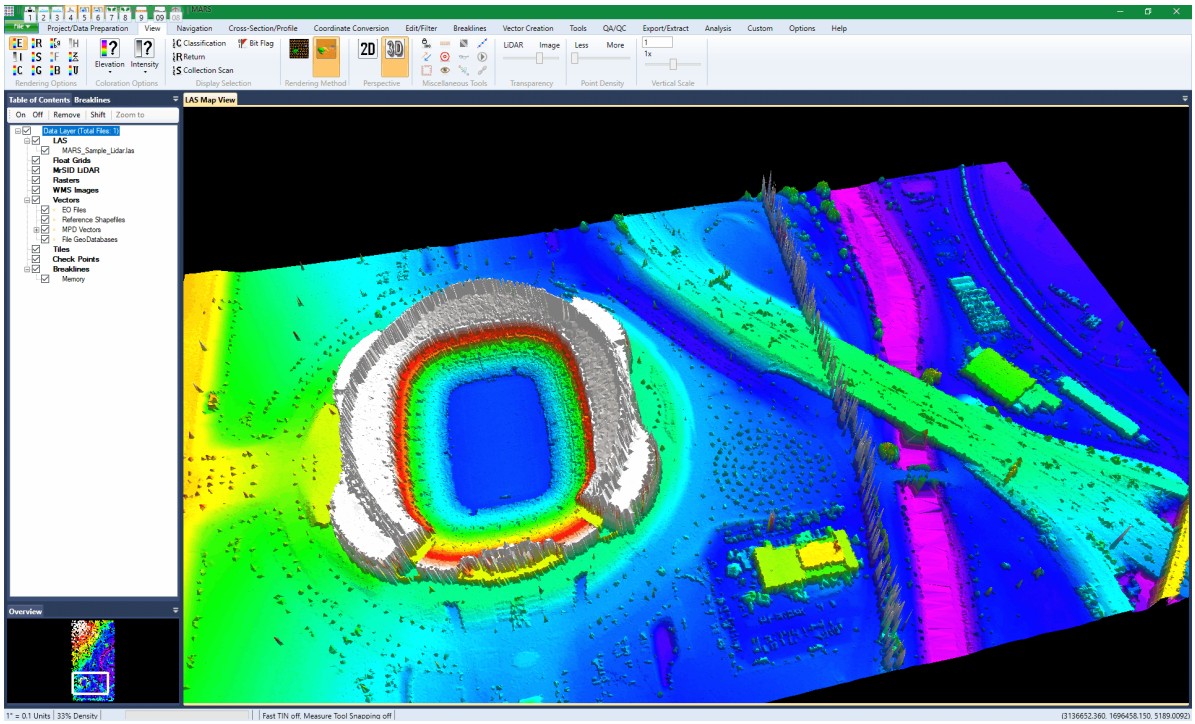
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The following image depicts a TINned surface colored by elevation in 3D (perspective) mode. To view the data in 3D (perspective) mode, click the **‘ 3D’**  button on the View Tab 192. Use the **‘Pan’**  function on the Navigation Tab 234 or the Quick Access Toolbar 65 to rotate the dataset.

Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.

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See also Elevation Rescale 886, Elevation Throughout 887, and Elevation Repeat 881.

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4.7.18 Elevation Repeat

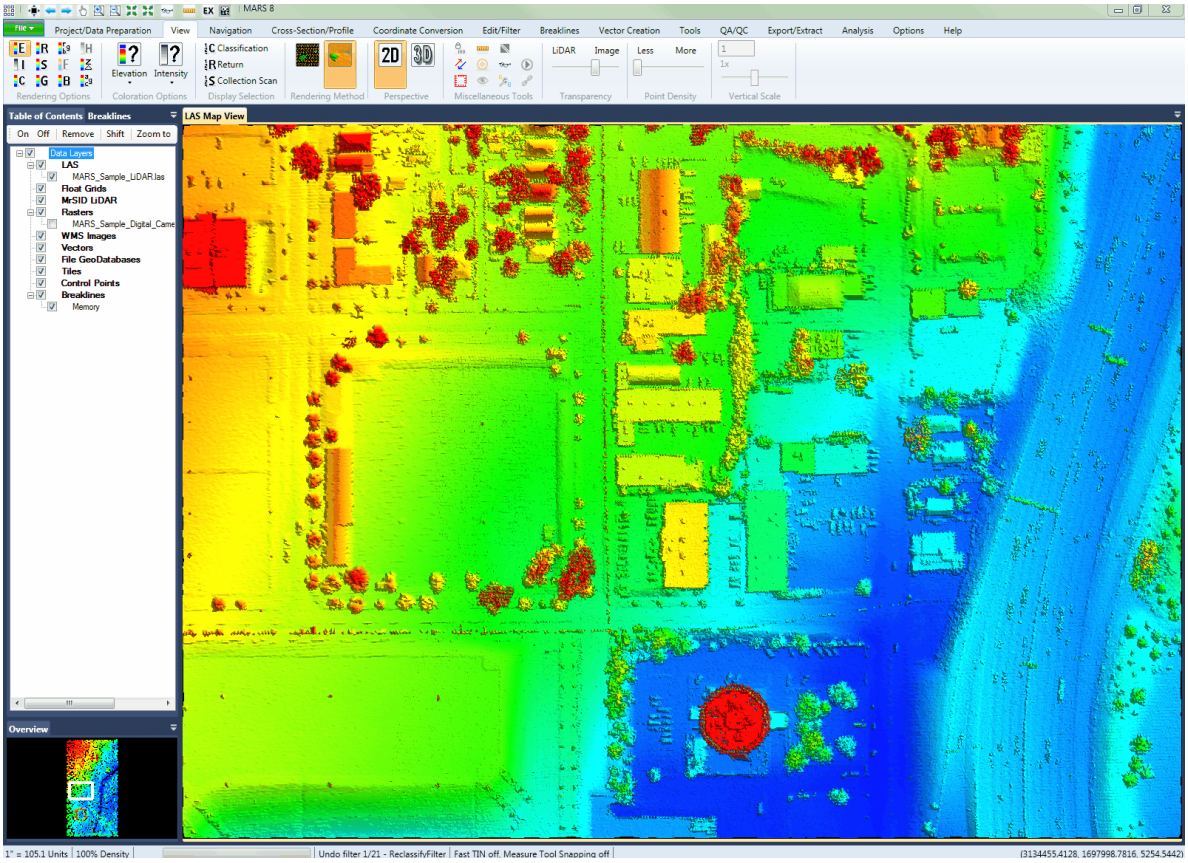
Elevation Repeating Color Cycles

Merrick Advanced Remote Sensing (MARS®) Software

Color cycles are used to alter the surface rendering for manual editing activities. By modifying the color cycle parameters, the user is able to visualize the surface for manual editing and where corrections

need to be made to the classified dataset. To view a LiDAR surface, the user must display only Ground (typically class 2) and Model Key-points (typically class 8), set the rendering style to display the LiDAR points by elevation  , and select the TIN mode  to generate a surface.

The following image shows the TINned LiDAR surface prior to modifying the default color cycles display. In general, modifying the color cycle settings allow the user to identify areas with small changes in elevation, where manual editing if most often necessary.

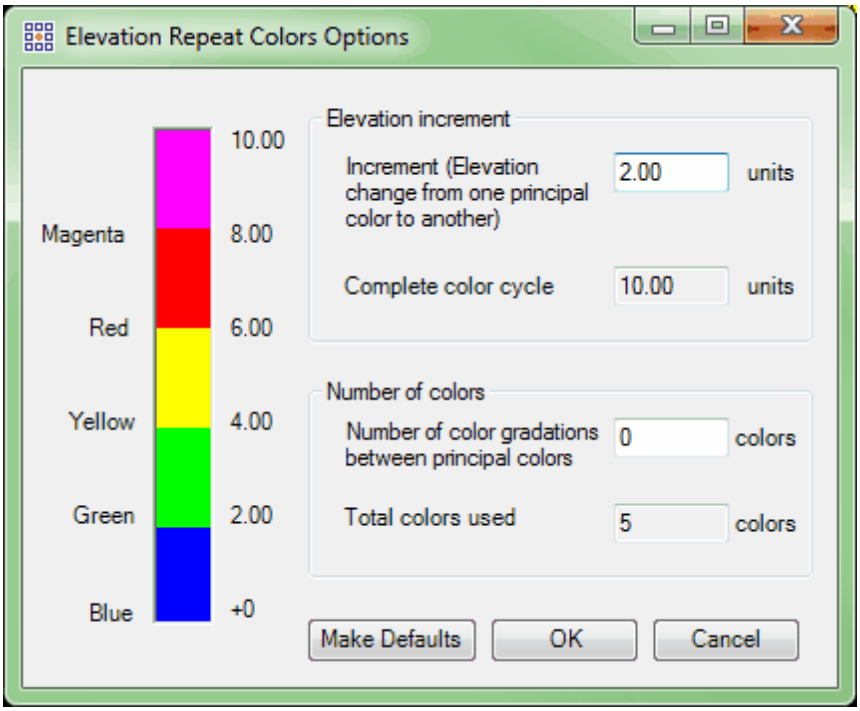


To update the color cycle parameters, the user can either press the **'Z'** button on the keyboard, or

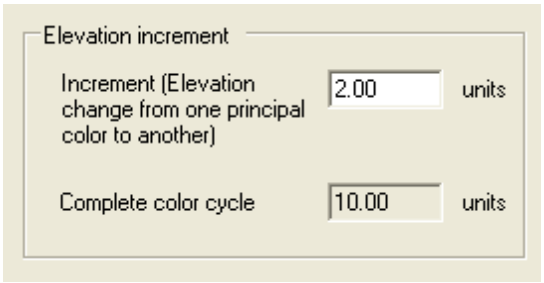
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click the '**Elevation Coloration Options**' button 

and choose the 'Repeat' option to open the following dialog:

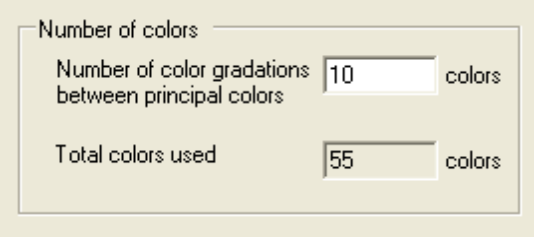


To update the elevation increment, type in a new value (must be greater than zero) in the **'Increment'** text box. This parameter allows the user to define the number of units between the principal color changes.

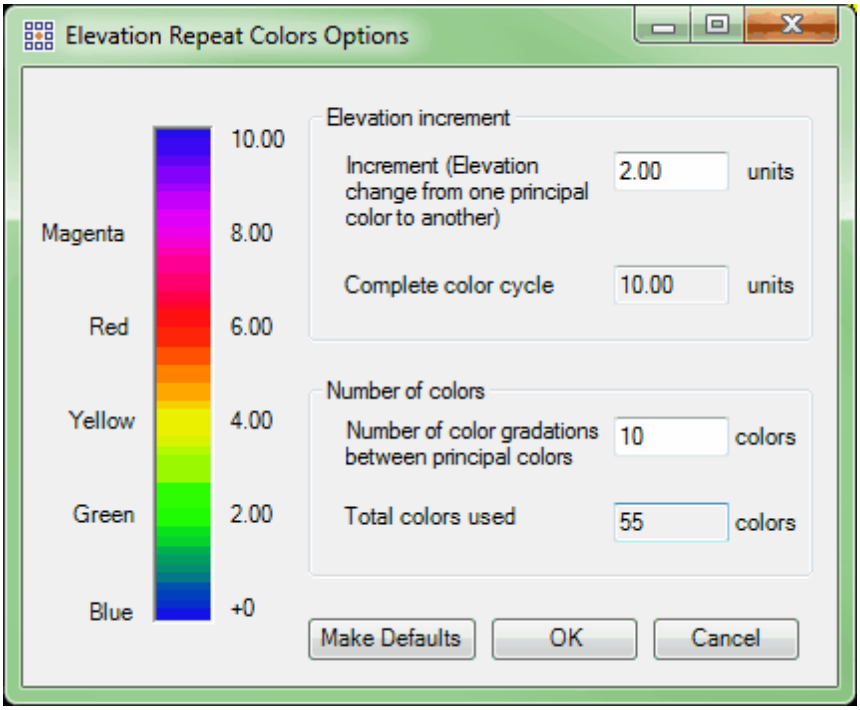


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The user may also update the number of color gradations by typing a new value in the **'Number of Colors'** section. This value controls how many colors are used within each elevation increment.



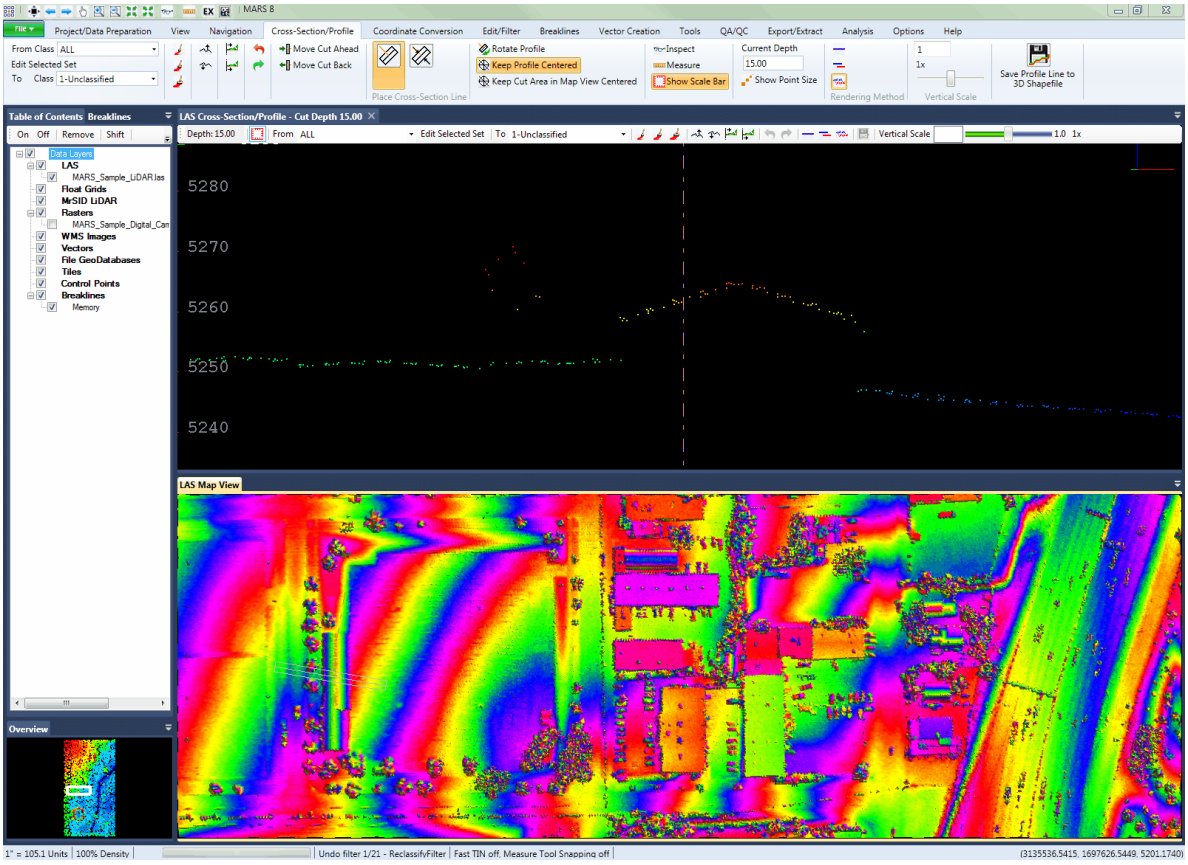
Once the use has input the new values, the color bar will update based on the new parameters. To make the specified settings the new default settings, click on the 'Make Defaults' button.



To view the changes to the color cycle parameter in the LAS Map View window, click **'OK'.** The following image displays the new color cycle rendering, based on the new parameters. The elevation repeat display option is also available in the Cross-Section/Profile window. To color the cross-section/ profile window by elevation repeat, follow the directions just described for the LAS Map View window.

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Make sure the cross-section/profile window is active (highlighted in yellow) by clicking on its tab before making coloration changes. The shortcut **'Z'** key will also bring up the **'Elevation Repeat Colors Options'** dialog for the cross-section/profile window. The settings inside this dialog will be applied to both the cross-section/profile window and the LAS Map View window.



Recommended Color Cycle Settings

The following list represents typical color cycle settings based on the client's contour interval requirement.

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Contour Interval	Cycles
1 foot	3-10
2 feet	4-10
5 feet	5-10
1/2 meter	1-10
1 meter	2-10

See also:

Elevation 878

Elevation Rescale 886

Elevation Throughout 887

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4.7.19 Elevation Rescale



By default the elevation color display is set to 'Rescale'. Pan around in the sample data and notice that the elevation colors displayed are constantly rescaled for the data contained in the current extent of the LAS Map View window. This can be set by clicking the '**Elevation Coloration Options**' button



on the View Tab 192 and choosing the 'Rescale' option from the drop-down list.

See also:

Elevation 878

Elevation Throughout 887

Elevation Repeat 881

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4.7.20 Elevation Throughout

Elevation Color Throughout

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To hold the Elevation coloring constant while panning through the data use the **'Elevation Throughout'** option. This is enabled by clicking the '**Elevation Coloration Options**' button 

on the View Tab 192 and choosing the 'Throughout' option from the drop-down list. Pan around through any loaded LAS data and notice that the coloration values are held constant regardless of extent.

See also:

Elevation 878

Elevation Rescale 886

Elevation Repeat 881

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4.7.21 Intensity

Color by Intensity

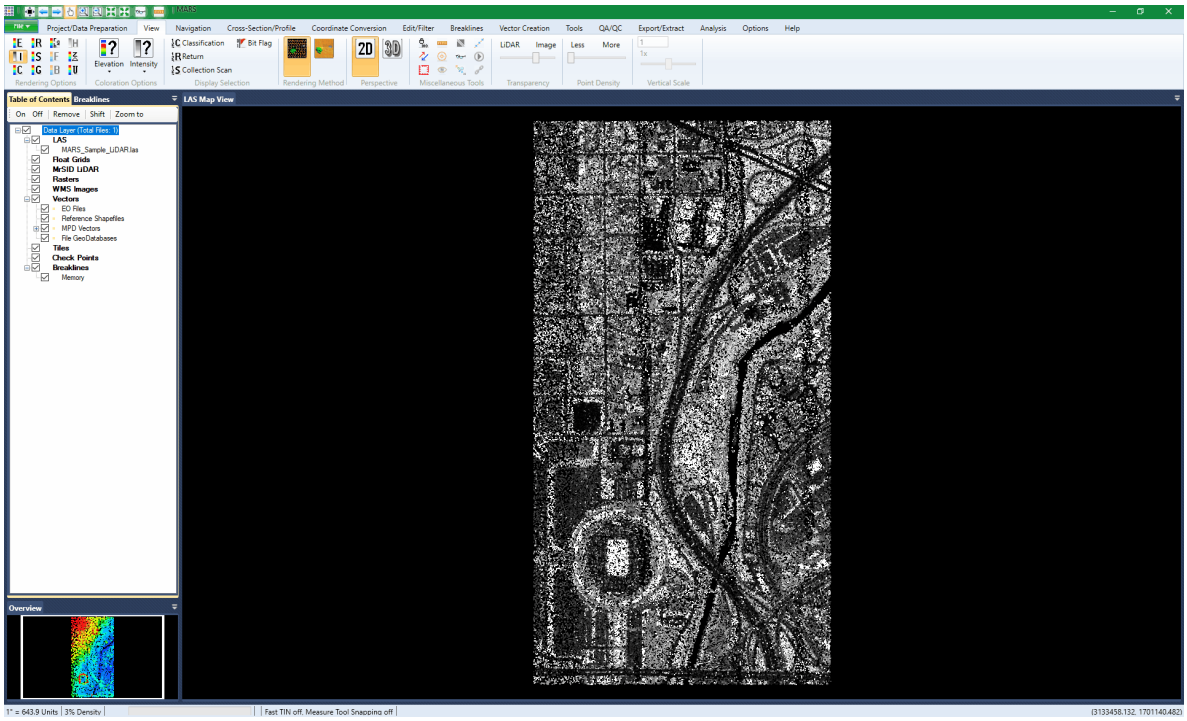
Merrick Advanced Remote Sensing (MARS®) Software

To see data colored by intensity, click on the **'Color by Intensity'**  button on the View Tab 192, or press Ctrl-I on the keyboard.

LiDAR data can be viewed by intensity, which is a quantitative measure of the intensity for each return. For 16-bit data the intensity values range from 0 to 65535, where 0 represents the darkest reflections (ex. new asphalt) and 65535 represents the brightest reflections (ex. white rooftop).

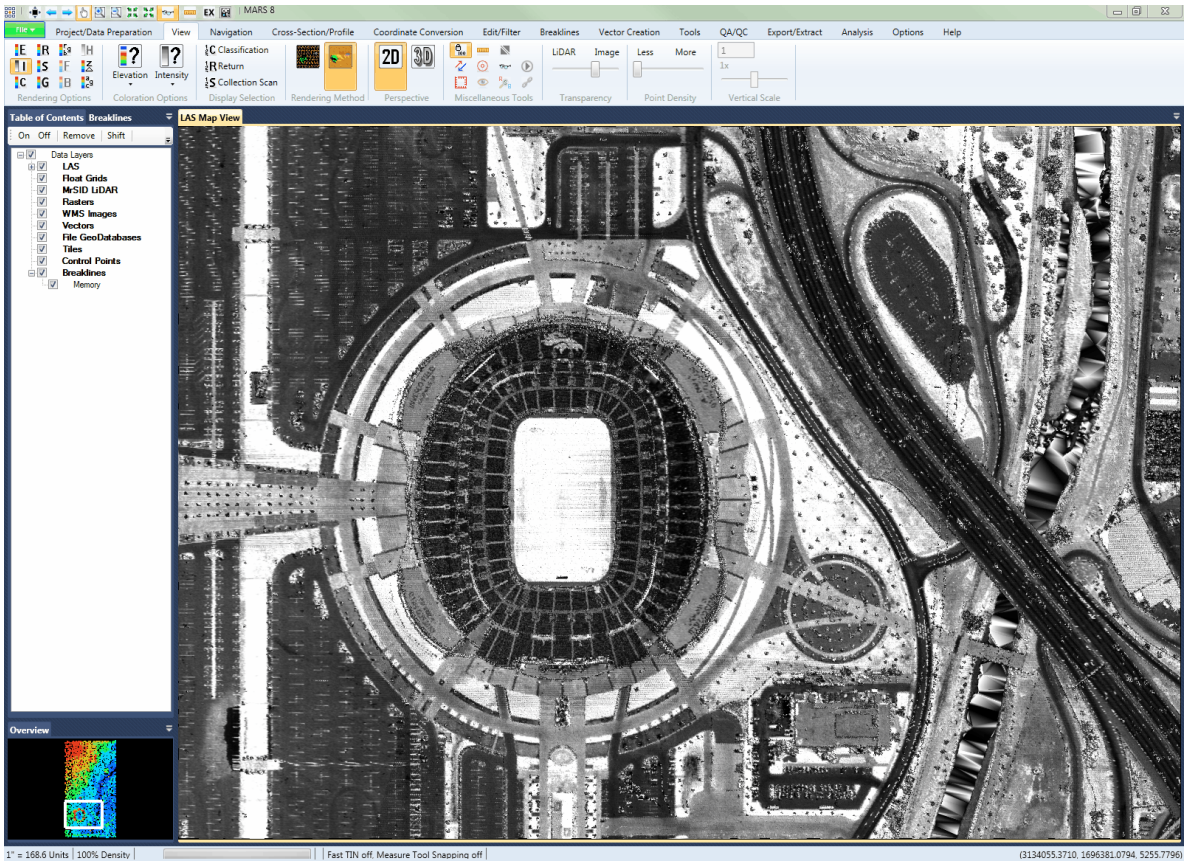
The following image shows the LiDAR point cloud data rendered by gray-scale intensity. Multi-color 896 intensity rendering is also available.

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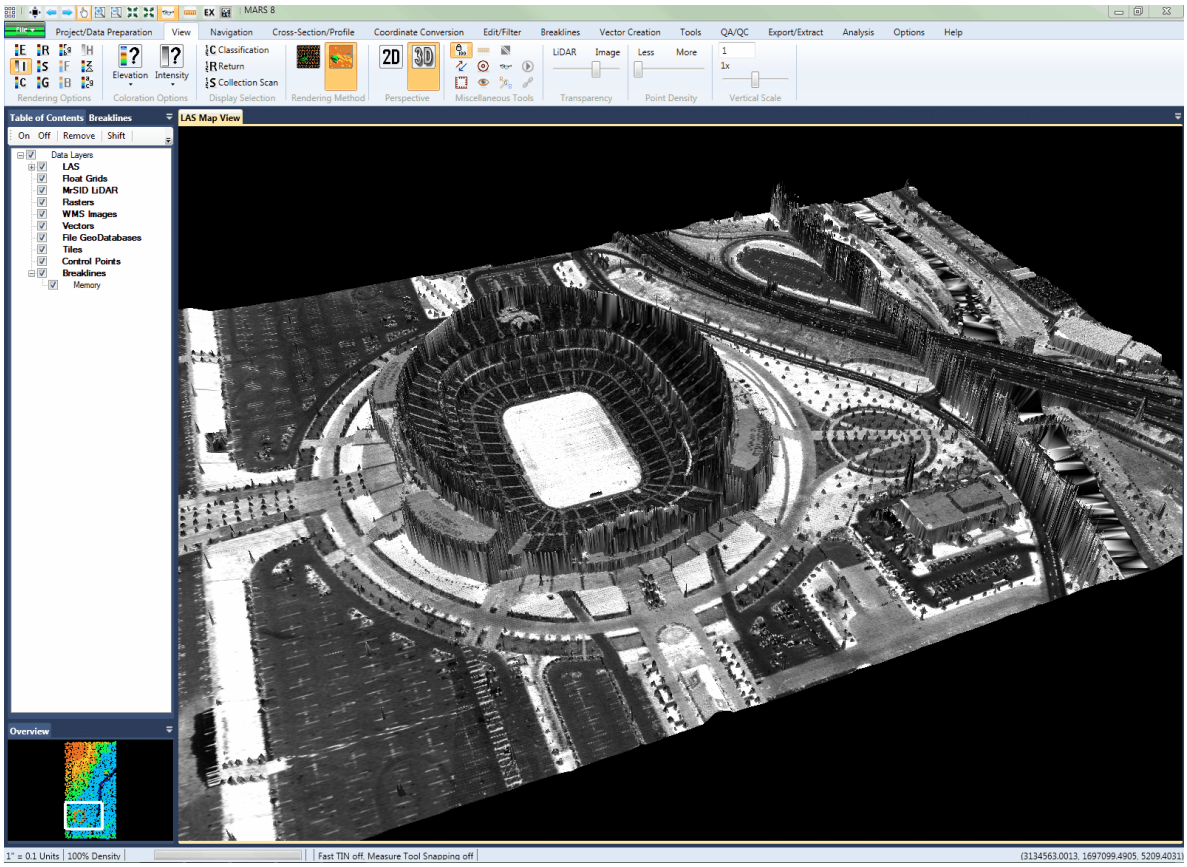
The following image shows a TINned surface of LiDAR data, rendered by intensity.

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The following image depicts a TINned surface colored by intensity in 3D (perspective) mode. To view the data in 3D mode, click the **'3D'**  button on the View Tab[192]. Use the **'Pan'**  function on the Navigation Tab[234] or the Quick Access Toolbar[65] to rotate the dataset. *Please note that the user must return to 2D View mode to update the display to a higher resolution or a different coverage area than the current 3D view.*

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See also:

Intensity Gray-scale Only 895

Multi-color 896

Intensity Color Extremes 892

Intensity Equalize 893.

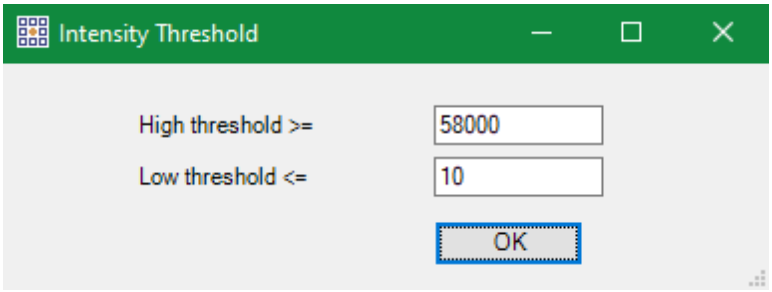
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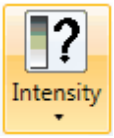
4.7.22 Intensity Color Extremes

Intensity Displayed in Color Extremes

Merrick Advanced Remote Sensing (MARS®) Software

This setting, one of the choices in the Coloration Options | Intensity 204 drop-down list, allows all extreme low and high intensity values to be displayed in color. When selected, a control pops up to allow the low and high thresholds to be entered. For example, if 58000 is entered as the 'High threshold' and 10 is entered as the 'Low threshold', all points with intensity values of 58000 or higher will be rendered in blue and all points with intensity values of 10 or lower will be rendered in yellow.



See the **'Coloration Options | Intensity'** 

section of the View Tab 192 topic for a description of intensity values. The user must select the **'Color by Intensity'**  button to be able to see the effect of this option.

See also:

Intensity 888

Intensity Gray-scale Only 895

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Intensity Multi-color 896

Intensity Equalize 893

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4.7.23 Intensity Equalize

Intensity Equalize

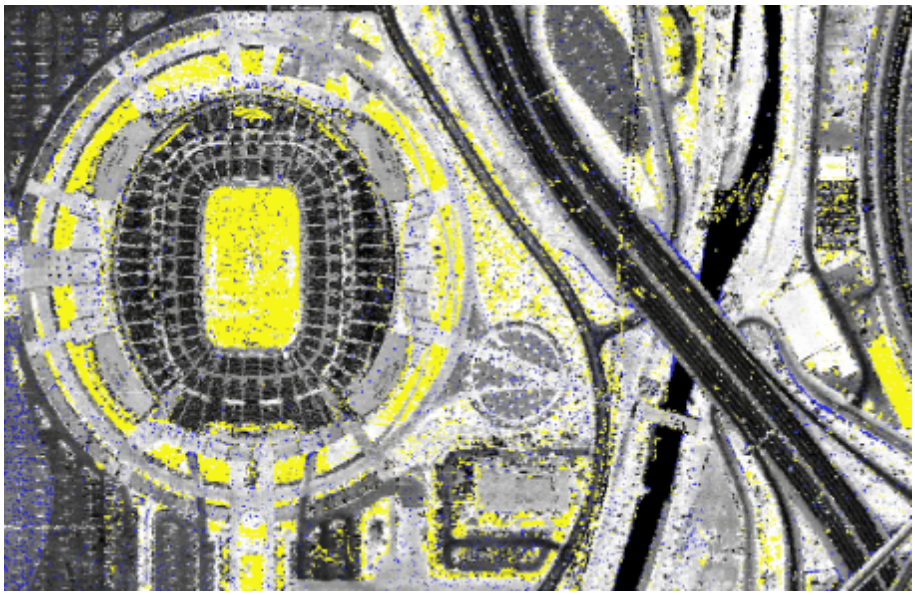
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To use the Intensity Equalize option, click the **'Coloration Options | Intensity'** button 

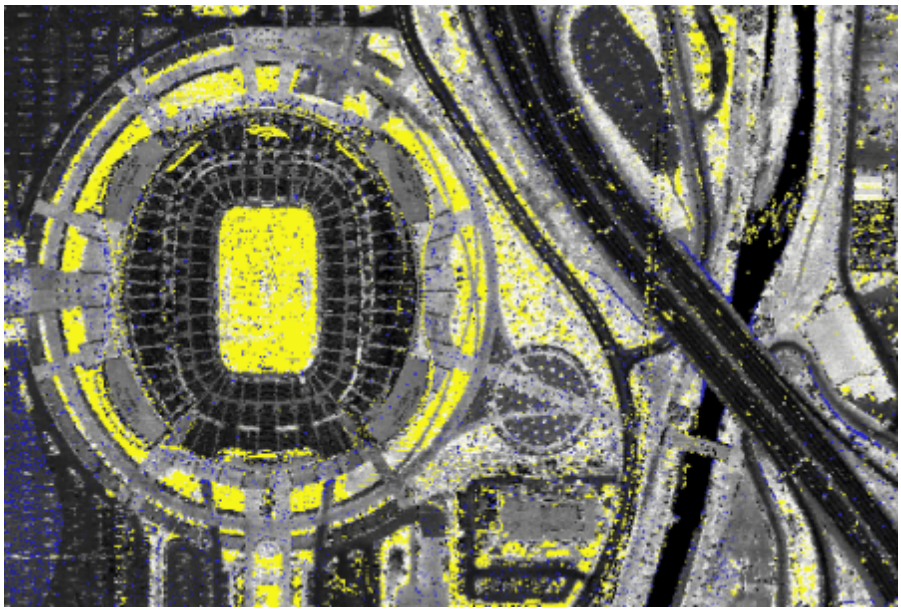
on the View Tab and check the 'Equalize" box.

Equalize: By default the intensity color display is set to 'Equalize'. Using this option, the intensity display will be equalized every time the user moves around the project, zooming in or out, or viewing different areas. This tool will take the intensity ranges within the LAS Map View window and use a histogram stretch on the data so the data is more defined and can be viewed more easily. This tool works similarly to the Elevation Rescale 886 option, but with intensity value data.

Ex: Below is an example of color extreme intensity data with the Equalize option checked on. Notice the detail of the data at all extents.



Ex: Below is an example of color extremes intensity data with the Equalize option checked off. There is less detail in the same data at the same zoom level as the screen shot above.



See also:

Intensity 888

Intensity Gray-scale Only 895

Intensity Multi-color 896

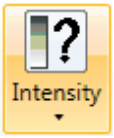
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Intensity Color Extremes 892

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4.7.24 Intensity Gray-scale Only



Intensity values rendered in gray-scale is the default mode of displaying intensity data. See the **'Coloration Options | Intensity'** 

section of the View Tab 192 topic for a description of intensity values. The user must select the **'Color by Intensity'**  button on the View Tab 192 to be able to see the effect of this option.

See also:

Intensity 888

Intensity Color Extremes 892

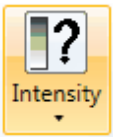
Intensity Equalize 893

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4.7.25 Intensity Multi-color

Intensity Displayed as Multi-color

Merrick Advanced Remote Sensing (MARS®) Software

This option displays Intensity values rendered by a color ramp, with the lowest values in magenta and the highest in white. See the **'Coloration Options | Intensity'** 

section of the View Tab 192 topic for a description of intensity values. The **'Color by Intensity'**  button on the View Tab 192 must be selected to see the effect of this option.

See also:

Intensity 888

Intensity Gray-scale Only 895

Intensity Color Extremes 892

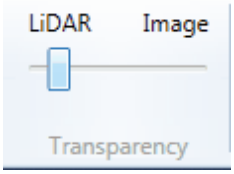
Intensity Equalize 893

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4.7.26 LiDAR/Imagery Transparency

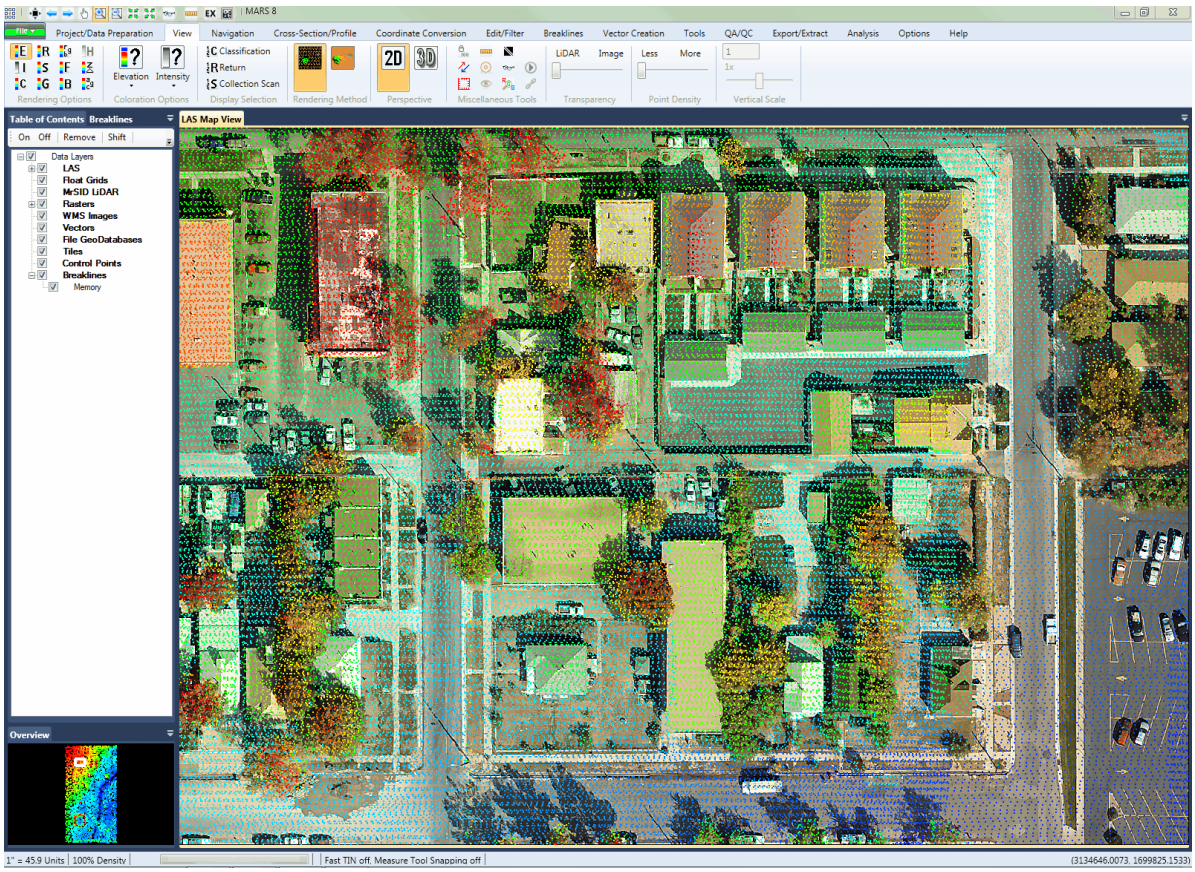
LiDAR/Imagery Transparency

Merrick Advanced Remote Sensing (MARS®) Software



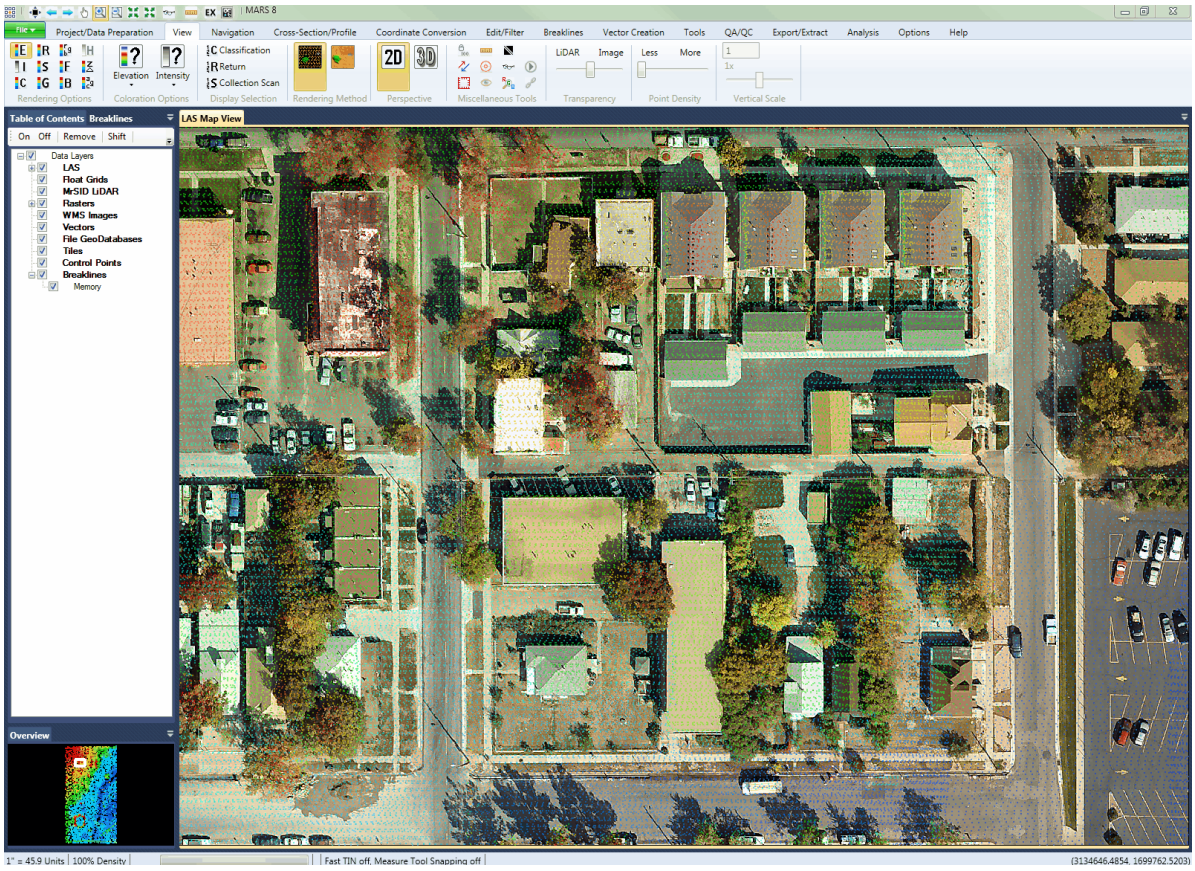
The **'LiDAR/Imagery Transparency'** slider bar is used to control the transparency of the LiDAR data loaded over an image file. Move the slider bar back and forth to see how the LiDAR can be made anywhere from 0 (left side of slider) to 100% (right side of slider) transparent. The transparency of the LiDAR data controls how much of the underlaying imagery is seen. This is helpful in checking the co-registration of datasets or identifying features in corresponding datasets.

The following examples show the effect of moving the slider to the left (LiDAR) position...



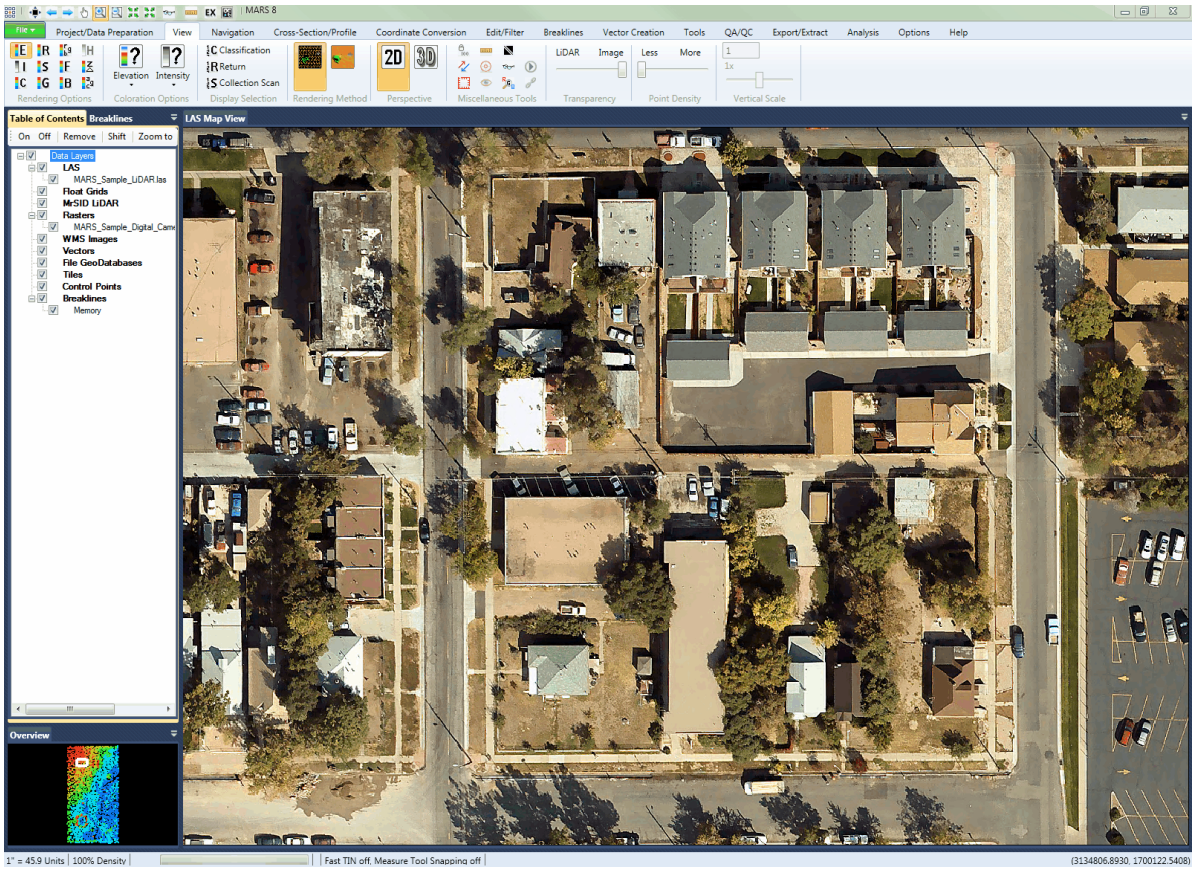
...to the center position...

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...and to the right (Image) position.

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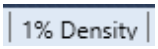
4.7.27 Lock to view 1%

Lock to view 1%

Merrick Advanced Remote Sensing (MARS®) Software

Lock to view 1%: This tool, found on the View Tab[192], locks on only the 'thinned points,' the minimum set of points that can be displayed for loaded LAS files. This can speed up panning

and zooming operations while the area of interest is being determined. The density percentage indicator on the left side of the Status Bar[158] shows the percentage of points which are currently being displayed.



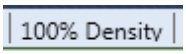
Note that the actual percentage of points displayed may be less than 1% depending on the data loaded.

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4.7.28 Lock to view 100%



Lock to view 100%: This tool, found on the View Tab[192], is intended for hand editing purposes, when using the Flood Fill[489] utility, and when displaying virtual contours. The density percentage on the left side of the Status Bar[158] tells the user the percentage of points which are currently being displayed.



Hand editing should be done ONLY when viewing points at 100% density. It is easy for the editor to zoom in/out or lose/gain point density frequently throughout the hand editing process by maneuvering around the project, and this tool allows the editor to lock the point density of the display at 100% regardless of zoom level.

If navigation is slowed too much with this tool enabled, toggle it off, move to the desired area, and re-

enable the tool. The tool will reset to the 'off' mode when all loaded LAS files are removed and must be manually toggled back on (if desired) after new data is loaded.

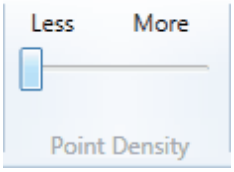
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4.7.29 Point Density

Point Density

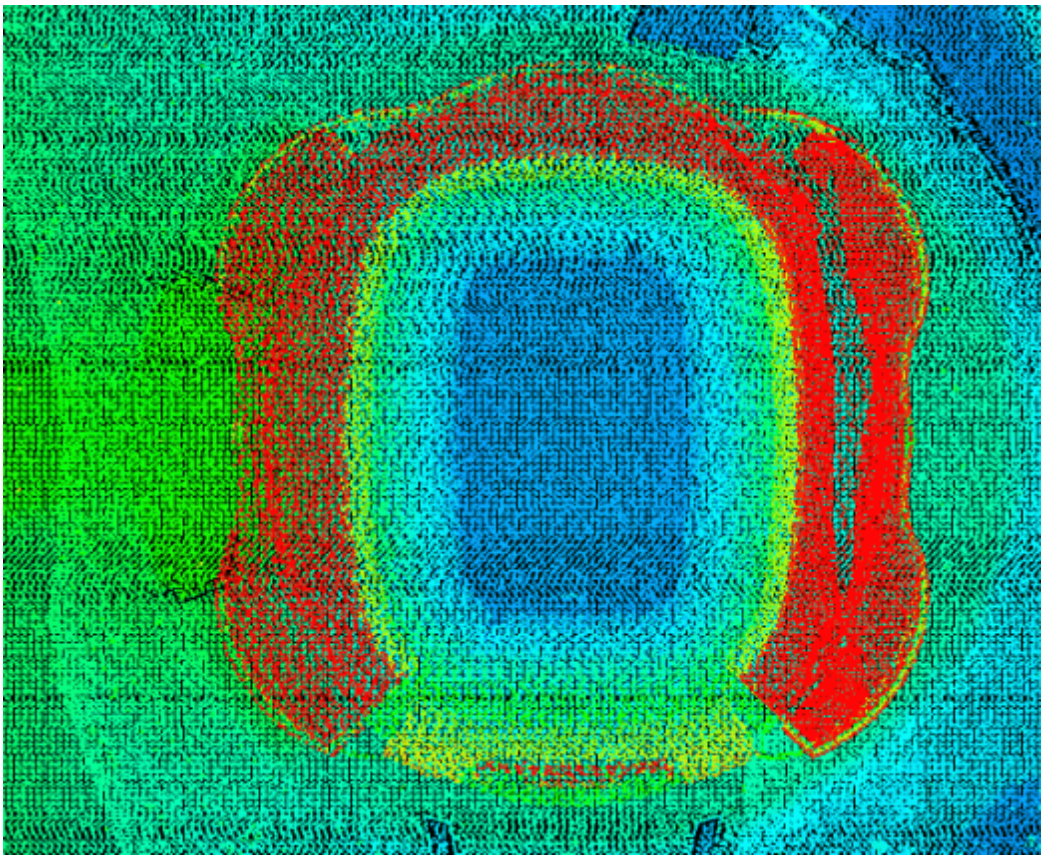
Merrick Advanced Remote Sensing (MARS®) Software

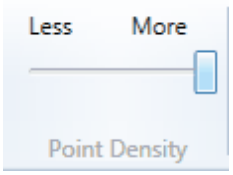
Point Density slider bar: This control, found on the View Tab[192], changes the point density in the LAS Map View window. The user must be zoomed in to at least 4% before the slider bar will take effect. The point density slider bar does not work inside the Cross-Section/Profile[240] window. To **TIN**  the data being viewed, the slider bar must be set to the far left. If the bar is not set to 0 before the TIN button is clicked, an error window will appear.

Ex: Point Density set at 'Less' position 

*to allow data to be rendered by **TIN***

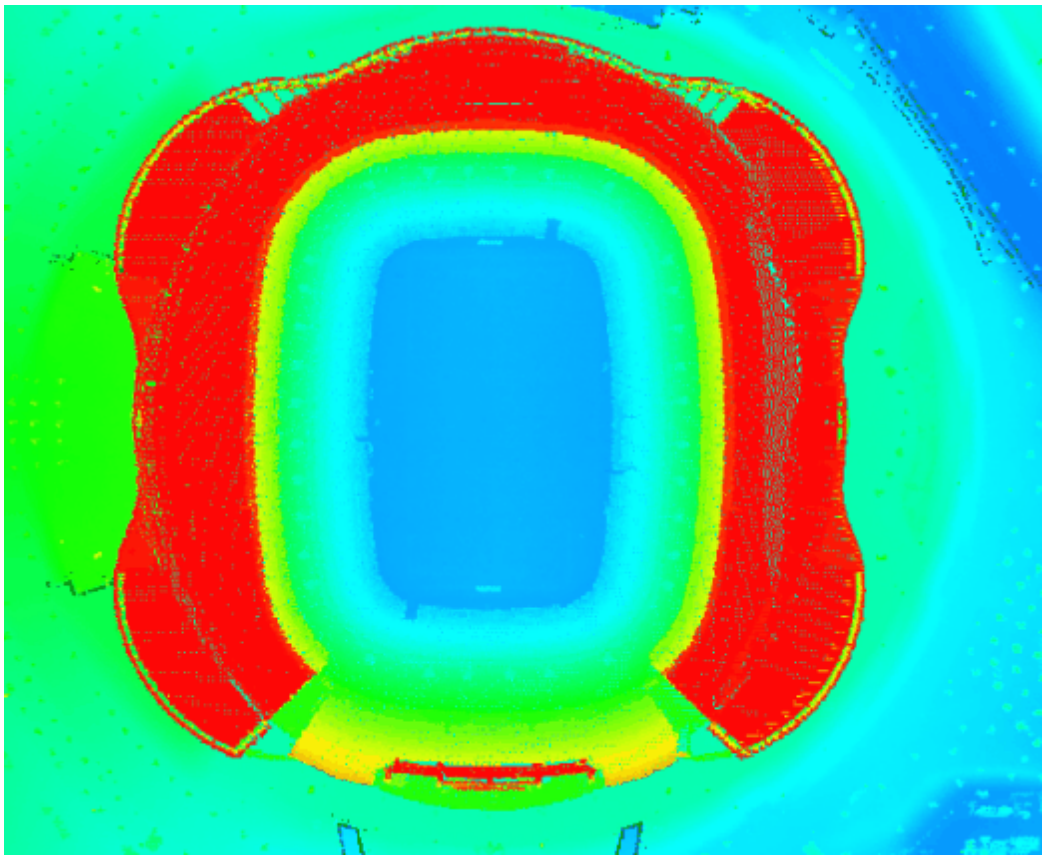
 .



Ex: Point Density set at 'More' position 

. TINning cannot be done at this setting.

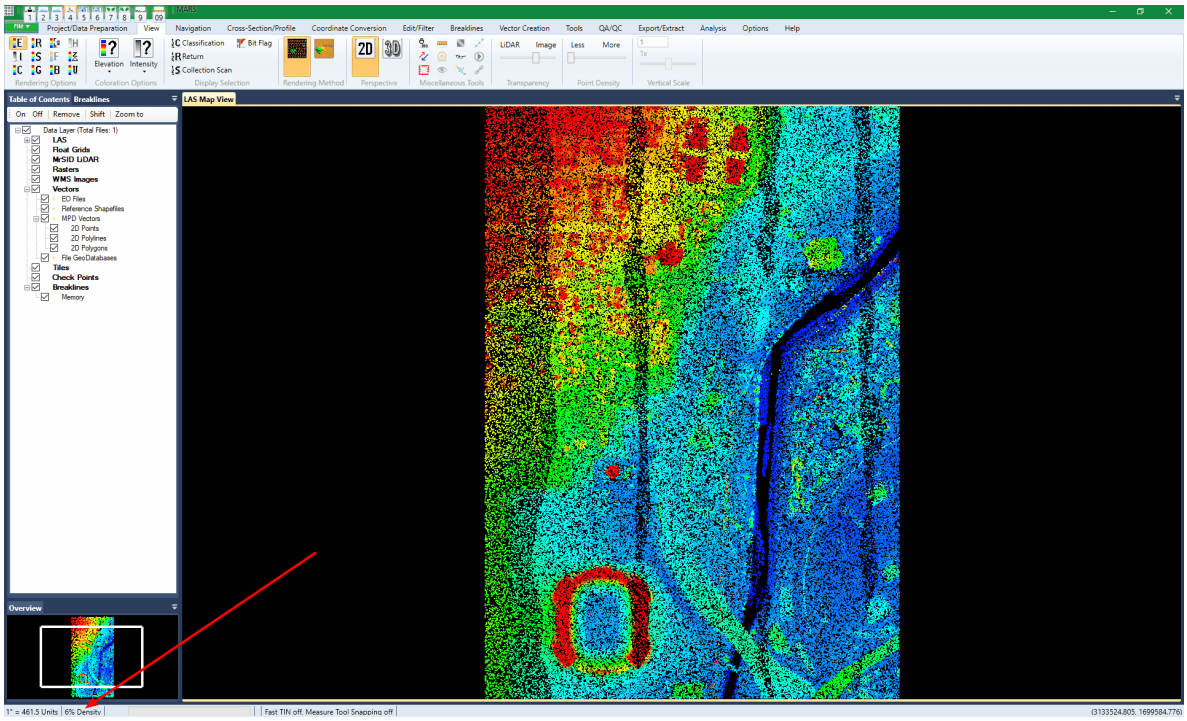
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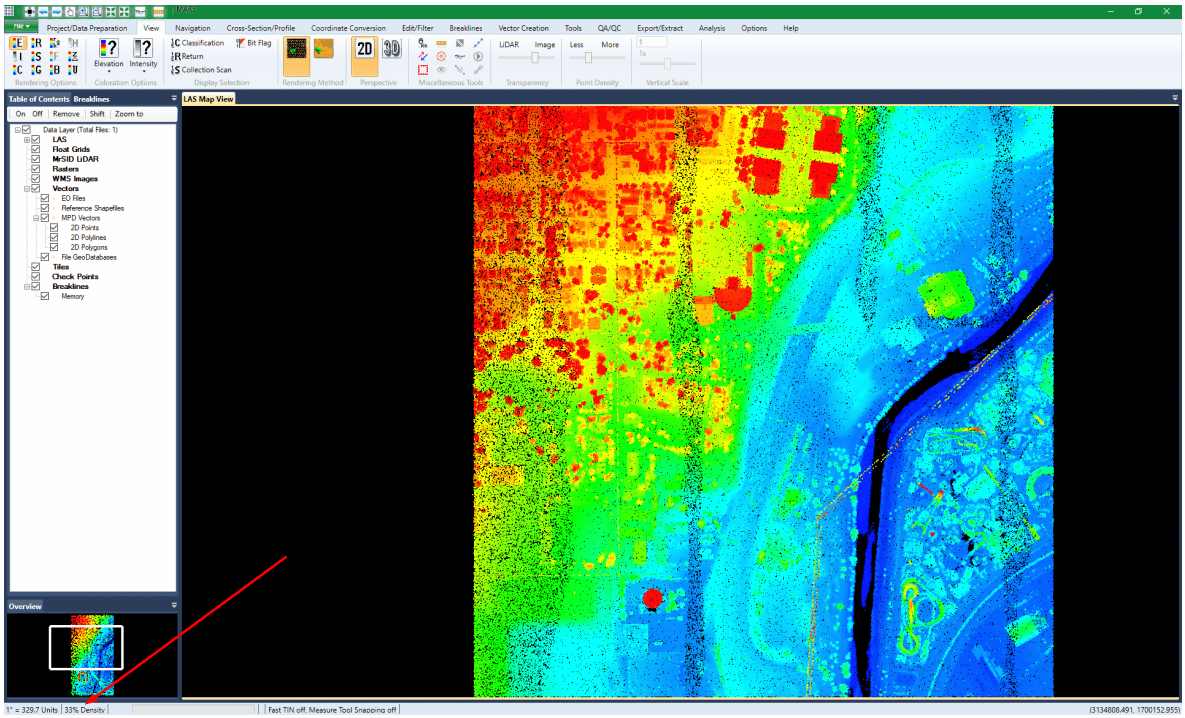
The actual percentage of points being displayed (point density) can be found on the left side of the Status Bar[158]. As the Point Density slider bar is moved left or right, this percentage will change accordingly.

In the example below, the slider bar is set to display fewer points. In this case, 9% of the points are being displayed.

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In the example below, the slider bar is set to display more points. In this case, 33% of the points are being displayed.



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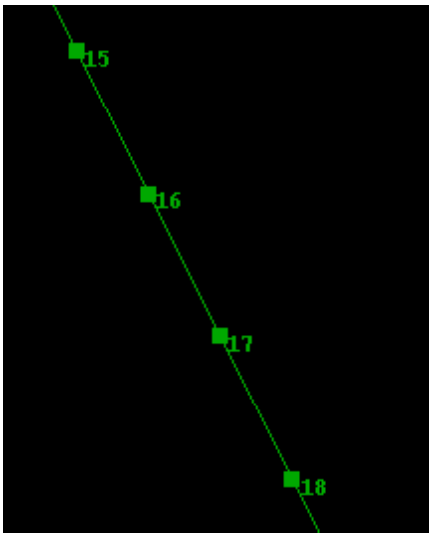
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4.7.30 Show Breakline Vertices

Show Breakline Vertices

Merrick Advanced Remote Sensing (MARS®) Software

Show Breakline Vertices *(available with Production license only)*: This tool, found on both the View Tab[192] and the Breaklines Tab[298], symbolizes the vertices for all loaded breaklines, and labels each with the ID number stored in the shapefile attribute table.

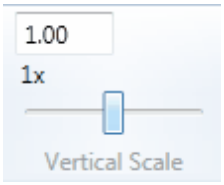


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4.7.31 Vertical Scale

Vertical Scale

Merrick Advanced Remote Sensing (MARS®) Software

Vertical Scale slider bar: 

MARS® is capable of vertically rescaling data while in 3D View[837] mode in the LAS Map View window. The slider can be dragged to the right (exaggerate) or left (de-exaggerate) from its center position. Above the slider bar is a vertical scale text box that allows entry of an exact scale value. Type in the scale (relative to horizontal) at which the data is to be viewed and press 'Enter' on the keyboard. The minimum value is 0.01 and the maximum is 1000. The '**1x**' button will revert back to a 1:1 scale.

A separate vertical scale control is located on the Cross-Section/Profile Tab[240] (and the optional Cross-Section/Profile toolbar) for use in the Cross-Section/Profile[146] window.

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4.8 Data Utilities

Data Utilities

Merrick Advanced Remote Sensing (MARS®) Software

For any LAS Tools (including 'Add Spatial Index') that allow files to be pathed out without

loading them in the Table of Contents in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.

MARS® includes a variety of tools and functions to aid in the exploitation and analysis of LiDAR data.

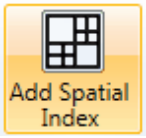
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4.8.1 Add Spatial Index



To use the 'Add Spatial Index' tool, please visit the Project/Data Preparation Tab 162 topic or follow the instructions below.

***NOTE:** For best stability and faster performance, LAS files that have been spatially indexed in an older version (v2019.3 or earlier) should be re-indexed using version 2020.0 or later of MARS®. This can be done quickly in two steps using the multi-threaded 'Add Spatial Index' tool - the 'Fast Remove Index' option followed by the 'Add Spatial Index' option. See the paragraph immediately before the screen shot of the tool interface for more information. Also note that issues may occur with LAS files if they are spatially indexed in a newer version of MARS® and then have their index records removed in an older version.*

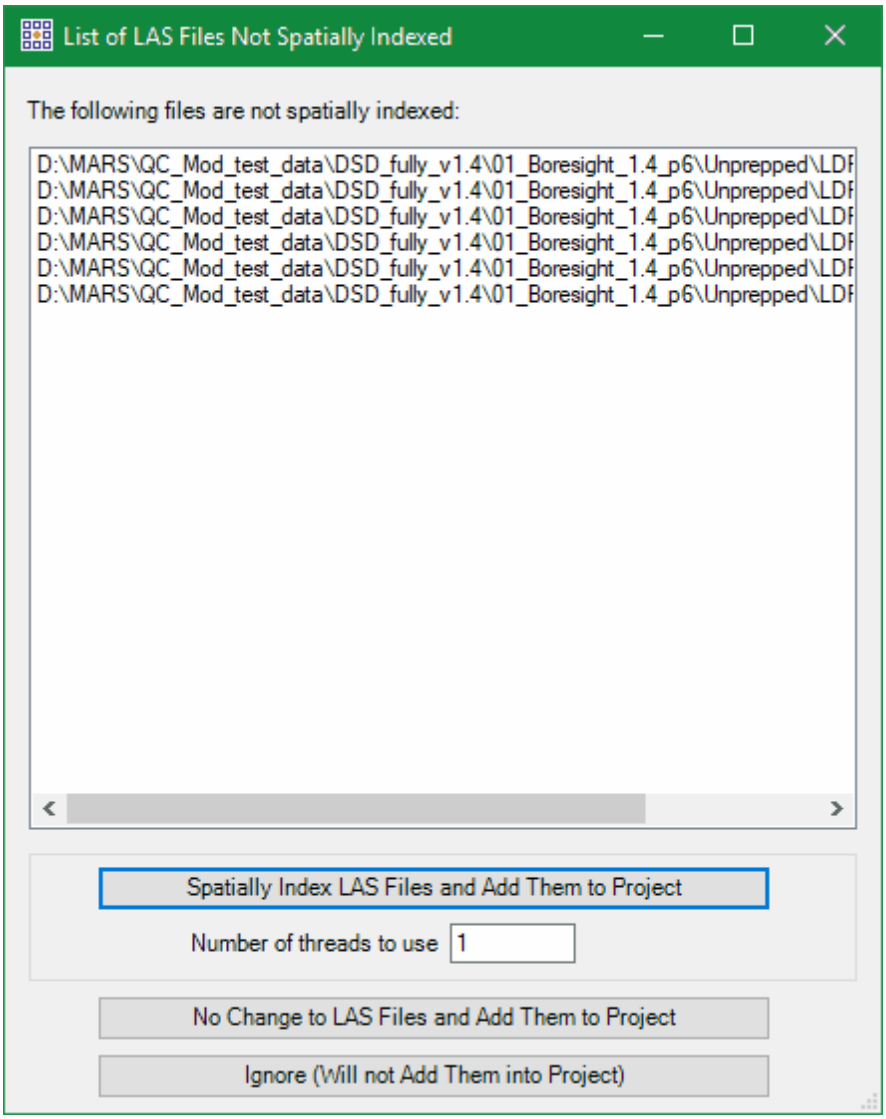
Add Spatial Index: This tool 

is found on the Project/Data Preparation Tab 162 and performs a spatial index on one or more LAS files to enable MARS® to read and display the point data. It can add spatial index information, remove it (which may be necessary for using the files in other software), or mark any existing spatial index records as superseded. There are two ways to use 'Add Spatial Index':

1) Add LAS files to MARS®

If LAS v1.4 data without the necessary spatial indexing is among the files selected to be loaded into MARS®, the user will be provided a list of those files and three options for handling them:

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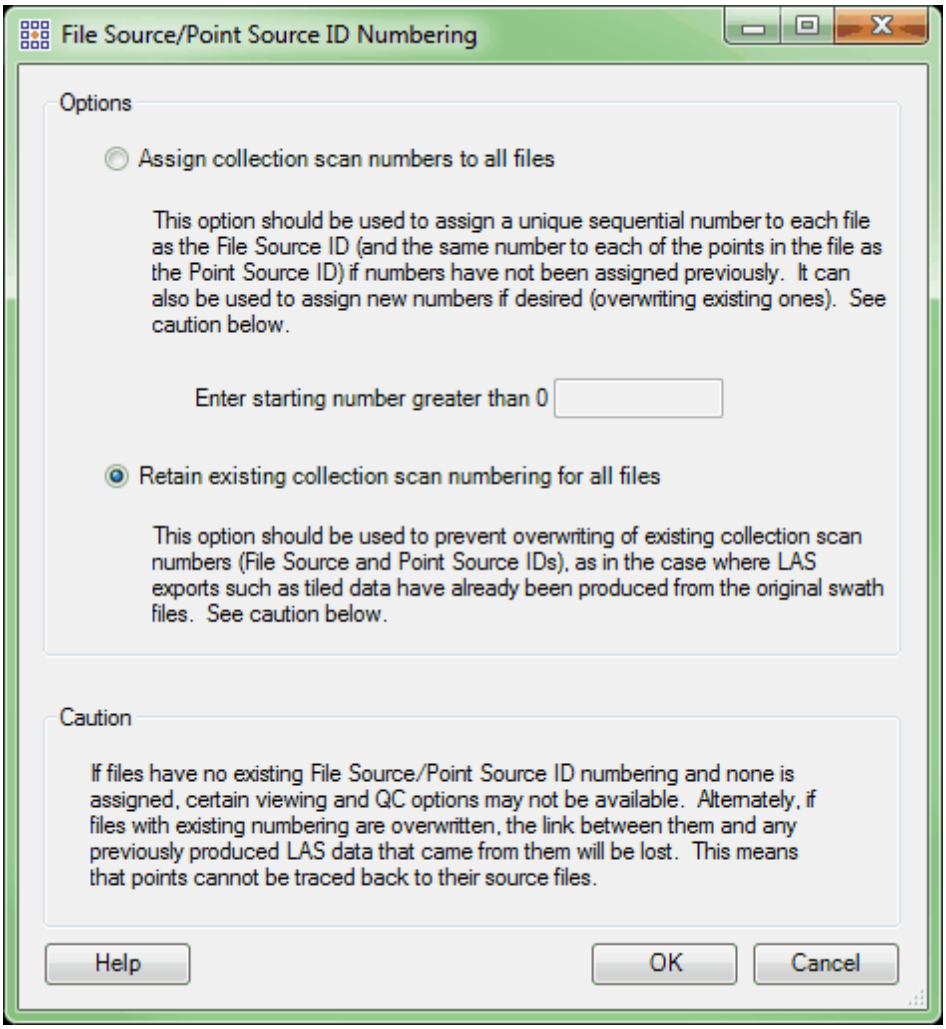


a) Choosing 'Spatially Index LAS Files and Add Them to Project' will permanently prepare the data (by modifying the file header) for viewing. This process may be multi-threaded by entering a number greater than 1 in the 'Number of threads to use' text box before clicking the 'Spatially Index...' button. ***Please note*** the explanatory text in the interface (see above) concerning multi-threading. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Multi-threading the Spatial Indexing functions across a USB 2.0 connection is not recommended as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can

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be used, but may be limited in performance depending on the access speed of the external drive.

A second window will appear with options for File Source / Point Source ID numbering.

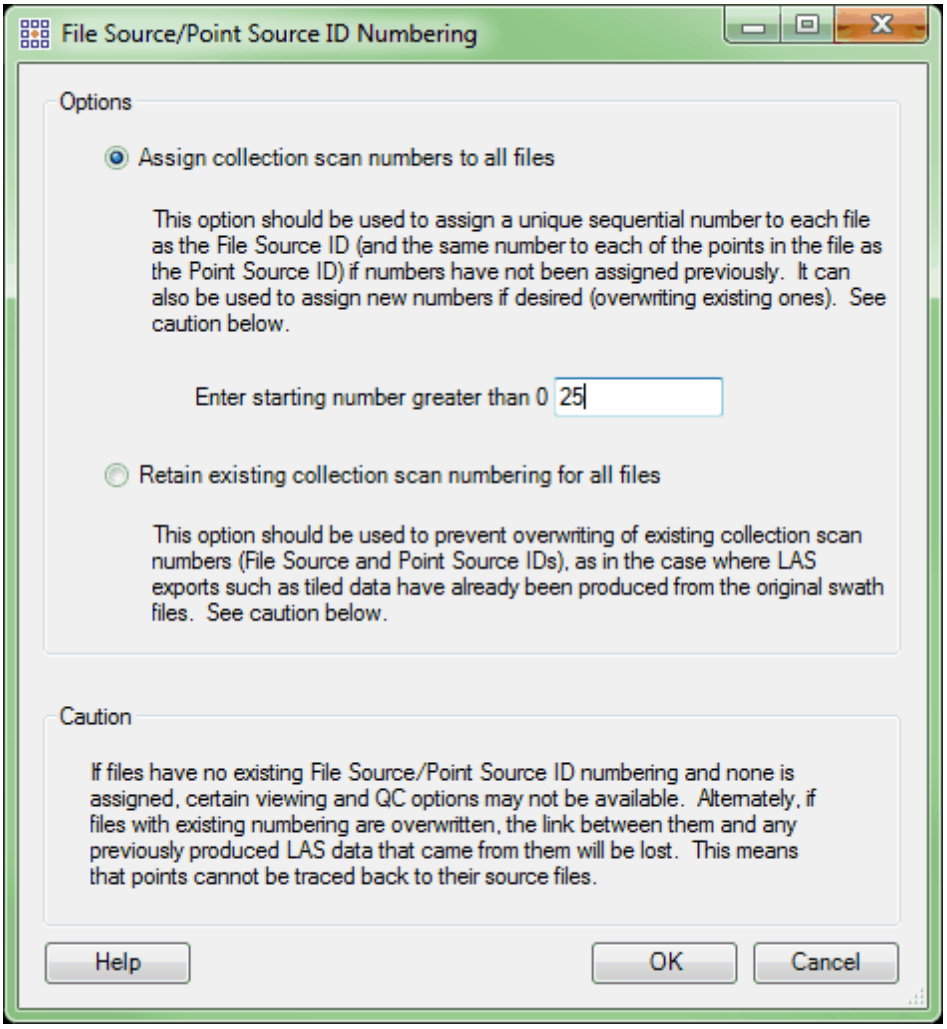


Depending on the user's preference or requirements, the files can be sequentially renumbered (in the order listed in the original window) by choosing the 'Assign collection scan numbers to all files' radio button and entering a starting number, or they can be indexed with no changes to any collection scan numbering they already have by choosing the 'Retain existing collection scan numbering for all files' radio button. The

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'Retain' option is the default. ***Please read the method descriptions and caution statement before proceeding.***

If using the 'Assign' option, please note that LAS version 1.4 files are limited to collection scan numbers of 1 to 65,535. Keep this limit and the total number of files in mind when entering a starting number.



After the choice has been made, click 'OK' to start the indexing and a status bar window will pop up. During this time, all files will be tested for empty 'System Identifier' header fields, and if found, will have this field populated with 'OTHER' (see the LAS file

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specifications on the ASPRS LAS File Format website). Files with values already in place will not have this field altered. When complete, the files will be loaded.

b) Choosing 'No Change to LAS Files and Add Them to Project' will *temporarily* prepare the data for the current session of MARS®. When indexed in this manner, no changes are made to the file header and the data will need to be re-indexed (either permanently or temporarily) if it is later loaded into another MARS® session.

c) Choosing 'Ignore (Will not Add Them into Project)' will cancel the loading of any files without spatial indexing, but will load any previously indexed ones that were part of the original selection.

2) Using the Add Spatial Index interface - This method will modify the LAS files when spatial index information is added, removed, or superseded.

To bring up the interface, click the '**Add Spatial Index**' button on the Project/Data Preparation Tab 162.

✓ Navigate to the files to be spatially indexed by clicking on the 'Add' button. Files may be removed from the list by highlighting them (using standard Windows mouse/ keyboard controls) and clicking on the 'Remove Selected' or 'Remove All' buttons.

✓ If adding spatial indexing, choose one of the 'Collection scan options':

- **Incremental:** Assigns sequential collection scan numbers to each LAS file in the list to be spatially indexed. Using this option will overwrite any existing collection scan numbering in the LAS files. Enter the desired starting number in the 'Starting collection scan number' text box, keeping in mind that LAS version 1.4 can have collection scan numbers of 1 to 65,535. If multi-channel files are being processed, check the 'Group Multi-

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Channel LAS files (one number per group)' box to have the same collection scan number assigned to each file in the group. ***The tool requires that files in a multi-channel group be named identically starting with the letter 'L' except for a unique digit denoting the channel number following the mandatory letter 'C' - for example, 'L1-1-140324_A-C1_r.las and 'L1-1-140324_A-C2_r.las' - for this collection scan numbering method to work.***

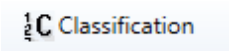
- **No Assign - Keep the collection scan number of every point:** No changes are made to collection scan numbering that may exist in the LAS files. This is the default.
- **Set all files to one collection scan number:** Assigns only one collection scan number to all listed files. This option will overwrite any existing collection scan numbering in the LAS files. Enter the desired number in the 'Starting collection scan number' text box, keeping in mind that LAS version 1.4 files are limited to collection scan numbers of 1 to 65,535.

✓ WKT: This area shows any existing WKT-based coordinate reference system definition for the added files and allows the information to be edited. Changes made here will be applied only when adding spatial indexing. See the procedure outlined in the 'Add CRS Info (to LAS Files)' topic in the Coordinate Conversion 254 section of this help file for details.

✓ Multi-Threading: The 'Add Spatial Index' tool is capable of multi-threading the indexing process. To multi-thread (which may shorten the processing time), enter the desired number of threads up to the maximum available for the computer in the text box. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Multi-threading the Spatial Indexing functions across a

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USB 2.0 connection is not recommended as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

✓ Class options: This option allows a second spatial index to be created based on all classes EXCEPT the one(s) listed in the 'Majority Classes' box. Click the 'Select' button to choose the desired majority classes. When one or more of the chosen classes are turned off using the Classification[192]  button on the View Tab[192], performance is increased during display-related operations such as pan and zoom. In addition, a higher percentage of the available point cloud will be displayed for a given window extent. If more than one class was chosen as a majority class during 'Add Spatial Index', the performance boost will be highest when all majority classes are turned off.

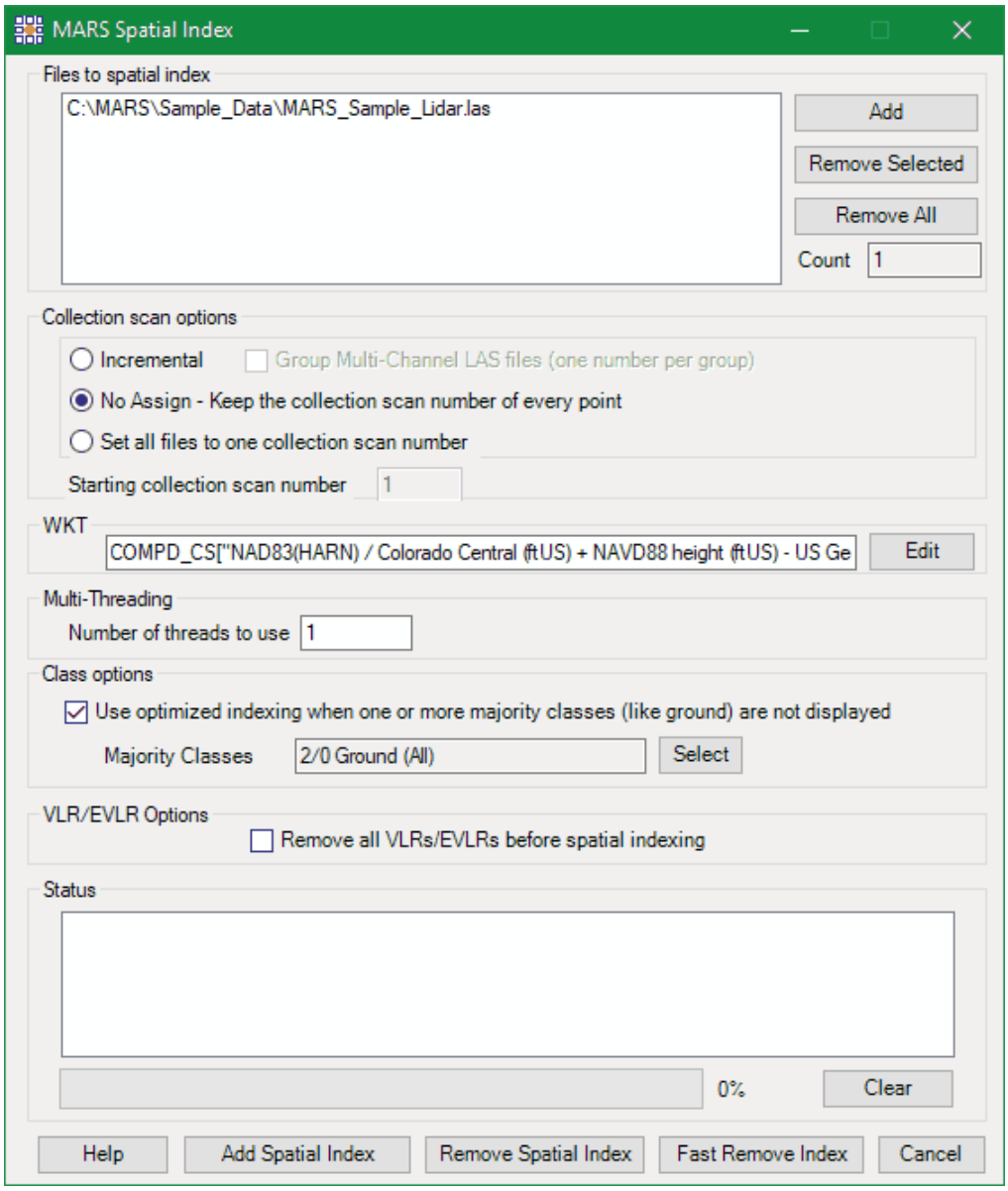
✓ VLR/EVLR options: The 'Remove all VLRs/EVLRs before spatial indexing' option (unchecked by default) can be used to completely remove *all* Variable Length and/or Extended Variable Length Records (not just indexing records) from the LAS files listed in the 'Files to spatial index' box during the 'Add Spatial Index' process. This function works only when adding indexing, not when using the 'Remove Spatial Index' or 'Fast Remove Index' buttons.

✓ Note: All files will be tested for empty 'System Identifier' header fields and, if found, will have this field populated with 'OTHER' (see the LAS file specifications on the ASPRS LAS File Format website). Files with values already in place will not have this field altered.

✓ Click 'Add Spatial Index' to index the data, or 'Remove Spatial Index' to delete any existing spatial index records. Removal will make LAS file sizes a little smaller, but will cause the files to be unloadable in future MARS sessions unless they are re-

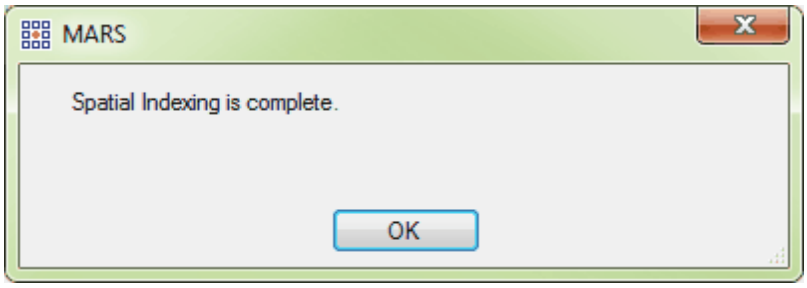
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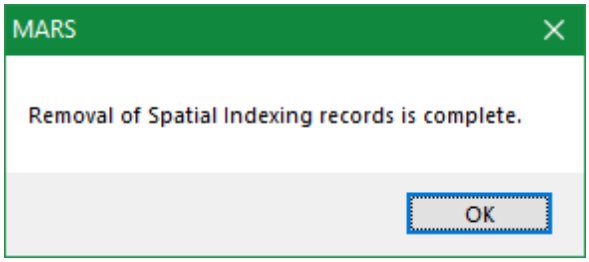
indexed. The 'Fast Remove Index' button will mark all indexing records as superseded (ignored) without actually deleting them. As with complete removal, this makes the files unreadable in future MARS sessions unless they are re-indexed, but the re-indexing process will be much faster. Either of the removal options may be helpful in loading data into other lidar software. Neither the 'Remove Spatial Index' function nor the 'Fast Remove Index' function will make any changes to collection scan numbering.

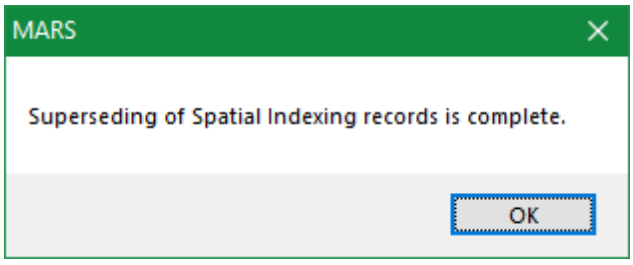


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When a spatial indexing or removal of spatial indexing is successfully completed, MARS® will alert the user with the following messages:







Clicking the 'Clear' button near the bottom of the interface will empty the 'Status' area so that more files can be spatially indexed.

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4.8.2 Advanced Profiler



 **Advanced Profiler:** This tool, found on the Export/Extract Tab[461], will create equally-spaced profile lines along a centerline at an interval specified by the user. This tool will perform on any polyline shapefile loaded into MARS®. There are three ways to use this tool: **1)** Using and showing only the centerline with *no profile lines*, **2)** using and showing *both* the centerline and profile lines, and **3)** using and showing only the profile lines with *no centerline*.

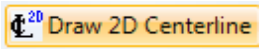
Parameters:

- **Centerline Shapefile:** Click 'Browse' to navigate to the centerline file to be used. This centerline file may be any polyline shapefile (.shp); for example - a road centerline, a stream centerline, or a river centerline.
- **Source Classifications:** Choose the 'Select' button to define which classifications will be used when creating the profile lines. To create an advanced profile line based on the ground surface, choose only those classes that represent the ground - typically Class 2 (Ground). Keep in mind that ground may exist in other classes, depending on the project data.
- **Interval along the Centerline:** The interval between profile lines (lines perpendicular to the original centerline shapefile) can be defined by the user here. A larger number indicates more space (horizontal units) between profile lines.
- **Profile Distance from the Centerline:** The user may specify the distance the profile line (which is perpendicular to the centerline) will extend from the centerline on both the right and left sides.
- **Draping Algorithm:** The user may choose to show and create the advanced profile by TIN or Grid. Using the Grid option allows the user to further define the grid cell size and to apply a Gaussian smoothing mechanism to the grid if need be.
- **Save Draped Centerline:** Checking this option will saved the draped centerline as well as the perpendicular profiles which lie along that line. When this option is not checked, MARS® saves only the profiles perpendicular to the centerline and not the draped centerline itself.

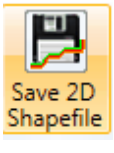
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- **Cut Depth:** This is the total width of the buffer (in project units) used to check for LiDAR points around the profile lines. Smaller values will speed processing and allow for longer input centerlines, but accuracy may suffer if there are not enough points in the Source Classifications in this buffer area.
- **Output Options:** Choose the output type - 'Save As Shapefile' for a 3D shapefile, 'Save As CSV' for a file of XYZ values that can be opened in Excel, or 'Save As DXF (2D Cross Section and Centerline)' for engineering use in a CAD program. Use the 'Browse' button to the right of the 'Output Shapefile', 'Output CSV file', or 'Output DXF File' text box and navigate to the output folder the advanced centerline shapefile, CSV file, or DXF file should be saved in. Name the new file, and click 'Save'. For the 'DXF' option, make the appropriate entries in the 'Number of Columns', 'X Step', 'Z Step', 'Vertical Exaggeration', and 'Beginning Station Number' text boxes. The effect of these five parameters can be seen in the examples at the bottom of this page.

Using the Advanced Profiler tool:

1) First use the **'Draw 2D Centerline'** tool on the Vector Creation Tab 364 to create a 2D shapefile centerline line along an area which is to be profiled. Do this by selecting the **'Draw 2D Centerline'** 

button and then left-clicking along the desired line. Right-click to end the centerline. In the examples below, the 2D centerline was drawn along a river.

2) To save this 2D centerline for use in the Advanced Profiler tool, click on the **'Save 2D Shapefile'** 

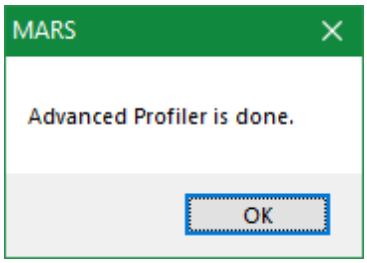
button. At this time, the 2D centerline just created will be unloaded from MARS®, but will be saved in the output folder which was specified by the user.

3) Click on the **'Advanced Profiler'**  button to bring up the interface. The parameters inside

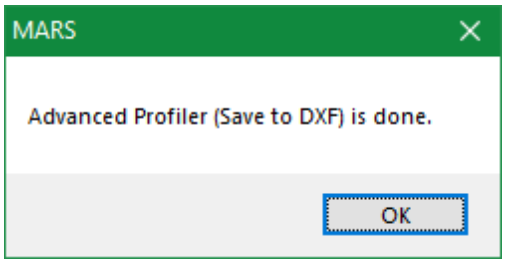
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the interface are described above. Choose the particular settings which are needed and click **'OK'** when finished. When an advanced profile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data, and if the output type is Shapefile. Please see the bottom of this section for more information on the three (3) different uses of this tool.

4) When the advanced profile has been created, the user will be notified with one of the following pop-up messages (depending on the output type):



for shapefile or CSV **-- or --**



for DXF

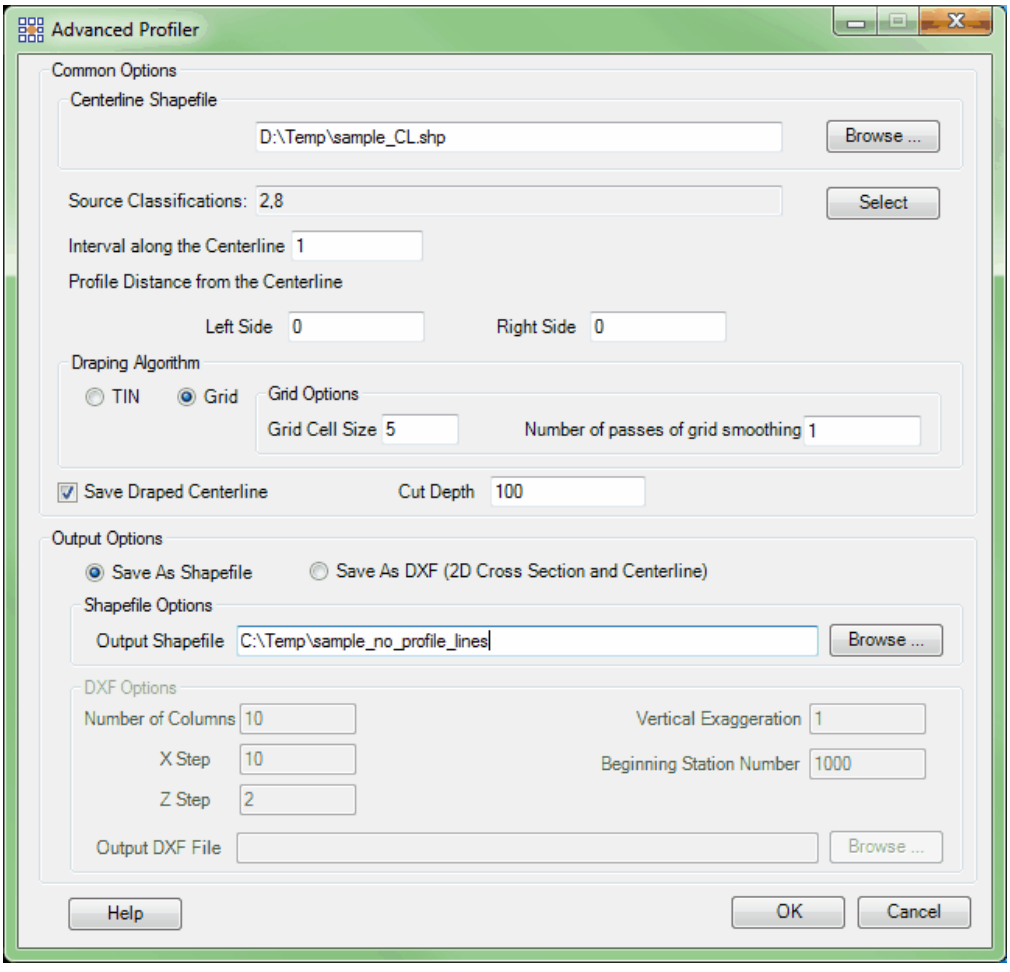
5) The advanced profiler has now created a 3D shapefile, CSV file of XYZ values, or 2D DXF file and stored it in the folder, and with the name, designated by the user. To load a newly created shapefile in MARS®, click on the **'Add Reference Shapefiles'** button on the Project/Data Preparation Tab 162. The shapefile will appear in the Table of Contents under the 'Vectors' layer, and can be viewed in either 2D or 3D. To open the CSV file, use Excel or a text editor. To view the output of the 2D DXF file option, load the file in any CAD or GIS program that can read DXF files.

6) To remove a loaded shapefile from MARS®, right-click on the file in the Table of Contents and choose 'Remove'.

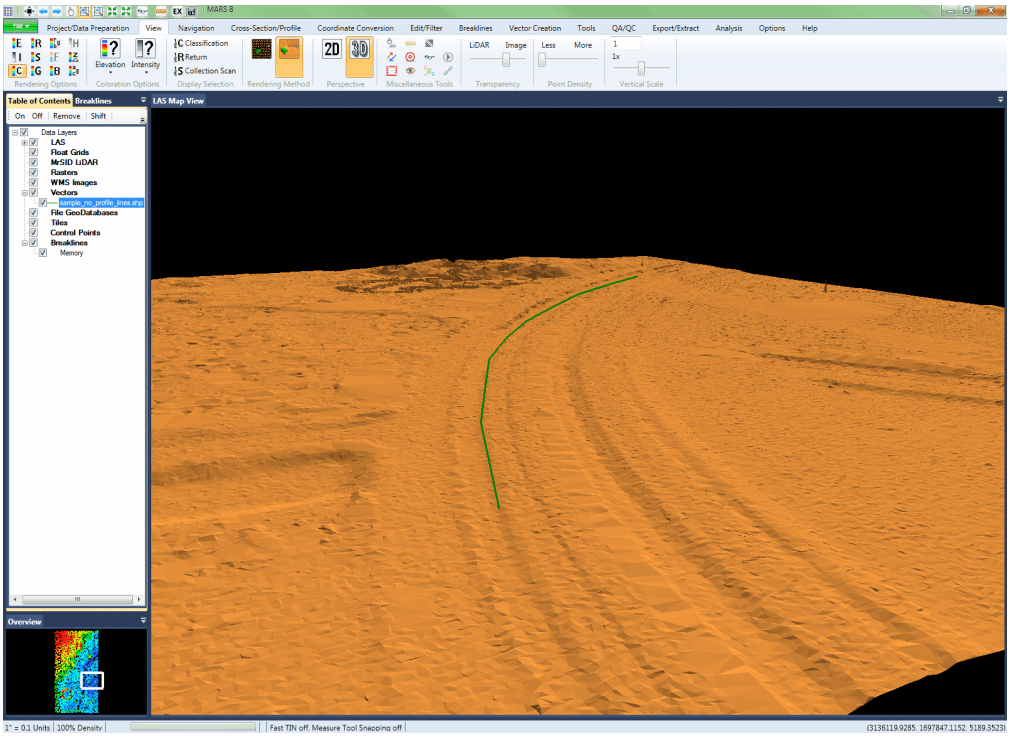
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The three uses of the Advanced Profiler tool:

1) Below is an example of the advanced profiler being used in 3D and showing only the centerline with *no profile lines*. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings are to enter a '0' in both the 'Left Side' and 'Right Side' text boxes. This tells MARS® to create profile lines with a length of '0' (zero), which would create no profile lines at all. Make sure the 'Save Draped Centerline' option *is chosen* to create the 3D centerline shapefile.

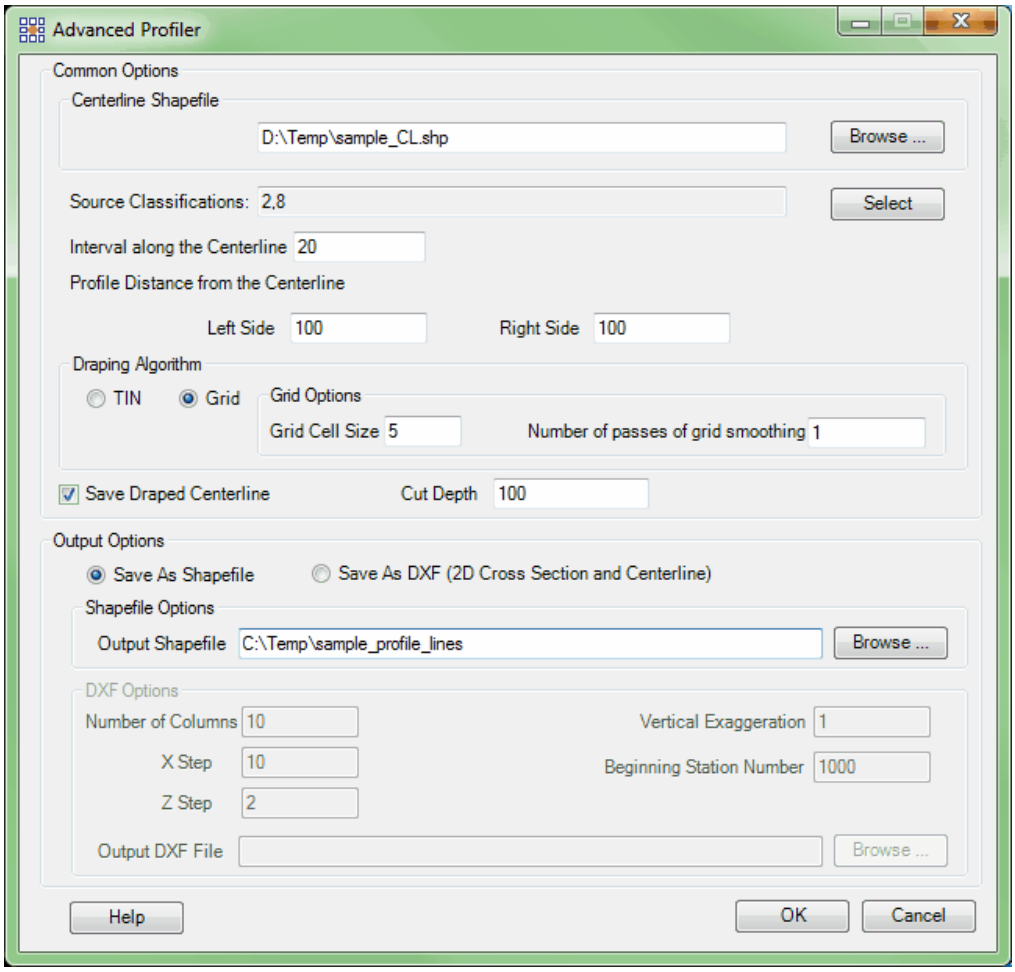


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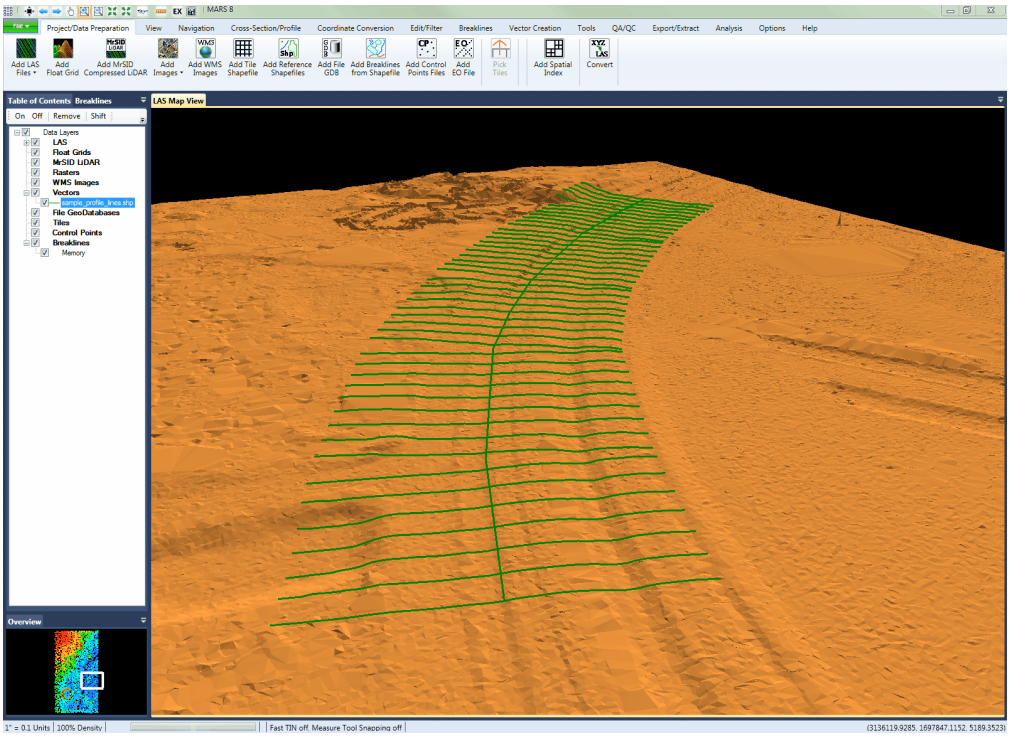


2) Below is an example of the advanced profiler being used in 3D and showing ***both*** a centerline and the profile lines associated with it. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings in this case are to enter an integer in both the 'Left Side' and 'Right Side' text boxes and in the 'Interval Along the Centerline' text box. This will create the profile lines perpendicular to the centerline. Make sure the 'Save Draped Centerline' option ***is chosen*** to also create the 3D centerline.

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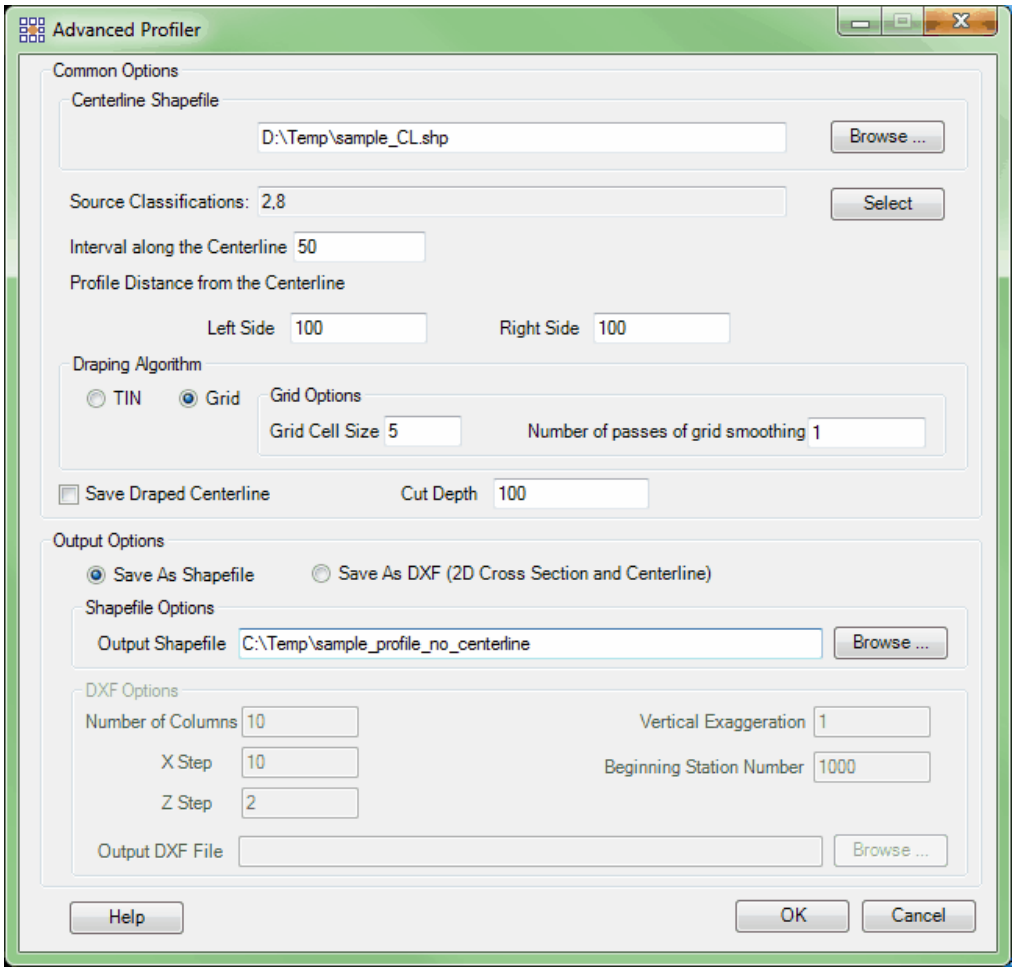


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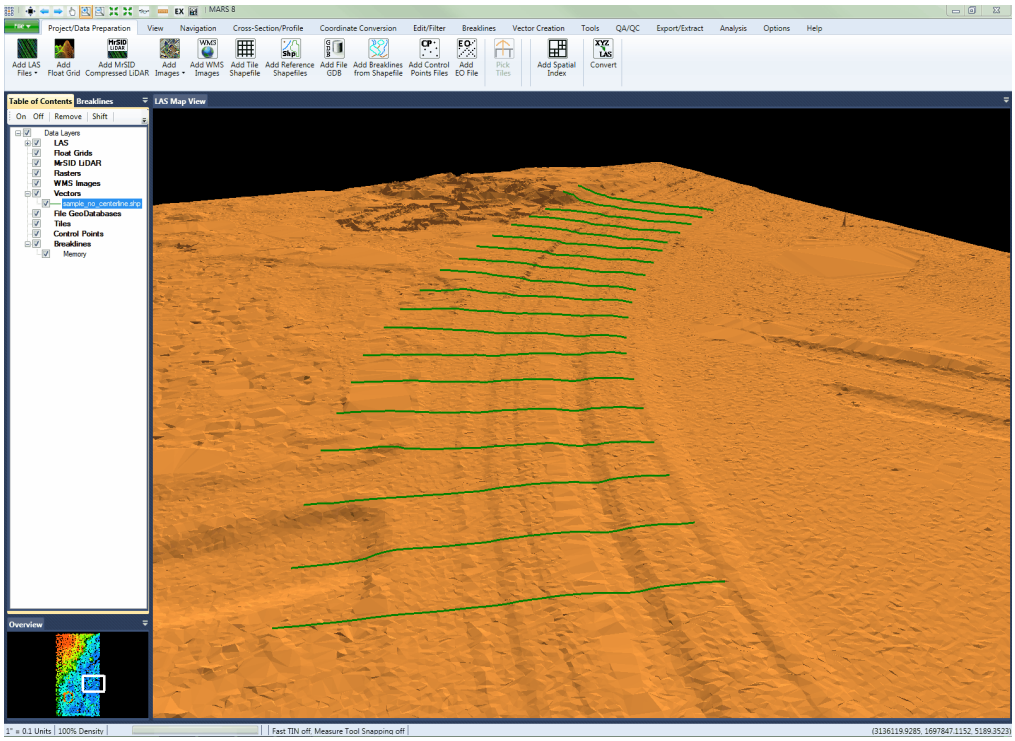


3) Below is an example of the advanced profiler tool being used in 3D and showing only the profile lines with *no centerline*. The corresponding settings are also shown in the 'Advanced Profiler' interface. The most important settings in this example are to enter an integer in both the 'Left Side' and 'Right Side' text boxes and in the 'Interval Along the Centerline' text box. This will create profile lines. Make sure the 'Save Draped Centerline' option is *unchecked* so a 3D centerline will *not* be created.

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CSV Output:

The table excerpt below shows the formatting of the CSV file output. The first column is the feature number, then X, Y, and Z in the last column. Feature number is based on start to end of the centerline used to generate the profile info. For example, if only the centerline is saved (example 1 of **'The three uses of the Advanced Profiler tool:'** topic, above), the feature number will be the same for all XYZ values of the centerline. If both the centerline and the transects (profile lines) are saved (example 2, above), the transects will be numbered from the beginning of the centerline to its end (as it was compiled) and the final feature number will be the centerline itself. If only the transects are saved (example 3, above), they will be numbered from the beginning of the centerline to its end as mentioned above.

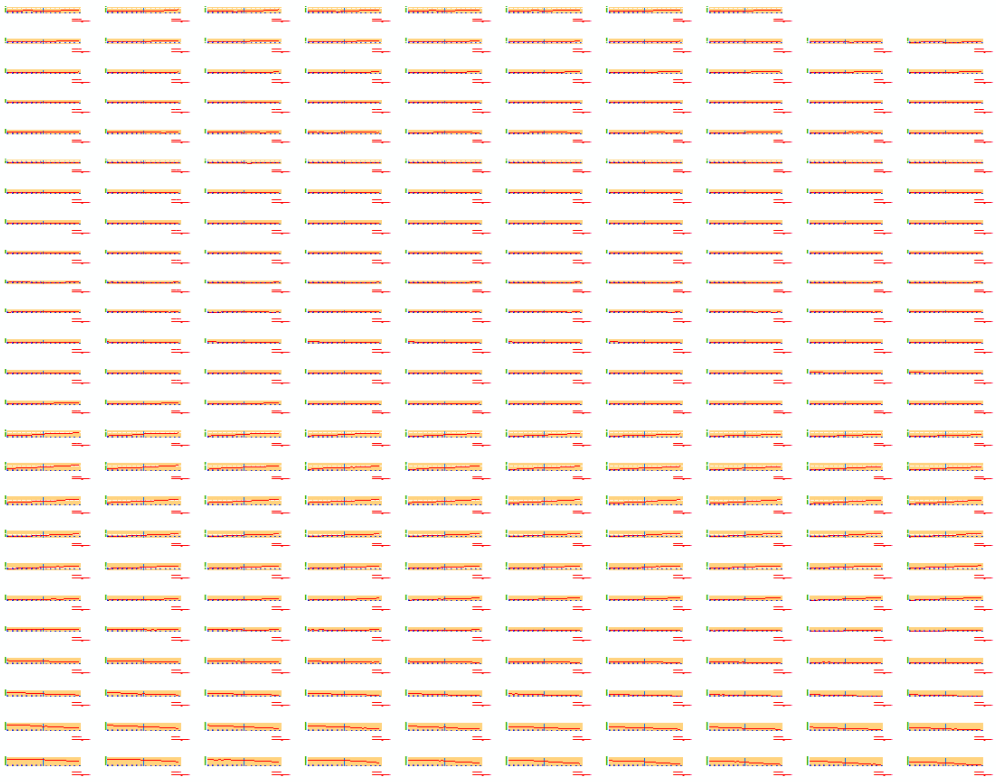
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	A	B	C	D	E
59	1	3134971.709	1697563.599	5215.602	
60	1	3134973.081	1697560.931	5214.856	
61	1	3134974.453	1697558.264	5214.469	
62	1	3134975.825	1697555.596	5214.294	
63	1	3134977.197	1697552.928	5213.974	
64	1	3134978.569	1697550.26	5213.974	
65	1	3134979.941	1697547.592	5213.758	
66	1	3134981.314	1697544.924	5213.705	
67	1	3134982.686	1697542.256	5213.392	
68	2	3134918.809	1697732.056	5230.824	
69	2	3134920.181	1697729.388	5229.692	
70	2	3134921.553	1697726.72	5229.02	
71	2	3134922.925	1697724.052	5229.042	
72	2	3134924.297	1697721.384	5228.855	
73	2	3134925.669	1697718.717	5228.742	

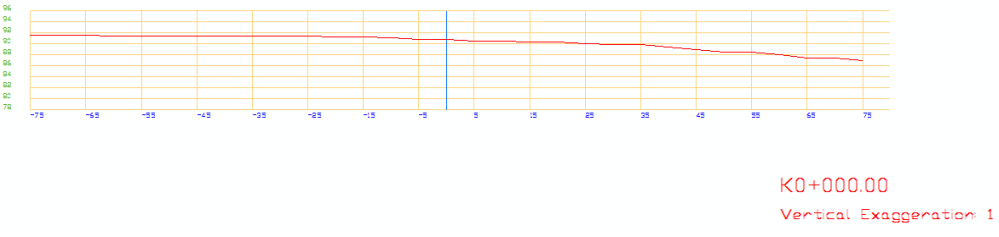
DXF Output:

Below are examples of the output when the 'Save As DXF' option is chosen. The first image shows the complete DXF with the profiles drawn at every 10 feet along the centerline ('Interval Along the Centerline' setting), starting in the lower left corner and proceeding to the right. Note the ten columns of profiles as per the 'Number of Columns' setting in the interface.

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A detail view of one profile from the above DXF is shown below. As per the parameters in the interface, the 'X Step' is 10 units (vertical tan-colored lines with blue annotation), the 'Z Step' is 2 units (horizontal tan-colored lines with green annotation), and the 'Vertical Exaggeration' is set to 1 (one vertical unit per one horizontal unit). The blue vertical line represents the position of the centerline, and the 'Left Side' and 'Right Side' values in the interface are set to 75 units. The red line shows the actual elevations of the profile line at this particular station (K0+000.00 units along the centerline - this is the beginning of the centerline where the first profile was created). The 'Beginning Station Number' can be set as needed, and the calculated values will be shown in the lower-right of each profile.



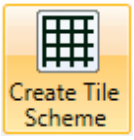
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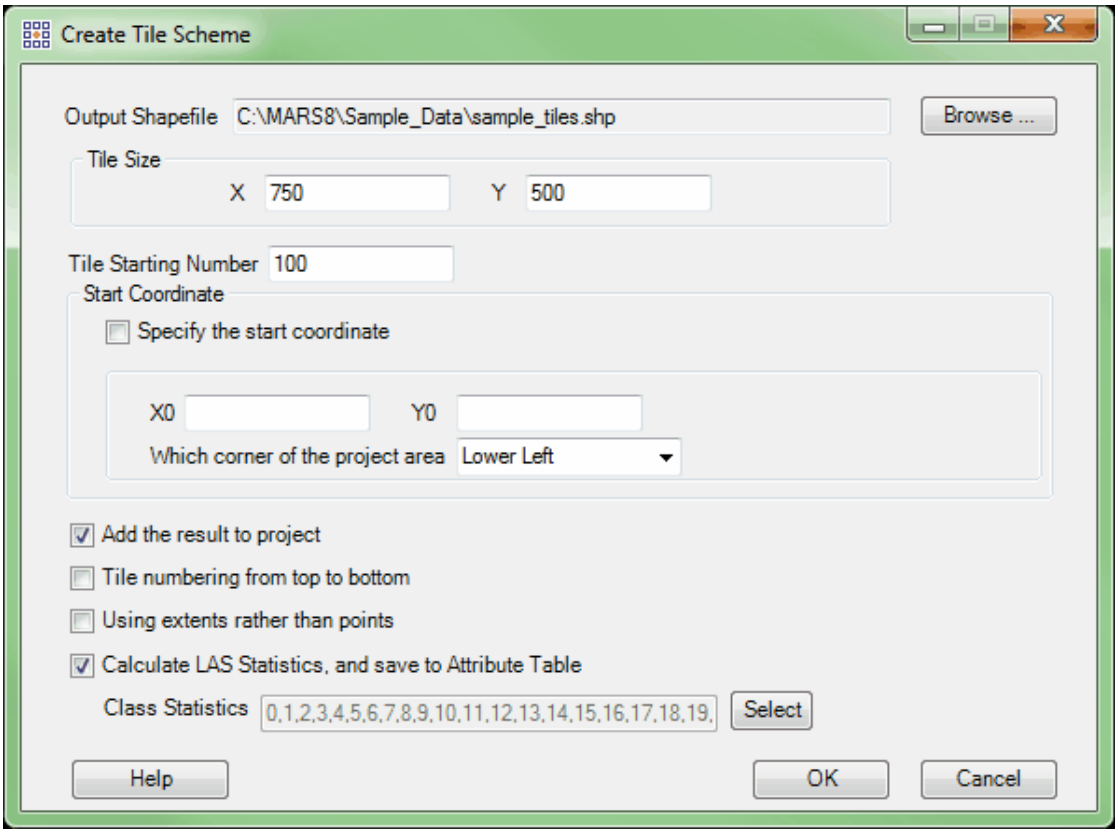
4.8.3 Create Tile Scheme



To use the Create Tile Scheme tool, found on the Vector Creation Tab 364, follow the instructions below:

Create Tile Scheme: This option 

allows the user to create a unique tile layout. The newly created tile layout will be found under the 'Tiles' 121 layer in the Table of Contents 67 where only one shapefile can be loaded at a time. If a tile shapefile is already loaded under the 'Tiles' layer, it will be removed and the new tile layout will be loaded in its place automatically.



- ✓ **Output Shapefile:** Click the 'Browse' button to designate an output folder and name for the tile shapefile being created. Once this is completed, click 'Save'. When a tile shapefile is generated, a *.prj (projection definition file) is created if the projection information is known for the source LAS data.
- ✓ **Tile Size:** Specify an X and Y length for the sides of each tile. A larger number in either text box will denote a larger tile.
- ✓ **Tile Starting Number:** Choose a number for the Tile Name labeling to start at. The tiles will be named upward from the number specified (for example, if 100 is the starting number, tiles numbered 101, 102, 103, 104... will follow).
- ✓ **Start Coordinate:** If the user would like to specify the coordinate at which the tile layout should start, check the 'Specify the start coordinate' check box. The X and Y coordinates may be specified in the text boxes following this option. After specifying

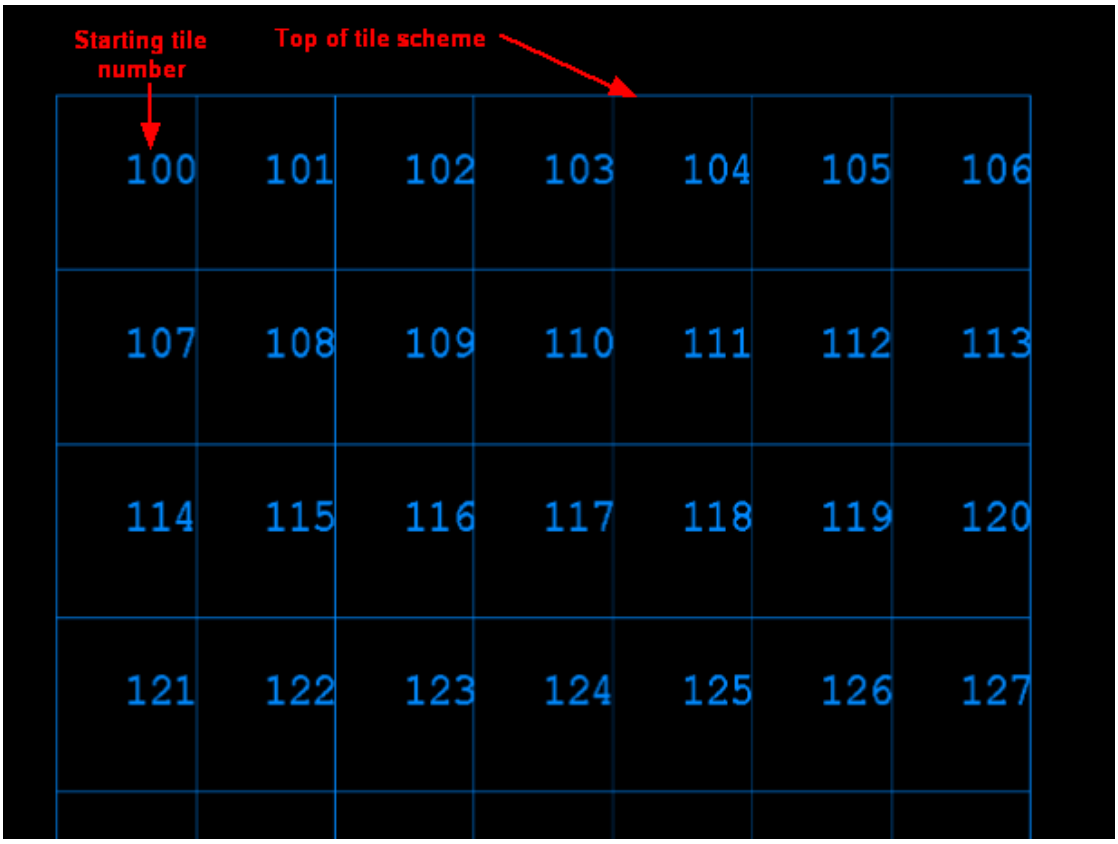
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the coordinates, the user may further define which corner of the created tile layout that the coordinates will represent. The user may choose from: Lower Left, Upper Left, Upper Right, Lower Right.

- ✓ **Add the Result to Project:** Checking this box option will load the new tile layout to the project after it is created. If a tile shapefile is already loaded into MARS® under the 'Tiles' tab and this option is checked, the shapefile already in MARS® will be removed and the new tile shapefile will take its place under the 'Tiles' tab. If this box is left unchecked, the new shapefile will not be loaded into MARS® upon creation, but it can be found in the output folder.
- ✓ **Tile numbering from top to bottom:** If this box is checked, the tiles will be labeled starting at the top left tile of the tiling layout and count upward, labeling tiles from left to right. When the end of the row is reached, the labeling will continue on the second row from the top on the left most tile and continue from left to right. If this box is left unchecked, tile labeling will begin in the bottom right tile in the tiling layout. Tiles will be labeled counting upward from left to right. When the end of the row is reached, labeling will continue in the second row from the bottom in the left most tile and count upward from the left end tile to the right end tile. See the screen shots below for visual examples.

EX: The following is an example of tile labeling with the 'Tile numbering from top to bottom' option chosen.

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EX: The following is an example of tile labeling without the 'Tile numbering from top to bottom' option chosen.

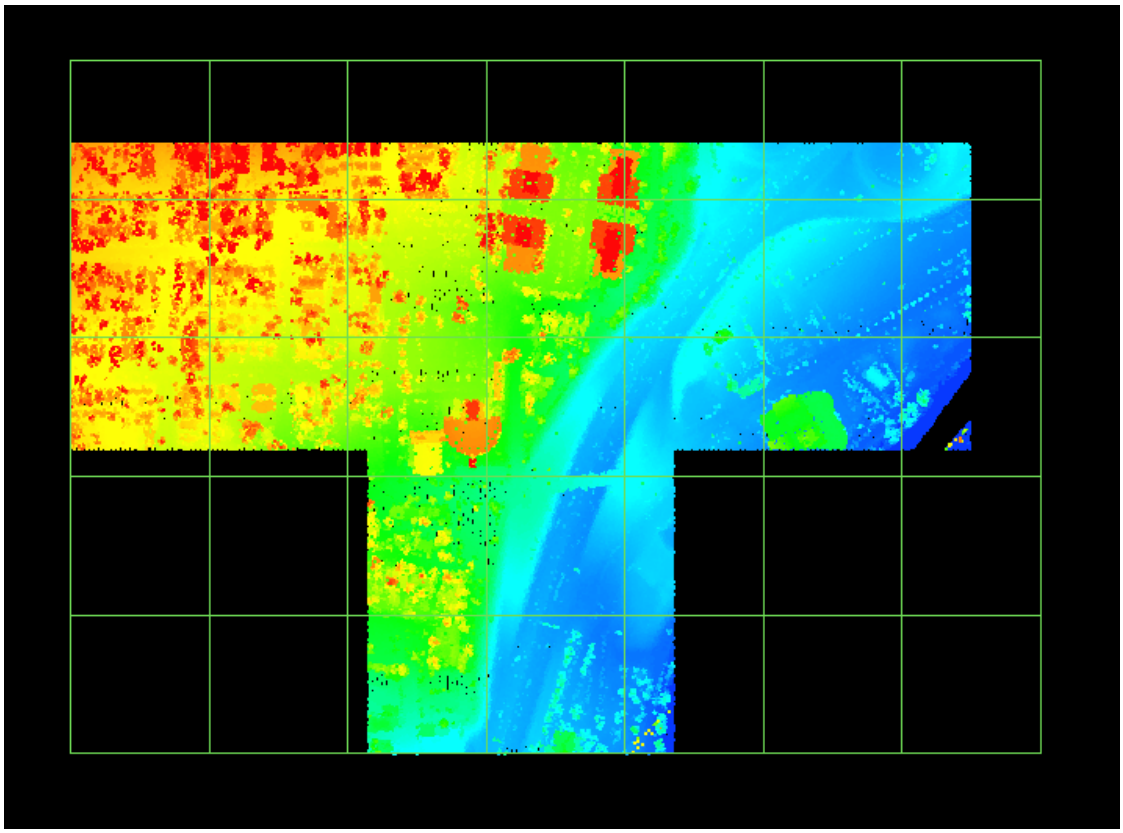
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✓ **Use extents rather than points:** Checking this option will produce an MBR rectangular tile layout that incorporates the extents of the data. In this case, some tiles in the tile layout that is produced may be empty tiles. To create a tile layout which only creates tiles which carry data, uncheck this option.

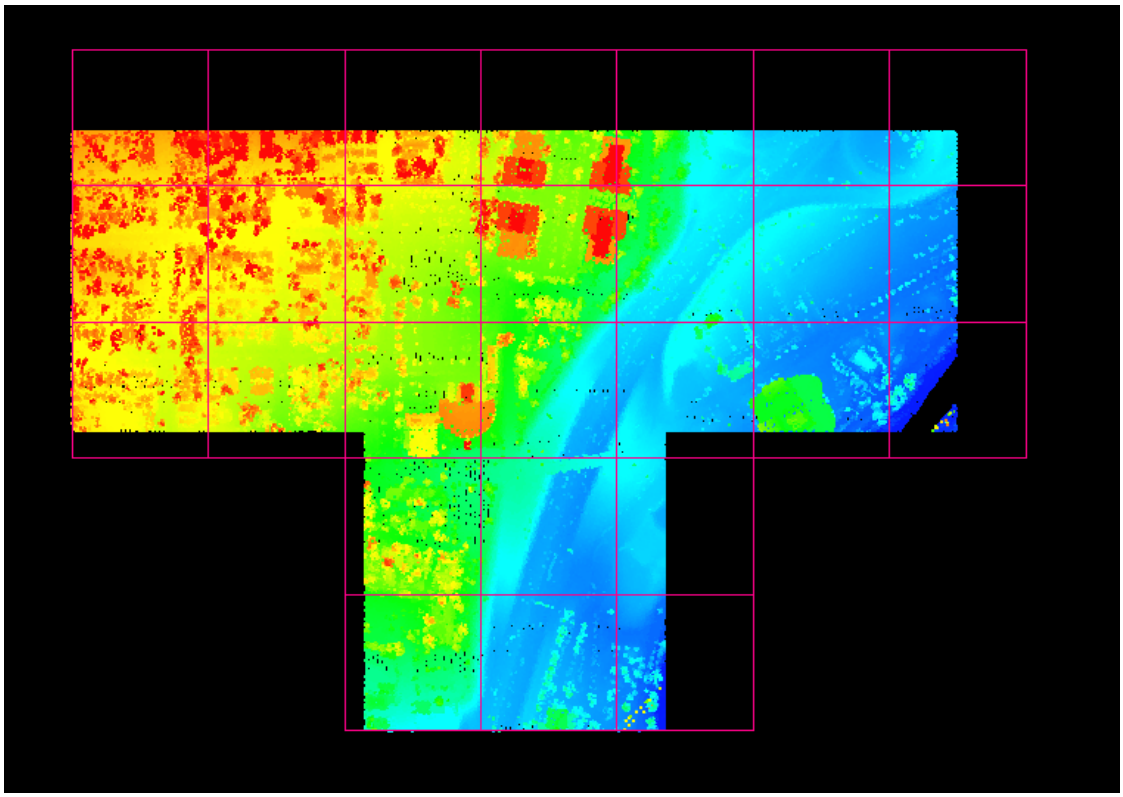
Ex. Tile layout created with the 'Use extents rather than points' option checked. Some empty tiles are produced to make the tiling layout rectangular.

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Ex. Tile layout created with the 'Use extents rather than points' option unchecked. Empty tiles are avoided and the tiling layout is produced based on LiDAR points instead of the data extents.

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✓ **Calculate LAS Statistics, and save to Attribute Table:** This option allows the user to create statistics for each LAS tile. By choosing this option, the user will make the 'Class Statistics' option available - the classes to be included in the statistics can then be selected. This option will populate the following statistics in the output tile shapefile attribute table:

ID: A uniquely generated ID number for each tile created.

TName: The TName is a uniquely-generated tile name with a starting number specified by the user.

AREA: The area in square project units of a particular tile.

ALLPCOUNT: A count of the total number of points within a particular tile.

DENSITY: The point density in points per square unit (using first

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returns only).

AVG_GSD: The average GSD (ground sample distance).

X_MIN: The x axis (easting) minimum within a particular tile.

X_MAX: The x axis (easting) maximum within a particular tile.

Y_MIN: The y axis (northing) minimum within a particular tile.

Y_MAX: The y axis (northing) maximum within a particular tile.

Z_MIN: The z axis (elevation) minimum within a particular tile.

Z_MAX: The z axis (elevation) maximum within a particular tile.

Z_DELTA: The difference between Z_MAX and Z_MIN within a particular tile.

COLL_SCAN: A listing of the different collection scan numbers which overlay a particular tile.

GPS_MIN: The GPS time (timestamp) minimum found within a particular tile.

GPS_MAX: The GPS time (timestamp) maximum found within a particular tile.

MIN_INT, MAX_INT, MEAN_INT, MED_INT, and **MODE_INT:** Various intensity value statistics.

RETURN_0: The number of 'other' returns found within a particular tile (returns that are missing or have incorrect point family info).

RETURN_1 through **RETURN_15:** The number of first returns through fifteenth returns (listed in individual attribute fields) found within a particular tile.

SYNTHETIC: The number of points bit-flagged as 'Synthetic' found within a particular tile.

MKP: The number of points bit-flagged as 'Model Key-point' found

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within a particular tile.

WITHHELD: The number of points bit-flagged as 'Withheld' found within a particular tile.

OVERLAP: The number of points bit-flagged as 'Overlap' found within a particular tile.

Class0 through **Class255:** The number of points in each class (listed in individual attribute fields) is recorded per tile.

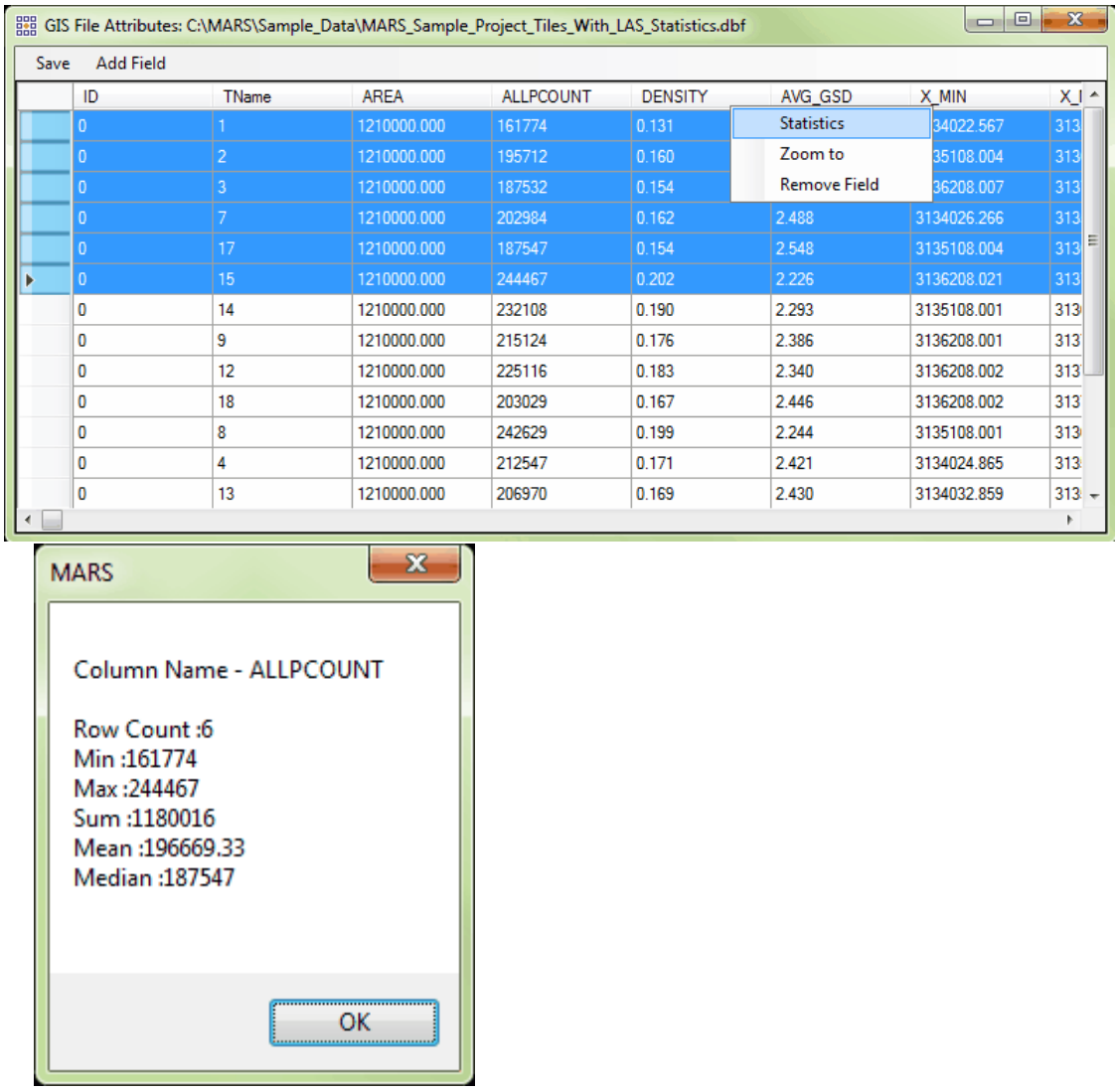
ClassWH0 through **ClassWH255**: The number of Withheld bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

iShape: A MARS®-specific value that is not relevant for the user.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>*'* fields that are zeroed out for every tile will be omitted from the final attribute table to simplify analysis.

It is also possible to view the statistics of attributes in a shapefile. The user may view the statistics of a single attribute, the statistics of an entire row or column, or the statistics of an entire table. Highlight the attributes of which statistics are to be viewed, right-click and choose 'Statistics'. The resultant table will tell the user the following statistics: the row count, minimum, maximum, sum, mean (average), median, and mode of every attribute. To select multiple attributes for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In the example below, the user is choosing to view the statistics of six rows of data for the 'ALLPCOUNT' field. The resulting statistics are also shown below.

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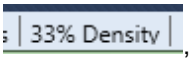
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4.8.4 Flood Fill

Flood Fill Tool

Merrick Advanced Remote Sensing (MARS®) Software

Flood Fill: This tool 

, found on the Analysis Tab 489, creates a virtual flood fill graphic that allows the user to view areas of the loaded LAS data which would be inundated during a flood. To use this tool, click on the 'Flood Fill' button and the 'Flood Fill' dialog box will appear. The user may specify the water elevation (MSL) to analyze by entering a value in the 'Elevation' text box or by using the 'Elevation' slider to simulate different flood levels. The user may also choose the color and transparency of the flood fill graphic. When all the selections have been made or when changing any of the parameters, click 'Display' to see the results. If the data is not already being rendered in TIN mode, the tool will change to, and stay in, that mode. The density of the LiDAR data currently being displayed, as shown on the left side of the Status Bar 158 

, will affect the accuracy of the TIN and, therefore, the flood fill. To obtain the most accurate results, the data should be viewed at 100% density. In 2D viewing mode, imagery may be used to aid in the flood analysis, but will be temporarily toggled off when switching to 3D viewing mode.

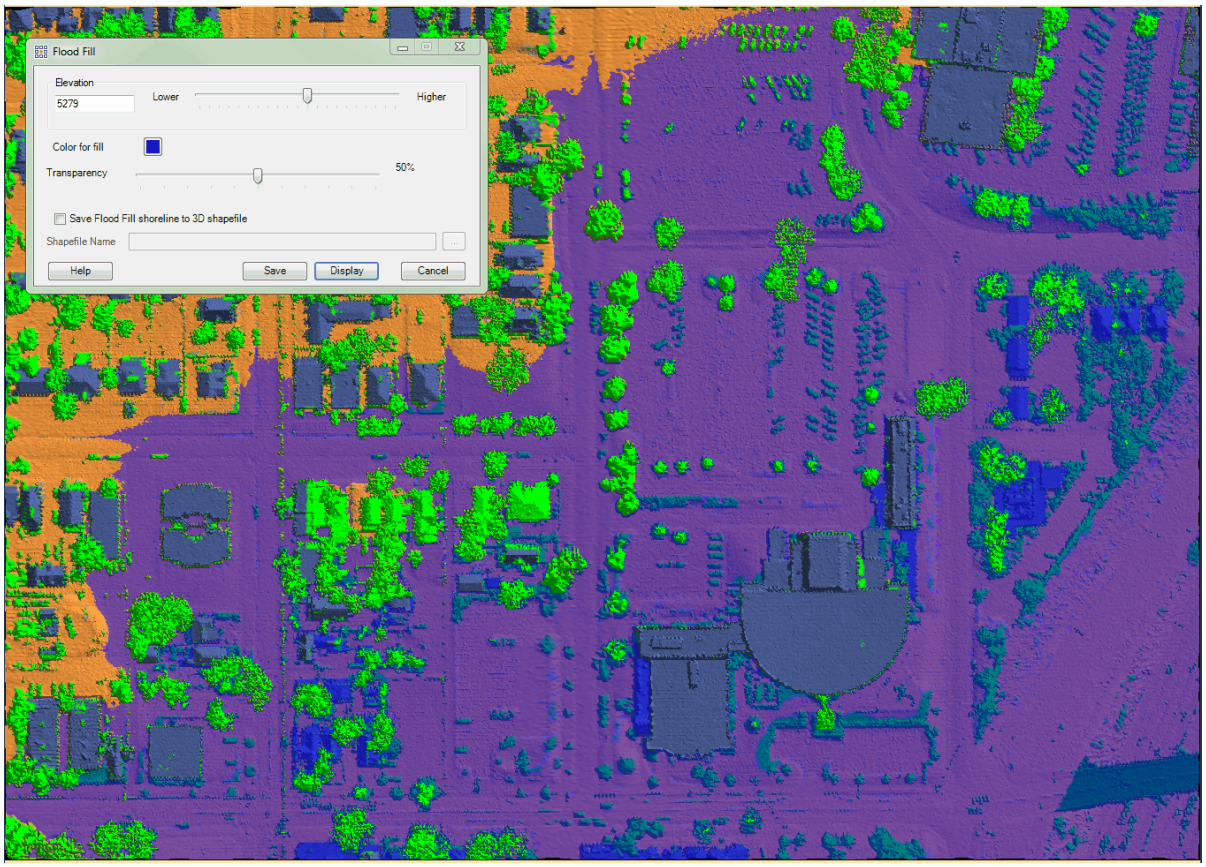
It is also possible to save the flood fill shoreline to a 3D shapefile. Check this option and choose a shapefile path and name to create a 3D shapefile, then click 'Save.' To dismiss the flood fill graphic, click 'Cancel' in the dialog box.

The examples below show the difference in flooding effects that can be expected at different water surface elevations. The example on the left is flooding up to an elevation of 5263 feet. The example on the right shows flooding up to 5277 feet. Note that the chosen fill color will change appearance depending on the way the data is colored.

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Another example of the Flood Fill tool in a 3D view:



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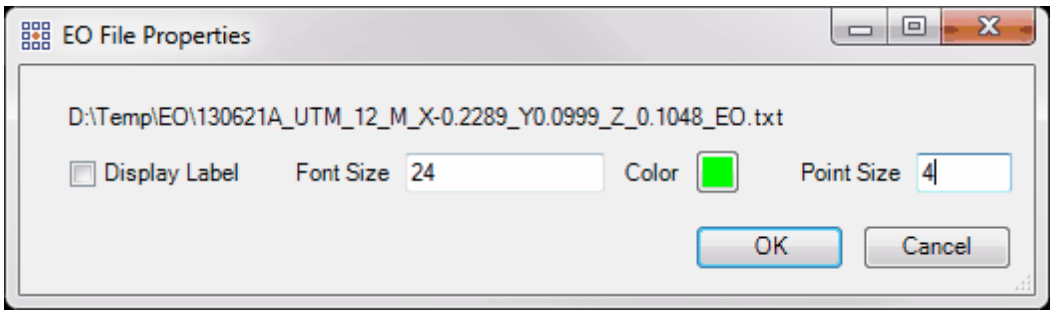
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4.8.5 Hyperlink

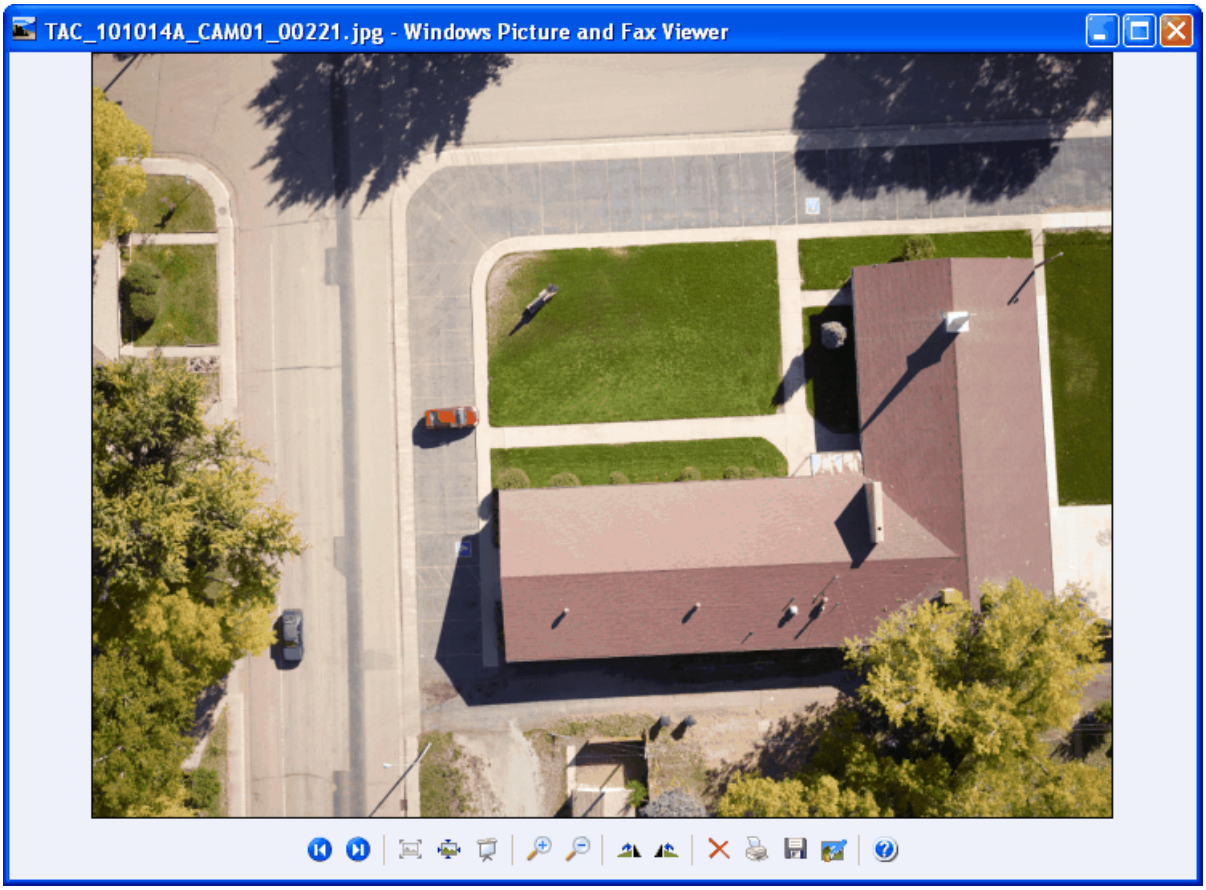
Hyperlink Tool

Merrick Advanced Remote Sensing (MARS®) Software

Hyperlink: The Hyperlink tool, found under the 'Miscellaneous Options' section of the View Tab 192, is associated with the 'Add EO File' tool which is located on the Project/Data Preparation Tab 162 tab. In order to use the Hyperlink tool, an EO file must be loaded into MARS® along with its associated imagery path. For more information concerning adding an EO file, please see the Project/Data Preparation Tab 162 topic. Once an EO file is loaded into MARS® the Hyperlink button will become enabled. The purpose of the Hyperlink tool is to provide the user with a way to display an aerial image associated with a particular EO event point. The EO file is displayed as a 3D point shapefile and each point, or event, in the EO shapefile is associated with imagery. Because it is displayed as a shapefile, it is also possible to change the display settings of an EO file by right-clicking on the file inside the Table of Contents and choosing 'Properties'. The resulting 'EO File Properties' window will allow the user to change the color and size of the point shapefile and will also allow the user to display labels.



When the user selects a point with the Hyperlink button toggled on, the associated image is then brought up in the Windows default viewing program. Below is an example of the imagery which will appear when an EO event point is selected. If the user selects a point from an EO file linked to RGB nadir imagery, this is the imagery which will be displayed. The same methodology applies for linking to CIR nadir, forward-facing, and aft-facing imagery.



It is possible to display multiple EO files at once in MARS®. The Hyperlink tool will only display imagery with an associated EO file which is currently displayed in MARS®. For example, if the user has a separate EO file loaded for the CIR nadir, RGB nadir, forward-facing, and aft-facing imagery, it can be difficult to select the proper EO event file to bring up only one type of imagery. By using the options within the Vectors 95 layer of the Table of Contents 67 to turn off the display

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of EO files which are not currently needed, it is much easier to select the proper point for display. It is possible to save all loaded EO files, paths to imagery, and any raster files which may be loaded to a MARS® project file (*.mpd) for use at a later time.

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4.8.6 Inspect



Inspect: This utility displays the attribute information of a single displayed LiDAR point, virtual contour line, check point, or shapefile feature (including breaklines), and it can be used in 2D View[835] or in the Cross-Section/Profile[240] window. The 'Inspect' tool can be found on the View Tab[192], Cross-Section/Profile Tab[240], and the Analysis Tab[489]. For LiDAR data, the chosen point will flash twice and then remain highlighted in white with a larger symbol size to identify itself when selected for inspection. If a Cross-Section/Profile window is open, the point may be chosen in either view, and will be highlighted in both views. The one exception to this is in the Cross-Section/Profile window, where the Inspect tool will identify the file name and collection scan number rather than a point when the data is viewed in Profile by Collection Scan mode.

For virtual contours, a pop-up will display with the chosen contour's elevation. For displayed check points, the selected point will be highlighted as defined in the 'Selected Feature Highlighting' section of the 'Display' interface on the Options Tab[519], and a pop-up will display the point's ID, XYZ values and (if stored), a description, the point's NVA / VVA status, and the survey date of the point. For displayed shapefiles (other than those loaded as tile layouts) and breaklines, the selected feature will be

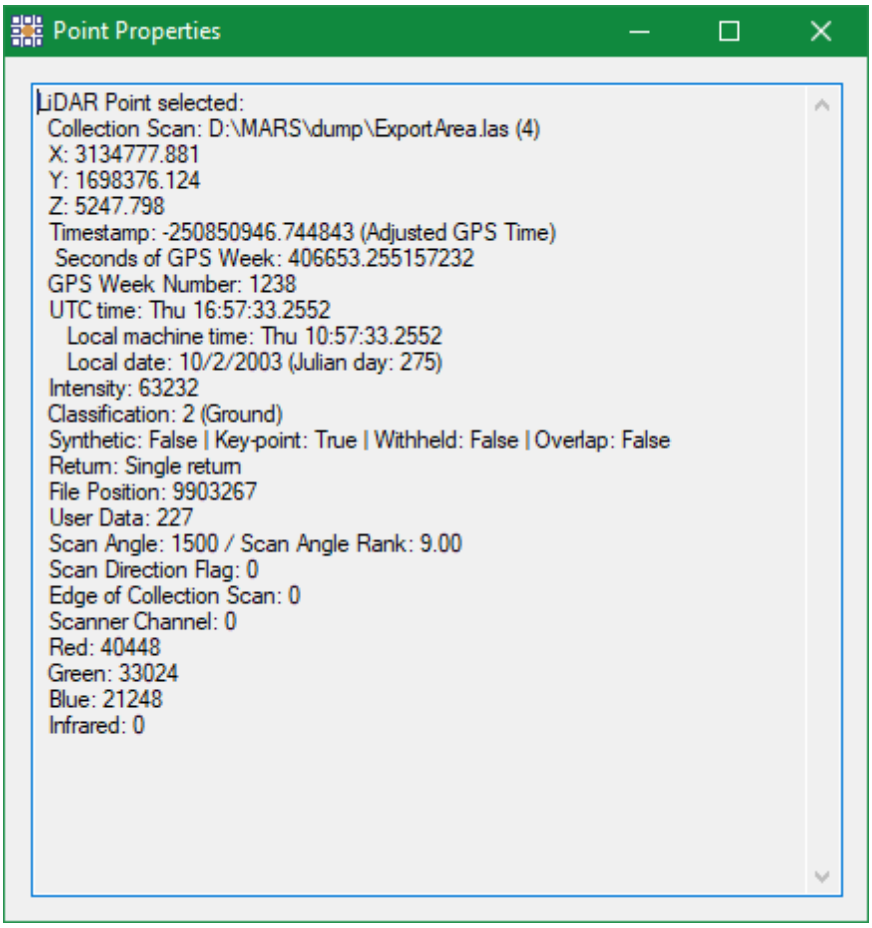
highlighted as defined in the 'Selected Feature Highlighting' section of the 'Display' interface on the Options Tab[519], and a Properties table will be displayed with X, Y, and Z (if 3D) information.

The following information is displayed for an inspected v1.4 PDRF 8 LiDAR point using Adjusted GPS Time (note that some fields are dependent on the data collected and the post-processing software used). Other LAS versions and PDRFs will vary from this example.

- Parent file path and point source ID (PSID) number
- X coordinate
- Y coordinate
- Z coordinate
- Timestamp (Seconds of GPS Week, GPS Week Number, UTC time, local machine time, local date, and Julian day)
- Intensity value (pulse return magnitude, values 0 - 255)
- Data Classification (0 – 255) and description
- Bit Flag status for Synthetic, Key-point, Withheld, and Overlap *(not stored for pre-LAS v1.4 data)*
- Return number (pulse return number out of number of discrete returns for a given outgoing pulse)
- File position
- User Data
- Scan Angle and legacy Scan Angle Rank (angle from nadir - including aircraft roll - that the point was output from the scanner. Negative is to the left as scanner moves forward, positive is to the right).
- Scan Direction (value = 0 for scanner mirror moving right to left as scanner moves forward, value = 1 for left to right)

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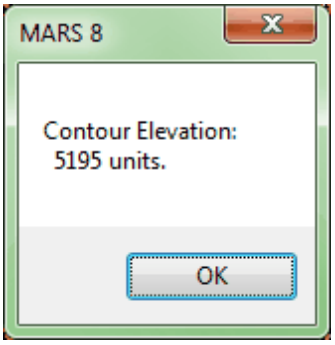
- Edge of Collection Scan
- Scanner Channel (single channel sensors will have all values set to 0)
- Red (color value in 16-bit format)
- Green (color value in 16-bit format)
- Blue (color value in 16-bit format)
- Infrared (color value in 16-bit format)



Elevation information is displayed when a virtual contour line is inspected. To inspect a virtual contour, make sure the **'Inspect'** tool is toggled on, and then hold the **'Ctrl'** key on the keyboard while clicking on the contour line to be inspected. The **'Ctrl'** key instructs MARS® to select the closest feature,

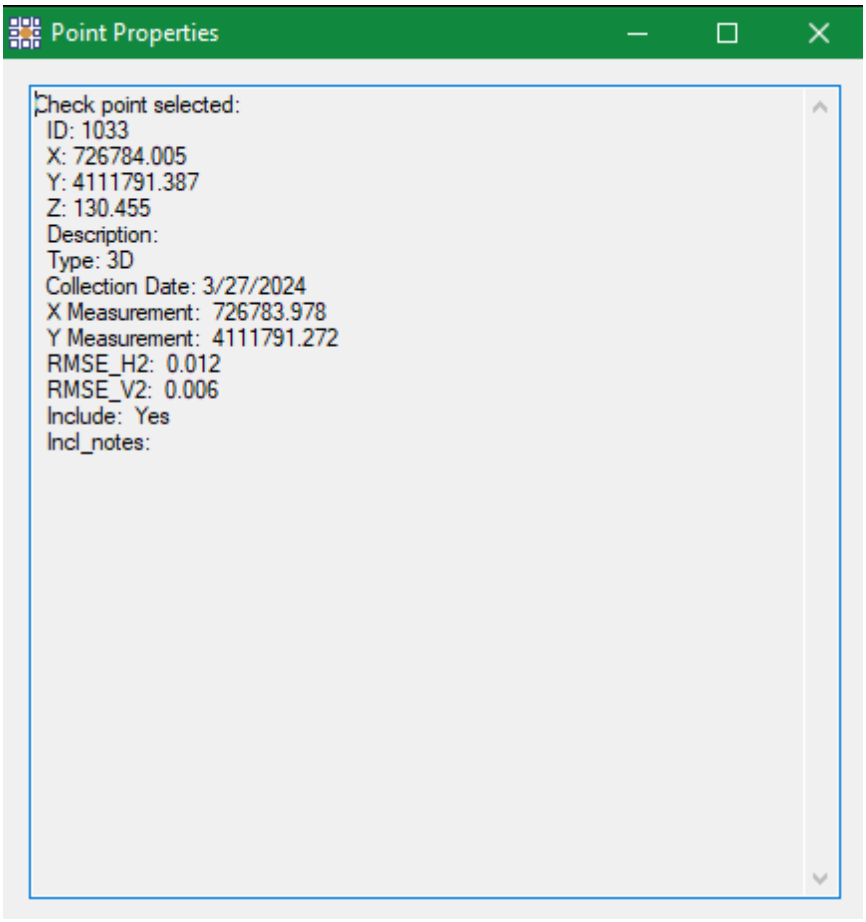
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other than a LiDAR point, for inspection. The following window will appear when a virtual contour line is inspected.



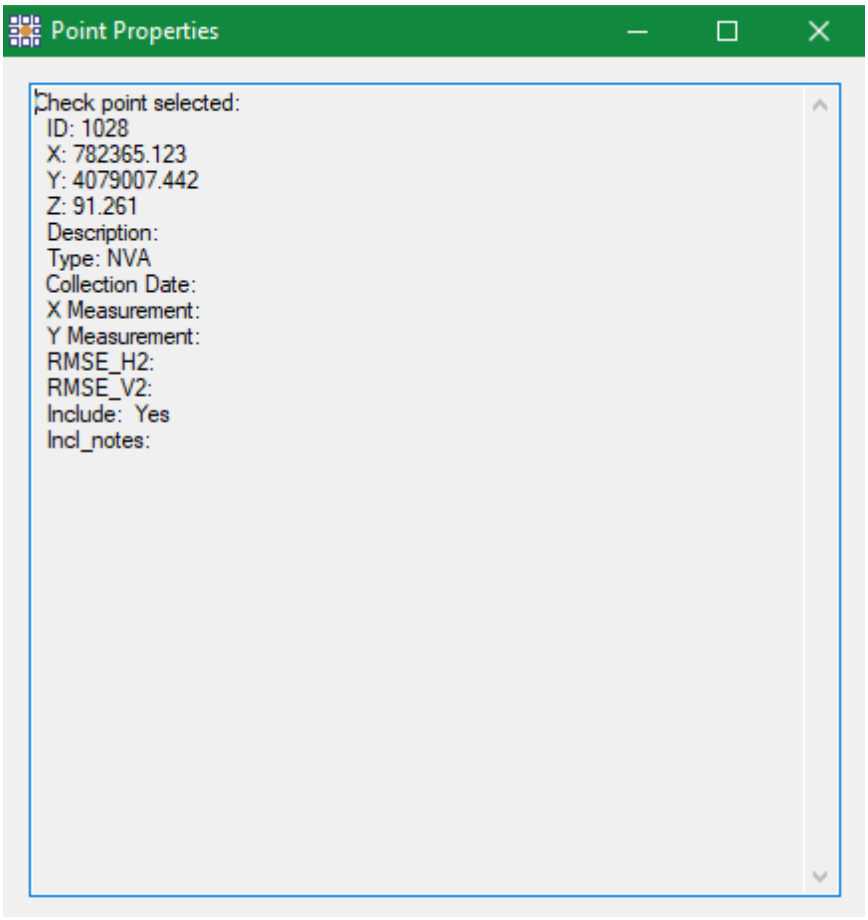
To select a displayed check point for inspection, click on the desired check point (the LAS data may need to be turned off to avoid selecting a LiDAR point instead). For points in a full 13-column check points CSV file, the window that opens will display the point's ID, XYZ values, a description (if stored), the point's 3D / NVA / VVA type, the collection (survey) date (if stored), X Measurement (3D type only), Y Measurement (3D type only), RMSE_H2 error value, RMSE_V2 error value, Include status (if stored), and Include notes (if stored).

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For an abbreviated 7-column check points CSV, the window that opens will display the point's ID, XYZ values, the point's NVA / VVA type, Include status (if stored), and Include notes (if stored).

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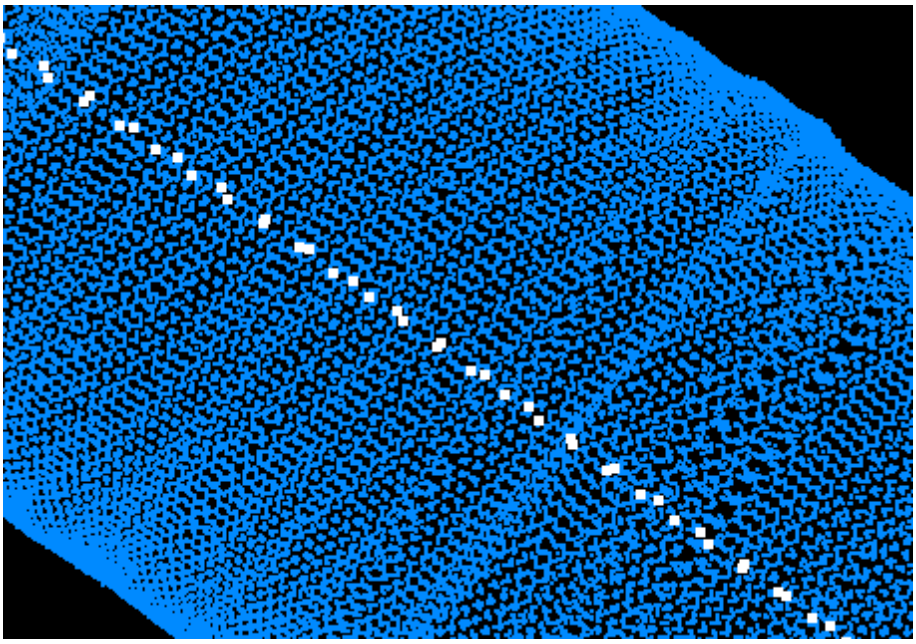


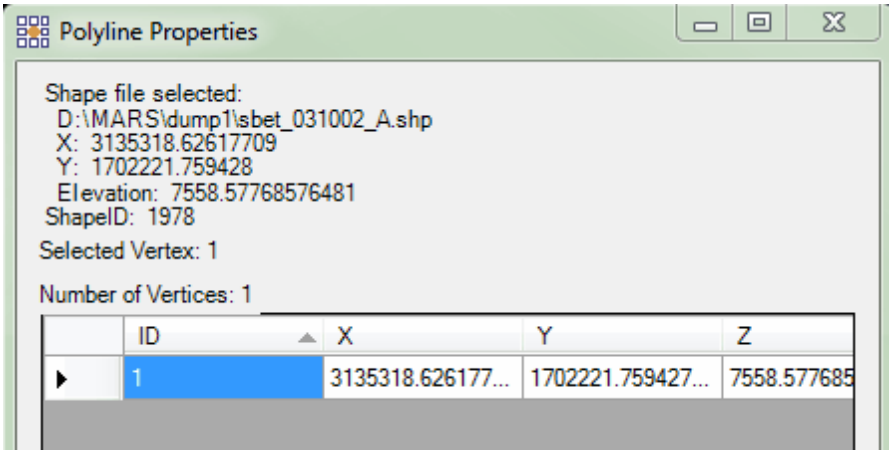
Windows copy-and-paste controls can be used in the resulting pop-up window.

To select a displayed reference shapefile (polyline or point) or breakline shapefile for inspection, make sure the **'Inspect'** tool is toggled on, and then hold the **'Ctrl'** key on the keyboard while clicking on the feature to be inspected. This instructs MARS® to select the closest feature, other than a LiDAR point, for inspection. The selected line or point will be highlighted, and the window that appears displays X, Y, (and Z-values for a 3D shapefile) for the nearest vertex (polyline) or the point. For example, in the example below it may be difficult to select the white shapefile points for inspection among the dense LiDAR data. Hold the **'Ctrl'** key and use the inspect tool in close vicinity of one the white shapefile points to select it for inspection. It is also possible to copy information from the resulting pop-up

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window when using the **'Inspect'** tool.





Click on the 'X' in the upper-right corner of any 'Point Properties' or 'Polyline Properties' window to close it. To unselect the **'Inspect'** tool and return the chosen feature to its original symbol and/or color, right-click the mouse.

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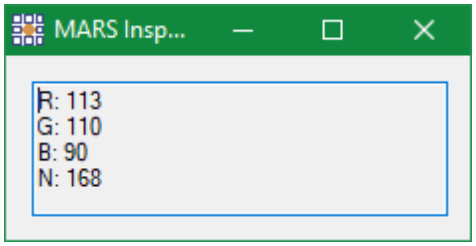
4.8.7 Inspect RGB(N)

Inspect RGB(N) Tool

Merrick Advanced Remote Sensing (MARS®) Software

Inspect RGB(N) Tool: This utility, found under the 'Miscellaneous Options' section of the View Tab[192] and on the Analysis Tab[489], allows the user to select individual pixels and display the RGB(N) - Red-Green-Blue and, if present, NIR - values from the loaded imagery data. One common use of the tool is to define RGB(n) values for the RGBNI Value Filter[1110]. This tool will only work on RGB or RGB (N) imagery (not ENVI rasters) and is only available to use when imagery is loaded into MARS®.

To use this tool, click in the desired location on the imagery. Once the user has selected a target, the **'Inspect RGB(N)'** dialog (see below) will be displayed, showing the RGB(N) values from the selected pixel. 3-band imagery will display 'N/A' for the 'N' field. Additional locations can be selected without closing the pop-up.



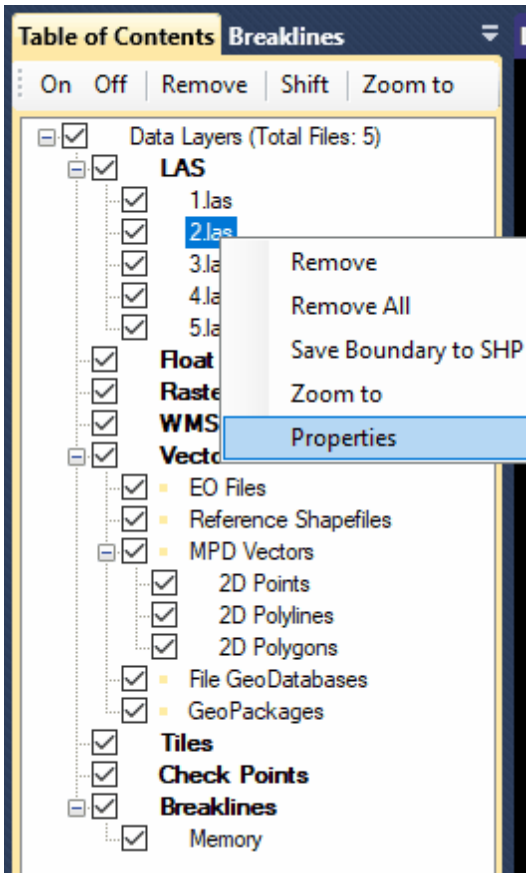
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4.8.8 LAS File Properties

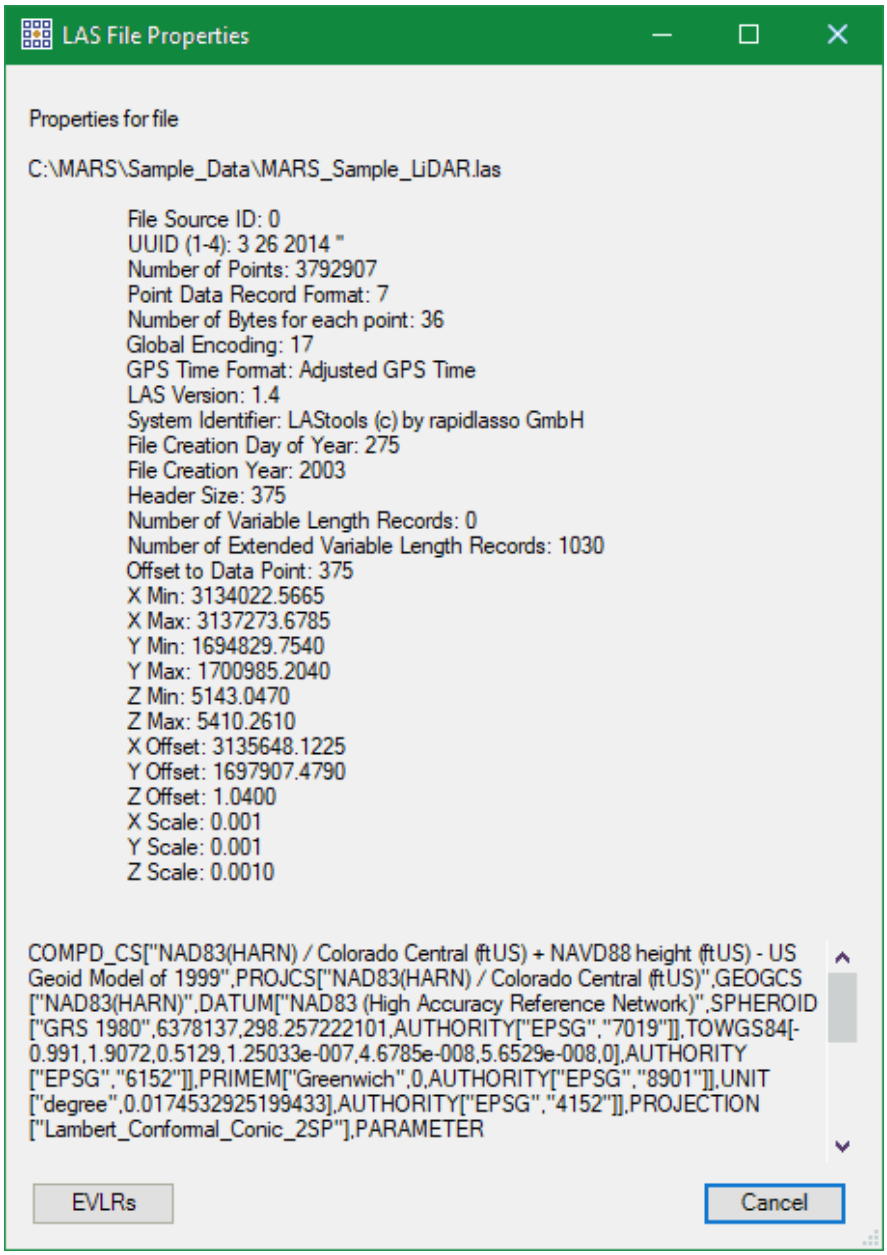
LAS File Properties

Viewing the Properties of LAS Files: To see the properties of any LAS file, first highlight (select) the file, then right-click and choose **'Properties'**. A listing of properties will be displayed for informational purposes including: the complete path and file name, File Source ID, the Number of Points, the Point Data Record Format, the Number of Bytes per point record, the GPS Time and WKT Format (Global Encoding), the LAS Version, the System Identifier, the File Creation Day (Julian Day) and Year, the Header Size, the Number of Variable Length and Extended Variable Length Records, the Offset to Data Point (the first point record), and the Min, Max, Offset, and Scale of each of the coordinates: X, Y, and Z. All known coordinate reference system (CRS) data is displayed near the bottom if the file has this information defined. The 'EVLRs' button presents a scrollable list of all the Extended Variable Length Records that the file contains, showing the total record count as well as the 'user ID', 'description', 'record ID', and 'length after header' info (in that order) for each record. It is also possible to highlight, right-click, and copy data from the resulting 'LAS File Properties' window.

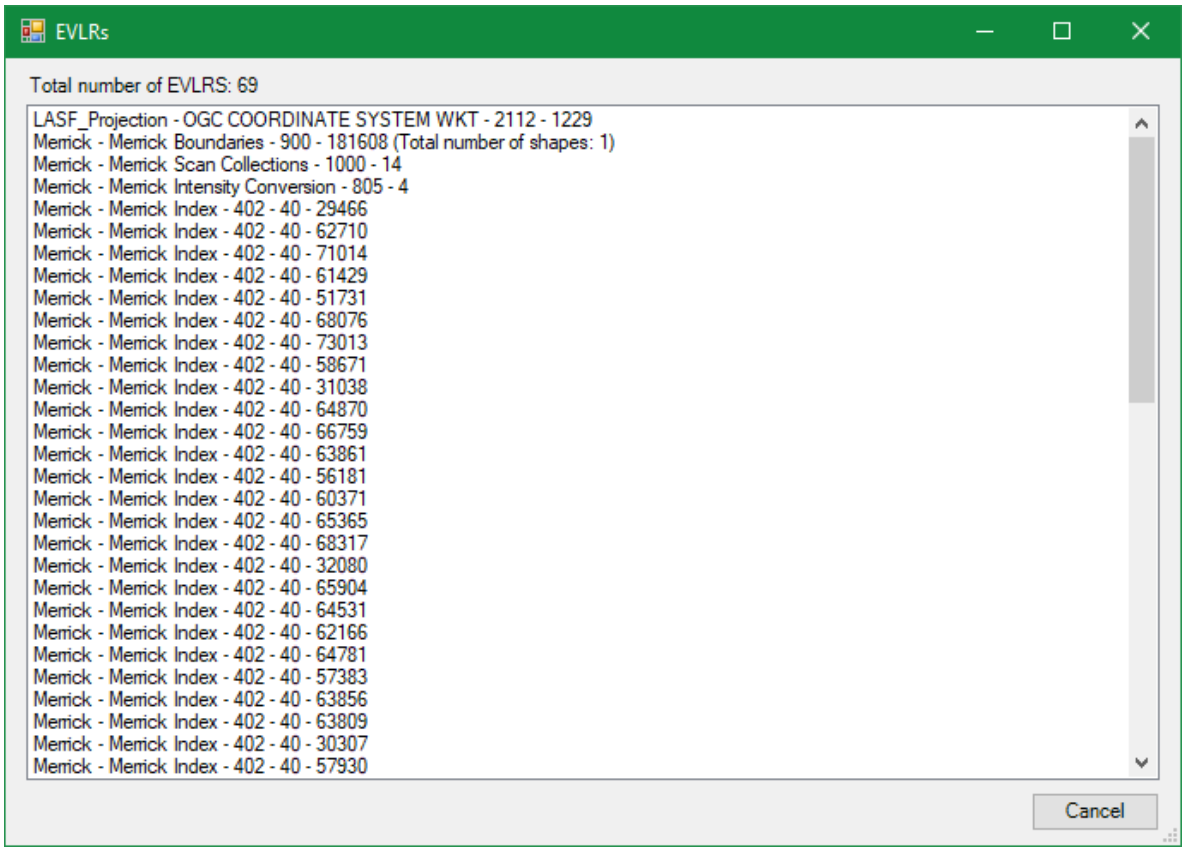
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4.8.9 Line-of-Sight Display



Line-of-Sight Display: MARS® supports the display of a source/target line-of-sight display (while in 3D perspective viewing mode only) for analysis purposes. The two buttons for this function can be found under the 'Miscellaneous Options' section of the View Tab 192.

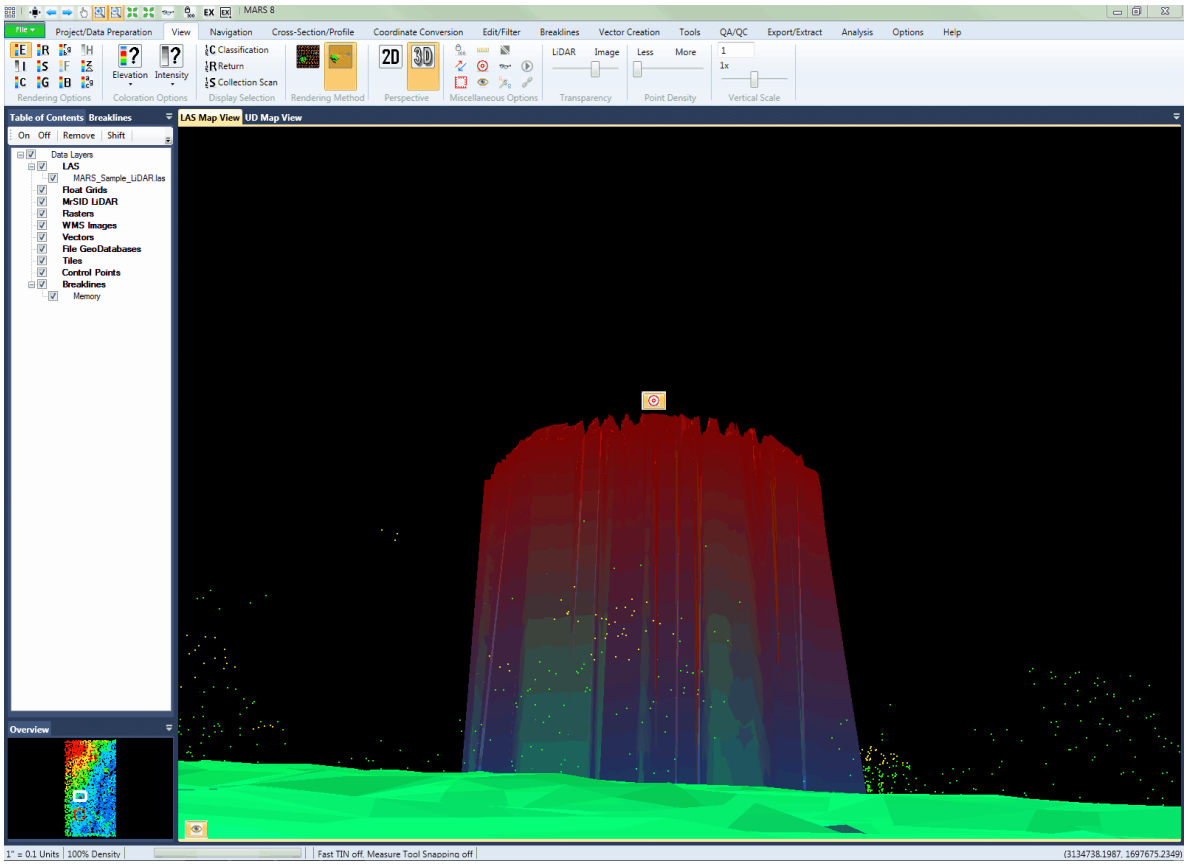
 **Place Target:** Allows the user to define a target location for an 'on-the-fly' line-of-sight display. With LAS data rendered in a 3D (Perspective) view, click on the 'Place Target' button and then click on a location in the data display. The data display will re-center around that point. Next, click on the 'Place Eye' button (see below) and then click on a location in the data display that will be the observer's location.

 **Place Eye:** Allows user to define a point of origin (viewer location) for an 'on-the-fly' line-of-sight display after a target location has been established (see above). With LAS data rendered in a 3D (Perspective) view and a target location already chosen, click on the 'Place Eye' button and then click on a location in the data display that will be the observer's location.

Example:

The user must select an area of interest and then change to 3D View 837 mode to use this tool. First, the user must define the line-of-sight target by clicking the **'Place Target'** button  on the View Tab 192 and defining a target location by clicking the mouse. The user must then define the point of origin (source) for the line-of-sight display by clicking the **'Place Eye'** button  and selecting a location by clicking the mouse. Once both locations have been defined, the LAS Map View display will update to show the view from 'eye' to 'target.'

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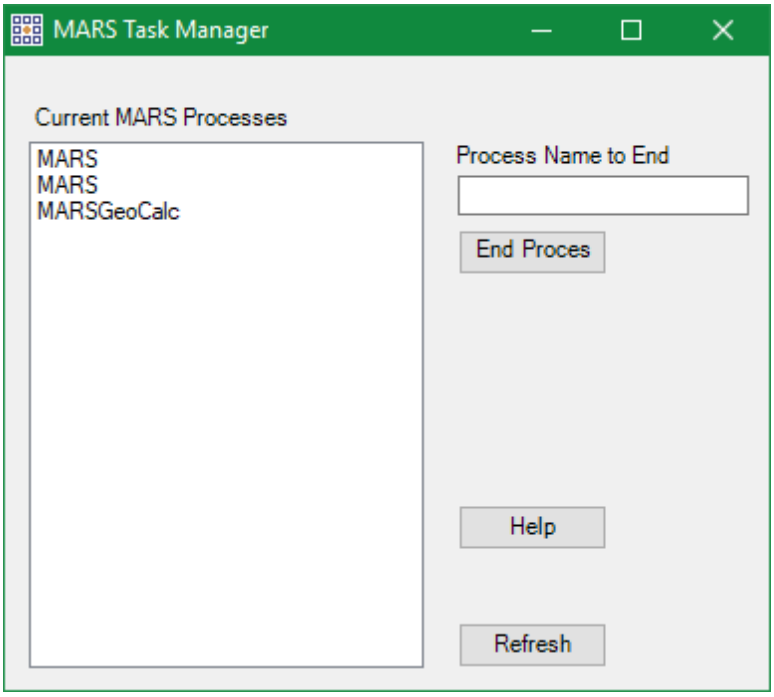
4.8.10 MARS® Task Manager

MARS® Task Manager

Merrick Advanced Remote Sensing (MARS®) Software

MARS® Task Manager: The task manager, found on the Tools Tab 389, will allow the user to monitor and/or end multiple MARS® processes at once. To end a process, highlight it and it will appear in the 'Process Name to End' text box. Click on the 'End Process' button to end the chosen process. The

session (instance) of MARS® that is running the Task Manager cannot be ended. The 'Refresh' button allows the user to refresh the 'MARS® Task Manager' without closing and re-opening the tool - ending a process will cause an automatic refresh.



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4.8.11 Measure

Measure Tool

Merrick Advanced Remote Sensing (MARS®) Software

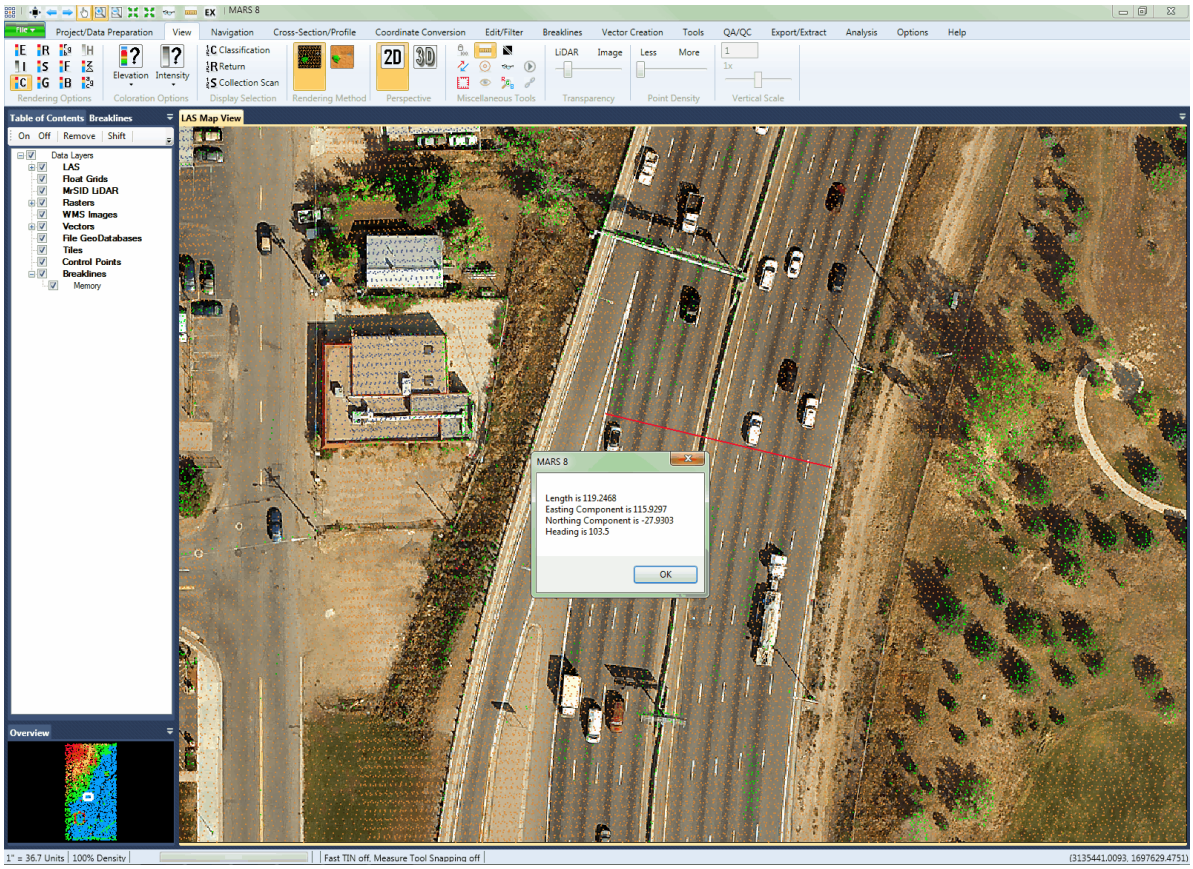
This tool allows the user to measure horizontal and vertical distances based on the project's units of measure (English or Metric). This tool can be used in the LAS Map View window while in 2D View[835], and in the Cross-Section/Profile[146] window. The measuring vector may be (optionally) snapped to the closest LiDAR points from each end. To toggle snapping on/off, go to the **'Miscellaneous Options'**

interface on the Options Tab[519] and use the checkbox in the 'Snapping Option' section. The current status of the snapping function is displayed on the Status Bar[158].

To use this utility in the LAS Map View window, click the **'Measure'** button  on the Quick Access Toolbar[65], the View Tab[192], or the Cross-Section/Profile Tab[240]. To determine a horizontal distance measurement, click and hold the left mouse button, drag the mouse to the target, and release the left mouse button to view the results (represented by the red line in the graphic below). The following information is displayed for each measurement in the LAS Map View window:

- Length in units
- Easting component
- Northing component
- Heading

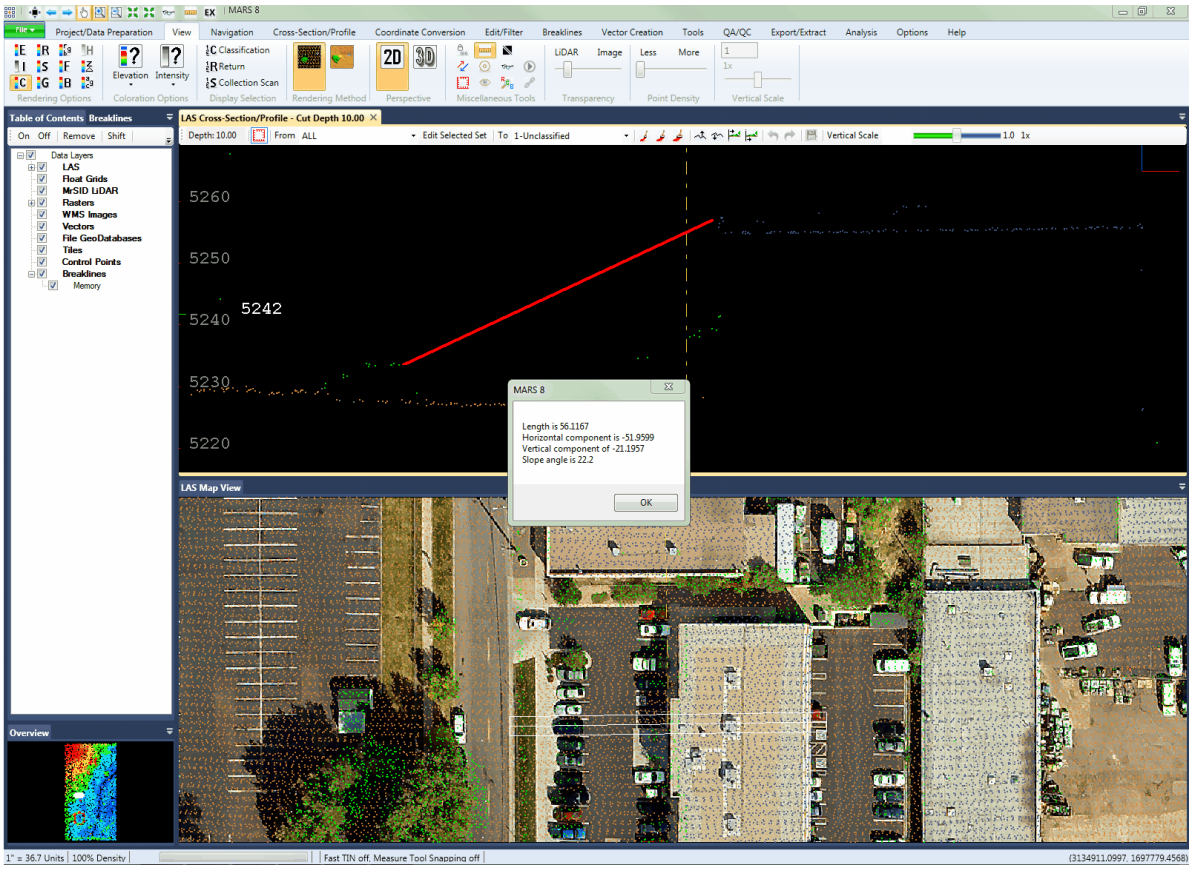
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To determine horizontal and vertical measurements in the Cross-Section/Profile[146] window, click and hold the left mouse button, drag the mouse to the target, and release the left mouse button to view results (represented by red line in graphic below). The following information is displayed for each measurement in the Cross-Section/Profile window:

- Length in units
- Horizontal component
- Vertical component
- Slope Angle in degrees

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4.8.12 Pick Tiles

Pick Tiles Tool

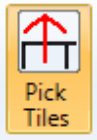
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Pick Tiles: This tool is used to select a single tile or multiple tiles for Project/Data

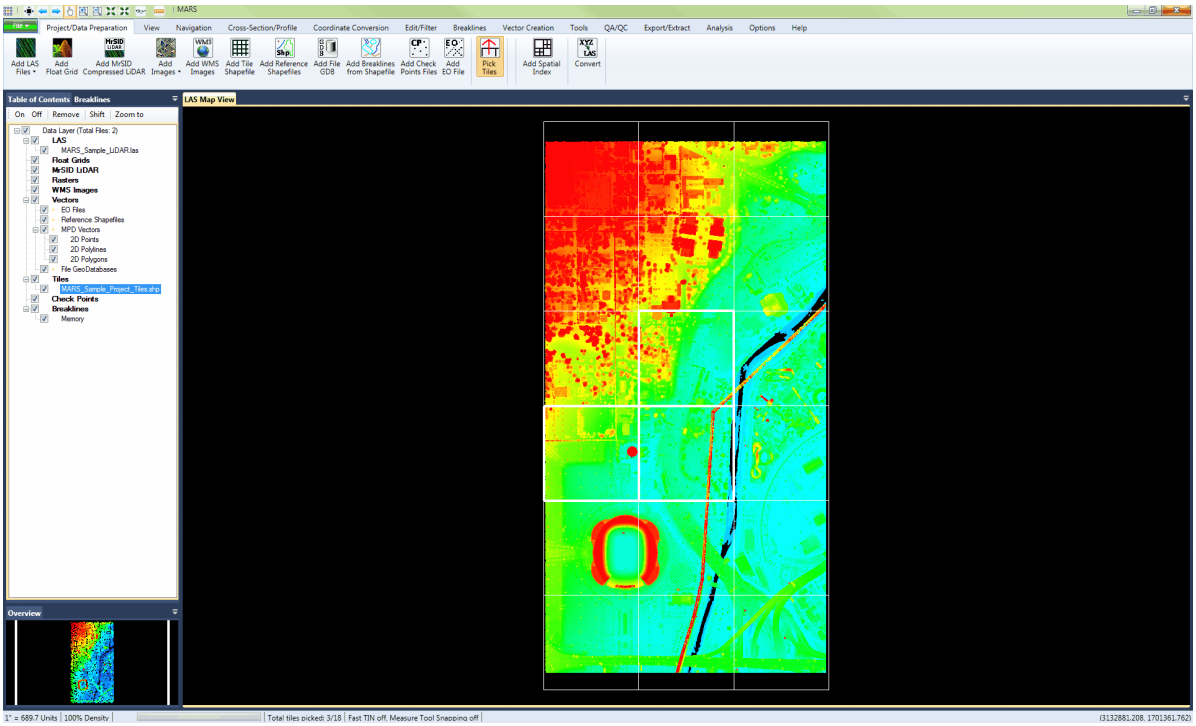
Preparation 162, Export/Extract 461, or Edit/Filter 270 activities. The button is disabled until a polygonal shapefile is loaded into MARS® as a tile layout. The 'Pick Tiles' tool will only work on data loaded as a tile shapefile. See the 'Add Tile Shapefile' section of the Project/Data Preparation Tab 162 topic for information on loading a tile layout. This tool works only in 2D View 835.

The 'Pick Tiles' tool allows the user to load a tile layout shapefile and then select a single tile or multiple tiles to be processed. The selected tiles will then appear selected in the attribute table representing the shapefile. To view the attribute file, right-click on the file in the 'Tiles' layer of the Table of Contents 67 and choose 'Attributes'. Conversely, it is possible to use the attribute table to select tiles from the shapefile. Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard to select the appropriate tile (s). The selected tile(s) will then appear selected in the LAS Map View window on the tile layout itself.

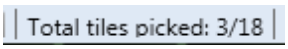
'Pick Tiles': To use the **'Pick Tiles'** tool, select the 

button. Move the cursor over tiles to be exported and left-click. Using the tool, draw a box over many tiles and they all will be selected, or use the **'Ctrl'** key on the keyboard to select single tiles without losing the ones already selected.

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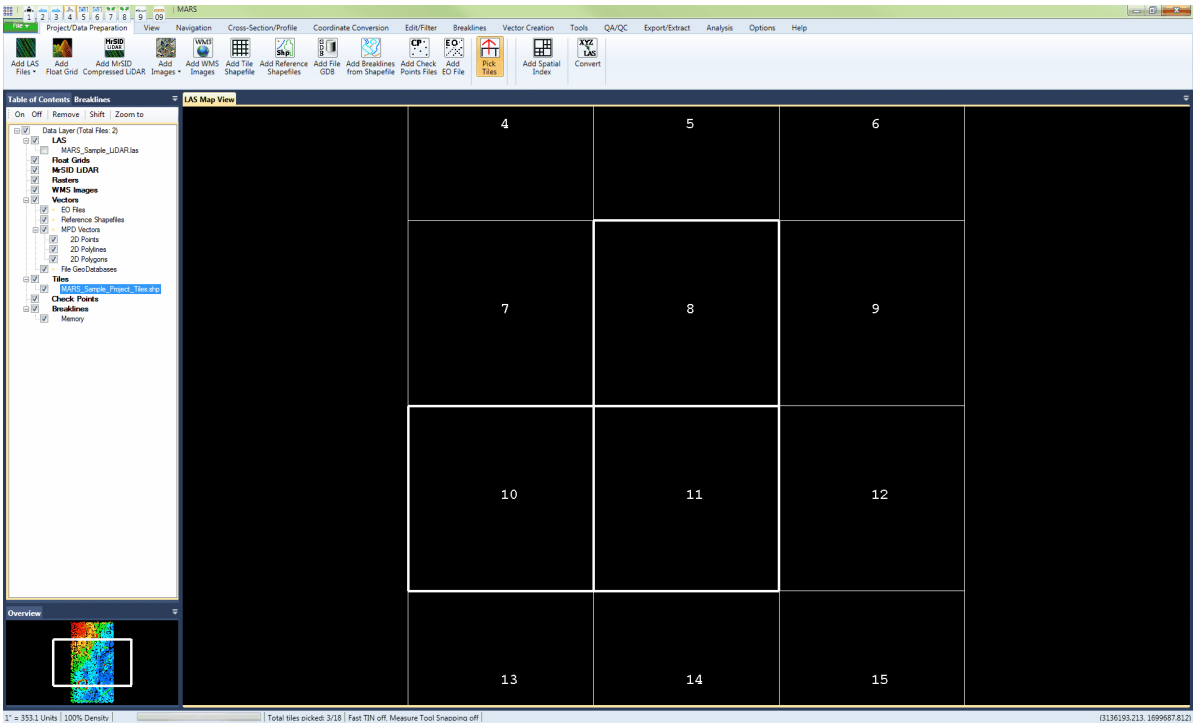
The following image shows an example of three selected tiles, which are outlined in bold when chosen. MARS® will keep a count of the tiles being chosen and the total number of tiles in the tile layout and display them as a ratio on the Status Bar 158.



The following image displays the selected tiles with tile names displayed. To see the tile name attributes, right-click on the file in the Table of Contents 67 and select 'Properties', then choose the appropriate name attribute (ex. TName) in the 'DB Field for Labeling' drop-down box. Check the box which says 'Display Label', change the 'Font Size' if desired, and click 'OK'. The labels will be displayed in the same color as the tile outlines, and the selected tiles will remain outlined in bold. The user's preference for the 'DB Field for Labeling' option will be stored by this tool until the MARS® application is closed. The field chosen will be synced with the same parameter in the 'Load LAS Files on Selected Tiles' option when adding LAS data. To read more concerning the 'Add LAS Files on Selected Tiles'

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option, please view the Project/Data Preparation Tab 162 topic. Once the desired tiles are selected, an Export 658, Extract 1175, Batch Process Tiles 1212, or Add LAS Files | From Selected Tiles 162 process can be started.



Tile Selection Methods

- **Individual:** To select an individual tile, use the 'Pick Tiles' tool to click on the desired tile.
- **Multiple:** To select multiple tiles, depress the CTRL key and use the 'Pick Tiles' tool to choose the desired tiles.
- **Drag Box:** For large areas, use the 'Pick Tiles' tool to click and drag a box. All tiles touched by the drag box will be selected. Additional tiles can be added to the selection set by holding down the CTRL key and clicking within the desired tile(s).
- **To unselect tiles:** In some cases, it may be easier to use the drag box to select a large area of tiles and unselect the few that are not needed. To unselect tiles, make sure the 'Pick Tiles' button is active, then hold the 'Ctrl' button on the keyboard and click on the tiles to be unselected. To

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unselect all tiles, click outside of any tiles while the 'Pick Tiles' button is active.

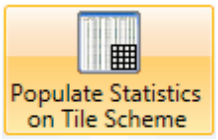
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4.8.13 Populate Statistics on Tile Scheme

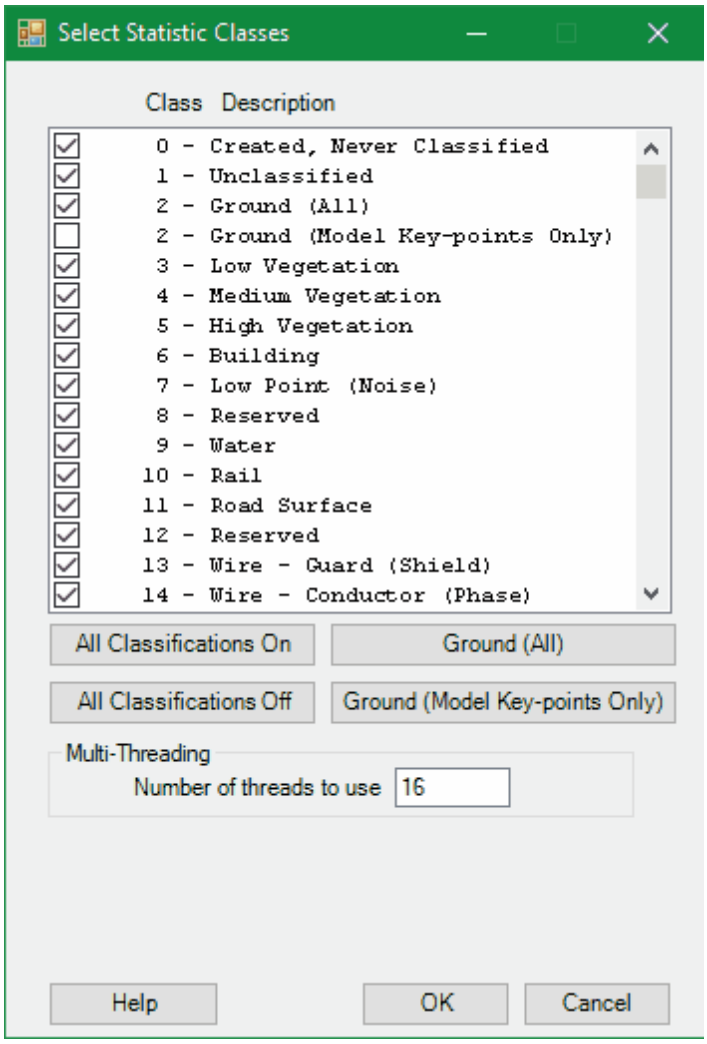
Populating Statistics on Tile Scheme Tool

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To use the 'Populate Statistics on Tile Scheme' tool, please visit the Analysis Tab[489] topic. The user must already have lidar data and a tile layout loaded in MARS® in order to use this tool. Another way to populate statistics on a tile layout is to have the statistics generated at the same time the tile layout is generated. To populate statistics in this way, please see the Create Tile Scheme[928] topic.

Populate Statistics on Tile Scheme: This tool 

will create a new shapefile in the same folder as the input tile layout, and it will contain newly calculated attribute fields for statistics including first returns, tile area, average GSD (ground sample distance), point density (points per square unit), and many more. An interface will appear where the classes to be included in the statistics calculations can be selected. Multi-threading is also available to shorten the processing time. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread. Clicking 'OK' will start the process, and the status can be tracked with the progress bar at the left side of the Status Bar[158].



When the processing is complete, a pop-up window will appear showing the complete path and file name of the new tile layout (with statistics included). The new shapefile will have the same name as the original shapefile, except that appended onto the end of the file name will be "…_With_LAS_Statistics". When the new tile shapefile is generated, a *.prj (projection definition file) will be created if the projection information is known for the source LAS data. The original shapefile will not be overwritten. Once the user has run the 'Populate Statistics on Tile Scheme' tool, the newly created shapefile will need to be loaded into MARS® - it is not loaded automatically.

The following statistics will be generated for each tile layout when the 'Populate Statistics on Tile

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Scheme' tool is used, and they may be viewed in the attribute table of the resulting tile shapefile:

ID: A uniquely generated ID number for each tile.

TName: A uniquely created tile name (or number) used for many program functions.

AREA: The area in square project units of a particular tile.

ALLPCOUNT: A count of the total number of points within a particular tile.

DENSITY: The point density in points per square unit (using first returns only).

AVG_GSD: The average GSD (ground sample distance).

X_MIN: The x axis (easting) minimum within a particular tile.

X_MAX: The x axis (easting) maximum within a particular tile.

Y_MIN: The y axis (northing) minimum within a particular tile.

Y_MAX: The y axis (northing) maximum within a particular tile.

Z_MIN: The z axis (elevation) minimum within a particular tile.

Z_MAX: The z axis (elevation) maximum within a particular tile.

Z_DELTA: The difference between Z_MAX and Z_MIN within a particular tile.

COLL_SCAN: A listing of the different collection scan numbers which overlay a particular tile.

GPS_MIN: The GPS time (timestamp) minimum found within a particular tile.

GPS_MAX: The GPS time (timestamp) maximum found within a particular tile.

MIN_INT, **MAX_INT**, **MEAN_INT**, **MED_INT**, and **MODE_INT:** Various intensity value statistics.

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RETURN_0: The number of 'other' returns found within a particular tile (returns that are missing or have incorrect point family info).

RETURN_1 through **RETURN_15:** The number of first returns through fifteenth returns (listed in individual attribute fields) found within a particular tile.

SYNTHETIC: The number of points bit-flagged as 'Synthetic' found within a particular tile.

MKP: The number of points bit-flagged as 'Model Key-point' found within a particular tile.

WITHHELD: The number of points bit-flagged as 'Withheld' found within a particular tile.

OVERLAP: The number of points bit-flagged as 'Overlap' found within a particular tile.

Class0 through **Class255:** The number of points in each class (listed in individual attribute fields) is recorded per tile.

ClassWH0 through **ClassWH255**: The number of Withheld bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

ClassMK0 through **ClassMK255**: The number of Model Key-Point bit-flagged points in each class (listed in individual attribute fields) is recorded per tile.

iShape: A MARS®-specific value that is not relevant for the user.

NOTE that 'RETURN_<*nn*>,' 'Class<*nnn*>,' and 'ClassWH<*nnn*>' fields that are zeroed out for every tile will be omitted from the final attribute table to simplify analysis.

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Please see the Populate Statistics on Tile Scheme 964 topic for additional information.

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4.8.14 Shifting LAS Files



The MARS LAS Shifter can be accessed from the **'XYZ Shift'** button on the Coordinate Conversion Tab 254 (affects all loaded data), or by choosing the **'Shift'** button at the top of the Table of Contents 67 (affects only those files that are selected, or highlighted, under the LAS layer).

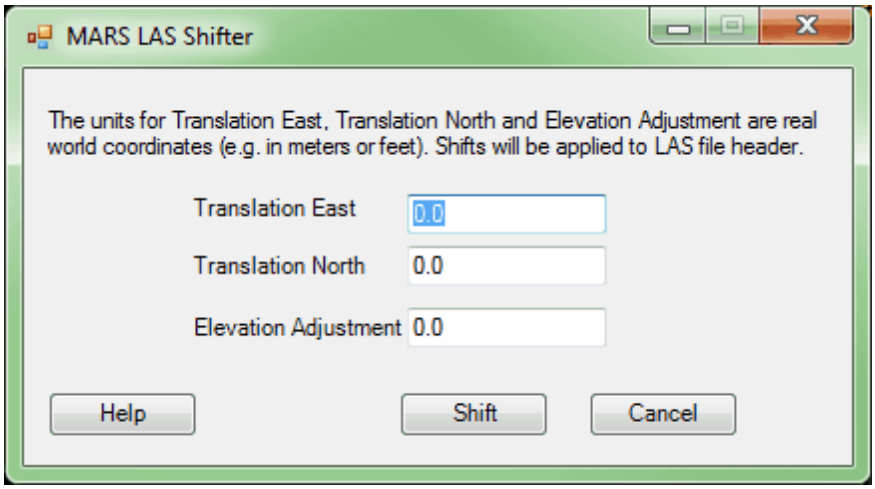
MARS LAS Shifter: This tool is used to shift LAS data in six (6) different directions:

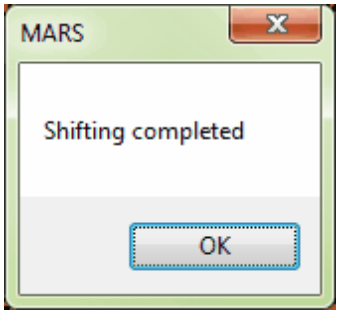
1. **East** (a positive shift in the Translation East text box)
2. **West** (a negative shift in the Translation East text box)
3. **North** (a positive shift in the Translation North text box)
4. **South** (a negative shift in the Translation North text box)
5. **Higher in Elevation** (a positive shift in the Elevation Adjustment box)
6. **Lower in Elevation** (a negative shift in the Elevation Adjustment box)

If the user chooses to shift files by using the table of contents, it is possible to select more than one LAS file at a time and apply the necessary shifts to them. Use the **'Shift'** key on the keyboard to select more than one file in a row, or use the **'Ctrl'** key on the keyboard to select several files in random order. The selected files will all have the same shifts, specified by the user in the 'MARS LAS Shifter' interface, applied to them.

**** NOTE: If multiple shifts are applied to a single project, the effect is cumulative. Each shift**

is applied to the existing XYZ offset in the header.**





An OFF file (*.off) will be created for each file that is shifted storing the X, Y, and Z offsets that existed in the file before the shift was processed. These 'offset' files will be created with the same name and in the same folder as their corresponding LAS file(s). They are used with the Report LAS Shift 570 tool (on the Coordinate Conversion Tab 254) as a baseline. If the *.off files are moved, renamed, or deleted, they will be recreated the next time the MARS LAS Shifter is run, but with the then-current offsets used as baselines.

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4.8.15 Snapshot

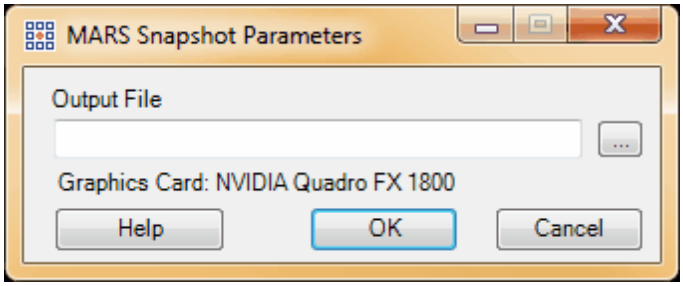
Snapshot Tool

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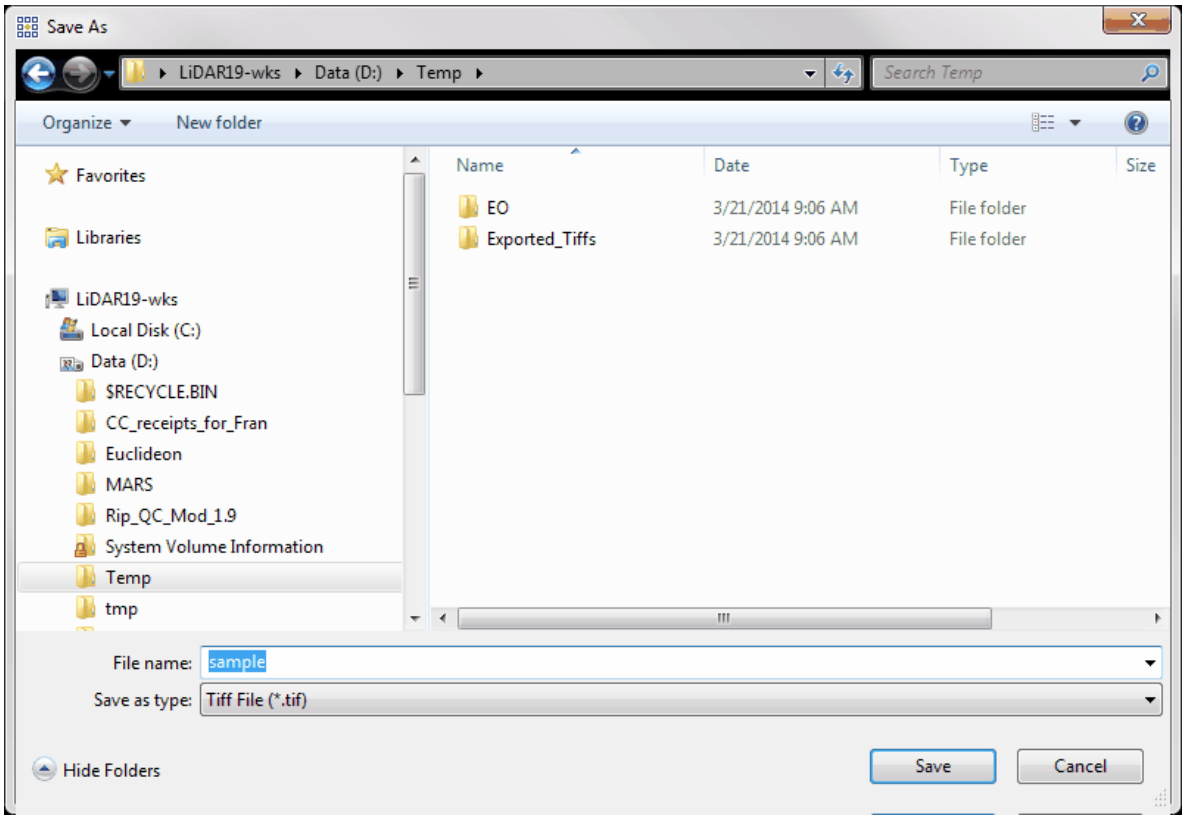
Snapshot **Snapshot:** This tool, found on the Tools Tab 389, creates a screen capture of the display in the LAS Map View window that is saved to a user-defined folder. Format options include: georeferenced TIFF (with TFW world file), georeferenced JPEG (with JGW world file), BMP, GIF, PNG, or WMF. The upper-left and lower-right corners of the TIFF or JPG format files are determined by the extent of the LAS Map View window. This utility works while in 2D View 835 or 3D View 837.

'Snapshot' is also a quick way to determine what graphics card is installed in the computer.

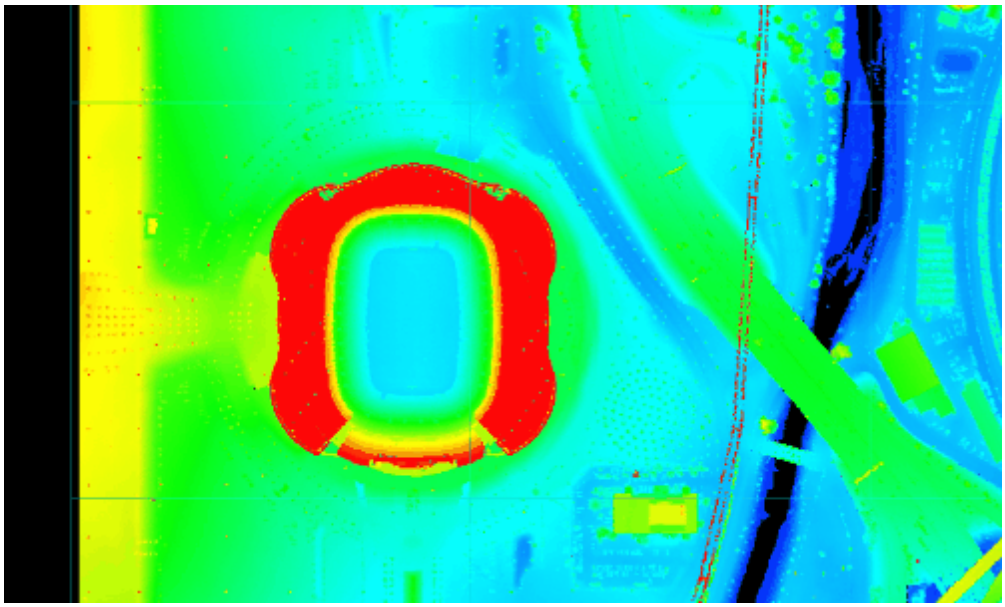
Once the **'Snapshot'** button Snapshot is clicked, the following dialog is displayed. Navigate to the desired folder ..., enter the file name to use, and click 'Save'. Click the 'OK' button to complete the save and exit the utility.



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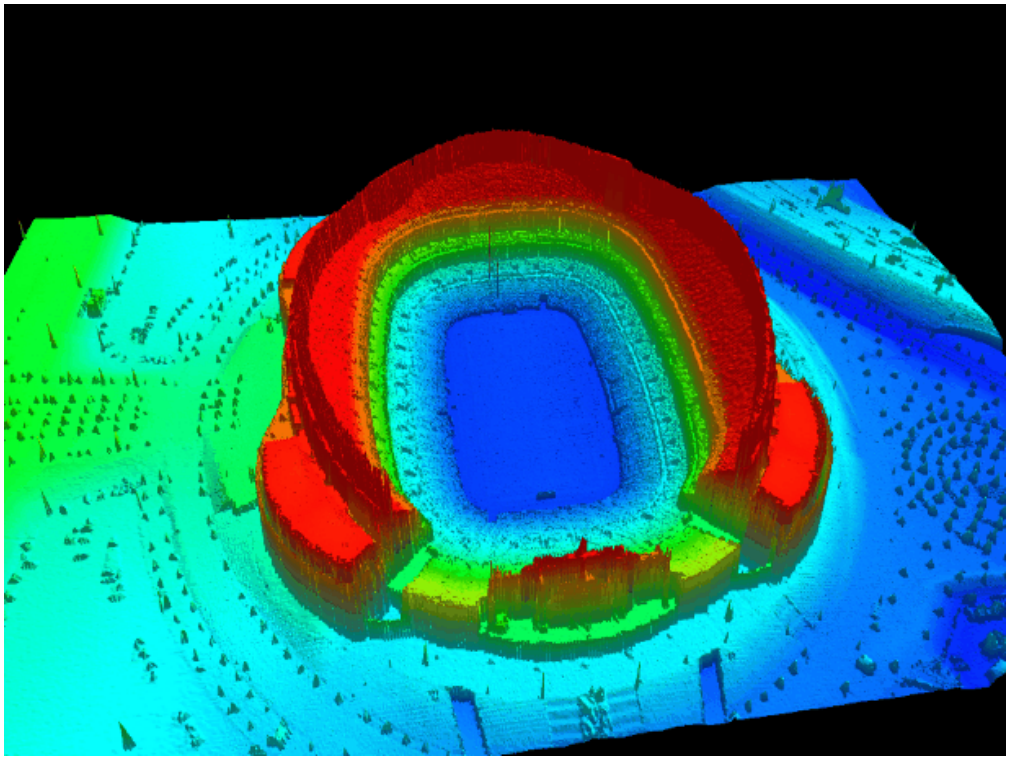


The following image is an example of an LAS Map View window snapshot in 2D.

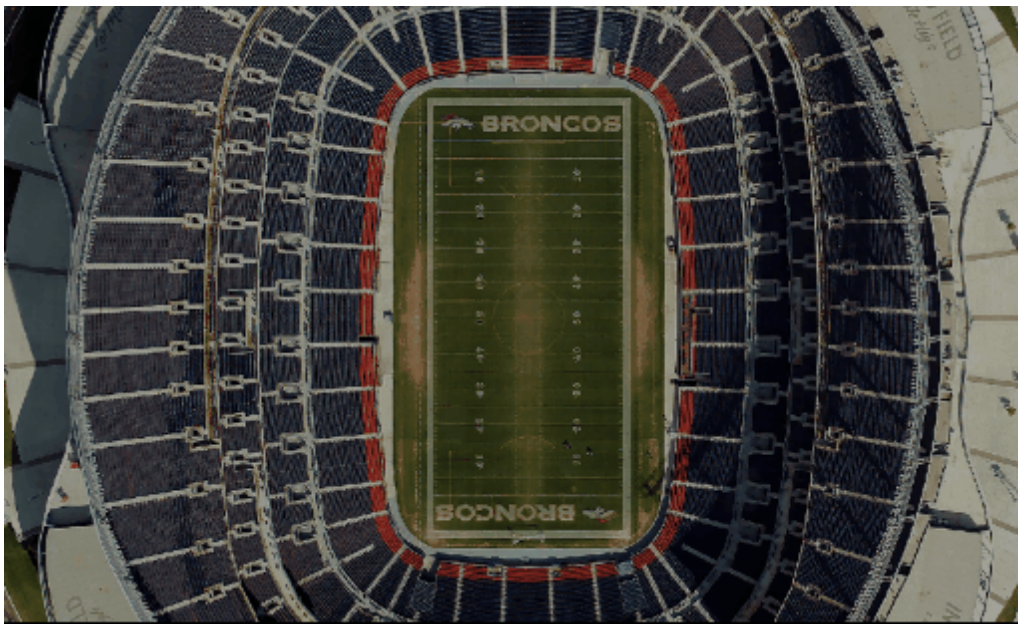


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The following image is an example of an LAS Map View window snapshot in 3D.



The following image is an example of a snapshot while raster data is loaded.



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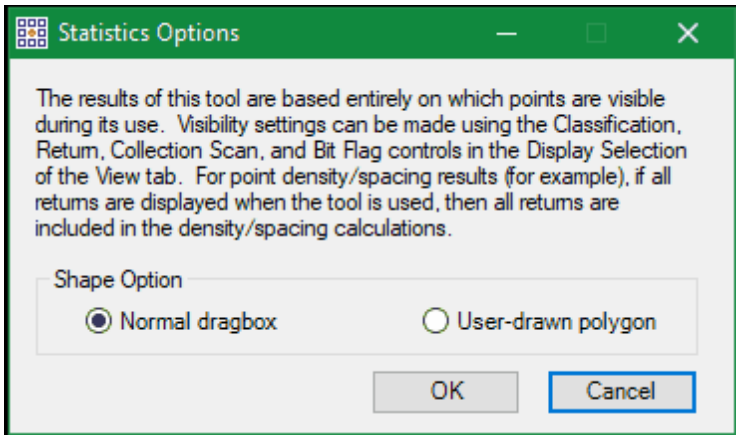
4.8.16 Statistics by Area

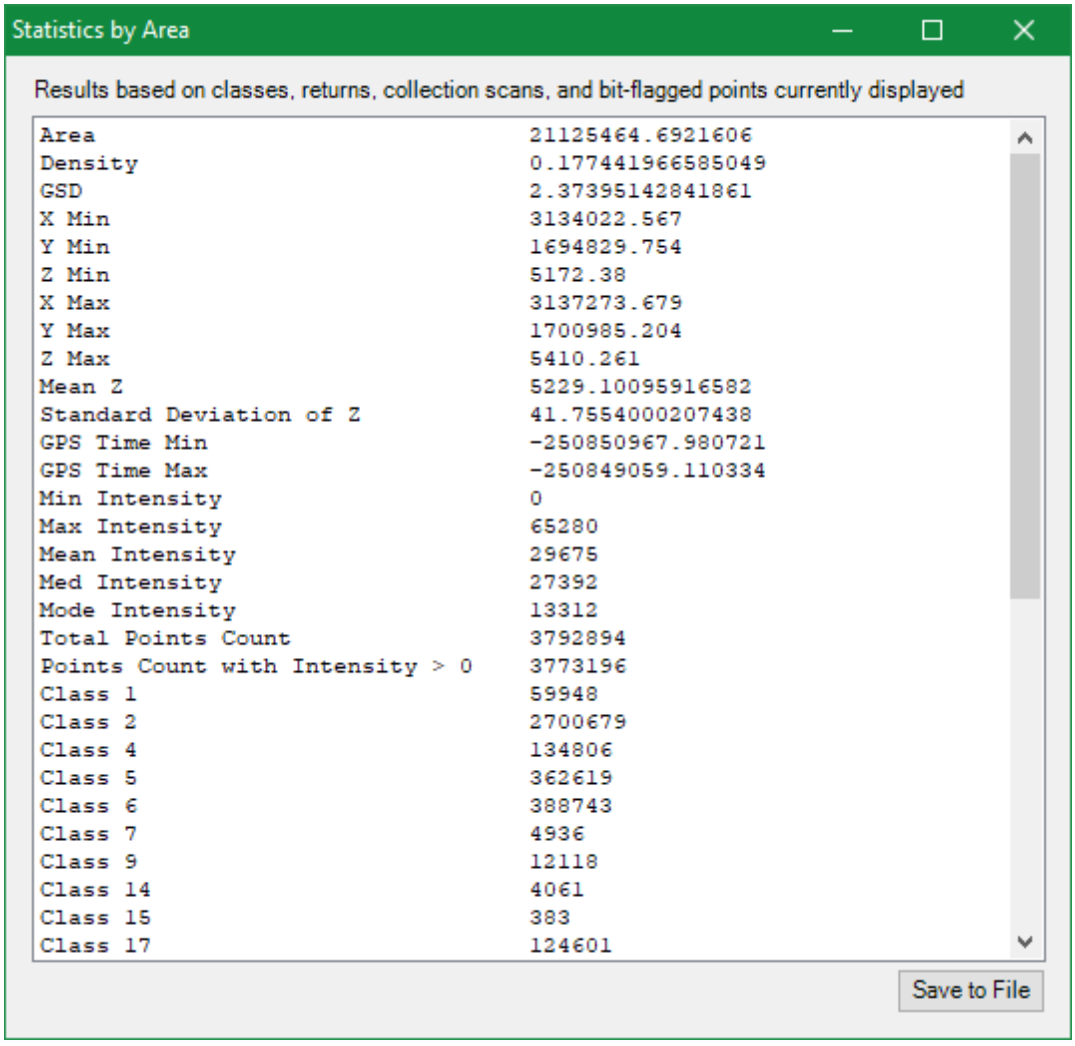
Statistics by Area Tool

Merrick Advanced Remote Sensing (MARS®) Software

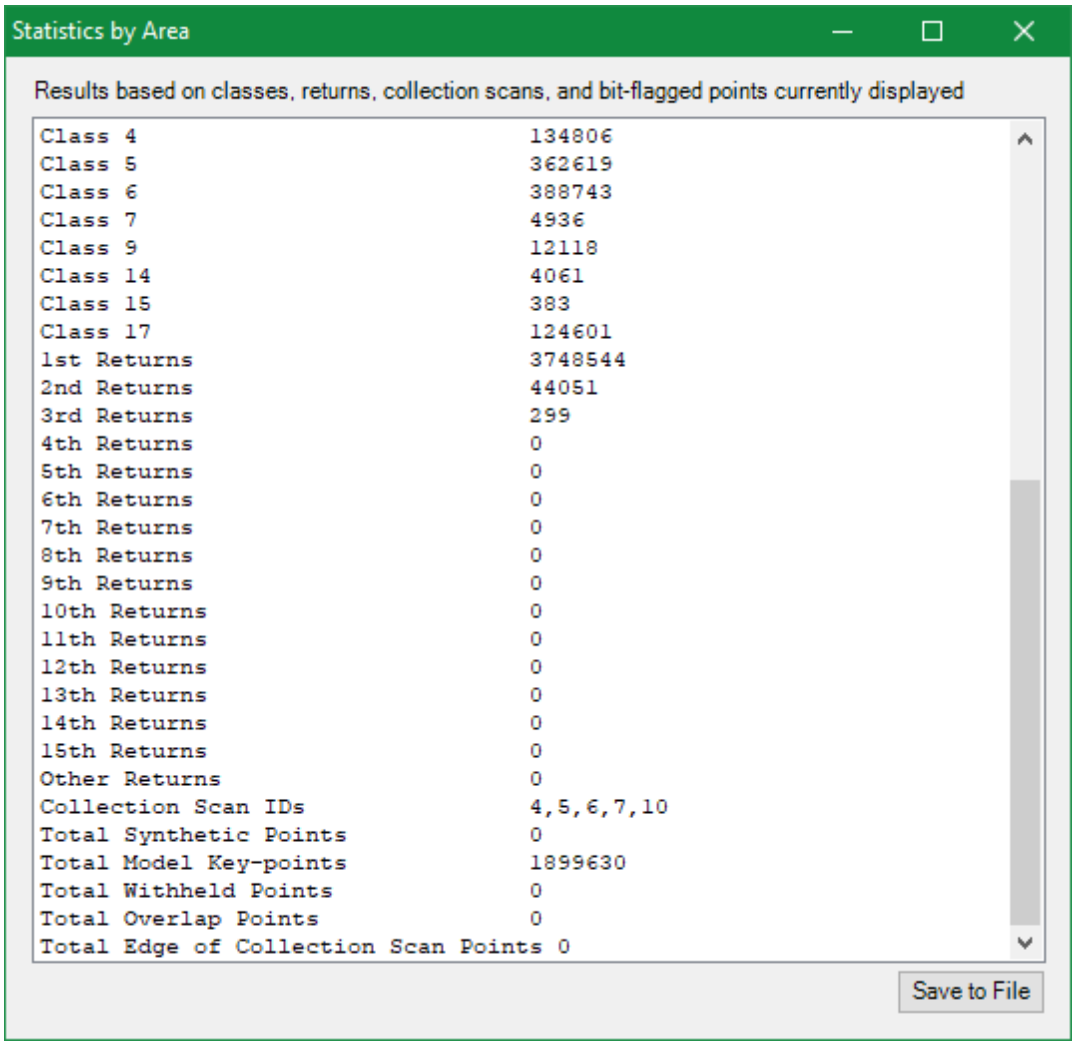
Statistics by Area: This tool 

, found on the Analysis Tab 489, allows the user to drag a box or create a user-drawn polygon over an area of LAS data to display statistics for that area. To use 'Normal dragbox' mode, left-click for a starting location, drag the mouse to define the opposite corner, and release the mouse button to define the area. For 'User-drawn polygon' mode, left-click to create the vertices of the polygon, and right-click to close from the last vertex placed back to the starting vertex. The results, which include most of the categories found in a full statistical analysis (see Populate Statistics on Tile Scheme 964), appear in a scrollable pop-up window with an option for saving to a text file. All results and statistics compiled are limited to only those classes, returns, collection scans, and bit flag types that are displayed at the time the area of interest is defined. To check multiple areas, close the results window and drag or draw a new area. To switch between the drag-box and user-drawn polygon methods, close the results window and click on the tool button to be prompted for the desired method. The tool remains active until dismissed by pressing the 'Esc' key on the keyboard, so multiple areas can easily be checked and the results saved if needed.





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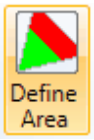
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4.8.17 Viewshed

Viewshed Tools

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Viewshed Grid generation: Viewsheds are available for use with LAS data and MrSID Compressed LiDAR data while in 2D mode only.

Define Area: Create a viewshed by clicking on the **'Viewshed - Define Area'** button 

.

Left-click inside the LAS Map View window (2D view only) where the viewshed is to start. While holding the left button, drag the mouse to the place where the viewshed is to end and release. The Viewshed options window will appear and give the user the ability to change the properties of the viewshed and, optionally, to save it. By checking the **'Field of View'** box, the user can switch the field of view from **'Azimuth'** (if the box remains unchecked) to **'Degrees'** and **'Direction'** (if the box is checked). The user can specify a radius, grid cell size, and can even specify an invisible or visible output file name to save. The Viewshed tool displays a 2-color grid to indicate the visibility of the user-defined field of view. Once generated, the viewshed may be viewed in 2D or 3D. The red areas of the viewshed represent areas which the 'viewer' would not be able to see from the starting point that was defined. The green areas represent areas which the 'viewer' would be able to see from the starting point that was defined. This color-coded display helps the user to understand where elevation changes, trees, or buildings may be. This tool is commonly used for security purposes, but can also be applied to land development and urban visualization activities. ***Note that the maximum distance (radius) that can be generated depends on available RAM, density of LAS data, field of view, and grid cell size.***

Parameters

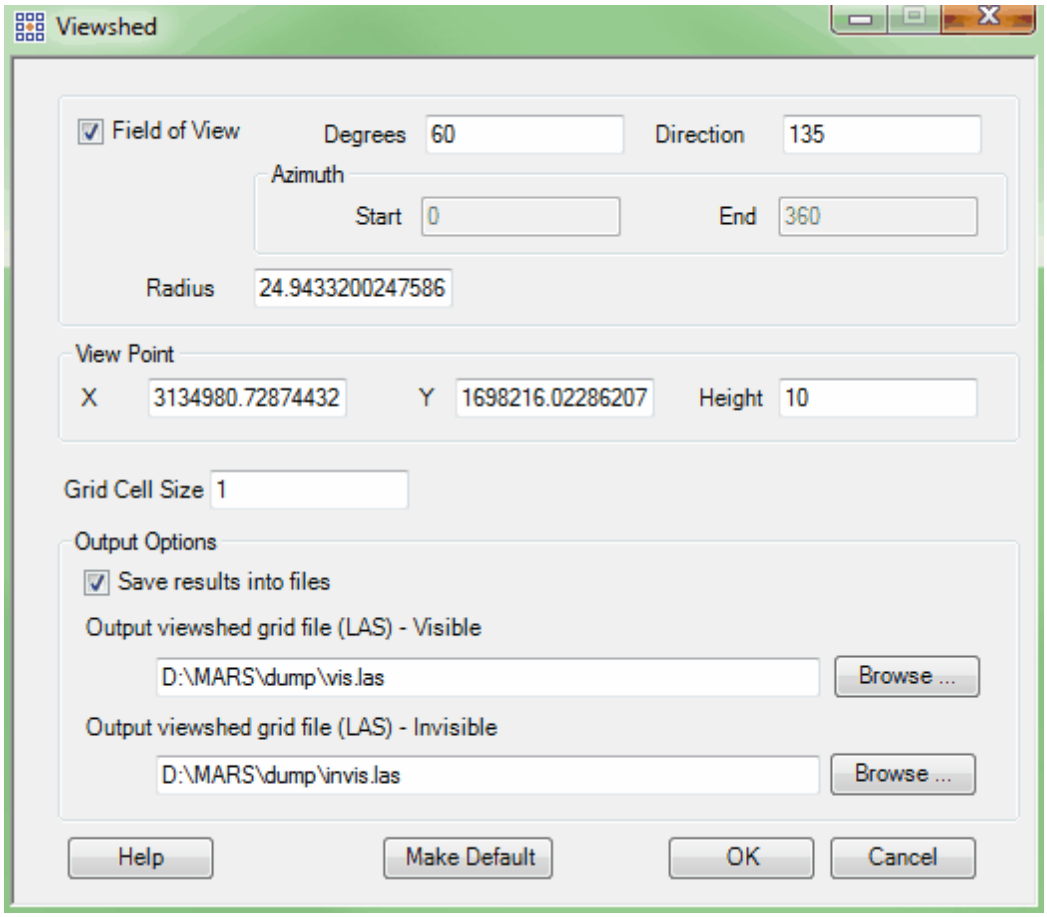
- **Field Of View:** When checked, enables manual entry of the **'Degrees'** and **'Direction'** of the desired field of view.
- **Degrees:** Enabled when **'Field Of View'** is checked. This value defines the angular width of the area to be studied. Valid values are 1 - 360.

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- **Direction:** Enabled when **'Field Of View'** is checked. This value represents the azimuth of the viewshed centerline in degrees. The width of the view (**'Degrees'**) will be centered around this vector. It is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **Azimuth Start:** Enabled when **'Field Of View'** is unchecked. This is the starting value for the horizontal component of the user-defined viewshed direction. Valid values range from 0 – 360, with 0 as the default value.
- **Azimuth End:** Enabled when **'Field Of View'** is unchecked. This is the ending value for the horizontal component of the user-defined viewshed direction. Valid values range from 0 – 360, with 360 as the default value.
- **Radius:** This value represents the radius length of the viewshed. This value is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **View Point X & Y:** These values represent the XY origin of the defined viewshed. This value is automatically populated in the Viewshed options dialog (but can be modified) once the user has defined the vector for the viewshed.
- **View Point Height:** The height value above the surface for the XY origin. A higher value will allow the 'viewer' to see more area within the viewshed.
- **Grid Cell Size:** This value represents the grid cell size of the displayed viewshed grid and the saved grids (both visible and invisible).
- **Save results into files:** When checked, allows the user to save the results of the viewshed analysis as LAS grids.
- **Output Viewshed Grid File:** This parameter allows the user to specify where the output files will be written.

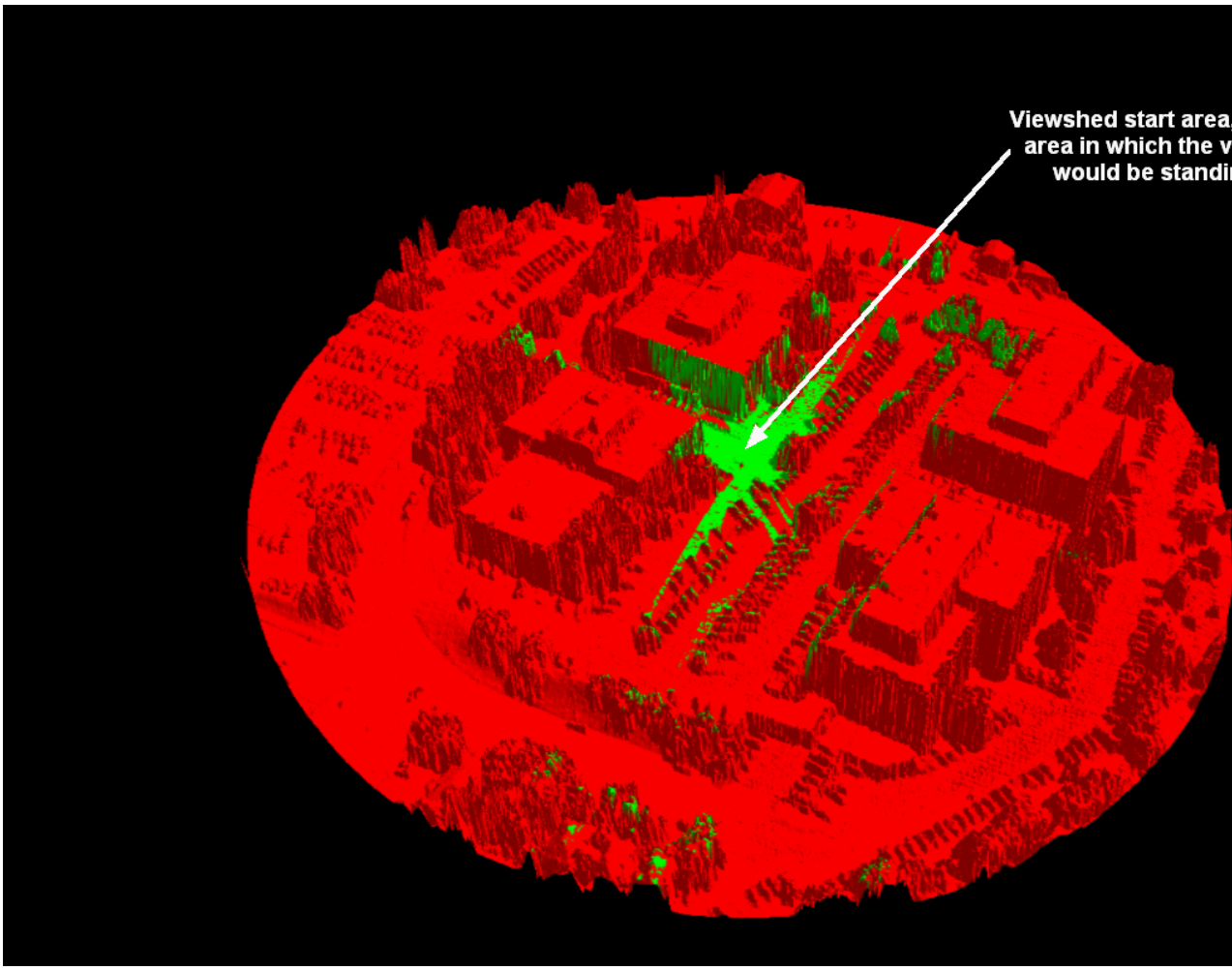
Viewshed Options Dialog

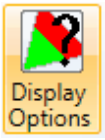
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In the Viewshed display below, the data which would be visible to the viewer if standing in the area defined as the center of the viewshed is colored green. The areas which would be invisible to the viewer if standing in the center of the viewshed are represented by red. The display shown below is in 3D and is rendered in TIN.

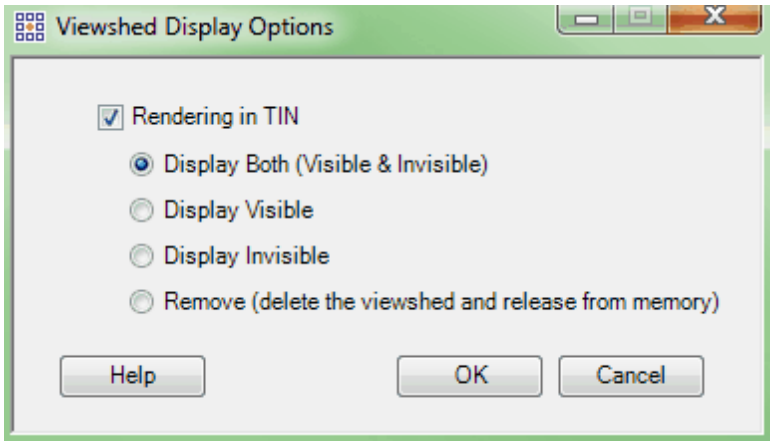
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Display Options: By clicking the **'Viewshed - Display Options'** button 

, the user has the option of displaying both visible and invisible data, only visible data, only invisible data, and viewing any of the data choices by TIN rendering. The user can also remove the viewshed grid completely and release it from memory. In the Viewshed display, the data which would be *visible* to the viewer if standing in the area defined as the center of the viewshed is colored green. The areas which would be *invisible* to the viewer if standing in the center of the viewshed are represented by red.

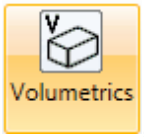
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4.8.18 Volumetrics

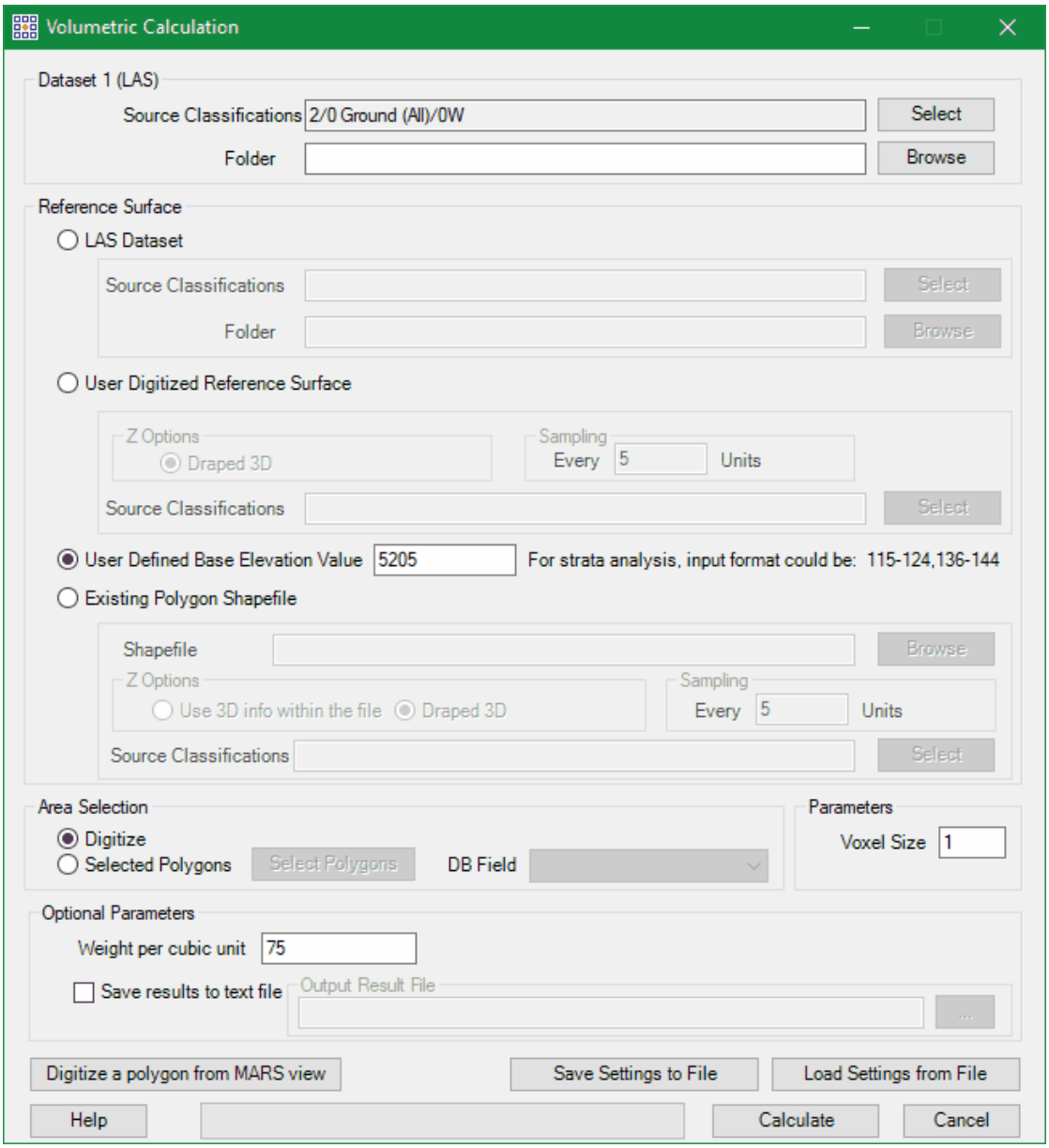


Volumetrics: This tool 

, found on the Analysis Tab 489, performs cut-and-fill analysis on a LiDAR dataset using various user-defined surfaces, boundaries, and values for reference. It is designed to be used on datasets where ground has been classified separately from other points. Accuracy of results is affected by the 'Voxel Size' (volume pixel, or 3D cell) entered - smaller sizes will produce more accurate results but will take longer to process. If a material weight is known, it can be entered in the 'Optional Parameters' section of the interface so that total weight of cut and/or fill can be calculated. For example, if the area being analyzed consists of bare soil and the weight is known to be 75 pounds per cubic foot (assuming the LiDAR project units are in feet), the total cut volume and/or total fill volume will be multiplied by the 'Weight per cubic unit' value to determine total cut and/or fill weight. An additional

option allows the results displayed in the pop-up window (below, right) to be saved as a text file.

Interface settings can be saved to an XML file ('Save Settings to File') for later use ('Load Settings from File').



There are several methods available to run a volumetric analysis. Note that whether loaded or referenced in the 'Folder' entry, Dataset 1 will always be the data being analyzed and reported on.

- ***LAS Dataset:*** Uses a second LAS dataset or a discrete set of classes from Dataset 1 as a

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reference surface. The data to be analyzed (Dataset 1) must be loaded in MARS®; Dataset 2 (if used) must be pathed out using the 'Folder' browse button (all LAS files in the selected folder will be used, so make sure it contains only the data that is to be compared with the loaded dataset). If using classes only from Dataset 1 (e.g., finding the volume of a building), the Source Classifications for Dataset 1 would be the ground class(es) and the Source Classifications for the Reference Surface would be the building class(es). If using a second dataset as a reference, the same classified feature(s) (e.g., ground points) chosen as the 'Source Classifications' for Dataset 1 must exist as one or more classes in Dataset 2, and must be selected using the 'Source Classifications' 'Select' button. A polygon must be digitized to delineate the analysis area, and all referenced datasets must completely cover the extent of that polygon.

- ***User Digitized Reference Surface:*** Uses a digitized, draped polygon drawn on Dataset 1, which must be loaded in MARS®. The draping will be done on a virtual surface built from the selected 'Source Classifications', and vertices with derived Z-values will be created along the polygon outline depending on the 'Sampling' interval entered. These vertices will be used to create a TIN that will be compared to Dataset 1 for the digitized polygon area. A shorter 'Sampling' distance (e.g., 'Every 3 Units' instead of 5) will result in a more accurate analysis, but will take longer to process.
- ***User Defined Base Elevation Value:*** Uses a defined base elevation value, or both base and upper elevation values for strata analysis. The digitized polygon becomes a planar surface or surfaces at the entered elevation or elevations. Dataset 1 must be loaded in MARS®. Note that for strata analysis, only a 'Cut' volume will be calculated.
- ***Existing Polygon Shapefile:*** Uses a pre-existing polygon shapefile that covers some or all of Dataset 1, which must be loaded in MARS®. The shapefile can be 3D or 2D - a 2D file will be draped as in ***'User Digitized Reference Surface'*** (above).

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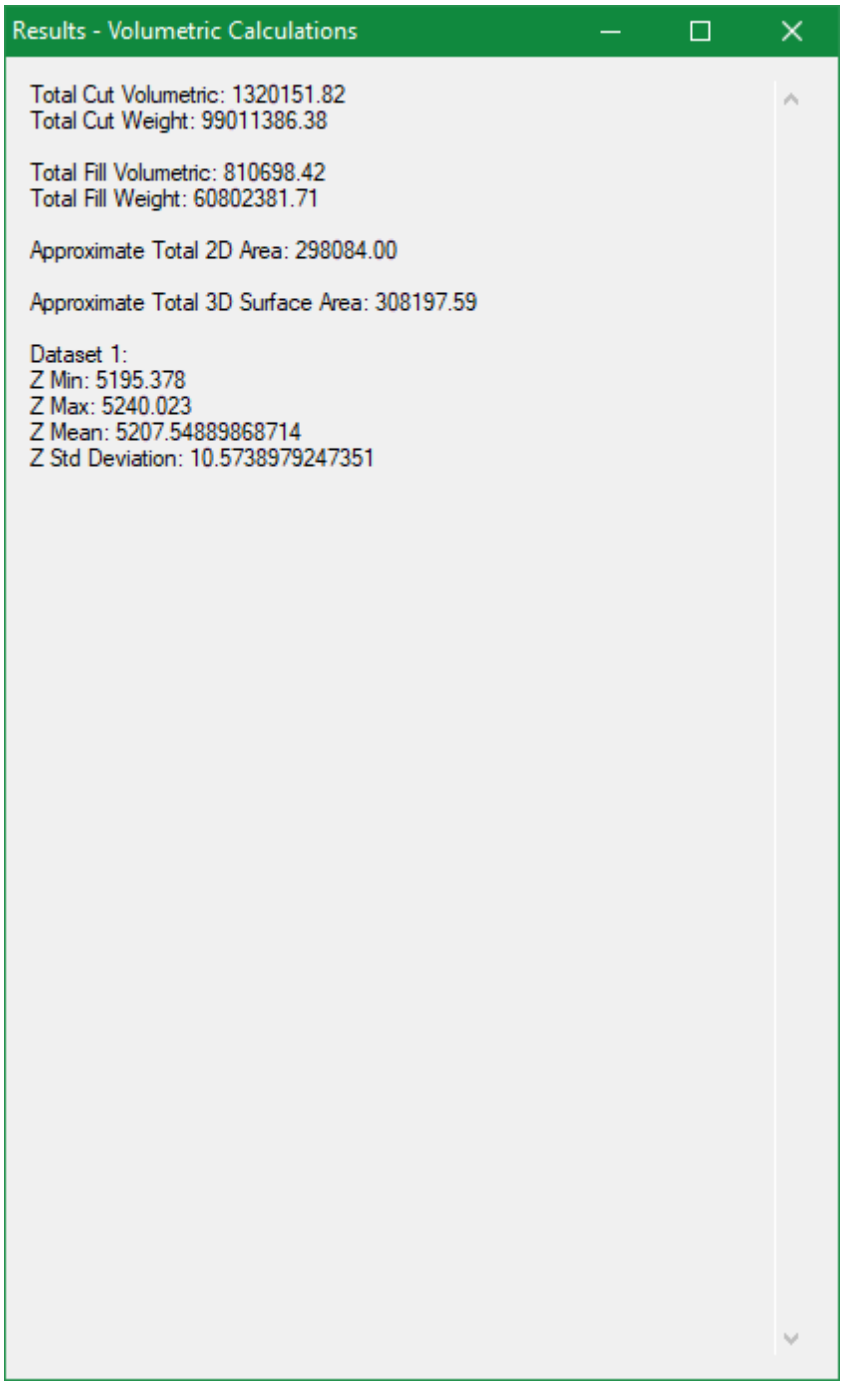
Area Selection section:

When all parameters are set, click the 'Digitize a polygon from MARS view' button to draw a polygon around the area of interest. The 'Existing Polygon Shapefile' method does not require a user-digitized polygon, nor does the "Selected Polygons' option in the 'Area Selection' section. Left-click the mouse to create the start point and vertices, and right-click to close the polygon from the last vertex created back to the start point. Once the polygon is complete and a 'Voxel Size' has been entered, click the 'Calculate' button to begin processing. To use the 'Selected Polygons' method for determining analysis areas, first load a polygonal shapefile as a Tile layout (see the 'Add Tile Shapefile' topic in the Project/ Data Preparation Tab 162 section of this Help Topics file). Select one or more polygons to analyze by clicking the 'Select Polygons' button and clicking in the desired polygon(s). The outlines of selected polygons will change to a thicker line type to indicate that they have been selected. Multiple polygons can be selected by holding down the 'Ctrl' key while selecting, or by dragging a box through the polygons. Selected polygons can be *unselected* by holding down the 'Ctrl' key and clicking in the polygon. Click outside of the loaded polygon shapefile to unselect all. When finished selecting, click the 'Calculate' button to begin processing. A results pop-up similar to one of the examples below will appear when the analysis is finished.

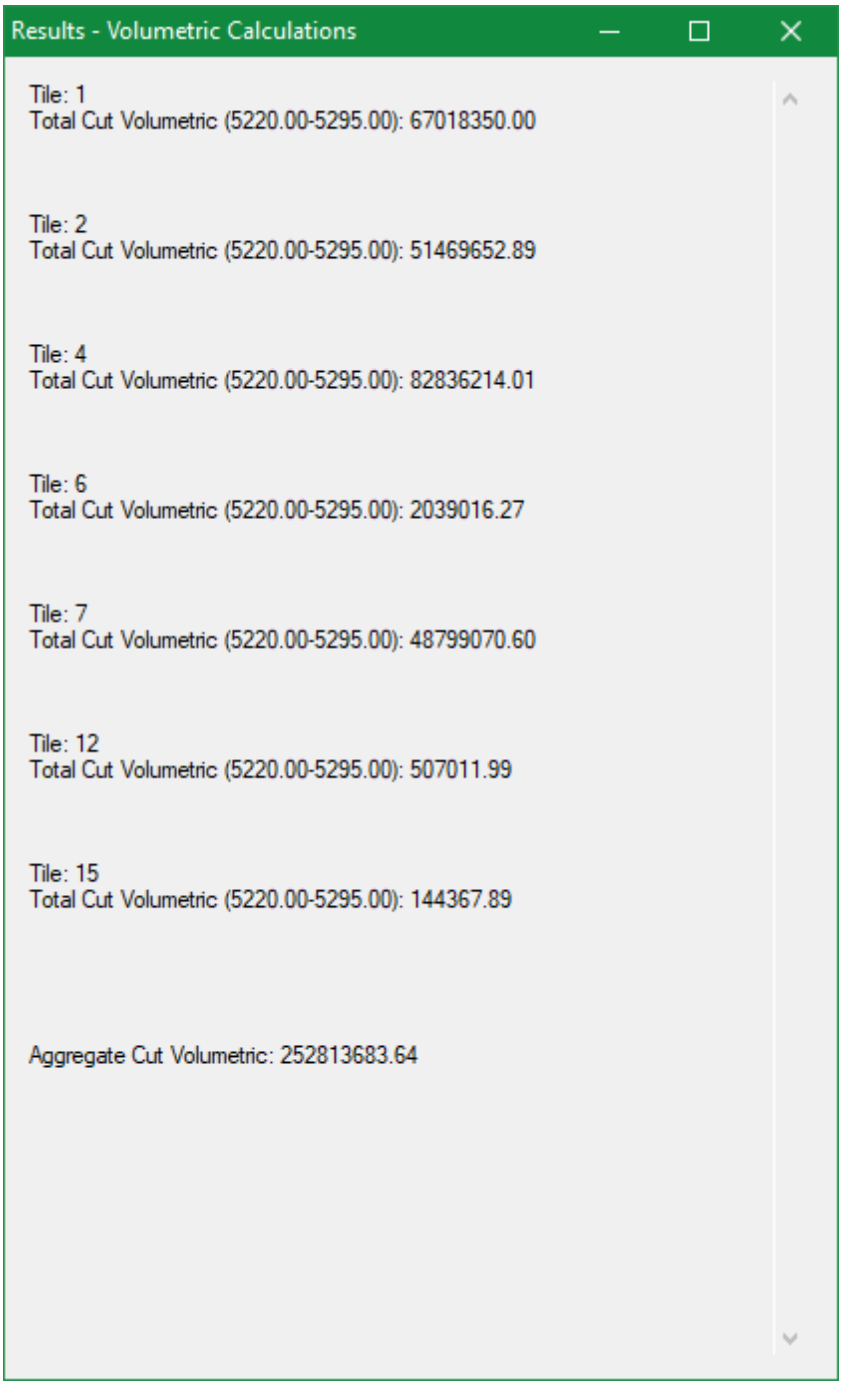
Results from a digitized polygon using a single User Defined Base Elevation Value (cut and fill both analyzed, 'Weight entered)

Results from multiple selected polygons using an elevation range (strata analysis, cut volume only, no 'Weight' entered)

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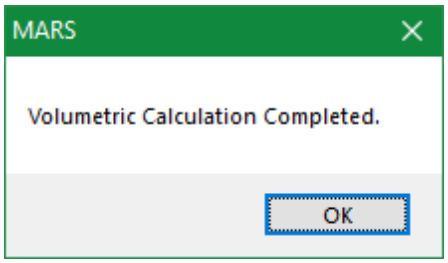


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When the results pop-up is closed, a completion message will appear:

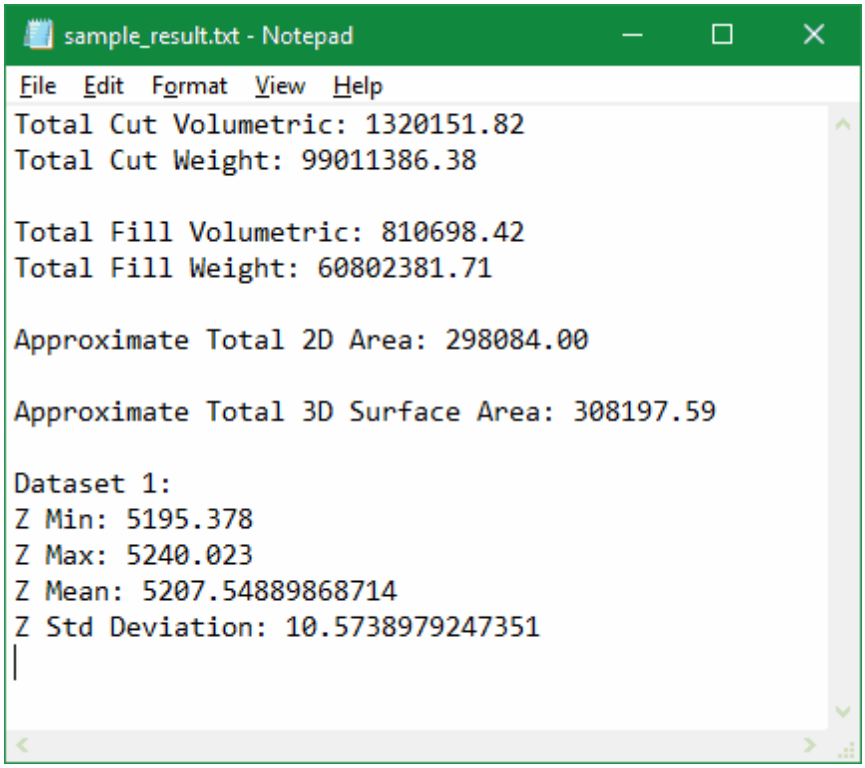
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Optional Parameters section:

Total Cut/Fill Weight values will be shown only if a 'Weight per cubic unit' entry is made. If the 'Save results to text file' box is checked, a file like the one shown below will be saved based on the name and path chosen in the 'Browse' box. When this option is used, a settings XML file will be saved automatically in the same path.

Sample of text file created when 'Save results to text file' box is checked.



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5 Data Classification (Manual & Batch)

5.1 Filter Action

Discrete Filter Use

Merrick Advanced Remote Sensing (MARS®) Software

The MARS® filter action module provides sophisticated filter algorithms for reclassifying LiDAR points. The MARS® filter action module contains 31 filter functions which can be used individually or as part of a macro within a batch script. To use these tools, go to the Edit/Filter Tab 270.

➤Building Filter 988 ➤Change Bit Flags Filter 994 ➤Consistent Return Filter 1001 ➤Ditch and Berm Filter 1008 ➤Elevation Filter 1013 ➤ENVI Reclass Filter 1018 ➤Extreme High Filter 1025 ➤Extreme Low Filter 1030 ➤Ground 1036 ➤Ground Distance Filter 1044 ➤Height From Surface Filter 1052 ➤Intensity Filter 1059 ➤Isolated Point Filter 1063 ➤Max Grid Filter 1068 ➤Median Grid Filter 1072 ➤Min Grid Filter 1077
➤Model Key-point Filter 1082 ➤Percolate Filter 1087 ➤Plane Analysis Filter 1095 ➤Reclassify Filter 1100 ➤Return Filter 1104 ➤RGBNI Value Filter 1110 ➤Scan Angle Filter 1118 ➤Slope Filter 1126 ➤Smart Clip Filter 1130
➤Smooth Grid Filter 1138 ➤Smooth Max Grid Filter 1144 ➤Smooth Min Grid Filter 1150 ➤ Timestamp Filter 1156 ➤XY Distance Filter 1161 ➤XYZ Distance Filter 1169

MARS® applies the data filtering algorithms to those LiDAR points (source classification) matching the parameters of the filter function. LiDAR points meeting those criteria are reclassified to the specified target classification. In addition, all filter functions have a set of one or more source classifications that

identify the pool of candidate points for each instance of a filter function.

PLEASE NOTE that the default values that exist in all filters are based on projects in U.S. feet. For project data in meters, these values will need to be converted appropriately. Also, the examples shown for each filter are based on LAS v1.4, PDRF 6 (or higher) data, except the Model Key-point Filter which is currently based on older LAS v1.2 data that uses a separate class for the Target points. The various classes used in the examples were chosen for visual clarity and may not necessarily reflect typical classes that would be used for the filter type.

In addition, some filter functions have a third set of classifications that may be specified. The third classification, also known as the reference classification, may be used to build a reference surface, or to seed a filter algorithm. There will be specific documentation regarding the reference surface classification if the selected filter (ex. Height From Surface filter) has this additional parameter.

Optional comments may be added to the Comments box at the bottom of each filter's interface. These comments will be saved if the filter is added to a macro as part of a batch script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

The user may also manually reclassify LAS 1824 files to enhance the quality of the LiDAR dataset.

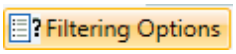
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5.1.1 Building Filter



The **Building Filter** uses an algorithm that literally identifies buildings from the ground up. The filter only looks for buildings in areas that are void of ground-classed points - the non-ground points can be in any class.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A classified dataset including ground and at least one other class.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage allows for a more precise output from the filter but requires a longer running time.

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- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Minimum area in detected building surface:** The minimum planar surface area required for the surface to be considered as significant. Minimum area value is in square units (ex. 300 square feet). The minimum area requirement applies to the planar surface built from 'Source Classifications' points.
- **Minimum number of triangles in detected building surface:** The minimum number of triangles required in a flat surface (a surface represented by contiguous TIN triangles) for the surface to be considered as significant. The minimum number of triangles applies to the flat surface built from 'Source Classifications' points.
- **Maximum slope variance amongst triangles in building surface (in degrees):** The maximum slope difference in degrees for any two TIN triangles on the planar surface.
- **LiDAR GSD:** The **G**round **S**ample **D**istance in project units of the collected LiDAR data.
- **Delta Z allowed for post reclass process:** The maximum allowable perpendicular distance that a candidate point can be from the plane of the roof surface.
- **Minimum roof height above ground:** The minimum elevation difference between the roof height of candidate features and the adjacent ground surface.
- **Options to Remove Isolated Points**
  - **Spherical Radius:** MARS® will search inside the user defined spherical radius distance (along the X, Y and Z axes) for candidate points. Points outside this radius that meet the other criteria are kept in the source class. This parameter is used in conjunction with **'Fewer Than'** (below).

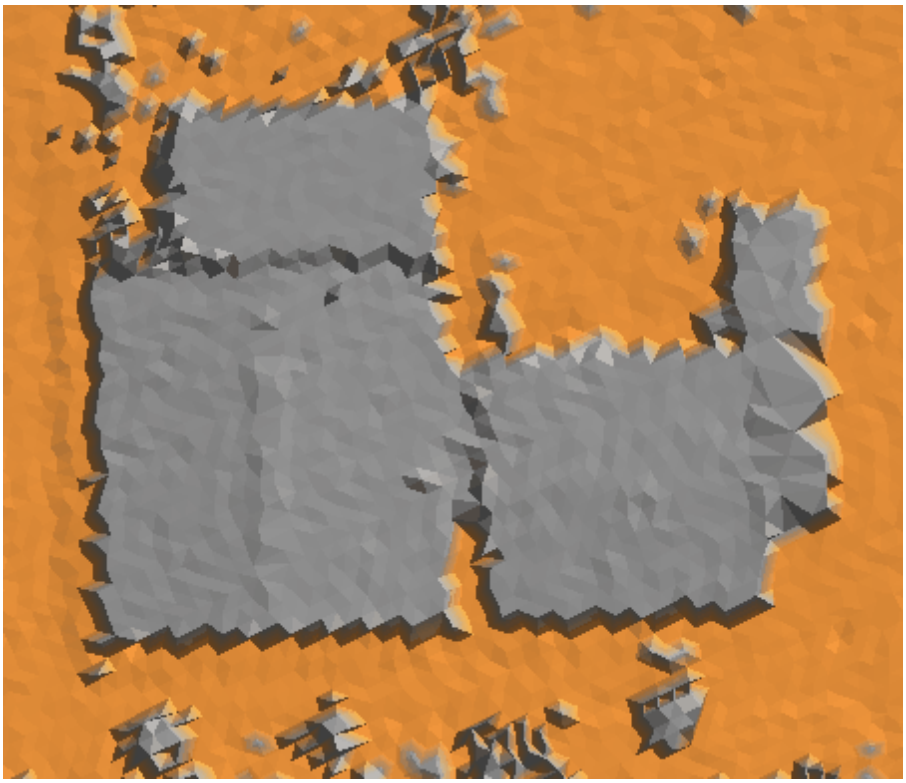
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- ❖ **Fewer Than:** The number of points in a cluster to be considered when applying the **'Spherical Radius'** test (above).

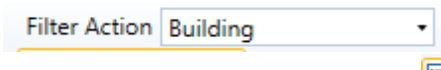
- **Ground Classifications:** The classification(s) that the ground surface is in.

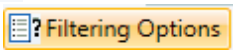
Example Filter Use:

Before: In the example below, the dataset has only Class 2 (ground - orange) and Class 1 (unclassified - gray). Using the TIN rendering function, the user can more easily identify possible buildings in the unclassified areas.



Manually Using the Filter: To use the Building Filter to extract buildings from other classes, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



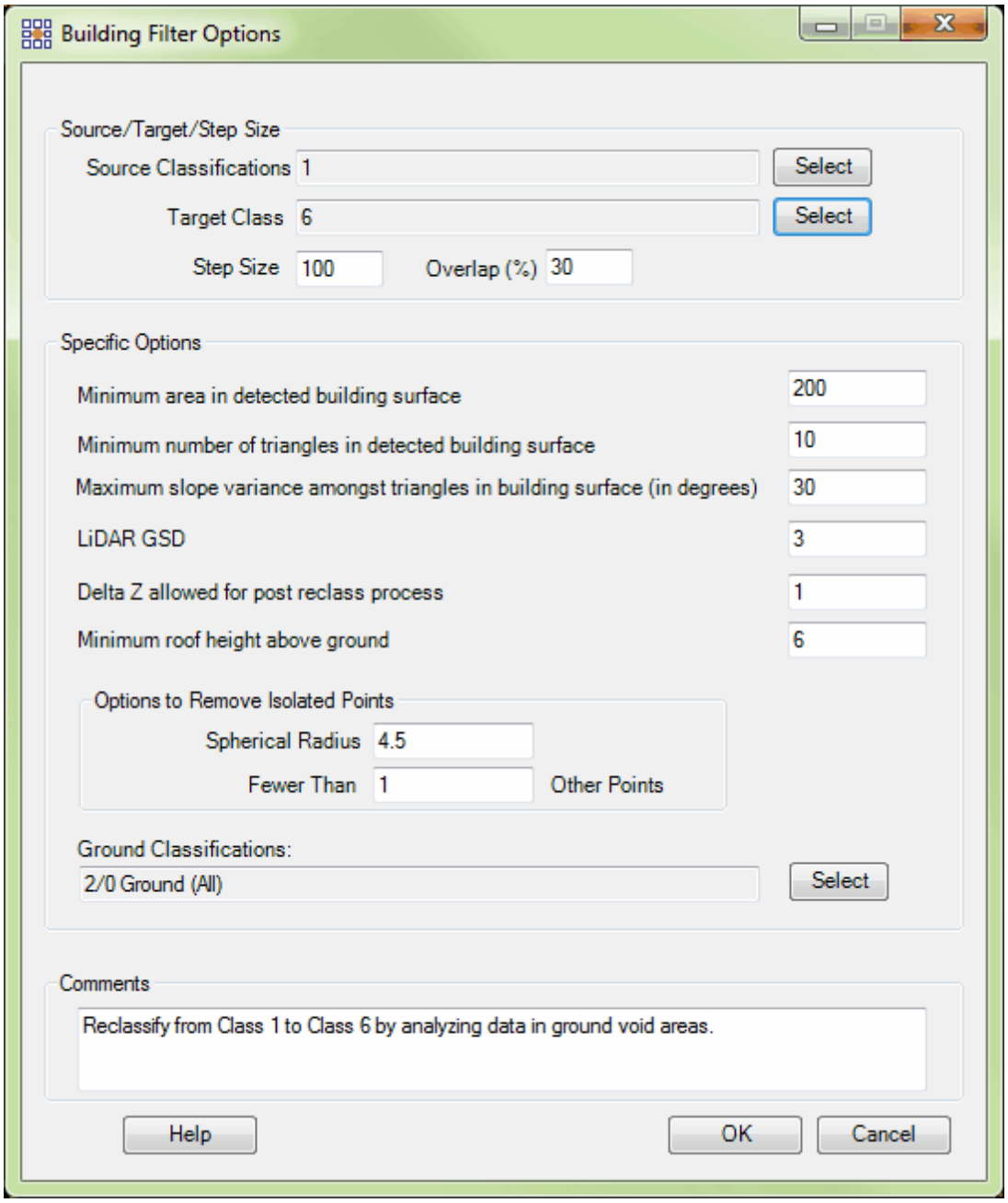
Next, click on the 'Filtering Options'  button to define the filter settings.

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'Building Filter Options' Dialog: The 'Building Filter Options' interface gives the user several options for specifying the filter's action. The Source Classification(s), Target Class, Step Size, and Overlap can be set as in other filters. Unique to this filter is the option to choose a minimum area and a minimum number of triangles in a detected building surface, a maximum slope variance amongst triangles in a building surface, the ground sample distance, the difference in elevation allowed for post-reclass processing, the minimum above-ground roof height, and the desired values for excluding isolated points.

In this example, the source classification will be Class 1: Unclassified, as all the non-ground points are in this classification. The target class will be Class 6: Building. The default settings for step size (100) and overlap percentage (30) will work for most projects but can be changed as desired. The default settings for 'Minimum area in a detected building surface', 'Minimum number of triangles in a detected building surface', and the remaining filter-specific settings will also be used for this example. The ground classification will be set as Class 2: Ground (All) which includes Model Key-points. Click **'OK'** to save the settings.

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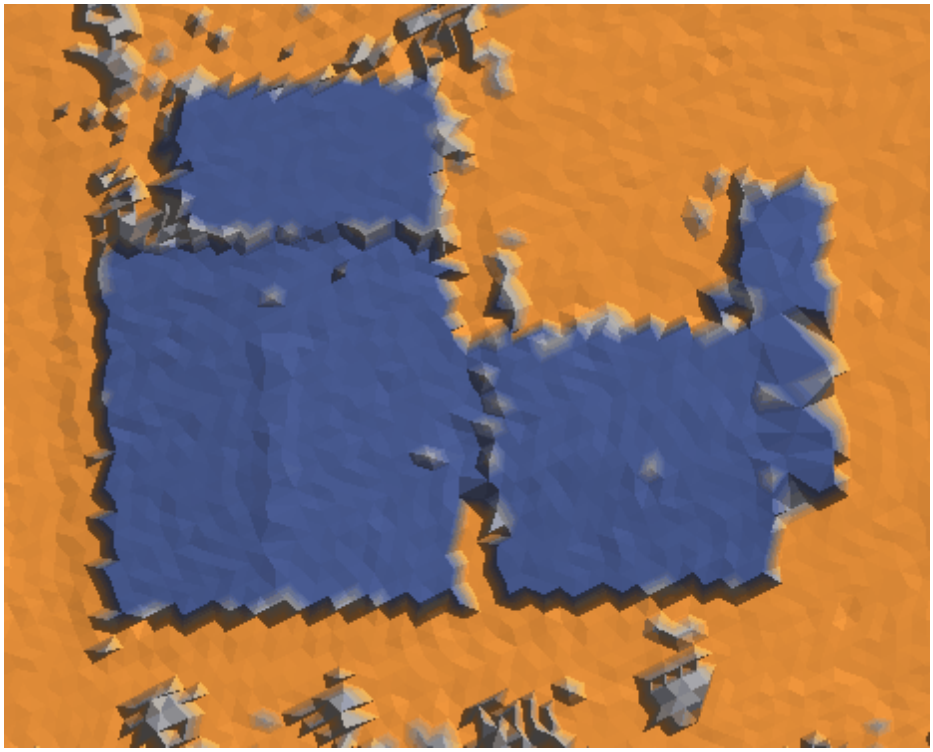


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected**

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Polygons' Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, the building points are now properly reclassified as Class 6 (dark blue), while the remaining Class 1 (gray) points are unchanged. This filter should reduce the amount of manual (hand) editing that needs to be completed by 80 to 90%.



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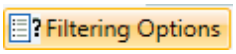
5.1.2 Change Bit Flags Filter

Change Bit Flags Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Change Bit Flags Filter** modifies the status (set/on or clear/off) of several of the bit flags that can be used with LAS v1.4 data: Synthetic, Model Key-point, Withheld, and Overlap. ***Specifically, this filter can be used only with LAS v1.4, Point Data Record Format (PDRF) 6 or higher data***. It can optionally reclass those points whose bit flag values have been modified, and its function can be limited to a single collection scan.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** Specifies which class(es) of points will be used as a source in identifying the proper points to have their bit flag status modified and, optionally, be reclassified.
- **Reclass Modified Points:** When checked, reclasses only those points whose bit flags have been modified to the **'Target Class'**.
- **Target Class:** If the **'Reclass Modified Points'** option is checked on, the class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of

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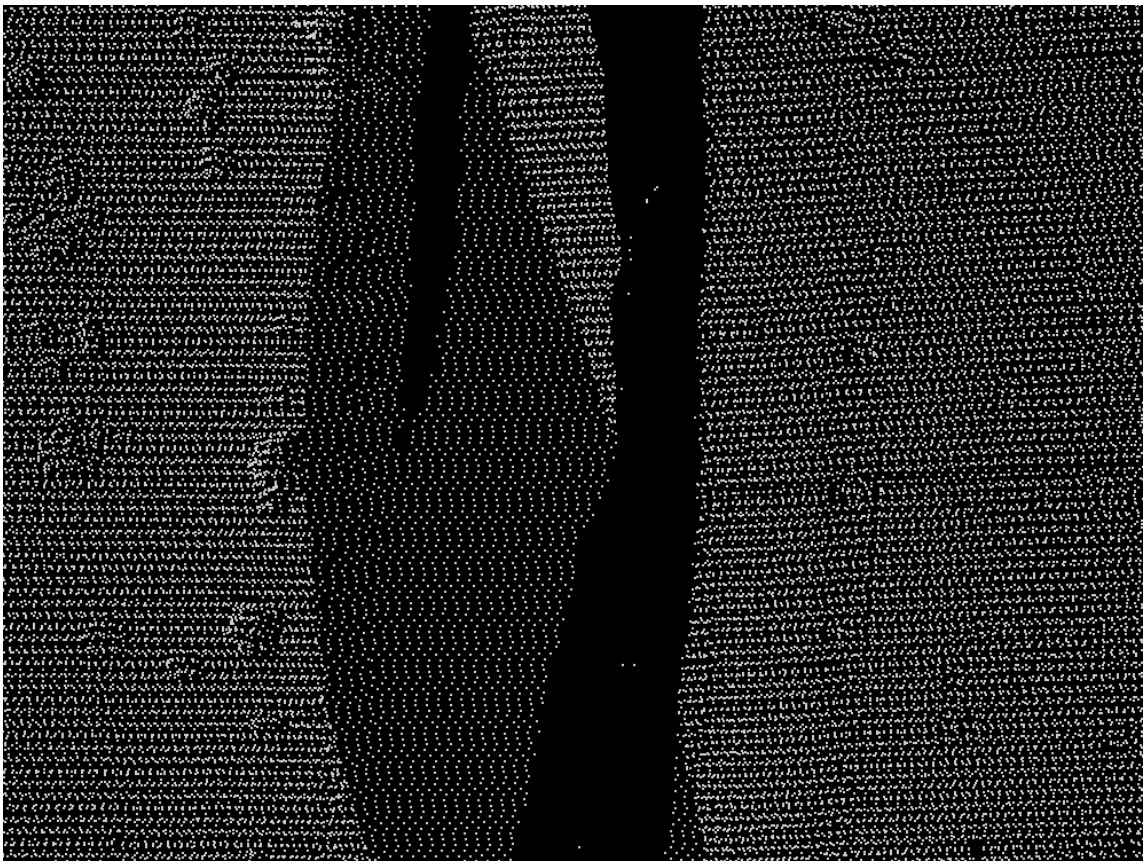
100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.

- **Overlap (%):** Not applicable for this filter.
- **Bit Flag Modification Options:** The four bit flags whose status can be changed are listed here. Either 'Set' or 'Clear' can be selected for each flag. If, for example, 'Set' is chosen for 'Withheld' and all 'Source Classification' points within the area to be filtered already have the 'Withheld' bit flag set, no action will be taken on those points.
- **Use All Collection Scans:** When checked, all collection scans within the defined area will be included in the modification. If unchecked, an individual **'Collection Scan Number'** must be entered for filtering.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

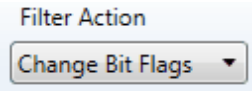
Example Filter Use:

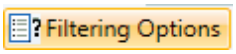
Before: In the example below, a section of Class 0 (gray) points east of the river needs to to be set as Withheld and re-classed to Class 23 (pink).

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Manually Using a Single Filter: To use the Change Bit Flags Filter to modify the bit flag status of specified points and, optionally, reclassify those points to a single Target Class, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



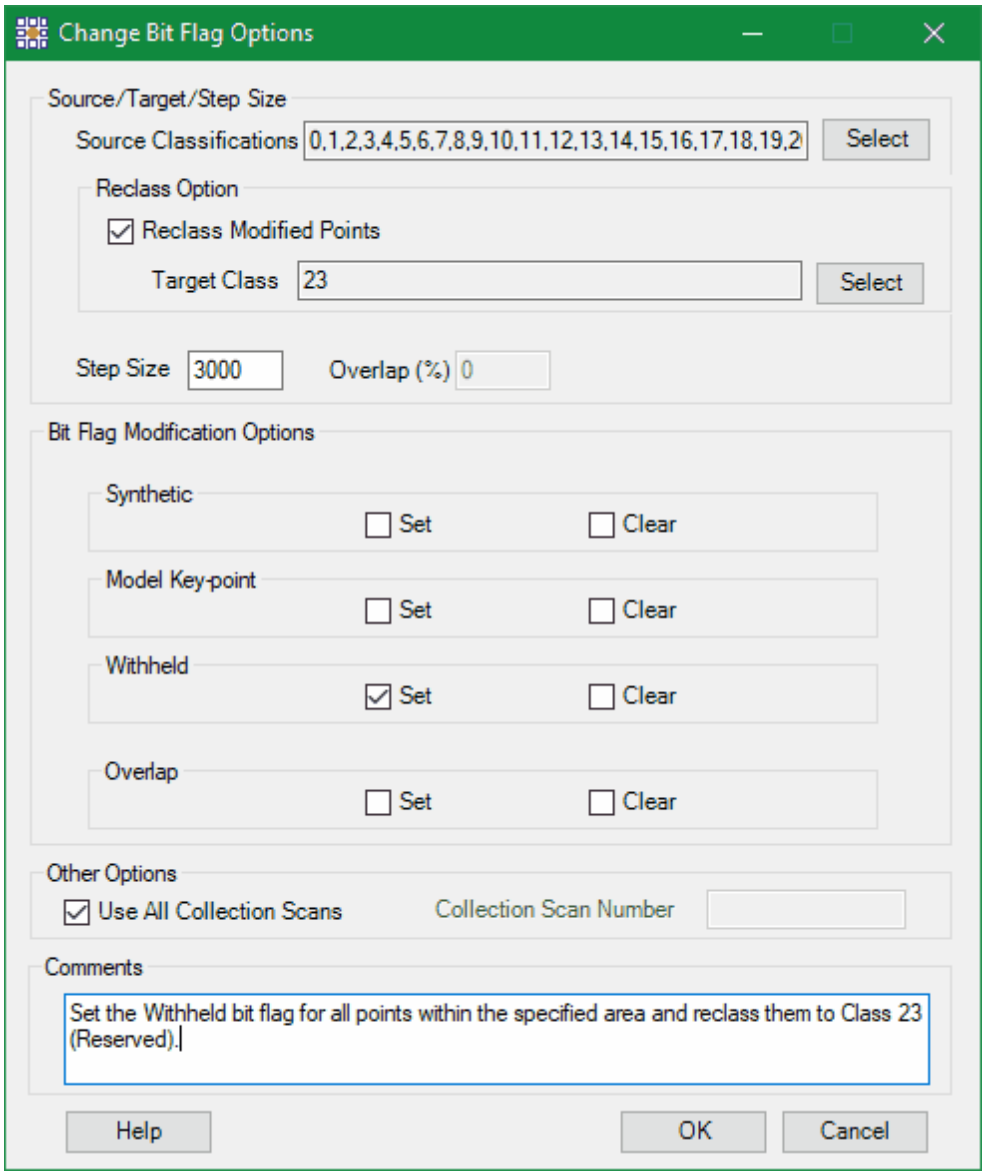
Next, click on the 'Filtering Options'  button to define the filter settings.

Change Bit Flags Filter Options Dialog: The 'Change Bit Flag Options' interface gives the user several options in specifying the filter. The Source Classifications and Step Size can be adjusted as in other filters. For optional reclassifying, the Target Class can be set. If not all collection scans are to be included, a specific collection scan can be identified by number.

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In this example, the Source Classification can be all classes, since all points are currently in Class 0: Created, Never Classified (gray). To set this, choose the **'All Classifications On'** button when selecting classes for the Source Classifications. The Target Class for the modified points will be Class 23: Reserved (pink), so the 'Reclass Modified Points' box must be checked to allow the Target Class to be selected. The default setting of 3000 for Step Size will work for most projects, so it will be used for this example. The 'Set' box is checked for 'Withheld' and all other bit flags are to be left as is, so neither the 'Set' nor 'Clear' boxes are checked for them. All collection scans are to be modified, so the 'Use All Collection Scans' box will remain checked. Click **'OK'** to save the settings.

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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data.

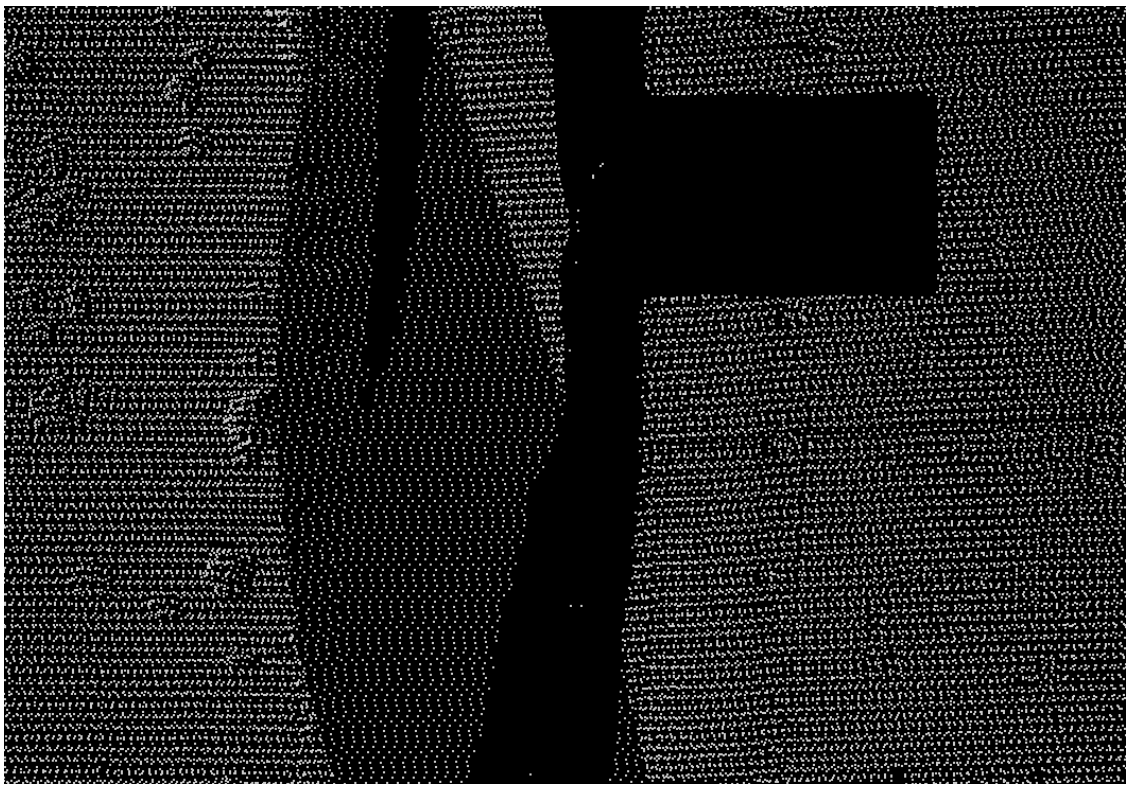
After:

After running the filter, the modified points now have their 'Withheld' bit flag set

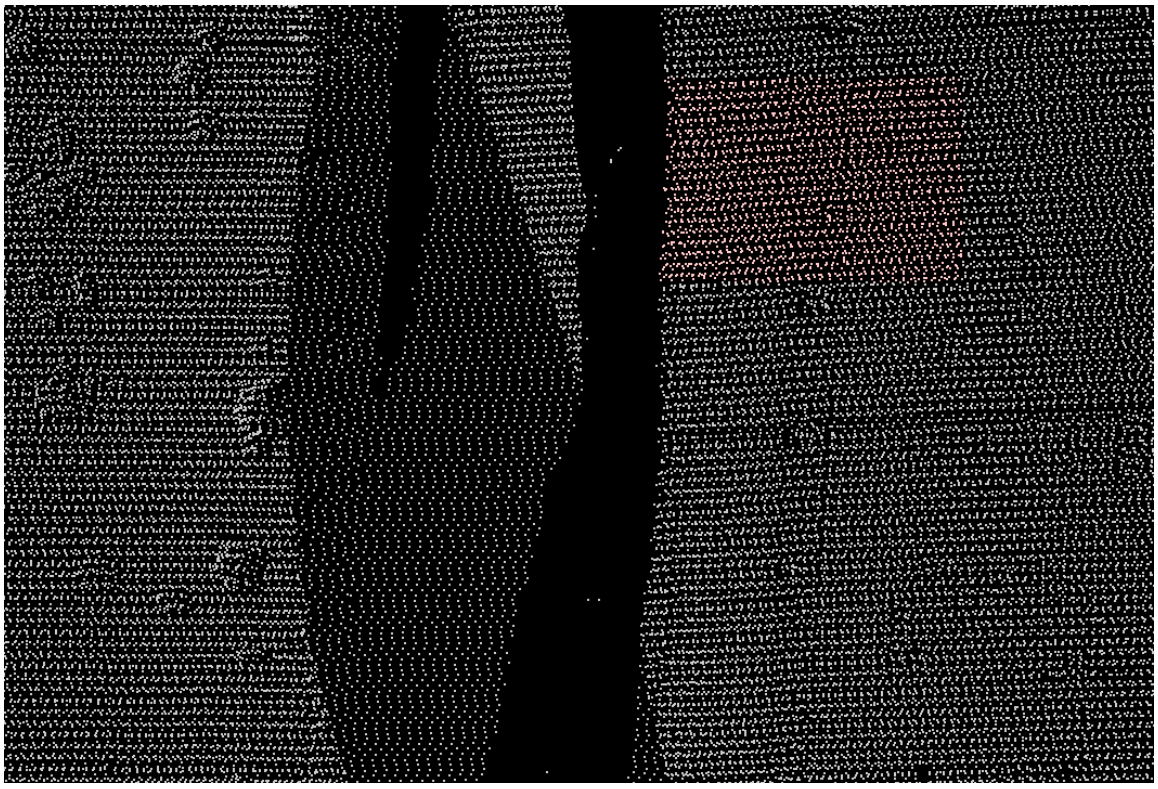
Below, the Bit Flag Display Settings 841 have been changed to allow the Withheld points (now assigned

(on), making them invisible, and have been reclassified to Class 23 (Reserved).

to Class 23) to be seen in pink.



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5.1.3 Consistent Return Filter

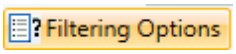
Consistent Return Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Consistent Return Filter** reclassifies points based on their source class and return value and a minimum distance from points with other return values. Specifically, a point is reclassified if its return value and the return values of all nearby points match the user-defined return value set. For example, source class points in the search radius with non-matching return values will not be reclassified, while source class points in the search radius with matching return values will be reclassified. For more

about return values, read the description under the Return Filter.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Returns are not listed only as 1st return, 2nd return, etc., but rather are identified in the context of how many total returns were recorded from the laser pulse (e.g., 1st of 3 returns). Any combination of these return values can be specified. (There are 36 possible values for a laser capable of sensing 8 returns from a single laser pulse.) To aid in the specification of the desired return values, there are shortcuts for describing some of the commonly used sets of possible return values. These are:

- **All returns:** Displays all possible return values, including Unknown.
- **Single returns:** Displays 1st of 1 return.
- **First (including single) returns:** Displays 1st return of any number of total returns.
- **First but not single returns (first of many):** Displays only 1st return of any 2 through 15 total returns.
- **Last including single returns (1st of 1, 2nd of 2, 3rd of 3, ...):** Displays only last returns of any number of total returns.
- **Last but not single returns (last of many):** Displays only 2nd of 2 returns, 3rd of 3 returns, and so on through 15th of 15 returns.
- **Intermediate:** Displays only returns that are neither the first nor the last return.
- **User-specified returns:** Allows selection from an array of return values.

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Please see the **'Display Selection: Return'** section of the View Tab 192 Help Topic for complete return selection options.

Requirements:

- Points with at least two different return values. This filter cannot be used unless the data to be filtered contains valid point family (discrete return) information. A pop-up warning will be displayed if this information is not present in the LAS files.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

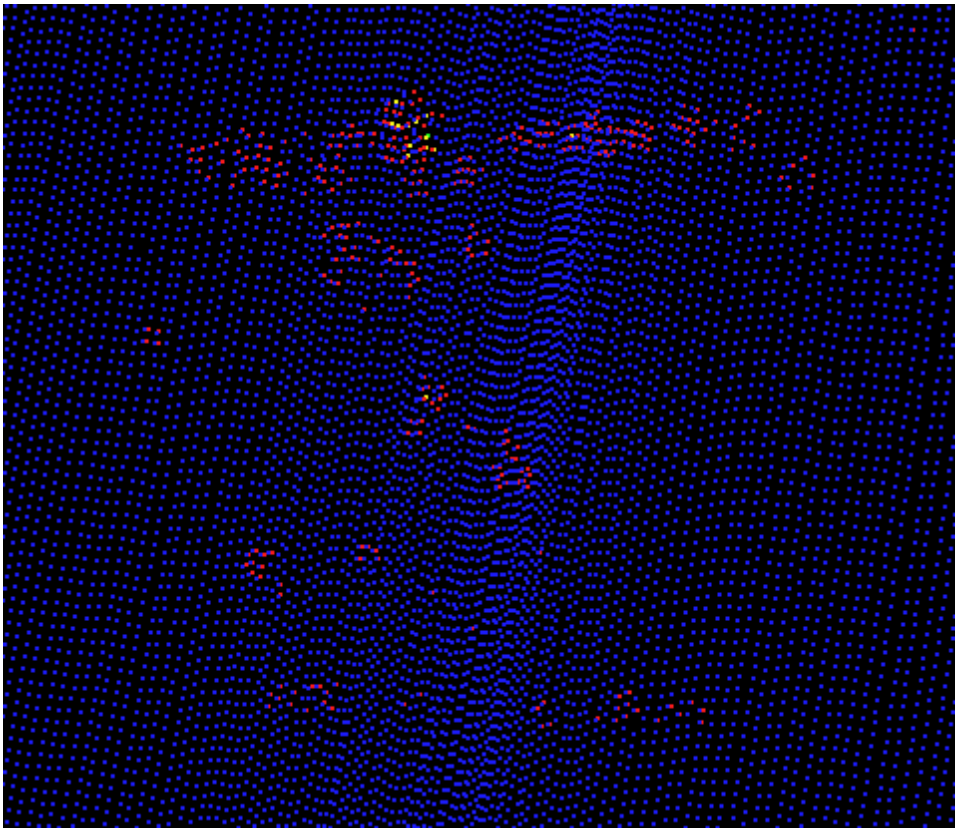
Filter Specific Parameters:

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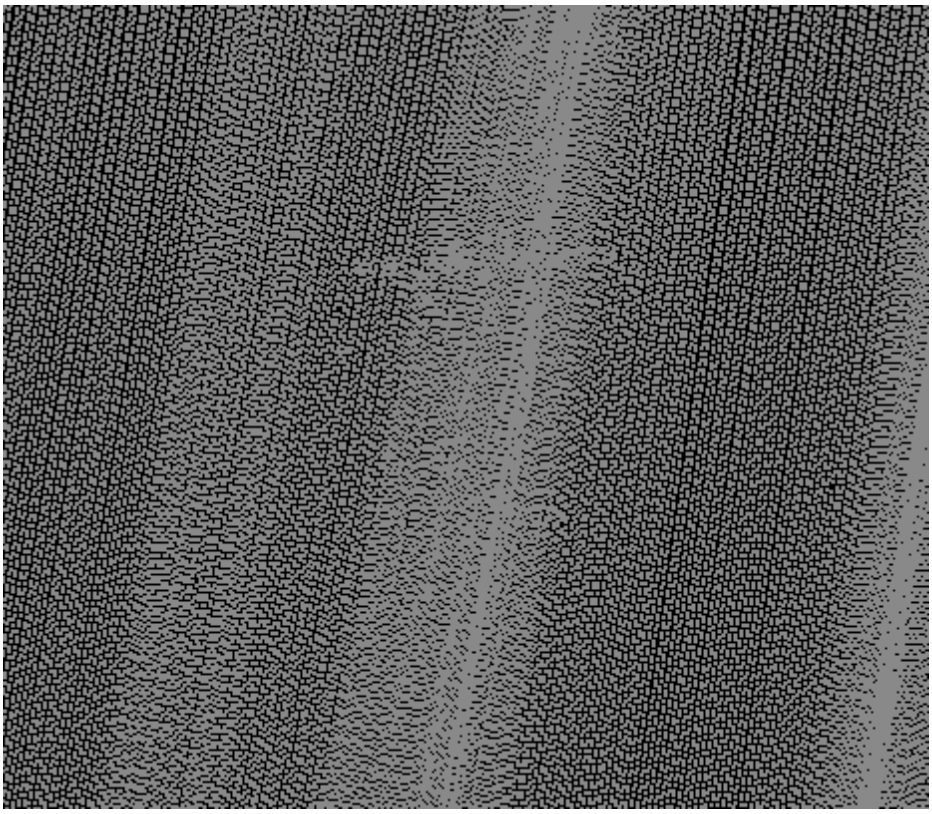
- **Return value set:** Those return values (within the source class or classes) that will define candidate points to be reclassed based on meeting the **'Search radius'** value (below).
- **Search radius:** The minimum distance (in horizontal units) a candidate point must be from points (of any class) having return values not listed in the **'Return value set'**.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

Example Filter Use:

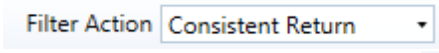
Before: In the first example below, there are several different return values as shown. The second example shows that all points are currently Class 1: Unclassified.

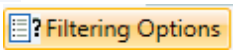


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Manually Using a Single Filter: To use the Consistent Return Filter to classify clusters of points based on return values, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



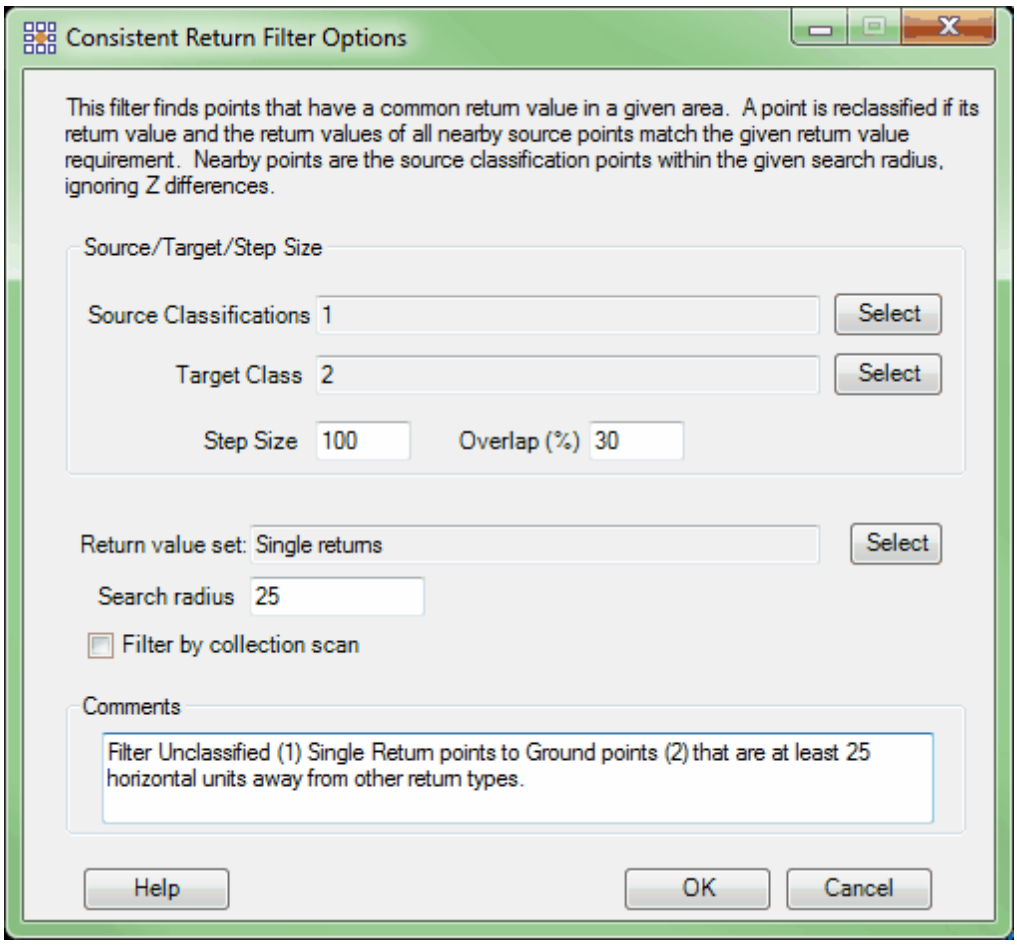
Next, click on the 'Filtering Options'  button to define the filter settings.

Consistent Return Filter Options Dialog: The 'Consistent Return Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose a return value set and to specify a search radius. The option to filter by collection scan is also available.

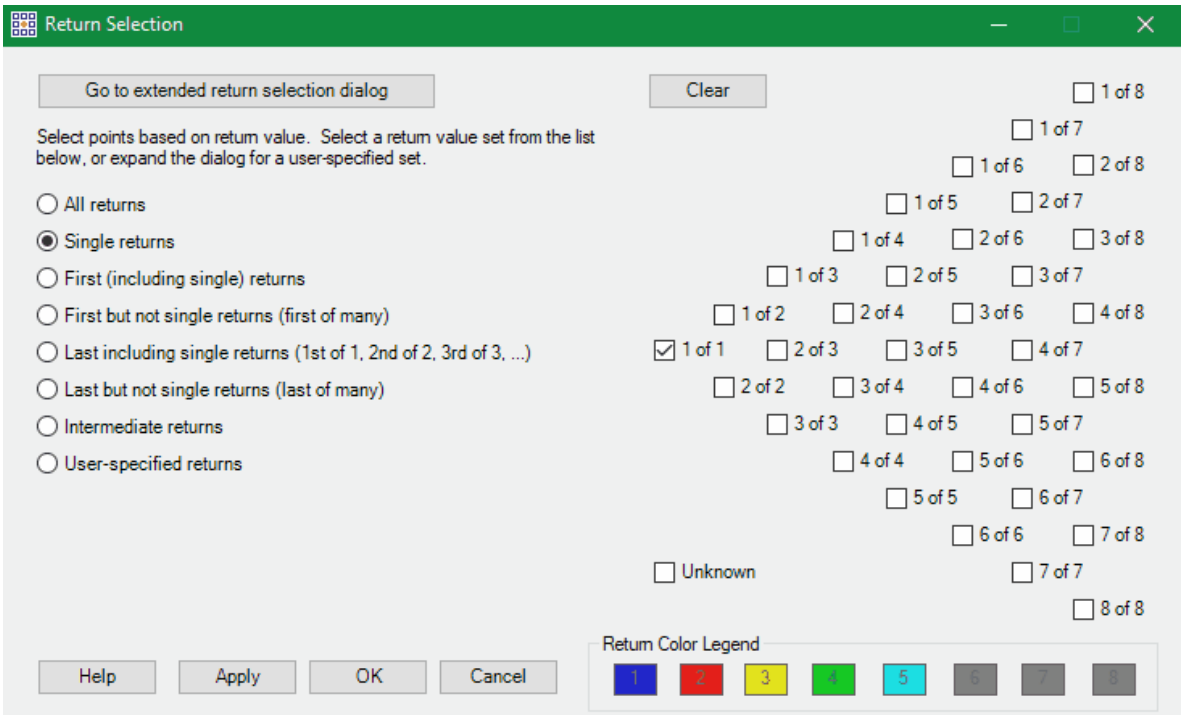
In this example, the source classification will be Class 1, as all the points are currently unclassified.

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The target classification will be Class 2: Ground. The default settings for 'Step Size' and 'Overlap' will work for most projects, so they will be left at their default settings of 100 and 30 respectively. The 'Return value set' will be set to 'Single returns' as they are the most numerous return type and will work well for this example. The default search radius of 25 units will be used for this example. Click **'OK'** to save the settings.



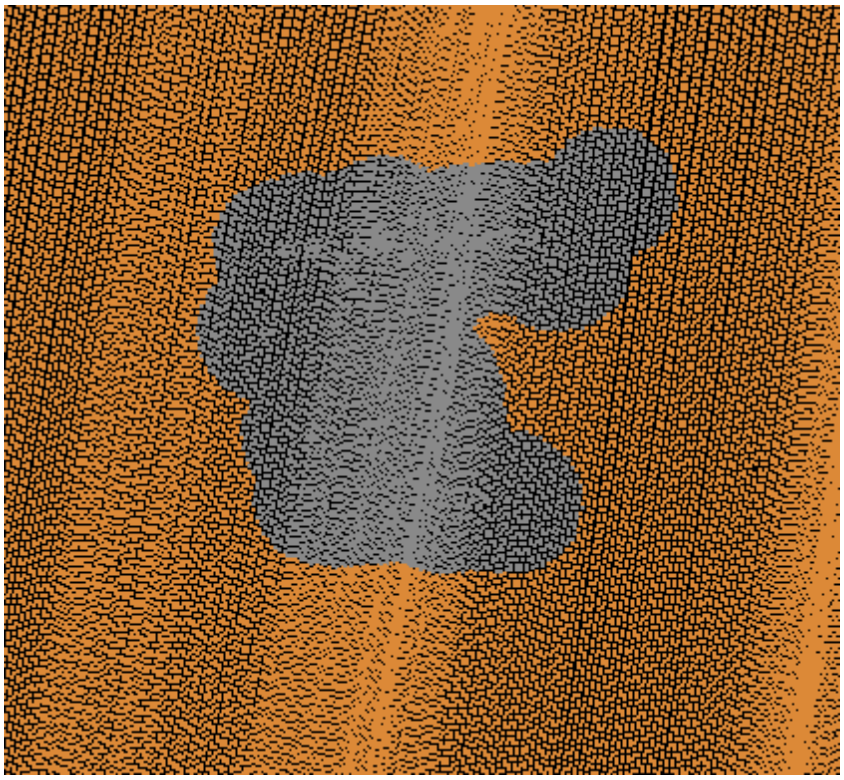
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.classified data.

After: After running the filter, any Single Return points which are more than 25 units from points with other than Single Return values are re-classified as Class 2: Ground. Due to the existence of First (of many) Returns and Second Returns in the middle of the example area, there is a 25 unit buffer placed around those points in which all Single Return source points remain in Class 1.

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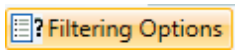
5.1.4 Ditch and Berm Filter

Ditch and Berm Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Ditch and Berm Filter** looks for ground-void areas at the top of berms and bottom of ditches and attempts to fill them from source class points that meet certain user-defined criteria.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- Classified ground plus at least one other classification.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a batch script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Grid Cell Size:** The size of the virtual grid (in horizontal units) that will be built to search for ground-

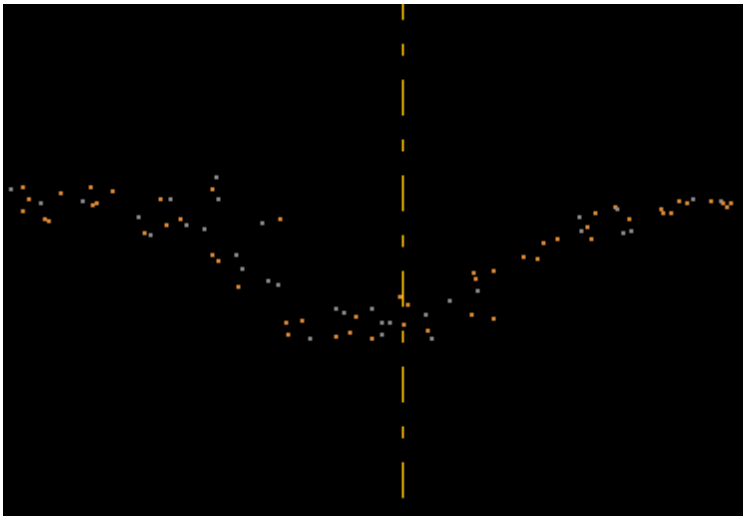
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void areas.

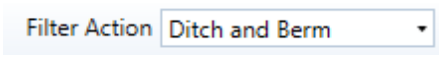
- **Minimum area (number of cells):** The minimum number of adjacent cells that contain no ground points. A smaller number will produce more candidate points.
- **Delta Z allowed:** The maximum difference in elevation allowed between candidate points. A larger number will produce more candidate points.
- **Number of points required within a cell meeting Delta Z criterion: T**he minimum number of points that must fall within the defined Delta Z range in each virtual cell. A smaller number will produce more candidate points
- **Ground Classifications:** The classification(s) that the ground surface is in.

Example Filter Use:

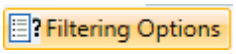
Before: In the example below, there are many points at the bottom of the ditch that are incorrectly classified as Class 1: Unclassified (gray) instead of the correct Class 2: Ground (orange). The Ditch and Berm filter will reclassify these to ground using the current ground points as a reference.



Manually Using a Single Filter: To use the Ditch and Berm Filter to add points to ground, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



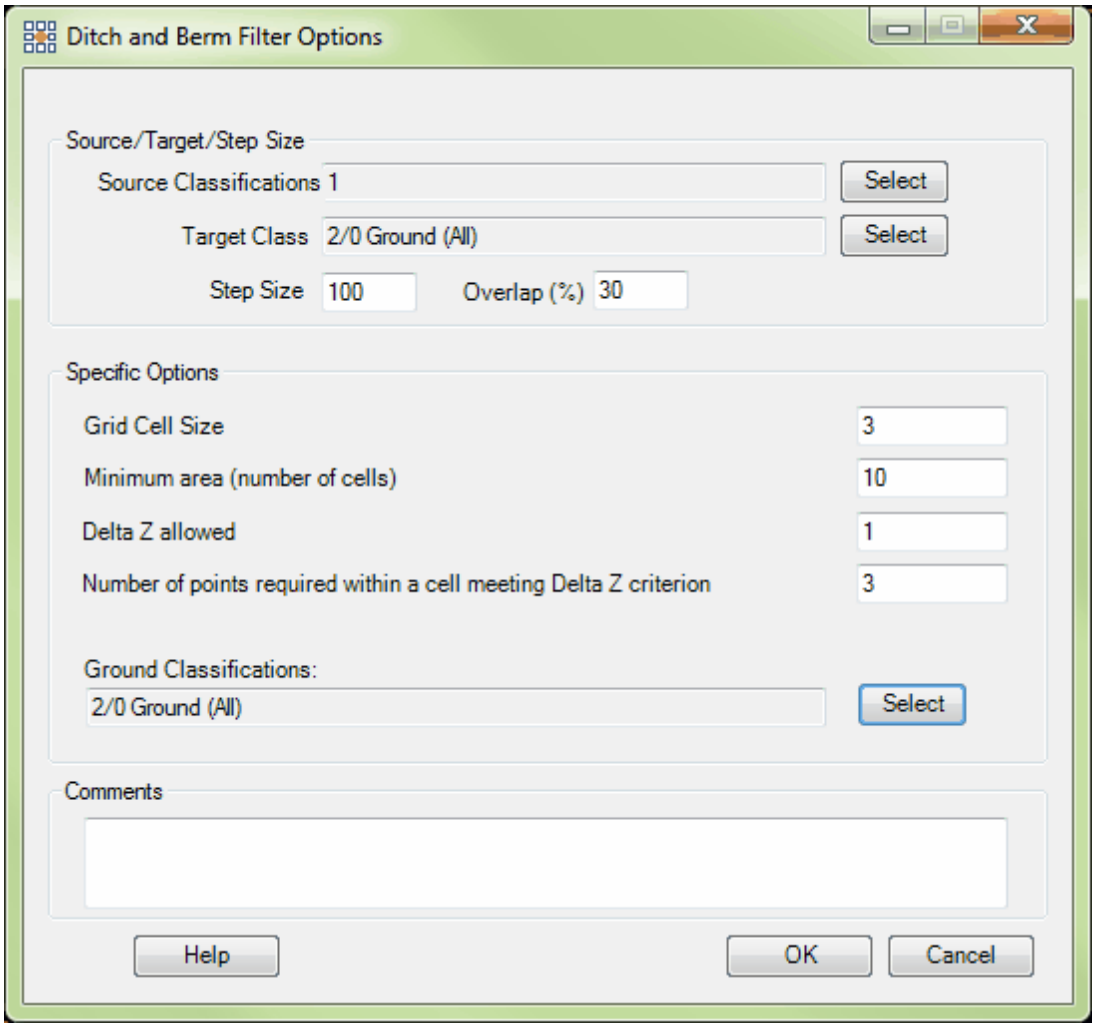
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Next, click on the 'Filtering Options'  button to define the filter settings.

Ditch and Berm Filter Options Dialog: The 'Ditch and Berm Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter are the settings for Grid Cell Size, Minimum area (number of cells), Delta Z allowed, Number of points required within a cell meeting Delta Z criterion, and Ground Classifications.

In this example, the Source classification will be Class 1, as all the non-ground points are currently unclassified. The Target classification will be Class 2: Ground, as the candidate points that meet the set parameters will be added to the ground class. The default settings for step size and overlap will work for most projects, so they will be left at their default settings of 100 and 30, respectively. The 'Grid Cell Size' of 3 indicates that a 3 x 3 unit virtual grid will be built to look for ground-void areas. A good starting point for this value is the GSD (ground sample distance) of the data being filtered. 'Minimum area (number of cells)' is the minimum number of adjacent cells that currently have no ground points in them. A smaller number will return more candidate points from the Source class and vice versa. 'Delta Z' is the maximum difference in elevation allowed between candidate points in the Source class. 'Number of points required within a cell meeting Delta Z criterion' is the minimum number of points that must fall within the defined Delta Z range in each virtual cell. A smaller number will return more candidate points from the Source class and vice versa. Click **'OK'** to save the settings.

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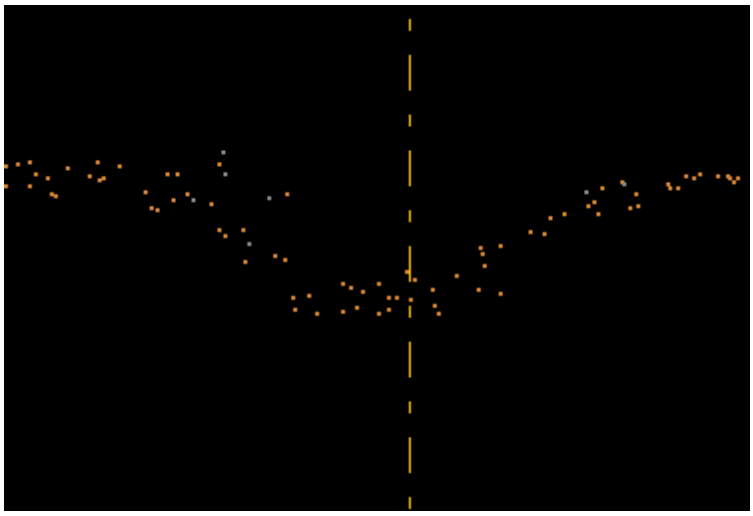


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, nearly all of the ground points that were previously in Class 1 have been

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correctly reclassed as ground (Class 2).



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5.1.5 Elevation Filter

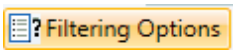
Elevation Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Elevation Filter** reclassifies LAS points based on their **absolute elevation (Z) value**. (If the user is interested in classifying points within a certain height from any surface, please use the Height From Surface 1052 filter). The user may select any one of three elevation modes: 'Above' (a specified elevation), 'Below' (a specified elevation), or 'Between' (two specified elevations).

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab

270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Not applicable for this filter.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

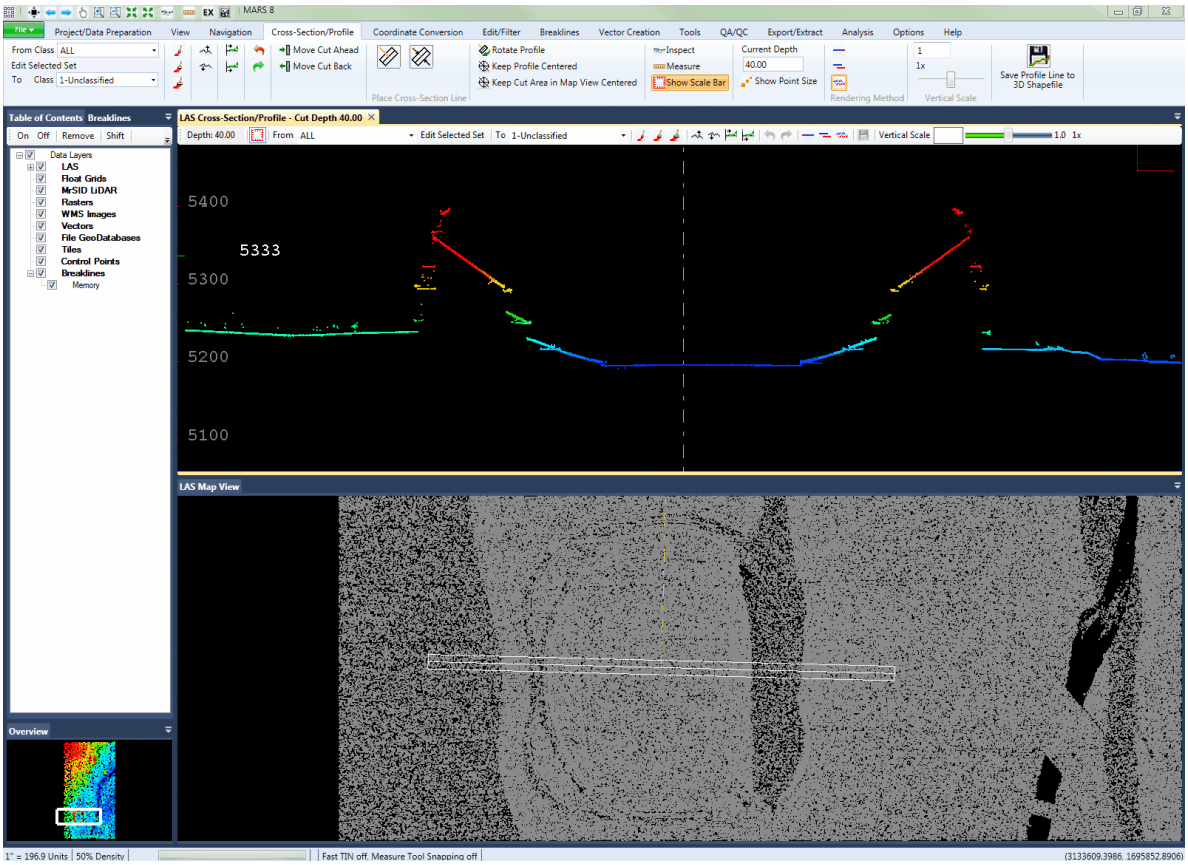
- **Above Mode:** Reclassifies all points above the upper elevation value.
- **Below Mode:** Reclassifies all points below the lower elevation value.
- **Between Mode:** Reclassifies all points between the lower and upper elevation values.
- **Above and Below Mode:** Reclassifies all points above and below specified elevation values.
- **Upper Limit:** Upper elevation value (in project units).

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- **Lower Limit:** Lower elevation value (in project units).

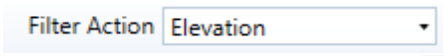
Example Filter Use:

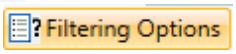
Before: In the example below, the data has all been reclassified to Class 1: Unclassified (gray) to make this example easier to see and understand. Also, a profile of the data is used to find that elevations in this area range from just less than 5200 units at the lowest to about 5400 units at the highest.



Manually Using a Single Filter: To use the Elevation Filter to classify data based on its absolute elevation, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.

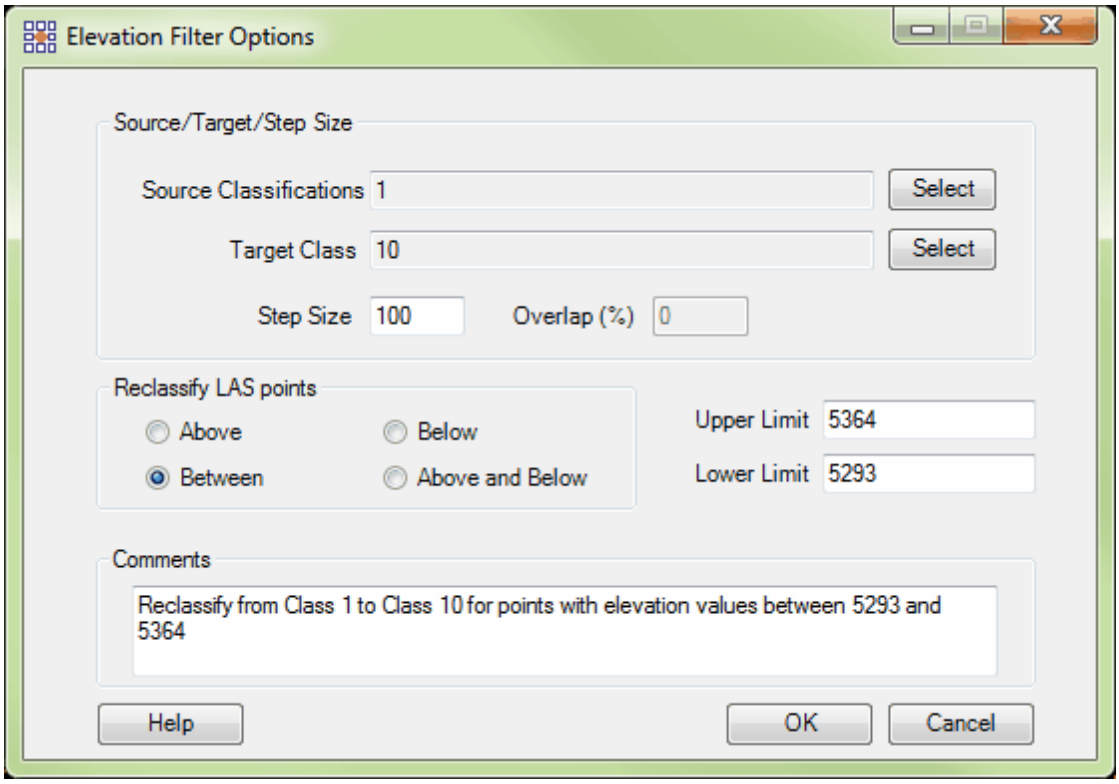
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Next, click on the 'Filtering Options'  button to define the filter settings.

Elevation Filter Options Dialog: The 'Elevation Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to reclassify points on either side of an elevation range or between two elevations. This filter can also reclass points above or below a particular elevation.

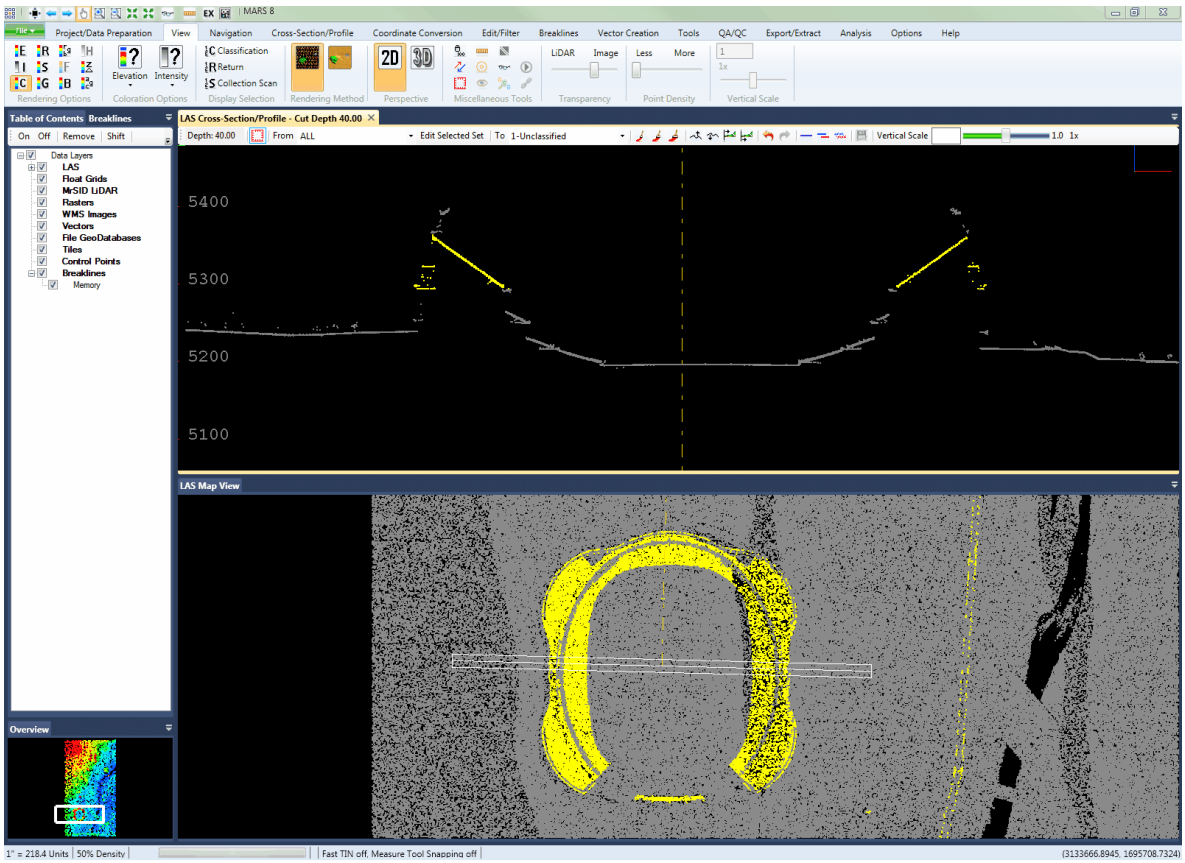
In this example, the source classification will be Class 1, as all the points are currently unclassified. The target classification will be Class 10 (yellow). The default settings for step size and overlap will work for most projects, so they will be left in their original settings of 100 and 0 respectively. In this example, the user chose to reclassify points between the elevations of 5293 units and 5364 units. Click **'OK'** to save the settings.



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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, the points which are between the elevations of 5293 and 5364 units have been reclassified to Class 10 (yellow). This 71 unit elevation range can be seen in the 2D orthographic view window as well as in the Cross-Section/Profile window.



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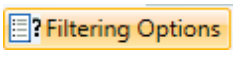
5.1.6 ENVI Reclass Filter

ENVI Reclass Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **ENVI Reclass Filter** allows LAS points to be reclassified based on an ENVI classification data set. ENVI data sets require two files: a header file (.hdr) and a data file (.dat). The filter works in a similar fashion to the RGB component filter except it reclassifies based on a specific ENVI class instead of RGB component ranges. When operating interactively, MARS® uses the currently displayed ENVI data set. When operating in batch mode, the user must specify an ENVI header file name.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A header file (*.hdr).
- A data file (*.dat).

General Parameters:

- **Source Classifications**: The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

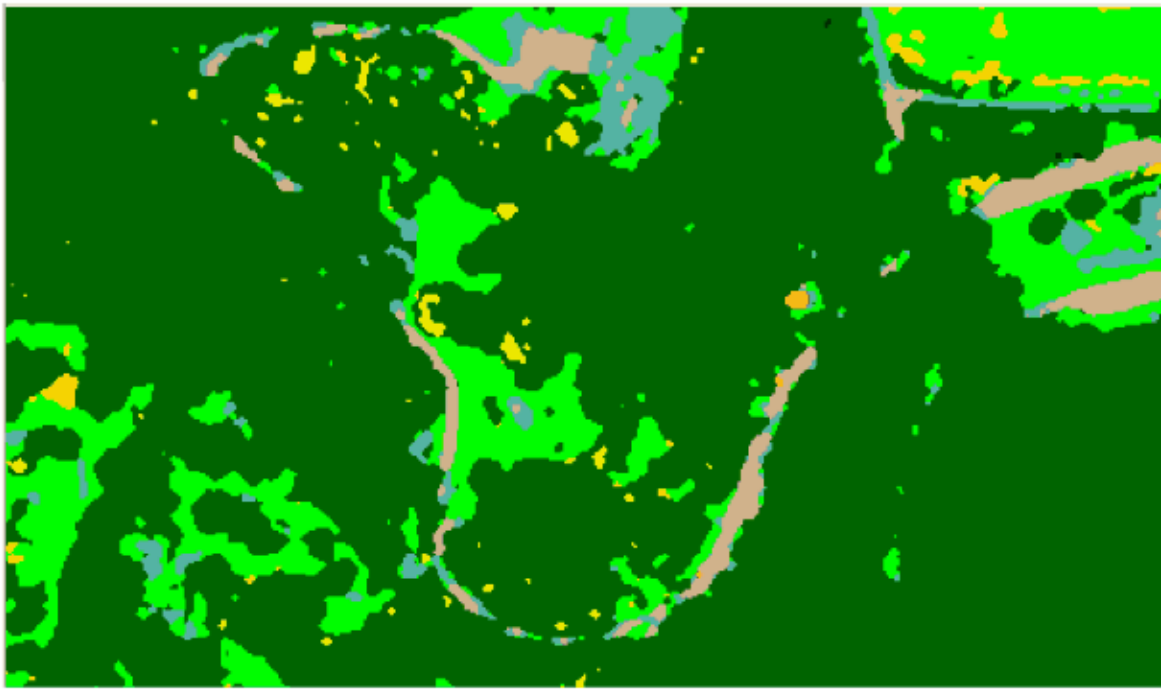
- **ENVI Source File:** Browse to the ENVI file (.dat) that will serve as the source file.
- **ENVI Classes:** Selects which class in the ENVI data set should be used.
- **Search Radius:** Search radius will be automatically populated based on ENVI raster pixel size.

Example Filter Use:

Before: In the example below, the user has hyperspectral imagery which has identified several different types of vegetation. The area of yellow represents hyperspectral Class 28: High Density

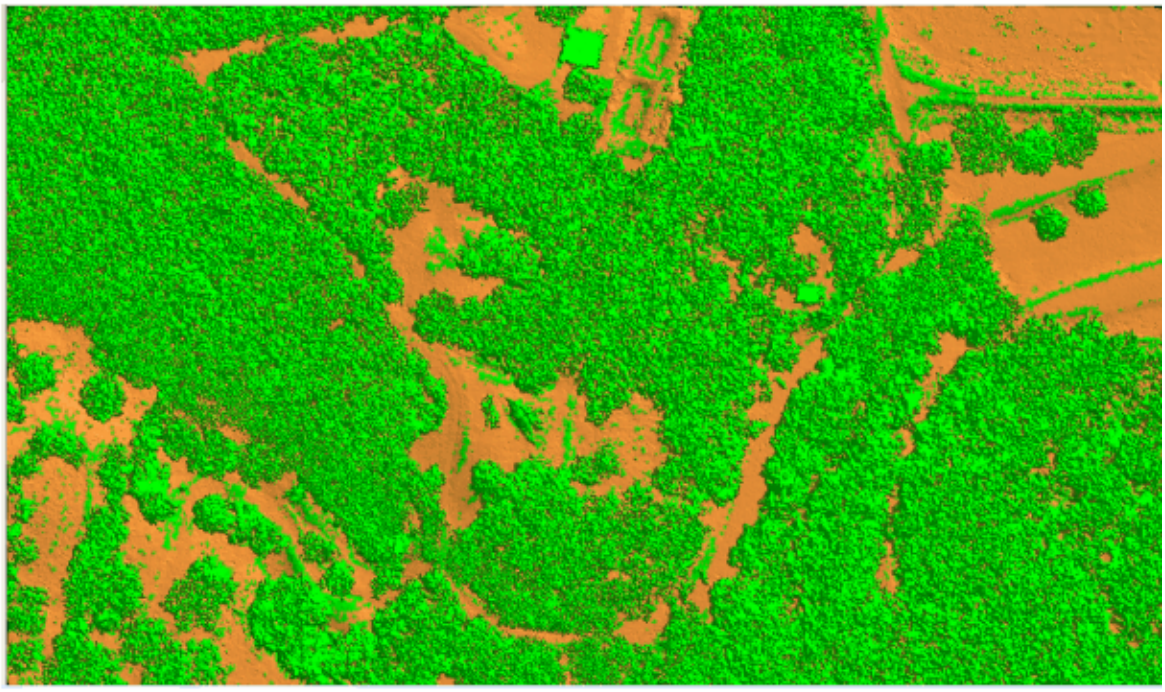
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Grass. The filter will be used to reclass all the Class 5 (High Vegetation) points within 15 units of this high density grass.

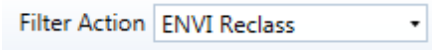


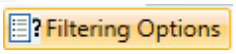
The screen shot below represents the unaltered hyperspectral data in LAS point format. The points are being shown by classification to demonstrate that only Class 5: High Vegetation has been defined so far.

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Manually Using a Single Filter: To use the ENVI Reclass Filter to reclassify points based on an ENVI classification data set, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



Next, click on the 'Filtering Options' 

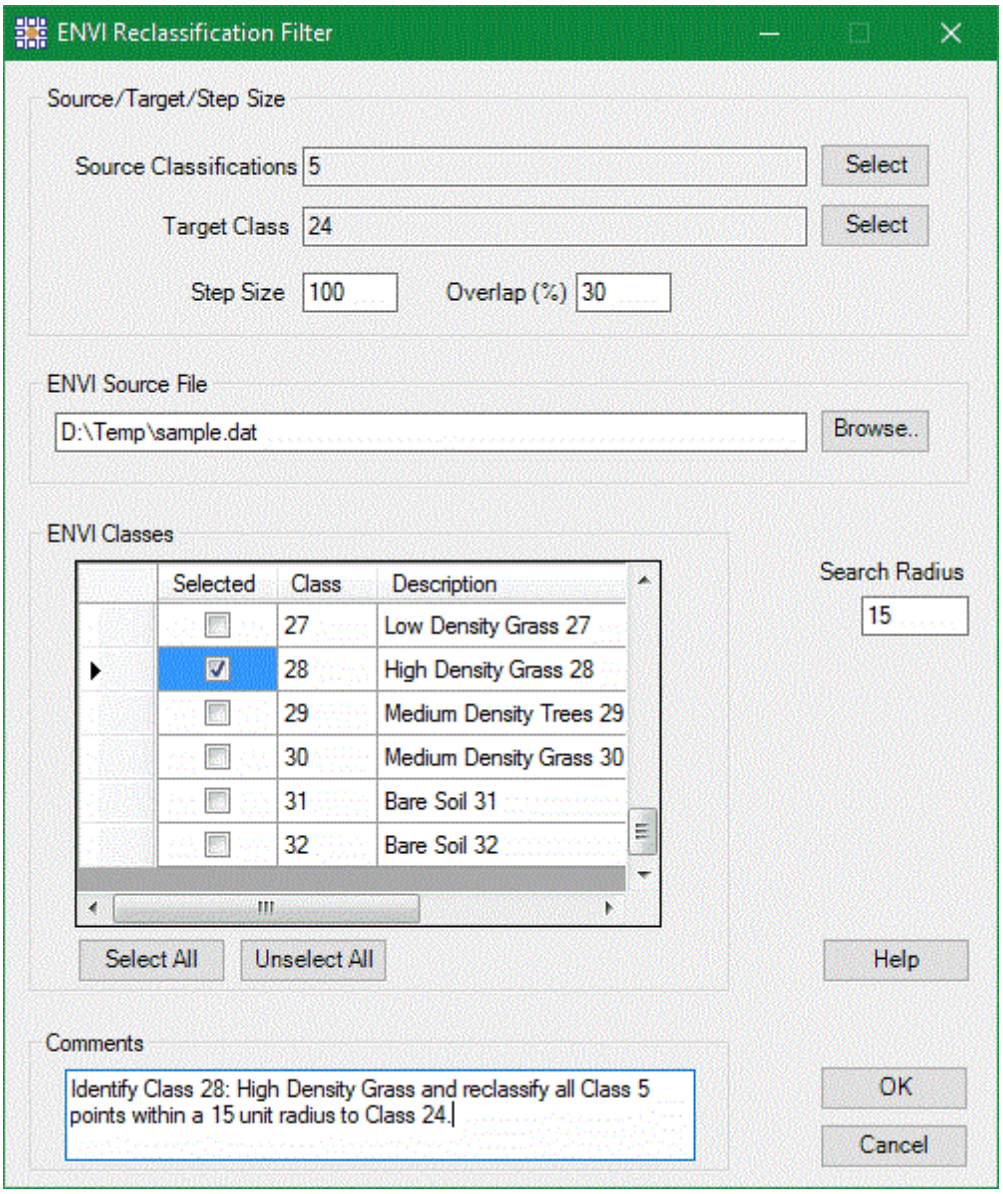
button to define the filter settings.

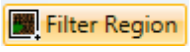
ENVI Reclass Filter Options Dialog: The 'ENVI Reclass Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the requirement to navigate to an ENVI source file, define the search radius, and select the ENVI classes to be used in the filter.

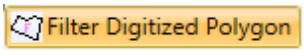
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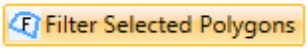
In this example, the source classification will be Class 5: High Vegetation, as seen in the example of LAS point classification above. The target class will be Class 15 (magenta). The default settings for step size and overlap are sufficient for this example and they will be left at 100 and 30 respectively. The ENVI source file has been defined and the ENVI class which is to be identified in the filter has been specified (Class 28: High Density Grass). The search radius will be left at 15 since the user is looking to reclassify all points within 15 units of the high density grasses. Click **'OK'** to save the settings.

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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** 

, **'Filter Digitized Polygon'** 

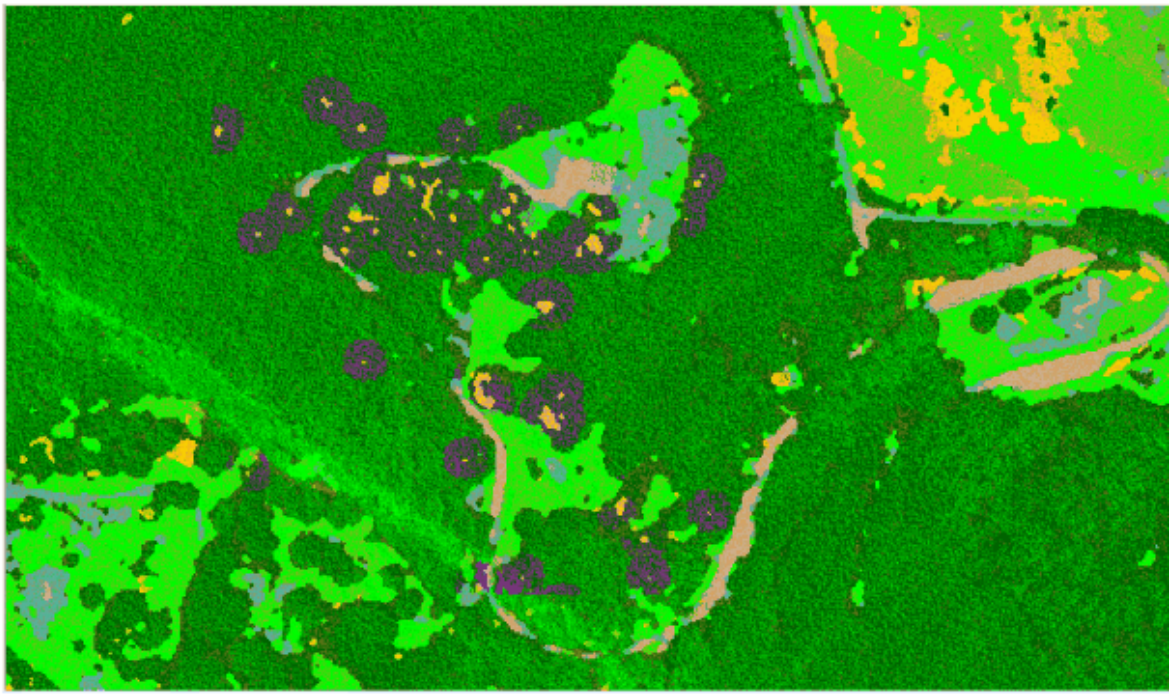
, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will

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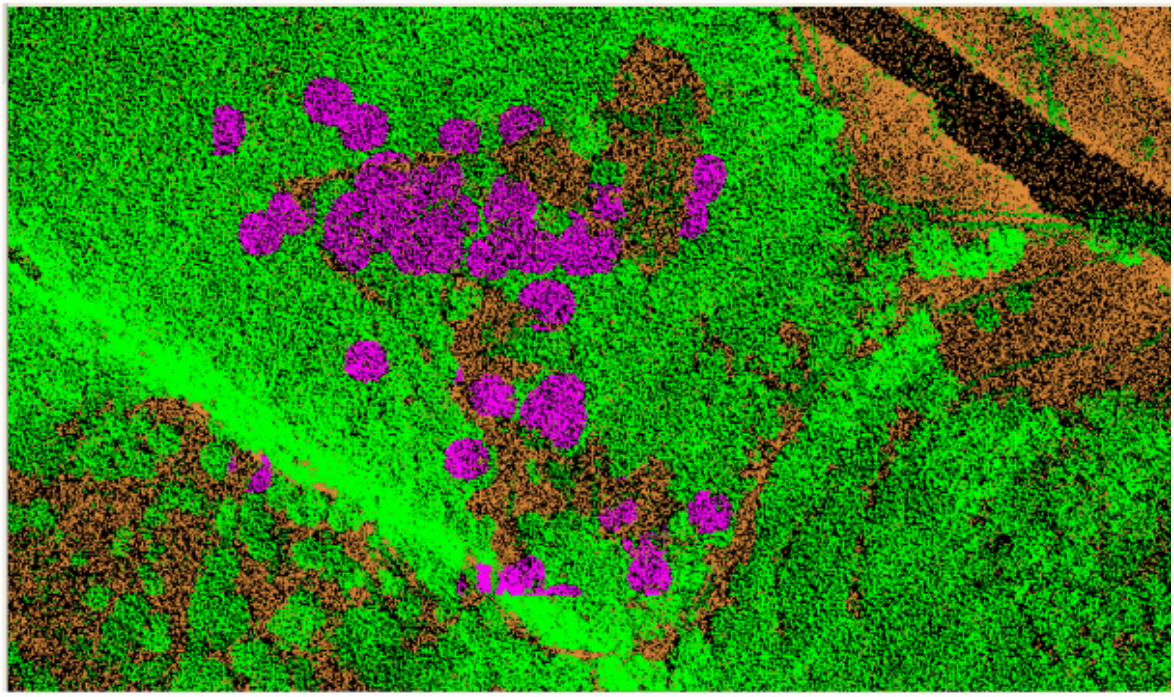
automatically refresh and show the reclassified data.

After: After the ENVI reclass filter has been run, it is possible to see the areas of points around the Class 28: High Density Grass (yellow) which have been reclassified to Class 24 (magenta). Points from source Class 5 have been reclassified to Class 24 if they fall within 15 units of any point classified as the hyperspectral Class 28.



The screen shot below is another example of the reclassification of points as seen above. In this example below, the hyperspectral data has been turned off to make it easier to view the change in classification of the LAS points. All of the magenta points (Class 24) are within 15 units of a hyperspectral Class 28 point.

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5.1.7 Extreme High Filter

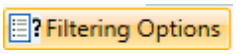
Extreme High Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Extreme High Filter** is intended to reclassify points that have a uniquely high elevation. Only points in the source data classification are considered. In the simplest case (**max_group_size** = 1), a point is reclassified if all other points within the **search_radius** are **elev_diff** lower than the point under consideration. When **max_group_size** is greater than one, a point is reclassified if all but the

max_group_size points are **elev_diff** lower than the point under consideration.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- Extremely high point(s) which are not true canopy (ex: a bird, airplane, or dense cloud cover).
- A single source class.
- A single target class.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 500.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.

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- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

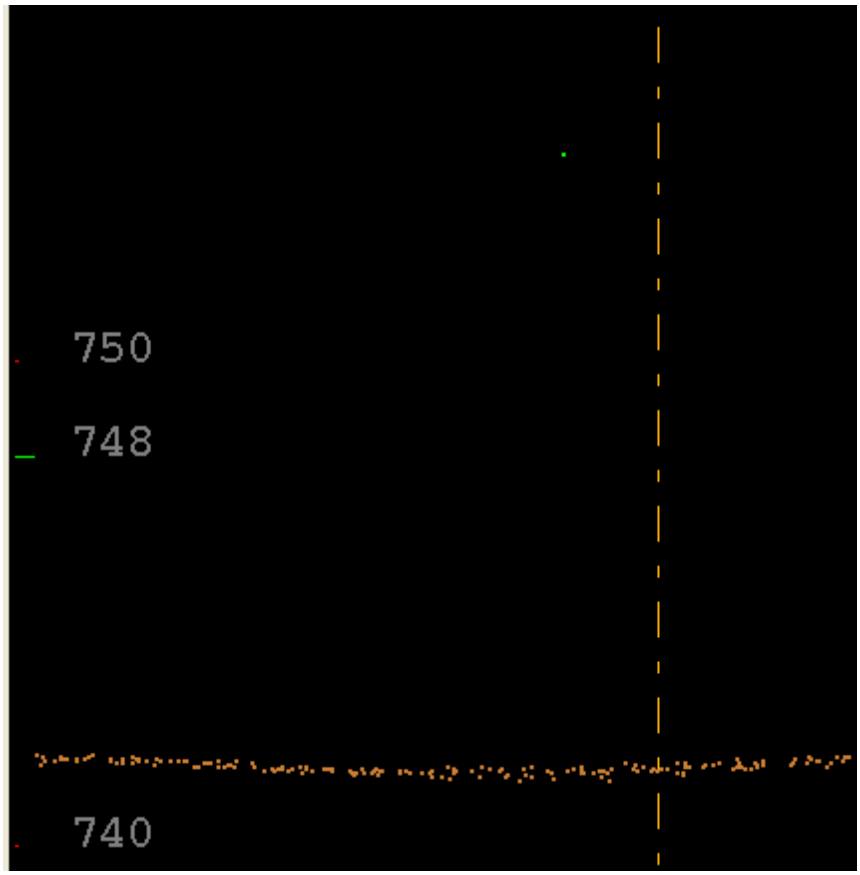
Filter Specific Parameters:

- **Search radius:** Specifies the search distance from a point under consideration to search for similar elevation points.
- **Elevation difference:** Maximum elevation distance a comparison point can be lower than the point under consideration.
- **Maximum number of points in a group:** Maximum number of points in a group of points with similar elevation that will be reclassified. The default value is 1.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

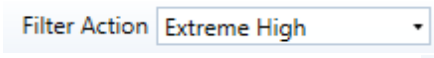
Example Filter Use:

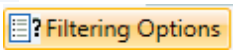
Before: In the example below, there is a cluster of canopy points far above the rest of the canopy that is not valid - they are not part of the true canopy. The LiDAR system could be showing returns from a bird, an airplane, or even dense cloud cover. The extreme high filter can be used in this instance to separate and filter these points to a more proper classification which will not be in the final, deliverable dataset. In this example, Class 25 will be used. The example below shows a random point about 14 units above the ground which stands alone. This return was most likely a bird and is not true canopy.

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Manually Using a Single Filter: To use the Extreme High Filter to correct this mistake, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.

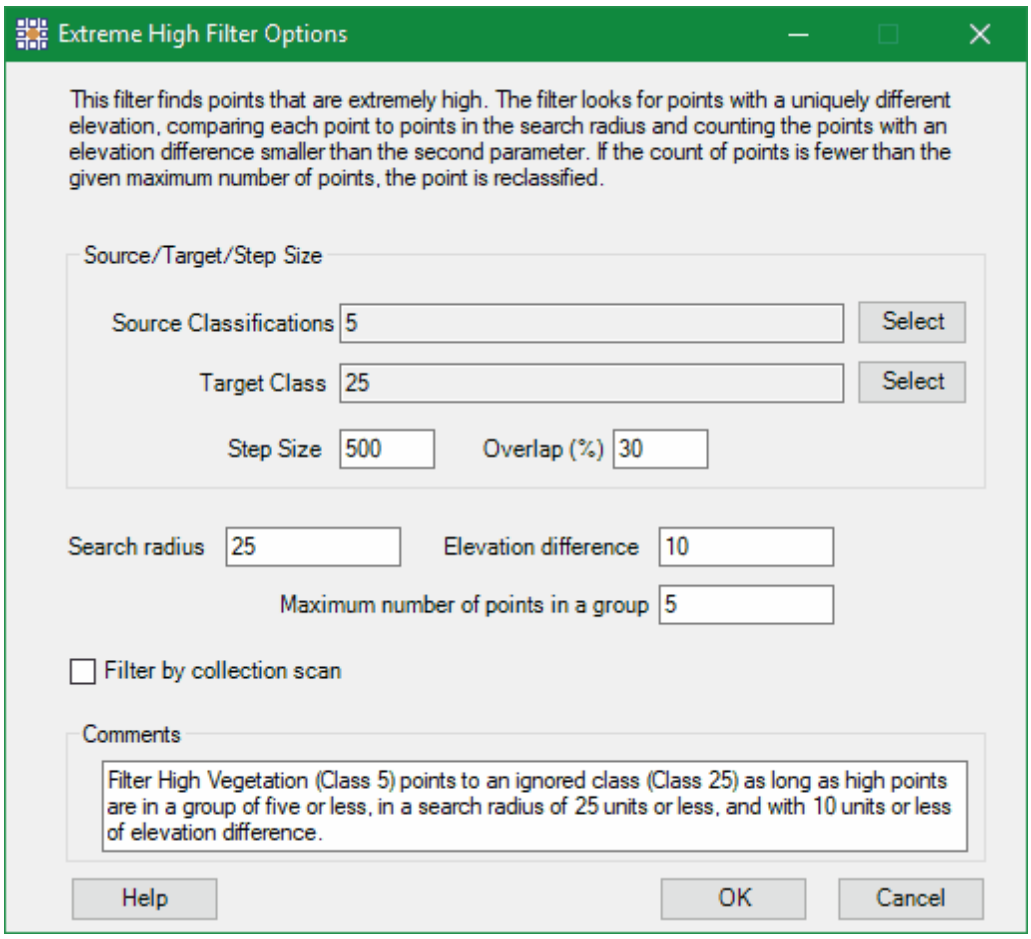


Next, click on the 'Filtering Options'  button to define the filter settings.

Extreme High Filter Options Dialog: The 'Extreme High Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose a search radius, elevation difference, and maximum number of points in a group.

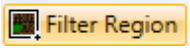
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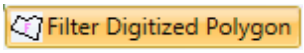
In this example, the source classification will be Class 5: High Vegetation, as the single high point shown above is classified as High Vegetation (Class 5). The target classification will be Class 25, as mentioned above. The default settings for step size, overlap, and search radius will work for most projects, so they will be left in their original settings of 500, 30, and 25 respectively. An elevation difference of 10 will be used. The Measure 957 tool was used to calculate the distance above the true ground surface (14 vertical units) and a setting of 10 will be sufficient for the filter to identify the point. The maximum number of points in a group will be set to 5 to make sure the entire cluster of points will be filtered, and not only a single high point. Click **'OK'** to save the settings.

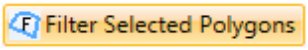


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter**

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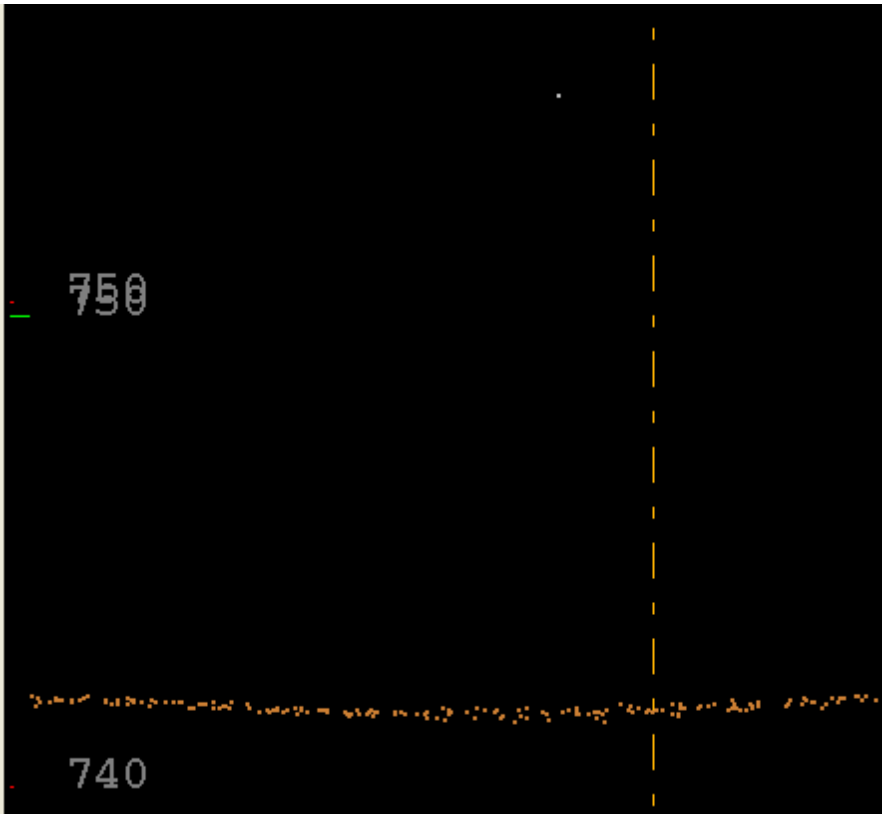
Region' 

, **'Filter Digitized Polygon'** 

, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.classified data.

After: After running the filter, the point is now properly classified as Class 25 (gray).



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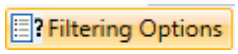
5.1.8 Extreme Low Filter

Extreme Low Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Extreme Low Filter** is intended to reclassify points that have a uniquely different and low elevation. Only points in the source classification set are considered. In the simplest case (**max_group_size**=1), a point is reclassified if all other points within the **search_radius** are **elev_diff** higher than the point under consideration. When **max_group_size** is greater than one, a point is reclassified if all but **max_group_size** points are **elev_diff** higher than the point under consideration.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- Extremely low point(s) which are not needed to make a true ground surface.
- A single source class.
- A single target class.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the

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step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 500.

- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

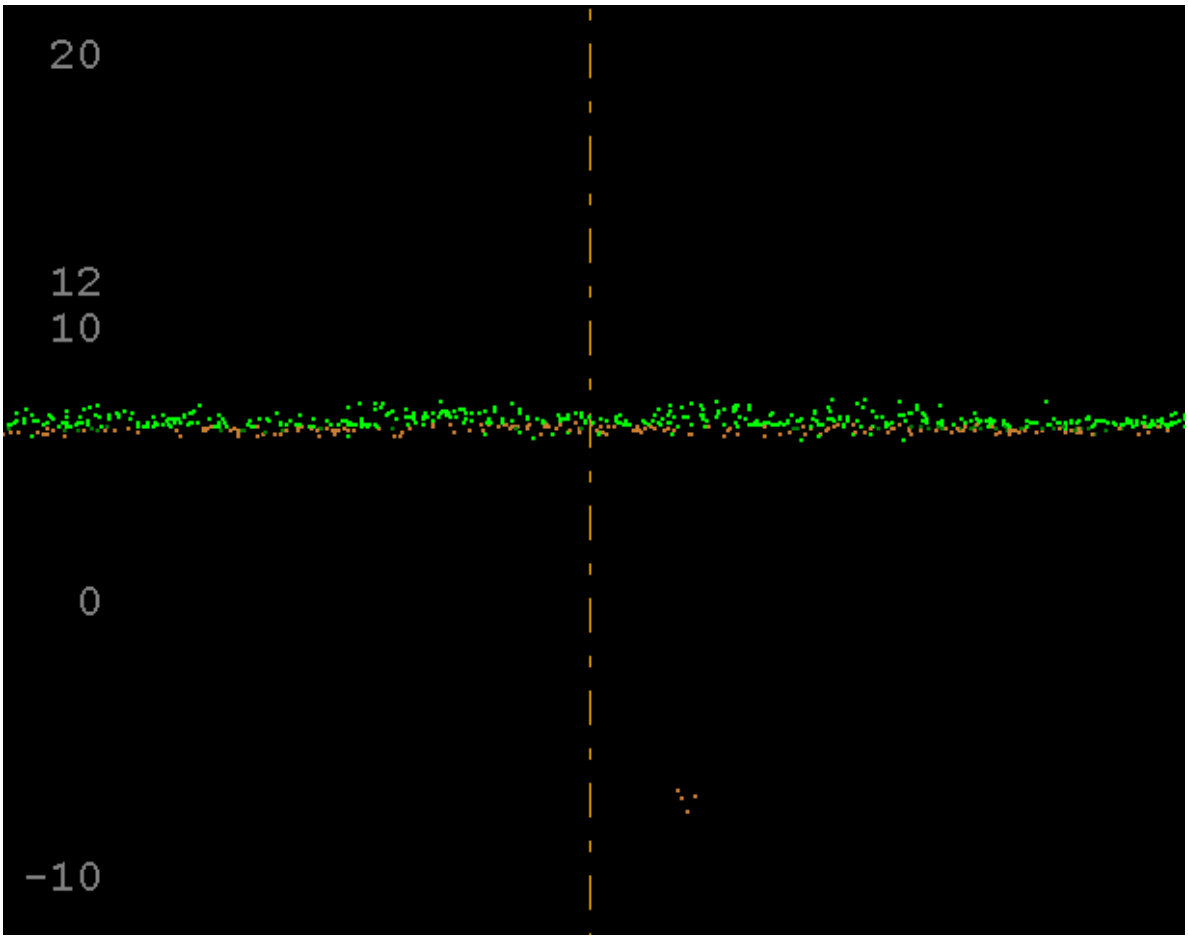
Filter Specific Parameters:

- **Search radius:** Distance from a point under consideration to look for similar elevation points.
- **Elevation difference:** Maximum amount a comparison point can be higher than the point under consideration.
- **Maximum number of points in a group:** Maximum number of points in a group of points with similar elevation that will be reclassified. Default is 1.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

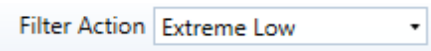
Example Filter Use:

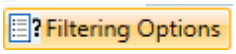
Before: In the example below, there is a cluster of ground points far below the rest of the ground surface that is not valid - they are not part of the true ground surface. The extreme low filter can be used in this instance to separate and filter these points to their proper classification, which would be 'Class 7: Low Point (Noise)'.

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Manually Using a Single Filter: To use the Extreme Low Filter to correct this mistake, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



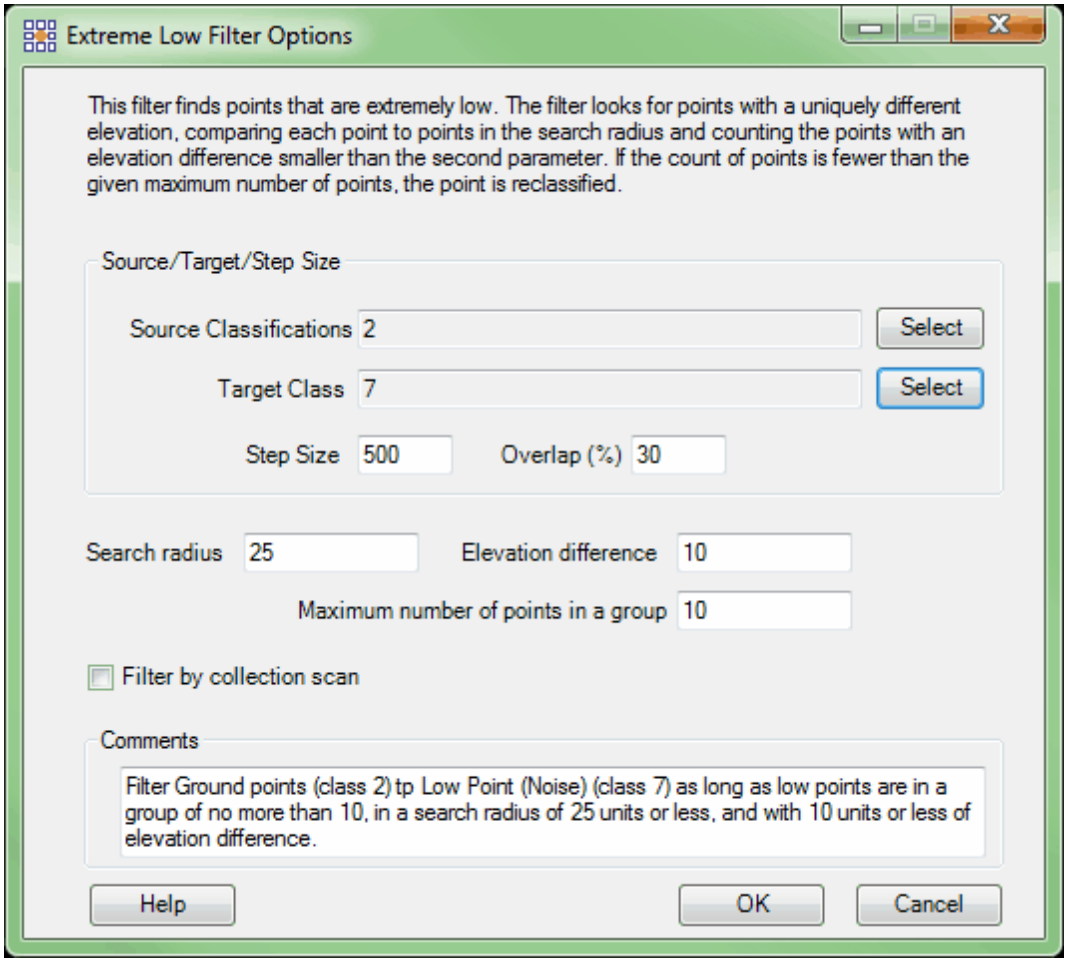
Next, click on the 'Filtering Options'  button to define the filter settings.

Extreme Low Filter Options Dialog: The 'Extreme Low Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose an elevation difference, the maximum number of points in a group, as well as a search radius.

In this example, the source classification will be Class 2: Ground, as the cluster of low points shown

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above are classified as Ground (Class 2). The target classification will be Class 7: Low Point (Noise), as this is the proper classification for these points. The default settings for step size, overlap, and search radius will work for most projects, so they will be left in their original settings of 500, 30, and 25 respectively. An elevation difference of 10 will be used. The Measure 957 tool was used to calculate the distance below the true ground surface (13 vertical units) and a setting of 10 should be sufficient for the filter to identify the points. The maximum number of points in a group will be set to 10 to make sure the entire cluster of points will be filtered, and not only a single low point. Click **'OK'** to save the settings.

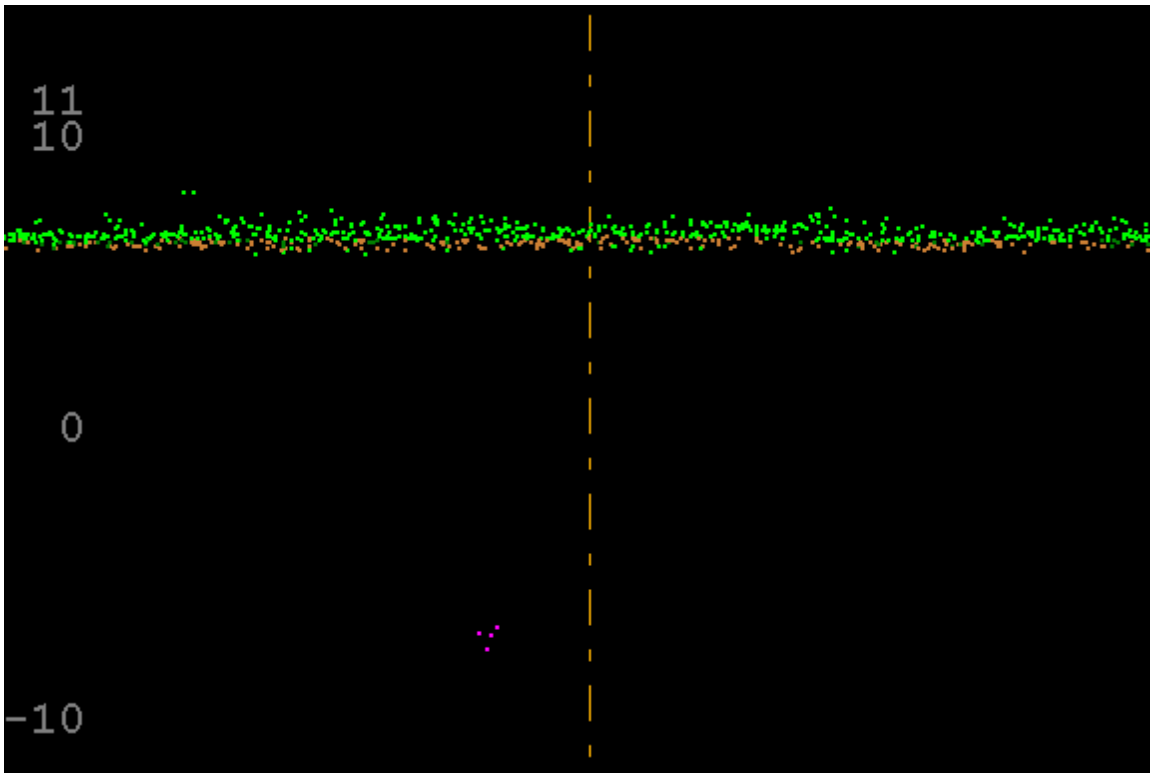


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter**

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Region' Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.classified data.

After: After running the filter, the cluster of points is now properly classified as Class 7: Low Point (Noise).



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5.1.9 Ground Filter



The **Ground Filter** reclassifies LAS points to ground based on algorithms and routines that are part of the **LAStools** software suite. Unlike the other 30 discrete filters, it is limited in application to the **'Filter Region'** method of manual editing (designed for relatively small areas), and therefore cannot be part of a macro or batch script XML.

Use of the **Ground Filter** requires that at least part of the LAStools suite ('*lasground_new.exe*' and '*lasground_new64.exe*') be present on the local computer or in an accessible network location that can be pathed out. The minimum required version of **LAStools** for use in MARS® will contain a 'CHANGES.txt' file dated November 8, 2018, or later. The LAStools suite can be downloaded at no charge, but licensing is required to use the classification routines in a commercial, government, or production environment. *Unlicensed use in any setting may cause data corruption!* As taken from the ***rapidlasso GmbH*** website, "Note that the output of the unlicensed version can be slightly distorted after certain point limits are exceeded." Please contact ***rapidlasso GmbH*** by e-mail directly at info@rapidlasso.de for general information including questions about licensing and allowable use, or see the ***rapidlasso GmbH*** website for details. For pricing information, go to https://rapidlasso.de/pricing. Licenses are available for the entire **LAStools** suite, or the one component needed for this 'Ground Filter' can be licensed separately at a reduced cost. All licensing, pricing, and payment is handled directly between the end user and ***rapidlasso GmbH*** - Merrick & Company has no involvement at this level.

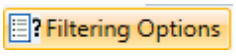
Remember that unlicensed use is limited (by ***rapidlasso GmbH***) to testing and/or evaluation only. A

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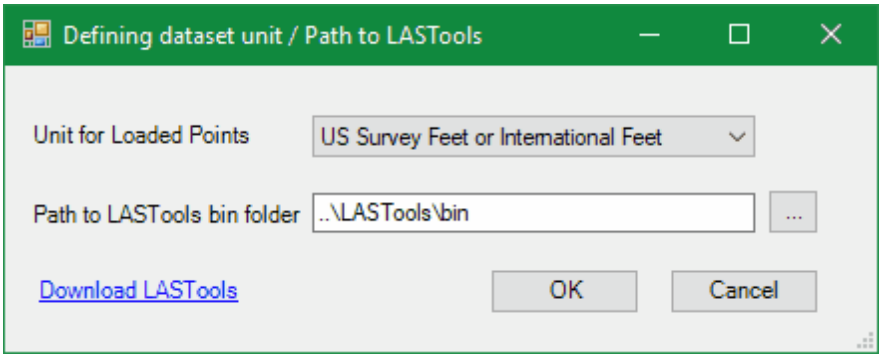
license purchased for the Quick Classifications 1201 batch filtering tool will authorize this filter as well.

License Status:

	Licensed	Unlicensed
lasground_new.exe and ***lasground_new64.exe*** files needed:	✓	✓

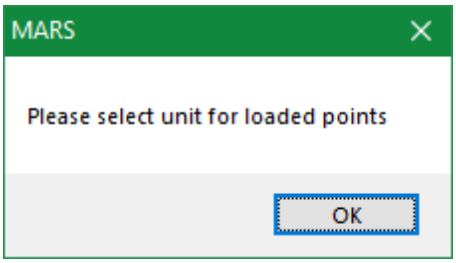
The LAS data to be re-classified must be loaded in order to use this filter. To begin, select **'Ground'** from the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Next, click the **'Filtering Options'** button 

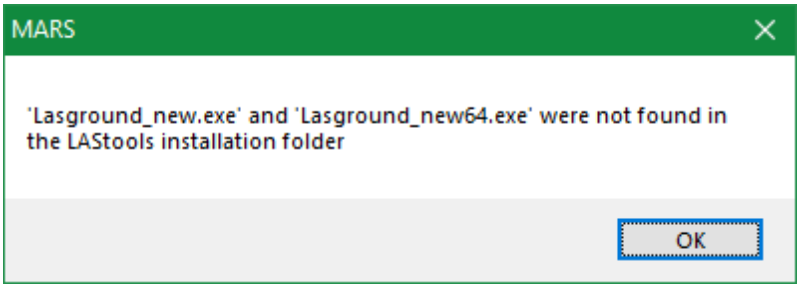
to set the parameters of the filter. A window will appear where both the data units and the path to the **LAStools** executable file(s) and the license file (if purchased) must be set. The LAStools software suite can be downloaded from a link on this interface. The minimum required version of **LAStools** for use in MARS® contains a 'CHANGES.txt' file dated November 8, 2018, or later.



The data units must be set each time the filter is used - a correct entry is critical to the operation and results of the classification routines. The path to the **LAStools** files will be stored for future use, but can be updated if the location of the files is ever changed. If the units are not selected or the path entered does not contain the *'lasground_new.exe'* and '*lasground_new64.exe*' files, the following messages will appear when the 'OK' button is clicked:

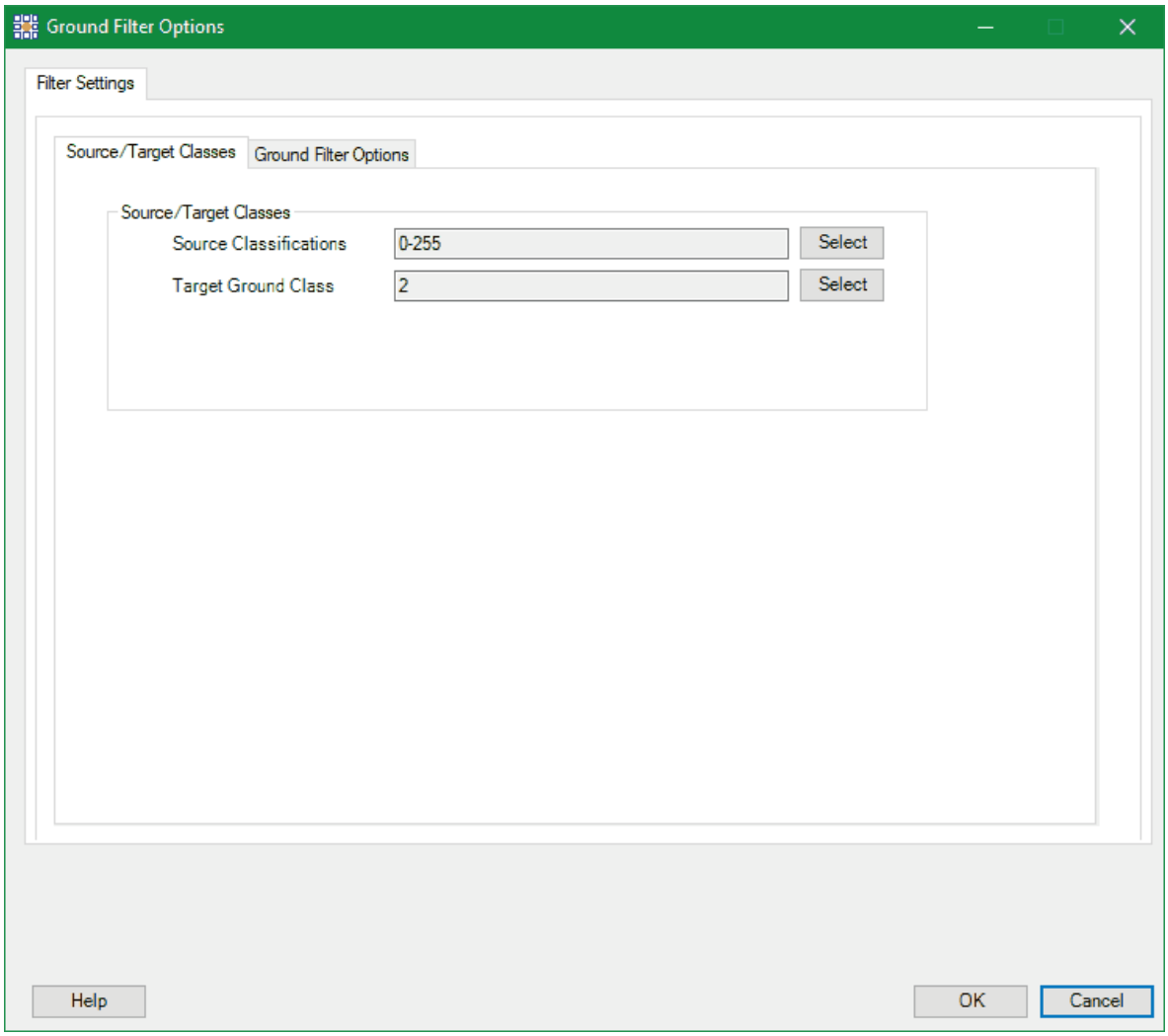
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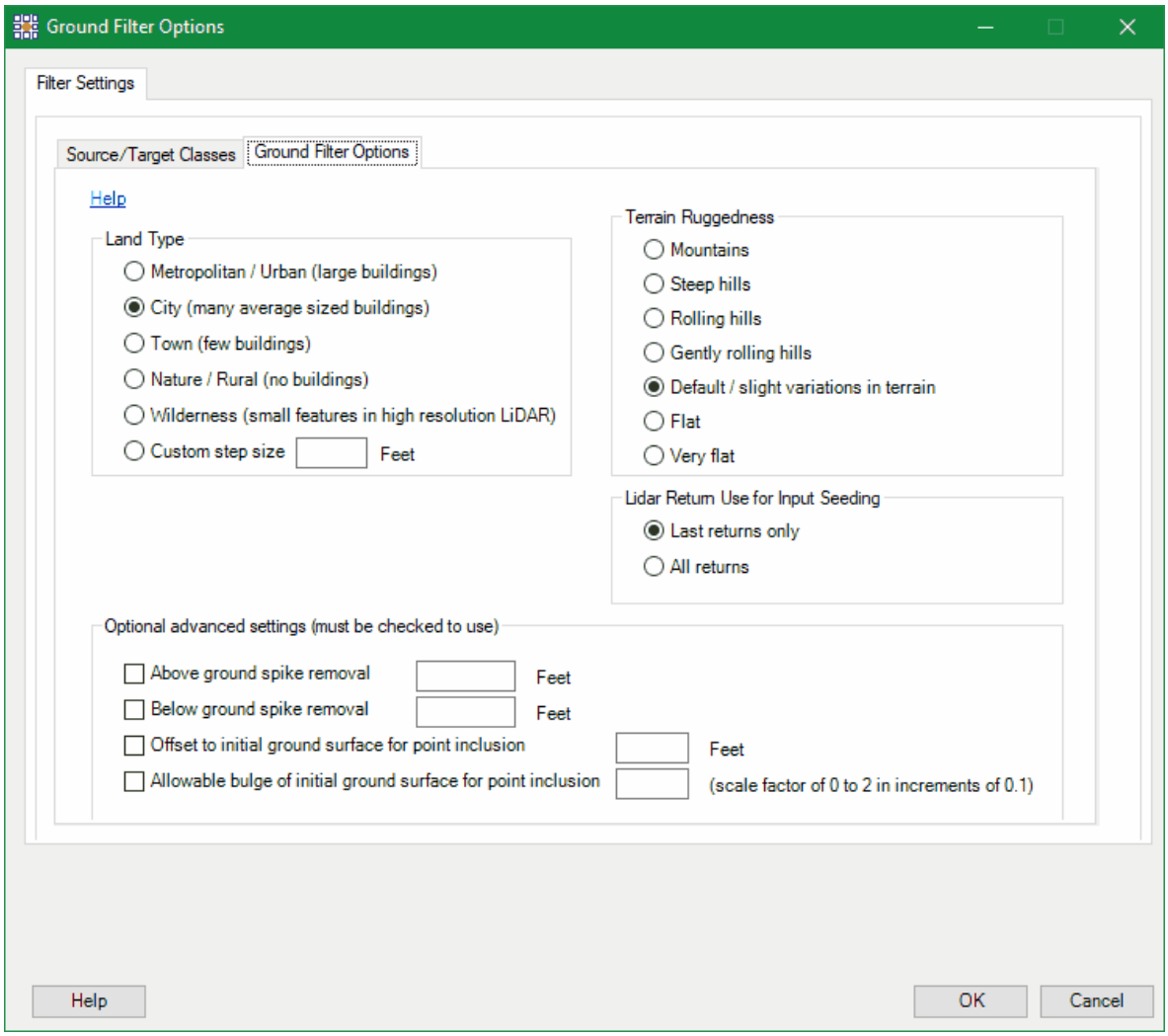


When the data units are entered and a valid **LAStools** path exists, click 'OK' to bring up the 'Ground Filter Options' interface. The interface consists of two Filter Settings tabs:

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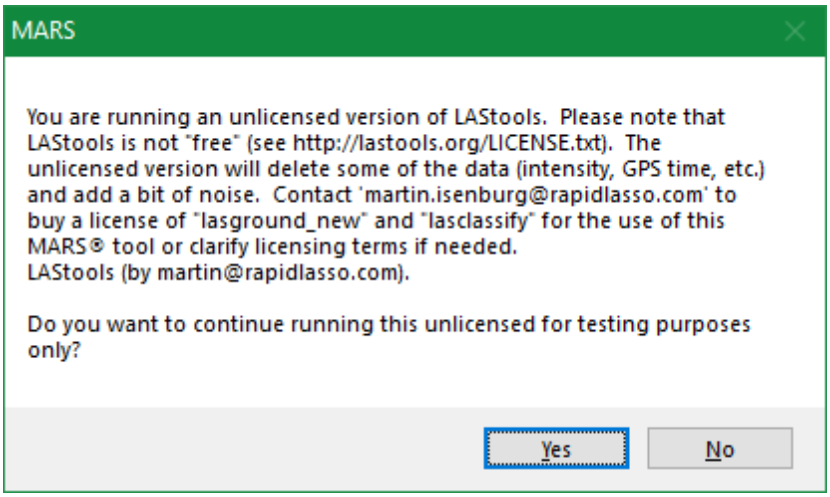


Source/Target Classes tab: The Source and Target classes are selected here. By default, all 256 classes are included in the 'Source Classifications', but this can be changed by clicking the 'Select' button. A default value of '2' is set for the 'Target Ground Class'. This is based on the ASPRS standard class for ground, but it can be modified by clicking the appropriate 'Select' button(s).

Ground Filter Options tab: This interface has a 'Help' link in the upper-left corner that goes directly to the **LAStools** read-me file for 'lasground'. The parameters on this tab are explained in the read-me file, which is updated and maintained solely by ***rapidlasso GmbH***. This read-me file

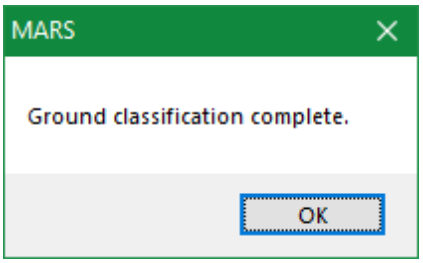
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is based on an earlier (but very similar) iteration of the ground classification executable. As of the release date of this version of MARS®, **LAStools** was not yet hosting a read-me file for the '*lasground_new.exe*' executable that is used in this filter. However, it is available in the downloaded LAStools suite package as '*lasground_new_README.txt*'. All the controls and entries on this tab feed directly into the arguments of the **LAStools** '*lasground_new.exe*' file. When all settings have been made, click the 'OK' button in the lower-right corner of the interface. If a license for **LAStools** has not been purchased or is not present in the path to the executable files, the following warning message will appear immediately after clicking 'Run':



If a license exists, or if 'Yes' is clicked when there is no license, filtering can begin. On the View Tab 192, set the Rendering Option to 'Color by Classification' C. This will allow the changes made by the filter to be visible. Click the **'Filter Region'** button and drag a box over the area to be filtered. The cursor will indicate that processing is taking place - the larger the area dragged, the longer the filtering will take. The routine temporarily buffers the defined area by 100 feet or 33 meters (depending on the units selected) and uses that expanded area for processing to improve accuracy. However, only those points within the original defined drag box will be reclassed. When complete, the following message will appear:

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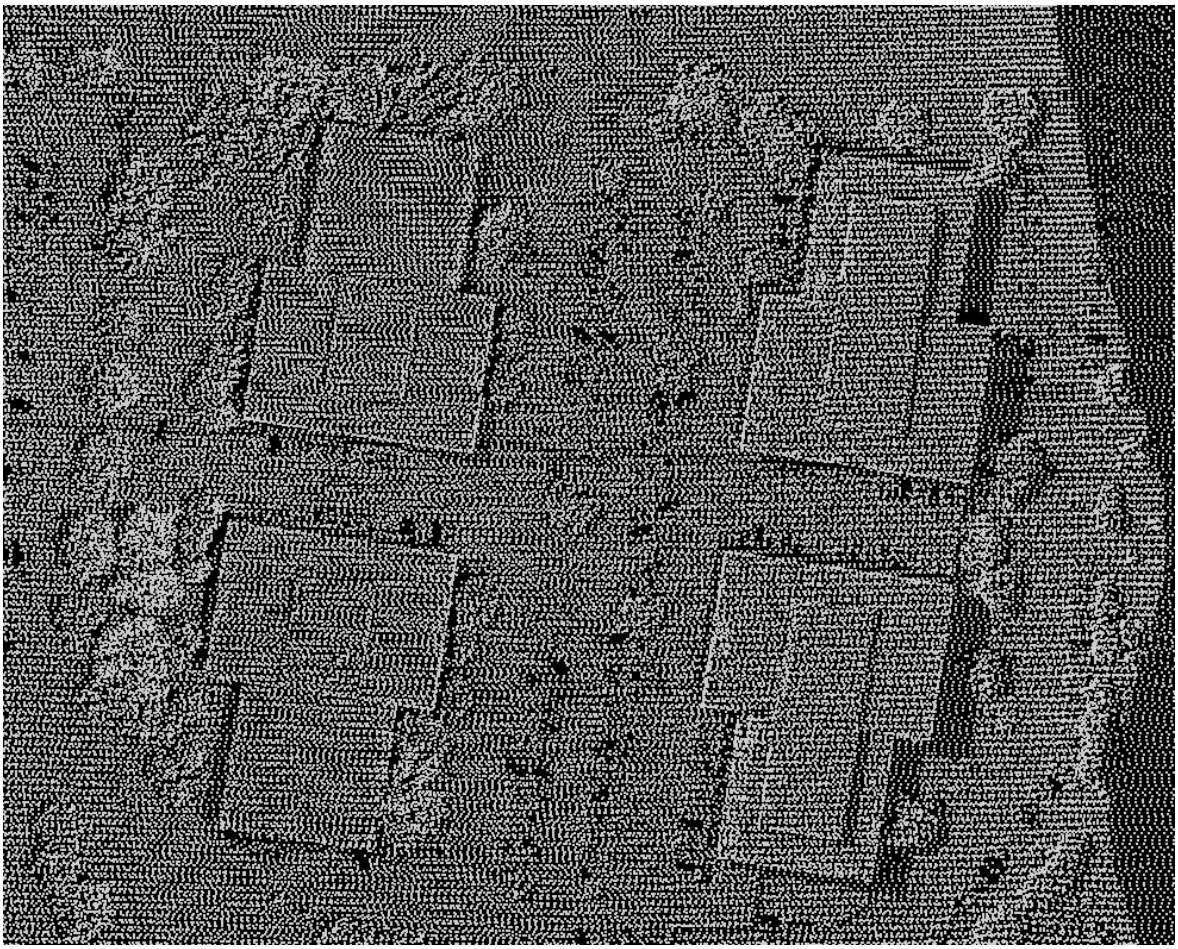
After dismissing this message, the LAS Map View window will refresh, and additional areas can then be dragged using the same settings. To change the filter's parameters, click the 'Filtering Options' button, make the modifications, and click 'OK'. The **'Filter Region'** button will stay active so that a new drag box can immediately be defined using the new settings.

Below is an example of the Ground Filter's results, using the sample LAS file that is installed with MARS®. All points were first manually re-classed to Class 0 (Created, Never Classified) for clarity. However, this is not necessary if all classes are used as 'Source Classifications' on the 'Source/ Target Classes' tab of the 'Ground Filter Option'. The default settings were used on the 'Ground Filter Options' tab: Land Type of 'City'; Terrain Ruggedness of 'Default / slight variations in terrain'; and Lidar Return Use for Input Seeding of 'Last returns only'. No entries were made or changed on the interface for this example.

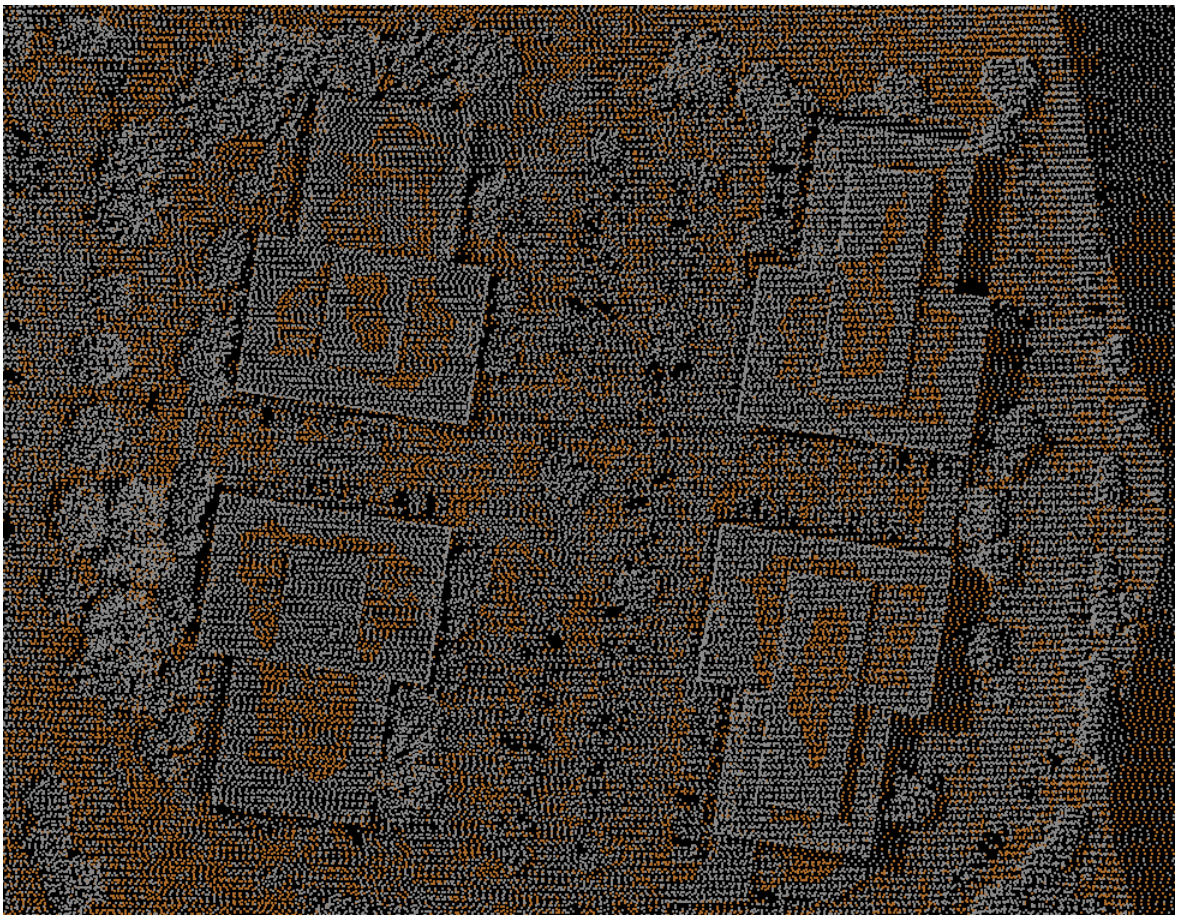
Before - all points in Class 0

After - Ground in Class 2 (orange), remainder in Class 1 (dark gray)

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Note that sections of large flat-roofed buildings will often be classed as ground since they consist of last returns only and are the lowest points within the extent of the building's outline.

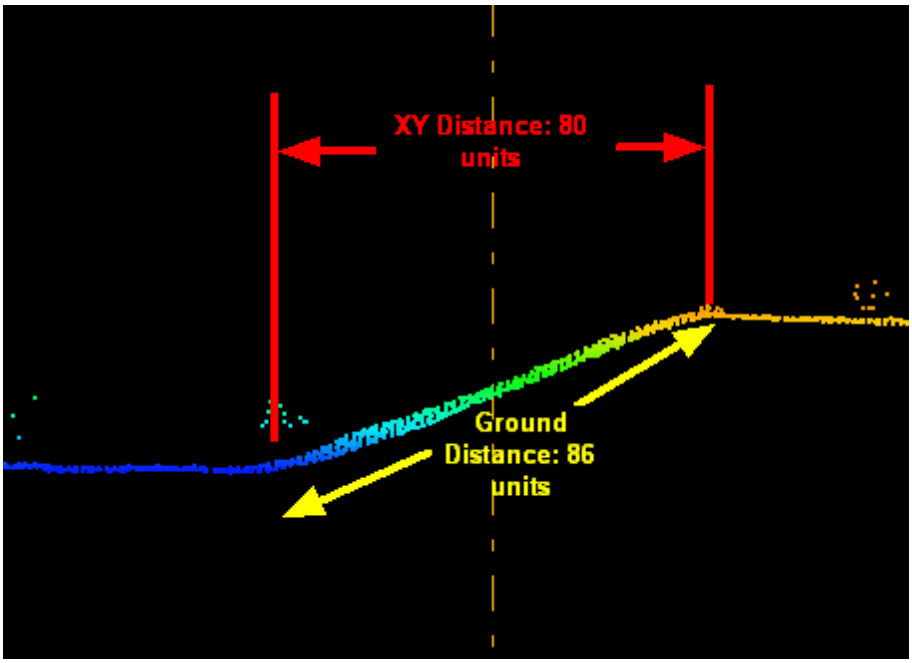
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5.1.10 Ground Distance Filter



The **Ground Distance Filter** is similar to the XY Distance filter, except for two differences: *1) The Ground Distance filter assumes 'above' or 'below' a surface is perpendicular to the slope of that*

surface. The XY Distance filter assumes that 'above' or 'below' a surface is above or below the XY horizontal axis and, 2) the Ground Distance filter will take the slope of the surface into account. The Ground Distance filter reclassifies points when they are within a specified ground distance of a point in the reference classification set. This filter is more useful than the XY Distance filter in areas with steep slopes. Since the XY Distance filter functions purely off of an XY horizontal distance and does not take the slope of an area into account, it may miss points to be reclassed in these areas. Since the Ground Distance filter considers the slope of an area, it measures the user defined distance along the reference surface and not along the XY horizontal axis. See the screen shot below for further clarification. In this example, it can be seen that the XY distance up a slope will be different than the actual distance along the surface. This can skew the user's results in hilly areas if the XY Distance filter is used.



To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** Filtering Options button, which will bring up the appropriate interface to enter in the desired settings.

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Requirements:

- A Reference Classification that is not also the Source Classification.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default Step Size suggested for most projects using this filter is 500.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More Overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Reference Classifications:** The point classification(s) that the Source Classifications data is compared against to find points to reclassify based on the specified parameters.
- **Ground Distance:** Distance requirement for determining candidate points. Candidate points must be within this distance of a Reference Classification point, as projected onto the gridded surface created from the Reference Classification set.

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- **Height Requirement**
  - **No limit:** Specifies no requirement in 'normal' (perpendicular) height distance from the gridded reference surface.
  - **Maximum limit:** Specifies a requirement that points that are reclassified are at most max_diff higher in elevation than the nearby reference point. Height is measured perpendicular to the ground surface. This value can be negative.
  - **Minimum limit:** Specifies a requirement that points that are reclassified are at least min_diff higher in elevation than the nearby reference point. Height is measured perpendicular to the ground surface. This value can be negative.
  - **Both max and min limit:** Specifies that both Maximum and Minimum height distance values will be used.
- **Angle Requirement**
  - **No limit:** Specifies no requirement in angle divergence from the slope of the gridded reference surface.
  - **Maximum limit:** Specifies a requirement that points that are reclassified are at most max_angle higher than the nearby reference point. Angles are measured from the ground surface. This value can be negative.
  - **Minimum limit:** Specifies a requirement that points that are reclassified are at least min_angle higher than the nearby reference point. Angles are measured from the ground surface. This value can be negative.
  - **Both max and min limit:** Specifies that both Maximum and Minimum limit angle values will be used.
- **Ground Slope Parameters**
  - **Grid cell size:** The grid cell size for the reference slope grid.
  - **Number of passes of grid smoothing:** The grid smoothing count for the slope grid, which is the number of times a grid is smoothed before the slope values are

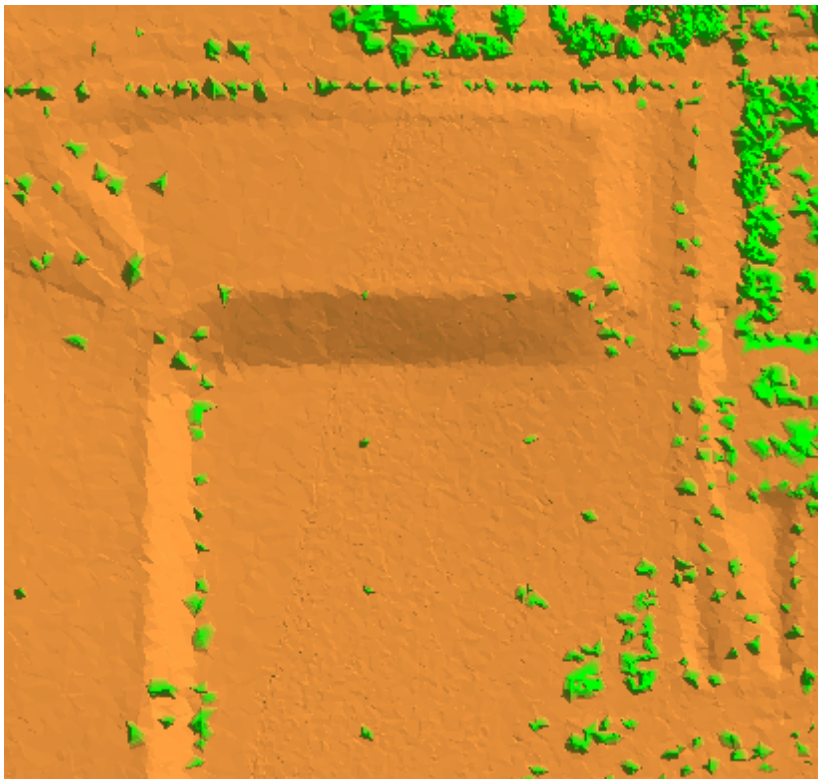
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calculated.

- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

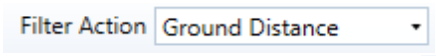
Example Filter Use:

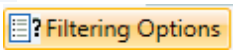
Before: In the example below, the user wishes to reclassify any ground point (Class 2, orange) within 15 units of any vegetation (Class 5, green) to Class 10 (yellow). This particular area has a steep slope which makes this filter a better choice for more accurate reclassifications than the 'XY Distance' filter.



Manually Using a Single Filter: To use the Ground Distance Filter to reclassify all Source points when they are within the specified parameters as compared to the gridded reference surface, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.

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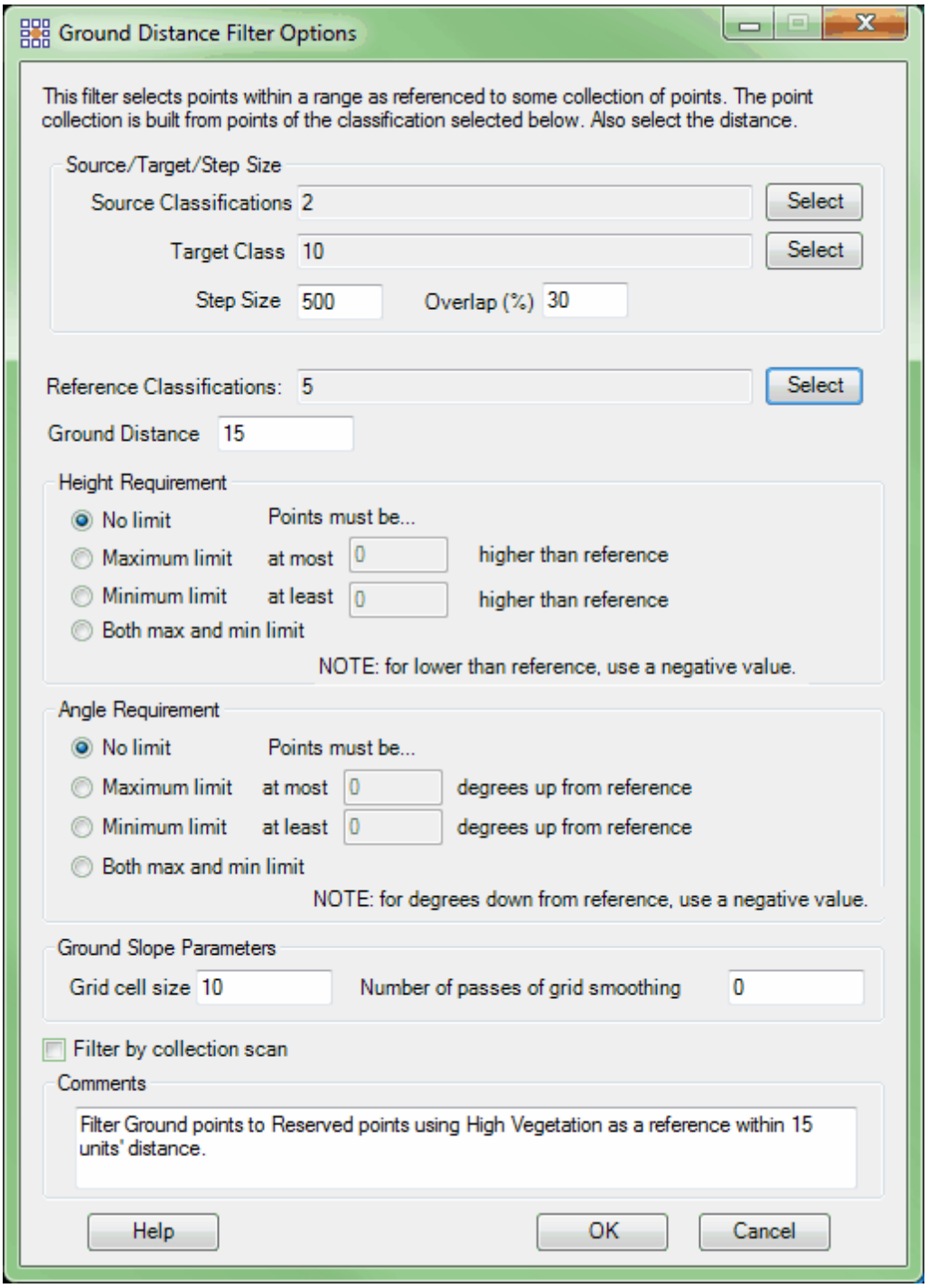
Next, click on the 'Filtering Options'  button to define the filter settings.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

Ground Distance Filter Options Dialog: The 'Ground Distance Filter Options' interface gives the user several options in specifying the filter. The Source Classification(s), Target Class, Step Size, and Overlap percentage can be adjusted as in other filters. Unique features to this filter include the ability to choose a Reference Classification(s), specify a Ground Distance for measurements against the Reference Classification set, as well as the Height and Angle Requirements of the points to be reclassified. Adjustments to the Grid cell size can be made, and the filter is also capable of running a Gaussian smoothing algorithm on the grid created.

In this example, the Source Classification will be Class 2: Ground (orange). The Target Class has been set to Class 10 (yellow). The default settings for Step Size and Overlap will be used for this example. The Reference Classification will be set to Class 5: High Vegetation, and the Ground Distance has been set to 15 units, because this is the class from which the user wishes to measure 15 units to determine candidate points. No limits of elevation or angles have been set to allow for the hilly setting in this example. The Grid cell size has been set to 10 and no Gaussian smoothing effect is to be applied to the gridded surface. Click **'OK'** to save the settings.

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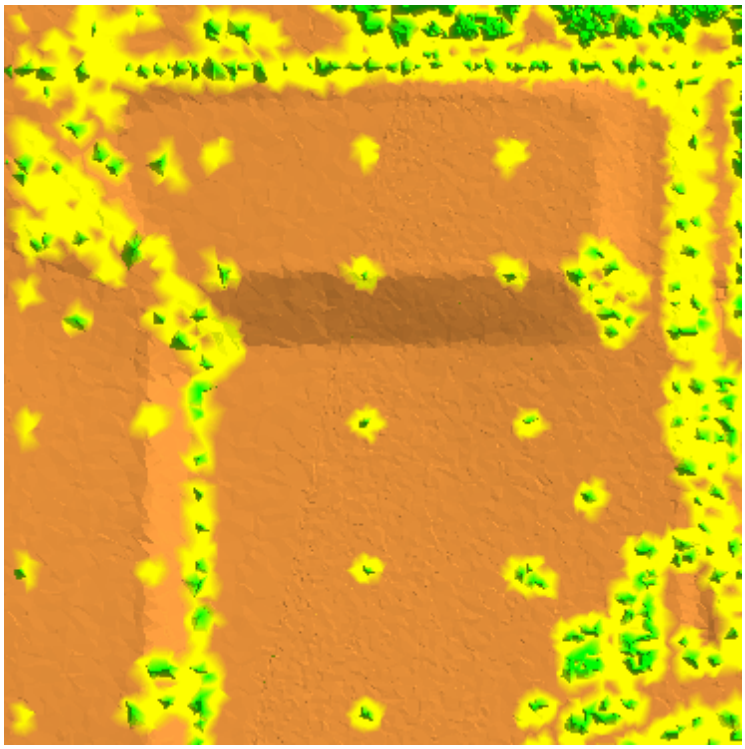


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter**

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Region' Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: The results can be seen below. Any ground point (orange) within 15 units of a reference class point (green) has been reclassified to Class 10 (yellow). The filter has taken the ground distance and slopes into consideration in the hilly areas.



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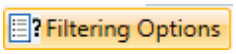
5.1.11 Height From Surface Filter

Height From Surface Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Height From Surface Filter** reclassifies points that are at a specified elevation above or below a surface (if the user is interested in classifying points by their absolute elevation (Z-value), please use the Elevation 1013 filter). To do this, a surface (either a grid or TIN) is built from the points of the surface classification. In the filter dialog, the reference surface classifications are specified within the Height From Surface filter options dialog (see below). In a macro filter script, the reference surface classifications are specified in the 'Surface Classifications' XML element nested within the Height From Surface filter element.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A source class(es).
- A reference class(es).

General Parameters:

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- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Classification:** The class to which the Source points that meet all criteria for each range in the 'Elevation Difference Requirement' table are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size (when the surface type is constructed as a grid) suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Elevation Difference Requirement**
  - **Maximum Z:** Specifies a requirement that points that are reclassified are at most max_diff higher in elevation than the grid surface. This value can be negative.
  - **Minimum Z:** Specifies a requirement that points that are reclassified are at least min_diff higher in elevation than the grid surface. This value can be negative.
- **Use slope:** If the user chooses this option, the height perpendicular to the surface will be measured and used.
- **Surface type constructed as reference:** Flag indicating the type of surface. False means build a

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TIN surface, true means build (and possibly smooth) a gridded surface.

- **TIN Options**
  - **Limit TIN triangle size via edge length:** By checking this option the user chooses to limit the TIN triangle size by limiting the edge length of any side of the triangle.
  - **Maximum triangle edge length:** Enabled when the above option is checked. Specify the maximum triangle edge length to be used here.
- **Grid Options**
  - **Grid cell size:** This value specifies the size of the cells of the grid. Used only if grid is specified as surface type.
  - **Number of passes of grid smoothing:** This value specifies how many times Gaussian smoothing is applied to the gridded surface. Used only if grid is specified as the surface type.
  - **Fill Gap:** The user has the option to fill voids which are found in the LiDAR data. If the 'Fill Gap' field is checked, MARS® will create as many grid cells in the gap as possible. This option is used to prevent NO DATA values. During the creation of the output grid, this option will allow the user to continue, or TIN, the surface across data voids.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

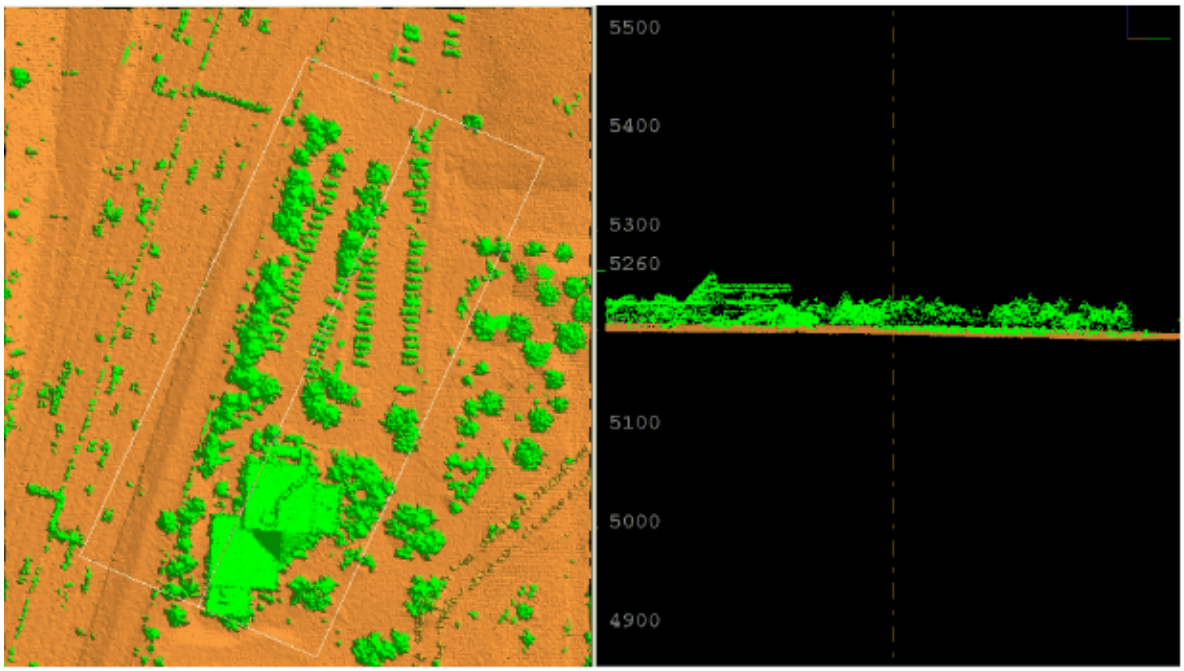
Reference Classification Set

- **Reference Surface Classifications**: The point classifications that are used to create the temporary comparison surface. Attribute of 'class' specifies one or more classifications, comma separated.

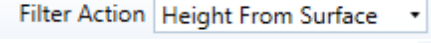
Example Filter Use:

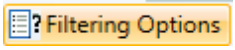
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Before: In the example below, the user has found an area with varying elevations. The example data below includes cars, vegetation, and a large building. The user wishes to reclassify points that are a specified elevation above or below a surface (in this case, the ground). In this example, the cars and building will be defined from the vegetation based upon the height of the particular features above the ground.



Manually Using a Single Filter: To use the Height From Surface Filter to reclassify points that are a specified elevation above or below a surface, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



Next, click on the 'Filtering Options' 

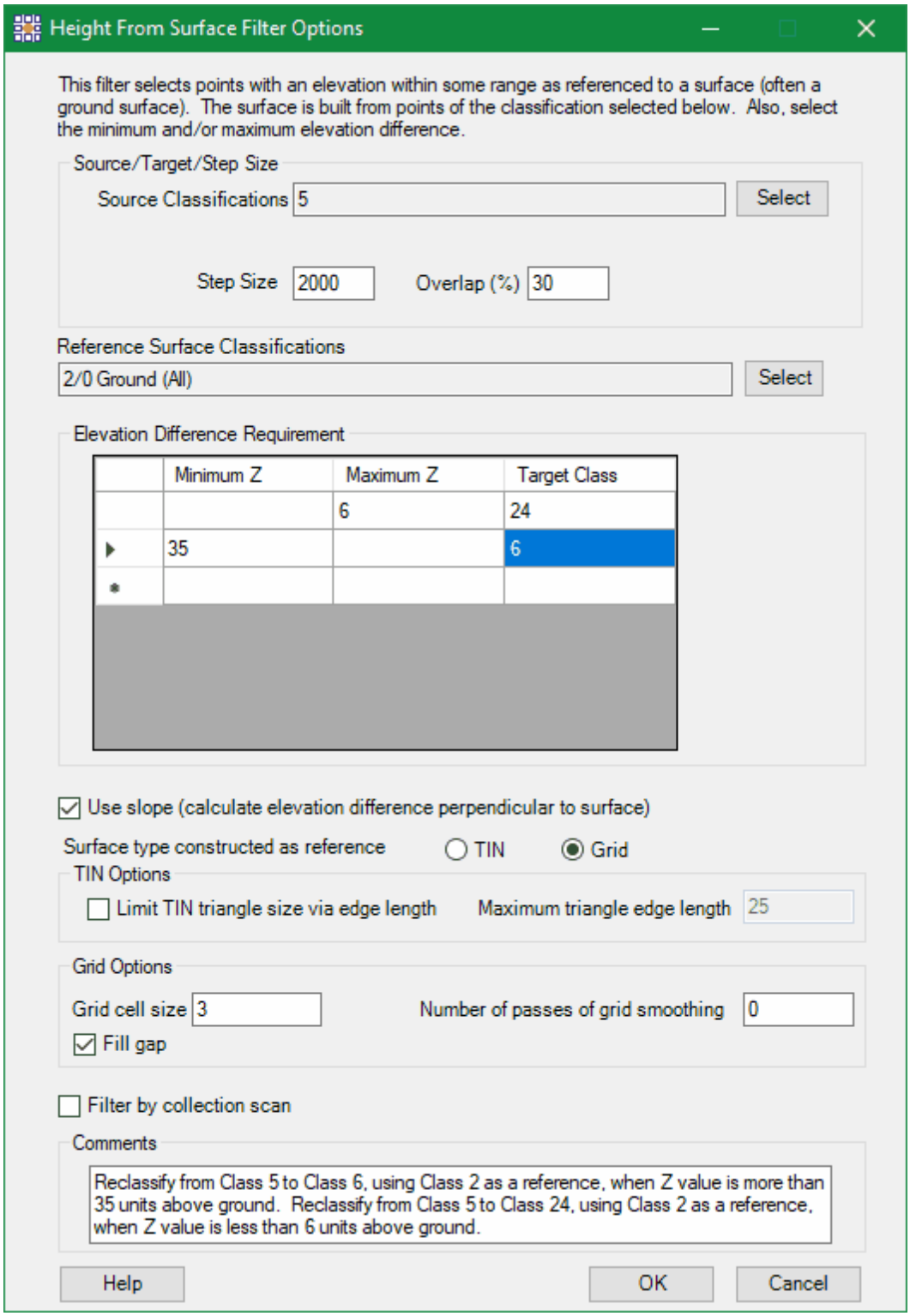
button to define the filter settings.

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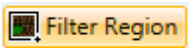
Height From Surface Filter Options Dialog: The 'Height From Surface Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to specify a reference surface classification, and choose elevation difference requirements to set the parameters of the filter. Other options include 'Use slope', TIN options or grid options, and a filter by collection scan option.

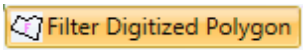
In this example, the source classification will be Class 5: High Vegetation, as all of the features that need to be reclassified are currently classed as High Vegetation. The default settings for step size and overlap will work for most projects, so they will be left in their original settings of 100 and 30 respectively. The reference surface classification will be Class 2: Ground as this is the surface from which the heights of the vegetation, cars, and buildings need to be measured. In many cases, the reference surface classification is the ground (including Model Key-points). A minimum Z requirement will be set at 35 units and a separate maximum Z requirement will be set at 6 units. A target class of 24 (pink) will be used to represent any point up to 6 units above the ground. These points will likely be cars. A target class of 6 (dark blue) will be used to represent any point higher than 35 units above the ground. These points will likely be buildings. Most points between 6 units and 35 units above the ground will be trees and will stay in Class 5: High Vegetation. The user has also chosen to use the Grid option so that the grid cell size can be specified to 3. Click **'OK'** to save the settings.

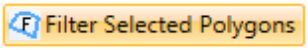
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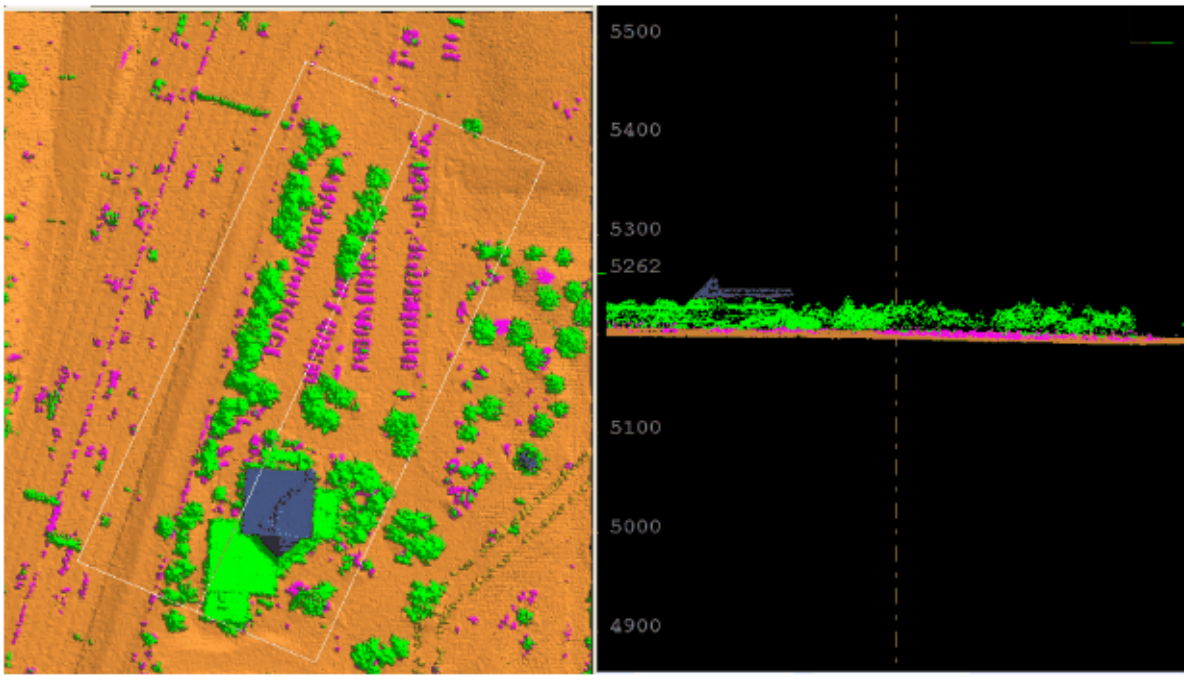
Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** 

, **'Filter Digitized Polygon'** 

, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After the filter has been run, it is easy to see that the cars (up to 6 units above the ground surface) were identified and the points reclassified to Class 24 (pink). The tallest parts of the building (more than 35 units above the ground surface) were identified also and those points were reclassed to Class 6 (dark blue). The points between 6 and 35 units above the ground were left alone and are still most properly classed as Class 5.



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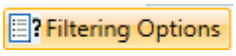
5.1.12 Intensity Filter

Intensity Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Intensity Filter** filter reclassifies LAS points based on the value of the intensity attribute. The user may select the upper and lower intensity values and the filter will reclassify all points with values within this range to the target classification.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data with intensity values (attributes).

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.

- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Not applicable for this filter.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

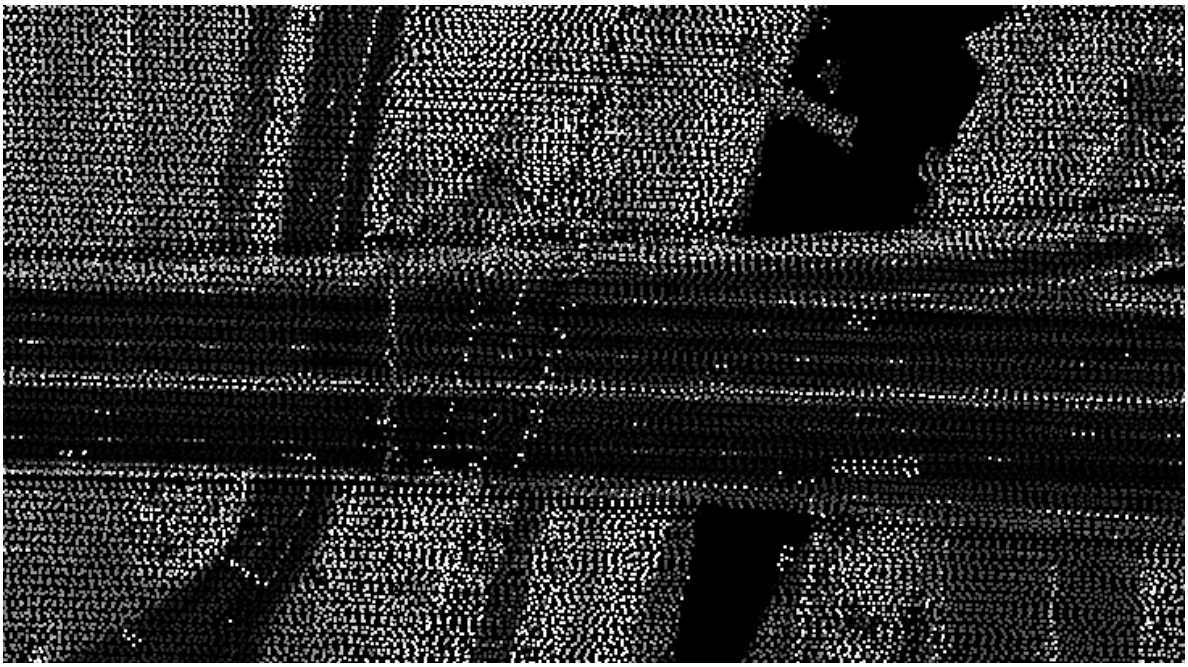
Filter Specific Parameters:

- **Intensity Range**: The range (inclusive) of intensity values to be reclassified. Possible intensity values are 0 (zero) through 65535.

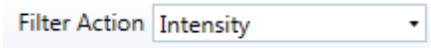
Example Filter Use:

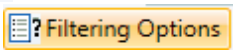
Before: In the example below, the LAS data is colored by intensity value. Low values of intensity indicate a darker, less-reflective surface such as a road or parking lot. Higher values of intensity indicate a very reflective or bright surface such as the metal roof of a building or the roof of a white car. In this case, the user would like to classify the road points.

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Manually Using a Single Filter: To use the Intensity Filter to classify points based on their intensity attribute value, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



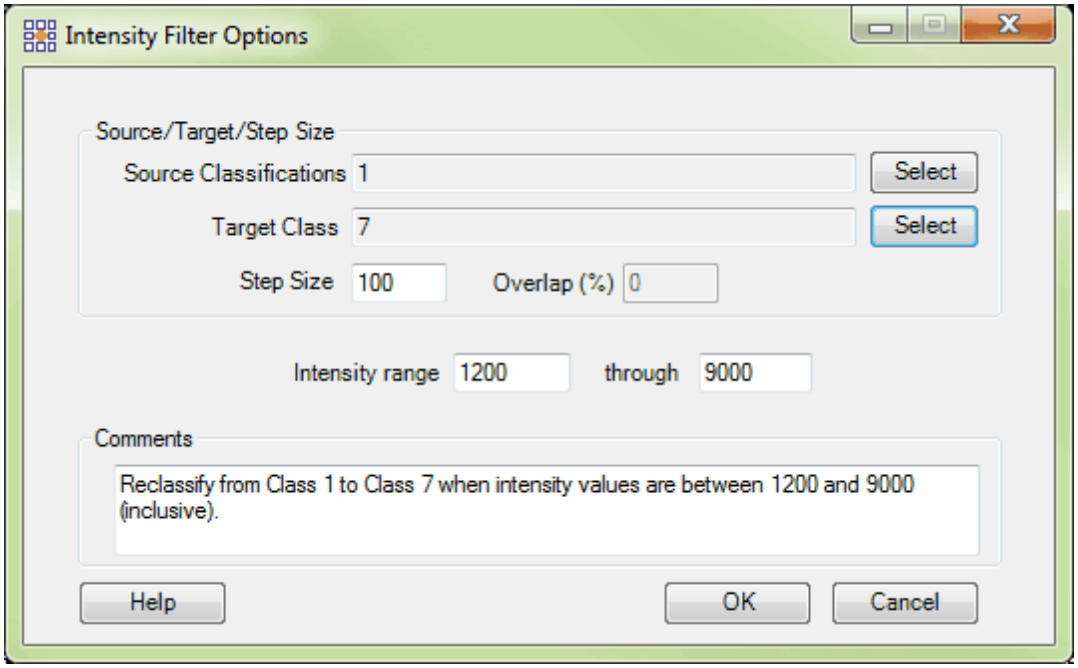
Next, click on the 'Filtering Options'  button to define the filter settings.

Intensity Filter Options Dialog: The 'Intensity Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, and step size can be adjusted as in other filters. Unique to this dialog and filter is the option to choose an intensity value range within which source points will be reclassified.

All LAS data in this particular data set is classified as Class 1 (gray), so this will be the source classification for this filter. The user wishes to classify the road by using intensity values, and so the target classification could be any class; in this example it will be Class 7 (magenta). The default value of 100 for the step size will be used for this particular example. Using the Inspect[943] tool, the user

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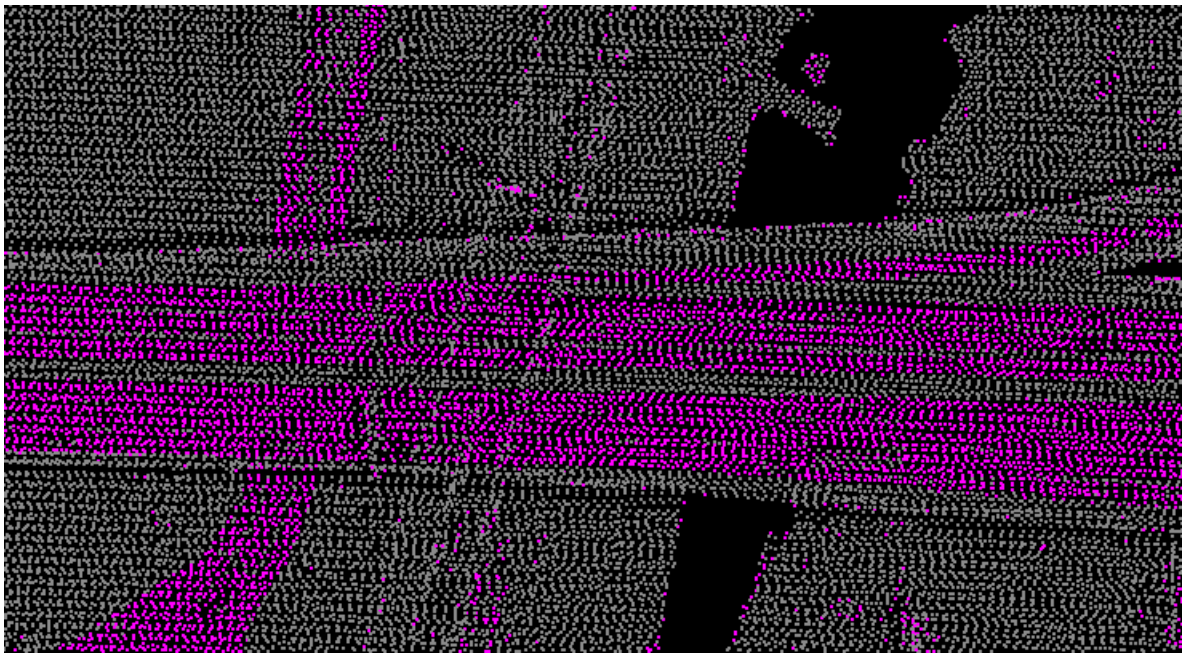
finds that the intensity values of the road points range from about 1200 to about 9000, so this will be the range entered into the filter. Click **'OK'** to save the settings.



Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, all source points whose intensity values are between 1200 and 9000 have been reclassified to Class 7 (magenta). Note that many non-road points were also reclassified since many other features can fall between the selected intensity value limits.

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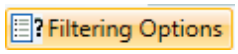
5.1.13 Isolated Point Filter

Isolated Point Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Isolated Point Filter** reclassifies an LAS point or a small group of points when there is no other point of a specified reference class within a user-defined spherical radius (this radius includes the X, Y, and Z axes).

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Reference Classifications:** The point classifications that the unfiltered data is compared against to

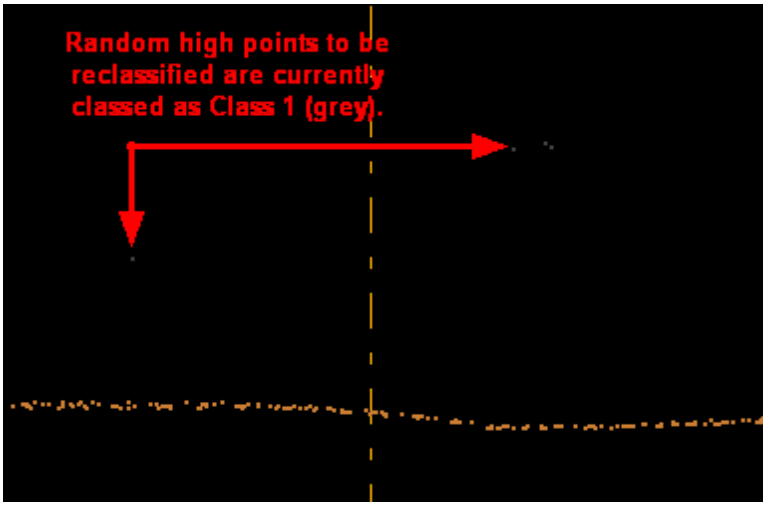
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find the proper points to reclassify.

- **Spherical Radius:** The software will search inside the user defined spherical radius distance (along X, Y and Z axis) for a point of the reference classification. If one is not found, the source point will be reclassified to the Target Classification.
- **Fewer Than:** This user defined setting allows the user to account for clusters of isolated points rather than only single points. If the user would like the filter to search for and reclassify clusters of 'Fewer Than __ Other Points' that specification may be made here. For example, the filter will search for and reclassify points in clusters fewer than 7 points if '7' is the number specified in this option. The availability of this option is especially useful for highly sensitive LiDAR equipment which may collect points on items like flying birds or dust particles -- items which are considered random high points in the LiDAR data set.

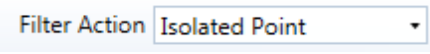
Example Filter Use:

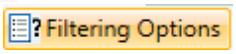
Before: In the example below the user has several single and one small cluster of random high, isolated points. These points are currently classified as Class 1: Unclassified (gray). The Isolated Point filter will be able to find and reclassify points such as these to a unique user-defined class.



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Manually Using a Single Filter: To use the Isolated Point filter to classify points, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab270.

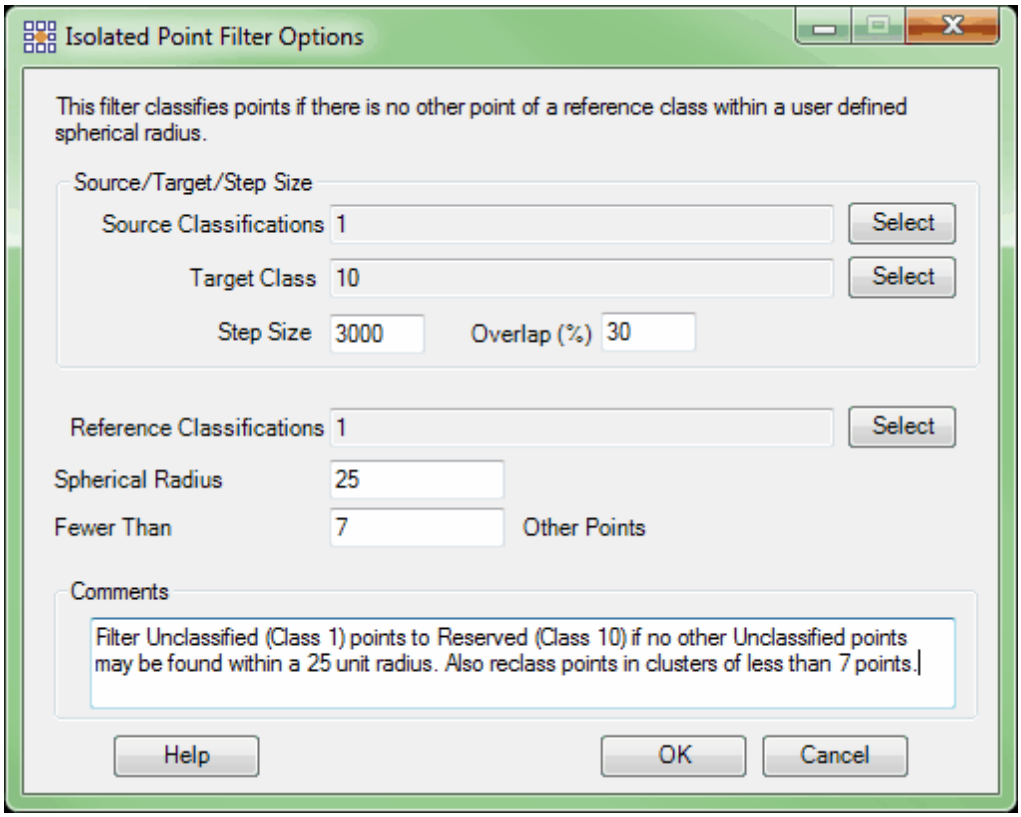


Next, click on the 'Filtering Options'  button to define the filter settings.

Isolated Point Filter Options Dialog: The 'Isolated Point Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose a reference classification, spherical radius, and the option to reclassify clusters of points.

The random high points which need to be reclassified in this dataset are currently in Class 1 (gray), so this will be the source classification for this filter. The user wishes to classify these points to a unique class, in this case Class 10 (yellow). The default value of 3000 for the step size and 30% for the overlap will be used for this particular example. The reference classification will also be Class 1 (gray). The default value of 25 units will be used for the spherical search radius. The user has decided to also reclass small clusters of points, specifically clusters of fewer than 7 points (6 points or less). Click **'OK'** to save the settings.

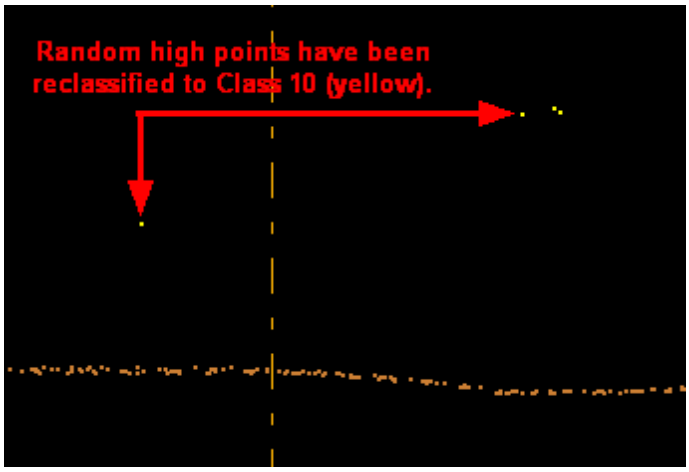
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, the isolated single points and small clusters of points are now classified as Class 10 (yellow).

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5.1.14 Max Grid Filter

Max Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Max Grid Filter** finds the highest single point - or, optionally, group of points - in each grid cell that matches the Source classification set. The filter then reclassifies those points to the Target classification.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** Filtering Options button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 1000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

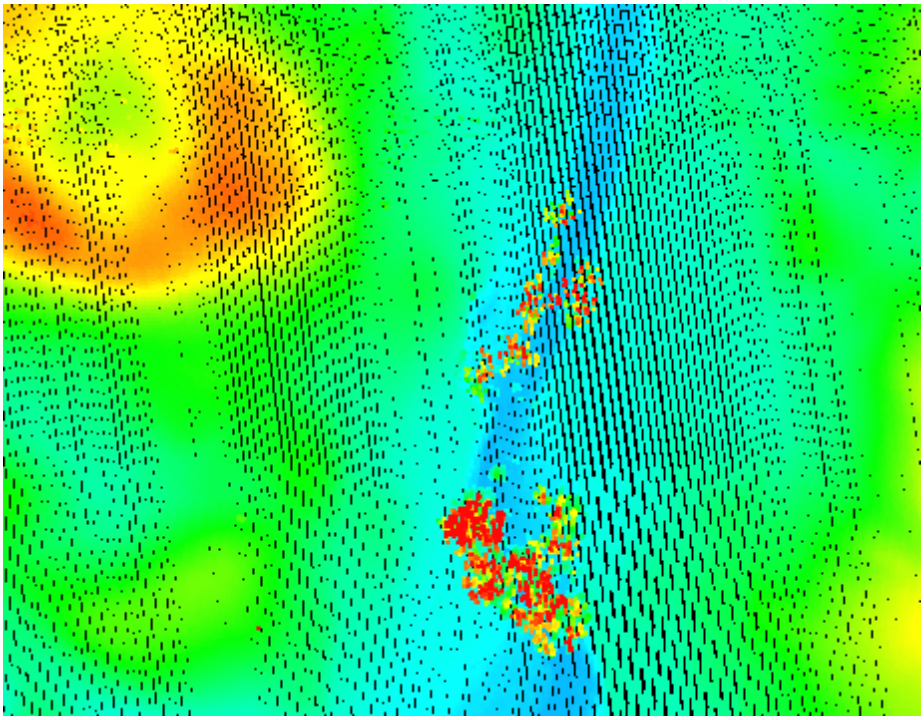
Filter Specific Parameters:

- **Grid cell size:** This value specifies the size of the cells of the grid in project units.
- **Number of points per cell to reclass:** The default is '1', but more can be reclassed if desired.
- **Filter by collection scan:** Filtering can be done by collection scan by checking this option.

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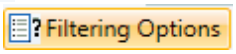
Example Filter Use:

Before: In the example below, the user wishes to reclassify the highest point in each grid cell from the source classification, Class 1: Unclassified (gray), to the target classification, Class 10 (yellow).



Manually Using a Single Filter: To use the Max Grid Filter to reclassify the highest point(s) in each grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



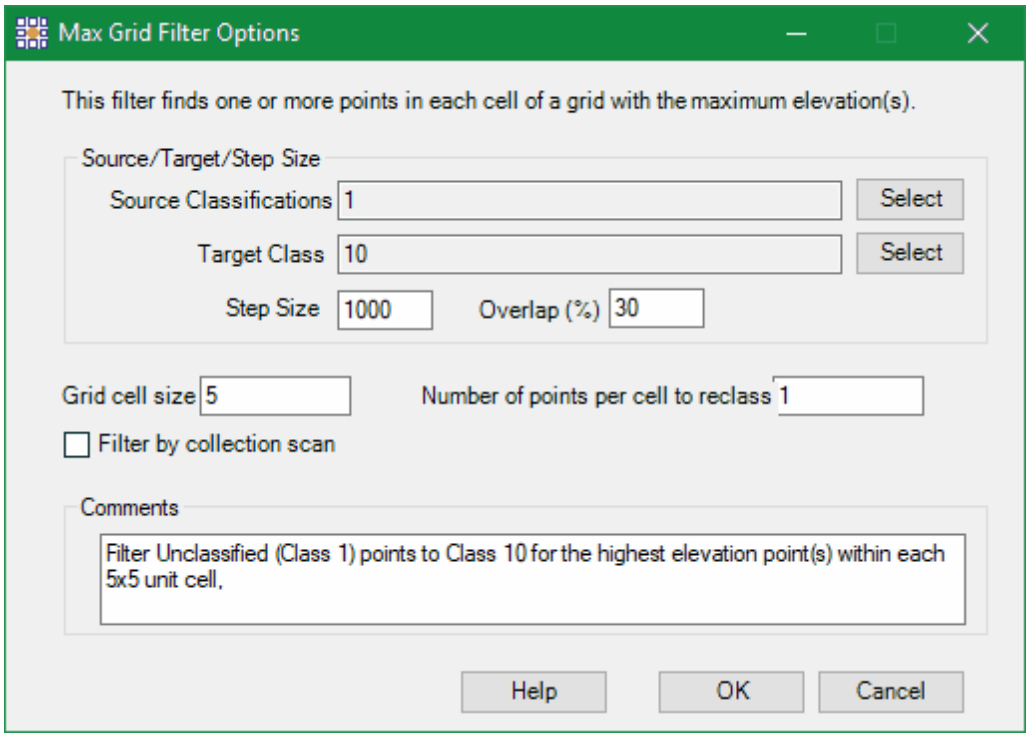
Next, click on the 'Filtering Options'  button to define the filter settings.

Max Grid Filter Options Dialog: The 'Max Grid Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose a grid cell size and the number of high points in each cell to be reclassed. The larger the grid cell size, the fewer points which will be reclassified. The user may also check the 'Filter by collection scan' option which will

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filter the data by collection scan rather than by tile or selected area.

In this example, the source classification will be Class 1: Unclassified (gray), as the whole data set is currently unclassified. The target classification will be Class 10 (yellow). The default settings for step size and overlap will work for most projects, so they will be used for this example. The grid cell size will be set to 5, and the number of points per cell will be left at the default of '1', to reclassify a single maximum elevation source point in each 5 x 5 unit grid cell. Click **'OK'** to save the settings.

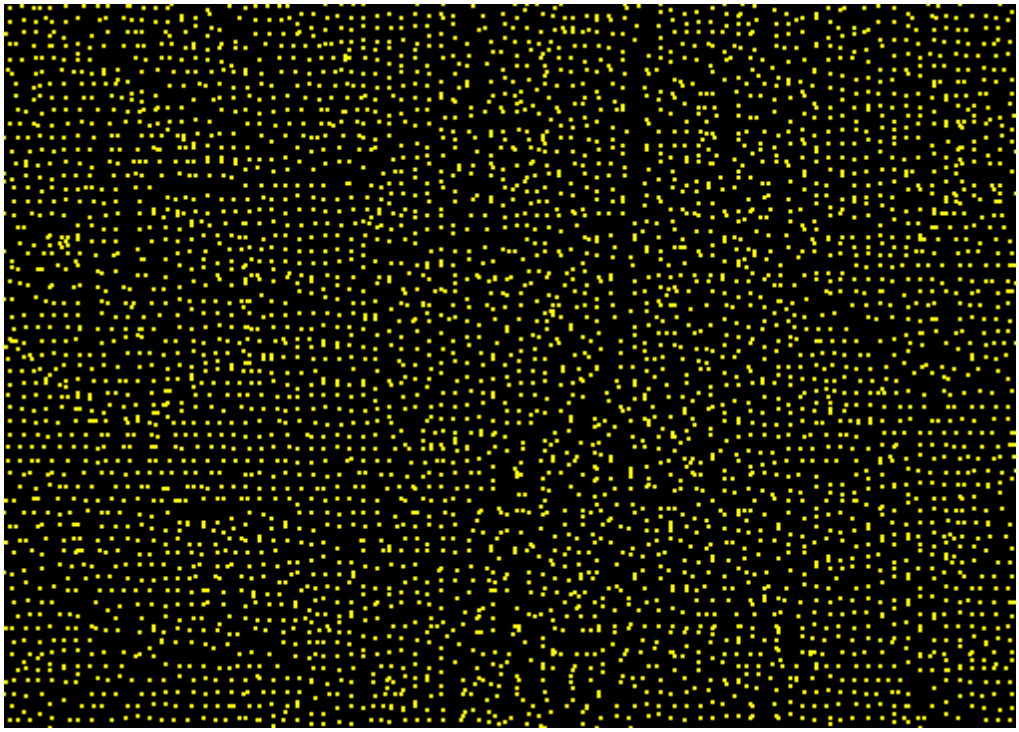


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data.

After: After running the filter, the highest point in every 5 by 5 unit grid cell has been reclassified to Class 10 (yellow). This explains the evenly spaced appearance of the reclassified points. The Class 1 points have been turned off in the display below to allow the reclassified points to be seen more easily.



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5.1.15 Median Grid Filter

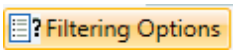
Median Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Median Grid Filter** finds the median elevation point of each grid cell that matches the source

classification set. The filter reclassifies the median elevation point (one per grid cell) to the target classification.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 1000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text

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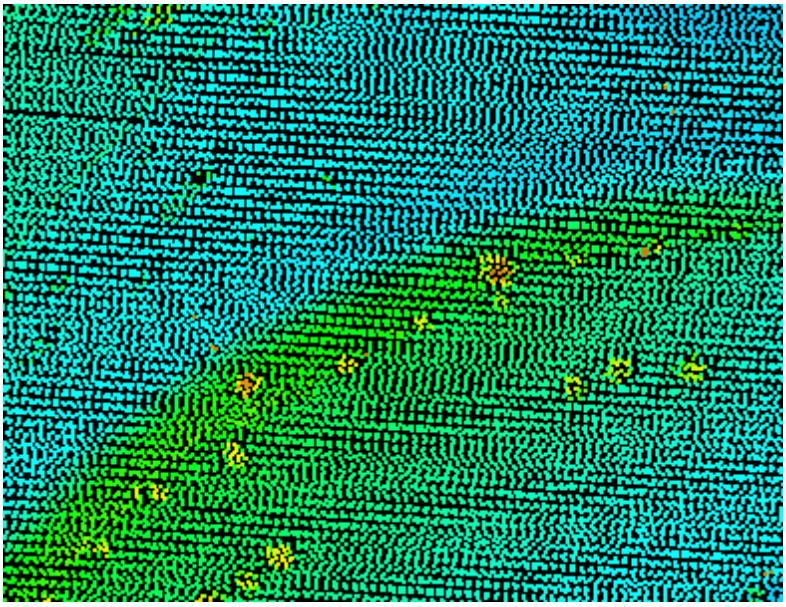
here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Grid cell size:** This value specifies the size of the cells of the grid in project units.
- **Filter by collection scan:** Filtering can be done by collection scan by checking this option.

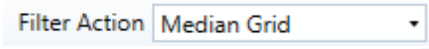
Example Filter Use:

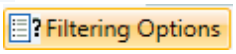
Before: In the example below, the user wishes to reclassify the median elevation point in each grid cell from the source classification, Class 1: Unclassified (gray), to the target classification, Class 11 (red).



Manually Using a Single Filter: To use the Median Grid Filter to reclassify the median elevation point in each grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.

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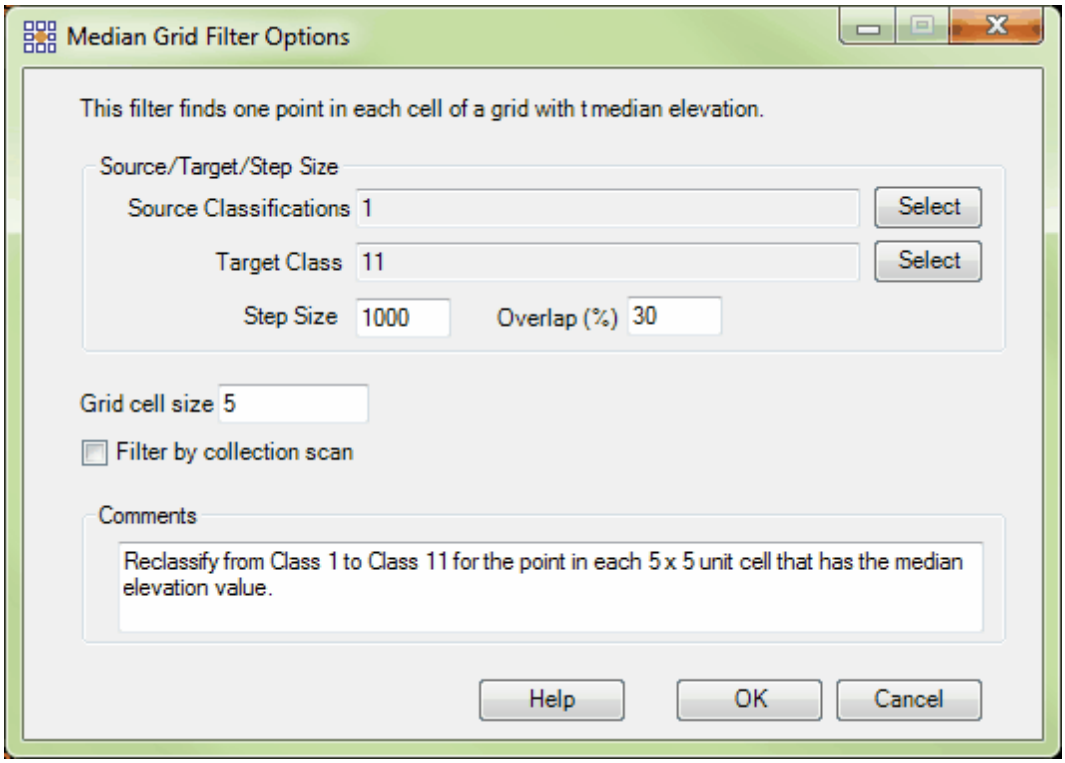


Next, click on the 'Filtering Options'  button to define the filter settings.

Median Grid Filter Options Dialog: The 'Median Grid Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to choose a grid cell size. The larger the grid cell size, the fewer points which will be reclassified. The user may also check the 'Filter by collection scan' option which will filter the data by collection scan rather than by tile or selected area.

In this example, the source classification will be Class 1: Unclassified (gray), as the whole data set is currently classified as Class 1. The target classification will be Class 11 (red). The default settings for step size and overlap will work for most projects, so they will be used for this example. The grid cell size will be set to 5, to reclassify the median elevation grid point in each 5 x 5 unit grid cell.
Click **'OK'** to save the settings

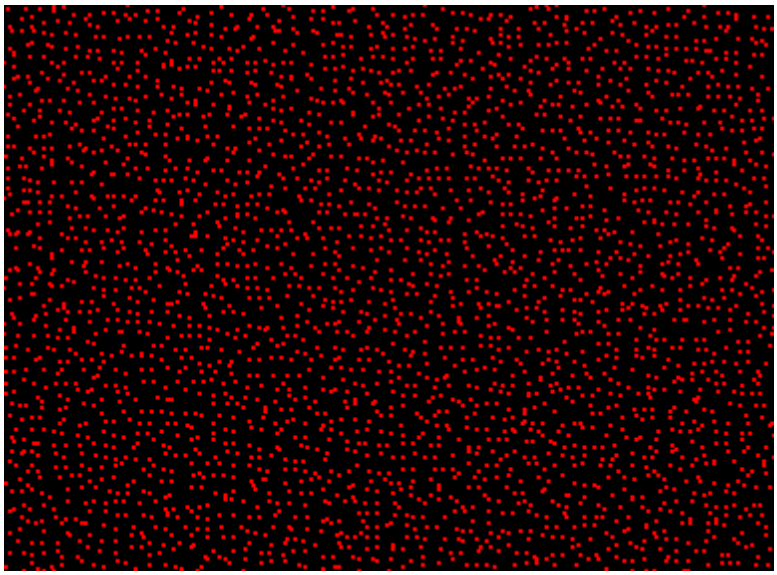
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Choosing the Area to be Filtered: NNow that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, the median elevation point in every 5 by 5 unit grid cell has been reclassified to Class 11 (red). This explains the evenly spaced appearance of the reclassified points. The Class 1 points have been turned off in the display below to allow the reclassified points to be seen more easily.

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5.1.16 Min Grid Filter

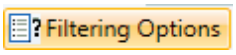
Min Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Min Grid Filter** finds the lowest point - or, optionally, points - of each grid cell that matches the Source classification set. The filter reclassifies those points to the Target classification.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab

270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 1000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

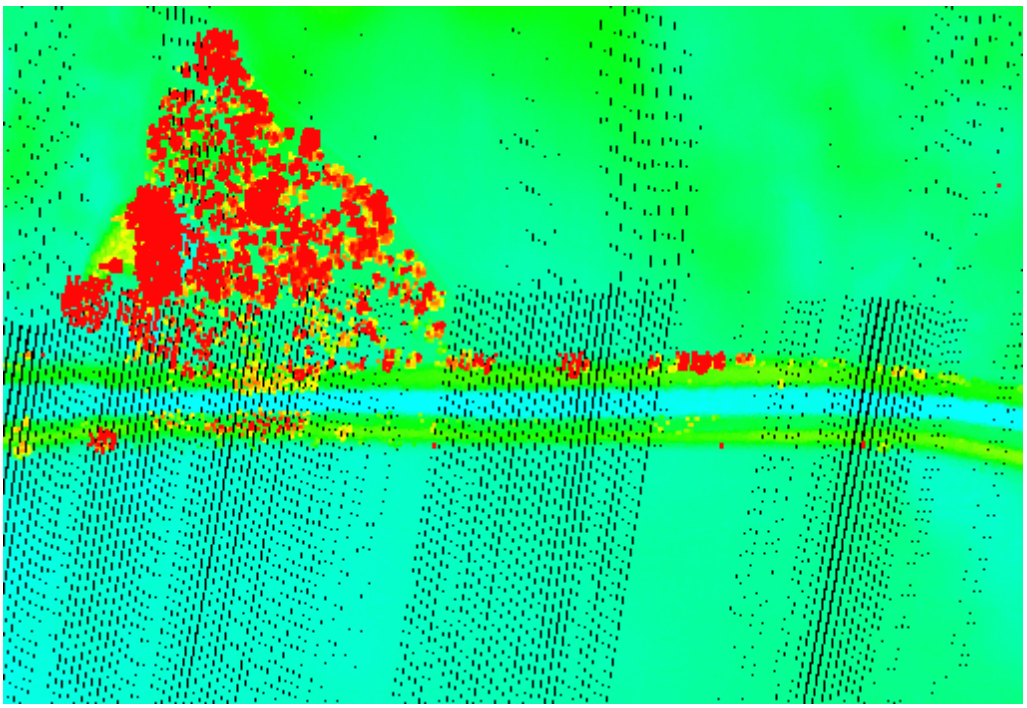
Filter Specific Parameters:

- **Grid cell size:** This value specifies the size of the cells of the grid in project units.
- **Number of points per cell to reclass:** The default is '1', but more can be reclassed if desired.
- **Filter by collection scan:** Filtering can be done by collection scan by checking this option.

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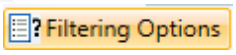
Example Filter Use:

Before: In the example below, the user wishes to reclassify the lowest point in each grid cell of a virtual grid from the source classification, Class 1: Unclassified (gray), to the target classification, Class 7: Low Point (pink).



Manually Using a Single Filter: To use the Min Grid Filter to reclassify the lowest point(s) in each grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



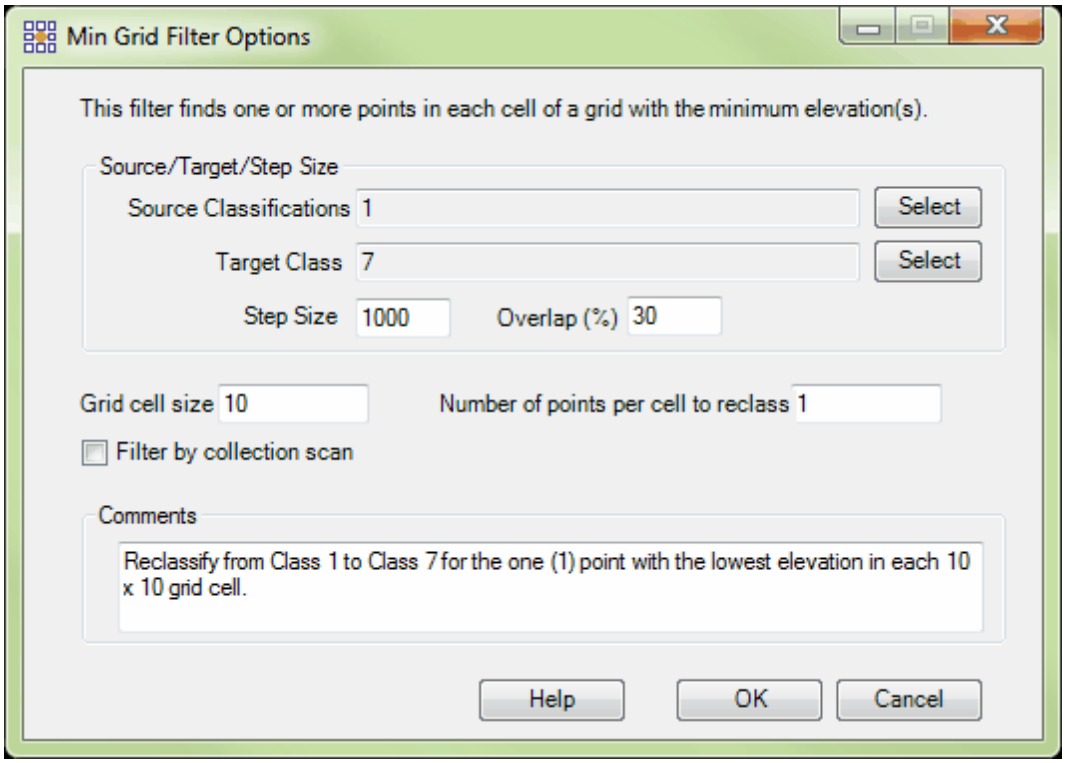
Next, click on the 'Filtering Options'  button to define the filter settings.

Min Grid Filter Options Dialog: The 'Min Grid Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted

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as in other filters. Unique to this dialog and filter is the option to choose a grid cell size and the number of low points in each cell to be reclassed. The larger the grid cell size, the fewer points which will be reclassified. The user may also check the 'Filter by collection scan' option which will filter the data by collection scan rather than by tile or selected area.

In this example, the source classification will be Class 1: Unclassified, as the whole data set is currently unclassified. The target classification will be Class 7 (pink), as this is the proper classification for these minimum points. The default settings for step size and overlap will work for most projects, so they will be used for this example. The grid cell size will be set to 10, and the number of points per cell will be left at the default of '1', to reclassify a single minimum elevation point in each 10 x 10 unit grid cell. Click **'OK'** to save the settings.

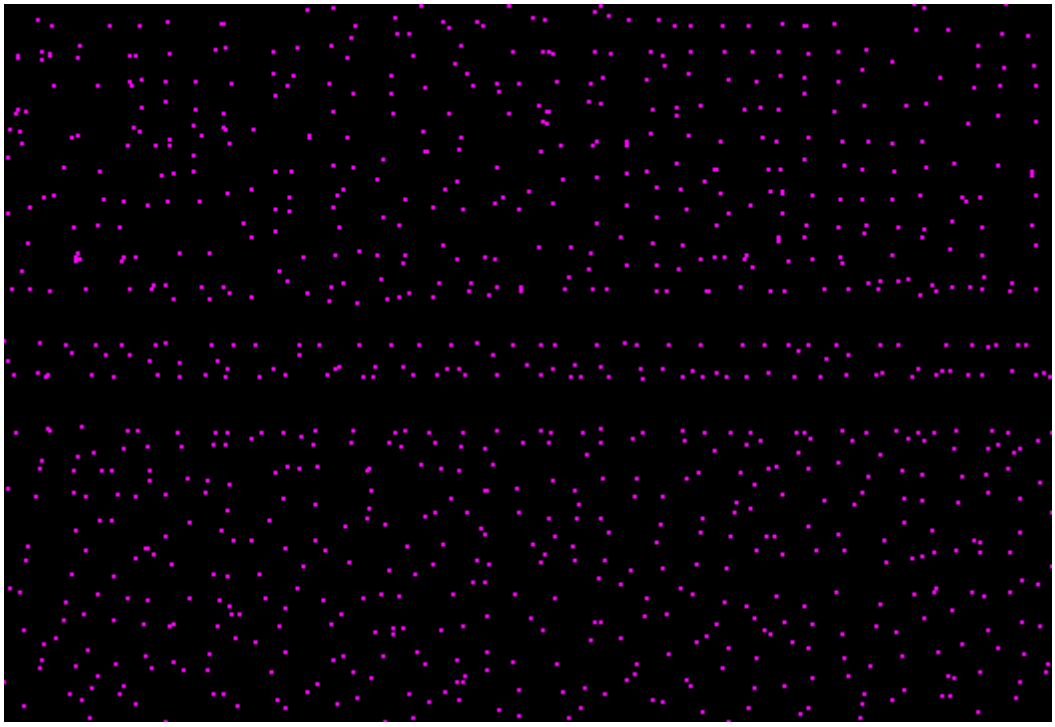


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this

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project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, the lowest point in every 10 by 10 unit grid cell has been reclassified to Class 7. This explains the evenly spaced appearance of the reclassified points. The Class 1 points have been turned off in the display below to allow the reclassified points to be seen more easily.



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5.1.17 Model Key-point Filter

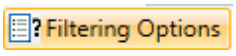
Model Key-point Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Model Key-point Filter** creates a new, thinned dataset from ground (surface) points by searching for the highest and lowest points in a user-defined area. Further specifications are made by the user to describe an elevation tolerance for other source points which will be considered for reclassification. The minimum density of the 'thinned' surface can also be determined by the user.

The filter is currently designed to output to a unique class and does not set the Model Key-point bit flag to 'on' for those reclassified points. A future release of MARS® will have a re-written Model Key-point Filter that will leave the candidate ground points in Class 2 and set their Model Key-point bit flag to 'on'. In the interim, LAS v1.4, PDRF 6 (or higher) compliant data can be created by using this workflow: 1. Use this filter to temporarily output to a unique class per the instructions below. 2. Use the 'Class to Bit Flag' tool (found under the 'Bit Flag Settings' drop-down on the Tools Tab 389) to set the Key-point Bit Flag to 'on' for the temporary points class. 3. Use the Reclassify Filter 1100 to set the temporary points class back to Class 2 (ground). All ground points will now be on Class 2 with the Model Key-points flagged appropriately.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate

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interface to enter in the desired settings.

Requirements:

- A final, hand-filtered ground surface.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter-Specific Parameters:

- **Use points every:** This option allows the user to specify the minimum density of the new surface classification. For example, if the user would like to have at least one model key-point every 20 horizontal units, set the 'Use points every:' setting to 20. This option will guarantee a minimum density of points even in flat areas where few points would typically be reclassified.
- **Tolerance above:** This setting specifies how far above the source classification (surface) a point may be to be considered for reclassification. All reclassified points will be outside of the elevation

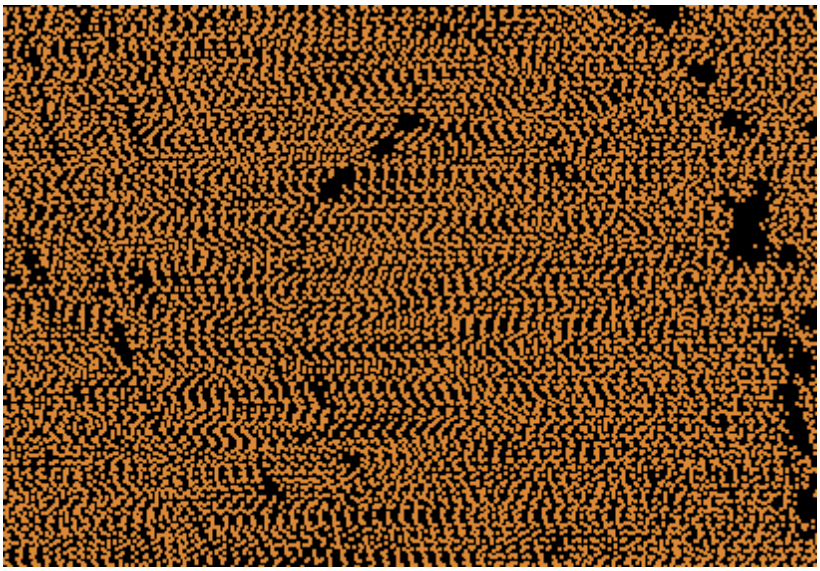
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tolerances defined by the user. The elevation tolerances allow the user to control the accuracy of the model key-point surface.

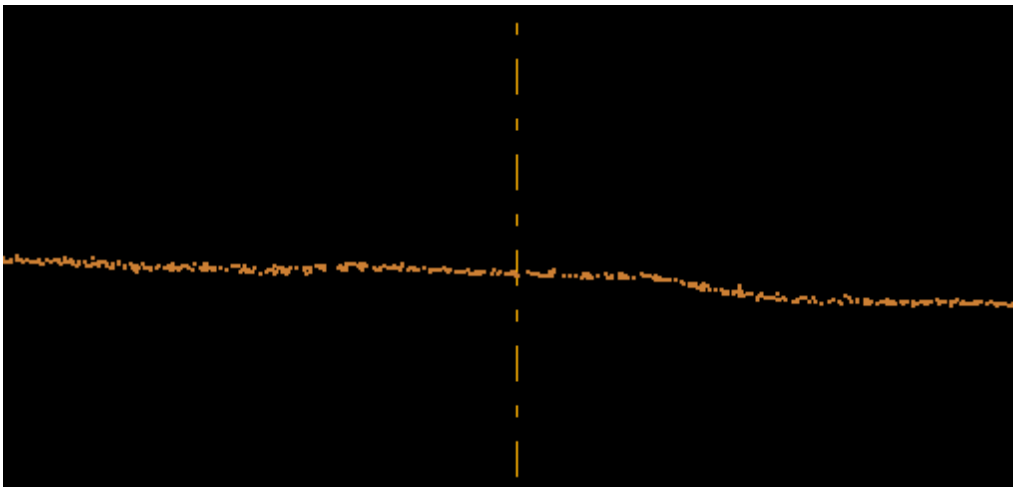
- **Tolerance below:** This setting specifies how far below the source classification (surface) a point may be to be considered for reclassification. All reclassified points will be outside of the elevation tolerances defined by the user. The elevation tolerances allow the user to control the accuracy of the model key-point surface.

Example of Filter Use:

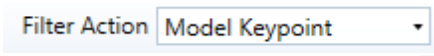
BEFORE: In the example below the user has a final, hand-filtered area of ground points on which to run the Model Key-point filter. The ground surface is currently in Class 2: Ground (orange) and the display of all other classifications has been turned off. The Model Key-point filter will provide a less dense dataset than the original ground surface.

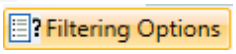


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Manually Using a Single Filter: To use the Model Key-point filter to classify points, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



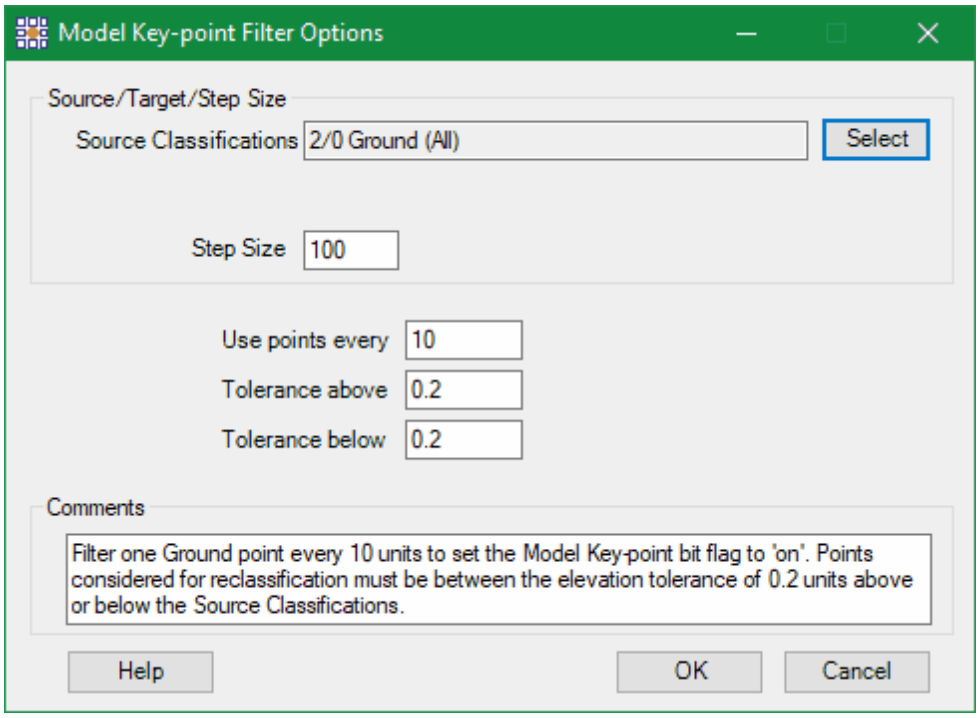
Next, click on the 'Filtering Options'  button to define the filter settings.

Model Key-point Filter Options Dialog: The 'Model Key-point Filter Options' interface gives the user several options to specify. The source classification, target class, and step size can be set as in other filters. Unique to this dialog and filter are the options to specify the minimum density of the new surface classification and the elevation tolerances for determining candidate points to be reclassified.

The hand-filtered ground surface points are currently in Class 2: Ground (orange), so this will be the source classification for this filter. The user wishes to reclassify some points in this surface as Model Key-points, so Class 8: Reserved will be the target classification. The default value of 100 units for the step size will be used for this particular example. The 'Use points every:' option will be kept at its default setting of 10. This ensures that at least one point in every 10 horizontal units will be reclassed from the Ground class to Model Key-point class. The default settings for elevation tolerance will also be used. These settings specify that only points more than 0.2 vertical units above or below the

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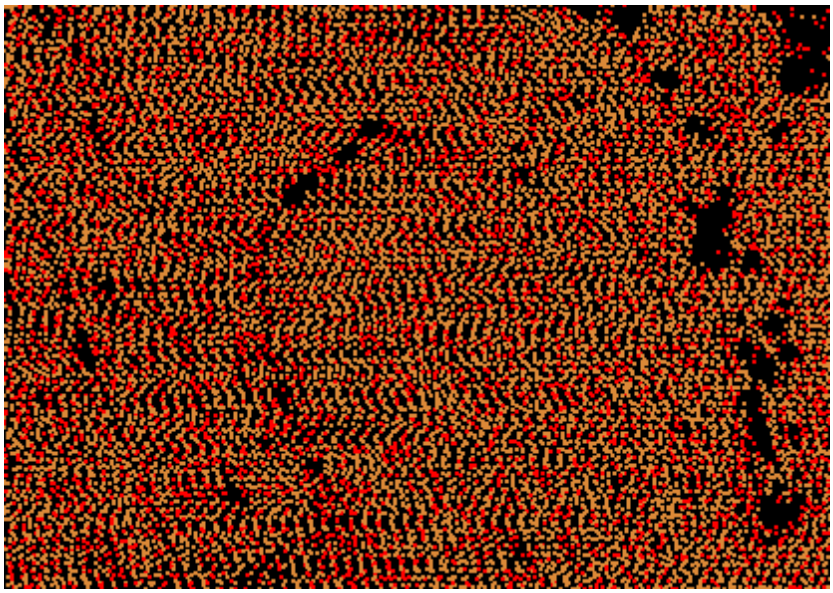
ground surface will be considered for reclassification.

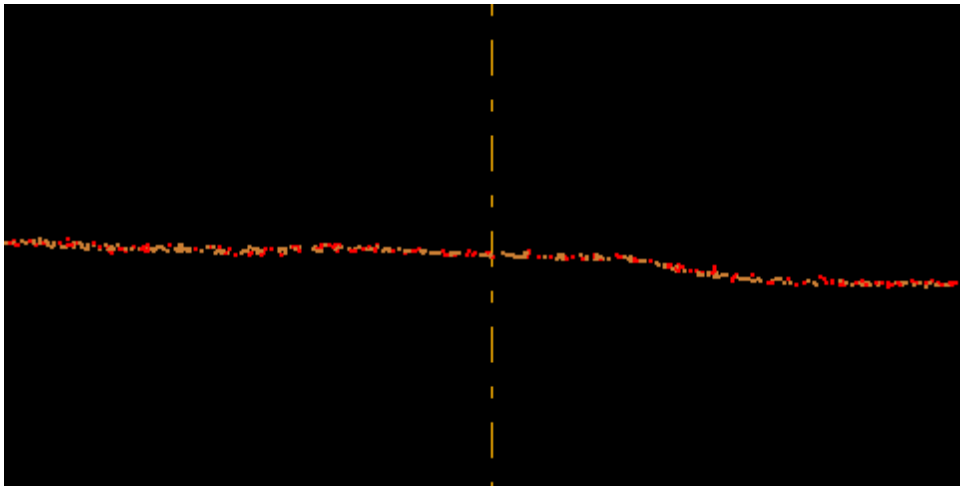


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

AFTER: After running the filter, the highest and lowest ground points from Class 2, within the elevation tolerances, have been reclassified. The "Use points every" setting ensures that there is at least one Model Key-point (red, below) in every 10 units.

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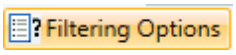
5.1.18 Percolate Filter



The **Percolate Filter** targets a sparse set of points of a certain classification and adds - or *percolates*

- more points to this set, thereby gradually making the surface built from this classification set more dynamic (greater number of points and greater undulation in elevation). This filter is typically used to build a more complete ground surface given some sparse initial ground point set. The Percolate filter reclassifies points in the source classification set that are relatively low (or high when the 'Invert' option is used) without exceeding limits on the steepness of a surface made from the target class.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.
- A ground surface or other planar surface.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned. This should be an existing surface class, typically Class 2: Ground.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default

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step size suggested for most projects using this filter is 100.

- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

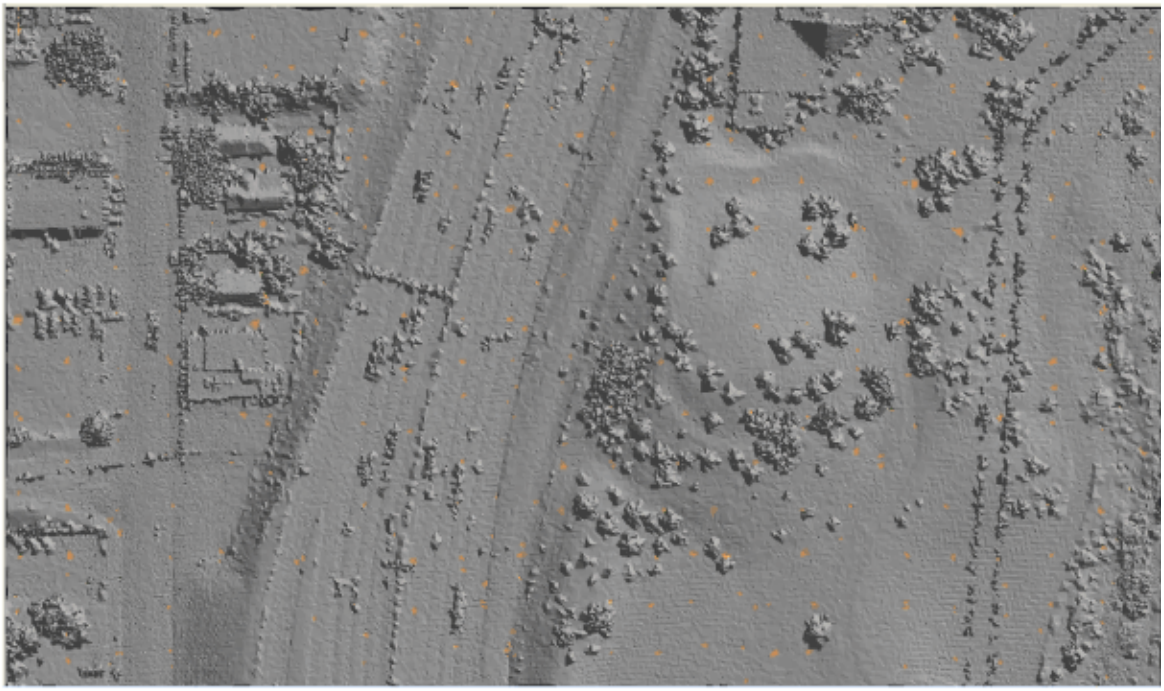
Filter Specific Parameters:

- **Terrain angle:** Maximum slope of the ground surface.
- **Step angle:** Maximum incremental slope change created in the ground surface. The angle is computed by measuring the angle between the new point, the nearest existing point, and the TIN triangle below the point under consideration.
- **Step distance:** Maximum distance a filtered point can be above the current surface. The distance is computed by measuring the perpendicular line from the point under consideration to the underlying TIN triangle.
- **Invert:** When chosen, this option allows the user to percolate points from above, rather than from below.
- **Density:** The user may choose from three density options: **1.** No limit in density. **2.** A density of one point every user-defined number of square units. **3.** A user-defined number of points per 1000 square units.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

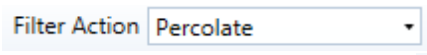
Example Filter Use:

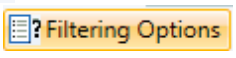
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Before: In the example below, the user would like to percolate the ground surface. A Min Grid Filter 1077 with a grid cell size of 40 units has already been run on the data below to provide seeding (or starting) data for the Percolate Filter. The small number of ground points (orange) are barely visible within the unclassified (gray) data. The Percolate Filter will be used to create more ground points by referencing the small number of ground points which currently exist.



Manually Using a Single Filter: To use the Percolate Filter to increase the density of the ground points, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



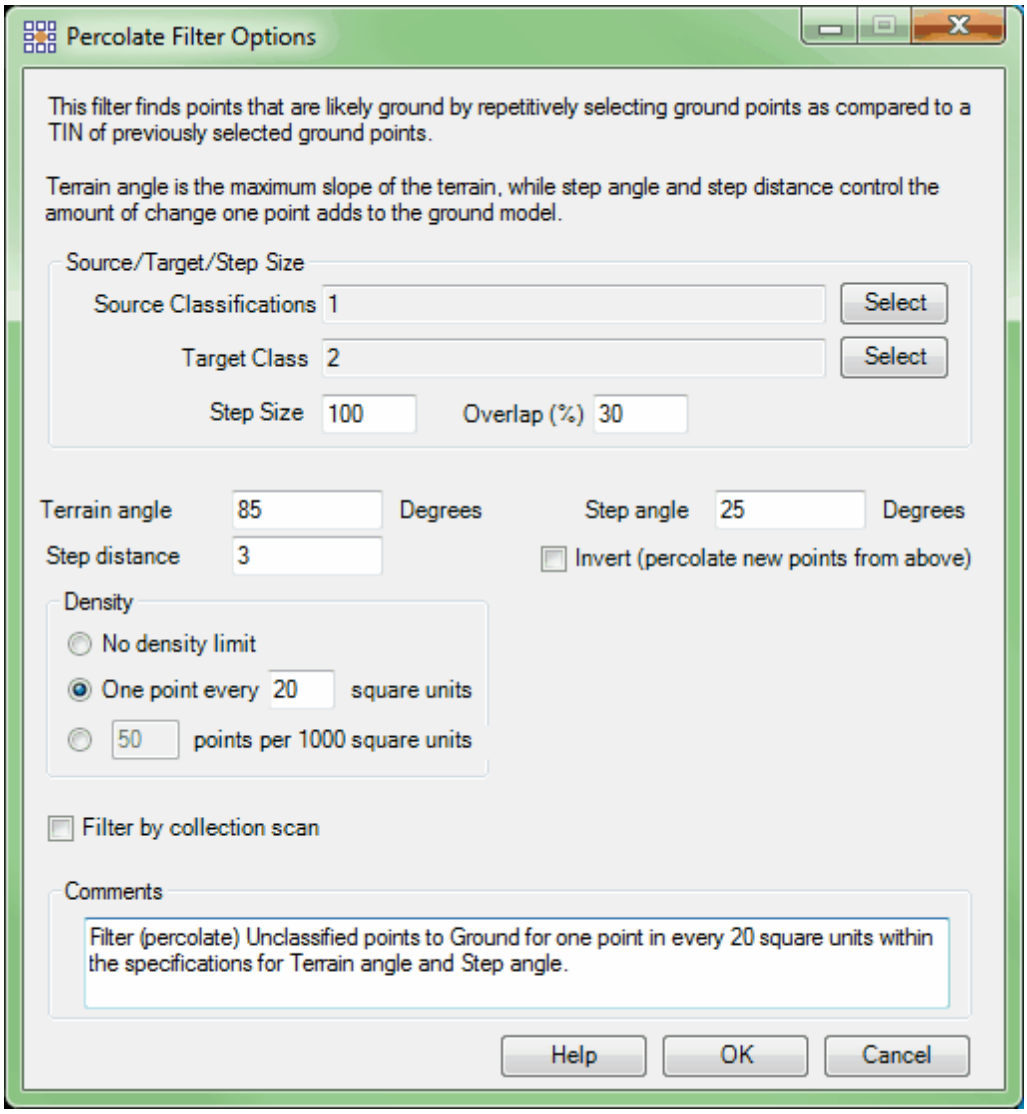
Now, click on the 'Filtering Options'  button to define the filter settings.

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Percolate Filter Options Dialog: The 'Percolate Filter Options' interface gives the user several options in specifying parameters for the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this filter's dialog is the option to choose the terrain angle of the TIN which the filter will use to find surface points, the step distance, the step angle, the choice to invert the percolate filter, and the option to specify the density of the points percolated.

In this example, the source classification will be Class 1 (gray), as most of the data set is currently unclassified. The target classification will be Class 2: Ground (orange).The default settings for Step Size and Overlap will work for most projects, so they will be used for this example. The Terrain angle and Step angle will be set to 85 and 25 respectively, allowing more angling in the surface since the area in question is relatively hilly. The Step distance has been set to 3. Finally, the filter has been set to percolate, or create, a point density of one point every 20 square units. Click **'OK'** to save the settings.

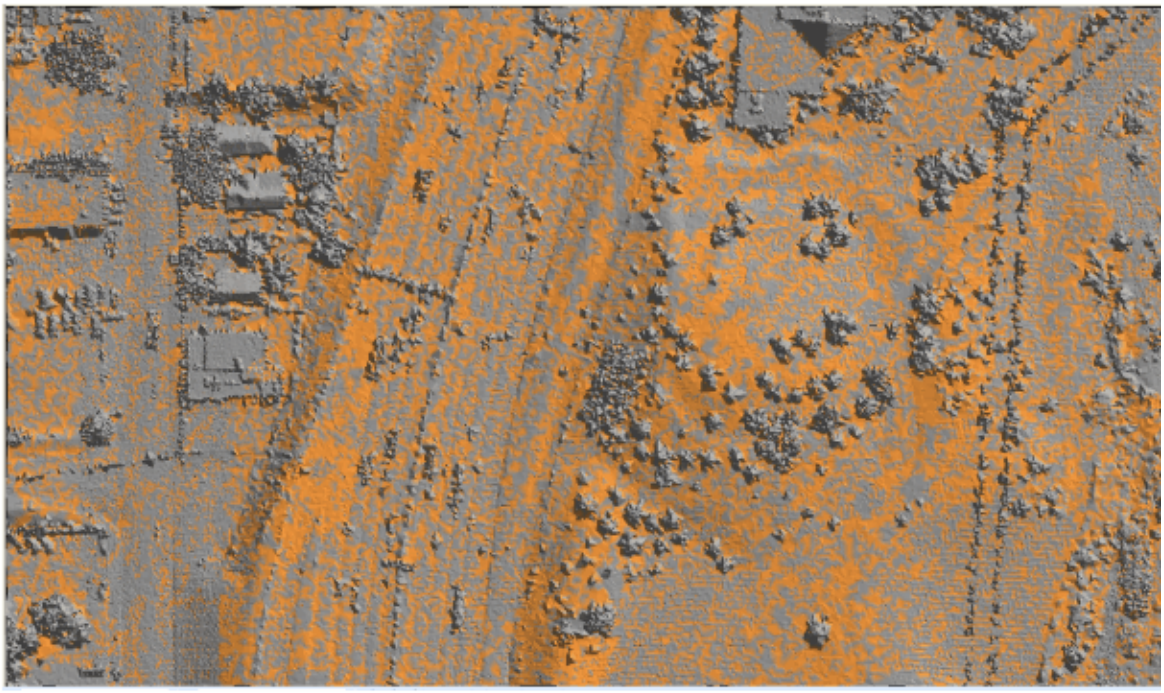
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

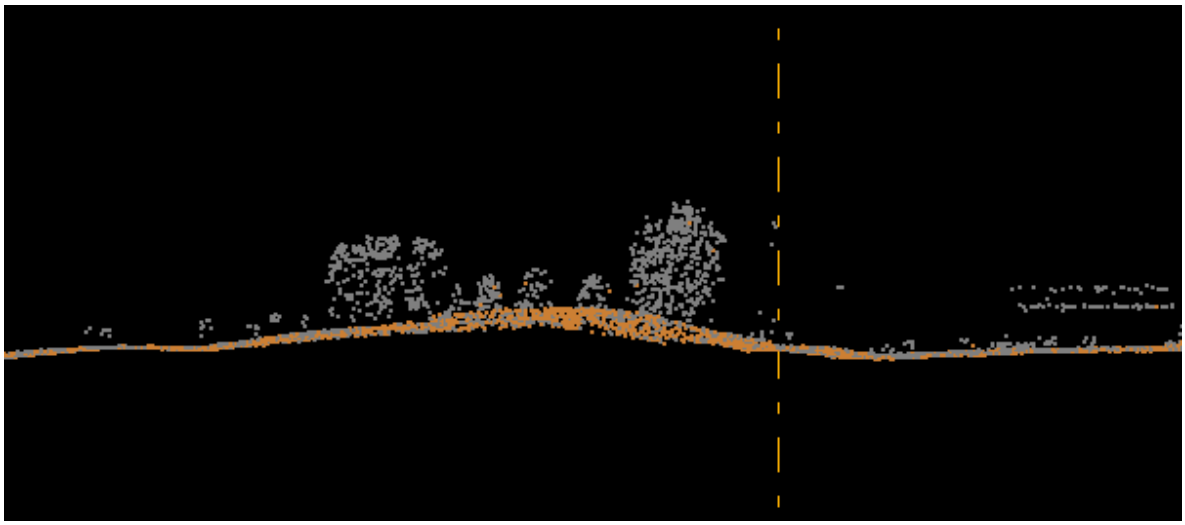
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After: After the filter has been run, there are many more ground points visible in the filtered area. The Percolate Filter has taken the ground points which already existed and used them to increase the density of ground points in the area specified by the user.

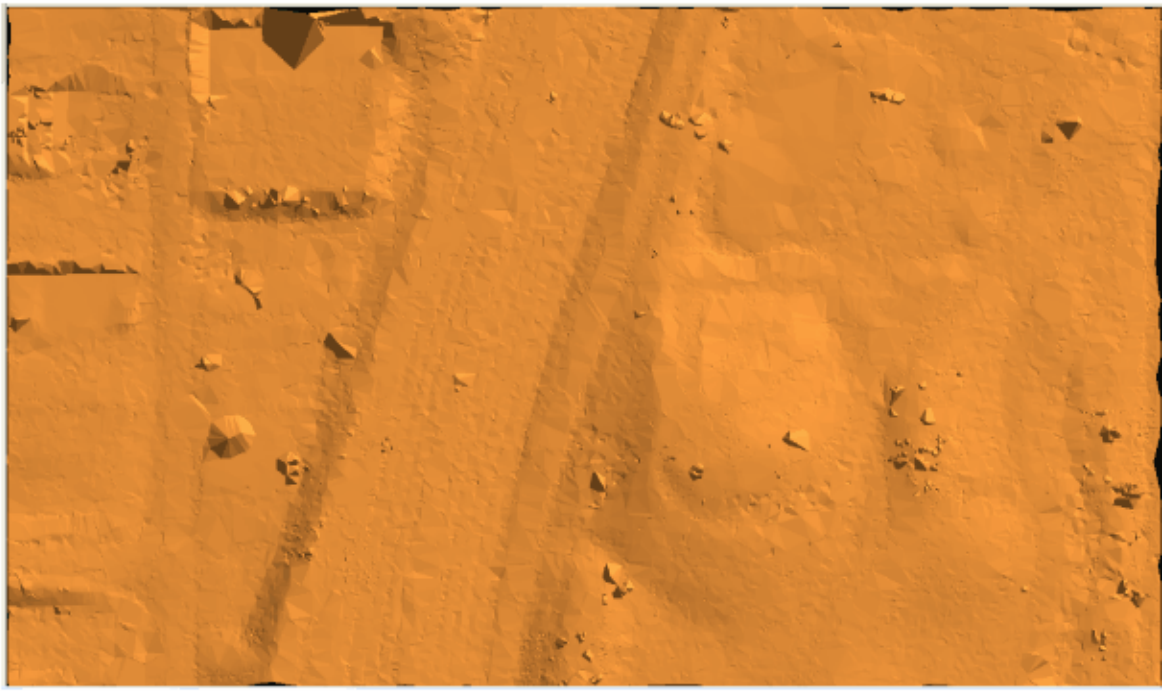


In the cross-section example below, it is easier to see the results of the Percolate Filter. The filter has accurately reclassified the ground in most cases. A few stray ground points can be seen in the vegetation above the ground, but these are easily removed either by hand editing or by use of another filter.

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If the ground points are turned on while all other points are turned off and the surface is then TINned, it is now possible to see the beginning of a ground surface.



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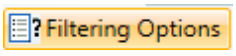
5.1.19 Plane Analysis Filter

Plane Analysis Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Plane Analysis Filter** is designed to find and reclassify groups of LAS points that form planar surfaces. This filter functions differently than the Building filter because it is capable of specifying different angles of planar surfaces such as roofs. This tool does not require a reference surface to separate features.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.

- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Min Area:** This value represents the minimum area required for inclusion into the Plane Analysis tool. Any planar feature with an area less than this value will be ignored. This value is in the same units as the LAS data (ex. feet or meters).
- **Grid Resolution:** This parameter sets the cell size of the grid created for feature extraction. This value is in the same units as the LAS data with a default value of 1. The grid resolution is defined for the sliding array of 5x5 grid cells on which the Planar Analysis algorithm operates. The grid resolution should be set to approximately what the GSD (ground sample distance) is.
- **Minimum Number of Cells to Calculate Slope (3 to 25):** Specifies the minimum number of cells from the 5x5 grid array to qualify the centroid cell as a planar point. This value must be greater than 3 and less than 25.
- **Minimum Std Z Error:** Specifies the minimum standard Z error for an acceptable least squares plane solution.
- **Maximum Angle:** Specifies the maximum angle of interest in degrees. LAS points associated with

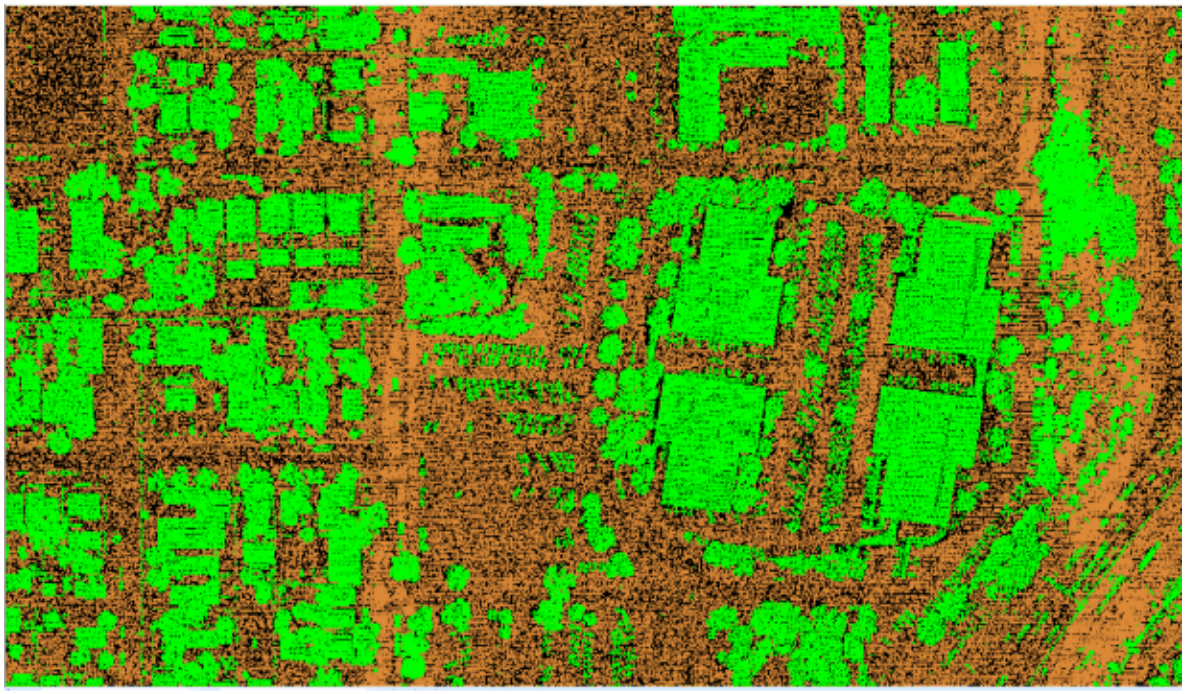
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planar features at angles greater than this value will not be reclassified.

- **Minimum Angle:** Specifies the minimum angle of interest in degrees. LAS points associated with planar features at angles less than this value will not be reclassified.

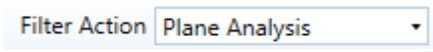
Example Filter Use:

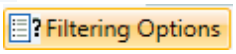
Before: In the example below, the user wishes to classify buildings from Class 5: High Vegetation (green) to Class 6: Building (dark blue).



Manually Using a Single Filter: To use the Plane Analysis Filter to classify planar (flat) features, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.

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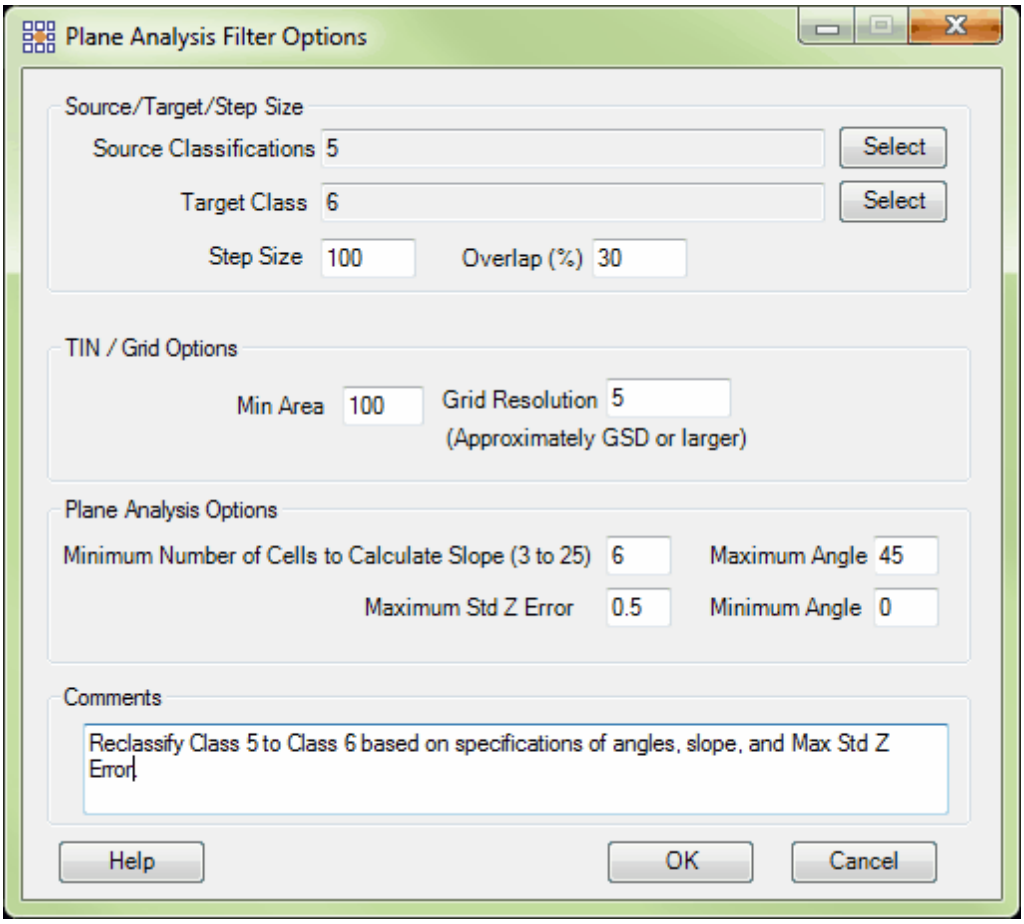


Next, click on the 'Filtering Options'  button to define the filter settings.

Plane Analysis Filter Options Dialog: The 'Plane Analysis Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique to this dialog is the option to define a min area, a grid resolution, the number of cells that should be used to calculate slope, the max Z error, and the minimum and maximum angle of the plane.

In this example, Class 5: High Vegetation will be the source classification since the buildings are currently classed as high vegetation. The target class will be Class 6: Building. The step size, overlap, and min area defaults will be used for this example. The grid resolution has been set to 5. The grid resolution should be set to approximately match the ground sample distance of the data, and in the example data the GSD is just under 5 units. The default values in the Plane Analysis Options section can be left as is. Click **'OK'** to save the settings.

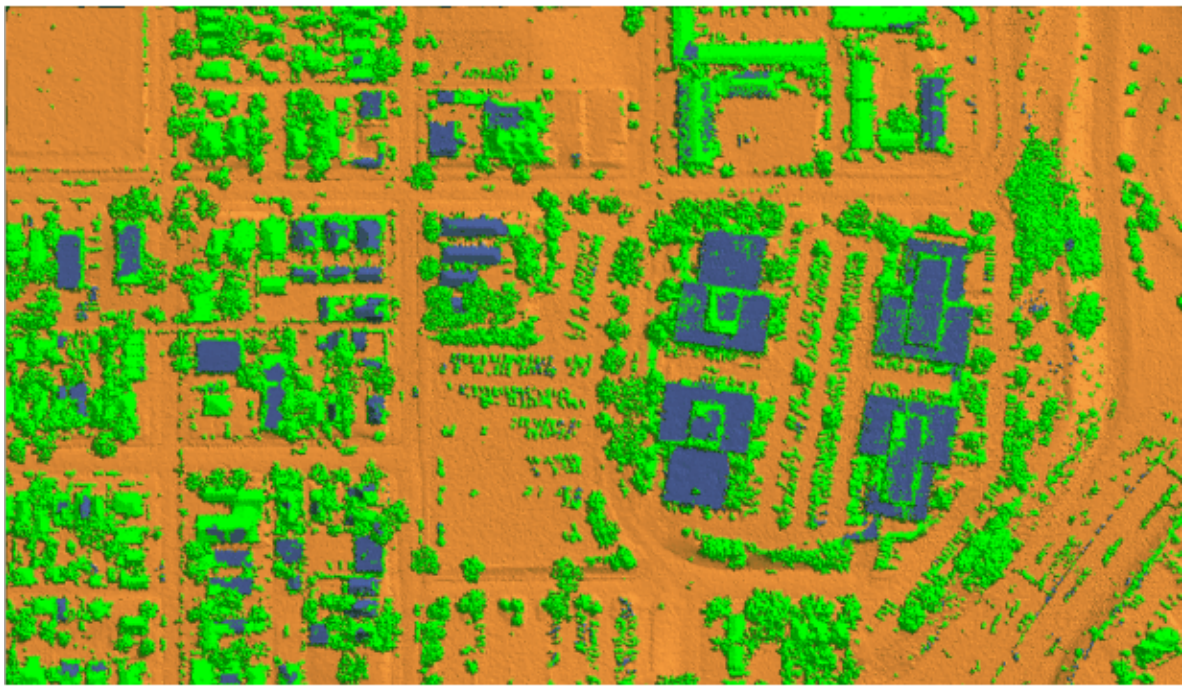
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: The filter has done a decent job of picking out the flat, planar surfaces of buildings and roofs in this example. Any Class 5 point matching the criteria as stated in the Plane Analysis Filter Options interface has been reclassified as a Class 6 building point.

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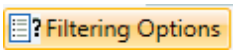
5.1.20 Reclassify Filter

Reclassify Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Reclassify Filter** reclassifies all points from the source classification(s) to the target classification. There are no additional parameters with this filter.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'**  button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

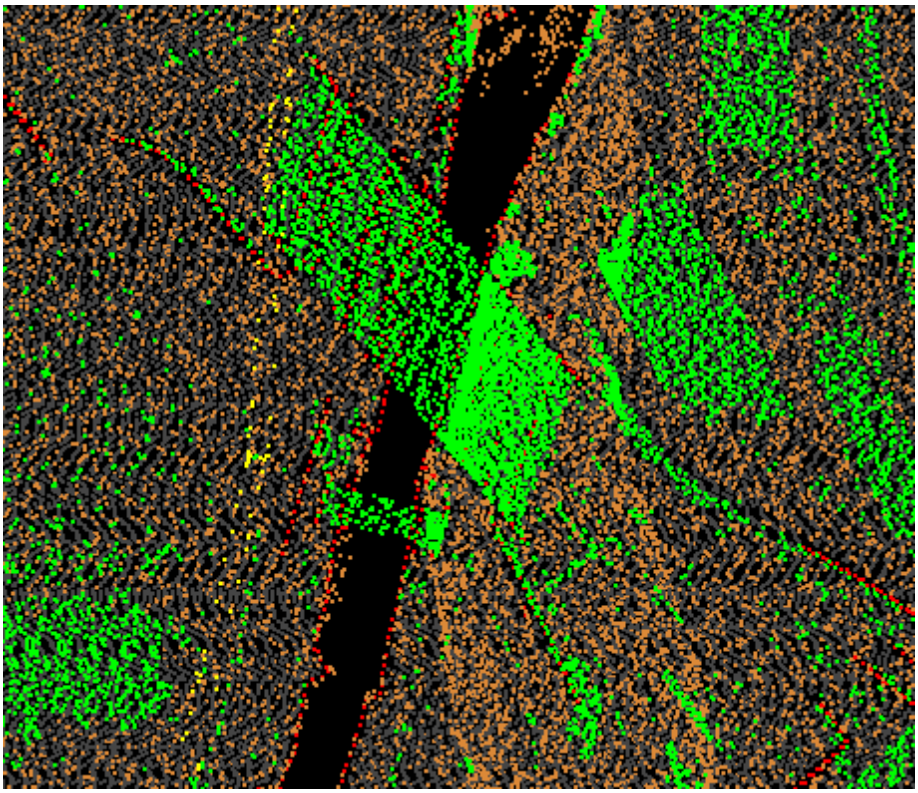
General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Not applicable for this filter.
- **Use All Collection Scans:** When checked, all collection scans will be included in the reclass. If unchecked, an individual collection scan number must be entered for filtering.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

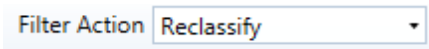
Example Filter Use:

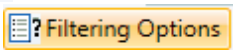
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Before: In the example below, all classifications are to be turned to Class 1: Unclassified (gray).



Manually Using a Single Filter: To use the Reclassify Filter to reclassify all points to a single target class, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



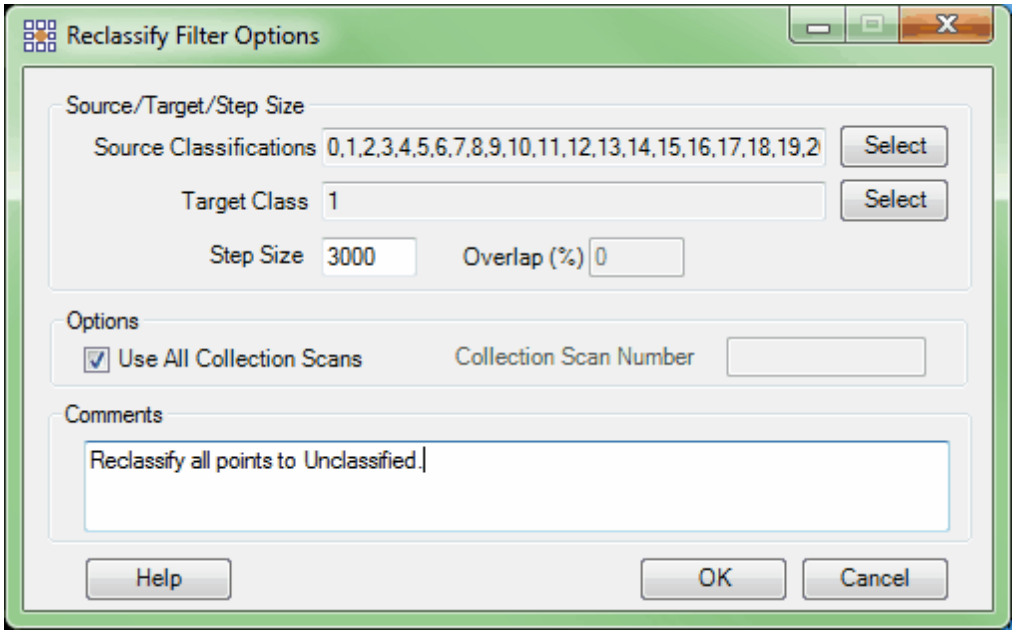
Next, click on the 'Filtering Options'  button to define the filter settings.

Reclassify Filter Options Dialog: The 'Reclassify Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, and step size can be adjusted as in other filters.

In this example, the source classification will be all classes. To set this, choose the **'All Classifications On'** button when selecting classes for the source classification. The target

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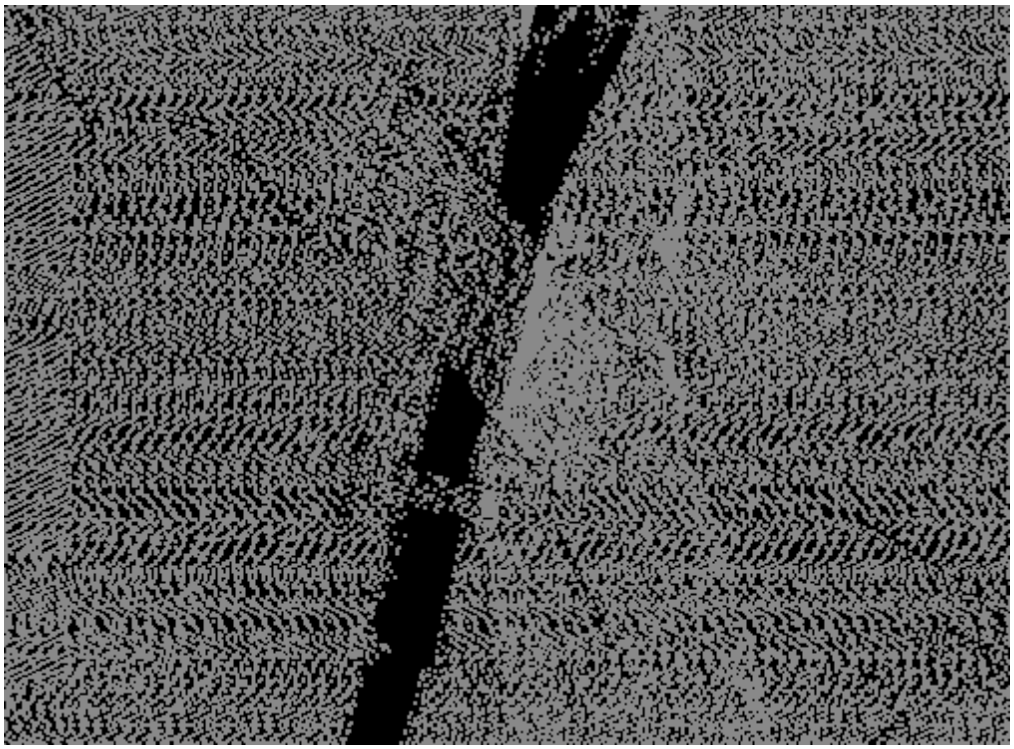
classification will be Class 1: Unclassified (gray). The default setting for step size will work for most projects, so it will be used for this example. Click **'OK'** to save the settings.



Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, all classes have been reclassified to Class 1 (gray).

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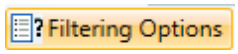
5.1.21 Return Filter

Return Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Return Filter** reclassifies source points that match the specified return value requirement. See also Consistent Return Filter 1001.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Returns are not listed only as 1st return, 2nd return, etc., but rather are identified in the context of how many total returns were recorded from the laser pulse (e.g., 1st of 3 returns). Any combination of these return values can be specified. (There are 36 possible values for a laser capable of sensing 8 returns from a single laser pulse.) To aid in the specification of the desired return values, there are shortcuts for describing some of the commonly used sets of possible return values. These are:

- **All returns:** Displays all possible return values, including Unknown.
- **Single returns:** Displays 1st of 1 return.
- **First (including single) returns:** Displays 1st return of any number of total returns.
- **First but not single returns (first of many):** Displays only 1st return of any 2 through 15 total returns.
- **Last including single returns (1st of 1, 2nd of 2, 3rd of 3, ...):** Displays only last returns of any number of total returns.
- **Last but not single returns (last of many):** Displays only 2nd of 2 returns, 3rd of 3 returns, and so on through 15th of 15 returns.
- **Intermediate:** Displays only returns that are neither the first nor the last return.
- **User-specified returns:** Allows selection from an array of return values.

Please see the **'Display Selection: Return'** section of the View Tab 192 Help Topic for complete return selection options.

Requirements:

- LAS data with discrete return values. This filter cannot be used unless the data to be filtered

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contains valid point family (discrete return) information. A pop-up warning will be displayed if this information is not present in the LAS files.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 1000.
- **Overlap (%):** Not applicable for this filter.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

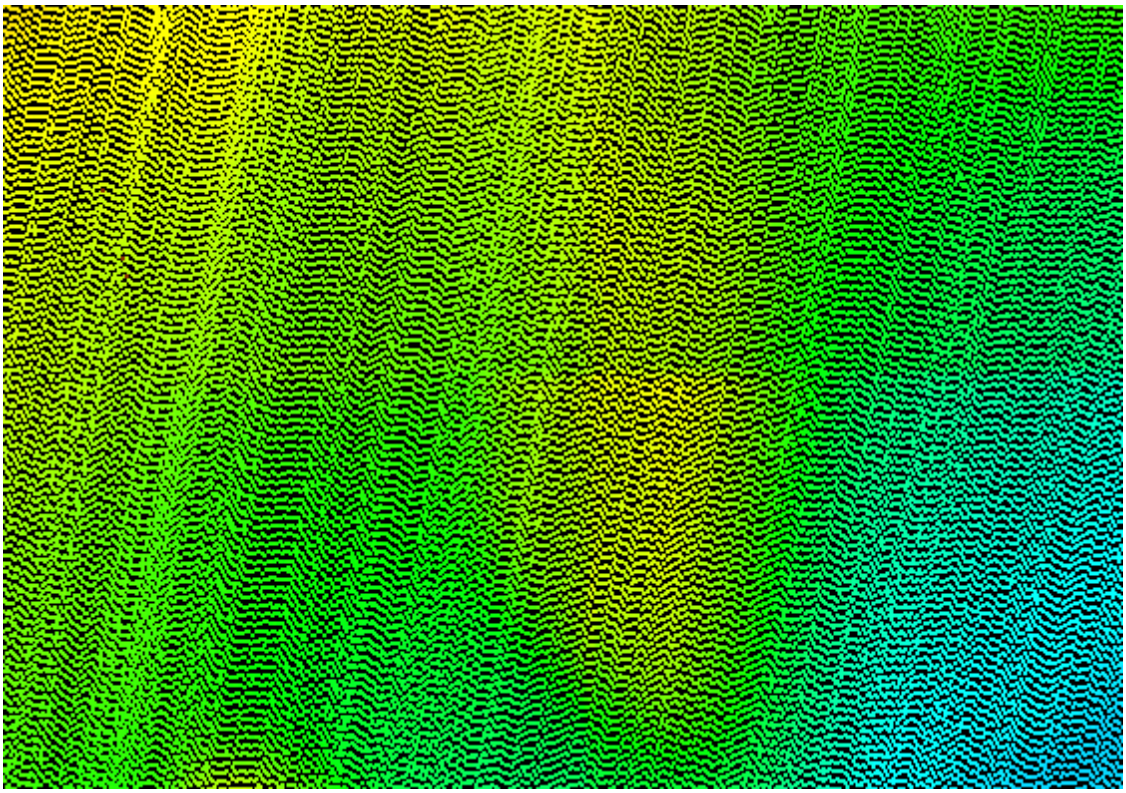
Filter Specific Parameters:

- **Return value set:** Comma-separated list of return value specifications. Each item in the list will be a string in the form **'R/T'** where **R** is the return number and **T** is the total number of returns.

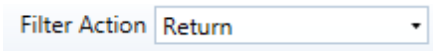
Example Filter Use:

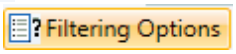
Before: In the example below, the user would like to reclassify all single returns to ground since the specified area does not contain any vegetation, buildings or other above-ground objects and is most likely all ground.

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Manually Using a Single Filter: To use the Return Filter to reclassify all points with specific return values to a single target class, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



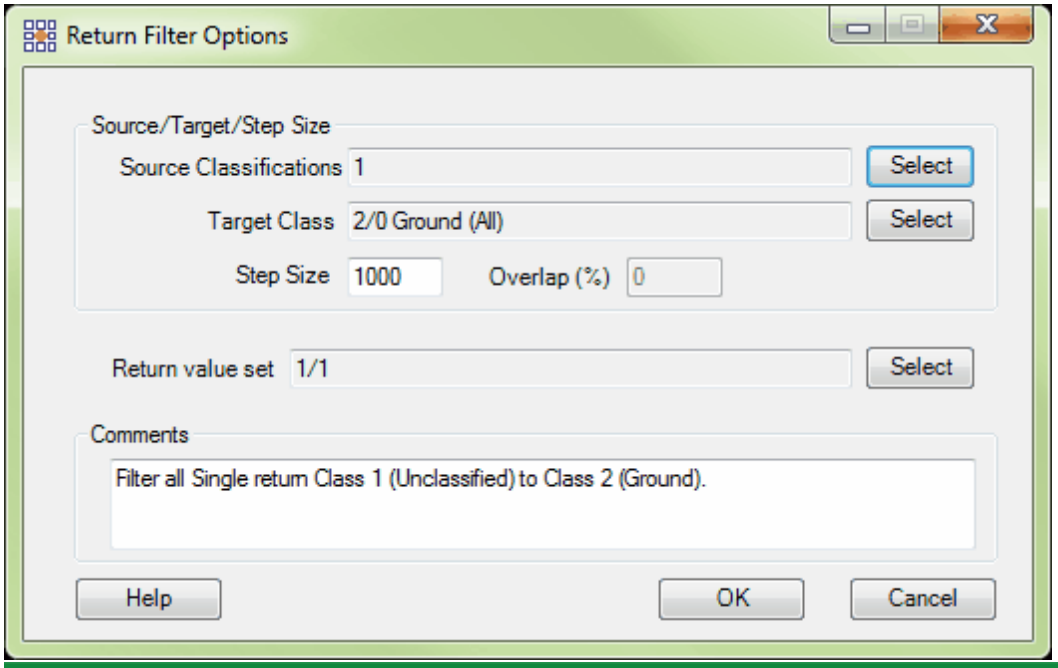
Next, click on the 'Filtering Options'  button to define the filter settings.

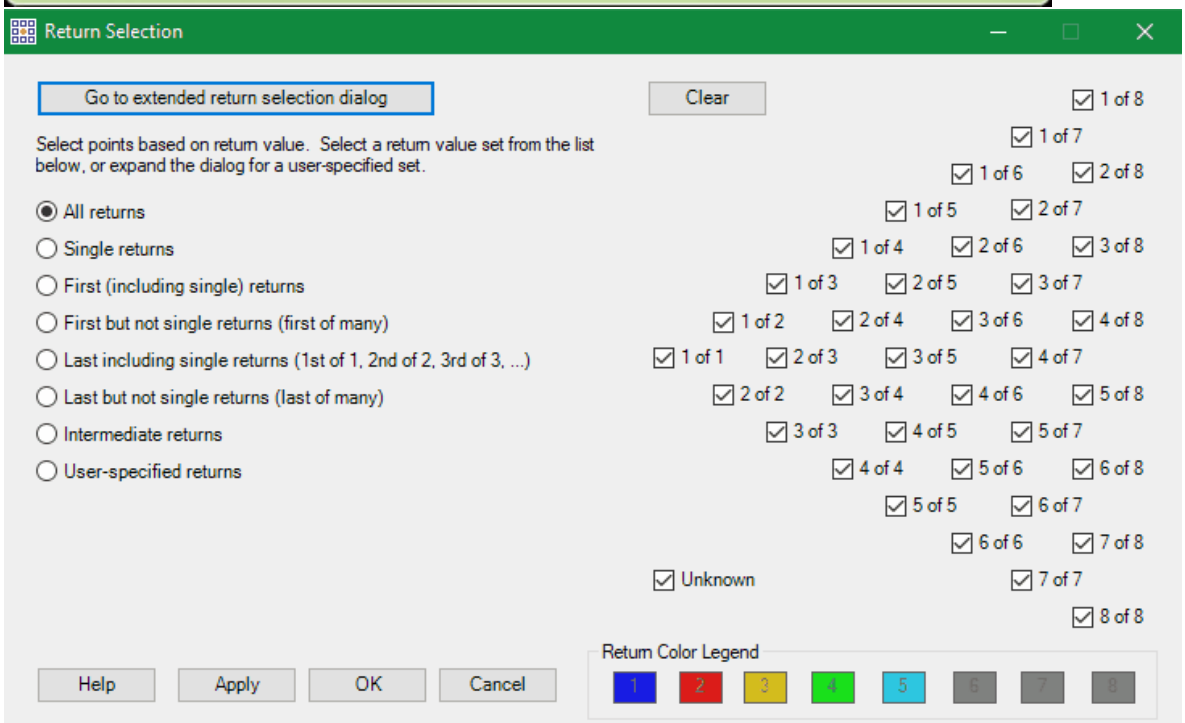
Return Filter Options Dialog: The 'Return Filter Options' interface has several parameters to control the filter's operation. The source classification, target class, and step size can be adjusted as in other filters. Unique to this filter is the ability to choose specific return values and reclass only source points with those values.

In this example, the source classification will be Class 1: Unclassified (gray) as the sample data is all

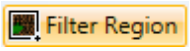
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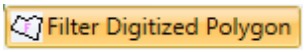
unclassified. The target classification will be Class 2: Ground (orange). The default setting for step size will work for most projects, so it will be used for this example. In choosing the return values for reclassification, the user may click one of the quick-set radio buttons on the left to make their selection, or the user can choose each return value individually with the check boxes on the right side of the interface. Click **'OK'** to save the settings.





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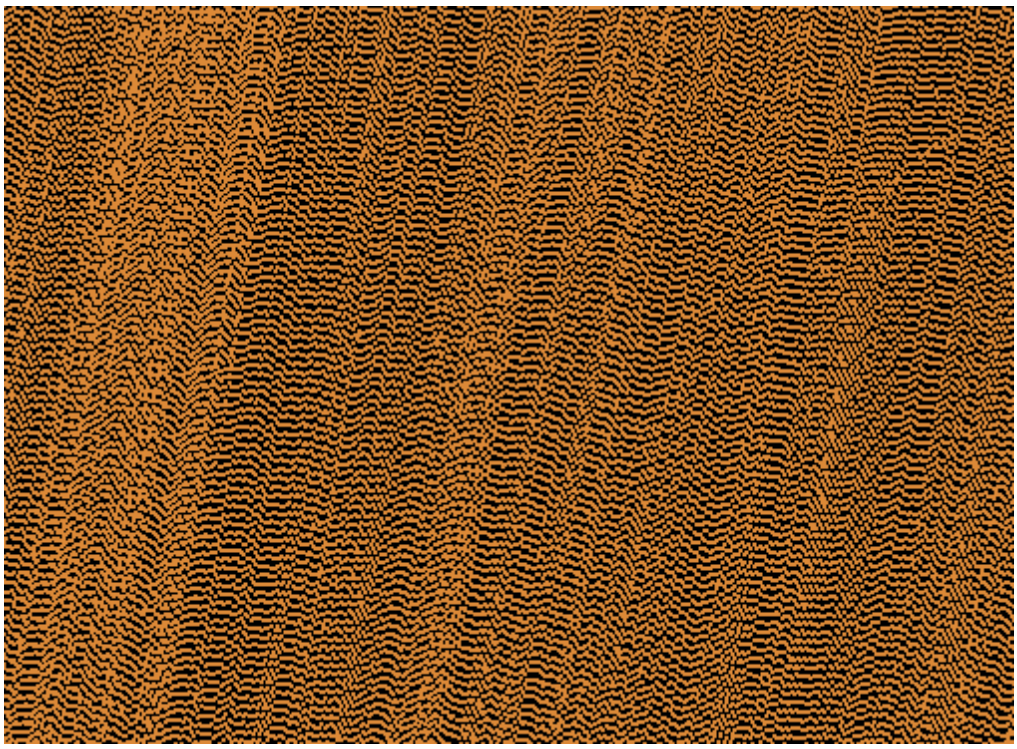
Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** 

, **'Filter Digitized Polygon'** 

, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: After running the filter, all single returns have been reclassified to Class 2. Because this area was so flat and did not contain any above-ground objects, every return was a single return and therefore, the entire filtered area is now classified as ground.



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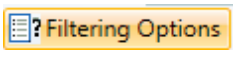
5.1.22 RGBNI Value Filter

RGBNI Value Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **RGBNI Value Filter** reclassifies LAS points based on the RGBN (Red, Green, Blue, NIR) values of a co-located imagery file, or the RGBN and Intensity values stored at the point level for an LAS file with Point Data Record Formats 7 (RGB) or 8 (RGBN). This filter operates on RGB or RGBN (NIR) imagery only and will not work on hyperspectral imagery; however, the filter will function with single band or gray-scale imagery. To use this filter, select or enter a target value and variance range for each of the color components. Depending on the 'Value Source' being used, any Source Classification LiDAR points within the user-defined 'Search radius' of an image pixel with the specified component values, or any Source Classification LiDAR points meeting the specified component values will be reclassified to the Target Class. *Please see the underlined note below in the 'RGBNI Value Filter Options Dialog' section regarding the use of this tool with WMS imagery.*

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- Classified LAS data.
- Co-located RGB or RGBN imagery is required unless the loaded LAS data has a PDRF where RGBN values are stored at the point level (PDRFs 7 or 8). *(Please see the underlined note below in the 'RGBNI Value Filter Options Dialog' section regarding the use of this tool with WMS imagery.)*

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 1000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Value Source:** This setting determines the source (either 'Raster Imagery' or 'LiDAR Points') that will be used to populate the 'Target Values' when the 'Pick Values' button is clicked. For the 'Raster Imagery' option, the 'Search radius' must be set to evaluate candidate Source Class points based on their proximity in project units to any pixels whose RGBN values fall within the range and

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variance populated for all channels. When single-band (grayscale) imagery is being used, check the 'Single-band Image' box to populate and use Target Values for the Red/Grayscale channel only.

- **Pick Values:** Allows the user to choose color values based on a raster image pixel or color and intensity values from a specific LiDAR point, depending on the 'Value Source' selected. For the 'Raster Imagery' option, at least one image must be loaded and checked on for display. The image (s) must contain 8-bit color values to be used with this filter. For the 'LiDAR Points' option, the loaded LiDAR data must be in PDRF 7 (RGB) or 8 (RGBN). *(Please see the underlined note below in the 'RGBNI Value Filter Options Dialog' section regarding the use of this tool with WMS imagery.)*
- **Use Red:** This is the target color value for the Red channel. The user can define the target component value within the range (0 – 65535) with an allowable variance value. Together, these values form the data reclassification criteria for the Red component of the filter when either multi-band 'Raster Imagery' or 'LiDAR Points' is the 'Value Source'. If the 'Single-band Image' box is checked for the 'Raster Imagery' option, this channel is used for the Grayscale values - 0 (pure black) to 65535 (pure white).
- **Use Green:** This is the target color value for the Green channel. The user can define the target component value within the range (0 – 65535) with an allowable variance value. Together, these values form the data reclassification criteria for the Green component of the filter.
- **Use Blue:** This is the target color value for the Blue channel. The user can define the target component value within the range (0 – 65535) with an allowable variance value. Together, these values form the data reclassification criteria for the Blue component of the filter.
- **Use NIR:** This is the target 'color' value for the Near Infrared channel. The user can define the target component value within the range (0 – 65535) with an allowable variance value. Together, these values form the data reclassification criteria for the Near Infrared component of the filter.
- **Use Intensity:** This is the target intensity value. This component is available to use only when the 'LiDAR Points' option is selected. The user can define the target component value within the range (0 – 65535) with an allowable variance value. Together, these values form the data reclassification

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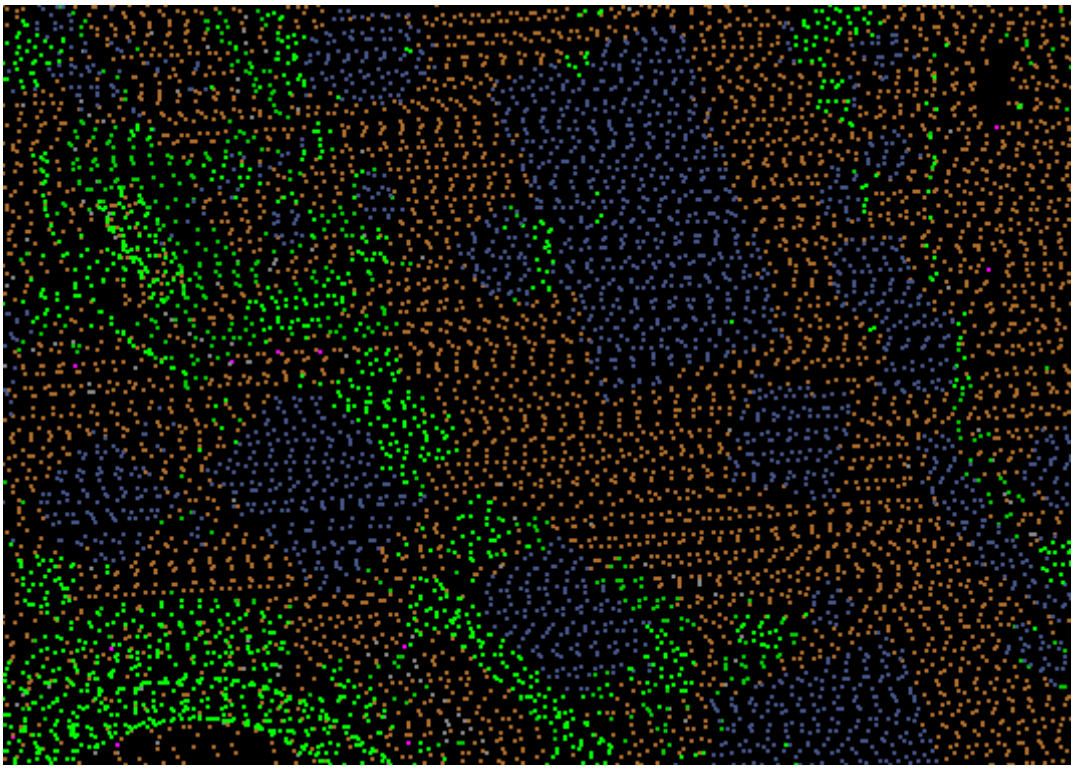
criteria for the Intensity value component of the filter.

Example Filter Use:

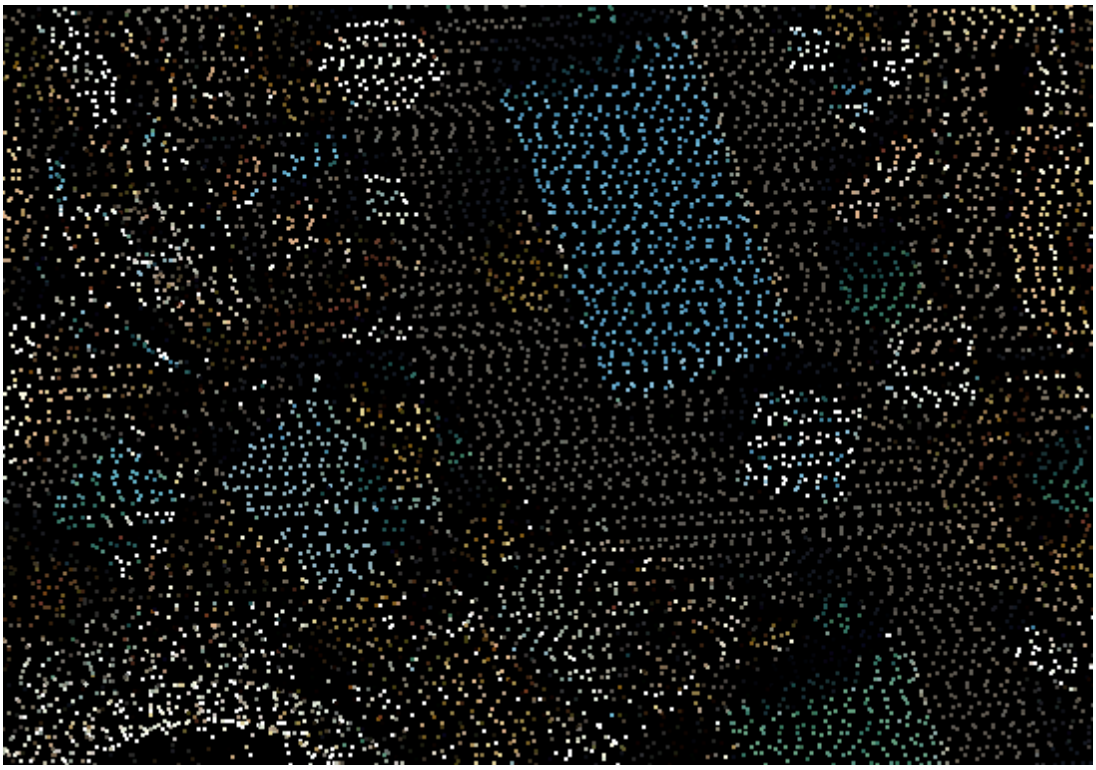
Before: In the example below, the user would like to reclassify Building (Class 6) points based upon the RGB values of the large blue-colored building roof (right graphic, top center) in the loaded LiDAR data. Intensity values are not being used in this example.

LAS data rendered by Class:

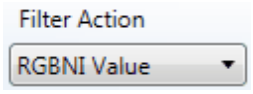
LAS data rendered by RGB values:

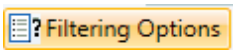


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Manually Using a Single Filter: To use the RGBNI Value Filter to reclassify points based on user-specified values, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



Next, click on the 'Filtering Options'  button to define the filter settings.

RGBNI Value Filter Options Dialog: The 'RGBNI Value Filter Options' interface gives the user several options in setting the parameters of the filter. The source classification, target class, step size, and overlap can be specified as in other filters. Unique features to this filter include the ability to select the desired components (red, green, blue, NIR, and intensity), as well as the exact values (with an optional variance range) for each of these components. The **'Pick Values'** button with the 'Raster Imagery' option selected allows the user to choose the color values from a pixel of the loaded imagery. The 'Search radius' setting determines how far away from the selected pixel the candidate Source Class points can be. The interface will disappear until a pixel is clicked on, and then reappear

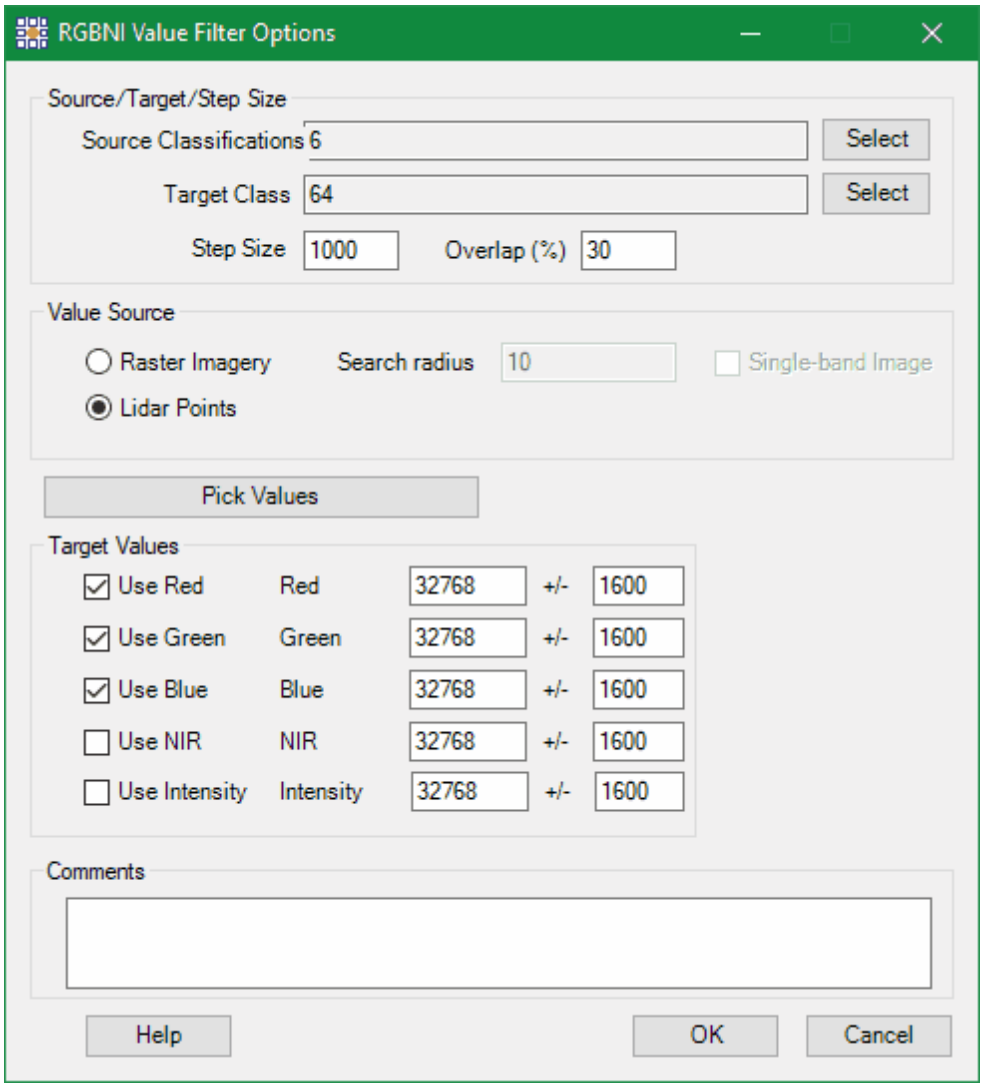
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with the RGBN values from that pixel populated in the 'Target Values' section. *Please note that the accuracy of the returned RGBN values when WMS imagery is loaded is dependent on the current resolution of the image. A single set of interpolated RGBN values can cover a large area on the image when viewed at a reduced resolution (wide extent).* The **'Pick Values'** button with the 'LiDAR Points' option selected allows the user to choose the color and intensity values from a specific LiDAR point. Points should first be rendered by RGBN values to aid in selection. The interface will disappear until a LiDAR point is clicked on, and then reappear with the RGBN values of that point populated in the 'Target Values' section. Target values and variances can also be entered manually without using the **'Pick Values'** button. Click **'OK'** to save the settings and exit the filter options window.

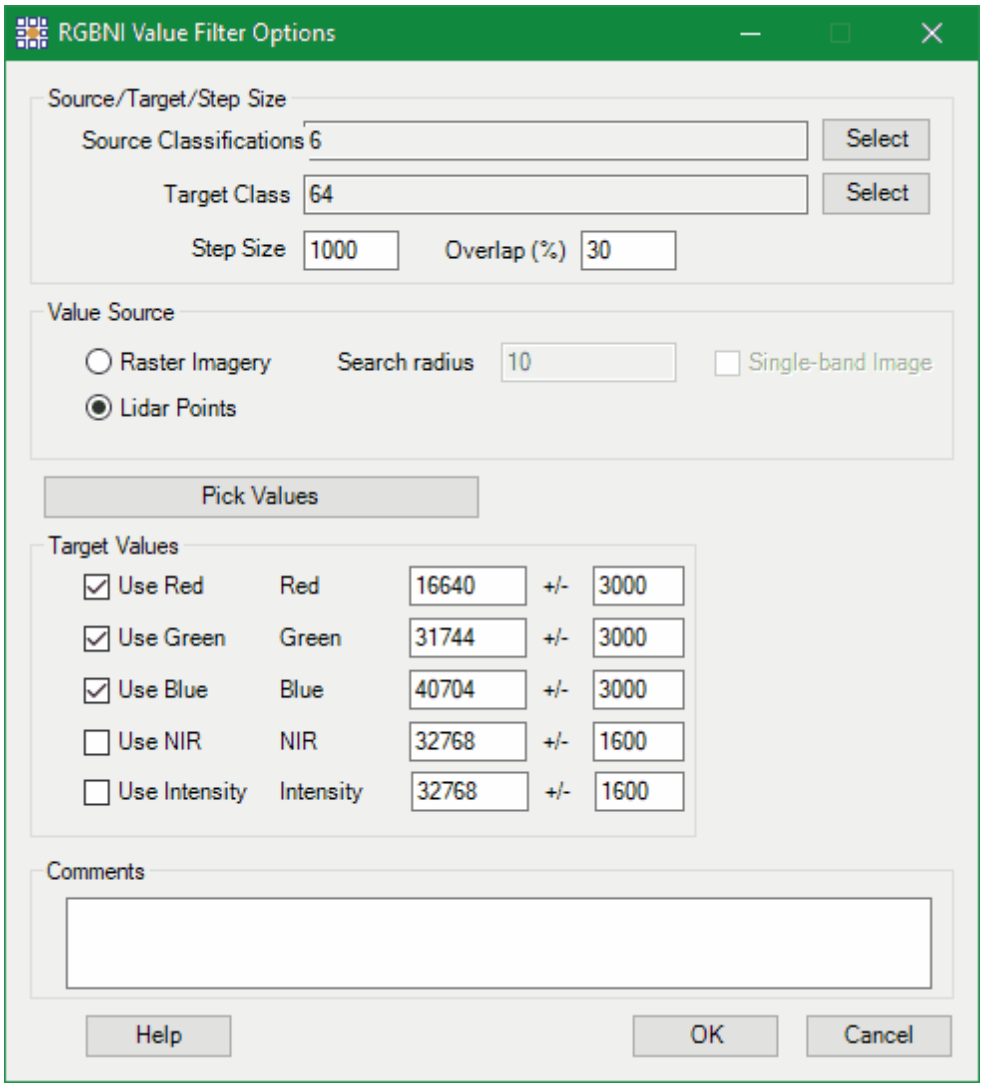
Below are examples of the filter options dialog when PDRF 7 LiDAR data is loaded and the 'LiDAR Points' option is being used. Class 6: Building (dark blue) is being reclassified to Class 64: User Definable (white) based on LiDAR point RGB values. The **'Pick Values'** button will be used to select a blue-colored building point from the loaded LAS data. Class 6 points whose RGB values fall within the 'Target Values' ranges will be reclassified to Class 64.

Before selecting a LiDAR point with the 'Pick Values' button: After selecting a LiDAR point and modifying the variance values:

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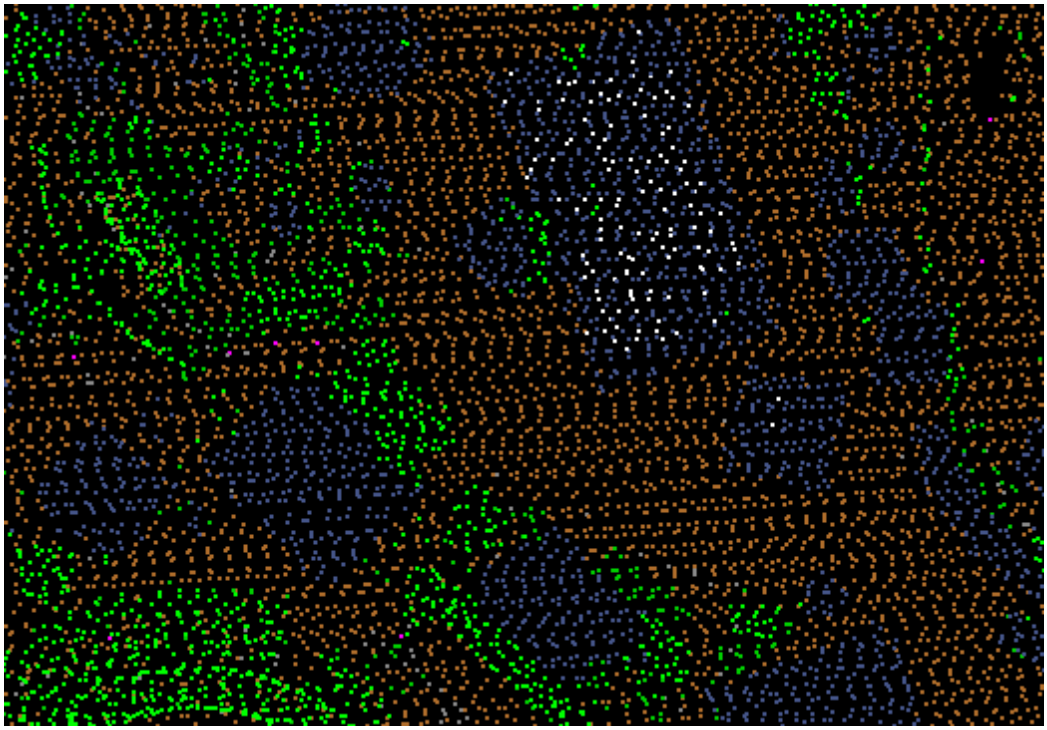
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

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After: After running the filter, the blue building points with the RGB values and ranges specified have been reclassified from Class 6 (dark blue) to Class 64 (white). Since not all the blue-colored building points are the same shade of blue, expanding the variance values would reclass more of them.



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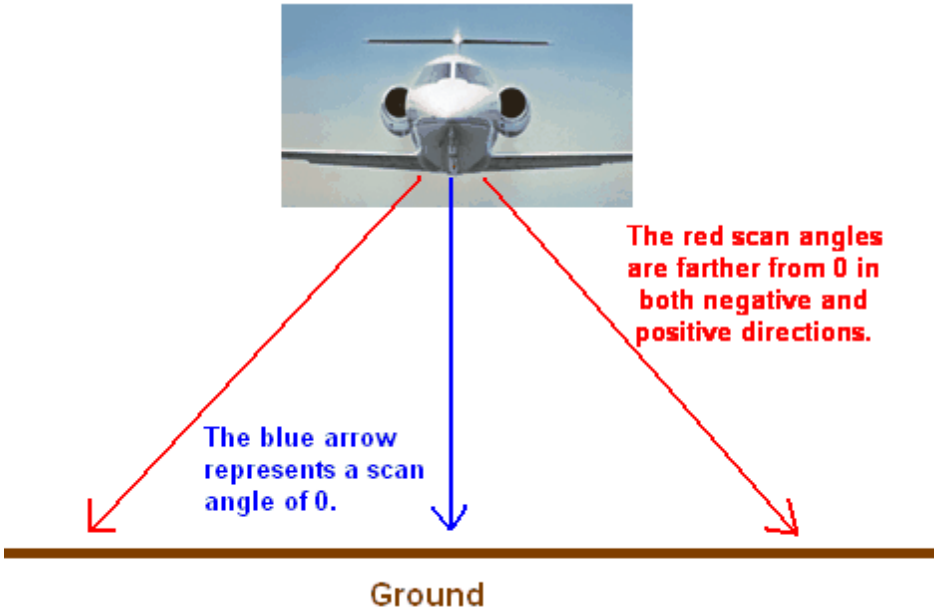
5.1.23 Scan Angle Filter

Scan Angle Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Scan Angle Filter** is made to be used with the 'Convert SBET to Shapefile' tool (found on the Vector Creation Tab 364). The Scan Angle filter is capable of using an SBET file which has been converted into a 3D shapefile to reclassify certain sets of points. Remember that the 3D shapefile

used in this filter represents the SBET, and this is the actual path of the plane in flight. The LiDAR data, represented by the ground beneath the plane, is collected at different angles in relation to the plane. See the diagram below for further explanation:

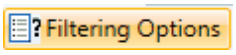


This filter is capable of reclassing points based on that angle, called the scan angle. In the diagram above, the points collected on the ground at the bottom of the blue arrow represent a different scan angle than those points collected on the ground at the bottom of either of the red arrows. This filter can reclass points based solely on their scan angle or, more accurately, their scan angle rank. The user may enter several different parameters based on minimum and maximum scan angle ranks, resulting in several different classes of points each representing a separate scan angle rank range. The output of this filter can be used to run statistics of density per class or to run statistics based on the density of the scan angle rank ranges.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab

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270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LiDAR data.
- Although this filter can reclassify data based on a 3D shapefile representing an SBET, a 3D SBET shapefile is *not* required to use this filter.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **SBET Shapefile:** This filter is capable of using a previously created 3D shapefile converted from an

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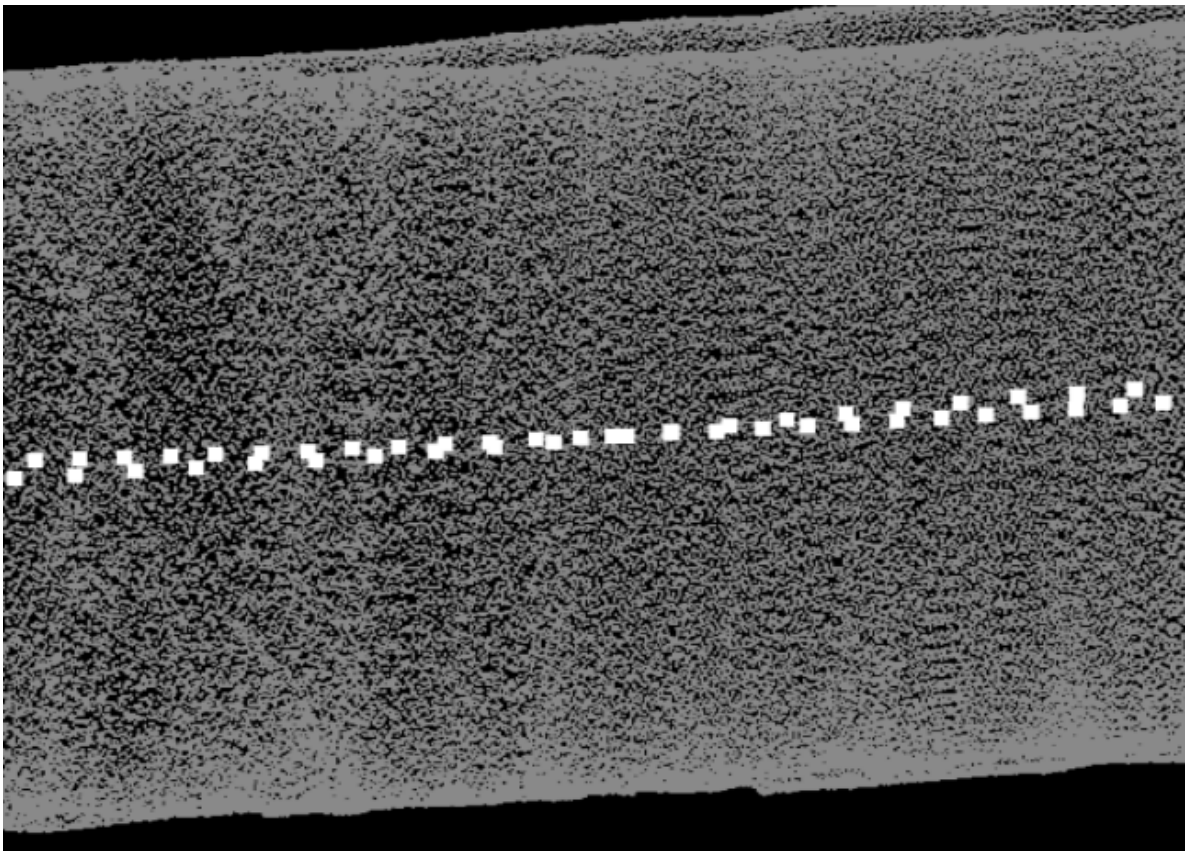
SBET file. To create this shapefile, please see the 'Convert SBET to Shapefile' tool located on the Vector Creation Tab 364. Once this file has been created, use this section of the interface to point to this file to be used in the filter. Make sure to check the box marked 'Use SBET Shapefile' if an SBET shapefile will be used in the filter. If this box remains unchecked, the filter will read the scan angle rank from the LiDAR points and reclass these points to the Target Class based on the angle requirements specified.

- **Angle Difference Requirement:** This section of the interface allows the user to enter one or many different minimum and maximum angle requirements for reclassification. The filter is capable of reclassifying multiple different scan angle rank ranges to discrete classes. Values can be positive or negative (representing each direction from nadir), but must be between -90 and 90. LAS v1.4 PDRF 6 or higher data stores both the newer scan angle (-15000 to 15000) and legacy scan angle rank (-90 to 90) values per point. The easier-to-understand scan angle rank values in degrees from nadir are used by this filter.
    - ✓ **Minimum Angle:** Enter the minimum angle requirement for the desired scan angle rank range (inclusive).
    - ✓ **Maximum Angle:** Enter the maximum angle requirement for the desired scan angle rank range (not inclusive).
    - ✓ **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned. Each minimum and maximum angle requirement range can (and should) be reclassified to a separate target class.

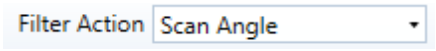
Example Filter Use:

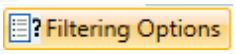
Before: In the example below, the LiDAR data associated with the 3D shapefile has not yet been classified. All points are currently in Class 1: Unclassified (gray). The 3D shapefile representing the SBET was used in this case and can be seen in white.

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Manually Using a Single Filter: To use the Scan Angle Filter to reclass points based on their scan angle rank, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



Next, click on the 'Filtering Options' 

button to define the filter settings.

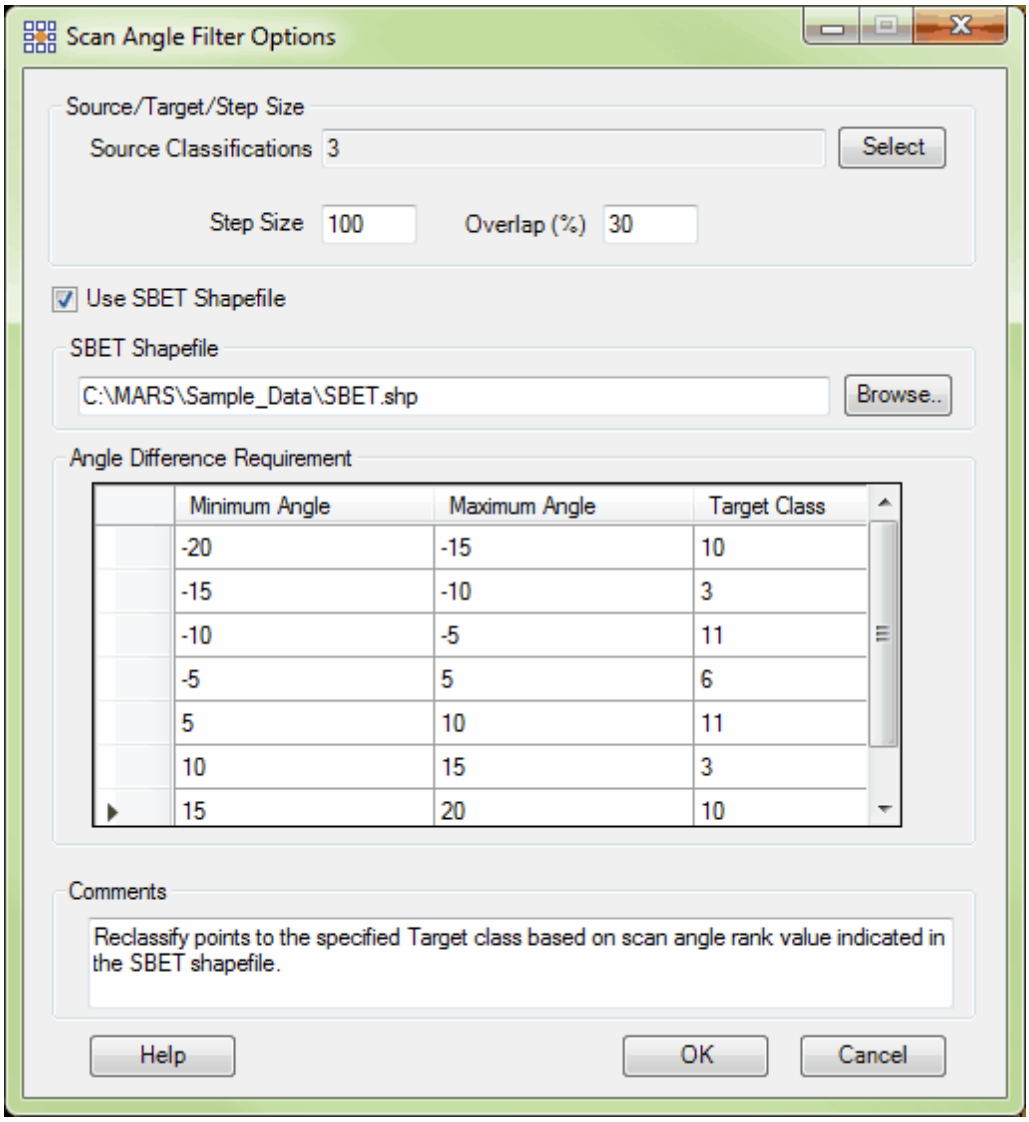
Scan Angle Filter Options Dialog: The 'Scan Angle Filter Options' interface gives the user several options in specifying the filter. The source classification, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the option to use a 3D shapefile representing an SBET file for reclassification, and the ability to specify certain scan angle rank ranges for reclassification into multiple discrete classes.

In this example, the source classification will be Class 1: Unclassified, as the LiDAR data being used

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in this example has not yet been classified. The default settings for step size and overlap will work for most projects, so they will be used for this example. The user has chosen to apply a 3D SBET Shapefile and so has checked the option called 'Use SBET Shapefile'. The 3D shapefile which represents the SBET file has been pathed out in the 'Browse...' box in the 'SBET Shapefile' section. Scan angle ranks can have negative and positive values as described above, and in this example the scan angle ranks will be split into 5 degree increment ranges except on either side of 0 (zero). Scan angle ranks between -20 and -15 degrees and +15 to +20 degrees are both to be reclassified to Class 10 (yellow), scan angle ranks between -15 and -10 degrees and +10 to +15 degrees are both to be reclassified to Class 3 (green), scan angle ranks between -10 and -5 degrees and +5 to +10 degrees are both to be reclassified to Class 11 (red), and scan angle ranks between -5 and 0 degrees and 0 to +5 degrees are both to be reclassified to Class 6 (dark blue). Click **'OK'** to save the settings.

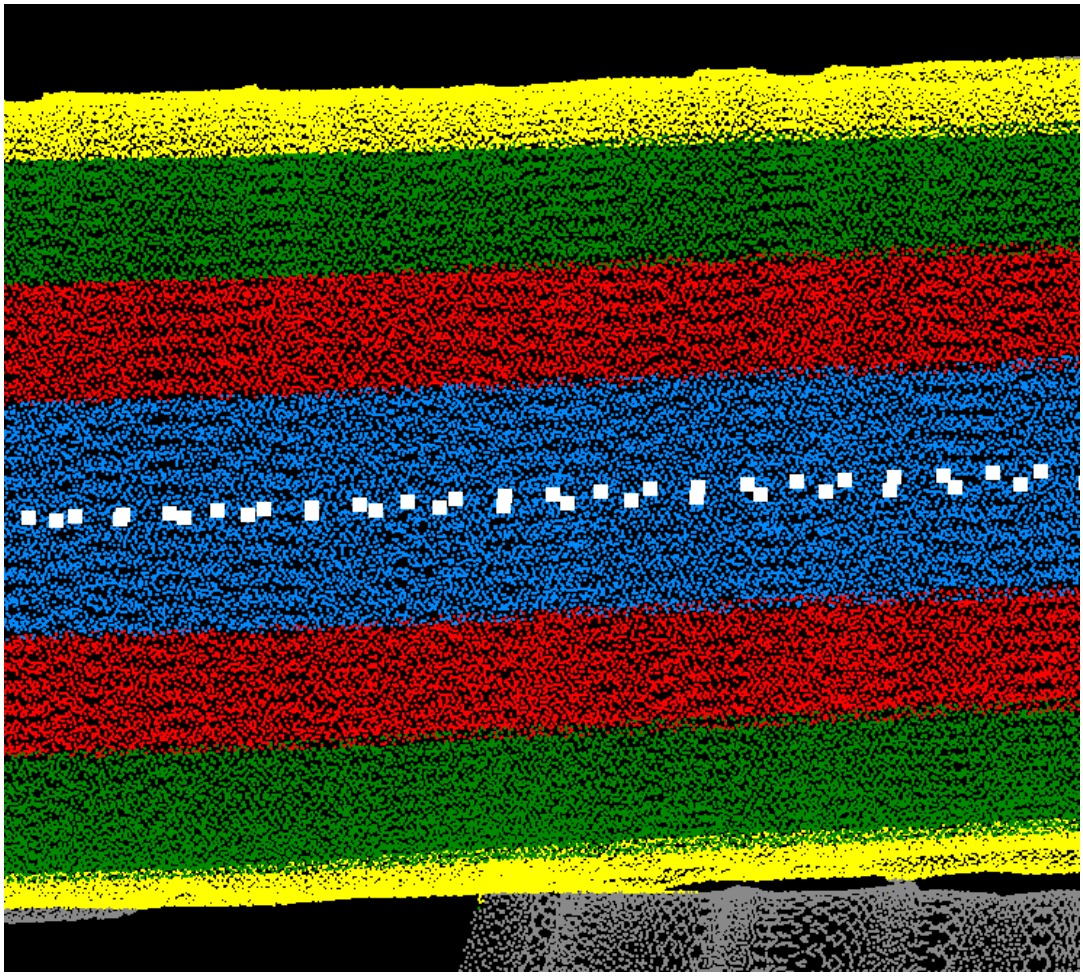
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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

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After: After running the filter, it can be seen that the points in each defined range have been reclassed based on their scan angle rank. Points with scan angle ranks closest to 0 (-5 to 0, and 0 to +5) have been reclassed to Class 6 (dark blue). Points with scan angle ranks between -5 and -10 and +5 to +10 degrees have been reclassed to Class 11 (red), and so on as described above.



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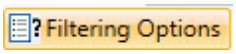
5.1.24 Slope Filter

Slope Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Slope Filter** reclassifies source LiDAR points to a specified target class based on them falling within a user-defined range of minimum and maximum angles for the slope they occupy. This filter is designed for general identification, not exact analysis.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A classified LiDAR dataset.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default

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step size suggested for most projects using this filter is 1000.

- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage allows for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

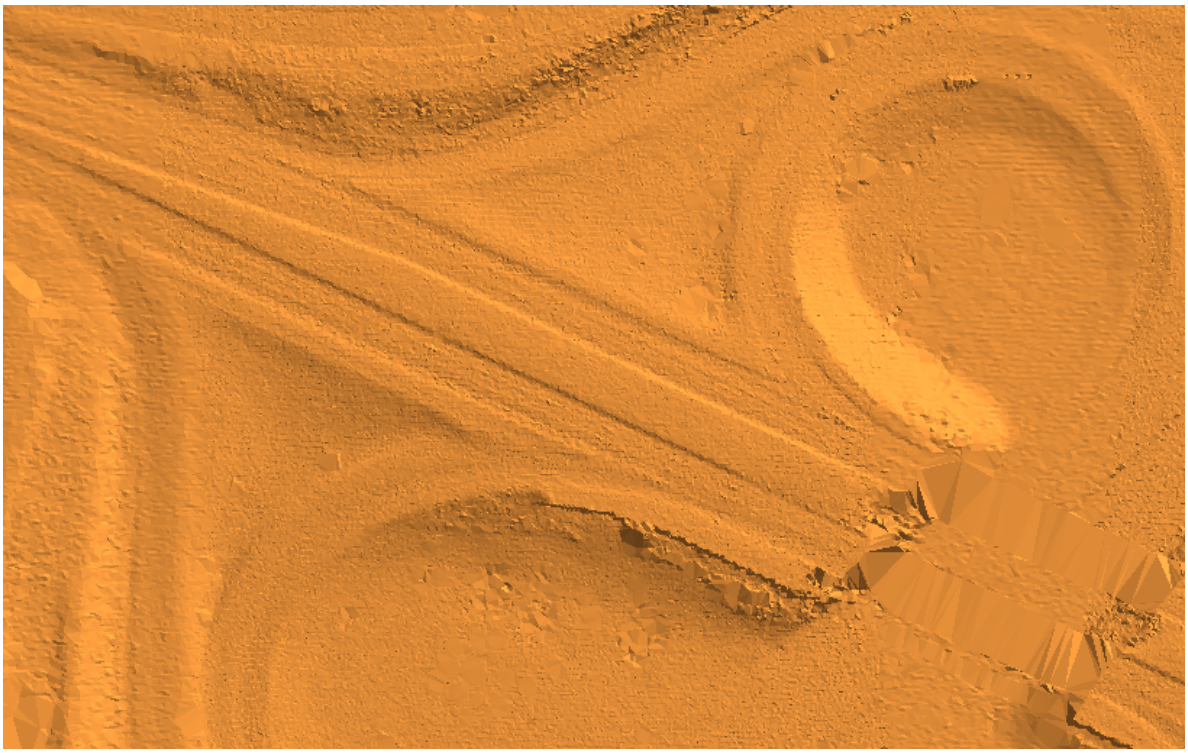
Filter Specific Parameters:

- **Slope Requirement Minimum:** To be considered for reclassification, the source points must exist on a slope of at least this angle (in degrees).
- **Slope Requirement Maximum:** To be considered for reclassification, the source points must exist on a slope of no more than this angle (in degrees).
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned. Each minimum and maximum slope requirement range can (and should) be reclassified to a separate target class.
- **Grid cell size:** The cell size (in horizontal project units) of the virtual grid built to determine slope angles. A smaller value provides more detail, but takes longer to process.

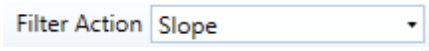
Example Filter Use:

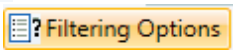
Before: In the example below, the dataset has only Class 2 (ground - orange) including Model Key-points. Using the TIN rendering function, sloped areas can be more easily identified.

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Manually Using the Filter: To use the Slope Filter to classify points based on the angle of the slope they occupy, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



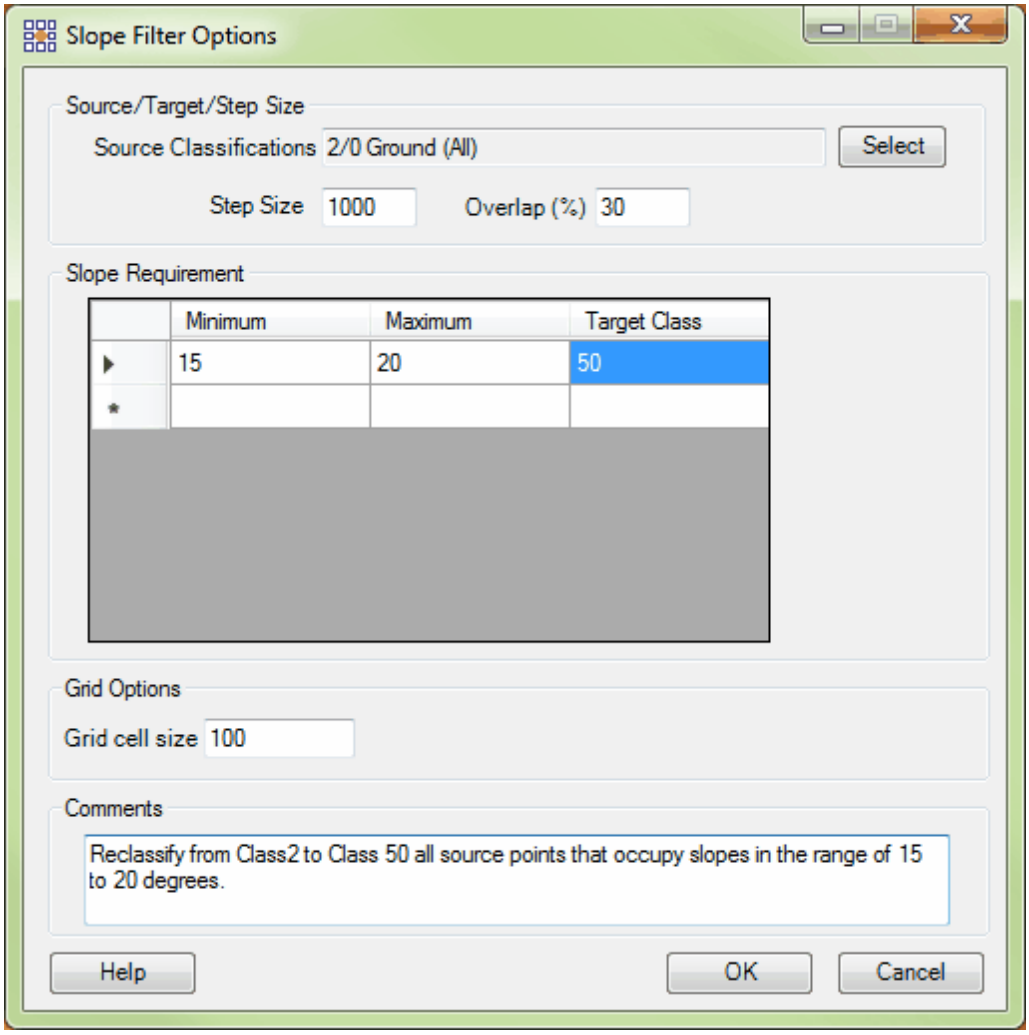
Next, click on the 'Filtering Options'  button to define the filter settings.

'Slope Filter Options' Dialog: The 'Slope Filter Options' interface gives the user several options for specifying the filter's action. The Source Classification(s), Target Class, Step Size, and Overlap can be set as in other filters. Unique to this filter are the settings for a minimum and maximum slope angle (in degrees), and the virtual grid cell size used to determine the slope of the source points.

In this example, the source classification will be Class 2: Ground (All). The target class will be Class 50 to aid in viewing the results below. The default settings for step size (1000) and overlap percentage

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(30) will work for most projects but can be changed as desired. The Minimum and Maximum slope angles are set to 15 and 20, respectively. The Grid cell size will be left at the default value, 100. Click **'OK'** to save the settings.

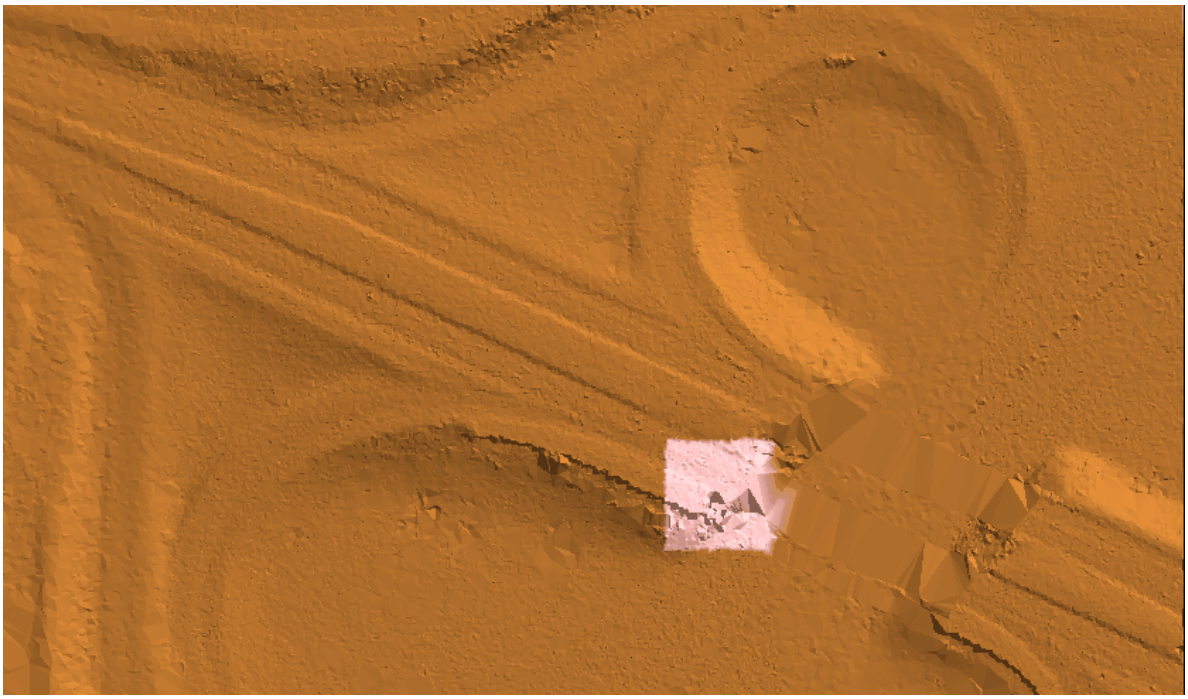


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data..

After: After running the filter, the area of the 100 foot virtual grid containing points that are on slopes with angles between 15 and 20 degrees has been reclassified to Class 50 (pink).



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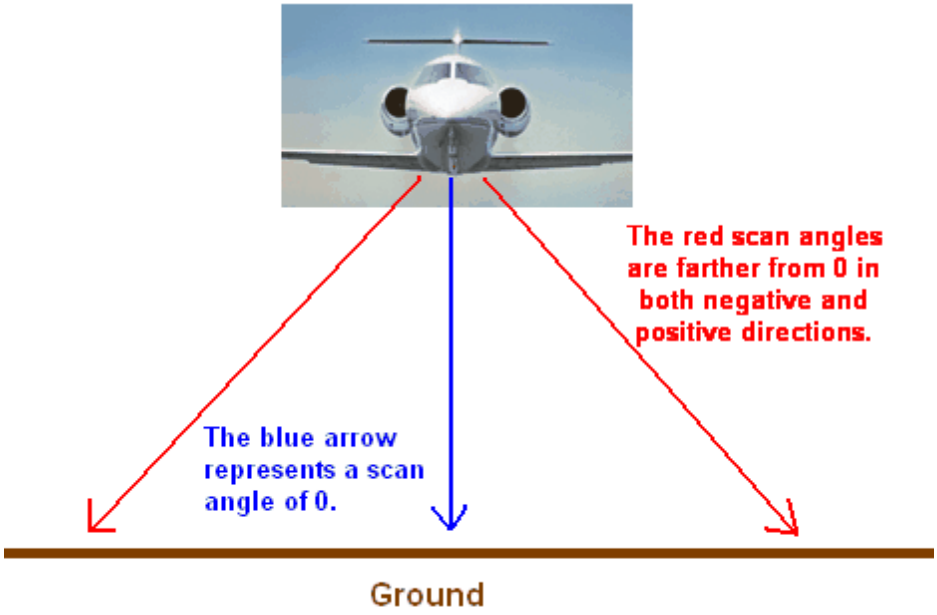
5.1.25 Smart Clip Filter

Smart Clip Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Smart Clip Filter** works very similarly to the Scan Angle Filter[1118], but contains a smart clipping improvement. This filter will reclass points at varying angles of the Field of View while still ensuring full coverage. It does not take into account the values from a corresponding SBET file, as it is intended

for data collected by the LiDAR sensor's full Field-of-View (FOV) with no roll compensation applied. This filter may be useful when calibrating the edge of the Field of View (edges of the LiDAR data) which can cause problems or errors when modeling. The illustration below further explains the 'scan angle value' or 'scan angle rank', which is specified in the filter options interface. The LiDAR data, represented by the ground beneath the plane, is collected at different angles in relation to the attitude of the plane. See the diagram below for further explanation:

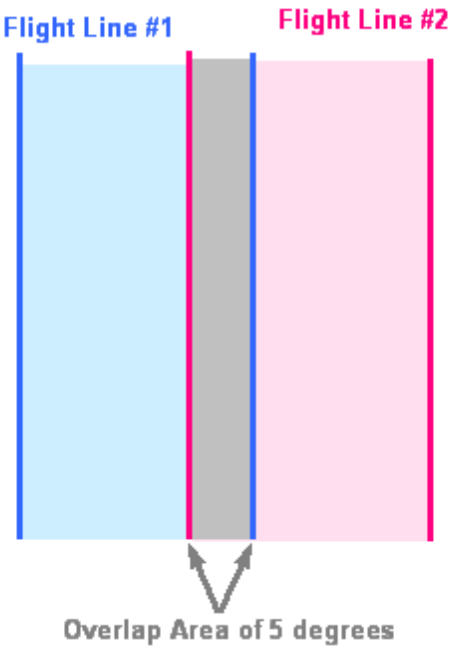


In the diagram above, the points collected on the ground at the bottom of the blue arrow represent a different scan angle than those points collected on the ground at the bottom of either of the red arrows. This filter reclasses points based on their scan angle or, more accurately, their scan angle rank, while preserving the overlapping collection scan data and ensuring complete coverage. The user may enter several different parameters based on minimum and maximum scan angle ranks resulting in several different classes of points, each representing a separate scan angle rank range. For example, the scan angle ranks above may run from -20 degrees (red arrow) to 0 degrees (blue arrow) and then up to +20 degrees (other red arrow). This would make the Field of View 40 degrees.

The Smart Clip filter calculates a boundary of each collection scan (flight line). In the example below,

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two separate collection scans are shown in blue and pink. The area in which they overlap is colored gray. There is a 5 degree overlap in collection scans in this particular area. If the user chooses to clip 3 degrees from the edge of each collection scan, a gap of 1 degree will be created between these scans. The Smart Clip filter will recognize this and clip only 2.5 degrees from each collection scan in this particular area to avoid creating a gap. The user may choose to clip out a number of degrees of data on each side of the Field of View with this tool and not cause data gaps in the process.



For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** Filtering Options button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

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- LiDAR data

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Scan Angle Rank Requirement:** This section of the interface allows the user to enter one or many different minimum and maximum angle requirements for reclassification. The filter is capable of reclassifying multiple different scan angle rank ranges to discrete classes. Values can be positive or negative (representing each direction from nadir), but must be between -90 and 90. LAS v1.4 PDRF 6 or higher data stores both the newer scan angle (-15000 to 15000) and legacy scan angle rank (-90 to 90) values per point. The easier-to-understand scan angle rank values, in degrees from nadir, are used by this filter.
    - ✓ **Minimum Angle:** Enter the minimum angle requirement for the desired scan angle

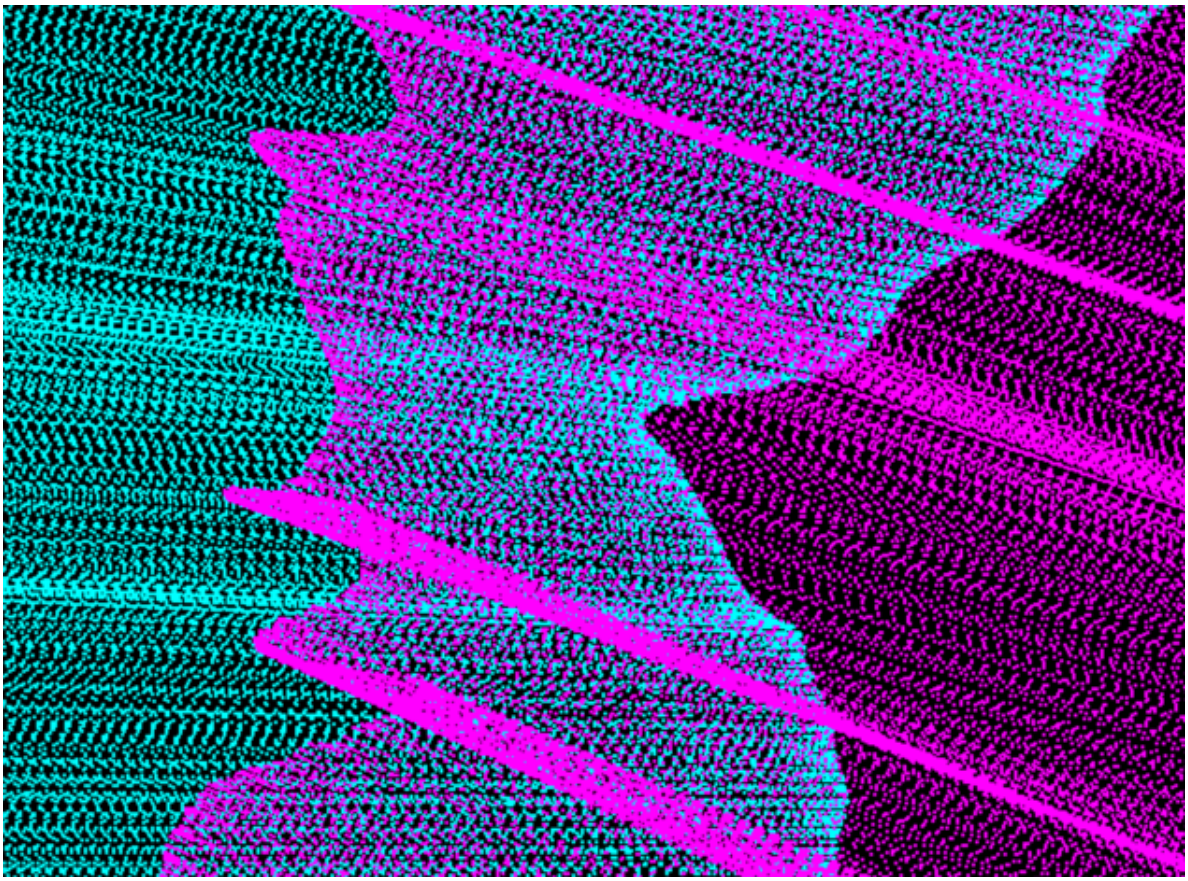
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rank range (inclusive).

- ✓ **Maximum Angle:** Enter the maximum angle requirement for the desired scan angle rank range (not inclusive).
- ✓ **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned. Each minimum and maximum angle requirement range can (and should) be reclassified to a separate target class.

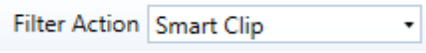
Example Filter Use:

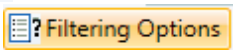
Before: The example below is shown colored by collection scan. Notice the overlap area between the cyan and magenta collection scans. There is some overlap in this area and no data gaps. The Smart Clip filter will be useful in this area to prevent clipping too much data off the edges of the collection scans and causing a data gap.



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Manually Using a Single Filter: To use the Smart Clip Filter to reclass points based on their scan angle rank, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



Next, click on the 'Filtering Options' 

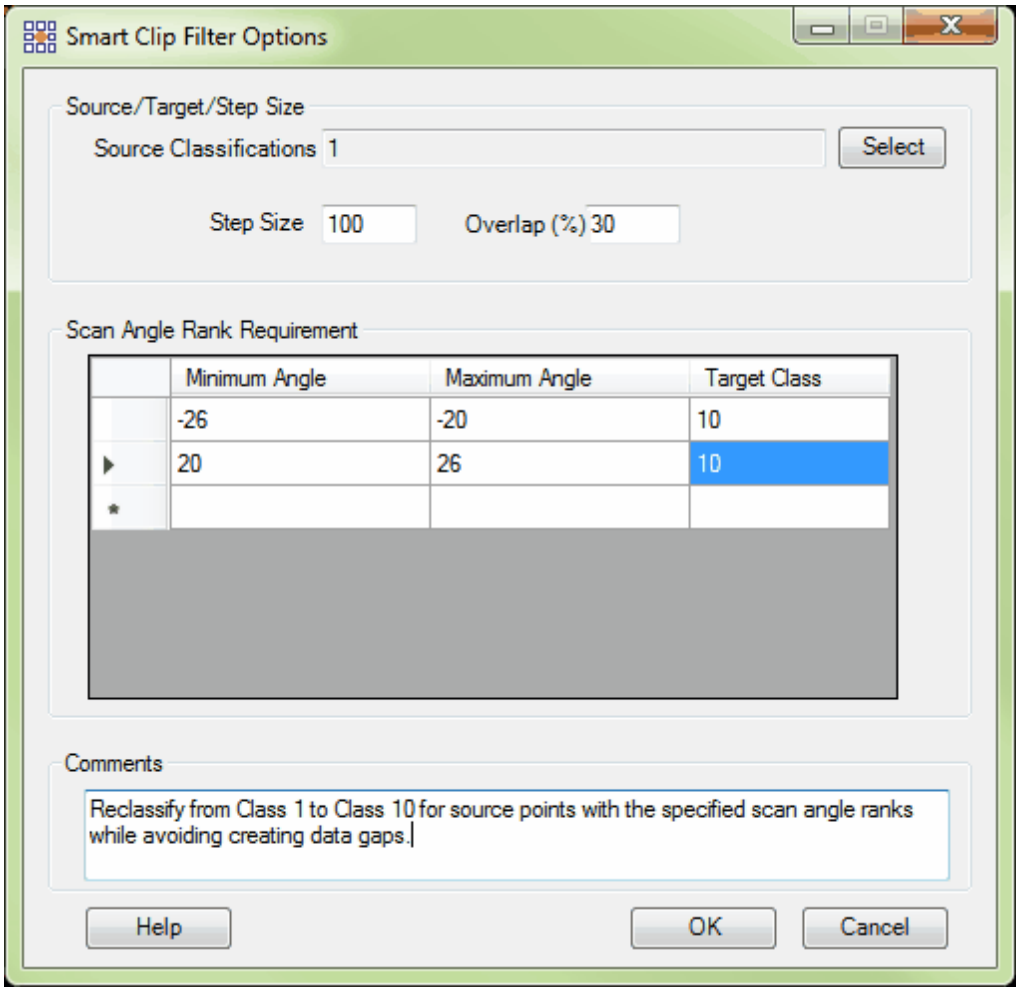
button to define the filter settings.

Smart Slip Filter Options Dialog: The 'Smart Clip Filter Options' interface gives the user several options in specifying the filter. The source classification, step size, and overlap can be adjusted as in other filters. Unique to this dialog and filter is the ability to denote certain scan angle rank ranges for reclassification into multiple discrete classes.

In this example, the source classification will be Class 1: Unclassified, as the LiDAR data being used in this example has not yet been classed. The default settings for step size and overlap will work for most projects, so they will be used for this example. In this example, the user has chosen to clip 6 degrees of data off both edges of each collection scan. To do this, the outermost scan angle ranks (in this case, scan angle ranks from -26 to -20 and from 20 to 26) are clipped out of the data. The points storing scan angle ranks which are specified for clipping will be reclassed from Class 1 (gray) to Class 10 (yellow). Click **'OK'** to save the settings.

****** A warning regarding Smart Clip filter use: ALL angle requirements must be stated within a single filter instance in a macro, or there will be a risk of creating gaps.***** The Smart Clip filter will ensure full coverage when all requirements are listed at once in the 'Scan Angle Rank Requirement' section of the filter, but if separate instances of the filter with separate requirements are processed on the same data, full coverage of data cannot be guaranteed.

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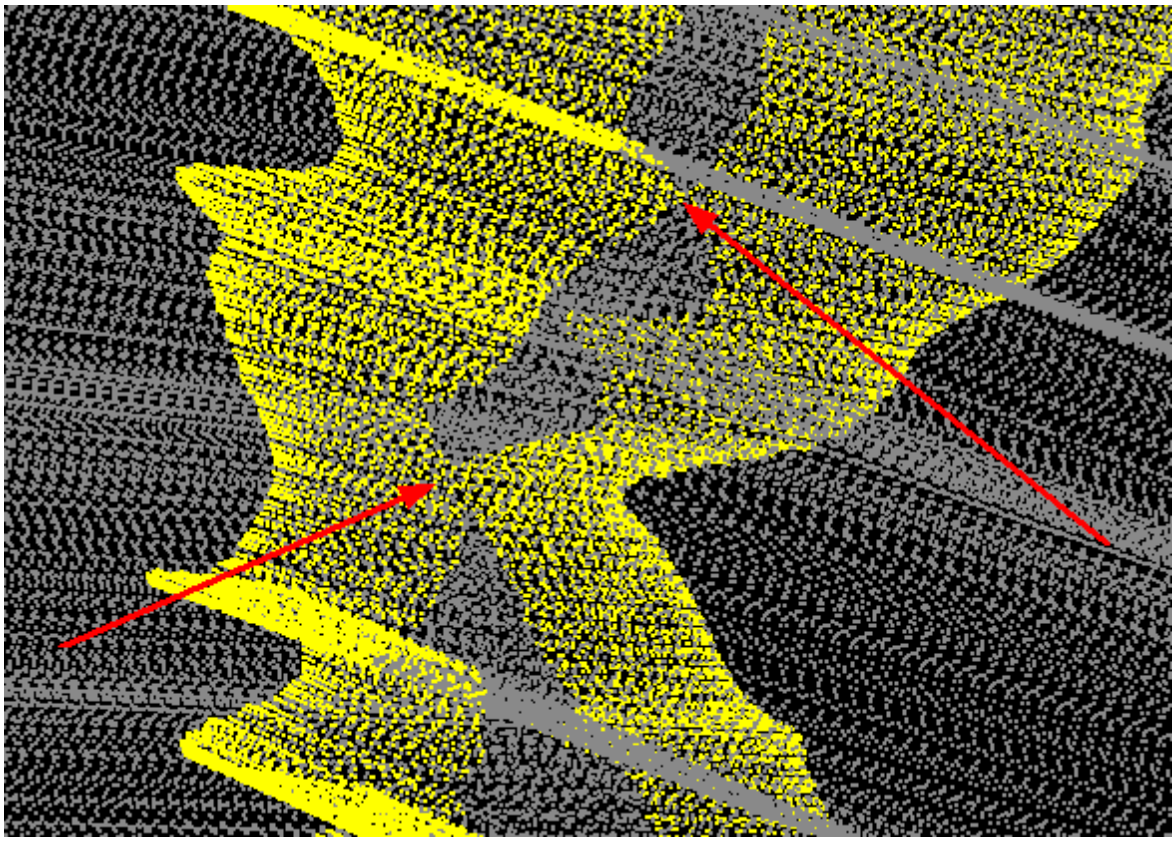


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data..

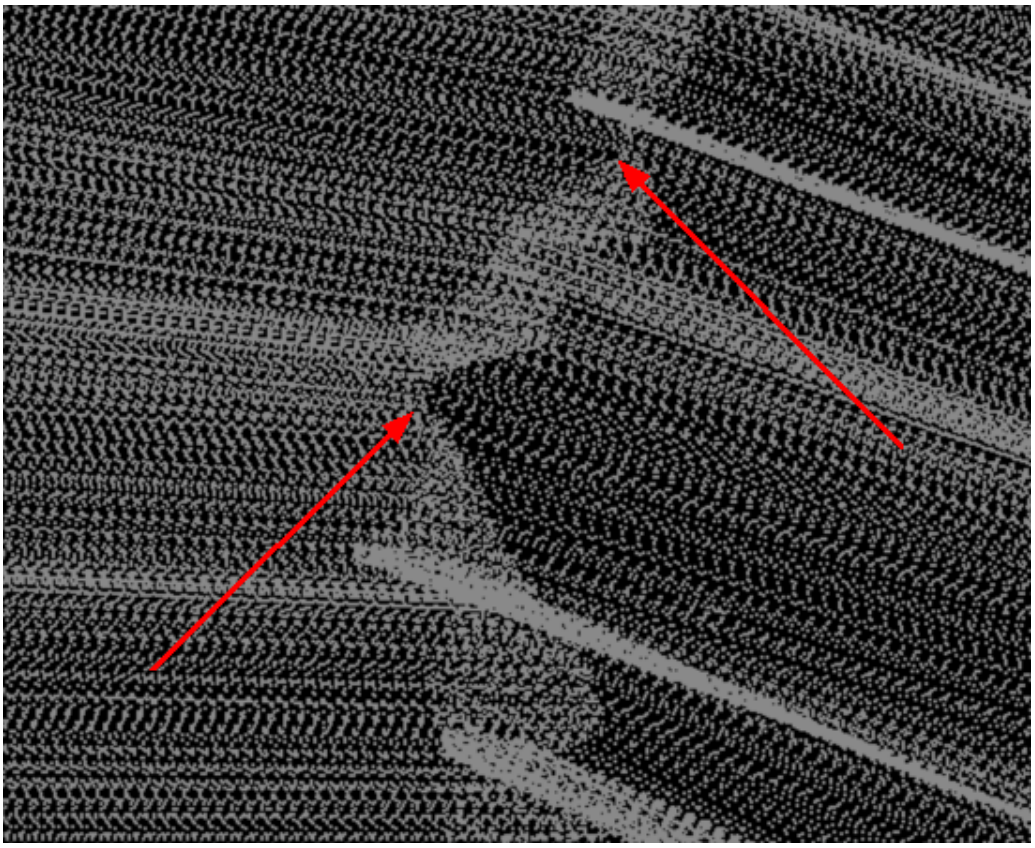
After: After running the filter, it can be seen that the source points as defined in the options window

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have been reclassed to Class 10 (yellow) based on their scan angle rank. In the particular area shown below the Smart Clip filter preserved data at the edges of these two collection scans rather than strictly following the input clip percentage. This prevented gaps in the areas indicated by red arrows. If the filter would have continued to clip a full 6 degrees in these areas, this would have produced a no-data gap since there was not sufficient overlap to clip and reclassify a full 6 degrees of LiDAR data. The Smart Clip filter clipped as much data as possible from these areas without creating a gap in coverage.



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5.1.26 Smooth Grid Filter

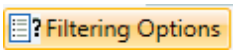
Smooth Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Smooth Grid Filter** builds a grid surface from the points of the source classification. The grid surface is built by creating a TIN from the source classification points, and then sampling elevations at each of the grid point coordinates. Next, a Gaussian smoothing function is (optionally) applied, repeating the smoothing as specified by the 'Number of passes ...' value. Finally, points in the source classification set are compared to this grid surface and reclassified to the target classification, if they

meet the elevation difference requirements as specified by the filter parameters.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored

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permanently if the filter is added and saved to a filter macro script[1212]. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

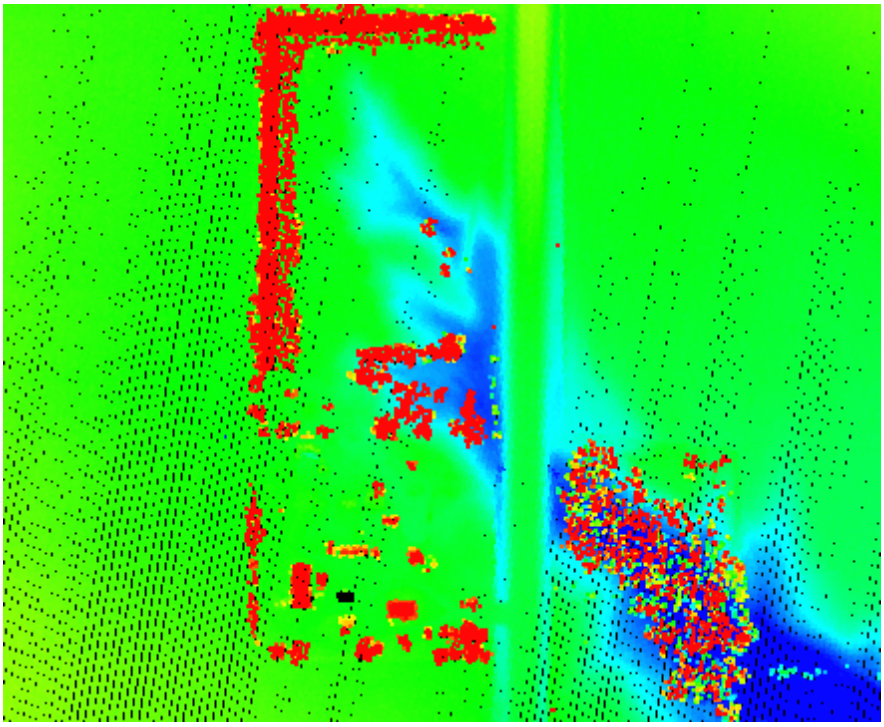
- **Grid cell size:** The size in project units of the cells of the grid.
- **Number of passes of grid smoothing:** Specifies how many times the Gaussian smoothing routine is applied to the grid surface.
- **Elevation Difference Requirement**
    - ❖ **Exactly at a minimum:** Specifies that reclassed points are exactly at a minimum elevation.
    - ❖ **Maximum limit:** Specifies that reclassified points are at most this difference in elevation higher than the grid surface. This value can be negative, in which case it represents the maximum limit below the grid surface.
    - ❖ **Minimum limit:** Specifies that reclassified points are at least this difference in elevation higher than the grid surface. This value can be negative, in which case it represents the minimum limit below the grid surface.
    - ❖ **Both max and min limit:** Specifies the software will use both maximum and minimum parameters set for elevation.
- **Use slope:** If checked, this option will calculate the elevation difference perpendicular ('normal') to the slope of the grid surface.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

Example Filter Use:

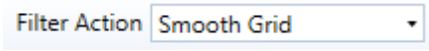
Before: In the example below, the user would like to create smooth gridded data based on the

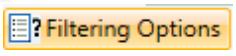
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elevation at the ***center*** of each grid cell, and reclassify points which are a specific elevation difference requirement from that gridded surface. This will include trees and other vegetation in this particular example.



Manually Using a Single Filter: To use the Smooth Grid Filter to reclassify points within a specific elevation difference from the surface and to smooth the data based on the ***center*** of the grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



Next, click on the 'Filtering Options'  button to define the filter settings.

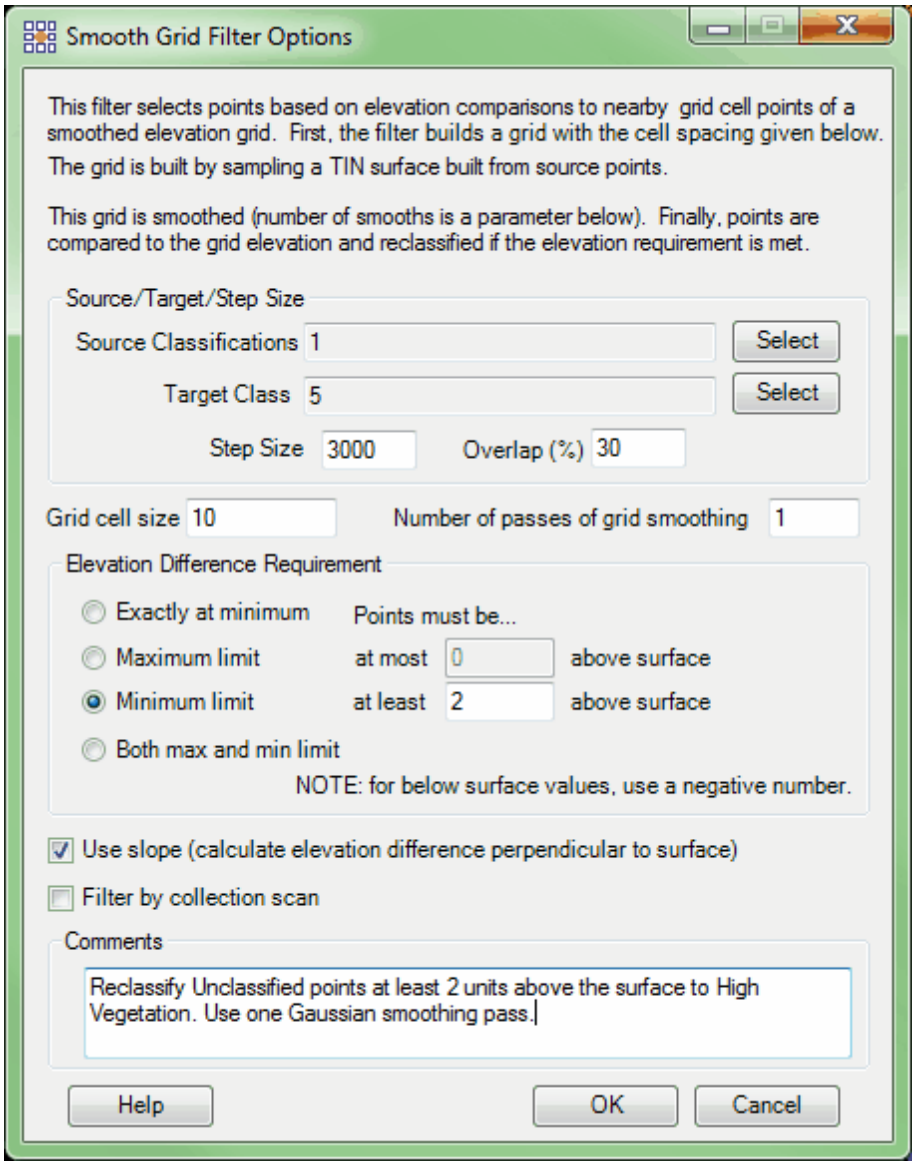
Smooth Grid Filter Options Dialog: The 'Smooth Grid Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique features to this filter include the ability to select the Grid cell size and the number of passes of grid smoothing. The user also has the option of specifying the elevation difference requirements for points to be reclassified. This filter also has the ability to filter by

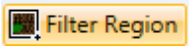
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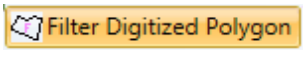
collection scan, and to use the slope in calculating the elevation difference. Click **'OK'** to save the settings.

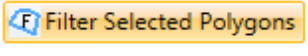
In this example, all data is initially classed as Class 1: Unclassified (gray) and filtered points will be reclassified to Class 5: High Vegetation (green). This makes Class 1 the source class and Class 5 the target class. Most of the points found above the surface in this example are actually trees, brush, and other vegetation so the points filtered out of the data will be reclassed to Class 5: High Vegetation. The default values for step size and overlap will be used for this example. The grid cell size has been set to 10, meaning a 10 unit by 10 unit area will be defined for each grid cell. The number of Gaussian smoothing passes has been set to 1. The elevation difference requirement states that any points which are at least 2 units above the gridded surface should be reclassed to Class 5: High Vegetation.

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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** 

, **'Filter Digitized Polygon'** 

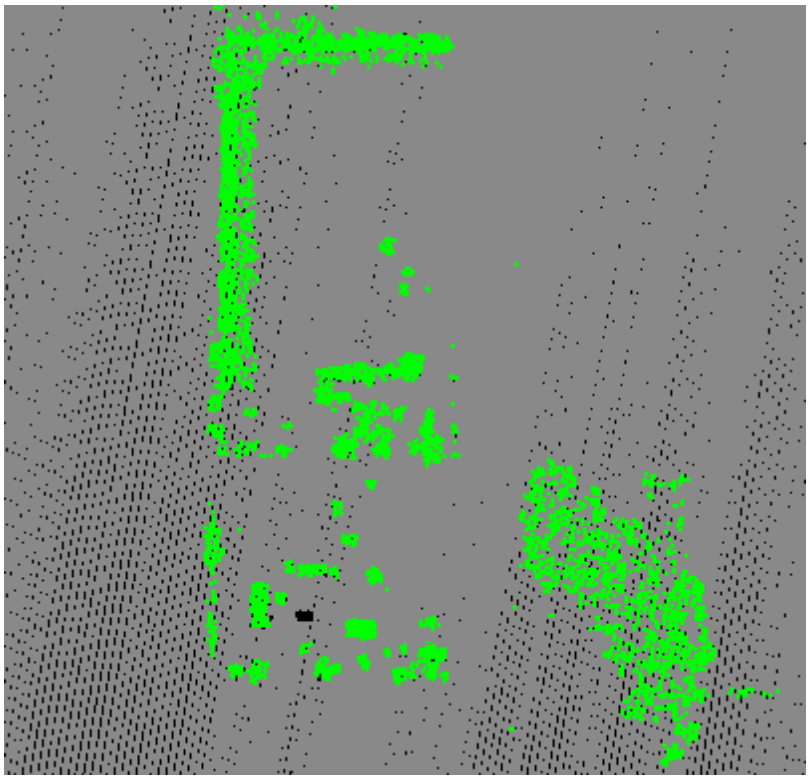
, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data.

After: After running the filter, the points more than the minimum elevation difference above the gridded surface (temporary ground) have been filtered out and reclassified as Class 5: High Vegetation.



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5.1.27 Smooth Max Grid Filter

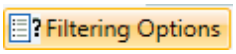
Smooth Max Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Smooth Max Grid Filter** builds a grid surface from the maximum elevation points of the source classification set. Then, a Gaussian smoothing function is applied, repeating the smoothing as

specified by the 'Number of passes ...' value. Finally, points in the source classification set are compared to this grid surface and reclassified to the target classification if they meet the elevation difference requirements as specified by the min_diff and max_diff parameters.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.

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- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Grid cell size:** The size of the cells of the grid.
- **Number of passes of grid smoothing:** Specifies how many times Gaussian smoothing is applied to the grid surface.
- **Elevation Difference Requirement**
  - ❖ **Exactly at a minimum:** Specifies that reclassed points are exactly at a minimum elevation.
  - ❖ **Maximum limit:** Specifies that reclassified points are at most max_diff higher in elevation than the grid surface. This value can be negative.
  - ❖ **Minimum limit:** Specifies that reclassified points are at least min_diff higher in elevation than the grid surface. This value can be negative.
  - ❖ **Both max and min limit:** Specifies the software will use both maximum and minimum parameters set for elevation.
- **Use slope:** If checked, this option will calculate the elevation difference perpendicular to the slope of the grid surface.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

Example Filter Use:

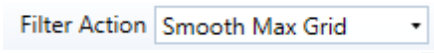
Before: In the example below, the user would like to create smooth gridded data based on the *maximum* elevation point of each grid cell, and reclassify points which are a specific elevation

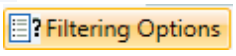
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difference requirement from that gridded surface. This will include reclassifying cars out of the vegetation class in this particular example.



Manually Using a Single Filter: To use the Smooth Max Grid Filter to reclassify points within a specific elevation difference from the surface and to smooth the data based on the *highest point* of the grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab[270].



Next, click on the 'Filtering Options'  button to define the filter settings.

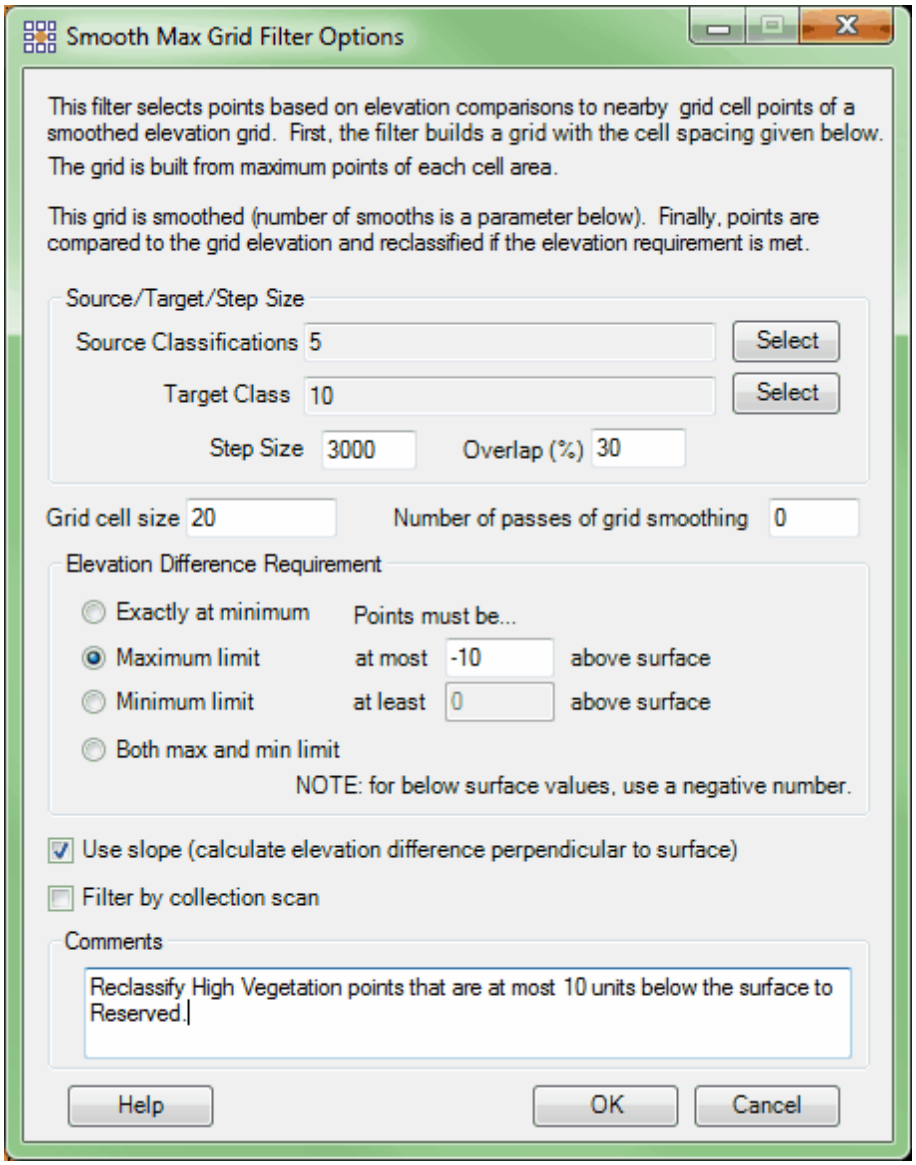
Smooth Max Grid Filter Options Dialog: The 'Smooth Max Grid Filter Options' interface is very similar to the other two smoothing filters. It gives the user several options in specifying the filter such as the source classification, target class, step size, and overlap. Unique features to this filter include the ability to select the grid cell size and the number of passes of grid smoothing. The user also has the option of specifying the elevation difference requirements for points to be reclassified. By default,

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the elevation difference requirement is set at the 'Maximum limit' to select those points with the max elevation for smoothing.

In this example, all buildings and cars are classed as Class 5: High Vegetation (green), and filtered points which represent cars will be reclassified to Class 10 (yellow). This makes Class 5 the source class and Class 10 the target class. Most of the points found above the surface in this example are actually buildings or cars, which can be separated by their elevation difference from the surface. The default values for step size and overlap will be used for this example. The grid cell size has been set to 20, meaning a 20 unit by 20 unit area will be defined for each grid cell. The elevation difference requirement states that any points which are at most 10 units below the surface data (which will include most cars) should be reclassed to Class 10.

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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data.

After: After running the filter, the cars surrounding the building in this example have been classified as Class 10 (yellow).



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5.1.28 Smooth Min Grid Filter

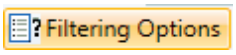
Smooth Min Grid Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **Smooth Min Grid Filter** builds a grid surface from the minimum elevation points of the source classification set. Then, Gaussian smoothing is applied, repeating the smoothing as specified by the 'Number of passes ...' value. Finally, the points in the source classification are compared to the grid

surface and reclassified to the target classification if they meet the elevation difference requirements as specified by the min_diff and max_diff parameters.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text

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here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

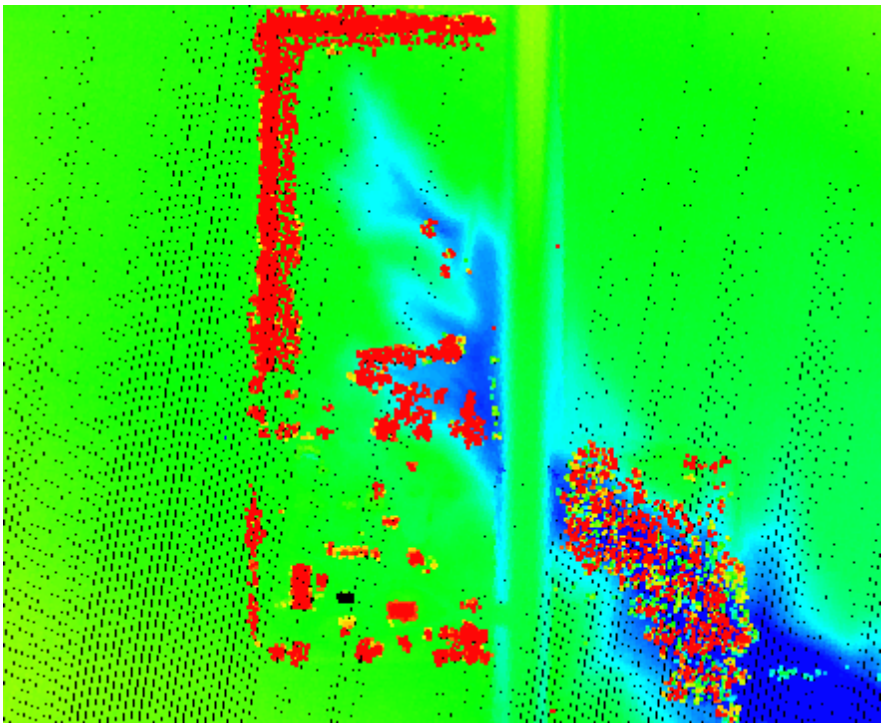
- **Grid cell size:** The size of the cells of the grid.
- **Number of passes of grid smoothing:** Specifies how many times Gaussian smoothing is applied to the grid surface.
- **Elevation Difference Requirement**
    - ❖ **Exactly at a minimum:** Specifies that reclassed points are exactly at a minimum elevation.
    - ❖ **Maximum limit:** Specifies that reclassified points are at most max_diff higher in elevation than the grid surface. This value can be negative.
    - ❖ **Minimum limit:** Specifies that reclassified points are at least min_diff higher in elevation than the grid surface. This value can be negative.
    - ❖ **Both max and min limit:** Specifies the software will use both maximum and minimum parameters set for elevation.
- **Use slope:** If checked, this option will calculate the elevation difference perpendicular to the slope of the grid surface.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

Example Filter Use:

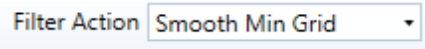
Before: In the example below, the user would like to create smooth gridded data based on the *minimum* elevation point of each grid cell, and reclassify points which are a specific elevation difference requirement from that gridded surface. This will include trees and other vegetation in this particular

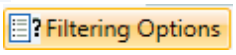
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example.



Manually Using a Single Filter: To use the Smooth Min Grid Filter to reclassify points within a specific elevation difference from the surface and to smooth the data based on the *lowest point* of the grid cell, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



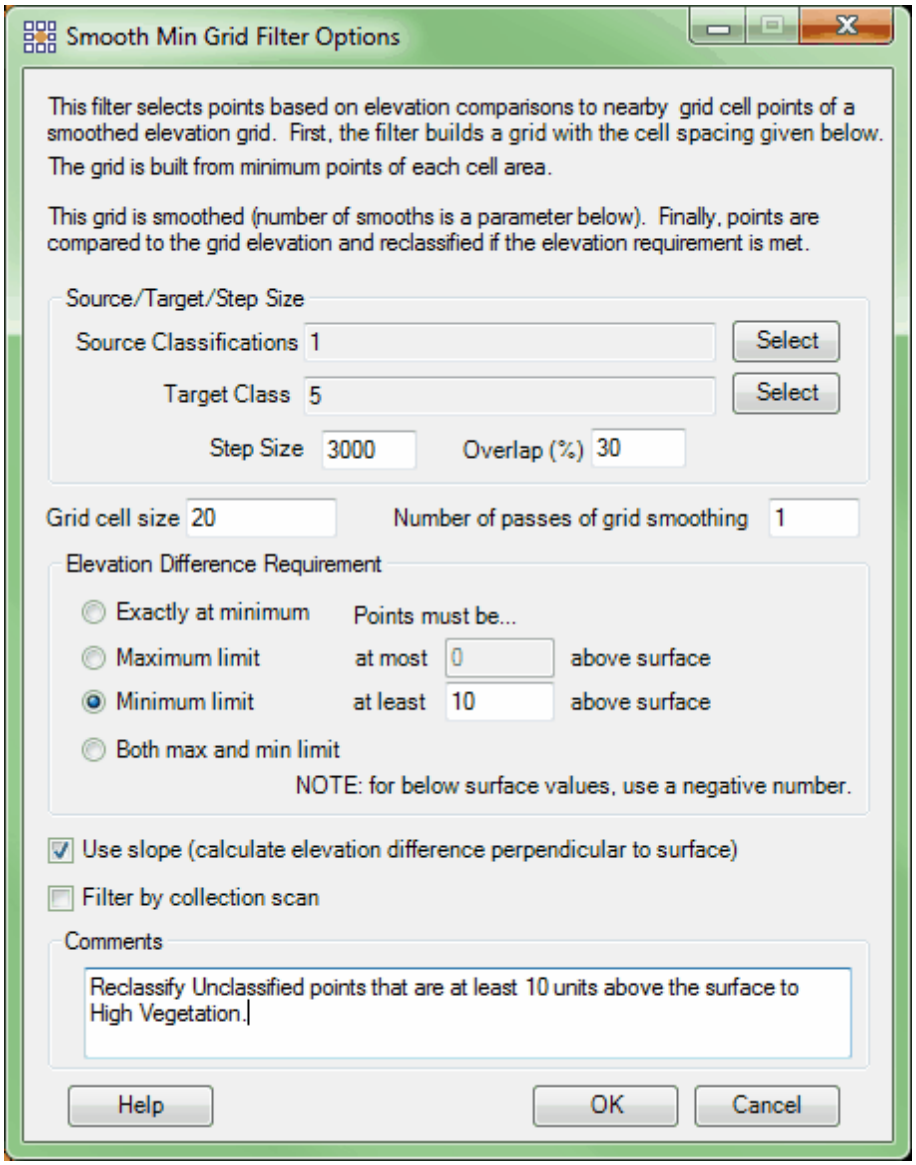
Next, click on the 'Filtering Options'  button to define the filter settings.

Smooth Min Grid Filter Options Dialog: The 'Smooth Min Grid Filter Options' interface is very similar to the other two smoothing filters offered. It gives the user several options in specifying the filter such as the source classification, target class, step size, and overlap. Unique features to this filter include the ability to select the grid cell size and the number of passes of grid smoothing. The user also has the option of specifying the elevation difference requirements for points to be reclassified. By default, the elevation difference requirement is set at the 'Minimum limit' to select those points with the min elevation for smoothing. Click **'OK'** to save the settings.

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In this example, all data is classed as Class 1: Unclassified (gray) and filtered points will be reclassified to Class 5: High Vegetation (green). This makes Class 1 the source class and Class 5 the target class. Most of the points found above the surface in this example are actually trees, brush, and other vegetation so the points filtered out of the data will be reclassed to Class 5: High Vegetation. The default values for step size and overlap will be used for this example. The grid cell size has been set to 20, meaning a 20 unit by 20 unit area will be defined for each grid cell. The number of Gaussian smoothing passes has been set to 1. The elevation difference requirement states that any points which are at least 10 units above the surface data should be reclassed to Class 5: High Vegetation.

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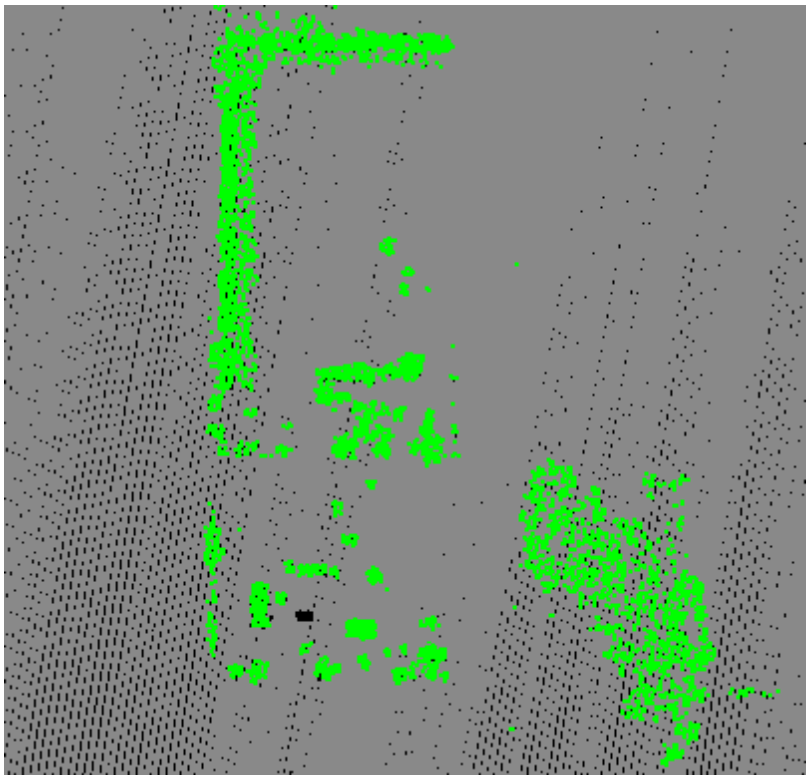


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will

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automatically refresh and show the reclassified data.

After: After running the filter, the points above the ground have been filtered out and reclassified as Class 5: High Vegetation.



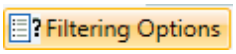
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5.1.29 Timestamp Filter



The **Timestamp Filter** uses stored timestamp values as a parameter in the reclassification of data.

For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** 

button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- LAS data with timestamp values stored at the point level. If the LAS data uses the preferred 'Adjusted GPS Time' as the stored time type, the filter reads those adjusted timestamps and ignores the 'Seconds of the GPS Week' values that are also stored at the point level. If the LAS data uses the older 'GPS Week Time' format, then the filter will read the 'Seconds of the GPS Week' values.

General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 100.
- **Overlap (%):** Not applicable for this filter.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored

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permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

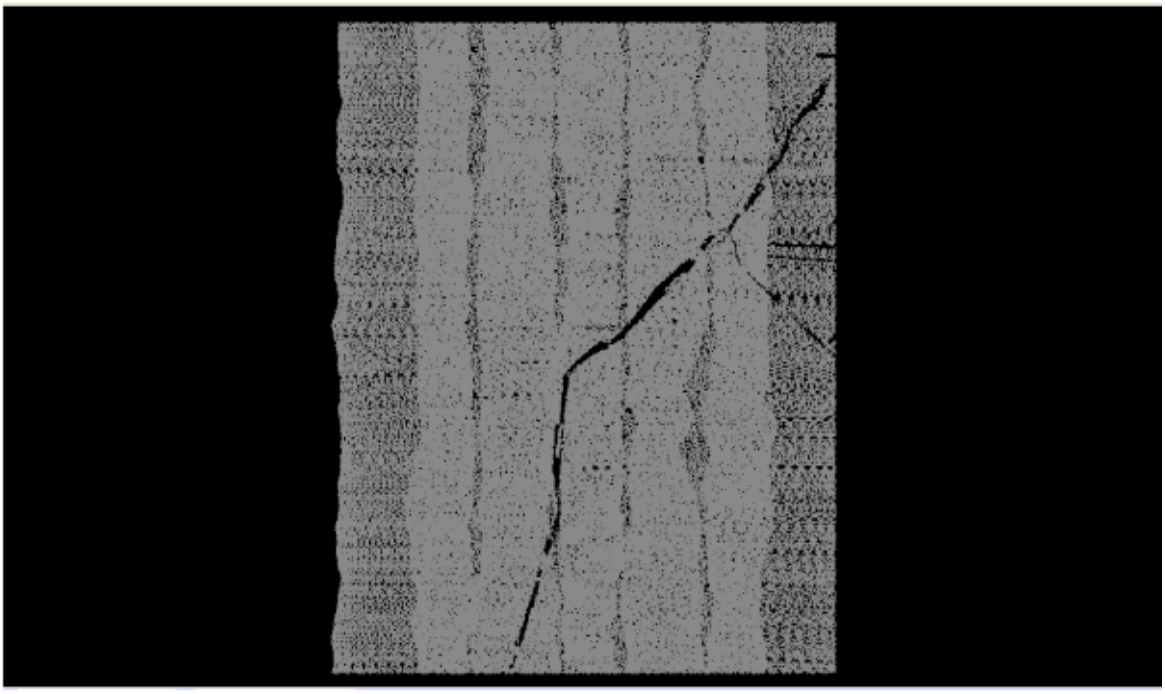
Filter Specific Parameters:

- **Above Mode:** Reclassifies all source points with timestamp values later than the specified Lower Limit value.
- **Below Mode:** Reclassifies all source points with timestamp values earlier than the specified Upper Limit value.
- **Between Mode:** Reclassifies all source points with timestamp values between the specified Lower and Upper Limit values.
- **Upper Limit:** When using Below Mode or Between Mode, this is the latest timestamp value to be considered.
- **Lower Limit:** When using Above Mode or Between Mode, this is the earliest timestamp value to be considered.

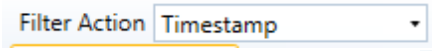
Example Filter Use:

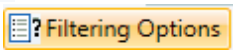
Before: In the example below, the user wishes to reclassify all the points between two timestamp values. Several LAS files are loaded for this example.

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Manually Using a Single Filter: To use the Timestamp Filter to reclassify all points with specific timestamp values to a single target class, choose it from the 'Filter Action' drop-down list on the Edit/ Filter Tab 270.



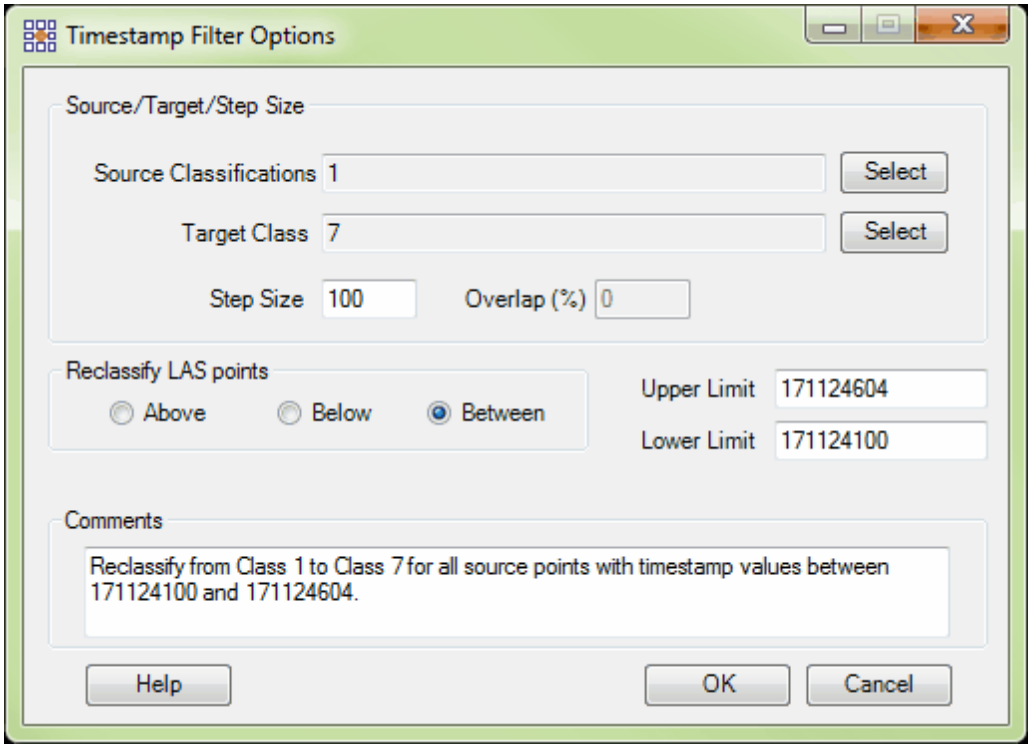
Next, click on the 'Filtering Options' 

button to define the filter settings.

Timestamp Filter Options Dialog: The 'Timestamp Filter Options' interface gives the user several options in specifying the parameters of the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique features to this filter include the ability to select which LAS points are reclassified by choosing Above, Below, or Between two timestamp values. The Upper Limit and Lower Limit entry boxes are used to set the timestamp range.

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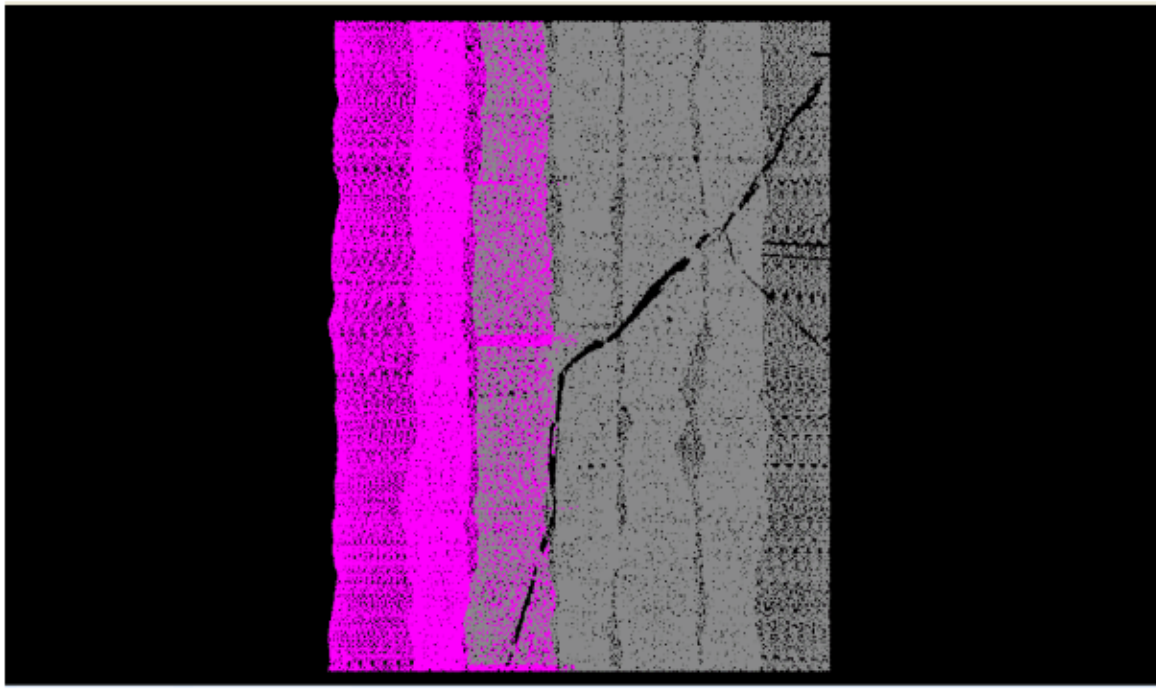
In this example, the source classification will be Class 1: Unclassified (gray) because the sample data set is unclassified. The target classification will be Class 7 (magenta). The default settings for step size and overlap will work for most projects, so they will be used for this example. Timestamp values were found using the Inspect 943 tool, and the points to be reclassified have timestamp values between 171124100 and 171124604. Click **'OK'** to save the settings.



Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

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After: After running the filter, all source points with timestamp values between the specified Lower and Upper Limit have been reclassified to Class 7 (magenta).



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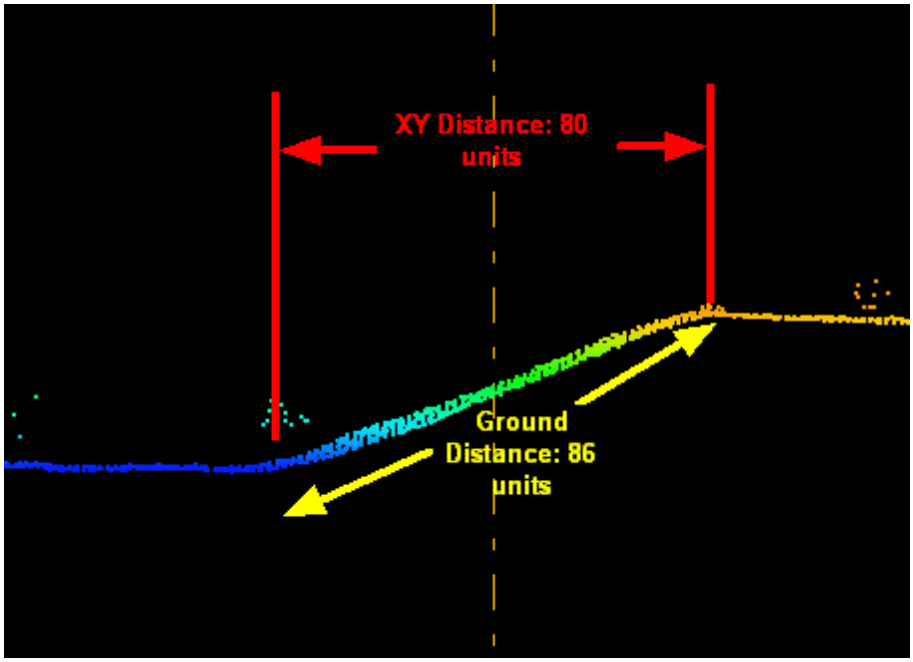
5.1.30 XY Distance Filter

XY Distance Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **XY Distance Filter** reclassifies points that are within a specific horizontal distance of a point in the reference classification set. **The radius distance measured when using this tool is measured**

only in an XY (horizontal) distance. This tool is very similar to the Ground Distance tool, except that the ground distance tool measures distance along the ground surface and slope. For more information, please see the Ground Distance Filter 1044.



For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab 270. Click the **'Filtering Options'** Filtering Options button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A reference classification that is not also the source classification.

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General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **XY Distance:** User-defined distance requirement for reclassified points. Reclassified points must be within xy_distance of the reference classification point.
- **Height Requirement**
  - **No limit:** Specifies no requirement in elevation.
  - **Maximum limit:** Specifies a requirement that points that are reclassified are at most max_diff higher in elevation than the nearby reference point. Height is measured perpendicular to the ground surface. This value can be negative.
  - **Minimum limit:** Specifies a requirement that points that are reclassified are at least min_diff higher in elevation than the nearby reference point. Height is measured

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perpendicular to the ground surface. This value can be negative.

- ❖ **Both max and min limit:** Specifies the software will use both maximum and minimum parameters set for elevation.

- **Angle Requirement**
  - ❖ **No limit:** Specifies no requirement in angle.
  - ❖ **Maximum limit:** Specifies a requirement that points that are reclassified are at most max_angle higher than the nearby reference point. Angles are measured from the ground surface. This value can be negative.
  - ❖ **Minimum limit:** Specifies a requirement that points that are reclassified are at least min_angle higher than the nearby reference point. Angles are measured from the ground surface. This value can be negative.
  - ❖ **Both max and min limit:** Specifies the software will use both maximum and minimum angle parameters.
- **Filter by collection scan:** The user has the ability to filter by collection scan by checking this option.

Reference Classification Set

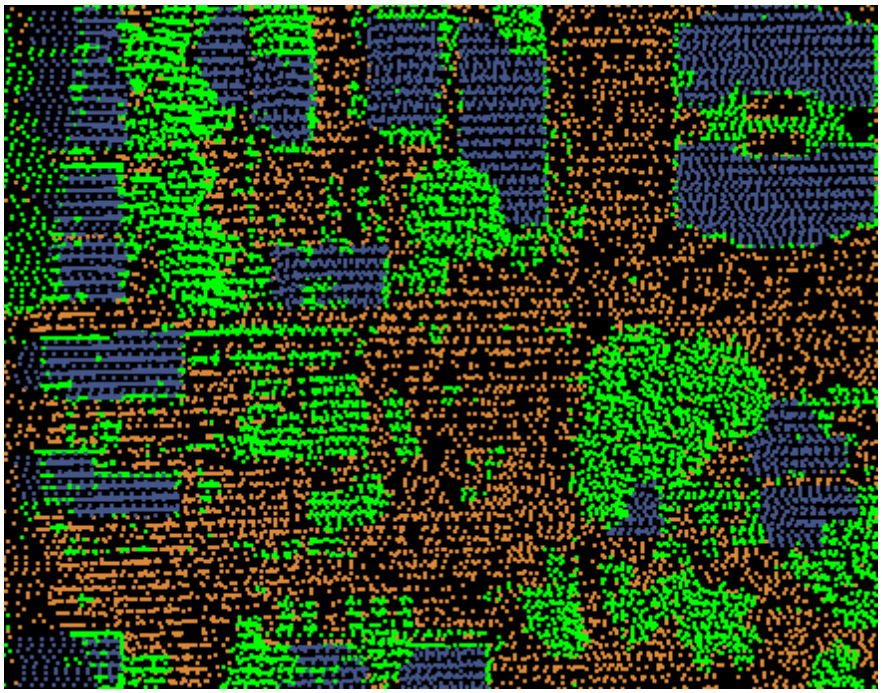
- **Reference Classifications:** The point data classification used to compare the unfiltered data against to find points to reclassify based on XY distance proximity. *Note: If the source and reference classification sets are the same, the XY Distance filter will not include the class of the point being measured from as a candidate for reclassifying itself. This is an automatic assumption of the filter.

Example Filter Use:

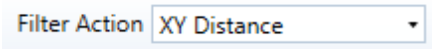
Before: In the example below, the user is attempting to separate vegetation within 25 horizontal units

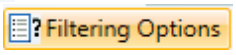
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from a building, from vegetation which is farther away.



Manually Using a Single Filter: To use the XY Distance Filter to reclassify all points that are within a specific horizontal distance of a point in the reference classification set, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



Next, click on the 'Filtering Options'  button to define the filter settings.

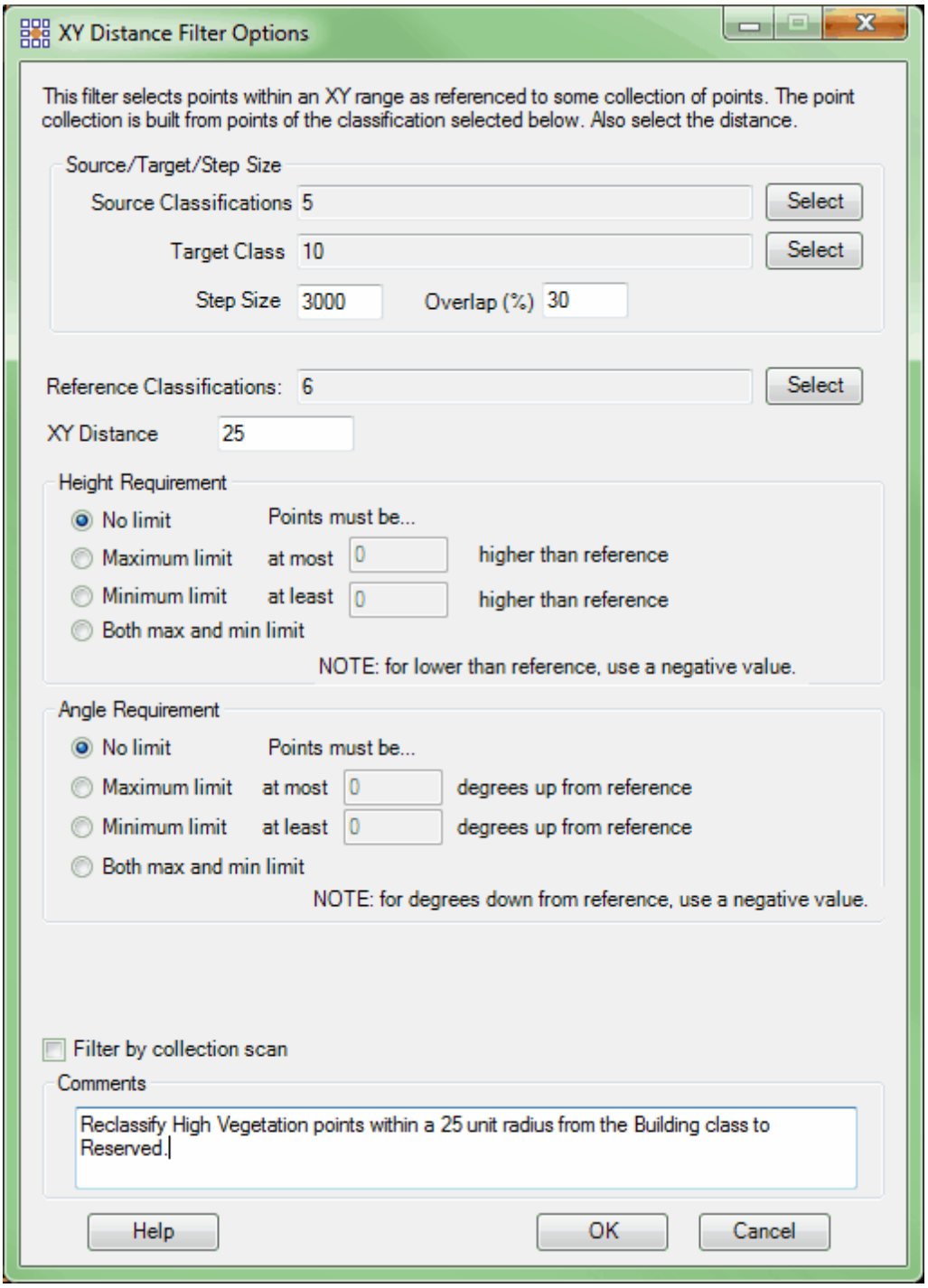
XY Distance Filter Options Dialog: The 'XY Distance Filter Options' interface gives the user several options in specifying the filter. The source classification, target class, step size, and overlap can be adjusted as in other filters. Unique features to this filter include the ability to choose a reference classification, specify an XY distance from the reference classification set, and the elevation requirements and angle requirements of the points to be reclassified.

In this example, the source classification will be Class 5: High Vegetation (green) because the user is

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only interested in high vegetation which is within 25 horizontal (XY) units from a building. The target classification will be Class 10 (yellow). The default settings for step size and overlap will work for most projects, so they will be used for this example. The reference classification is Class 6: Building (dark blue) because the user is interested only in points which are within 25 horizontal units from this particular class. There is no elevation requirement so that all vegetation within the specified distance from a building point will be reclassed to Class 10. There is no angle requirement restriction for the same reason. Click **'OK'** to save the settings.

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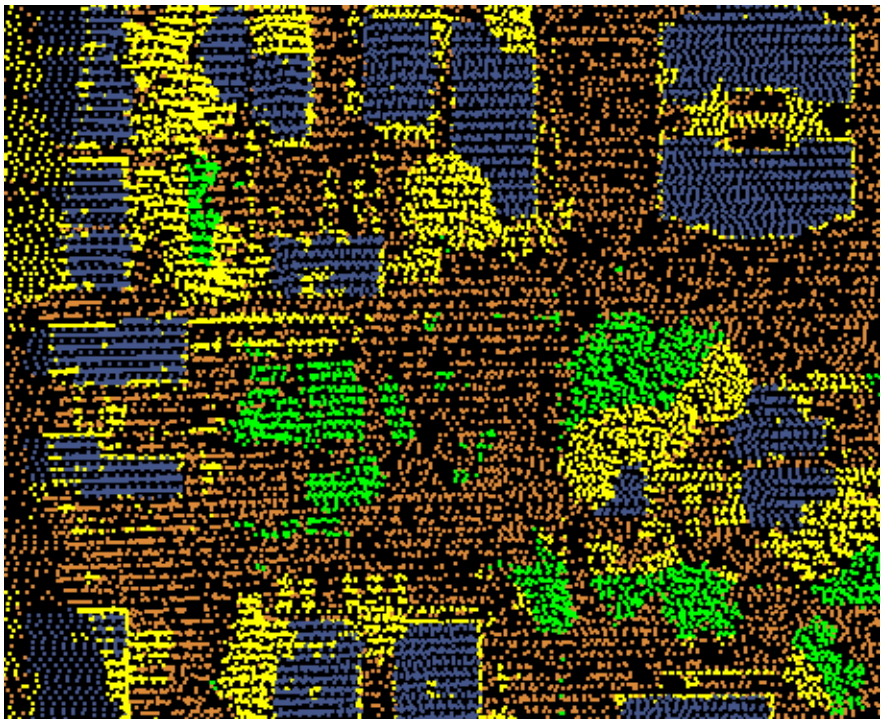


Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter**

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Region' Filter Region, **'Filter Digitized Polygon'** Filter Digitized Polygon, or **'Filter Selected Polygons'** Filter Selected Polygons button. The different operation of these tools is described in the Edit/Filter Tab[270] help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: When the filter is finished running it is possible to see all of the areas in which vegetation was within 25 horizontal units of a building. These areas have been colored yellow to represent Class 10, as intended.



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5.1.31 XYZ Distance Filter

XYZ Distance Filter

Merrick Advanced Remote Sensing (MARS®) Software

The **XYZ Distance Filter** reclassifies points that are within a specific spherical distance of a point in the reference classification set. In the example below, a red circle with a 25 unit radius is centered over the corner of a building. Any source class points (Class 5: High Vegetation in this example) within a 25 unit radius of any reference class points (Class 6: Building) will be reclassified to Class 10. Each reference class point is tested individually for source class points within the specified radius, so the virtual sphere is moved from point to point until all reference class points in the area being filtered have been tested.

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For details on adding this filter to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab topic.

To use this filter on loaded data, choose it in the **'Filter Action'** drop-down list on the Edit/Filter Tab. Click the **'Filtering Options'** Filtering Options button, which will bring up the appropriate interface to enter in the desired settings.

Requirements:

- A reference classification(s) that is not also the source classification(s).

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General Parameters:

- **Source Classifications:** The user will specify here which class(es) of points will be used as a source in identifying the proper points to be reclassified.
- **Target Class:** The class to which the Source points that meet all criteria of the filter are assigned.
- **Step Size:** Specifies how much data the filter will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used as step size increases. The default step size suggested for most projects using this filter is 3000.
- **Overlap (%):** Specifies the amount of overlap percentage to be used between steps (see **Step Size**). More overlap percentage can allow for a more precise output from the filter but requires a longer running time.
- **Comments:** This area of the filter allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the filter is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

Filter Specific Parameters:

- **Spherical Distance:** User-defined distance requirement for reclassified points. Reclassified points must be within xyz_distance of the reference classifications points.
- **Filter by collection scan:** The user has the ability to filter by collection scan line by checking this option.

Reference Classification Set

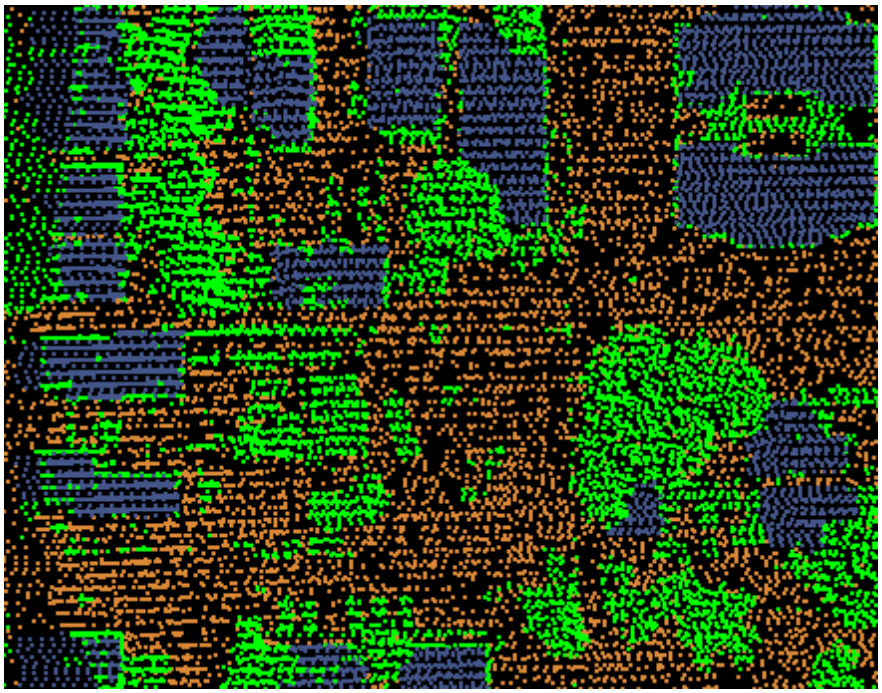
- **Reference Classifications:** The point data classification(s) used to compare the unfiltered

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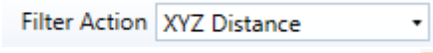
(source) data against to find points to reclassify based on XYZ distance proximity. *Note: If the source and reference classification sets are the same, the XYZ Distance filter will not include the class of the point being measured from as a candidate for reclassifying itself. This is an automatic assumption of the filter.

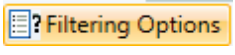
Example Filter Use:

Before: In the example below, the user is attempting to separate high vegetation within 25 units of a building from vegetation which is farther away.



Manually Using a Single Filter: To use the XYZ Distance Filter to reclassify all points that are within a specific spherical distance of all points in the reference classification set, choose it from the 'Filter Action' drop-down list on the Edit/Filter Tab 270.



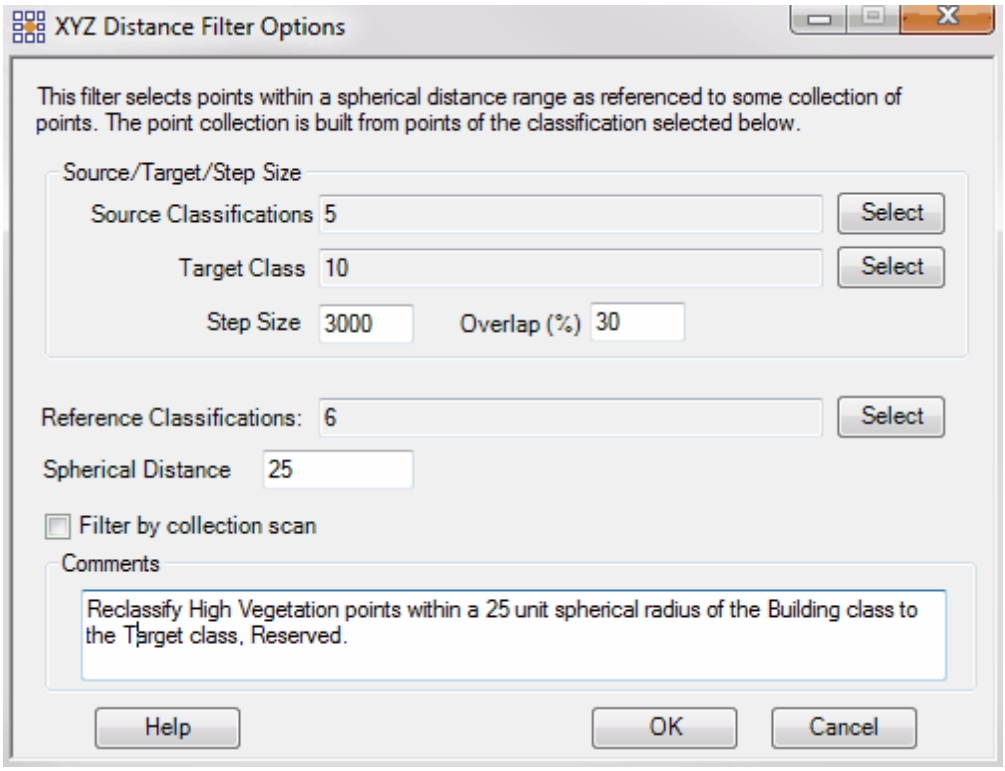
Next, click on the 'Filtering Options' 

button to define the filter settings.

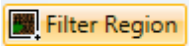
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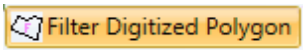
XYZ Distance Filter Options Dialog: The 'XYZ Distance Filter Options' interface gives the user several options in specifying the filter. The source classifications, target class, step size, and overlap can be adjusted as in other filters. Unique features to this filter include the ability to choose a reference classification(s), specify an XYZ distance (radius) from the reference classification set, and filter by collection scan.

In this example, the source classification will be Class 5: High Vegetation (green) because the user is only interested in high vegetation which is within 25 spherical units from a building. The target classification will be Class 10 (yellow). The default settings for step size and overlap will work for most projects, so they will be used for this example. The reference classification is Class 6: Building (dark blue) because the user is interested only in points which are 25 spherical units from this particular class. The Spherical Distance has been specified as 25 units for the reasons stated above. Click **'OK'** to save the settings.



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Choosing the Area to be Filtered: Now that the filter options have been specified for use in this project, the user can define the area in which the filter should run. To do this, click on the **'Filter Region'** 

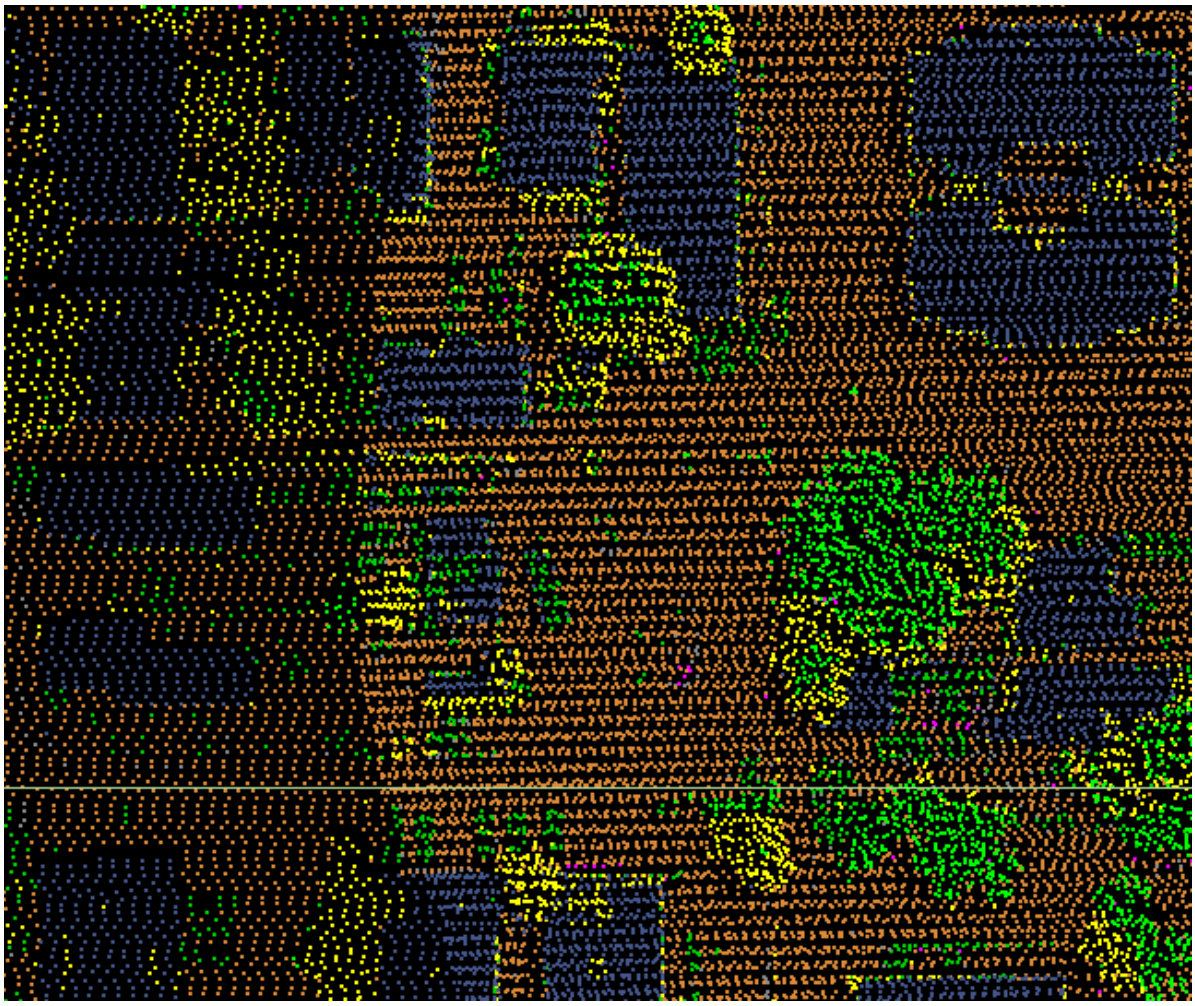
, **'Filter Digitized Polygon'** 

, or **'Filter Selected Polygons'** 

button. The different operation of these tools is described in the Edit/Filter Tab 270 help topic. The LAS Map View and Cross-Section/Profile windows will automatically refresh and show the reclassified data.

After: When the filter is finished running it is possible to see all of the high vegetation which is within 25 spherical units of a building. These points have been colored yellow to represent Class 10, as intended. The remaining green points within 25 spherical units of the buildings are Class 4: Medium Vegetation, which was not chosen as a Source Class.

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5.2 Extraction Tools

Extraction Tools

Merrick Advanced Remote Sensing (MARS®) Software

NOTE: The extraction tools are not available with the Evaluation license.

The MARS® extraction tools provide sophisticated filter algorithms for reclassifying LiDAR points and/or creating feature-bounding shapefile polygons. The tools consist of four (4) extraction functions which can be used individually. To use these tools, go to the Export/Extract Tab 461.

➤Area by Slope 1177 ➤Building Polygons 1182 ➤Canopy Density 1188 ➤Class Polygons 1196

MARS® applies the data filtering algorithms to those LiDAR points (source classification) matching the parameters of the tool function. LiDAR points meeting those criteria are reclassified to the specified target classification. In addition, all tool functions have a set of one or more source classifications that identify the pool of candidate points for each instance of use. For all but the 'Canopy Density' tools, shapefiles are produced including a *.prj (projection definition file) if the projection information is known for the source LAS data.

PLEASE NOTE: the default values that exist in all four extraction tools are based on projects in U.S. feet. For project data in meters, these values will need to be converted appropriately.

Optional comments may be added to the Comments box at the bottom of each extraction tool's interface. These comments will be saved if the extraction tool is added to a macro as part of a batch script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

The user may also manually reclassify LAS 1824 files to enhance the quality of the LiDAR dataset.

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5.2.1 Area by Slope

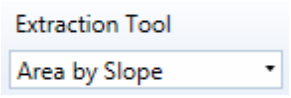
Area by Slope Tool

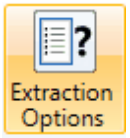
Merrick Advanced Remote Sensing (MARS®) Software

NOTE: The extraction tools, including 'Area by Slope', are not available with the Evaluation license.

The **'Area by Slope'** extraction tool in MARS® is designed to analyze the slope of the ground in any particular area. This tool may be used to determine areas meeting specific slope criteria and output polygons to a 3D shapefile. Uses include well pad sites, landing zones, and other land base applications that need to determine the most logical sites given user-specified criteria.

For details on adding this extraction tool to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this extraction tool on loaded data, choose 

from the **'Extraction Tool'** drop-down list on the Export/Extract Tab 461. Click the **'Extraction Options'** 

button, which will bring up the appropriate interface to enter the desired settings.

Requirements:

- Ground class(es)
- An output path and shapefile name (shapefile name is ignored when used in a macro script - in this case, naming is determined by the 'Output' tab settings in the Batch Process Tiles 1212 tool.)

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Filter Specific Parameters:

- **Source Classifications:** The source classification designated is the class which will be tested for slope by this tool. In most cases this is the ground class: Class 2. If optionally re-classing points, the source classification will be the class(es) of points to be reclassed to the Target Class.
- **Reclass Interior Points:** Choose this option if the source points inside the resulting shapefile's polygons should be reclassed. When this option is chosen, the 'Target Class' becomes available. When used as part of a macro script with the Batch Process Tiles tool, this option will create new LAS files in the path specified for that tool. The output shapefiles will be in the path specified below (**Path**).
- **Target Class:** This option is available only when the 'Reclass Interior Points' option is chosen. The 'Target Class' option allows the user to specify what class the points chosen from the source classification(s) should be reclassified to.
- **Step Size:** The user may specify here how much data the extraction tool will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used for larger step sizes. The default step size suggested for most projects using this tool is 100.
- **Overlap (%) :** The user may specify the percentage of overlap to be used between adjacent 'Step Size' areas. More overlap percentage allows for a more precise output from the filter but requires a longer running time.
- **Path:** In this area the user can specify an output folder where the resulting shapefile(s) (*.shp) will be stored. This must be specified before the tool can be run. ***If this tool is used multiple times within a*** Batch Script***, or in combination with the 'Building Polygons' and/or 'Class Polygons' tools, be sure to use unique output folders for each instance to avoid overwriting files!***
- **Shapefile Name:** The user specifies the desired shapefile name here. When this tool is used as

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a step in a macro script that is called by the Batch Process Tiles tool, the shapefile names will match the LAS file naming convention that is set in the batch tool's 'Output' tab. In that case, the entry box can be left blank.

- **Add the result to project:** If checked, adds the resulting shapefiles as reference shapefiles under the 'Vectors' layer. This option is ignored when the tool is used in a Batch Script.
- **Desired Slope:** This user-defined value determines the target slope for the extraction tool. For example, when attempting to find flat areas of ground (a slope of 0), a 0 is entered here and the resulting polygons will show areas with no slope.
- **Slope Deviation:** This value is the amount of tolerance the user wants to allow in deviation from the 'Desired Slope'. This value is entered in degrees. For example, if the user is looking for an area with a slope of 3 degrees or less a '0' would be entered in the 'Desired Slope' text box, and a '3' would be entered in the 'Slope Deviation' text box.
- **Exclusion Classifications:** Selecting a class(es) here will allow the user to exclude certain points from being included in the polygons generated during extraction. For example, the user may not want to include areas of vegetation or buildings (typically Classes 3, 4, 5, and 6) within an open area being analyzed.
- **Minimum Diameter:** This value, chosen by the user, dictates the minimum diameter of an area to be included in the extraction.
- **Comments:** This area of the extraction tool allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the extraction tool is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

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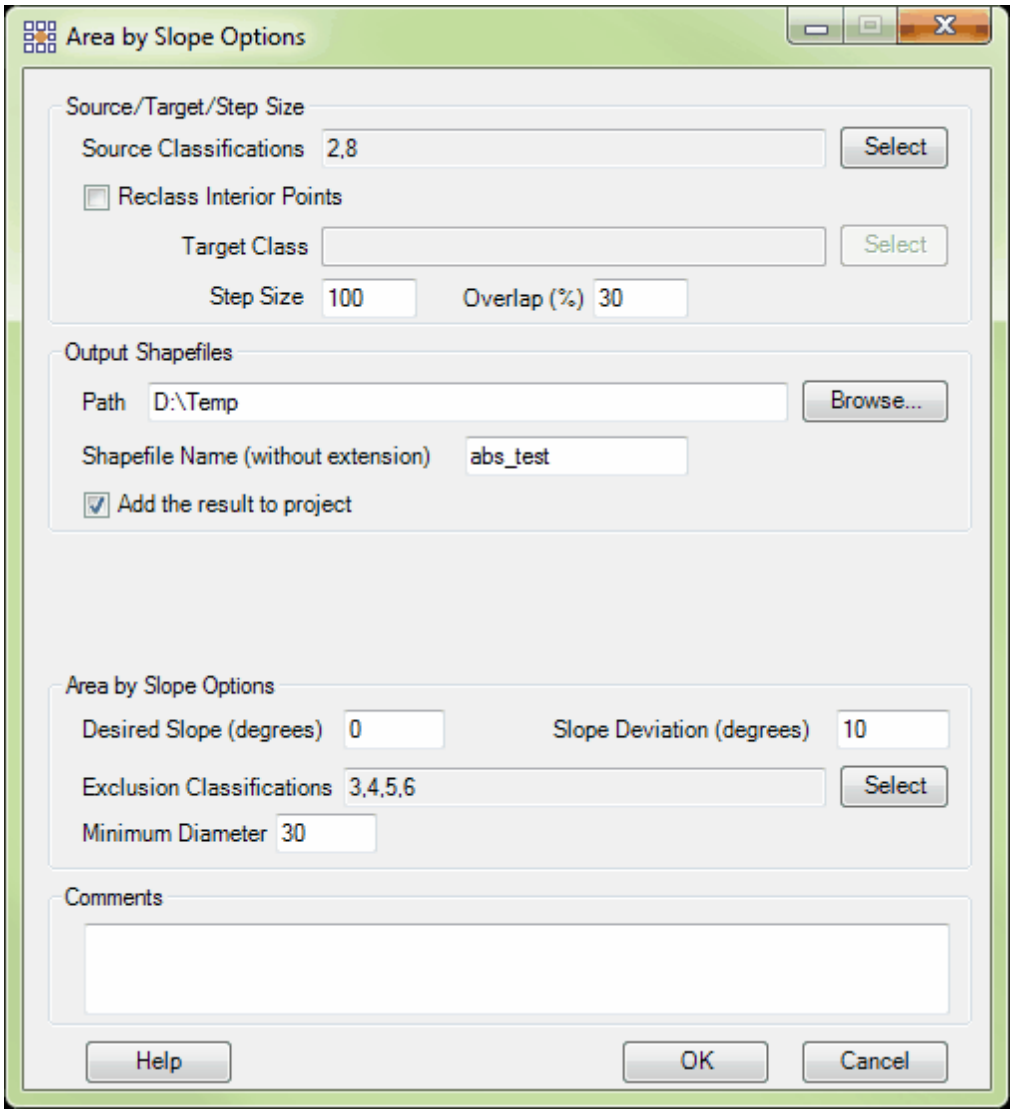
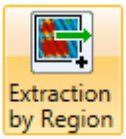


Figure 1: 'Area by Slope Options' interface

Once the user has defined all of the required parameters, an area can be specified for extraction by using the **'Extraction by Region'** 

button to click-drag a rectangular area-of-interest (AOI). When the extraction has completed and the new *.shp file is written to the specified directory, it will be loaded into the current MARS® project if the 'Add the result to project' box was checked. If not, it can be

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loaded manually at a later time as a Reference Shapefile 95.

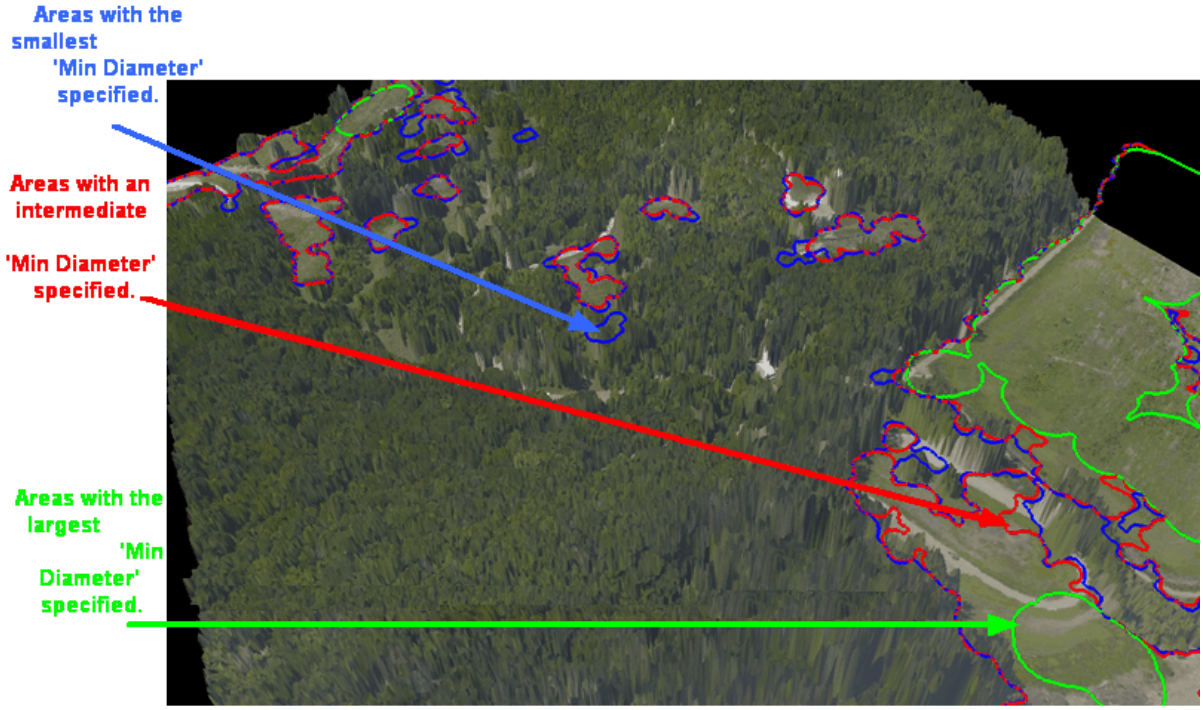


Figure 2: *In this example, the Area by Slope tool demonstrates its capabilities to find areas of ground meeting the user-defined parameters. The user has specified 3 different sizes of open area to be found in this example. The blue areas have the smallest 'Minimum Diameter' defined by the user, and so are the most numerous. The red areas have intermediate values and represent less areas available then the blue with the given limitations, but more areas available than the green. The green areas represent areas with the largest 'Minimum Diameter' values, and so are the least numerous.*

In this example all three areas were given the same specifications for slope - the only difference was the specification for 'Minimum Diameter'.

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5.2.2 Building Polygons

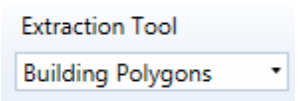
Building Polygons Tool

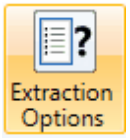
Merrick Advanced Remote Sensing (MARS®) Software

NOTE: The extraction tools, including 'Building Polygons', are not available with the Evaluation license.

The **'Building Polygons'** extraction tool in MARS® is designed to place polygons around a specified class. The difference between the building polygons tool and the class polygons tool is that the building tool takes into account the class and the elevation of the points, whereas the class polygon tool is only concerned with the class of the points in the extraction. This tool may be used to determine areas meeting specific criteria and output user-defined polygons to a 3D shapefile.

For details on adding this extraction tool to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this extraction tool on loaded data, choose 

from the **'Extraction Tool'** drop-down list on the Export/Extract Tab 461. Click the **'Extraction Options'** 

button, which will bring up the appropriate interface to enter the desired settings.

Requirements:

- Building class(es)

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- Ground class(es)
- An output path and shapefile name (shapefile name is ignored when used in a macro script - in this case, naming is determined by the 'Output' tab settings in the Batch Process Tiles 1212 tool.)

Filter Specific Parameters:

- **Reclass interior points:** Choose this option if the source points inside the resulting shapefile's polygons should be reclassed. When this option is chosen, the 'Source Classifications' option becomes available. When used as part of a macro script with the Batch Process Tiles 1212 tool, this option will create new LAS files in the path specified for that tool. The output shapefiles will be in the path specified below (**Path**).
- **Source Classifications:** The source classification is only needed if the 'Reclass interior points' option is chosen. If re-classing points, the source classification will be the class(es) of points to be reclassed to the Target Class.
- **Target Class:** If the 'Reclass interior points' option is chosen, the 'Target Class' option allows the user to specify what class the points chosen from the source classification should be reclassified to. If the 'Reclass interior points' option is not chosen, the target class will be building class, or the class which should be surrounded by the extraction polygons.
- **Step Size:** The user may specify here how much data the extraction tool will work on at a time. For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used for larger step sizes. The default step size suggested for most projects using this tool is 100.
- **Overlap (%) :** The user may specify the percentage of overlap to be used between adjacent 'Step Size' areas. More overlap percentage allows for a more precise output from the filter but requires a longer running time.
- **Path:** In this area the user can specify an output folder where the resulting shapefile(s) (*.shp) will be stored. This must be specified before the tool can be run. ***If this tool is used multiple times***

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within a Batch Script, or in combination with the 'Area by Slope' and/or 'Class Polygons' tools, be sure to use unique output folders for each instance to avoid overwriting files!

- **Shapefile Name:** The user specifies the desired shapefile name here. When this tool is used as a step in a macro script that is called by the Batch Process Tiles tool, the shapefile names will match the LAS file naming convention that is set in the batch tool's 'Output' tab. In that case, the entry box can be left blank.
- **Add the result to project:** If checked, adds the resulting shapefiles as reference shapefiles under the 'Vectors' layer. This option is ignored when the tool is used in a Batch Script.
- **Max TIN Edge Length:** The maximum length of a TIN edge to qualify as an input into the creation of the grid used in the analysis.
- **Minimum Area:** This value, determined by the user, dictates the minimum area (minimum size of a polygon) which may be included in the analysis. No area less than the value defined here will be encircled with a polygon and included in the analysis.
- **Cell Size:** This parameter sets the cell size of the grid created for feature extraction. This value is in the same units as the LAS data (ex. English or Metric) with a default value of 1. The cell size should be set to approximately what the GSD (ground sample distance) is.
- **Building Classes:** The user should specify the building class in this text box. In most cases this will be Class 6: Building.
- **Ground Classes:** The user should specify the ground class in this text box. In most cases this will be Class 2: Ground.
- **Square Boundary:** This option will attempt to square the corners of the polygons created during extraction. It is possible that some points within the polygons will not be classed as building and some points outside the polygons will, since squaring causes a generalization of the polygon shape.
- **Single Gutter Polygon:** Checking this option will provide one polygon around each building around the top edges of the building. Unselecting this option will result in 2 polygons around each building: one around the top edges of the building and one of the footprint of the building. See **Figures 1 and**

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2 below for further explanation.

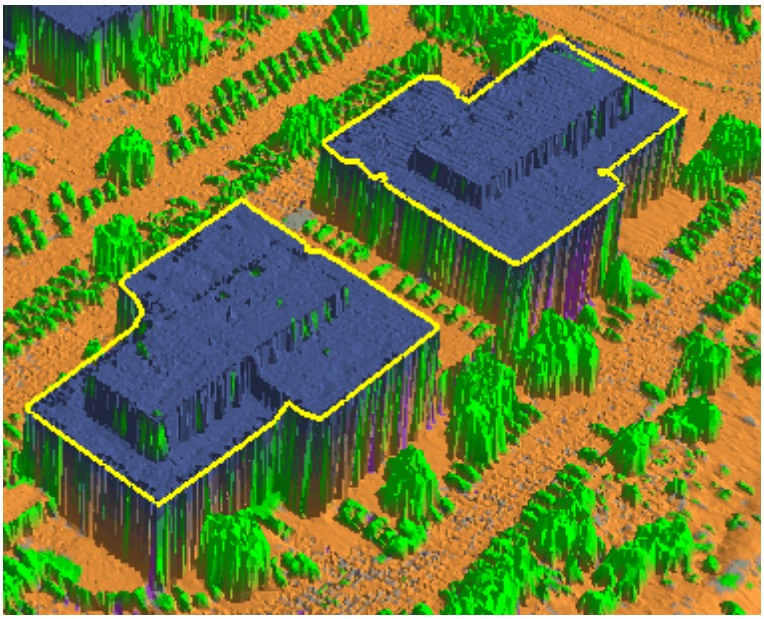


Figure 1: *The 'Single Gutter Polygon' option is chosen in this example (shapefile shown in yellow), resulting in a single polygon around the top edges of each building.*

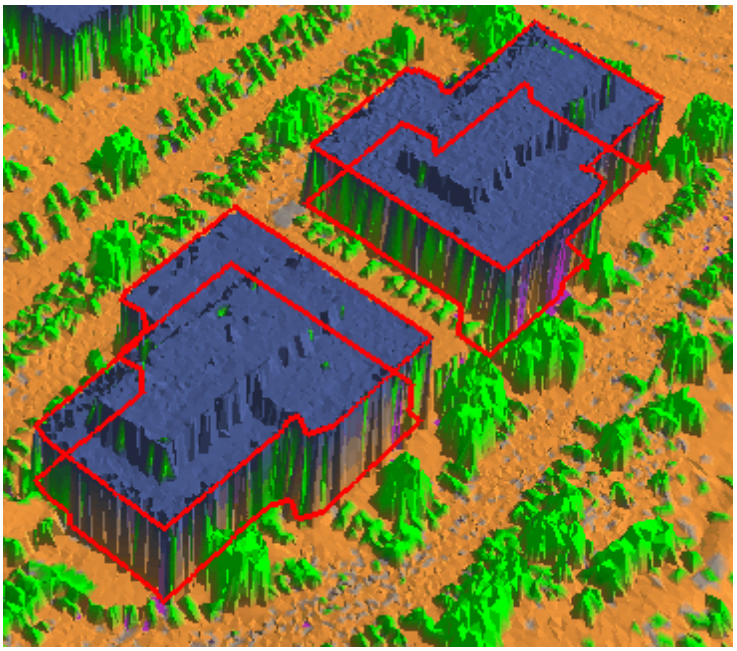


Figure 2: *The 'Single Gutter Polygon' option is NOT chosen in this example (shapefile shown in red), resulting in two polygons being created for each building. The first polygon outlines the top edges of the building and the second polygon outlines the footprint of the building. When*

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unchecking the 'Single Gutter Polygon' option, it is important to make sure the correct ground class has been entered into the analysis tool because the footprint polygon will be placed at the elevation of the ground points.

- **Comments:** This area of the extraction tool allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the extraction tool is added and saved to a filter macro script 1212. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

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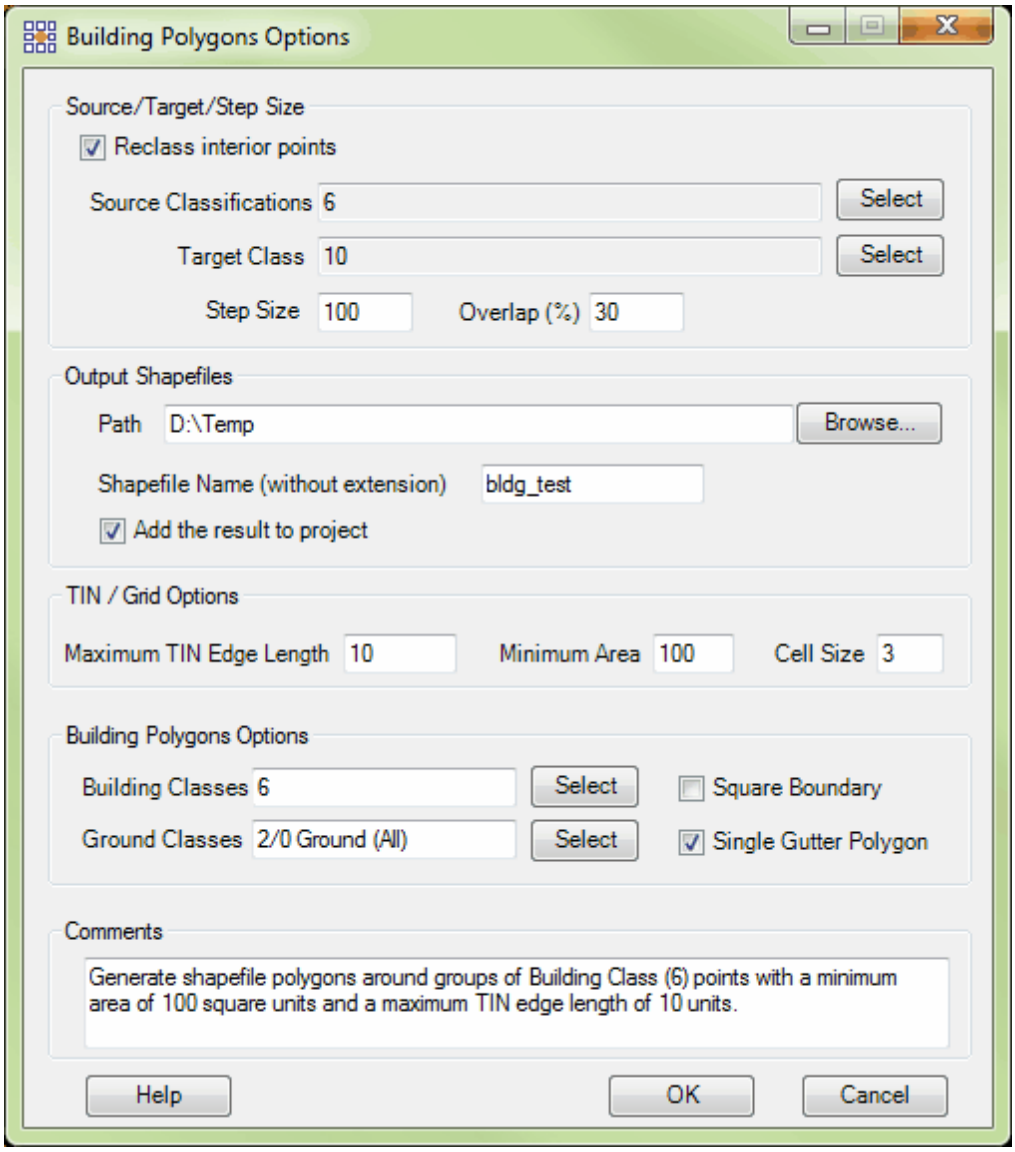
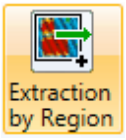


Figure 3: 'Building Polygons Options' interface

Once the user has defined all of the required parameters, an area can be specified for analysis by using the **'Extraction by Region'** 

button to click-drag a rectangular area-of-interest (AOI). When the extraction has completed and the new *.shp file is written to the specified directory, it will be loaded into the current MARS® project if the 'Add the result to project' box was checked. If not, it can be loaded

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manually as a Reference Shapefile 95.

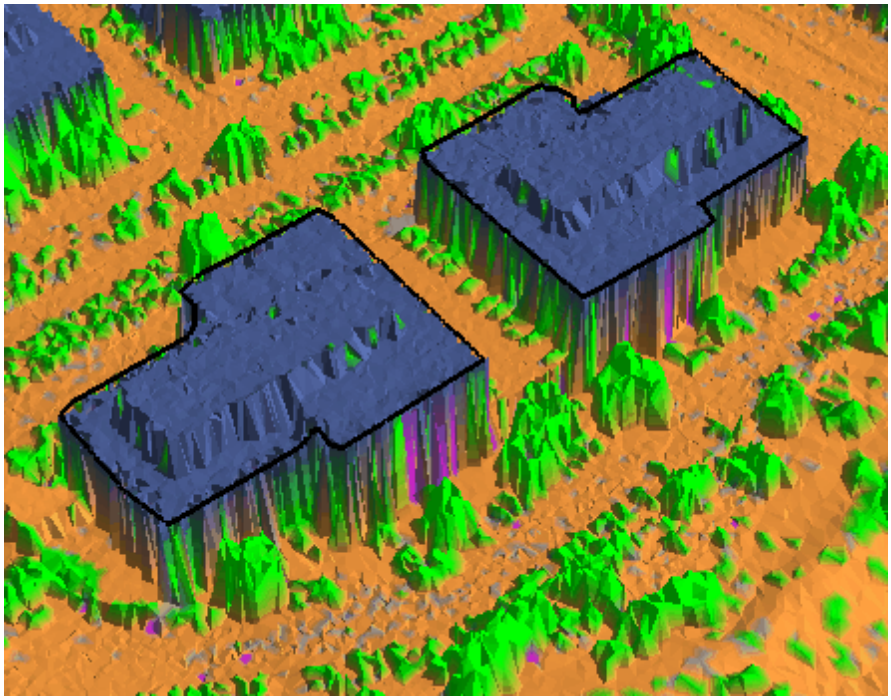


Figure 4: *A properly created building polygon shapefile.*

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5.2.3 Canopy Density

Canopy Density Tool

Merrick Advanced Remote Sensing (MARS®) Software

NOTE: The extraction tools, including 'Canopy Density', are not available with the Evaluation license.

The **'Canopy Density'** extraction tool in MARS® is designed to analyze canopy points above the ground and provide a display of the density of a vertical column. This is done by counting the number of returns within a user-defined voxel. A voxel is a volume pixel (**Figures 1 and 2** below), which means it is literally a volume of area defined by the tool dialog's **'Horizontal Grid Cell Size'** squared, multiplied by the **'Interval Size'** value (**X** x **Y** x **Z**).

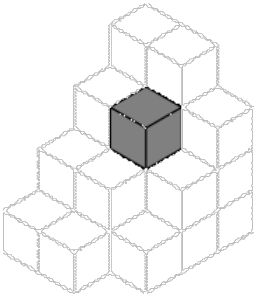


Figure 1: A series of voxels in a random stack. A single voxel is highlighted.

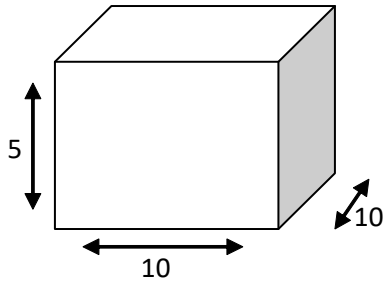
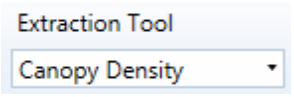


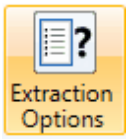
Figure 2: Individual voxel.

For example, in the Canopy Density dialog (**Figure 3** below), the voxel is defined as 10 units in the **X**, 10 units in the **Y**, and 5 units in the **Z** direction for a total volume of 500 cubic units. This tool counts the number of returns within each voxel and writes the results to an ENVI (*.DAT) data file. The results can be used to characterize canopy density and other meaningful quantitative vegetation metrics. The user can also define the desired elevation values within the **'Elevation Difference Requirement'** section of the 'Canopy Density' dialog, which allows them to specify elevation limit values for their analysis.

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For details on adding this extraction tool to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this extraction tool on loaded data, choose 

from the **'Extraction Tool'** drop-down list on the Export/Extract Tab 461. Click the **'Extraction Options'** 

button, which will bring up the appropriate interface to enter the desired settings.

Requirements:

- Ground class(es)
- Canopy class(es)
- An output path and file name

Filter Specific Parameters:

- **'Elevation Difference Requirement' Section:** The user can enter settings here which would restrict the extraction tool to certain vertical limits. Maximum and Minimum limits can be set individually, or both limits can be used to define a particular volume between the two.
- **Horizontal Grid Cell Size:** The horizontal grid cell size determines the horizontal dimension of the voxels. As seen in Figure 2 (above), the Horizontal Grid Cell Size would be 10.
- **Create Vertical Intervals:** The user can choose to 'Create Vertical Intervals' for the voxel by checking this box. When this option is chosen, the 'Interval Size (Z)' becomes available for the user to specify. The 'Interval Size (Z)' determines the vertical dimension of the voxels. As seen in Figure 2 (above), the Interval Size (Z) would be 5.
- **Fixed Number of Intervals:** The user can also choose to use a 'Fixed Number of Intervals' which

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would limit the number of voxels to a particular height, also limiting the number of 'bands' available to be viewed in the 'Hyperspectral Option' dialog of ENVI. For example, if the user were to specify a 'Fixed Number of Intervals' to be set at 5 and the 'Interval Size' was also set at 5, then the total area in which the canopy density analysis would be run would be 25 units in height and offer 5 different bands for viewing in the 'Hyperspectral Option' interface of ENVI. Each voxel layer offers one band to be viewed.

- **Ground Classes:** The user will specify here which points will be used as a reference in identifying the canopy points. The ground class is usually Class 2: Ground, which represents the bare earth points.
- **Canopy Classes:** The point class(es) chosen here will be the points on which the extraction tool is run. Typically, classes 3, 4, and 5 are all canopy classes (Low, Medium, and High Vegetation respectively).
- **Use First Returns Only:** The user should check this box if first returns are the only returns (for canopy) to be used in the extraction. The Canopy Density tool will ignore points that are any other return value.
- **ENVI Output File:** In this area the user must define an output folder for the resulting ENVI (*.dat) file to be stored in and give the new file a name. This must be specified before the tool can be run.
- **Average density by collection scans:** This box is checked by default. Results from the Canopy Density tool can be extremely skewed by the collection scan overlap regions since the data in these regions are roughly twice the density of the non-overlapping areas. The 'Average density by collection scans' option computes the density statistics per collection scan and then averages the results in the overlap regions for the output of the final ENVI .dat file creation.
- **Reclass Options:** *These controls are currently disabled and setting them will have no affect on the input LAS data or the output raster.*
- **Comments:** This area of the analysis tool allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored

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permanently if the extraction tool is added and saved to a filter macro script. Note that the reserved XML characters <, >, /, %, &, ', " cannot be used in the Comments box.

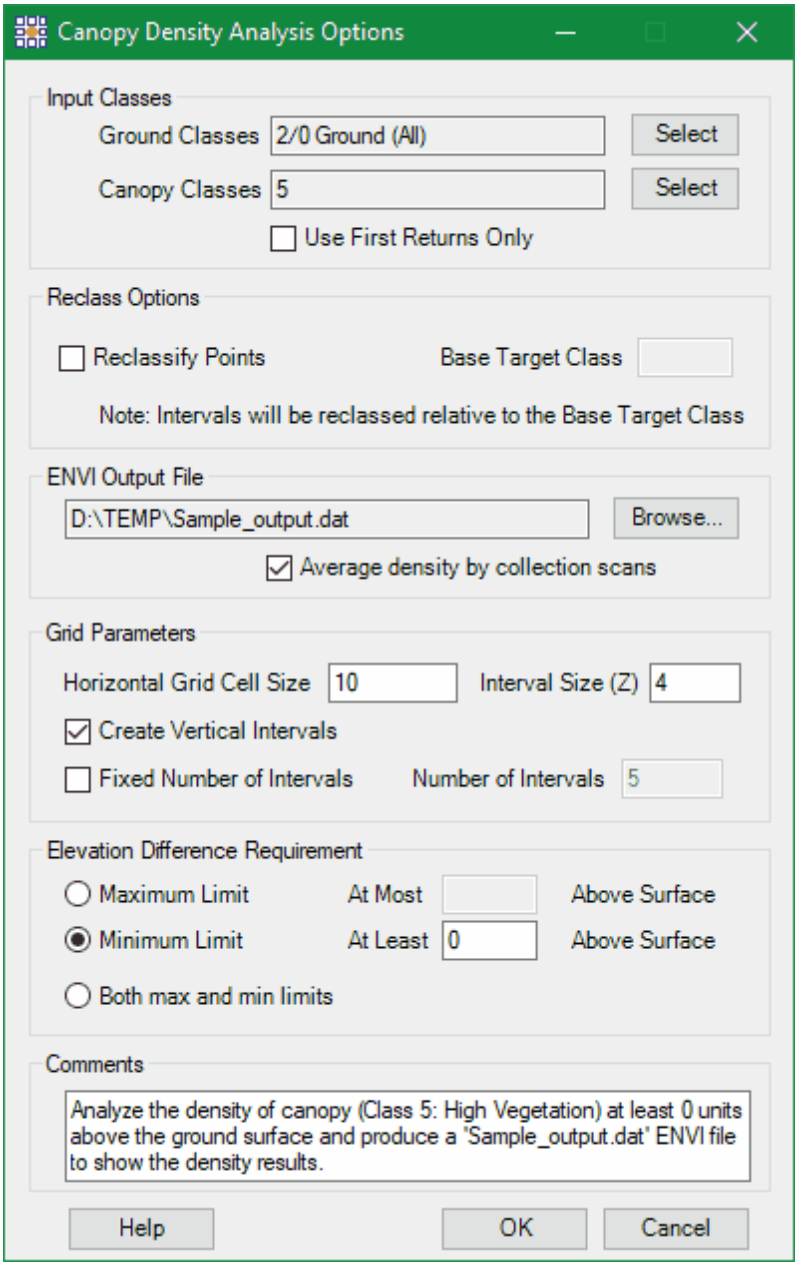
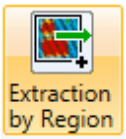


Figure 3: 'Canopy Density Analysis Options' interface

Once the user has defined all of the required parameters, an area can be specified for analysis by using

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the **'Extraction by Region'** 

button to click-drag a rectangular area-of-interest (AOI). The 'Extraction by Polygon' and 'Extraction from Selected Polygons' options may also be used, but only one polygon can be selected for the latter option. When the extraction has completed and the new ENVI file is written to the specified directory, it can be loaded into the current MARS® project as a Raster 86. This raster type can also be viewed in ENVI or ArcGIS software.

To view the properties of the ENVI raster, right-click the file in the Table of Contents and choose **'Properties'** to display the **'Hyperspectral Option'** dialog (Figure 4).

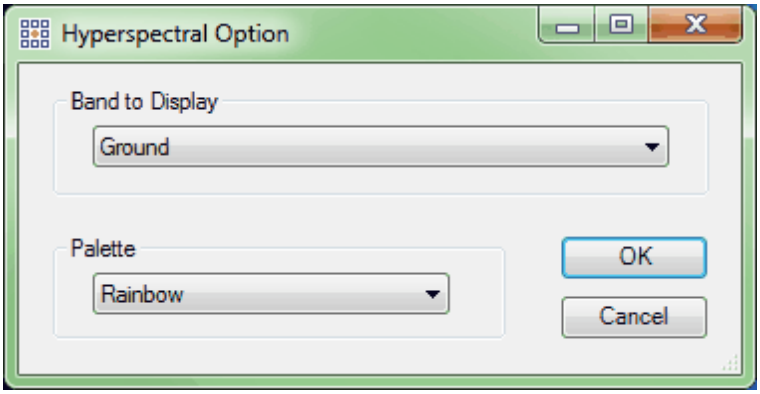


Figure 4: The 'Hyperspectral Option' interface.

The following image (Figure 5) shows the ENVI rendered by the **'Rainbow'** palette, where the 'hotter' colors indicate more returns than the 'cooler' colors. In fact, each square represents the voxel element (in 2D) with the number of returns embedded as an integer value.

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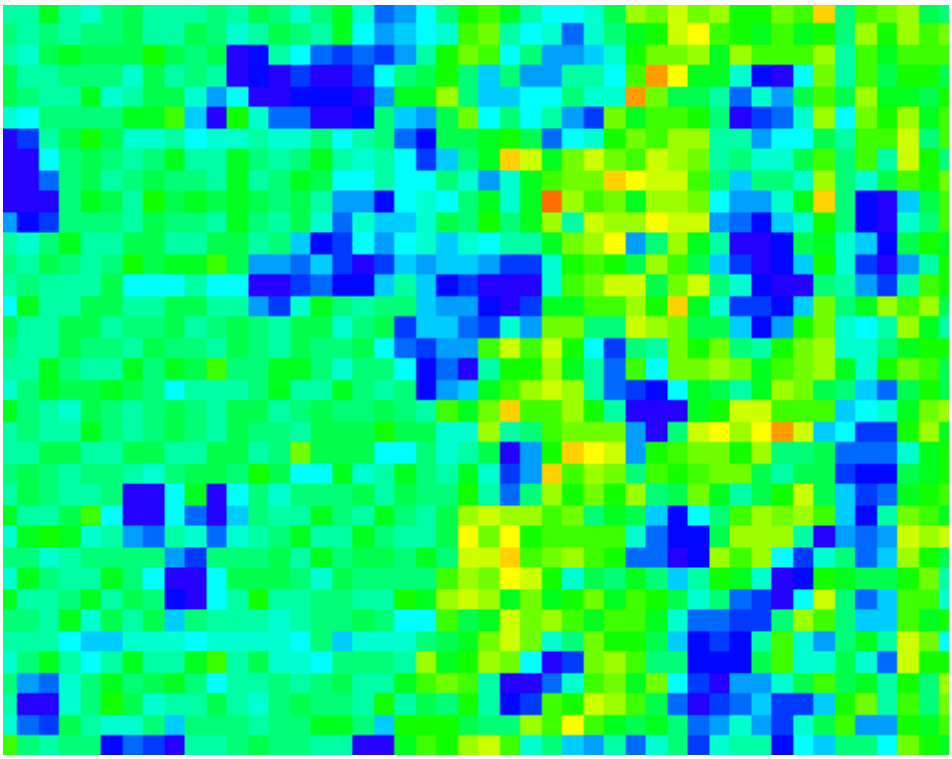


Figure 5: 'Ground' level band results in Rainbow.

Using the **'Band to Display'** drop-down list, the user can select the specific voxel band to display. In the following example (Figures 6a and 6b), the user has selected **'Zone 4'**, which corresponds to the voxels that are between 15.00 – 19.99 units above the ground surface.

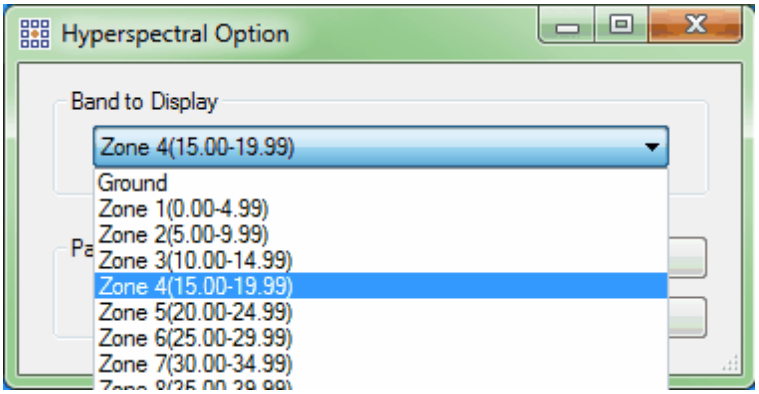


Figure 6a: MARS® Hyperspectral Options dialog – Zone 4 band display.

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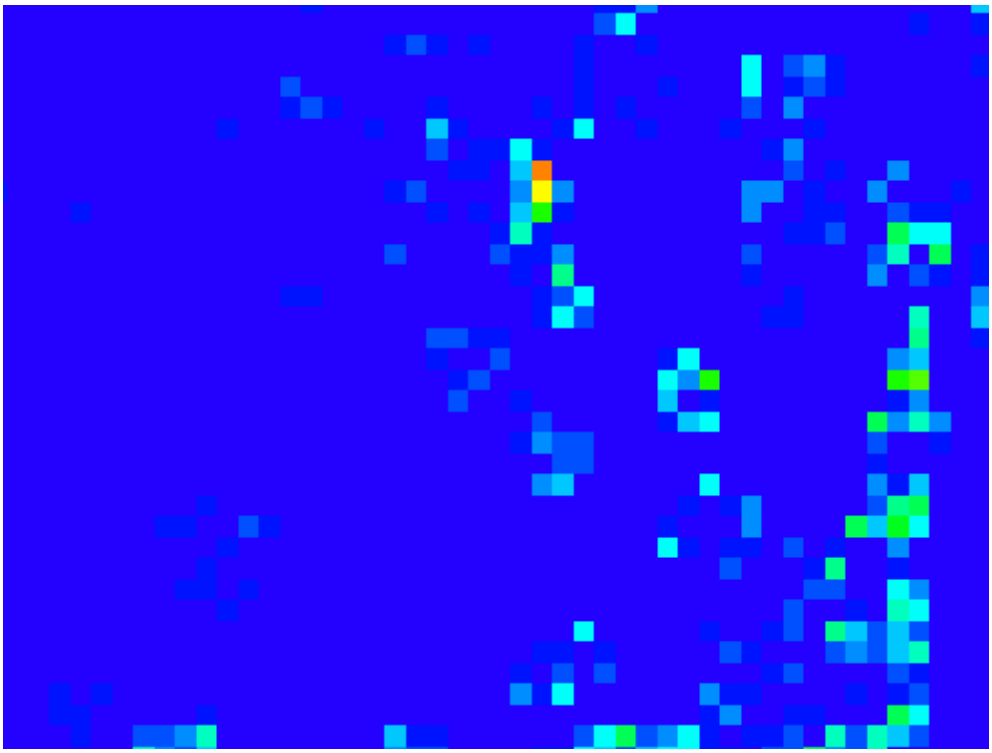
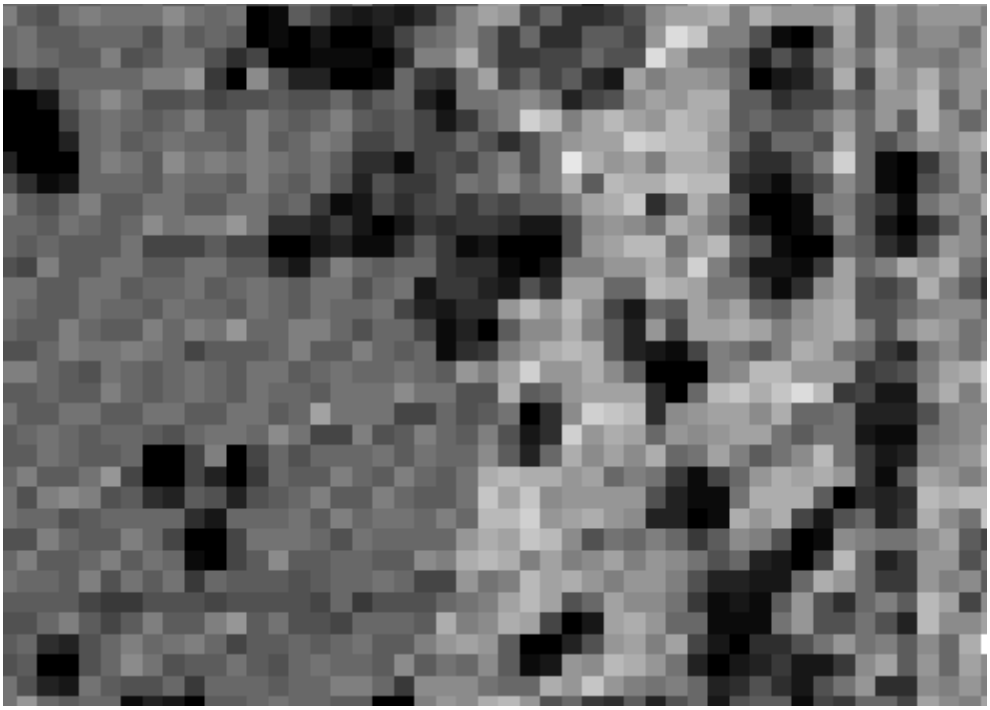


Figure 6b: 'Zone 4' level band results.

The user may also change the ENVI file rendering to **'Grayscale'** (Figure 7) or **'Spectrum'** (Figure 8).



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Figure 7: 'Ground' level band results in Grayscale.

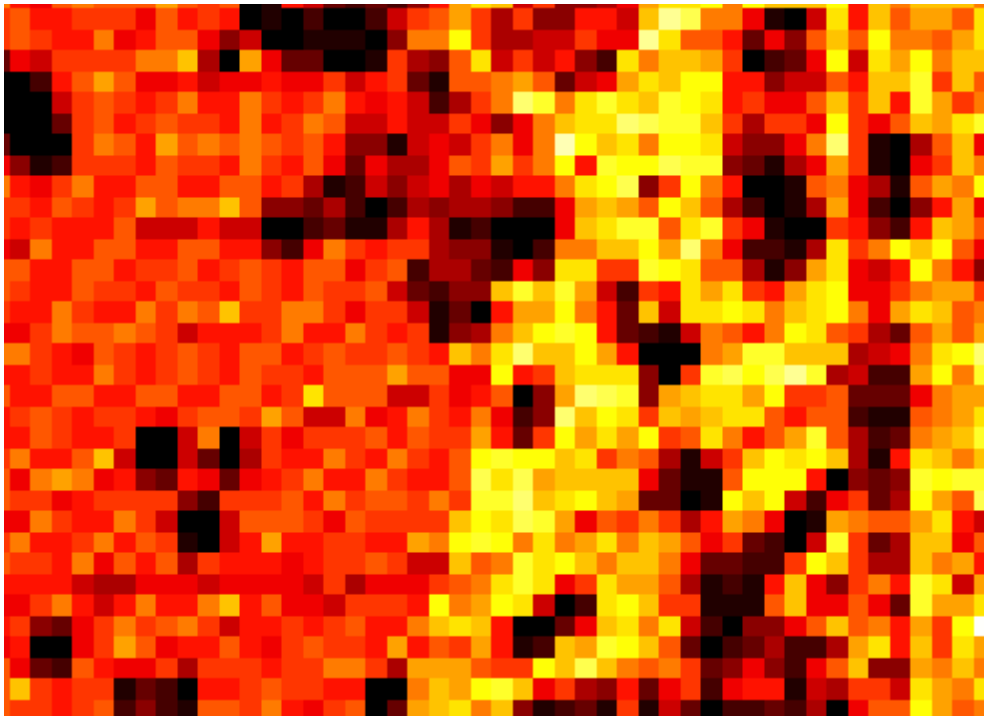


Figure 8: 'Ground' level band results in Spectrum.

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5.2.4 Class Polygons

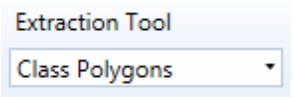


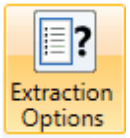
NOTE: The extraction tools, including 'Class Polygons', are not available with the Evaluation license.

The **'Class Polygons'** extraction tool in MARS® is designed to place polygons around any specific class

in any particular area. The difference between the building polygons tool and the class polygons tool is that the building tool takes into account the class and the elevation of the points, whereas the class polygon tool is only concerned with the class of the points in the extraction. This tool may be used to determine areas meeting specific class criteria and output polygons to a 3D shapefile. Uses include placing polygons around tree canopies, determining low confidence areas, and even using return value to eliminate edge matching requirements in ortho procedures.

For details on adding this extraction tool to a macro within a batch script, see the **'Create/Edit Batch Script'** section in the Edit/Filter Tab 270 topic.

To use this extraction tool on loaded data, choose 

from the **'Extraction Tool'** drop-down list on the Export/Extract Tab 461. Click the **'Extraction Options'** 

button, which will bring up the appropriate interface to enter the desired settings.

Requirements:

- Source class(es)
- An output path and shapefile name (shapefile name is ignored when used in a macro script - in this case, naming is determined by the 'Output' tab settings in the Batch Process Tiles 1212 tool.)

Filter Specific Parameters:

- **Source Classifications:** The source classifications designated are the classes which will be targeted for extraction by this tool. In most cases this is a canopy, or vegetation, class - usually Class 3: Low Vegetation, Class 4: Medium Vegetation, and/or Class 5: High Vegetation are used.
- **Step Size:** The user may specify here how much data the extraction tool will work on at a time.

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For example, a step size of 100 means that processing will occur in areas of 100 units x 100 units. In general, the larger the step size the faster the filter will run, but more RAM is used for larger step sizes. The default step size suggested for most projects using this tool is 100.

- **Overlap (%) :** The user may specify the percentage of overlap to be used between adjacent 'Step Size' areas. More overlap percentage allows for a more precise output from the filter but requires a longer running time.
- **Path:** In this area the user can specify an output folder where the resulting shapefile(s) (*.shp) will be stored. This must be specified before the tool can be run. ***If this tool is used multiple times within a*** Batch Script***, or in combination with the 'Area by Slope' and/or 'Building Polygons' tools, be sure to use unique output folders for each instance to avoid overwriting files!***
- **Shapefile Name:** The user specifies the desired shapefile name here. When this tool is used as a step in a macro script that is called by the Batch Process Tiles tool, the shapefile names will match the LAS file naming convention that is set in the batch tool's 'Output' tab. In that case, the entry box can be left blank.
- **Add the result to project:** If checked, adds the resulting shapefiles as reference shapefiles under the 'Vectors' layer. This option is ignored when the tool is used in a Batch Script.
- **Maximum TIN Edge Length:** The maximum length of a TIN edge to qualify as an input into the creation of the grid used in the extraction.
- **Minimum Area:** This value dictates the minimum area (minimum size of a polygon) which will be included in the extraction. No area less than the value specified here will be encircled with a polygon and included in the extraction.
- **Cell Size:** This parameter sets the cell size of the grid created for feature extraction. This value is in the same units as the LAS data (ex. English or Metric) with a default value of 1. The cell size should be set to approximately equal the GSD (ground sample distance).
- **Exclusion Classifications:** Selecting a class(es) here will allow the user to exclude certain points from being included in the polygons generated during extraction. For example, the user may not

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want to include the area of a building (typically Class 6) within a stand of trees.

- **Comments:** This area of the extraction tool allows the user to enter any desired comments. Type any text here and that text will remain for the remainder of the MARS® session, and will be stored permanently if the extraction tool is added and saved to a filter macro script. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Comments box.

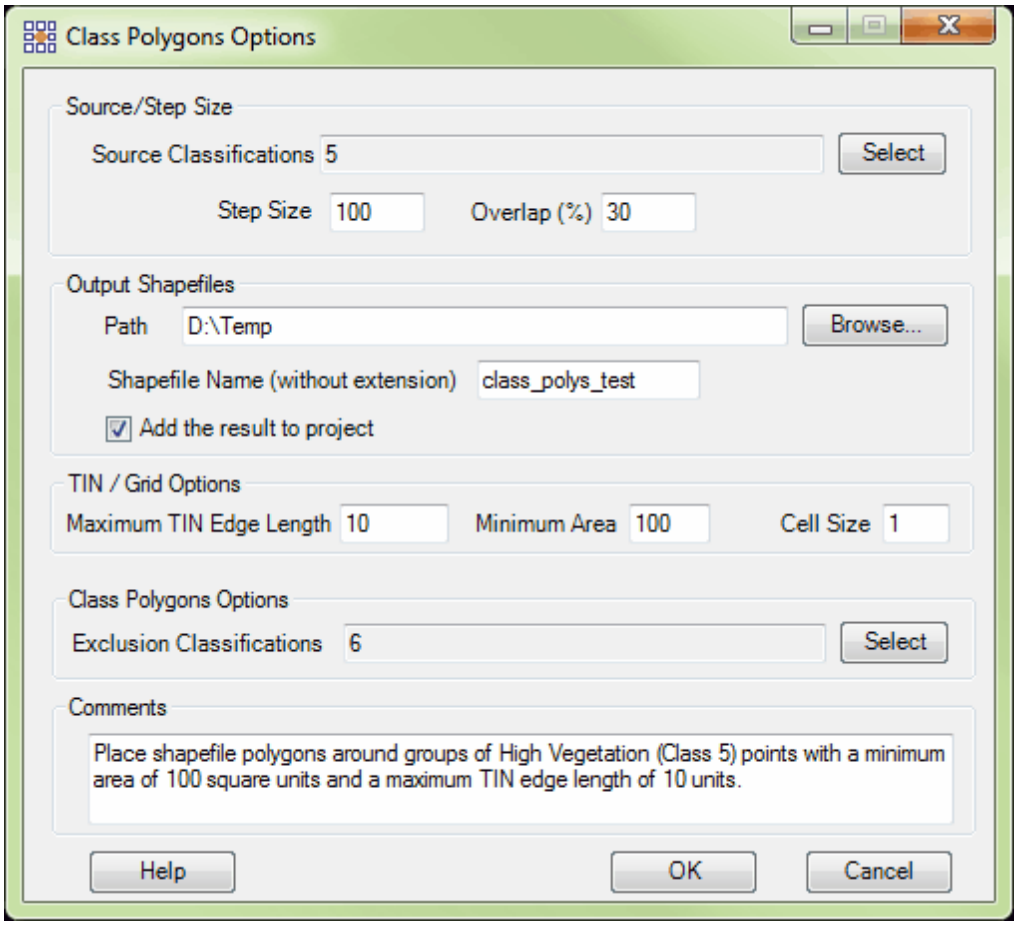
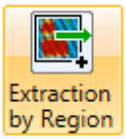


Figure 1: 'Class Polygons Options' interface

Once the user has defined all of the required parameters, an area can be specified for extraction by

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using the **'Extraction by Region'** 

button to click-drag a rectangular area-of-interest (AOI). When the extraction has completed and the new *.shp file is written to the specified directory, it will be loaded into the current MARS® project if the 'Add the result to project' box was checked. If not, it can be loaded manually as a Reference Shapefile 95.

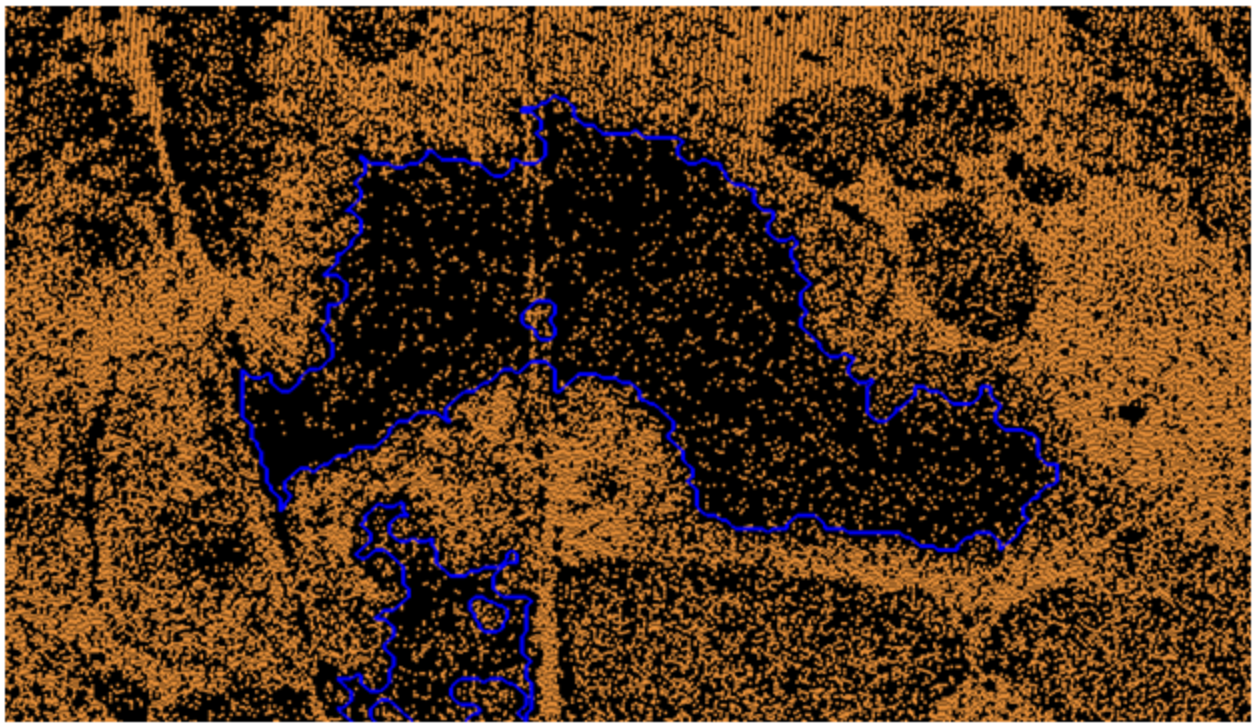


Figure 2: *The Class Polygons tool is being used in the example above to create polygons around low confidence areas. The polygons display the areas of a project in which the ground is obscured and LiDAR penetration is low.*

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5.3 Quick Classifications

Quick Classifications

Merrick Advanced Remote Sensing (MARS®) Software

- **Quick Classifications:** This filtering method - written, distributed, and licensed by ***rapidlasso GmbH*** - uses algorithms and routines that are part of the **LAStools** software suite to classify ground and, optionally, high vegetation and buildings. This tool is found on the Edit/Filter Tab 270. Its use requires that at least part of the LAStools suite ('*lasground_new.exe*' and '*lasground_new64.exe*' at a minimum) be present on the local computer or in an accessible network location that can be pathed out. The minimum required version of **LAStools** for use in MARS® will contain a 'CHANGES.txt' file dated November 8, 2018, or later. The LAStools suite can be downloaded at no charge, but licensing is required to use the classification routines in a commercial, government, or production environment. *Unlicensed use in any setting may cause data corruption!* As taken from the ***rapidlasso GmbH*** website, "Note that the output of the unlicensed version can be slightly distorted after certain point limits are exceeded." Please contact ***rapidlasso GmbH*** by e-mail directly at info@rapidlasso.de for general information including questions about licensing and allowable use, or see the ***rapidlasso GmbH*** website for details. For pricing information, go to https://rapidlasso.de/pricing. Licenses are available for the entire **LAStools** suite, or the components needed for the 'Quick Classifications' tool can be licensed separately at a reduced cost. All licensing, pricing, and payment is handled directly between the end user and ***rapidlasso GmbH*** - Merrick & Company has no involvement at this level. Note that a license purchased for the 'Quick Classifications' tool will authorize the Ground Filter 1036 tool as well.

If the vegetation and building filtering option will be used:

Either two or four additional executable files (*.exe) - depending on the license status - from the

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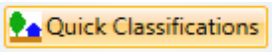
LAStools suite must be in the path entered as in the example shown in the first graphic following the '**License Status**' table. Both '*lasclassify.exe*' and '*lasclassify64.exe*' are needed with or without a license, while '*lasheight.exe*' and '*lasheight64.exe*' are additionally required when no license is present. Remember that unlicensed use is limited (by ***rapidlasso GmbH***) to testing and/or evaluation only.

License Status:

	Licensed	Unlicensed
lasground_new.exe and ***lasground_new64.exe*** files needed:	✓	✓
lasclassify.exe and ***lasclassify64.exe*** files needed:	✓1	✓1
lasheight.exe and ***lasheight64.exe*** files needed:	N/A	✓1

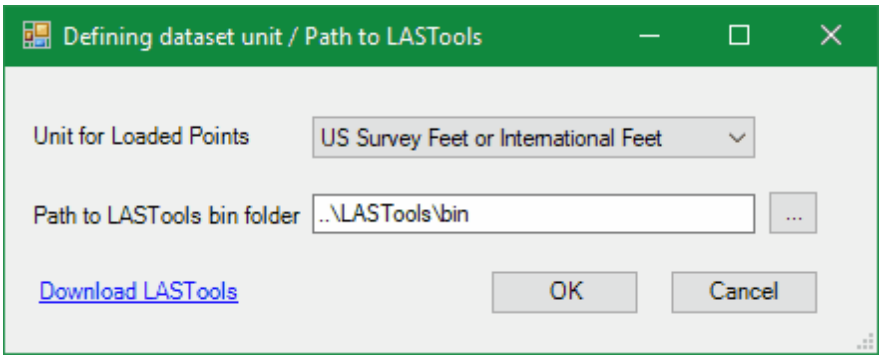
✓1 - required only if the vegetation and building filtering option is used.

As implemented in MARS®, 'Quick Classifications' is used to produce tiled, classified LAS files based on an existing tile layout shapefile. The tool takes unclassified or partially classified data as the input and creates tiled files with ground points and unclassified points, with an option to also classify buildings and high vegetation once ground is known. The input data will not be altered with this tool.

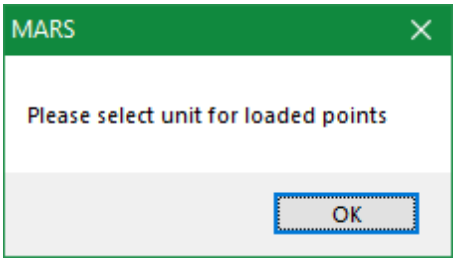
The LAS data to be re-classified must be loaded along with a polygonal tile shapefile that has the same coordinate reference system definition. Once these are loaded, click the 'Quick Classifications' button 

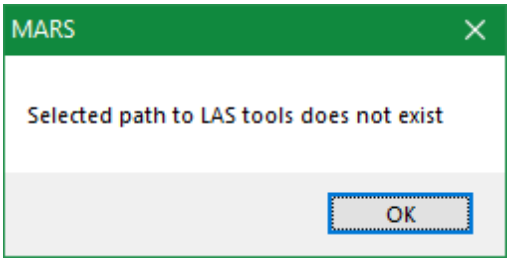
to get started. A window will appear where both the data units and the path to the **LAStools** executable files and the license file (if purchased) must be set. The LAStools software suite can be downloaded from a link on this interface. The minimum required version of **LAStools** for use in MARS® contains a 'CHANGES.txt' file dated November 8, 2018, or later.

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The data units must be set each time the tool is used - a correct entry is critical to the operation and results of the classification routines. The path to the **LAStools** files will be stored for future use, but can be updated if the location of the files is ever changed. If the units are not selected, or the path entered to the LAStools folder does not exist, or the path entered does not contain the minimum required **LAStools** files, the following messages will appear when the 'OK' button is clicked:

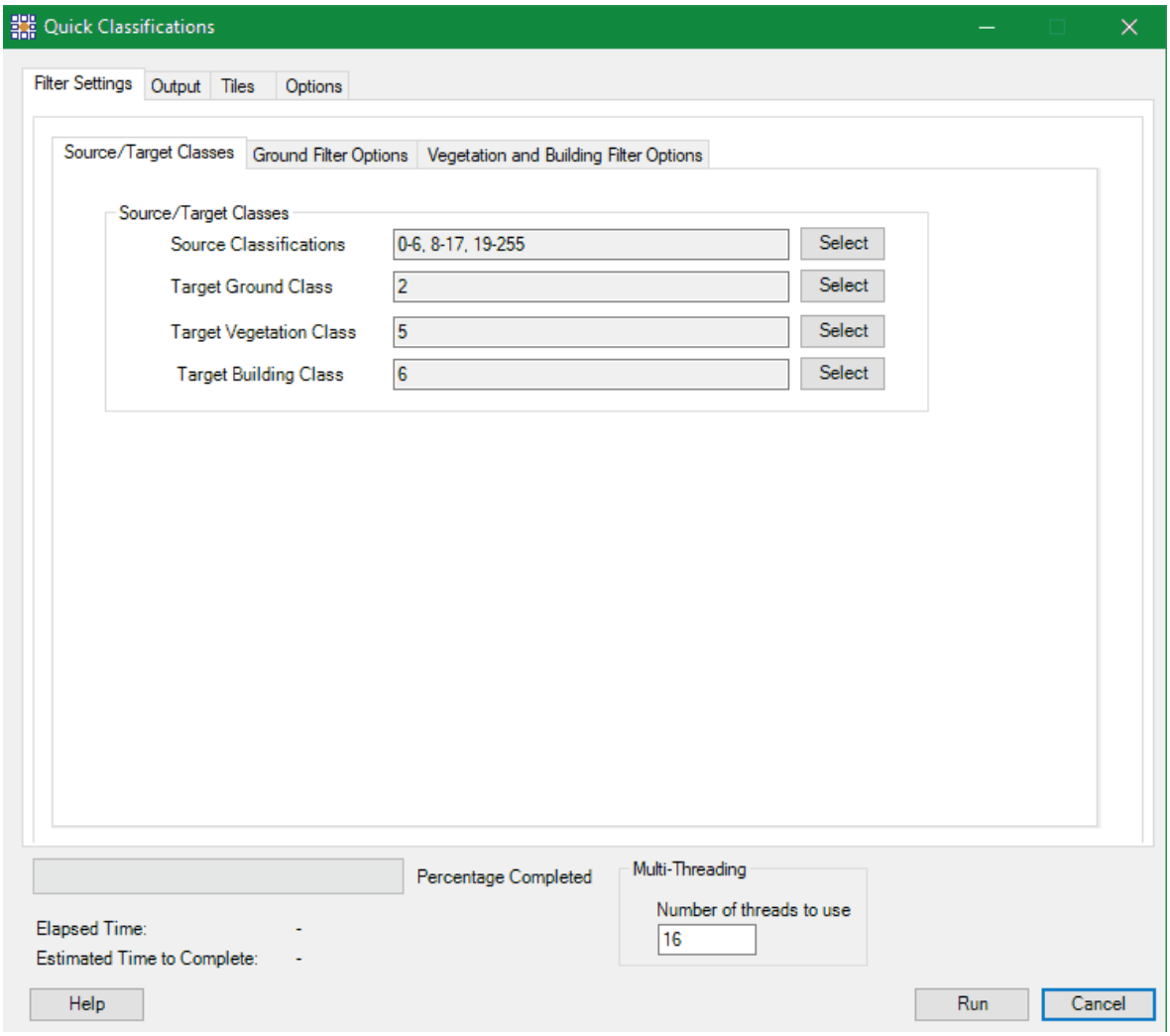




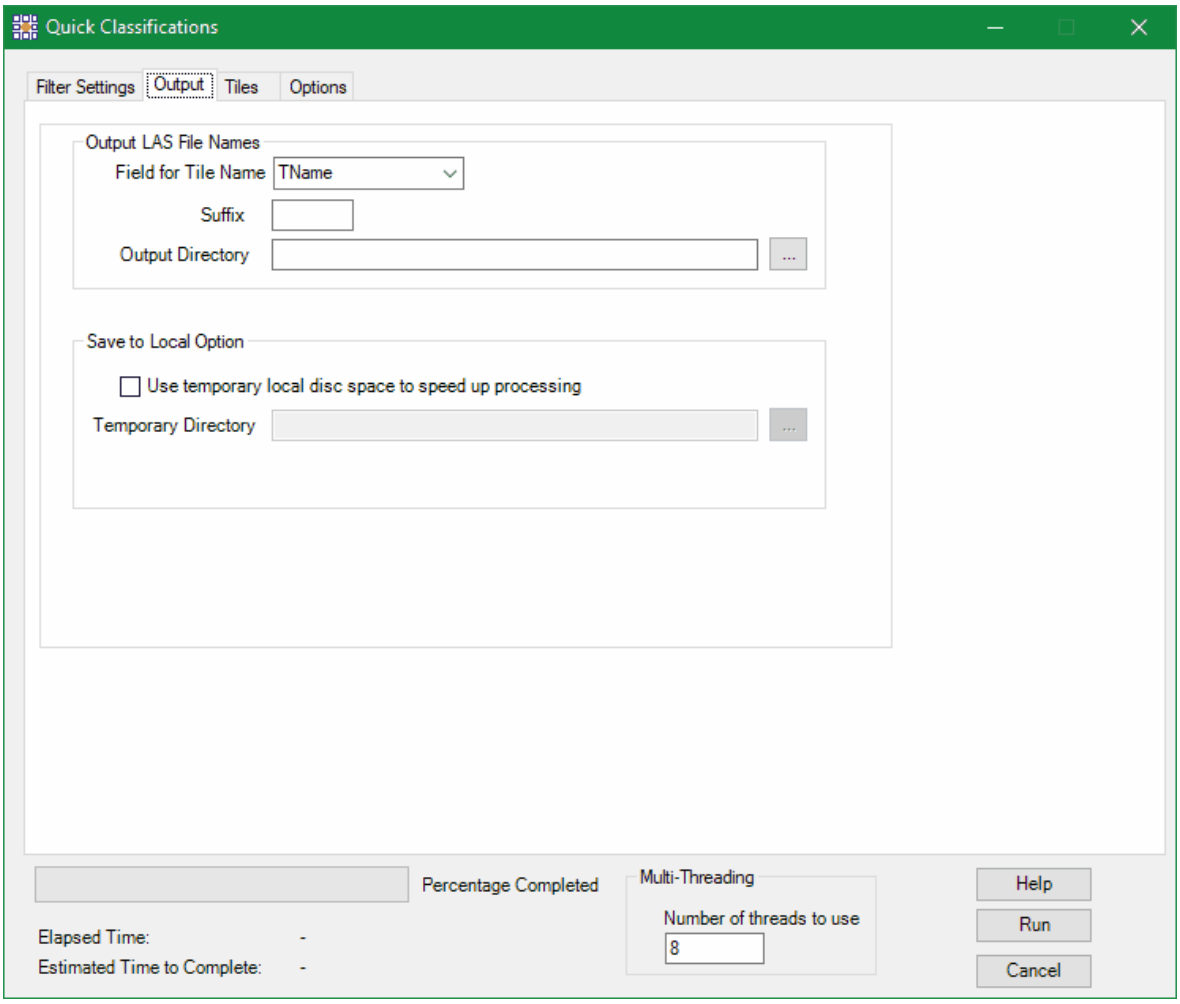


When the data units are entered and a valid **LAStools** path exists, click 'OK' to bring up the main 'Quick Classifications' interface. The interface consists of four tabs:

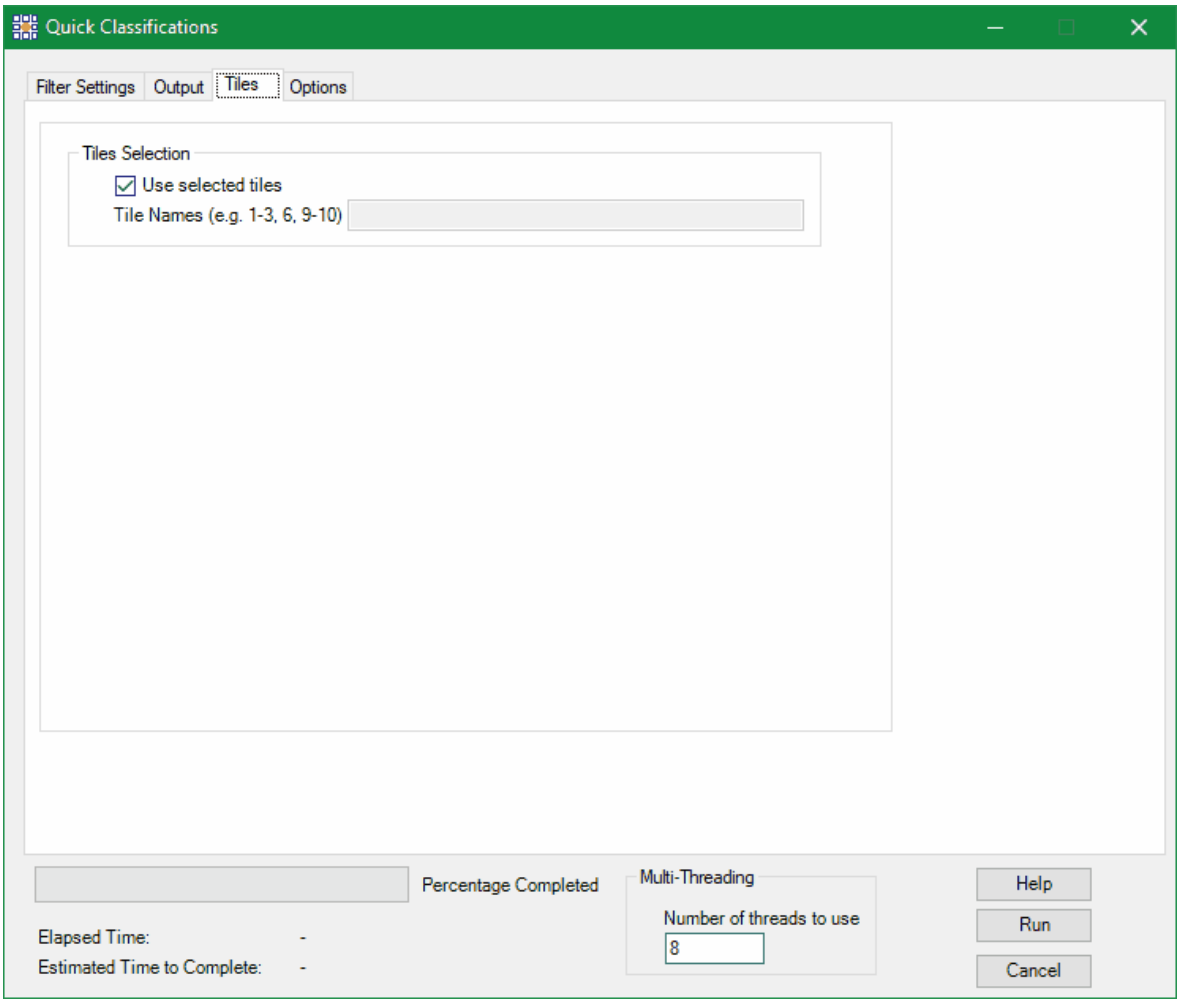
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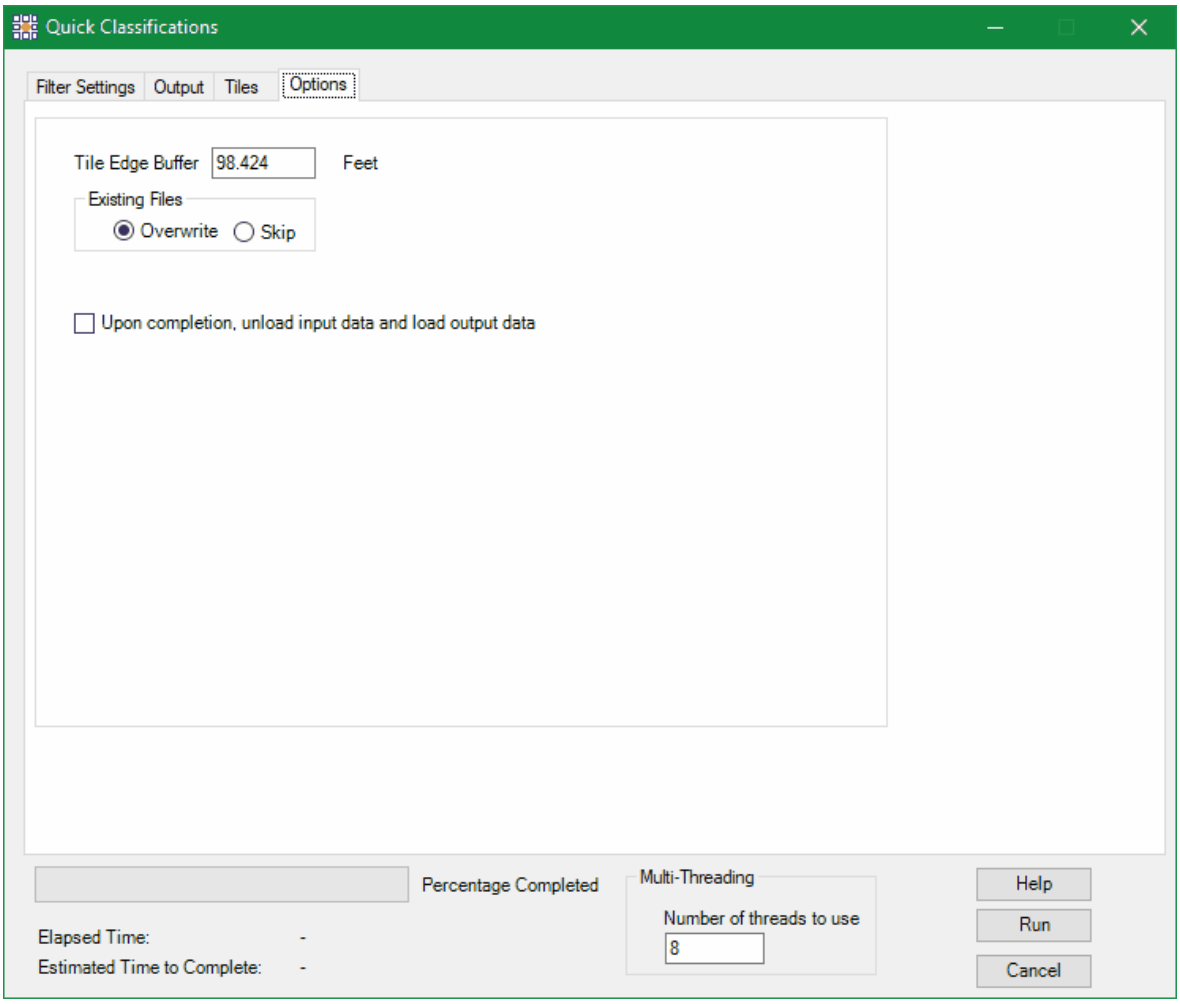
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Filter Settings tab: The Source and Target classes are selected here. By default, all 256 classes are included in the 'Source Classifications', but this can be changed by clicking the 'Select' button. Likewise, defaults are set for the 'Target Ground Class' as well as the optional 'Target Vegetation Class' and 'Target Building Class'. These are based on the ASPRS standard classes for these features, but they can be modified by clicking the appropriate 'Select' button (s). For info regarding the 'Ground Filter Options' and 'Vegetation and Building Filter Options' tabs, see below.

Output tab:

- ***Field for Tile Name:*** Select an attribute field with unique values for the output tile naming.
- ***Suffix:*** Optionally, specify a suffix to be appended to the tile name for the output files.

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NOTE: The naming convention selected will be applied to all output LAS files.

- ***Output Directory:*** Browse to select an output folder where the final processed tiled LAS files will be stored.
- ***Save to Local Option*****:** When the 'Output Directory' is a network location, temporary local disk space can be used to speed up processing. Select this option by checking the box and then specify a temporary local folder with sufficient free space. The 'Temporary Folder' specified WILL NOT be the final output folder, but rather is a local directory which can be used to speed up the processing. The output data will be moved to the 'Output Directory' when all processing is complete. ***NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***

Tiles tab:

- ***Tiles Selection*****:** The 'Use selected tiles' check box is checked on by default. Keep this box checked if the tiles which are to be processed have been selected in the tile layout. If the user would like to run 'Quick Classifications' on other (specified) tiles, enter those tile names (using the 'Field for Tile Name' attribute) into the 'Tile Names' text box separated by commas.

Options tab:

- ***Tile Edge Buffer:*** The default value, as recommended by ***rapidlasso GmbH***, is '30' when the data units have been set to 'Meters'. When 'US Survey Feet or International Feet' is set, the value is automatically converted to 98.424 units. In either case, this value can be modified. This buffer will be added during processing to improve the results, and cut back to the original tile boundary when processing is finished.
- ***Existing Files*****:** The 'Skip' radio button can used as a safeguard if for some reason processing is stopped (e.g., power failure, computer shuts down, an error occurs, etc.). When the user starts processing again, checking this button will cause the software to skip any tiles which already exist in the specified output folder. Tiles which have already been processed will not

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be run again and the software will process only those tiles which are not found in the output folder. (For this reason it is suggested that if processing stops for any reason, the user should go into the output folder and delete the last tile that was processed based on the timestamp. This tile may not be complete, but since the tile name exists in the output folder it would otherwise be skipped.) The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.

- ***Upon completion, unload input data and load output data*:** This option is self-explanatory.

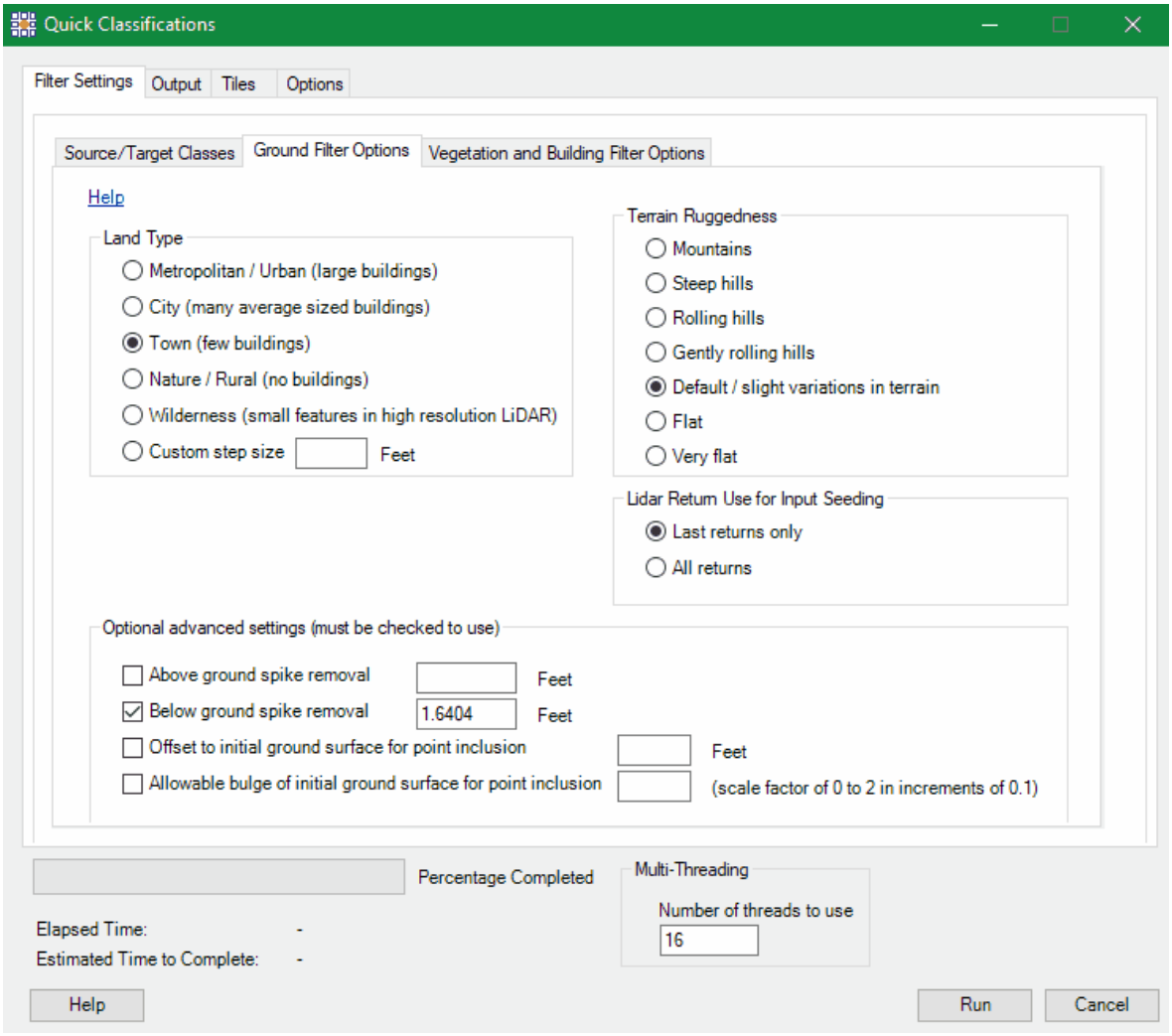
General interface options:

- ***'Multi-Threading'* section:** To help speed up processing, multi-threading is available for this tool. Enter any number of threads from 2 to the maximum number available in the text box. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

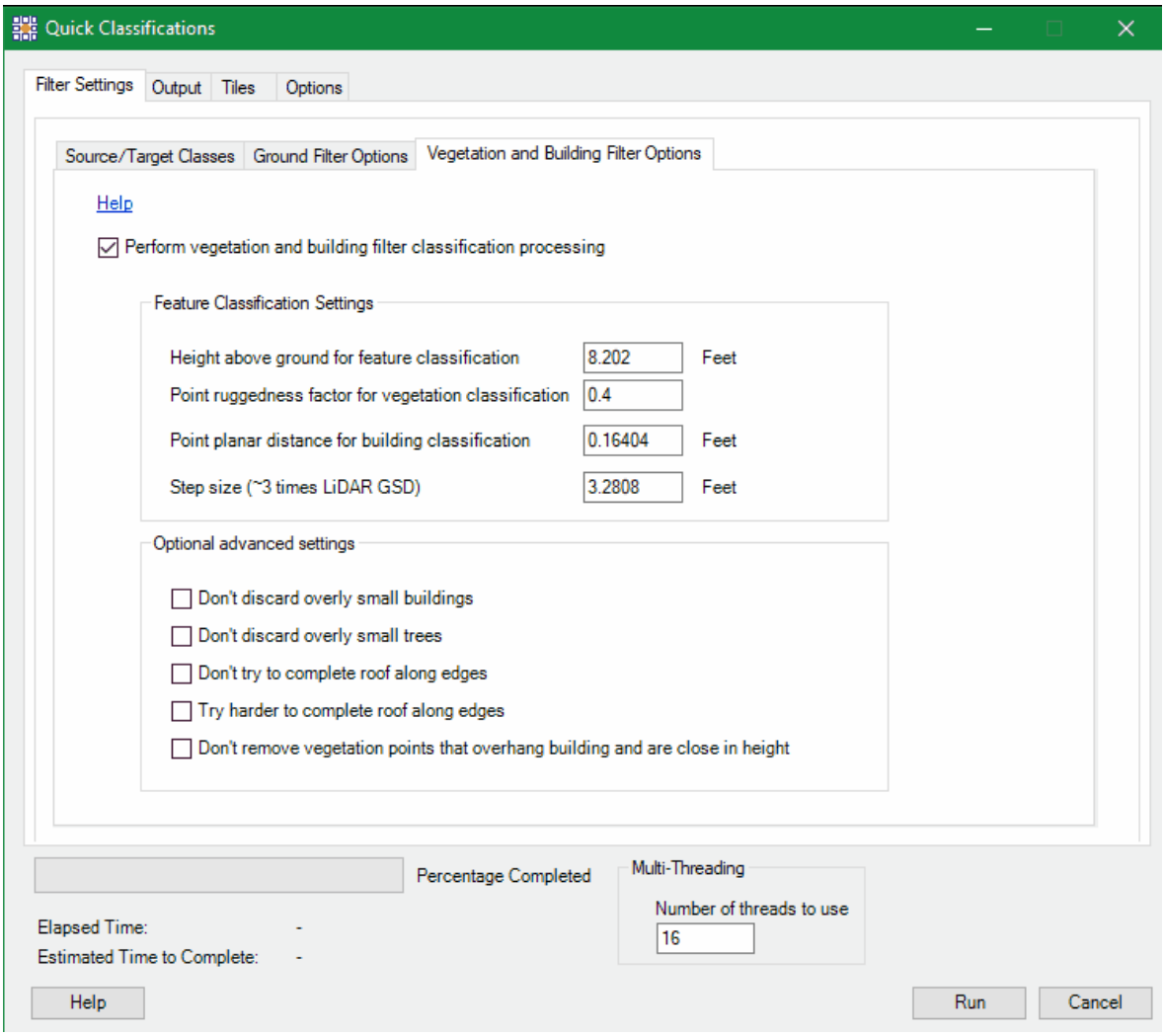
The 'Filter Settings' tab is further divided into 'Source/Target Classes' (see description and upper-left graphic, above), 'Ground Filter Options', and 'Vegetation and Building Filter Options'. By default, the 'Perform vegetation and building filter classification processing' box is checked on the "Vegetation and Building Filter Options' tab. To use this option, '*lasclassify.exe*' (as described near the top of this topic) must exist in the specified LAStools path. The latter two interfaces (shown below) have 'Help' links in the upper-left corners that go directly to the **LAStools** read-me files for 'lasground' and 'lasclassify', respectively. The parameters on these tabs are explained in those read-me files, which are updated and maintained solely by ***rapidlasso GmbH***. The 'lasground' read-me file is based on an earlier (but very similar) iteration of the ground classification executable. As of the release date of this version of MARS®, **LAStools** was not yet hosting a read-me file for the '*lasground_new.exe*' executable that is used in this batch filter tool. However, it is available in the downloaded LAStools suite package as '*lasground_new_README.txt*'. All the controls and entries on this tab feed directly

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into the arguments of the **LAStools** *'lasground_new.exe'* file. All the controls and entries within the red boxes (see below) feed directly into the arguments of the **LAStools** executables. When all settings have been made, click the 'Run' button in the lower-right corner of the interface.

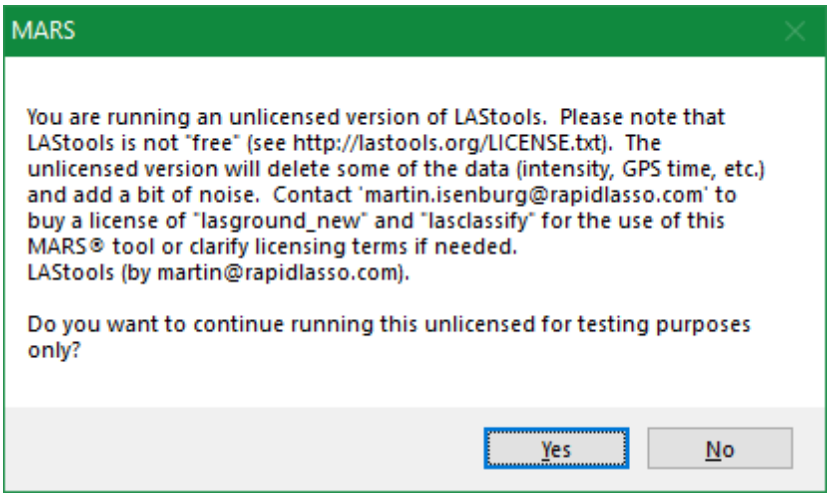


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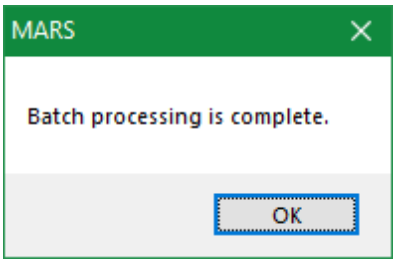
If a license for **LAStools** has not been purchased or is not present in the path to the executable files, the following warning message will appear immediately after clicking 'Run':

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See the notes in the first two paragraphs of this topic regarding unlicensed use.

The following message will appear when the 'Quick Classifications' routine is finished:



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5.4 Batch Filter/Extraction Processing

Batch Script Processing

Merrick Advanced Remote Sensing (MARS®) Software

Multiple filter/extraction algorithms can be aggregated into a macro (or macros) within a batch script. Each macro is a collection of filters and/or extraction tools within an XML file that will be run in sequence over the selected tiles of the project. There is no limit to the number of macros or filters/

extraction tools within a macro that can be included within a batch script XML file.

Utilizing this batch processing technique allows the user to filter and/or extract from very large LAS datasets more quickly by dividing the work among multiple threads and outputting tiles of the filtered data. The output of the 'Create/Edit Batch Script' 270 function is an XML file which is used by the **'Batch Process Tiles'** tool to control the filtering/extracting steps. Within each batch script, the user must define the macro name(s) and the required parameters for each filter/extraction tool algorithm within a macro.

To use batch processing, please follow these steps:

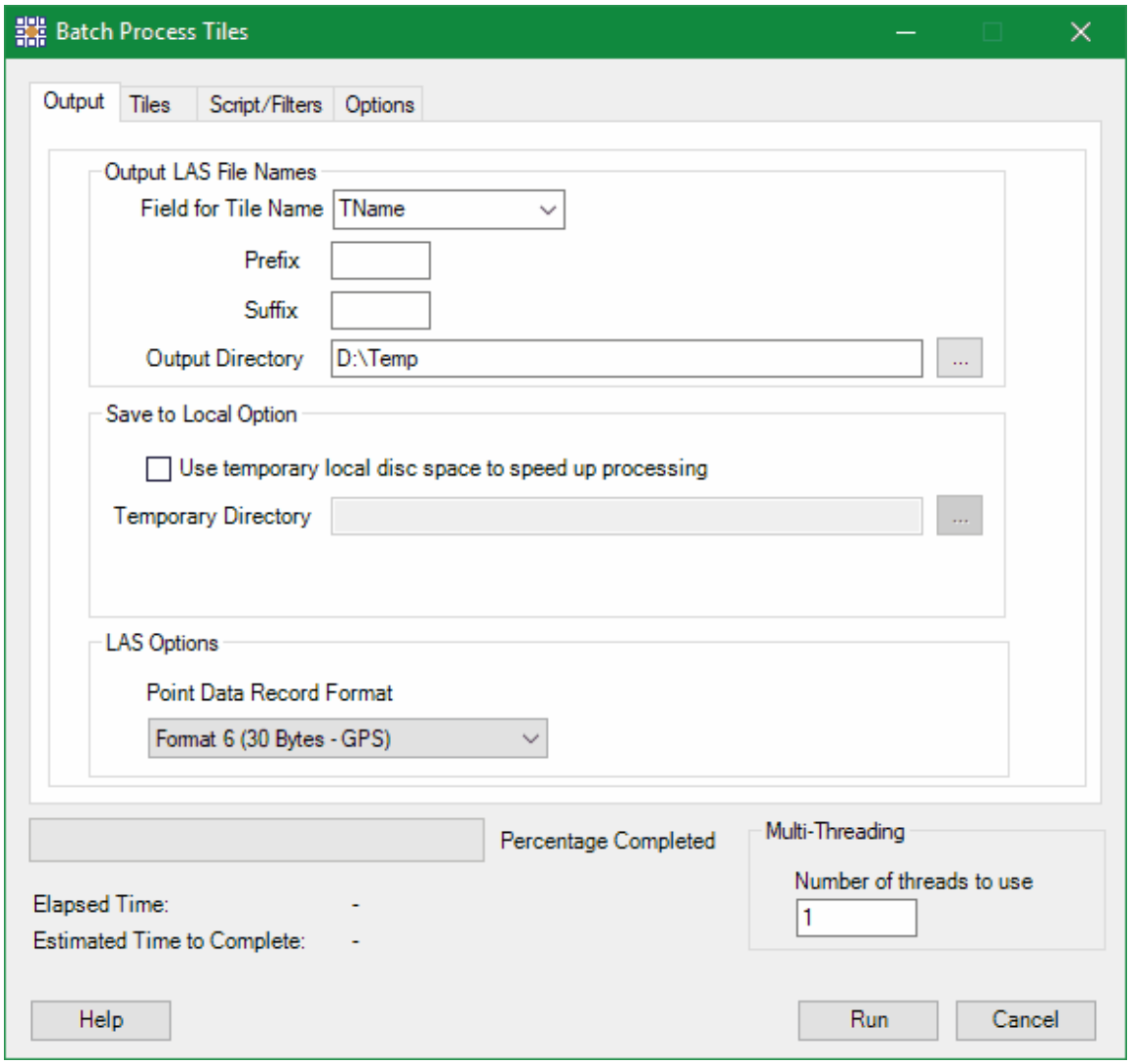
1.) Start by loading the LiDAR data to be processed and a tile layout shapefile. Batch processing must have a tile shapefile loaded so that the desired tiles can be chosen for processing. To load a tile shapefile, go to the 'Project/Data Preparation 162' tab and click '**Add Tile Shapefile**'. Browse to the required shapefile and select '**Open'.**

2.) Once a tile shapefile is loaded, go to the 'Edit/Filter 270' tab and use the **'Pick Tiles'** tool to select the tiles which will have the batch script run on them. (To learn more about how to select tiles, see the Pick Tiles 960 utility.)

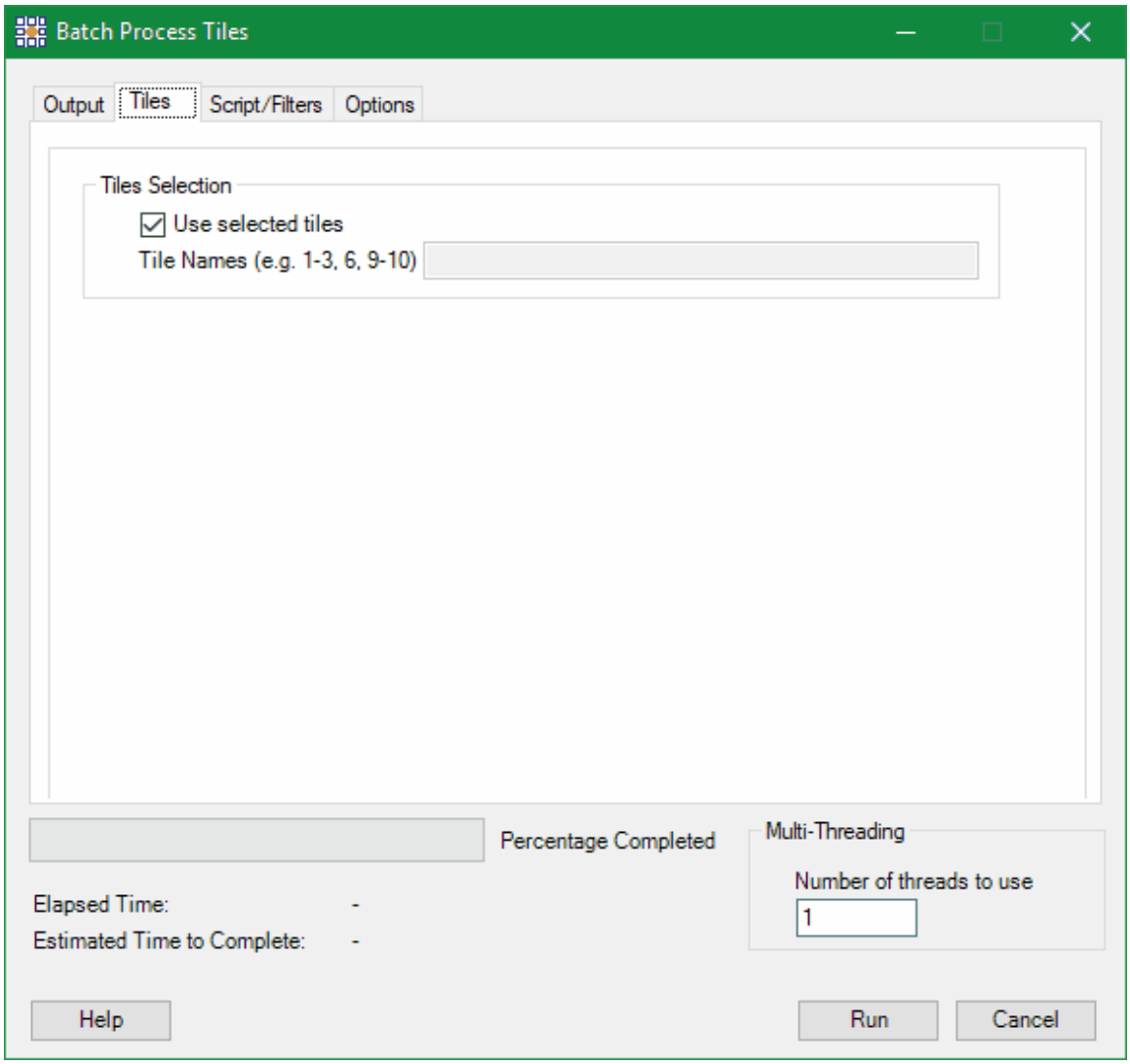
3.) Next, select the '**Batch Process Tiles**'  button on the same tab.

4.) The 'Batch Process Tiles' dialog box will appear. Select and specify the parameters (see below) on each of the individual tabs and at the bottom of the interface.

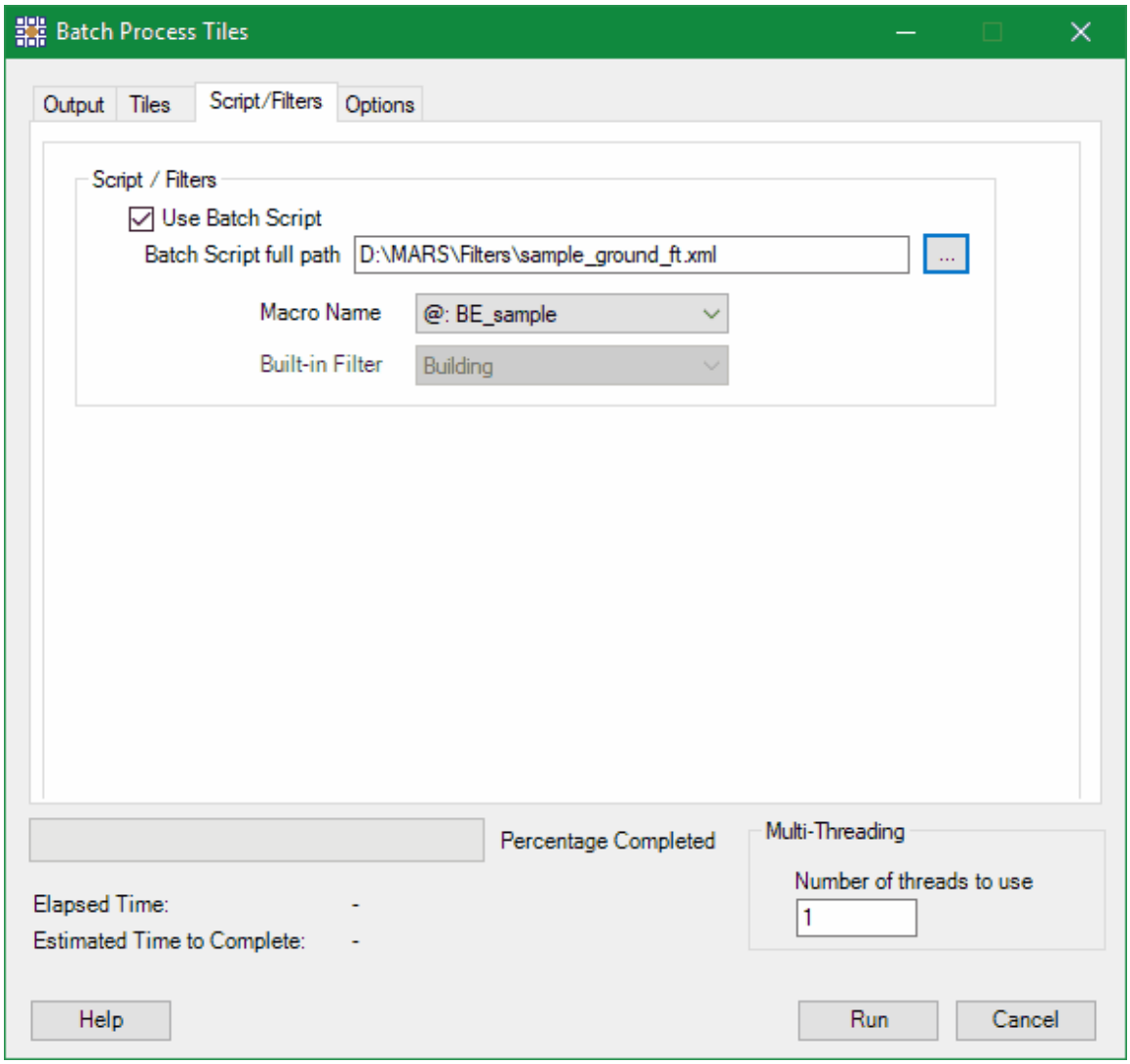
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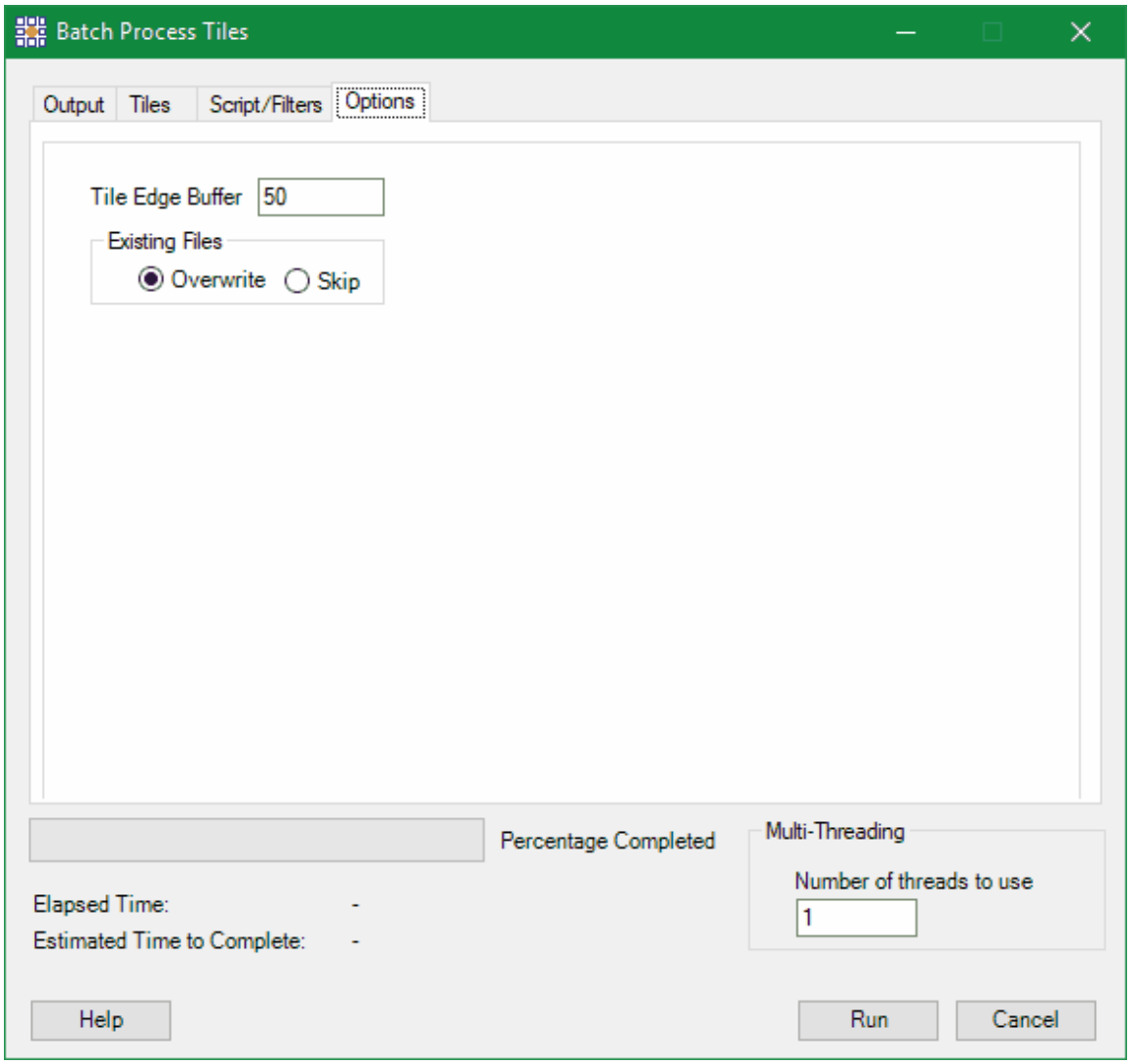
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Output tab:

- ***Field for Tile Name:*** Select an attribute field with unique values for the output tile naming.
- ***Prefix and/or Suffix:*** Optionally, specify a prefix and/or suffix to be appended to the tile name for the output files.

  NOTE: The naming convention selected will be applied to all output LAS files as well as any shapefiles that are created when the 'Area by Slope', 'Building Polygons', and/or 'Class Polygons' extraction tools are used in a script.

- ***Output Directory:*** Browse to select an output folder where the final processed tiled LAS files

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will be stored.

NOTES:

1. When a macro script contains only the extraction tool 'Class Polygons', no tiled LAS files will be produced in this folder as the tool produces only shapefiles that will be stored in the path specified on the 'Class Polygons' options interface.
2. When a macro script contains only the extraction tools 'Area by Slope' and/or 'Building Polygons', no tiled LAS files will be produced in this folder unless the 'Reclass Interior Points' option is used on the tool's options interface.
3. Any shapefiles that are created when the 'Area by Slope', 'Building Polygons', and/or 'Class Polygons' extraction tools are used in a script will be written to the folders specified on those tools' options interfaces, not the 'Output Directory' where the tiled and filtered LAS files will be stored. ***Always use unique output folders for each instance of these extraction tools within a script to avoid overwriting files!***

- ***'Save to Local Option'* section:** When the 'Output Directory' is a network location, temporary local disk space can be used to speed up processing. Select this option by checking the box and then specify a temporary local folder with sufficient free space. The 'Temporary Folder' specified WILL NOT be the output folder, but rather is a local directory which can be used to speed up the batch processing. The final output data will be moved to the 'Output Directory' when all processing is complete. ***NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***
- ***'LAS Options'* section:** Choose between three 'Point Data Record Format' choices - 6, 7, or 8. Data will be output in the same GPS time format as the input data unless the input data is in mixed format (GPS Week Time and Adjusted GPS Time). In this case, a pop-up message will offer two options: 1) continuing with the process, in which case the output data will all be in GPS Week Time or, 2) canceling so that the GPS Week Time data can first be converted to

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Adjusted GPS Time using the 'GPS Time Conversion 570' tool on the Tools 389 tab.

Tiles tab:

- ***'Tiles Selection'* section:** The 'Use selected tiles' check box is checked on by default. Keep this box checked if tiles which are to be processed have been selected in the tile layout. If the user would like to run the script on other (specified) tiles, enter those tile names (using the 'Field for Tile Name' attribute) into the 'Tile Names' text box separated by commas.

Script/Filters tab:

- ***'Script / Filters'* section:** Choose a custom batch script or use a discrete built-in filter. If the user checks the 'Use Batch Script' box then the 'Batch Script full path' and the 'Macro Name' will need to be defined. Choose this box only if there is an XML file already created and ready to use. (In many cases this will be the XML containing a macro used to test data for filtering with the debug tools on the Edit/Filter Tab 270). To browse to a script which has already been created, use the '...' (ellipsis) button to the right of the 'Batch Script full path' text box and navigate to the XML file. Once this path has been defined, the user can choose the 'Macro Name' (if the script contains more than one macro) to be used from the drop-down box which will be populated when the 'Batch Script full path' is defined. If there is no script XML already created, the 'Use Batch Script' box must be unchecked. When this box is unchecked, the 'Built-in Filter' option becomes available. Choose a built-in method for filtering from the drop-down list.

Options tab:

- ***Tile Edge Buffer:*** The user may choose to add a buffer to each tile as it is processed. The buffer (in project units) will be added during processing and cut back to the original tile boundary when processing is finished. A larger buffer will more accurately process the data around the edges of the tiles, but will take longer to run. A typical default buffer size is 50 - 100 units.
- ***'Existing Files'* section:** The 'Skip' radio button can used as a safeguard if for some reason

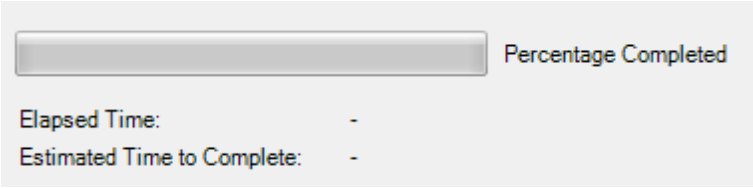
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processing is stopped (e.g., power failure, computer shuts down, an error occurs, etc.). When the user starts processing again, checking this button will cause the software to skip any tiles which already exist in the specified output folder. Tiles which have already been processed will not be run again and the software will process only those tiles which are not found in the output folder. (For this reason it is suggested that if processing stops for any reason, the user should go into the output folder and delete the last tile that was processed based on the timestamp. This tile may not be complete, but since the tile name exists in the output folder it would otherwise be skipped.) The 'Overwrite' radio button will cause the software to start processing from the beginning and silently overwrite all the files in the output folder.

General interface options:

- ***'Multi-Threading'* section:** To help speed up batch processing, multi-threading is available for this tool, but only when running a batch script (XML) - single thread processing is used when an individual filter has been chosen. Enter any number of threads from 2 to the maximum number available in the text box. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

5.) When all the parameters have been set, click the 'Run' button to start processing. The progress bar will not become active until the first tile has been completed. This is because the software will estimate the total amount of time for processing based on the time per tile. The elapsed time and estimated time remaining for processing will also be shown below the progress bar.



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6.) When processing is complete, a log file will be created in the same folder that was specified for the output tiles. This output log stores the details of the batch process such as the total elapsed time, the list of tiles handled by each thread (threads will be shown as 'Process 0' through 'Process <*n*>'), the time it took to run each tile, the filters/extraction tools run on each tile, and how long it took each filter/extraction tool to run on each tile. See below for an example of an output log:

```
=============== Process 7 ================
Tile List: 9,16
Started at: 3:24:44 PM Wednesday, December 11, 2013
Processing tile: 9
Reading XML complete with total functors of 8.
Tile# 1/2 Filter# 1/8 ReclassifyFilter: 0 s
Tile# 1/2 Filter# 2/8 ReturnFilter: 0 s
Tile# 1/2 Filter# 3/8 MinGridFilter: 0 s
Tile# 1/2 Filter# 4/8 HeightFromSurfaceFilter: 0 s
Tile# 1/2 Filter# 5/8 ReclassifyFilter: 0 s
Tile# 1/2 Filter# 6/8 PercolateFilter: 6 s
Tile# 1/2 Filter# 7/8 PercolateFilter: 6 s
Tile# 1/2 Filter# 8/8 ReclassifyFilter: 0 s
Total Elapsed time for the tile: 15 s
Processing tile: 16
Reading XML complete with total functors of 8.
Tile# 2/2 Filter# 1/8 ReclassifyFilter: 0 s
Tile# 2/2 Filter# 2/8 ReturnFilter: 0 s
Tile# 2/2 Filter# 3/8 MinGridFilter: 0 s
Tile# 2/2 Filter# 4/8 HeightFromSurfaceFilter: 1 s
Tile# 2/2 Filter# 5/8 ReclassifyFilter: 0 s
Tile# 2/2 Filter# 6/8 PercolateFilter: 10 s
Tile# 2/2 Filter# 7/8 PercolateFilter: 8 s
Tile# 2/2 Filter# 8/8 ReclassifyFilter: 0 s
```

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```
Total Elapsed time for the tile: 20 s
Ended at: 3:25:21 PM Wednesday, December 11, 2013
Total Elapsed time: 36 s
================================================
Started at: 3:24:44 PM Wednesday, December 11, 2013
Ended at: 3:25:36 PM Wednesday, December 11, 2013
Total Elapsed time: 51 s
```

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6 Quality Control



Quality Control (QC) Tools

QA/QC Methodologies

The MARS® software suite can be used to monitor and analyze data collection activities and client data deliveries. The following quality control methodologies represent only a portion of the overall quality control procedures available with MARS®, but these tools do provide an accurate assessment of potential data quality issues. The license level (Production, Explorer QC, or Explorer) needed for each tool or function can be found in the Functionality Matrix 23.

The following is a list of the most frequently used QA/QC procedures:

- ✓ Check Point Report 1224
- ✓ Color By Collection Scan Separation Analysis 1718
- ✓ Color By Z Delta Analysis 1731
- ✓ Contour By Collection Scan Analysis 1733
- ✓ Cross-Section/Profile Analysis 1738
- ✓ Swipe Raster Over LiDAR Tool 1744
- ✓ Coverage Tracking Tools 1745
- ✓ Swath shapes to overlap JP2 1745

QC Module (on the QA/QC Tab 458):

USGS NGP LBS 1313 options:

ASPRS 1659 options:

Other 1675 options:

USGS 2025 rev. A QC Module 1315

Voronoi Density Reporting 1660

LiDAR Workflow QC - 1

LiDAR Data Checks 1677

USGS 2024 rev. A QC Module 1351

LiDAR Workflow QC - 2 LiDAR

Calibration Checks 1698

USGS 2023 rev. A QC Module 1386

USGS 2022 rev. A QC Module 1421

USGS 2021 rev. A QC Module 1455

USGS 2020 rev. A QC Module 1490

USGS 2.1 QC Module 1525

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USGS 1.3 QC Module 1559

USGS 1.2 QC Module 1592

USGS 1.0 QC Module 1622

Raster QC 1651

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6.1 Check Point Report

Check Point Report

Merrick Advanced Remote Sensing (MARS®) Software

Overview

A typical LiDAR project (one that includes collection of ground features) can be checked for 3D 1283 and/or Vertical Accuracy 1236 in MARS® using the methods and standards described in the **ASPRS Positional Accuracy Standards for Digital Geospatial Data** (Edition 2, Version 2), published in June 2024. An abbreviated method for vertical testing - known as 'RMSEz testing (Product Fit to Checkpoints)' - can be used when survey accuracy values are not available. Note that there are no established standards for the RMSEz method.

For LiDAR data that has been corrected for systematic errors, the project's derived ground surface can be validated against the ground check points via the Check Point Report utility within MARS®. The four types of check points used by this tool and referenced in this help topic are: **NVA** (Non-Vegetated Vertical Accuracy), **VVA** (Vegetated Vertical Accuracy), **3D** (an NVA point whose XY location is identifiable in an intensity rendering of the lidar data), and **2D** (a 3D point whose Z-value has been determined to be unusable). This tool verifies the accuracy requirements for the LiDAR data and

serves as a critical tie between project control and coordinate systems. For Vertical Accuracy 1236 testing, MARS® allows the user to specify the desired USGS Quality Level/Vertical Accuracy Class for the statistical analysis of the LiDAR dataset against the check points. For 3D Accuracy 1283 testing, a Three-Dimensional Accuracy Class is selected for the statistical analysis. The report compares the accuracy of the remotely collected data with the known points on the ground, which can help uncover data integrity issues within the dataset.

Check points must be stored in a *.CSV file, and must have one of the following two formats. **NOTE** - ***Do Not Use*** commas in any entries in the CSV file - either in the column headers or in any of the values for the check points. By definition, CSV means Comma Separated Values, and the use of commas within cells may cause the file interpreter to store incomplete values or store them for the wrong field.

1. For complete 3D 1283 and/or Vertical Accuracy 1236 testing, a ***13-column CSV-format file*** consisting of **Point ID, XYZ coordinates, Description** (entries optional)**, NVA / VVA / 3D** point types (values optional), **Collection Date** (values optional), horizontal and vertical survey accuracies, point exclusion status (values optional), and point exclusion comments (entries optional) that must be formatted in the following order:

- **ID** - unique identifier for each individual check point. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **X** - check point Easting coordinate. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **Y** - check point Northing coordinate. Any unique name can be used for this field. This column (with the name in the first row) must be present and

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populated for every point.

- **Z** - check point Elevation value. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **X_Meas** - Easting coordinate of user-measured point or line intersection. Any unique name can be used for this field. This column (with the name in the first row) must be present and will initially be blank until populated as described in the 3D Accuracy 1283 help topic. Values are not required for Vertical Accuracy 1236 testing.
- **Y_Meas** - Northing coordinate of user-measured point or line intersection. Any unique name can be used for this field. This column (with the name in the first row) must be present and will initially be blank until populated as described in the 3D Accuracy 1283 help topic. Values are not required for Vertical Accuracy 1236 testing.
- **Desc** - description of check point (often location related, such as *parking lot* or *intersection*). Any unique name can be used for this field. This column (with the name in the first row) must be present even if no descriptions are populated. If used, not every row (point record) in the file needs a value for this field.
- **N_V_3D_2D** (Type) - The type of check point - NVA, VVA, 3D, or 2D - as described above. Any unique name can be used for this field. This column (with the name in the first row) must be present even if no types are populated. If used, not every row (point record) in the file needs a value for this field. The **2D** type may be present in a CSV file if a determination has been made that one or more 3D points does not have a usable Z-value. There is a function within the Check Point Report tool to convert 3D check points to

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2D in this situation. Any value that is not stored exactly as **3D, 2D,** or **VVA** (not case-specific) or is empty will be interpreted as **NVA**. One or more check points must be stored as **3D** for either 3D Accuracy 1283 testing or the 'RMSEv testing (Vertical Product Accuracy 1244)' method. For vertical testing only, one or more check points must be stored as **NVA** for the 'RMSEv testing (Vertical Product Accuracy 1244)' method.

- **Coll_Date** - the date that each check point was collected (surveyed). Any unique name can be used for this field. This column (with the name in the first row) must be present even if no dates are populated. If used, not every row (point record) in the file needs a value for this field. The date format must be either MM/DD/YYYY or YYYY-MM-DD to be interpreted correctly.
- **$RMSE_{H2}$** - survey check point accuracies for the X and Y (horizontal) values. Any unique name can be used for this field. Values are required for the **3D** and **2D** type check points for 3D Accuracy 1283 testing.
- **$RMSE_{V2}$** - survey check point accuracies for the Z (vertical) values. Any unique name can be used for this field. Values are required for the **3D** type check points for 3D Accuracy 1283 testing, and also for any **NVA** type check points for the 'RMSEv testing (Vertical Product Accuracy 1244)' method.
- **Include** - the status of each check point (included or excluded from analysis). Any unique name can be used for this field. If used, not every row (point record) in the file needs a value for this field. Any value that is not stored exactly as **No** (not case-specific) or is empty will be interpreted as a true statement, meaning the check point will be included in the analysis.
- **Incl_notes** - if the check point has its 'Include' field set to '**No**,' this free-form text field can be used for storing optional notes about why this check point is being excluded. Any unique name can be used for this field.

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	A	B	C	D	E	F	G	H	I	J	K	L	M
1	ID	X	Y	Z	X_Meas	Y_Meas	Desc	N_V_3D_2D	Coll_Date	RMSE_H2	RMSE_V2	Include	Comments
2	1001	687378.315	4043709.207	134.281				NVA	3/15/2024	0.013	0.034	Y	
3	1002	791846.154	4050394.942	88.365				NVA	3/21/2024	0.013	0.016	Y	
4	1003	715087.356	4080224.943	194.76				3D	3/16/2024	0.01	0.02	Y	
5	1004	806999.401	4135145.286	130.098	806999.462	4135145.267		3D	3/25/2024	0.017	0.006	Y	
6	1005	724031.022	4103465.798	201.662				NVA	3/27/2024	0.002	0.011	Y	
7	1006	826498.751	4092506.49	98.078	826498.778	4092506.406		3D	3/24/2024	0.01	0.058	Y	

The first row of the file must contain column headers (labels) and not actual check point values. As mentioned above, the column headers do not have to be named as shown in the examples. All 13 columns must be present and in the listed order, and must be labeled in the first row. Requirements for values in columns 5, 6, 8, 10, and 11 are detailed in the listing above.

- ***NOTE*** that this 13-column CSV file format must be used as the 'Lidar Check Points file' input in the 'USGS NGP LBS - 2024 rev. A' (and later versions) selection in the USGS NGP LBS section of the QC Module if tests **DPH-10 Check Points** and **DPH-11 Absolute Horizontal and Vertical Accuracy** will be run. A 7-column CSV file format is required for all older versions of the USGS NGP LBS tool. Those columns must contain ID, X, Y, Z, Description, Type, and Collection Date in that order. The Description and Collection Date columns do not need to be populated, but they must be present. See above for a description of each required column.

	A	B	C	D	E	F	G
1	ID	X	Y	Z	Desc	Type	Coll_Date
2	1001	687378.315	4043709.207	134.281		NVA	3/18/2023
3	1002	791846.154	4050394.942	88.365		NVA	3/18/2023
4	1003	715087.356	4080224.943	194.76		NVA	3/18/2023
5	1004	806999.401	4135145.286	130.098		NVA	3/18/2023
6	1005	724031.022	4103465.798	201.662		NVA	3/18/2023

2. For abbreviated Vertical Accuracy 1259 testing - known as 'Product Fit to Checkpoints' - a ***7-column CSV-format file*** consisting only of **Point ID, XYZ coordinates, NVA / VVA point types** *(values*

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optional), point exclusion status (values optional), and point exclusion comments (entries optional) that must be formatted in the following order:

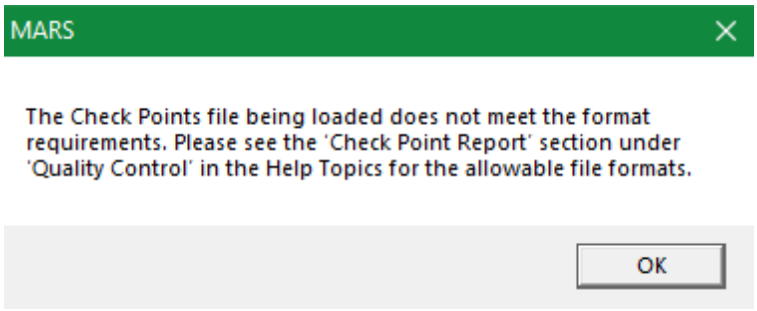
- **ID** - unique identifier for each individual check point. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **X** - check point Easting coordinate. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **Y** - check point Northing coordinate. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **Z** - check point Elevation value. Any unique name can be used for this field. This column (with the name in the first row) must be present and populated for every point.
- **N_V** - optional NVA or VVA type of the check point. Any unique name can be used for this field. Not every row (point record) in the file needs a value for this attribute. Any value that is not stored exactly as **VVA** (not case-specific) or is empty will be interpreted as **NVA**.
- **Include** - the status of each check point (included or excluded from analysis). Any unique name can be used for this field. If used, not every row (point record) in the file needs a value for this field. Any value that is not stored exactly as **No** (not case-specific) or is empty will be interpreted as a true statement, meaning the check point will be included in the analysis.
- **Incl_notes** - if the check point has its 'Include' field set to '**No**,' this free-form text field can be used for storing optional notes about why this check point is being excluded. Any unique name can be used for this field.

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	A	B	C	D	E	F	G
1	ID	X	Y	Z	N_V	Include	Incl_notes
2	MILE_HIGH	3134197.99	1697221.03	5243.83	VVA		
3	101	3134317.7	1697177.02	5218.11	3D		
4	102	3134166.64	1696104.25	5244.01	NVA		
5	103	3134317.54	1695249.07	5211.59	3D		
6	104	3135486.86	1695195.46	5194.14	NVA		

The first row of the CSV file must contain column headers (labels) and not actual check point values. As previously mentioned, the column headers do not have to be named as shown in the examples. All seven columns must be present and in the listed order, and must be labeled in the first row.

To generate a check point report, the project LAS data and an associated check points file must first be loaded. If trying to load a check points file in a non-allowed format, a warning pop-up message will be displayed as shown below.



All LAS data and check points must be in the same Coordinate Reference System (CRS).

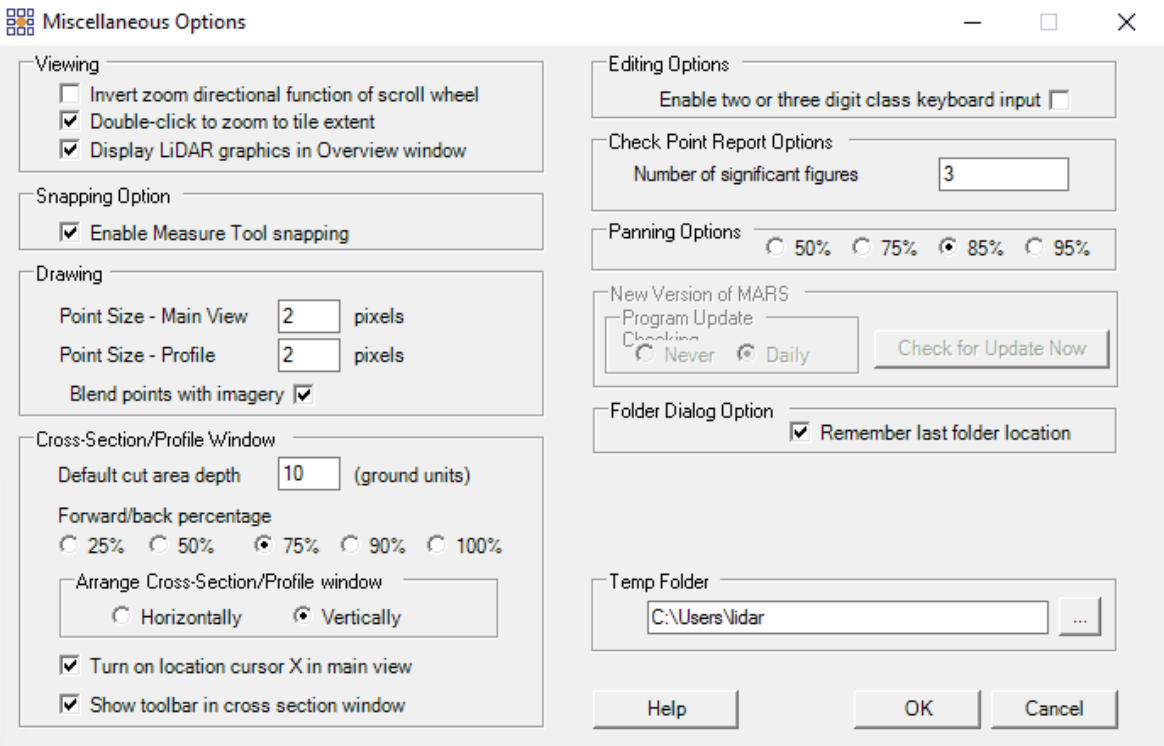
For best results, it is recommended that classified data be used, with points representing ground in a discrete class.

For fastest processing, use a computer that has a discrete, high-end graphics card when the LAS dataset to be loaded is several hundred GBs or more in size. For this tool, rendering power is more important than CPU speed, the number of processor threads, or the amount of installed RAM. Load

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the LAS data - when complete, uncheck the 'LAS' layer in the Table of Contents but be sure to leave the boxes checked on for all individual LAS file entries in the layer. With the LAS data display now turned off, load the check points file. Another option to improve performance is to use 'swatches' of LAS data, which are buffered areas around each check point having a radius of at least 15x the ground sample distance (GSD) of the data. Now continue with the steps listed below.

The number of significant figures which will appear in the Check Point Report can be set. To modify this number ('3' by default), go to the Options Tab and click the **'Miscellaneous'** button. In the interface that appears (below), see the 'Check Point Report Options' section.



To run the Check Point Report utility, follow these steps:

After loading the project LAS data and the check points file, click the **'Check Point Report'** button

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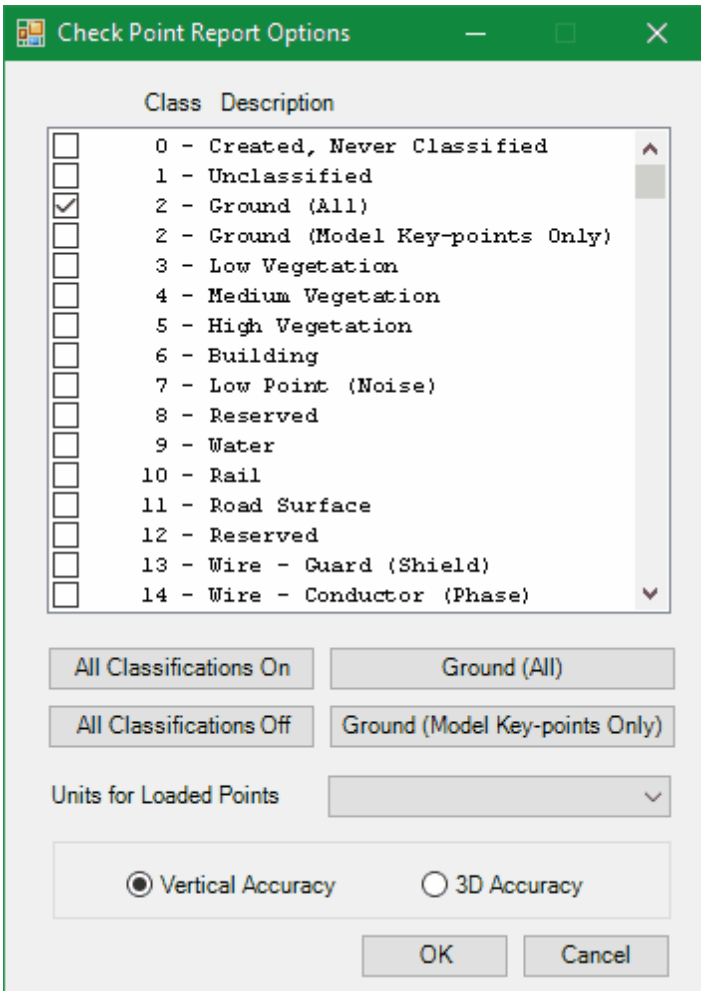
on the QA/QC Tab[458]. Each time a check point report is created, the user can select which point classification(s) to include in the report calculations, what the unit of the project data is, and whether 'Vertical Accuracy' or '3D Accuracy' testing will be run.

By default, Ground (Class 2) is checked on but other selections can be made depending on the data. When Class 2 (Ground) is included, the status of the Model Key-point bit flag, if present, is ignored. In other words, all Class 2 ground points will be included, whether or not they have the Model Key-point bit flag set. For data that has not yet been classified, turn all classifications on.

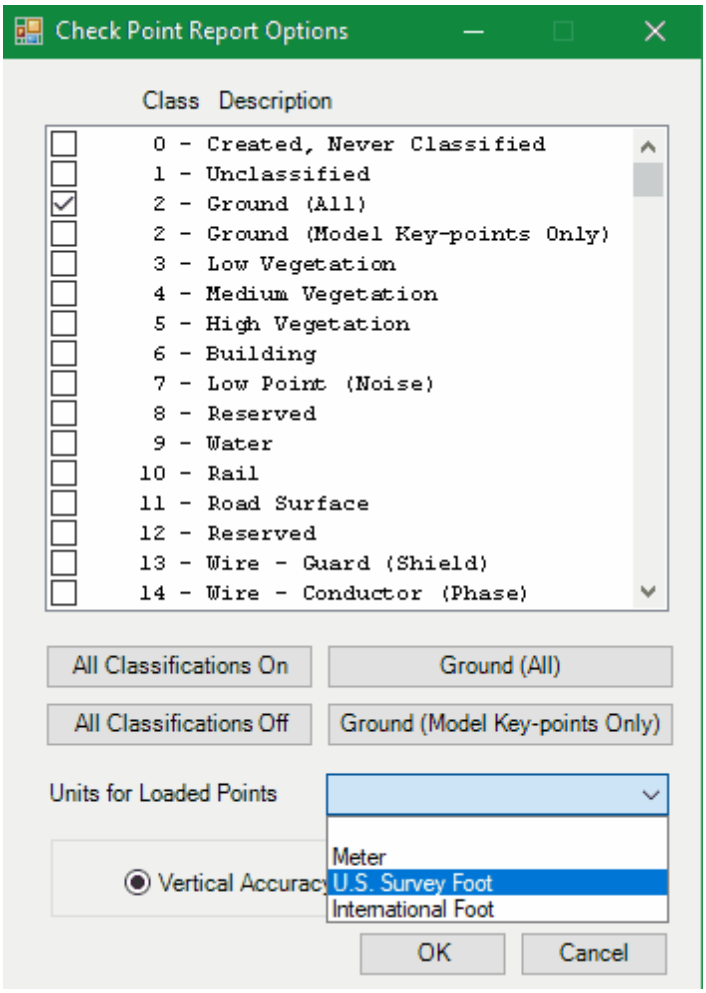
Now choose the **'Units for Loaded Points'** from the drop-down list. Note that this option has no default to ensure that the correct units are always chosen (project data in U.S. Survey Feet or International Feet are internally converted to metric values for comparison to the Requirement table and Standards sections).

Finally, select either the '**Vertical Accuracy**' (default) or '**3D Accuracy**' radio button for the desired testing type.

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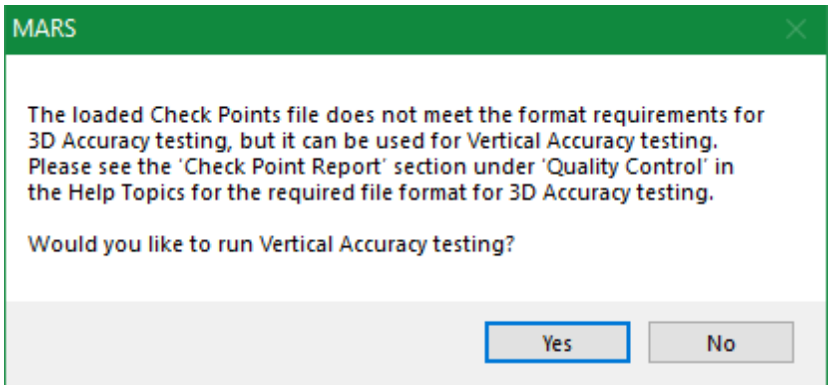
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Click **'OK'** when finished. The loaded check points CSV file will be analyzed to see what testing options are available based on the information it contains:

- If '3D Accuracy' testing was selected and a properly formatted and populated 13-column check points file is loaded, the '3D Accuracy' interface will open (link 1283 to that topic for more information).
- If '3D Accuracy' testing was selected but only a minimum set of values are present in a loaded 7-column check points file, an option is displayed to run 'Vertical Accuracy' testing:

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A 'No' response will stop any processing and a complete 13-column check points file can be loaded if available.

A 'Yes' response will open the 'Vertical Accuracy' interface in either 'RMSEv testing' mode or 'RMSEz testing' mode, depending on the information available in the loaded check points file (link to the 'Vertical Accuracy 1236' topic for more information).

- If '3D Accuracy' testing was selected and a 13-column check points file is loaded, but has the wrong information in the columns or the columns are correctly populated but in the wrong order, one of several possible warning messages may appear. Check that the loaded CSV is correctly formatted and completely populated per the instructions 1225 (above).
- If 'Vertical Accuracy' testing was selected and a properly formatted and populated 13- or 7-column check points file is loaded, the 'Vertical Only' interface will open (link 1236 to that topic for more information).
- If 'Vertical Accuracy' testing was selected and either a 13- or 7-column check points file is loaded, but has the wrong information in the columns or the columns are correctly populated but in the wrong order, one of several possible warning messages may appear. Check that the loaded CSV is correctly formatted and completely populated per the appropriate 13-column instructions 1225 or 7-column instructions 1228 (above).

See

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Vertical Accuracy 1236

3D Accuracy 1283

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6.1.1 Vertical Accuracy

Check Point Report: Vertical Accuracy (RMSEv and RMSEz)

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If 'Vertical Accuracy' was selected in the initial 'Check Point Report' interface and a properly formatted and populated ***13-column*** check points CSV file is loaded, the **'Check Point Report - Vertical Only'** interface will appear with the '**RMSEv testing** 1243 **(Vertical Product Accuracy)**' radio button selected in the '**Testing Method**' section near the top of the interface. The path and name of the loaded check points file is shown on the Windows title bar for reference. The '**Elevation Calculation Method**' is set to 'TIN' which is the preferred method per the ASPRS Positional Accuracy Standards, Edition 2, Version 2 (2024). The results of the analysis will be presented based on the default QL1 10.0-cm Vertical Accuracy Class which can be changed as needed.

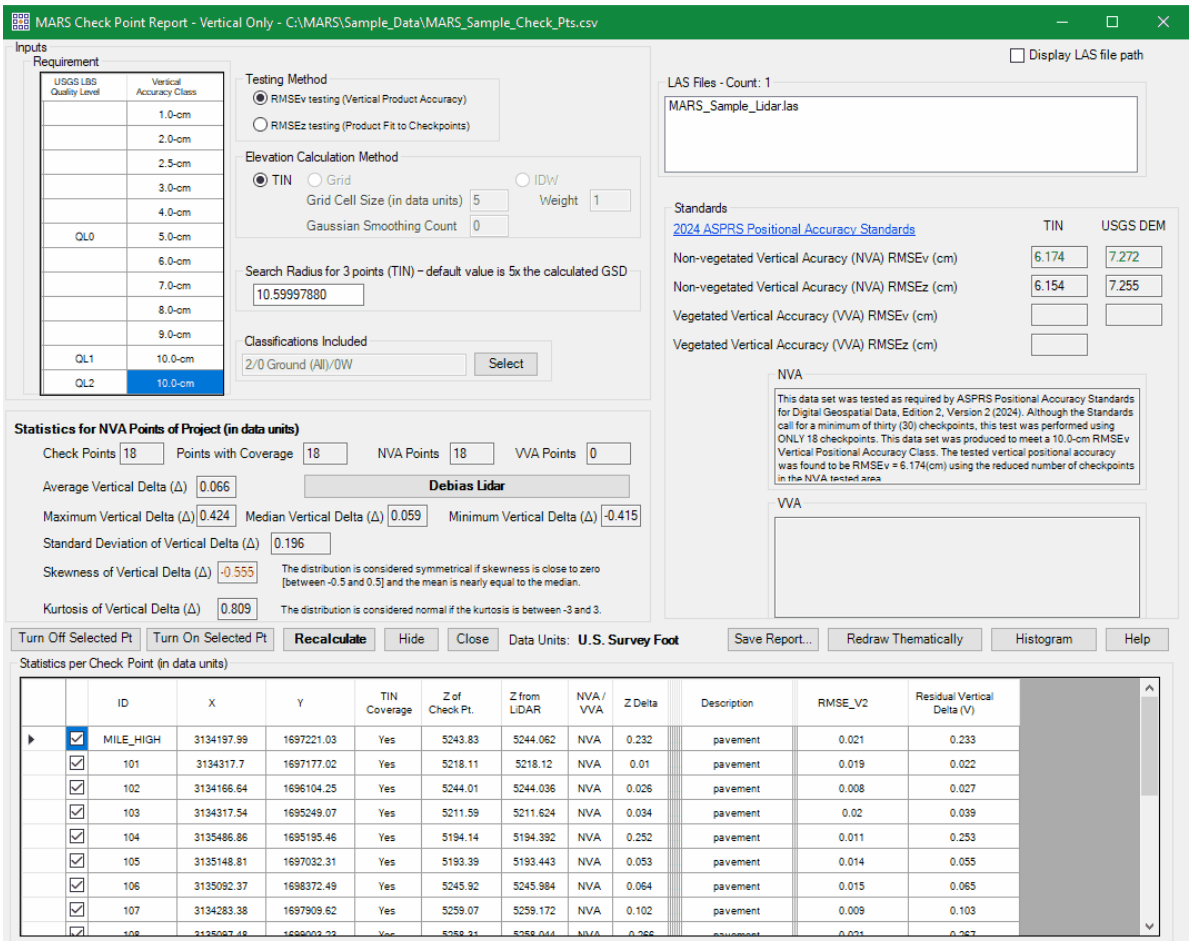
If 'Vertical Accuracy' was selected in the initial 'Check Point Report' interface and a properly formatted and populated ***7-column*** check points CSV file is loaded, the **'Check Point Report - Vertical Only'** interface will appear with the '**RMSEz testing** 1257 **(Product Fit to Checkpoints)**' radio button selected in the '**Testing Method**' section near the top of the interface. The path and name of the loaded check

points file is shown on the Windows title bar for reference. The '**Elevation Calculation Method**' defaults to 'TIN' which is generally the most accurate way to compare a LiDAR ground surface to check points, but two other options are available. The results of the analysis will be presented based on the default QL1 10.0-cm Vertical Accuracy Class which can be changed as needed.

Check points in the 7-column CSV format 1228 can only be tested using the '**RMSEz testing (Product Fit to Checkpoints)**' method. Check points in the full 13-column CSV format 1225 can be tested using either method. ***NOTE*** that to test for compliance with the latest ASPRS Positional Accuracy Standards, the '**RMSEv testing (Vertical Product Accuracy)**' method must be used.

The interface contains project accuracy statistics in the **'Statistics for NVA Points of Project'** section, a comparison of those statistics to the chosen vertical accuracy class as well as accuracy reporting statements in the **'Standards'** section, and the **'Statistics per Check Point'** info in the table at the bottom of the window. Project data in U.S. Survey Feet or International Feet are internally converted to metric values for comparison to the Requirement table and Standards section.

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Many parameters can be changed from their default or original settings including the USGS Quality Level/Vertical Accuracy Class to be tested against, the specific TIN, Grid, or IDW (Inverse Distance Weighting) 'Elevation Calculation Method' (only when 'RMSEz testing' is done), the Search Radius for finding lidar points around each check point, the 'Classifications Included' (typically representing ground), and the exclusion of one or more check points. Most changes will trigger an automatic recalculation, but the manual '**Recalculate**' button can be used at any time.

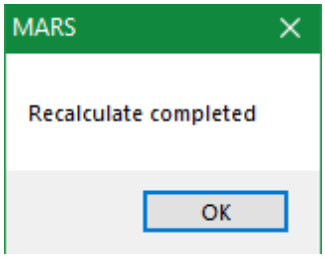
Function Buttons:



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Turn Off Selected Pt / Turn On Selected Pt: Depending on the 'Include' status of each point in the loaded check points CSV file[1225], individual check points are turned on or off when the Check Point Report tool is first opened. Individual points can be manually unchecked (excluded from analysis and reporting) or checked (included) in the table at the bottom of the interface by clicking the corresponding check box. In addition, multiple points can be selected using standard Windows controls and then turned on/off. Clicking in the blank space to the left of a row will select that row. Clicking and dragging the cursor through the blank spaces of multiple adjacent rows will select all rows within the drag area. Likewise, clicking a row, holding down the 'Shift' key, and clicking another row higher or lower in the table will select all rows between, inclusive. Clicking the blank areas for individual rows while holding down the 'Ctrl' key will select only those rows. When finished selecting rows, click on either the '**Turn Off Selected Pt**' or '**Turn On Selected Pt**' button as appropriate.

Recalculate: If any check points are turned off or on as described above, click the **'Recalculate'** button to generate updated results. Changing the status of one or more check points will cause the 'Recalculate' button to change from black to blue font as a reminder. The button can also be used anytime a setting change does not trigger an automatic recalculation. Automatically triggered recalculations will always be followed by a small pop-up window.



Hide: This option allows the user to hide the check point report without actually closing it. Closing the report would require it to regenerate the results if it needed to be viewed again. To bring the hidden check point report back up, click the **'Check Point Report'** button on the QA/QC Tab[458] again. The report window is redisplayed immediately with the values that were previously generated.

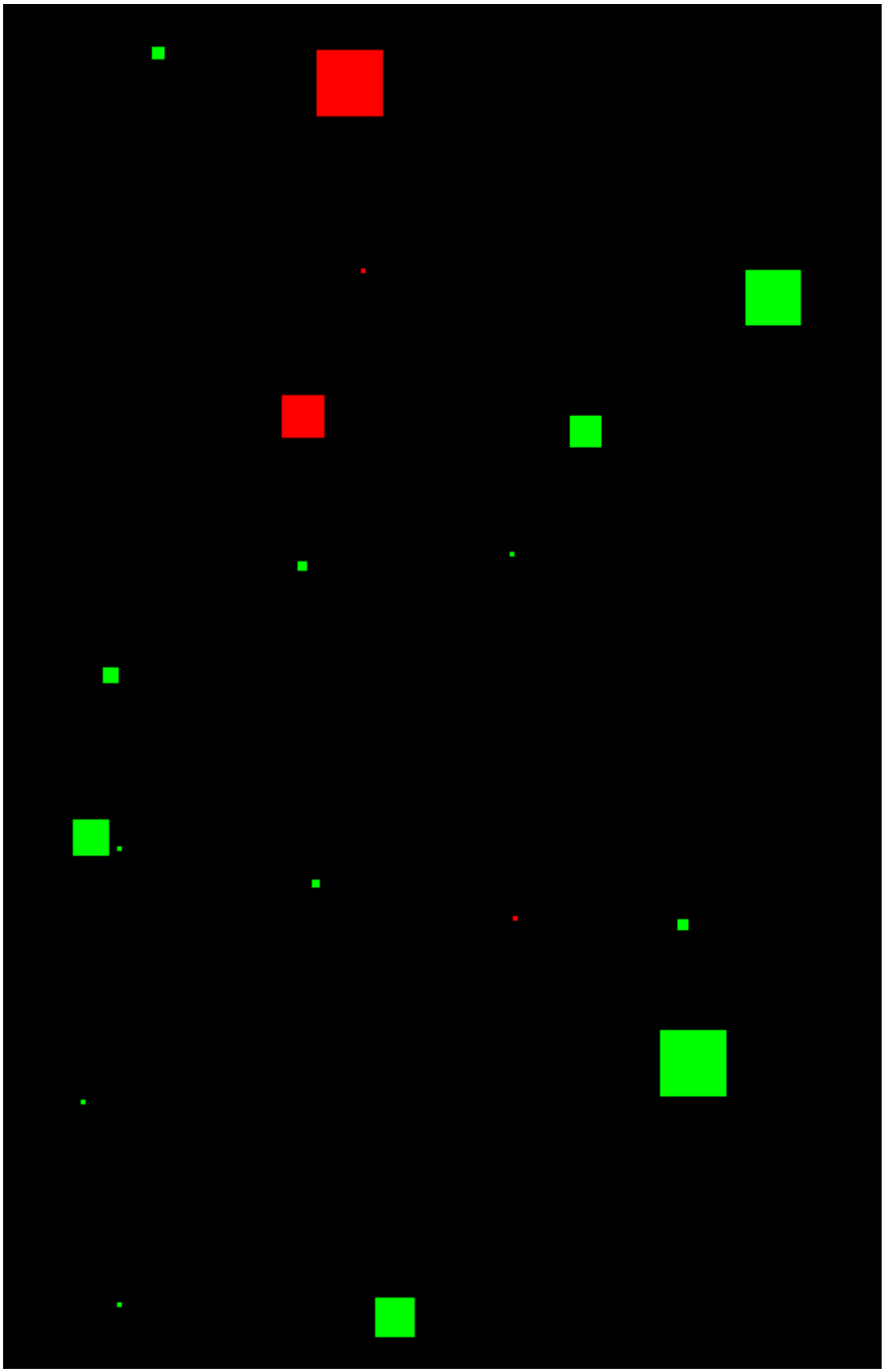
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Close: To completely close (rather than hide) the check point report, click on the **'Close'** button. To view the report again, it will need to be regenerated by clicking the **'Check Point Report'** button on the QA/QC Tab458 to start the process over.

Save Report... : To save the check point report to a comma-separated value (CSV) file and a separate PDF file, click on the **'Save Report...'** button, navigate to the desired folder, enter a filename, and click the **'Save'** button. If the LiDAR data is being displayed, it will switch to Intensity rendering for a screen capture that is made for the PDF version of the report. A 2D point shapefile of the check points that are turned on (included) in the report will also be saved in the output folder.

Redraw Thematically: Use this button to show 'Z Error' values per check point thematically. All other data besides the check points can be turned off in the Table of Contents to more easily view this display. Red squares represent negative error (surrounding LiDAR surface lower than check point) and green squares represent positive error (surrounding LiDAR surface higher than check point). The magnitude of the error is shown by the relative size of the square - the larger the square, the larger the 'Z Error'. To return to the previous display, click the button in the same location, which will now be labeled **'Redraw Normal'**.

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Histogram: This button displays a histogram of the 'Z Error' for the NVA points with the amount of Z delta (error) on the X-axis and the number of occurrences within specified Z Delta ranges on the Y-axis. If there are VVA points in the loaded check points CSV file, a **'VVA'** button will be available at the bottom to switch to a separate histogram for those points. The Histogram window also contains a button labeled 'Redraw Thematically' - clicking it will apply a color ramp to the yellow (by default) bars in the histogram, better differentiating the amounts of Z Error. The color ramp uses up to 24 discrete shades, ranging from **red** for the largest amount of negative Z Error, to **green** for near-zero Z Error, to **magenta** for the largest amount of positive Z Error. In the LAS Map View window (main MARS® view), the check points that fall within each of the Histogram error ranges (bars) will be displayed in the same color as the bars themselves. Clicking the **'Back'** button on either histogram display will return to the interactive report window.

'Statistics per Check Point' table tools:

Point Status checkboxes: The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

Data Sorting: Click any of the column headings (e.g., Z Delta) in the **'Statistics per Check Point'** table to sort the data in ascending or descending order based on that column.

Jump to Display: To view any of the individual check points in the LAS Map View window, double-click anywhere in that row within the **'Statistics per Check Point'** table. The selected check point will be centered in the LAS Map View window.

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See also

Check Point Report Overview 1224

RMSEv Testing Method Inputs Section 1244

RMSEz Testing Method Inputs Section 1259

RMSEv Statistics for NVA Points of Project Section 1248

RMSEz Statistics for NVA Points of Project Section 1263

RMSEv Standards Section

RMSEz Standards Section 1269

RMSEv Statistics per Check Point Table 1254

RMSEz Statistics per Check Point Table 1271

Finishing and Saving the Check Point Report 1281

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6.1.1.1 RMSEv Testing

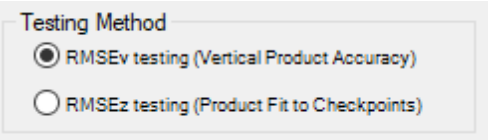
Check Point Report: Vertical Accuracy - RMSEv Testing

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The 'RMSEV' method of vertical testing does a complete analysis of accuracy by combining 'Delta Z' - the comparison of the surveyed Z-value of each 3D, NVA, or VVA check point to the calculated Z-value of the lidar data at each point's XY location - with the survey error values (RMSE_V2). This ASPRS-

compliant method of analysis is often referred to 'Vertical Product Accuracy,' and it requires that all check points have RMSE_V2 values in the CSV file. The Elevation Calculation Method[1260] for the lidar data is set to 'TIN' and cannot be changed.

'RMSEv testing' can be run only when using a properly formatted and populated 13-column[1225] check points CSV file. To use this testing method, select 'Vertical Accuracy' from the initial 'Check Point Report[1224]' tool interface. When the main tool interface opens, the 'Testing Method' will default to 'RMSEv testing'.



See

Check Point Report Overview[1224]

Inputs Section[1244]

Statistics for NVA Points of Project Section[1248]

Standards Section[1251]

Statistics per Check Point Table[1254]

Finishing and Saving the Check Point Report[1281]

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6.1.1.1.1 Inputs Section

Check Point Report: Vertical Accuracy - RMSEv

Testing - Inputs Section

Merrick Advanced Remote Sensing (MARS®) Software

Inputs:

- **USGS LBS Quality Level / Vertical Accuracy Class (Requirement table):** This is the target root mean squared error (RMSEv) value for the project, which defines the Vertical Accuracy Class requirement. During the calculation of the check point statistics, comparisons are made to this value to see if the dataset meets the desired accuracy requirements. To achieve the target accuracy requirements, the calculated RMSEz value is compared to the target value to determine if the LiDAR surface at each check point is within an acceptable margin of error to be displayed in green font in the 'Standards' section. The default value is 'QL1' which equates to a 10.0-cm Vertical Accuracy Class, but it can be changed as needed.

Requirement

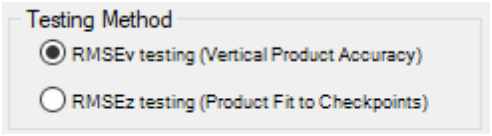
USGS LBS Quality Level	Vertical Accuracy Class
	1.0-cm
	2.0-cm
	2.5-cm
	3.0-cm
	4.0-cm
QL0	5.0-cm
	6.0-cm
	7.0-cm
	8.0-cm
	9.0-cm
QL1	10.0-cm
QL2	10.0-cm

Selecting a different USGS LBS Quality Level/Vertical Accuracy Class will trigger an automatic

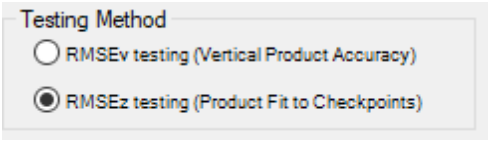
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recalculation of the results.

- **Testing Method:** This is where the selection is made between RMSEv (Vertical Product Accuracy) or RMSEz (Product Fit to Checkpoints) testing. When a properly populated 13-column CSV 1225 check points file is loaded, the default method is RMSEv, which uses survey crew supplied point accuracy error values (RMSE_V2) in the calculations.



- The older (ASPRS 2014) method - RMSEz 1257 - can be selected if needed. This method will be the only option available if no survey point accuracy error values exist in the loaded check points file (7-column CSV 1228).

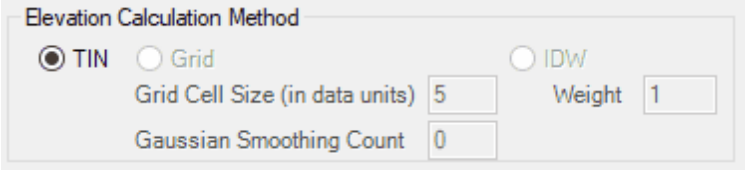


Selecting a different Testing Method will trigger an automatic recalculation of the results.

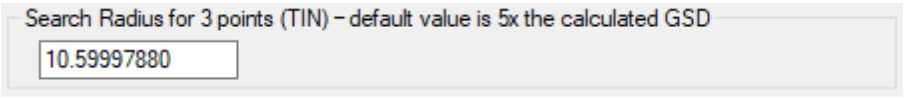
- **Elevation Calculation Method:** This is set to 'TIN' for 'RMSEv testing' which is the preferred method per the ASPRS Positional Accuracy Standards, Edition 2, Version 2 (2024) - the 'Grid' and 'IDW' methods are disabled. With this method, a TIN is created around each check point, using LiDAR points from the selected class(es) within a search radius of five times (5x) the Ground Sample Distance (as determined through testing). Then the *one* TIN triangle that covers the check point being tested is selected. The XY location on the surface of this triangle that matches the check point XY location provides the elevation value. This elevation value is a linear interpolation of the elevations of

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the three (3) TIN vertices or, more clearly stated, it is the point in 3D space on the TIN triangle at the check point's XY coordinates.



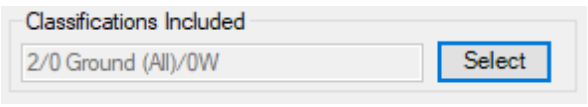
- **Search Radius for 3 points (TIN):** This value is calculated from the loaded LAS data. The default value is five times (5x) the Ground Sample Distance (GSD). This value can be modified with the following caveats: too small of a value will result in some check points not being compared to their surrounding LAS data. This may be the case when the 'TIN Coverage' value in the 'Statistics per Check Point' table is 'No', resulting in those points in the table having some blank fields. Too large of a Search Radius value may result in overly-long processing times.



Modifying the Search Radius value followed by either the 'Enter' or 'Tab' key will trigger an automatic recalculation of the results.

- **Classifications Included:** This list box shows which data classifications are to be used to calculate elevation. Only those data classifications that are displayed in the box will be included in the elevation calculation. When Class 2 (Ground) is included, the status of the Model Key-point bit flag, if present, is ignored.

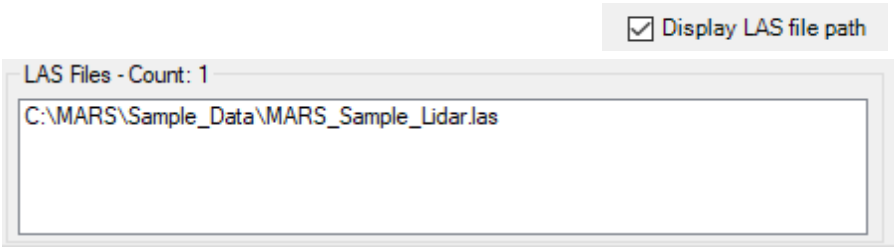
  Note that points flagged as 'Withheld', regardless of classification, will not be used in this tool.



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Selecting a different classification or set of classifications will trigger an automatic recalculation of the results.

- **LAS Files - Count:** This section shows a list of all LAS files loaded into the project and their count. A checkbox option to display the complete file path is available. The status of this 'Display LAS file path' check box will also affect the (optional) saved check point reports (see Finishing and Saving the Check Point Report 1281).



See Also

Check Point Report Overview 1224

Statistics for NVA Points of Project Section 1248

Standards Section 1251

Statistics per Check Point Table 1254

Finishing and Saving the Check Point Report 1281

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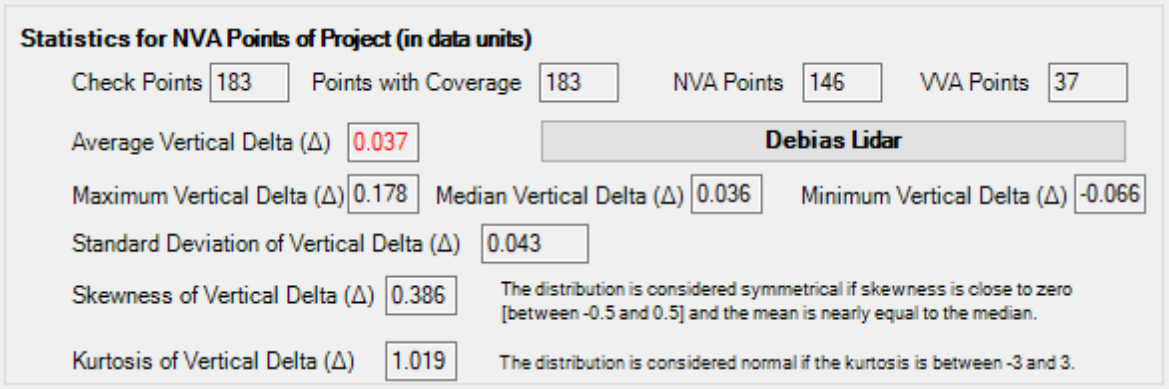
6.1.1.1.2 Statistics for NVA Points of Project Section

Check Point Report: Vertical Accuracy - RMSEv

Testing - Statistics for NVA Points of Project Section

Merrick Advanced Remote Sensing (MARS®) Software

Statistics for NVA Points of Project (in data units):



- **Check Points:** This is the total number of included check points in the project.

- **Points with Coverage:** This is the number of included check points with an elevation value that can be computed from nearby LiDAR data. More specifically, when computing the Z-value from a TIN, this is the number of check points where a covering triangle is found.

- **NVA Points:** The total count of all included check points identified in the file as 3D, NVA, or not defined (unidentified check points are assumed to be NVA). Only these points (not VVA) are used in calculating the results shown in this section of the tool.

- **VVA Points:** The total count of all included check points specifically identified in the CSV file as VVA. These points are used only to calculate the results for the 'Vegetated Vertical Accuracy

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(VVA)' item(s) and as input for the VVA accuracy reporting statement in the 'Standards' section.

- **Average Vertical Delta (Δ):** For all included NVA check points, this is the average of the **'Z Delta'** values shown in the 'Statistics per Check Point' table. An absolute value more than 25% of the specified RMSE (Vertical Accuracy Class), when compared in the same units, will be displayed in red font.

- **Debias Lidar:** This button will modify all loaded LAS files by applying an opposite Z shift (vertical) to the header of those files, causing the 'Average Vertical Delta (Δ)' value to be recalculated to '0' (zero).

- **Maximum Vertical Delta (Δ):** For all included NVA check points, this is the highest positive **'Z Delta'** value.

- **Median Vertical Delta (Δ):** For all included NVA check points, this is the median of the **'Z Delta'** values.

- **Minimum Vertical Delta (Δ):** For all included NVA check points, this is the lowest negative **'Z Delta'** value.

- **Standard Deviation of Vertical Delta (Δ):** This is the standard deviation of the **'Z Delta'** for the NVA check point values.

- **Skewness of Vertical Delta (Δ):** This is the measure of symmetry or asymmetry within a dataset, in this case the vertical errors (**Z Delta**). The distribution is considered symmetrical if skewness is

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close to zero (between -0.5 and 0.5) and the mean (average) is nearly equal to the median. Calculated values outside this range will be displayed in red font.

- **Kurtosis of Vertical Delta (Δ):** This is the measure of relative 'peakedness' or flatness of a distribution compared with a normally distributed dataset. Positive kurtosis indicates a relatively peaked distribution near the mean (average) while negative kurtosis indicates a flat distribution near the mean. The distribution is considered normal if the kurtosis is between -3 and 3. Calculated values outside this range will be displayed in red font.

See Also

Check Point Report Overview 1224

Inputs Section 1244

Standards Section 1251

Statistics per Check Point Table 1254

Finishing and Saving the Check Point Report 1281

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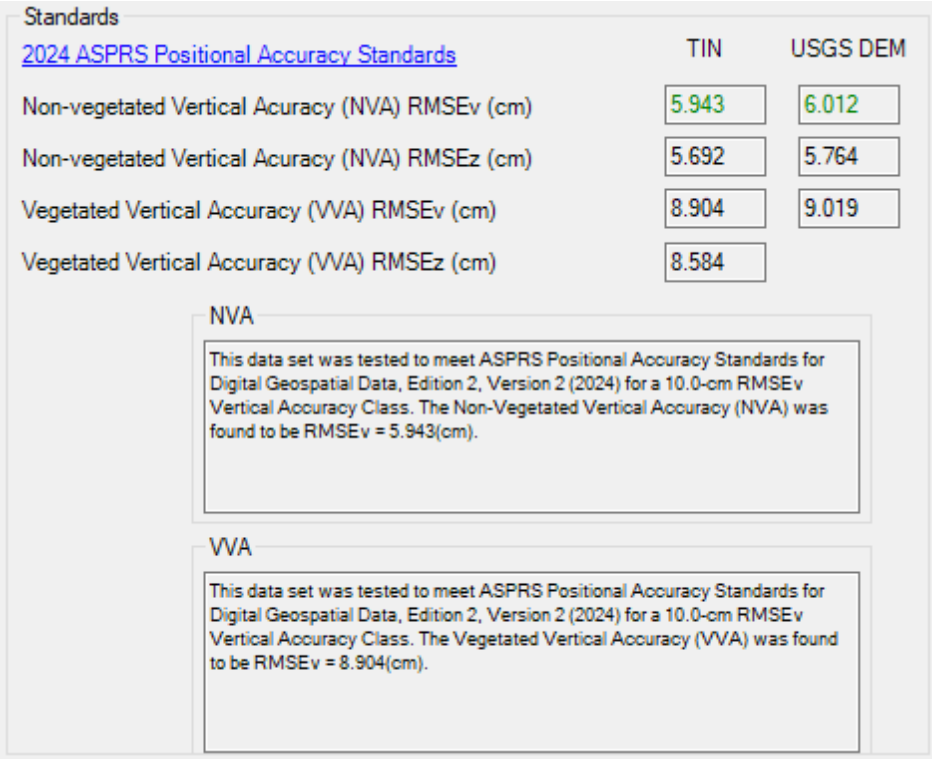
6.1.1.1.3 Standards Section

Check Point Report: Vertical Accuracy - RMSEv

Testing - Standards

Merrick Advanced Remote Sensing (MARS®) Software

Standards and Accuracy Reporting Statements:



Note: The 'USGS DEM' column in the above screen capture shows the values calculated when a virtual (RAM-based) grid of the selected lidar point class(es) is created to compare with the surveyed check points. The grid cell size is determined by the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section[1244]). These values are calculated only when a Vertical Accuracy Class that has a corresponding USGS Quality Level associated with it is selected. Cell sizes are taken from the USGS NGP Lidar Base Specification Version 2024 rev. A (Table 6). For example, for projects in U.S. Survey Feet the cell size used for the 10.0-cm Vertical Accuracy Class (QL2) is 2 feet. Pass/Fail (green/red) is reported only for Non-vegetated Vertical Accuracy (NVA) RMSEv.

- **Non-vegetated Vertical Accuracy (NVA) RMSEv:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed NVA check points, with the effects of the survey error

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(RMSE_V2) factored in. There will be values shown only if at least one check point is identified as 3D or NVA. A green value indicates compliance with the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244); a red value indicates non-compliance.

- **Non-vegetated Vertical Accuracy (NVA) RMSEz:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed NVA check points. There will be values shown only if at least one check point is identified as 3D or NVA. The RMSEz values for NVA are reported for informational purposes only - they are not tied to any standards.

- **Vegetated Vertical Accuracy (VVA) RMSEv:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed VVA check points, with the effects of the survey error (RMSE_V2) factored in. There will be values shown only if at least one check point is identified as VVA. The VVA results are reported 'as found' - they are not tied to any standards.

- **Vegetated Vertical Accuracy (VVA) RMSEz:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed VVA check points. There will be values shown only if at least one check point is identified as VVA. The RMSEz values for VVA are reported for informational purposes only - they are not tied to any standards.

- **Reporting statement(s):** There are two possible accuracy reporting statements that may be displayed in this section - NVA and VVA - depending on the check point types present in the loaded CSV file. The actual wording is dependent on the number of each type in the CSV, either 30+ or less than 30. The statements conform to the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024).

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See Also

Check Point Report Overview 1224

Inputs Section 1244

Statistics for NVA Points of Project Section 1248

Statistics per Check Point Table 1254

Finishing and Saving the Check Point Report 1281

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6.1.1.1.4 Statistics per Check Point Table

Check Point Report: Vertical Accuracy - RMSEv

Testing - Statistics per Check Point Table

Merrick Advanced Remote Sensing (MARS®) Software

Statistics per Check Point table:

This table is found in the bottom half of the interface.

Statistics per Check Point (in data units)

	ID	X	Y	TIN Coverage	Z of Check Pt.	Z from LiDAR	NVA / VVA	Z Delta	Description	RMSE_V2	Residual Vertical Delta (V)
▶ ☑	1015	795731.028	4161182.877	Yes	161.794	161.972	NVA	0.178		0.016	0.178
☑	1101	794789.097	4134444.802	Yes	126.254	126.319	3D	0.065		0.019	0.067
☑	1018	749098.16	3993132.793	Yes	74.944	75.036	3D	0.092		0.012	0.093
☑	1087	739399.075	4102758.9	Yes	122.892	122.928	3D	0.036		0.017	0.04
☑	1104	763722.523	4156552.788	Yes	210.871	210.982	3D	0.111		0.024	0.114
☑	1023	836358.448	4092979.824	Yes	95.449	95.405	3D	-0.044		0.036	0.057
☑	1121	734883.945	4072665.755	Yes	102.556	102.62	3D	0.064		0.001	0.064
☑	1075	787372.314	3993949.222	Yes	79.449	79.486	NVA	0.037		0.028	0.046

- The checkbox column at the left of the table shows the status of each check point in the loaded

CSV file. A check mark indicates that the point is included in the analysis and all results.

- **ID -** This is the ID (label) of the check point, as found in the first column of the check point file. If a point's row is checked on, that point is included in project statistics - otherwise it is excluded from analysis.

  Note: Double-clicking on a point's row will display that check point in the center of the LAS Map View window.

- **X -** This is the surveyed X (easting) coordinate of the check point, as found in the second column of the check point file.

- **Y -** This is the surveyed Y (northing) coordinate of the check point, as found in the third column of the check point file.

- **TIN Coverage -** To determine an elevation for the LiDAR data at the XY location of each check point, a TIN is created using LiDAR points within the specified search radius distance (as auto-calculated or manually set) of the check point location. A TIN triangle may or may not cover the check point location. If a TIN was made that covers, then this field is set to “Yes” - otherwise it is set to “No”.

- **Z of Check Pt. -** This is the surveyed Z-value (elevation) of the check point, as found in the fourth column of the check point file.

- **Z from LiDAR -** The Z-value of the data, as computed from nearby LiDAR points. The methodology is to create a TIN using lidar points in the selected classes within the 'Search Radius' (see Inputs Section 1244) of the check point location. Then, the *one* TIN triangle that covers the check point being tested is selected. The XY location on the surface of this triangle that matches the check

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point XY location provides the elevation value. This elevation value is a linear interpolation of the elevations of the three (3) TIN vertices or, more clearly stated, it is the point in 3D space on the TIN triangle at the check point's XY coordinates.

- **NVA / VVA** - This is the (optional) 3D, NVA, or VVA type of each check point, as found in the eighth column of the check point file. Not every check point in the file needs a value for this field. Any value that is not stored exactly as **VVA** (not case-specific) or is empty will be interpreted as **NVA** (including 3D).

- **Z Delta -** The difference between the surveyed Z-value of the check point and the Z-value computed from the LiDAR data. A value more than three (3) times the calculated 'Standard Deviation of Vertical Delta (Δ)' will cause the entire row for that check point to be displayed in red font (see point '1015' in the example above). A positive (>0) Z Delta indicates that the Z-value calculated from the LiDAR data is higher than the surveyed Z-value of the check point. Conversely, a negative (<0) Z Delta indicates that the Z-value calculated from the LiDAR data is lower than the surveyed Z-value of the check point.

- **Description** - This is the optional description of each check point, as found in the seventh column of the check point file.

- **RMSE_V2** - This is the survey check point accuracy for the elevation (Z) values, as found in the 11th column of the check point file.

- **Residual Vertical Error (V)** - This is the final error value calculated using both the '**Z Delta**' (see above) - also known as V1 - and the '**RMSE_V2**' value described in the previous item.

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See Also

Check Point Report Overview 1224

Inputs Section 1244

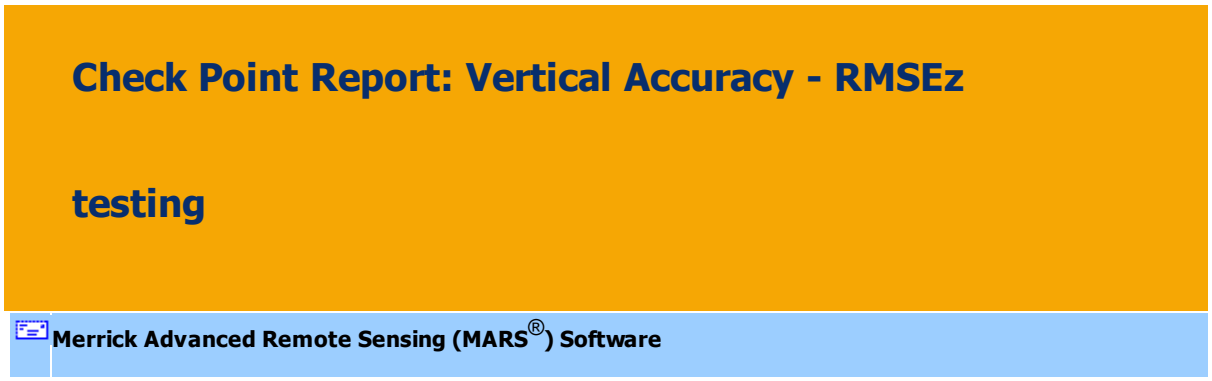
Statistics for NVA Points of Project Section 1248

Standards Section 1251

Finishing and Saving the Check Point Report 1281

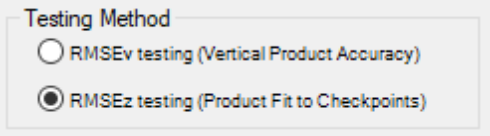
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6.1.1.2 RMSEz Testing

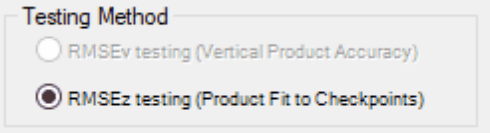


The 'RMSEz' method of vertical testing does a basic 'Delta Z' that compares the surveyed Z-value of each NVA or VVA check point to the calculated Z-value of the lidar data at each point's location. This method of analysis is often referred to as 'Product Fit to Checkpoints.' It does not require any survey error values (RMSE_V2), or that any of the NVA check points be identifiable in an intensity rendering of the lidar data. The Elevation calculation 1260 for the lidar data can be performed via 'TIN,' 'Grid,' or 'IDW.' ***NOTE*** that this method is not compliant with the **ASPRS Positional Accuracy Standards for Digital Geospatial Data** (Edition 2, Version 2, 2024) as a vertical accuracy testing method.

'RMSEz testing' can be run using a full 13-column 1225 check points CSV file, or a simplified 7-column 1228 CSV. To use this testing method, select 'Vertical Accuracy' from the initial 'Check Point Report 1224' tool interface. When the main tool interface opens, either select 'RMSEz testing' manually (when a properly formatted and populated 13-column CSV is loaded)...



or 'RMSEz testing' will the only option available when a 7-column CSV is loaded...



See

Check Point Report Overview 1224

Inputs Section 1259

Statistics for NVA Points of Project Section 1263

Standards Section 1269

Statistics per Check Point Table 1271

Finishing and Saving the Check Point Report 1281

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6.1.1.2.1 Inputs Section

Check Point Report: Vertical Accuracy - RMSEz

Testing - Inputs Section

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Inputs:

- **USGS LBS Quality Level / Vertical Accuracy Class (Requirement table):** This is the target root mean squared error (RMSEz) value for the project, which defines the Vertical Accuracy Class requirement. During the calculation of the check point statistics, comparisons are made to this value to see if the dataset meets the desired accuracy requirements. To achieve the target accuracy requirements, the calculated RMSEz value is compared to the target value to determine if the LiDAR surface at each check point is within an acceptable margin of error to be displayed in green font in the 'Standards' section. The default value is 'QL1' which equates to a 10.0-cm Vertical Accuracy Class, but it can be changed as needed.

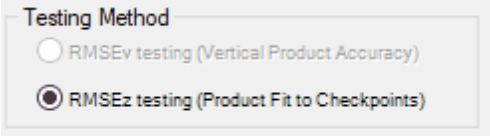
Requirement

USGS LBS Quality Level	Vertical Accuracy Class
	1.0-cm
	2.0-cm
	2.5-cm
	3.0-cm
	4.0-cm
QL0	5.0-cm
	6.0-cm
	7.0-cm
	8.0-cm
	9.0-cm
QL1	10.0-cm
QL2	10.0-cm

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Selecting a different USGS LBS Quality Level/Vertical Accuracy Class will trigger an automatic recalculation of the results.

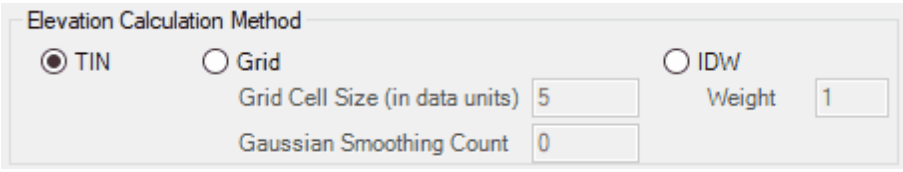
- **Testing Method:** This is where the selection is made between RMSEv (vertical product accuracy) or RMSEz (product fit to checkpoints) testing. The default method is RMSEv, which uses survey crew supplied point accuracy error values in the calculations if present in the input CSV file. The older (ASPRS 2014) method - RMSEz - can be selected if needed, and this method will be the only option available if no survey point accuracy error values exist in the input file (7-column CSV 1228).



Selecting a different Testing Method will trigger an automatic recalculation of the results.

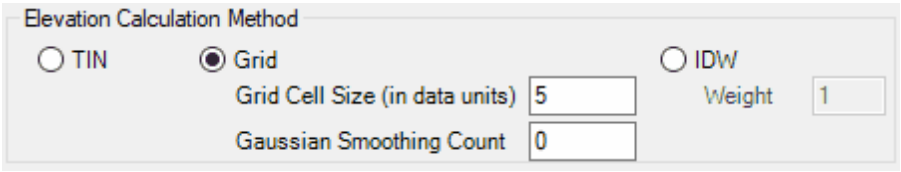
- **Elevation Calculation Method:** There are three (3) elevation calculation methods for this version of the check point report: TIN, Grid, and IDW (Inverse Distance Weighting).

1. The default method is 'TIN' - a TIN is created around each check point using LiDAR points from the selected class(es) within a search radius of five times (5x) the Ground Sample Distance (as determined through testing). Then the *one* TIN triangle that covers the check point being tested is selected. The XY location on the surface of this triangle that matches the check point XY location provides the elevation value. This elevation value is a linear interpolation of the elevations of the three (3) TIN vertices or, more clearly stated, it is the point in 3D space on the TIN triangle at the check point's XY coordinates.

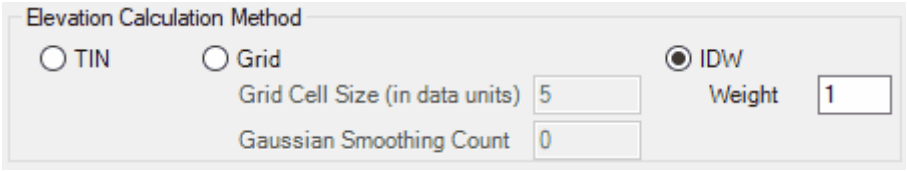


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2. The second method, 'Grid', allows check point report statistics to be created using a virtual grid built with the same parameters that will be used to create raster and contour deliverables. This method is not available when the loaded LAS data is auto-detected as Lat/Long (Geographic). Options when using the 'Grid' method include the 'Grid Cell Size' (default is '5') and the 'Gaussian Smoothing Count' (number of passes, default is '0'). As with raster and contour creation, the more the data is smoothed, the more accuracy is lost.



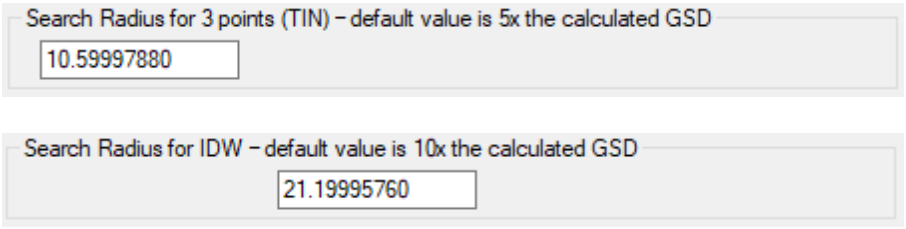
3. The third method, IDW, uses an inverse weighting distance algorithm to calculate accuracy. The 'Weight' value (default is '1') changes the relative importance of lidar point distance in determining the interpolated elevation that will be compared to the check point's known elevation.



Selecting a different calculation method will trigger an automatic recalculation of the results.

- **Search Radius for ... :** This value is calculated from the loaded LAS data. The default value is five times (5x) the Ground Sample Distance (GSD) for both TIN and Grid, and 10x the GSD for IDW. This value can be modified with the following caveats: too small of a value will result in some check points not being compared to their surrounding LAS data. This may be the case when the 'TIN Coverage' value in the 'Statistics per Check Point' table is 'No', resulting in those points in the table having some blank fields. Too large of a Search Radius value may result in overly-long processing times.

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Modifying the Search Radius value followed by either the 'Enter' or 'Tab' key will trigger an automatic recalculation of the results.

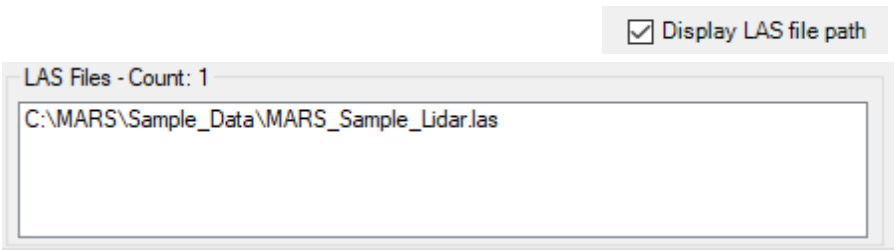
- **Classifications Included:** This list box shows which data classifications are to be used to calculate elevation. Only those data classifications that are displayed in the box will be included in the elevation calculation. When Class 2 (Ground) is included, the status of the Model Key-point bit flag, if present, is ignored.

  Note that points flagged as 'Withheld', regardless of classification, will not be used in this tool.



Selecting a different classification or set of classifications will trigger an automatic recalculation of the results.

- **LAS Files - Count:** This section shows a list of all LAS files loaded into the project and their count. An option to display the complete file path is available. The status of this 'Display LAS file path' check box will also affect the (optional) saved check point reports (see Finishing the Check Point Report 1312).



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See Also

Check Point Report Overview 1224

Statistics for NVA Points of Project Section 1263

Standards Section 1269

Statistics per Check Point Table 1271

Finishing and Saving the Check Point Report 1281

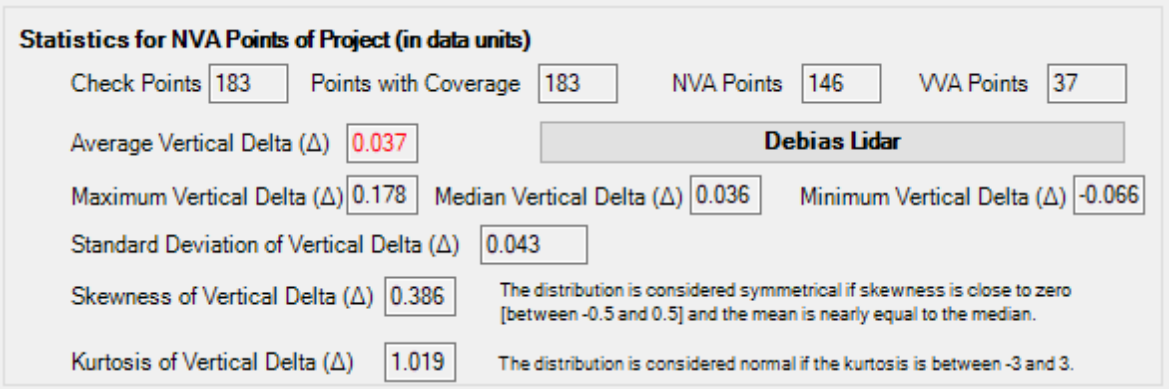
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6.1.1.2.2 Statistics for NVA Points of Project Section

Check Point Report: Vertical Accuracy - RMSEz Testing - Statistics for NVA Points of Project Section

Merrick Advanced Remote Sensing (MARS®) Software

Statistics for NVA Points of Project (in data units):



- **Check Points:** This is the total number of included check points in the project.

- **Points with Coverage:** This is the number of included check points with an elevation value that can be computed from nearby LiDAR data. More specifically, when computing the Z-value from a TIN, this is the number of check points where a covering triangle is found.

- **NVA Points:** The total count of all included check points identified in the file as 3D, NVA, or not defined (unidentified check points are assumed to be NVA). Only these points (not VVA) are used in calculating the results shown in this section of the tool.

- **VVA Points:** The total count of all included check points specifically identified in the CSV file as VVA. These points are used only to calculate the results for the 'Vegetated Vertical Accuracy (VVA)' item(s) and as input for the VVA accuracy reporting statement in the 'Standards' section.

- **Average Vertical Delta (Δ):** For all included NVA check points, this is the average of the **'Z Delta'** values shown in the 'Statistics per Check Point' table. An absolute value more than 25% of the specified RMSE (Vertical Accuracy Class), when compared in the same units, will be displayed in red font.

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- **Debias Lidar:** This button will modify all loaded LAS files by applying an opposite Z shift (vertical) to the header of those files, causing the 'Average Vertical Delta (Δ)' value to be recalculated to '0' (zero).

- **Maximum Vertical Delta (Δ):** For all included NVA check points, this is the highest positive **'Z Delta'** value.

- **Median Vertical Delta (Δ):** For all included NVA check points, this is the median of the **'Z Delta'** values.

- **Minimum Vertical Delta (Δ):** For all included NVA check points, this is the lowest negative **'Z Delta'** value.

- **Standard Deviation of Vertical Delta (Δ):** This is the standard deviation of the **'Z Delta'** for the NVA check point values.

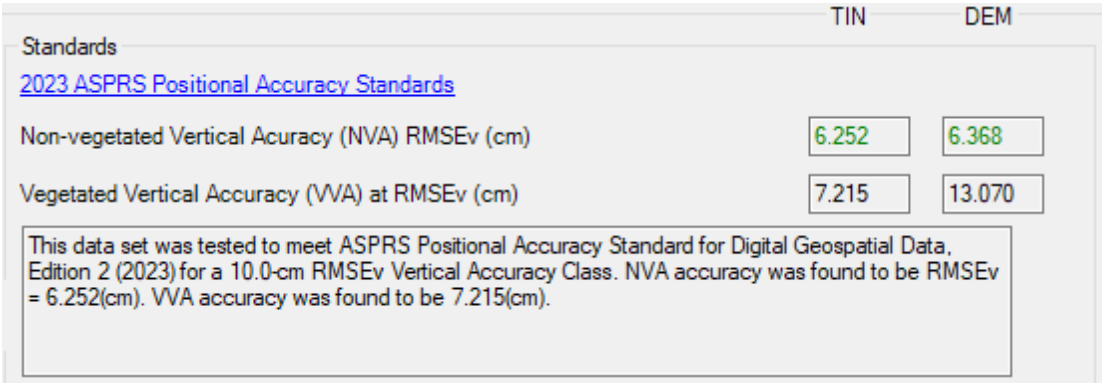
- **Skewness of Vertical Delta (Δ):** This is the measure of symmetry or asymmetry within a dataset, in this case the vertical errors (**Z Delta**). The distribution is considered symmetrical if skewness is close to zero (between -0.5 and 0.5) and the mean (average) is nearly equal to the median. Calculated values outside this range will be displayed in red font.

- **Kurtosis of Vertical Delta (Δ):** This is the measure of relative 'peakedness' or flatness of a distribution compared with a normally distributed dataset. Positive kurtosis indicates a relatively peaked distribution near the mean (average) while negative kurtosis indicates a flat distribution near the mean. The distribution is considered normal if the kurtosis is between -3 and 3. Calculated values

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outside this range will be displayed in red font.

Statistics for Project - Standards (TIN method):



Note: The 'DEM' column in the above screen capture shows the values calculated when a virtual (RAM-based) grid of the selected lidar point class(es) is created to compare with the check points. The grid cell size is determined by the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244). These values are calculated only when a Vertical Accuracy Class that has a corresponding USGS Quality Level associated with it is selected. Cell sizes are taken from the USGS NGP Lidar Base Specification Version 2024 rev. A (Table 6). For example, for projects in U.S. Survey Feet the cell size used for the 10.0-cm Vertical Accuracy Class (QL2) is 2 feet.

- **Non-vegetated Vertical Accuracy (NVA) RMSEz:** This is the RMSE of the Z-values from the TINned data as compared to the NVA check points. There will be a value in the 'TIN' column (see screen capture, above) only if at least one check point is identified as NVA. A green value indicates compliance with the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244); a red value indicates non-compliance.

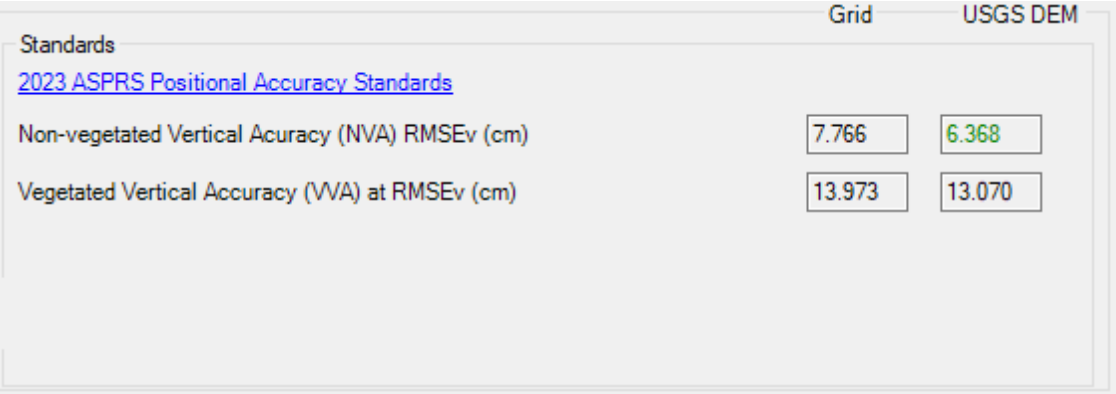
- **Vegetated Vertical Accuracy (VVA) RMSEz:** There will be a value in the 'TIN' column only if at

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least one check point is identified as VVA. The VVA results are reported 'as found' - they are not tied to any standards.

- **Testing statement:** This statement is displayed only when using the 'TIN' elevation calculation method. It summarizes the Vertical Accuracy Class selected and the resulting NVA and VVA vertical accuracy statistics as taken from the first three of the four values described immediately above. If no VVA check points exist in the loaded check points file, accuracy values will be summarized only for NVA.

Statistics for Project - Standards (Grid method):



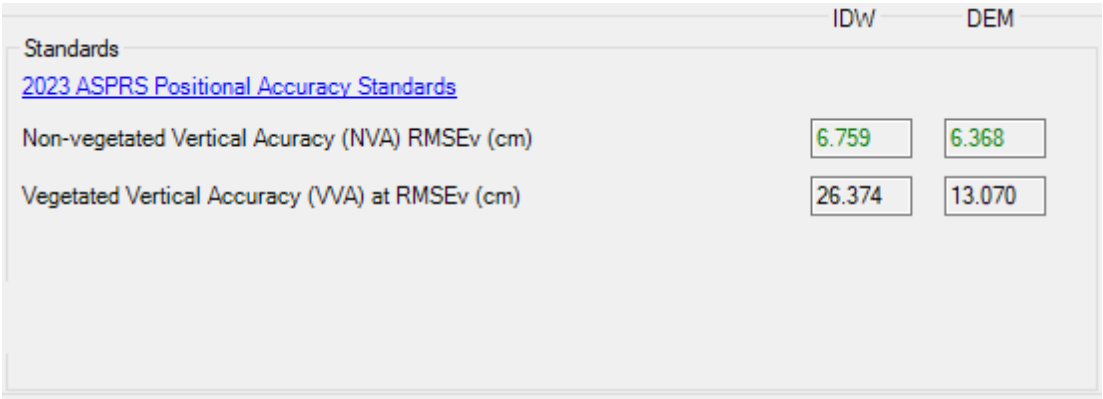
Note: The 'USGS DEM' column in the above screen capture shows the values calculated when a virtual (RAM-based) grid of the selected lidar point class(es) is created to compare with the check points. The grid cell size is determined by the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244). These values are calculated only when a Vertical Accuracy Class that has a corresponding USGS Quality Level associated with it is selected. Cell sizes are taken from the USGS NGP Lidar Base Specification Version 2024 rev. A (Table 6). For example, for projects in U.S. Survey Feet the cell size used for the 10.0-cm Vertical Accuracy Class (QL2) is 2 feet.

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- **Non-vegetated Vertical Accuracy (NVA) RMSEz:** This is the RMSE of the Z-values from the virtually gridded data as compared to the NVA check points. There will be a value in the 'Grid' column only if at least one check point is identified as NVA. Since the 'Grid Cell Size' and 'Gaussian Smoothing Count' (number of passes) can be set by the user, the calculated value in the 'Grid' column (see screen capture, above) is displayed in black font - it is not tied to any standards.

- **Vegetated Vertical Accuracy (VVA) RMSEz:** There will be a value in the 'Grid' column only if at least one check point is identified as VVA. The VVA results are reported 'as found' - they are not tied to any standards.

Statistics for Project - Standards (IDW method):



Note: The 'DEM' column in the above screen capture shows the values calculated when a virtual (RAM-based) grid of the selected lidar point class(es) is created to compare with the check points. The grid cell size is determined by the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244). These values are calculated only when a Vertical Accuracy Class that has a corresponding USGS Quality Level associated with it is selected. Cell sizes are taken from the USGS NGP Lidar Base Specification Version 2024 rev. A (Table 6). For example, for projects in U.S. Survey Feet the cell size used for the 10.0-cm Vertical Accuracy Class (QL2) is 2 feet.

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- **Non-vegetated Vertical Accuracy (NVA) RMSEz:** This is the RMSE of the Z-values from the virtually gridded data as compared to the NVA check points. There will be a value in the 'Grid' column only if at least one check point is identified as NVA. The calculated value in the 'Grid' column (see screen capture, above) is displayed in black font - it is not tied to any standards.

- **Vegetated Vertical Accuracy (VVA) RMSEz:** There will be a value in the 'IDW' column only if at least one check point is identified as VVA. The VVA results are reported 'as found' - they are not tied to any standards.

See Also

Check Point Report Overview 1224

Inputs Section 1259

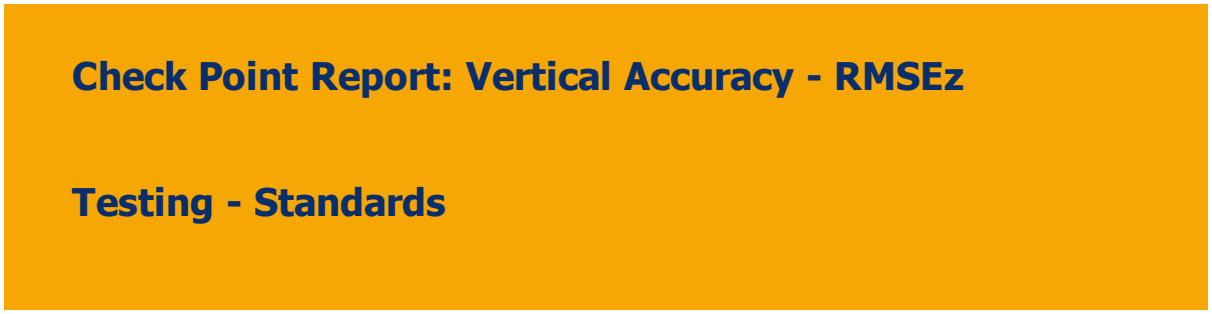
Standards Section 1269

Statistics per Check Point Table 1271

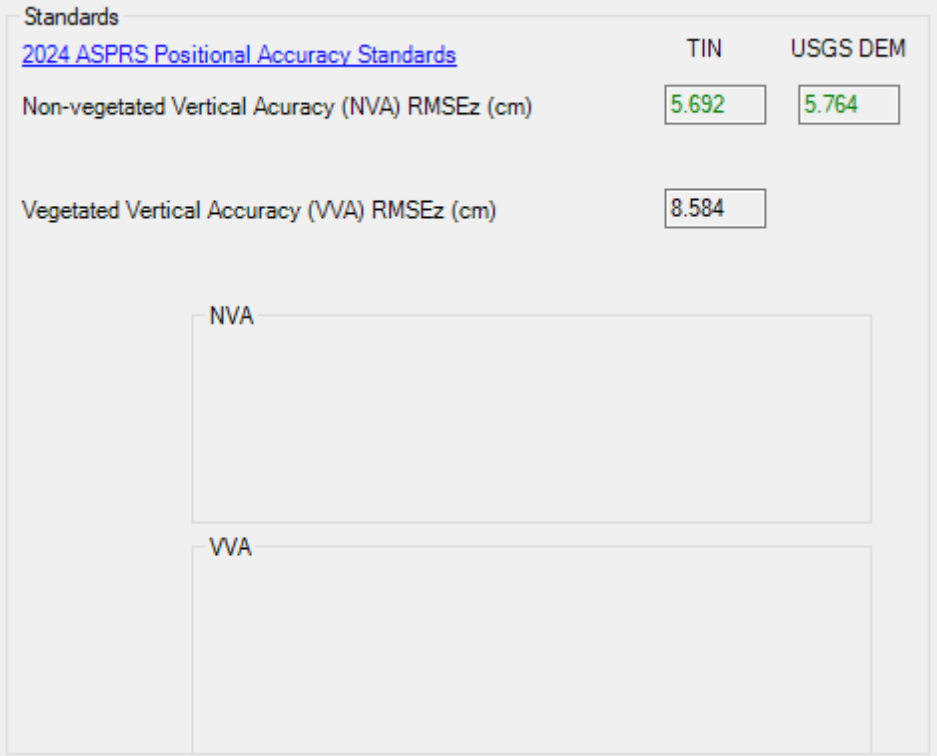
Finishing and Saving the Check Point Report 1281

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6.1.1.2.3 Standards Section



Standards:



Note: The 'USGS DEM' column in the above screen capture shows the values calculated when a virtual (RAM-based) grid of the selected lidar point class(es) is created to compare with the surveyed check points. The grid cell size is determined by the Vertical Accuracy Class value selected in the Requirement table (see Inputs Section 1244). These values are calculated only when a Vertical Accuracy Class that has a corresponding USGS Quality Level associated with it is selected. Cell sizes are taken from the USGS NGP Lidar Base Specification Version 2024 rev. A (Table 6). For example, for projects in U.S. Survey Feet the cell size used for the 10.0-cm Vertical Accuracy Class (QL2) is 2 feet.

- **Non-vegetated Vertical Accuracy (NVA) RMSEz:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed NVA check points. There will be values shown only if at least

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one check point is identified as 3D or NVA. The RMSEz values for NVA are reported for informational purposes only - they are not tied to any standards.

- **Vegetated Vertical Accuracy (VVA) RMSEz:** This is the RMSE of the Z-values from the lidar data as compared to the surveyed VVA check points. There will be values shown only if at least one check point is identified as VVA. The RMSEz value for VVA is reported for informational purposes only - it is not tied to any standards.

- **Reporting statement(s):** Accuracy reporting statements are not provided for RMSEz testing.

See Also

Check Point Report Overview 1224

Inputs Section 1259

Statistics for NVA Points of Project Section 1263

Statistics per Check Point Table 1271

Finishing and Saving the Check Point Report 1281

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6.1.1.2.4 Statistics per Check Point Table

Check Point Report: Vertical Accuracy - RMSEz

Testing - Statistics per Check Point Table

Merrick Advanced Remote Sensing (MARS®) Software

Statistics per Check Point table:

This table is found in the bottom half of the interface. See 'TIN[1272]', 'Grid[1275]', or 'IDW[1278]' for a description of the columns and values displayed for each of these 'Elevation Calculation Methods[1260]'.

See Also

Check Point Report Overview[1224]

Inputs Section[1259]

Statistics for NVA Points of Project Section[1263]

Standards Section[1269]

Finishing and Saving the Check Point Report[1281]

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6.1.1.2.4.1 TIN

Check Point Report: Vertical Accuracy - RMSEz

Testing - Statistics per Check Point Table (TIN)

Merrick Advanced Remote Sensing (MARS®) Software

Statistics per Check Point table (TIN method):


Statistics per Check Point (in data units)

	ID	X	Y	TIN Coverage	Z of Check Pt.	Z from LiDAR	NVA / VVA	Z Delta	Min. Z	Median Z	Max. Z	Description	RMSE_V2	Residual Vertical Delta (V)
▸	1015	795731.028	4161182.877	Yes	161.794	161.972	NVA	0.178	161.951	161.956	161.986		0.016	
	1101	794789.097	4134444.802	Yes	126.254	126.319	3D	0.065	126.314	126.324	126.327		0.019	
	1018	749098.16	3993132.793	Yes	74.944	75.036	3D	0.092	75.017	75.03	75.037		0.012	
	1087	739399.075	4102758.9	Yes	122.892	122.928	3D	0.036	122.9	122.93	122.934		0.017	
	1104	763722.523	4156552.788	Yes	210.871	210.982	3D	0.111	210.923	210.933	211.026		0.024	
	1023	836358.448	4092979.824	Yes	95.449	95.405	3D	-0.044	95.39	95.415	95.441		0.036	
	1121	734883.945	4072665.755	Yes	102.556	102.62	3D	0.064	102.596	102.626	102.631		0.001	
	1075	787372.314	3993949.222	Yes	79.449	79.486	NVA	0.037	79.478	79.49	79.51		0.028	
	1101A	800367.312	4134246.272	Yes	139.1	139.14	3D	0.04	139.103	139.139	139.145		0.001	
	1106	794101.15	4154518.484	Yes	186.913	187.085	3D	0.172	187.074	187.087	187.094		0	
	1097	694134.062	4054311.386	Yes	102.094	102.125	3D	0.031	102.119	102.131	102.132		0.006	
	1004	806999.401	4135145.286	Yes	130.098	130.089	3D	-0.009	130.048	130.093	130.098		0.006	
	1025	784705.26	4056281.74	Yes	85.494	85.556	3D	0.062	85.534	85.562	85.583		0.005	
	1049	748887.914	4091496.008	Yes	105.812	105.81	3D	-0.002	105.787	105.811	105.827		0.007	
	1078	705085.974	4042309.14	Yes	89.231	89.284	3D	0.053	89.262	89.269	89.289		0.018	
	1122	770418.404	4077529.753	Yes	116.652	116.709	3D	0.057	116.671	116.677	116.76		0.01	

- The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

- **ID -** This is the ID (label) of the check point, as found in the first column of the check point file. If a point's row is checked on, that point is included in project statistics - otherwise it is excluded from analysis.

  Note: Double-clicking on a point's row will display that check point in the center of the LAS Map View window.

- **X -** This is the surveyed X (easting) coordinate of the check point, as found in the second column of the check point file.

- **Y -** This is the surveyed Y (northing) coordinate of the check point, as found in the third column of the check point file.

- **TIN Coverage -** To determine an elevation for the LiDAR data at the XY location of each check point, a TIN is created using LiDAR points within the specified search radius distance (as auto-calculated or manually set) of the check point location. A TIN triangle may or may not cover the check point location. If a TIN was made that covers, then this field is set to “Yes” - otherwise it is set to “No”.

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- **Z of Check Pt. -** This is the surveyed Z-value (elevation) of the check point, as found in the fourth column of the check point file.

- **Z from LiDAR -** The Z-value of the data, as computed from nearby LiDAR points. The methodology is to create a TIN using lidar points in the selected classes within the 'Search Radius' (see Inputs Section 1259) of the check point location. Then, the *one* TIN triangle that covers the check point being tested is selected. The XY location on the surface of this triangle that matches the check point XY location provides the elevation value. This elevation value is a linear interpolation of the elevations of the three (3) TIN vertices or, more clearly stated, it is the point in 3D space on the TIN triangle at the check point's XY coordinates.

- **NVA / VVA** - This is the (optional) NVA or VVA type of each check point, as found in the eighth column of the check point file. Not every check point in the file needs a value for this field. Any value that is not stored exactly as **VVA** (not case-specific) or is empty will be interpreted as **NVA** (including 3D).

- **Z Delta -** The difference between the Z-value of the check point and the Z-value computed from the LiDAR data. A value more than three (3) times the calculated 'Standard Deviation of Vertical Delta (Δ)' will cause the entire row for that check point to be displayed in red font (see points '1015' and '1106' in the example above). A positive (>0) Z Delta indicates that the Z-value calculated from the LiDAR data is higher than the surveyed Z-value of the check point. Conversely, a negative (<0) Z Delta indicates that the Z-value calculated from the LiDAR data is lower than the surveyed Z-value of the check point.

- **Min. Z -** When computing the Z elevation from a TIN, this is the Z of the lowest LiDAR point of the three (3) points that define the covering triangle.

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- **Median Z -** When computing the Z elevation from a TIN, this is the median Z-value for the three (3) LiDAR points that define the covering triangle.

- **Max. Z -** When computing the Z elevation from a TIN, this is the Z of the highest LiDAR point of the three (3) points that define the covering triangle.

- **Description -** This is the optional description of each check point, as found in the seventh column of the check point file.

- **RMSE_V2** - This field is not used in any analysis or results for RMSEz testing.

- **Residual Vertical Error (V)** - This field is not used in any analysis or results for RMSEz testing and will be blank.

See Also

Grid 1275

IDW 1278

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6.1.1.2.4.2 Grid

Check Point Report: Vertical Accuracy - RMSEz Testing - Statistics per Check Point Table (Grid)

Merrick Advanced Remote Sensing (MARS®) Software

Statistics per Check Point table (Grid method):



Statistics per Check Point (in data units)

	ID	X	Y	TIN Coverage	Z of Check Pt.	Z from LiDAR	NVA / VVA	Z Delta	Min. Z	Median Z	Max. Z	Description	RMSE_V2	Residual Vertical Delta (V)
▸	1015	795731.028	4161182.877	Yes	161.794	161.857	NVA	0.063	-	-	-		0.016	
	1101	794789.097	4134444.802	No	126.254		3D						0.019	
	1018	749098.16	3993132.793	Yes	74.944	74.948	3D	0.004	-	-	-		0.012	
	1087	739399.075	4102758.9	Yes	122.892	122.679	3D	-0.213	-	-	-		0.017	
	1104	763722.523	4156552.788	Yes	210.871	210.992	3D	0.121	-	-	-		0.024	
	1023	836358.448	4092979.824	No	95.449		3D						0.036	
	1121	734883.945	4072665.755	Yes	102.556	102.623	3D	0.067	-	-	-		0.001	
	1075	787372.314	3993949.222	Yes	79.449	79.476	NVA	0.027	-	-	-		0.028	
	1101A	800367.312	4134246.272	Yes	139.1	139.083	3D	-0.017	-	-	-		0.001	
	1106	794101.15	4154518.484	Yes	186.913	186.991	3D	0.078	-	-	-		0	
	1097	694134.062	4054311.386	Yes	102.094	102.1	3D	0.006	-	-	-		0.006	
	1004	806999.401	4135145.286	No	130.098		3D						0.006	
	1025	784705.26	4056281.74	No	85.494		3D						0.005	
	1049	748887.914	4091496.008	Yes	105.812	105.803	3D	-0.009	-	-	-		0.007	
	1078	705085.974	4042309.14	Yes	89.231	89.13	3D	-0.101	-	-	-		0.018	
	1122	770418.404	4077529.753	No	116.652		3D						0.01	

- The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

- **ID -** This is the ID (label) of the check point, as found in the first column of the check point file. If a point's row is checked on, that point is included in project statistics - otherwise it is excluded from analysis.

  Note: Double-clicking on a point's row will put that check point in the center of the LAS Map View window.

- **X -** This is the surveyed X (easting) coordinate of the check point, as found in the second column of the check point file.

- **Y -** This is the surveyed Y (northing) coordinate of the check point, as found in the third column of the check point file.

- **TIN Coverage -** To determine an elevation for the LiDAR data at the XY location of each check point, a TIN is first created using LiDAR points within the specified search radius distance (as auto-calculated or manually set) of the check point location. A Grid is then built from the TIN and each

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check point's surveyed elevation is compared to the elevation of the cell that covers that check point. A TIN triangle may not cover every check point location and, in that case, there will be no corresponding cell. If a cell exists in the Grid that covers a check point, then this field is set to "Yes" - otherwise it is set to "No".

- **Z of Check Pt. -** This is the surveyed Z-value of the check point, as found in the fourth column of the check point file.

- **Z from LiDAR -** The Z-value of the data, as computed from a Grid of nearby LiDAR points. The methodology is to create a TIN using lidar points in the selected classes within the 'Search Radius' (see Inputs Section 1259) of the check point location. The TIN is then gridded using the specified cell size and smoothing values, with each cell receiving a Z-value from the TIN. The Z-value listed is taken from the cell that covers the check point.

- **NVA / VVA** - This is the (optional) NVA or VVA type of each check point, as found in the eighth column of the check point file. Not every check point in the file needs a value for this field. Any value that is not stored exactly as **VVA** (not case-specific) or is empty will be interpreted as **NVA** (including 3D).

- **Z Delta -** The difference between the surveyed Z-value of the check point and the Z-value computed from the LiDAR data. A value more than three (3) times the calculated 'Standard Deviation of Vertical Delta (Δ)' will cause the entire row for that check point to be displayed in red font (see point '1087' in the example above). A positive (>0) Z Delta indicates that the Z-value calculated from the LiDAR data is higher than the surveyed Z-value of the check point. Conversely, a negative (<0) Z Delta indicates that the Z-value calculated from the LiDAR data is lower than the surveyed Z-value of the check point.

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- **Min. Z -** Not applicable for this method.
- **Median Z -** Not applicable for this method.
- **Max. Z -** Not applicable for this method.
- **Description** - This is the optional description of each check point, as found in the seventh column of the check point file.
- **RMSE_V2** - This field is not used in any analysis or results for RMSEz testing.
- **Residual Vertical Error (V)** - This field is not used in any analysis or results for RMSEz testing and will be blank.

See Also

TIN 1272

IDW 1278

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6.1.1.2.4.3 IDW

Check Point Report: Vertical Accuracy - RMSEz Testing - Statistics per Check Point Table (IDW)

Statistics per Check Point table (IDW method):

Statistics per Check Point (in data units)

	ID	X	Y	TIN Coverage	Z of Check Pt.	Z from LiDAR	NVA / VVA	Z Delta	Min. Z	Median Z	Max. Z	Description	RMSE_V2	Residual Vertical Delta (V)
▶	1015	795731.028	4161182.877	Yes	161.794	161.963	NVA	0.169	-	-	-		0.016	
	1101	794789.097	4134444.802	Yes	126.254	126.308	3D	0.054	-	-	-		0.019	
	1018	749098.16	3993132.793	Yes	74.944	74.953	3D	0.009	-	-	-		0.012	
	1087	739399.075	4102758.9	Yes	122.892	122.872	3D	-0.02	-	-	-		0.017	
	1104	763722.523	4156552.788	Yes	210.871	210.944	3D	0.073	-	-	-		0.024	
	1023	836358.448	4092979.824	Yes	95.449	95.393	3D	-0.056	-	-	-		0.036	
	1121	734883.945	4072665.755	Yes	102.556	102.592	3D	0.036	-	-	-		0.001	
	1075	787372.314	3993949.222	Yes	79.449	79.485	NVA	0.036	-	-	-		0.028	
	1101A	800367.312	4134246.272	Yes	139.1	139.116	3D	0.016	-	-	-		0.001	
	1106	794101.15	4154518.484	Yes	186.913	187.082	3D	0.169	-	-	-		0	
	1097	694134.062	4054311.386	Yes	102.094	102.115	3D	0.021	-	-	-		0.006	
	1004	806999.401	4135145.286	Yes	130.098	130.097	3D	-0.001	-	-	-		0.006	
	1025	784705.26	4056281.74	Yes	85.494	85.532	3D	0.038	-	-	-		0.005	
	1049	748887.914	4091496.008	Yes	105.812	105.794	3D	-0.018	-	-	-		0.007	
	1078	705085.974	4042309.14	Yes	89.231	89.204	3D	-0.027	-	-	-		0.018	
	1122	770418.404	4077529.753	Yes	116.652	116.704	3D	0.052	-	-	-		0.01	

- The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

- **ID -** This is the ID (label) of the check point, as found in the first column of the check point file. If a point's row is checked on, that point is included in project statistics - otherwise it is excluded from analysis.

  Note: Double-clicking on a point's row will put that check point in the center of the LAS Map View window.

- **X -** This is the surveyed X (easting) coordinate of the check point, as found in the second column of the check point file.

- **Y -** This is the surveyed Y (northing) coordinate of the check point, as found in the third column of the check point file.

- **TIN Coverage -** Informational only for the 'IDW' elevation calculation method. Lidar elevations are

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interpolated based on the principle of Inverse Distance Weighting.

- **Z of Check Pt. -** This is the surveyed Z-value of the check point, as found in the fourth column of the check point file.

- **Z from LiDAR -** The Z-value of the data, as computed from nearby LiDAR points. IDW (Inverse Distance Weighting) is used to determine the Z-value of the lidar data at the check point's XY location. Points closer to the check point are given more 'weight' than those farther away.

- **NVA / VVA** - This is the (optional) NVA or VVA type of each check point, as found in the eighth column of the check point file. Not every check point in the file needs a value for this field. Any value that is not stored exactly as **VVA** (not case-specific) or is empty will be interpreted as **NVA** (including 3D).

- **Z Delta -** The difference between the surveyed Z-value of the check point and the Z-value computed from the LiDAR data. A value more than three (3) times the calculated 'Standard Deviation of Vertical Delta (Δ)' will cause the entire row for that check point to be displayed in red font (see points '1015' and '1106' in the example above). A positive (>0) Z Delta indicates that the Z-value calculated from the LiDAR data is higher than the surveyed Z-value of the check point. Conversely, a negative (<0) Z Delta indicates that the Z-value calculated from the LiDAR data is lower than the surveyed Z-value of the check point.

- **Min. Z -** Not applicable for this method.

- **Median Z -** Not applicable for this method.

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- **Max. Z -** Not applicable for this method.

- **Description** - This is the optional description of each check point, as found in the seventh column of the check point file.

- **RMSE_V2** - This field is not used in any analysis or results for RMSEz testing.

- **Residual Vertical Error (V)** - This field is not used in any analysis or results for RMSEz testing and will be blank.

See Also

TIN 1272

Grid 1275

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6.1.1.3 Finishing and Saving the Check Point Report

Check Point Report: Vertical Accuracy - Finishing and Saving the Check Point Report

Merrick Advanced Remote Sensing (MARS®) Software

Finishing and Saving the Check Point Report:

The values displayed in the Check Point Report window for either RMSEv or RMSEz testing can be saved to both a comma separated value (CSV) file and a PDF file. The CSV file can be opened with a

spreadsheet application (e.g., Microsoft Excel). The PDF report will additionally contain the NVA and VVA histograms and a screen capture of the the thematically-rendered Z errors. In addition, a 2D point shapefile of the check points that are turned on (included) in the report will be saved in the output folder.

To generate the permanent check point reports, follow these steps:

- Click the **'Save Report...'** button.
- Navigate to the desired folder, enter a filename, and click the **'Save'** button. The CSV and PDF reports, and the 2D point shapefile will all be given the same name.

To temporarily hide the Check Point Report window but have it quickly available for further viewing:

- Click the **'Hide'** button.
- Once hidden, the Check Point Report window can be re-opened for viewing by clicking the **'Check Point Report'** button on the QA/QC Tab 458. The window will immediately re-open with the last results displayed.

The **'Close'** button will completely close the Check Point Report and remove any calculations stored in RAM.

See Also

Check Point Report Overview 1224

3D Accuracy 1283

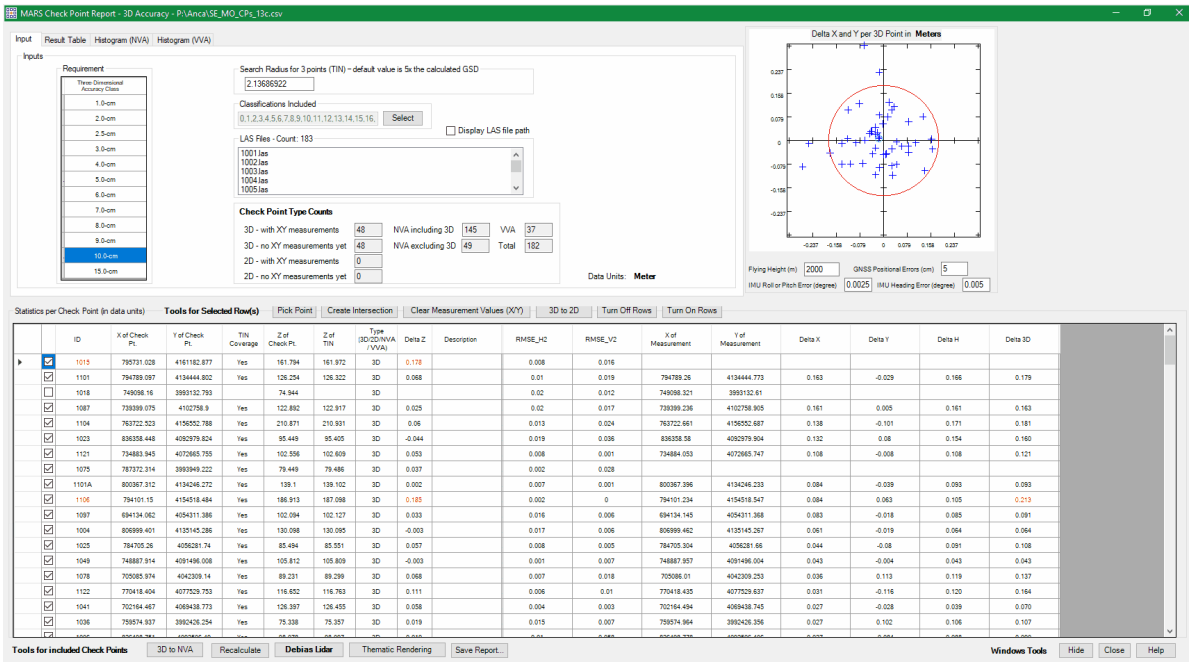
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6.1.2 3D Accuracy

Check Point Report: 3D Accuracy

Merrick Advanced Remote Sensing (MARS®) Software

If '3D Accuracy' was selected in the initial 'Check Point Report' interface and all required values are present in the loaded 13-column 1225 check point CSV file, the **'Check Point Report - 3D Accuracy'** interface will appear. The path and name of the loaded check points file is shown on the Windows title bar for reference.



When the '3D Accuracy' interface is opened for the first time in a project, check points with Type=3D and Type=2D (8th column of the CSV file) will likely not have values populated for 'X of Measurement,' 'Y of Measurement,' 'Delta X,' 'Delta Y,' 'Delta H,' and 'Delta 3D.' To perform 3D Accuracy analysis, measurements will need to be made for all **3D** and **2D** check points whose location is identifiable in an intensity-rendered display of the lidar data. The lidar data must be viewed at 100% point density 900 to

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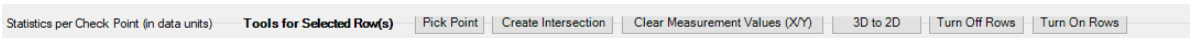
ensure the user measurements are as accurate as possible.

Many parameters can be changed from their default or original settings including the 'Three-Dimensional Accuracy Class' to be tested against, the 'Search Radius' for finding lidar points around each check point, the 'Classifications Included' (typically representing ground), the project's average 'Flying Height (m)', the three specifications of the collection system that was used during data acquisition, and the exclusion of one or more check points. Most changes will trigger an automatic recalculation, but the manual '**Recalculate**' button can be used at any time.

Interface Tabs: There are four tabs available in the interface with status and calculated result information -- Input[1293], Result Table[1297], Histogram (NVA)[1302], and Histogram (VVA)[1303].

Delta X/Y Plot: This graphic is always visible in the upper-right of the interface regardless of which tab is being viewed. It displays the 'Delta X[1310]' / 'Delta Y[1311]' pair values of the **3D** (and any **2D**) check points, as taken from the 'Statistics per Check Point' table. Any **Type 3D** or **2D** point rows selected in the individual check point table[1308] will have their corresponding point marker(s) highlighted by a small red circle on this plot to aid in analysis.

Function Buttons:



Pick Point: This button is one of two options to create XY user measurements for 3D check points (see 'Create Intersection', directly below). The XY coordinates of the user's determination of the check point's location are picked (by mouse click) in the LAS Map View window, and this action will immediately populate the 'X of Measurement[1310]' and 'Y of Measurement[1310]' fields in the 'Statistics per Check Point[1308]' table. When the 'Recalculate' button is clicked, 'Delta X[1310],' 'Delta Y[1311],' 'Delta H[1311]'

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,' and 'Delta 3D' are calculated and populated in the table, and any new XY measurement pairs are added to the Delta X/Y plot. The Result Table and 'Check Point Type Counts' on the Input Tab are also updated at this time.

Create Intersection: This button is an alternative to the 'Pick Point' tool to create XY user measurements for 3D check points. Both tools results in the same outcome - a user-measured XY coordinate of where the check point is believed to be. The coordinate pair is created by drawing two intersecting lines with the mouse. After the second line is completed, the 'X of Measurement' and 'Y of Measurement' fields in the 'Statistics per Check Point' table will be immediately populated. When the 'Recalculate' button is clicked, 'Delta X,' 'Delta Y,' 'Delta H,' and 'Delta 3D' are calculated and populated in the table, and any new XY measurement pairs are added to the Delta X/Y plot. The Result Table and 'Check Point Type Counts' on the Input Tab are also updated at this time.

NOTE: These two tools are intended to be used with an intensity-rendered display of the lidar data. Lidar point density should be viewed at 100% for the most accurate results. ***Do not use imagery to pick a location for the check point!*** - imagery is usually less accurately georeferenced than the lidar data.

See below for a sample workflow.

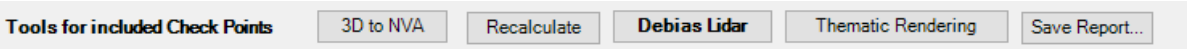
Clear Measurement Values (X/Y): X and Y user measurements can be cleared for one or more check points (rows in the 'Statistics per Check Point' table). All Delta X, Delta Y, Delta H, and Delta 3D values calculated for the cleared points will be removed from the 'Statistics per Check Point' table, and values affecting the entire collection will be recalculated in the Result Table.

3D to 2D: Converts selected 3D check points to 2D (X / Y values only) when it has been determined

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that the surveyed Z-value is incorrect and/or not usable. All TIN Coverage, Delta Z, and Delta 3D values calculated for the converted points will be removed from the 'Statistics per Check Point 1308' table, and values affecting the entire collection will be recalculated in the Result Table 1297.

Turn Off Rows / Turn On Rows: All check points are checked on by default when the tool is first opened unless the 'Include' field has a value of 'No' entered for one or more points in the loaded check points CSV file. Individual points can be manually unchecked (excluded from analysis and reporting) or checked (included) in the table at the bottom of the check point report by clicking the corresponding check box. In addition, multiple points can be selected and turned on/off by using standard Windows controls. Clicking in the blank space to the left of a row will select that row. Clicking and dragging the cursor through the blank spaces of multiple adjacent rows will select all rows within the dragged area. Likewise, clicking a row, holding down the 'Shift' key, and clicking another row higher or lower in the table will select all rows between, inclusive. Clicking the blank areas for individual rows while holding down the 'Ctrl' key will select only those rows. When finished selecting rows, click on either the '**Turn Off Rows**' or '**Turn On Rows**' button as appropriate.

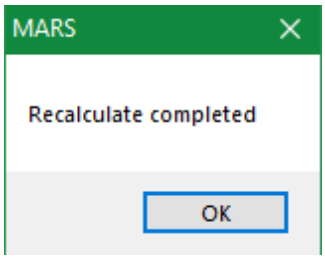


3D to NVA: After all possible user measurements have been made, this button is used to convert the type for any check points that were not measured from **3D** to **NVA**. The loaded CSV file will automatically be updated and a backup version will be created.

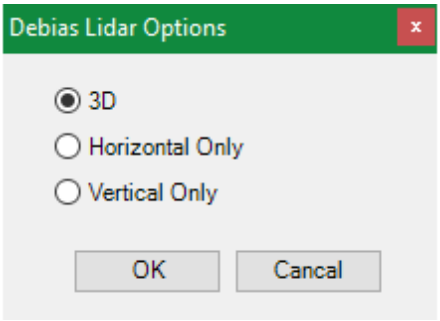
Recalculate: If any check points are turned off or on as described above, click the **'Recalculate'** button to generate updated results. The button can also be used anytime a setting change does not trigger an automatic recalculation, such as after XY user measurements have been made.

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Automatically triggered recalculations will always be followed by a small pop-up window.



Debias Lidar: This button opens a small tool used to debias the loaded LAS files with options for '3D,' 'Horizontal Only,' or 'Vertical Only.'

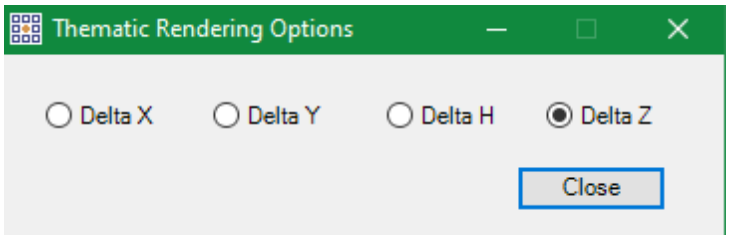


In this context, debias means to apply one or more shift values (combined XYZ, combined XY, or Z only) to the headers of the loaded LAS files so that the corresponding 'Mean Delta (Δ)' value(s) will be recalculated to '0' (zero). ***NOTE*** that the loaded LAS files and the check points CSV file are automatically saved after any shifts that this tool applies to the project.

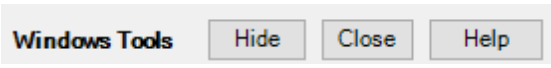
Thematic Rendering: Use this button to show 'Delta X,' 'Delta Y,' 'Delta H,' or 'Delta Z' values per check point thematically in the main MARS® window. All other data besides the check points can be turned off in the Table of Contents to more easily view this display. When this button is clicked, the main interface is temporarily hidden (but not closed) and the control shown below appears. By default, the 'Delta Z' option is selected and all the loaded check points will be rendered based on those values. Red squares represent negative error (lidar surface is lower than the Z-value of the surveyed check

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point), and green squares represent positive error (lidar surface is higher than the Z-value of the surveyed check point). The magnitude of the error is shown by the relative size of the square - the larger the square, the larger the 'Delta Z.' Selecting any of the other three radio buttons will render *only* the '3D' type check points by that parameter's values. The same red/green/square size criteria are used, with the delta calculated between the user XY measurements and the surveyed values. For these htree options, any non-3D check points will be rendered in their normal symbology (white by default). Closing the 'Thematic Rendering Options' control will re-open the main '3D Accuracy' interface, and the 'Thematic Rendering' button will be labeled 'Redraw Normal.' Click this button to return the check points to their default symbology.



Save Report... : To save the check point report to a PDF file, click on the **'Save Report...'** button, navigate to the desired folder, enter a filename, and click the **'Save'** button. If the LiDAR data is being displayed, it will switch to Intensity rendering for a screen capture that is made for the report. A 2D point shapefile of the check points that are turned on (included) in the report will also be saved in the output folder, as well as a settings TXT file that is required when running test 'DPH-11 Absolute Horizontal and Vertical Accuracy' of the 'USGS NGP LBS - 2024 rev. A' option in the QC Module.



Hide: This option allows the tool's interface to be hidden temporarily without actually closing it. This

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can be useful when dragging the interface does not make the entire Map View window visible. Closing the report would require it to regenerate the results if the report needed to be viewed again. To bring the hidden check point report back up, click the **'Check Point Report'** button on the QA/QC Tab[458] again. The report window is redisplayed immediately with the values that were most recently calculated.

Close: To completely close (rather than hide) the check point report, click on the **'Close'** button. To view the report again, it will need to be regenerated by clicking the **'Check Point Report'** button on the QA/QC Tab[458] to start the process over.

'Statistics per Check Point' table tools:

Point Status checkboxes: The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

Data Sorting: Click any of the column headings (e.g., Delta X) in the 'Statistics per Check Point[1308]' table to sort the data in ascending or descending order based on that column.

Jump to Display: To view any of the individual check points in the LAS Map View window, double-click anywhere in that row within the 'Statistics per Check Point' table. The selected check point will be centered in the LAS Map View window.

Overview and sample workflow for XY user measurements:

XY user measurements are performed manually to allow comparisons to be made between the surveyed XY location of a 3D check point and its user-determined location when viewing the lidar data

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by intensity values. Either Gray-scale[895] or Multi-color[896] intensity rendering may be used, with or without the Equalize[893] setting, to find the best location. In all cases, point density should be viewed at 100%[900] and at a sufficient zoom level to make the selection of a location as accurate as possible. The user measurements create XY coordinate pairs that are compared against the surveyed XY coordinates to help determine 3D Accuracy. The following steps represent a sample workflow.

1. With the lidar data and check points CSV file loaded and the 3D Accuracy interface open, look for any 3D point in the 'Statistics per Check Point[1308]' table that does not have values in the 'X of Measurement[1310]' and 'Y of Measurement[1310]' fields. The first time the 'MARS Check Point Report - 3D Accuracy' interface is opened for a project, all type 3D check points will usually show these fields as blank. Any 3D points that do have values can be reviewed and either left as-is or new measurements can be made that will overwrite the existing ones.
2. Double-click anywhere in the row for a 3D point that has no measurement values. The row will be highlighted in blue and the LAS Map View window will pan to place that point in the center. Use the navigation controls as needed to zoom in enough that the point density is showing 100% in the Status Bar[158], or force the point density to 100% with the 'Lock to view 100%[900]' button. Unless manually changed, this zoom level will be used when moving from point to point.
3. Click either the 'Pick Point[1284]' or 'Create Intersection[1285]' button at the lower-left of the 3D Accuracy interface to initiate the measurement process. If neither button is enabled, check to see that the selected point is listed as '3D' in the Type column of the table. 'Pick Point' uses the left mouse button to click on a single location that is seen as best representing the actual location of the check point as compared to the lidar data display. 'Create Intersection' uses two intersecting lines to store that location. If either tool has been selected and the other might be better for a particular location, press the 'Esc' key and select the other tool.
    a. 'Pick Point' - as soon as the left mouse button is used to pick a location in the LAS Map View window, the 'X of Measurement[1310]' and 'Y of Measurement[1310]' fields in the 'Statistics

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per Check Point 1308 table will be immediately populated with that location's values and the 3D Accuracy interface will re-open. If the wrong location was chosen, use the tool again to overwrite the previous values. When complete, return to Step 2 and repeat for the next unmeasured 3D point. The 'Recalculate 1286' button can be used at any time in the measurement process, after one measurement has been made or many. When clicked, ' Delta X 1310,' 'Delta Y 1311,' 'Delta H 1311,' and 'Delta 3D 1311' are calculated and populated in the table, and any new XY measurement pairs are added to the Delta X/Y plot 1305. The Result Table 1297 and 'Check Point Type Counts' on the Input Tab 1293 are also updated at this time.

b. 'Create Intersection' - The left mouse button is used to draw the first of two lines (any length) in the LAS Map View, with a right-click to end it. The first line will turn cyan and a second, intersecting, line is now drawn using the same mouse button sequence. The lines should intersect at the location that is seen as best representing the actual location of the check point as compared to the lidar data display. If the two lines do not intersect, a pop-up message will appear and the mouse cursor will be ready to re-draw beginning with the the first line. If the lines do intersect, the display will clear and the 3D Accuracy interface will re-open with the 'X of Measurement 1310' and 'Y of Measurement 1310' fields in the 'Statistics per Check Point 1308' table populated. Pressing the 'Esc' key at any time before the second line is completed will cancel the measurement and the tool can be re-started. If the intersection is completed and the wrong location was chosen, use the tool again to overwrite the previous values, or use the 'Pick Point' tool instead. When complete, return to Step 2 and repeat for the next unmeasured 3D point. The 'Recalculate 1286' button can be used at any time in the measurement process, after one measurement has been made or many. When clicked, 'Delta X 1310,' 'Delta Y 1311,' 'Delta H 1311,' and 'Delta 3D 1311' are calculated and populated in the table, and any new XY measurement pairs are added to the Delta X/Y plot 1305. The Result Table 1297 and 'Check Point Type Counts' on

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the Input Tab[1293] are also updated at this time.

4. Check points can be re-visited and measurements cleared or updated at any time. Double-click on any 3D point row in the table to re-center that point in the LAS Map View. Any new measurement made (with either the 'Pick Point' or 'Create Intersection' tool) will overwrite any previous values. Use the 'Clear Measurement Values (X/Y)[1285]' button to remove the XY user measurements and all associated values for any selected rows in the table. The decision to do this depends on the user's confidence in the check point's original surveyed location being more accurate than a user measurement. Clearing a value or values with this tool will trigger an automatic recalculation.
5. When all possible user XY measurements have been made, the '3D to NVA[1286]' button should be clicked to convert all unmeasured 3D check points to NVA. This will automatically update the 'Check Point Type Counts' values on the Input Tab[1293], the Delta X/Y plot[1305], the Result Table[1297], and it will overwrite the loaded CSV file with all the current point types and measurements. A backup copy of the loaded CSV file is made before the new one is written.
6. If the Z value of any checkpoint is unusable for various reasons, the point can be converted to 2D type using the button '3D to 2D'. The horizontal component will be used in the 3D Calculations but the vertical component will be ignored. The row must be selected first by clicking in the empty box at the beginning of the row thus changing the highlight of the row to **blue**. This will automatically update the 'Check Point Type Counts' values on the Input Tab[1293], the Delta X/Y plot[1305], the Result Table[1297], and it will overwrite the loaded CSV file with all the current point types and measurements. A backup copy of the loaded CSV file is made before the new one is written.
7. When a point is decided to not be valid or useful, it can be unchecked, however the CSV does not automatically update. Click the Recalculate button to complete the update. This remains true if the point is checked again.
8. The 3D Control Report Tool accepts CSV files in all available configurations: All 3D, 3D/NVA, 2D/

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NVA, 3D/ 2D/NVA. VVA points can be present in either.

See Also

Check Point Report Overview 1224

Input Tab 1293

Result Table Tab 1297

Histogram Tabs 1300

Delta X/Y Plot Section 1305

Statistics per Check Point Table 1308

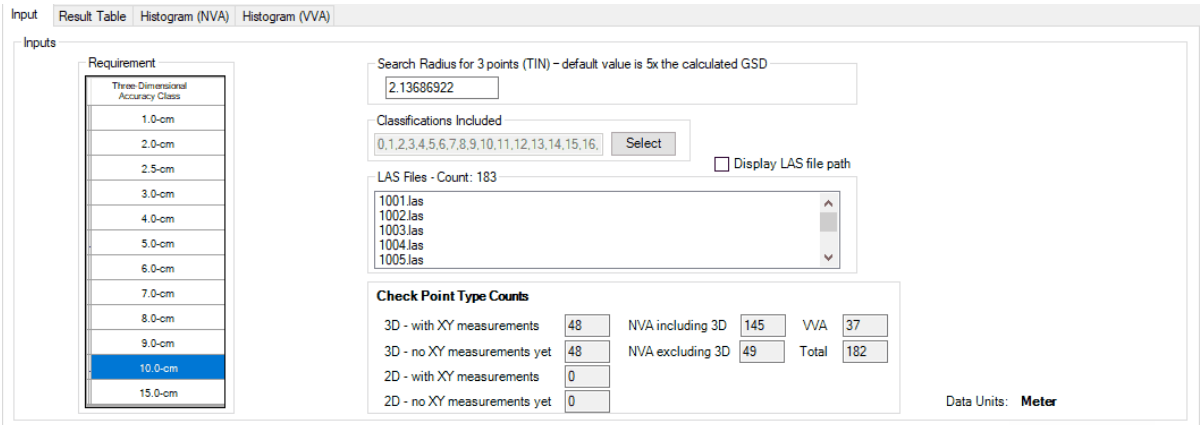
Finishing and Saving the Check Point Report 1312

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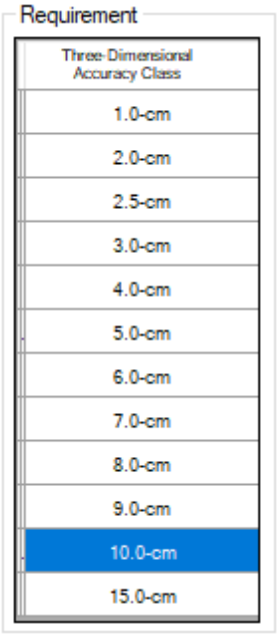
6.1.2.1 Input Tab



Input:



- **Three-Dimensional Accuracy Class (Requirement table):** This is the target root mean squared error ($RMSE_{3D}$) value for the project, which defines the Three-Dimensional Accuracy Class requirement. During the calculation of the check point statistics, comparisons are made to this value to see if the dataset meets the desired accuracy requirements. To achieve the target accuracy requirements, the calculated $RMSE_{3D}$ value is compared to the target value to determine if the LiDAR surface at each surveyed check point is within an acceptable margin of error to be displayed in green font on the 'Result Table'1297 tab. The default value is '10.0-cm' but can be changed as needed.

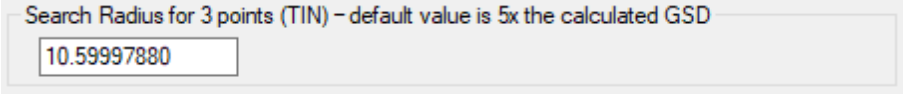


Selecting a different Three-Dimensional Accuracy Class will trigger an automatic recalculation of the results.

- **Search Radius for 3 points (TIN):** This value is calculated from the loaded LAS data. The default value is five times (5x) the Ground Sample Distance (GSD). This value can be modified with the following caveats: too small of a value will result in some check points not being compared to their surrounding LAS data. This may be the case when the 'TIN Coverage' value in the 'Statistics per

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Check Point' table is 'No', resulting in those points in the table having many blank fields. Too large of a Search Radius value may result in overly-long processing times.



Modifying the Search Radius value followed by either the 'Enter' or 'Tab' key will trigger an automatic recalculation of the results.

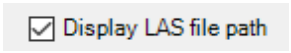
- **Classifications Included:** This list box shows which data classifications are to be used to calculate elevation. Only those data classifications that are displayed in the box will be included in the elevation calculation. When Class 2 (Ground) is included, the status of the Model Key-point bit flag, if present, is ignored.

  Note that points flagged as 'Withheld', regardless of classification, will not be used in this tool.

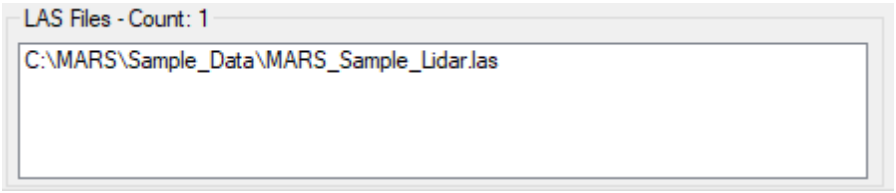


Selecting a different classification or set of classifications will trigger an automatic recalculation of the results.

- **LAS Files - Count:** This section shows a list of all LAS files loaded into the project and their count. A checkbox option to display the complete file path is available. The status of this 'Display LAS file path' check box will also affect the (optional) saved check point reports (see Finishing the Check Point Report 1312).



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- **Check Point Type Counts:**
  - **3D - with XY measurements** - the total of all 3D points whose status boxes are checked for inclusion, and for which XY user measurements have been made. This count is updated as additional measurements are made or previous values are cleared.
  - **3D - no XY measurements yet** - the total of all 3D points whose status boxes are checked for inclusion, and for which XY user measurements have not yet been made. This count is updated as additional measurements are made or previous values are cleared, and also when the ' Convert to NVA button is clicked.
  - **2D - with XY measurements** - the total of all 2D points (that were converted from 3D points) whose status boxes are checked for inclusion. This count is updated each time 3D points are converted to 2D.
  - **2D - no XY measurements yet** - the total of all 2D points whose status boxes are checked for inclusion, and for which XY user measurements have not yet been made.
  - **NVA including 3D** - the total of all NVA points (including all 3D points) whose status boxes are checked for inclusion. This value will not change unless the loaded check points CSV file is modified and re-loaded.
  - **NVA excluding 3D** - the total of all NVA points (excluding all 3D points) whose status boxes are checked for inclusion. This value will not change unless the loaded check points CSV file is modified and re-loaded.
  - **VVA** - the total of all VVA points whose status boxes are checked for inclusion. This value will not change unless the loaded check points CSV file is modified and re-loaded.

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- **Total** - the total of all points whose status boxes are checked for inclusion. This value will not change unless the loaded check points CSV file is modified and re-loaded.

Changing the inclusion of one or more check points by checking/unchecking their status boxes will be reflected in the above counts on-the-fly.

See Also

Check Point Report Overview 1224

Result Table Tab 1297

Histogram Tabs 1300

Delta X/Y Plot Section 1305

Statistics per Check Point Table 1308

Finishing and Saving the Check Point Report 1312

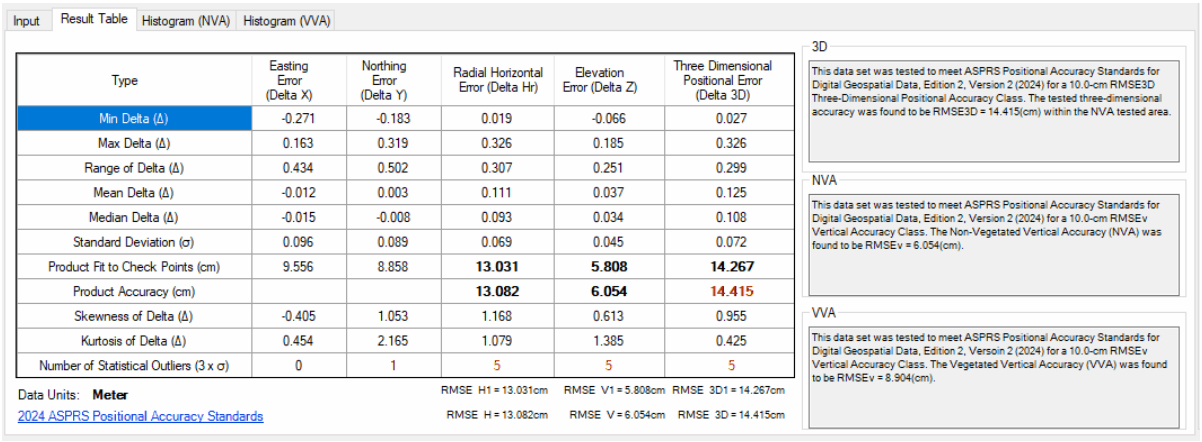
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6.1.2.2 Result Table Tab

Check Point Report: 3D Accuracy - Result Table Tab

Merrick Advanced Remote Sensing (MARS®) Software

Result Table and Accuracy Reporting Statements:



*All numerical and statistical results in this table are based on **3D, 2D,** and **NVA** points - VVA points are not included here.*

The table reports on 11 types of values or statistics in five error categories for the project as a whole:

- Min Delta (Δ) - for all included 3D and 2D check points, this is the lowest negative **'Delta X'** or **'Delta Y'** value. For **'Delta Hr'** and **'Delta 3D'** (3D points only), it is the lowest value. For **'Delta Z** ,' it is the lowest negative value for the 3D and NVA points combined.
- Max Delta (Δ) - for all included 3D and 2D check points, this is the highest positive **'Delta X'** or **'Delta Y'** value. For **'Delta Hr'** and **'Delta 3D'** (3D points only), it is the highest value. For **'Delta Z** ,' it is the highest positive value for the 3D and NVA points combined.
- Range of Delta (Δ) - for all included 3D and 2D check points, this is the range from Min Delta to Max Delta for each of the **'Delta X,' 'Delta Y,' 'Delta Hr,'** and **'Delta 3D'** (3D points only) error categories. For **'Delta Z**,' it is the range of Min Delta to Max Delta for the 3D and NVA points combined.
- Mean Delta (Δ) - for all included 3D and 2D check points, this is the mean (average) **'Delta X,' 'Delta Y,' 'Delta Hr,'** and **'Delta 3D'** (3D points only) value. For **'Delta Z**,' it is the mean value for the 3D and NVA points combined.
- Median Delta (Δ) - for all included 3D and 2D check points, this is the median **'Delta X,' 'Delta**

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Y,' 'Delta Hr,' and **'Delta 3D'** (3D points only) value. For **'Delta Z**,' it is the median value for the 3D and NVA points combined.

- Standard Deviation (σ) - for all included 3D and 2D check points, this is the standard deviation for all the **'Delta X,' 'Delta Y,' 'Delta Hr,'** and **'Delta 3D'** (3D points only) values. For **'Delta Z**,' it is the standard deviation for the 3D and NVA points combined.
- Product Fit to Check Points (cm) - these are the RMSE calculations, ignoring the effects of the RMSE_H2 and RMSE_V2 (survey error) values, for each of the **'Delta X,' 'Delta Y,' 'Delta Z,' ' Delta Hr,'** and **'Delta 3D'** error categories.
- Product Accuracy (cm) - these are the RMSE calculations, including the effects of the RMSE_H2 and RMSE_V2 (survey error) values, for each of the **'Delta Z,' 'Delta Hr,'** and **'Delta 3D'** error categories. A green value indicates compliance with the Three-Dimensional Accuracy Class value selected in the Requirement table (see Input Tab 1293); a red value indicates non-compliance.
- Skewness of Delta (Δ) - this is the measure of symmetry or asymmetry within a dataset. The distribution is considered symmetrical if skewness is close to zero (between -0.5 and 0.5) and the mean (average) is nearly equal to the median.
- Kurtosis of Delta (Δ) - this is the measure of relative 'peakedness' or flatness of a distribution compared with a normally distributed dataset. Positive kurtosis indicates a relatively peaked distribution near the mean (average) while negative kurtosis indicates a flat distribution near the mean. The distribution is considered normal if the kurtosis is between -3 and 3.
- Number of Statistical Outliers (3x σ) - this is a count of check points whose value in the error category in which the outlier count is displayed is more than 3x the standard deviation for that error category. In the sample table above, the '5' in the **'Delta Hr'** error category indicates that there are five check points whose **'Delta Hr'** value is at least 3x the standard deviation value of 0.069 (at least 0.207). The 'ID' and 'Delta H' fields in those check points' rows will be displayed in red font in the 'Statistics per Check Point 1308' table.

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In the lower-right of the Result Table, the calculated RMSE values for '**Delta Hr**,' '**Delta Z**,' and '**Delta 3D**' are repeated with labels that are used in the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024).

NOTE that 2D points (no usable Z-value) and NVA points (no XY measurements) are also used to calculate the entire dataset's 'Delta 3D' results.

Reporting statement(s): There are three possible accuracy reporting statements that may be displayed in this section - 3D, NVA, and VVA - depending on the check point types present in the loaded CSV file. The actual wording is dependent on the number of each check point type in the loaded CSV, either 30+ or less than 30. The reporting statements conform to the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024).

See Also

Check Point Report Overview 1224

Input Tab 1293

Histogram Tabs 1300

Delta X/Y Plot Section 1305

Statistics per Check Point Table 1308

Finishing and Saving the Check Point Report 1312

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6.1.2.3 Histogram Tabs

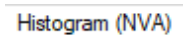


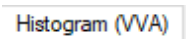
Tabs

Merrick Advanced Remote Sensing (MARS®) Software

Histogram Tabs:

Depending on the check point types present in the loaded CSV file, one or both tabs (NVA and VVA) will have a Z Error histogram chart displayed.





See Also

Check Point Report Overview 1224

Input Tab 1293

Result Table Tab 1297

Histogram (NVA) 1302

Histogram (VVA) 1303

Delta X/Y Plot Section 1305

Statistics per Check Point Table 1308

Finishing and Saving the Check Point Report 1312

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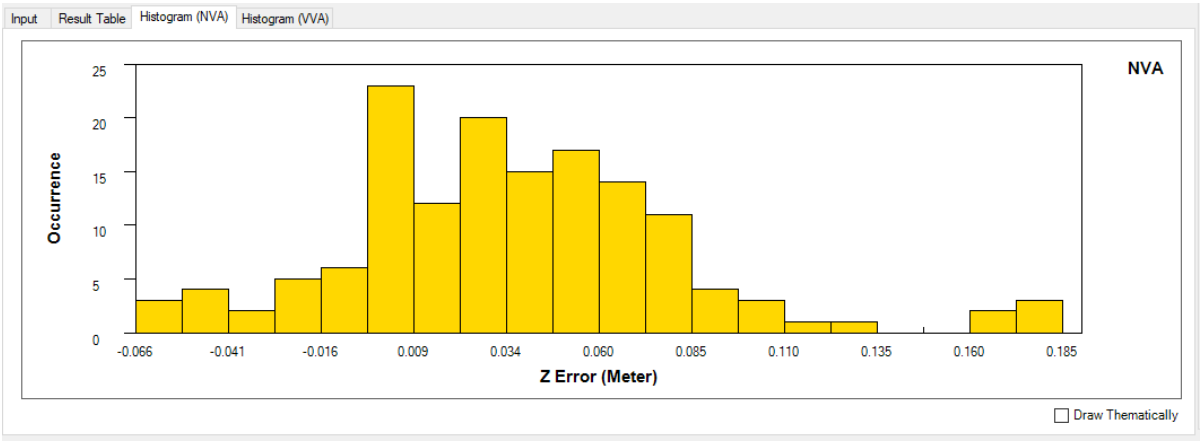
6.1.2.3.1 Histogram (NVA)

Check Point Report: 3D Accuracy - Histogram (NVA) Tab

Merrick Advanced Remote Sensing (MARS®) Software

Histogram (NVA):

This chart displays the frequency ('Occurrence') of Delta Z ('Z Error') in ranges determined by the extents of the deltas. In the example below, there are 29 **3D** or **NVA** check points whose Delta Z falls between -0.016 and 0.009 meters.

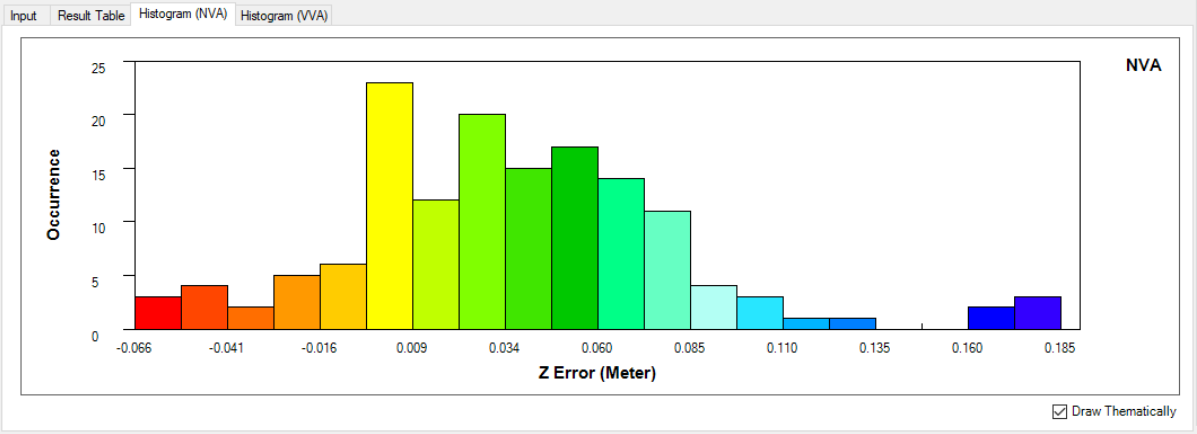


Positive Z Error means the calculated Z-value of the lidar data is higher than the Z-value of the surveyed check point. Conversely, negative Z Error means the calculated Z-value of the lidar data is lower than the Z-value of the surveyed check point.

Checking the 'Draw Thematically' box in the lower-right of the tab will display the frequency bars of the histogram using a color ramp from red at the left side (greatest negative Z Error), to dark purple at the

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right (greatest positive Z Error). The Check Points in the main MARS window will be colorized to match the bar they belong to.



See Also

Histogram Tabs 1300

Histogram (VVA) Tab 1303

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6.1.2.3.2 Histogram (VVA)

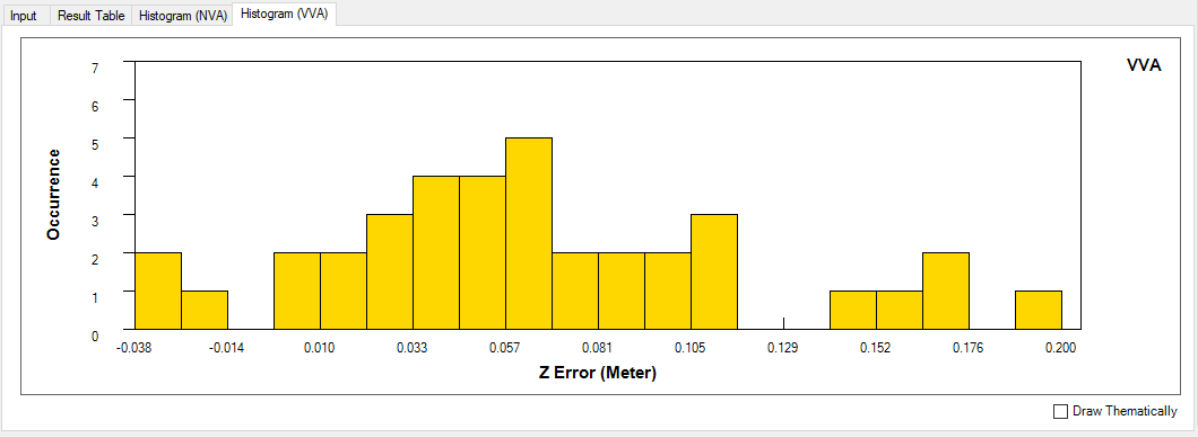
Check Point Report: 3D Accuracy - Histogram (VVA) Tab

Merrick Advanced Remote Sensing (MARS®) Software

Histogram (VVA):

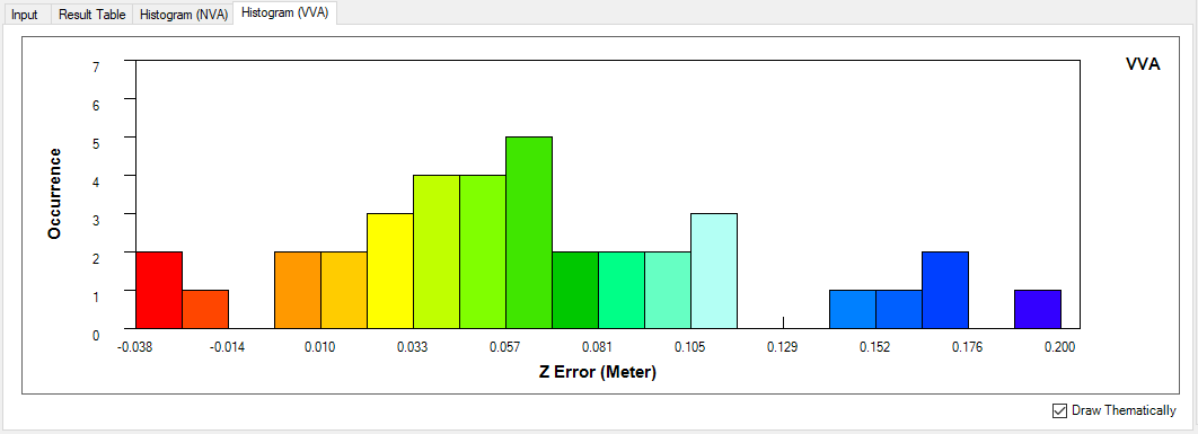
This chart displays the frequency ('Occurrence') of Delta Z ('Z Error') in ranges determined by the extents

of the deltas. In the example below, there are 7 **VVA** check points whose Delta Z falls between 0.057 and 0.081 meters.



Positive Z Error means the calculated Z-value of the lidar data is higher than the Z-value of the surveyed check point. Conversely, negative Z Error means the calculated Z-value of the lidar data is lower than the Z-value of the surveyed check point.

Checking the 'Draw Thematically' box in the lower-right of the tab will display the frequency bars of the histogram using a color ramp from red at the left side (greatest negative Z Error), to dark purple at the right (greatest positive Z Error). The Check Points in the main MARS window will be colorized to match the bar they belong to.



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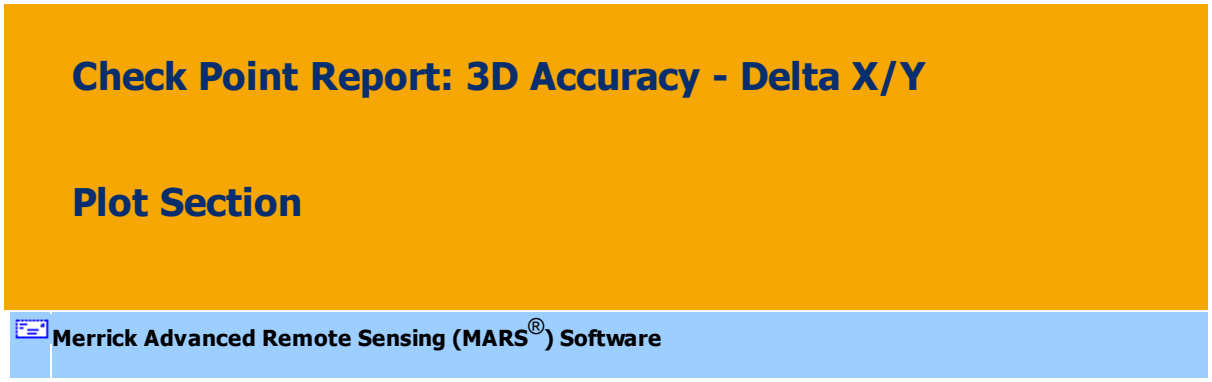
See Also

Histogram Tabs 1300

Histogram (NVA) Tab 1302

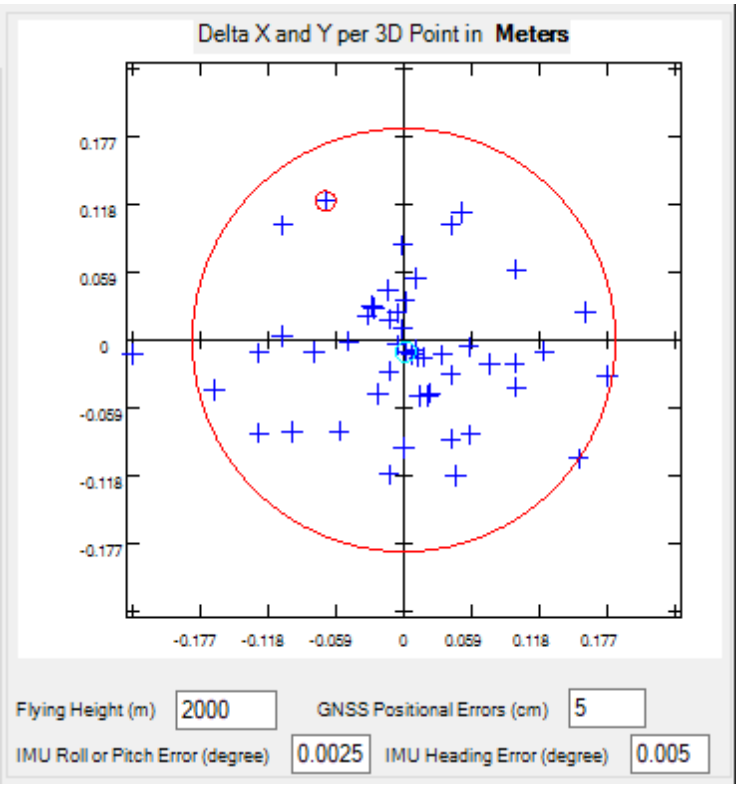
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6.1.2.4 Delta X/Y Plot Section



Delta X/Y Plot:

This graphic is visible regardless of which tab is being viewed. It displays the Delta X 1310 / Delta Y 1311 values of the **3D** and **2D** check points as '+' symbols. A 3D or 2D point with Delta X=0 and Delta Y=0 would be plotted in the exact center, at the intersection of the crosshairs.



The red circle's position in the plot is determined by a formula that uses the Flying Height, GNSS positional error, and IMU errors as inputs. The formula is published on page 21 of the ASPRS Positional Accuracy Standards for Digital Geospatial Data, Edition 2, Version 2 (2024). The circle is meant to be a guide intended to show the maximum horizontal accuracy limits of uncorrected, direct georeferencing, discrete lidar points. In the sample plot above, the radius of the limit circle is about 18cm. A final calibrated lidar dataset's horizontal measurements should fall within this circle. If all points fall inside, the circle will be plotted in green. If one or more points lands outside, the plotted circle will be red. The small cyan circle represents the average X/Y delta which ideally should be located near the center of the plot.

The four inputs to the formula that determines the bounding circle's location in the plot are:

- 'Flying Height (m)' - this is the average AGL (**A**bove **G**round **L**evel) height of the collection system for the project as a whole, in meters.

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- 'GNSS Positional Errors (cm)' - this is the error in the **G**lobal **N**avigation **S**atellite **S**ystem receiver, in centimeters. The value can be obtained from published manufacturer specifications.
- 'IMU Roll or Pitch Error (degree)' - this is an error inherent in the **I**nertial **M**easurement **U**nit, in angular units (degrees). The value can be obtained from published manufacturer specifications.
- 'IMU Heading Error (degree)' - this is an error inherent in the **I**nertial **M**easurement **U**nit, in angular units (degrees). The value can be obtained from published manufacturer specifications.

The Check Point Report tool opens with the default values shown in the example graphic above. These will almost certainly need to be modified for each project. ***Modifying any of these values, followed by pressing either the 'Enter' or 'Tab' key, will trigger an automatic recalculation of the results.***

Changing the inclusion of one or more measured 3D check points (or 2D check point) by checking/ unchecking their status boxes in the 'Statistics per Check Point' table, followed by clicking the 'Recalculate' button, will add or remove that point from the Delta X/Y plot. Any **Type 3D** or **2D** point rows selected in the individual check point table 1308 will have their corresponding point marker(s) highlighted by a small red circle on this plot to aid in analysis.

See Also

Check Point Report Overview 1224

Input Tab 1293

Result Table Tab 1297

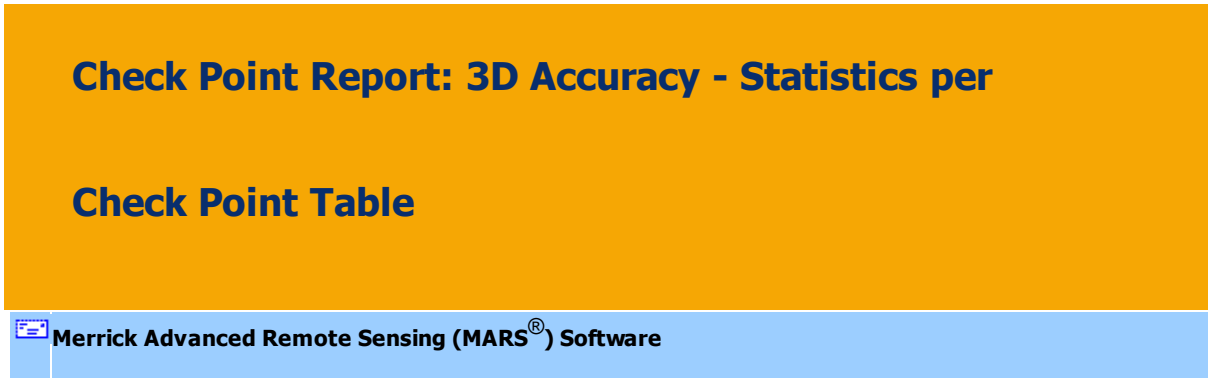
Histogram Tabs 1300

Statistics per Check Point Table 1308

Finishing and Saving the Check Point Report 1312

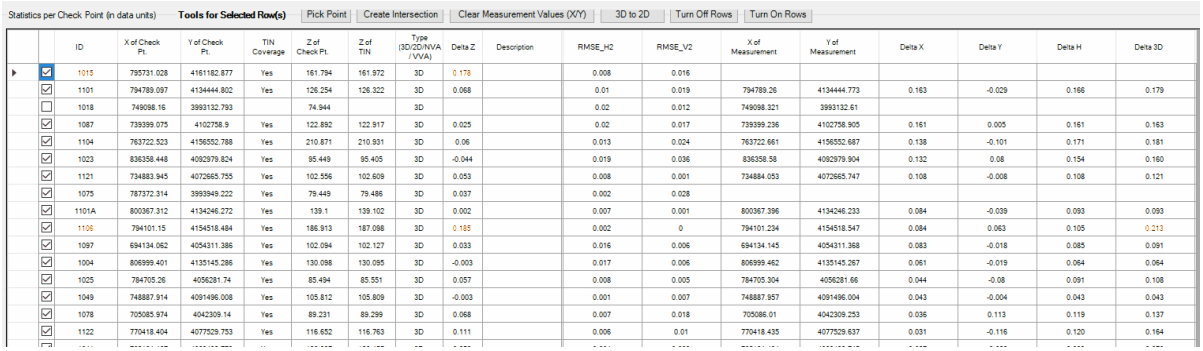
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6.1.2.5 Statistics per Check Point Table



Statistics per Check Point table:

This table is found in the bottom half of the interface.



	ID	X of Check Pt.	Y of Check Pt.	TIN Coverage	Z of Check Pt.	Z of TIN	Type (3D/2D/NVA / VVA)	Delta Z	Description	RMSE_H2	RMSE_V2	X of Measurement	Y of Measurement	Delta X	Delta Y	Delta H	Delta 3D
▸	1015	795731.028	4161182.877	Yes	161.794	161.972	3D	0.178		0.008	0.016						
	1101	794789.097	4134444.802	Yes	126.254	126.322	3D	0.068		0.01	0.019	794789.26	4134444.773	0.163	-0.029	0.166	0.179
	1018	749098.16	3993132.793		74.944		3D			0.02	0.012	749098.321	3993132.61				
	1087	739399.075	4102758.9	Yes	122.892	122.917	3D	0.025		0.02	0.017	739399.236	4102758.905	0.161	0.005	0.161	0.163
	1104	763722.523	4156552.788	Yes	210.871	210.931	3D	0.06		0.013	0.024	763722.661	4156552.687	0.138	-0.101	0.171	0.181
	1023	836358.448	4092979.824	Yes	95.449	95.405	3D	-0.044		0.019	0.036	836358.58	4092979.904	0.132	0.08	0.154	0.160
	1121	734883.945	4072665.755	Yes	102.556	102.609	3D	0.053		0.008	0.001	734884.053	4072665.747	0.108	-0.008	0.108	0.121
	1075	787372.314	3993949.222	Yes	79.449	79.486	3D	0.037		0.002	0.028						
	1101A	800367.312	4134246.272	Yes	139.1	139.102	3D	0.002		0.007	0.001	800367.396	4134246.233	0.084	-0.039	0.093	0.093
	1106	794101.15	4154518.484	Yes	186.913	187.098	3D	0.185		0.002	0	794101.234	4154518.547	0.084	0.063	0.105	0.213
	1097	694134.062	4054311.386	Yes	102.094	102.127	3D	0.033		0.016	0.006	694134.145	4054311.368	0.083	-0.018	0.085	0.091
	1004	806999.401	4135145.286	Yes	130.098	130.095	3D	-0.003		0.017	0.006	806999.462	4135145.267	0.061	-0.019	0.064	0.064
	1025	784705.26	4056281.74	Yes	85.494	85.551	3D	0.057		0.008	0.005	784705.304	4056281.66	0.044	-0.08	0.091	0.108
	1049	748887.914	4091496.008	Yes	105.812	105.809	3D	-0.003		0.001	0.007	748887.957	4091496.004	0.043	-0.004	0.043	0.043
	1078	705085.974	4042309.14	Yes	89.231	89.299	3D	0.068		0.007	0.018	705086.01	4042309.253	0.036	0.113	0.119	0.137
	1122	770418.404	4077529.753	Yes	116.652	116.763	3D	0.111		0.006	0.01	770418.435	4077529.637	0.031	-0.116	0.120	0.164

- The checkbox column at the left of the table shows the status of each check point in the loaded CSV file. A check mark indicates that the point is included in the analysis and all results.

- **ID -** This is the ID (label) of the check point, as found in the first column of the check point file. If a point's row is checked on, that point is included in project statistics - otherwise it is excluded from analysis.

Note: Double-clicking on a point's row will display that check point in the center of the LAS Map View window.

- **X of Check Pt. -** This is the surveyed X (easting) coordinate of the check point, as found in the second column of the check point file.

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- **Y of Check Pt. -** This is the surveyed Y (northing) coordinate of the check point, as found in the third column of the check point file.

- **TIN Coverage -** To determine an elevation for the LiDAR data at the XY location of each check point, a TIN is created using LiDAR points within the specified search radius distance (as auto-calculated or manually set) of the check point location. A TIN triangle may or may not cover the check point location. If a TIN was made that covers, then this field is set to “Yes” - otherwise it is set to “No”. For points converted from 3D to 2D, this field will be empty.

- **Z of Check Pt. -** This is the surveyed Z-value (elevation) of the check point, as found in the fourth column of the check point file.

- **Z of TIN -** The Z-value of the data, as computed from nearby LiDAR points. The methodology is to create a TIN using lidar points in the selected classes within the 'Search Radius' (see Input Tab 1293) of the check point location. Then, the one triangle in the TIN is found which covers, in two dimensions, the XY location. The three points of this triangle are used to calculate a height. More specifically, a location on the 3D triangle is found with the XY coordinates of the check point. The Z-value of this location is the Z-value used, as this represents a linearly interpolated value for the elevation from the three TIN points.

- **Type (3D/2D/NVA/VVA)** - This is the (optional) 3D, 2D, NVA, or VVA type of each check point, as found in the eighth column of the check point file. Not every check point in the file needs a value for this field. Any value that is not stored exactly as either **3D, 2D,** or **VVA** (not case-specific) or is empty will be interpreted as **NVA**.

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- **Delta Z -** The difference between the surveyed Z-value of the check point and the Z-value computed from the LiDAR data combined with RMSE_V2[1310]. A value more than three (3) times the calculated 'Standard Deviation' of 'Elevation Error (Delta Z)' - as shown in the Result Table[1297] - will cause the 'ID' field and the 'Delta Z' field in that check point's row to be displayed in red font. A positive (>0) Delta Z indicates that the Z-value calculated from the LiDAR data is higher than the surveyed Z-value of the check point. Conversely, a negative (<0) Delta Z indicates that the Z-value calculated from the LiDAR data is lower than the surveyed Z-value of the check point. For points converted from 3D to 2D, this field will be empty.

- **Description** - This is the optional description of each check point, as found in the seventh column of the check point file.

- **RMSE_H2** - This is the survey check point accuracy for the horizontal (XY) values, as found in the 10th column of the check point file.

- **RMSE_V2** - This is the survey check point accuracy for the elevation (Z) values, as found in the 11th column of the check point file.

- **X of Measurement -** The X-value of a user measurement (see the Pick Point[1284] and Create Intersection[1285] methods) based on where the 3D (or 2D) check point appears to be when viewing an intensity rendering of the lidar data.

- **Y of Measurement** - The Y-value of a user measurement (see the Pick Point[1284] and Create Intersection[1285] methods) based on where the 3D (or 2D) check point appears to be when viewing an intensity rendering of the lidar data.

- **Delta X -** The difference between the surveyed X-value of the check point and the 'X of Measurement'

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value (see above). A value more than three (3) times the calculated 'Standard Deviation' for 'Easting Error (Delta X)' - as shown in the Result Table 1297 - will cause the 'ID' field and the 'Delta X' field in that check point's row to be displayed in red font.

- **Delta Y** - The difference between the surveyed Y-value of the check point and the 'Y of Measurement' value (see above). A value more than three (3) times the calculated 'Standard Deviation' for 'Northing Error (Delta Y)' - as shown in the Result Table 1297 - will cause the 'ID' field and the 'Delta Y' field in that check point's row to be displayed in red font.

- **Delta H** - This is calculated by first finding the square root of the sum of the squares of Delta X and Delta Y. This intermediate result is known as H_1. Next, the square root of the sum of the squares of H_1 and RMSE_H2 1310 is calculated to produce Delta H. Thought of another way, it is the distance from the check point's surveyed XY location and the 'X of Measurement' / 'Y of Measurement' location with the horizontal survey error (RMSE_H2) factored in. A value more than three (3) times the calculated 'Standard Deviation' for 'Radial Horizontal Error (Delta Hr)' - as shown in the Result Table 1297 - will cause the 'ID' field and the 'Delta H' field in that check point's row to be displayed in red font.

- **Delta 3D** - This is calculated as the square root of the sum of the squares of Delta H and Delta Z with both survey errors (RMSE_V2 1310 and RMSE_H2 1310) factored in. A value more than three (3) times the calculated 'Standard Deviation' for 'Three Dimensional Positional Error (Delta 3D)' - as shown in the Result Table 1297 - will cause the 'ID' field and the 'Delta 3D' field in that check point's row to be displayed in red font. For points converted from 3D to 2D, this field will be empty.

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See Also

Check Point Report Overview 1224

Input Tab 1293

Result Table Tab 1297

Histogram Tabs 1300

Delta X/Y Plot Section 1305

Finishing and Saving the Check Point Report 1312

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6.1.2.6 Finishing and Saving the Check Point Report

Check Point Report: 3D Accuracy - Finishing and Saving the Check Point Report

Merrick Advanced Remote Sensing (MARS®) Software

Finishing and Saving the Check Point Report:

The values displayed in the Check Point Report window can be saved to a PDF file. The saved report will additionally contain the NVA and VVA histograms and screen captures of the the thematically-rendered X, Y, H, and Z errors (deltas). In addition, a 2D point shapefile of the check points that are turned on (included) in the report will be saved in the output folder, as well as a text file of the collection system's AGL/GNSS/IMU settings. The text file is needed as an input when running test 'DPH-11 Absolute Horizontal and Vertical Accuracy' in the USGS NGP LBS - 2024 rev. A 1351 version of the QC Module.

To generate the permanent check point report, follow these steps:

- Click the **'Save Report...'** button.
- Navigate to the desired folder, enter a filename, and click the **'Save'** button. The PDF report and the 2D point shapefile will be given the same name. The text file will be named 'AGL_GNSS_IMU.txt'.

To temporarily hide the Check Point Report window but have it quickly available for further viewing:

- Click the **'Hide'** button.
- Once hidden, the Check Point Report window can be re-opened for viewing by clicking the **'Check Point Report'** button on the QA/QC Tab 458. The window will immediately re-open with the last results displayed.

The **'Close'** button will completely close the Check Point Report and remove any calculations stored in RAM.

See Also

Check Point Report Overview 1224

Vertical Accuracy 1236

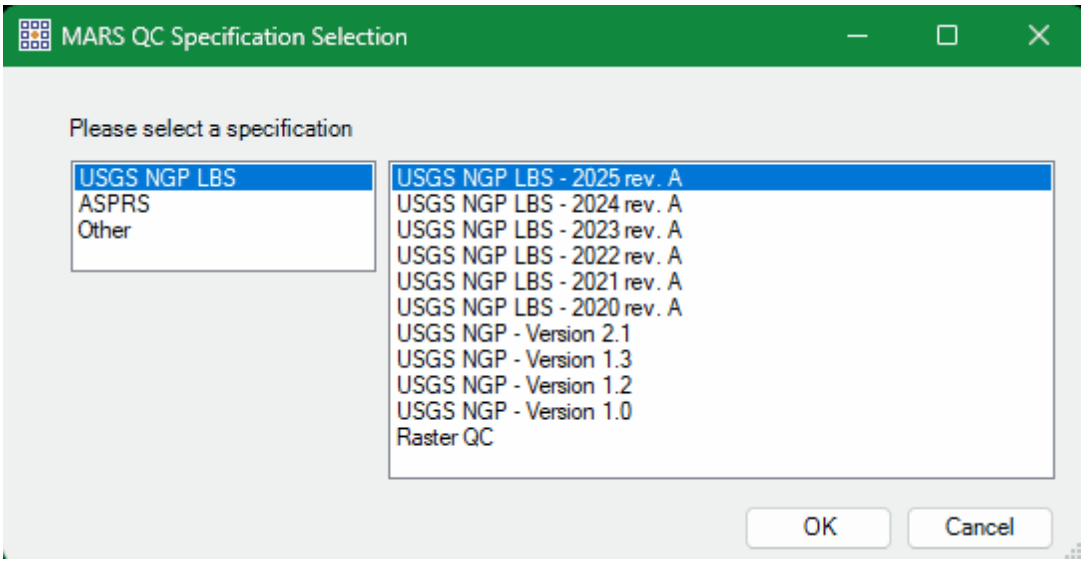
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6.2 QC Module - USGS NGP LBS

QC Module - USGS NGP LBS

The following selection list window will appear after clicking the 'QC Module' button 

on the QA/QC Tab[458]. The list is divided into USGS NGP LBS, ASPRS, and Other sections.



See

USGS NGP LBS - 2025 rev. A[1315]

USGS NGP LBS - 2024 rev. A[1351]

USGS NGP LBS - 2023 rev. A[1386]

USGS NGP LBS - 2022 rev. A[1421]

USGS NGP LBS - 2021 rev. A[1455]

USGS NGP LBS - 2020 rev. A[1490]

USGS NGP LBS - Version 2.1[1525]

USGS NGP LBS - Version 1.3[1559]

USGS NGP LBS - Version 1.2[1592]

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USGS NGP LBS - Version 1.0 1622

Raster QC 1651

See Also

QC Module - ASPRS 1659

QC Module - Other 1675

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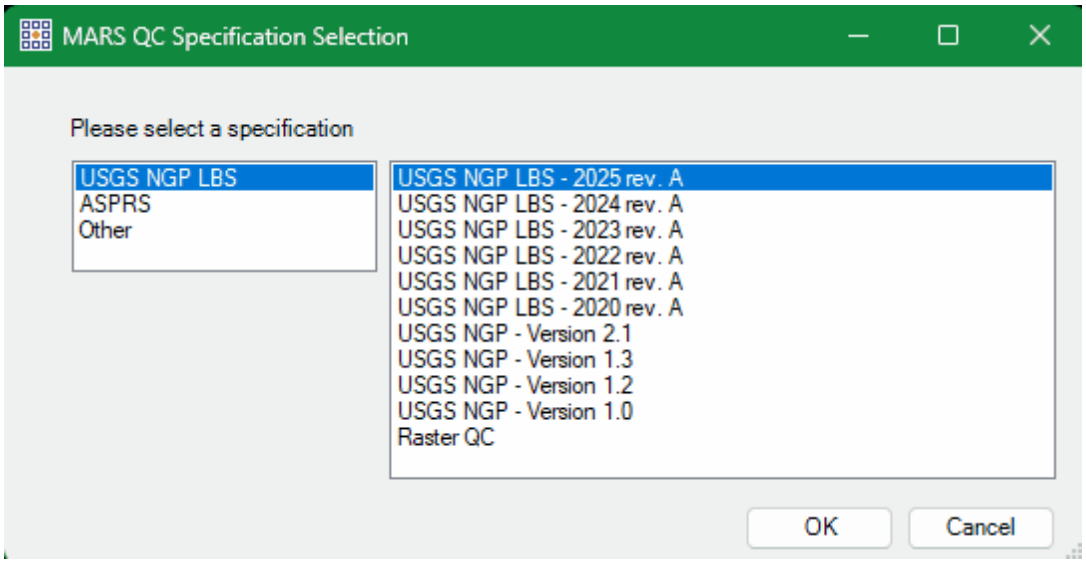
6.2.1 2025 rev. A

2025 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab 458, the 'USGS NGP LBS - 2025 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



This is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.1.1 General Information

USGS 2025 rev. A QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP LBS - 2025 rev. A' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2025 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS

2025 rev. A (January 2025) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1333 topic).

There are 24 possible tests that can be run in the USGS 2025 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1342 sub-topic for more information.

The USGS 2025 rev. A QC Module tests are divided into **Collection** 1329 and **Data Processing/Handling** 1333 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, USGS NGP - Version 1.0 1622, and Raster QC 623 tools, the Voronoi Density Reporting 1660 tool, and the LiDAR Data Checks 1677 and LiDAR Calibration Checks 1698 tools - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Data

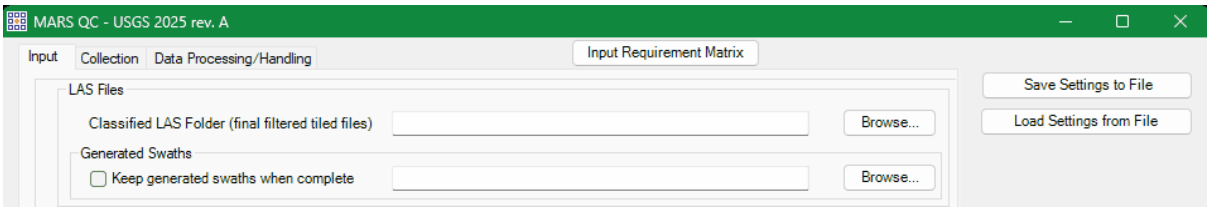
These are the datasets and files needed to run all tests:

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- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For this version of the LBS, the CSV file must adhere to the latest **13-column** format, as specified in the Check Point Report 1224 help topic.
- AGL_GNSS_IMU settings (TXT file format created by the Check Point Report 1224 tool)

Note that each test requires one or more of the inputs listed above. ***None of the input data should be loaded in the Map View window prior to running this tool***. The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Horizontal and Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.



Each Input Dataset should be in a separate folder to ensure proper operation and to avoid

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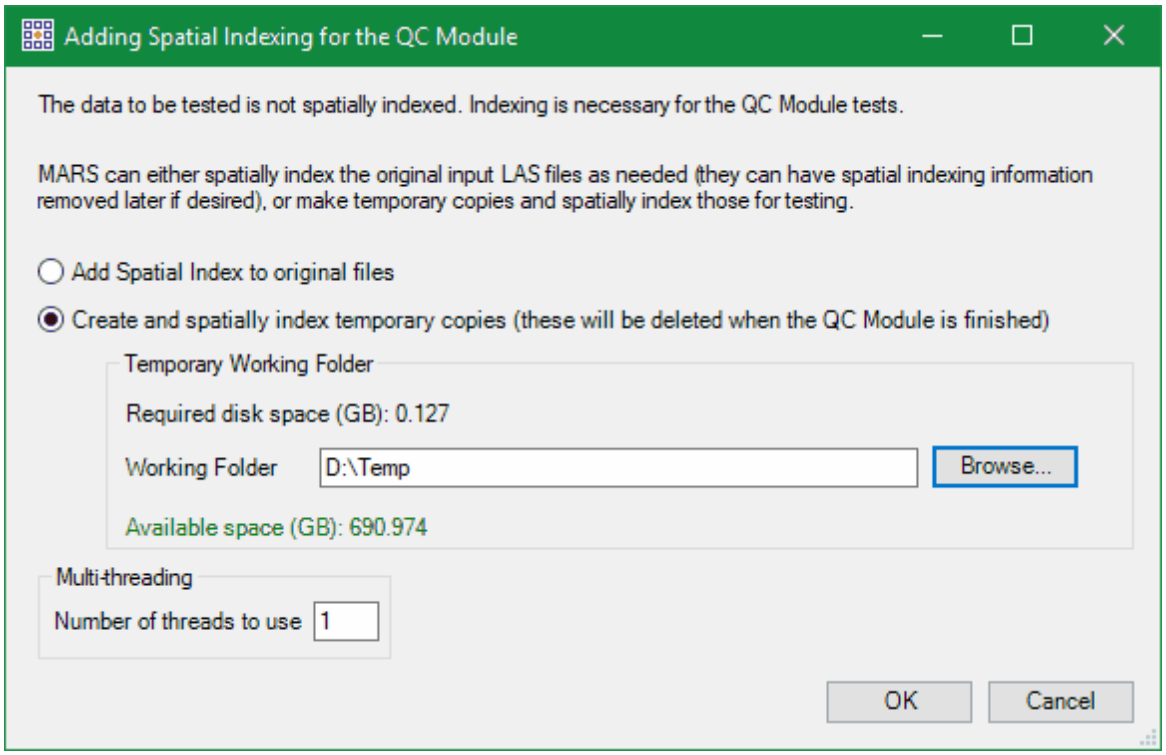
confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

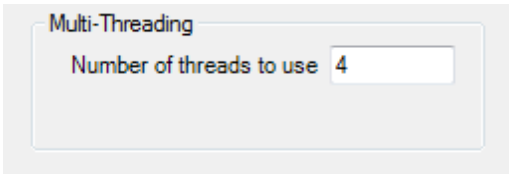
LAS data must be spatially indexed before it can be tested with the USGS 2025 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1324) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2025 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



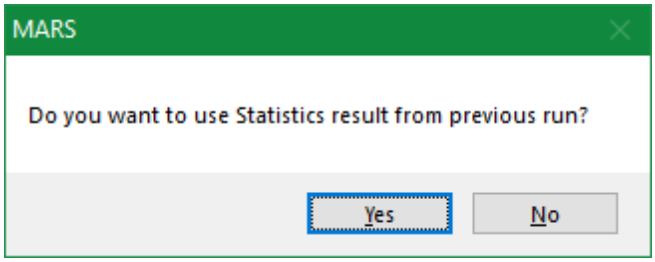
Running the* USGS 2025 rev. A *QC Module

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When all necessary entries have been made on the Input 1324, Collection 1329, and Data Processing/ Handling 1333 tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab 1324 for details), and whether data exists in these folders from previous runs of this USGS 2025 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

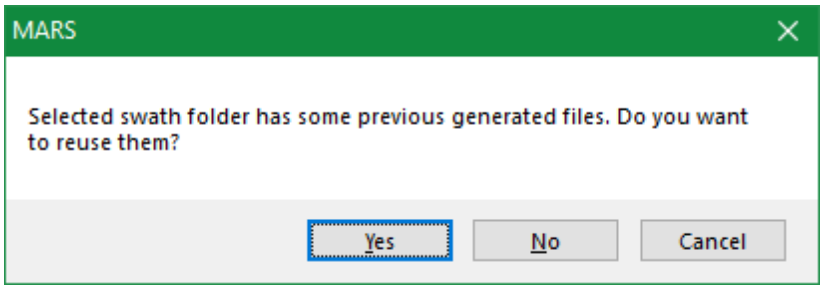
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab 1324. If there is data, the following message will appear:

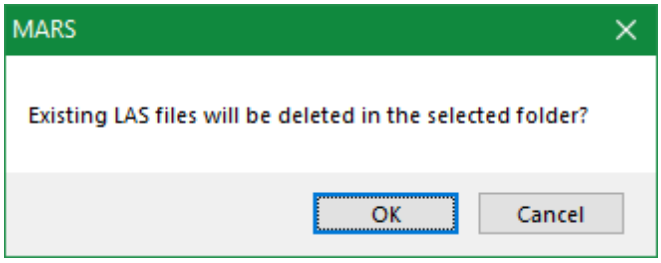
2.

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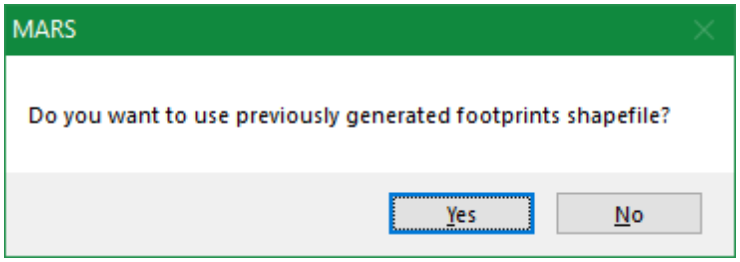
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1324] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1324] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab 1324. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2025 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2025 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1324. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 9:53:55 am on June 17, 2025.

Settings_USGS_2025_QC_20250617_095355.xml

This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2025 rev. A QC Module runs. After opening the USGS 2025 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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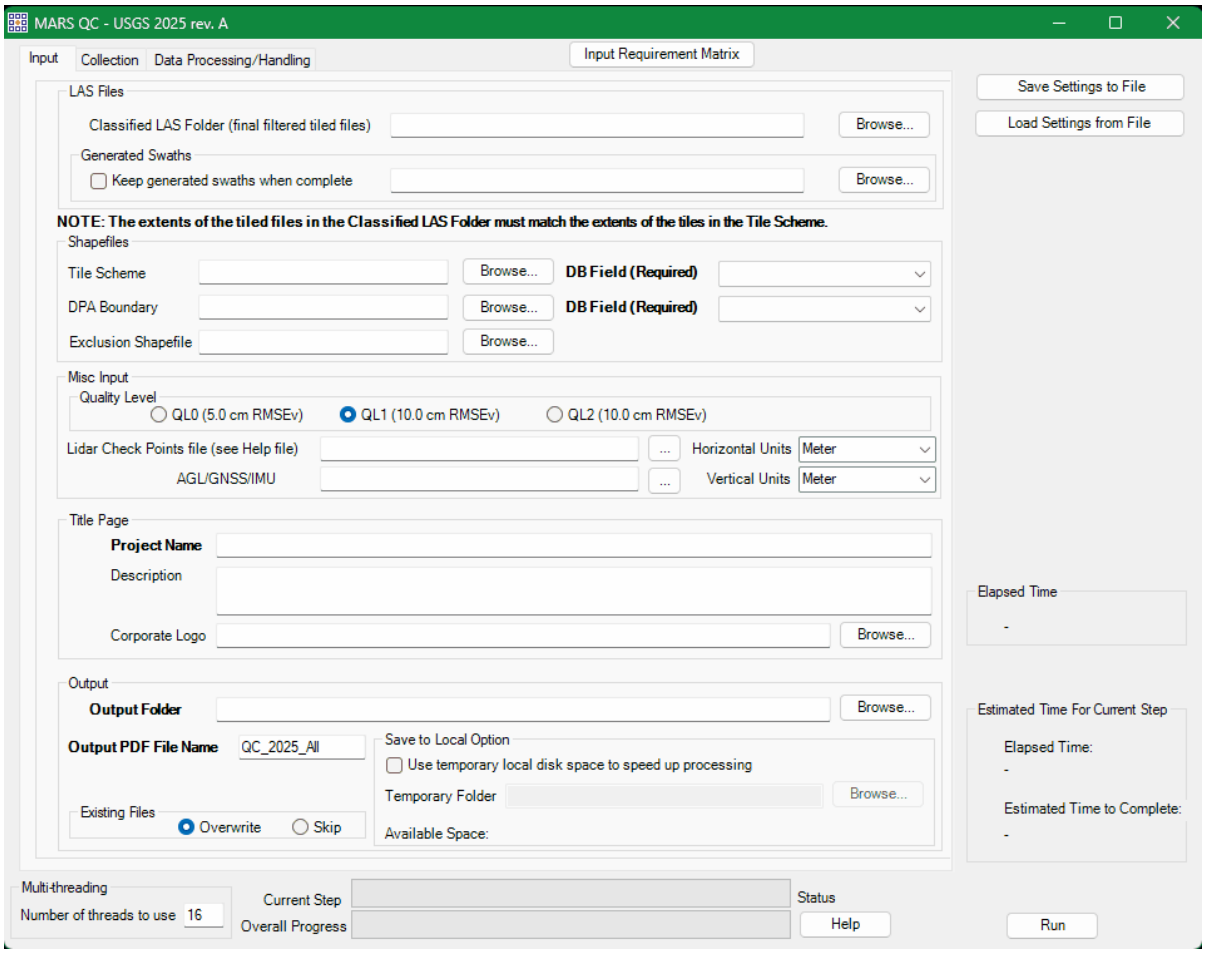
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2025 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.1.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs found in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab 1329 and Data Processing/Handling Tab 1333 topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2025 rev. A. By default, 'QL1 (10.0 cm RMSEz)' is pre-selected but this can be changed to 'QL0' or 'QL2' as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2025 rev. A QC Module.

A LiDAR Check Points file, in 13-column CSV format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points,** and **DPH-11 Absolute Horizontal and Vertical Accuracy**. Check points files in shapefile format cannot be used as input for this version of the USGS QC Module. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

A four-line text (*.txt) file ('AGL/GNSS/IMU') containing Flying Height, GNSS Positional Errors, and IMU errors is needed for complete results in test **DPH-11 Absolute Horizontal and Vertical Accuracy**. This file will be created when a report is saved from the '3D Accuracy' option of the Check Point Report 1312 tool. It will initially be stored in the same folder as the saved report.

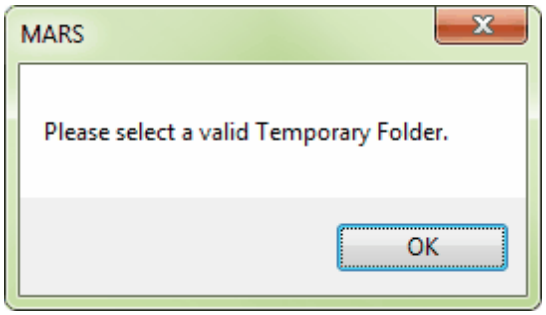
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results

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in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



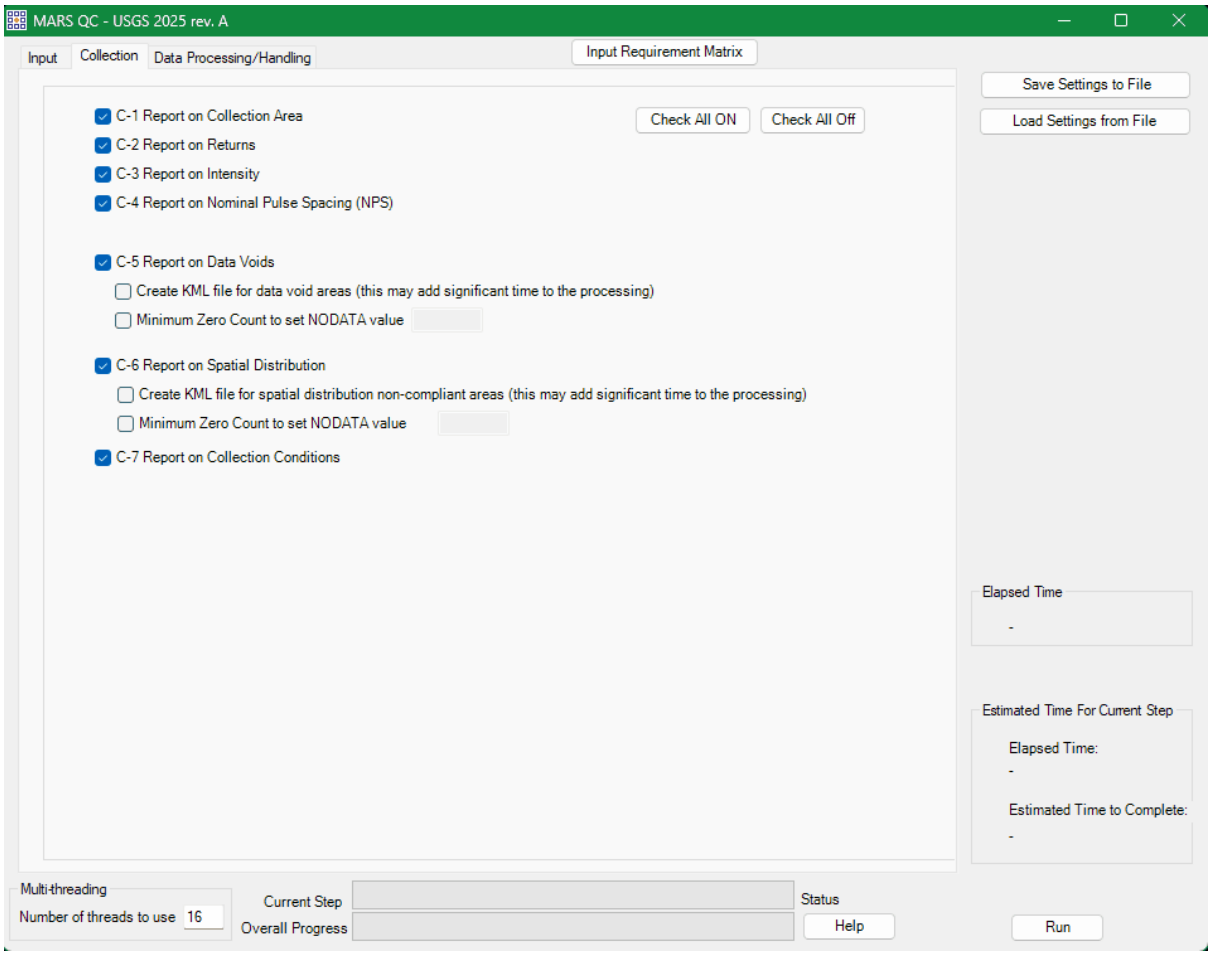
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1342 sub-topic).

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6.2.1.3 Collection Tab



The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/

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paragraph in the USGS NGP Lidar Base Specification 2025 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1342). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

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C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1324 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc.

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Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1324 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

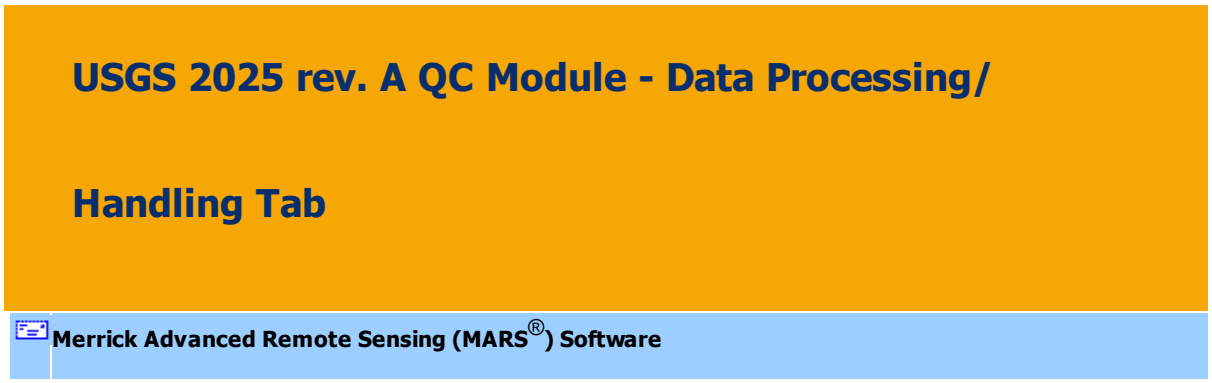
The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

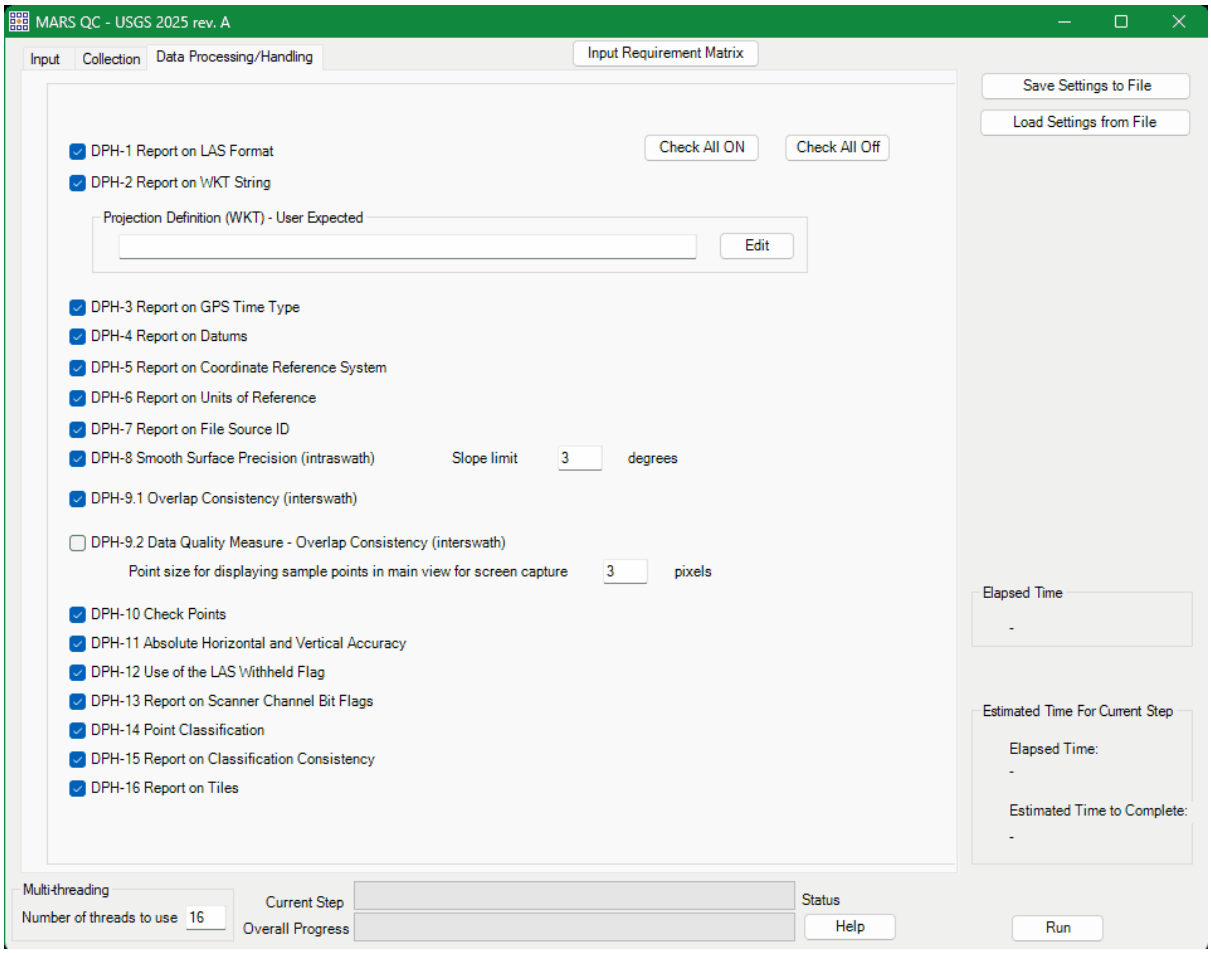
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6.2.1.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests.

Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2025 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1342). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

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The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1324.

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DPH-2 Report on WKT String

The purpose of this section is to show the expected WKT (Well-Known Text) string containing CRS (Coordinate Reference System) information for the lidar tiled data. Counts for matching and non-matching tiles are provided. Files that do not match the expected WKT entry are listed in red font for review.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A list of all unique horizontal and vertical datum names and associated EPSG codes is created for review.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the CRS definitions of the LAS files for the lidar tiled data. A list of unique horizontal and vertical CRS names, Geoid (height) Model names, and associated EPSG codes is created for review.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units (by file) is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units and their adherence to

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the user-input units values. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2025 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to create a Measurable Flight Line Separation Raster (FSR) for all of the data processed. This image shows the vertical separation of adjacent flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This thematic rendering is modulated by intensity to show land cover features. Along with the elevation difference raster of the overlap areas, a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels is created for review. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2025 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

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Multiple area-named sub-folders will be created if the Defined Project Area (DPA Boundary) shapefile consists of more than one polygon (e.g., 'Area1,' 'Area2,' etc.). The final PDF reports will indicate multiple DPA boundaries if present.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2025 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data. This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (Horizontal/NVA, NVA-only, and VVA). A screen capture of the Horizontal/NVA (shown in red), NVA-only (shown in yellow), and VVA (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

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DPH-11 Absolute Horizontal and Vertical Accuracy

The purpose of this section is to report on the absolute horizontal and vertical accuracy of the lidar data by testing for Horizontal/NVA, NVA-only, and VVA against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (Horizontal/NVA, NVA-only, or VVA), along with overall H and V error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of Horizontal/NVA check points with point-by-point error and descriptive information as compared to user XY measurements based on an intensity rendering of the lidar ground data, along with a DeltaX/DeltaY plot; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

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(DPH-13 Report on Scanner Channel Bit Flags

The purpose of this section is to report on the Scanner Channel bit flag values present in the input tiled data. For a single channel sensor, all points should have a scanner channel value of '0.' For a dual channel sensor, values should be either '0' or '1.' Three and four channel sensors should have values of '0' through '2' and '0' through '3,' respectively. A table of point counts and a bar graph are presented for review.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Additionally, any points in any classifications that are bit-flagged as Overlap will be reported in red font as this bit flag is no longer used for USGS data deliveries.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points

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(Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1324. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

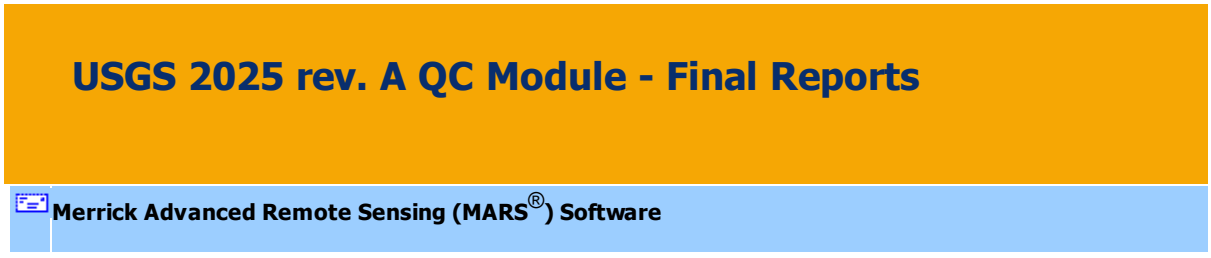
The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.1.5 Final Reports



QC Reporting

The output of the USGS 2025 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1324. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1324. The default name is 'QC_2025_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1324.

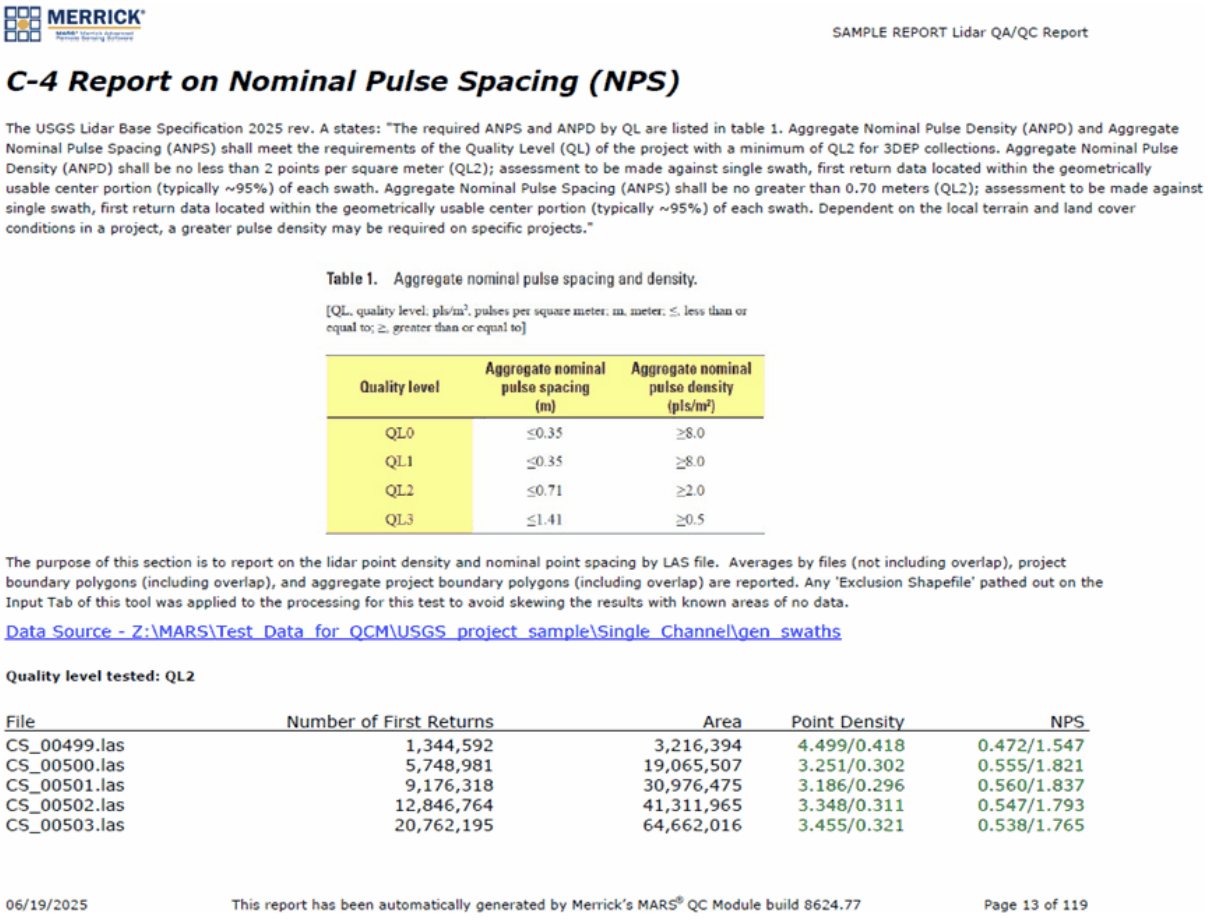
Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1316 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2025 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output**

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Folder will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDF reports are generated.

Sample Report Pages:



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SAMPLE REPORT Lidar QA/QC Report

C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2025 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

06/19/2025 This report has been automatically generated by Merrick's MARS® QC Module build 8624.77 Page 13 of 119

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294 pp Square Meter/ pp Square US Survey Foot	0.563/1.846 Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824 pp Square Meter/ pp Square US Survey Foot	0.336/1.102 Meter/ US Survey Feet

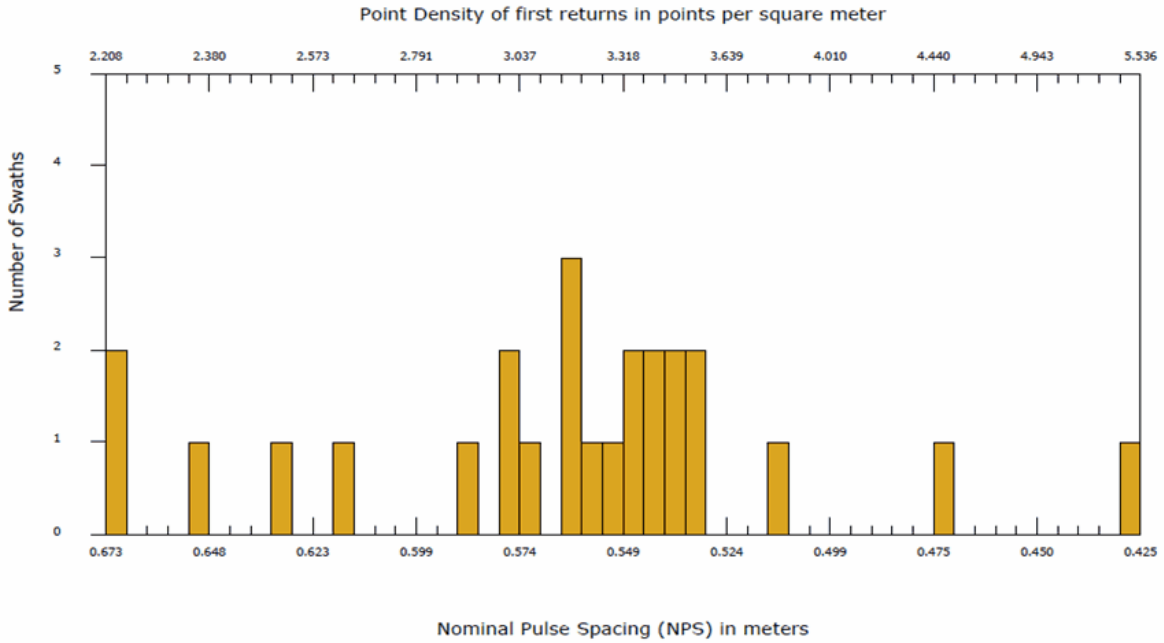
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2024 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show a mosaicked version of a thematically rendered map of swath separation for all the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For this product – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2025 rev. A states: "Interswath (overlap) consistency shall be assessed across the entirety of the project at the work unit level. Interswath (overlap) consistency shall be assessed through the use of swath separation images. " (Note: swath separation images are not created by this QC Module tool, but can be exported separately for delivery.) "Areas of overlap within the swath separation images shall be evaluated locally and wholistically. Densely vegetated land cover types, as well as abrupt changes in elevation may require a more wholistic assessment of the swath overlap area versus a more localized assessment.

- Examples of areas that shall undergo localized assessment include, but are not limited to, the following: improved and unimproved roadways, bare round open areas with less than 10 degrees of slope, and roofs with less than 10 degrees of slope.
- Wholistic assessments will be conducted across areas of swath overlap that span multiple adjoining terrain types."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show a mosaicked version of a thematically rendered map of swath separation for all the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For this product – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2025 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

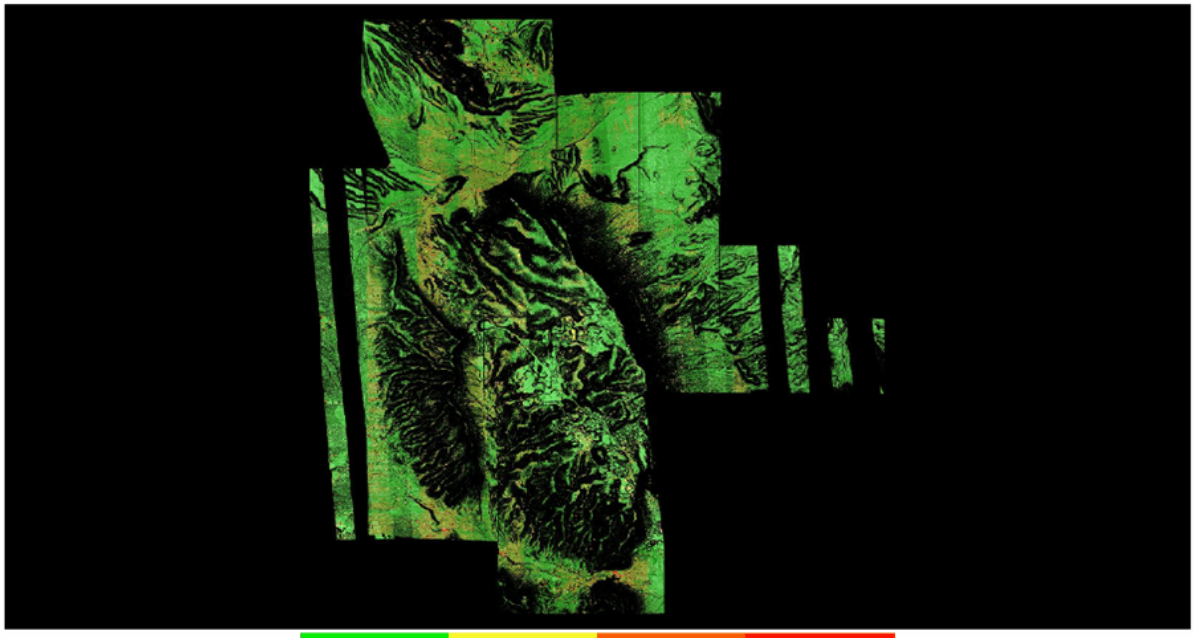
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

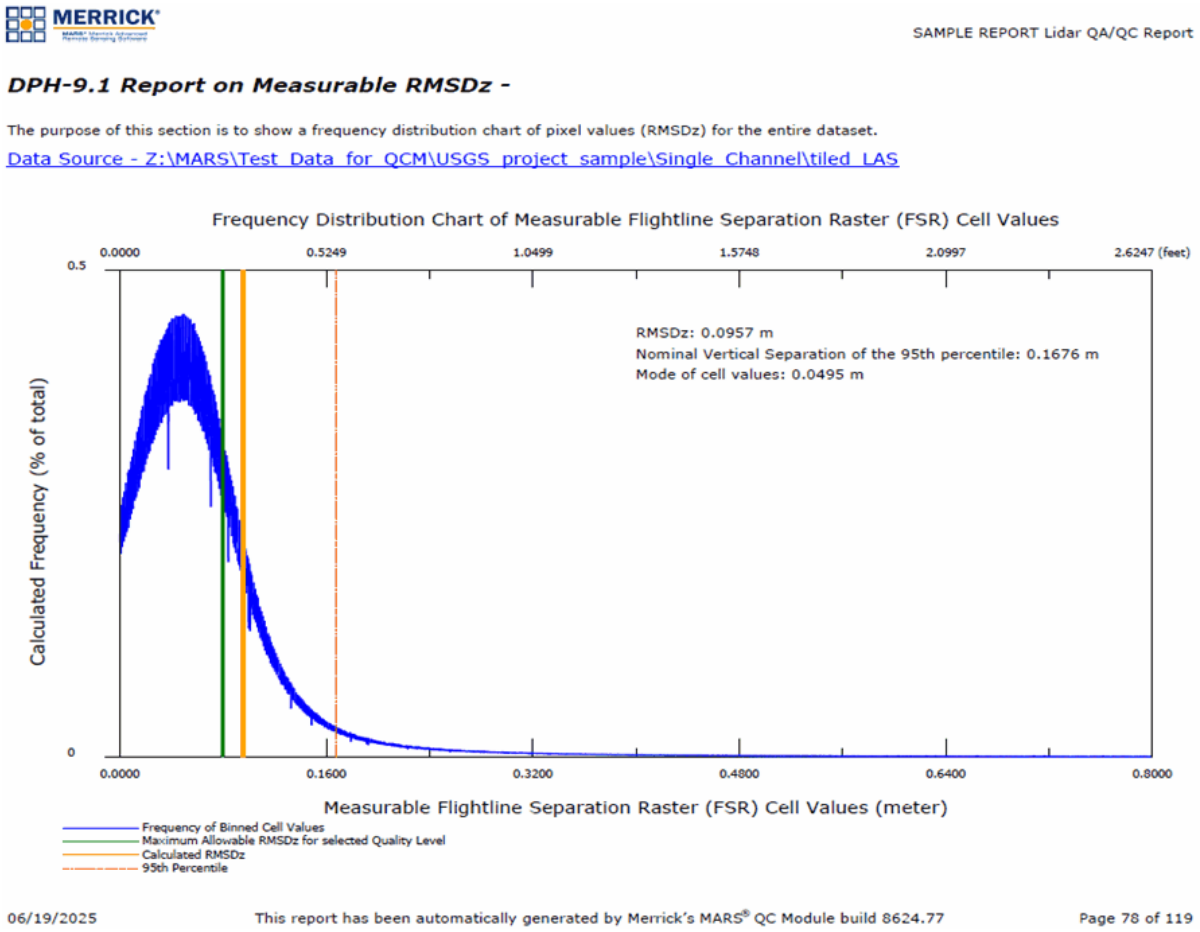
Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths
Result Path - D:\Temp\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jpg



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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6.2.2 2024 rev. A

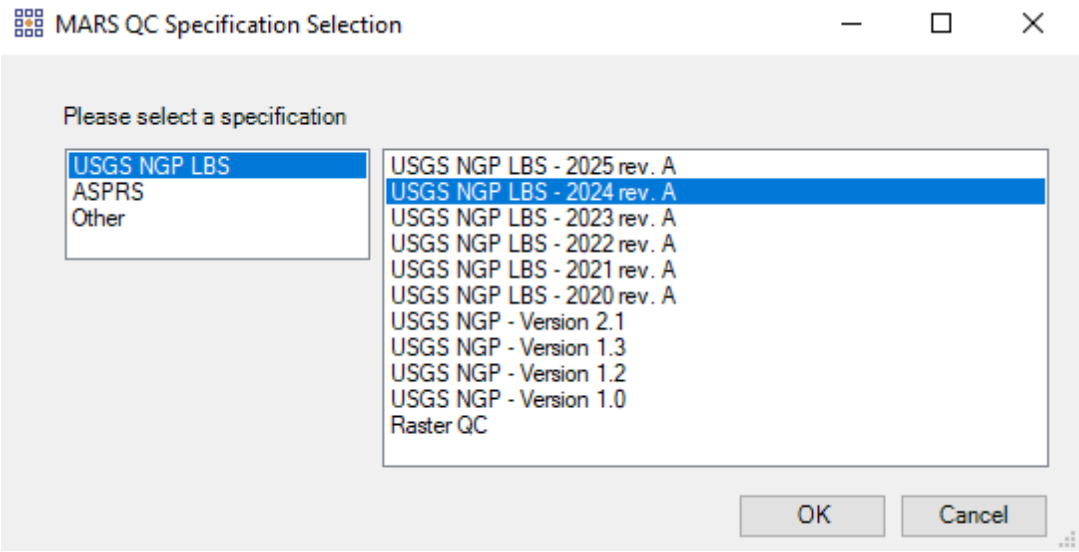
2024 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP LBS - 2024 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as

shown …

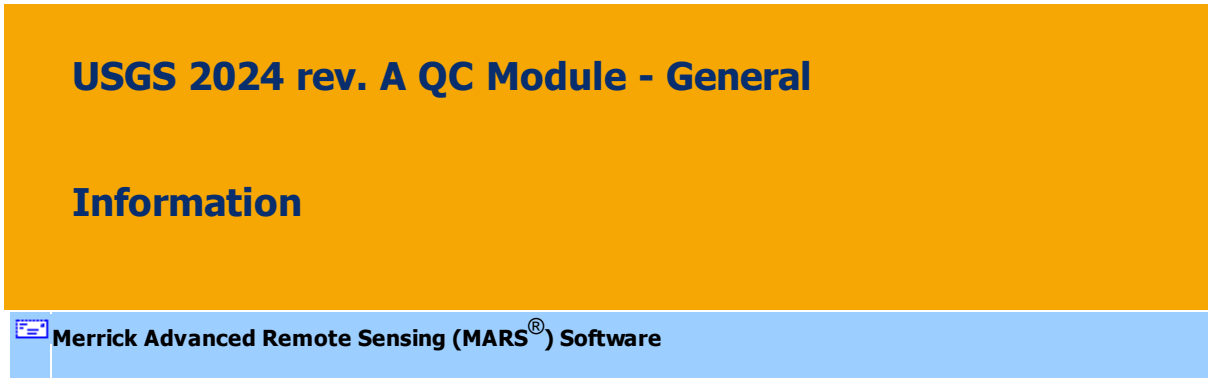


Note that the 'USGS NGP LBS - 2025 rev. A 1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.2.1 General Information



Purpose and Description

The purpose of the 'USGS NGP LBS - 2024 rev. A' quality control (QC) module in MARS® is to provide

an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2024 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS 2024 rev. A (January 2024) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1369 topic).

There are 24 possible tests that can be run in the USGS 2024 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1378 sub-topic for more information.

The USGS 2024 rev. A QC Module tests are divided into **Collection** 1365 and **Data Processing/Handling** 1369 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR Data Checks 1677 and LiDAR Calibration Checks 1698 tools, and the Voronoi Density Reporting 1660 tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

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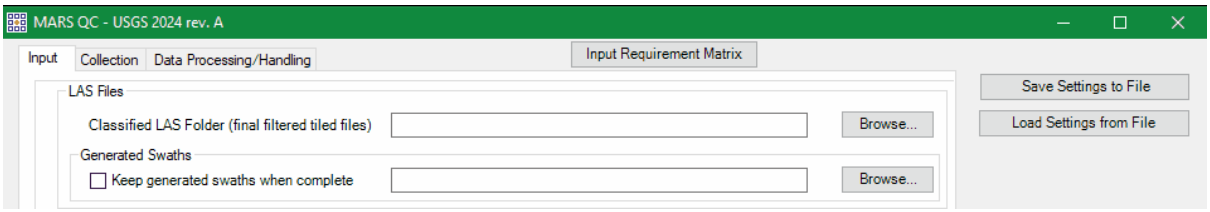
Input Data

These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For this version of the LBS, the CSV file must adhere to the latest **13-column** format, as specified in the Check Point Report 1224 help topic.
- AGL_GNSS_IMU settings (TXT file format created by the Check Point Report 1224 tool)

Note that each test requires one or more of the inputs listed above. ***None of the input data should be loaded in the Map View window prior to running this tool***. The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Horizontal and Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.



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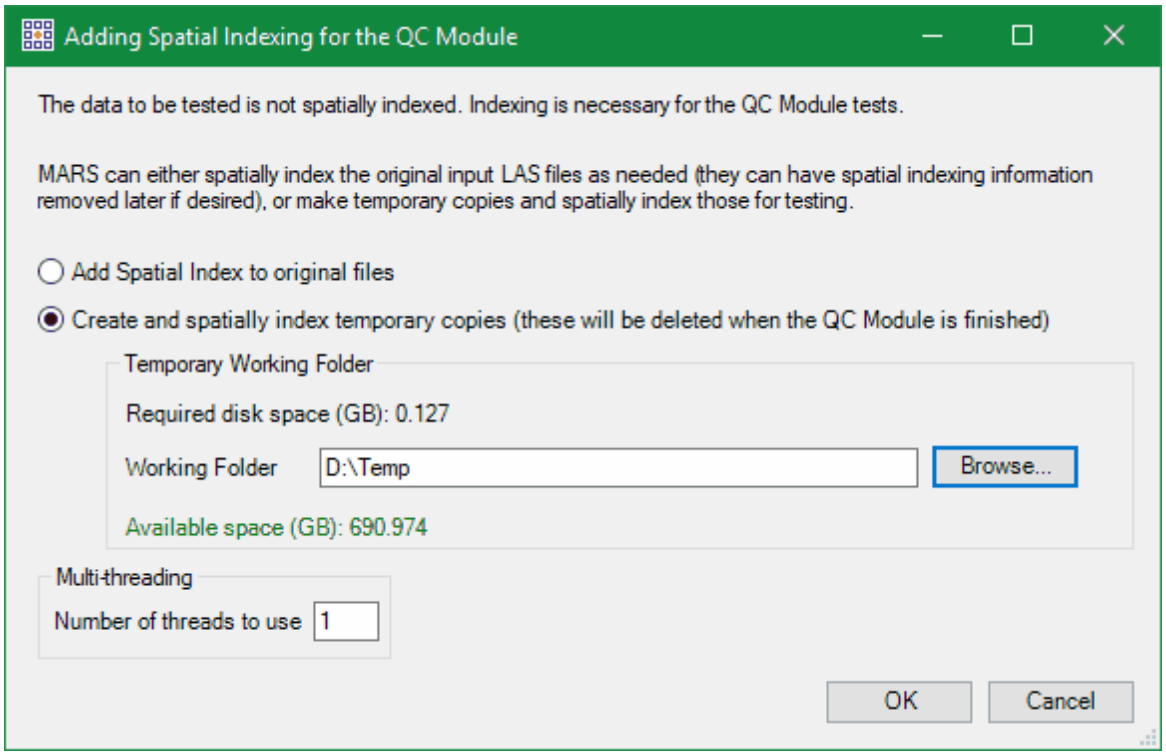
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<**, **>**, **%**, **&**, **'**, **"** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

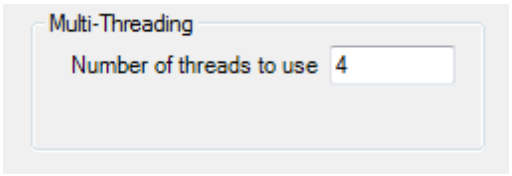
LAS data must be spatially indexed before it can be tested with the USGS 2024 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1360) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2024 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



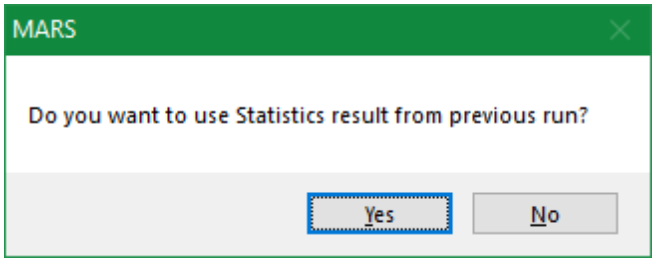
Running the* USGS 2024 rev. A *QC Module

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When all necessary entries have been made on the Input, Collection, and Data Processing/ Handling tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab for details), and whether data exists in these folders from previous runs of this USGS 2024 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

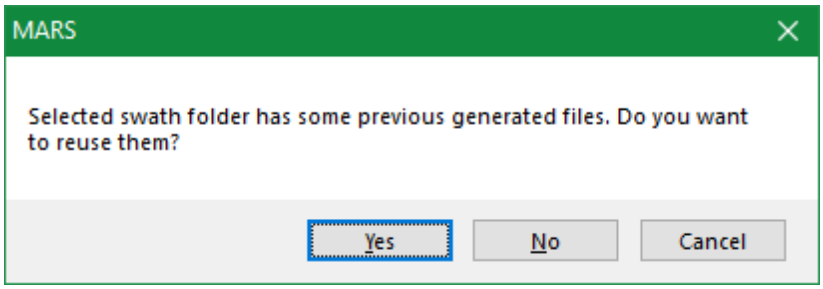
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab. If there is data, the following message will appear:

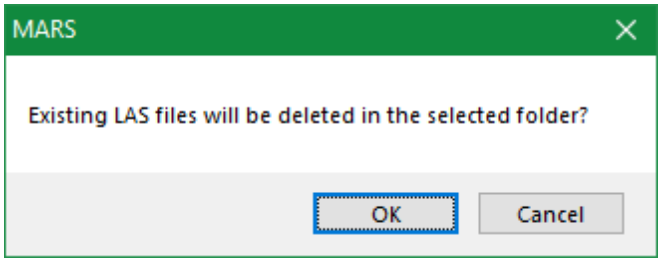
2.

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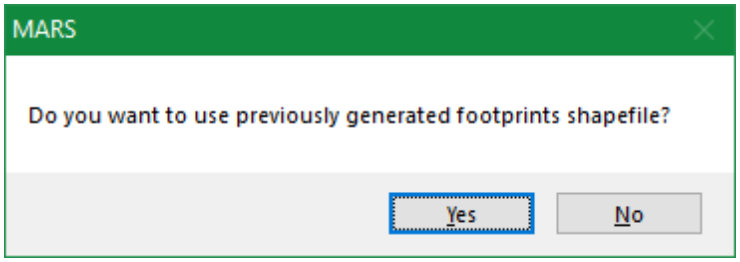
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1360] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1360] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



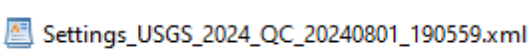
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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab 1360. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2024 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2024 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1360. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 7:05:59 pm on August 1, 2024.



This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2024 rev. A QC Module runs. After opening the USGS 2024 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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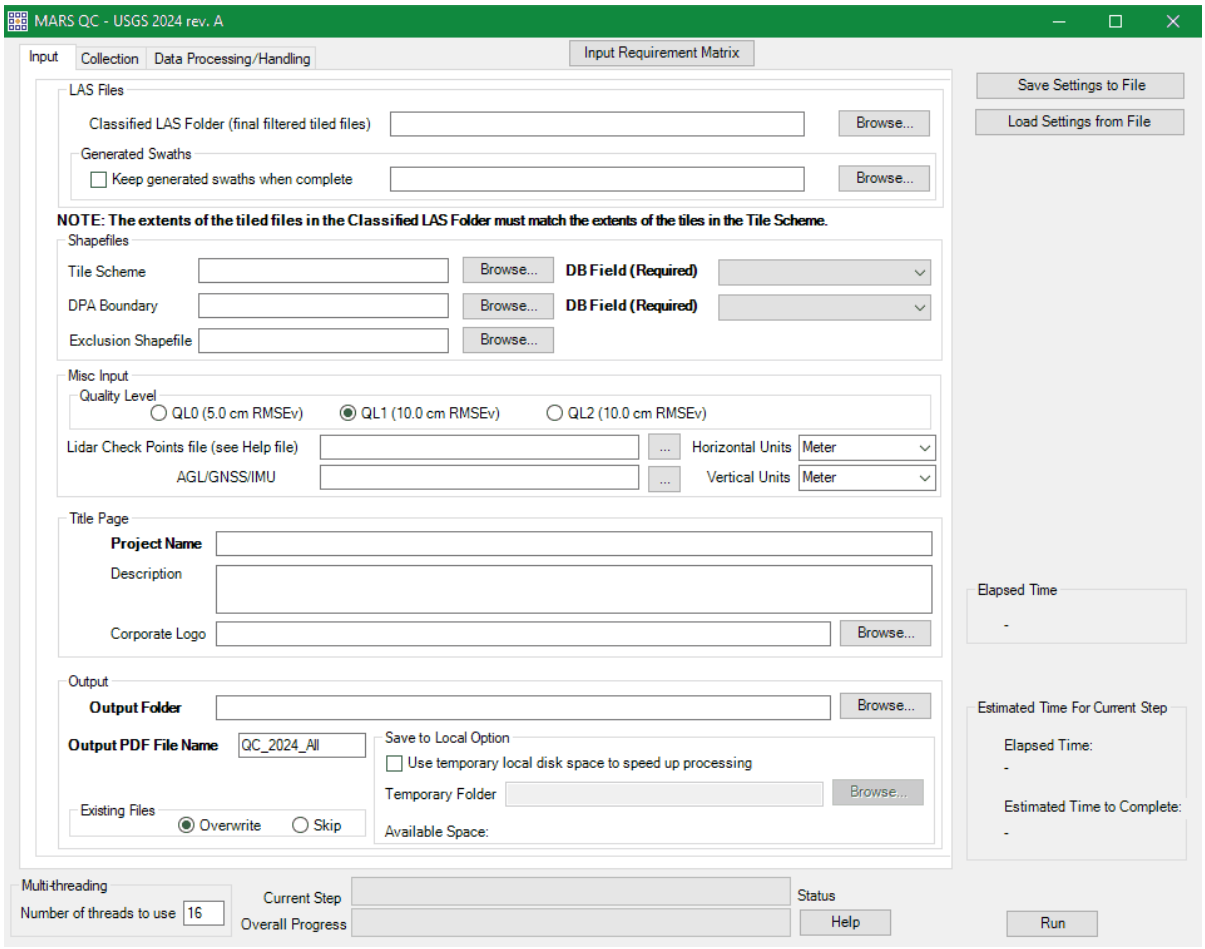
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2024 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.2.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs found in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab 1365 and Data Processing/Handling Tab 1369 topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2024 rev. A. By default, 'QL1 (10.0 cm RMSEz)' is pre-selected but this can be changed to 'QL0' or 'QL2' as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2024 rev. A QC Module.

A LiDAR Check Points file, in 13-column CSV format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points,** and **DPH-11 Absolute Horizontal and Vertical Accuracy**. Check points files in shapefile format cannot be used as input for this version of the USGS QC Module. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

A four-line text (*.txt) file ('AGL/GNSS/IMU') containing Flying Height, GNSS Positional Errors, and IMU errors is needed for complete results in test **DPH-11 Absolute Horizontal and Vertical Accuracy**. This file will be created when a report is saved from the '3D Accuracy' option of the Check Point Report 1312 tool. It will initially be stored in the same folder as the saved report.

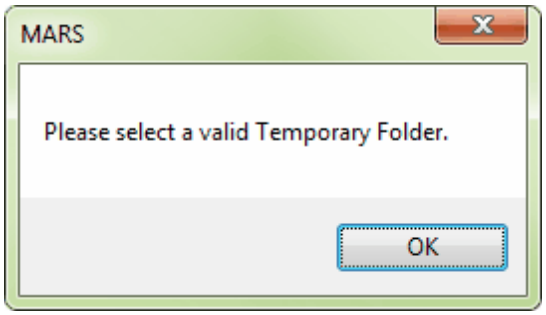
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results

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in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



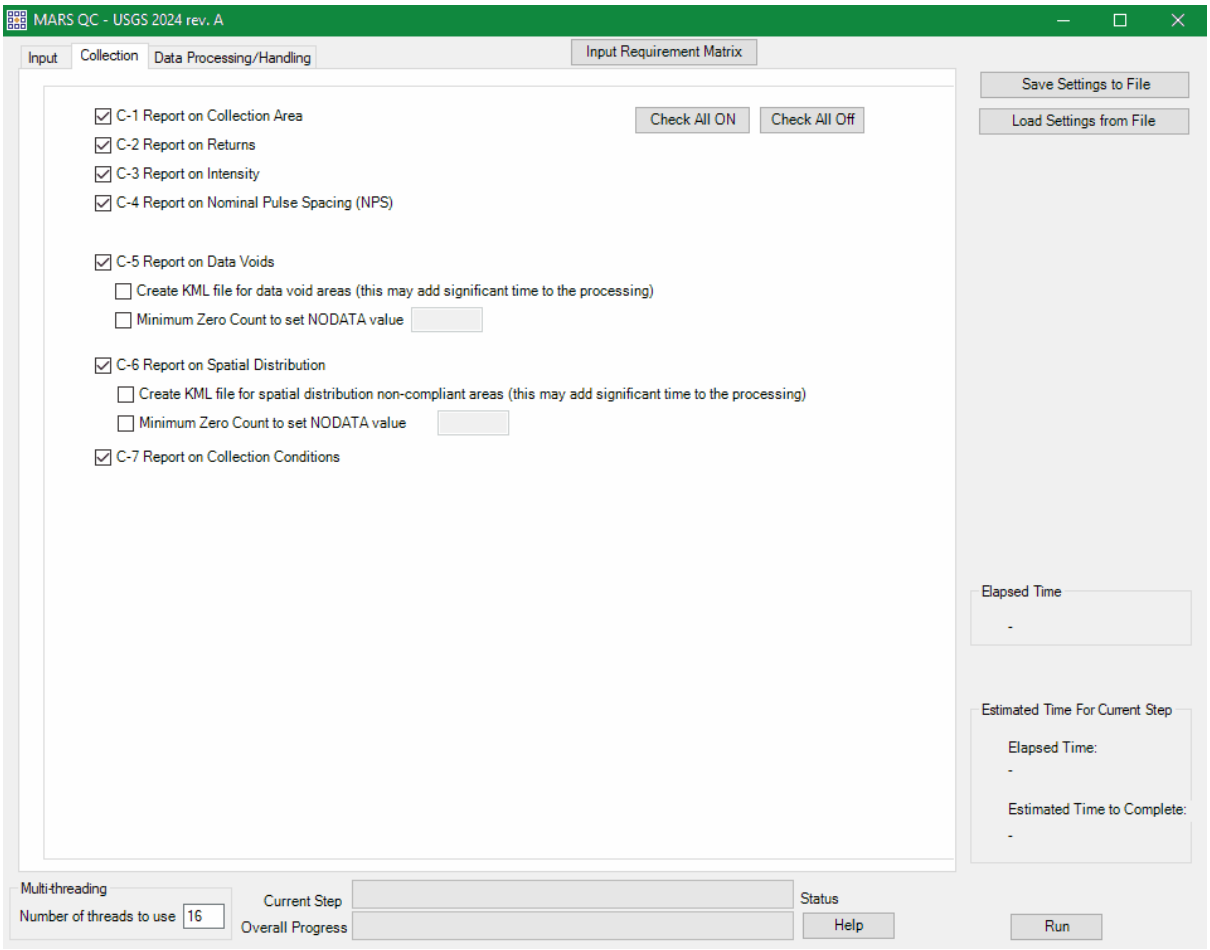
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1378 sub-topic).

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6.2.2.3 Collection Tab



The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/

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paragraph in the USGS NGP Lidar Base Specification 2024 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1378). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

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C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1360 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc.

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Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1360 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

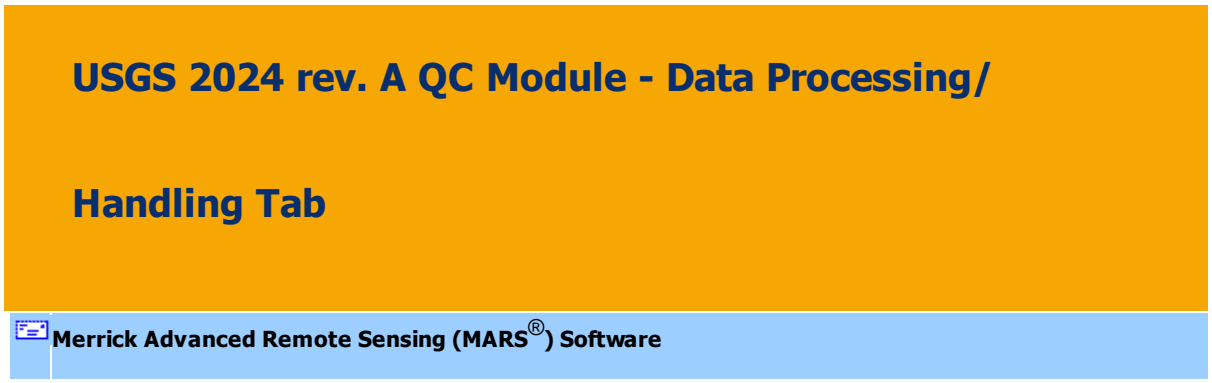
The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

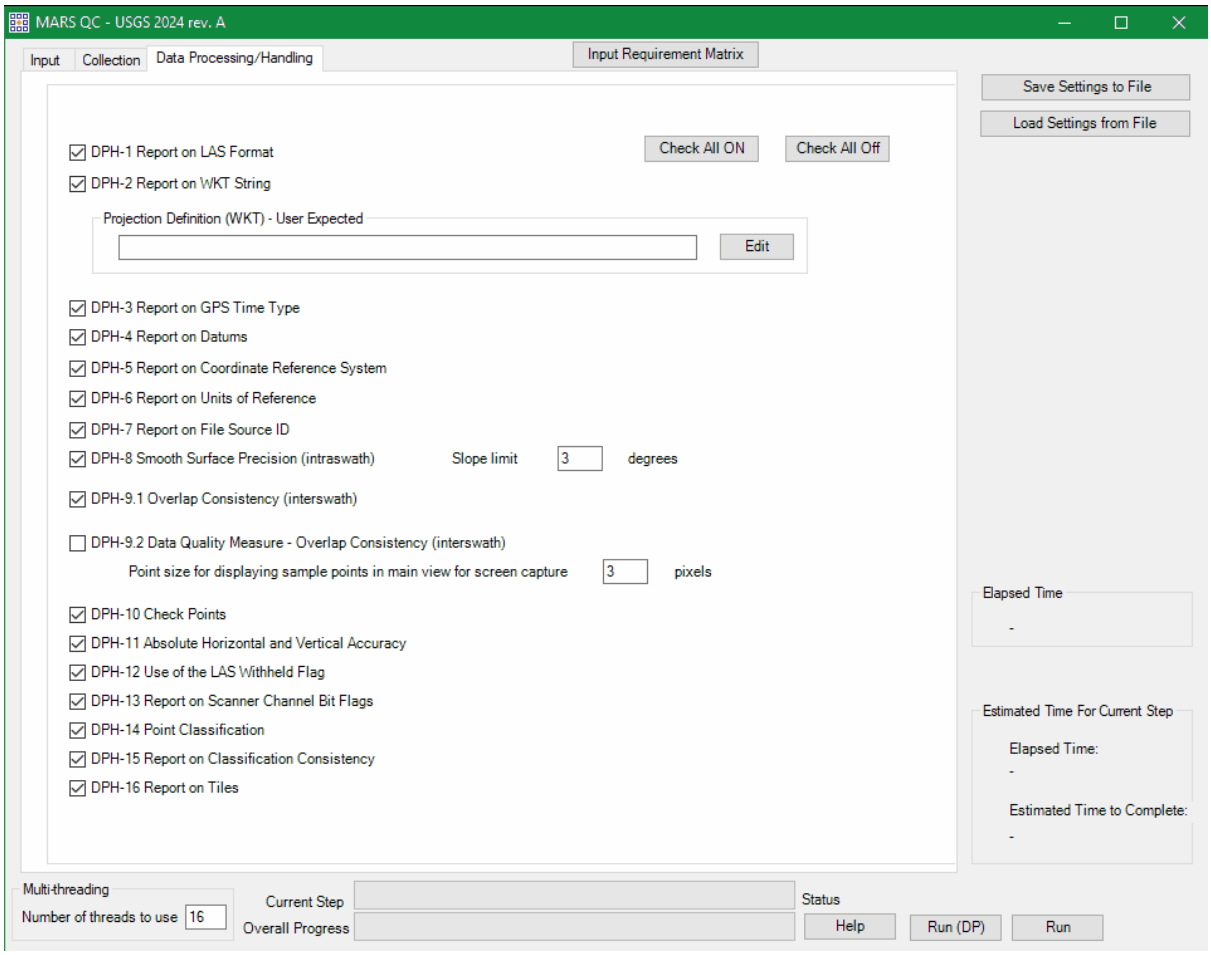
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6.2.2.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests.

Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2024 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1378). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

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The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1360.

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DPH-2 Report on WKT String

The purpose of this section is to show the expected WKT (Well-Known Text) string containing CRS (Coordinate Reference System) information for the lidar tiled data. Counts for matching and non-matching tiles are provided. Files that do not match the expected WKT entry are listed in red font for review.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A list of all unique horizontal and vertical datum names and associated EPSG codes is created for review.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the CRS definitions of the LAS files for the lidar tiled data. A list of unique horizontal and vertical CRS names, Geoid (height) Model names, and associated EPSG codes is created for review.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units (by file) is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units and their adherence to

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the user-input units values. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2024 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to create a Measurable Flight Line Separation Raster (FSR) for all of the data processed. This image shows the vertical separation of adjacent flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This thematic rendering is modulated by intensity to show land cover features. Along with the elevation difference raster of the overlap areas, a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels is created for review. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2024 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

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Multiple area-named sub-folders will be created if the Defined Project Area (DPA Boundary) shapefile consists of more than one polygon (e.g., 'Area1,' 'Area2,' etc.). The final PDF reports will indicate multiple DPA boundaries if present.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2024 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data.

This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (Horizontal/NVA, NVA-only, and VVA). A screen capture of the Horizontal/NVA (shown in red), NVA-only (shown in yellow), and VVA (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

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DPH-11 Absolute Horizontal and Vertical Accuracy

The purpose of this section is to report on the absolute horizontal and vertical accuracy of the lidar data by testing for Horizontal/NVA, NVA-only, and VVA against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (Horizontal/NVA, NVA-only, or VVA), along with overall H and V error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of Horizontal/NVA check points with point-by-point error and descriptive information as compared to user XY measurements based on an intensity rendering of the lidar ground data, along with a DeltaX/DeltaY plot; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

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(DPH-13 Report on Scanner Channel Bit Flags

The purpose of this section is to report on the Scanner Channel bit flag values present in the input tiled data. For a single channel sensor, all points should have a scanner channel value of '0.' For a dual channel sensor, values should be either '0' or '1.' Three and four channel sensors should have values of '0' through '2' and '0' through '3,' respectively. A table of point counts and a bar graph are presented for review.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Additionally, any points in any classifications that are bit-flagged as Overlap will be reported in red font as this bit flag is no longer used for USGS data deliveries.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points

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(Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1360. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

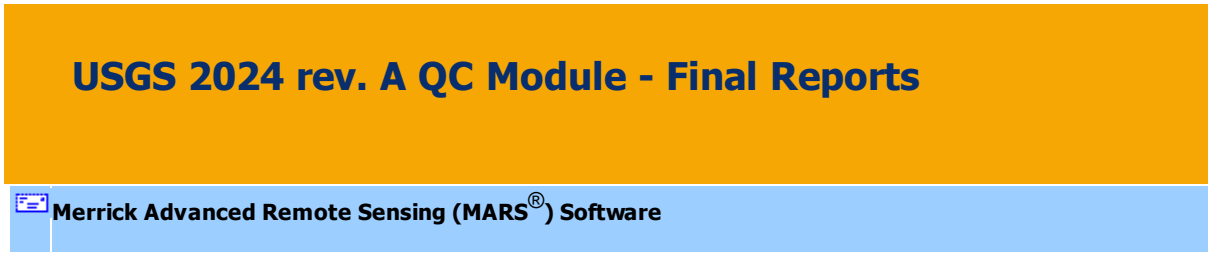
The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.2.5 Final Reports



QC Reporting

The output of the USGS 2024 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1360. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1360. The default name is 'QC_2024_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1360.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1352 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2024 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output**

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Folder will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDF reports are generated.

Sample Report Pages:



SAMPLE REPORT Lidar QA/QC Report

C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2024 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

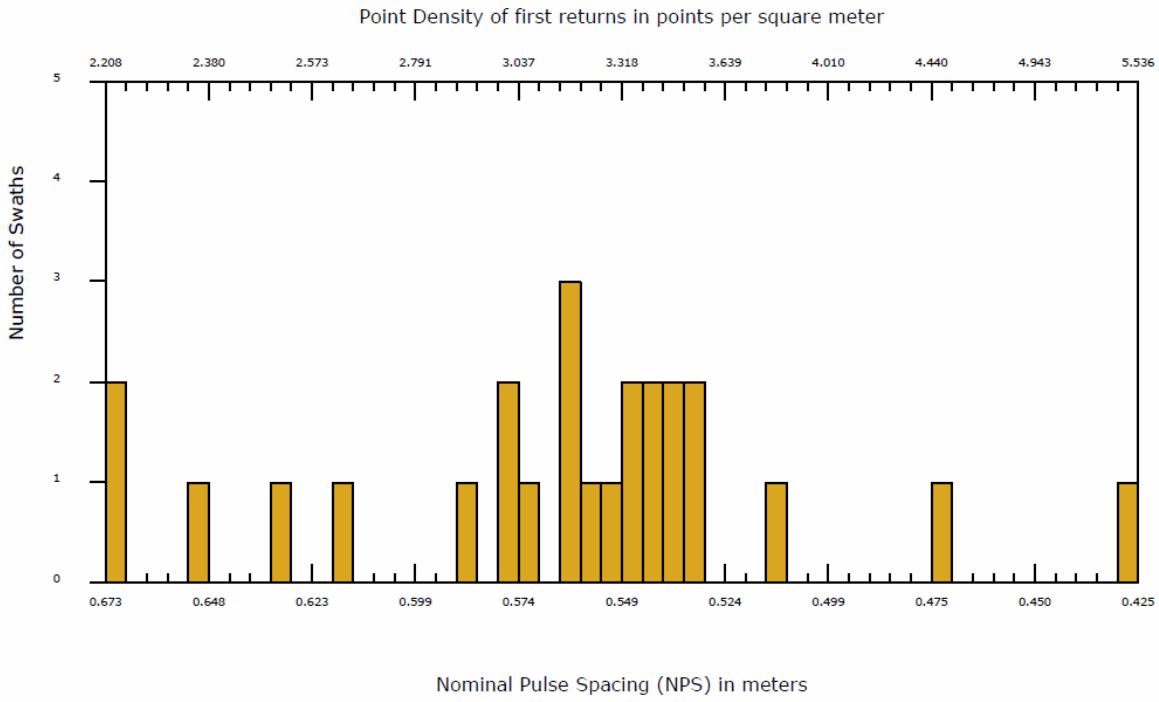
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2024 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show a mosaicked version of a thematically rendered map of swath separation for all the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For this product – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2024 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

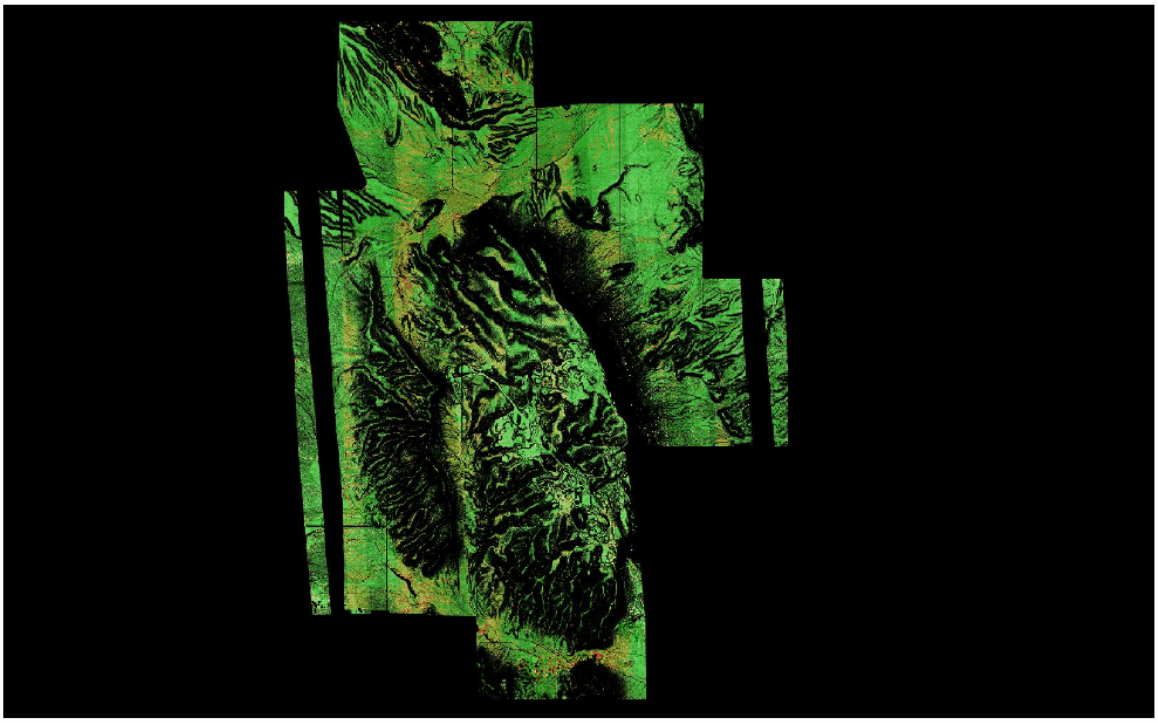
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

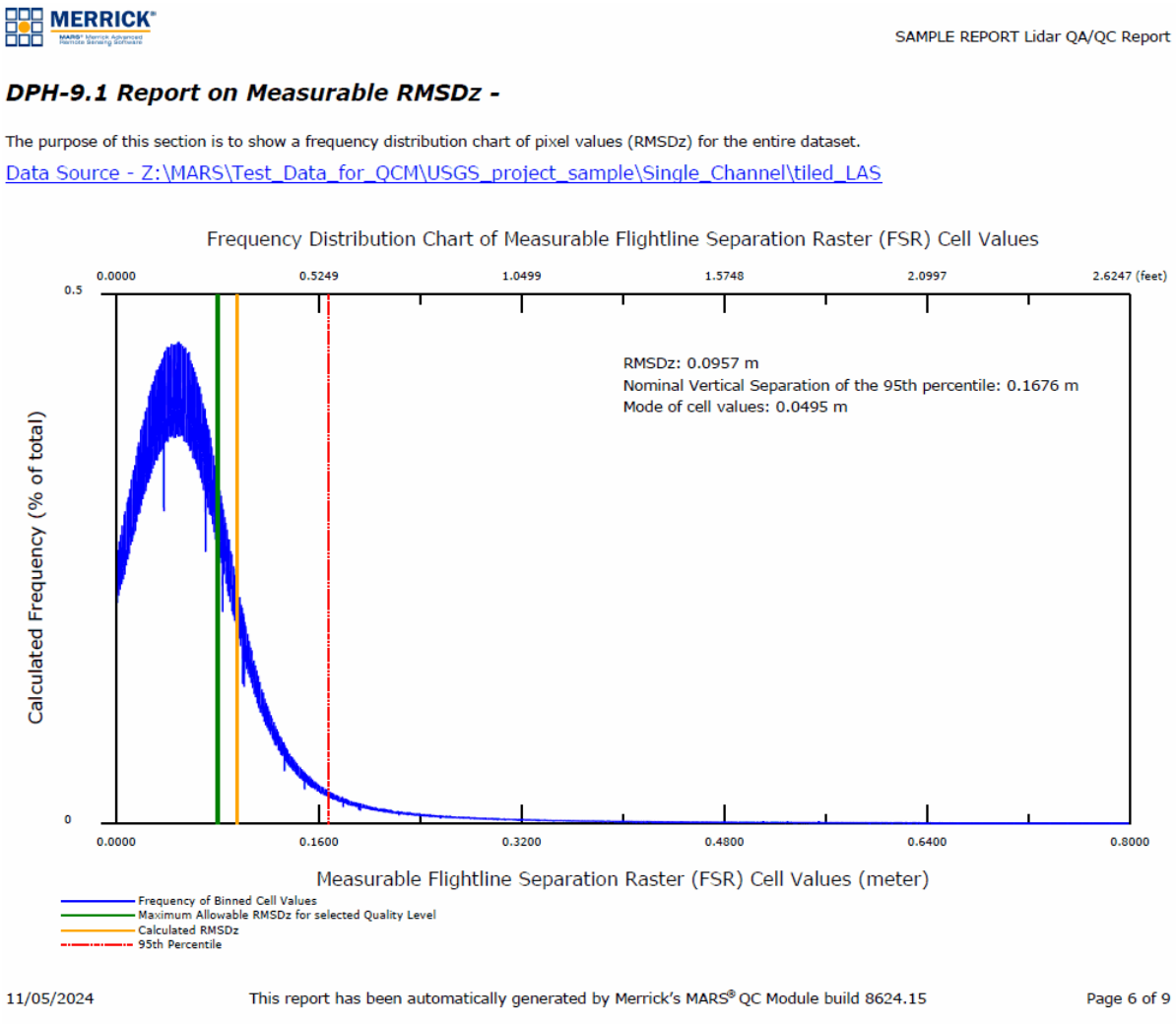
Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths
Result Path - D:\MARS\Dump9\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jpg



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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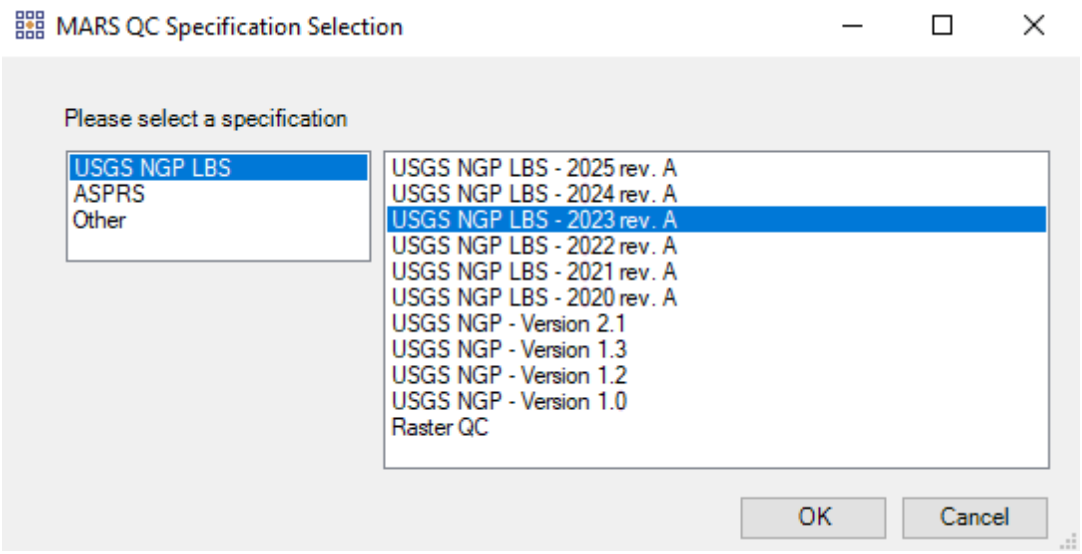
6.2.3 2023 rev. A

2023 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP LBS - 2023 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...

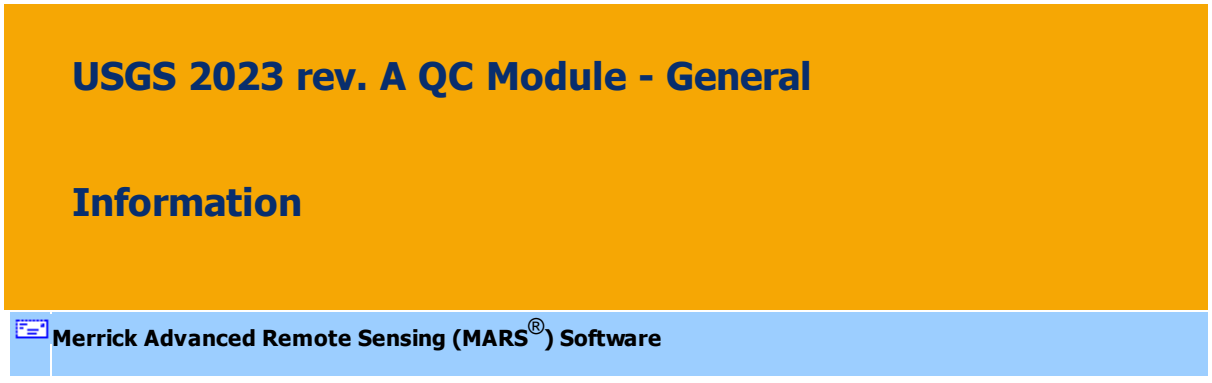


Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.3.1 General Information



Purpose and Description

The purpose of the 'USGS NGP LBS - 2023 rev. A' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2023 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS 2023 rev. A (September 2023) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1404 topic).

There are 23 possible tests that can be run in the USGS 2023 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1413 sub-topic for more information.

The USGS 2023 rev. A QC Module tests are divided into **Collection** 1400 and **Data Processing/Handling** 1404 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR Data Checks 1677 and LiDAR Calibration Checks 1698 tools, and the Voronoi Density Reporting 1660 tool - is

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enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

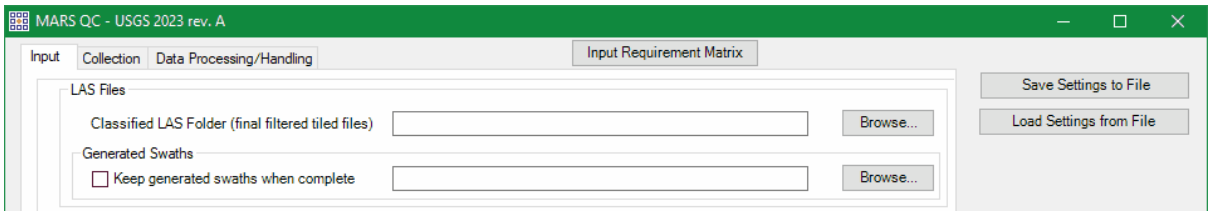
These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report 1224 help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.

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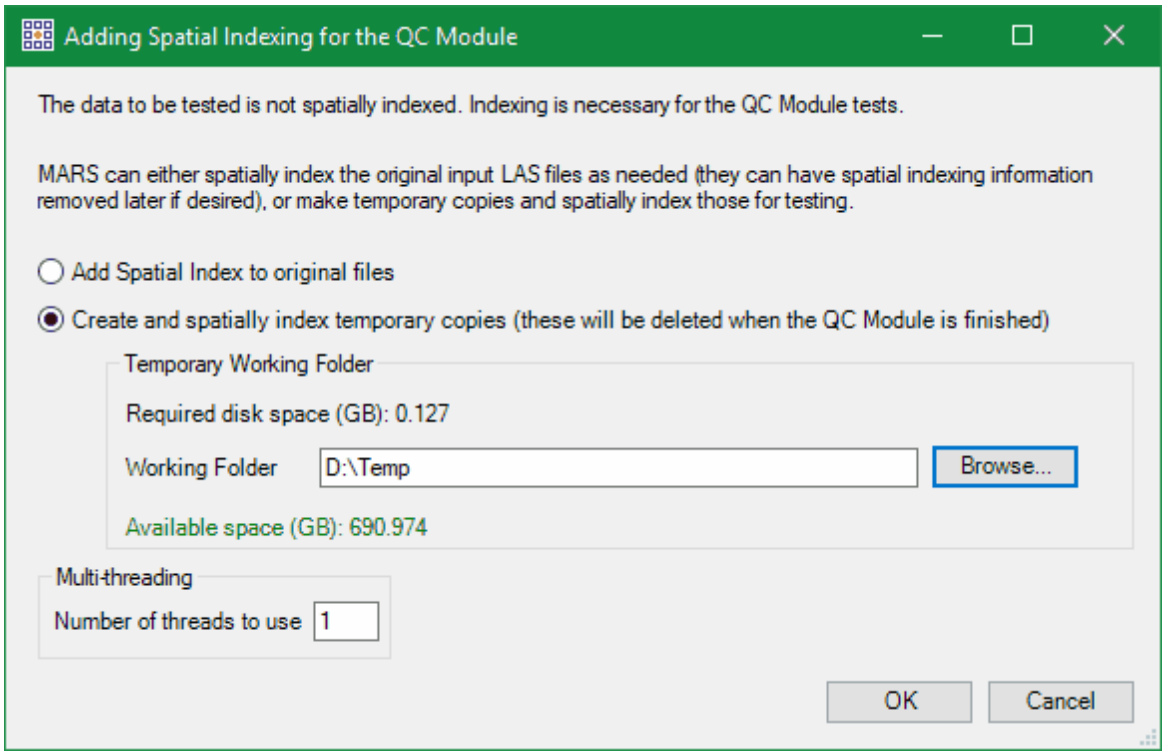
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

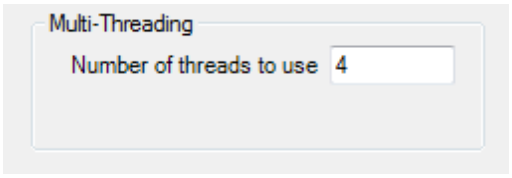
LAS data must be spatially indexed before it can be tested with the USGS 2023 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1395) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2023 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



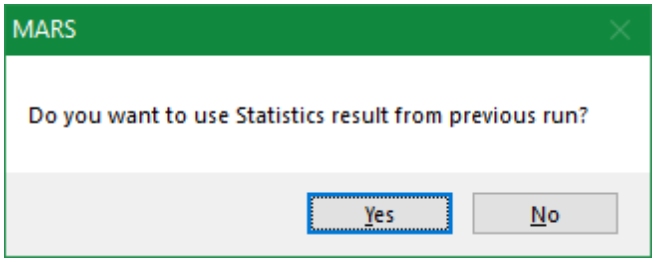
Running the* USGS 2023 rev. A *QC Module

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When all necessary entries have been made on the Input[1395], Collection[1400], and Data Processing/ Handling[1404] tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab[1395] for details), and whether data exists in these folders from previous runs of this USGS 2023 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

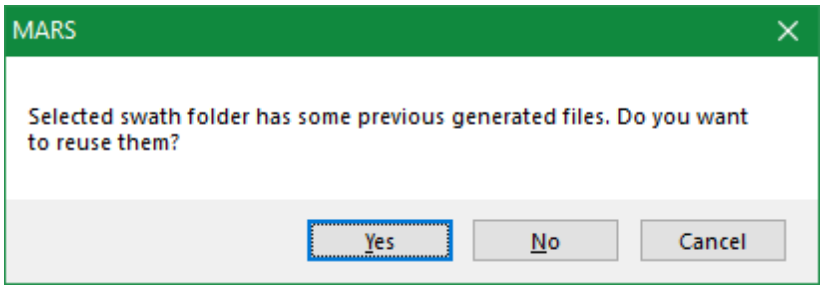
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab[1395]. If there is data, the following message will appear:

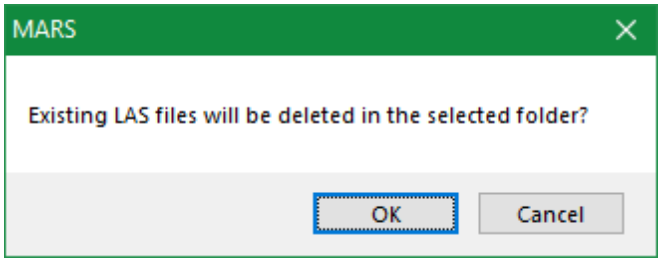
2.

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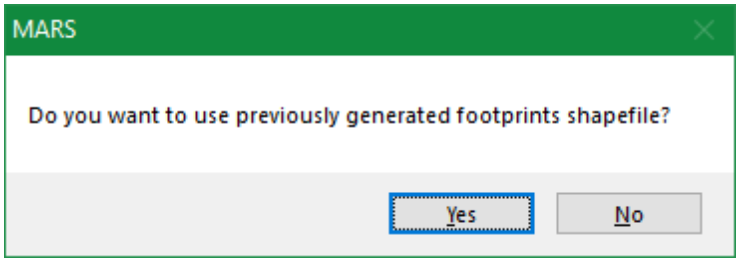
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1395] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1395] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



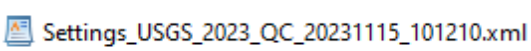
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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab[1395]. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2023 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2023 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab[1395]. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 10:12:10 am on November 15, 2023.



This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2023 rev. A QC Module runs. After opening the USGS 2023 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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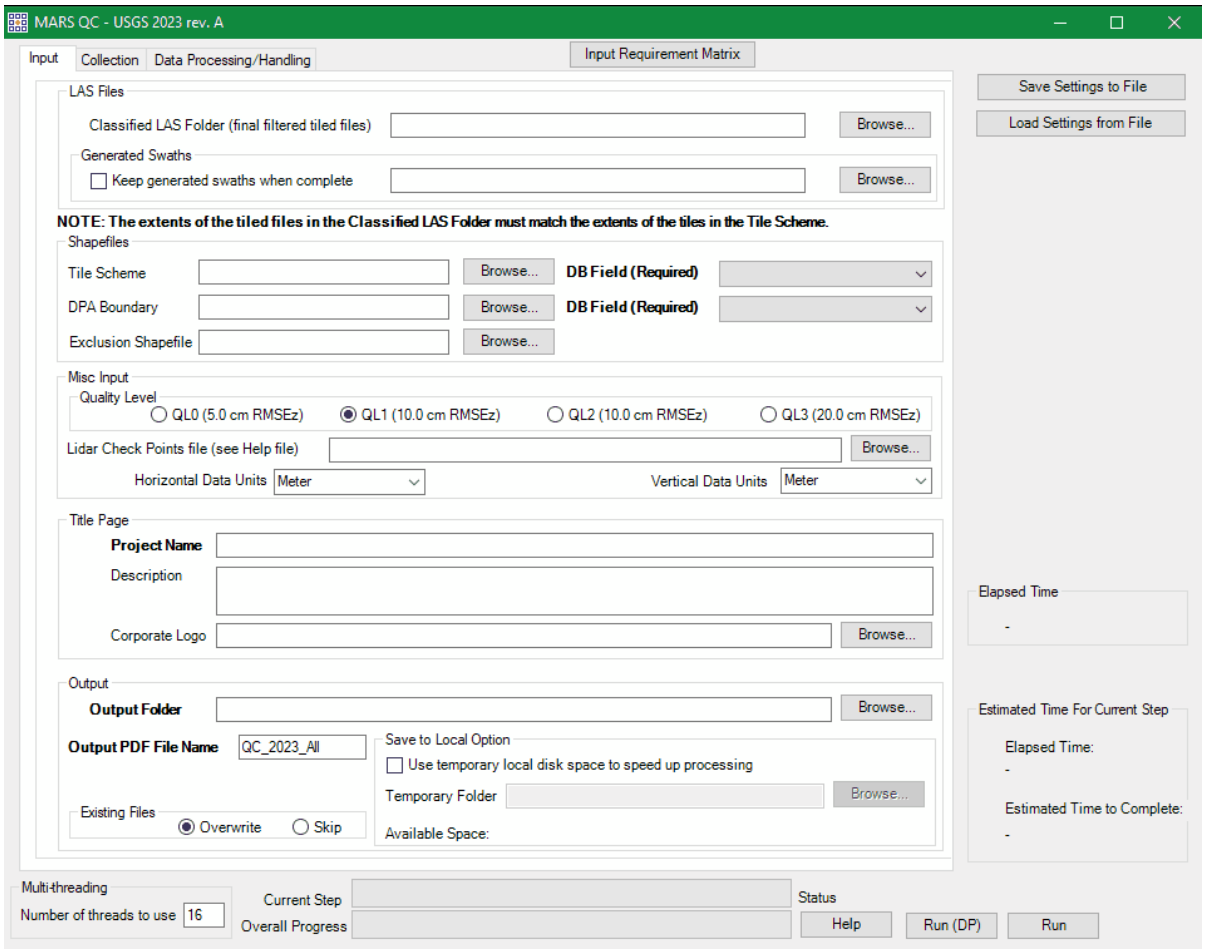
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2023 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.3.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs found in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

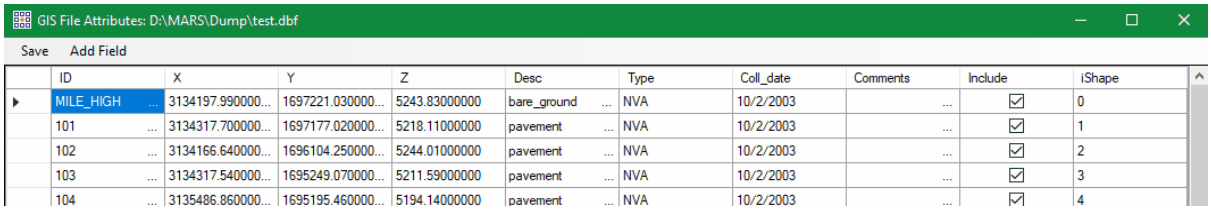
If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab[1400] and Data Processing/Handling Tab[1404] topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2023 rev. A. By default, 'QL1 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2023 rev. A QC Module.

A LiDAR Check Points file, in either a 7-column CSV or 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report[1224] Help Topic for more details on check point CSV files. If a 3D shapefile is used,it must adhere to the following format:



ID	X	Y	Z	Desc	Type	Coll_date	Comments	Include	iShape
MILE_HIGH	3134197.990000...	1697221.030000...	5243.83000000	bare_ground	NVA	10/2/2003		☑	0
101	3134317.700000...	1697177.020000...	5218.11000000	pavement	NVA	10/2/2003		☑	1
102	3134166.640000...	1696104.250000...	5244.01000000	pavement	NVA	10/2/2003		☑	2
103	3134317.540000...	1695249.070000...	5211.59000000	pavement	NVA	10/2/2003		☑	3
104	3135486.860000...	1695195.460000...	5194.14000000	pavement	NVA	10/2/2003		☑	4

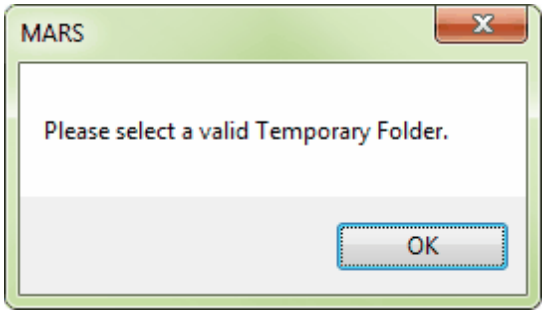
The 'Include' field must be a Boolean (True/False) type, and the 'Desc' and 'Comments' fields do not need to be populated.

Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

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The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



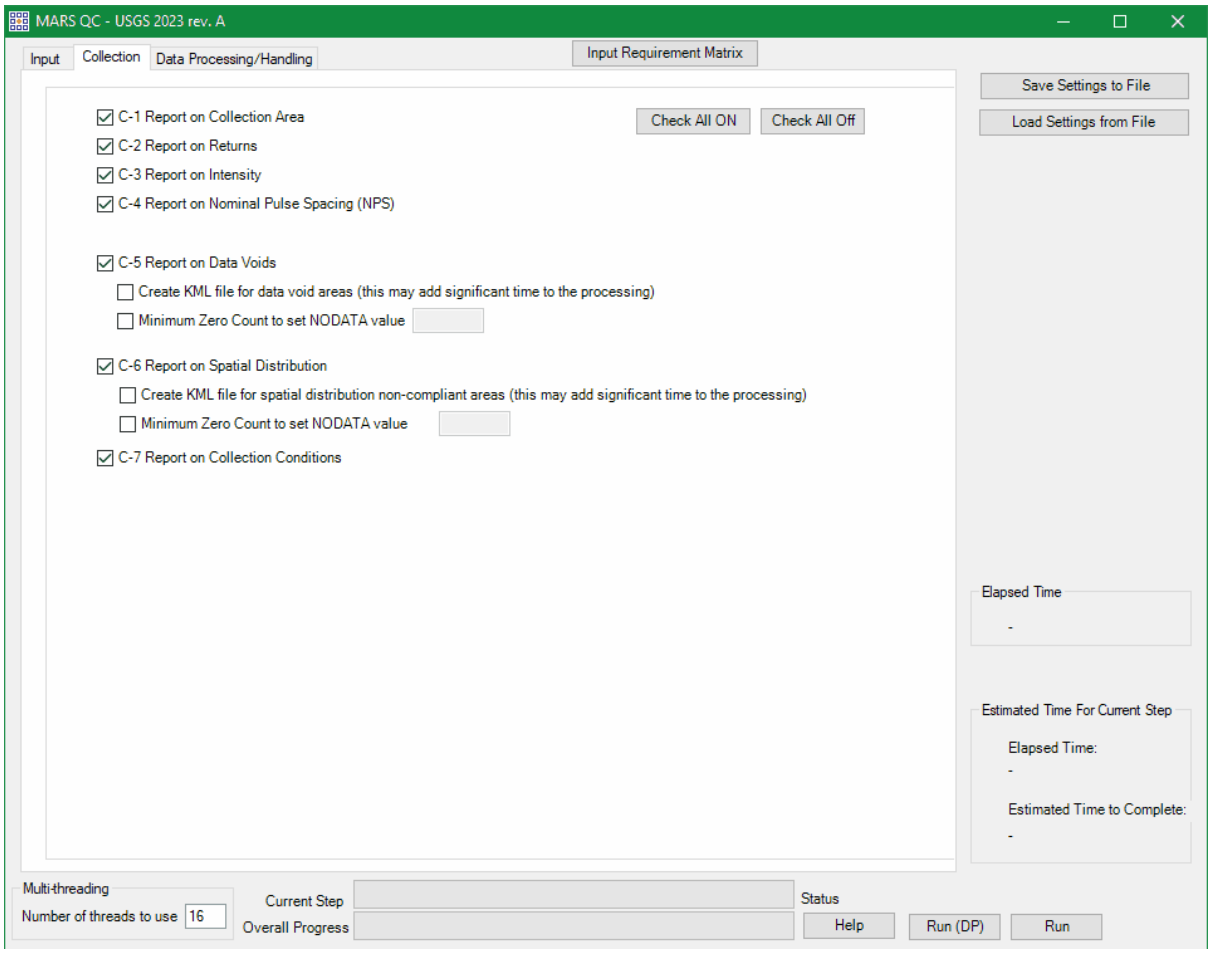
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1413 sub-topic).

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6.2.3.3 Collection Tab



The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/

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paragraph in the USGS NGP Lidar Base Specification 2023 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1413). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

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C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1395 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc.

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Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1395 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

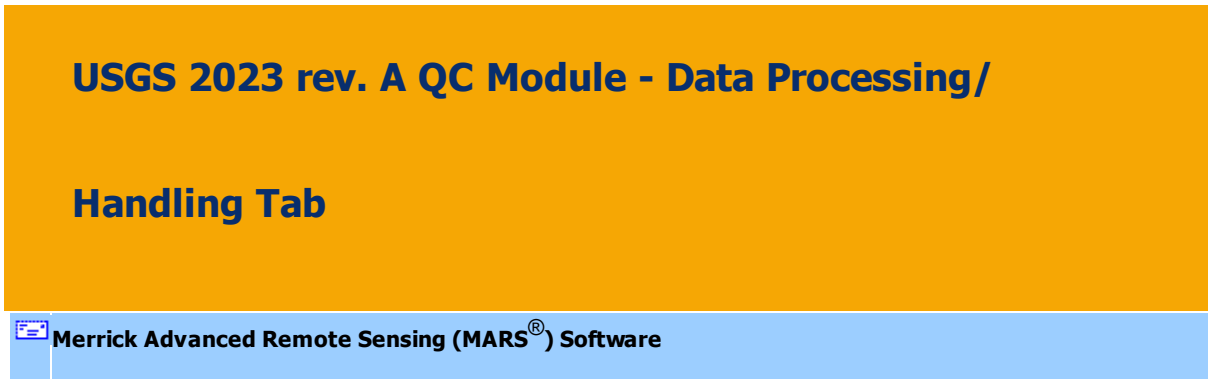
The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

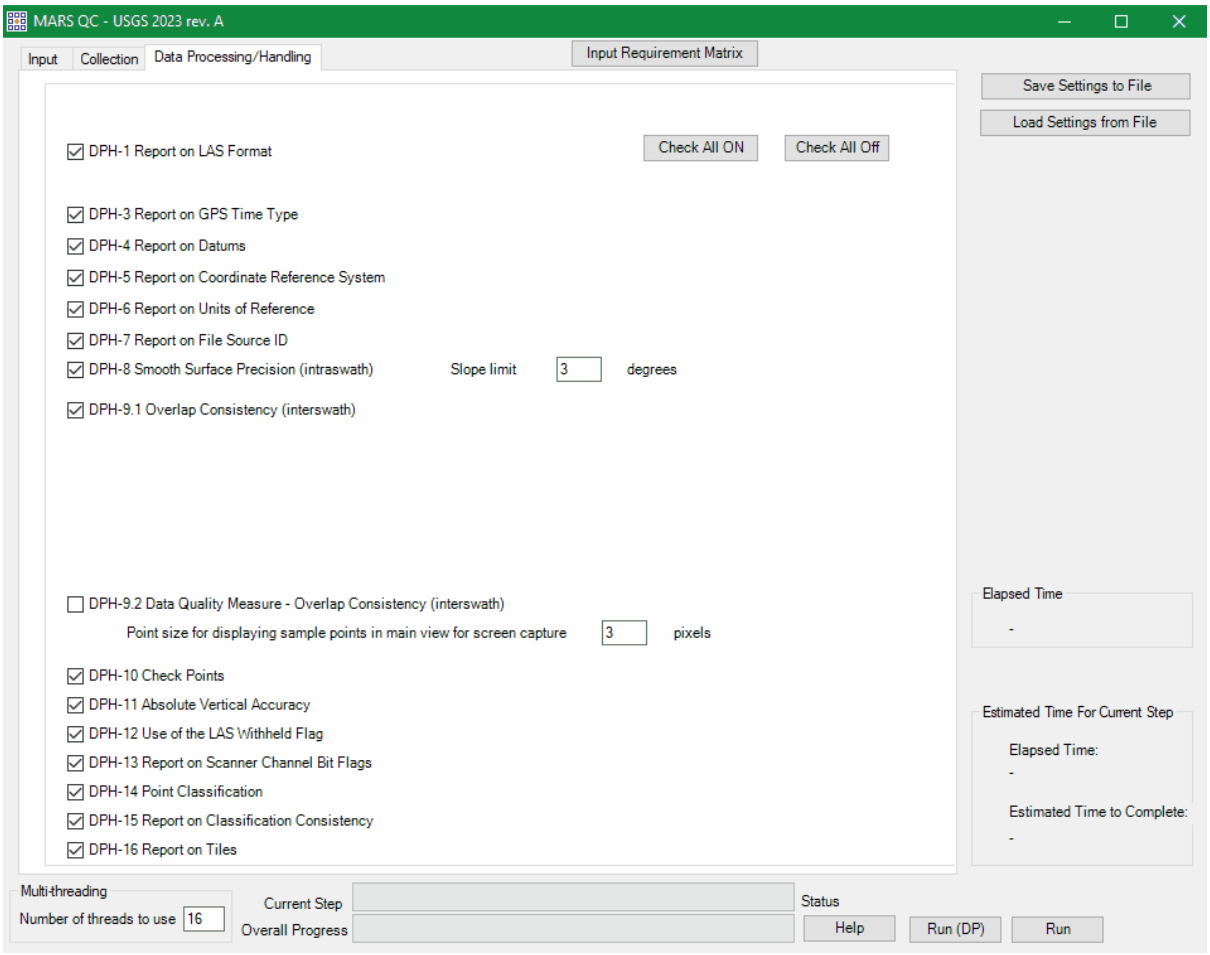
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6.2.3.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Note that there is a gap in the test numbering sequence - test **DPH-2** is no longer included.

Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2023 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1413). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

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DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the

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Input Tab 1395.

(DPH-2 is intentionally omitted)

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units (by file) is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS

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specifications regarding the presence of both horizontal and vertical units and their adherence to the user-input units values. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2023 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to create a Measurable Flight Line Separation Raster (FSR) for all of the data processed. This image shows the vertical separation of adjacent flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This thematic rendering is modulated by intensity to show land cover features. Along with the elevation difference raster of the overlap areas, a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels is created for review. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2023 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

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Multiple area-named sub-folders will be created if the Defined Project Area (DPA Boundary) shapefile consists of more than one polygon (e.g., 'Area1,' 'Area2,' etc.). The final PDF reports will indicate multiple DPA boundaries if present.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2023 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data.

This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

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DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

(DPH-13 Report on Scanner Channel Bit Flags

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The purpose of this section is to report on the Scanner Channel bit flag values present in the input tiled data. For a single channel sensor, all points should have a scanner channel value of '0.' For a dual channel sensor, values should be either '0' or '1.' Three and four channel sensors should have values of '0' through '2' and '0' through '3,' respectively. A table of point counts and a bar graph are presented for review.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Additionally, any points in any classifications that are bit-flagged as Overlap will be reported in red font as this bit flag is no longer used for USGS data deliveries.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the

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nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1395. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

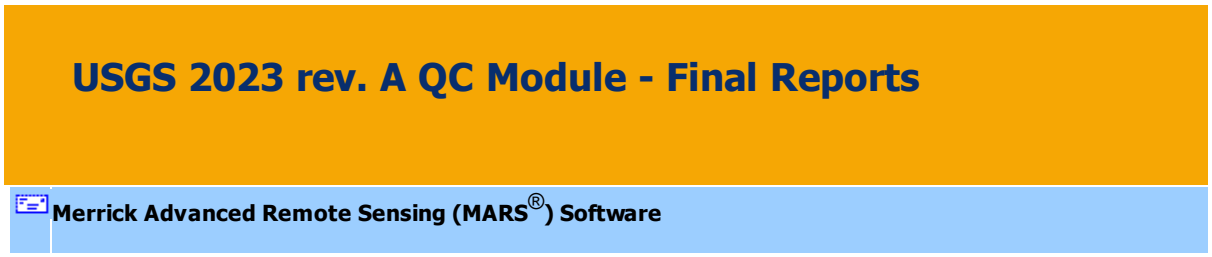
The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.3.5 Final Reports



QC Reporting

The output of the USGS 2023 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1395. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1395. The default name is 'QC_2023_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1395.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 23 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1387 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2023 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters,

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shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDF reports are generated.

Sample Report Pages:

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SAMPLE REPORT Lidar QA/QC Report

C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2023 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

08/02/2024 This report has been automatically generated by Merrick's MARS® QC Module build 8613.96 Page 3 of 12

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

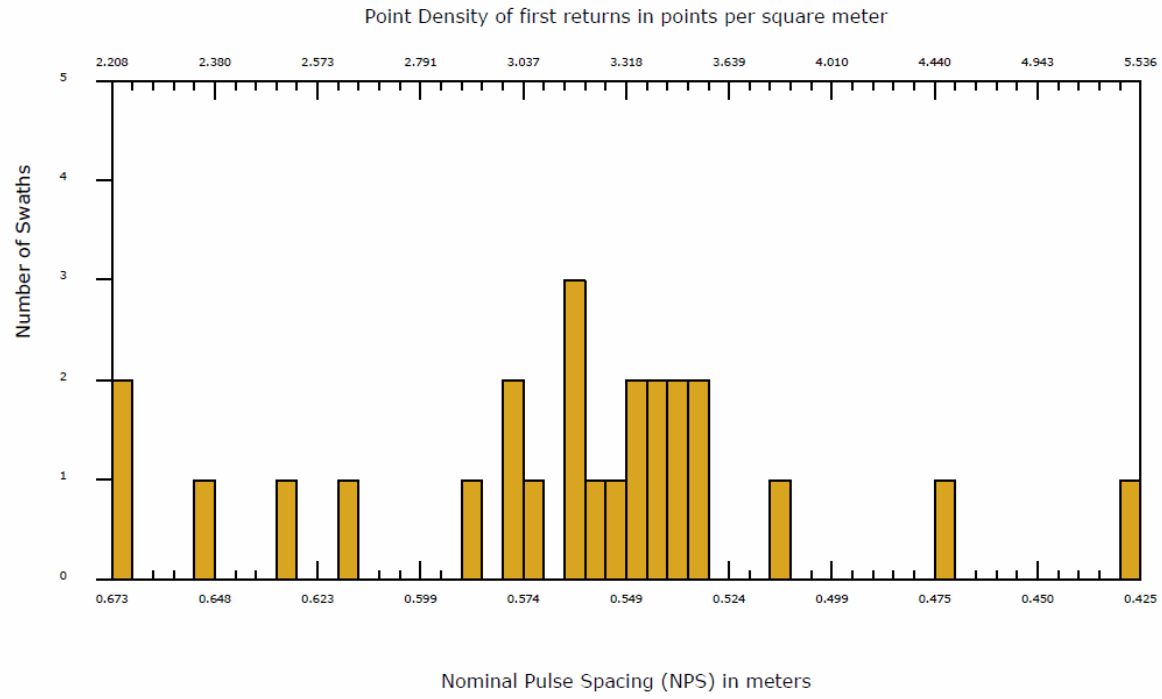
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2023 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the *z* direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show a mosaicked version of a thematically rendered map of swath separation for all the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For this product – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2023 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

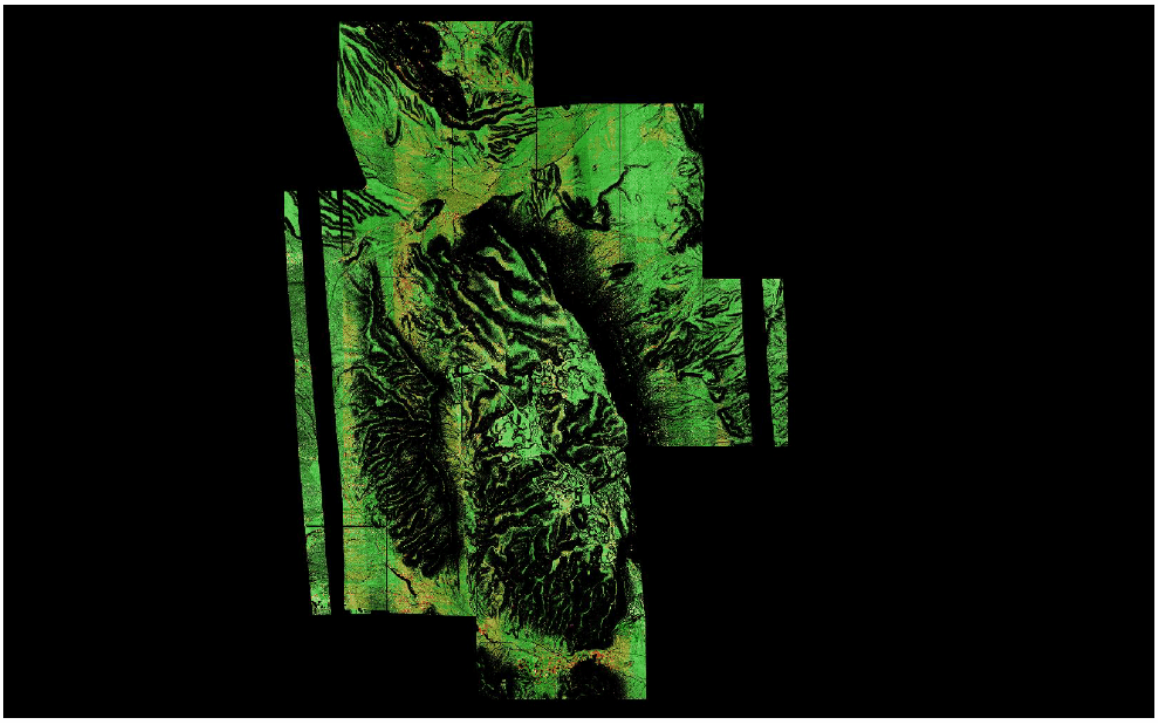
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths
Result Path - D:\MARS\Dump9\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jpg



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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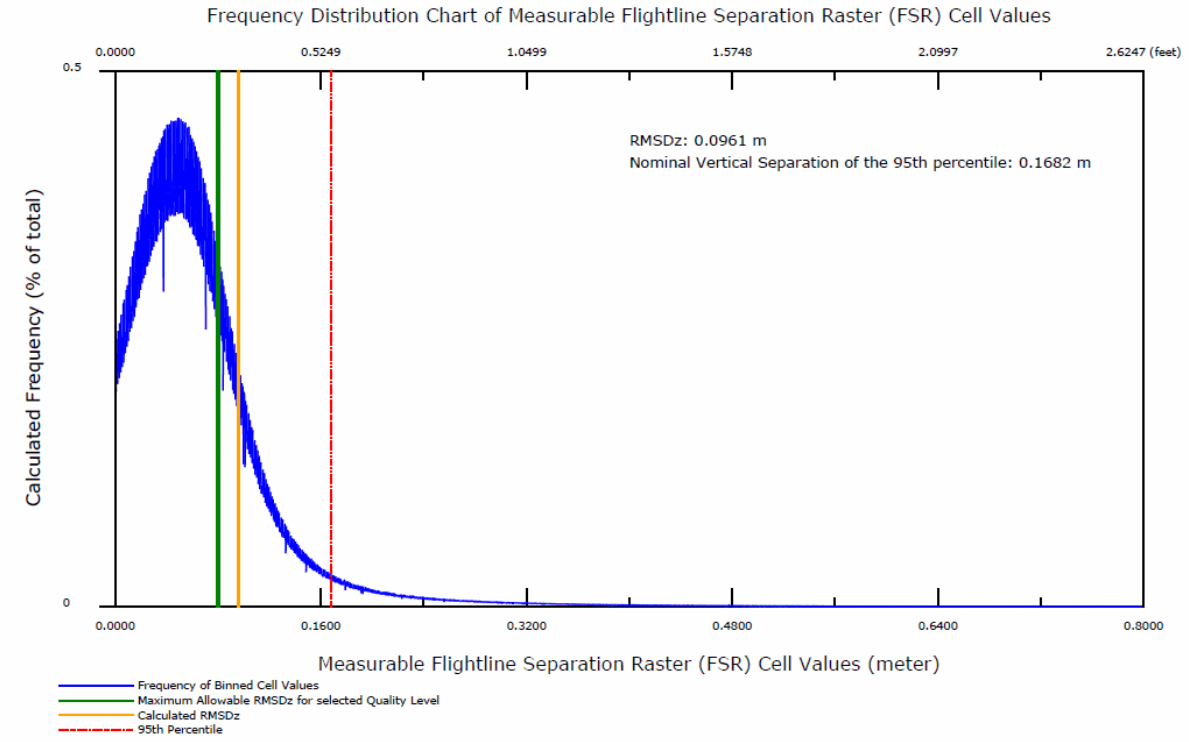
MERRICK

SAMPLE REPORT Lidar QA/QC Report

DPH-9.1 Report on Measurable RMSDz -

The purpose of this section is to show a frequency distribution chart of pixel values (RMSDz) for the entire dataset.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\tiled_LAS



08/02/2024 This report has been automatically generated by Merrick's MARS® QC Module build 8613.96 Page 9 of 12

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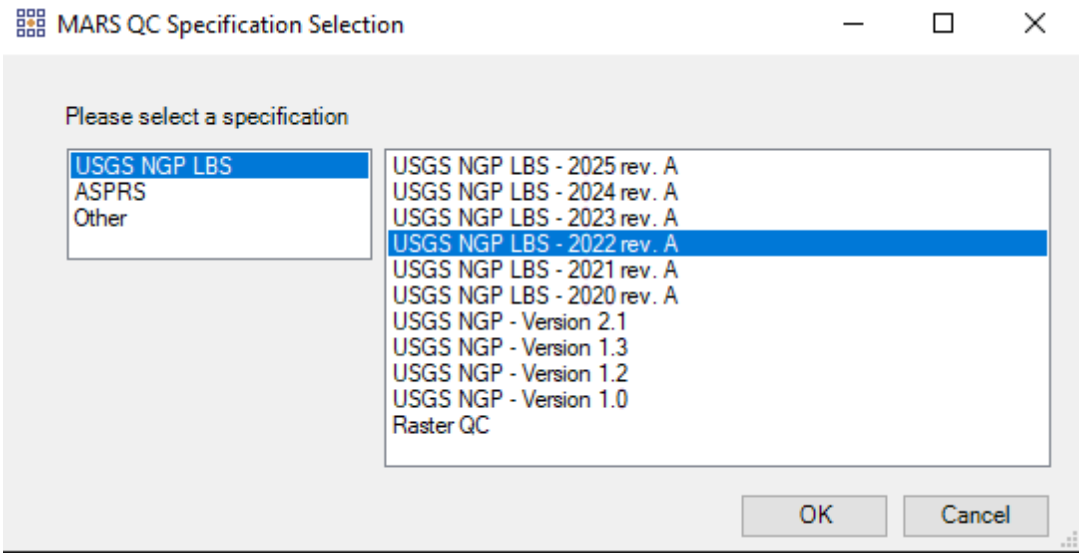
6.2.4 2022 rev. A

2022 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP LBS - 2022 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.4.1 General Information

USGS 2022 rev. A QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP LBS - 2022 rev. A' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2022 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS 2022 rev. A (August 2023) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1438 topic).

There are 22 possible tests that can be run in the USGS 2022 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1448 sub-topic for more information.

The USGS 2022 rev. A QC Module tests are divided into **Collection** 1434 and **Data Processing/Handling** 1438 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR

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Data Checks[1677] and LiDAR Calibration Checks[1698] tools, and the Voronoi Density Reporting[1660] tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

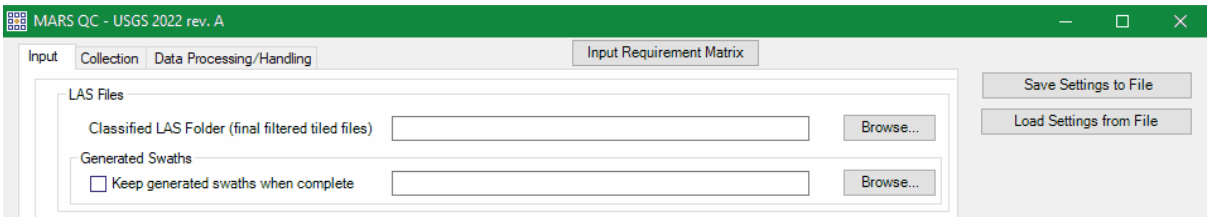
These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report[1224] help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.

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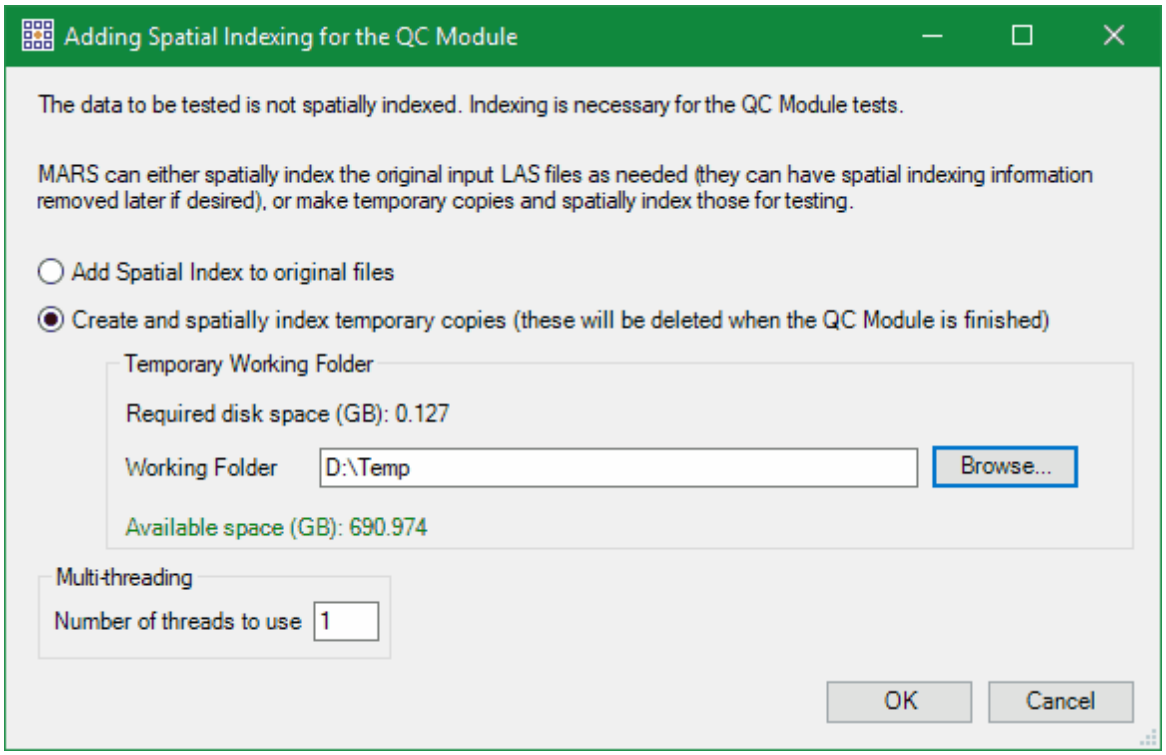
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

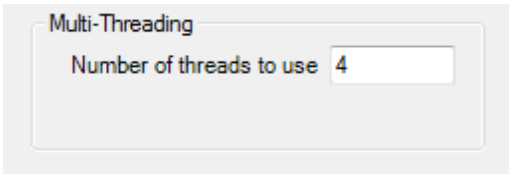
LAS data must be spatially indexed before it can be tested with the USGS 2022 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1430) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2022 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



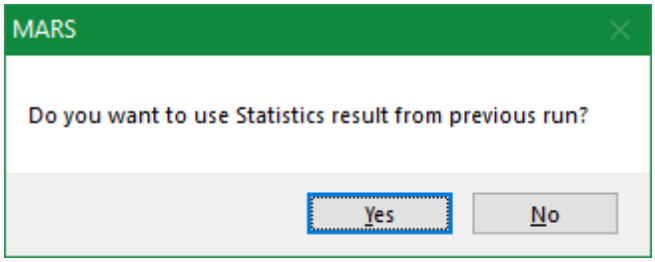
Running the* USGS 2022 rev. A *QC Module

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When all necessary entries have been made on the Input 1430, Collection 1434, and Data Processing/ Handling 1438 tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab 1430 for details), and whether data exists in these folders from previous runs of this USGS 2022 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

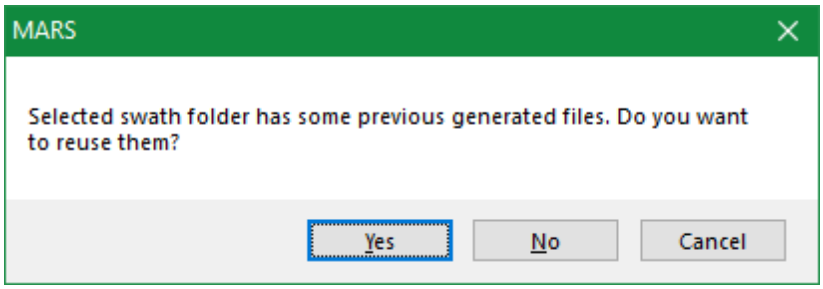
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab 1430. If there is data, the following message will appear:

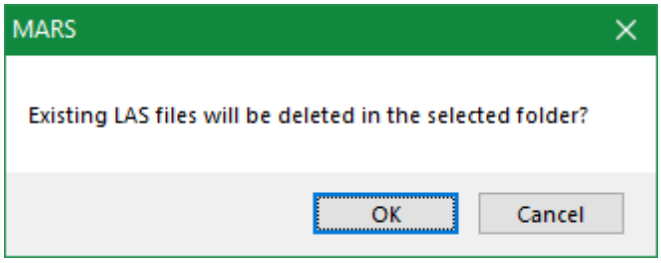
2.

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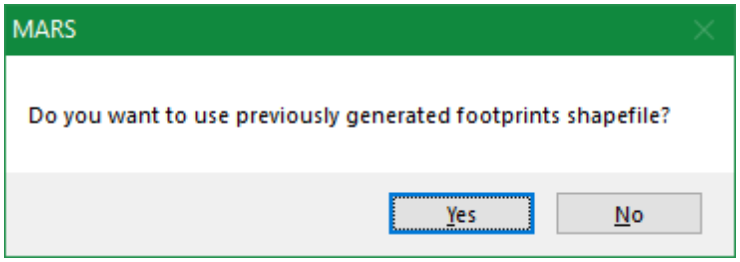
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1430] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1430] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



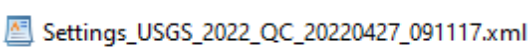
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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab 1430. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2022 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2022 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1430. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 9:11:17 am on April 27, 2022.



This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2022 rev. A QC Module runs. After opening the USGS 2022 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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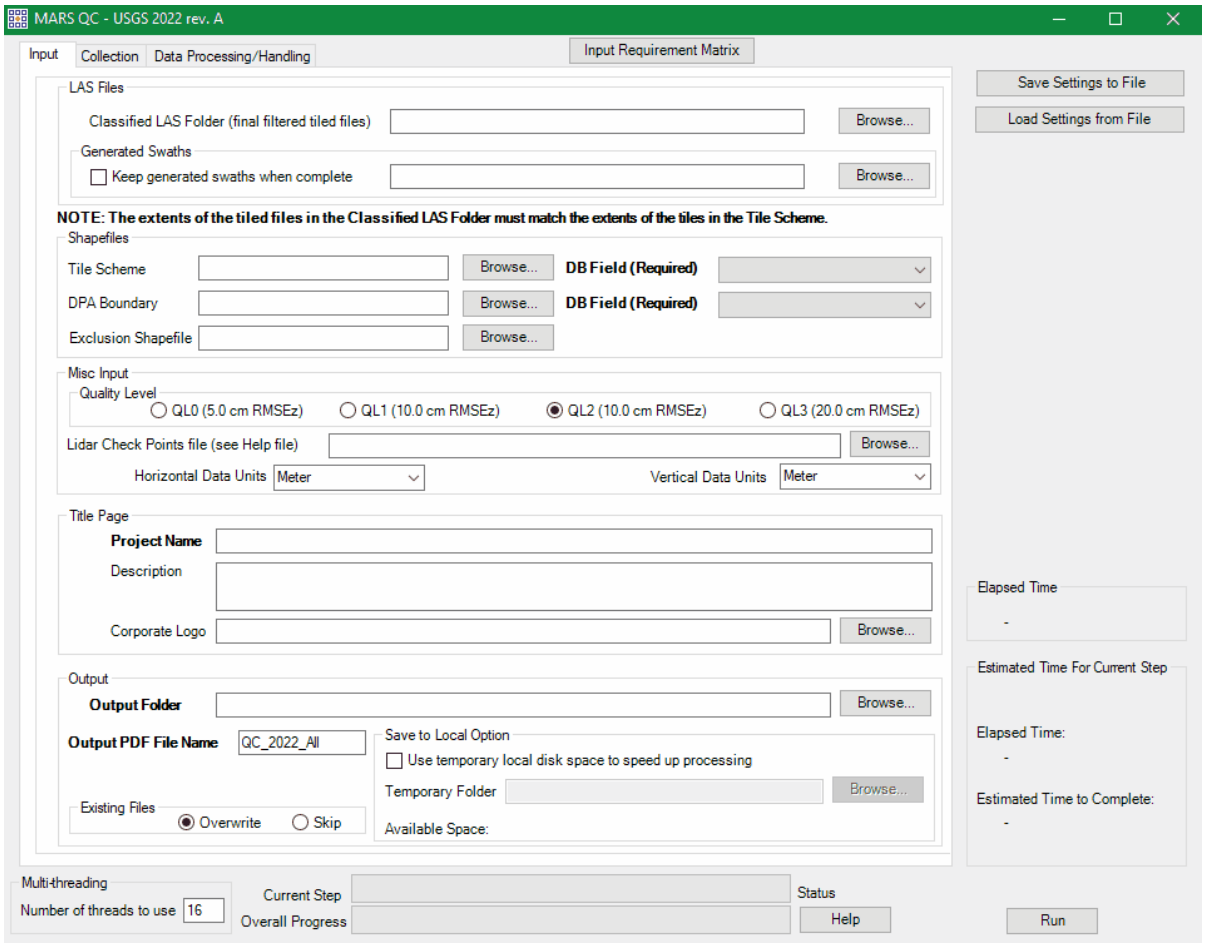
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2022 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.4.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

This version of the USGS QC Module reads the files that are pathed out and determines whether multi-

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channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs found in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed

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out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab 1434 and Data Processing/Handling Tab 1438 topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2022 rev. A. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2022 rev. A QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

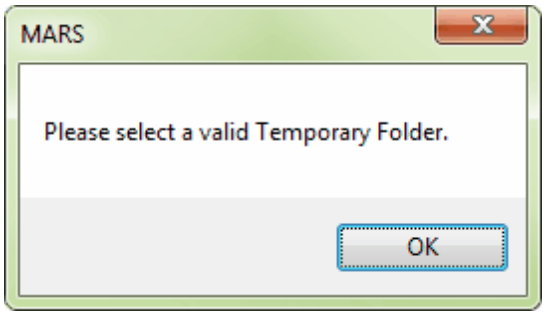
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a

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temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1448 sub-topic).

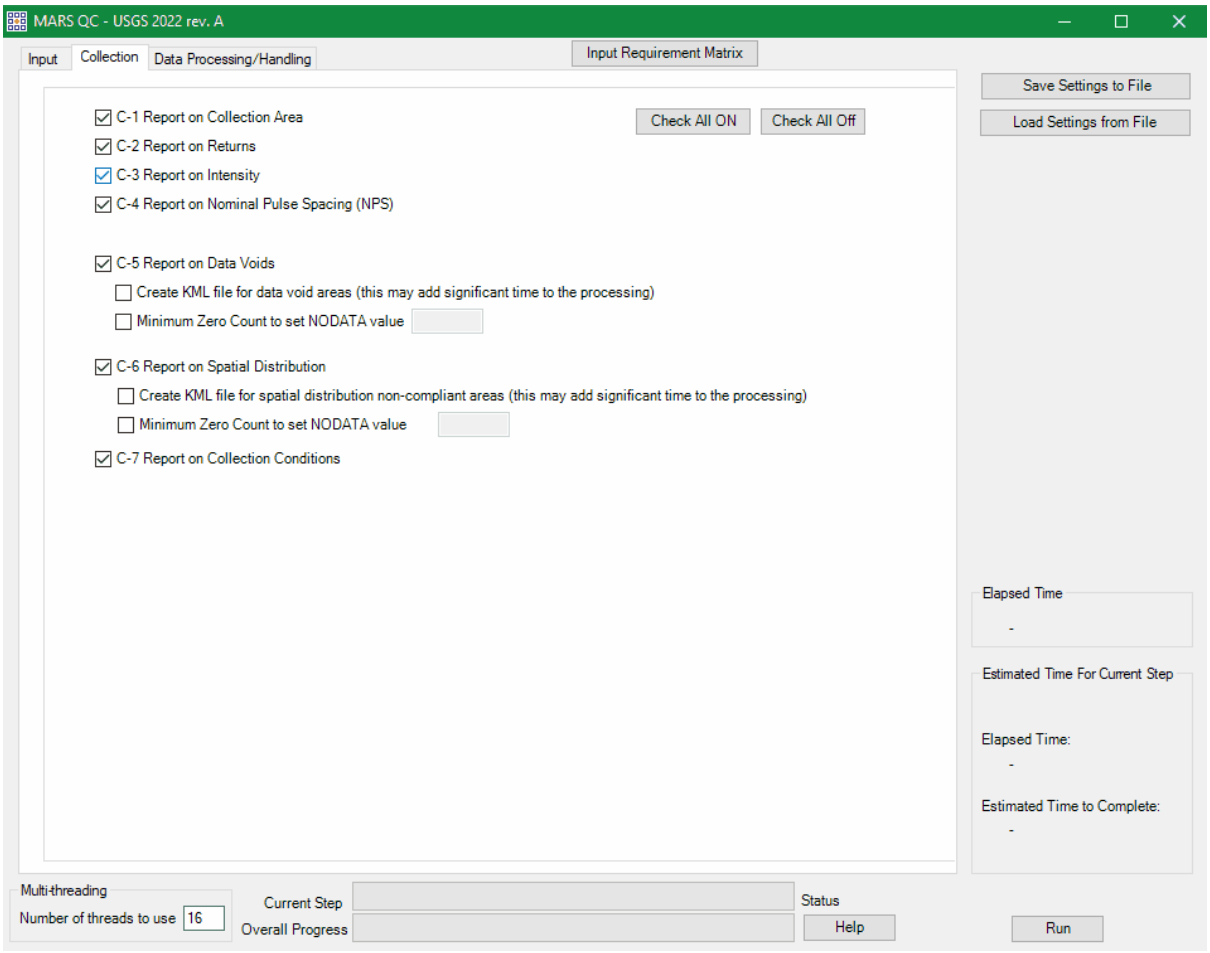
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6.2.4.3 Collection Tab

USGS 2022 rev. A QC Module - Collection Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/ paragraph in the USGS NGP Lidar Base Specification 2022 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1448). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary

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superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-

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compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1430 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the

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USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1430 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

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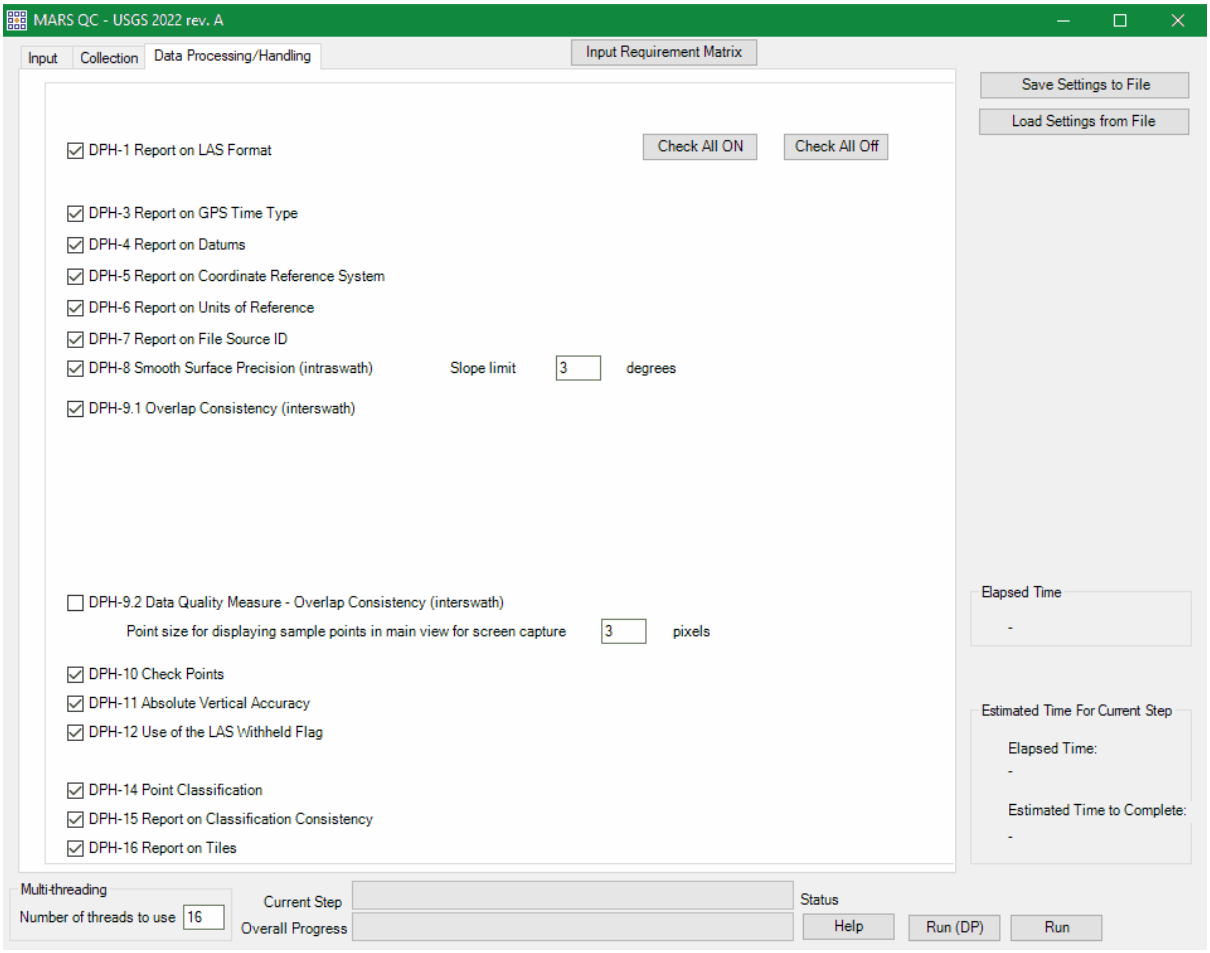
6.2.4.4 Data Processing/Handling Tab

USGS 2022 rev. A QC Module - Data Processing/

Handling Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. (Note that two previous tests no longer exist: **DPH-2 Report on Waveform Data** and **DPH-13 Use of the LAS Overlap Flag**.

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DPH-2 was dropped for this USGS specification, and **DPH-13** was dropped beginning with the 2021 rev. A[1455] specification.

Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2022 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports[1448]). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the

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classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1430.

(DPH-2 is intentionally omitted)

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the

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lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units (by file) is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units and their adherence to the user-input units values. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by

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the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2022 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to create a Measurable Flight Line Separation Raster (FSR) for all of the data processed. This image shows the vertical separation of adjacent flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This thematic rendering is modulated by intensity to show land cover features. Along with the elevation difference raster of the overlap areas, a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels is created for review. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2022 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

Multiple area-named sub-folders will be created if the Defined Project Area (DPA Boundary) shapefile consists of more than one polygon (e.g., 'Area1,' 'Area2,' etc.). The final PDF reports will indicate multiple DPA boundaries if present.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2022 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data.

This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

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- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the

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surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

(DPH-13 is intentionally omitted)

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Additionally, any points in any classifications that are bit-flagged as Overlap will be reported in red font as this bit flag is no longer used for USGS data deliveries.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

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Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1430. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.4.5 Final Reports

USGS 2022 rev. A QC Module - Final Reports

Merrick Advanced Remote Sensing (MARS®) Software

QC Reporting

The output of the USGS 2022 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1430. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1430. The default name is 'QC_2022_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1430.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 22 tests that can be run. If any tests were unchecked by the user, a

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listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1422 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2022 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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SAMPLE REPORT Lidar QA/QC Report

C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2022 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - D:\MARS\Dump6

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,215,298	4.499/0.418	0.471/1.546
CS_00500.las	5,748,981	19,065,533	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,977,619	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,314,761	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,659,848	3.455/0.321	0.538/1.765

08/24/2023 This report has been automatically generated by Merrick's MARS® QC Module build 8602.42 Page 13 of 107

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,392,491	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,951,142	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,460,286	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,234,518	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,126,551	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,469,063	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,678,942	3.175/0.295	0.561/1.841
CS_00528.las	49,869,586	153,064,531	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,102,278	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,101,322	3.466/0.322	0.537/1.761
CS_00531.las	36,879,558	130,184,484	3.046/0.283	0.573/1.879
CS_02117.las	22,438,290	92,065,629	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,910	2.885/0.268	0.588/1.930
CS_02121.las	46,452,576	211,885,553	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,574,973	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,157	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,537,767	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,416,433	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,749	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,749	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

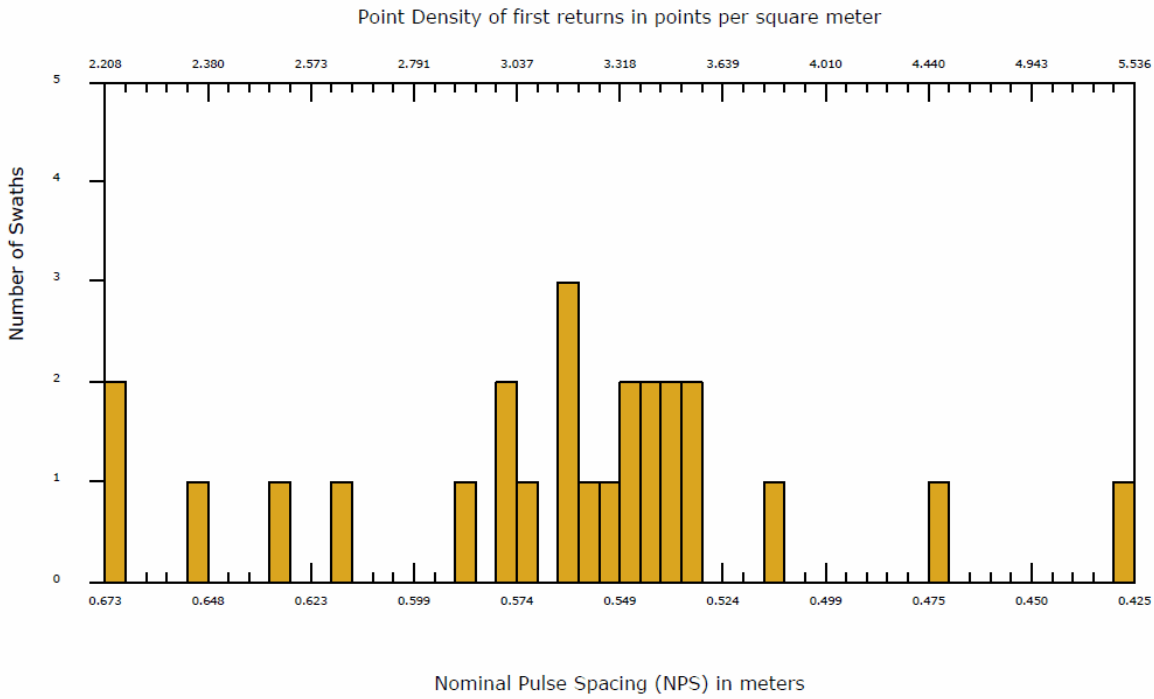
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - D:\MARS\Dump6



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2022 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show two separate mosaicked versions of a thematically rendered map of swath separation for all of the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For the first – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

For the second raster – known as a Swath Separation Image and found at the end of this test section – there are no limitations on slope angles and return types are user defined. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the RGB raster. The color is overlaid on a lidar intensity background to show land cover features. Tiled GeoTIFFs of this mosaicked raster can be found in the output folder for this test.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2022 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

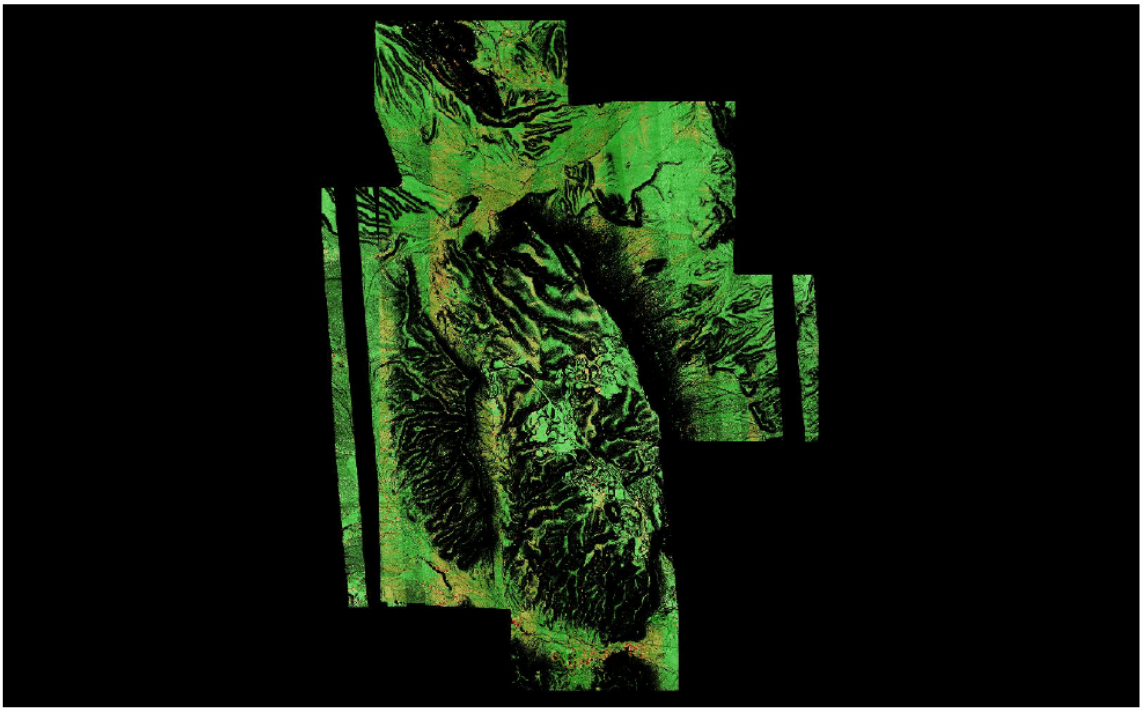
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

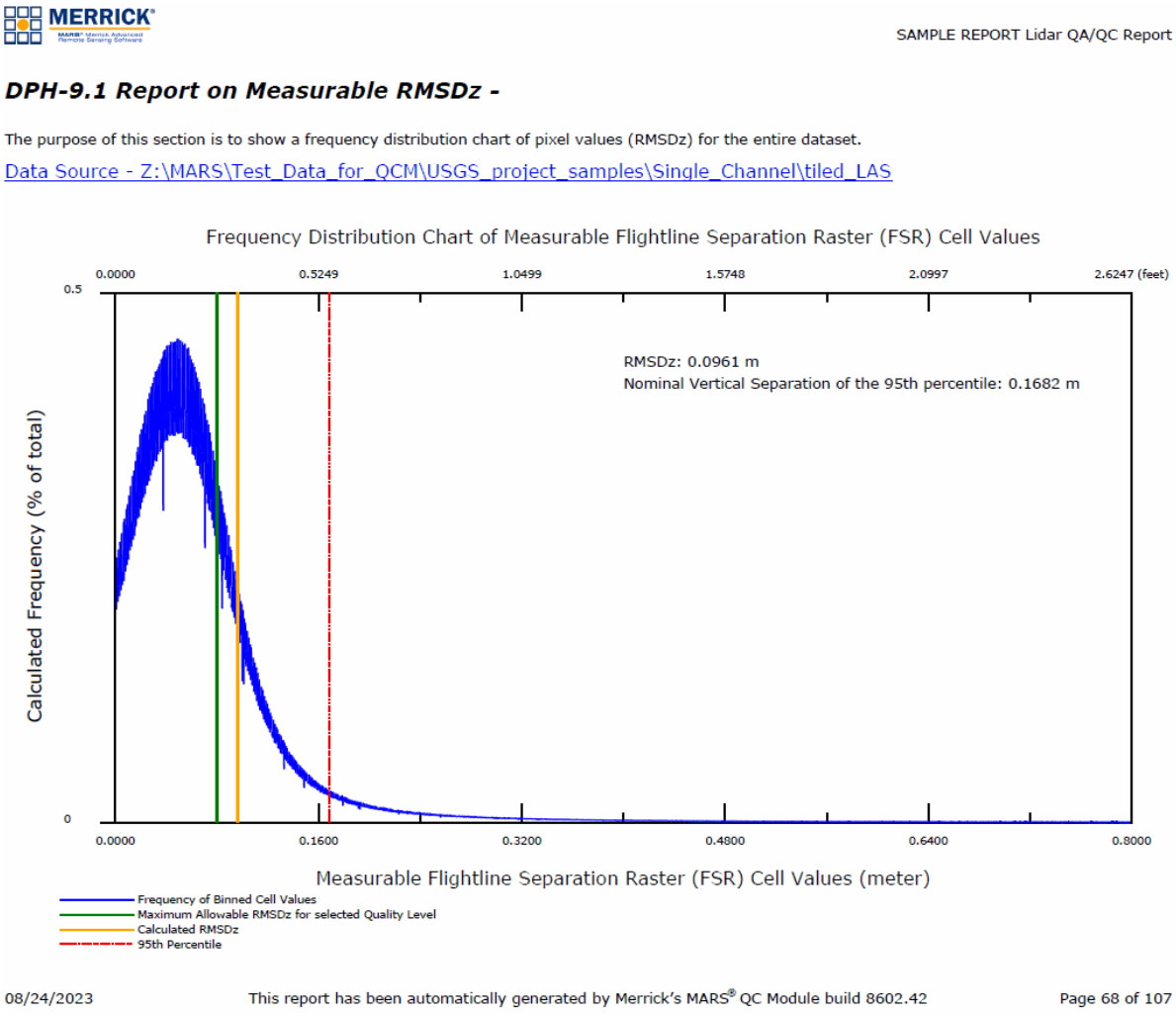
Data Source - D:\MARS\Dump6
Result Path - D:\MARS\Dump7\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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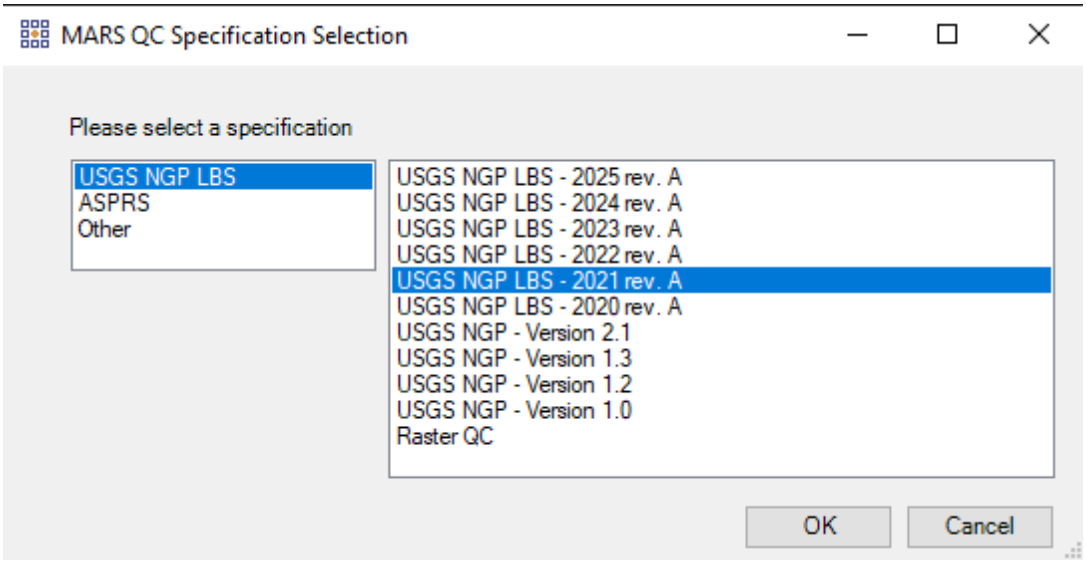
6.2.5 2021 rev. A

2021 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab, the 'USGS NGP LBS - 2021 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Note that the 'USGS NGP LBS - 2025 rev. A' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.5.1 General Information

USGS 2021 rev. A QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP LBS - 2021 rev. A' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2021 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS 2021 rev. A (June 2021) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1472 topic).

There are 23 possible tests that can be run in the USGS 2021 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1482 sub-topic for more information.

The USGS 2021 rev. A QC Module tests are divided into **Collection** 1468 and **Data Processing/Handling** 1472 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR

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Data Checks[1677] and LiDAR Calibration Checks[1698] tools, and the Voronoi Density Reporting[1660] tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

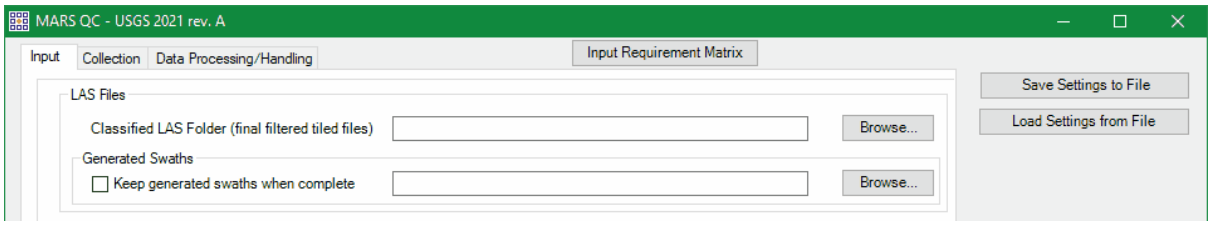
These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report[1224] help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.

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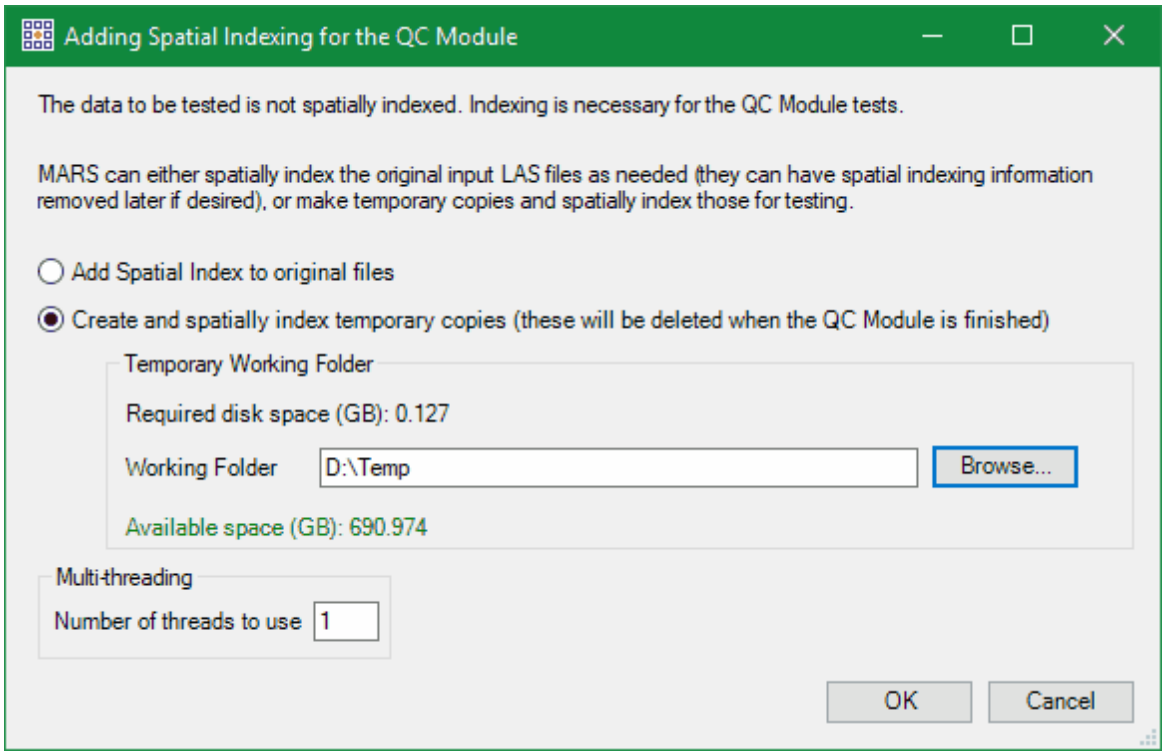
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

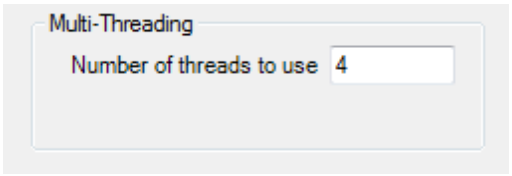
LAS data must be spatially indexed before it can be tested with the USGS 2021 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1464) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2021 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



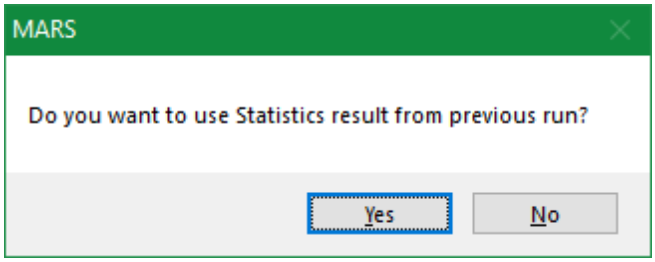
Running the USGS 2021 rev. A QC Module

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When all necessary entries have been made on the Input 1464, Collection 1468, and Data Processing/ Handling 1472 tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab 1464 for details), and whether data exists in these folders from previous runs of this USGS 2021 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

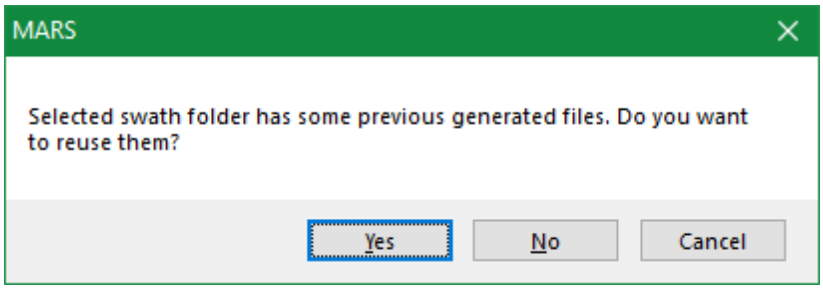
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab 1464. If there is data, the following message will appear:

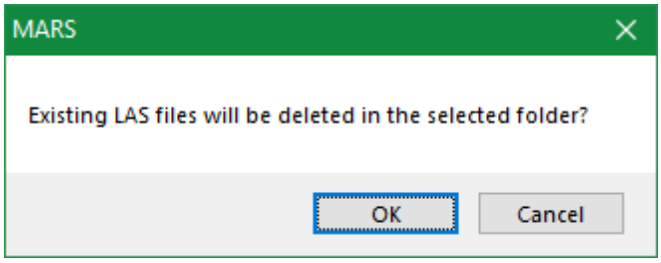
2.

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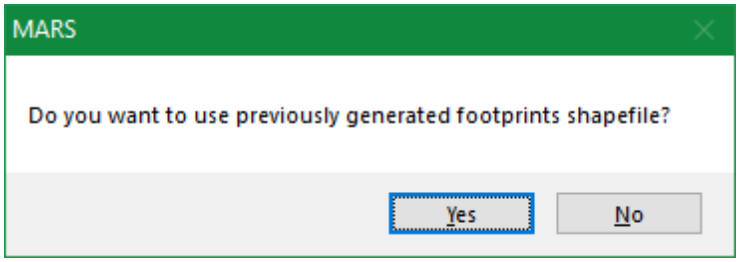
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1464] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1464] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



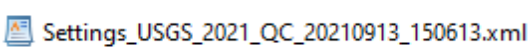
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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab 1464. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2021 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2021 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1464. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 3:06:13 pm on September 13, 2021.



This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2021 rev. A QC Module runs. After opening the USGS 2021 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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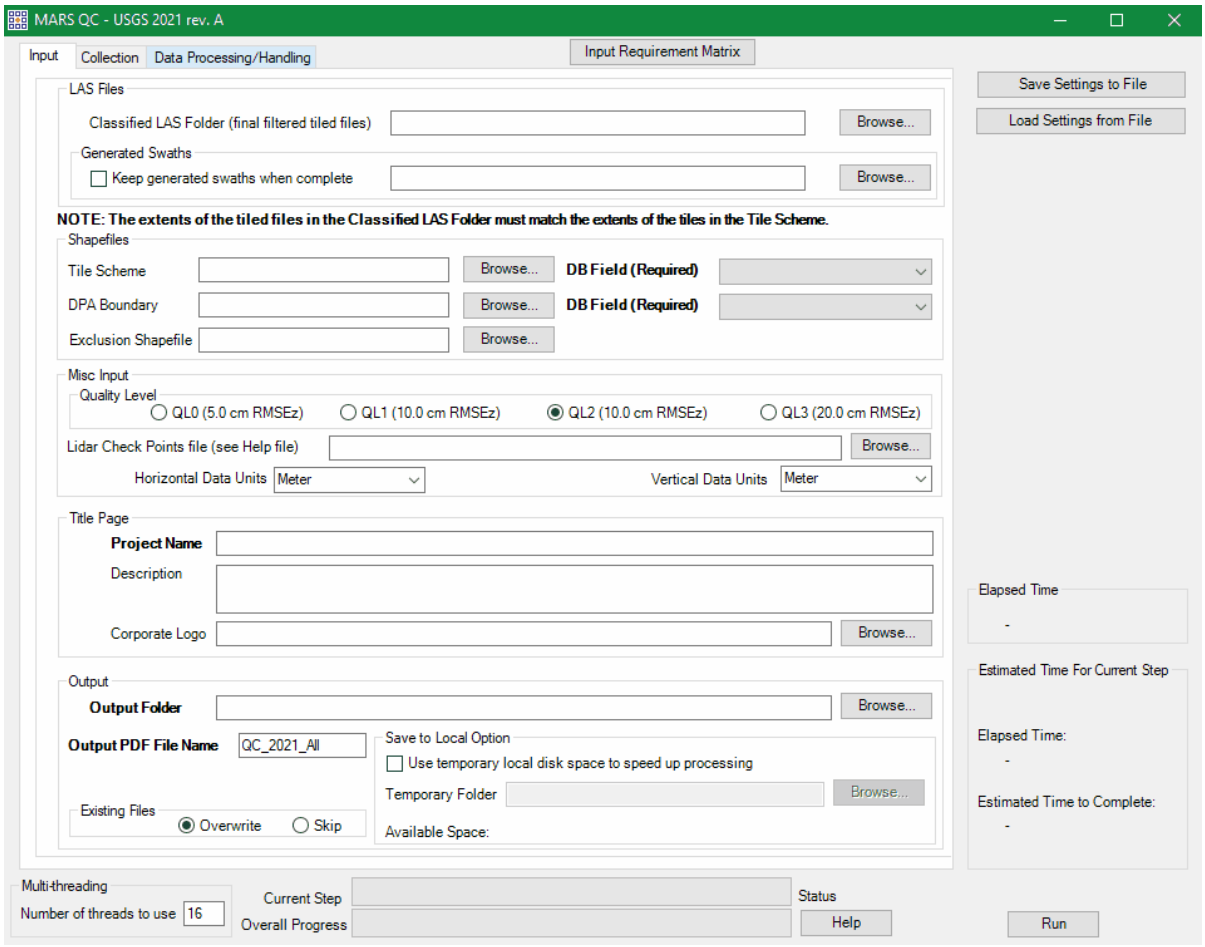
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2021 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.5.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab 1468 and Data Processing/Handling Tab 1472 topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2021 rev. A. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2021 rev. A QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

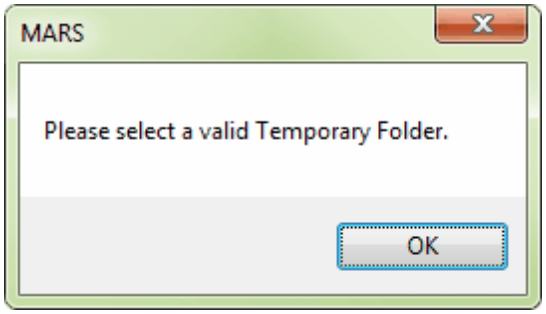
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user

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checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1482 sub-topic).

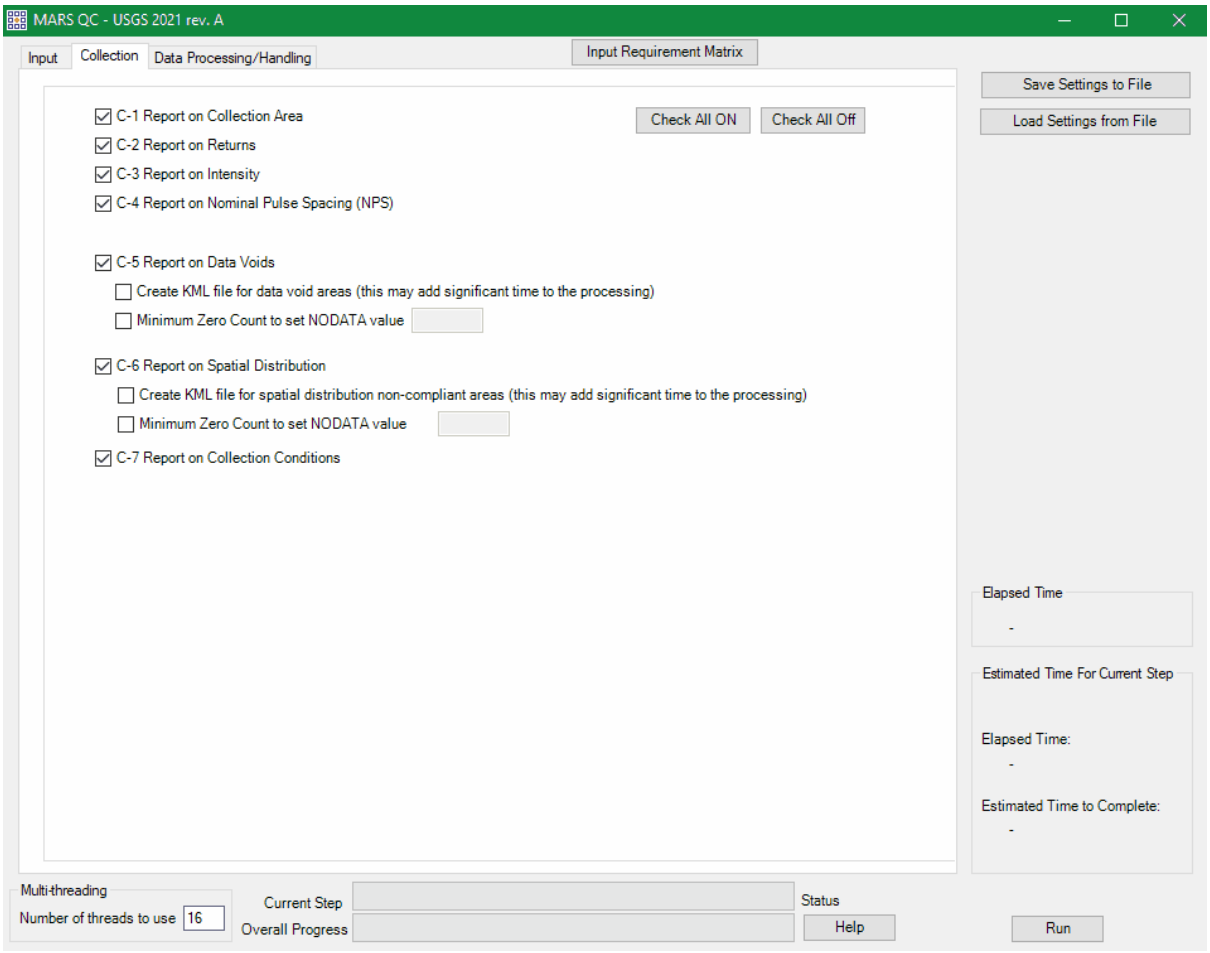
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6.2.5.3 Collection Tab

USGS 2021 rev. A QC Module - Collection Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/ paragraph in the USGS NGP Lidar Base Specification 2021 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1482). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary

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superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-

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compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1464 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the

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USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1464 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

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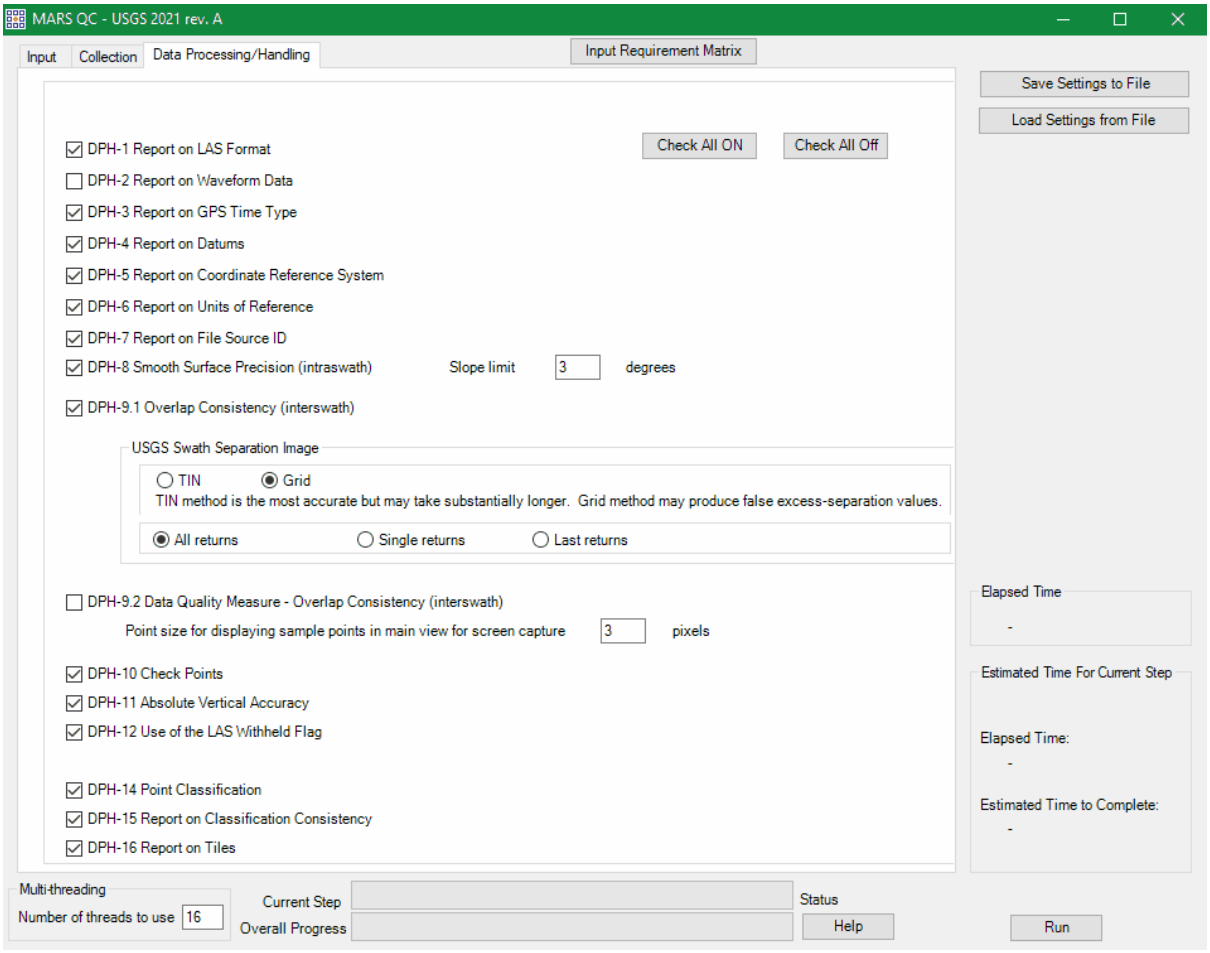
6.2.5.4 Data Processing/Handling Tab

USGS 2021 rev. A QC Module - Data Processing/

Handling Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-2** and **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. (Note that there is no longer a **DPH-13** test - this test for Overlap/Overage points was dropped for the current

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specification. Overlap bit-flagged points are no longer accepted for USGS data deliveries, and the existence of the Overlap bit flag will be reported in test **DPH-14** Point Classification so that corrective steps can be taken.

Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2021 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1482). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

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In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1464.

DPH-2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the lidar tiled data. A statement of waveform data file count is created for review. This test is unchecked by default.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

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DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-

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Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2021 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to show graphics of two distinct flight line separation rasters for all of the data processed - a Measurable raster and a Swath Separation Image raster. These images show the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Color-coded elevation difference rasters of the overlap areas are created for review, along with a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2021 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

For the Swath Separation Image raster (SSI), all returns are used and no cut-off is applied to the maximum elevation difference shown. In addition to a project-wide mosaicked raster, individual tiled SSI rasters are produced and stored in a sub-folder named 'SSI' found in the 'DPH_9_1' output folder.

There are two user-definable settings for the SSI raster portion of this test: 1.) an option to choose either TIN or Grid (the default) as the basis for the difference calculations in the raster (please see the notes in the DPH-9.1 section of the interface regarding TIN vs Grid), and; 2.) an option for which returns - 'All' (the default), 'Single', or 'Last' - are used in the creation of the raster. Note that the current USGS specifications allow for any of these options to be used.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2021 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

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DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data. This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart

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showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

(DPH-13 is intentionally omitted)

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Additionally, any points in any classifications that are bit-flagged as Overlap will be reported in red font as this bit flag is no

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longer used for USGS data deliveries.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1464. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

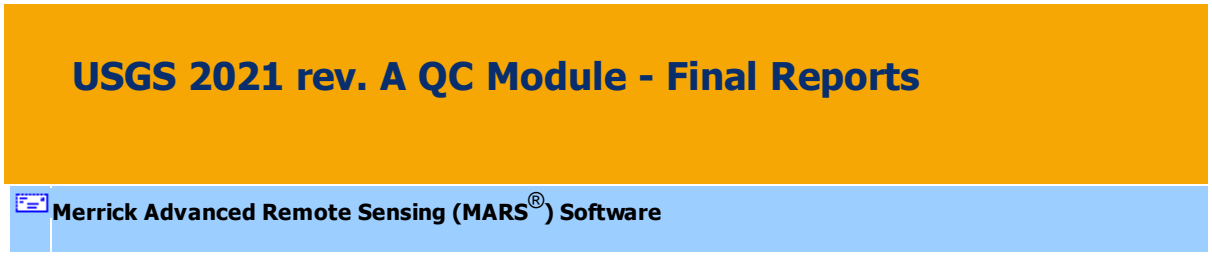
The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate

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height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.5.5 Final Reports



QC Reporting

The output of the USGS 2021 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1464. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1464. The default name is 'QC_2021_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was

chosen on the Input Tab 1464.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 23 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1456 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2021 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2021 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

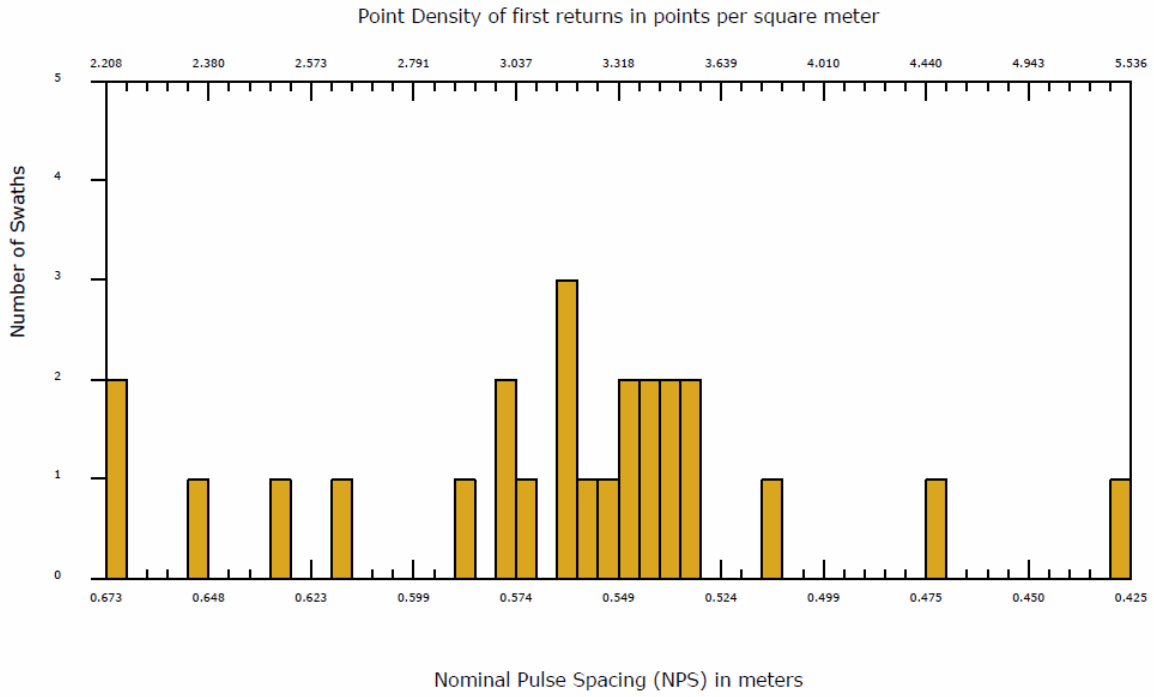
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2021 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show two separate mosaicked versions of a thematically rendered map of swath separation for all of the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For the first – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

For the second raster – known as a Swath Separation Image and found at the end of this test section – there are no limitations on slope angles and return types are user defined. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the RGB raster. The color is overlaid on a lidar intensity background to show land cover features. Tiled GeoTIFFs of this mosaicked raster can be found in the output folder for this test.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2021 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

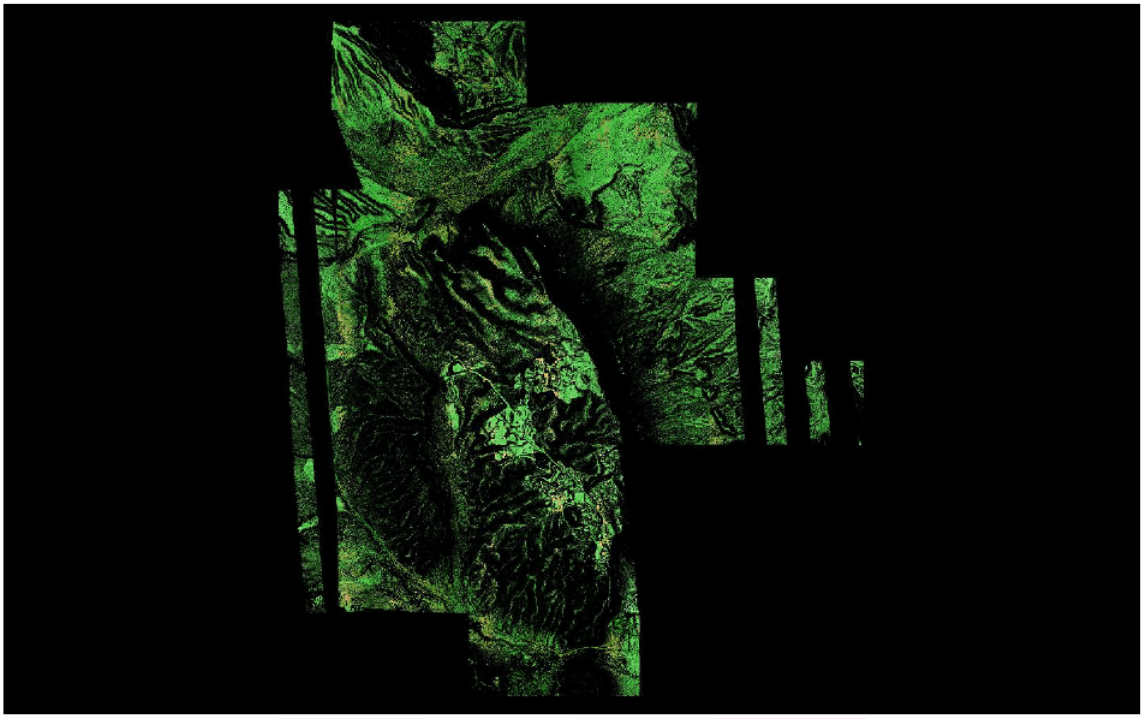
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

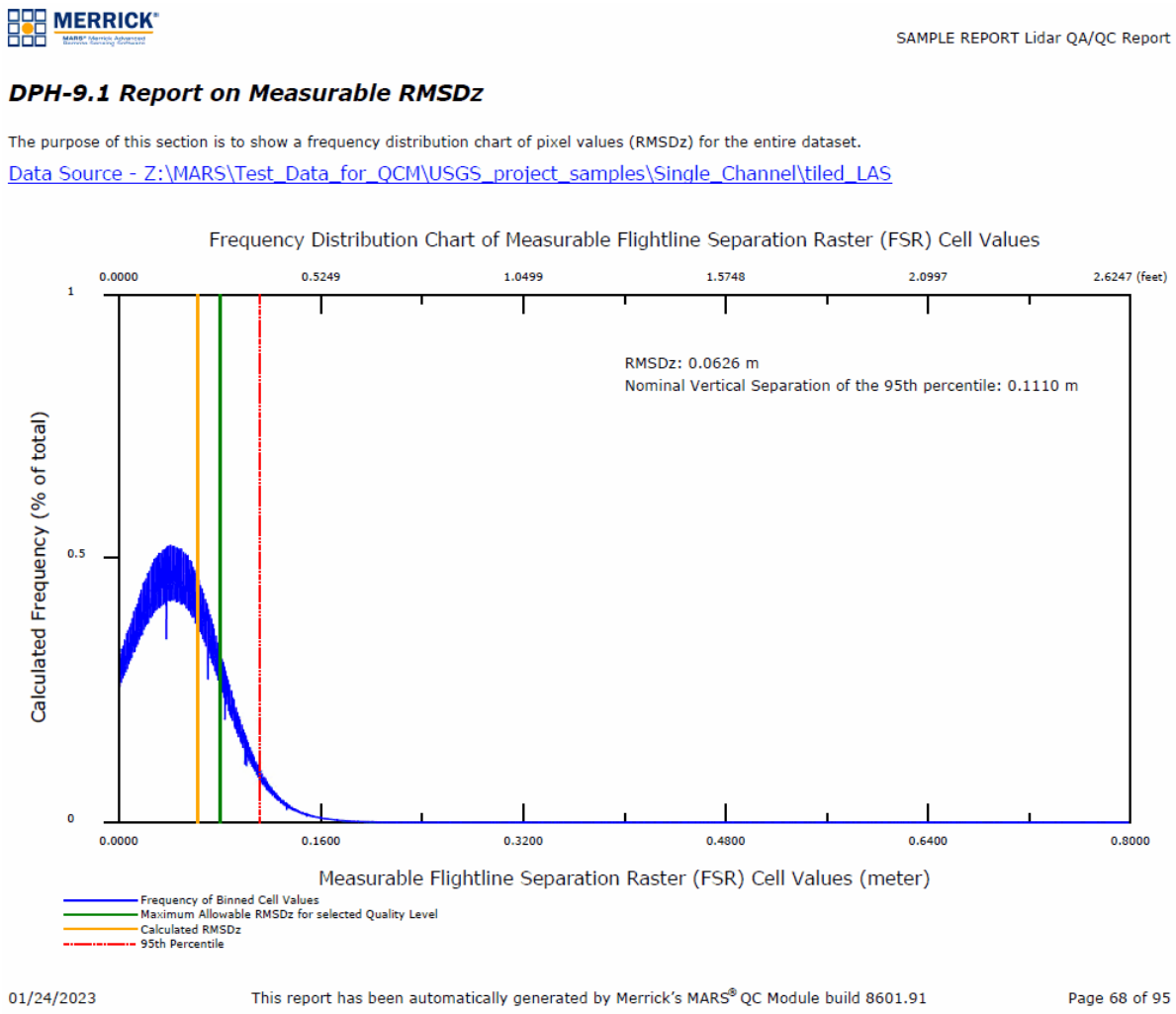
Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths
Result Path - D:\Temp\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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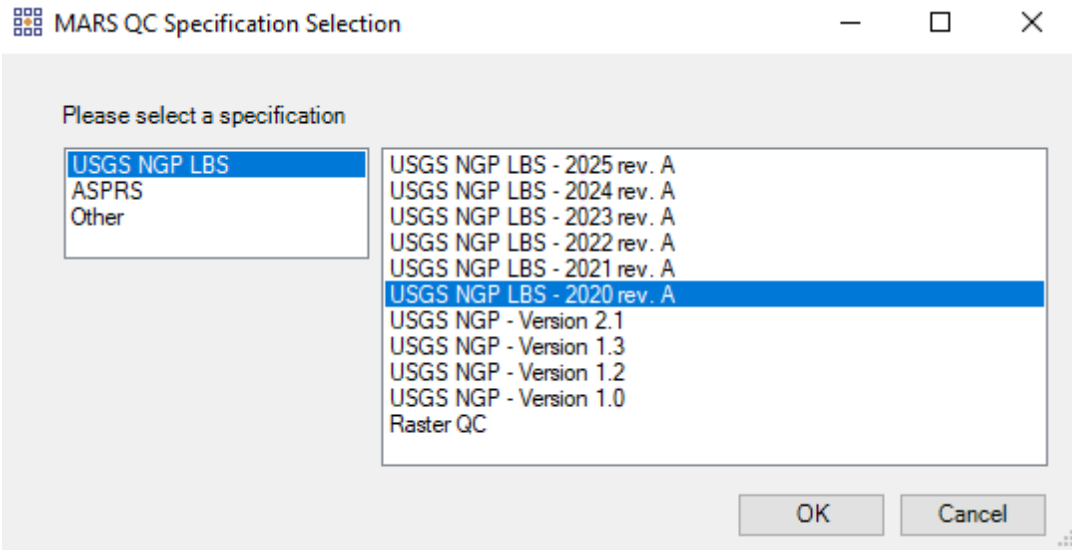
6.2.6 2020 rev. A

2020 rev. A

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP LBS - 2020 rev. A' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



.

Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.6.1 General Information

USGS 2020 rev. A QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP LBS - 2020 rev. A' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification 2020 rev. A from the U.S. Geological Survey (USGS). The content of USGS NGP LBS 2020 rev. A (August 2020) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1507 topic).

There are 24 possible tests that can be run in the USGS 2020 rev. A QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1517 sub-topic for more information.

The USGS 2020 rev. A QC Module tests are divided into **Collection** 1503 and **Data Processing/Handling** 1507 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR

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Data Checks[1677] and LiDAR Calibration Checks[1698] tools, and the Voronoi Density Reporting[1660] tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

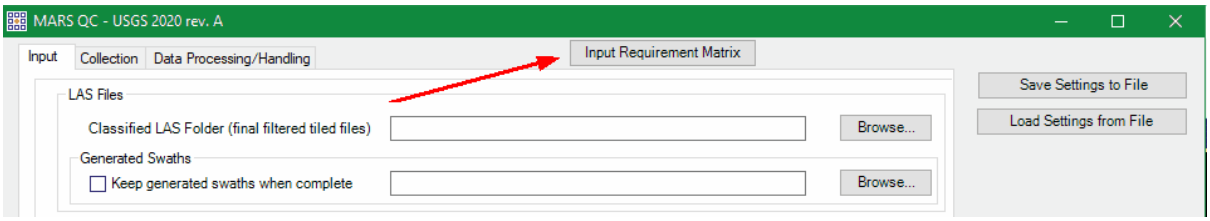
These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report[1224] help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.

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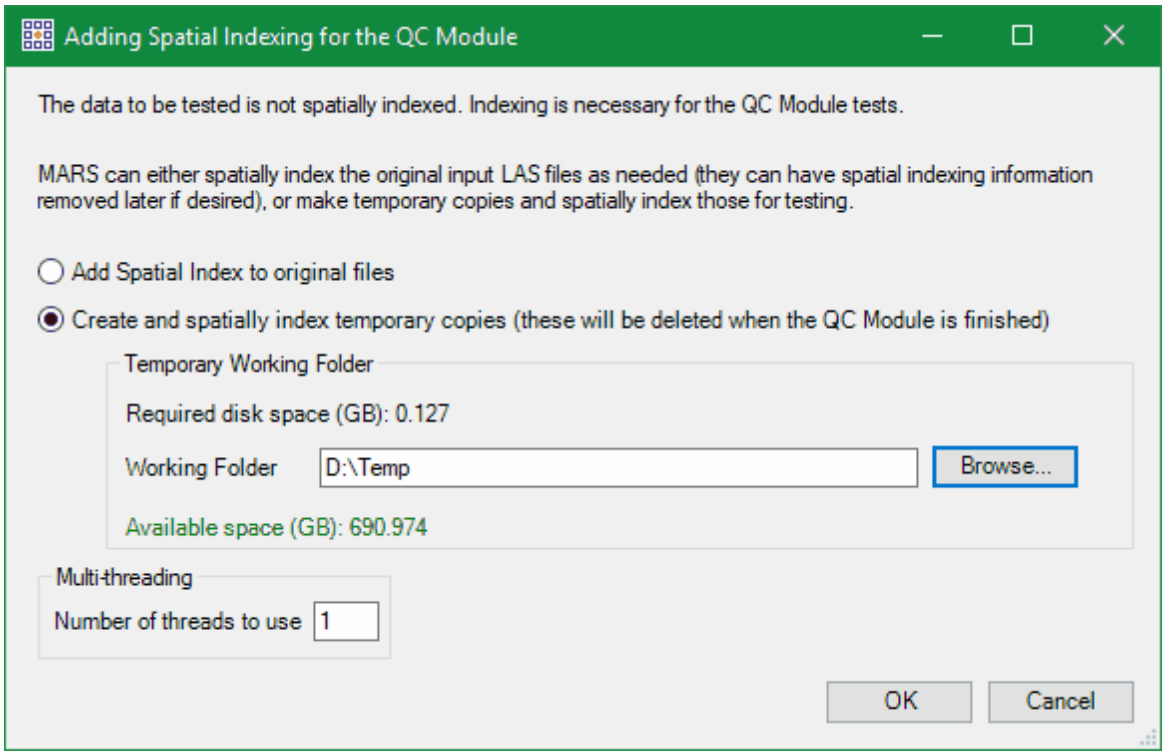
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

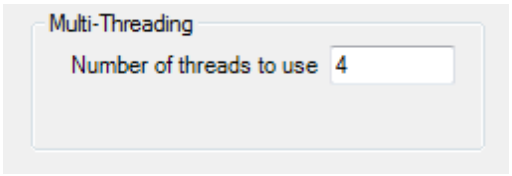
LAS data must be spatially indexed before it can be tested with the USGS 2020 rev. A QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1499) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2020 rev. A QC Module interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



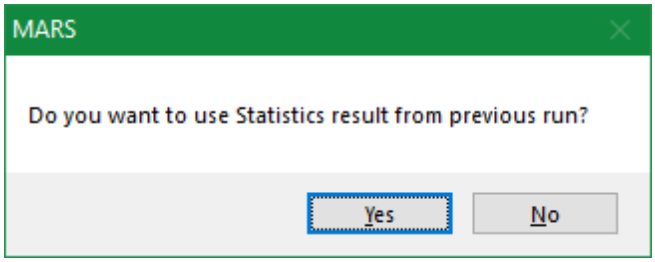
Running the USGS 2020 rev. A QC Module

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When all necessary entries have been made on the Input[1499], Collection[1503], and Data Processing/ Handling[1507] tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab[1499] for details), and whether data exists in these folders from previous runs of this USGS 2020 rev. A QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

NOTE - the following tests require that statistics be compiled for the input LAS files: C-2, C-3, DPH-1, DPH-12, and DPH-14. If any of these tests is selected, the QC Module tool will check for an existing 'Statistics' folder in the output path. If present, a prompt will appear asking for confirmation to re-use the statistics or create new ones. If not present, prompt **#1** (below) will be skipped.

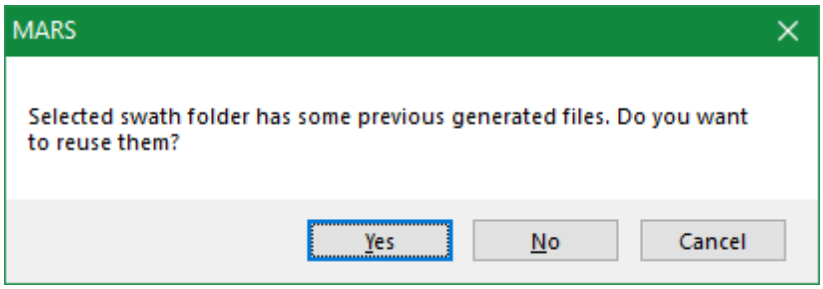
1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab[1499]. If there is data, the following message will appear:

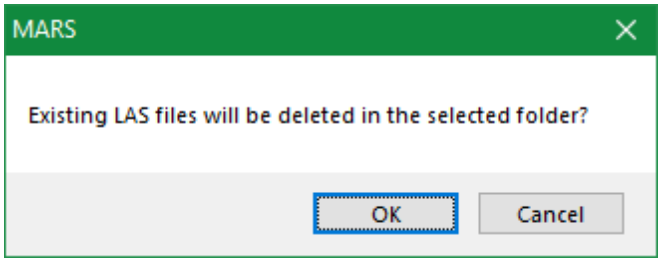
2.

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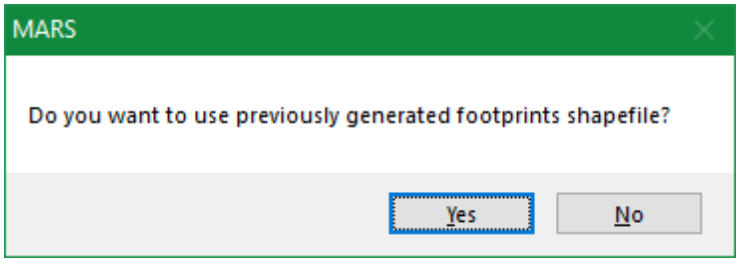
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1499] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1499] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



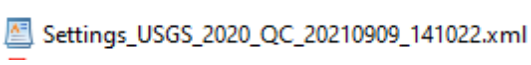
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After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab 1499. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2020 rev. A QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2020 rev. A QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1499. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 2:10:22 pm on September 9, 2021.



This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2020 rev. A QC Module runs. After opening the USGS 2020 rev. A QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be

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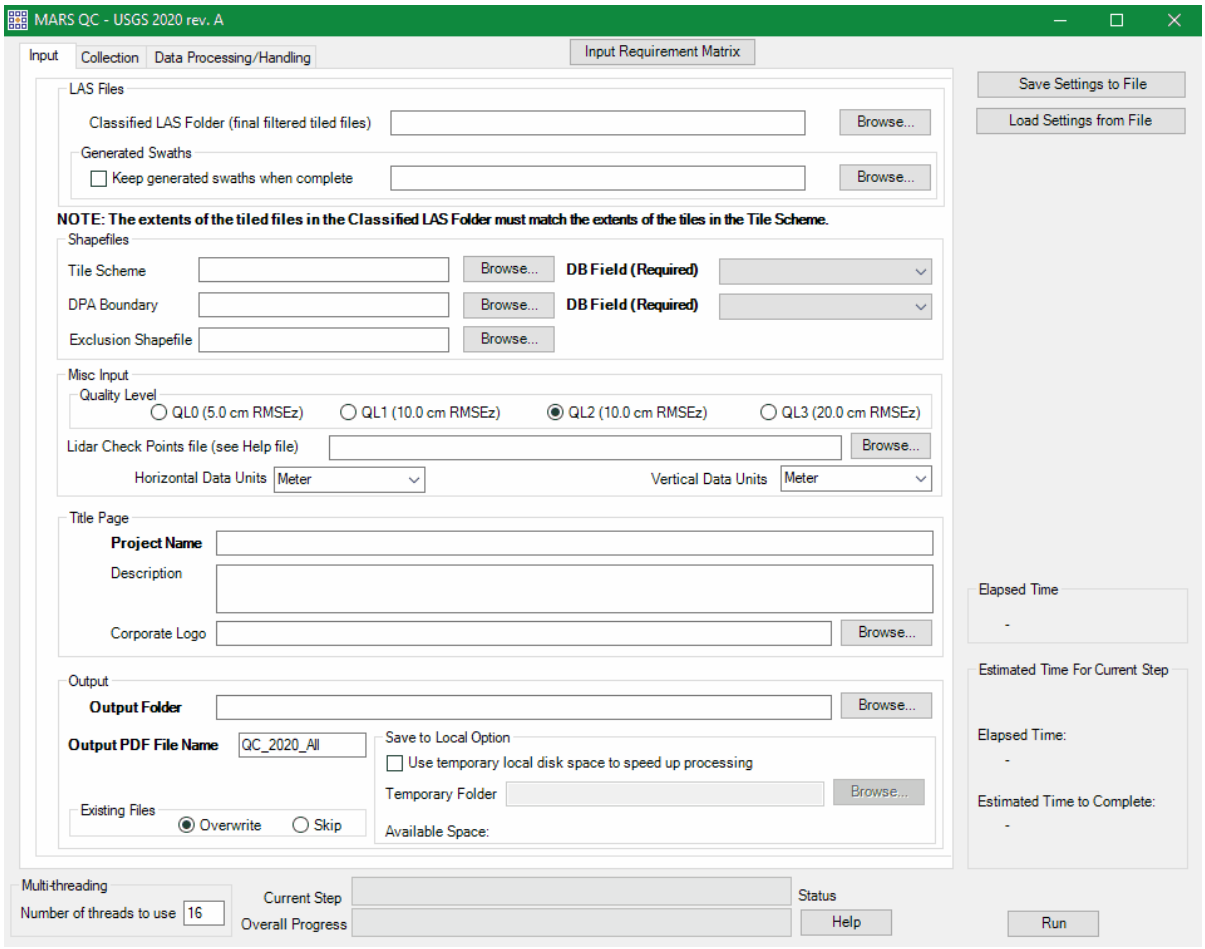
used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2020 rev. A QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.6.2 Input Tab



The Input Tab



This tab is where all input data is pathed out, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab[1503] and Data Processing/Handling Tab[1507] topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification 2020 rev. A. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2020 rev. A QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report[1224] Help Topic for more details on the check points.

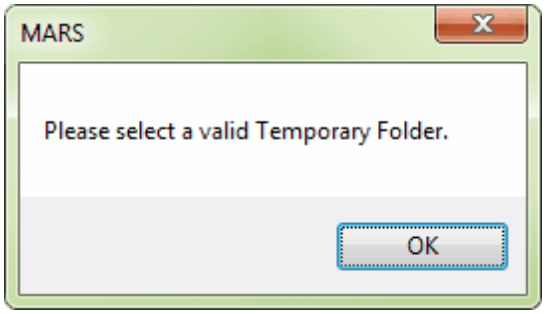
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user

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checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1517 sub-topic).

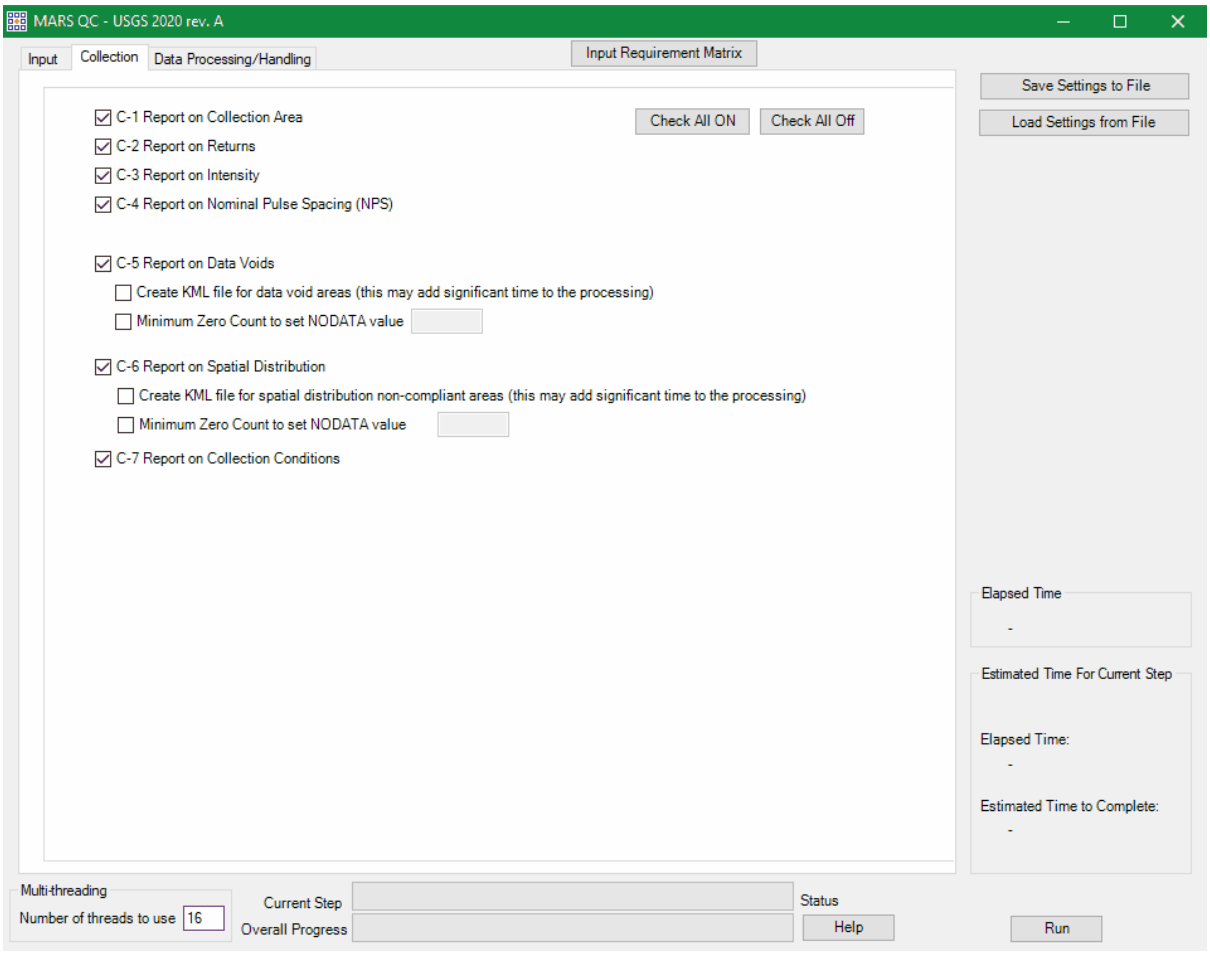
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6.2.6.3 Collection Tab

USGS 2020 rev. A QC Module - Collection Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/ paragraph in the USGS NGP Lidar Base Specification 2020 rev. A in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1517). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary

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superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-

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compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab[1499] topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the

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USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1499 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

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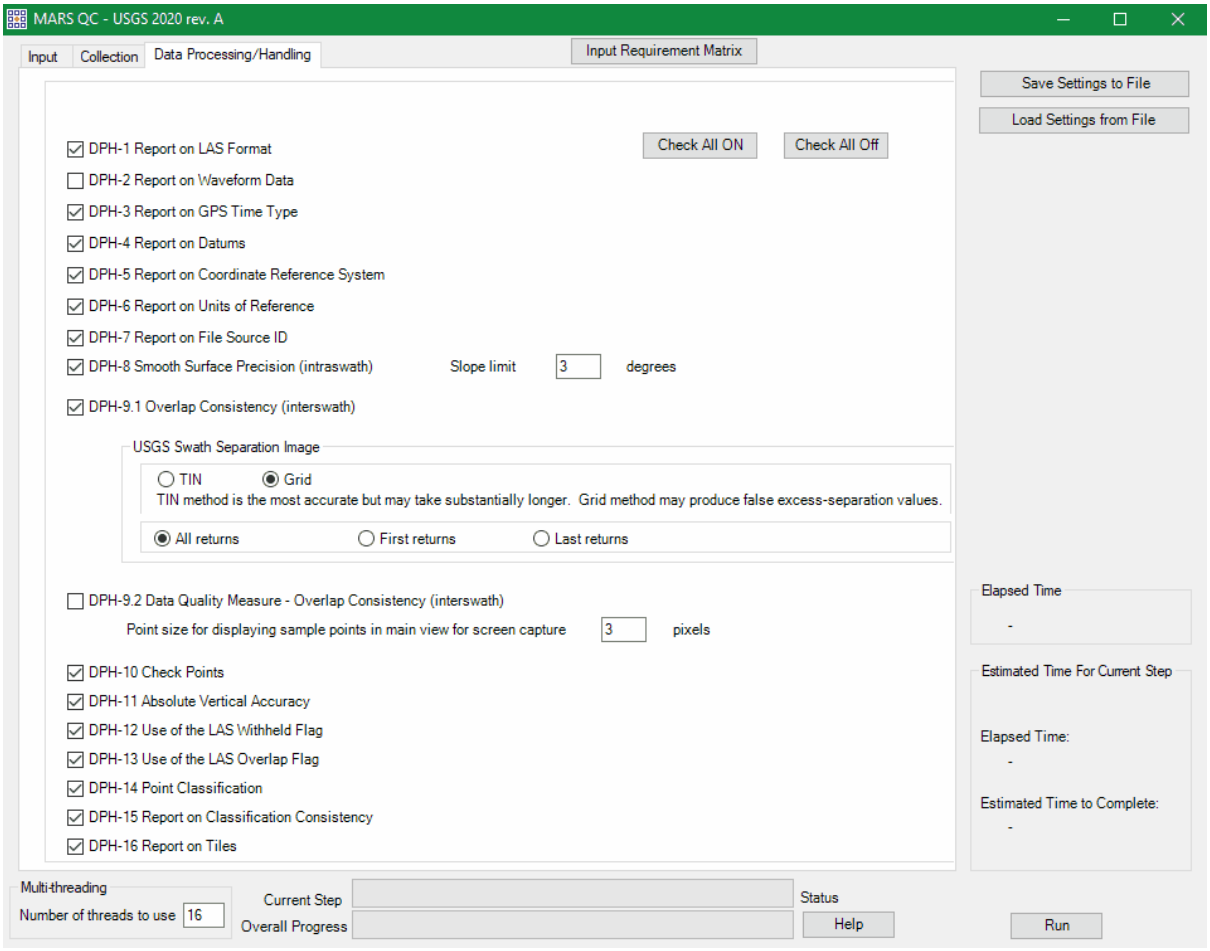
6.2.6.4 Data Processing/Handling Tab

USGS 2020 rev. A QC Module - Data Processing/

Handling Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-2** and **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification 2020 rev. A in

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which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1517). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as

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appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1499.

DPH-2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the lidar tiled data. A statement of waveform data file count is created for review. This test is unchecked by default.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be

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promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units. Red items will be promoted to the top of the table.

DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID and Point Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table. In addition, sub-section **DPH-7.2** reports on Swath Geographic Locations to indicate possible problems when a given swath (generated based on Point Source IDs) exists in more than one contiguous geographic location. This may occur if a large water body (or other no-data area) crosses the swath to separate the 'footprint' into two or more non-contiguous polygons.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of

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the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2020 rev. A document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to show graphics of two distinct flight line separation rasters for all of the data processed - a Measurable raster and a Swath Separation Image raster. These images show the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Color-coded elevation difference rasters of the overlap areas are created for review, along with a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification 2020 rev. A document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

For the Swath Separation Image raster (SSI), all returns are used and no cut-off is applied to the maximum elevation difference shown. In addition to a project-wide mosaicked raster, individual tiled SSI rasters are produced and stored in a sub-folder named 'SSI' found in the 'DPH_9_1' output folder.

There are two user-definable settings for the SSI raster portion of this test: 1.) an option to choose either TIN or Grid (the default) as the basis for the difference calculations in the raster (please see the notes in the DPH-9.1 section of the interface regarding TIN vs Grid), and; 2.) an option for which returns - 'All' (the default), 'First', or 'Last' - are used in the creation of the raster. Note that the USGS specifications call for all returns to be used.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the USGS NGP LBS 2020 rev. A specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

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DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data. This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart

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showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

DPH-13 Use of the LAS Overlap Flag

The purpose of this section is to list the presence and quantities of points flagged as Overlap for all the lidar tiled data. A statement of total Overlap point count for all classes/all files is created for review, along with a screen capture of the Overlap-flagged points for the tiled data.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**.

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Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1499. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

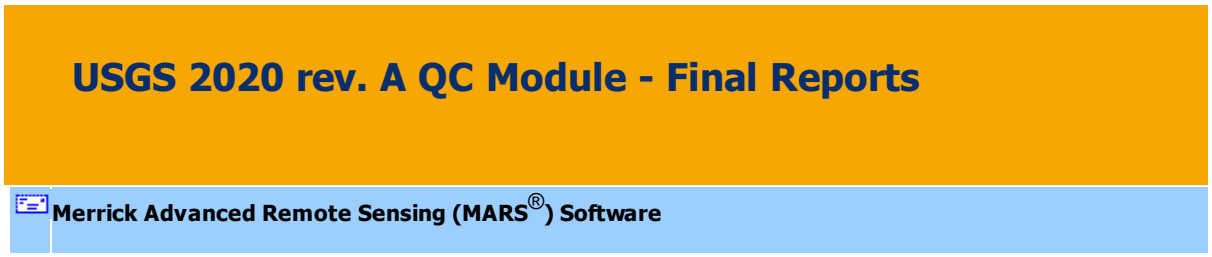
The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red

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font.

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6.2.6.5 Final Reports



QC Reporting

The output of the USGS 2020 rev. A QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1499. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1499. The default name is 'QC_2020_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1499.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1491 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2020 rev. A QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification 2020 rev. A states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

ms

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

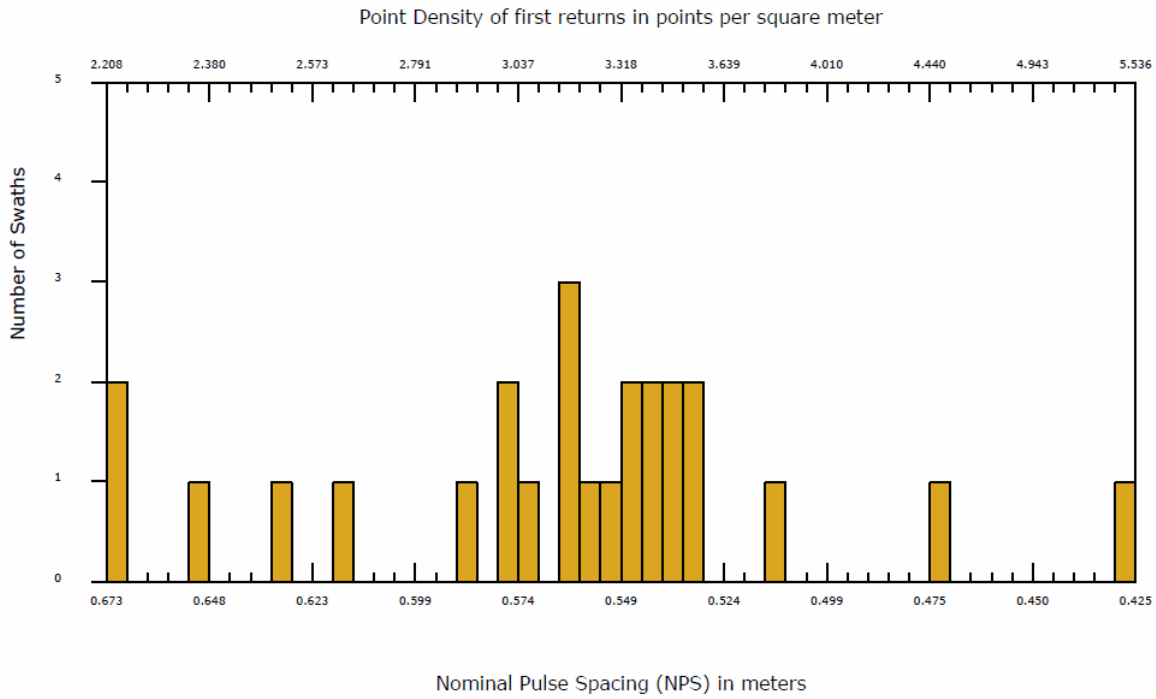
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification 2020 rev. A states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show two separate mosaicked versions of a thematically rendered map of swath separation for all of the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For the first – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

For the second raster – known as a Swath Separation Image and found at the end of this test section – there are no limitations on slope angles and return types are user defined. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the RGB raster. The color is overlaid on a lidar intensity background to show land cover features. Tiled GeoTIFFs of this mosaicked raster can be found in the output folder for this test.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification 2020 rev. A. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

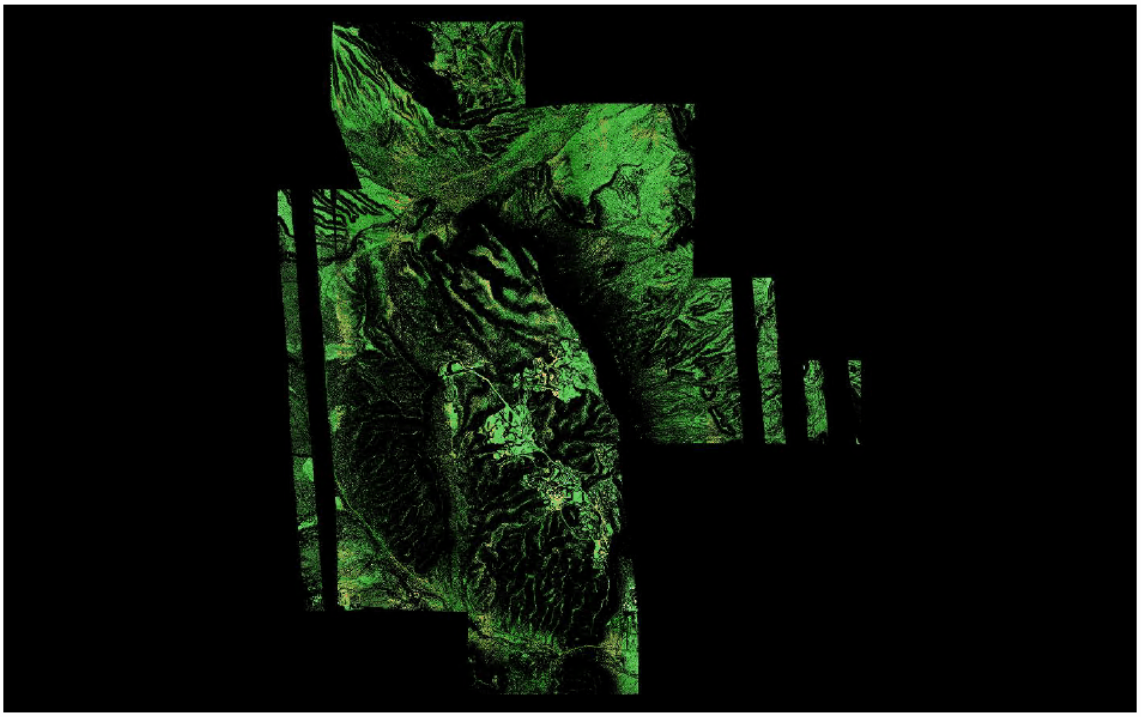
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

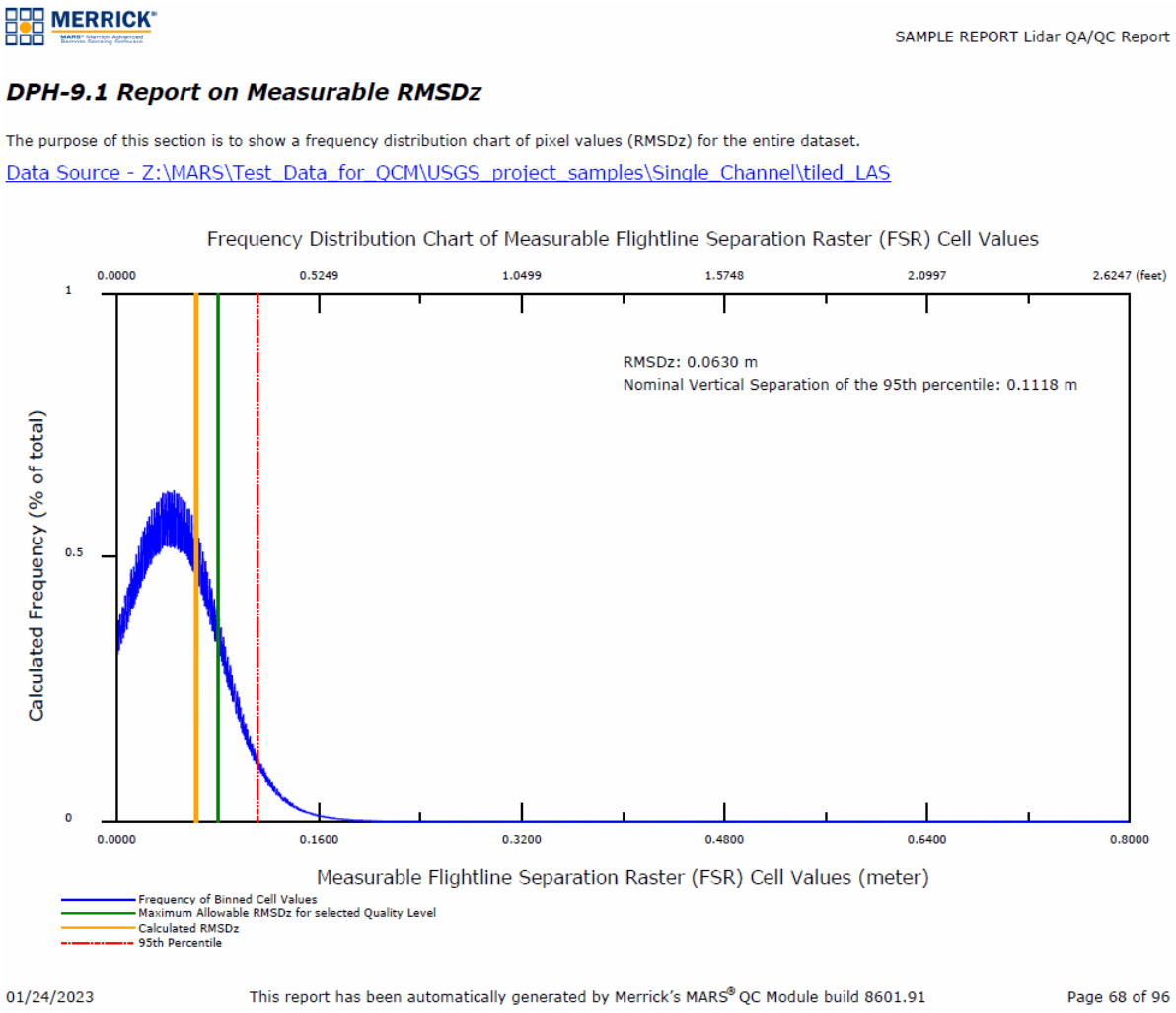
Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths
Result Path - D:\Temp\QCM_2020\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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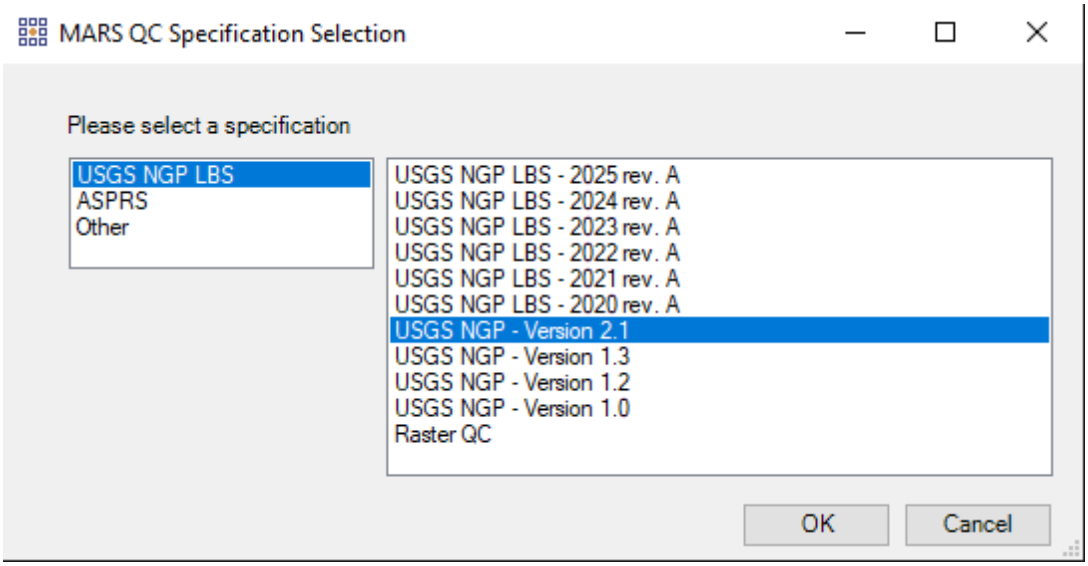
6.2.7 Version 2.1

Version 2.1

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP - Version 2.1' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.7.1 General Information

USGS 2.1 QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP - Version 2.1' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification Version 2.1 from the U.S. Geological Survey (USGS). The content of USGS NGP Lidar Base Specification Version 2.1 (October 2019) can be downloaded as a PDF.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1542 topic).

There are 24 possible tests that can be run in the USGS 2.1 QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1551 sub-topic for more information.

The USGS 2.1 QC Module tests are divided into **Collection** 1572 and **Data Processing/Handling** 1577 tabs as categorized in the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 1.3 1559, USGS NGP - Version 1.2 1592, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR Data Checks 1677 and LiDAR Calibration Checks 1698 tools, and the Voronoi Density Reporting 1660 tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

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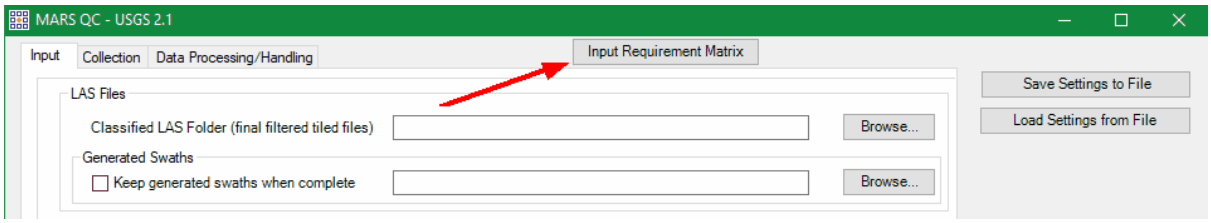
Input Datasets

These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report 1224 help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-8 Smooth Surface Precision (intraswath), DPH-10 Check Points, and DPH-11 Absolute Vertical Accuracy. Many tests require the existence or generation of swath LAS data files. If any of these tests are selected to be run, a warning prompt will appear when the 'Run' button is clicked. Use the 'Browse' button to the right of the 'Generated Swaths' entry box to select a folder of existing project swaths, or a folder in which swaths will be generated from the tiled data. Optionally, check the 'Keep generated swaths when complete' box to retain the existing or generated swaths at the end of the processing.

A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.



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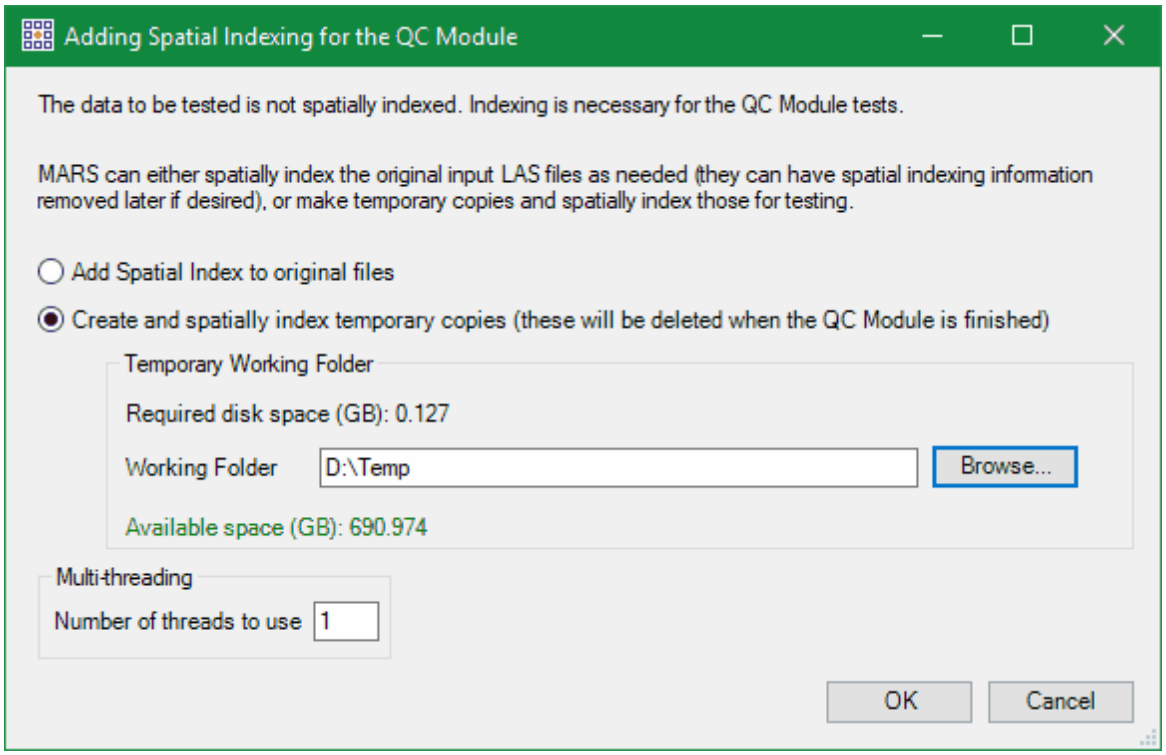
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

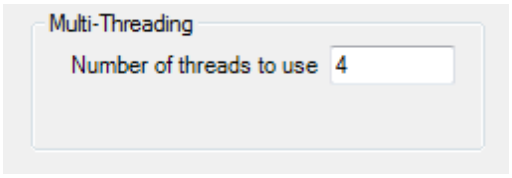
LAS data must be spatially indexed before it can be tested with the USGS 2.1 QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1534) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 2.1 QC Module tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

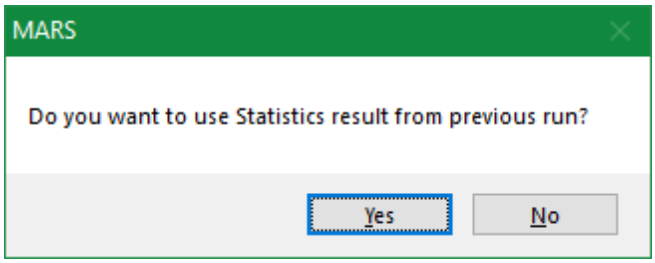


Running the USGS 2.1 QC Module

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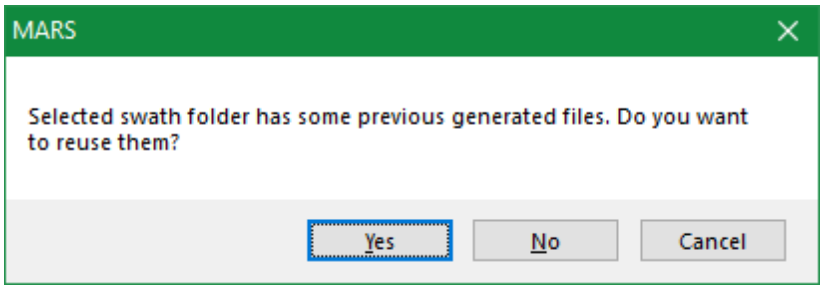
When all necessary entries have been made on the Input[1534], Collection[1538], and Data Processing/Handling[1542] tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab[1534] for details), and whether data exists in these folders from previous runs of this USGS 2.1 QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previously generated data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folders before running this module.

1.



A 'Yes' answer will reuse previously generated statistics in the output folder path for both tiled and swaths data. Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab[1534]. If there is data, the following message will appear:

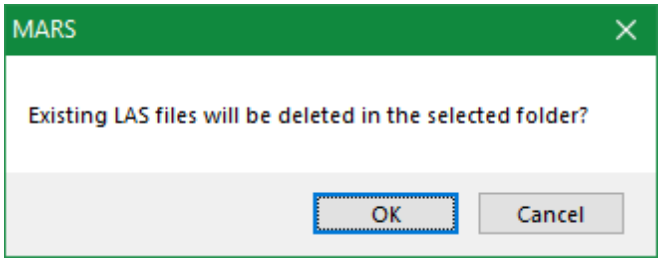
2.



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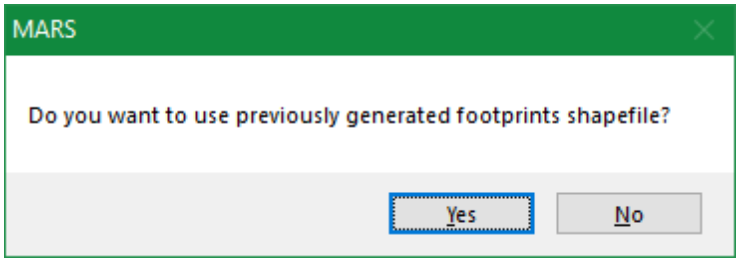
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1534] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1534] section. Finally, a check is done for an existing swath footprints shapefile in the output folder path:

4.



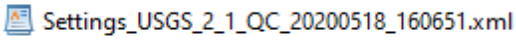
After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab[1534]. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

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While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 2.1 QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 2.1 QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1534. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 4:06:51 pm on May 18, 2020.

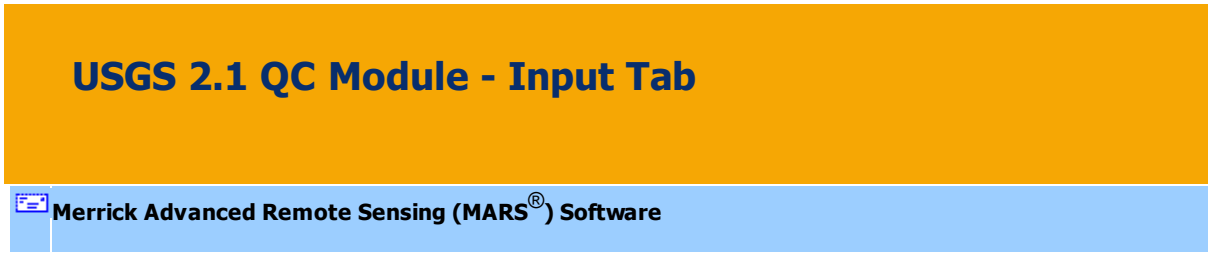


This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 2.1 QC Module runs. After opening the USGS 2.1 QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 2.1 QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

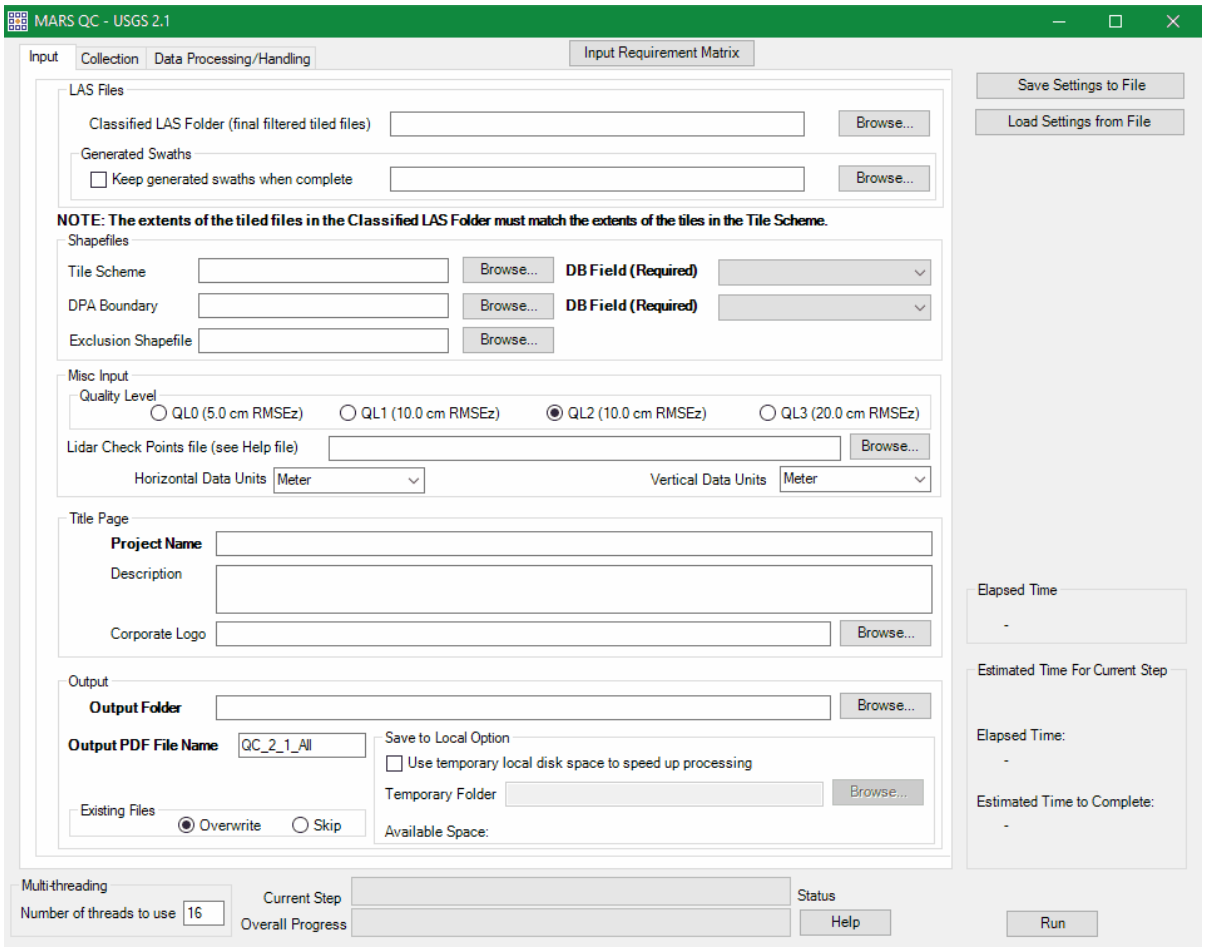
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6.2.7.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear

on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

Depending on the test(s) selected, a 'Generated Swaths' folder may need to be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs in the Classified LAS (tiled) data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag refers to 'Collection Scan'). These swaths are used as input for the following tests: C-2, C-3, C-4, C-5, C-6, DPH-8, and DPH-9.1. An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS

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Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests C-4, C-5, C-6, DPH-9.1, and DPH-15 (see the Collection Tab[1538] and Data Processing/Handling Tab[1542] topics).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification Version 2.1. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 2.1 QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report[1224] Help Topic for more details on the check points.

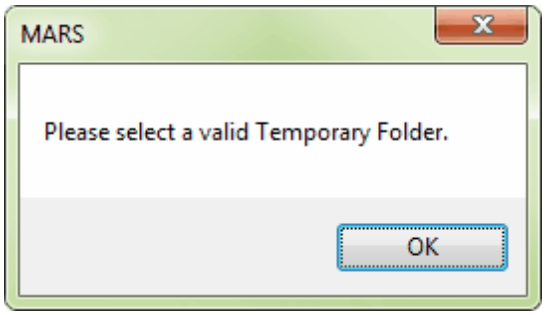
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are

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Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



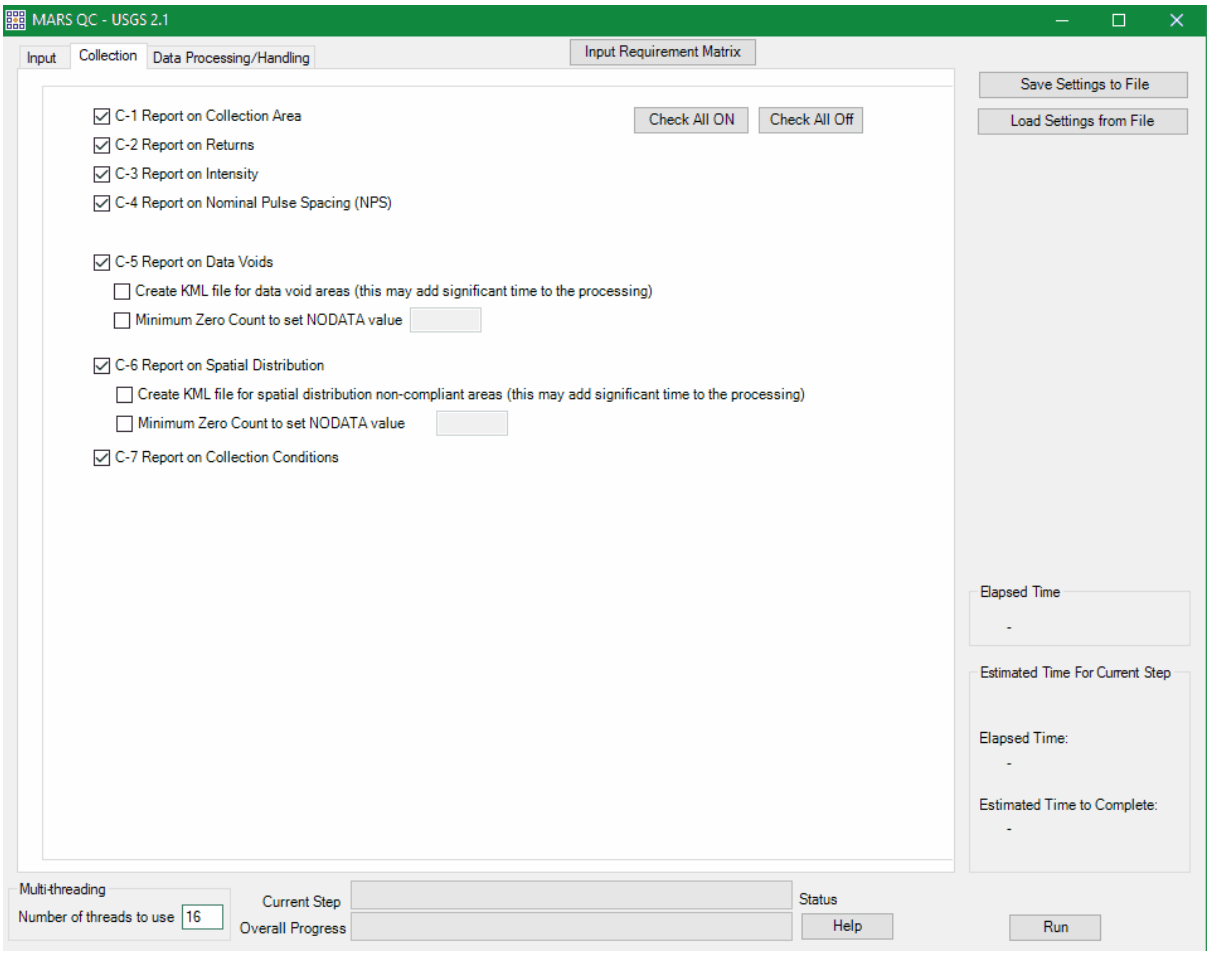
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1551 sub-topic).

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6.2.7.3 Collection Tab



The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section/

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paragraph in the USGS NGP Lidar Base Specification Version 2.1 in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1551). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of the defined project area (DPA) boundary. A screen capture of the lidar tiled data with the DPA boundary superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values at the individual swath level are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

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C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1534 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc.

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Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. When possible, using the 'Exclusion Shapefile' option described in the Input Tab 1534 topic will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

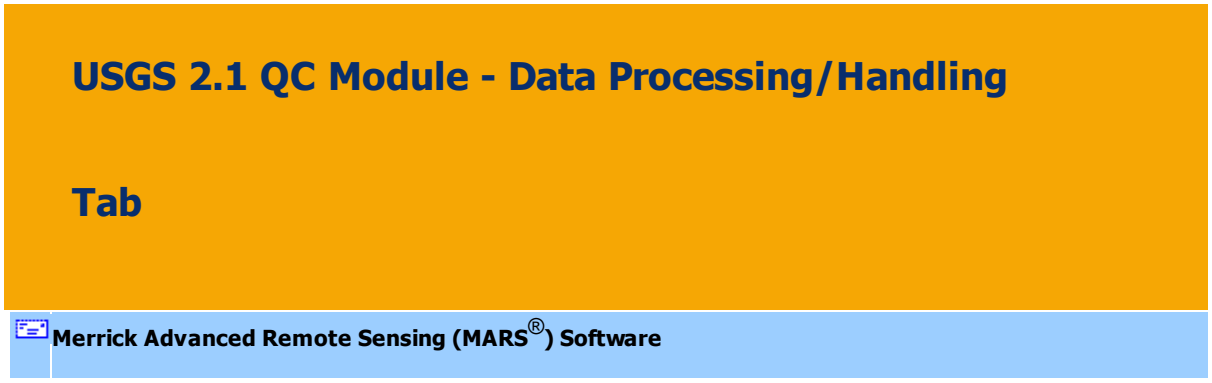
The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection at the time of acquisition.

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

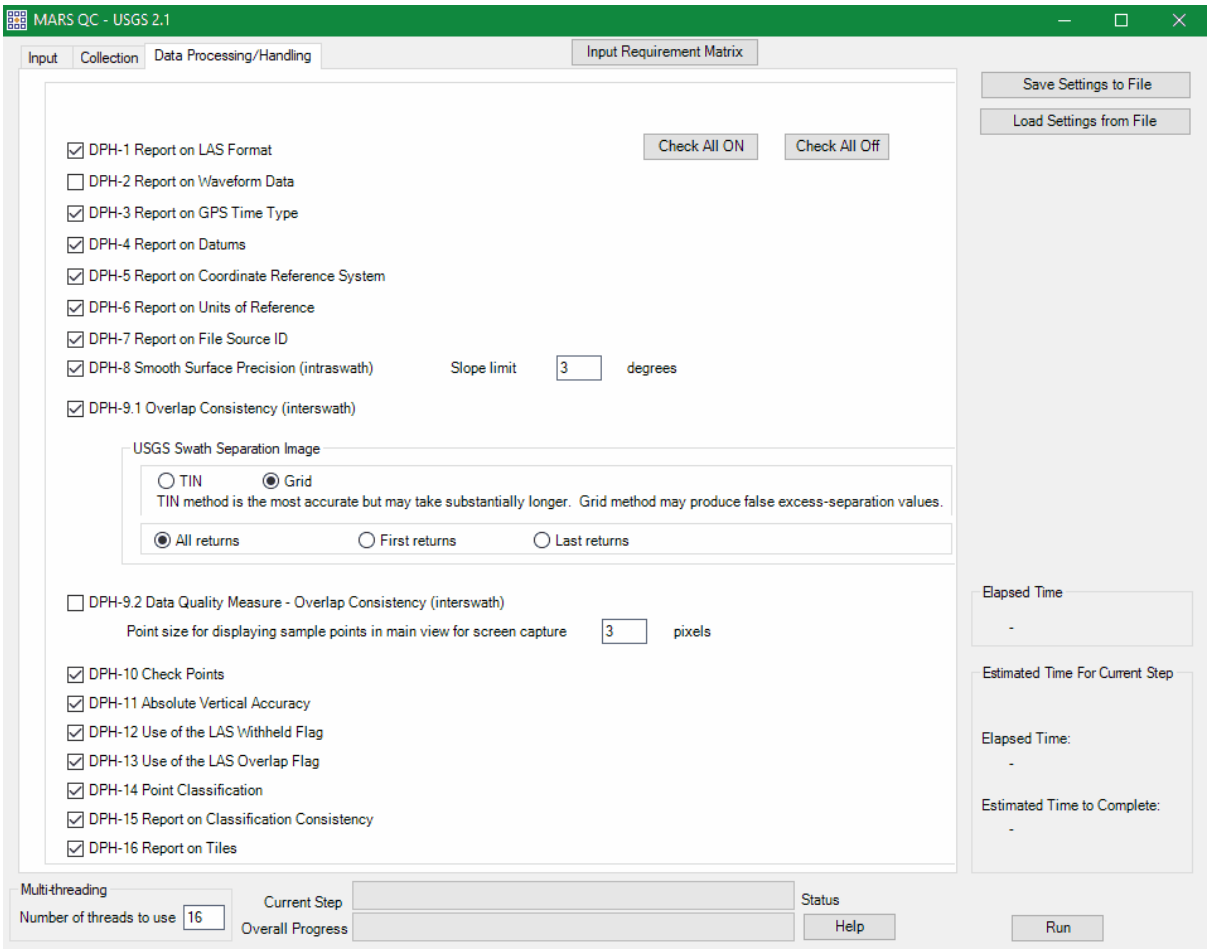
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6.2.7.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests except **DPH-2** and **DPH-9.2** are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 2.1 in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1551). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review

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for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1534.

DPH-2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the lidar tiled data. A

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statement of waveform data file count is created for review. This test is unchecked by default.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units. Red items will be promoted to the top of the table.

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DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID and Point Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table. In addition, sub-section **DPH-7.2** reports on Swath Geographic Locations to indicate possible problems when a given swath (generated based on Point Source IDs) exists in more than one contiguous geographic location. This may occur if a large water body (or other no-data area) crosses the swath to separate the 'footprint' into two or more non-contiguous polygons.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification Version 2.1 document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined

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Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to show graphics of two distinct flight line separation rasters for all of the data processed - a Measurable raster and a Swath Separation Image raster. These images show the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Color-coded elevation difference rasters of the overlap areas are created for review, along with a frequency distribution chart of relative accuracy RMSDz values of the Measurable raster pixels. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification Version 2.1 document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

Table 2: Relative vertical accuracy for light detection and ranging swath data.

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$, (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

For the Measurable separation raster, overlap areas are further refined before analysis by creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other

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obstacles. Additionally, only areas of less than 10 degree slope are analyzed.

For the Swath Separation Image raster (SSI), all returns are used and no cut-off is applied to the maximum elevation difference shown. In addition to a project-wide mosaicked raster, individual tiled SSI rasters are produced and stored in a sub-folder named 'SSI' found in the 'DPH_9_1' output folder.

There are two user-definable settings for the SSI raster portion of this test: 1.) an option to choose either TIN or Grid (the default) as the basis for the difference calculations in the raster (please see the notes in the DPH-9.1 section of the interface regarding TIN vs Grid), and; 2.) an option for which returns - 'All' (the default), 'First', or 'Last' - are used in the creation of the raster. Note that the USGS specifications call for all returns to be used.

DPH-9.2 Data Quality Measure - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the NGP USGS LBS v 2.1 specification. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measure (DQM) and introduce the usage of DQM testing to the lidar community. This test is unchecked by default.

DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data.

This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%

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- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view

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background of the tiled lidar data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count by class for all files is created for review, along with a screen capture of the Withheld-flagged points for the tiled data.

DPH-13 Use of the LAS Overlap Flag

The purpose of this section is to list the presence and quantities of points flagged as Overlap for all the lidar tiled data. A statement of total Overlap point count for all classes/all files is created for review, along with a screen capture of the Overlap-flagged points for the tiled data.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Classes 0, 7, and 18 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0, 7, and/or 18 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**.

Model Key-points (if present) must be in either Class 2 (Ground) or in Class 8 (Reserved) and the appropriate bit flag must be set to 'on'. If Class 2 is used for Model Key-points, there can be no points in Class 8. If Class 8 is used for Model Key-points, all points must be bit-flagged appropriately and there can be no points in Class 2 bit flagged as Model Key-point. Any violations of these Model Key-points requirements will be shown in red font.

Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points

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(Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will be stored in the 'Statistics\Tile' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1534. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.7.5 Final Reports

USGS 2.1 QC Module - Final Reports

Merrick Advanced Remote Sensing (MARS®) Software

QC Reporting

The output of the USGS 2.1 QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab[1534]. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab[1534]. The default name is 'QC_2_1_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab[1534].

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information[1526] topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 2.1 QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also

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contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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SAMPLE REPORT Lidar QA/QC Report

C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification Version 2.1 states: "The required ANPS and ANPD by QL are listed in table 1. Aggregate Nominal Pulse Density (ANPD) and Aggregate Nominal Pulse Spacing (ANPS) shall meet the requirements of the Quality Level (QL) of the project with a minimum of QL2 for 3DEP collections. Aggregate Nominal Pulse Density (ANPD) shall be no less than 2 points per square meter (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Aggregate Nominal Pulse Spacing (ANPS) shall be no greater than 0.70 meters (QL2); assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~95%) of each swath. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,344,592	3,216,394	4.499/0.418	0.472/1.547
CS_00500.las	5,748,981	19,065,507	3.251/0.302	0.555/1.821
CS_00501.las	9,176,318	30,976,475	3.186/0.296	0.560/1.837
CS_00502.las	12,846,764	41,311,965	3.348/0.311	0.547/1.793
CS_00503.las	20,762,195	64,662,016	3.455/0.321	0.538/1.765

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,714	79,387,793	3.552/0.330	0.530/1.740
CS_00505.las	35,243,463	98,958,037	3.832/0.356	0.511/1.676
CS_00523.las	9,961,764	31,468,408	3.412/0.317	0.542/1.777
CS_00524.las	29,875,164	97,226,691	3.305/0.307	0.550/1.804
CS_00525.las	33,521,458	119,134,072	3.025/0.281	0.575/1.885
CS_00526.las	42,147,135	134,460,091	3.369/0.313	0.544/1.786
CS_00527.las	41,816,564	141,669,002	3.175/0.295	0.561/1.841
CS_00528.las	49,869,559	153,046,644	3.509/0.326	0.534/1.752
CS_00529.las	45,447,313	153,055,113	3.197/0.297	0.559/1.835
CS_00530.las	46,456,390	144,078,669	3.466/0.322	0.537/1.761
CS_00531.las	36,879,557	130,192,981	3.046/0.283	0.573/1.879
CS_02117.las	22,438,288	92,065,641	2.626/0.244	0.618/2.026
CS_02118.las	9,737,373	47,538,593	2.207/0.205	0.674/2.210
CS_02120.las	55,171,785	205,545,906	2.885/0.268	0.588/1.930
CS_02121.las	46,452,635	211,886,912	2.357/0.219	0.651/2.136
CS_02122.las	68,314,197	215,578,234	3.412/0.317	0.541/1.776
CS_02123.las	53,100,492	228,583,234	2.497/0.232	0.632/2.075
CS_02124.las	59,027,760	210,538,565	3.014/0.280	0.576/1.889
CS_02125.las	36,608,695	178,426,569	2.207/0.205	0.673/2.208
CS_02126.las	387,339	752,747	5.543/0.515	0.425/1.394
Average			3.165/0.294	0.563/1.846
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	786,559,779	954,668,300	8.869/0.824	0.336/1.102
Aggregate	786,559,779	954,668,300	8.869/0.824	0.336/1.102
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

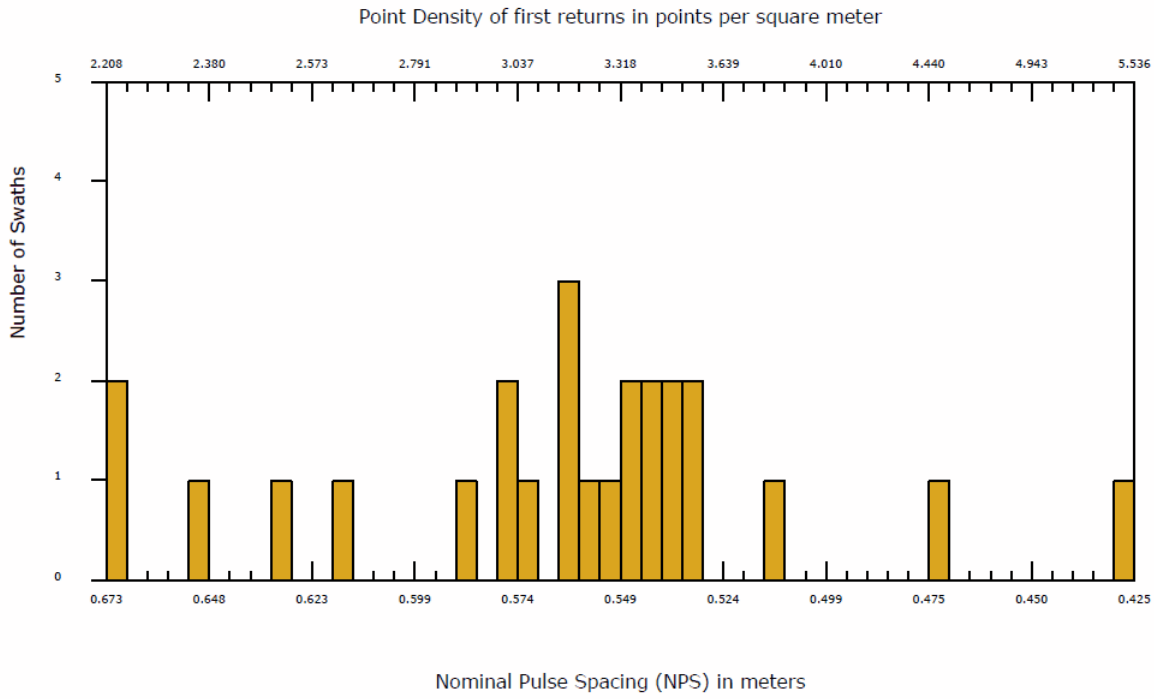
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 2.1 states: "Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns and with slopes of less than 10 degrees. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
- adjacent, overlapping parallel swaths within a project,
- cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
- adjacent, overlapping lifts.

Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled (Cellsize=CEILING(ANPS)×2). The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in table 2 for the QL of information that is being collected."

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show two separate mosaicked versions of a thematically rendered map of swath separation for all of the data processed. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

For the first – known as a Measurable Flightline Separation Raster (FSR) - processing has been done to isolate measurements to clusters of single returns and is limited to areas of < 10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. A frequency distribution chart of RMSDz raster values can be found on the page following the raster graphic.

For the second raster – known as a Swath Separation Image and found at the end of this test section – there are no limitations on slope angles and return types are user defined. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only swath overlap areas are shown in the RGB raster. The color is overlaid on a lidar intensity background to show land cover features. Tiled GeoTIFFs of this mosaicked raster can be found in the output folder for this test.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable FSR

Description of the process that generates the Measurable Flightline Separation Raster (FSR):

a. Areas of swath overlap are determined within each delivery tile.

b. A TIN is created for the overlap areas of each swath within a tile, and a Grid is overlaid on those TINs. Grid cell sizes are 3x the aggregate nominal pulse spacing (ANPS) as shown in Table 1 of the USGS Lidar Base Specification Version 2.1. ANPS varies depending on the Quality Level of the data.

c. The grid cells are populated with the vertical separation values between the underlying TINs as measured at the centroid of each grid cell. When three or more swaths coincide with a cell, the value is set to the difference between the maximum and minimum of all elevations. Only areas of slope < 10 degrees are measured. Points flagged as Withheld, including those points classed as High or Low Noise, are excluded from this analysis.

d. The Measurable FSR uses a pre-filtering algorithm that selects only clusters of single returns for use in the RMSDz analysis. The algorithm's purpose is to find areas for measurement that are in the open, away from roof edges, trees, etc. - it is not designed to find ground below vegetation canopy. By using only clusters of single returns (at a minimum distance from any multiple returns) and ignoring cells with NODATA values, reliable RMSDz values are produced.

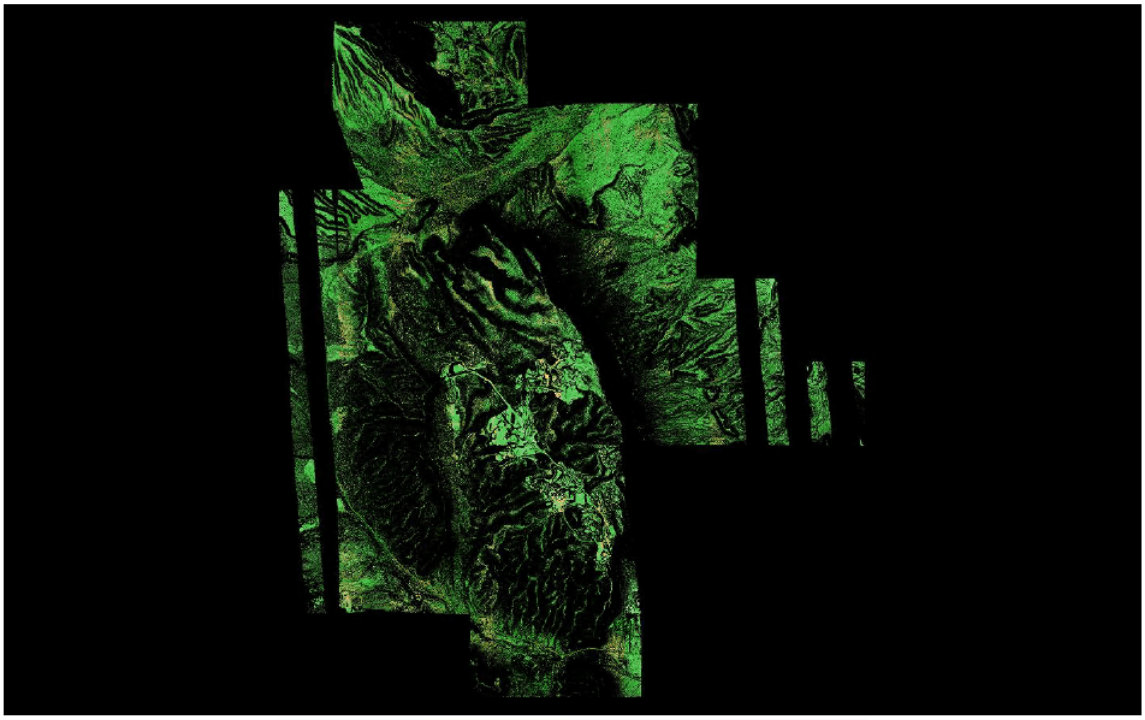
e. A vertical separation cut-off is used to remove values that are not appropriate for separation measurements (e.g., trees, moving objects, etc.). This cut-off is set to 10 times the color gradation interval value.

f. The tiled rasters are mosaicked into a single project-wide flight separation raster. A single, aggregate RMSDz is calculated from this complete grid, and the final thematic raster is generated. This raster graphic is found on the following page.

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DPH-9.1 Report on Overlap Consistency (interswath) - Measurable

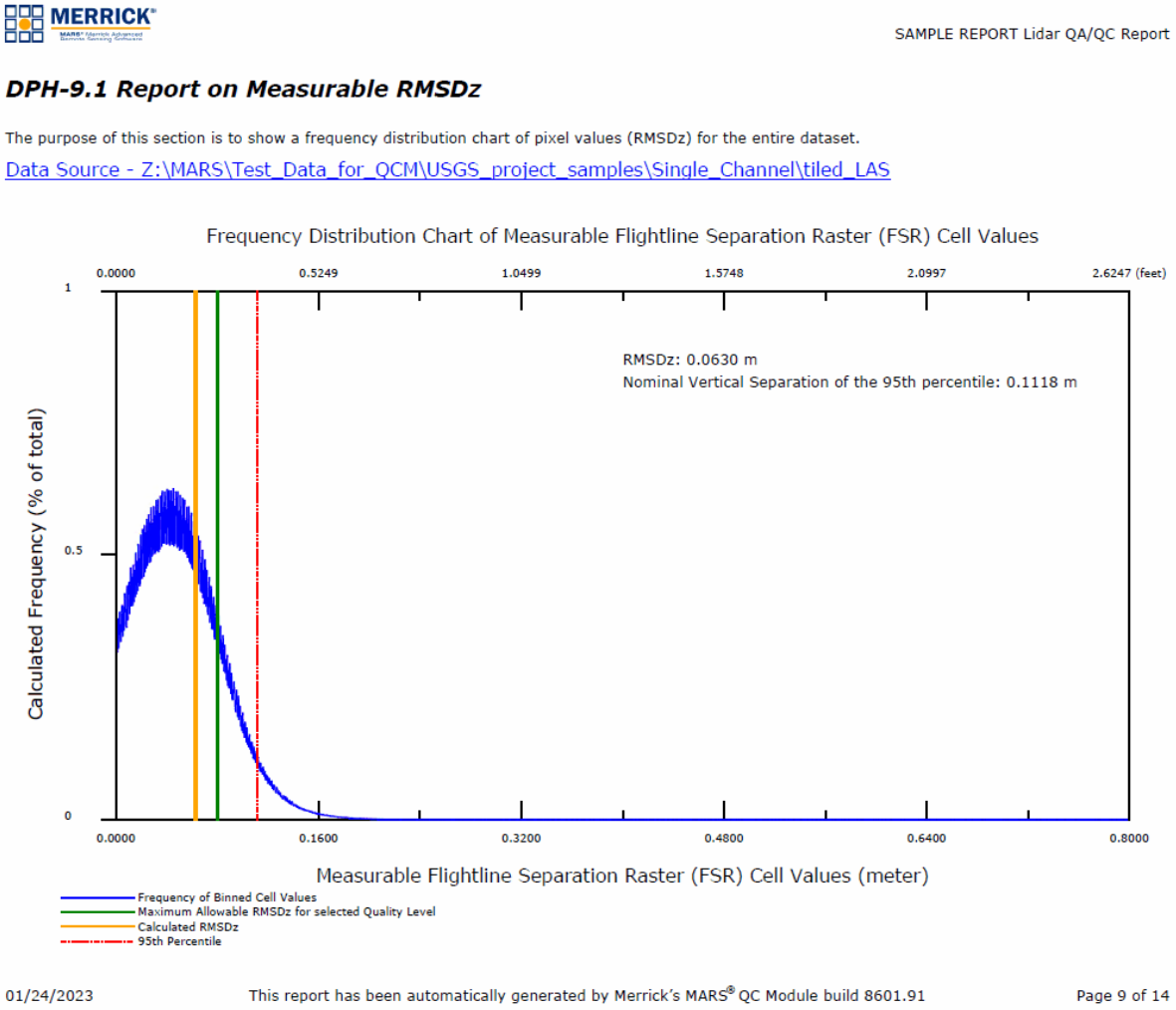
Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths
Result Path - D:\Temp\QCM_2.1\DPH_9_1\FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.080	0.160	0.240	0.800 (Meter)
0	0.262	0.525	0.787	2.625 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.).

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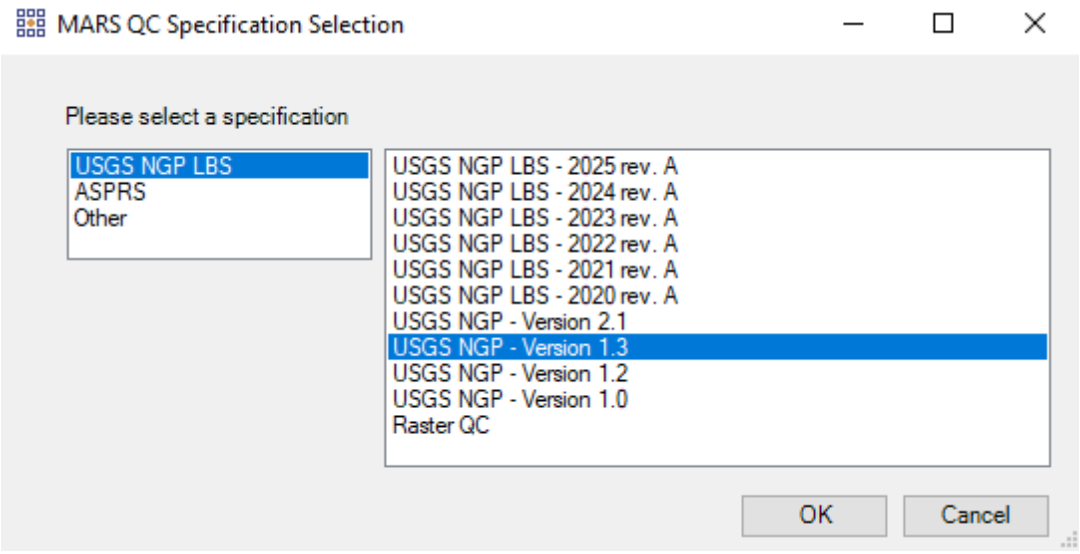
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6.2.8 Version 1.3



After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP - Version 1.3' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.8.1 General Information

USGS 1.3 QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP - Version 1.3' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification Version 1.3 from the U.S. Geological Survey (USGS). The primary intent of this USGS lidar specification is to create consistency across all of USGS's National Geospatial Program (NGP) funded lidar data collections, in particular those undertaken in support of the 3D Elevation Program (3DEP). As mentioned in the specification, "Unlike most other lidar data procurement specifications, which largely focus on the products derived from lidar data such as the bare-earth digital elevation model (DEM), this specification places particular emphasis on the handling of the source lidar data." ***Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/ Handling Tab 1577 topic).***

There are 24 possible tests that can be run in the USGS 1.3 QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - which include a one-page test results summary table, supporting raster analysis images, tabular data, charts, and other statistical information. See the Final Reports 1586 sub-topic for more information.

For a copy of the USGS NGP Lidar Base Specification Version 1.3 (February 2018), please click this link to access the PDF file (approximately 4.5 MB). This document explains the requirements and expectations of each test. The USGS 1.3 QC Module tests are divided into **Collection** 1572 and **Data Processing/Handling** 1577 tabs and are ordered to match the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

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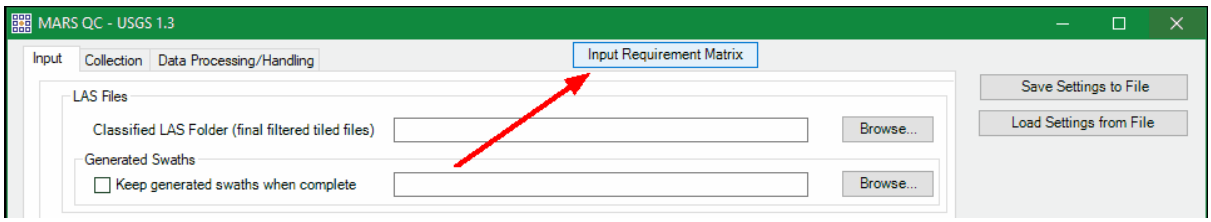
The entire MARS® QC Module - including this tool, the USGS 2024 rev. A[1351], USGS 2023 rev. A[1386], USGS 2022 rev. A[1421], USGS 2021 rev. A[1455], USGS 2020 rev. A[1490], USGS NGP - Version 2.1[1525], USGS NGP - Version 1.2[1592], and USGS NGP - Version 1.0[1622] tools, the Raster QC[623], LiDAR Data Checks[1677] and LiDAR Calibration Checks[1698] tools, and the Voronoi Density Reporting[1660] tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

These are the datasets and files needed to run all tests:

- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report[1224] help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-10 (Check Points) and DPH-11 (Absolute Vertical Accuracy). A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.



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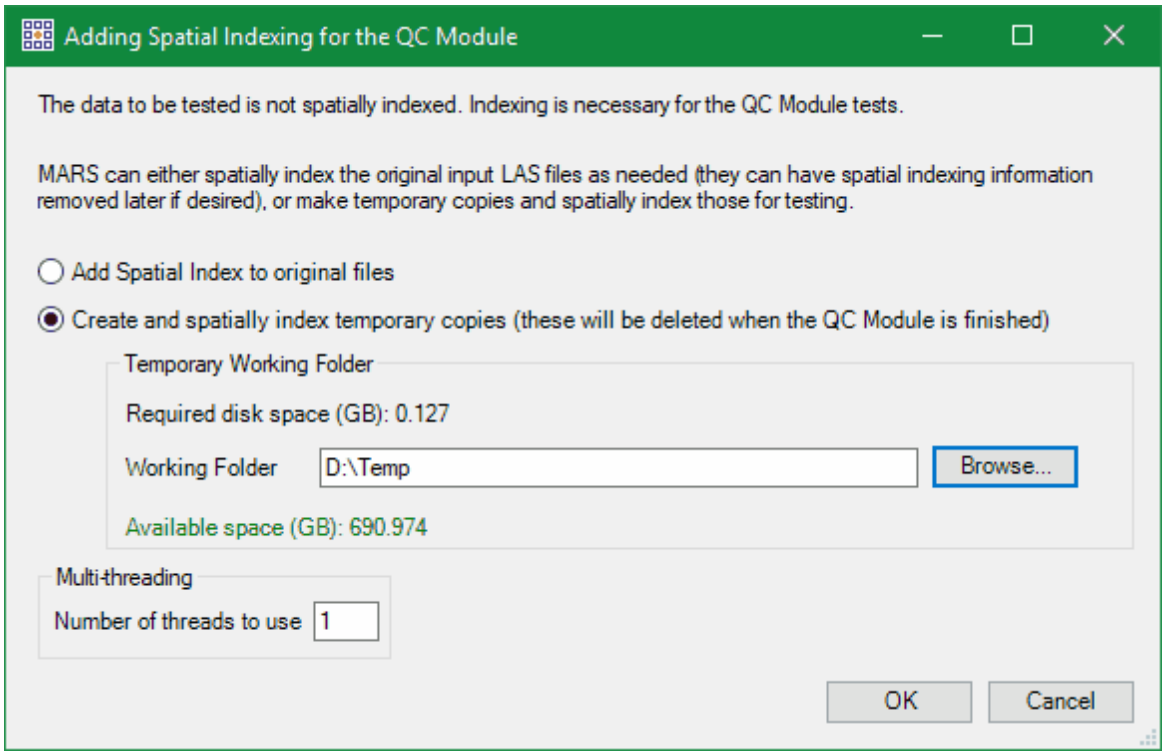
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<**, **>**, **%**, **&**, **'**, **"** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile or LiDAR Check Points CSV file.*

Classified (also referred to as tiled or delivery) Data Preparation

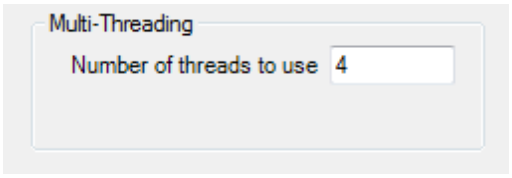
LAS data must be spatially indexed before it can be tested with the USGS 1.3 QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1568) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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Multi-threading

A multi-threading option can be found on the USGS 1.3 QC Module tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

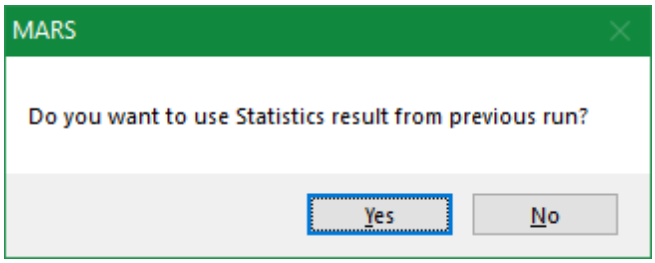


Running the USGS 1.3 QC Module

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When all necessary entries have been made on the Input[1568], Collection[1572], and Data Processing/ Handling[1577] tabs, click the 'Run' button in the lower-right to begin the processing. Depending on the 'Output Folder' and 'Generated Swaths' folder selected (see Input Tab[1568] for details), and whether data exists in these folders from previous runs of this USGS 1.3 QC Module, one or more of the following pop-up messages may appear. Reusing 'Statistics', 'Generated Swaths', and/or the 'Generated Footprints Shapefile' will save processing time, but be sure that no changes have been made to any of the input datasets before reusing any previous data. To guarantee a completely 'fresh' run, empty the 'Output Folder' and 'Generated Swaths' folder before running this module.

1.

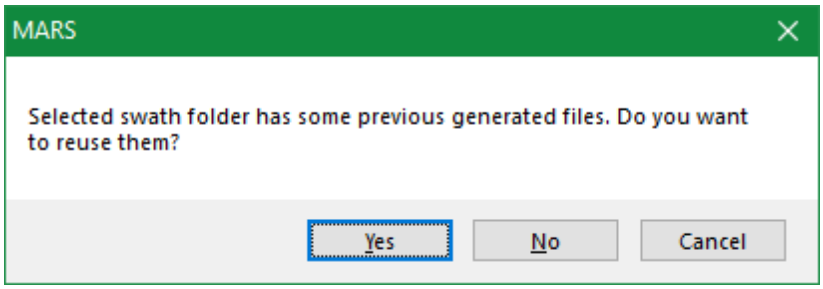


A 'Yes' answer will assume that any 'Generated Swaths' data is to be reused as well, and MARS® will proceed to the next data check, testing for existing generated footprints shapefile data (skip to graphic # **4** - 'Do you want to use previously generated footprints shapefile?', below).

Answering 'No' here will allow the 'Statistics' folder to be overwritten, and MARS® will then check to see if LAS data exits in the 'Generated Swaths' folder as selected on the Input Tab[1568]. If there is data, the following message will appear:

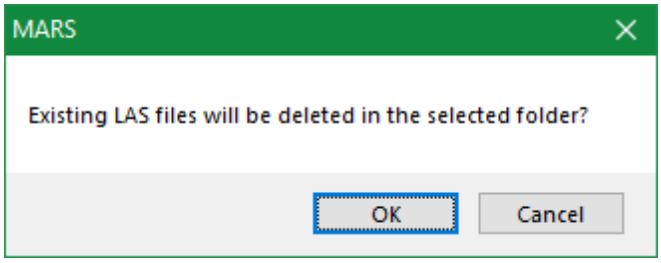
2.

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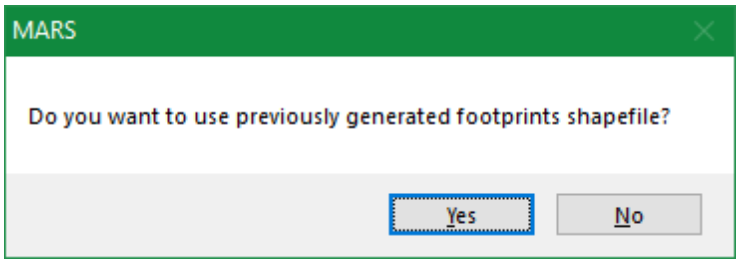
The user must decide if the pre-existing data is the correct generated swath data for the testing to be conducted, and must ensure that no other LAS data exists in that folder. If these conditions are true, click 'Yes' - the 'Keep generated swaths when complete' box on the Input Tab[1568] will be checked if it is not already, and processing will continue. If 'No' is clicked, the following message will appear:

3.



Clicking 'OK' for this message will clear out the selected 'Generated Swaths' folder and regenerate the swaths as described in the Input Tab[1568] section.

4.



After clicking either 'Yes' or 'No', a pop-up may appear if any selected tests require data that has not

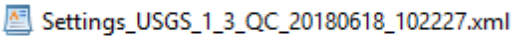
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been pathed out on the Input Tab[1568]. Dismiss the pop-up by clicking 'OK' and either uncheck the tests that don't have supporting data or supply the path/name to the required file(s). Click 'Run' again to re-start the above pre-checks.

While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 1.3 QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 1.3 QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab[1568]. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 10:22:27 am on June 18, 2018.



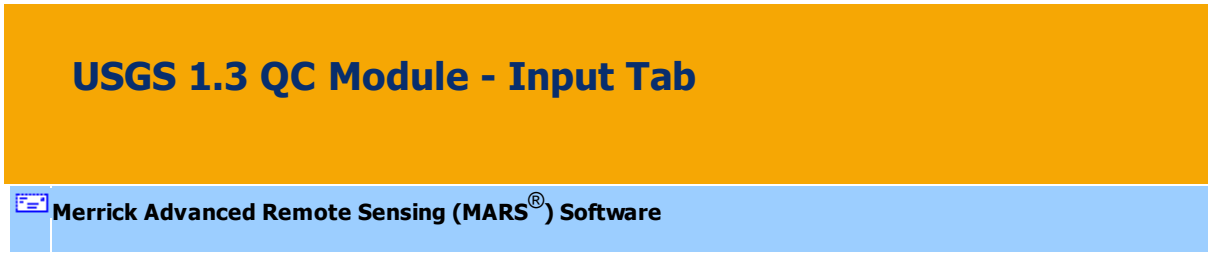
This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 1.3 QC Module runs. After opening the USGS 1.3 QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed as needed before starting the processing. In addition, a settings file can be created and saved for future use without actually running

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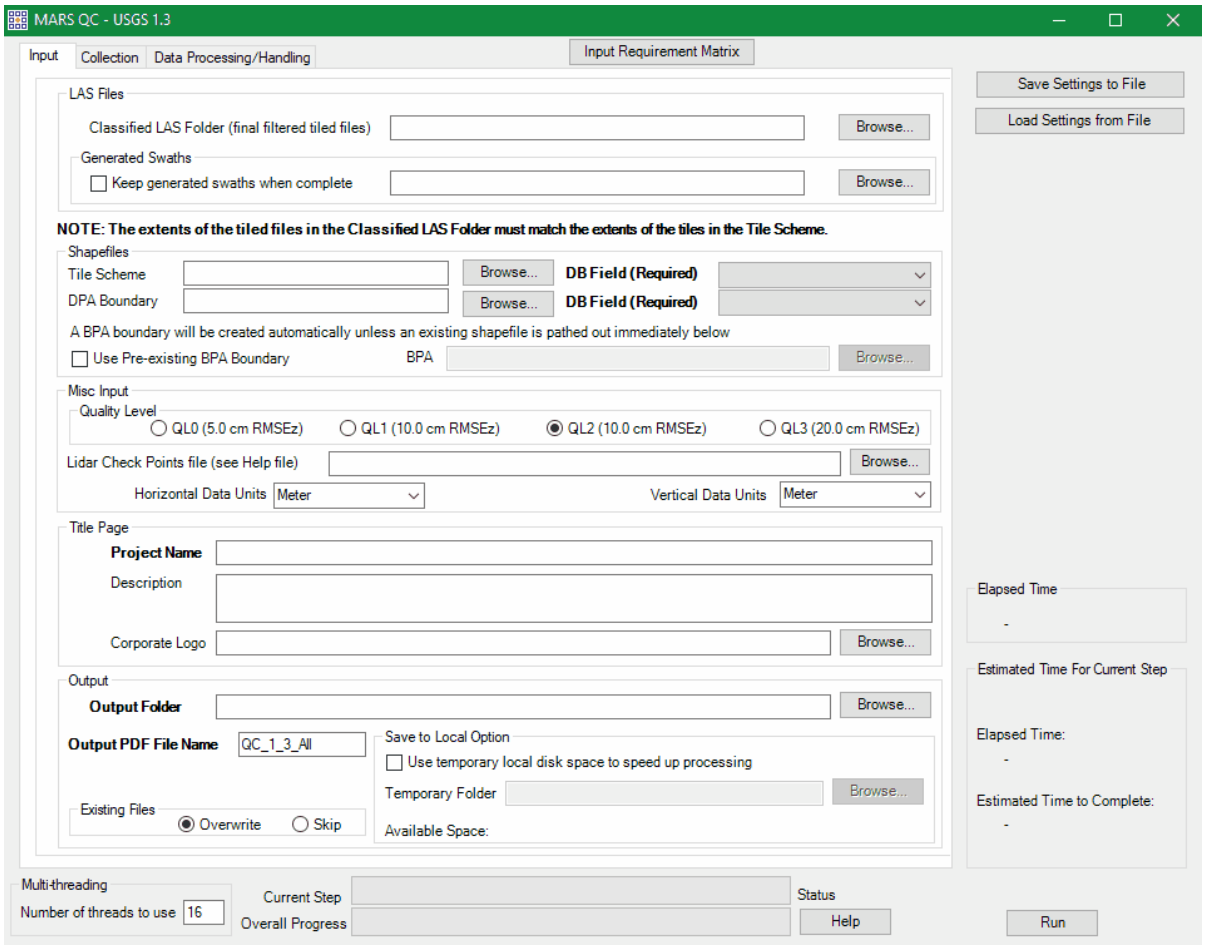
the USGS 1.3 QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not automatically be stored in the chosen **Output Folder** like it is when the module is actually run.

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6.2.8.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - the Classified LAS data, Lidar Check Points and DPA Boundary, or Tile Scheme must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.*** Note that when both the Classified LAS data and Tile Scheme are used as inputs, the extents of the tiled files in the Classified LAS Folder ***must*** match the extents of the tiles in the Tile Scheme.

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This version of the USGS QC Module reads the files that are pathed out and determines whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

A 'Generated Swaths' folder must be pathed out and, unless there is LAS data already in the path, swaths will be automatically created in it by assembling files from identical Point Source IDs in the Classified LAS data. For example, all points in all tiles in the 'Classified LAS Folder' that have a Point Source ID of 503 will be combined into one generated swath named ***CS_00503.las*** (the 'CS' tag means 'Collection Scan'). These swaths are used as input for some of the tests (see the final PDF reports for details). An option to 'Keep generated swaths when complete' is available to save time for additional QC Module runs that will use the same data, and/or to preserve the LAS data for any other purpose. Do not use the same folder for the 'Generated Swaths' and the '**Output Folder**' - this may cause the output results to be deleted. ***Also, if using pre-existing swath data that is not classified, some tests will not produce complete results.***

The generated swaths will be used to create a swath footprints polygon shapefile in a sub-folder named 'Swath_footprints' in the selected **Output Folder**. Attributes for beginning and ending Adjusted GPS Times (GPS_MIN and GPS_MAX) for each swath - along with many other useful attributes - will be stored for each swath footprint polygon.

If a 'Tile Scheme' and/or 'DPA Boundary' (Defined Project Area) shapefile is pathed out, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'DPA Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying the tabular results of various tests in the final reports.

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Unless an optional custom BPA (Buffered Project Area) boundary shapefile is pathed out, MARS® will generate a 100-meter BPA boundary for test C-1 (see Collection Tab 1572).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification Version 1.3. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 1.3 QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-8 Smooth Surface Precision (intraswath)**, **DPH-10 Check Points**, and **DPH-11 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

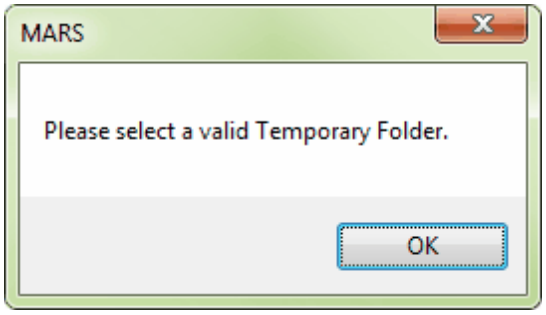
Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local

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disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1586 sub-topic).

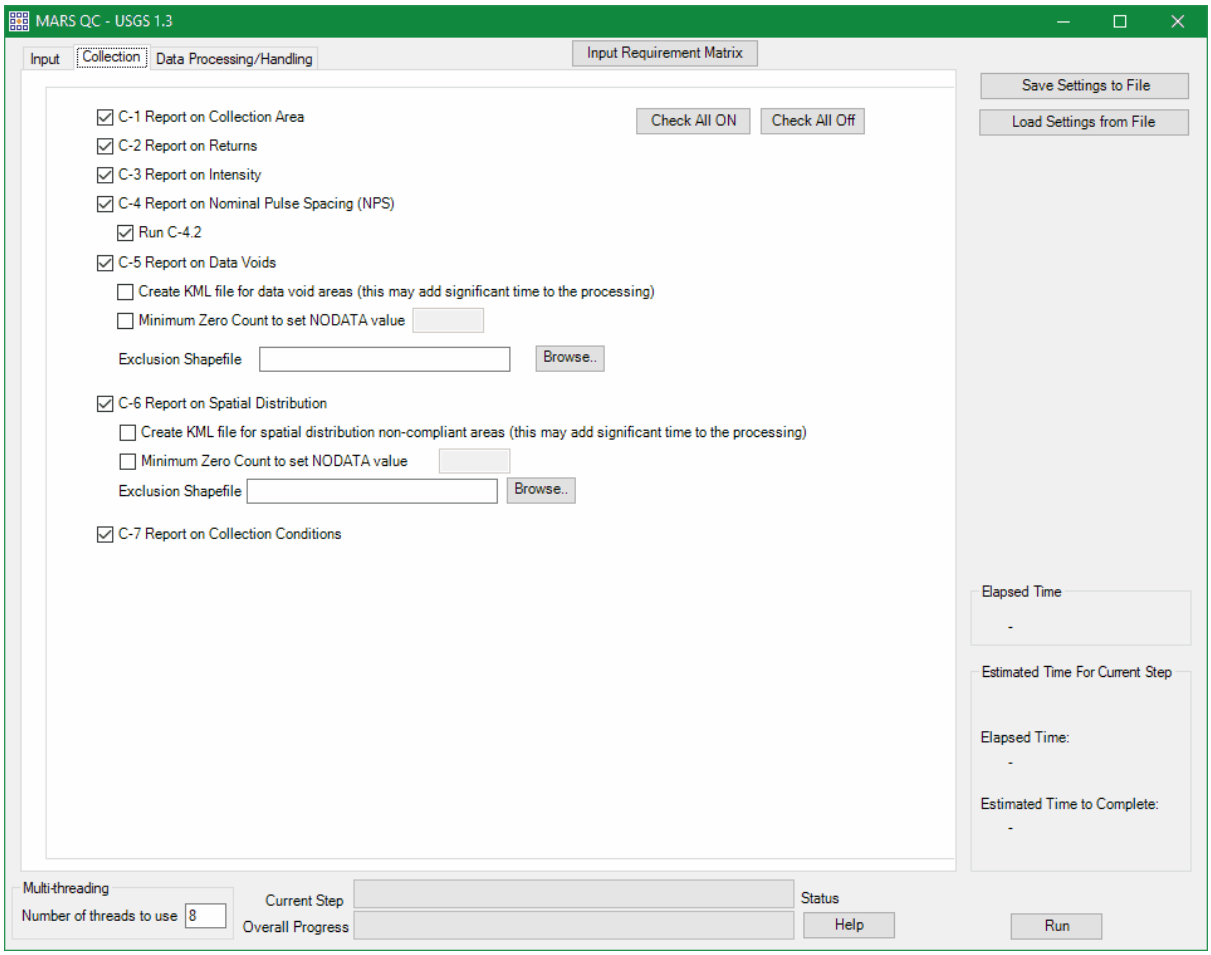
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6.2.8.3 Collection Tab

USGS 1.3 QC Module - Collection Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 1.3 in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1586). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show tiled lidar coverage to the extent of a 100 meter buffer beyond the defined project area boundary. A screen capture of the lidar tiled data with the DPA

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(defined project area) and BPA (buffered project area) boundaries superimposed is created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of multiple discrete lidar returns in the LAS data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this sub-section **C-4** is to report on the lidar point density and nominal point spacing by generated swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review, along with a frequency distribution chart of density/spacing results. 'Point Density' and 'NPS' values are color-coded to indicate compliance (green) or non-compliance (red) with the selected USGS specifications.

In addition, the results of supplemental point density testing methods are presented in the (optional) sub-section **C-4.2**. These include Nyquist Sampling (using a grid cell size that is 2x the required NPS), and grid cell sizes of 1m, 10m, 100m, and 1km. These supplementary results are presented in both raster and tabular form, with and without overlap bit-flagged points included.

C-5 Report on Data Voids

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The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. The other option is 'Exclusion Shapefile', where a pre-existing polygon shapefile of allowable exclusion areas can be pathed out so that all the raster cells within those polygons will be set to a value of NODATA. Using this option, when feasible, will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam

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back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first listed example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. The other option is 'Exclusion Shapefile', where a pre-existing polygon shapefile of allowable exclusion areas can be pathed out so that all the raster cells within those polygons will be set to a value of NODATA. Using this option, when feasible, will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) and other weather and land-area data for the extent of the lidar collection

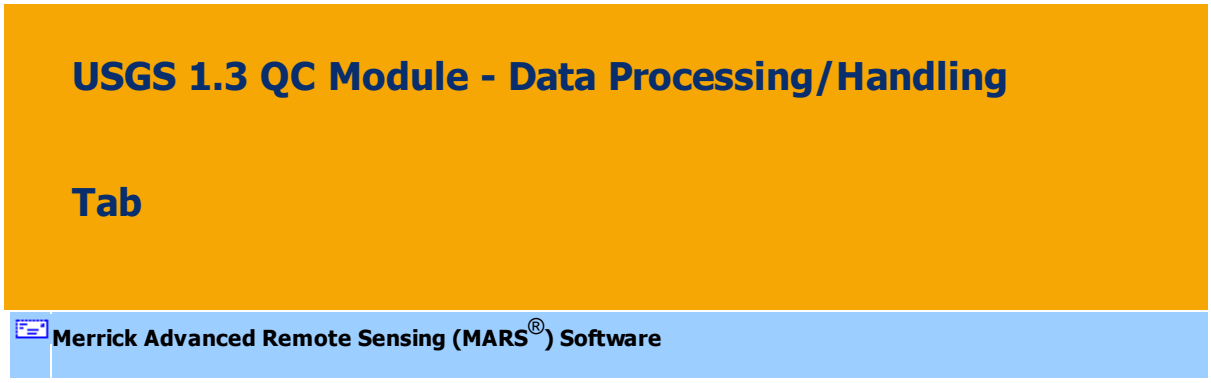
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at the time of acquisition.

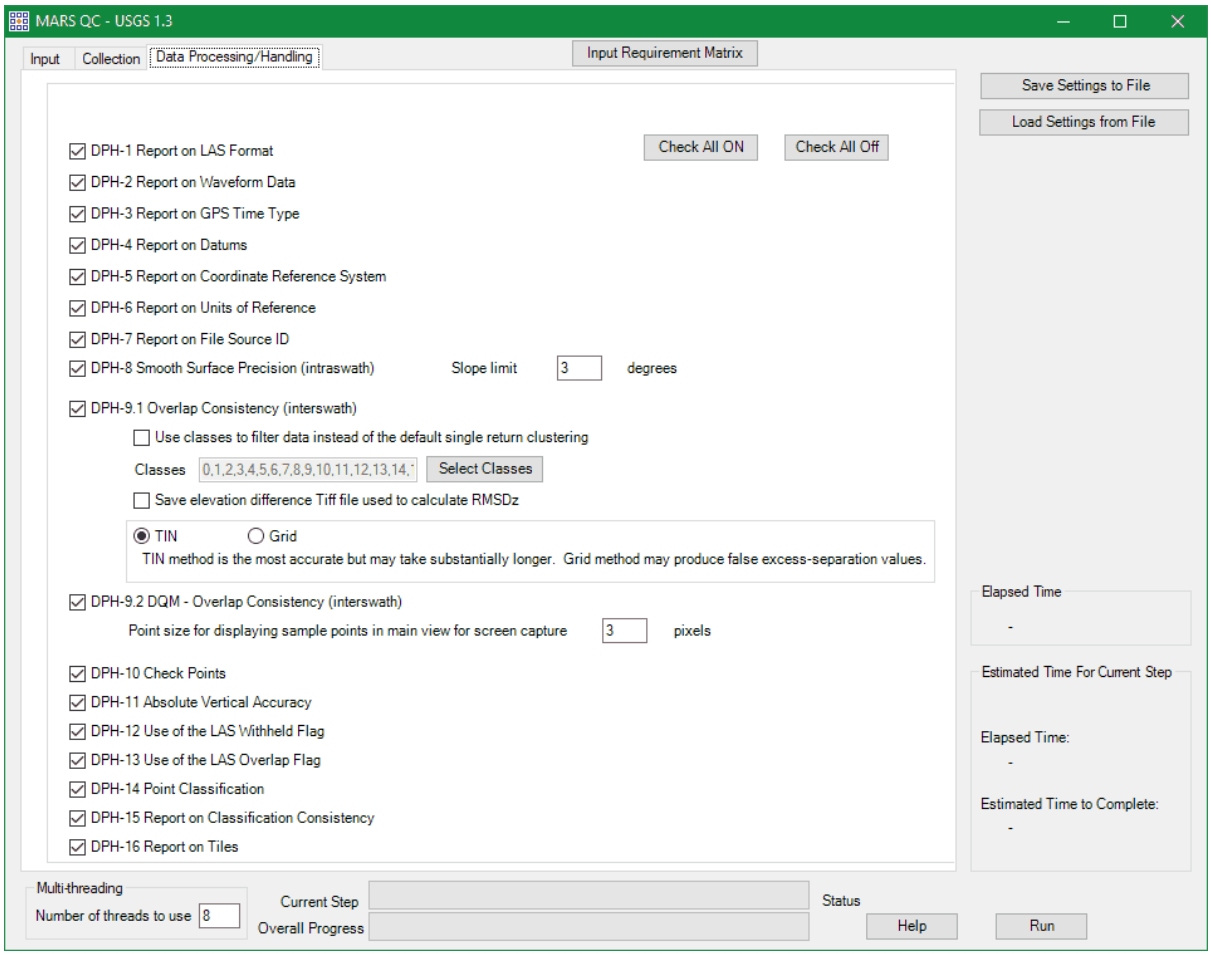
[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

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6.2.8.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-16** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 1.3 in which they are referenced. Note that the following descriptions of what is created for these tests pertain primarily to the Detailed PDF report (see Final Reports 1586). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, general information, and elevation by class test results for each tiled file. Tables are created for review

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for all four sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity' (reported on per dataset), and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, Number of Duplicate Points, and Return Counts in LAS Header.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: GPS Time min, GPS Time max, Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

In the **Elevation by Class** sub-section (**DPH-1.4**), each tiled file is listed with the classifications that exist for it along with the minimum and maximum elevations (Z values) for each of those classes.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables. This test also generates a polygon shapefile of the tiles with hundreds of attributes populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1568.

DPH-2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the lidar tiled data. A

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statement of waveform data file count is created for review.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar tiled data. A table of types (either Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the lidar tiled data. A table of horizontal and vertical datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of datums. Red items will be promoted to the top of the table.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar tiled data. A table of coordinate reference system names, Geoid Model names, and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar tiled data. A table of horizontal and vertical units is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of both horizontal and vertical units. Red items will be promoted to the top of the table.

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DPH-7 Report on File Source ID

The purpose of sub-section **DPH-7.1** is to report on the File Source ID and Point Source ID values for the lidar tiled data. A table of File Source ID values is created for review, with the specification being that File Source IDs shall be set to zero (0) for tiled data. File Source IDs are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table. In addition, sub-section **DPH-7.2** reports on Swath Geographic Locations to indicate possible problems when a given swath (generated based on Point Source IDs) exists in more than one contiguous geographic location. This may occur if a large water body (or other no-data area) crosses the swath to separate the 'footprint' into two or more non-contiguous polygons.

DPH-8 Smooth Surface Precision (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). The slope of areas selected for testing can be limited by using the 'Slope limit' entry box - the default is set to '3' degrees. Test areas are initially established by intersecting the Tile Scheme with the Non-Vegetated Area (NVA) Check Points to determine which tiles will be used to clip out portions of the generated swaths for analysis. Each of these tile/swath testing areas is further refined by the 'Slope limit' and is also limited to clusters of single returns. An elevation value difference raster for each of these tile/swath test areas is created for review. The raster cells are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. In addition, an attributed polygon shapefile is produced in the DPH-8 output sub-folder for the area of each raster, with one feature (polygon) for each sample area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification Version 1.3 document - it lists the allowable 'Smooth surface repeatability, RMSDz' values (in meters) for the four defined

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Quality Levels:

Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

DPH-9.1 Overlap Consistency (interswath)

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. A color-coded elevation difference raster of the overlap areas is created for review, along with a table of relative accuracy RMSDz values for those areas and a frequency distribution chart of the values. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. An attributed polygon shapefile is also produced in the DPH-9_1 output sub-folder with one feature (polygon) for each test area, per USGS requirements. The table shown here is from the USGS NGP Lidar Base Specification Version 1.3 document - it lists the allowable 'Swath overlap difference, RMSDz' values (in meters) for the four defined Quality Levels:

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Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

Before analysis, overlap areas are further refined by either: 1) creating clusters of single-return data at a minimum distance from any multiple-return data, thereby ensuring that the areas analyzed are open and void of canopy cover, buildings, or other obstacles. This is the default method, and all classes are initially selected. 2) limiting the data to be analyzed to the ground classification (Class 2 by default). Another class (or classes) may be selected if ground is not in Class 2.

There are two other user-definable settings for this test: An option to save the elevation difference raster that is used to calculate the RMSDz values in a TIFF file format, and an option to choose either TIN or Grid as the basis for the difference calculations. The TIFF raster allows for individual cell inspection of elevation difference values. The TIN/Grid selector (TIN by default) determines the method used to calculate the elevation differences. Please see the notes on this option in the DPH-9.1 section of the interface.

DPH-9.2 DQM - Overlap Consistency (interswath)

This section reports on an additional test not currently listed in the NGP USGS LBS v 1.3. The reason for its inclusion is to prepare for expected future integration of the USGS/ASPRS led development of interswath Data Quality Measures (DQM) and introduce the usage of DQM testing to the lidar community.

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DQM analysis and reporting is intended to quantify the relative horizontal and vertical errors observed between conjugate features in the overlapping regions of lidar data. This test produces tabular data, an RMSDz frequency distribution chart and raster, and a scatterplot of Point-to-Plane distances across the scan field of view.

Much more information on DQM can be found in the links below:

- General documentation: https://www.asprs.org/wp-content/uploads/LidarInterswath_CleanCopyASPRSV2.pdf

- Equations: https://edcftp.cr.usgs.gov/project/rst/DQM/DQMDocumentation.docx

- Operational Testing: https://edcftp.cr.usgs.gov/project/rst/DQM/DQM_Operational_Testing%202017-2-7.pptx

- Executable: https://edcftp.cr.usgs.gov/?dir=project/rst/DQM

DPH-10 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart

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showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the lidar data - NVA with the swath data and VVA with the tiled data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar tiled data. A statement of total Withheld point count for all classes/all files) is created for review, along with screen captures of the Withheld-flagged points for the tiled data.

DPH-13 Use of the LAS Overlap Flag

The purpose of this section is to list the presence and quantities of points flagged as Overlap for all the lidar tiled data. A statement of total Overlap point count for all classes/all files is created for review, along with screen captures of the Overlap-flagged points for the tiled data.

DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the lidar tiled data. A table of points by classification is created for review, with any counts greater than zero (0) shown in red font for Class 0 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Any points outside of Class 2 (Ground) that are flagged as Model Key-points will also be shown in red font. Minimum required classes

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per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low noise points (Class 7), Water points (Class 9), Bridge deck points (Class 17), High noise points (Class 18), Ignored ground points (Class 20), Snow points (Class 21), or Temporal exclusion points (Class 22), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background. This test also generates a polygon shapefile of the tiles with hundreds of attributes (including point count per Class) populated for analysis and to aid in error correction (see Populate Statistics on Tile Scheme 964 topic for details). The shapefile will reside in the 'Statistics' sub-folder that is created in the **Output Folder** as pathed out on the Input Tab 1568. If test **DPH-1 Report on LAS Format** is also being run, the shapefile will be created during that test.

DPH-15 Report on Classification Consistency

The purpose of this section is to show a bare earth surface hillshade raster for classification consistency inspection. A bare earth hillshade screen capture is created for a visual review.

DPH-16 Report on Tiles

The purpose of this section is to report on the unallowed presence of polygon overlap in the project tiling scheme. A table of tiles by name/number with approximate width, approximate height, and overlap status is created for review. Overlap reported as 'True' will be shown in red font.

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6.2.8.5 Final Reports

USGS 1.3 QC Module - Final Reports

QC Reporting

The output of the USGS 1.3 QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. A one-page test results summary table can be found immediately after the title page of each report, followed by the individual test sections. At the end of the individual test sections in the Detailed report, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats.

All tabular results are shown in Meters and also in either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1568. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1568. The default name is 'QC_1_3_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1568.

Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1560 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS

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1.3 QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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SAMPLE REPORT Lidar QA/QC Report

C-4.1 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification Version 1.3 states: "Assessment and reporting of the NPS are made against single swath, single instrument, first-return-only data, including only the geometrically usable part of the swath and excluding acceptable data voids. Higher net densities of lidar point measurements are being achieved more often by flying multiple passes of the lidar instrument over the project area or flying with large amounts (greater than [>] 50 percent) of overlap between swaths, creating a need for a new term to describe total pulse density without being confused with NPS and NPD. This specification will use the terms aggregate nominal pulse spacing (ANPS) and aggregate nominal pulse density (ANPD) to describe the net overall pulse spacing and density, respectively. The required ANPS and ANPD by QL are listed in Table 1. Dependent on the local terrain and land cover conditions in a project, a greater pulse density may be required on specific projects."

Table 1. Aggregate nominal pulse spacing and density.

[QL, quality level; pls/m², pulses per square meter; m, meter; ≤, less than or equal to; ≥, greater than or equal to]

Quality level	Aggregate nominal pulse spacing (m)	Aggregate nominal pulse density (pls/m²)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by LAS file. Averages by files (not including overlap), project boundary polygons (including overlap), and aggregate project boundary polygons (including overlap) are reported.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths

Quality level tested: QL2

File	Number of First Returns	Area	Point Density	NPS
CS_00499.las	1,346,050	3,268,608	4.435/0.412	0.475/1.558
CS_00500.las	5,748,981	19,141,056	3.229/0.300	0.556/1.825
CS_00501.las	9,176,415	29,065,216	3.401/0.316	0.543/1.780
CS_00502.las	12,847,497	41,409,472	3.337/0.310	0.547/1.795
CS_00503.las	20,764,364	62,470,720	3.574/0.332	0.529/1.735

04/24/2020 This report has been automatically generated by Merrick's MARS® QC Module build 8404.53 Page 13 of 119

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C-4.1 Report on Nominal Pulse Spacing (NPS) - continued

File	Number of First Returns	Area	Point Density	NPS
CS_00504.las	26,213,747	79,534,464	3.552/0.330	0.531/1.742
CS_00505.las	35,243,889	95,049,024	3.993/0.371	0.500/1.642
CS_00523.las	9,961,773	31,608,896	3.391/0.315	0.543/1.781
CS_00524.las	29,875,611	97,412,672	3.305/0.307	0.550/1.806
CS_00525.las	33,521,783	114,658,176	3.143/0.292	0.564/1.849
CS_00526.las	42,147,264	134,552,704	3.369/0.313	0.545/1.787
CS_00527.las	41,816,755	141,831,424	3.175/0.295	0.561/1.842
CS_00528.las	49,870,017	153,206,592	3.509/0.326	0.534/1.753
CS_00529.las	45,448,474	153,166,976	3.197/0.297	0.560/1.836
CS_00530.las	46,456,931	140,109,056	3.574/0.332	0.529/1.737
CS_00531.las	36,879,774	130,401,792	3.046/0.283	0.573/1.880
CS_02117.las	22,438,974	92,509,376	2.616/0.243	0.619/2.030
CS_02118.las	9,739,063	47,725,120	2.196/0.204	0.675/2.214
CS_02120.las	55,171,974	206,961,024	2.874/0.267	0.590/1.937
CS_02121.las	46,453,706	209,589,440	2.390/0.222	0.647/2.124
CS_02122.las	68,316,922	216,472,384	3.401/0.316	0.543/1.780
CS_02123.las	53,100,562	223,830,848	2.551/0.237	0.626/2.053
CS_02124.las	59,027,979	211,038,592	3.014/0.280	0.576/1.891
CS_02125.las	36,608,907	173,168,832	2.271/0.211	0.663/2.175
CS_02126.las	28,056,901	109,433,472	2.756/0.256	0.602/1.975
Average			3.111/0.289	0.567/1.861
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet
1	813,966,427	954,668,300	9.182/0.853	0.330/1.083
Aggregate	813,966,427	954,668,300	9.182/0.853	0.330/1.083
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

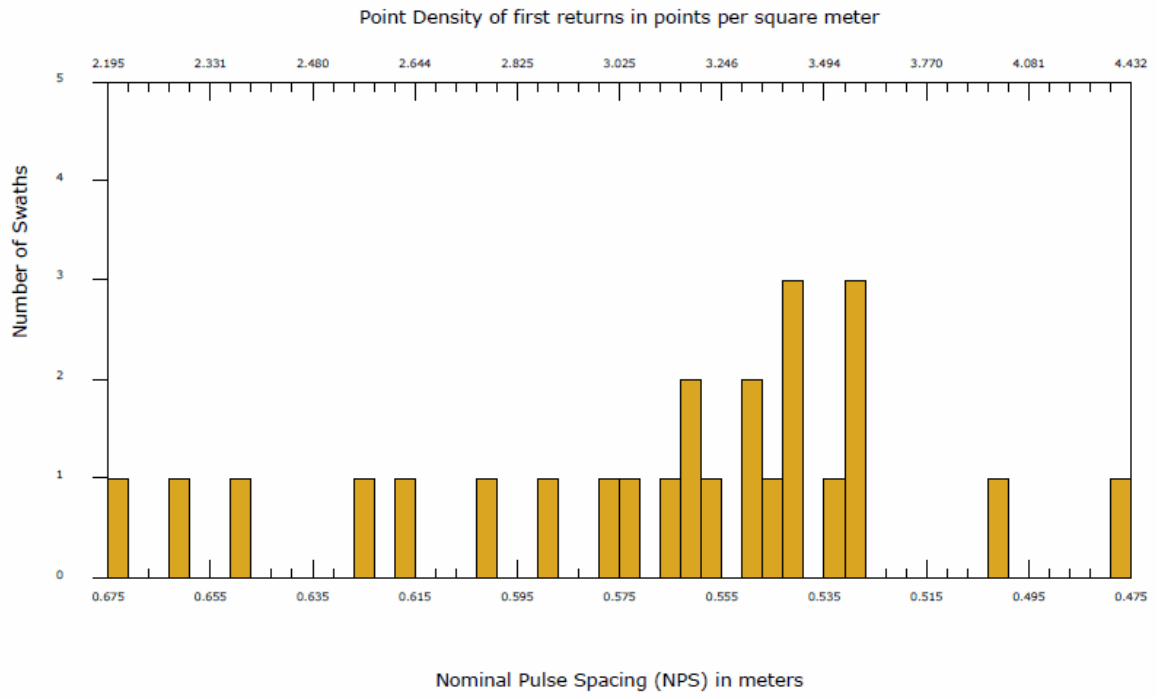
* - indicates a swath whose NPS and Point Density were brought up to specifications due to the inclusion of one or more re-flight swaths.

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C-4.1 Report on Nominal Pulse Spacing (NPS) - continued

The purpose of this section is to show a frequency distribution chart of Point Density and Nominal Pulse Spacing (NPS) for the generated LAS swaths.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths



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DPH-9.1 Report on Overlap Consistency (interswath)

The USGS Lidar Base Specification Version 1.3 states: "Overlap consistency is a measure of the geometric agreement of two overlapping swaths, and a fundamental measure of the quality of the calibration or boresight adjustment of the data in each lift. It is of particular importance because the match between the swaths of a single lift is a strong indicator of the geometric quality of the overall dataset, establishing the quality and accuracy limits of all downstream data and products. The principles used with swaths can also be applied to the overlap between lifts and projects as well. Overlap consistency will be assessed at multiple locations within overlap in nonvegetated areas of only single returns. Assessment is limited to areas of <10-degree slope. To the degree that the data allow, test areas should be located such that the full width of the overlap is represented. The overlap areas that will be tested are those between the following:
(1) Adjacent, overlapping parallel swaths within a project,
(2) Cross-tie swaths and a sample of intersecting project swaths in both flight directions; and
(3) Adjacent, overlapping lifts.
Each overlap area will be evaluated using a signed difference raster with a cell size equal to the ANPS, rounded up to the next integer, then doubled. The difference rasters will be statistically summarized to verify that RMSDz values do not exceed the limits set forth in the 'Swath overlap' column of Table 2 for the QL of information that is being collected."

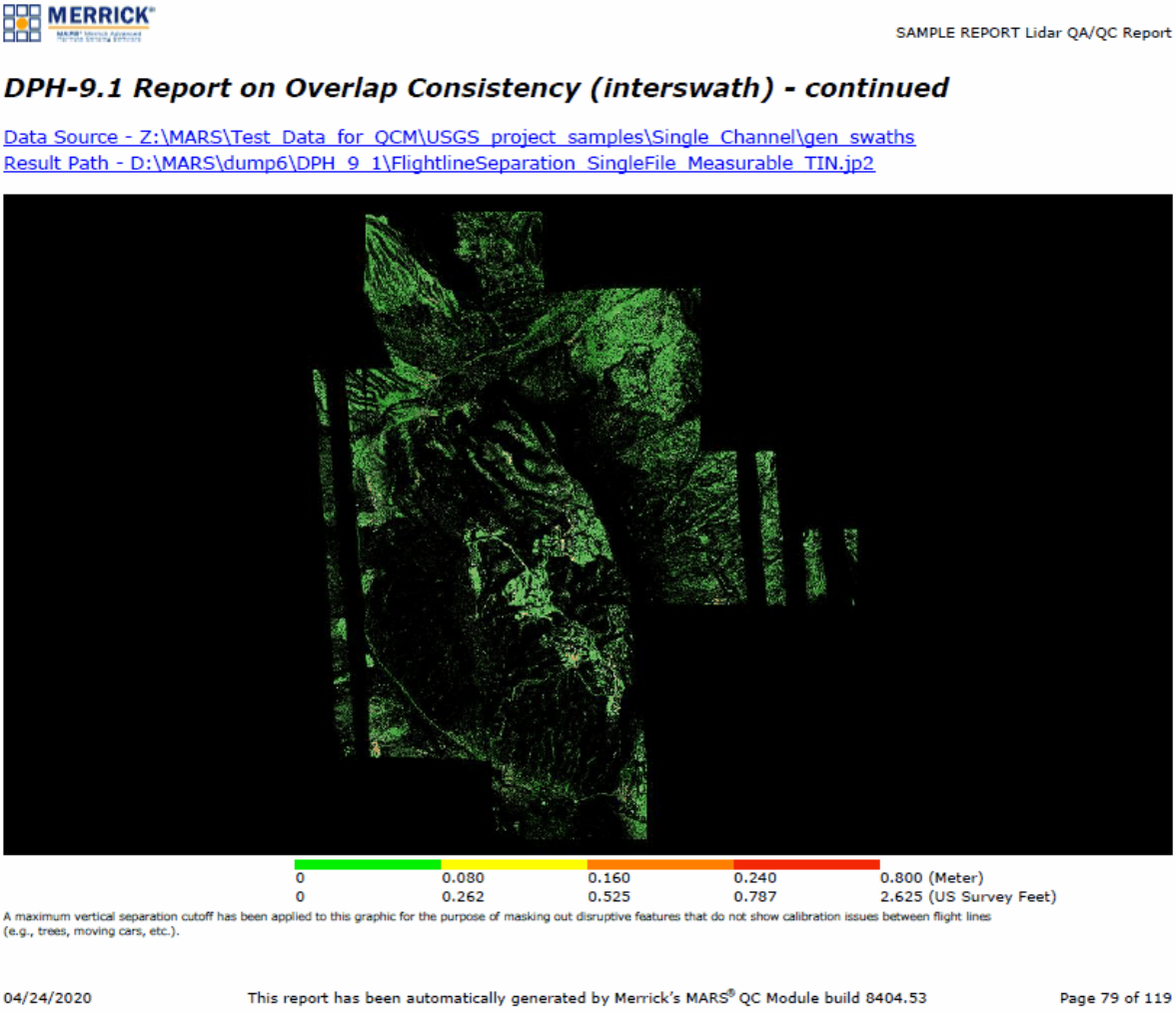
Table 2. Relative vertical accuracy for light detection and ranging swath data.

[QL, quality level; $RMSD_z$, root mean square difference in the z direction; m, meter; ≤, less than or equal to]

Quality level	Smooth surface repeatability, $RMSD_z$ (m)	Swath overlap difference, $RMSD_z$ (m)
QL0	≤0.03	≤0.04
QL1	≤0.06	≤0.08
QL2	≤0.06	≤0.08
QL3	≤0.12	≤0.16

The purpose of this section is to show a thematically rendered map of a flightline separation raster for all of the data processed. Processing has been done to isolate measurements either to specific classes of points or to clusters of single returns (depending on the method selected), limited within areas of <10 degree slope. The colors are gradated by the selected QL's swath overlap difference RMSDz limits. Only overlap areas are shown in the raster. The color is overlaid on a lidar intensity background to show land cover features. The swath overlap difference RMSDz values are reported on the following page(s).

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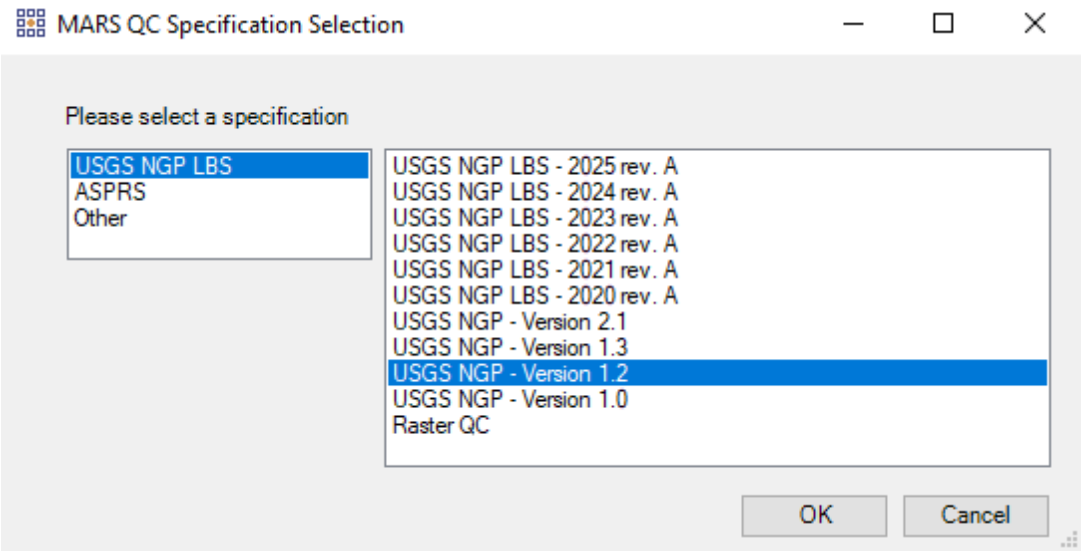
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6.2.9 Version 1.2



After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP - Version 1.2' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...

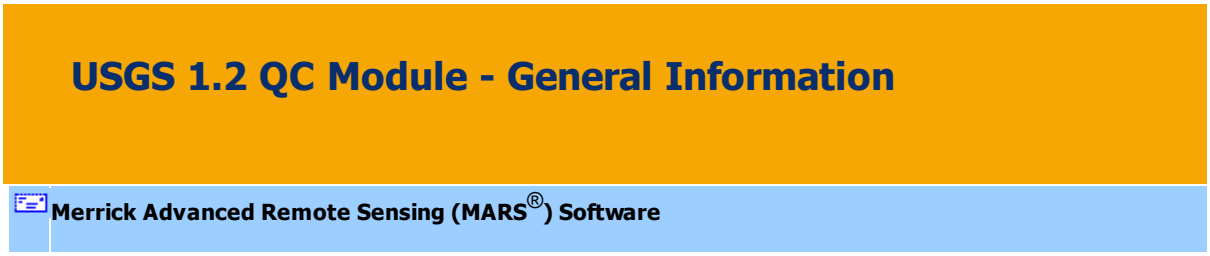


Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.4 LAS files. If earlier versions of LAS data are pathed out, a pop-up warning will appear.

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6.2.9.1 General Information



Purpose and Description

The purpose of the 'USGS NGP - Version 1.2' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.4 lidar point cloud datasets to the Lidar Base Specification Version 1.2 from the U.S. Geological Survey (USGS). The primary intent of this updated USGS lidar specification is to create consistency across all of USGS's National Geospatial Program (NGP) funded lidar data collections, in particular those undertaken in support of the National Elevation Dataset (NED) and the 3D Elevation Program (3DEP). Unlike most other "lidar specs," which focus on the derived bare-earth digital elevation model (DEM) product, this specification primarily focuses on the collection, processing, and handling of the source lidar point cloud data. ***Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool with the following exceptions: tests DPH-12 and DPH-14 (see the Data Processing/Handling Tab 1608 topic).***

There are 26 possible tests that can be run in the USGS 1.2 QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – Detailed and Summary - along with supporting raster analysis images, tabular data, and other statistical information. See the Final Reports 1616 sub-topic for more information.

For a copy of the USGS NGP Lidar Base Specification Version 1.2 (November 2014), please click this link to access the PDF file (approximately 2.1 MB). This document explains the requirements and expectations of each test. The USGS 1.2 QC Module tests are divided into **Collection** 1604 and **Data Processing/Handling** 1608 tabs and are ordered to match the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386,

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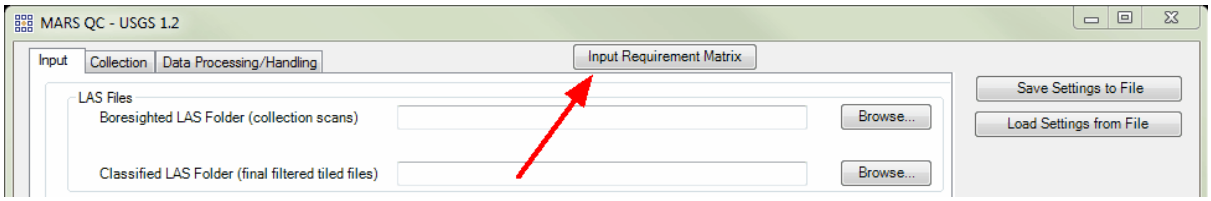
USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, and USGS NGP - Version 1.0 1622 tools, the Raster QC 623, LiDAR Data Checks 1677 and LiDAR Calibration Checks 1698 tools, and the Voronoi Density Reporting 1660 tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

These are the datasets and files needed to run all tests:

- Swath LAS data (also referred to as collection scan)
- Classified (final filtered) LAS data (typically as tiled files)
- Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute whose values ***exactly match*** the file names of the Classified data files. In addition, the tiles in the Tile Scheme ***must*** match the extents of the tiled files in the Classified LAS data.
- DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) with at least one attribute field that contains unique values
- LiDAR Check Points (CSV file format). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report 1224 help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if a LiDAR Check Points file is not available, the module will not be able to run tests DPH-11.2 (Report on Check Points) and DPH-11.3 (Report on Absolute Vertical Accuracy). A matrix chart PDF of input data and available tests can be accessed by clicking the **'Input Requirement Matrix'** button at the top of the module interface.



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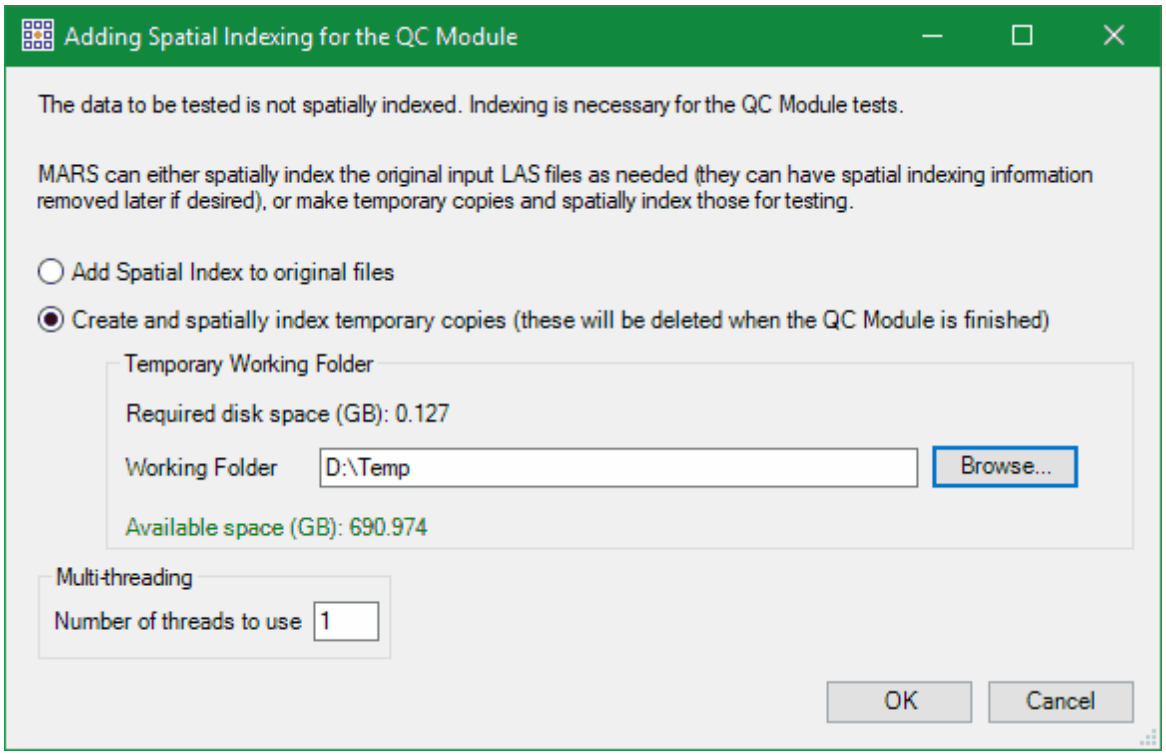
Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile, SBET file, or LiDAR Check Points CSV file.*

Swath (also referred to as flight line or collection scan) and Classified (also referred to as tiled or delivery) Data Preparation

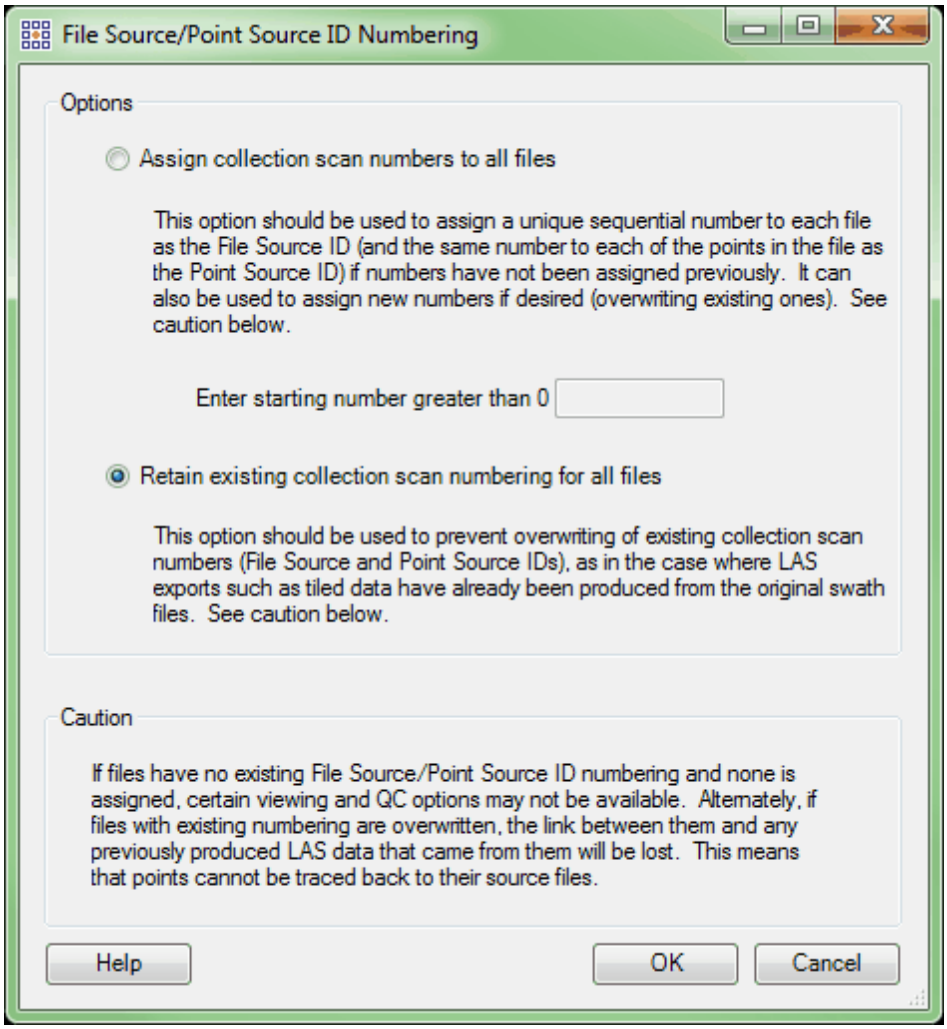
LAS data must be spatially indexed before it can be tested with the USGS 1.2 QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Swath LAS Folder' or 'Classified LAS Folder' (see Input Tab 1600) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options. See also Add Spatial Index 907. Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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If the 'Add Spatial Index to original files' option is chosen (the 'permanent' indexing option), a second dialog will open when the 'OK' button is clicked:

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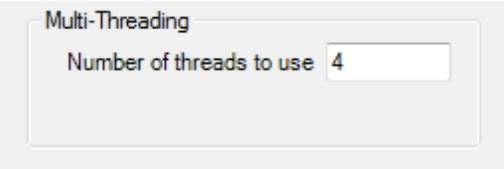
This window allows new collection scan numbers to be assigned to the files. The default is to retain existing numbering.

Multi-threading

A multi-threading option can be found on the USGS 1.2 QC Module tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just

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installed) per thread.

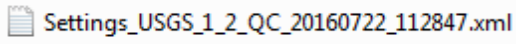


Running the USGS 1.2 QC Module

When all necessary entries have been made on the Input[1600], Collection[1604], and Data Processing/ Handling[1608] tabs, click the 'Run' button in the lower-right to begin the processing. A pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab[1600]. While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 1.2 QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 1.2 QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab[1600]. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 11:28:47 am on July 22, 2016.



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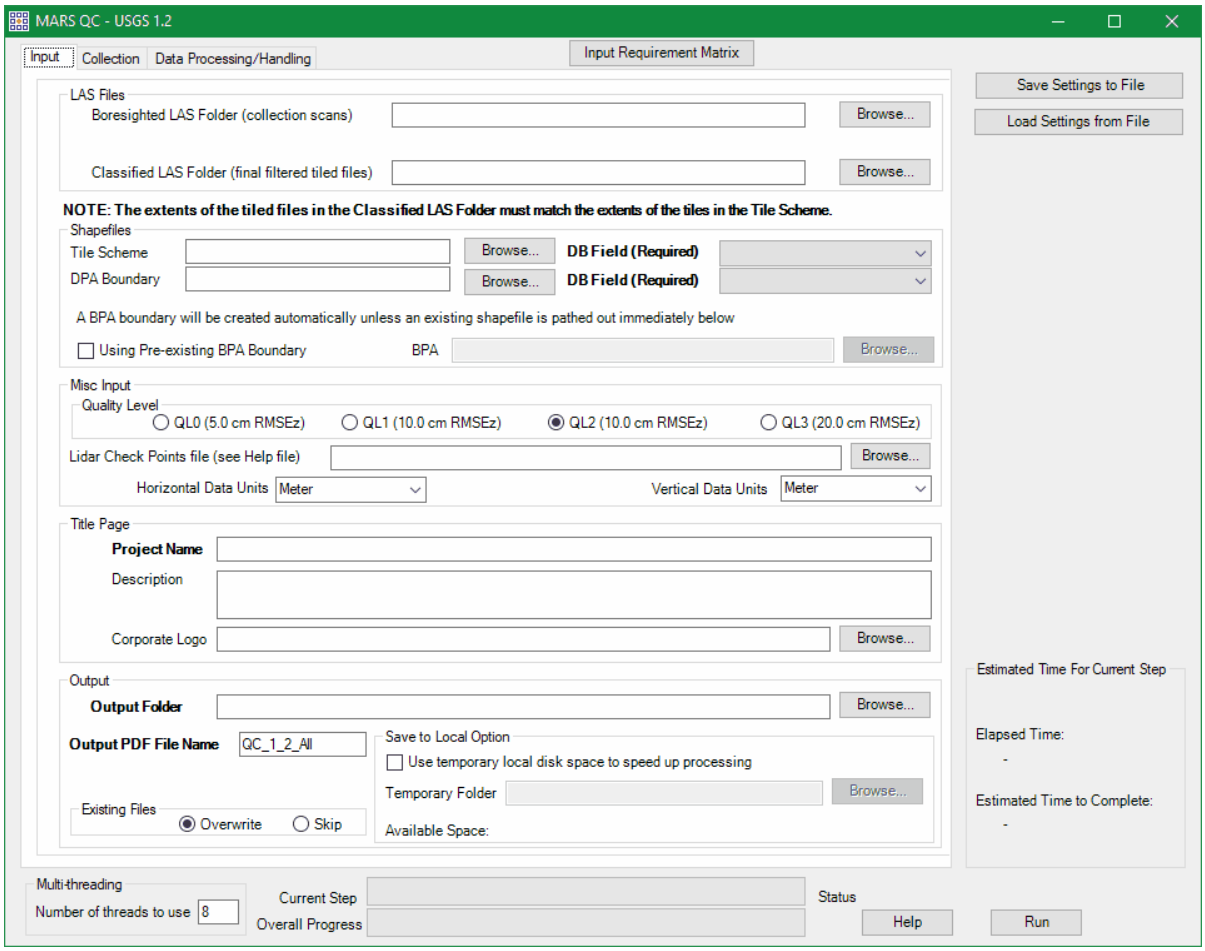
This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 1.2 QC Module runs. After opening the USGS 1.2 QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 1.2 QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not be stored in the chosen **Output Folder** automatically like it is when the module is actually run.

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6.2.9.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum - and depending on the specific tests to be run - either the **Swath LAS** or **Classified LAS** data must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.***

Unlike the original USGS 1.0 QC Module, which relies on the user specifying if and how multi-channel data is stored in the files to be tested, this version reads the files that are pathed out and determines

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whether multi-channel data exists based on Scanner Channel bit flag values that are present in the data. Modifications to the testing methods and results are then made automatically.

If a 'Tile Scheme' and/or 'Project Boundary' shapefile is included, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'Project Boundary' shapefile). For the 'Tile Scheme', the 'DB Field' selected must have values that ***exactly match*** the file names of the tiled files in the Classified LAS Folder. The attribute values for both of these shapefiles are used for identifying many of the tabular results in the final reports. Unless an optional custom BPA (Buffered Project Area) boundary shapefile is pathed out, MARS® will generate a 100-meter BPA boundary for test C-1 (see Collection Tab 1604) and test DPH-10 (see Data Processing/Handling Tab 1608).

The 'Quality Level' section is directly related to the levels defined in the USGS NGP Lidar Base Specification Version 1.2. By default, 'QL2 (10.0 cm RMSEz)' is pre-selected but this can be changed as necessary. The selection made here determines the standards to be met (and the methodologies to be used) for a large part of the testing done in the USGS 1.2 QC Module.

A LiDAR Check Points file, in either a 7-column CSV or MARS®-generated 3D shapefile format, is needed for tests **DPH-11.2 Check Points** and **DPH-11.3 Absolute Vertical Accuracy**. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

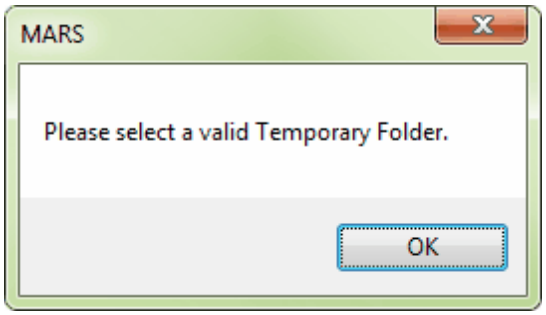
Make sure the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results

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in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



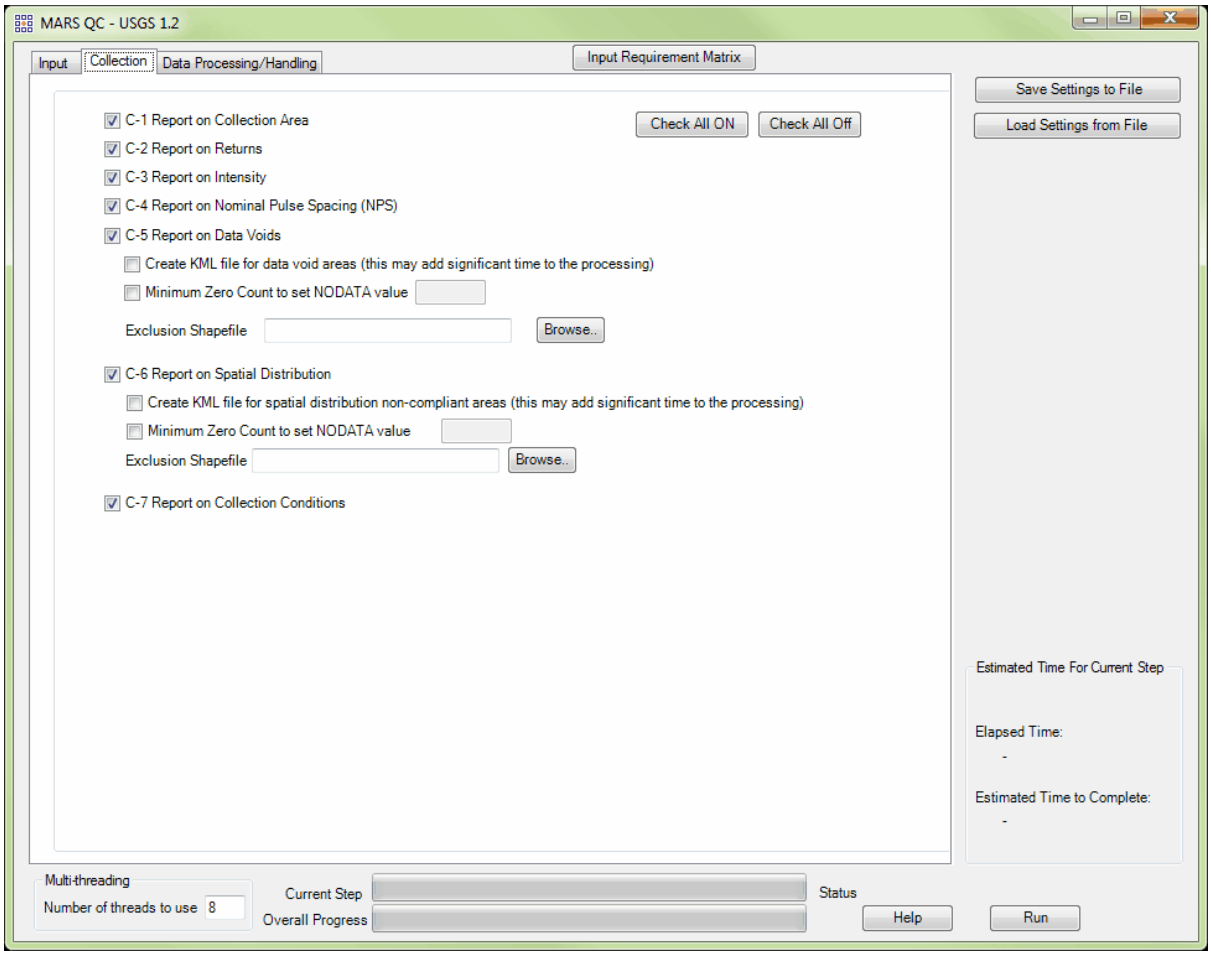
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1616 sub-topic).

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6.2.9.3 Collection Tab



The Collection Tab



Check boxes and options for tests **C-1** through **C-7** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section

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and paragraph in the USGS NGP Lidar Base Specification Version 1.2 in which they are referenced. Note that the following descriptions of what is created for these tests pertain only to the Detailed PDF report (see Final Reports 1616). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

C-1 Report on Collection Area

The purpose of this section is to show swath and tiled lidar coverage to the extent of a 100 meter buffer of the defined project area boundary. Screen captures of the lidar swath and tiled data with the DPA (defined project area) and BPA (buffered project area) boundaries superimposed are created for review.

C-2 Report on Returns

The purpose of this section is to report on the presence and quantities of lidar returns in the LAS swath and tiled data. Screen captures colored by the various return values, along with tables of the return values, are created for review. Empty return columns can indicate a collection or processing problem dealing with lidar return attribute information.

C-3 Report on Intensity

The purpose of this section is to report on the presence and values of lidar intensity in the LAS swath and tiled data. Histograms, screen captures colored by intensity, and tables are created for review.

C-4 Report on Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the lidar point density and nominal point spacing by swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported in a table for review. 'Point Density' and 'NPS' values are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications.

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C-5 Report on Data Voids

The purpose of this section is to show graphically where possible lidar data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser pulse back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of lidar data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the lidar coverage was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review, along with an optional KML file for use with Google Earth[1]. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. The other option is 'Exclusion Shapefile', where a pre-existing polygon shapefile of allowable exclusion areas can be pathed out so that all the raster cells within those polygons will be set to a value of NODATA. Using this option, when feasible, will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will cut down on the time needed to investigate failing (red) cells.

C-6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable lidar spatial distributions are located. Lidar spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or

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tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, lidar occlusions caused by objects above ground like tall buildings, etc. Not all lidar spatial distribution violations are truly problematic. The intention of this test is to isolate the first example of lidar spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the lidar spatial distribution was collected and processed to meet the intended specifications. A raster of compliant (green cells), non-compliant (red cells), and null data areas (black cells) is created for review (sub-section **C-6.1**), along with a table of compliant cells as a percentage of all non-null cells per file (sub-section **C-6.2**), and an optional KML file for use with Google Earth[1]. The tabular results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

Besides the KML creation option, there are two other user-definable settings: 'Minimum Zero Count to set NODATA value' and 'Exclusion Shapefile'. The first allows a minimum count of adjacent empty cells to be entered so that the test will flag those clusters of raster cells as NODATA (black) rather than failing (red). A hypothetical example would be allowable void areas such as water bodies, where each feature would cover an area of at least 20 adjacent cells. The other option is 'Exclusion Shapefile', where a pre-existing polygon shapefile of allowable exclusion areas can be pathed out so that all the raster cells within those polygons will be set to a value of NODATA. Using this option, when feasible, will create a more accurate raster result than the 'Minimum Zero Count' method. In either case, the cells flagged as NODATA will improve the ratio of passing (green) cells to the total of all passing and failing (red) cells, and cut down on the time needed to investigate the failing cells.

C-7 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow

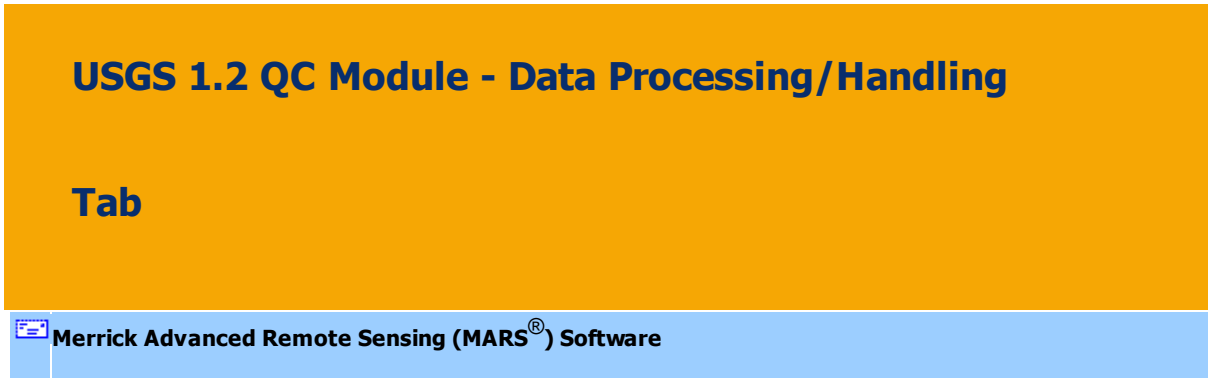
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depth map for the extent of the lidar at the time of collection.

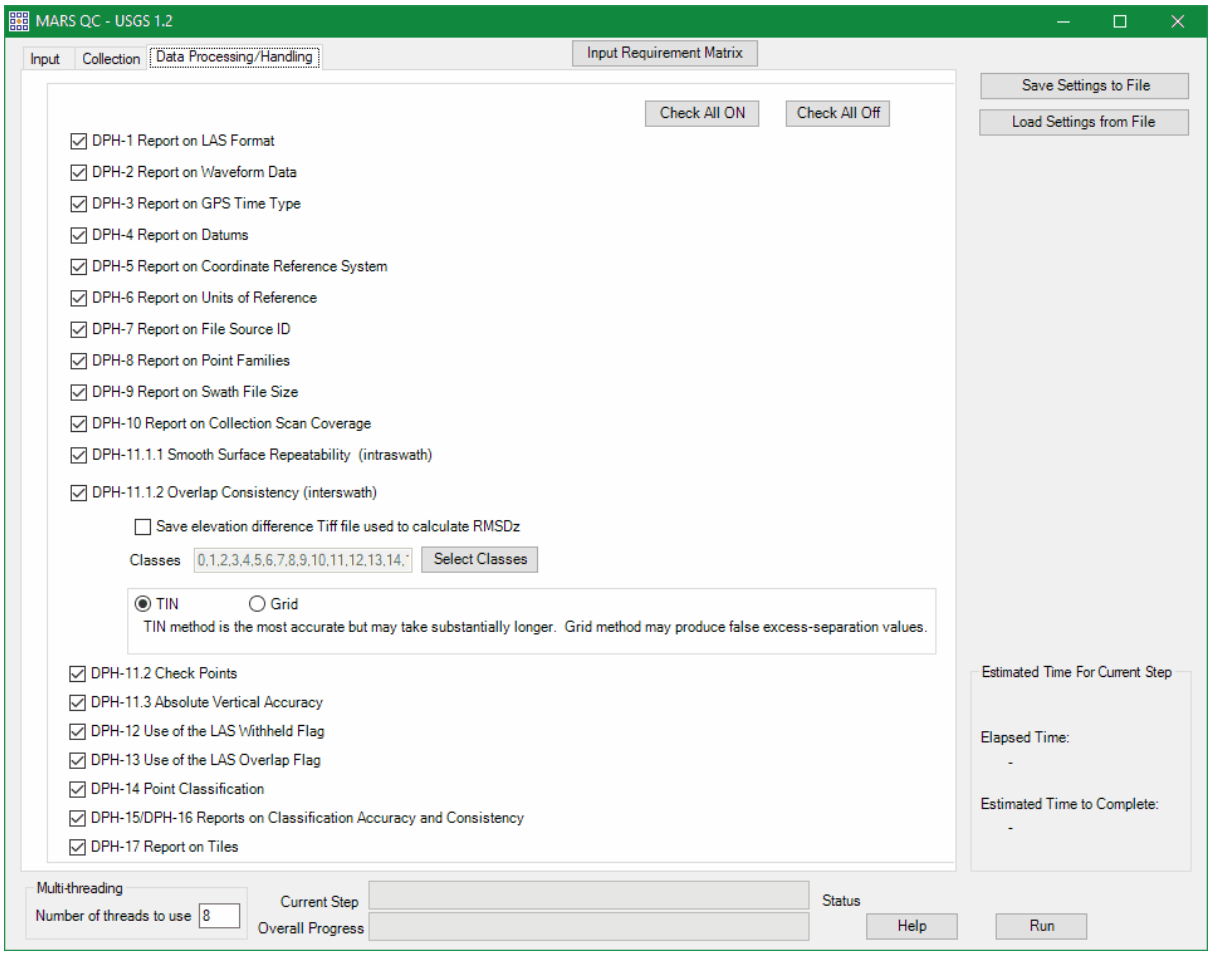
[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

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6.2.9.4 Data Processing/Handling Tab



The Data Processing / Handling Tab



Check boxes and options for tests **DPH-1** through **DPH-17** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 1.2 in which they are referenced. Note that the following descriptions of what is created for these tests pertain only to the Detailed PDF report (see Final Reports 1616). Summary PDF reports contain a condensed version of the aggregate results, usually without reference to individual files.

DPH-1 Report on LAS Format

The purpose of this section is to show a table of LAS 1.4 compliance, file integrity, and informational test results for each swath and tiled file. Tables are created for review for all three

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sub-sections:

In the **Compliance** sub-section (**DPH-1.1**), the following items are reported on per file: 'LAS Version/PDRF', 'System ID', 'Legacy Point Count', 'Legacy Return Counts', 'PSID/FSID Match', 'Global Encoding', 'VLRs / EVLRs', 'WKT', 'Intensity', and 'Point Count with Bad Return Info'. For 'WKT', fail codes are shown as needed and those codes are described at the bottom of the report page.

In the **File Integrity** sub-section (**DPH-1.2**), the following items are reported on per file: Number of Points Outside Extent, Offset To Point Data, Offset To EVLR, Number of Points, Number of Points by Return, and Number of Duplicate Points.

In the **Informational** sub-section (**DPH-1.3**), the following items are reported on per file: (Xmin, Ymin, Zmin), (Xmax, Ymax, Zmax), Extended Scan Angle, Scan Angle Rank, Scanner Channel, Scan Direction, Edge of Flight Line, User Data, Counts for Synthetic, Key-points (also known as Model Key-points), Withheld, and Overlap.

The tabular results are color-coded in sub-sections **DPH-1.1** and **DPH-1.2** to indicate compliance (green) or non-compliance (red) with the USGS or ASPRS specifications, as appropriate. Red items will be promoted to the top of the tables.

DPH-2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the lidar swath and tiled data. A statement of waveform data file count is created for review.

DPH-3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the lidar swath and tiled data. A table of types (Adjusted GPS Time or GPS Week Time) is created for review. The results are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-4 Report on Datums

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The purpose of this section is to show the datums of the LAS files for the lidar swath and tiled data. A table of horizontal and vertical (if present) datum names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of horizontal datums. As the USGS does not require vertical coordinate information in the NGP Lidar Base Specification Version 1.2, missing vertical datums will not be flagged unless some files in the dataset do have that info. In that case, a yellow bar in the 'Vertical Datum' column will indicate those files that are missing it. Red items will be promoted to the top of the table, followed by any yellow bar items.

DPH-5 Report on Coordinate Reference System

The purpose of this section is to show the coordinate reference systems of the LAS files for the lidar swath and tiled data. A table of coordinate reference system names and associated EPSG codes is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-6 Report on Units of Reference

The purpose of this section is to show the horizontal and vertical units of the LAS files for the lidar swath and tiled data. A table of horizontal and vertical (if present) units is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications regarding the presence of horizontal units. As the USGS does not require vertical coordinate information in the NGP Lidar Base Specification Version 1.2, missing vertical units will not be flagged unless some files in the dataset do have that info. In that case, a yellow bar in the 'Vertical Unit' column will indicate those files that are missing it. Red items will be promoted to the top of the table, followed by any yellow bar items.

DPH-7 Report on File Source ID

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The purpose of this section is to report on the File Source ID and Point Source ID values for the lidar swath data. Note that sub-swaths of original swaths (see **DPH-9**) may violate the unique values specification described in this test. A table of File Source ID and Point Source ID values is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-8 Report on Point Families

The purpose of this section is to report on the presence and integrity of point families for the lidar swath and tiled data. A table is created for review. File names are color-coded to indicate compliance (green) or non-compliance (red) with the USGS specifications. Red items will be promoted to the top of the table.

DPH-9 Report on Swath File Size

The purpose of this section is to show the file sizes of the LAS files for the lidar swath data. A table with multiple size units is created for review.

DPH-10 Report on Collection Scan Coverage

The purpose of this section is to show collection scan overlap. Lack of overlap would be displayed as black polygons or slivers between collection scans. A screen capture of the lidar swath data with the BPA (buffered project area) boundary superimposed is created for review.

DPH-11.1.1 Smooth Surface Repeatability (intraswath)

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). An elevation value difference raster for each swath is created for review. The raster cells are color-coded to

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indicate compliance (green) or non-compliance (red) with the USGS specifications.

DPH-11.1.2 Overlap Consistency (interswath)

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. A color-coded elevation difference raster of the overlap areas is created for review, along with a table of relative accuracy RMSDz values for those areas. Only overlap areas are shown in the raster.

There are three user-definable settings for this test: An option to save the elevation difference raster that is used to calculate the RMSDz values in a TIFF file format, a classes participating selector, and an option to choose either TIN or Grid as the basis for the difference calculations. The TIFF raster allows for individual cell inspection of elevation difference values. The class selector, which defaults to all classes used for a typical unfiltered swath workflow, allows for choosing ground only points if the swath data being tested has been filtered. Lastly, the TIN/ Grid selector (TIN by default) determines the method used to calculate the elevation differences. Please see the notes on this option in the DPH-11.1.2 section of the interface.

DPH-11.2 Check Points

The purpose of this section is to show check points (NVA and VVA). A screen capture of the non-vegetated (shown in yellow) and vegetated (shown in green) check points with the DPA (defined project area) superimposed is created for review, along with a table of check point and boundary area statistics.

DPH-11.3 Absolute Vertical Accuracy

The purpose of this section is to report on the absolute vertical accuracy of the lidar data by testing for NVA (Nonvegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy)

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against surveyed ground check points. A special version of the 'Check Point Report' tool is used for this test with the USGS specifications and ASPRS Positional Accuracy Standards pre-set internally. Several items are created for review - a table of check point information listing point types (NVA / VVA), along with overall Z error values and statistics in a color-coded (PASS / FAIL) format where applicable; a table of NVA check points with point-by-point error and descriptive information as compared to a TIN of the lidar ground data, along with a bar chart showing error distribution; a table of NVA check points with point-by-point error and descriptive information as compared to a RAM-based virtual grid (DEM grid of the lidar ground data, along with a bar chart showing error distribution; a table of VVA check points with point-by-point error and descriptive information as compared to a DEM grid of the lidar ground data, along with a bar chart showing error distribution; point shapefiles of the check points with attributes including the Z value of the surface and the Z error at each point's location; and screen captures of both the NVA and VVA check points rendered thematically using color and relative error size on an Intensity view background of the lidar data - NVA with the swath data and VVA with the tiled data.

DPH-12 Use of the LAS Withheld Flag

The purpose of this section is to list the presence and quantities of points flagged as Withheld for all lidar swath and tiled data files. A statement of total Withheld point count for Class 0 (all swaths/tiles), as well as all classes and all swaths/tiles, is created for review, along with screen captures of the Withheld-flagged points for both the swath and tiled data.

DPH-13 Use of the LAS Overlap Flag

The purpose of this section is to list the presence and quantities of points flagged as Overlap for all lidar swath and tiled data files. A statement of total Overlap point count for all classes and all swaths/tiles is created for review, along with screen captures of the Overlap-flagged points for both the swath and tiled data.

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DPH-14 Point Classification

The purpose of this section is to report total numbers of points (and certain bit flag counts in some cases) for each class within the tile based LAS files. A table of points by classification (from the tiled data) is created for review, with any counts greater than zero (0) shown in red font for Class 0 (unless those points are bit-flagged as Withheld) to indicate non-compliance with the USGS specifications. If some Class 0 points are flagged as Withheld but some are not, those points counts will be shown in black with a **red background**. Any points outside of Class 2 (Ground) that are flagged as Model Key-points will also be shown in red font. Minimum required classes per the USGS specifications have their point totals in **bold** font. Note, however, that some datasets may not have Low Noise points (Class 7), Water points (Class 9), Ignored ground (near a breakline) (Class 10 or Class 20), Bridge decks (Class 17), or High noise (Class 18), depending on the nature of the project. Also, additional classes may be required on specific projects - non-zero counts for these classes will be displayed with a yellow background.

DPH-15/DPH-16 Reports on Classification Accuracy and Consistency

The purpose of the DPH-15 section is to overlay a 1km x 1km tile scheme over the bare earth surface hillshade product to use for ground filter QC inspection. The purpose of the DPH-16 section is to show the bare earth surface hillshade product for classification consistency inspection. Bare earth hillshade screen captures are created for a visual review.

DPH-17 Report on Tiles

The purpose of this section is to report on the unallowed presence of skew and/or polygon overlap in the project tile scheme. A table of tiles by name/number with skew, width, height, and overlap is created for review.

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6.2.9.5 Final Reports

USGS 1.2 QC Module - Final Reports

Merrick Advanced Remote Sensing (MARS®) Software

QC Reporting

The output of the USGS 1.2 QC Module is written to two (2) PDF files – Detailed and Summary - that contain the results of the point cloud, check points, and tile scheme analysis. All tabular results are shown in Meters and either US Survey Feet or International Feet, depending on the project units chosen on the Input Tab 1600. If either Meter or US Survey Feet is selected, results will be listed as 'Meter/US Survey Feet'. If International Feet is selected, results will be listed as 'Meter/International Feet'.

The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab 1600. The default name is 'QC_1_2_All' but can be changed before running the module. 'Summary_' will be appended to the summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1600. Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 24 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1593 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 1.2 QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables,

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interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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C-4 Report on Nominal Pulse Spacing (NPS)

The USGS Lidar Base Specification Version 1.2 states: "Assessment and reporting of the NPS is made ag
only data, including only the geometrically usable part of the swath (typically the center 95 percent) an
densities of lidar point measurements are being achieved more often by using multiple coverages, creat
with NPS and NPD. This specification will use the terms aggregate nominal pulse spacing (ANPS) and ag
overall pulse spacing and density, respectively. The table "Aggregate nominal pulse spacing and density
the required ANPS and ANPD by QL. Dependent on the local terrain and land cover conditions in a proje
projects."

Table 1. Aggregate nominal pulse spacing and density, Qual
Level 0–Quality Level 3.

[m, meters; pls/m^2, pulses per square meter; ≤, less than or equal to; ≥, g
than or equal to]

Quality Level (QL)	Aggregate nominal pulse spacing (ANPS) (m)	Aggregate nominal pu density (ANPD) (pls/m^2)
QL0	≤0.35	≥8.0
QL1	≤0.35	≥8.0
QL2	≤0.71	≥2.0
QL3	≤1.41	≥0.5

The purpose of this section is to report on the lidar point density and nominal point spacing by swath fil
boundary polygons (including swath overlap), and aggregate project boundary polygons (including swat

Boresighted Files - D:\MARS\QC Mod test data\USGS LBS 1.2 Samples\Single

Quality level tested: QL2

File	Number of First Returns	Area of Swa
L018-1-160421A-C1.las	28,611,533	118,473,9
L019-1-160421A-C1.las	15,384,791	70,741,7
L021-1-160421A-C1.las	57,027,507	212,809,4
L022-1-160421A-C1.las	50,212,761	227,400,1
L023-1-160421A-C1.las	70,365,618	224,119,8

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C-4 Report on Nominal Pulse Spacing (NPS) - con

File	Number of First Returns	Area of Swath
L024-1-160421A-C1.las	57,856,447	242,609,984
L025-1-160421A-C1.las	67,391,957	246,363,008
L026-1-160421A-C1.las	46,250,363	221,201,856
L027-1-160421A-C1.las	51,502,235	201,194,304
L113-1-160427A-C1.las	8,320,147	26,966,336
L114-1-160427A-C1.las	7,968,302	25,348,032
L115-1-160427A-C1.las	14,583,706	46,373,824
L116-1-160427A-C1.las	13,752,754	44,177,536
L117-1-160427A-C1.las	28,543,676	85,477,632
L118-1-160427A-C1.las	27,193,454	82,457,600
L119-1-160427A-C1.las	50,385,255	138,419,648
L321-1-160509A-C1.las	30,360,811	101,052,160
L322-1-160509A-C1.las	31,797,774	101,337,216
L323-1-160509A-C1.las	40,776,870	139,471,104
L324-1-160509A-C1.las	43,340,384	137,980,032
L325-1-160509A-C1.las	46,433,483	158,946,816
L326-1-160509A-C1.las	51,259,815	156,910,016
L327-1-160509A-C1.las	46,272,535	156,113,344
L328-1-160509A-C1.las	51,000,479	154,279,936
L329-1-160509A-C1.las	39,783,838	137,772,224
Average		
1	813,966,465	954,668,300
Aggregate	813,966,465	954,668,300

05/18/2018 This report has been automatically generated by Merrick's MARS® QC Module

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DPH-11.1.1 Report on Smooth Surface Repeatability (intraswath)

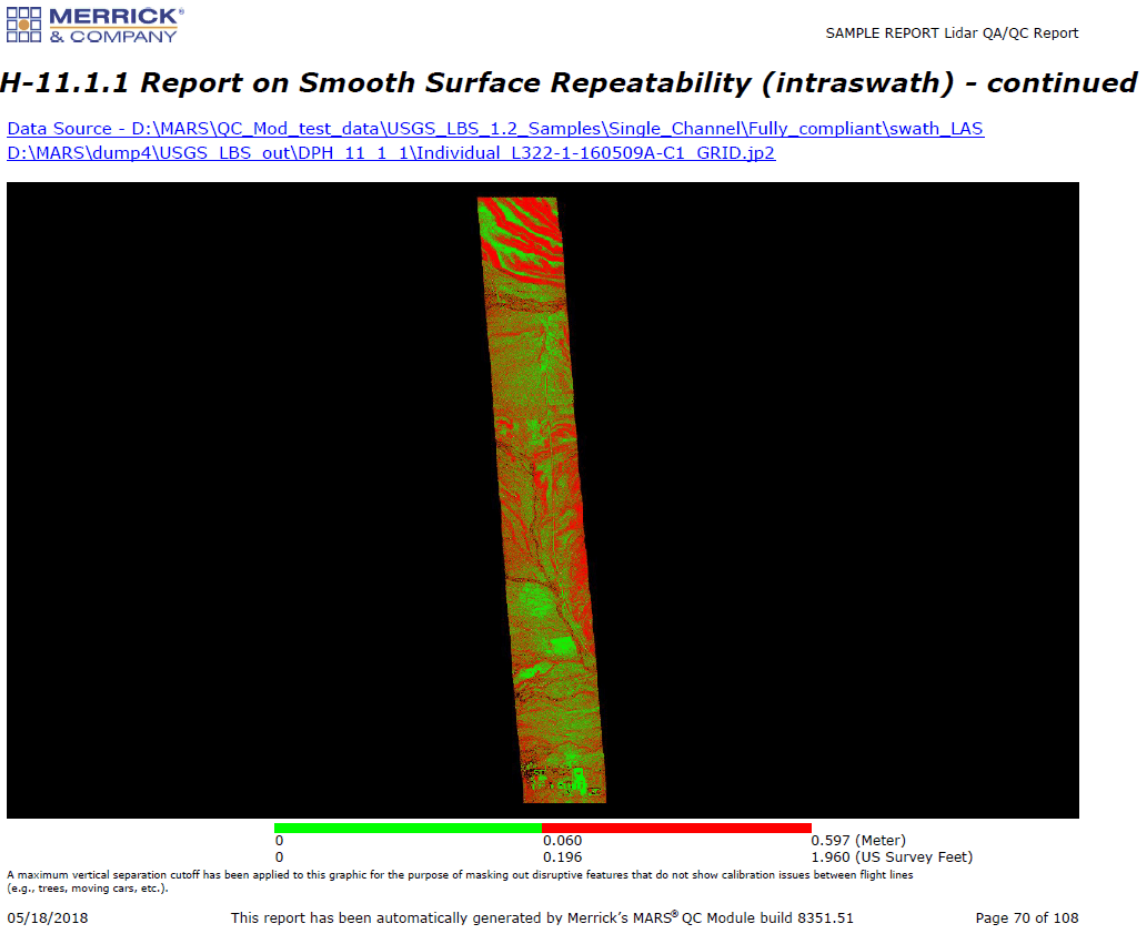
The USGS Lidar Base Specification Version 1.2 states: "In ideal theoretical conditions, smooth surface repeatability is a measure of variations documented on a surface that would be expected to be flat and without variation. Users of lidar technology commonly refer to these variations as "noise." Single-swath data will be assessed using only single returns in nonvegetated areas. Repeatability will be evaluated by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns will then be assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops). Each sample area will be evaluated using a signed difference raster (maximum elevation - minimum elevation) at a cell size equal to twice the ANPS, rounded up to the next integer. Sample areas will be approximately 50 square meters. The maximum acceptable variations within sample areas at each QL are listed in the table "Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3" (table 2). Isolated noise is expected within the sample areas and will be disregarded."

Table 2. Relative vertical accuracy for lidar-swath data, Quality Level 0–Quality Level 3.
[cm, centimeter]

Quality Level (QL)	Smooth surface repeatability (cm)
QL0	≤3
QL1	≤6
QL2	≤6
QL3	≤12

The purpose of this section is to evaluate smooth surface repeatability by measuring departures from planarity of single returns from hard planar surfaces, normalizing for actual variation in the surface elevation. Repeatability of only single returns is then assessed at multiple locations within hard surfaced areas (for example, parking lots or large rooftops).

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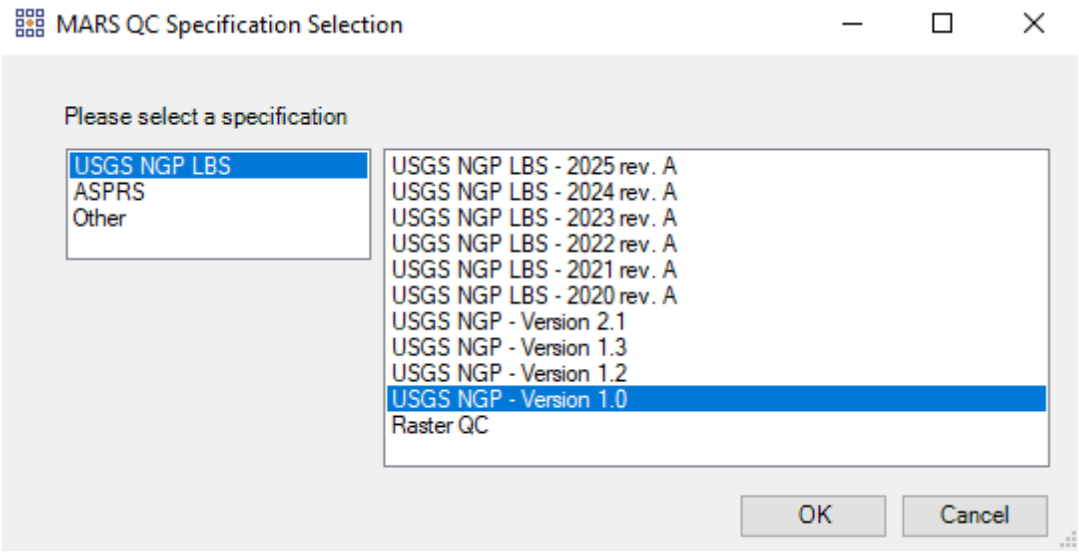
6.2.10 Version 1.0

Version 1.0

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'USGS NGP - Version 1.0' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Note that the 'USGS NGP LBS - 2025 rev. A1315' option is the latest Lidar Base Specification published by the USGS, as of the date of this release.

This version of the USGS QC Module is intended for, and can be run only on, ASPRS version 1.3 or earlier LAS files. If LAS v1.4 data is pathed out, a pop-up warning will appear.

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6.2.10.1 General Information

USGS 1.0 QC Module - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'USGS NGP - Version 1.0' quality control (QC) module in MARS® is to provide an automated tool for verifying compliance of LAS v1.0 - LAS v1.3 LiDAR point cloud datasets to the Lidar Base Specification Version 1.0 from the U.S. Geological Survey (USGS). The primary intent of the USGS LiDAR specification is to create consistency across all of USGS's National Geospatial Program (NGP) funded LiDAR data collections, in particular those undertaken in support of the National Elevation Dataset (NED) and the 3D Elevation Program (3DEP). Unlike most other "LiDAR specs," which focus on the derived bare-earth digital elevation model (DEM) product, this specification places unprecedented emphasis on the handling of the source LiDAR point cloud data.

There are 30 possible tests that can be run in the USGS 1.0 QC Module. The user can customize QC tasks by selecting the individual QC standards that they wish to analyze. The results of the point cloud, check points, and tile scheme analysis are contained in two (2) PDF reports – detailed and summary - along with supporting raster analysis images, tabular data, shapefiles, and other statistical files. See the Final Reports 1648 sub-topic for more information.

For a copy of the USGS NGP Lidar Base Specification Version 1.0 (August 2012), please click this link to access the PDF file (approximately 10.9 MB). This document explains the requirements and expectations of each test. The USGS 1.0 QC Module tests are organized and numbered to match the USGS specifications document. Please note that for non-quantitative tests a visual inspection of the data may still be required.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2024 rev. A 1351, USGS 2023 rev. A 1386, USGS 2022 rev. A 1421, USGS 2021 rev. A 1455, USGS 2020 rev. A 1490, USGS NGP - Version 2.1 1525, USGS NGP - Version 1.3 1559, and USGS NGP - Version 1.2 1592 tools, the Raster QC 623, LiDAR Data

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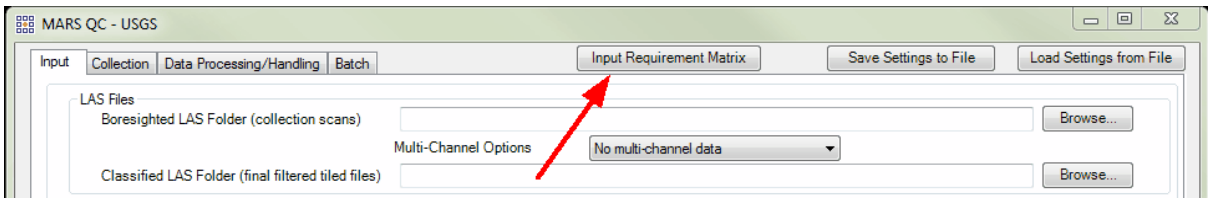
Checks 1677 and LiDAR Calibration Checks 1698 tools, and the Voronoi Density Reporting 1660 tool - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

These are the datasets and files needed to run all tests:

- Boresighted Swath Data (LAS)
- Classified LiDAR files (LAS)
- Project Tile Scheme (Esri-compatible polygon shapefile) with a unique tile number/name attribute
- Project Boundary file (Esri-compatible polygon shapefile) with at least one attribute field that contains unique values
- Smoothed Best Estimate of Trajectory (SBET) file (as an Esri point shapefile) which includes the flight date
- LiDAR Check Points (CSV file). For LBS versions 2023 and older, this file must adhere to the latest **7-column** format, as specified in the Check Point Report 1224 help topic.

Note that each test requires one or more of the inputs listed above. ***None of the data should be loaded in the Map View window prior to running this tool.*** The module will run only those QC analysis tests that are supported by the available input datasets/files. For example, if an SBET file is not available, the module will not be able to analyze the scan angle violations or link to the NOAA website for collection conditions. A matrix chart PDF of input data and available tests can be accessed by clicking the "**Input Requirement Matrix**" button at the top of the module interface.



Each Input Dataset should be in a separate folder to ensure proper operation and to avoid

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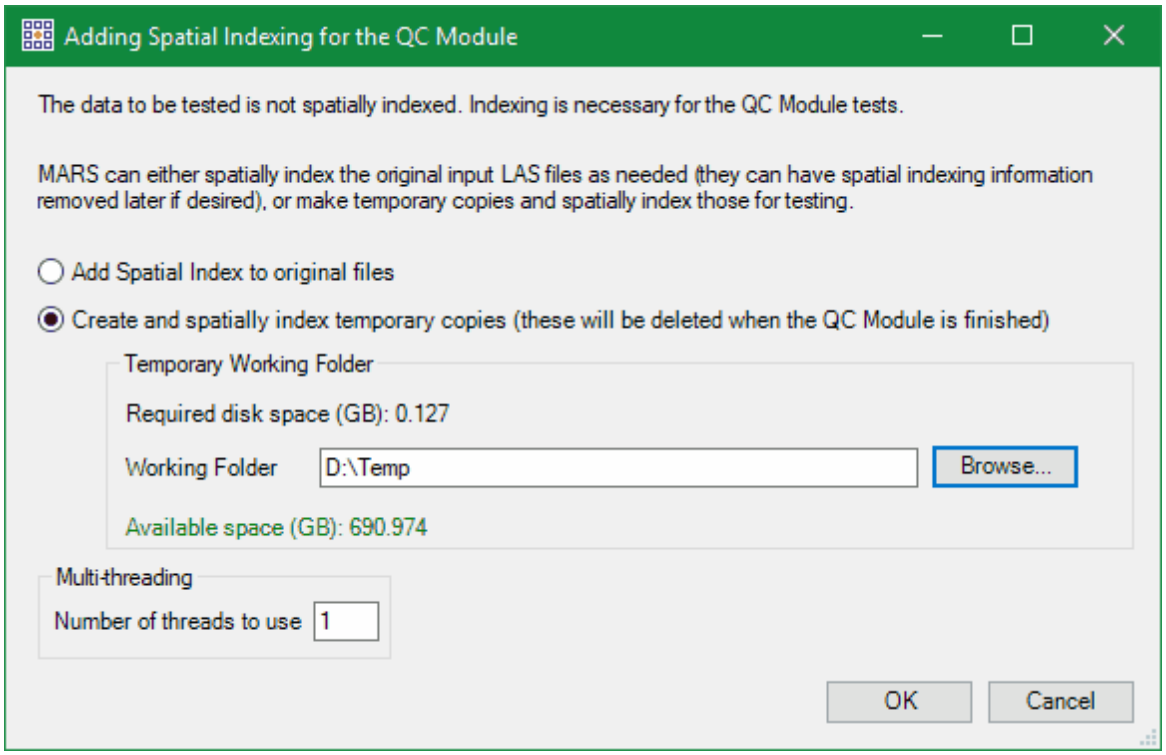
confusion when pathing out the various sources.

Also note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile, SBET file, or LiDAR Check Points CSV file.*

Boresighted (also referred to as swath, flightline, or collection scan) and Classified (also referred to as tiled or delivery) Data Preparation

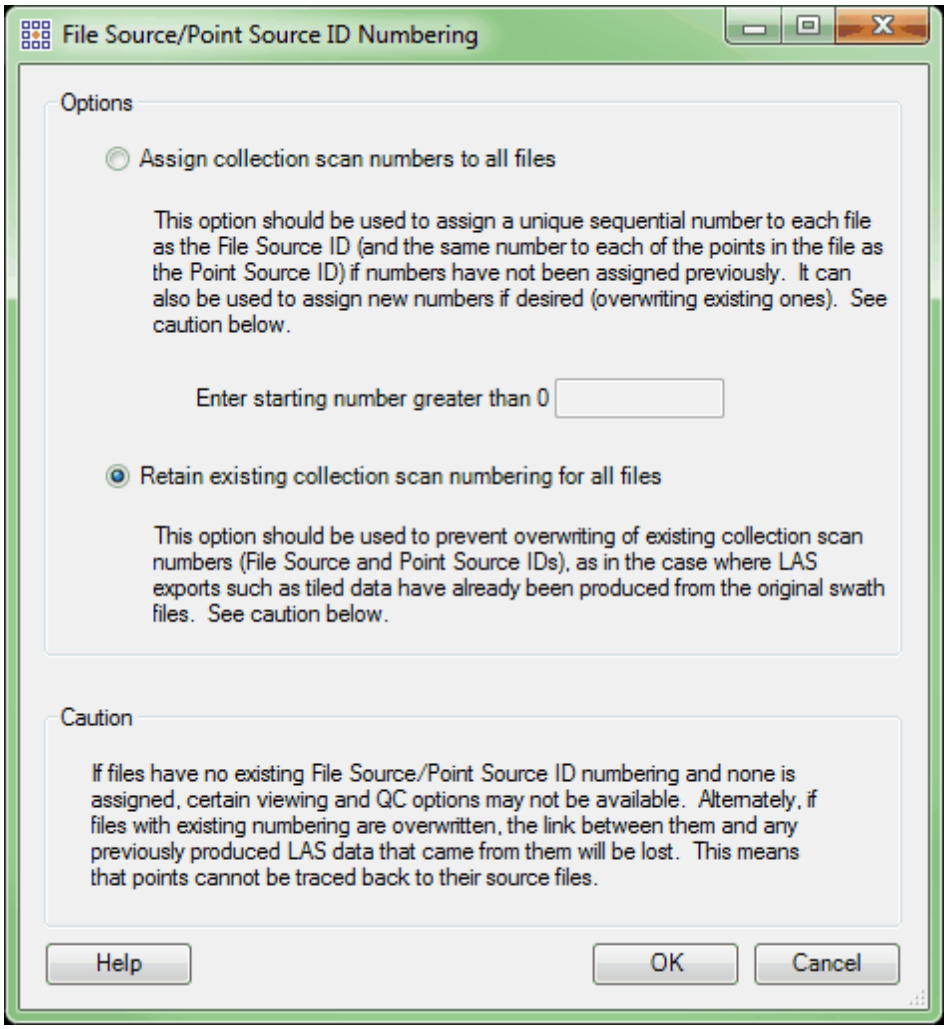
LAS data must be spatially indexed before it can be tested with the USGS 1.0 QC Module, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Boresighted LAS Folder' or 'Classified LAS Folder' (see Input Tab 1630) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options. See also Add Spatial Index 907. Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

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If the 'Add Spatial Index to original files' option is chosen (the 'permanent' indexing option), a second dialog will open when the 'OK' button is clicked:

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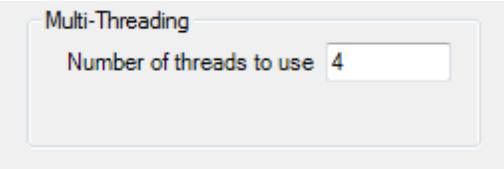
This window allows new collection scan numbers to be assigned to the files. The default is to retain existing numbering.

Multi-threading

A multi-threading option can be found on the USGS 1.0 QC Module tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just

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installed) per thread.

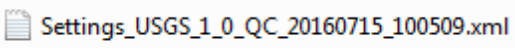


Running the USGS 1.0 QC Module

When all necessary entries have been made on the Input[1630], Collection[1634], and Data Processing/ Handling[1643] tabs, click the 'Run' button in the lower-right to begin the processing. A pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab[1630]. While running, the individual tabs can be viewed, the 'Help' and 'Input Requirement Matrix' buttons remain active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the USGS 1.0 QC Module begins the screen capture portion of the processing.***

Settings Files

Every time the USGS 1.0 QC Module is run, MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab[1630]. Each unique *.xml file name will contain the date and time that the module run was started as seen in the example below. For example, this particular run was started at 10:05:09 am on July 15, 2016.



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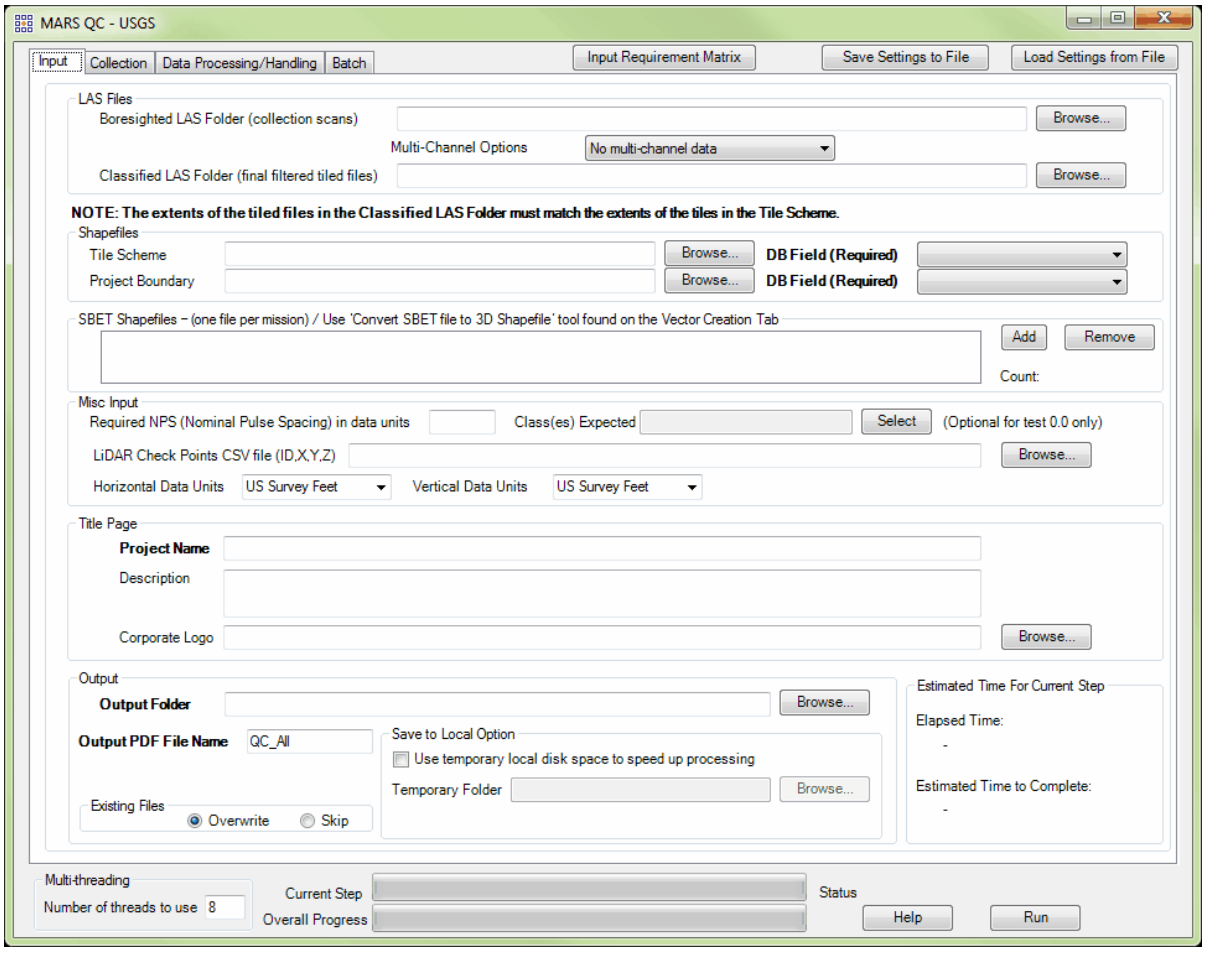
This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between USGS 1.0 QC Module runs. After opening the USGS 1.0 QC Module interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the USGS 1.0 QC Module - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to to a folder to store the file as it will not be stored in the chosen **Output Folder** automatically like it is when the module is actually run.

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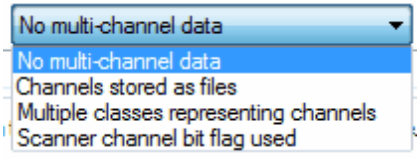
6.2.10.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a <u>minimum</u> - and depending on the specific tests to be run - either the **Boresighted LAS** or **Classified LAS** data must be included, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**. ***<u>Each Input Dataset should be in a separate folder to ensure proper operation and to avoid confusion when pathing out the various sources - a unique Output Folder should also be used.</u>***

The 'Multi-Channel Options' drop-down 

in the 'LAS Files' section

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should be used as follows:

'No multi-channel data' (the default) should be used when the project to be tested was collected by a single-channel sensor (the most common type).

'Channels stored as files' should be used when data is stored as one file per channel for each swath (for example, a pair of files per swath for a dual-channel sensor). By default, the naming convention expected for multi-channel files (assuming a two-channel system) is L#-<*filename*>-C1_r.las and L#-<*filename*>-C2_r.las, where **#** is the same collection scan number and the two channels are identified by '**C1**' and '**C2**' near the end of the file name. In this example, the two channels of collection scan '**23**' would then be named '**L23-1-140529A-C1_r.las**' and '**L23-1-140529A-C2_r.las**'.

'Multiple classes representing channels' should be used when the data to be tested stores one channel's points in one class (for example, class 1), and the other channel's points in a different class (for example, class 3) in the *same* swath file. This will allow the creation and testing of separate 'virtual' LAS files to obtain proper results. This example assumes a dual-channel sensor and post-processing software such as those produced by Leica.

'Scanner channel bit flag used' should be selected when the swath files have multi-channel data stored using the Scanner Channel bit flag available with LAS v1.4 files using a Point Data Record Format of 6 or higher. In a dual-sensor setup, bit flag values are typically 0 and 1 for the two channels.

If a 'Tile Scheme' and/or 'Project Boundary' shapefile is included, unique-value attribute fields must be chosen (e.g., a 'Tilename' field for the 'Tile Scheme' shapefile, and an 'Areaname' field for the 'Project Boundary' shapefile). These attribute values are used for identifying many of the tabular results in the final reports.

When SBET (**S**moothed **B**est **E**stimate of **T**rajectory) files are included, they must be in Esri-compatible point shapefile format. MARS® includes a tool to convert true SBET files into the shapefile format including an attribute field for Flight Date that is required for tests **1.7** and **1.12**. This tool, 'Convert SBET

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to Shapefile', is found on the Vector Creation Tab 364.

The entry for 'Required NPS (Nominal Pulse Spacing) in data units' must be in horizontal project units and can be derived from the point density using this formula: NPS = 1/√Density (i.e., the inverse of the square root of the point density).

Make sure the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter, US Survey Feet, and International Feet.

The optional 'Class(es) Expected' box in the 'Misc Input' section allows for a selection of the classes the user expects to be in the **Classified LAS** data to be entered. This can then be compared to the actual existing classes reported on in test **0.0** (Collection Tab 1634).

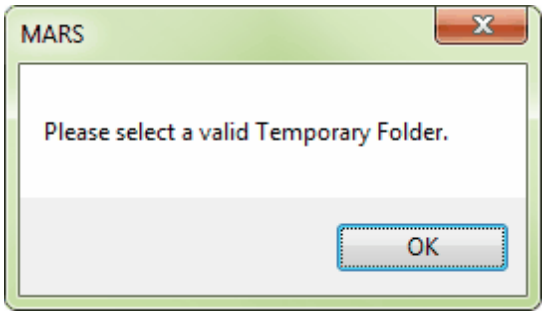
A LiDAR Check Points file, in a 7-column CSV file format, is needed for the two accuracy tests, **1.8** and **2.13**. See the 'Overview' section of the Check Point Report 1224 Help Topic for more details on the check points.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a

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temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. New final reports will be produced in either case (see Final Reports 1648 sub-topic).

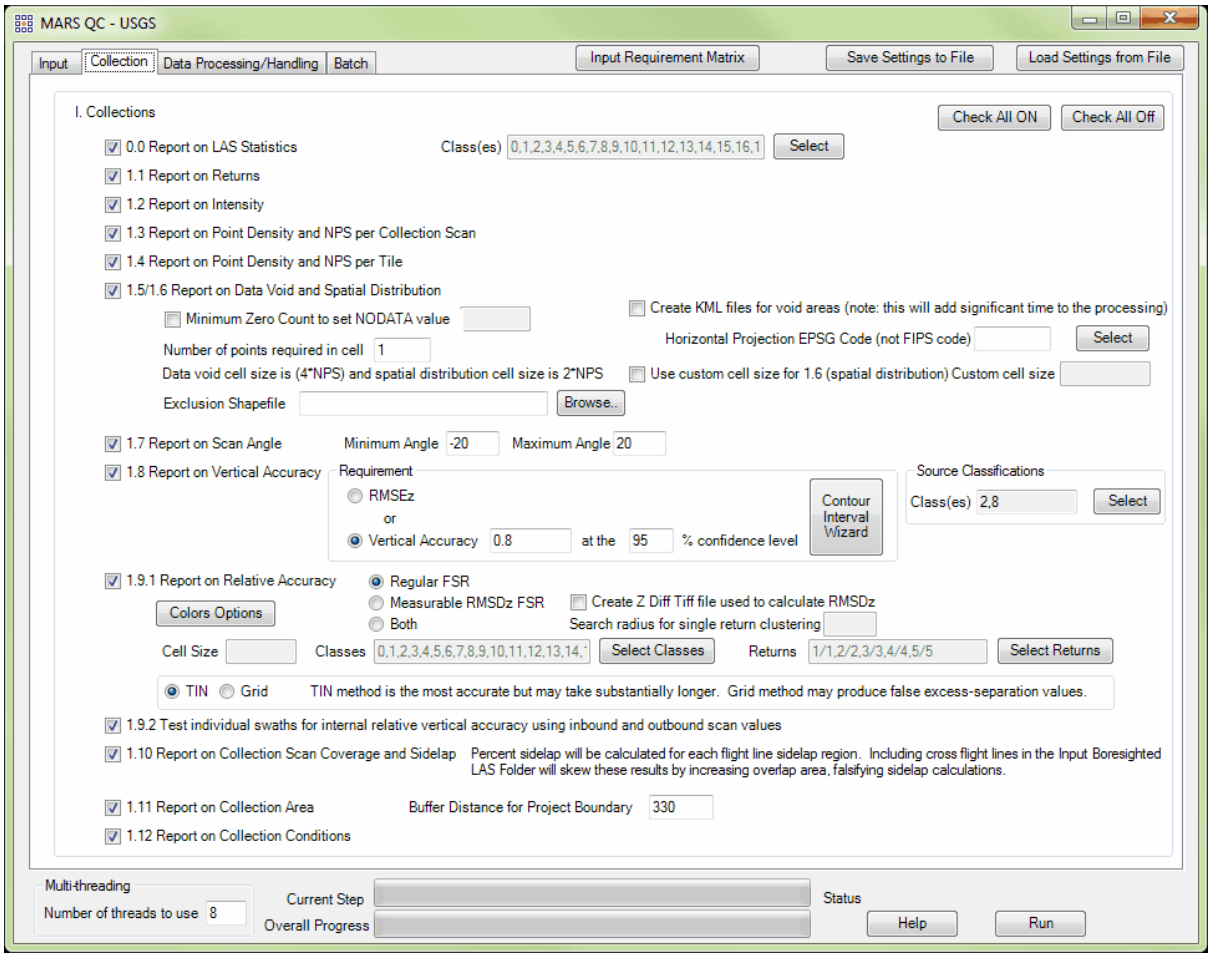
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6.2.10.3 Collection Tab

USGS 1.0 QC Module - Collection Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Check boxes and options for tests **0.0** through **1.12** are located on this tab. By default, all tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 1.0 in which they are referenced.

0.0 Report on LAS Statistics

The purpose of this section is to show detailed LAS statistics that MARS typically reports on but are not entirely covered by the USGS NGP Lidar Base Specification Version 1.0. A user may find this useful by inspecting the values for expected ranges, values, etc., and looking for outliers that would indicate an acquisition or processing error. This test is run on the **Classified**

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LAS (tiled) data.

By default all classes are selected, but the option exists to choose specific classes by clicking the 'Select' button.

1.1 Report on Returns

The purpose of this section is to report on the presence and quantities of LiDAR returns in the LAS swath data. Empty return columns can indicate a collection or processing problem dealing with LiDAR return attribute information. The test is divided into 'Swath Data' and 'Tiled Data' sections.

1.2 Report on Intensity

The purpose of this section is to report on the presence and values of LiDAR intensity in the LAS swath data. It is important to understand that 8-bit intensity LiDAR systems have a valid intensity range from 0-255, and 12-bit intensity LiDAR systems have a valid intensity range from 0-4095. The test is divided into 'Swath Data' and 'Tiled Data' sections.

1.3 Report on Point Density and NPS per Collection Scan

The purpose of this section is to report on the LiDAR point density and nominal point spacing by swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported. This test is run on the **Boresighted LAS** (swath) data.

1.4 Report on Point Density and NPS per Tile

The purpose of this section is to report on the LiDAR point density and nominal point spacing by tiled file. Point densities and NPS by tile are calculated by including any overlapping swath data within each tile. These statistics are for tiled LAS files. Not all LAS files fill tiles completely,

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especially along project boundaries. This may skew the calculated density and NPS values for partially filled tiles. This test is run on the **Classified LAS** (tiled) data.

1.5 Report on Data Void

The purpose of this section is to show graphically where possible LiDAR data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, LiDAR occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of LiDAR data voids - a lack of coverage at the time of collection. A close inspection must be done on the results to determine if the LiDAR coverage was collected and processed to meet the intended specifications. This test is run on the **Boresighted LAS** (swath) data and is combined with test **1.6** due to their related nature and similar testing options.

There are several options that can be set or modified for this test. The 'Minimum Zero Count to set NODATA value' checkbox and entry box will allow the user to specify a quantity of adjacent empty cells that can exist before the cells are designated as 'NODATA' rather than void of data. Cells marked as void in areas where no data is expected will skew the results. For example, assume a nominal pulse spacing of 2.5 feet, which will use a 10 foot cell size (10 x 10) for this test due to the USGS specification that the raster cells be 4 times (4x) NPS. If the project area is covered by ponds that are a minimum of 500 square feet in area (for example), it is likely that many cells will have no points. Since water typically absorbs laser energy, there is no expectation that returns will be collected for these ponds. Therefore, rather than have possibly dozens or hundreds of cells marked void that should not be part of the results, a Minimum Zero Count of '5' could be entered for this option which will result in all empty cells in adjacent groupings of 5 or more being marked as 'NODATA' and omitted from the final results. If a

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polygon shapefile exists for these water bodies (or any type of known exclusion areas), an even better method is to browse to it using the 'Exclusion Shapefile' option. Cells that fall wholly or partially within the polygon boundaries will be designated as 'NODATA'. The minimum 'Number of points required in cell' to meet the USGS specification is 1, the default, but this can be changed for other needs.

A KML file can be created of void areas to be used with Google Earth[1] to investigate the voids. This requires that the 'Horizontal Projection EPSG Code' of the data be known. When the data has this information defined, it will be stored in the files and the EPSG Code box will be populated accordingly. If the data is undefined but the horizontal projection system is known, the EPSG Code can be found by clicking the 'Select' button to the right of the entry box and searching the Coordinate System Datasource. For example, the EPSG Code for 'NAD83 (HARN) / Colorado Central' State Plane Zone in U.S. Survey Feet is '2877'.

1.6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable LiDAR spatial distributions are located. LiDAR spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, LiDAR occlusions caused by objects above ground like tall buildings, etc. Not all LiDAR spatial distribution violations are truly problematic. The intention of this test is to isolate the first example of LiDAR spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the LiDAR spatial distribution was collected and processed to meet the intended specifications. This test is run on the **Boresighted LAS** (swath) data and is combined with test **1.5** due to their related nature and similar testing options.

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The same options used for test **1.5 Report on Data Voids** are available for this test, plus one additional option. The cell size used for the Spatial Distribution grid may be modified from the USGS specification of 2 times (2x) the NPS by checking the box labeled 'Use custom cell size for 1.6' and entering a value in the 'Custom cell size' entry box. Be aware that any deviation from the 2 times NPS value will make this test non-compliant with the USGS specification.

1.7 Report on Scan Angle

The purpose of this section is to show graphically where the LiDAR scan angle exceeds the specified limitation, measured in degrees on either side of nadir (+/- angles with respect to 0 degrees where 0 degrees is straight down or plumb). This test is run on the **Boresighted LAS** (swath) data.

By default the Minimum and Maximum Angles are set to -20 and 20 (respectively) based on the USGS specification, but other values may be entered in the text boxes.

1.8 Report on Vertical Accuracy

The purpose of this section is to report on the fundamental vertical accuracy of the LiDAR data measured against surveyed ground check points. This reports only the Fundamental Vertical Accuracy (FVA). This test is run on the **Classified LAS** (tiled) data.

This test is similar to the 'Vertical Accuracy' (RMSEz testing) analysis method available in the Check Point Report 1224 that can be run independently from the QA/QC Tab 458. If available, **Classified LAS** (tiled) data is used to compare to the check points - otherwise, the test will use **Boresighted LAS** (swath) data. The accuracy Requirement defaults to a Vertical Accuracy of '0.8' (achievable contour interval) at the 95% confidence level. Remember that the achievable contour interval value is in the 'Reporting Horizontal Units', as defined on the Input

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Tab[1630]. The 'Source Classifications' default to 'Class(es)' 2 (Ground) and 8 (Model Key-points), but if **Classified LAS** (tiled) data is not available this should be set to All classes.

1.9.1 Report on Relative Accuracy

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. If there is no flight line overlap, the raster is displayed as grayscale intensity alone. When either the 'Measurable RMSDz FSR' or 'Both' option is selected, the relative accuracy RMSDz values are reported in a table following the Measurable raster in the final PDF report. This test is run on the **Boresighted LAS** (swath) data.

This test is nearly identical to the 'Flightline Separation - JPEG 2000' export type and most details about the various settings can be found in the Flightline Separation - JPEG 2000[668] sub-topic of the 'Export Type tab' topic (lower half of page) and the Grid tab[783] sub-topic of the 'Export Type tab' topic (paragraph 3, **Color by Collection Scan Separation**). This area of the Help Topics[538] file is found under the MARS® Tools[540] | Data Export[658] section.

As implemented in the QC Module, however, there are a few minor differences. In addition to the option of choosing either a 'Regular FSR' or a 'Measurable RMSDz FSR' (described here[668]), both FSR types can be created for this test. When either the 'Measurable RMSDz FSR' or 'Both' option is chosen, the 'Search radius for single return clustering' value will be automatically set to 10 times the 'Required NPS' value as entered on the 'Input' tab. This value can be changed if necessary. The 'Cell Size' will be automatically calculated at 3 times (3x) the NPS value entered on the Input Tab[1630] for best results, but can be modified. All 'Classes' are

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selected by default since the test is run on **Boresighted LAS** (swath) data, but the 'Select Classes' button can be used to make changes. Also, only last returns are selected by default to comply with the USGS specification, but the 'Select Returns' button can be used to make changes. Testing will be done by creating a virtual TIN by default, but a Grid option is available (note the disclaimer to the right of the radio buttons).

1.9.2 Test individual swaths for internal relative vertical accuracy using inbound and outbound scan values

The purpose of this section is to show a graphic of the relative vertical accuracy within each flight line, individually. This is done by comparing the inbound and outbound scan lines to each other as two separate surfaces and then generating a vertical separation raster from their TIN deltas. This is displayed by thematically coloring the separation magnitude on a color ramp based on absolute distance. Good LiDAR data should have a consistent green coloration across the flight line (perpendicular to flight), ignoring warmer colorations due to above ground surface features. Small color variations are to be expected. The purpose of this test is to find problematic data indicated by warming color variation trends away from the center of the scan line. Flight lines that have inconsistent colorations from the center towards the edges of the flight line would highlight the possibility of a sensor or internal calibration problem, usually an incorrect encoder latency value. Note: data from sensors that do not store differentiating Scan Direction values cannot be used to create rasters for this test (current Riegl airborne sensors are an example of this). An explanation of the absence of rasters will be listed in the PDF report for this test section. This test is run on the **Boresighted LAS** (swath) data.

1.10 Report on Collection Scan Coverage and Sidelap

The purpose of this section is to show flight line overlap (including sidelap). Lack of flight line overlap would be displayed as black polygons or slivers between flight lines. This test is run on

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the **Boresighted LAS** (swath) data.

1.11 Report on Collection Area

The purpose of this section is to show LiDAR coverage to the extent of a 100 meter buffer of the project boundary. This test is run on the **Boresighted LAS** (swath) data.

By default the 'Buffer Distance for Project Boundary' value is set to 330 ('Reporting Horizontal Units' in US Survey Feet or International Feet on the Input Tab[1630]), or to 100 ('Reporting Horizontal Units' in Meters on the Input Tab[1630]), to comply with the USGS 100 meter specification, but other values can be entered in the text box.

1.12 Report on Collection Conditions

The purpose of this section is to provide a hyperlink to a NOAA website that shows the snow depth map (by default) for the extent of the LiDAR collection at the time of acquisition. *Note: Other collection condition requirements are also listed in the USGS specification but may not be available to view with this reporting tool.*

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

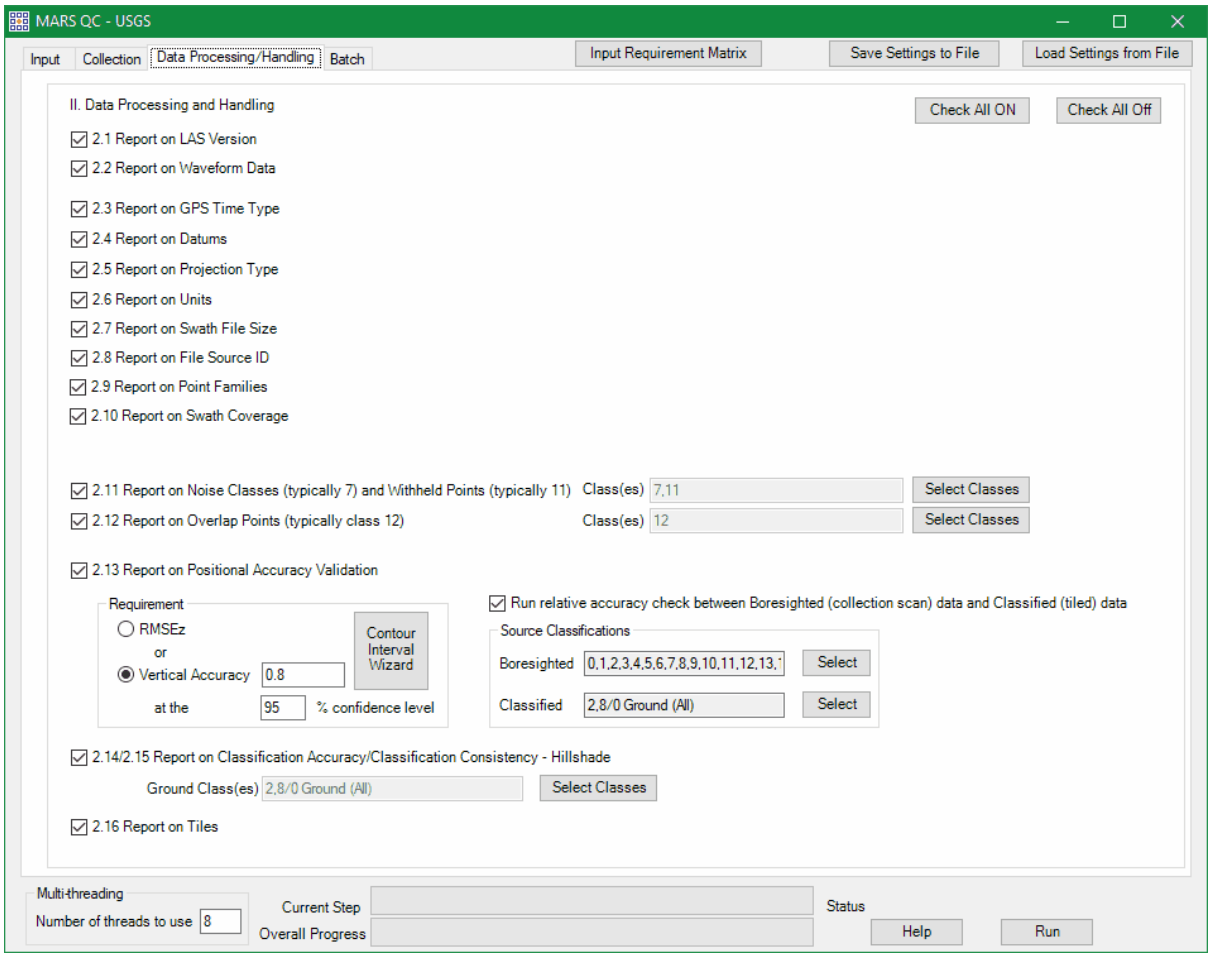
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6.2.10.4 Data Processing/Handling Tab

USGS 1.0 QC Module - Data Processing/Handling Tab

Merrick Advanced Remote Sensing (MARS®) Software

The Data Processing / Handling Tab



Check boxes and options for tests **2.1** through **2.16** are located on this tab. By default, all tests are

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checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Tests are generally named for the section and paragraph in the USGS NGP Lidar Base Specification Version 1.0 in which they are referenced.

2.1 Report on LAS Format

The purpose of this section is to show the LAS version for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.2 Report on Waveform Data

The purpose of this section is to show the presence of waveform data for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.3 Report on GPS Time Type

The purpose of this section is to show the GPS time type within the LAS files for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.4 Report on Datums

The purpose of this section is to show the datums of the LAS files for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.5 Report on Projection Type

The purpose of this section is to show the projections of the LAS files for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.6 Report on Units

The purpose of this section is to show the horizontal and vertical units of the LAS files for the

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LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.7 Report on Swath File Size

The purpose of this section is to show the files sizes of the LAS files for the LiDAR data. This test is run on the **Swath LAS** data.

2.8 Report on File Source ID

The purpose of this section is to report on the File Source ID and Point Source ID values for the LiDAR data. Note that sub-swaths of original swaths (created for Test 2.7 compliance) may violate the unique values specification described in this test. This test is run on the **Boresighted LAS** (swath) data.

2.9 Report on Point Families

The purpose of this section is to report on the presence and integrity of point families for the LiDAR data. The test is divided into 'Swath Data' and 'Tiled Data' sections.

2.10 Report on Swath Coverage

The purpose of this section is to show the presence and extent of all LiDAR data files. This test is run on the **Boresighted LAS** (swath) data.

2.11 Report on Noise Classes and Withheld Points

The purpose of this section is to list the presence and quantities of noise and withheld points for all LiDAR data files. The test is divided into 'Swath Data' and 'Tiled Data' sections.

By default the classes for Noise and Withheld points are 7 and 11, respectively, as they are typically used for these purposes in LAS v1.0 through v1.3 files, but other classes can be

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selected.

2.12 Report on Overlap Points

The purpose of this section is to list the presence and quantities of overlap and unclassified points for all LiDAR swath data files. The test is divided into 'Swath Data' and 'Tiled Data' sections.

By default the class for Overlap points is 12, as it is typically used for this purpose in LAS v1.0 through v1.3 files, but another class(es) can be selected.

2.13 Report on Positional Accuracy Validation

The purpose of this section is to compare the fundamental vertical accuracy of the LiDAR swath data and the tiled data measured against surveyed ground check points. The reason for this comparison is to ensure that inappropriate steps were not taken after the filtering process to "warp" the tiled LiDAR data to check points. The check point statistics of each dataset should look very similar, with only constant offsets as differences or variations due to the filtering process. The test is run as a comparison of the 'Swath Data' and 'Tiled Data'.

The accuracy requirement defaults to a Vertical Accuracy of '0.8' (achievable contour interval) at the 95% confidence level, but other options are available (see the Check Point Report 1236 Help Topic and its Inputs Section 1244 sub-topic). Remember that the achievable contour interval value is in the 'Reporting Horizontal Units', as defined on the Input Tab 1630. An option to create a separation raster (JPEG 2000) between the Boresighted and Classified Data - 'Run relative accuracy check ...' - is checked on by default. This will be reported as **2.13.2** in the final reports. By default the classes to be used in the tabular phase of the testing (2.13.1) are 'All' for the Boresighted Data since it is usually not classified, and 2 (Ground) and 8 (Model Key-points) for

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the Classified Data, but other classes can be selected. All classes of the 'Classified' data are automatically used for the relative accuracy raster to make it easier to interpret.

2.14 Report on Classification Accuracy - Hillshade

The purpose of this section is to overlay a 1km x 1km tile scheme over the bare earth surface hillshade product to use for ground filter QC inspections. This test is run on the **Classified LAS** (tiled) data and is combined with test **2.15** due to their related nature and identical class selection options.

By default the classes for ground points are 2 (Ground) and 8 (Model Key-points), as they are typically used for these purposes in LAS v1.0 through v1.3 files, but another class(es) can be selected.

.

2.15 Report on Classification Consistency - Hillshade

The purpose of this section is to show the bare earth surface hillshade product for classification consistency inspection. This test is run on the **Classified LAS** (tiled) data and is combined with test **2.14** due to their related nature and identical class selection options.

By default the classes for ground points are 2 (Ground) and 8 (Model Key-points), as they are typically used for these purposes in LAS v1.0 through v1.3 files, but another class(es) can be selected.

2.16 Report on Tiles

The purpose of this section is to report on the unallowed presence of skew and/or polygon overlap in the project tile scheme. This test is run on the **Tile Scheme** selected on the Input Tab 1630.

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6.2.10.5 Batch Tab



The Batch Tab

This tab has not been implemented.

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6.2.10.6 Final Reports



QC Reporting

The output of the USGS 1.0 QC Module is written to two (2) PDF files – detailed and summary - that contain the results of the point cloud, check points, and tile scheme analysis. The reports will be named using the entry in the **Output PDF File Name** box on the Input Tab. The default name is 'QC_1_0_All' but can be changed before running the module. 'Summary_' will be appended to the

summary report file name. Both reports can be found in the **Output Folder** that was chosen on the Input Tab 1630. Once processing is complete, the detailed report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for each of the 30 tests that can be run. If any tests were unchecked by the user, a listing of **Skipped Tests** will be appended to the end of both PDF reports followed by a printout of the **Input Requirement Matrix** (see ***Input Datasets*** in the General Information 1623 topic).

In addition to the two PDF reports of the point cloud, check points, and tile scheme analysis, the USGS 1.0 QC Module will also generate several raster images (JPEG and JPEG 2000 format), shapefiles, and optional KML files that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final reports. These sub-folders can be deleted if no longer needed after the module has completed and the final PDFs are generated.

Sample Report Pages:

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1.3 Report on Point Density and Nominal Pulse Spacing (NPS) (Swath Data)

The USGS LiDAR Base Specification Version 1.0 states: "An NPS of 2 meters or less is required. Dependent on the local terrain and land cover conditions in the project area, a greater point density may be required on specific projects. Assessment of the NPS will be made against single swath, first-return only data, located within the geometrically usable center portion (typically 90 percent) of each swath, acceptable data voids excluded. NPS will be calculated as the square root of the average area per point. Average along-track and cross-track point spacing should be comparable (within 10 percent)."

The purpose of this section is to report on the LiDAR point density and nominal point spacing by swath file. Averages by swath files (not including overlap), project boundary polygons (including swath overlap), and aggregate project boundary polygons (including swath overlap) are reported.

Boresighted Files - D:\MARS\QC_Mod_test_data\Denver_Sample_Data\01_Boresight_1.0_p1

Units: US Survey Feet

File	Number of First Returns	Area of Swath	Point Density	NPS
LDR031002_180130_1.LAS	2,157,059	18,491,136	0.117/1.259	2.928/0.892
LDR031002_180615_1.LAS	1,967,821	18,695,936	0.105/1.130	3.082/0.939
LDR031002_181124_1.LAS	2,101,106	19,158,528	0.110/1.184	3.020/0.920
LDR031002_181630_1.LAS	1,904,356	17,895,232	0.106/1.141	3.065/0.934
LDR031002_183237_1.LAS	2,287,291	20,271,232	0.113/1.216	2.977/0.907
LDR031002_183709_1.LAS	2,022,585	18,948,288	0.107/1.152	3.061/0.933
Average			0.109/1.173	3.022/0.921
			pp Square US Survey Feet/ pp Square Meter	US Survey Feet/ Meter
0	2,825,365	14,350,260	0.197/2.120	2.254/0.687
Aggregate	2,825,365	14,350,260	0.197/2.120	2.254/0.687
			pp Square US Survey Feet/ pp Square Meter	US Survey Feet/ Meter

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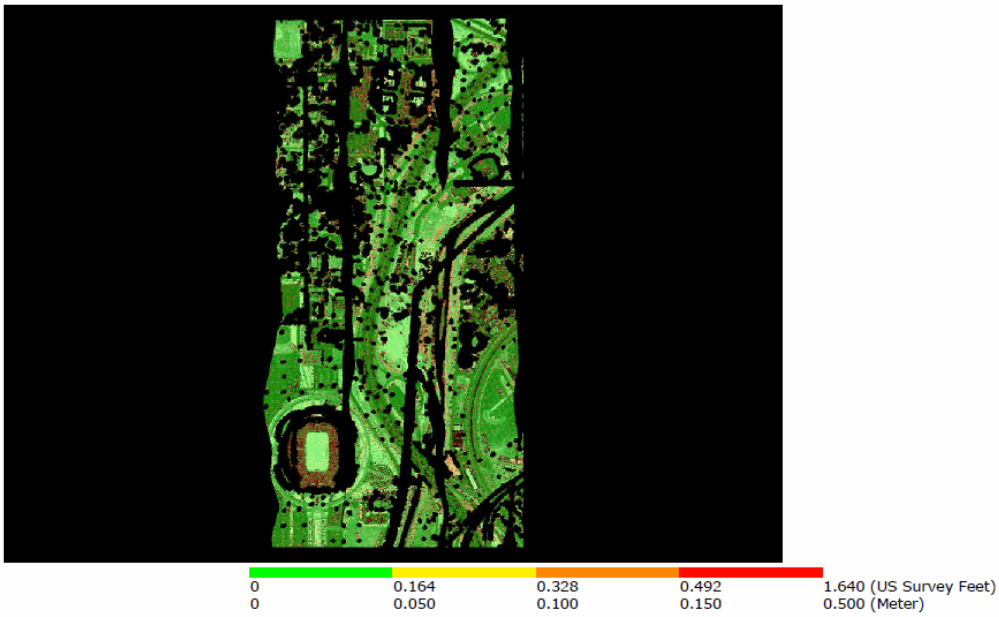
QC Module Sample Report LiDAR QA/QC Report

1.9.1 Report on Flight Line Separation (Relative Accuracy) per Project (Measurable)

The USGS LiDAR Base Specification Version 1.0 states that: "Relative accuracy within overlap between adjacent swaths:<=10 cm RMSDz"

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. If there is no flight line overlap, the raster is displayed as grayscale intensity alone. The relative accuracy RMSDz values are reported on the following page(s).

Data Source - D:\MARS\QC_Mod_test_data\Denver_Sample_Data\01_Boresight_1.0_p1
D:\Temp\1_9_1\Boresighted_FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.164	0.328	0.492	1.640 (US Survey Feet)
0	0.050	0.100	0.150	0.500 (Meter)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between flight lines (e.g., trees, moving cars, etc.). This can be modified in the Color Options settings window.

04/06/2016 This report has been automatically generated by Merrick's MARS® QC Module build 8198.34 Page 29 of 72

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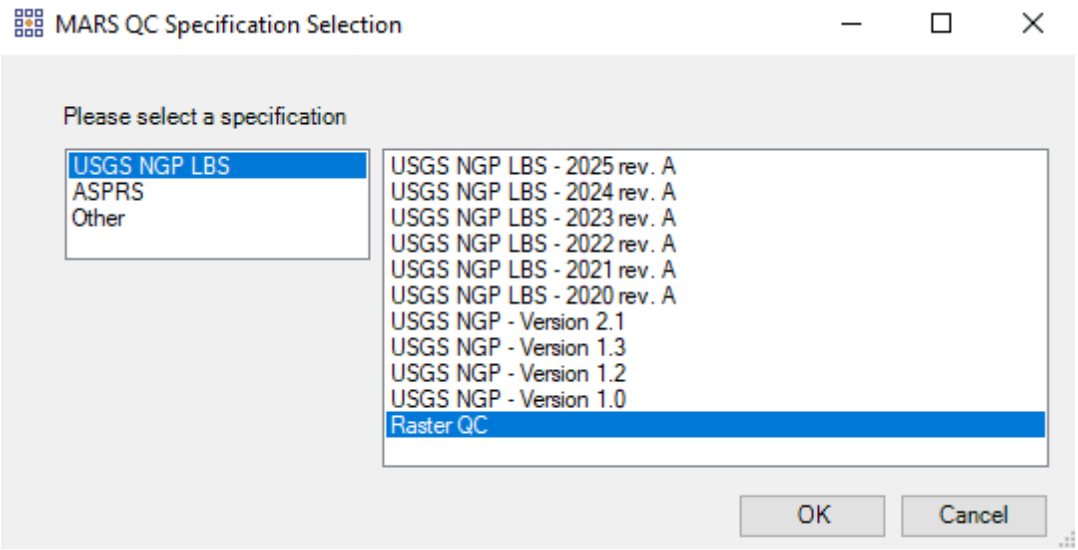
6.2.11 Raster QC

Raster QC

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab458, the 'Raster QC' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



Description and Purpose

The purpose of the Raster QC tool is to provide an automated tool for verifying the format, structure, and contents of DEM (Digital Elevation Model), MSHR (Maximum Surface Height Raster), and Intensity rasters. All rasters are expected to be in GeoTIFF format. Any combination of the three types of rasters (stored in separate folders) can be tested in a single session. In addition, testing of water body flatness can be done if polygonal 3D breaklines are included with the inputs. See the ***Inputs*** section below for more details.

The output of this tool is a report in TXT format and one or more attributed tile-based shapefiles for each of the input raster datasets. Each output shapefile will be an enhanced copy of the input Tile Scheme shapefile (described below) with attributes populated specific to the dataset it represents. Individual tile point shapefiles will be generated for any tile(s) where the raster contains one or more NODATA cells.

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See the ***Output*** section below for more details.

Inputs

A minimum of one of the three possible raster types must be selected to run the tool. Each raster type must be in a different folder (any sub-folders are ignored), and must adhere to a specific naming format with a '.tif' extension. For the DEMs, the file names must begin with 'DEM_'; for MSHRs, the names must begin with 'MSHR_'; for Intensity rasters, the names must begin with 'INT_'. For example, one tile's rasters might be named 'DEM_111ABC.tif, 'MSHR_111ABC.tif', and 'INT_111ABC.tif'.

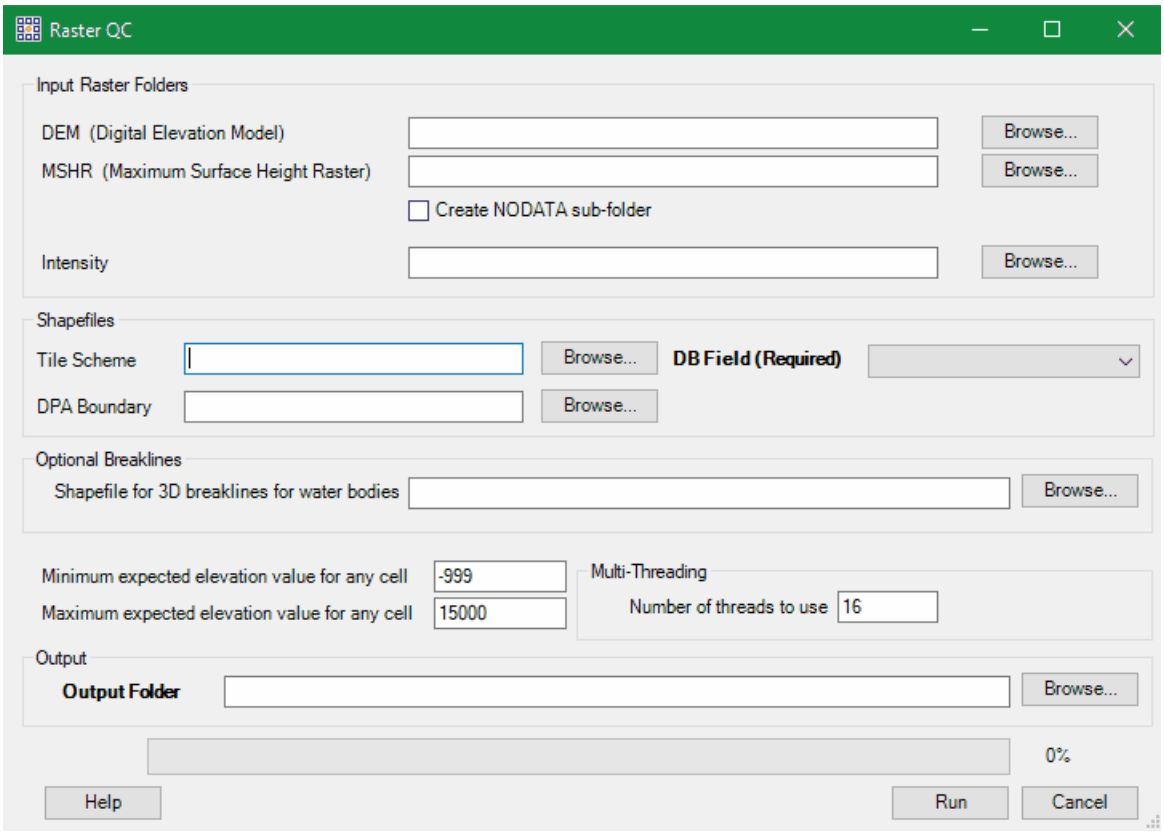
In addition, a Tile Scheme and a DPA (Defined Project Boundary), both in polygon shapefile format, must be supplied. The Tile Scheme must contain an attribute that is populated with the unique names of the rasters. For example, if the DEM rasters are named 'DEM_111ABC.tif', 'DEM_222ABC.tif', 'DEM_333ABC.tif', etc., there must be an attribute populated with '111ABC', '222ABC', '333ABC', etc. There should be a one-to-one correlation between the Tile Scheme shapefile and the raster files in each input dataset. In other words, if the Tile Scheme contains 657 uniquely named tile features, there must be 657 matching rasters for each dataset that will be tested.

For the Optional Breaklines testing, the format must be a 3D, polygonal shapefile (Polygon Z or Polygon ZM).

***Note** that the reserved XML characters **<, >, %, &, ', "** cannot be used as part of a folder path or as part of the name of any input shapefile.*

Note also that all input rasters and shapefiles (including optional breaklines) must be in the same coordinate reference system.

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Usage

At least one type of supported raster must be supplied in the 'Input Raster Folders' section of the tool interface. Use the 'Browse...' buttons to the right of each raster type to navigate to and select a folder containing the rasters to be tested. Use the 'Browse...' buttons to the right of the 'Tile Scheme' and 'DPA Boundary' entry boxes in the 'Shapefiles' section to select those required shapefiles. Select the attribute field that contains the unique raster file names in the Tile Scheme shapefile using the '**DB Field (Required)**' drop-down list. Use the 'Browse...' button to the right of the 'Shapefile for 3D breaklines for water bodies' entry box to include water body breaklines for the optional raster flatness testing.

Minimum and Maximum elevation values for any cell are pre-populated with '-999' and '15000' respectively, but these can be changed as needed for each project. MARS® is unit-less, so use values

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that make sense for the project area and coordinate system units. These values will be used to flag possible problem elevations in the final reports.

Finally, select an Output Folder for the final text file reports and shapefiles using the 'Browse...' button to the right of the entry box.

When all needed entries have been made, click the 'Run' button to begin the processing - a progress bar is located directly above this button. A 'Report Completed' message will appear when the tool is finished.

Output

In the selected Output Folder, one text file report will be generated for each of the tested datasets. For the DEM dataset, this final report will be named 'DEM_report.txt'. The MSHR and Intensity reports will be named accordingly. Folders will also be created in the output folder for each of the raster types, and a NODATA sub-folder will be created under each of these (for MSHR, the 'Create NODATA sub-folder' box must be checked). In other words, in the main Output Folder there will be a 'DEM' folder with a 'DEM_NODATA' sub-folder. The DEM_NODATA sub-folder will contain individual point shapefiles for any tiles whose associated rasters ('DEM_<*tilename*>.tif') have one or more cells populated as NODATA, with a point placed at the center of each NODATA cell. This same folder structure will be created for the MSHR and Intensity rasters with corresponding naming.

For the DEM dataset only, an additional sub-folder named 'Non_Flat_points' will be created if a 'Shapefile for 3D breaklines for water bodies' has been supplied. This sub-folder will store a point shapefile for each tile that contains one or more locations where the Z-values of the breakline vertices differ from the cell's value covering that vertex. Additionally, elevation corrections are automatically made to the DEM rasters (when possible), and any corrected rasters will be stored in a new sub-folder named

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'Raster_QC_tool_corrections' in the path of the original input DEM rasters. The original rasters are not altered.

For the report files, the format will look similar to the following sample (from a DEM report):

```
File Format:
        Valid COG: 2

-----------------------------------------------
Compression Type:
        LZW: 2

-----------------------------------------------
Pixel Type:
        GDT_Float32: 2

-----------------------------------------------
Ground Grid Cell Size:
        1.0000Meter,1.0000Meter: 2

-----------------------------------------------
Rows and Columns:
        1000,1000: 2
```

Each section will list the name of the value being tested, with the next line(s) showing the actual value and the raster file count. For example, in the above sample report the first section is reporting on File Format. The only value found is 'Valid COG' (meaning Cloud Optimized GeoTIFF) and both DEM rasters in the input dataset have that value. For the final section displayed in the sample, both rasters have 1000 Rows and 1000 Columns.

The reported values for **DEM** rasters are: File Format, Compression Type, Pixel Type, Ground Grid Cell Size, Rows and Columns, Compound Spatial Reference System, Horizontal Reference System EPSG, Vertical Reference System EPSG, Horizontal Datum and EPSG, Horizontal Spatial Reference Units, Vertical Datum and EPSG, Vertical Spatial Reference Units, NODATA Values Set/Not Set in Headers, NODATA Values Found in Header, Suspect Values Found Below <*min elev set by user*>, Suspect Values Found Above <*max elev set by user*>, Minimum Elevation Value for the Project, Maximum

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Elevation Value for the Project, and Non-flat Water Body Breaklines.

The reported values for **MSHR** rasters are: File Format, Compression Type, Pixel Type, Ground Grid Cell Size, Rows and Columns, Compound Spatial Reference System, Horizontal Reference System EPSG, Vertical Reference System EPSG, Horizontal Datum and EPSG, Horizontal Spatial Reference Units, Vertical Datum and EPSG, Vertical Spatial Reference Units, NODATA Values Set/Not Set in Headers, NODATA Values Found in Header, Suspect Values Found Below <*min elev set by user*>, Suspect Values Found Above <*max elev set by user*>, Minimum Elevation Value for the Project, and Maximum Elevation Value for the Project.

The reported values for **Intensity** rasters are: File Format, Compression Type, Pixel Type, Ground Grid Cell Size, Rows and Columns, Projected Spatial Reference System and EPSG, Horizontal Datum and EPSG, Horizontal Spatial Reference Units, NODATA Values Set/Not Set in Headers, NODATA Values Found in Header, Minimum Intensity Value for the Project, and Maximum Intensity Value for the Project.
~~~~~~~~~~~~~~~~~~~~

In addition to the text file reports, an enhanced version of the input Tile Scheme shapefile will be generated for each tested dataset. These project-wide shapefiles will also be stored in the selected Output Folder. For the DEM dataset, this shapefile will be named 'DEM_tile_layout.shp'. The MSHR and Intensity shapefiles will be named accordingly.

Each tile feature (record) in the shapefile will be attributed with the values from the report, and the attribute fields will be in the same order as the corresponding sections of the report.

The attributes (limited to 10 character field names) for the **DEM** shapefile are: <*tile_name from input shapefile*>, File_Formt, Compr_Type, Pixel_Type, Grd_Cell_Sz, Rows_Cols, Compd_SRS, Proj_EPSG,

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~~~~~~~~~~~~~~~~~~~~

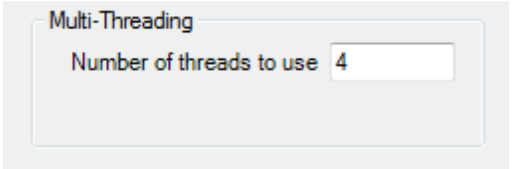
Vert_EPSG, Horz_Datum, Horz_Units, Vert_Datum, Vert_Units, NODATA_Sts, NODATA_Val, Susp_Lo_Z, Susp_Hi_Z, Min_Elev, Max_Elev, Diff_Elev, ZDiff_Err, and NODATA_YN. If one or more non-flat DEM point shapefiles were generated, a lone attribute will be named ZDiff_Err.

The attributes (limited to 10 character field names) for the **MSHR** shapefile are: *<tile_name from input shapefile>*, File_Formt, Compr_Type, Pixel_Type, Grd_Cell_Sz, Rows_Cols, Compd_SRS, Proj_EPSG, Vert_EPSG, Horz_Datum, Horz_Units, Vert_Datum, Vert_Units, NODATA_Sts, NODATA_Val, Susp_Lo_Z, Susp_Hi_Z, Min_Elev, Max_Elev, Diff_Elev, ZDiff_Err, and NODATA_YN.

The attributes (limited to 10 character field names) for the **Intensity** shapefile are: *<tile_name from input shapefile>*, File_Formt, Compr_Type, Pixel_Type, Grd_Cell_Sz, Rows_Cols, Proj_SRS, Proj_EPSG, Horz_Datum, HDATM_EPSG, Horz_Units, NODATA_Sts, NODATA_Val, Min_Inten, Max_Inten, and NODATA_YN.

Multi-threading

A multi-threading option is available on the Raster QC tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. By default, the box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



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Licensing

The Raster QC tool is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

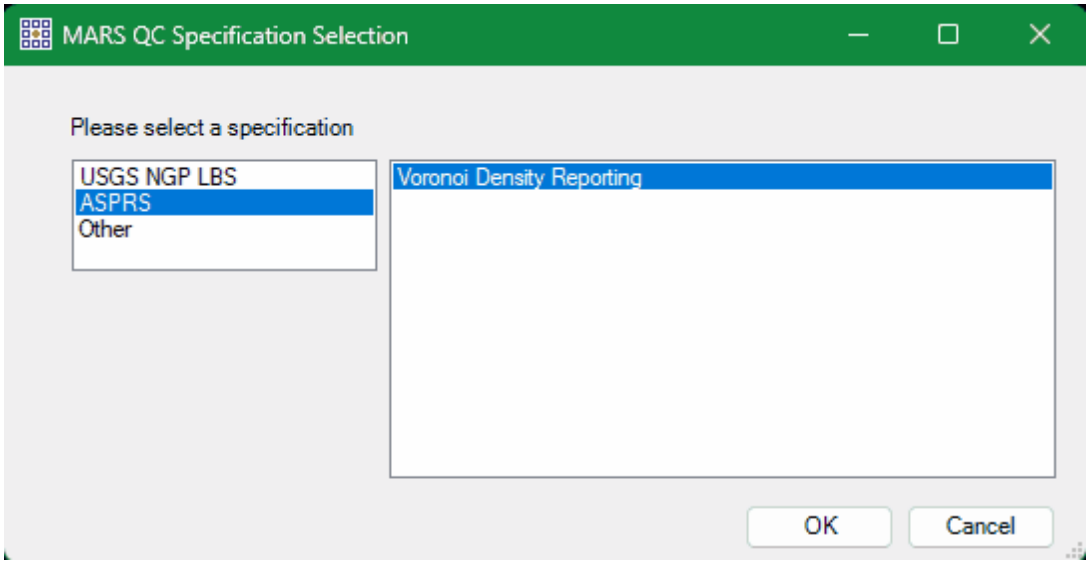
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6.3 QC Module - ASPRS



The following selection list window will appear after clicking the 'QC Module' button 

on the QA/QC Tab[458]. The list is divided into USGS NGP LBS, ASPRS, and Other sections.



See

Voronoi Density Reporting 1660

See Also

QC Module - USGS NGP LBS 1313

QC Module - Other 1675

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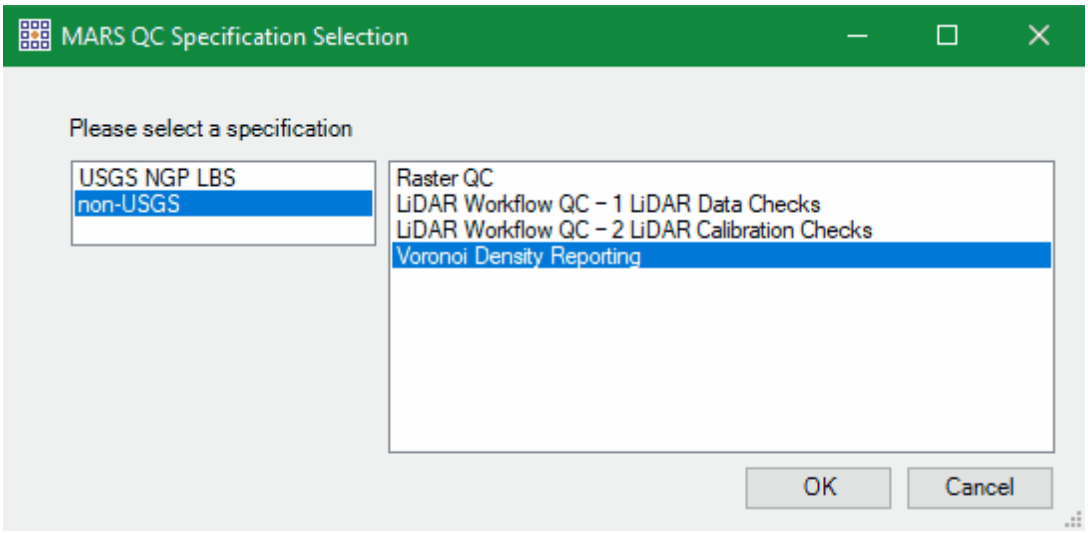
6.3.1 Voronoi Density Reporting

Voronoi Density Reporting

Merrick Advanced Remote Sensing (MARS®) Software

After clicking the QC Module button 

on the QA/QC Tab 458, the 'Voronoi Density Reporting' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



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6.3.1.1 General Information

Voronoi Density Reporting

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the Voronoi Density Reporting tool in the MARS® QC Module is to provide an accurate and unbiased method for reporting lidar point cloud density. In summary, this is done by first creating a TIN (triangulated irregular network) - a set of adjacent, non-overlapping triangles constructed from all the lidar points in the input dataset. The mid-point of each triangle leg is calculated, and non-overlapping polygons are generated by connecting those mid-points such that each polygon contains only one point and each point is contained by only one polygon. The area of each polygon is determined, and the

inverse of each area is stored as the density value.

The results of the point cloud density testing are contained in a PDF report, including a summary of the process, a frequency distribution chart with statistical information, and density and pass/fail assessment rasters. See the Final Reports[1671] sub-topic for more information.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2025 rev. A[1315], USGS 2024 rev. A[1351], USGS 2023 rev. A[1386], USGS 2022 rev. A[1421], USGS 2021 rev. A[1455], USGS 2020 rev. A[1490], USGS NGP - Version 2.1[1525], USGS NGP - Version 1.3[1559], USGS NGP - Version 1.2[1592], and USGS NGP - Version 1.0[1622] tools, and the LiDAR Data Checks[1677] and LiDAR Calibration Checks[1698] tools - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

A folder of Classified (final filtered) LAS data (typically as tiled files) is required to run the test. Additionally, a DPA Boundary (defined project area, as an Esri-compatible polygon shapefile) that includes a 100-meter (or equivalent in other units) buffer, and with at least one attribute field that contains unique values, can optionally be included to confine the testing and results to the project's boundary.

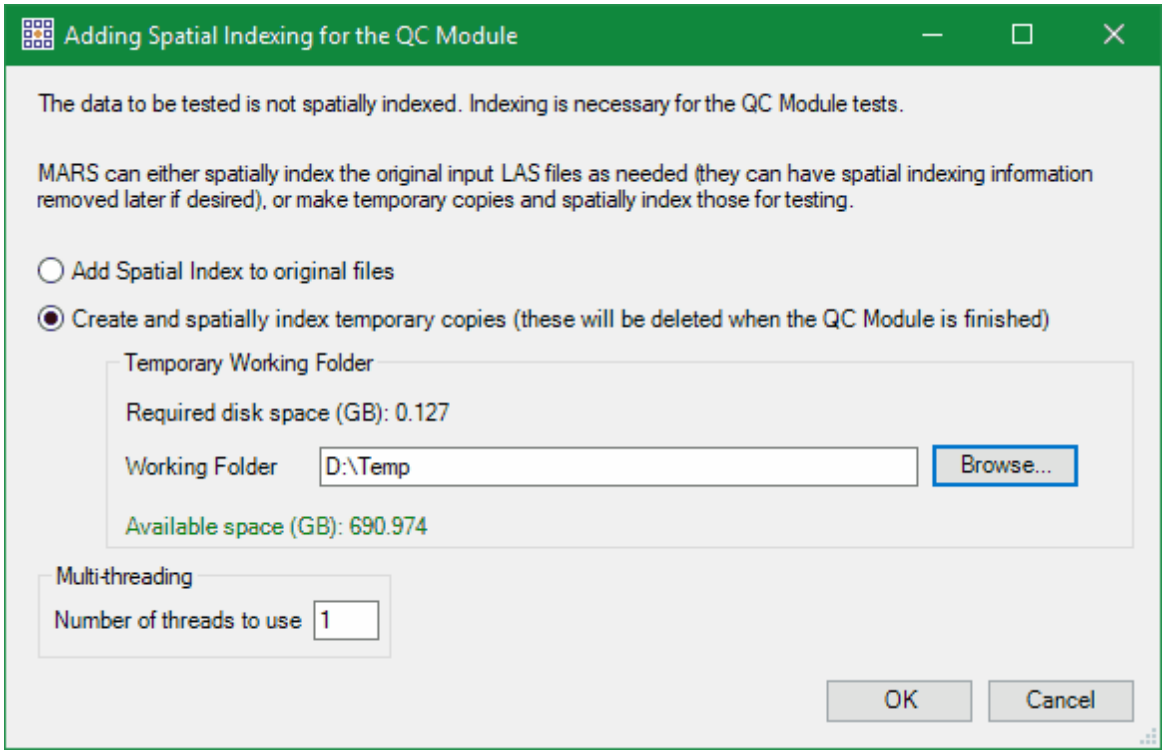
***Note** that the reserved XML characters **<**, **>**, **%**, **&**, **'**, **"** cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile.*

Classified (also referred to as tiled or delivery) Data Preparation

LAS data must be spatially indexed before it can be tested with the Voronoi Density Reporting tool, just

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as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Classified LAS Folder' (see Input Tab 1665) has not been through the 'Add Spatial Index' process, the following window will pop up to explain the options (see also Add Spatial Index 907). Multi-threading the Spatial Indexing functions across a USB 2.0 connection *is not recommended* as the intensive file reads/writes (disk I/O) may cause hangs or slower overall performance than single-threading. USB 3.0 or later can be used, but may be limited in performance depending on the access speed of the external drive.

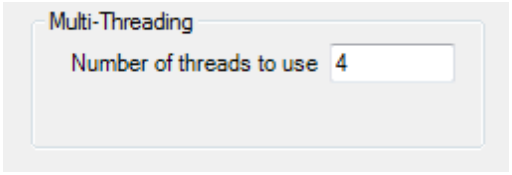


Multi-threading

A multi-threading option may be found on the Voronoi Density Reporting tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower

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number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

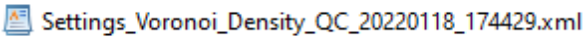


Input/Output Location Advisory

Use of an external USB-connected drive, including solid state drives (SSDs), is not recommended for either input or output data due to the high bandwidth used during Voronoi processing.

Settings Files

Every run of Voronoi Density Reporting in MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1665. Each unique *.xml file name will contain the date and time that the tool run was started as seen in the example below. For example, this particular run was started at 5:44:29 pm on January 18, 2022.



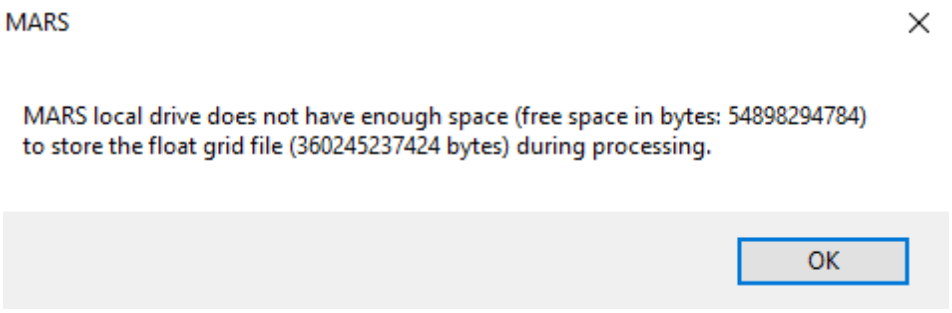
This file can be renamed as needed and loaded for future testing to cut down on data entry and ensure consistency between Voronoi Density Reporting runs. After opening the Voronoi Density Reporting interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on either of the the interface tabs can be changed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the Voronoi Density Reporting tool - make all the parameter entries on the two tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not be stored in the

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chosen **Output Folder** automatically like it is when the tool is actually run.

Storage Space Pre-Check

When the 'Run' button is clicked to begin the processing, a test is done to determine if there will be adequate space for the temporary local files that will be created. This is separate from the 'Save to Local Option' setting (see Input Tab 1665 section) that may be used to speed up processing when the output is being sent to a network path. If there is not enough space, a message will appear as shown below:



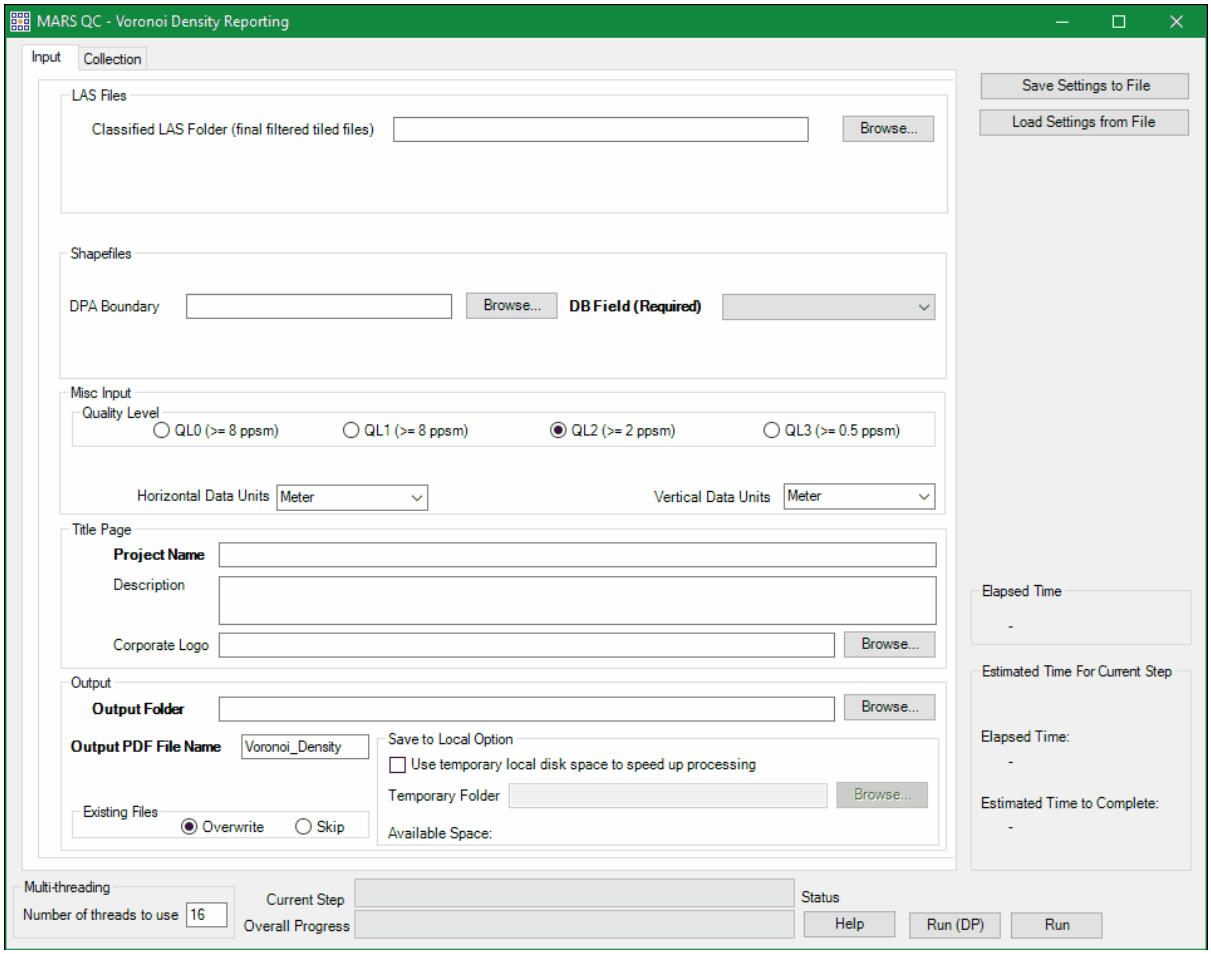
The choices to resolve this issue are to move the MARS® working folder to a local drive with sufficient space (see Options Tab 519 | Miscellaneous | Temp Folder), or run the process on a computer with more free space for the working folder.

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6.3.1.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final report, **Output Folder**, and **Output PDF File Name**. The Classified LAS (tiled) data must be included and a Quality Level (expected/required density) must be selected, along with a **Project Name**, **Output Folder**, and **Output PDF File Name**.

If a 'DPA Boundary' (Defined Project Area) shapefile is pathed out, a unique-value attribute field must be chosen (e.g., an 'Areaname' field). The attribute values for this shapefile is used for identifying the

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results of the test in the final report.

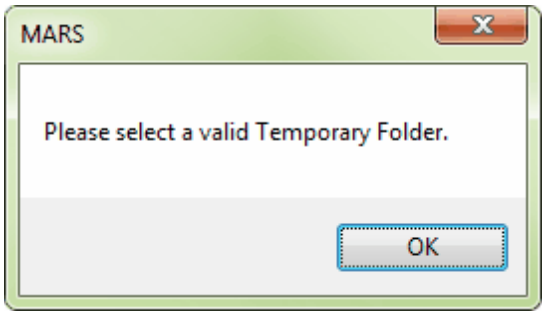
The 'Quality Level' section is taken from the levels defined by the USGS NGP Lidar Base Specification as a reference - by default, 'QL2 (>= 2 ppsm)' is selected. The selection made here determines the points per square meter (ppsm) density standard to be met (and the methodologies to be used) for the testing done in the Voronoi Density Reporting tool. Other densities can be entered by using the advanced options on the Collection Tab 1668.

Ensure that the 'Horizontal Data Units' and 'Vertical Data Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the test!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option - the 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established.

NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.

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NOTE that the use of an external USB-connected drive - including solid state drives (SSDs) - is not recommended for input/output, or as a temporary local disk space location due to the high data bandwidth used during Voronoi processing.

The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only a new final PDF report. Regardless of the option used, a PDF file of the results will be created as described in the Final Report 1671 help topic.

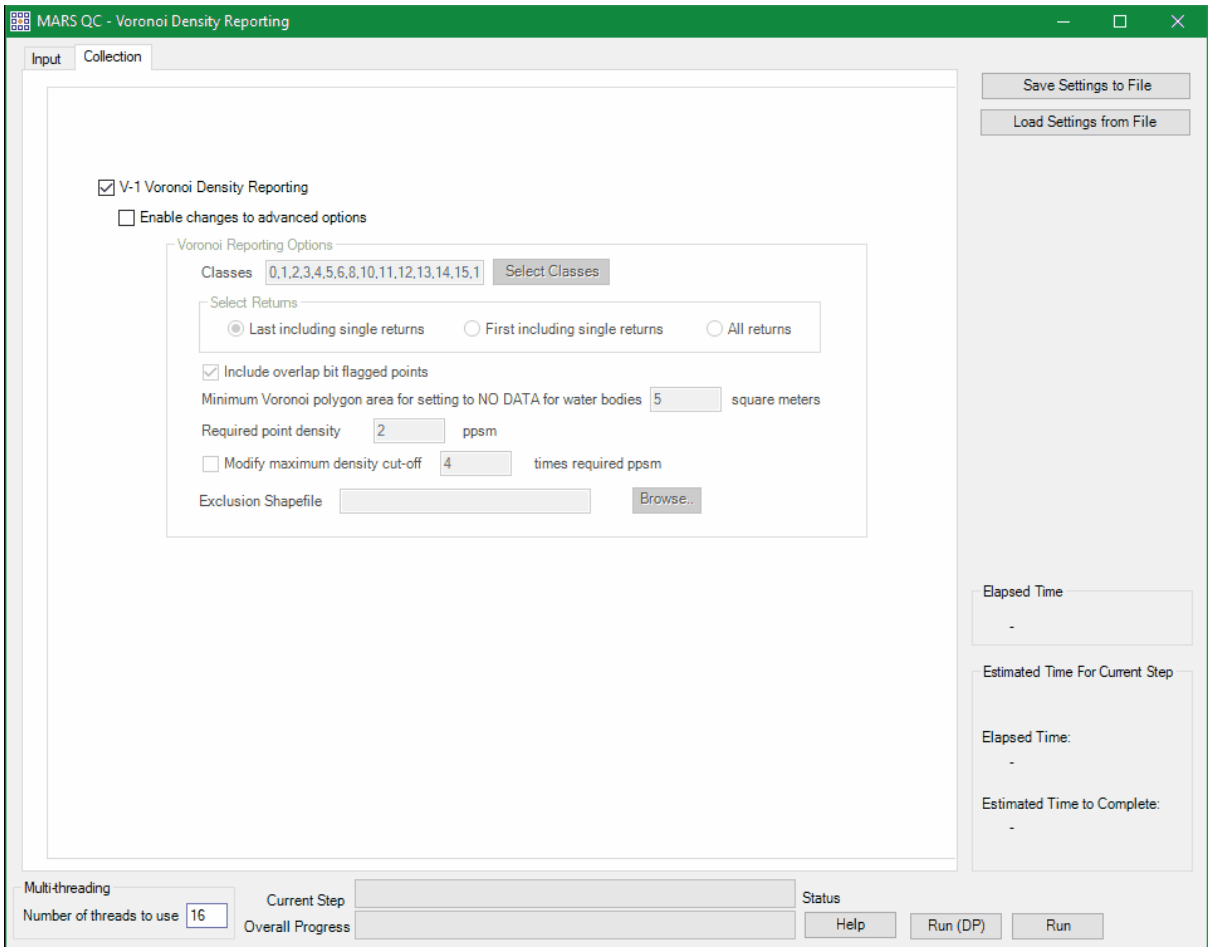
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6.3.1.3 Collection Tab

Voronoi Density Reporting

Merrick Advanced Remote Sensing (MARS®) Software

The Collection Tab



Options for test **V-1** are located on this tab. Make sure the box labeled 'V-1 Voronoi Density Reporting' remains checked.

If changes to any of the test's settings are needed, check the box labeled 'Enable changes to advanced options':

- '*Classes*' -- by default all classes are included in the density testing, but this can be modified by clicking the 'Select Classes' button and making the desired changes. Regardless of the classes selected, points that have the Withheld bit flag set will not be included in testing.

- *'Select Returns*' -- last returns (including single returns) will be used by default, but 'First

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including single returns' and 'All returns' are also available as options.

- '*Include overlap bit flagged points*' -- by default points with the Overlap bit flag set are included in testing, but can be ignored by unchecking the box. Omitting these points will produce a more accurate result of the density that a single swath can produce, but requires that overlap points be appropriately bit-flagged.

- '*Minimum Voronoi polygon area for setting to NO DATA for water bodies*' -- by default, Voronoi polygons that are five (5) square meters or larger in size (indicating areas of very low point density) will be set to 'NO DATA' (black) rather than colorized based on the actual density value. This minimum area can be edited as needed, and is applied even in the absence of a pathed-out 'Exclusion Shapefile' (see below). 'NO DATA' areas are not used to calculate density statistics and will not impact the 'pass/fail' raster results.

- '*Required point density*' -- the default value is 2 ppsm, but can be modified to test for any required density.

- '*Modify maximum density cut-off*' -- defaults to four (4) times the input ppsm (either from a selected QL on the Input Tab 1665 or as entered in the setting described above). Density values above this limit are aggregated into a single color band (white) in the 'V-1.2' raster.

- '*Exclusion Shapefile*' -- allows a polygon shapefile to be selected that will create an exclusion area in the dataset being tested, to avoid meaningless rasterized results in areas known to be low (or no) density. For example, a shapefile of water body outlines can be pathed out to avoid having those areas tested and reported on. The polygon areas will be set to 'NO DATA' (appearing as black in the raster) rather than being colored as red, orange, or yellow

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cells that might indicate a collection issue. 'NO DATA' areas are not used to calculate density statistics and will not impact the 'pass/fail' raster results.

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6.3.1.4 Final Report



Density Reporting

The output of this tool is written to a PDF file that contains the results of the point cloud density analysis. At the end of the report, a page titled 'Time Spent On Each Step' will be created to show processing times for the sub-sections of the test in tabular and chart formats.

The report will be named using the entry in the **Output PDF File Name** box on the Input Tab 1665. The default name is 'Voronoi_Density' but can be changed before running the tool. The report can be found in the **Output Folder** that was chosen on the Input Tab 1665.

Once processing is complete, the final report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for the density testing.

The report contains a summary description of the measurement methodology and three output items: a

frequency distribution chart that plots point density results and presents statistics of the density distribution; a point density thematic raster consisting of cells that are 0.5 x NPS (nominal pulse spacing) as derived from the input denity requirement, colorized based on the density values from the underlying Voronoi polygons, and a 'pass/fail' raster using cells that are 100 x NPS to quickly show areas that may need further investigation for insufficient density.

In addition to the PDF report of the point cloud analysis, the **Output Folder** will contain a sub-folder named 'V_1' where the two raster images (JPEG 2000 format) mentioned above are available for a more detailed visual review of the analysis results. These rasters, along with other result info, are used to create the final report. This sub-folder can be deleted if no longer needed after the tool has completed and the final PDF is generated.

Sample Report Pages:

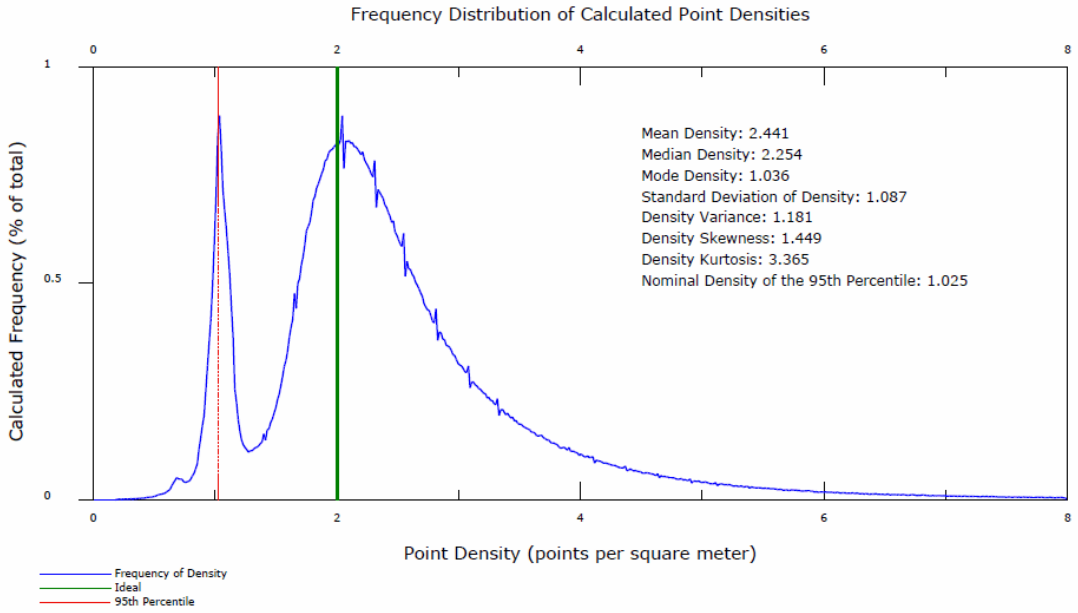
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V-1.1 Report on Point Density via Voronoi Polygons

The purpose of this section is to show a frequency distribution chart of lidar point density for the entire dataset based on the calculated inverse of generated Voronoi polygons (1/Voronoi area) for each lidar point. This inverse of area equates to point density represented in points per square meter (ppsm) in this report. This method is the most accurate way to report on lidar point density and avoids the aliasing problems of the more common point in polygon reporting method.

Data Source - D:\MARS\Dump\DSD_unprepped_tiles

Required PPSM >= 2

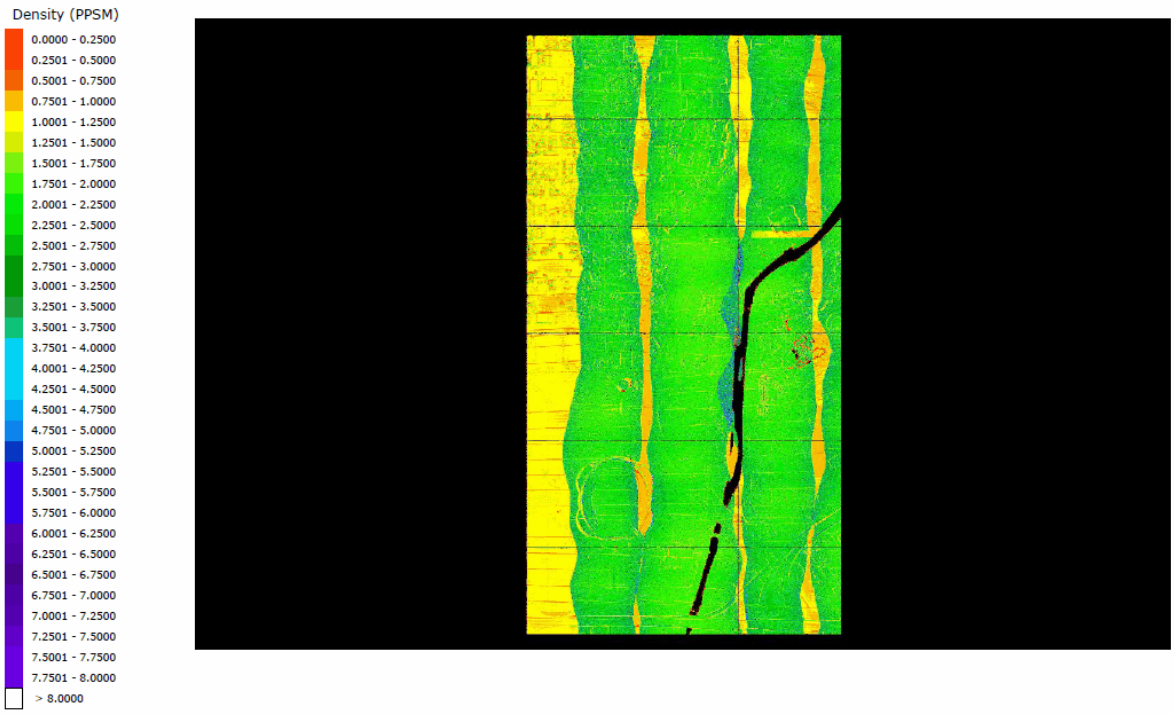


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V-1.2 Raster Rendering of Voronoi Polygons

Required PPSM >= 2

Point Density Thematic Raster



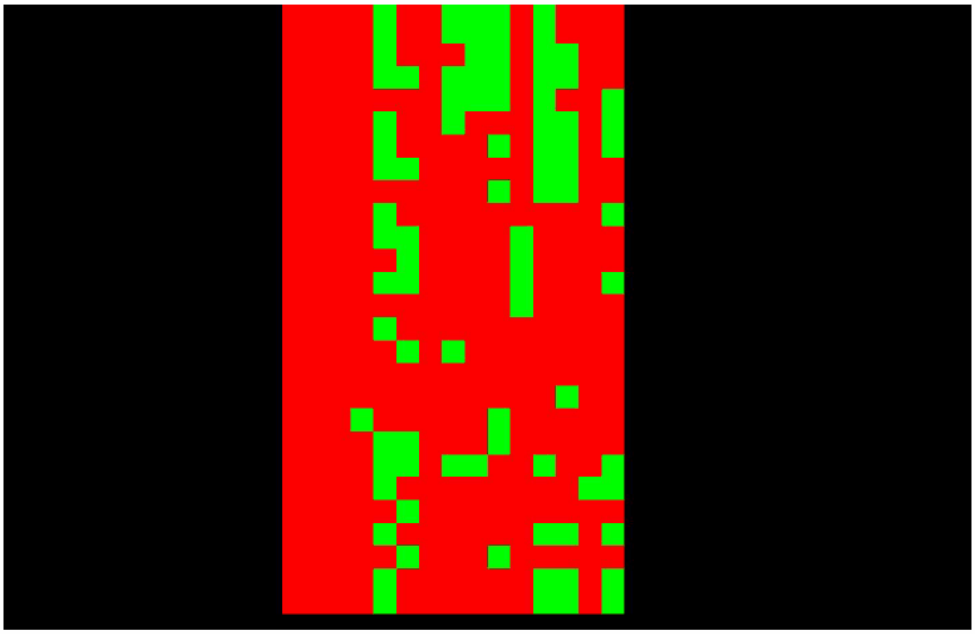
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TEST Lidar QA/QC Report

V-1.3 Pass/Fail Assessment Raster

Required PPSM >= 2



Cell size: 70.711 US Survey Feet

Green: Cells containing at least the required number of points per square meter (number of cells = 168)
Red: Cells containing less than the required number of points per square meter (number of cells = 280)
Background Color: Exclusion areas, not included in assessment

Percentage of cells that contain at least the required number of points per square meter = 37.50%

See JPG2000 file for full resolution results

01/21/2022 This report has been automatically generated by Merrick's MARS® QC Module build 8503.55 Page 5 of 6

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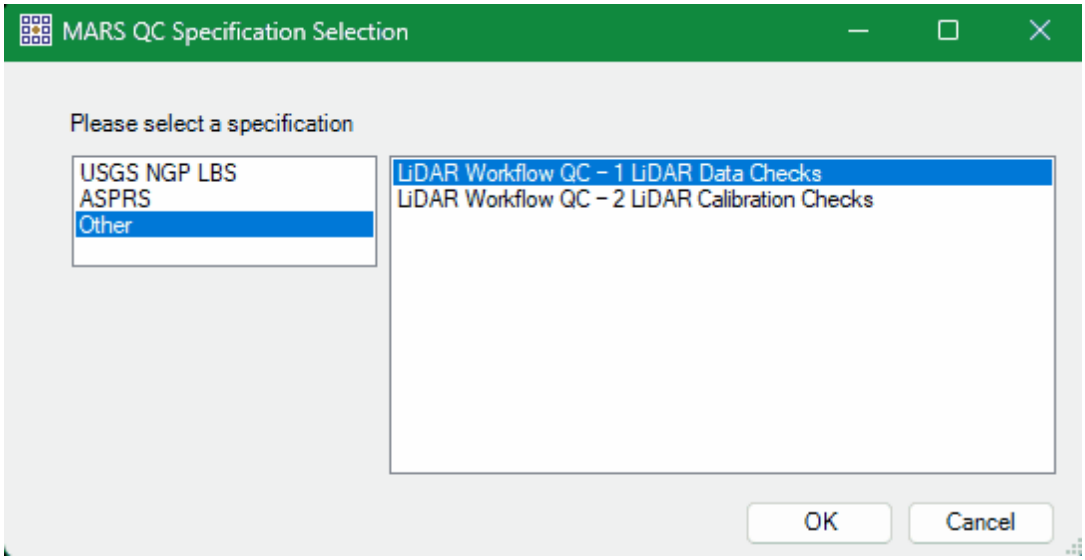
6.4 QC Module - Other

QC Module - Other

Merrick Advanced Remote Sensing (MARS®) Software

The following selection list window will appear after clicking the 'QC Module' button 

on the QA/QC Tab[458]. The list is divided into USGS NGP LBS, ASPRS, and Other sections.



See

LiDAR Workflow QC - 1 LiDAR Data Checks[1677]

LiDAR Workflow QC - 2 LiDAR Calibration Checks[1698]

See Also

QC Module - USGS NGP LBS[1313]

QC Module - ASPRS[1659]

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6.4.1 LiDAR Workflow QC - 1 LiDAR Data Checks

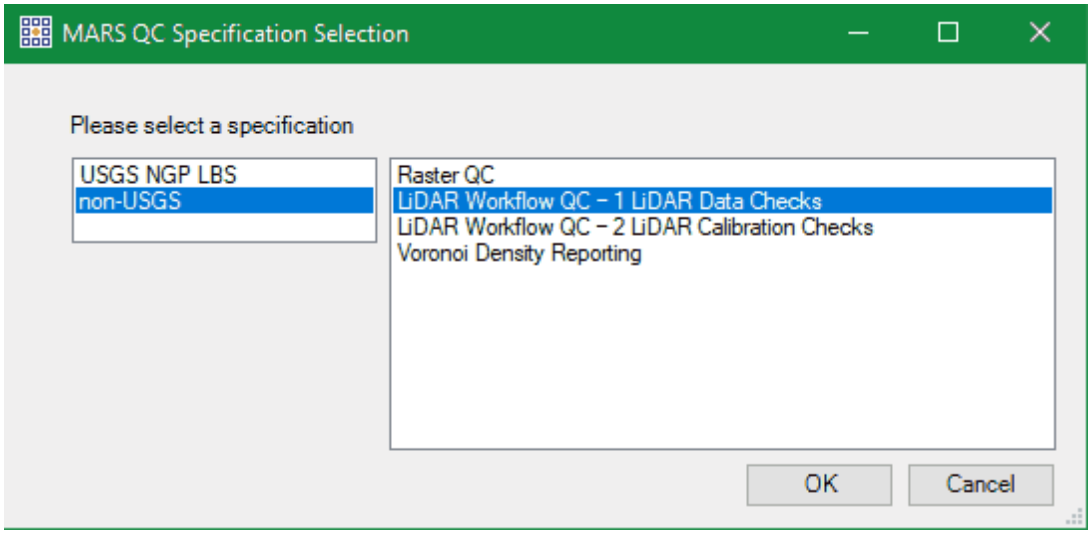
LiDAR Workflow QC - 1 LiDAR Data Checks

Merrick Advanced Remote Sensing (MARS®) Software

The 'LiDAR Workflow QC - 1 LiDAR Data Checks' tool is a set of tests designed to check swath LAS data.

After clicking the QC Module button 

on the QA/QC Tab458, the 'LiDAR Workflow QC - 1 LiDAR Data Checks' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



See also

LiDAR Workflow QC - 2 LiDAR Calibration Checks1698

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6.4.1.1 General Information

1 LiDAR Data Checks - General Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'LiDAR Data Checks' quality control tool in MARS® is to provide an automated method for verifying the expected data attributes, coverage, point density, and relative accuracy of a LiDAR point cloud dataset.

There are 12 possible tests that can be run in the 'LiDAR Data Checks' module. The user has the ability to customize QC tasks by selecting the individual tests that they wish to run. *Any points flagged as Withheld are ignored for all tests.* A 'pre-filtering' option is included to re-classify High and Low Noise points by comparing their elevations to USGS Digital Elevation Models (DEMs), assigning them the Withheld bit flag at the same time. **(Merrick & Company does not guarantee the accuracy of the DEMs stored by the USGS!)**

The results of the point cloud analysis are contained in a detailed PDF report along with supporting raster analysis images, tabular data, charts, shapefiles, and other statistical files. See the Final Report 1695 sub-topic for more information.

Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool.

Licensing

The entire MARS® QC Module - including this tool, the USGS 2025 rev. A 1315, USGS 2024 rev. A 1351,

USGS 2023 rev. A[1386], USGS 2022 rev. A[1421], USGS 2021 rev. A[1455], USGS 2020 rev. A[1490], USGS NGP - Version 2.1[1525], USGS NGP - Version 1.3[1559], USGS NGP - Version 1.2[1592], and USGS NGP - Version 1.0[1622] tools, and the LiDAR Data Checks[1677] and LiDAR Calibration Checks[1698] tools - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

These are the datasets and files needed to run the 'LiDAR Data Checks' tool:

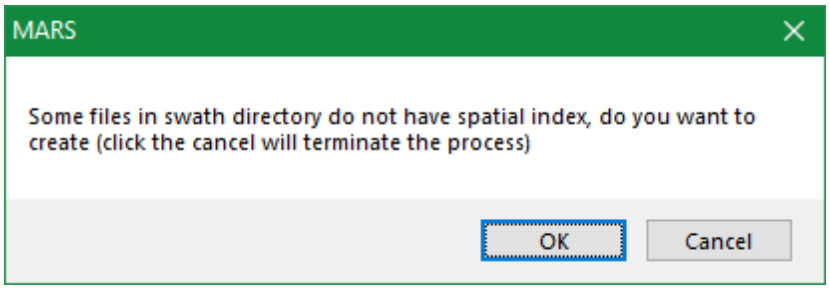
- Swath Data (LAS) - required
- Project Boundary file (in the form of a polygon shapefile) with at least one attribute field that contains unique values - optional

Optionally, an Exclusion Shapefile can be pathed out on the Input Tab[1683] for polygon areas that should be ignored in the processing. This may include water polygons and/or other known void areas.

***Note** that the reserved XML characters **<**, **>**, **%**, **&**, **'**, **"** cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile.*

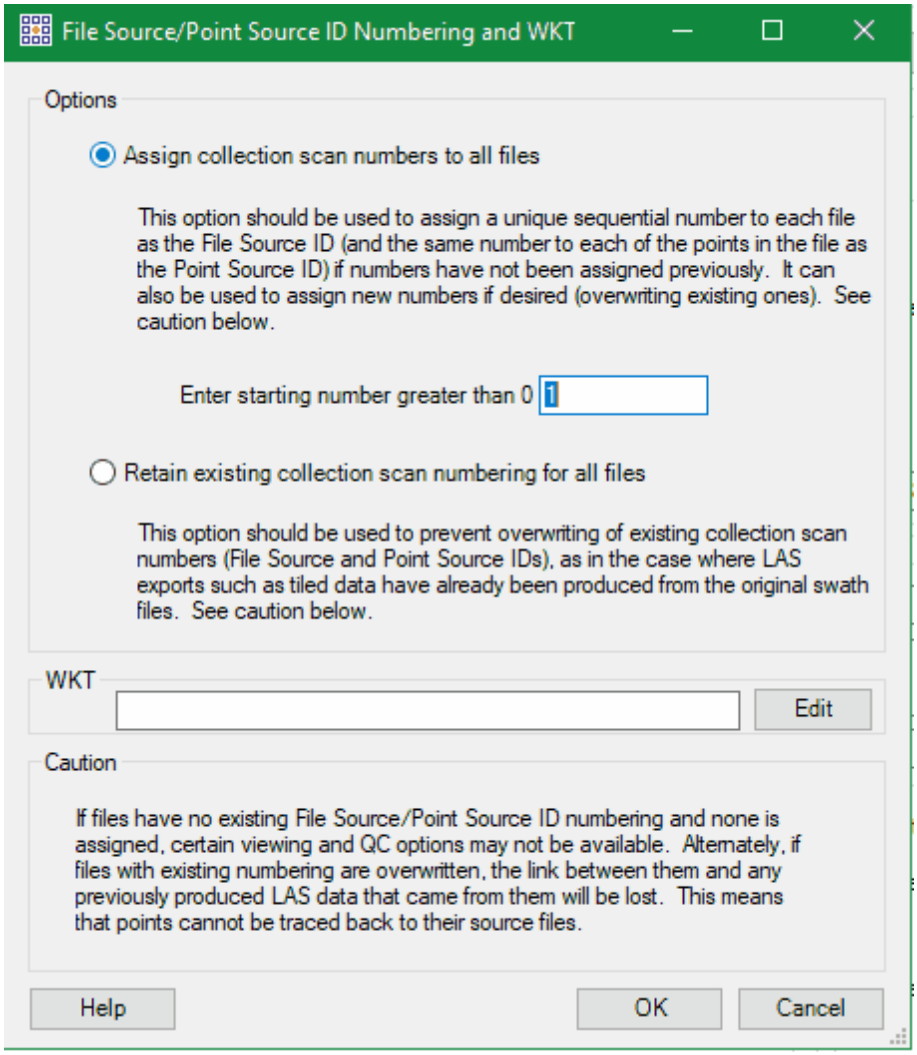
Swath (also referred to as flight line or collection scan) Data Preparation

LAS data must be spatially indexed before it can be tested with the LiDAR Data Checks tool, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the 'Swath LAS Folder' (see Input Tab[1683]) has not been through the 'Add Spatial Index' process, the following prompt window will pop up (see also Add Spatial Index[907]).



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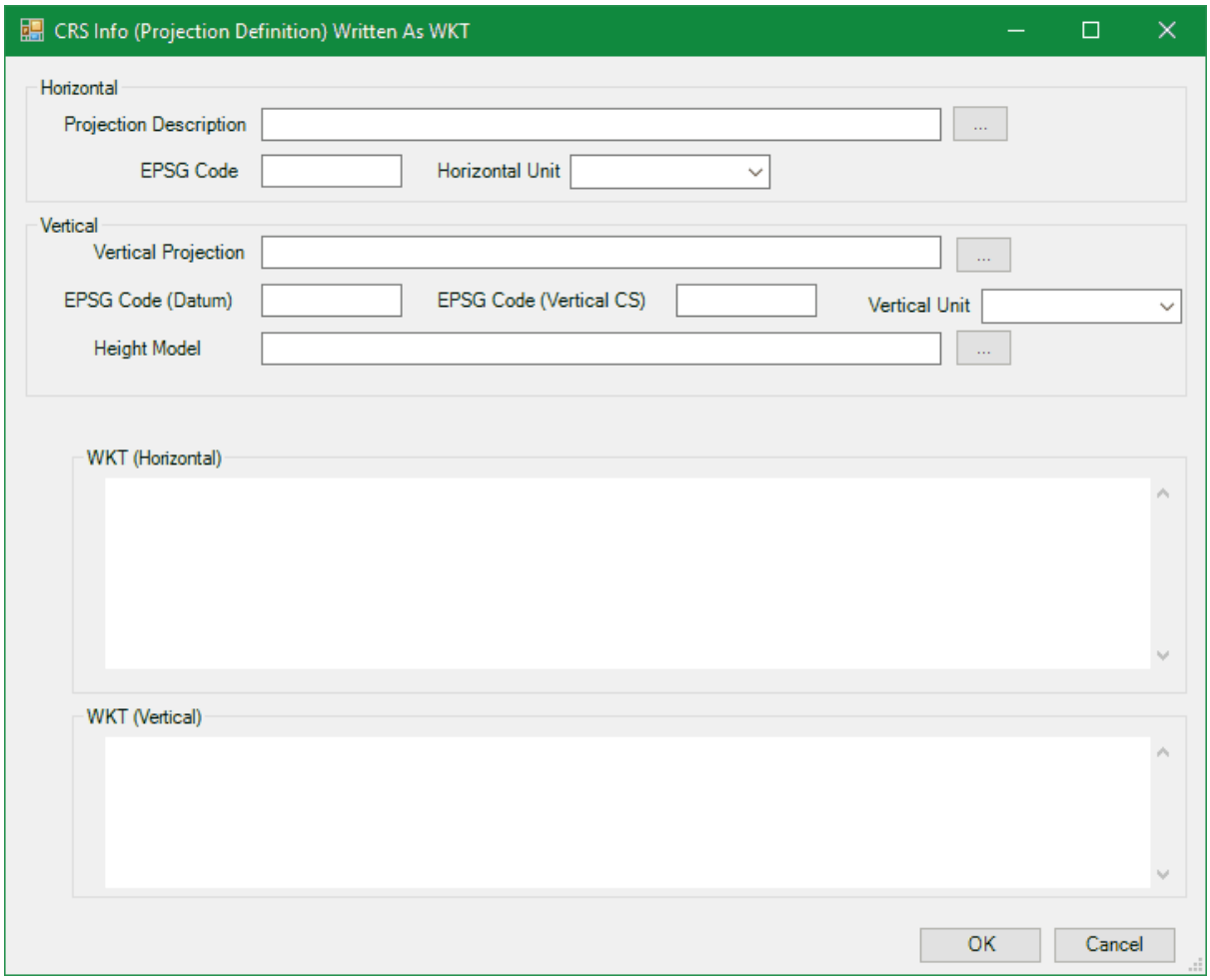
Clicking 'OK' will bring up the 'File Source/Point Source ID Numbering and WKT' interface, with the 'Assign collection scan numbers to all files' option selected and a default starting value of '1' entered. The option or the starting ID number can be changed as needed.



Read the information on this interface carefully before continuing with indexing.

Additionally, the Coordinate Reference System WKT string, if it exists for the input LAS data, will be displayed in the 'WKT' box on the interface. If it does not exist (blank) or is incorrect, it can be added or edited by clicking the 'Edit' button to the right of the entry box.

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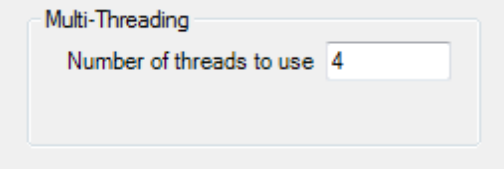


See the '***Add CRS Info (to LAS Files)***' section in the Coordinate Conversion Tab 254 help topic for details on using this interface.

Multi-threading

A multi-threading option can be found on the LiDAR Data Checks tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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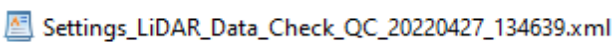
Running the LiDAR Data Checks tool

When all necessary entries have been made on the Input[1683] and Processing[1688] tabs, click the 'Run' button in the lower-right to begin the processing. A pop-up may appear if any selected tests require data that has not been pathed out on the Input Tab[1683]. While running, the individual tabs can be viewed, the 'Help' button remains active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked.

There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the LiDAR Data Checks tool begins the screen capture portion of the processing.***

Settings Files

Every run of the LiDAR Data Checks tool will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab[1683]. Each unique *.xml file name will contain the date and time that the tool run was started as seen in the example below. For example, this particular run was started at 1:46:39 pm on April 27, 2022.



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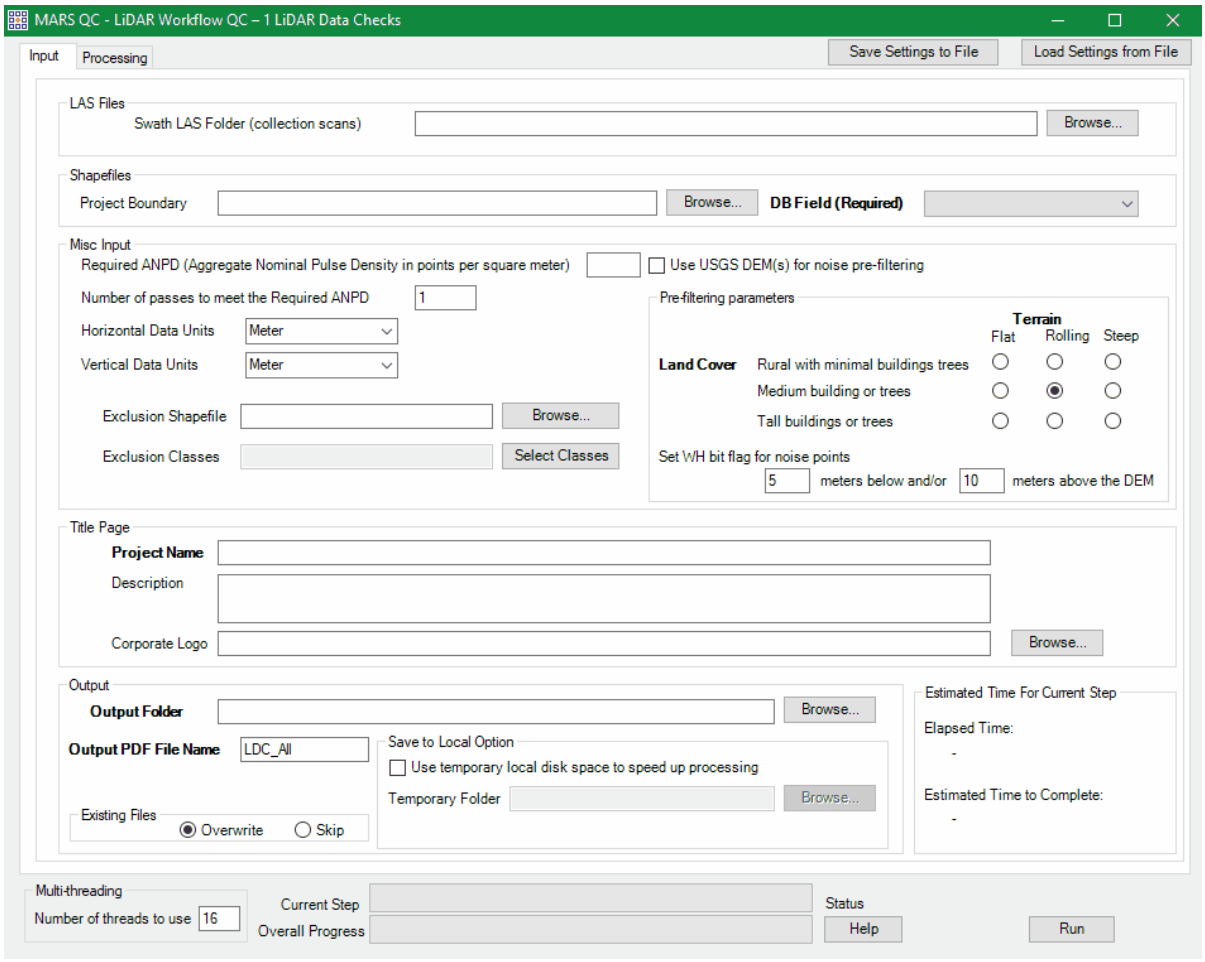
This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between runs. After opening the LiDAR Data Checks tool interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the tool - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not be stored in the chosen **Output Folder** automatically like it is when the tool is actually run.

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6.4.1.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum, the **Swath LAS** data must be included, along with the Required Aggregate Nominal Pulse Density (ANPD), Number of (collection) passes to meet the Required ANPD, a **Project Name**, **Output Folder**, and **Output PDF File Name**. Multi-channel data will be automatically detected and processed based on Scanner Channel bit flag values in the LAS files.

If a 'Project Boundary' shapefile is included, a unique-value attribute field must be chosen (e.g., an 'Areaname' field for the 'Project Boundary' shapefile). These attribute values are used for identifying

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many of the tabular results in the final report.

The entry for 'Required ANPD (Aggregate Nominal Pulse Density)' must be in PPSM (points per square meter), regardless of the actual units that the input data is in.

The 'Number of passes to meet the Required ANPD' entry box defaults to '1'. This is the correct value for a typical airborne project using a single sensor with standard flightline sidelap of 20-30%. Examples of variations include (but are not limited to) a configuration where two separate sensors are collecting simultaneously with 20-30% sidelap, and where two separate sensors are collecting simultaneously with 55% sidelap - entry box values of '2' and '4' (respectively) would be appropriate in those cases. The title page of the final PDF report 1695 will show this information.

Both the 'Horizontal Data Units' and 'Vertical Data Units' drop-downs must be set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

If a polygon shapefile exists for water bodies (or any type of known exclusion areas), it can be pathed out using the 'Browse' button to the right of the '**Exclusion Shapefile**' entry box. These areas will be omitted from the testing and analysis for tests DC3, DC4, DC5/DC6, DC7, DC11, and DC12 (see Processing Tab 1688). Also, any class(es) selected with the '**Exclusion Classes**' control will be ignored for all tests.

An option to clean up potential High and/or Low Noise points before running any tests can be enabled by checking the box labeled 'Use USGS DEMs for noise pre-filtering'. This can improve overall run time for the tool as well as produce cleaner and more useable test results by setting points that meet user-defined criteria to Withheld and reclassing them to Low Noise (Class 7) or High Noise (Class 18), as

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appropriate. They will then be omitted from processing for all tests that are chosen to be run. The workflow for this pre-filtering option is as follows:

1. Any one of nine **Land Cover**/**Terrain** combinations can be selected from the radio button matrix, based on the input data to be tested. This selection will populate the entry boxes below the selection buttons with pre-determined values (in meters) for how far any lidar point must be below and/or above a DEM of the project area in order to be considered noise. The DEMs, stored and maintained by the USGS, will be automatically downloaded during processing and stored with the input LAS swaths to cover the extent of the project and are used for all elevation comparisons.

2. Each point in the input LAS data is compared to the corresponding DEM cell's elevation value. Points that are outside of the 'Below' limit are reclassified as Low Noise (Class 7); points outside of the 'Above' limit and reclassified as High Noise (Class 18). Both classes are then assigned the Withheld point bit flag.

3. This pre-filtered LAS data is then used as the input for the chosen tests with all Withheld points ignored.

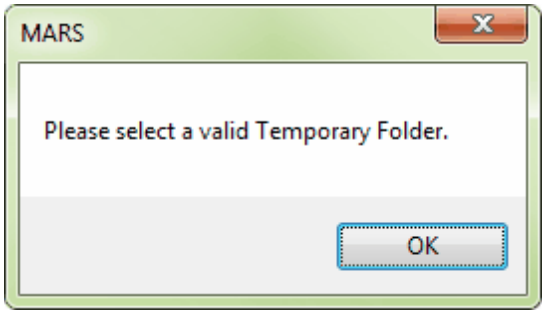
If the reclassification/bit flag assignment does not seem to be appropriate for the dataset (i.e., points that appear to represent valid features have been set to Withheld), the input LAS data can be 'reset' to its original status. Also, if the horizontal correlation between the lidar data and the DEM(s) is more than a few meters off, the data should be reset and the pre-filtering option should not be used (the data and downloaded DEM(s) can be viewed together in MARS® to check the registration). Using the 'Clear Bit Flag' tool in the 'Bit Flag Settings' drop-down on the Tools Tab 389, browse to the input data, check the 'Withheld' box in the lower-left of the tool, check the 'Reassign to new class' box, select '0' (zero) as the 'Target Class', and click the 'Clear Bit Flags' button. **In any case, Merrick & Company does not guarantee the accuracy of the DEMs stored by the USGS!**

Regardless of whether this option is checked on, a preliminary step (internally known as 'Step 0') will be performed silently as soon as the 'Run' button is clicked. This step finds all existing Class 18 (High

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Noise) points in the input swaths and sets the Withheld bit flag to 'On' - these points are then ignored for all tests. Although this step will make for a cleaner dataset, it can add time to the overall processing. To omit this step, select the 'Skip' option in the 'Existing Files' section of the Input Tab 1683 before running. The 'Skip' option is further explained below in the final paragraph.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous

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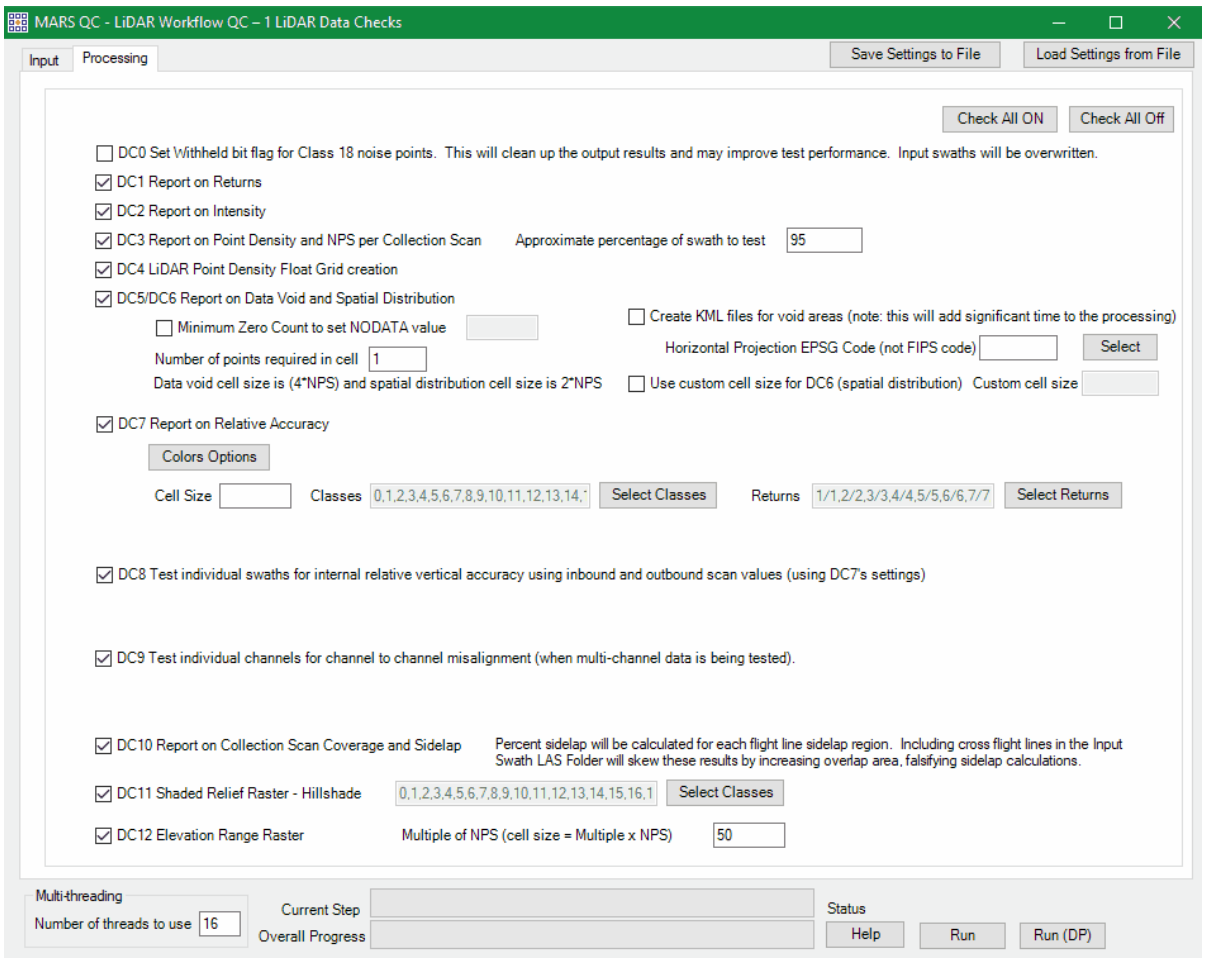
run. A new final report will be produced in either case (see Final Report 1695 sub-topic).

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6.4.1.3 Processing Tab



The Processing Tab



Options for tests **DC0** through **DC12** are located on this tab. By default, all tests except DC0 are checked ON to be run and can be controlled by the 'Check All On' and 'Check All Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Test **DC9** will be run only if multi-channel LAS data is detected (based on Scanner Channel bit flag values).

DC0 Set Withheld bit flag for Class 18 noise points

This option (unchecked by default) will clean up the testing results and potentially improve performance by setting all Class 18 points in the Input 1683 swaths to Withheld. The input swaths will be silently overwritten. If this step has been performed previously on the input swaths, it can be unchecked for subsequent processing runs to save time.

DC1 Report on Returns

The purpose of this section is to report on the presence and quantities of LiDAR returns in the LAS swath data. Empty return columns can indicate a collection or processing problem dealing with LiDAR return attribute information.

DC2 Report on Intensity

The purpose of this section is to report on the presence and quantities of LiDAR intensity in the LAS swath data. This is done for each scan direction independently and also combined. Note that the intensity values have been normalized to 16-bit as required by the LAS version 1.4 specification. It is important to understand that 8-bit intensity LiDAR systems have a valid native intensity range from 0-255, and 12-bit intensity LiDAR systems have a valid native intensity range from 0-4095.

DC3 Report on Point Density and NPS per Collection Scan

The purpose of this section is to report on the LiDAR point density and nominal point spacing by

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swath file. Values for individual swaths and a project average (not including overlap) are reported in tabular form, and a frequency distribution chart of density/spacing results is produced. By default, the center 95% of the swath width is tested to avoid the artificially higher densities present at the edges of collection scans for many sensors. This value can be modified as needed in the 'Approximate percentage of swath to test' entry box. In the results table, 'Point Density' and 'NPS' values are color-coded at the individual swath level to indicate compliance (green) or non-compliance (red) with the 'Required ANPD (Aggregate Nominal Pulse Density)' as entered on the 'Input' tab. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab 1683, all polygons within it will be omitted from testing and analysis for this step.

DC4 LiDAR Point Density Float Grid creation

The purpose of this section is to present a raster of relative point density using last returns only, based on a cell size of 1-meter or 3.2808 US Feet depending on the project data units selected. The result is color-coded using a red to magenta color ramp - red cells are the least dense and magenta cells are the most dense. Black cells indicate no last return points were found. A frequency distribution chart is also created to aid in the analysis of the results. Several statistics are compiled on this page of the final report. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab 1683, all polygons within it will be omitted from testing and analysis for this step.

DC5 Report on Data Void

The purpose of this section is to show graphically where possible LiDAR data voids are located. Data voids can be caused by a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, LiDAR occlusions caused by objects above ground like tall buildings, etc. Not all data voids are problematic. The intention of this test is to isolate the first example of LiDAR data voids - a lack of coverage at the time of collection. A

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close inspection must be done on the results to determine if the LiDAR coverage was collected and processed to meet the intended specifications. This test is combined with test **DC6** due to their related nature and similar testing options. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab[1683], all polygons within it will be omitted from testing and analysis for this step.

There are several options that can be set or modified for this test. The 'Minimum Zero Count to set NODATA value' checkbox and entry box will allow the user to specify a quantity of adjacent empty cells that can exist before the cells are designated as 'NODATA' rather than void of data. Cells marked as void in areas where no data is expected will skew the results. For example, assume a nominal pulse spacing of 2.5 feet, which will use a 10 foot cell size (10 x 10) for this test (4x NPS). If the project area is covered by ponds that are a minimum of 500 square feet in area (for example), it is likely that many cells will have no points. Since water typically absorbs laser energy, there is no expectation that returns will be collected for these ponds. Therefore, rather than have possibly dozens or hundreds of cells marked void that should not be part of the results, a Minimum Zero Count of '5' could be entered for this option which will result in all empty cells in adjacent groupings of 5 or more being marked as 'NODATA' and omitted from the final results. Cells that fall wholly or partially within any of the polygon boundaries will be designated as 'NODATA'. The minimum 'Number of points required in cell' defaults to '1', but this can be changed.

A KML file can be created of void areas to be used with Google Earth[1] to investigate those areas. This requires that the 'Horizontal Projection EPSG Code' of the data be known. When the data has this information defined, it will be stored in the files and the EPSG Code box will be populated accordingly. If the data is undefined but the horizontal projection system is known, the EPSG Code can be found by clicking the 'Select' button to the right of the entry box and searching the Coordinate System Datasource. For example, the EPSG Code for 'NAD83

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(HARN) / Colorado Central' State Plane Zone in U.S. Survey Feet is '2877'. The KML option is unchecked by default. Note that the KML file cannot be created when the input data straddles two or more projection zone boundaries.

DC6 Report on Spatial Distribution

The purpose of this section is to show graphically where unacceptable LiDAR spatial distributions are located. LiDAR spatial distribution can be affected by problems in flight planning (e.g., incorrect scan frequency / pulse rate pairing) or flight execution (e.g., strong headwinds or tailwinds), a lack of coverage at the time of collection, water bodies not reflecting the laser beam back to the receiver, LiDAR occlusions caused by objects above ground like tall buildings, etc. Not all LiDAR spatial distribution violations are truly problematic. The intention of this test is to isolate the first example of LiDAR spatial distribution violations - problems in flight planning or flight execution. A close inspection must be done on the results to determine if the LiDAR spatial distribution was collected and processed to meet the intended specifications. This test is combined with test **DC5** due to their related nature and similar testing options. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab[1683], all polygons within it will be omitted from testing and analysis for this step.

The same options used for test **DC5 Report on Data Void** are available for this test, plus one additional option. The cell size used for the Spatial Distribution grid may be modified from the default '2x NPS' by checking the box labeled 'Use custom cell size for DC6' and entering a value in the 'Custom cell size' entry box. Note that if the 'Create KML ...' option is (optionally) checked, the KML file cannot be created when the input data straddles two or more projection zone boundaries.

DC7 Report on Relative Accuracy

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The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. If there is no flight line overlap, the raster is displayed as grayscale intensity alone. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab 1683, all polygons within it will be omitted from testing and analysis for this step.

This test is very similar to the 'Flightline Separation - JPEG 2000' export type and most details about the various settings can be found in the Flightline Separation - JPEG 2000 668 sub-topic of the 'Export Type tab' topic (lower half of page) and the Grid tab 783 sub-topic of the 'Data export' topic (paragraph 3 **Color by Collection Scan Separation**). This area of the Help Topics 538 file is found under the MARS® Tools 540 | Data Export 658 section.

As implemented in the QC Module, however, there are a few differences. The 'Cell Size' will be automatically calculated at 3 times (3x) the NPS value for best results, as determined from the required density entered on the Input Tab 1683, but can be modified. All 'Classes' are selected by default since the test is run on **Swath LAS** data, but the 'Select Classes' button can be used to make changes. Also, only last returns are selected by default, but the 'Select Returns' button can be used to make changes.

DC8 Test individual swaths for internal relative accuracy using inbound and outbound scan values

The purpose of this section is to show a graphic of the relative vertical accuracy within each flight line, individually. This is done by comparing the inbound and outbound scan lines to each other as two separate surfaces and then generating a vertical separation raster from their deltas.

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This is displayed by thematically coloring the separation magnitude on a color ramp based on absolute distance - 0 to 2 cm (or the foot equivalent) is green, 2 to 4 cm is yellow, 4 to 6 cm is orange, and greater than 6 cm is red. Good LiDAR data should have a consistent green coloration across the flight line (perpendicular to flight), ignoring warmer colorations due to above-ground surface features. Some small color variations are to be expected. The purpose of this test is to find problematic data indicated by warming color variation trends away from the center of the scan line. Flight lines that have inconsistent colorations from the center towards the edges of the flight line would highlight the possibility of a sensor or internal calibration problem, usually an incorrect encoder latency value.

DC9 Test individual channels for channel-to-channel misalignment

The purpose of this section is to check the channel-to-channel sensor calibration of a multi-channel LiDAR system to ensure proper 3D alignment within a single swath. During this step, each channel is processed as a separate collection scan and compared to its paired channel. A surface-to-surface vertical separation is calculated per swath between the two channels. The results are then thematically rendered in the output rasters, one for each swath. This test is run only if multi-channel data is detected based on Scanner Channel bit flag values, so it does not need to be unchecked for single channel datasets.

DC10 Report on Collection Scan Coverage and Sidelap

The purpose of this section is to show flight line overlap (including sidelap). Lack of flight line overlap would be displayed as black polygons or slivers between flight lines.

DC11 Shaded Relief Raster - Hillshade

The purpose of this section is to present a first return digital surface model for all of the data processed to more easily see unexpected high and low areas and other anomalies. By default

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all classes are selected for this raster, but the 'Select Classes' button can be used to make changes. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab[1683], all polygons within it will be omitted from testing and analysis for this step.

DC12 Elevation Range Raster

The purpose of this section is to create a thematic raster displaying the range of elevations present in a cell whose size is a user-supplied multiplier of the NPS (Nominal Pulse Spacing) for the input data - the default value is '50'. The NPS is automatically calculated in the Horizontal Data Units as selected on the Input Tab[1683], based on the user-supplied ANPD (Aggregate Nominal Pulse Density). A histogram stretch is done with the highest and lowest 5% of the range values discarded and the remainder split into 24 equal-range groups that are each assigned a unique color in the final JPEG 2000 raster. A float grid is also generated that stores the actual numeric range value for each cell. Those values can be inspected in ArcGIS or another software package that reads the numeric cell values. This test can be helpful in pointing out where extreme high and/or low points are present that may need to be reclassified or flagged as Withheld. ***NOTE*** - if an 'Exclusion Shapefile' is included on the Input Tab[1683], all polygons within it will be omitted from testing and analysis for this step.

[1] -- Google Earth is copyright 2025 Google LLC. All rights reserved.

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6.4.1.4 Final Report



QC Reporting

The output of this LiDAR Data Checks tool is written to a detailed PDF file that contains the test-by-test results of the point cloud analysis. At the end of the individual test sections, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats. The report will be named using the entry in the **Output PDF File Name** box on the Input Tab. The default name is 'LDC_All' but can be changed before running the tool. The report can be found in the **Output Folder** that was chosen on the Input Tab. Once processing is complete, the report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for the 11 tests that can be run.

In addition to the PDF report of the point cloud analysis, the tool will also generate several raster images (JPEG and JPEG 2000 format) and shapefiles that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final report. These sub-folders can be deleted if no longer needed after the tool has completed and the final PDF is generated.

Sample Report Pages:

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DC3 Report on Point Density and Nominal Pulse Spacing (NPS)

The purpose of this section is to report on the LiDAR point density and nominal point spacing by individual swath file. Averages for the project are also reported. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

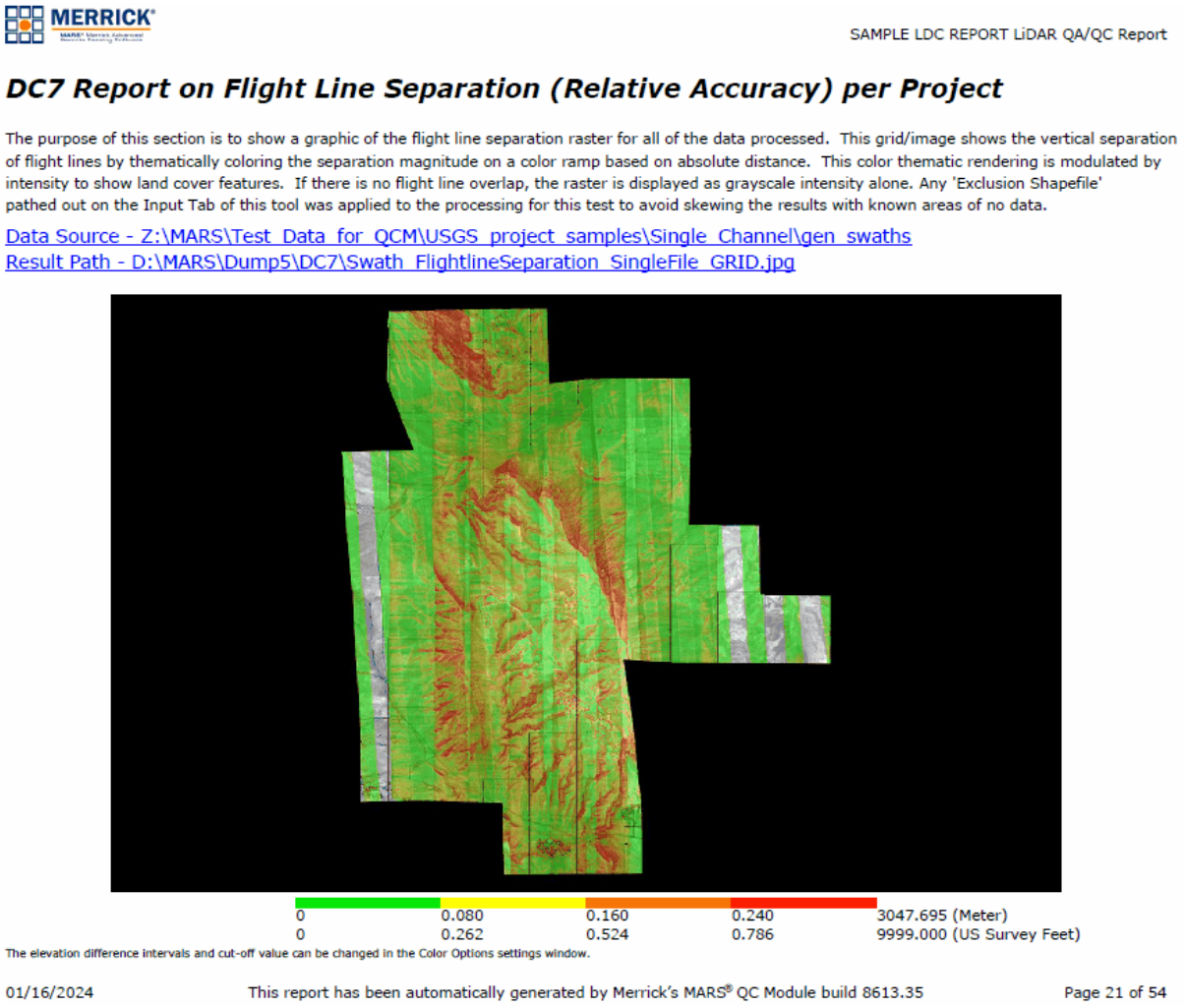
Swath Files - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths

Units: US Survey Feet

Percentage of swath footprint width tested: 95

File	Number of First Returns	Area of Swath	Point Density	NPS
CS_00499.las	1,279,760	3,113,731	4.424/0.411	0.475/1.560
CS_00501.las	7,956,415	31,596,514	2.713/0.252	0.607/1.993
CS_00503.las	18,679,443	62,395,264	3.218/0.299	0.557/1.828
CS_00505.las	34,544,138	97,281,136	3.821/0.355	0.511/1.678
CS_00524.las	26,487,684	92,651,066	3.078/0.286	0.570/1.870
CS_00526.las	36,833,465	127,975,939	3.100/0.288	0.568/1.864
CS_00528.las	43,869,143	146,377,081	3.229/0.300	0.557/1.827
CS_00530.las	40,154,785	135,163,879	3.197/0.297	0.559/1.835
CS_02117.las	18,536,296	88,397,973	2.260/0.210	0.666/2.184
CS_02120.las	47,788,282	195,090,665	2.637/0.245	0.616/2.020
CS_02122.las	58,790,833	204,540,880	3.089/0.287	0.568/1.865
CS_02124.las	51,120,854	214,831,509	2.562/0.238	0.625/2.050
CS_02125.las	33,140,486	173,086,164	2.056/0.191	0.696/2.285
CS_02126.las	355,841	708,212	5.403/0.502	0.430/1.411
CS_00500.las	5,191,895	18,132,538	3.078/0.286	0.570/1.869
CS_00502.las	11,167,999	39,312,180	3.057/0.284	0.572/1.876
CS_00504.las	22,589,055	75,354,233	3.229/0.300	0.557/1.826
CS_00523.las	9,118,863	30,337,774	3.240/0.301	0.556/1.824
CS_00525.las	31,112,739	116,937,350	2.863/0.266	0.591/1.939
CS_00527.las	36,326,852	139,478,454	2.799/0.260	0.597/1.959
CS_00529.las	39,836,542	146,383,498	2.928/0.272	0.584/1.917
CS_00531.las	33,130,119	125,022,874	2.852/0.265	0.592/1.943
CS_02118.las	8,701,571	45,158,579	2.077/0.193	0.694/2.278
CS_02121.las	40,173,959	205,365,756	2.110/0.196	0.689/2.261
CS_02123.las	45,303,322	212,141,489	2.303/0.214	0.660/2.164
Average			2.906/0.270	0.587/1.925
			pp Square Meter/ pp Square US Survey Foot	Meter/ US Survey Feet

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SAMPLE LDC REPORT LiDAR QA/QC Report

DC7 Report on Flight Line Separation (Relative Accuracy) per Project

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. If there is no flight line overlap, the raster is displayed as grayscale intensity alone. Any 'Exclusion Shapefile' pathed out on the Input Tab of this tool was applied to the processing for this test to avoid skewing the results with known areas of no data.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_samples\Single_Channel\gen_swaths
Result Path - D:\MARS\Dump5\DC7\Swath_FlightlineSeparation_SingleFile_GRID.jpg

The elevation difference intervals and cut-off value can be changed in the Color Options settings window.

01/16/2024 This report has been automatically generated by Merrick's MARS® QC Module build 8613.35 Page 21 of 54

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6.4.2 LiDAR Workflow QC - 2 LiDAR Calibration Checks

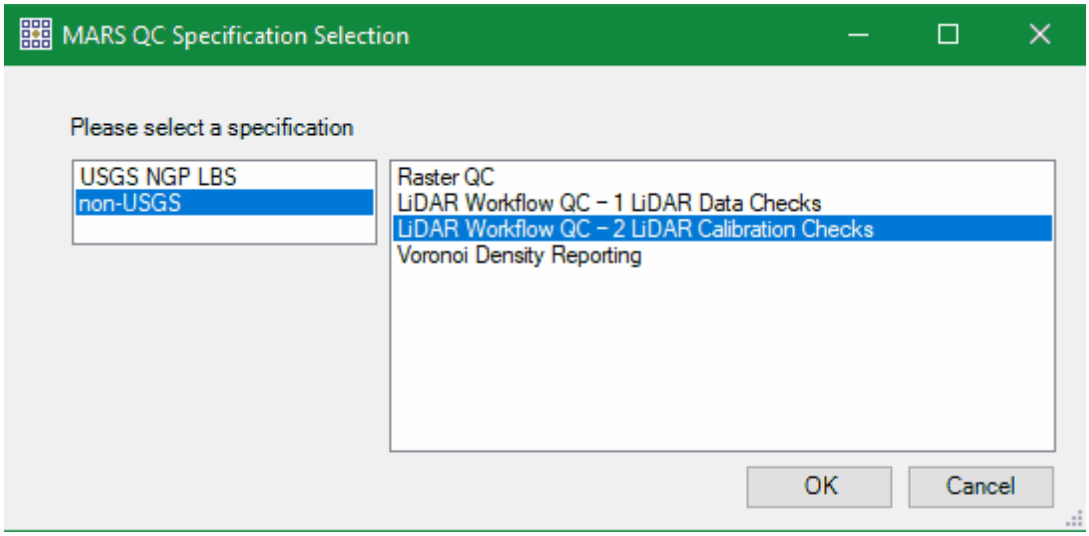
LiDAR Workflow QC - 2 LiDAR Calibration Checks

Merrick Advanced Remote Sensing (MARS®) Software

The 'LiDAR Workflow QC - 2 LiDAR Calibration Checks' tool is a set of tests designed to check swath or tiled LAS data.

After clicking the QC Module button 

on the QA/QC Tab458, the 'LiDAR Workflow QC - 2 LiDAR Calibration Checks' tool ***(available at the Explorer QC and Production license levels)*** can be accessed from a list as shown ...



See also

LiDAR Workflow QC - 1 LiDAR Data Checks1677

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6.4.2.1 General Information

2 LiDAR Calibration Checks - General

Information

Merrick Advanced Remote Sensing (MARS®) Software

Purpose and Description

The purpose of the 'LiDAR Calibration Checks' quality control tool in MARS® is to provide an automated method for verifying correct LiDAR collection system function by testing the relative accuracy and channel alignment (when applicable) of a LiDAR point cloud dataset.

There are three (3) possible tests that can be run in the 'LiDAR Data Checks' module. The user has the ability to customize QC tasks by selecting the individual tests that they wish to run. The results of the point cloud analysis are contained in a detailed PDF report along with supporting raster analysis images, tabular data, and charts. See the Final Report[1712] sub-topic for more information. ***Note that points flagged as 'Withheld', regardless of classification, will not be used in any processing for this tool.***

Licensing

The entire MARS® QC Module - including this tool, the USGS 2025 rev. A[1315], USGS 2024 rev. A[1351], USGS 2023 rev. A[1386], USGS 2022 rev. A[1421], USGS 2021 rev. A[1455], USGS 2020 rev. A[1490], USGS NGP - Version 2.1[1525], USGS NGP - Version 1.3[1559], USGS NGP - Version 1.2[1592], and USGS NGP - Version 1.0[1622] tools, and the LiDAR Data Checks[1677] and LiDAR Calibration Checks[1698] tools - is enabled in either the **Explorer QC** (MARSEXQC) or **Production** (MARSPROD) license versions, and it can be added to the **Explorer** (MARSEXPL) license for an additional fee.

Input Datasets

These are the datasets and files needed to run all tests:

- Swath Data (LAS) ***-or-*** Tiled Data (LAS) derived from swath data

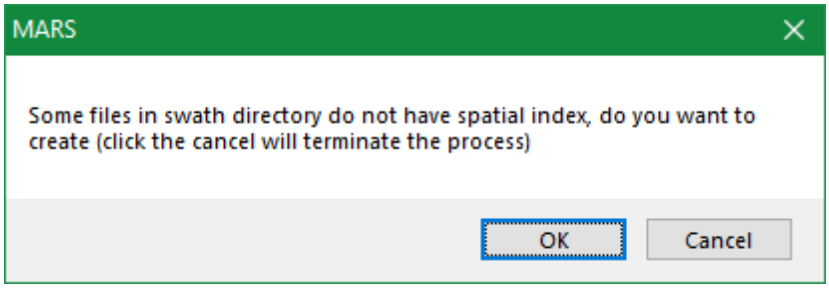
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- Project Boundary file (Esri-compatible polygon shapefile) with at least one attribute field that contains unique values

Note *that the reserved XML characters* **<, >, %, &, ', "** *cannot be used as part of a folder path, Project Name, Description, Corporate Logo file name, Output PDF File Name, or as part of the name of any input shapefile.*

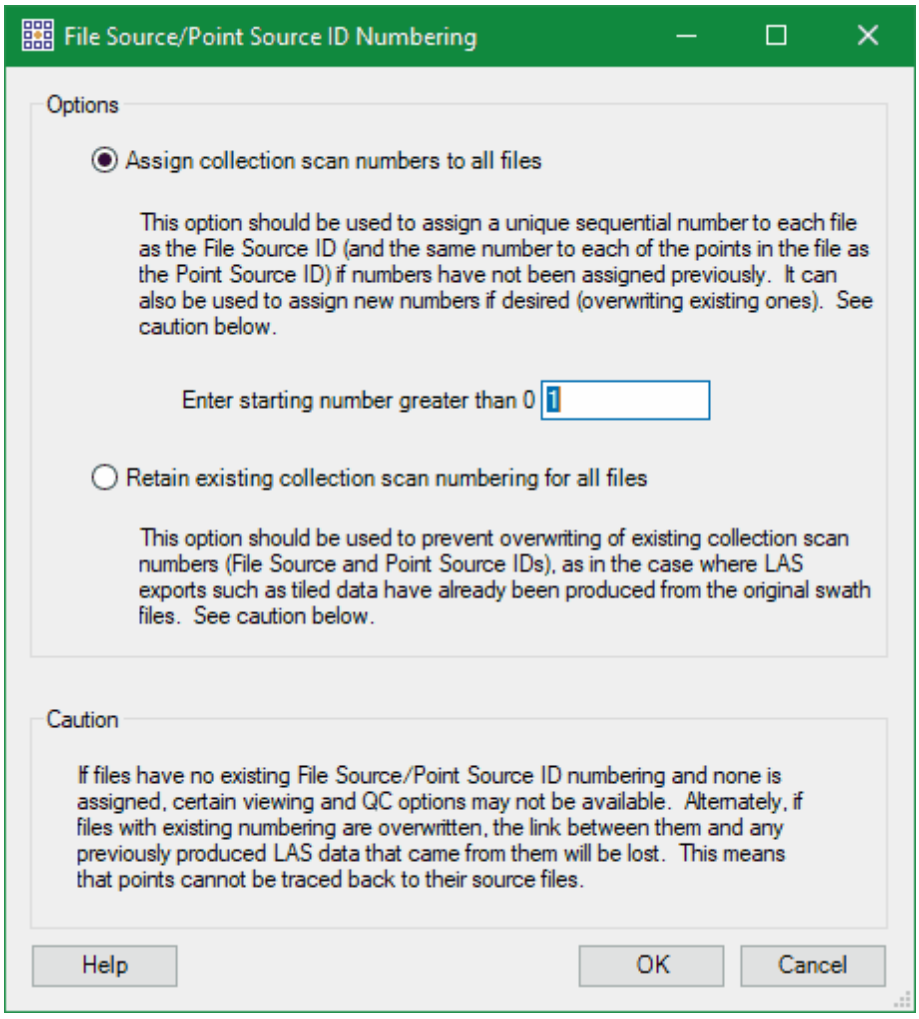
Swath (also referred to as flight line or collection scan) or Tiled (also referred to as classified or delivery) Data Preparation

LAS data must be spatially indexed before it can be tested with the LiDAR Calibration Checks tool, just as it must be before it can be displayed and utilized in other MARS® functions. If any of the LAS data pathed out in the Swath 'LAS Folder' or Classified 'LAS Folder' (see Input Tab 1705) has not been through the 'Add Spatial Index' process, the following window will pop up (see also Add Spatial Index 907).

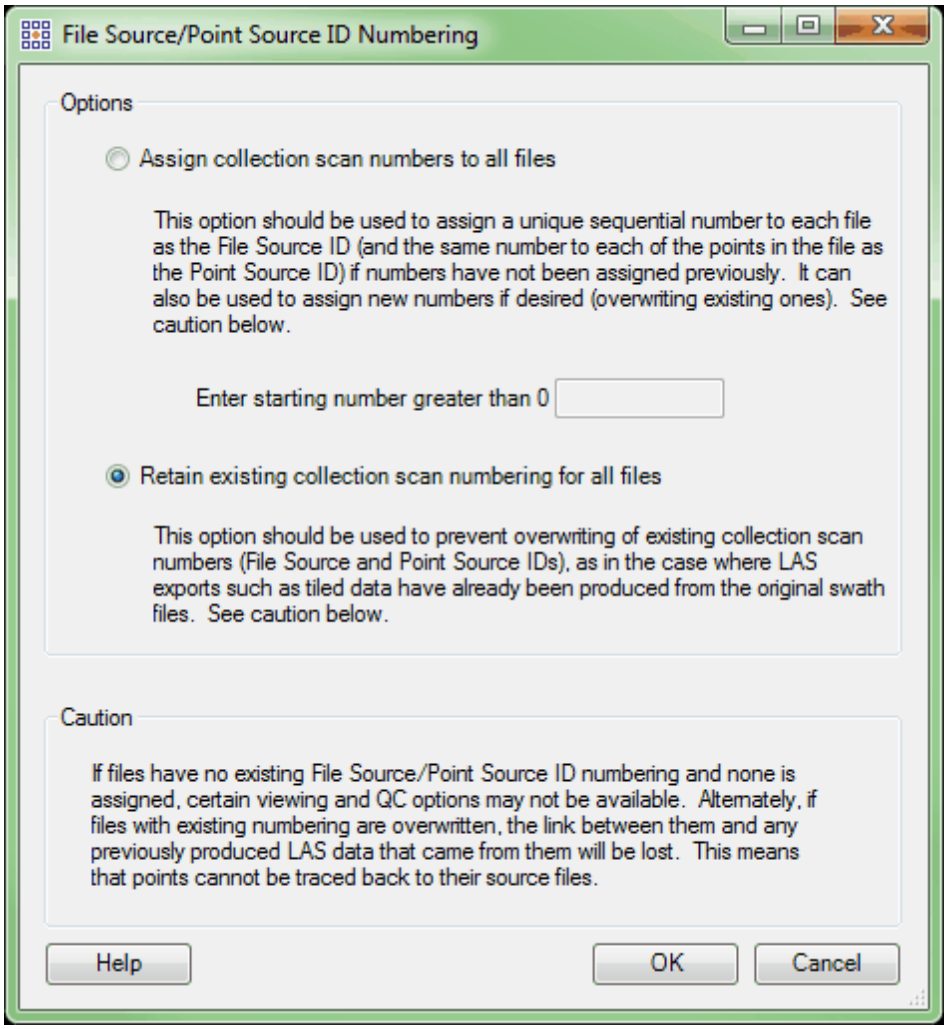


Clicking 'OK' will bring up the 'File Source/Point Source ID Numbering' interface. If Swath Data is being pathed out, the 'Assign collection scan numbers to all files' option will be selected and a default starting value of '1' entered (below, left). If Tiled Data is being pathed out, the 'Retain existing collection scan numbering for all files' option will be selected (below, right). The option or the starting ID number can be changed as needed. Read the information on this interface carefully before continuing with indexing.

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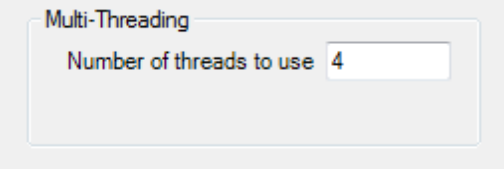
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Multi-threading

A multi-threading option can be found on the LiDAR Calibration Checks tool interface. It speeds up processing by using a specified amount of a computer's CPU processing power. The multi-threading control can be found at the lower-left corner of the interface. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.

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Running the LiDAR Calibration Checks tool

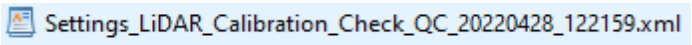
When all necessary entries have been made on the Input[1705] and Processing[1708] tabs, click the 'Run' button in the lower-right to begin the processing. A pop-up will appear if any selected tests require data that has not been pathed out on the Input Tab[1705]. If 'Swath Data' (the default) is used as the input and either the 'Measurable RMSDz FSR' or 'Both' option is selected for test CC1 on the Processing[1708] tab, the tool will check for pre-existing filtered swath data to save time. This data - filtered to contain only buffered single returns to ensure accuracy - could exist from either a previous run of this tool or test DPH-9.1 in the USGS NGP - Version 2.1[1525] tool. To be reused, it must be in a folder named 'Filtered_LAS' directly under the input swath path.

If Tiled Data is used, the tool will first export all points in the tiles to individual collection scan files based on each point's Point Source ID number, then use that data for testing. While running, the individual tabs can be viewed, the 'Help' button remains active, and a 'Cancel' button will appear if the user wants to terminate the process (note that the cancellation may take several minutes). However, no changes can be made to any entries on the tabs once the 'Run' button is clicked. There are two progress bars at the bottom of the interface - one for the current step and one for the overall processing. To the right of the 'Current Step' bar, information about the current test number and total tests to be run will be displayed. Tests may appear out of order and the same test number may be displayed more than once due to grouping similar tasks together for efficiency. ***Any data and imagery loaded in the Table of Contents will be removed after the 'Run' button is clicked, and the 'LAS Map View' window will be cleared once the LiDAR Calibration Checks tool begins the screen capture portion of the processing.***

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Settings Files

Every LiDAR Calibration Checks tool run in MARS® will generate an XML file containing the settings used in the processing. This file will be saved in the **Output Folder** specified on the Input Tab 1705. Each unique *.xml file name will contain the date and time that the tool run was started as seen in the example below. For example, this particular run was started at 12:21:59 pm on April 28, 2022.



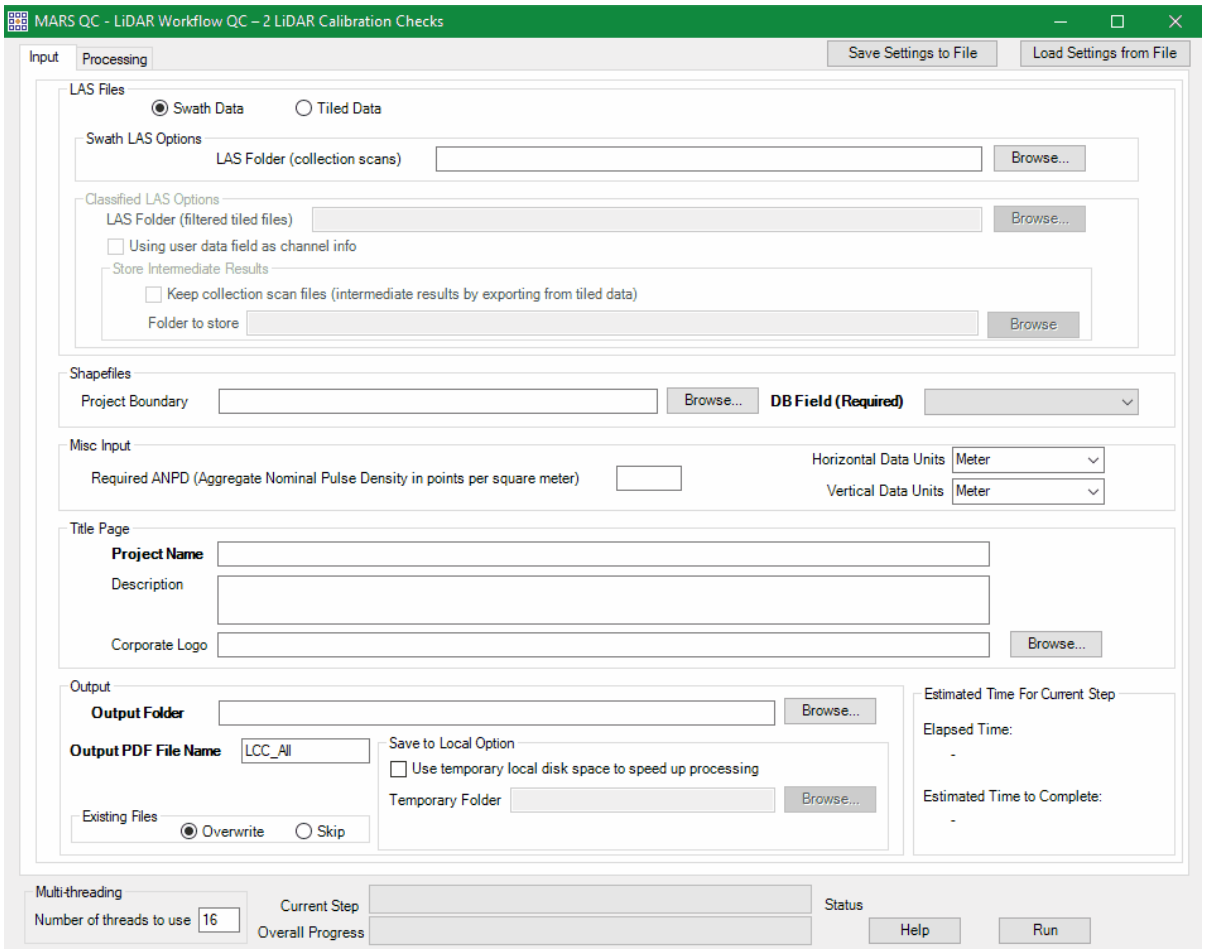
This file can be renamed as needed and loaded for future runs to cut down on data entry and ensure consistency between runs. After opening the LiDAR Calibration Checks tool interface, click the 'Load Settings from File' button and navigate to an existing settings file to be used. Any individual parameters on any of the the interface tabs can be changed before starting the processing. In addition, a settings file can be created and saved for future use without actually running the tool - make all the parameter entries on the various tabs and click the 'Save Settings to File' button when finished. Navigate to a folder to store the file as it will not be stored in the chosen **Output Folder** automatically like it is when the tool is actually run.

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6.4.2.2 Input Tab



The Input Tab



This tab is where all input data is pathed out and general settings are made, and includes entry fields for the **Project Name** and optional Description, an optional Corporate (or organization) Logo that will appear on each page of the final reports, **Output Folder**, and **Output PDF File Name**. At a minimum, the **Swath LAS** or **Classified LAS** (tiled) data must be included, along with the **Required ANPD** (Aggregate Nominal Pulse Density in points per square meter), a **Project Name**, **Output Folder**, and **Output PDF File Name**. Multi-channel data will be automatically detected based on Scanner Channel bit flag values in the LAS files, unless 'Tiled Data' is being used for the input and the 'Using user data as channel info' box is checked.

When using multi-channel 'Tiled Data', the channel numbers are often stored in the User Data section of

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the LAS file headers when the tiles are produced from the original swath data in some third-party software packages. In this case, checking the box for 'Using user data field as channel info' will automatically group multi-channel files together based on identical Point Source IDs found in the tiled datasets. The tool will build collection scan files from the tiled data using these Point Source IDs and the channel info and use these created files for testing. Unless the 'Keep collection scan files' box is checked and a storage folder is pathed out, these collection scan files will be deleted after the tool has completed. In either case, the tiled data is not altered in any way.

If a 'Project Boundary' shapefile is included, a unique-value attribute field must be chosen (e.g., an 'Areaname' field for the 'Project Boundary' shapefile). These attribute values are used for identifying some of the tabular results in the final report.

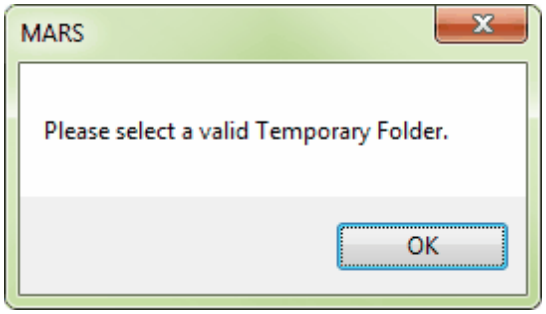
The entry for 'Required ANPD (Aggregate Nominal Pulse Density in points per square meter)' will be converted internally for projects in units other than meters.

Make sure the 'Reporting Horizontal Units' and 'Reporting Vertical Units' are set to match the data being tested. ***This is critical to the correct operation and reporting of the tests!*** Choices in the drop-down are Meter (default), US Survey Feet, and International Feet.

The 'Use temporary local disk space to speed up processing' option allows the user to save the results in the specified output folder (typically a network location), but use local disk space from another specified directory to speed up processing. To use this option, check the 'Use temporary local disk space to speed up processing' option. The 'Temporary Folder' browse box will become available. Browse to any local folder which has space available in it. The interface will then tell the user how much space is required and how much free space is in the folder the browse box is pointing to. If there is enough disk space, the QC Module process will use the local space to speed up processing. If the user checks the

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box labeled 'Use temporary local disk space to speed up processing', but does not point to a temporary folder in the text box an error message will appear as seen below. The 'Use temporary local disk space to speed up processing' option cannot be used without a temporary folder established. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that a sub-folder be used for this option.***



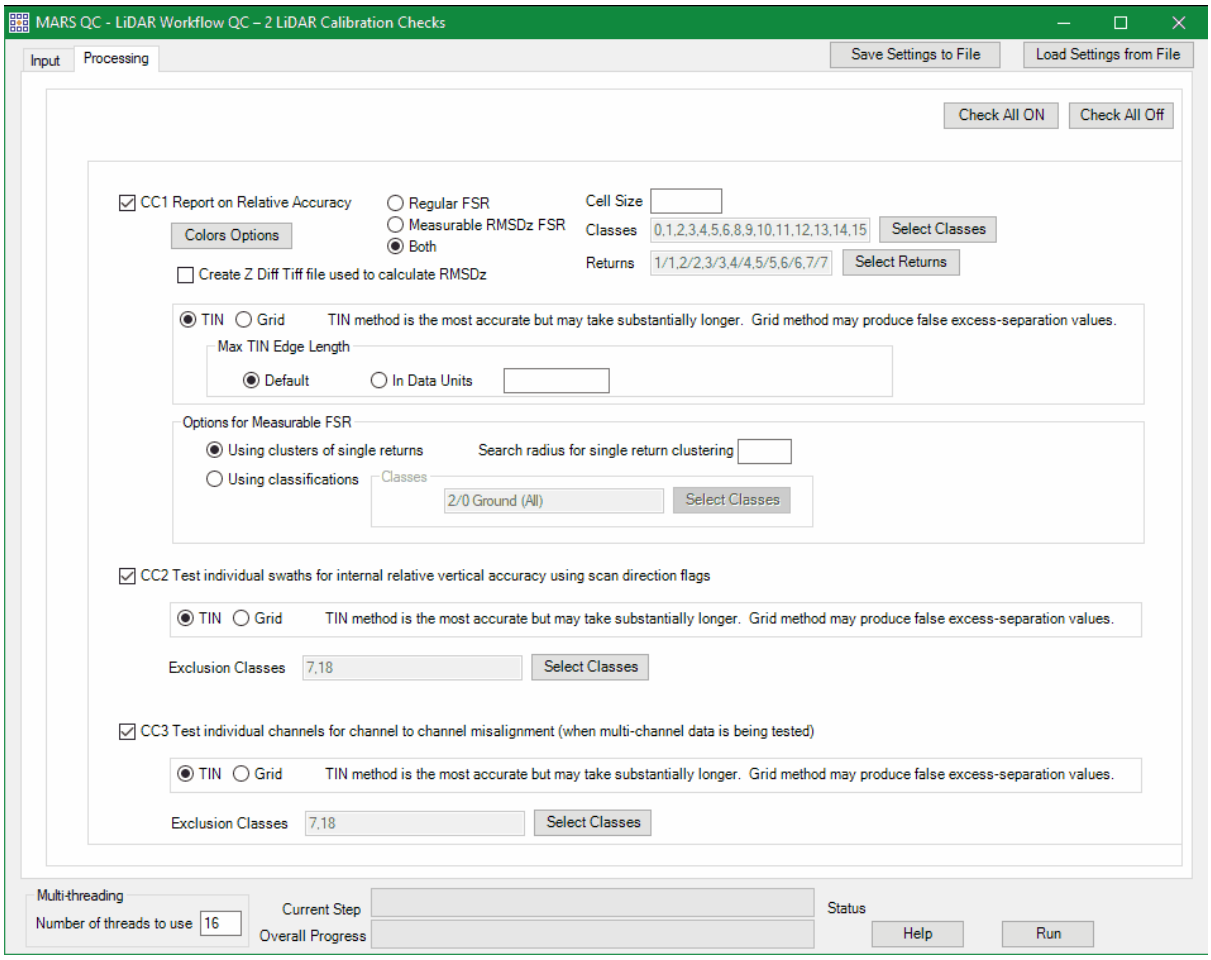
The 'Existing Files' section allows for a complete overwrite of existing data in the **Output Folder** ('Overwrite' radio button, selected by default), or a 'Skip' option that will preserve completed test results from a previous run and write out only those test results that were incomplete or omitted in a previous run. A new final report will be produced in either case (see Final Report 1712 sub-topic).

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6.4.2.3 Processing Tab



The Processing Tab



Options for tests **CC1** through **CC3** are located on this tab. By default, all three tests are checked ON to be run and can be controlled by the 'Check All On / Off' buttons near the upper-right, or by checking/unchecking the individual boxes for the tests. Test **CC3** will be run only if multi-channel LAS data is detected (based on Scanner Channel bit flag values).

CC1 Report on Relative Accuracy

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This grid/image in the final PDF report[1712] shows the vertical separation of flight lines by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features.

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For the Measurable FSR option, only overlap areas are shown in the raster. The relative accuracy RMSDz values for each overlap area are reported in a table and a frequency distribution chart following the raster(s).

This test is nearly identical to the 'Flightline Separation - JPEG 2000' export type and most details about the various settings can be found in the Flightline Separation - JPEG 2000 668 sub-topic of the 'Export Type tab' topic (lower half of page) and the Grid tab 783 sub-topic of the 'Export Type tab' topic (paragraph 3, **Color by Collection Scan Separation**). This area of the Help Topics 538 file is found under the MARS® Tools 540 | Data Export 658 section.

As implemented in the QC Module, however, there are a few differences. In addition to the option of choosing either a 'Regular FSR' or a 'Measurable RMSDz FSR' (described here 668), both FSR types can be created for this test in a single run. The 'Cell Size' will be automatically calculated at 3 times (3x) the NPS values entered on the Input Tab 1630 for best results, but can be modified. All 'Classes' except 7 (Low Noise) and 18 (High Noise) are selected by default, but the 'Select Classes' button can be used to make changes. Only last returns are selected by default, but the 'Select Returns' button can be used to make changes. Also, for the 'Measurable RMSDz FSR' output, an option exists to use either clusters of single returns or existing ground classes to define the areas to be tested. When the 'Using clusters of single returns' option is chosen, the 'Search radius for single return clustering' value will be automatically set to 10 times the 'Required NPS' value as entered on the 'Input' tab. This value can be changed if necessary. Testing will be done by creating a virtual TIN by default, but a Grid option is available (note the disclaimer to the right of the radio buttons). In TIN mode, the 'Max TIN Edge Length' is set to 'Default' which is 2.5x the 'Cell Size' described above. The 'In Data Units' radio button can be selected to allow user input of a different actual value (not a multiplier), as needed.

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CC2 Test individual swaths for internal relative vertical accuracy using scan direction flags

The purpose of this section is to show a graphic of the relative vertical accuracy within each flight line, individually. This is done by comparing the opposing scan directions to each other as two separate surfaces and then generating a vertical separation raster from their TIN (or Grid) deltas. The result is displayed by thematically coloring the separation magnitude on a color ramp based on absolute distance. Good LiDAR data should have a consistent green coloration across the flight line (perpendicular to flight), ignoring warmer colorations due to above ground surface features. Small color variations are to be expected. The purpose of this test is to find problematic data indicated by warming color variation trends away from the center of the scan line. Flight lines that have inconsistent colorations from the center towards the edges of the flight line would highlight the possibility of a sensor or internal calibration problem, usually an incorrect encoder latency value. The relative accuracy RMSDz is reported in the bottom left of each page. Testing will be done by creating a virtual TIN by default, but a Grid option is available (note the disclaimer to the right of the radio buttons). By default, Classes 7 (Low Noise) and 18 (High Noise) will be excluded from this test, but other selections can be made using the 'Select Classes' button.

CC3 Test individual channels for channel to channel misalignment

The purpose of this section is to check the channel-to-channel sensor calibration of a multi-channel LiDAR system to ensure proper 3D alignment within a single swath. During this step, each channel is processed as a separate collection scan and compared to its paired channel. A surface-to-surface vertical separation is calculated per swath between the two channels. The results are then thematically rendered in the output rasters, one for each swath. Testing will be done by creating a virtual TIN by default, but a Grid option is available (note the disclaimer to the right of the radio buttons). By default, Classes 7 (Low Noise) and 18 (High Noise) will be excluded from this test, but other selections can be made using the 'Select Classes' button.

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This test is run only if multi-channel data is detected, based on Scanner Channel bit flag values.

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6.4.2.4 Final Report



QC Reporting

The output of this LiDAR Calibration Checks tool is written to a detailed PDF file that contains the results of the point cloud analysis. At the end of the individual test sections, a page titled 'Time Spent On Each Step' will be created to show processing times in tabular and chart formats. The report will be named using the entry in the **Output PDF File Name** box on the Input Tab 1705. The default name is 'LCC_All' but can be changed before running the tool. The report can be found in the **Output Folder** that was chosen on the Input Tab 1705. Once processing is complete, the report will open automatically if the computer has software installed to read and display PDF files. The following **Sample Report Pages** are representative of the analysis results for the three (3) tests that can be run.

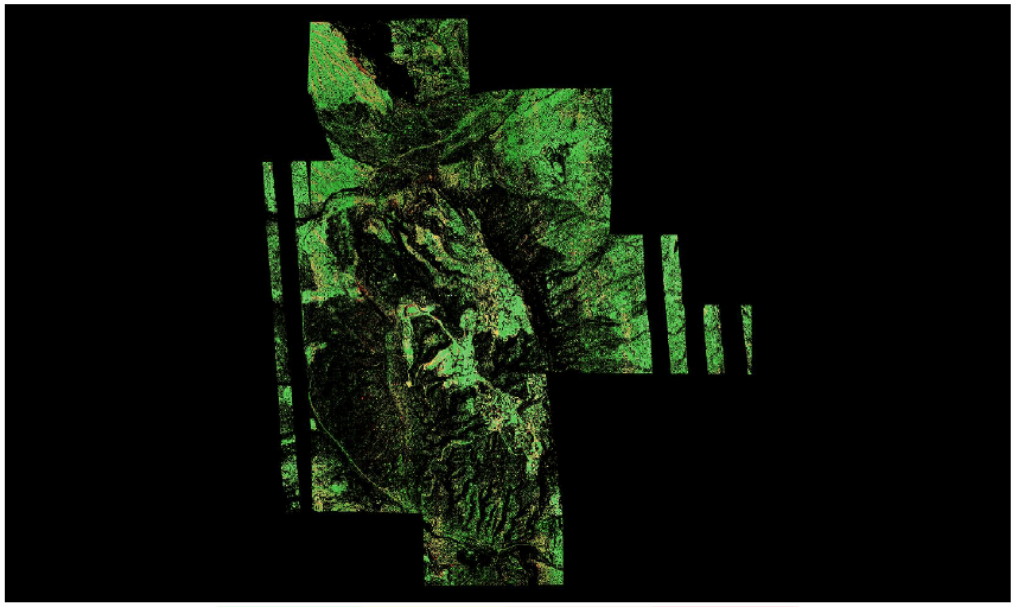
In addition to the PDF report of the point cloud analysis, the tool will also generate several raster images (JPEG and JPEG 2000 format) and shapefiles that support the visual review of the analysis results. The **Output Folder** will also contain sub-folders named for each test that was run. These will hold any rasters, shapefiles, tables, interim PDFs, etc., that were created and used to build the final report. These sub-folders can be deleted if no longer needed after the tool has completed and the final PDF is generated.

Sample Report Pages:

CC1 Report on Flight Line Separation (Relative Accuracy) per Project (Measurable)

The purpose of this section is to show a graphic of the flight line separation raster for all of the data processed. This image shows the vertical separation of swaths by thematically coloring the separation magnitude on a color ramp based on absolute distance. This color thematic rendering is modulated by intensity to show land cover features. Only swath overlap areas are shown in the raster. When either the 'Measurable RMSDz FSR' or 'Both' option is selected, the relative accuracy RMSDz values are reported in a table following the Measurable raster.

Data Source - Z:\MARS\Test_Data_for_QCM\USGS_project_sample\Single_Channel\gen_swaths
D:\MARS\Dump9\CC1\Boresighted_FlightlineSeparation_SingleFile_Measurable_TIN.jp2



0	0.080	0.160	0.240	0.799 (Meter)
0	0.262	0.524	0.786	2.620 (US Survey Feet)

A maximum vertical separation cutoff has been applied to this graphic for the purpose of masking out disruptive features that do not show calibration issues between swaths (e.g., trees, moving cars, etc.). This can be modified in the Color Options settings window.

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CC1 Report on FSR per Project (Measurable) - Continued

Adjacent Flight Line 1	Adjacent Flight Line 2	Area 1	Area 2	Overlap Area	RMSDz (Meter/US Survey Feet)
CS_00499	CS_00500	3199457.364	8733232.846	2811785.412	0.066 / 0.218
CS_00500	CS_00501	9879847.031	16925931.073	6648506.797	0.060 / 0.196
CS_00501	CS_00502	28508068.879	39731606.299	13926116.099	0.051 / 0.166
CS_00502	CS_00503	38912678.416	38400577.819	12674022.826	0.045 / 0.148
CS_00502	CS_02126	38912678.416	60188893.728	5315869.698	0.050 / 0.165
CS_00503	CS_00504	62343216.941	77778306.920	24646190.482	0.066 / 0.218
CS_00503	CS_02125	51327675.814	146778075.044	4551094.409	0.072 / 0.237
CS_00503	CS_02126	62343216.941	107152301.185	54861462.648	0.059 / 0.192
CS_00504	CS_00505	78668556.208	72898215.722	24670811.791	0.047 / 0.155
CS_00504	CS_02117	8060725.797	34631330.434	7351191.451	0.056 / 0.185
CS_00504	CS_02125	77540917.866	123541760.848	55898916.085	0.054 / 0.177
CS_00504	CS_02126	77915188.108	107152301.185	75364787.857	0.040 / 0.132
CS_00505	CS_00531	95652361.944	119328081.286	45629032.533	0.059 / 0.193
CS_00505	CS_02117	18289615.495	19769134.169	11297433.525	0.044 / 0.144
CS_00505	CS_02124	285725116.122	628064361.279	37200700.088	0.067 / 0.219
CS_00505	CS_02125	45192511.047	123529918.110	96108142.552	0.049 / 0.161
CS_00505	CS_02126	74519114.662	107281974.473	24146821.099	0.058 / 0.190
CS_00523	CS_00524	29204222.573	87133830.523	27704096.393	0.066 / 0.215
CS_00524	CS_00525	88603713.181	96809500.947	32644757.620	0.047 / 0.154
CS_00524	CS_02120	229502632.596	362830204.296	3165257.662	0.087 / 0.284
CS_00525	CS_00526	116028512.024	132725381.701	40382888.878	0.044 / 0.146
CS_00525	CS_02117	7904675.542	63912551.504	8455375.663	0.036 / 0.120
CS_00525	CS_02118	2827550.960	19265038.937	7458283.189	0.056 / 0.183
CS_00525	CS_02120	232057024.048	405931027.876	95038653.587	0.074 / 0.242
CS_00525	CS_02121	35834502.218	56193363.744	5390354.980	0.112 / 0.368
CS_00526	CS_00527	133365441.039	134972257.575	41548606.411	0.057 / 0.188
CS_00526	CS_02117	18281941.064	44003315.883	19728913.349	0.051 / 0.168
CS_00526	CS_02118	31566476.396	38633204.424	12946322.056	0.068 / 0.225
CS_00526	CS_02120	131725067.182	202965513.938	128166624.571	0.065 / 0.214
CS_00526	CS_02121	132496770.342	200946739.299	72268023.906	0.121 / 0.397
CS_00526	CS_02122	52329517.582	80295645.796	3167487.789	0.076 / 0.251
CS_00527	CS_00528	140959881.259	150932445.648	47699915.057	0.056 / 0.183
CS_00527	CS_02117	27780944.580	48097424.490	19673099.004	0.048 / 0.159
CS_00527	CS_02118	17998794.040	24696930.812	13638293.734	0.065 / 0.212

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CC1 Report on FSR per Project (Measurable) - Continued

Adjacent Flight Line 1	Adjacent Flight Line 2	Area 1	Area 2	Overlap Area	RMSDz (Meter/US Survey Feet)
CS_00527	CS_02120	134206733.753	202661315.144	57377035.088	0.072 / 0.236
CS_00527	CS_02121	136116038.630	211416914.098	135660968.534	0.082 / 0.270
CS_00527	CS_02122	135987239.595	214807505.957	67199388.560	0.092 / 0.303
CS_00527	CS_02123	19676764.293	50833881.769	3908606.679	0.122 / 0.402
CS_00528	CS_00529	150370115.790	150754735.693	47359328.440	0.055 / 0.179
CS_00528	CS_02117	27303057.708	47212967.888	20501846.535	0.063 / 0.206
CS_00528	CS_02118	39822703.862	56138549.184	14089867.153	0.071 / 0.233
CS_00528	CS_02121	137363830.643	211401931.646	84355842.047	0.090 / 0.294
CS_00528	CS_02122	412228766.850	645286467.009	120849925.626	0.081 / 0.266
CS_00528	CS_02123	150825507.400	226811284.888	62208072.582	0.092 / 0.302
CS_00528	CS_02124	11396585.366	36046401.146	47640.760	0.053 / 0.175
CS_00529	CS_00530	150912210.477	142921214.372	43927689.787	0.063 / 0.207
CS_00529	CS_02117	30028586.847	47221009.296	21594310.047	0.062 / 0.202
CS_00529	CS_02118	17063388.744	22345586.633	15183100.558	0.056 / 0.183
CS_00529	CS_02121	98336898.228	153114387.772	10173610.360	0.081 / 0.265
CS_00529	CS_02122	136800958.736	214760634.889	93669807.369	0.069 / 0.226
CS_00529	CS_02123	150736319.521	227465479.903	130695346.759	0.069 / 0.226
CS_00529	CS_02124	254279131.400	405618989.852	32891627.794	0.084 / 0.276
CS_00530	CS_00531	129714413.178	121815904.853	36550821.333	0.061 / 0.200
CS_00530	CS_02117	24283990.846	43669120.898	17485334.787	0.054 / 0.177
CS_00530	CS_02118	5075170.000	29411874.479	7140550.904	0.061 / 0.199
CS_00530	CS_02122	43866770.114	77315384.403	13805681.517	0.054 / 0.177
CS_00530	CS_02123	143060016.623	227261173.861	75877101.713	0.079 / 0.258
CS_00530	CS_02124	129714413.178	209256337.912	115447145.220	0.083 / 0.273
CS_00530	CS_02125	103320153.928	83956208.048	10655024.773	0.103 / 0.338
CS_00531	CS_02117	20160630.220	12666408.616	11266759.336	0.048 / 0.157
CS_00531	CS_02123	41501061.041	70043188.143	12939036.482	0.082 / 0.270
CS_00531	CS_02124	121815904.853	209354787.093	113821330.971	0.079 / 0.258
CS_00531	CS_02125	243631809.706	352547536.368	83494534.601	0.069 / 0.227
CS_00531	CS_02126	2019.835	7437.842	751062.972	0.079 / 0.261
CS_02117	CS_02118	67117576.906	41727761.449	18605854.203	0.057 / 0.185
CS_02117	CS_02120	46212758.788	47289999.139	29691410.268	0.048 / 0.158
CS_02117	CS_02121	47140958.665	52883058.741	30966731.175	0.067 / 0.219

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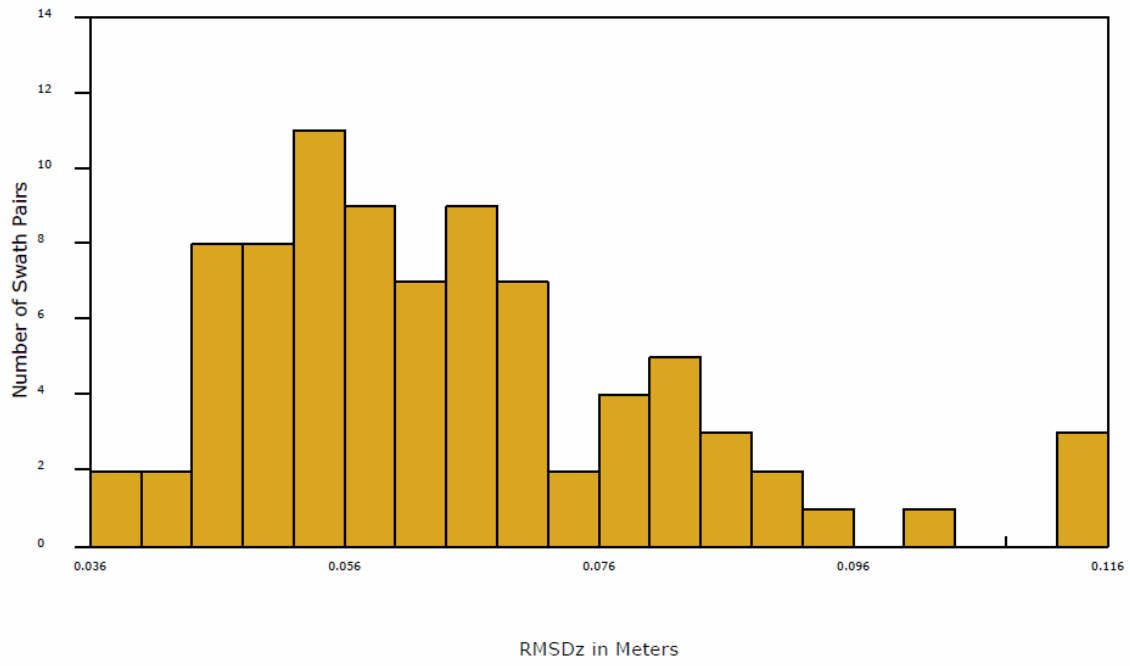
CC1 Report on FSR per Project (Measurable) - Continued

Adjacent Flight Line 1	Adjacent Flight Line 2	Area 1	Area 2	Overlap Area	RMSDz (Meter/US Survey Feet)
CS_02117	CS_02122	54843193.856	53559814.756	32206891.350	0.052 / 0.169
CS_02117	CS_02123	44892124.579	50047426.031	23754906.684	0.060 / 0.197
CS_02117	CS_02124	36428067.031	34333023.352	17260503.860	0.040 / 0.132
CS_02117	CS_02125	24499381.227	25102426.634	15540251.039	0.037 / 0.120
CS_02117	CS_02126	26959146.665	63219.904	5281512.541	0.059 / 0.192
CS_02118	CS_02120	25610297.289	39908144.399	20245620.781	0.049 / 0.161
CS_02118	CS_02121	31259087.280	39661947.156	21240090.647	0.055 / 0.181
CS_02118	CS_02122	22701429.913	43562845.712	28877447.904	0.045 / 0.149
CS_02118	CS_02123	37425284.545	6354391.442	12995109.474	0.044 / 0.145
CS_02118	CS_02124	13624813.176	78376.708	261817.532	0.056 / 0.182
CS_02120	CS_02121	204271152.849	202802360.775	87821196.035	0.086 / 0.283
CS_02121	CS_02122	420250450.048	429510008.578	109657224.997	0.062 / 0.203
CS_02121	CS_02123	1049686756.695	1053421413.750	1035759.672	0.069 / 0.228
CS_02122	CS_02123	211411813.744	208745734.456	103671136.800	0.065 / 0.213
CS_02123	CS_02124	207074839.670	207536302.145	85459356.884	0.059 / 0.195
CS_02124	CS_02125	209354787.093	176273768.184	83866141.233	0.067 / 0.220
CS_02125	CS_02126	137066765.537	107748388.608	55370609.794	0.053 / 0.173
Aggregate					0.090 / 0.294

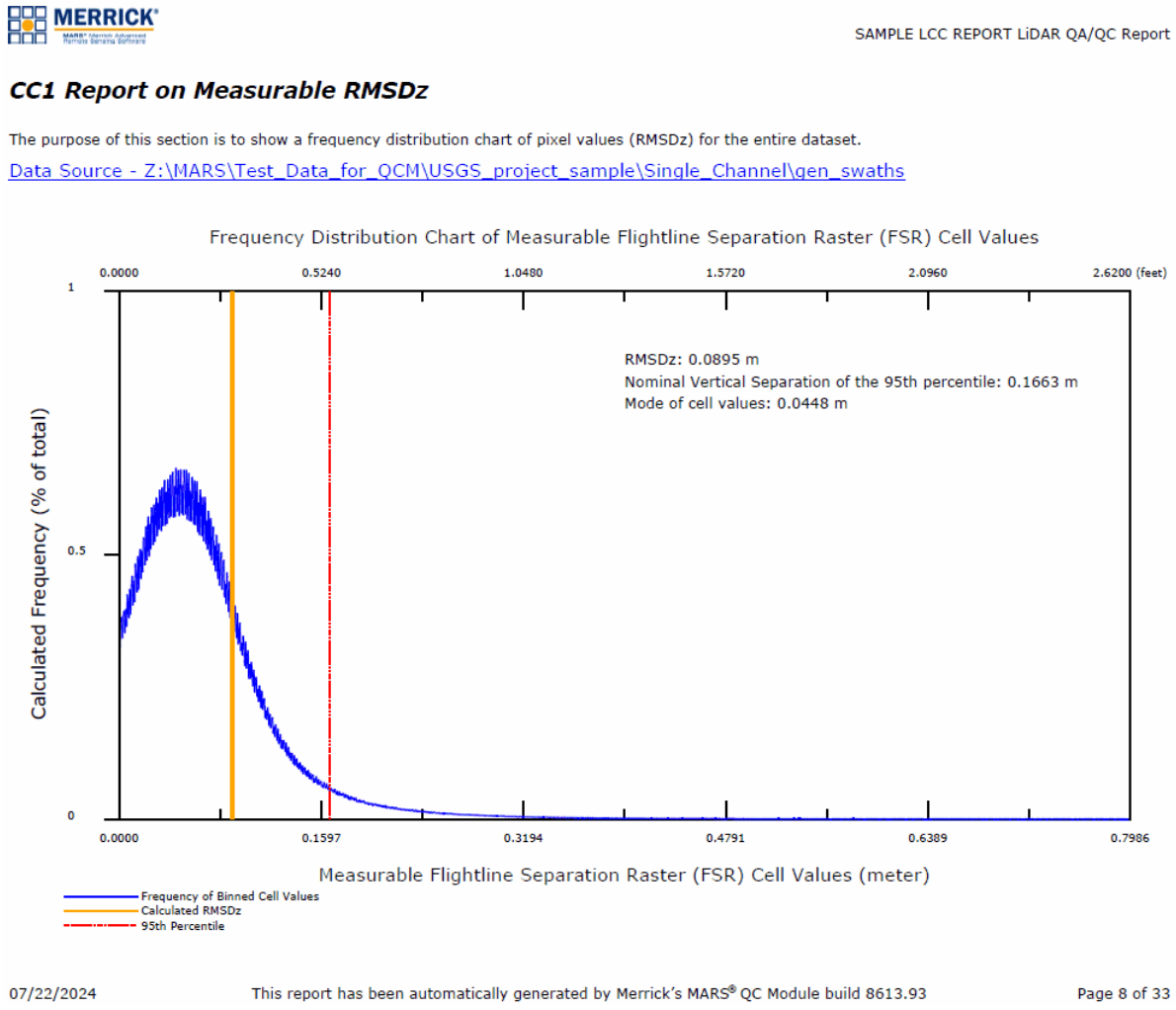
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CC1 Report on FSR per Project (Measurable) - Continued

The purpose of this section is to show a frequency distribution chart of RMSDz



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6.5 Color By Collection Scan Separation Analysis

Color By Collection Scan Separation Analysis

Merrick Advanced Remote Sensing (MARS®) Software

Color By Collection Scan Separation Analysis

Another QA/QC tool available in MARS® is the **'Color by Collection Scan Separation'** option found on

the Grid Tab 783 in the export interface when either the 'Flightline Separation - JPEG 2000' or 'Flightline Separation - Tiled GeoTIFF' export type is selected. Images are generated based on the relative elevation differences between LiDAR data in overlapping/sidelapping areas. The overlap area differences are color coded, allowing immediate detection of relative vertical accuracy problems. The non-overlapping areas will show Intensity 888 gridded data for reference purposes only. These export types are useful for rapidly assessing the consistency of the LiDAR dataset's height and can be useful in boresighting. Over hard surfaces (such as roads) the user can expect the vertical height (elevation) of points within the same 'cell' to be very similar regardless of the LiDAR collection scan from which the data originates. Differences are an indicator of a potential mission anomaly (typically a GPS/IMU problem) or a post-processing data adjustment issue. In areas such as forests or fields, where vegetation growth varies according to the time of year, understandable error may be seen. The overlaid collection scan separation coloration will have a 50% transparency set so that the output raster will still have some feature definition visibility from the background Intensity layer. For more information on the use of this tool, please see the Export Grid Tab 783 section.

Analysis Steps

The **'Color By Collection Scan Separation'** option can be a useful tool for evaluating boresighted data and the overall quality of the project's sensor alignment. The following steps outline how to generate data colored by collection scan separation, which provide the user with a useful methodology for identifying boresighting issues within a LiDAR dataset.

i. 'Flightline Separation - JPEG 2000' export type:

This methodology is typically utilized for a quick analysis of an entire LiDAR dataset and is intended to support QA/QC activities.

a) With the lidar data and tile layout shapefile loaded, click either the **'Export'** button

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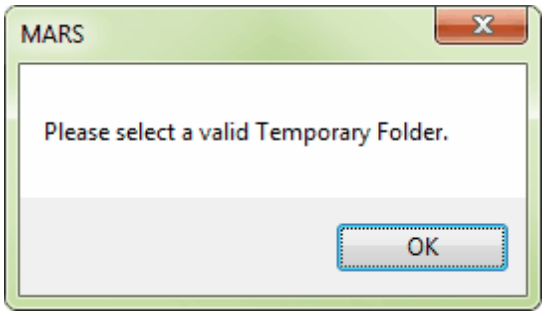


(Single File export of the entire loaded dataset), or the **'Export Area'** button 

(User-defined Box) to select the area which will be colored by collection scan separation. (For more information on the use of these tools, please see the Data Export 658 section.) Select 'Flightline Separation - JPEG 2000' from the drop-down list of export types and click the 'OK' button.

b) When the export interface opens, click on the 'Output' tab and browse to an 'Output Directory' to specify where the raster should be exported. The 'Use temporary local disk space to speed up processing' option allows the exported raster to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required (for Single File layout raster exports) and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

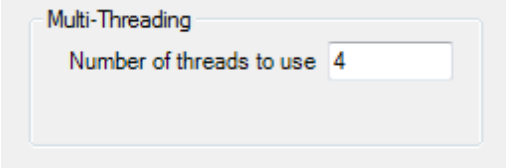
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An additional option in the lower part of the 'Output' tab allows for producing a measurable vertical separation value (RMSDz) for the collection scan separation by limiting the analysis to areas of single returns. See the Flightline Separation - JPEG 2000 668 export topic for more details).

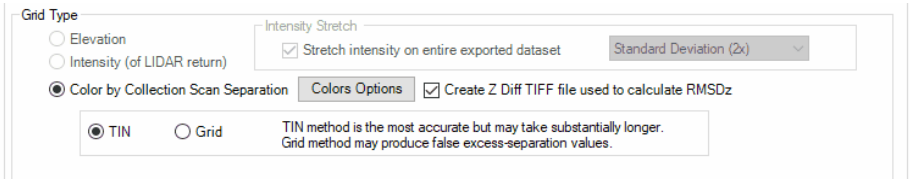
c) Select the classifications, returns, and collection scans for export on the 'Filters' tab. At least one class, return type, and collection scan must be selected for export to take place. By default, all classes and collection scans are used, but only Last Return points. If the 'Measurable RMSDz FSR' option is used (see the Flightline Separation - JPEG 2000 668 topic), then Single Returns are used instead. Note that 'Withheld' bit-flagged points are excluded by default from this export type.

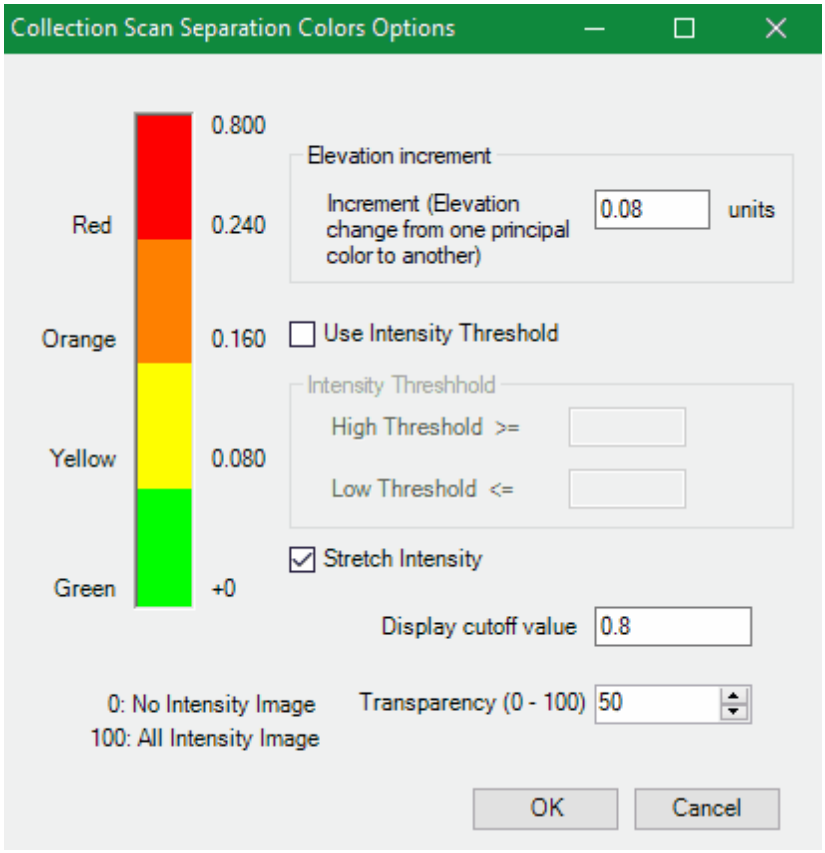
d) The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



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e) There are several settings and options on the **'Grid'** tab. The user also has the option to **'Create Z Diff TIFF file used to calculate RMSD$_Z$'** by checking the labeled box. This option creates an elevation TIFF grid of the resulting RMSD$_Z$ calculation. Click on the **'Colors Options'** button to define the elevation increment and color representation options as seen in the screen shots below, then click 'OK.'





✓ **Elevation increment:** Specify here how many elevation units should be between

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principal colors. To test against the USGS LiDAR specification (for example, less than or equal to 8cm Z difference), a value of '0.08' should be entered for projects in meters so that green raster cells would show compliance with the specification - yellow, orange, and red would not. Projects in feet should use a value of '0.26'.

- ✓ **Use Intensity Threshold:** Check this box to set high and low intensity value ranges. Pixels meeting these criteria will be rendered in magenta and blue, respectively, and will be displayed on top of collection scan separation rendered pixels.
- ✓ **Stretch Intensity:** Uncheck to disable intensity stretching for the background image of the raster.
- ✓ **Display cutoff value:** The user has the option of entering a unit value in this text box which would be considered out of the realm of possibility. For example, in one collection scan a car may have been present from which LiDAR returns were collected. In the next collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Display cutoff value' text box will tell the software to ignore data outside this value range. In this way entering a value of '1.0' meters, for example, the vertical discrepancy between a car versus no car will be ignored. A good starting point for this value is 10 times the '**Elevation increment**'.
- ✓ **Transparency (0-100):** The user can set the transparency of the collection scan separation coloration over the output raster. The default value is set to 50. As stated in the interface itself, a value of 0 would show no intensity image and only show the collection scan separation coloration. A value of 100 would show the intensity image only and show no collection scan separation coloration.

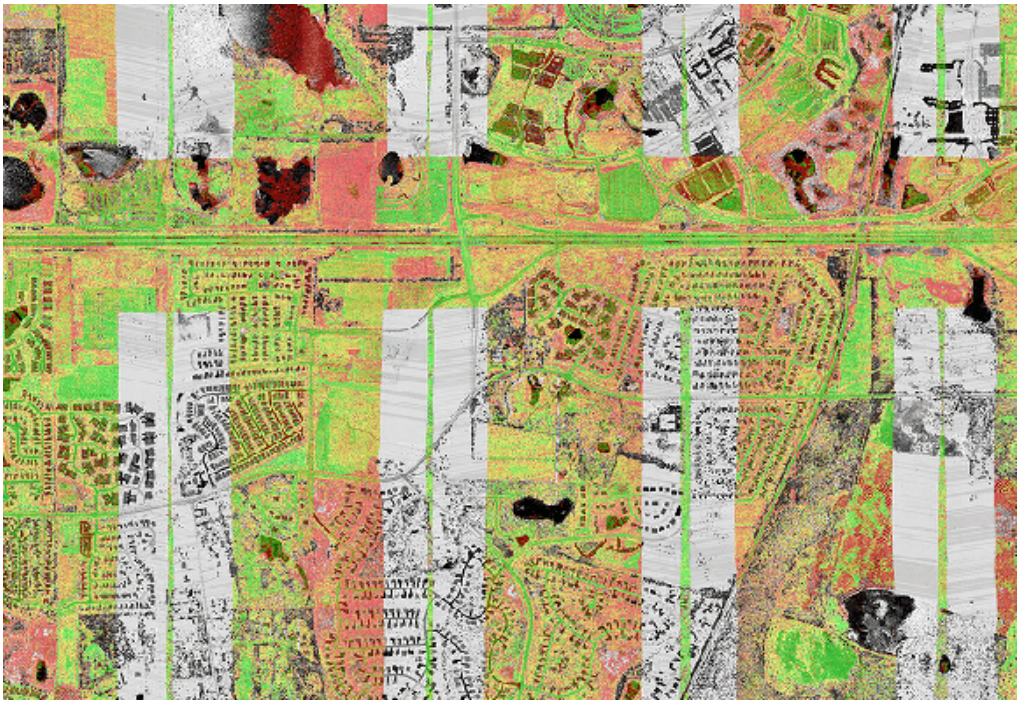
By default, a **TIN** will be created from which the final raster is made. As noted on the

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interface, this method is the most accurate but also the slowest. Using the **Grid** option can save time but may produce false excess-separation values depending on the area's terrain.

When all settings have been made on all tabs, click on the 'Export' button to export the data by collection scan separation.

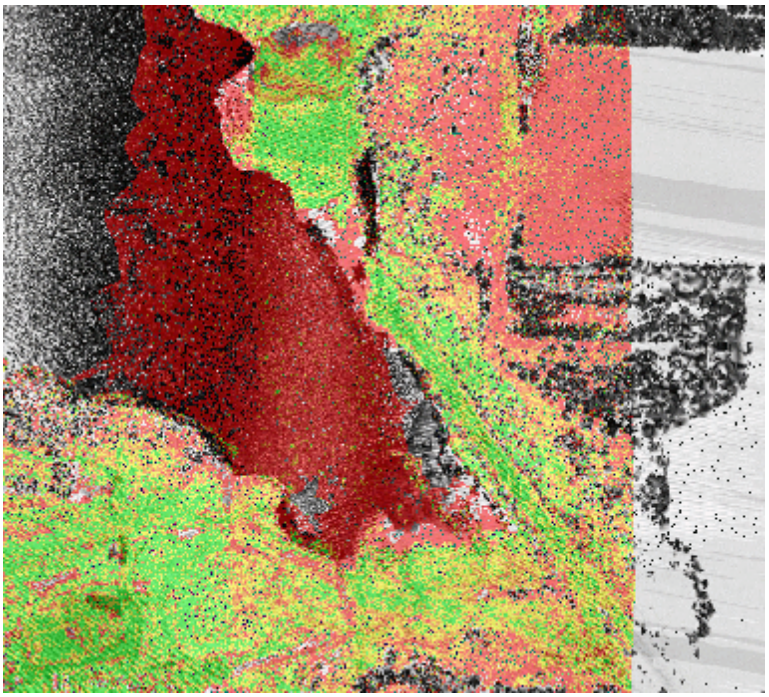
Example: The Color by Collection Scan Separation grid type has been used on the data below which is shown as a JPEG 2000 raster image. The collection scan overlap is represented by the colored sections of data. There is a cross scan included in this example which runs East-West rather than the North-South pattern of the main collection scans. The areas between overlaps are shown in intensity-only (gray-scale) rendering.



Example: As defined by the user in the 'Collection Scan Separation Colors Options'

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window, the colors in the example below represent varying amounts of elevation (Z) difference. Green represents areas with the least amount of Z difference between the collection scans, whereas red areas indicate the largest amounts of Z difference. These red (and even orange) areas are indicators of possible problems with the GPS, IMU, or post-processing data adjustment. In this example, the Color by Collection Scan Separation tool has colored a lake red. For this particular project, the East-West cross scan was flown a month after the other collection scans and the red coloration is explained by the water level of the lake being different for each flight date. On the other hand, the road by the lake should be at the same elevation in both collection scans. The road is green, indicating that the cross scan and overlapping North-South collection scan are properly boresighted.



There will be one raster file exported to the specified output folder unless the **'Create Z Diff TIFF file used to calculate $RMSD_Z$'** option was checked for export, in which case an elevation TIFF grid and a TXT file (with numeric results) will also be saved:

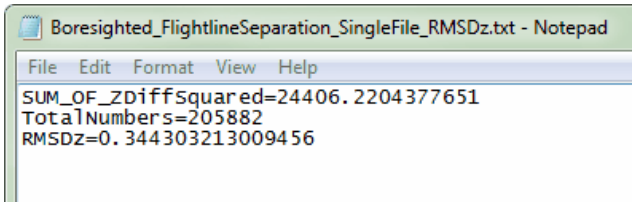
1.) A **JPEG 2000 raster image**, or *.jp2, which will allow the user to

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access the collection scan separation results as a raster image. The user must remember that this thematic rendering represents *values of separation* between two collection scans and is not representative of distance values. An example of a JPEG 2000 raster image may be seen above.

2.) An **Elevation TIFF Grid**, or *.tif, file which will contain the EXACT values of separation for each colored cell in the collection scan separation export (JPEG 2000, above). This file is only saved if the user has checked the **'Create Z Diff TIFF file used to calculate $RMSD_Z$'** option on the **'Grid'** export tab.

3.) A ***.txt** (or text) file, which will contain the numerical results of the collection scan separation export including the calculated $RMSD_Z$ value. Below is a screen shot of a sample .txt file. This file is only created if the user has checked the **'Create Z Diff TIFF file used to calculate $RMSD_Z$'** option on the **'Grid'** export tab. This TXT file is always created and saved when the 'Measurable RMSDz FSR' option (on the "Export Type' tab) is used (see the Flightline Separation - JPEG 2000 668 topic).



The resulting JPEG 2000 raster file can be automatically loaded in MARS® when the export is complete if the box for that option has been checked on the Options 780 tab.

ii. 'Flightline Separation - Tiled GeoTIFF' export type:

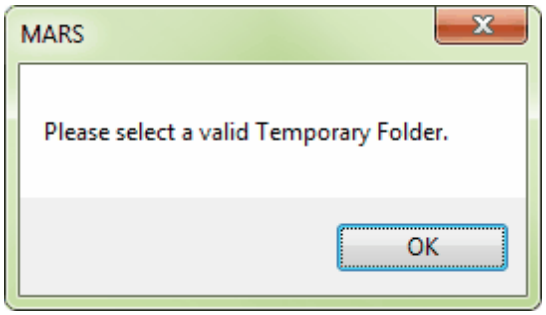
As the name of the export implies, this methodology is typically utilized for a tile-by-tile analysis in support of QA/QC activities.

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a) With the lidar data and tile layout shapefile loaded, click the **'Export'** button 

to see the drop-down list of export types. Select 'Flightline Separation - Tiled GeoTIFF' from the drop-down list of export types and click the 'OK' button.

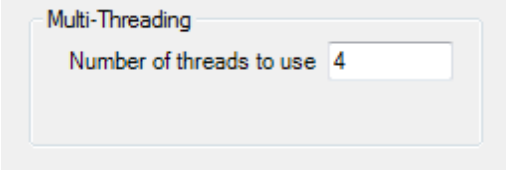
b) When the export interface opens, click on the 'Output' tab and browse to an 'Output Directory' to specify where the tiled raster(s) should be exported. The 'Use temporary local disk space to speed up processing' option allows the exported raster(s) to be written to the specified 'Output Directory', but uses local disk space to speed up processing. A typical situation for this option is when the 'Output Directory' is a network location. To use this option, check the 'Use temporary local disk space to speed up processing' box. Browse to any local folder which has available space - the export interface will display how much space is required and how much free space is in the selected folder. If there is enough disk space, the export process will use the local space to speed up processing. If the 'Use temporary local disk space to speed up processing' box is checked but a temporary folder is not specified, an error message will appear as seen below. ***NOTE:*** ***Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***



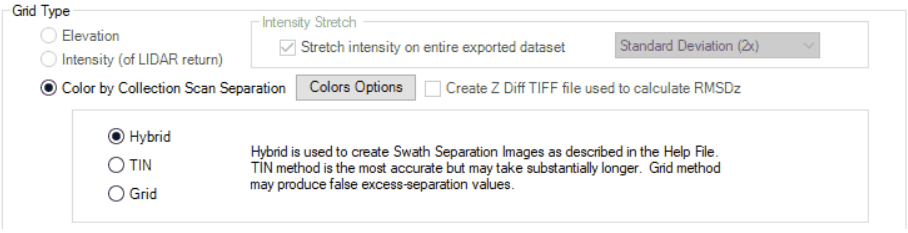
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c) Select the classifications, returns, and collection scans for export on the 'Filters' tab. At least one class, return type, and collection scan must be selected for export to take place. By default, all classes and collection scans are used, but only Last Return points. Note that 'Withheld' bit-flagged points are excluded by default from this export type.

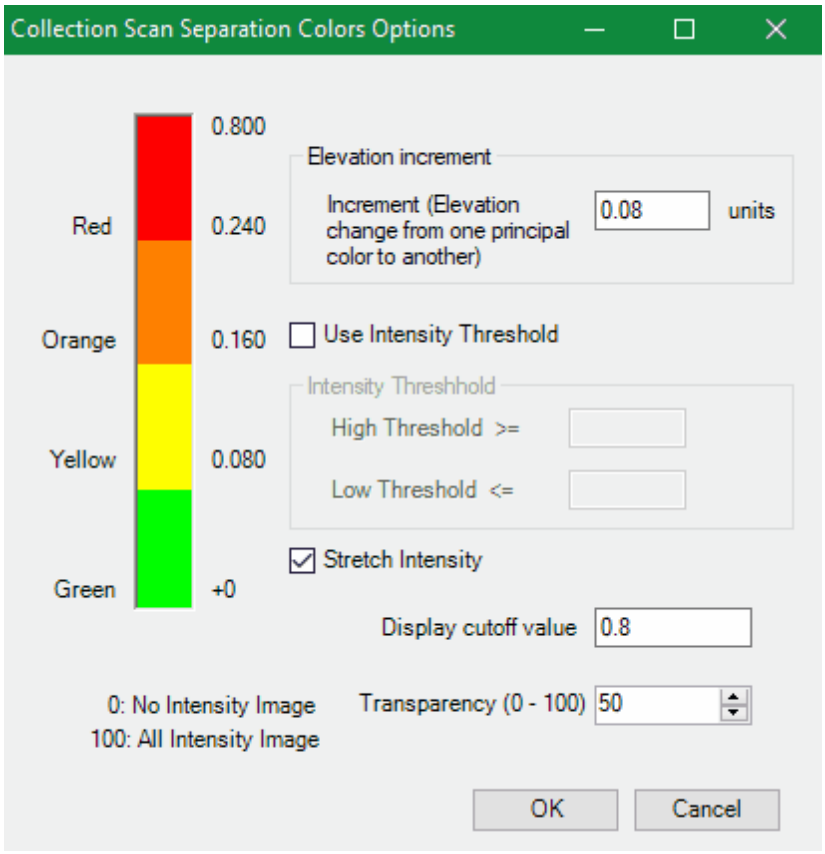
d) The 'Multi-Threading' option is available for this export type. It speeds up export by using a specified amount of a computer's CPU processing power. By default, the text box will show the maximum number of threads the computer has available for processing. Leave as is, or enter a lower number of threads to be used. If '1' is entered in the text box, it is equivalent to single-threading the process. For best performance, there should be a minimum of eight (8) GB of RAM available (not just installed) per thread.



e) There are several settings and options on the **'Grid'** tab. Click on the **'Colors Options'** button to define the elevation increment and color representation options as seen in the screen shots below, then click 'OK.'



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✓ **Elevation increment:** Specify here how many elevation units should be between principal colors. To test against the USGS LiDAR specification (for example, less than or equal to 8cm Z difference), a value of '0.08' should be entered for projects in meters so that green raster cells would show compliance with the specification - yellow, orange, and red would not. Projects in feet should use a value of '0.26'.

✓ **Use Intensity Threshold:** Check this box to set high and low intensity value ranges. Pixels meeting these criteria will be rendered in magenta and blue, respectively, and will be displayed on top of collection scan separation rendered pixels.

✓ **Stretch Intensity:** Uncheck to disable intensity stretching for the background image of the raster.

✓ **Display cutoff value:** The user has the option of entering a unit value in this text box which would be considered out of the realm of possibility. For example, in one

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collection scan a car may have been present from which LiDAR returns were collected. In the next collection scan the car is absent, and LiDAR points were collected from the road which was beneath the car. Because the two collection scans collected slightly different data, they will vary vertically in this area. The 'Display cutoff value' text box will tell the software to ignore data outside this value range. In this way entering a value of '1.0' meters, for example, the vertical discrepancy between a car versus no car will be ignored. A good starting point for this value is 10 times the '**Elevation increment**'.

- ✓ **Transparency (0-100):** The user can set the transparency of the collection scan separation coloration over the output raster. The default value is set to 50. As stated in the interface itself, a value of 0 would show no intensity image and only show the collection scan separation coloration. A value of 100 would show the intensity image only and show no collection scan separation coloration.

By default, a **Hybrid** of **TIN** (for ground points) and **Grid** (for non-ground points) is used in creating the final rasters to give the best combination of usability and speed. **TIN** and **Grid** can also be selected individually. As noted on the interface, the TIN method is generally the most accurate but also the slowest. However, it may introduce some undesirable raster artifacts if there are outlier points from a swath that are at a greater-than-normal-spacing distance from the rest of the swath they belong to. Using the **Grid** option can save time but may produce false excess-separation values depending on the area's terrain.

When all settings have been made on all tabs, click on the 'Export' button to export the data by tiled collection scan separation.

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6.6 Color By Z Delta Analysis

Color By Z Delta Analysis

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Color By Z Delta Analysis

Another QA/QC tool available in MARS® is the **'Color by Z Delta'** option found in the 'Rendering Options' section of the View Tab[192] ***(not available with Evaluation license)***. This tool is a virtual (visual only) version of the 'Color By Collection Scan Separation'[1718] tool and will color the points in the LiDAR data by the vertical difference in collection scans.

For more information on the use of this tool, please see the Color By Z Delta[868] section.

Analysis Steps

The **'Color By Z Delta'** option can be a useful tool for evaluating boresighted data and the overall quality of the project's sensor alignment. The following steps outline how to generate data colored by Z-Delta (Δ), which provide the user with a useful methodology for identifying boresighting issues within a LiDAR dataset. This methodology is typically utilized for a quick analysis of a small area of LiDAR data and is intended to support QA/QC activities.

Step 1- *Data Loading:* Load LiDAR dataset (ex. LiDAR, imagery, tiles, check points, etc.) into MARS®.

Step 2- *Data Rendering:* Zoom in to an area where there is an overlap of collection scans (use the 'Color by Collection Scan' rendering option ). Look for structures that are covered by a minimum of two

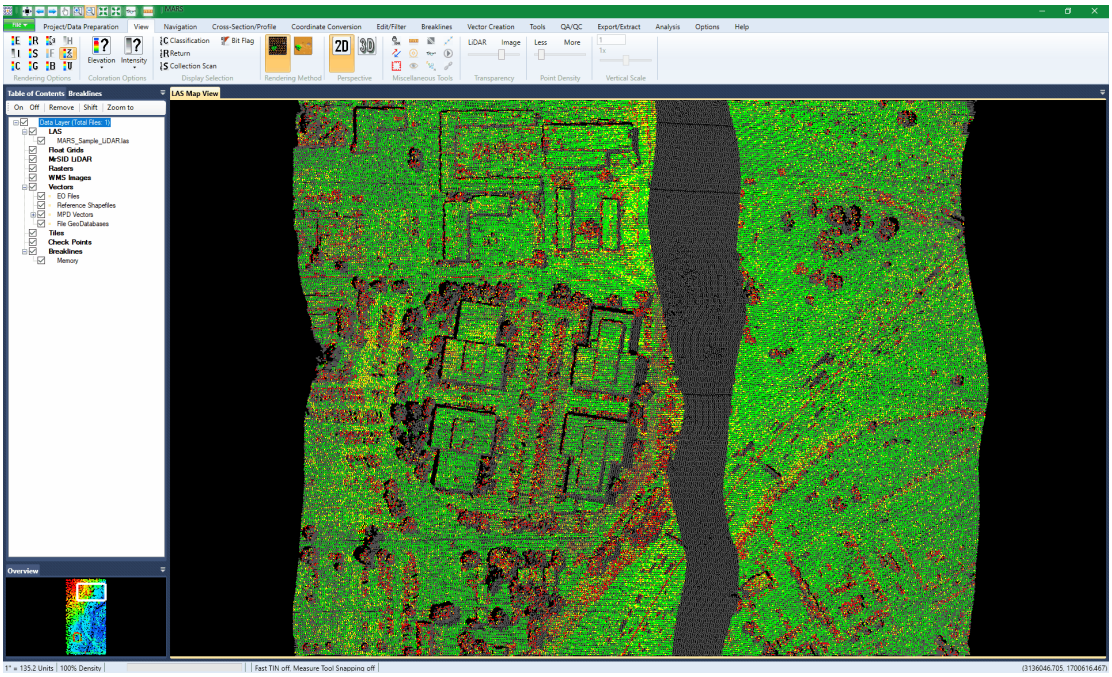
collection scans, which are rendered in separate colors for identification purposes.

Step 3- *Z Delta Colors Options:* Click the **'Color By Z Delta'**  button on the View Tab 192 and enter the desired Z-Delta options. To learn more about each aspect of this interface, please visit the Color By Z Delta 868 section of the help. Make sure to choose a collection scan as a reference. This drop-down box will be automatically populated with the collection scans currently being displayed in the LAS Map View window. Choose **'OK'** and the data currently displayed will be colored by Z-Delta.

Step 5- *Visual Analysis:* The user will be able to quickly determine if the swath data has been properly boresighted and processed by visually inspecting the colors that are generated.

Example: The data in the screen shot below has been properly boresighted. The user has chosen a collection scan as a reference compared to any overlapping collection scans, and an increment of 0.15 units. The results show that most of the ground points are green - this means that the Z-Delta in these overlap areas is less than or equal to 0.15 units. The areas of yellow show a Z-delta between 0.15 and 0.30 units, the areas of orange show a Z-delta between 0.30 and 0.45 units, and the red areas show a Z-delta between 0.45 and 0.60 units. These areas of yellow, orange, and red should be QC'ed carefully to make sure that the larger Z differences are explainable.

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If the 'Increment' value was set properly, areas indicated as green when using this tool indicate excellent to good sensor calibration, data accuracy, and boresighting. Areas of yellow, orange, or red indicate poor sensor calibration, substandard data accuracy, and/or possible boresighting issues.

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6.7 Contour By Collection Scan Analysis

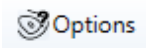
Contour By Collection Scan Analysis

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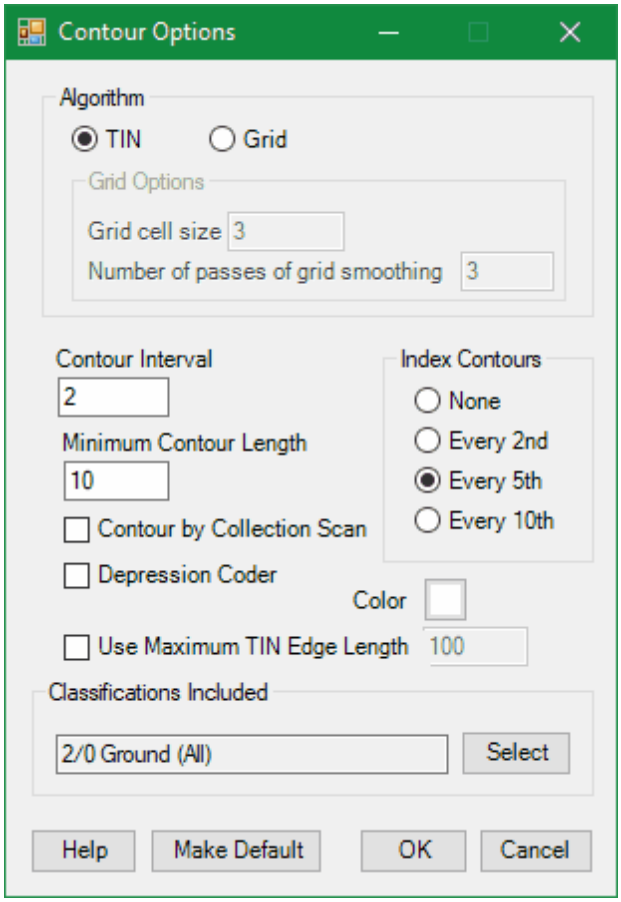
Contour by Collection Scan Analysis

Another QA/QC tool available in MARS® is the **'Contour by Collection Scan'** option within the Contour Options dialog ***(not available with Evaluation license)***. This tool generates individual contour lines based on the collection scans within the area-of-interest, which can help the user determine the overall

accuracy of the collection scans in relation to each other.

This method of contour generation is an option within the **'Contour Options'** dialog, which can be launched by clicking the **'Options'** 

button in the 'Virtual Contours' section of the Analysis Tab 489.



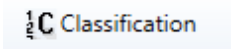
Analysis Steps

The **'Contour by Collection Scan'** option can be a useful tool for evaluating calibrated collection scan data and the overall quality of the project's sensor alignment. The following steps outline how to generate contours by collection scan - a helpful methodology for identifying data quality issues within a LiDAR dataset. This methodology is typically utilized for a quick analysis of LiDAR data and is intended

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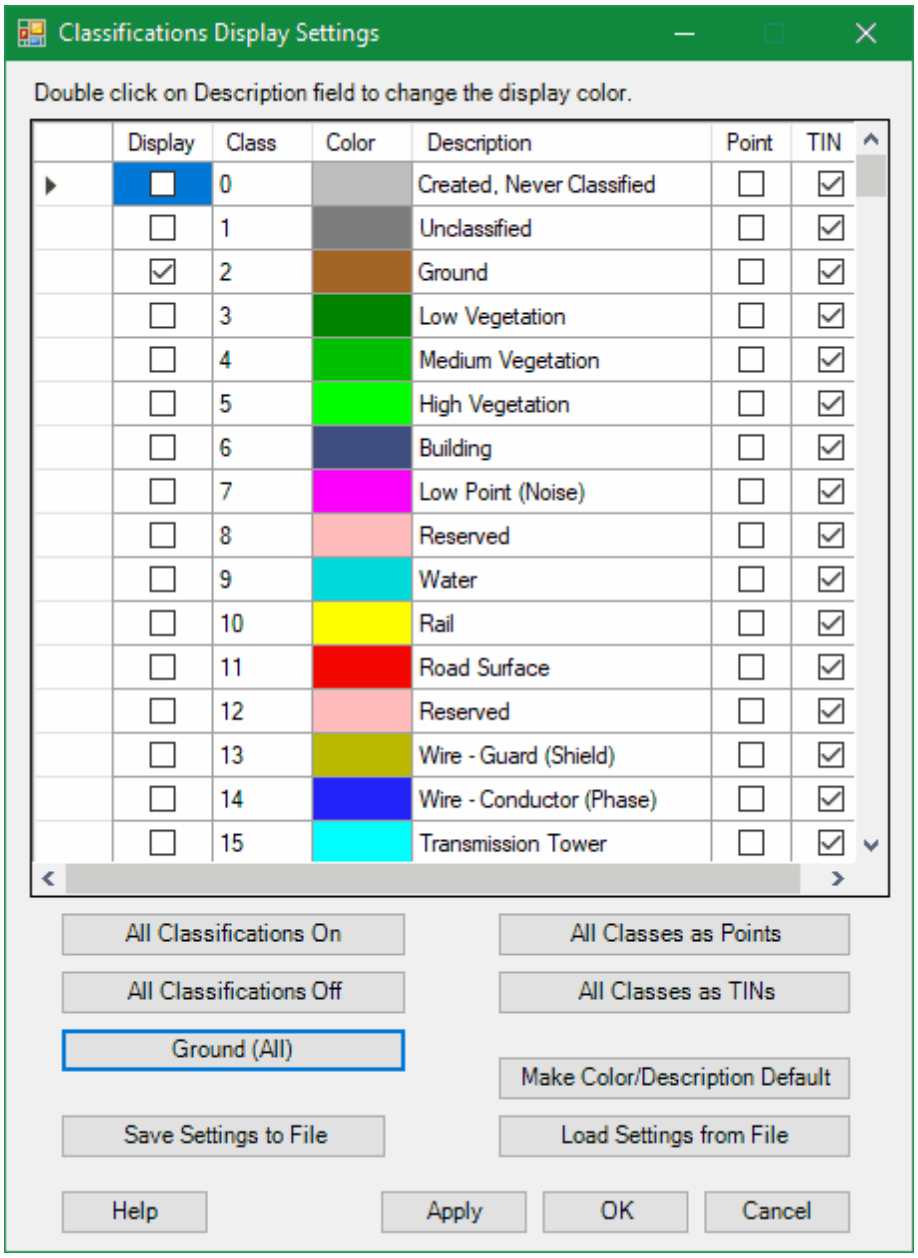
to support QA/QC activities.

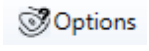
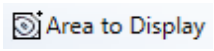
Step 1- *Data Loading:* Load LiDAR dataset (ex. LiDAR, imagery, tiles, check points, etc.) into MARS®.

Step 2- *Data Rendering:* Change the default point rendering to **'Color by Classification'**  , which will display all of the LiDAR data classifications. Click the **'Classification'** 

button on the View Tab 192 to launch the **'Classifications Display Settings'** dialog, which can be used to toggle the data classifications display. Click the **'Ground (All)'** button to render Class2, which is typically used for ground. Zoom in to an area where there is an overlap of collection scans. Click the **'TIN'**  button on the ribbon to switch from a point display to a TIN display to view the data more easily.

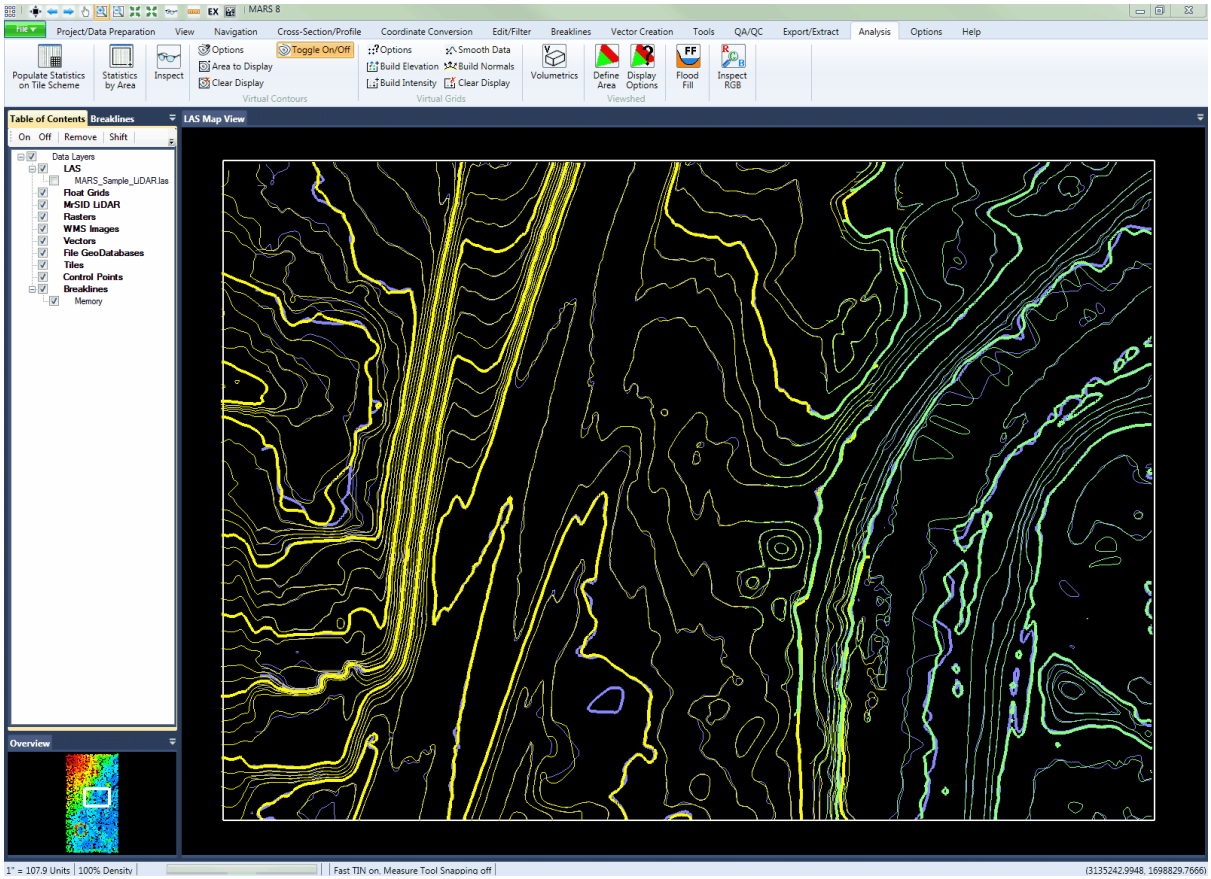
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Step 3- *Contouring Options:* Click the **'Options'**  button on the Analysis Tab 489 and enter the desired contouring options including selecting the **'Contour by Collection Scan'** radio button. To generate 'ad hoc' contours, click the **'Area to Display'**  button and drag a box over the area of interest. This action will cause MARS® to generate a set of contours for each of the available

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collection scans (see the figure below), which provides the user with a method to visually examine the resulting contours.



Step 4- *Visual Analysis*: The user will be able to quickly determine if the data has been properly calibrated and post-processed by visually inspecting the proximity of the collection scan contours.

Collection scan contours that are very close in proximity with each other indicate excellent sensor calibration and data accuracy. Collection scan contours that diverge or have a large spatial difference indicate poor sensor calibration and substandard data accuracy.

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6.8 Cross-Section/Profile Analysis

Cross-Section/Profile Analysis

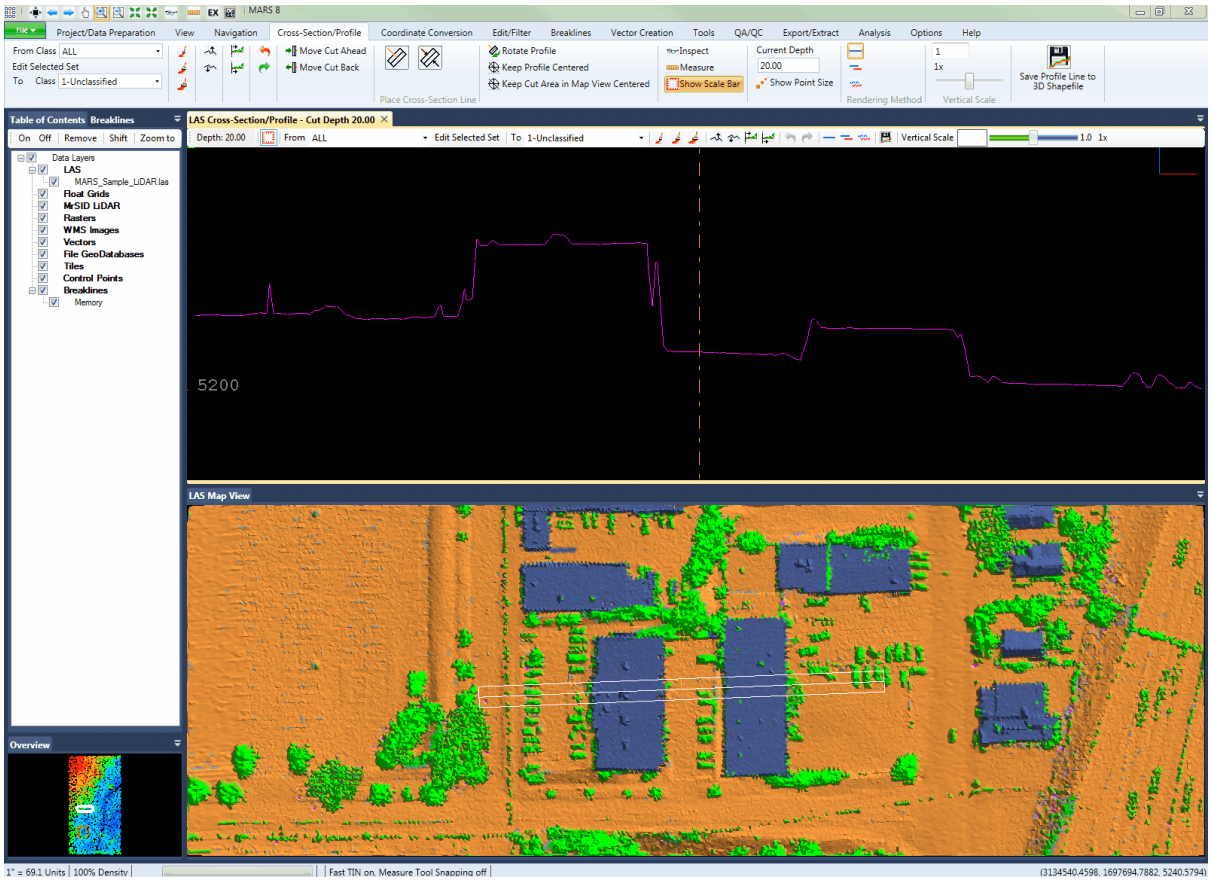
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Cross-Section/Profile Analysis

MARS® includes functionality to create and display a cross-section/profile view of a LiDAR dataset or breakline data, which provides the user with the ability to view a cross-section or profile of the area of interest. The profile functions of the tool are useful in evaluating data for calibration (collection scan/ mission alignment) and generating cross-section data for export.

MARS® Cross-Section/Profile & LAS Map View windows-- Rendered by 'Profile Combined' .

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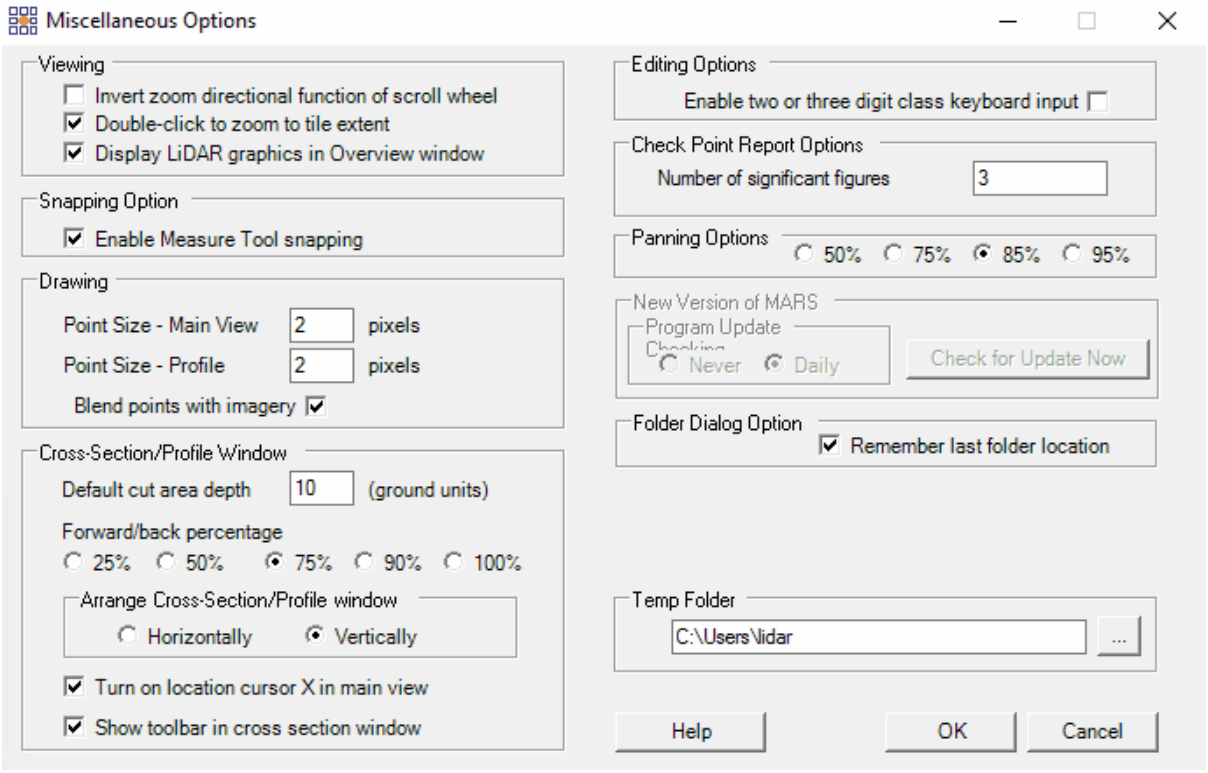


To generate a new cross-section/profile, click either the **'Place Cross-Section Line'**  or **'Place Adjustable Cross-Section Line'**  buttons on the Cross-Section/Profile Tab 240.

By selecting the **'Place Cross-Section Line'** option, the user is prompted to define a starting point and end point for the desired cut area. This option includes a default cross-section/profile cut depth of 10 units. To modify the default cut depth, click the **'Miscellaneous'** button on the Options Tab 519, which will display the following dialog:

MARS® Miscellaneous Options dialog

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Enter the desired depth for the cross-section/profile cut in the **'Default cut area depth'** text box. It is also possible to change the way the cross-section/profile window will appear in relation to the LAS Map View window. To have the windows tile horizontally, as shown throughout this section, select the **'Horizontally'** radio button. To have the cross-section/profile window tile vertically (side by side) with the LAS Map View window, choose the **'Vertically'** radio button.

Selecting the **'Place Adjustable Cross-Section Line'**  option, the user is prompted to define a starting point, end point, and cross-section/profile cut depth for the desired cross-section/profile.

Below, the optional MARS® Cross-Section/Profile Edit Toolbar is shown. It is enabled by checking the box labeled 'Show toolbar in cross-section window' in the 'Miscellaneous Options' interface shown above. This toolbar has most of the frequently used editing tools so that the user can have other tabs active

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and still have easy access to the tools.



For operational instructions of the Cross-Section/Profile edit toolbar within MARS®, please refer to the Cross-Section/Profile Window 146 section.

Analysis Steps

The cross-section/profile tool can be useful for evaluating calibrated collection scan data and the overall quality of the project's sensor alignment. The following steps outline how the cross-section/profile tool is used to identify data quality issues within a LiDAR dataset. This methodology is typically utilized for a quick analysis of LiDAR data and is normally used in conjunction with the Check Point Report tool.

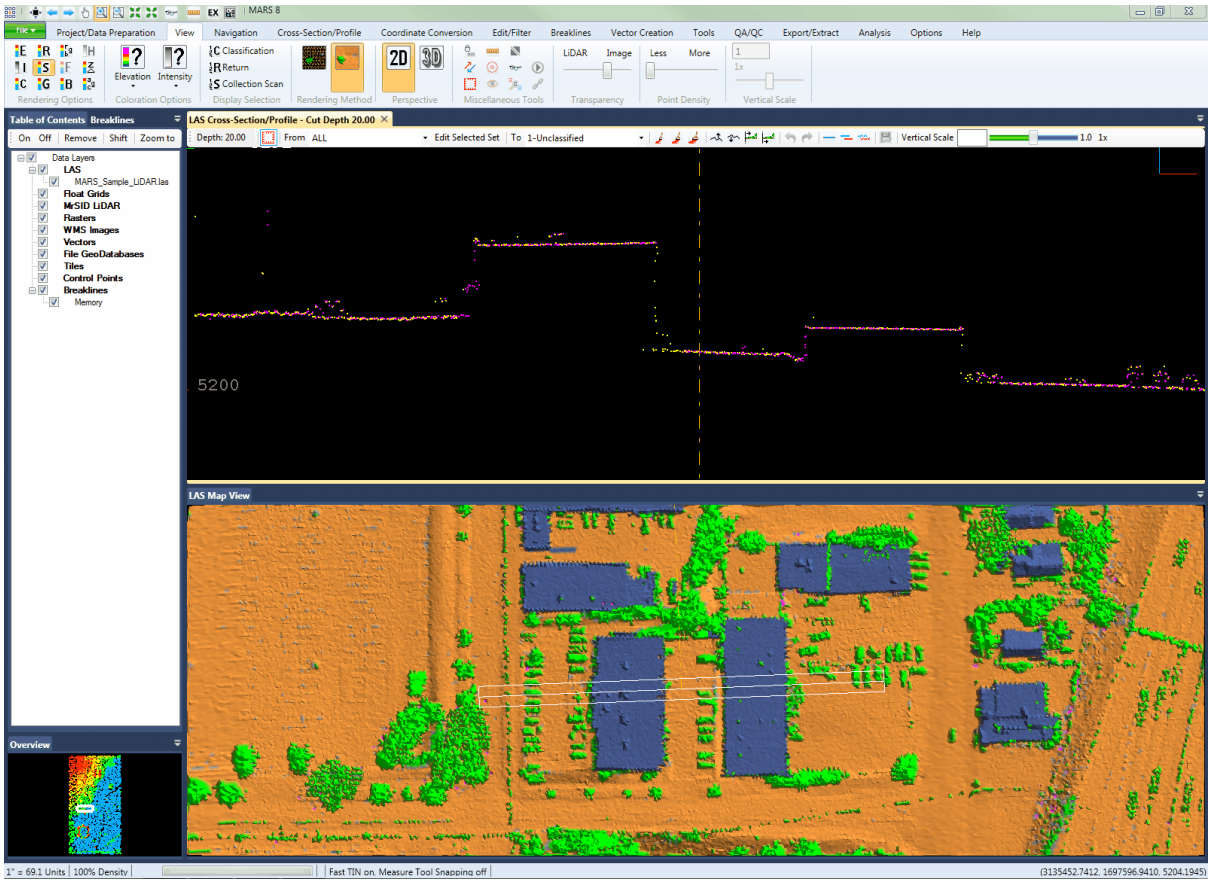
Step 1 - *Data Loading:* Load LiDAR dataset (ex. LiDAR, imagery, tiles, check points, etc.) into MARS®.

Change the default point rendering to **'Color by Collection Scan'**  , which will display the individual collection scans. To learn more about data loading, please visit Setting up a Project 1762.

Step 2 - *Collection Scan Rendering:* Zoom in to an area where there is an overlap of collection scans (an example is shown below). Look for structures that are covered by a minimum of two collection scans, which are rendered in separate colors for identification purposes.

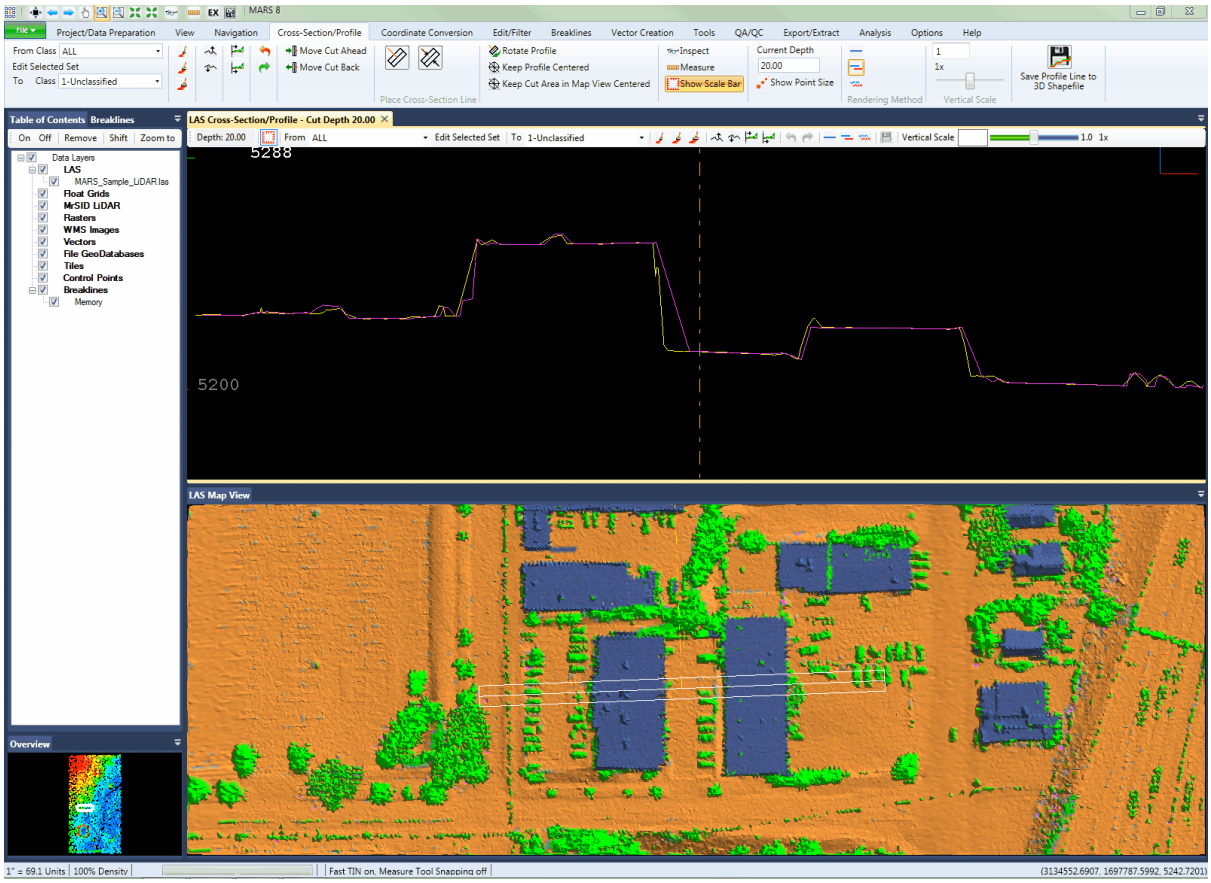
Step 3 - *Cross-Section/Profile Generation:* Click the **'Place Profile Line'**  button to activate the cross-section/profile tool. Draw a cross-section/profile line across a building (see the example below).

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Step 4 - *Profile Rendering:* Highlight the cross-section/profile window and click the **'Profile by Collection Scan'** button on the Cross-Section/Profile Tab[240] to change the display to individual profile lines colored by collection scan.

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Step 5- *Visual Analysis:* Using the **'Measure'** tool to calculate the approximate distance between collection scans, the user will be able to quickly determine if the data has been properly calibrated and post-processed. Those areas with a large difference between the collection scans indicate data accuracy issues for this portion of the dataset.

Collection scans that are coincident or very close (in proximity with each other) indicate excellent sensor calibration and data accuracy. Collection scans that diverge and have a large difference between them suggest poor sensor calibration and are indicative of datasets with poor accuracy.

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6.9 Swipe Raster Over LiDAR Tool

Swipe Raster Over LiDAR Tool

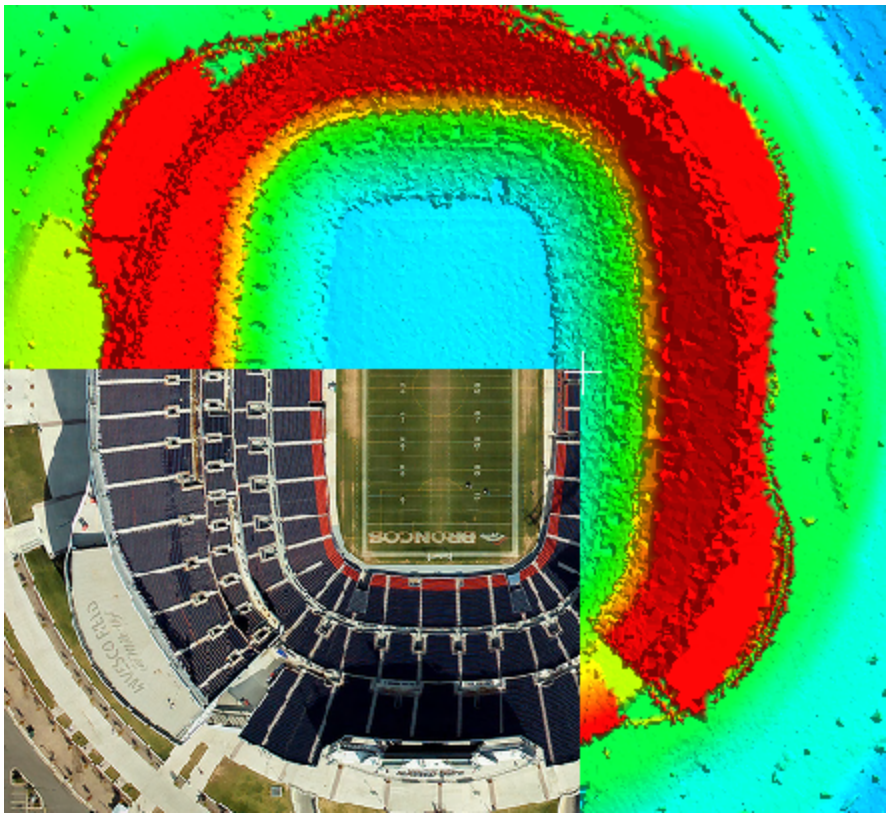
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Another QA/QC tool available in MARS® is the **'Swipe Raster Over LiDAR'** tool found on the View Tab 192. Both a raster image (or images) and LiDAR data must be loaded to use this tool. When checking the alignment of these two data types, it is most advantageous to have the LiDAR data in TIN mode.

Swipe Raster Over LiDAR: This tool allows the user to move imagery over LiDAR data for rapid viewing of the alignment between the two. To use the tool, hold the Left Mouse button to swipe.

The MARS® window below shows the Swipe Raster Over LiDAR tool working between imagery and LiDAR.

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6.10 Coverage Tracking Tools

Coverage Tracking Tools

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Coverage Tracking Tools (*available with Production license only*):

The Coverage Tracking function, found on the QA/QC Tab[458], makes a polygon shapefile noting where the user has been in the project. This helps to document which areas of a project have editing coverage. For example, when going into coverage check, the user would be able to distinguish what

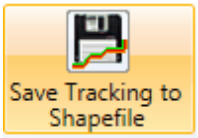
areas have been checked versus not checked. These tools work like a recorder in that the user is capable of starting recording, leaving the tool running while performing coverage checks to record movement, and then stopping recording. The user can also save the recorded data for later use.



Stop Recording: Select this button to stop the recording process. At this time, the user's movements across a project will no longer be noted in the shapefile created when the tracking path is saved.



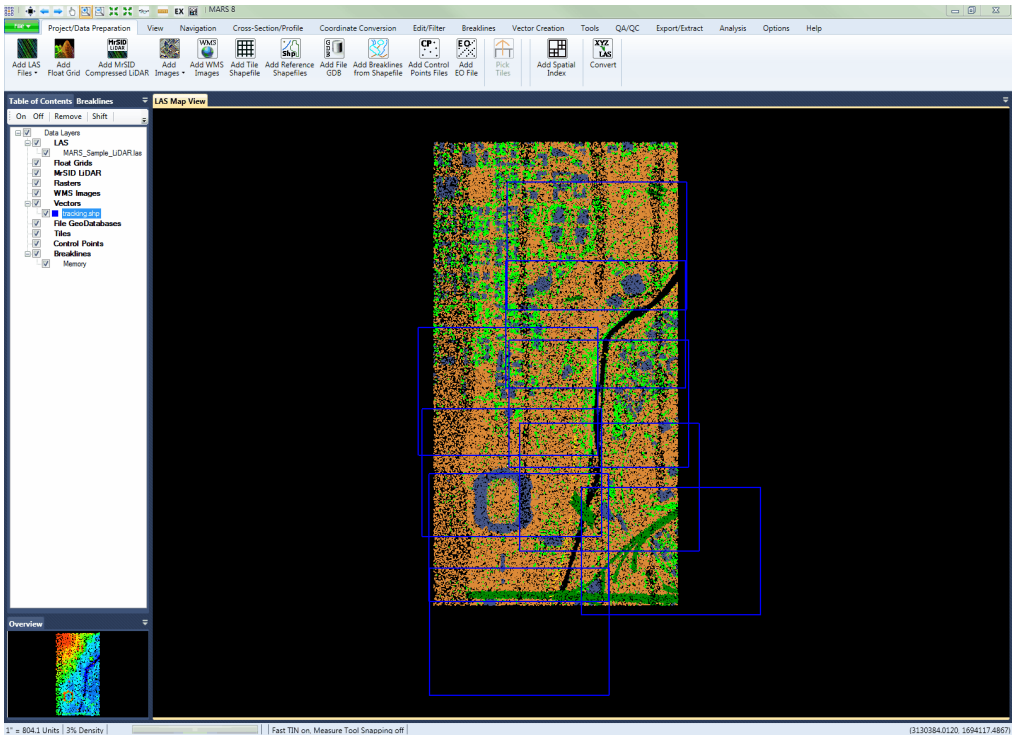
Start Recording: Use this tool when coverage checking, editing, or during any other activity where it is useful for the user to track movements across the project. Clicking the 'Start Recording' button will start the process of recording the user's movements across the data.



Save Recording to Shapefile: When the user has started and stopped a recording tracking the movements across a project, the recording can then be saved as a polygon shapefile. When a tracking shapefile is saved, a *.prj (projection definition file) is created if the projection information is known for the source LAS data. This shapefile will show the areas in which the user has visited. This can be useful in double checking that a project area has been fully examined. .

Ex: Each rectangle represents an area of the LAS Map View window and the data that was viewed inside that area. With this coverage checking tool, it is easy to see that all of the data below has been viewed and no area was left unchecked.

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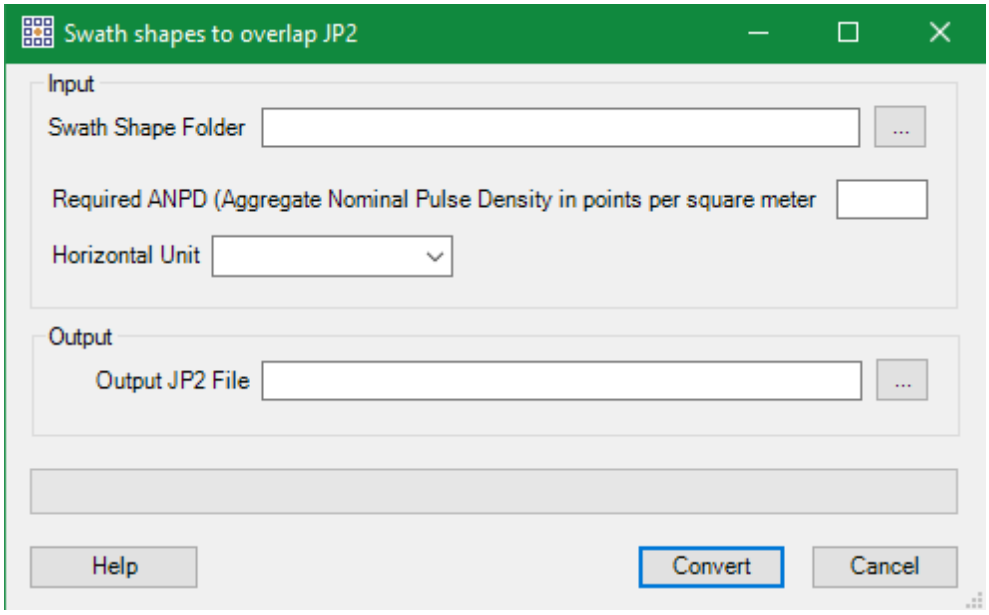
6.11 Swath shapes to overlap JP2 Tool

Swath shapes to overlap JP2

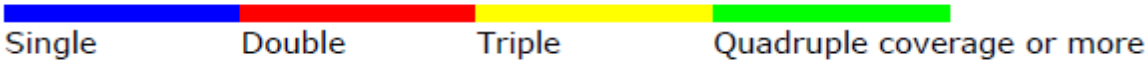
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This tool, found on the Tools Tab 389 under the 'Format Conversion' drop-down, is available with Explorer QC and Production licenses only. It converts a folder of swath footprint shapefiles into a JPEG 2000 raster to allow faster and more complete coverage checking. Browse to and select the folder containing the swath footprint shapefiles (these must be polygons), and select the output file name and location. The 'Required ANPD' (Aggregate Nominal Pulse Density) must be input, and the 'Horizontal Units' (e.g.,

Meters or US Survey Feet) must be selected from the drop-down list to ensure the proper cell size is used in the raster creation.



The output raster uses the same color coding as the 'Flight Line Overlap' raster in test DC10.1 of the Lidar Data Checks 1677 tool:



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7 3-D Coordinate Transformation

7.1 GeoCalc



For any LAS tools (including 'GeoCalc') that allow files to be pathed out without loading them in the Table of Contents in MARS®, an up-conversion prompt will appear when executing the tool if the LAS files do not meet the minimum MARS® compliancy requirements. This prompt is described in the Project/Data Preparation Tab 162 topic.

The 'GeoCalc' tool allows for the transformation of LAS data to different horizontal coordinate systems, horizontal and/or vertical datums, height models, and units. The tool reads from both the 'built-in' list of coordinate information and an optional custom list that can be created using GeoEdit 1754. *It is assumed that the user has a working knowledge of geodesy and coordinate systems/map projections when using this tool.* GeoCalc can take advantage of multi-threading to make processing faster.

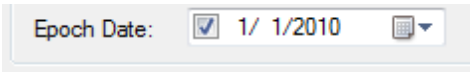
Click the **'GeoCalc'** button 

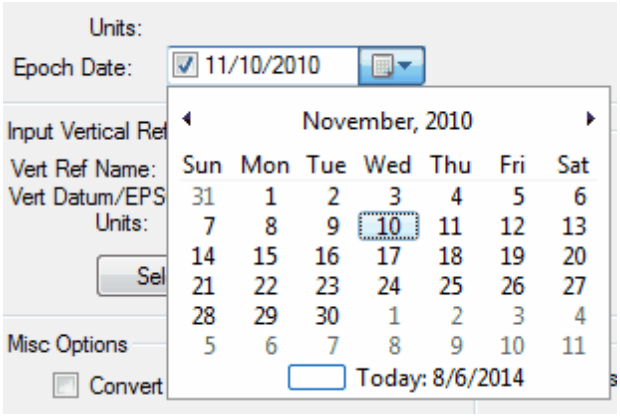
on the Coordinate Conversion Tab 254:

1. Add the LAS file(s) to be converted by choosing the **'Add'** button and navigating to the appropriate files. The **'Count'** feature in the lower-right corner of the 'Translate Files' section counts the number of files listed in the 'Translate Files' text box and is for informational purposes only.
2. The tool allows for removal of single or multiple files, or removing all files. To remove every file which has been added to the tool, choose the **'Remove All'** button. To remove multiple, but not all, files use the standard Windows selection controls (Ctrl-click or Shift-click) to make multiple selections and choose the **'Remove'** button. To remove a single file, highlight that file and choose the **'Remove'** button.
3. Select the input and output horizontal coordinate system, datum, units and Epoch Date. To help find the correct coordinate system, consider using the search engine at the bottom of the coordinate system window. Recently used systems can be found by selecting the ' *Recent* ' layer name in the left pane of the 'Select Coordinate System from

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Datasource' interface. All recent folder entries can be cleared by right-clicking the ' *Recent* ' layer name in the left pane and choosing the 'Clear Recent Object History' pop-up button. Individual recent folder entries can be cleared by right-clicking on the entry in the list to be removed and choosing 'Remove From Recent' in the context menu that appears. The Epoch Date option is not required for GeoCalc, but it is designed to be used with certain datums - it is up to the user to understand when Epoch Dates should be used. If they are to be used, check the box next to 'Epoch Date' and edit the date as appropriate (below, left). Another option is to click the drop-down arrow at the right of the entry box and a calendar will appear for the user to choose the correct date (below, right). In calendar mode, any item that turns blue when hovered over can be clicked on to speed the selection process, or the left and right arrows bracketing the month and year can be used to ahead/back one month at a time.

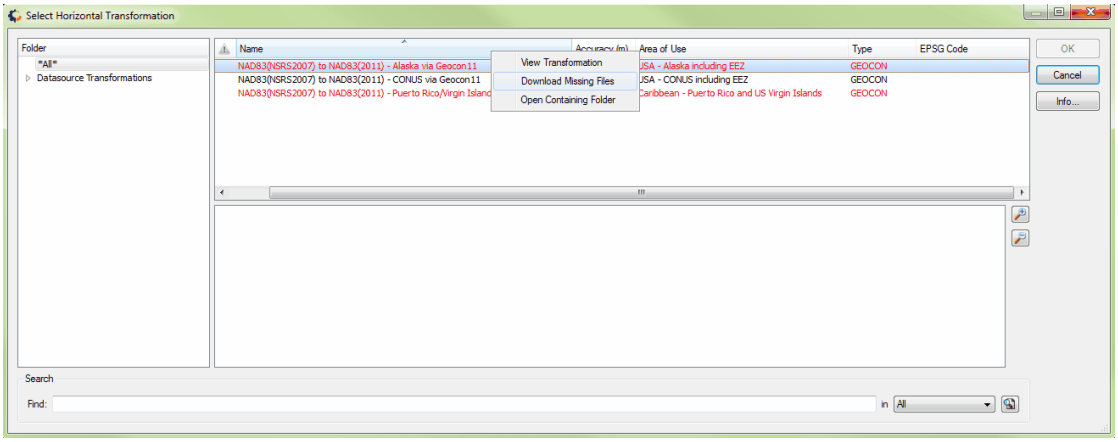


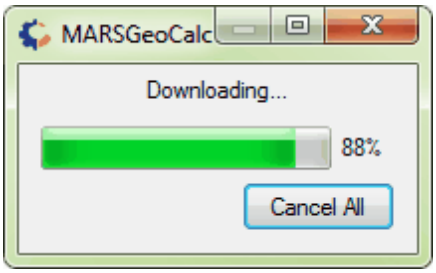


4. Optional - Select the input and output vertical system, datum, and units. Vertical references are not required but if used, both the Input and Output must be selected. ***However, if they are not used, the Z-value (height) of all output points will be set to 0.*** To carry over Z-values when no vertical change is being made, set both the 'Input Vertical Reference' and 'Output Vertical Reference' to the same system and units.

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To help find the correct coordinate system, reference, datum, transformation, or linear units, consider using the search engine at the bottom of each Datasource window. If the desired entry is listed in red, that indicates the supporting file or files needed for the conversion are missing from the correct folder. Right-click on the system name and choose 'Download Missing Files' (if available) to obtain the file directly from Blue Marble Geographics and have it automatically installed in the correct folder (requires an Internet connection). Once this is complete, the entry name will change to black and can then be used.





5. Like many other MARS® tools, the GeoCalc tool is also capable of multi-threading. The **'Multi-Threading | Number of threads to use'** text box in the 'Misc Options' section will automatically be populated with the maximum number of threads available on the particular computer in use. A lower number of threads can be entered as needed. A value of '1' is equivalent to single-thread processing. For best performance, there should

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be a minimum of eight (8) GB of RAM available (not just installed) per thread.

6. Choose an 'Output File Folder' for the translated files to be stored in. If no 'Output File Folder' is selected, a prompt asking for confirmation of an overwrite will appear. A 'No' response will allow a new path to be chosen for the transformed data before continuing.

7. At this point, the settings can be saved to an XML file for later use if a translation is not going to be run at this time. Once all entries are confirmed, click the **'Save Settings to File'** button at the bottom of the interface and a browse window will appear where the path and file name can be entered. Click **'Save'** in this window to store the settings file - if a Horizontal and/or Vertical Transformation needs to be chosen (depending on the translation entries that were made), the appropriate selection window(s) will appear. When those selections have been made, the file will be saved. The GeoCalc interface stays open to allow for other settings to be entered and saved, or the actual translation can be run at this time. Any number of settings files can be saved. Settings files can be loaded at a later time - even in a different MARS® session - populating all the settings except the list of files to be translated. To load a previously saved settings file, click the **'Load Settings from File'** button directly below the **'Save Settings to File'** button and browse to the settings file to be used. Click **'Open'** in the browsing window to load the settings.

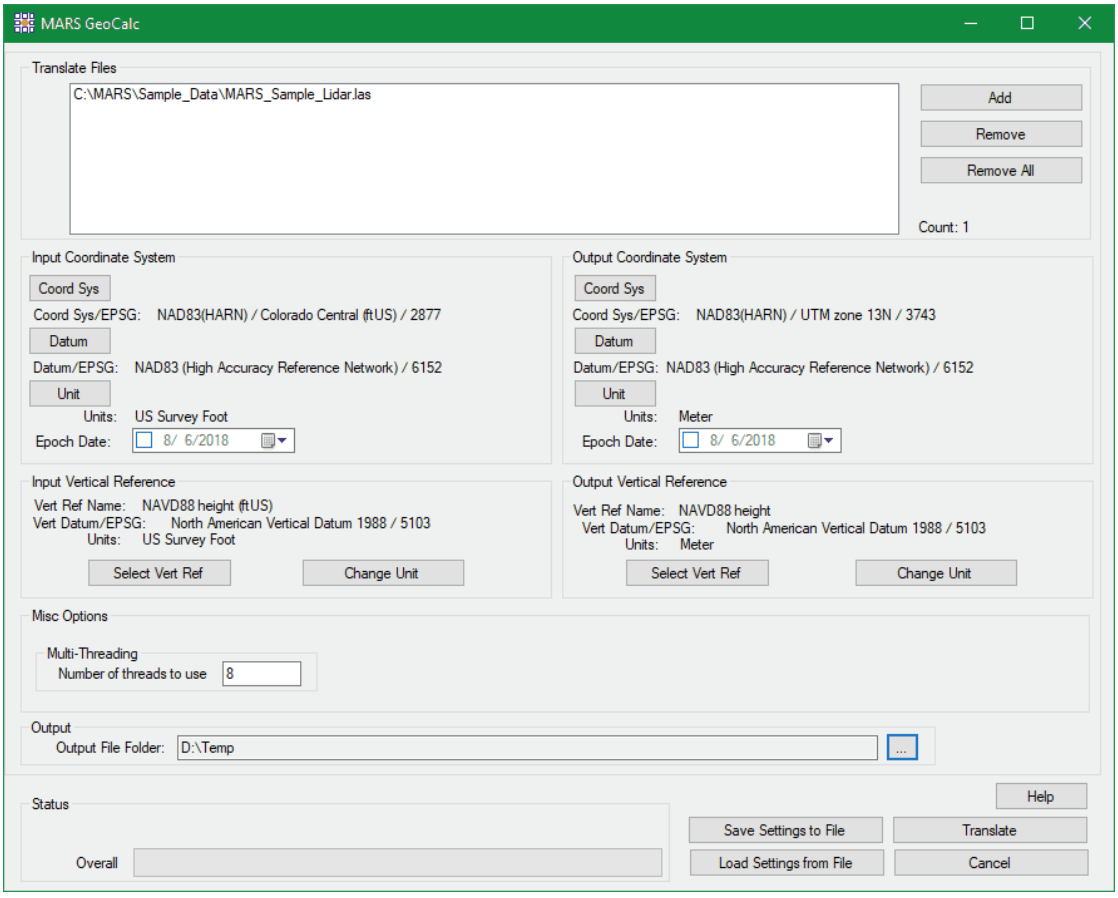
8. Click **'Translate'**. If needed based on the entries made in the interface, Horizontal and/or Vertical Transformation selection windows will appear. The translation will begin once those selections have been made. A settings file is saved automatically whenever a translation is run - even if one was saved manually just before - and the file will be stored in the 'Output File Folder' specified in step 7, above. This file will be named by GeoCalc as 'Settings_GeoCalc_*yyyymmdd_hhmmss*.xml' and can be loaded for use later in the same way as manually saved settings files can.

9. The **'Current File'** progress bar will show the user the progress of the file currently being

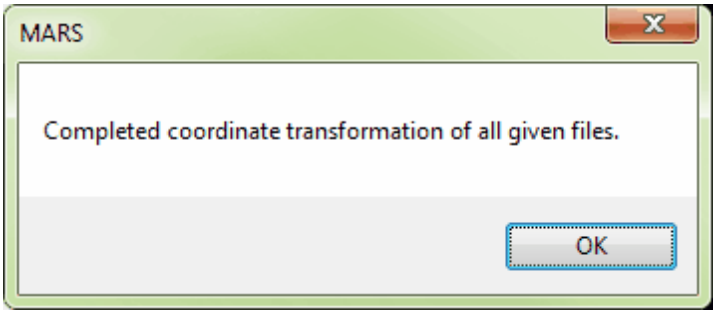
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translated (only visible when in single-thread mode), while the **'Overall'** progress bar will show the user the progress of the entire translation being processed.

10. Click the **'Cancel'** button to stop processing at any time.



When processing is finished the following message will appear:



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Version 1.4 LAS files with the preferred PDRFs of 6 or higher will be output with projection information stored in WKT (Well-Known Text) format in an Extended Variable Length Record (EVLR) for each file.

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7.2 GeoEdit



NOTE: It is expected that the user has a sufficient understanding of geodesy and map projections to properly use this tool and the GeoCalc 1748 tool.

The GeoEdit tool is meant to process a translation on a single point to test the coordinate conversion and make sure the source is converting to a known target. Once it is proven that the conversion is working properly, the GeoCalc 1748 tool can be used to convert an entire project's LAS data. This tool is also used to create and edit custom coordinate system definitions.

The left side of the GeoEdit tool is where the user enters the original projection information (the 'From:' side). The right side of the interface is where the user specifies what projection system the new data is to be converted to (the 'To:' side). In the example farther down this page, the **'Convert ➔'** button would convert Colorado Central State Plane data to UTM Zone 13N. The GeoEdit tool also allows the user to define custom coordinate systems, horizontal and vertical datums, and height models. These are stored in a separate file ('custom.xml') in the **C:\MARS\Data** folder which GeoCalc will then read along with the original installed coordinate system information. To share any custom-defined systems with

another MARS® installation, the 'custom.xml' and 'geodata_82.xw' files must be copied to the additional computer(s) in the **C:\MARS\Data** folder. Be careful to not overwrite any custom files that the other computer may already contain.

Glossary Terms to Understand:

- **Projection:** The process of going from geographic (latitude and longitude - spherical) data to a projected coordinate system (flat 2D surface).
- **Reprojection:** Converting from one projection system to another.
- **Datum Transformation:** Transforming from one datum to another. This could be a vertical or horizontal transformation.
    - ✓ **Horizontal:** (example: NAD 83 to NAD 27)
    - ✓ **Vertical:** (example: Ellipsoidal Height to NAVD 88 Height)
- **Unit Transformation:** Converting from one unit to another (example: U.S. Survey Feet to Meters).

Using GeoEdit:

Click the **'GeoEdit'** button 

on the Coordinate Conversion Tab 254:

1. Add the coordinate information **Data Source** to be used for the conversion. The default file is 'C:\MARS\Data\geodata_82.xml.' It includes all built-in systems plus any custom made systems from an optional "custom.xml" file (see "**Creating and saving custom coordinate systems**", below). At this time it is not necessary to use the "Load" button.

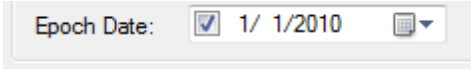
2. Specify the conversion by entering: a.) input and output Coordinate Systems, b.) input and output Vertical Reference (optional) and, c.) Coordinate Point Definition values. Recently used systems can be found by selecting the ' *Recent* ' layer name in the left pane of the 'Select Coordinate System from Datasource' interface. All recent entries can be cleared by right-clicking

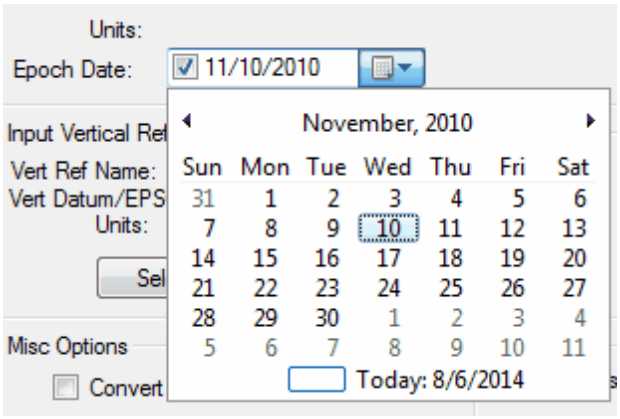
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the ' *Recent* ' layer name in the left pane and choosing the 'Clear Recent Object History' pop-up button.

'Coordinate System' Input and Output sections:

- **Select Coord Sys:** Choose the coordinate systems for both input and output from the pop-up windows.
- **Change Datum:** The datum can be (optionally) modified for input and/or output from the pop-up windows.
- **Epoch Date:** The Epoch Date option is not required for GeoEdit, but it is designed to be used with certain datums - it is up to the user to understand when Epoch Dates should be used. If they are to be used, check the box next to 'Epoch Date' and edit the date as appropriate (below, left). Another option is to click the drop-down arrow at the right of the entry box and a calendar will appear for the user to choose the correct date (below, right). In calendar mode, any item that turns blue when hovered over can be clicked on to speed the selection process, or the left and right arrows bracketing the month and year can be used to ahead/back one month at a time.





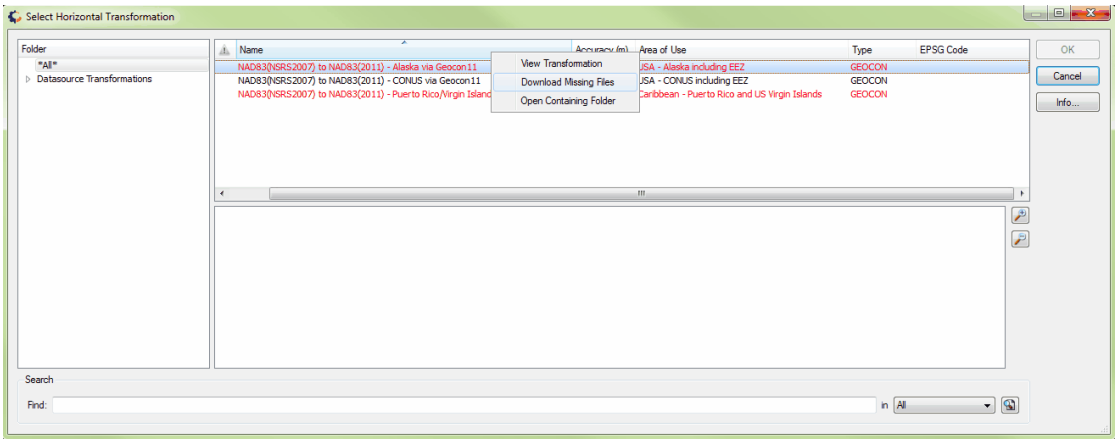
'Vertical Reference' Input and Output sections (optional):

- **Select Vertical Ref:** Choose the vertical reference systems for both input and output from the pop-up windows.

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- **Change Datum:** The datum can be (optionally) modified for input and/or output from the pop-up windows.

If the desired vertical system is listed in red, that indicates the grid file needed for the conversion is missing from the correct folder. Right-click on the system name and choose 'Download Missing Files' to obtain the file directly from Blue Marble Geographics and install it automatically in the correct folder. Once this is complete, the system name will change to black and may be used.



'Coordinate Point Definition' input and output sections (these will appear once input and output Coordinate Systems are chosen):

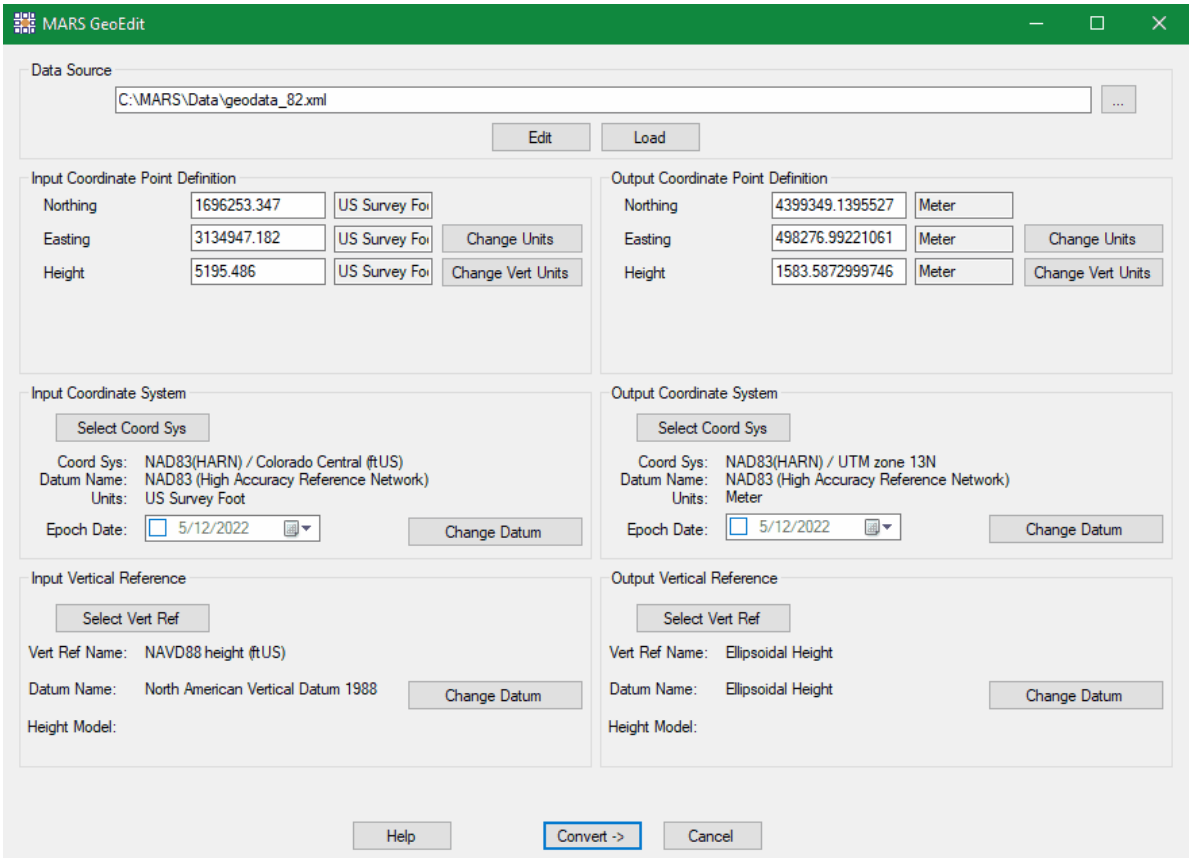
- **Northing:** Enter the value of the Northing coordinate (Y coordinate) to be converted.
- **Easting:** Enter the value of the Easting coordinate (X coordinate) to be converted. The units for Northing and Easting (U.S. Survey feet in the example below) can be changed by clicking on the **'Change Units'** button.
- **Height:** This optional field is only available if a Vertical Reference has been set. Enter the elevation value (Z-value) to be converted. The vertical units (U.S. Survey feet in the example below) can be changed by clicking on the **'Change Vert Units'** button.
- **Scale Factor at Point:** The scale factor at the origin. This represents the ratio of distance on the projection (grid) to distance on the surface of the earth (ground). *This*

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option is only available for some coordinate systems.

- **Convergence:** Convergence is the angle between the geographic north direction and the grid north direction. The earth is spherical (3D) and so the geographic north direction would differ from the 2D grid north direction at an angle called 'convergence'. *This option is only available for some coordinate systems.*

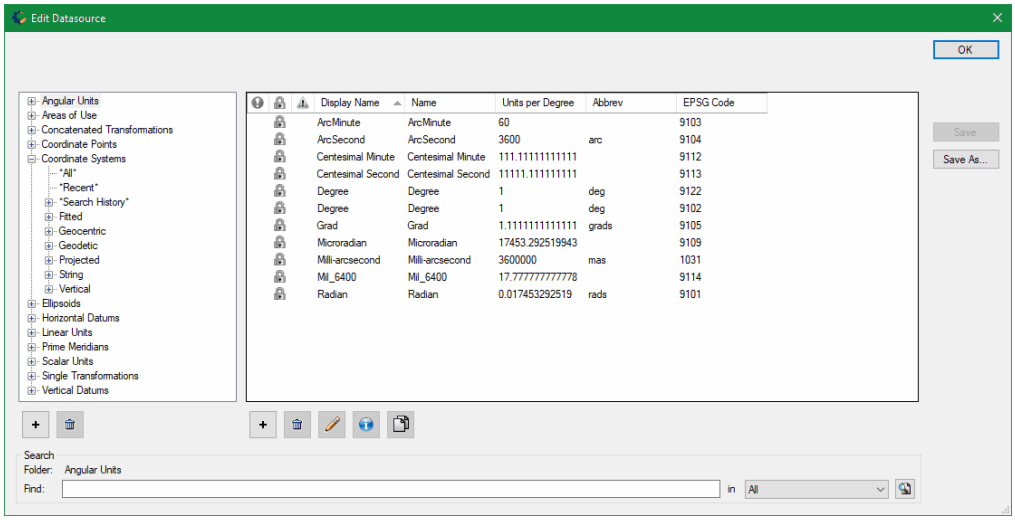
3. Click **'Convert ➔'** and the coordinates are translated into the system in the right half of the 'Coordinate Point Definition' section.



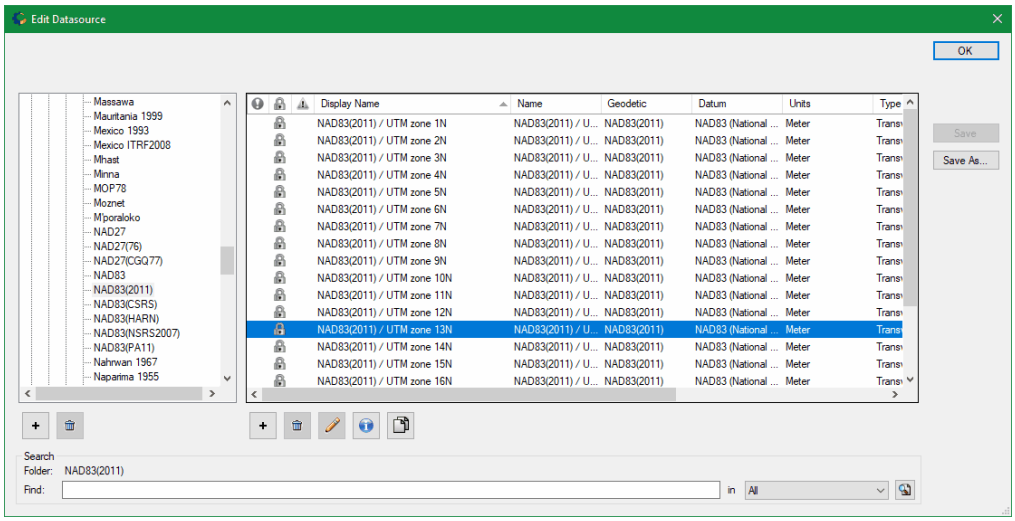
Creating and saving custom coordinate systems:

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To create custom coordinate systems (such as local or county-based), click on the 'Edit' button at the top of the interface. The following window will appear, containing all definitions from both the original installed data source ('geodata_82.xml') and any custom data source ('custom.xml').



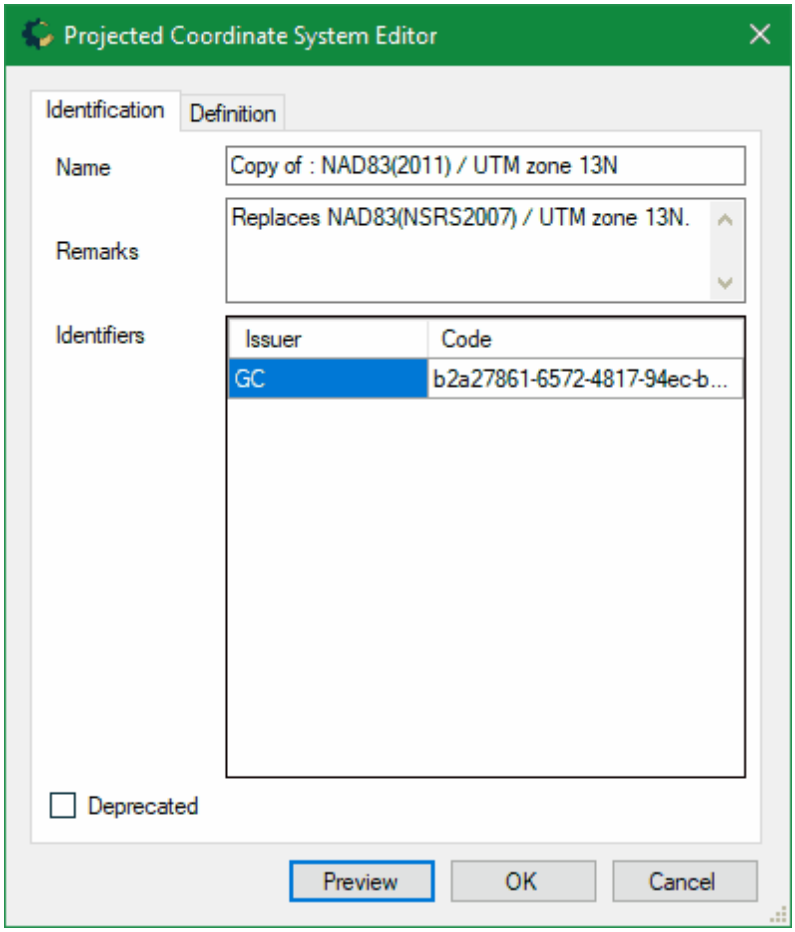
Navigate to a coordinate system that the custom one will be based on (e.g., a county-based system may be based on a UTM system). Highlight the source system in the right pane and click the 'Copy Object' button  .



In the window that pops up, give the custom system a descriptive name on the 'Identification' tab. The

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optional 'Remarks' section can be edited at this time, also. Next, click on the 'Definition' tab to make the desired changes to the system's parameters.



Finally, click 'OK' and after the window is dismissed, the new coordinate system will appear in the 'Edit Datasource' list. The blue text (and lack of a lock icon) indicates that it was not part of the original list of coordinate systems. Click 'Save' to create (or edit if already created) the custom XML file. The 'Edit Datasource' and 'MARS GeoEdit' windows can now be closed, and the new definition will be available to GeoCalc 1748. To edit this new definition, highlight it in the 'Edit Datasource' window and click the 'Edit Object' button . Make the desired changed on the 'Identification' and 'Definition' tabs, click 'OK', and then click 'Save' in the 'Edit Datasource' window.

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8 Tutorials

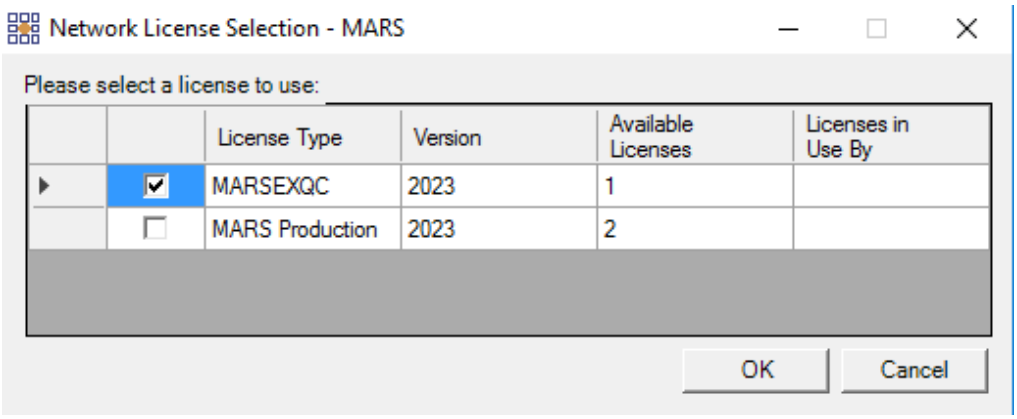
8.1 Starting MARS®

Starting MARS®

Merrick Advanced Remote Sensing (MARS®) Software

When starting the MARS® application, a prompt will appear if accessing a floating network license that contains multiple features (license types).

Network License Selection: Upon MARS® start up, the 'Network License Selection' window appears after a few seconds to select a license for use when more than one license type is available in a floating network configuration. Information about each available license will include the license type, major version number, the number of available licenses, and who the license(s) are being used by if they are not available. Only one license type can be chosen at a time from the list for any given client computer. Any additional instances of MARS® will be at that same license level. An example of the 'Network License Selection' window prompt is shown below.



MARS® installation includes two helpful documents called 'MARS Performance' and 'MARS QA QC'. To reach these documents after installing MARS®, please go to the 'MARS' program group in 'All Apps' from the Windows 'Start' button. The 'MARS QA QC' document offers insight into most of the QA and QC functions the software offers and a brief description of how to use each tool. The 'MARS Performance' document lists and describes the features and options which increase the speed and performance of the software.

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8.2 Setting Up a Project

Setting Up a Project

Merrick Advanced Remote Sensing (MARS®) Software

Starting with this version of MARS®, there are minimum requirements for any LAS files being loaded in the Table of Contents, or pathed out for processing with any of the standalone tools where LAS data does not need to be loaded first. A 'permission to up-convert' prompt will appear if the LAS data does not meet these minimums. See the Project/Data Preparation Tab 162 topic for details.

Supported Types of Elevation Data: MARS® natively supports elevation data in the LAS and MrSID Compressed LiDAR file formats (See the ASPRS Online Website). All elevation data can be loaded into MARS®, however data that is not in either of these formats will need to be converted in MARS® by using the 'Convert 640' tool located on

the Project/Data Preparation Tab 162. This tool converts various types of elevation data file formats into LAS for the purpose of efficient viewing in MARS®. The following list shows the supported elevation data formats that can be converted: (Inquire to MARS® Technical Support Information 59 to have extra elevation formats enabled for loading.)

- **ASCII (*.txt, *.csv, *.xyz, *.dat, *.grd)**
- **Esri ASCII Grid (*.asc)**
- **Float Grid (*.flt, *.hdr)**
- **GeoTIFF or TIFF (*.tif, *.tif / *.tfw)**

Supported Types of Imagery: MARS® provides the user with the ability to overlay and fuse imagery with LiDAR data. The following list shows the supported image formats: (Inquire to MARS® Technical Support Information 59 to have extra image formats enabled for loading.)

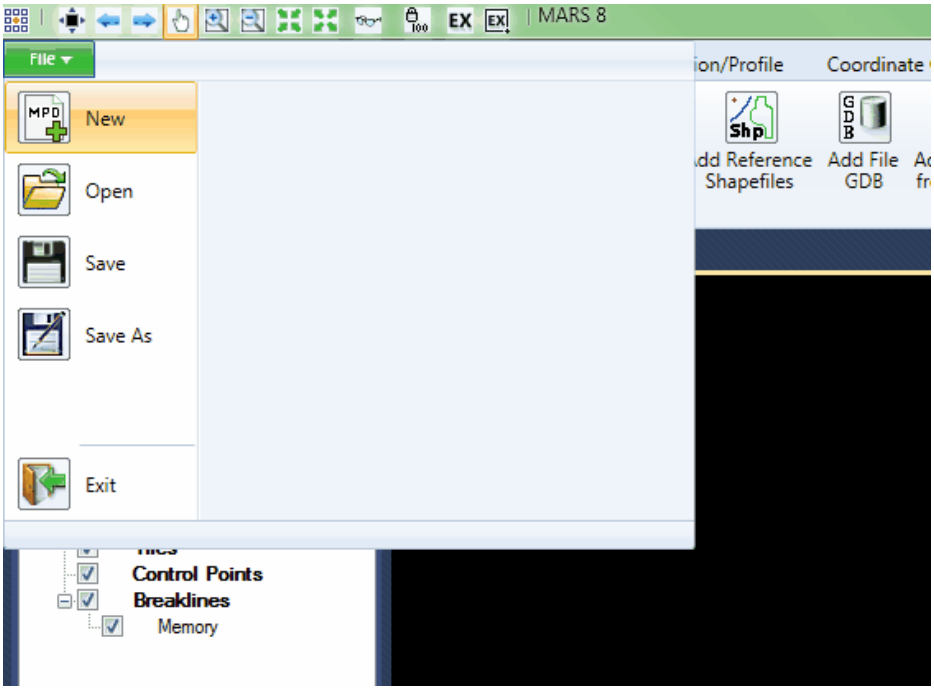
- **ER Mapper (*.ecw)**
- **TIFF (*.tif, *.tfw)**
- **NITF (*.ntf)**
- **JPEG (*.jpg) & JPEG 2000 (*.jp2)**
- **ERDAS (*.img)**
- **MrSid (*.sid)**
- **ENVI Raster Grid (*.dat, *.hdr)**
- **PNG (*.png)**
- **WMS (Web Map Service) -- requires an Internet connection**
- **MARS® has the GDAL (Generic Data Abstraction Libraries www.gdal.org) embedded and can support any image format supported by GDAL.**

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1. To create a MARS® project, first open the application by double-clicking on the MARS® shortcut 

on the desktop or use the Windows 'Start' button to go to All Apps and click on 

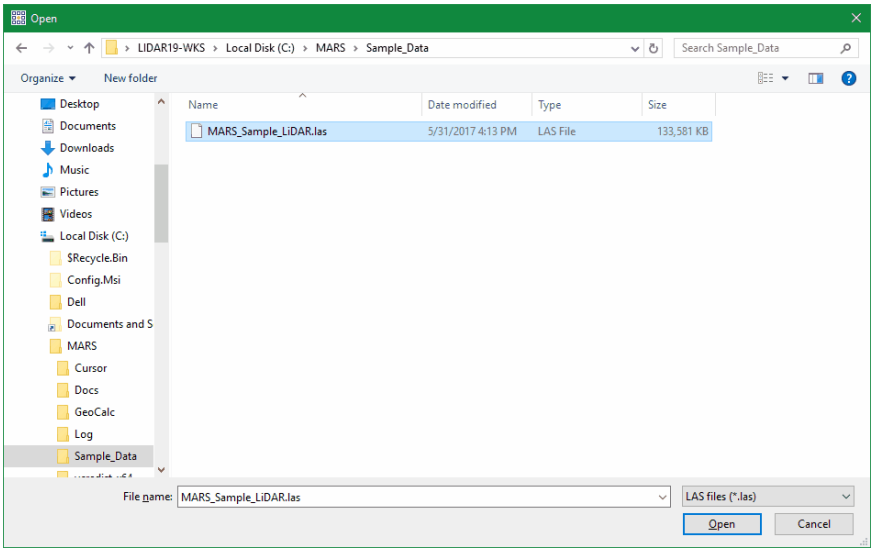
in the 'MARS' program group. The application will automatically open to a new, empty project. If a new project is needed at any point while MARS® is already open, click 'New" on the File Tab 160 and answer **'Yes'** to the **'Do you want to save your project?'** prompt. MARS® will save the current project, close it, and a new, empty project will open. Only one document may be open at a time.



2. The Table of Contents and Breaklines windows will both automatically be open in the MARS® project with the Table of Contents 67 window on top. To toggle between the two windows, click on the appropriate tab at the top of the window.

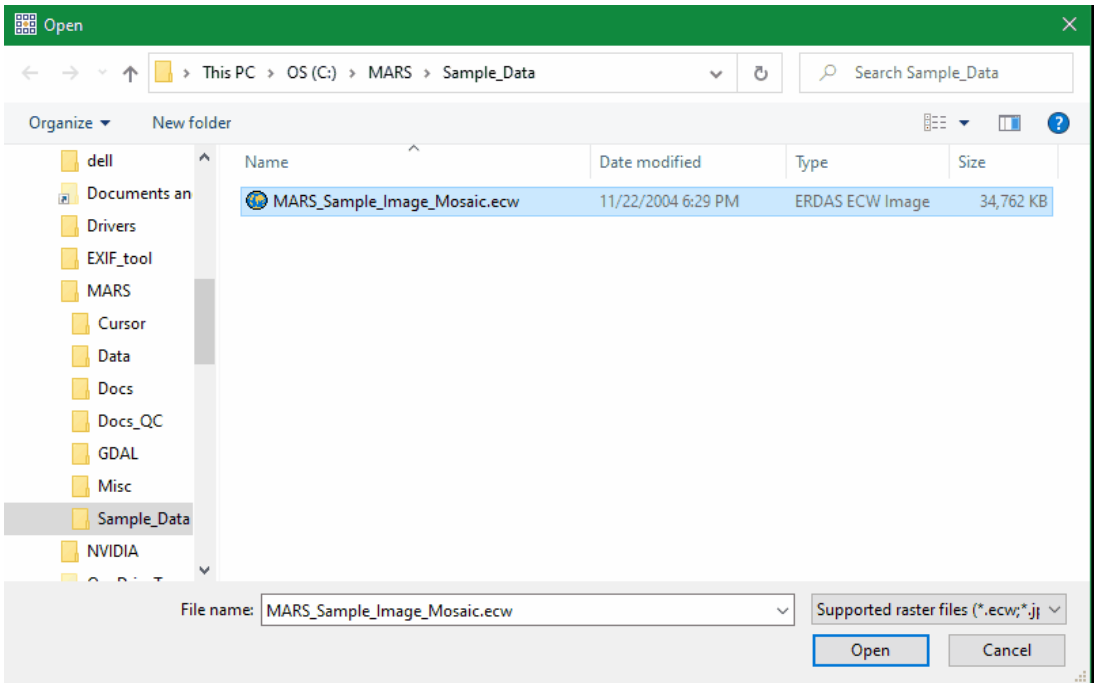
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3. To add the included sample data to a new project, go to the Project/Data Preparation Tab 162 and click on the upper-half of the **'Add LAS Files'** button. Browse to the sample data folder **C:\MARS\Sample_Data**. To load the sample .las file, choose 'MARS_Sample_LiDAR.las' and then click 'Open'.



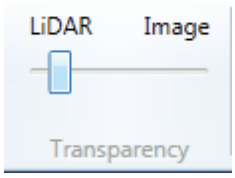
4. To add the sample RGB imagery to the project, click on the upper half of the **'Add Images'** button (on the same tab). Browse again to the sample data folder (*C:\MARS\Sample_Data)* and open the .ecw raster file.

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Now check that the image file has been loaded by unchecking the **'LAS'** layer in the Table of Contents 67. Imagery can also be toggled on and off the same way using the **'Rasters'** layer checkbox. The ability to check and uncheck files to be displayed is helpful when more than one raster is loaded in the **'Rasters'** layer.

With both LiDAR and image data checked on, use the **'LiDAR/Image Transparency'**

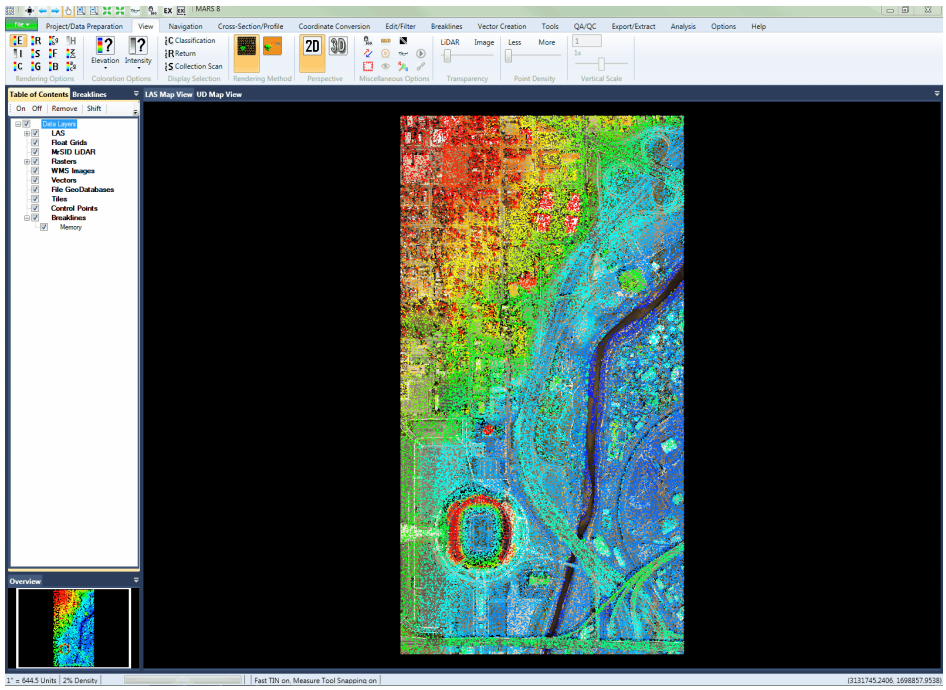


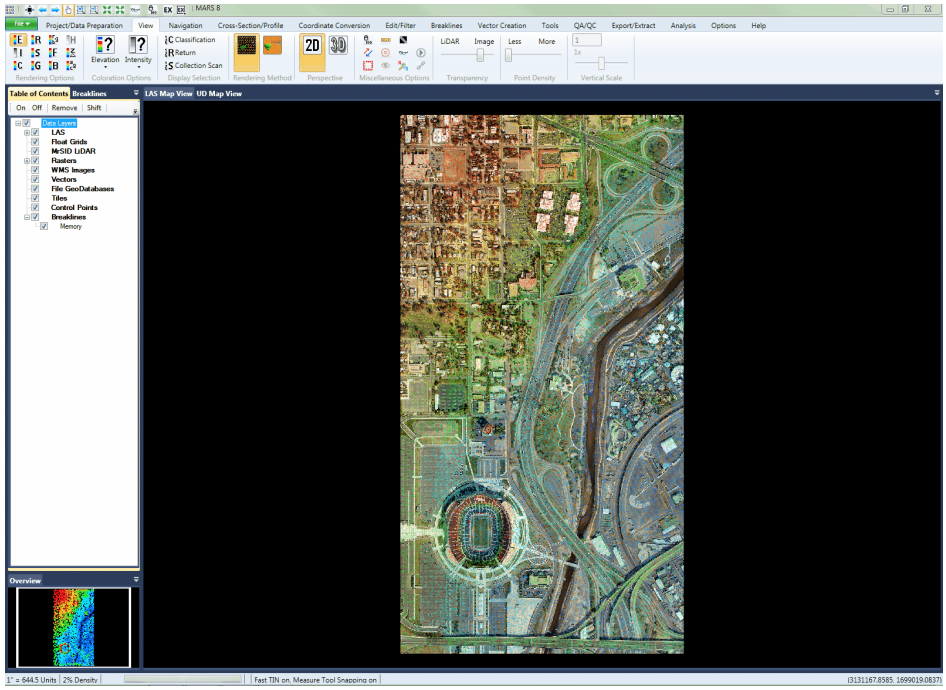
slider bar on the View Tab 192 to give priority to one or the other. Left-click and drag the slider bar back and forth (or click on a location along the line) to see how this function works. This is helpful in checking the co-registration of datasets or identifying features in corresponding datasets.

LiDAR priority

Image priority

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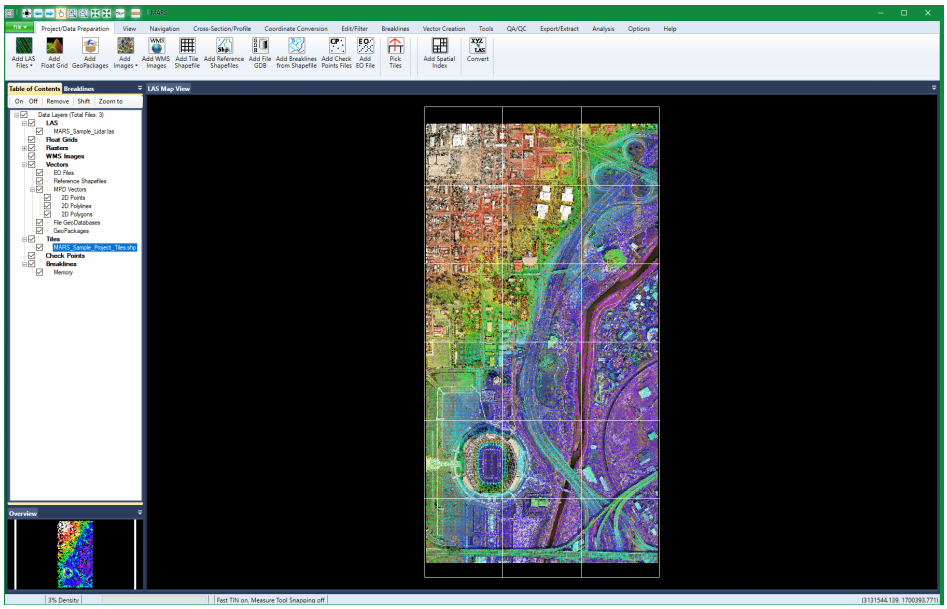




5. To add a tile layout shapefile to the project, click on the **'Add Tile Shapefile'** button on the Project/Data Preparation Tab 162. Browse to the sample folder (*C:\MARS\Sample_Data)* and select 'MARS_Sample_Project_Tiles.shp. By adding

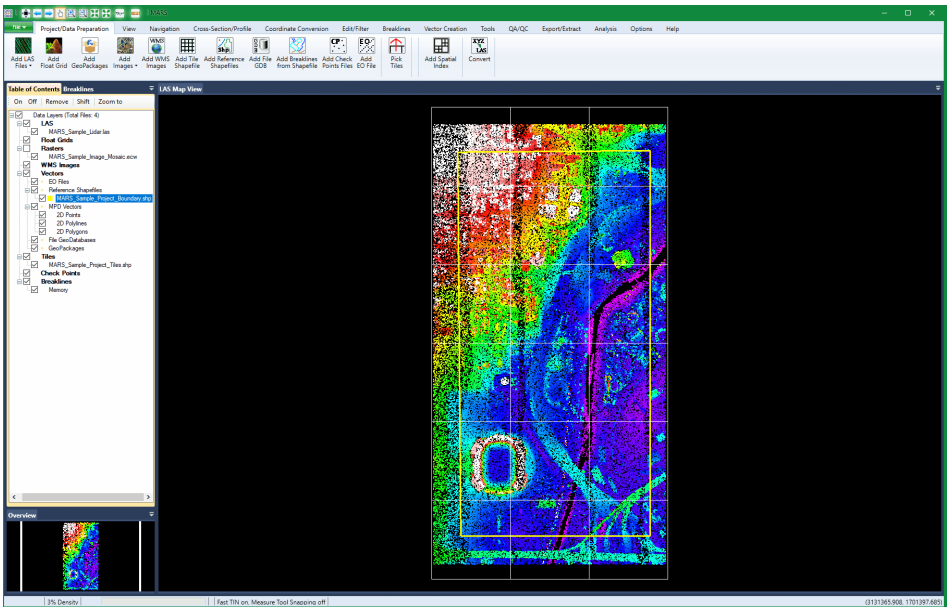
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vector (shapefile) data using with this button, the layout will be loaded under the **'Tiles'** layer in the Table of Contents.

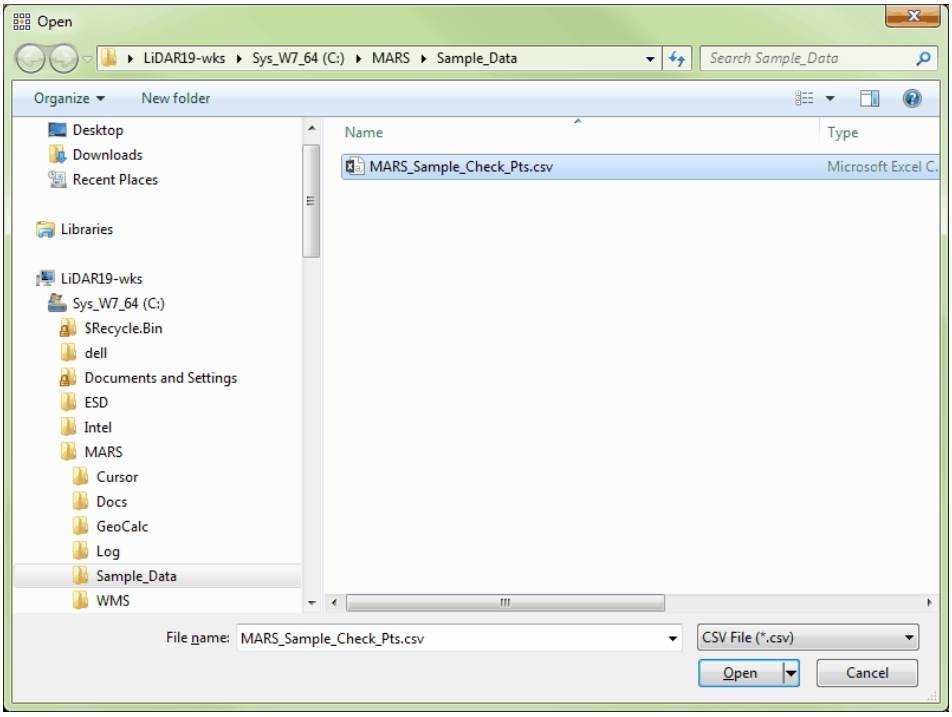


6. To load a shapefile as a reference layer (but not as a tile layout) click on the **'Add Reference Shapefiles'** button. This method of adding data is used to load any type of shapefile - polygon, point, or line (including breaklines if needed only as a reference). The loaded data will appear under the **'Vectors'** layer in the Table of Contents.

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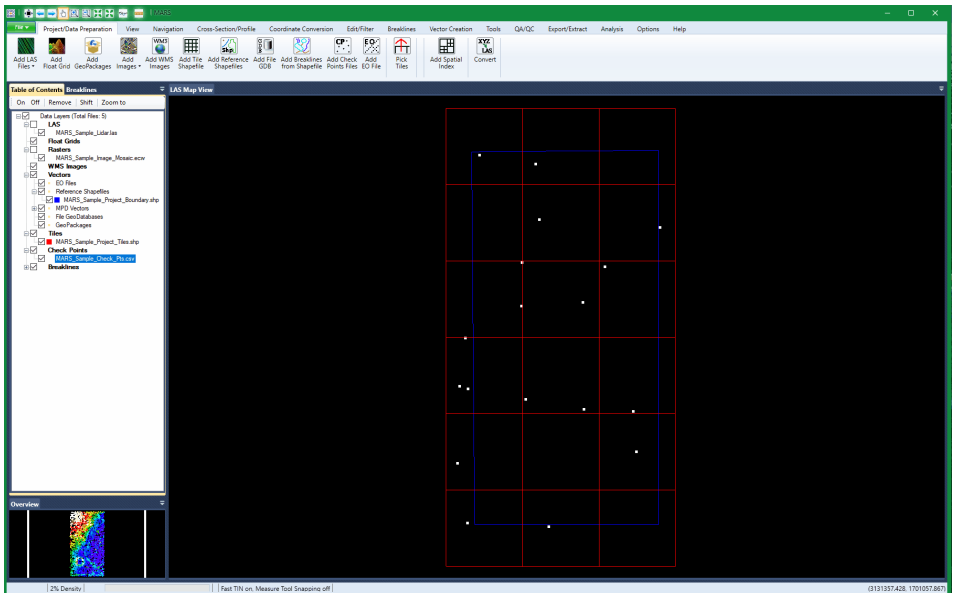


7. Check Points can be added to the project by clicking on the **'Add Check Points Files'** button. Browse to the sample data folder (*C:\MARS\Sample_Data)* and add the check points file 'MARS_Sample_Check_Pts.csv' to the project. This file will appear under the **'Check Points'** layer in the Table of Contents.



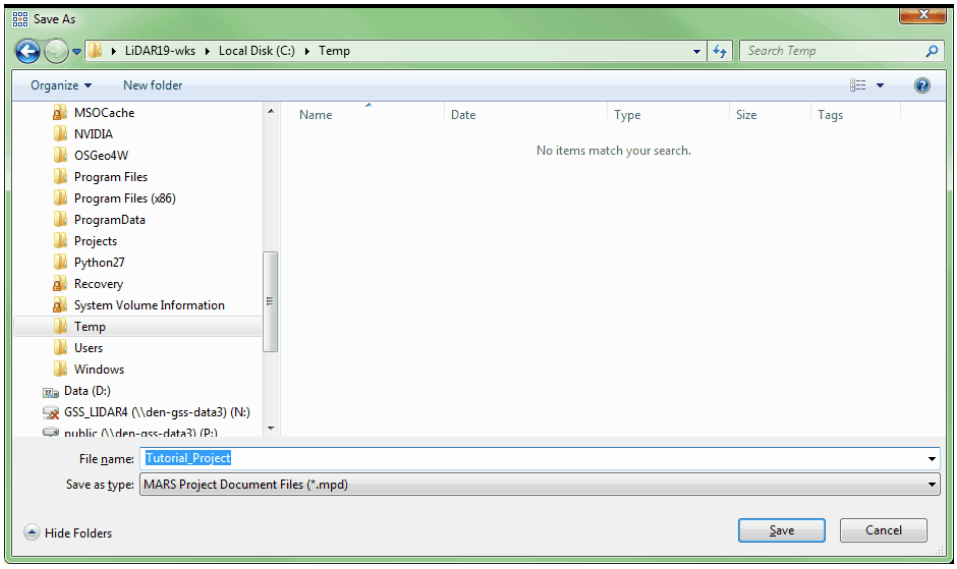
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Verify that the check points have been added to the project by unchecking the **'LAS'** and **'Rasters'** layers in the Table of Contents. Individual entries under a data layer can be unchecked without affecting other entries.

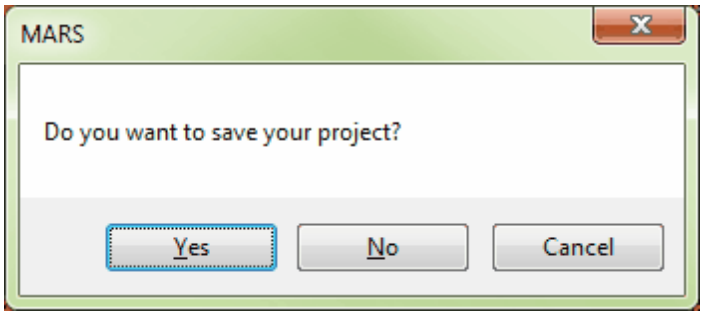


8. Now save the project by going to the File Tab[160] and clicking on **'Save'**. Navigate to the desired folder, give the project a name, and click the **'Save'** button. The project file (**Tutorial_Project.mpd** in this example) will be created with relative paths stored to the entries for each layer. The Table of Contents status (expanded or collapsed) is also saved.

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If the user attempts to exit MARS® without saving the open project, a prompt will appear as seen below.



The user may then choose to save the project, close MARS® without saving, or choose **'Cancel'** and return to the project. Now that a project has been set up and saved, proceed to the next tutorial (Displaying Data 1772) to learn about the different ways data can be displayed.

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8.3 Displaying Data

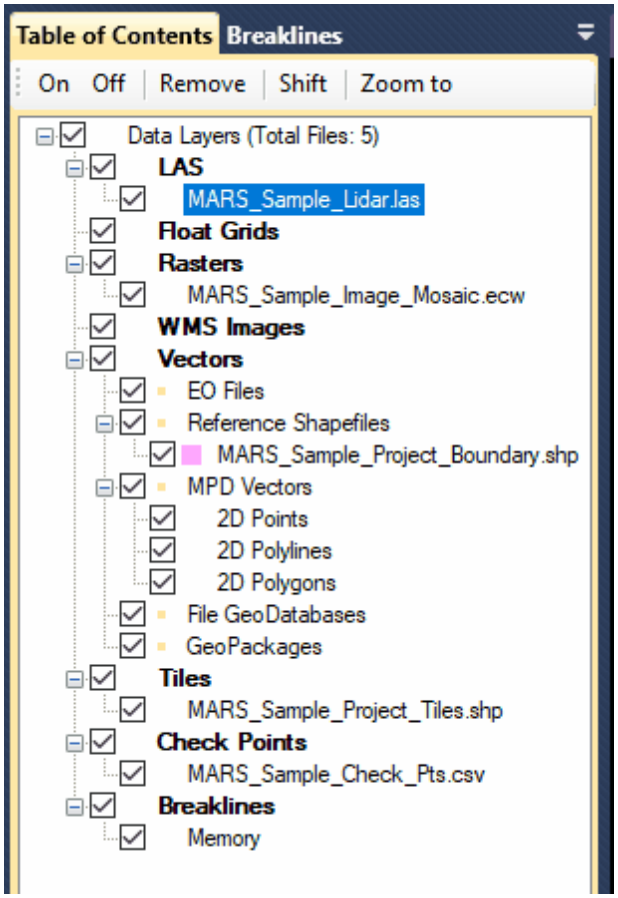
Displaying Data

Merrick Advanced Remote Sensing (MARS®) Software

Now that a MARS® project has been set up, follow this tutorial to learn how to render and navigate through data in different ways. If the project file saved in the previous tutorial is not already open, go to the File Tab[160] and click **'Open'**. Navigate to the folder where the project was saved, select the file, and open it. Make sure that the **'LAS'** and **'Tiles'** layers and their entries are checked on, and uncheck the **'Rasters'** and **'Check Points'** layers.

Table of Contents: As seen briefly in the Setting up a Project[1762] tutorial, the Table of Contents allows for the addition, removal, and manipulation of datasets. Display colors for most shapefile entries and other vector types can be modified by double-clicking the symbol between the checkbox and the entry name. See the Table of Contents[67] section to learn more about this tool.

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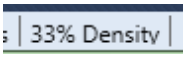
Using the layer and entry checkboxes in the Table of Contents 67, the user may control the display of data in any combination.

Start with the data being viewed in 2D View 835 mode by clicking the 2D button  on the View Tab 192. Zoom in to the data by clicking on the 'Zoom In Window' button on either the Navigation Tab 234 or the Quick Access Toolbar 65 and moving the cursor to the upper left extent of the area to be viewed (see Zoom In/Out 826 for more information on these tools). Left-click and drag to the lower right extent of the data to be viewed and then release the mouse button. The scroll button on

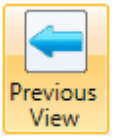
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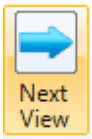
the mouse also allows the user to zoom in/out, as does right-clicking the mouse and dragging forward or backward. Notice that as the user zooms in/out on the data, the percentage of LiDAR points displayed changes. This percentage can be viewed on the left side of the Status Bar[158].

This example shows that the user is currently zoomed in to 33% points density displayed.



Zoom in until the percentage of points displayed equals 100%. All points in the LiDAR dataset (within the extent of the LAS Map View window) are now visible. Practice zooming in and out with both of the 'Window" tools and also the '25%' tools to see how they affect the data view and the point density being displayed. Then, use the **'Pan'** 

button to move laterally through the data. Now try the 'Previous View' 

and 'Next View' 

buttons to move between views.

To view the data in 3D View[837] mode (also known as perspective view), click the 3D button 

on the View Tab[192]. Any displayed imagery will be temporarily turned off while in 3D mode, but will reappear when switching back to 2D. Navigation in 3D mode is considerably different than in 2D:

1. Using the **'Pan'** tool, click and hold the left mouse button. Move the cursor around to

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see how the data pivots around the center of the view.

2. With the **'Pan'** tool still active, click and hold both mouse buttons simultaneously. Now move the cursor and notice that the data moves more like a normal pan without losing the particular perspective in which the data is currently being viewed.
3. Click and hold only the right mouse button and move the mouse forward to zoom out and backward to zoom in. To view a different area in 3D, first switch back to 2D and pan or zoom to the desired extent, then click the '3D' button.

Click the 2D button to return to the standard 2D view, and display the full extent of the data by clicking the **'Fit to View'** 

button on the Navigation Tab 234 or Quick Access Toolbar 65.

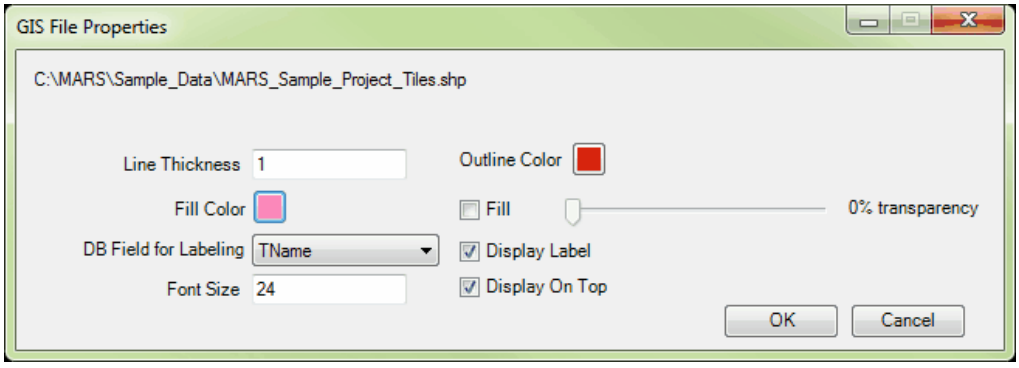
Working with Tile Shapefiles: This part of the tutorial will use the tile shapefile that was loaded and saved in the previous topic, Setting up a Project 1762. Before continuing, uncheck the **'LAS'** layer in the Table of Contents.

When a tile shapefile is loaded, the user can zoom to a single tile by double-clicking within that tile. This action can be disabled by unchecking the 'Double-click to zoom to tile extent' box near the top of the 'Miscellaneous Options' interface found on the Options Tab 519.

The 'GIS File Properties' window will display the full path and name of the tile shapefile, and allow the user to change the line thickness, the outline and fill colors, the font size of the displayed label, and the labeling field (information which comes from the

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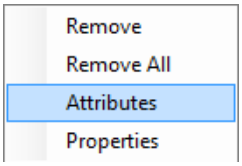
shapefile's attribute table). The user may choose whether or not to display a label by checking or unchecking the box next to this option. The labeling field can be changed in the **'GIS File Properties'** window. In the **'Table of Contents'**, right-click on the tile shapefile in question and choose **'Properties'**. Under the **'DB Field for Labeling'** drop-down box, choose **'TName'** to show the tile names. The user's preference for the 'DB Field for Labeling' option will be stored by this tool until the MARS® application is closed. The user may also choose to color fill the shapefile. If the user chooses to fill a shapefile, the transparency of the fill may be adjusted using the slider bar provided. To force the tile shapefile to display on top of other layers, check the box next to **'Display On Top.'**

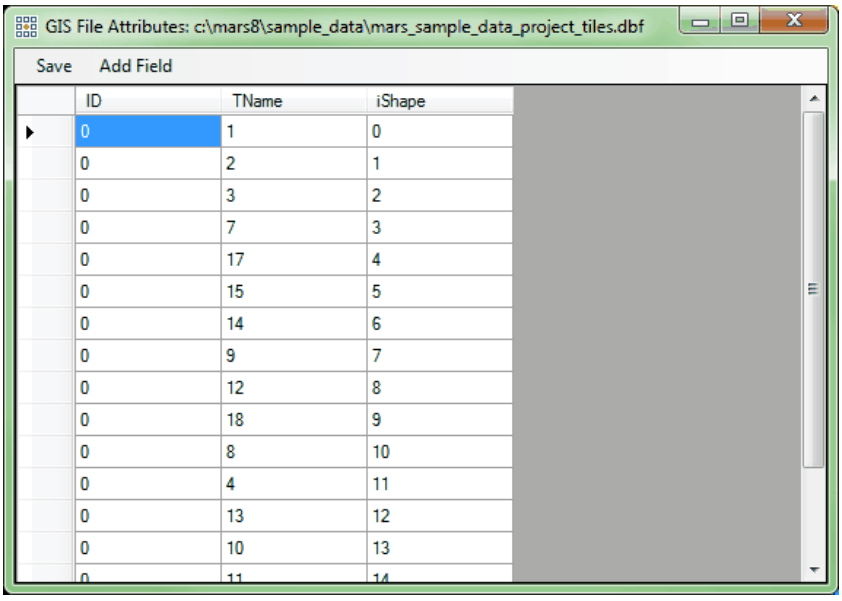


This tool is also linked to the only other tool in MARS® which allows the user to choose the DB field for labeling: the **'Add LAS Files | From Selected Tiles'** option. This option may be found by clicking on the bottom half of the **'Add LAS Files'** button on the Project/Data Preparation Tab 162. These two tools are synced and reflect the same choice in 'DB Field for Labeling'. For example, if the user selects the DB labeling field 'TName' in the 'GIS File Properties' window, this choice will be reflected automatically in the **'Add LAS Files | From Selected Tiles'** option and vice versa. To read more concerning the **'Add LAS Files | From Selected Tiles'** option, please view the Project/Data Preparation 162 topic.

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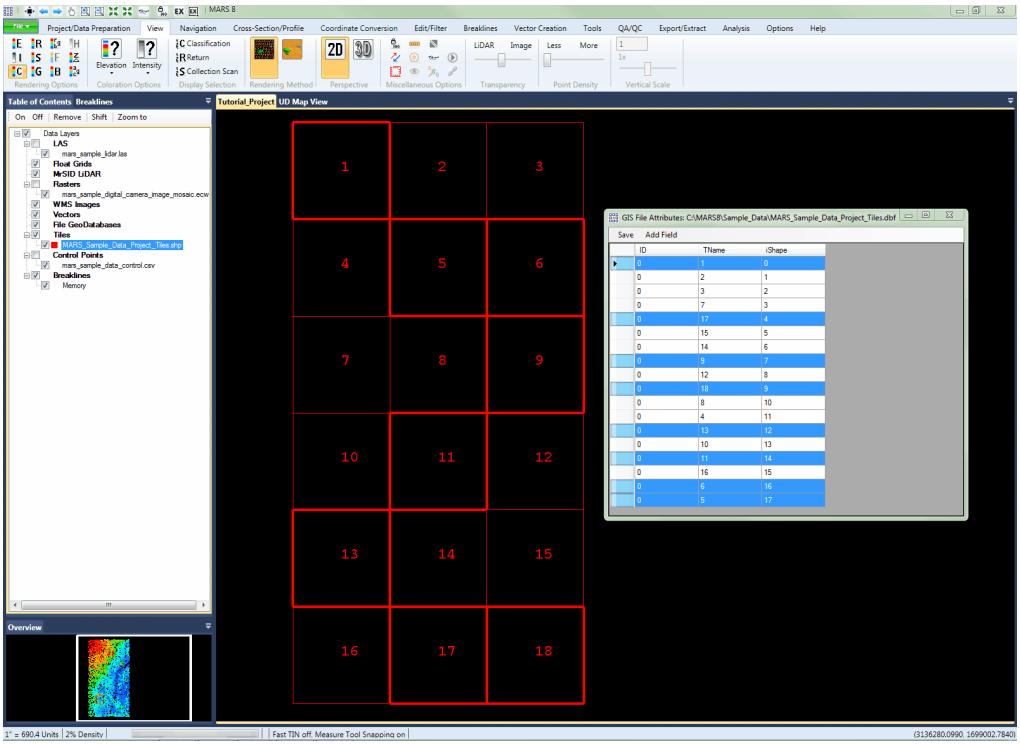
Viewing and Editing Attributes; Zooming to Shapefile Record : To view or edit a shapefile's attribute table, right-click on the shapefile in the table of contents and select **'Attributes'.** The attribute table will open in a new window. It is possible to use the attribute table to select tiles or polygons (or points / polylines) from the shapefile by clicking at the far left of the desired record (row). Use the **'Shift'** and/or **'Ctrl'** keys on the keyboard the select the multiple polygons/tiles. There is a linked selection between the polygons selected and the corresponding rows (features) in the attribute table. Polygons or tiles selected using the 'Pick Tiles' utility will show up as selected, or highlighted, inside the attribute table and vice versa. Tiles or polygons selected in the attribute table will be highlighted in the LAS Map View window.





ID	TName	iShape
0	1	0
0	2	1
0	3	2
0	7	3
0	17	4
0	15	5
0	14	6
0	9	7
0	12	8
0	18	9
0	8	10
0	4	11
0	13	12
0	10	13
0	11	14

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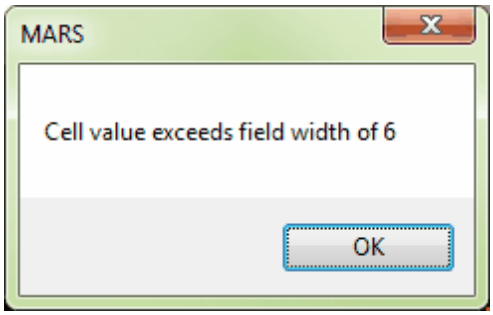
It is possible to edit the attribute table of a shapefile by adding new fields, changing the values of fields, or deleting fields. The only exception is the 'iShape' field, which cannot be edited. To add a new field (column) to the attribute table, click on the 'Add Field' button at the top of the window. The 'Add Field' window will appear and the user may specify the structure of the new field as follows:

Creating a New Field:

1) First, give the new field a name in the **'Field Name'** text box. The attribute table will display up to ten (10) characters in the column heading.
2) Then define the **'Field Type'** to be used in the new column.
3) Define the **'Width'** of the column. The width defines how many characters will be stored for the field's values. For example, if the user chooses a Width of 6, only that many characters will be saved when the field is populated. If the user exceeds the amount of allowable characters while editing in the attribute table, a warning will appear letting the user know that the field width

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has been exceeded.



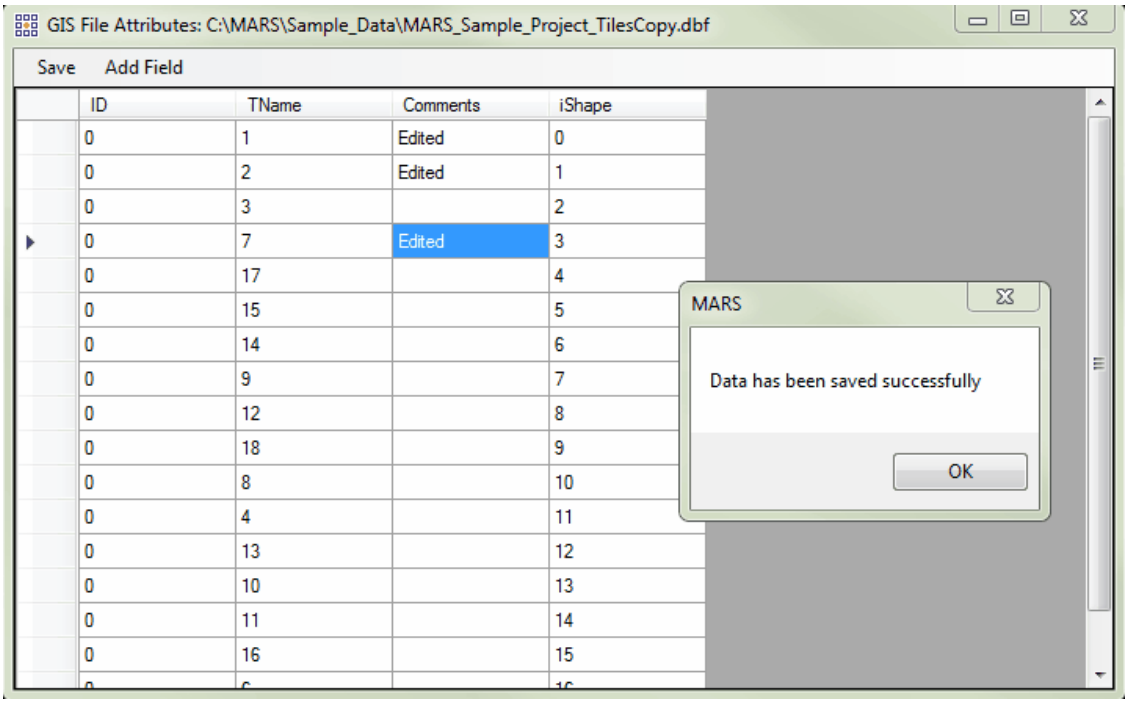
4) If the defined field type is 'Double,' the **'Number of Decimals'** text box will be available to the user. If the user enters more decimal places in a value than the definition allows, the decimal places will be rounded and truncated upon saving.

5) Click the 'Save' button at the top of the window to make permanent.

Editing a Field:

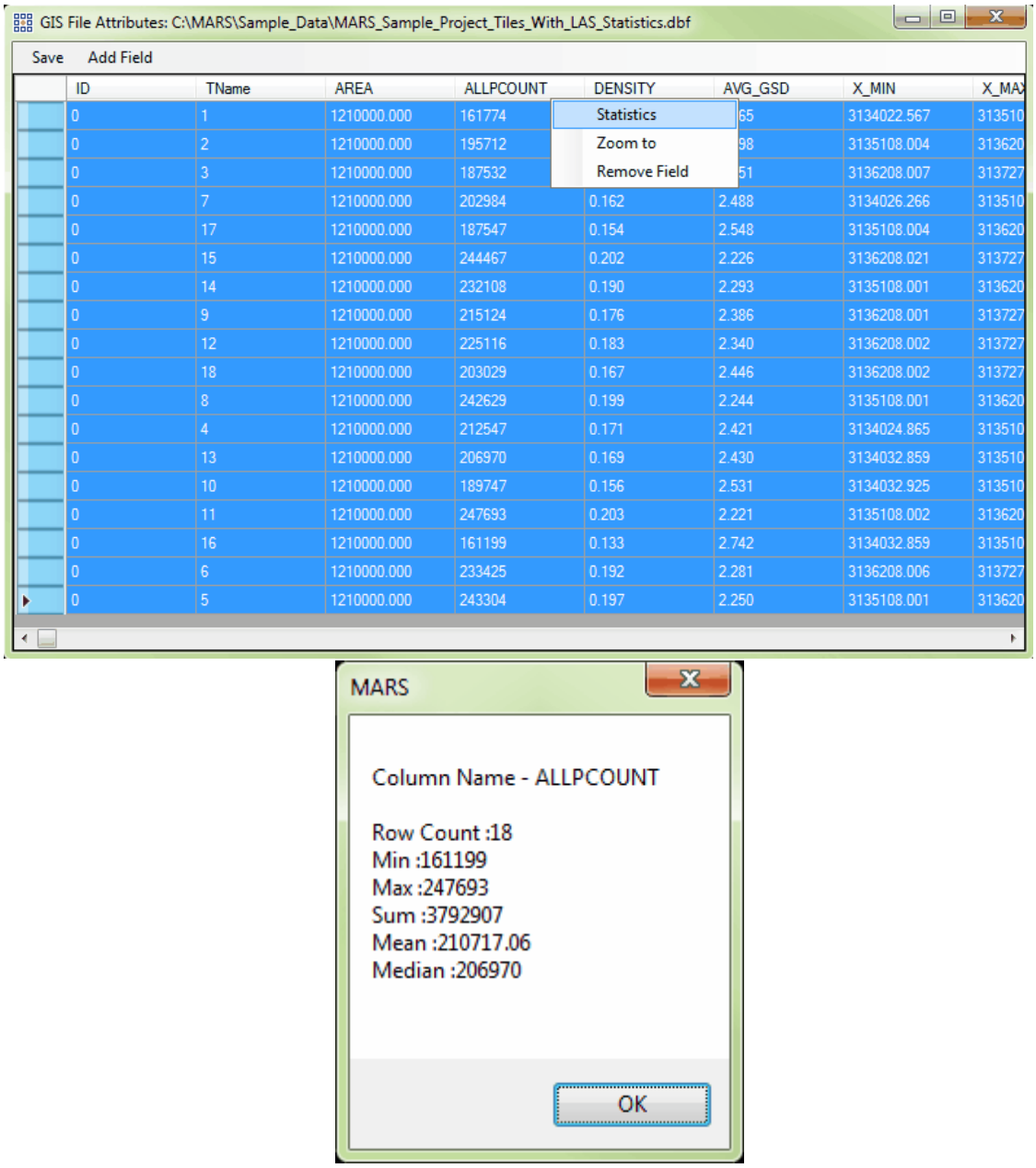
Click at the left end of a row to see the corresponding feature highlighted in the LAS Map View window. To edit any attribute information, double-click on the appropriate attribute and make the necessary changes. When finished, click on the 'Save' button at the top left of the window to save the modified information. The user will receive a prompt confirming the data was saved inside the shapefile. This ability may be very useful when editing data to keep track of tiles or areas which have or have not been edited, for example.

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It is also possible to view the statistics of attribute values in a shapefile. The user may view the statistics of a single attribute (column), for one or more tiles (rows) or the entire table. Highlight the records (rows) for which statistics are to be viewed, right-click on the desired column header, and choose **'Statistics'**. The resultant pop-up will show the user the following statistics: the row count, minimum, maximum, sum, mean (average), and median of the chosen attribute. To select multiple rows for statistic viewing at once, use the **'Shift'** or **'Ctrl'** keys on the keyboard. In the example below, the user is choosing to view the statistics of the entire 'ALLPCOUNT' column.

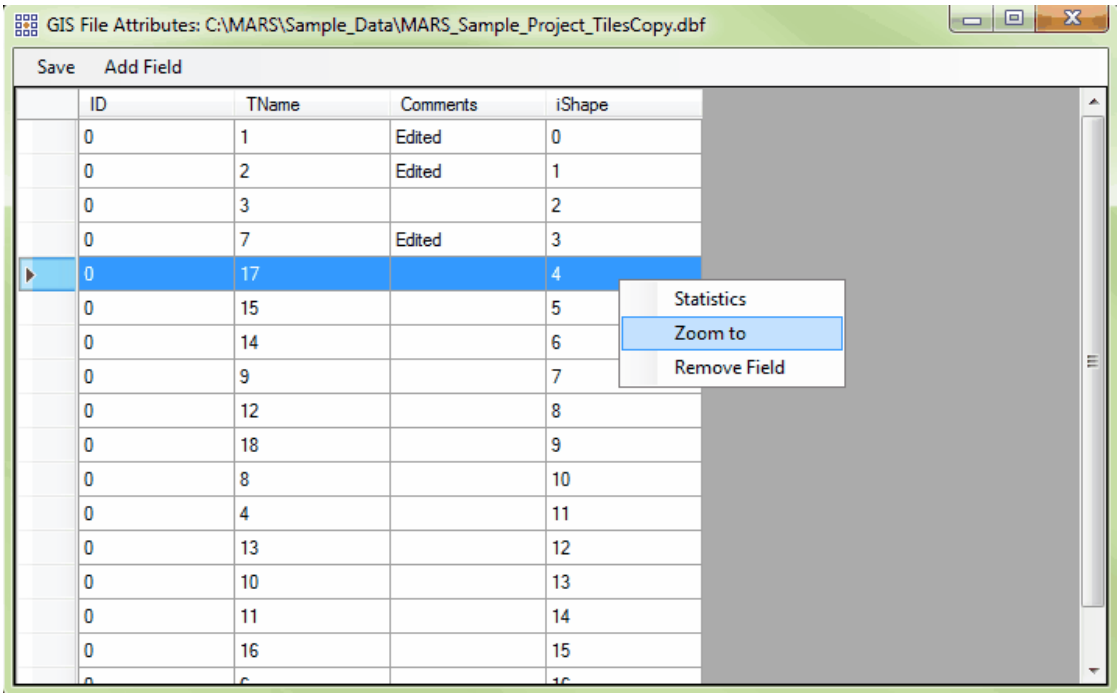
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ID	TName	AREA	ALLPCOUNT	DENSITY	AVG_GSD	X_MIN	X_MAX
0	1	1210000.000	161774		65	3134022.567	313510
0	2	1210000.000	195712		98	3135108.004	313620
0	3	1210000.000	187532		51	3136208.007	313727
0	7	1210000.000	202984	0.162	2.488	3134026.266	313510
0	17	1210000.000	187547	0.154	2.548	3135108.004	313620
0	15	1210000.000	244467	0.202	2.226	3136208.021	313727
0	14	1210000.000	232108	0.190	2.293	3135108.001	313620
0	9	1210000.000	215124	0.176	2.386	3136208.001	313727
0	12	1210000.000	225116	0.183	2.340	3136208.002	313727
0	18	1210000.000	203029	0.167	2.446	3136208.002	313727
0	8	1210000.000	242629	0.199	2.244	3135108.001	313620
0	4	1210000.000	212547	0.171	2.421	3134024.865	313510
0	13	1210000.000	206970	0.169	2.430	3134032.859	313510
0	10	1210000.000	189747	0.156	2.531	3134032.925	313510
0	11	1210000.000	247693	0.203	2.221	3135108.002	313620
0	16	1210000.000	161199	0.133	2.742	3134032.859	313510
0	6	1210000.000	233425	0.192	2.281	3136208.006	313727
0	5	1210000.000	243304	0.197	2.250	3135108.001	313620

Lastly, it is possible to zoom to a particular record in a shapefile from within the attribute table. To use this function, highlight the desired row in the attribute table by clicking to the far left. Then right-click anywhere in that row and choose 'Zoom to.' The selected tile or polygon will fit to the LAS Map View window.

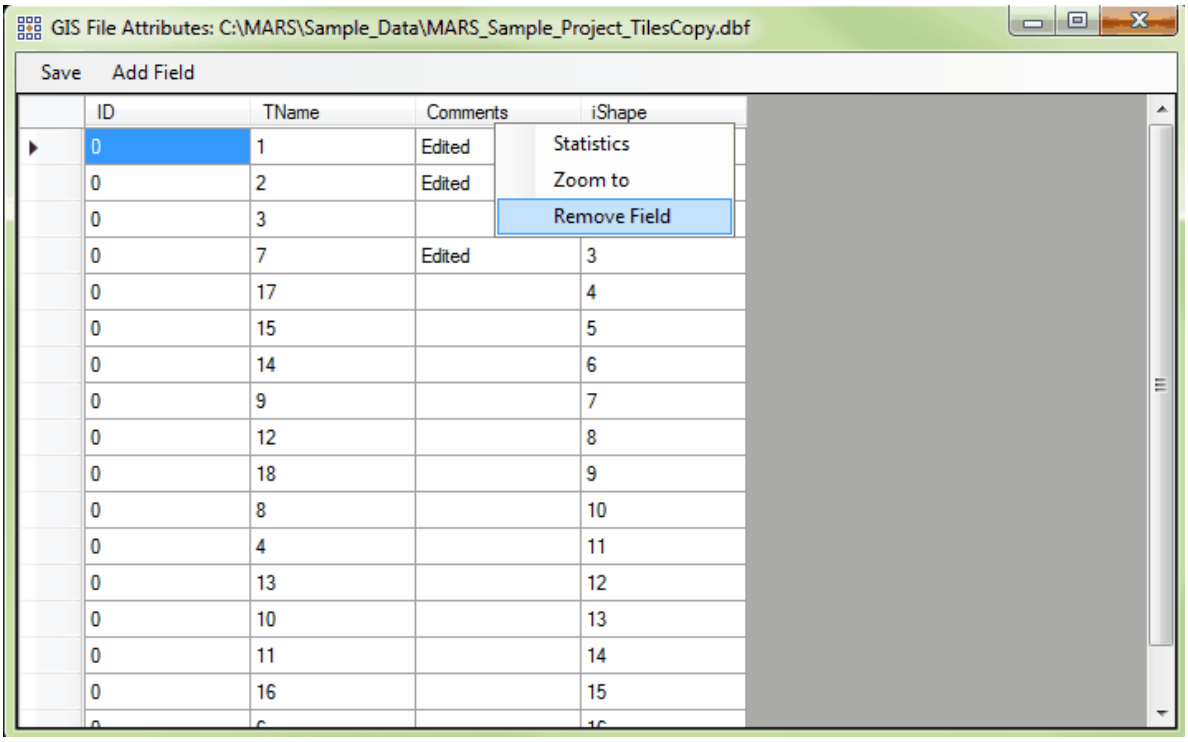
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Deleting a Field:

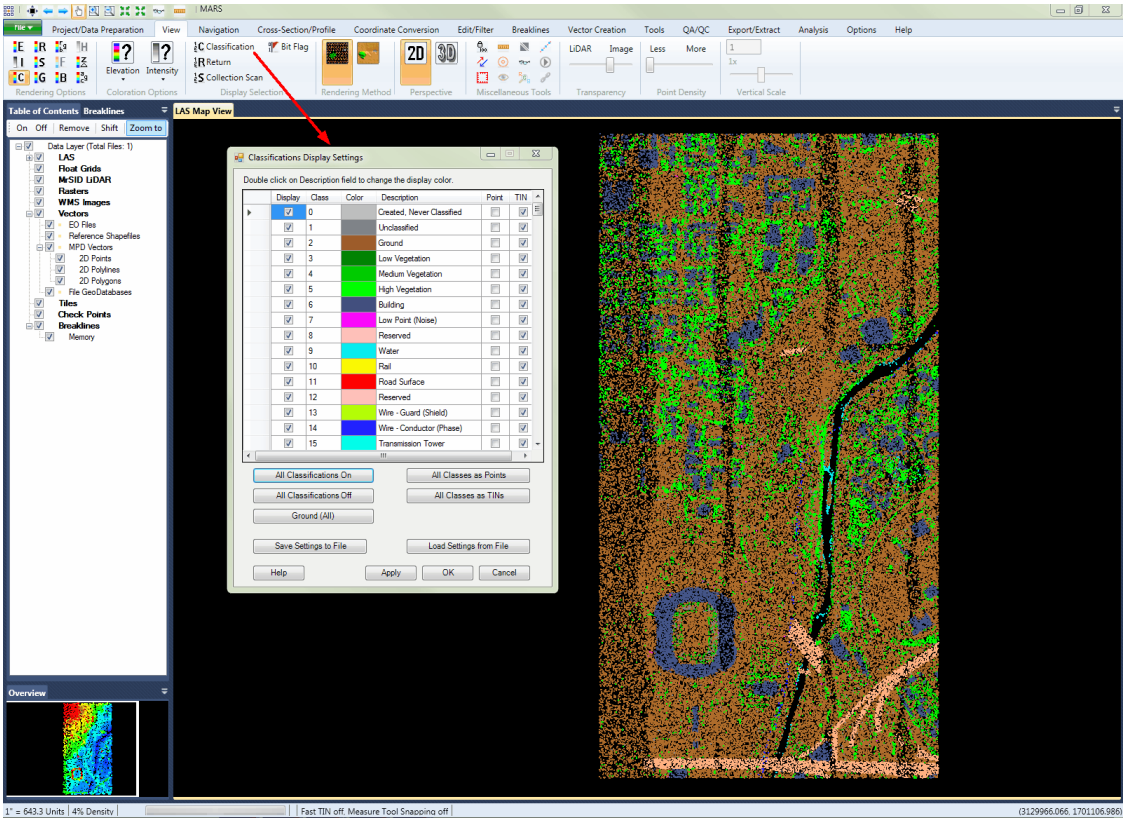
To delete an attribute field right-click on the column heading ('temp_field' in the example below) and choose 'Remove Field', then click 'Save' to make permanent. The field and all information contained in it will be deleted. The 'iShape' field cannot be deleted.

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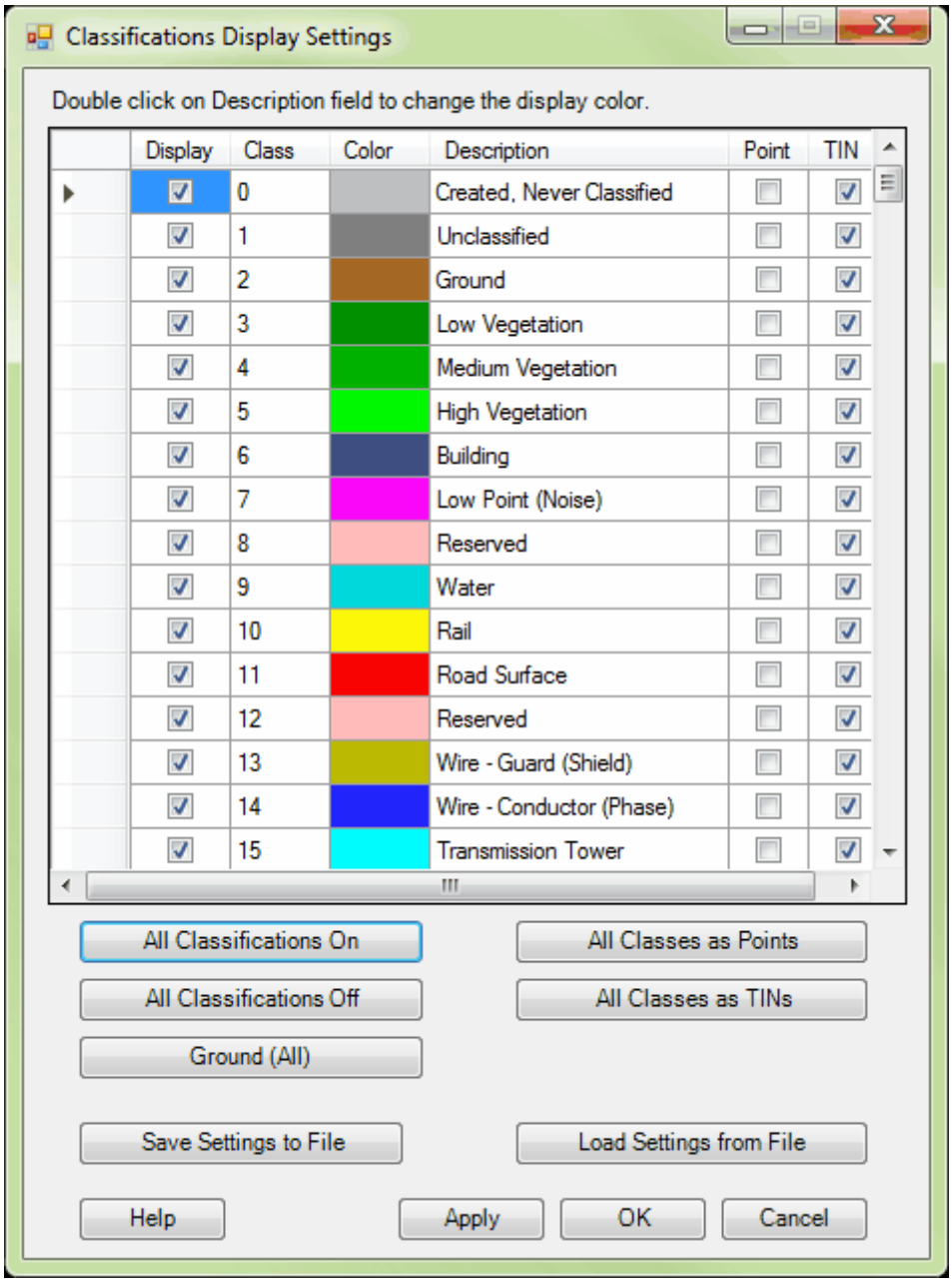


Classification **Display Selection | Classification:** This tool, found on the View Tab[192], allows the user to set specific classifications to be displayed. This interface works by checking or unchecking the boxes in the 'Display' column next to the respective classes to turn on or off their display. A checked box means that classification will be displayed. The tool also allows the colors and descriptions associated with classes to be edited and, optionally, saved as settings files for specific projects/uses. Individual settings files can be created, saved, and loaded (as XML files) to allow for an unlimited number of settings combinations. Note that the reserved XML characters **<**, **>**, **/**, **%**, **&**, **'**, **"** cannot be used in the Description field.

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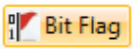


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There are two different versions of the interface - one when the LAS Map View window is active (see above), and one when the Cross-Section/Profile window is active. Each will affect the display only for its corresponding window. Changes made to the colors or descriptions for classes in either interface will, however, carry over to the other interface the next time it is opened. The LAS Map View interface allows the user to choose specific classifications for

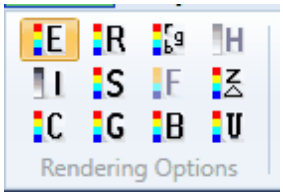
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viewing, and to change their colors and descriptions. (A complete description and example of the interface when the Cross-Section/Profile window is active can be found in the **'Display Selection'** section of the View Tab 192 topic.) Check/uncheck the **'Display'** boxes for the classes to be viewed/hidden. The shortcut buttons at the bottom of the interface offer quick settings: The **'All Classifications On/Off'** buttons will turn all classes on/off. The **'Ground (All)'** button will turn on Class 2 only and will, by default, include those ground points that are bit-flagged as Model Key-points. Separate Bit Flag display settings for all bit flag types can be found in the 'Bit Flag' display settings tool 

below. Additionally, the user can change the color representing a class (double-click on a **'Color'** box to change it), the **'Description'** used for a class (highlight the text and then click on it), and how that class will be displayed (as **'Point'** or **'TIN'**) when the LAS Map View window is using the TIN Rendering Method (see below). For Point/TIN rendering, the individual boxes may be checked per class, or the shortcut buttons **'All Classes as Points'** and **'All Classes as TINs'** may be used. ***Note that the interface Class/ Description combinations are correct for LAS v1.4, Point Data Record Format (PDRF) 6 or higher per the ASPRS specification.*** An unlimited number of settings files may be created and saved for later use (**'Save Settings to File'** and **'Load Settings from File'**). These files can save the display status, class color and description, and Point/TIN status for each class.

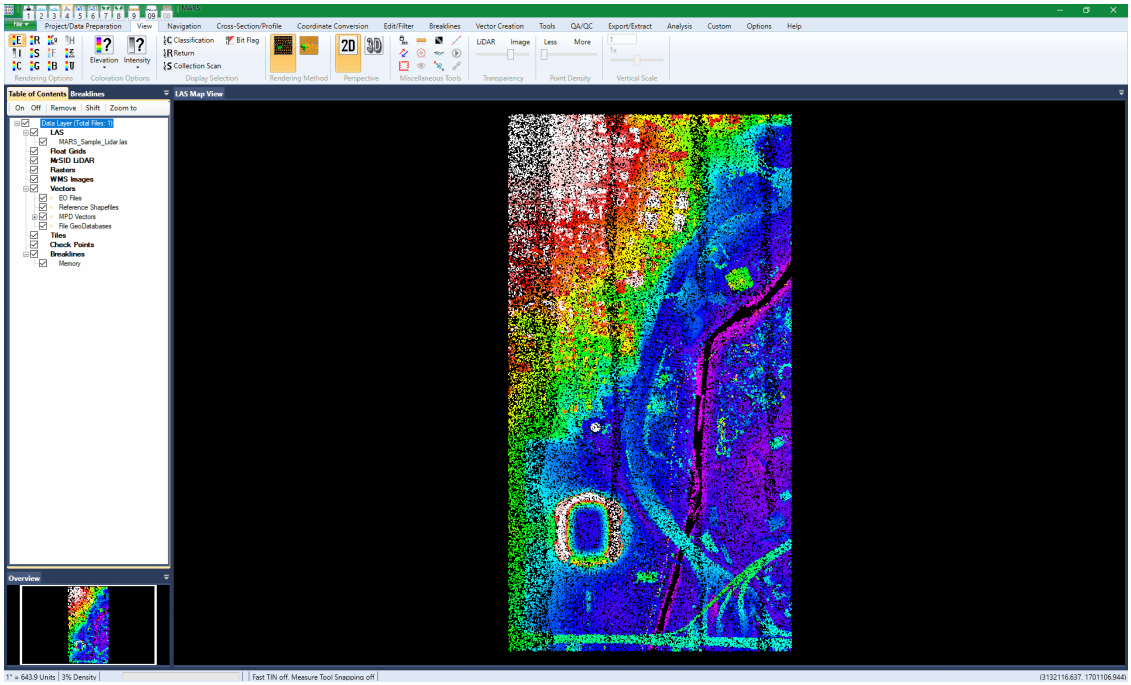
For more details on the **'Classifications Display Settings'** interface, see the **'Display Selection | Classification'** section of the View Tab 192 topic, or the Color by Classification 846 topic.

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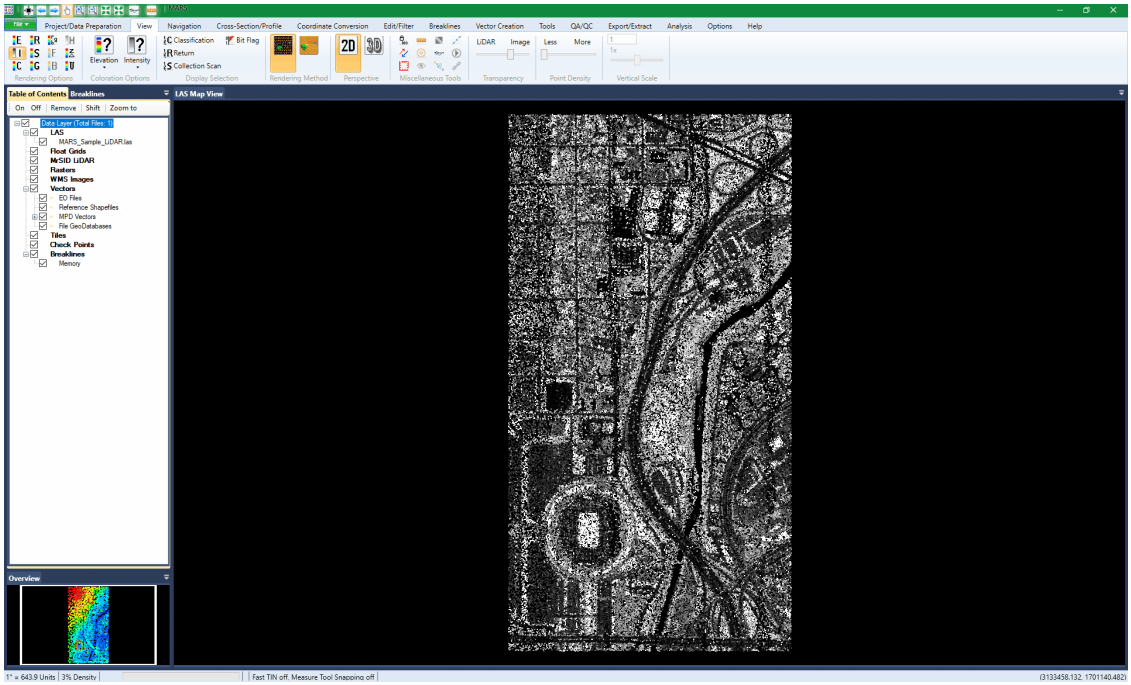
The following seven rendering methods have their buttons on the View Tab[192] :

Color by Elevation[878]: Displays LiDAR points colored by elevation. The color ramp is relative and, by default, changes as the user zooms in or out. Within the current view extent, white points are the highest elevations and magenta the lowest. To view more information about rendering LiDAR data by elevation, please visit the section on data viewing by Elevation[878].



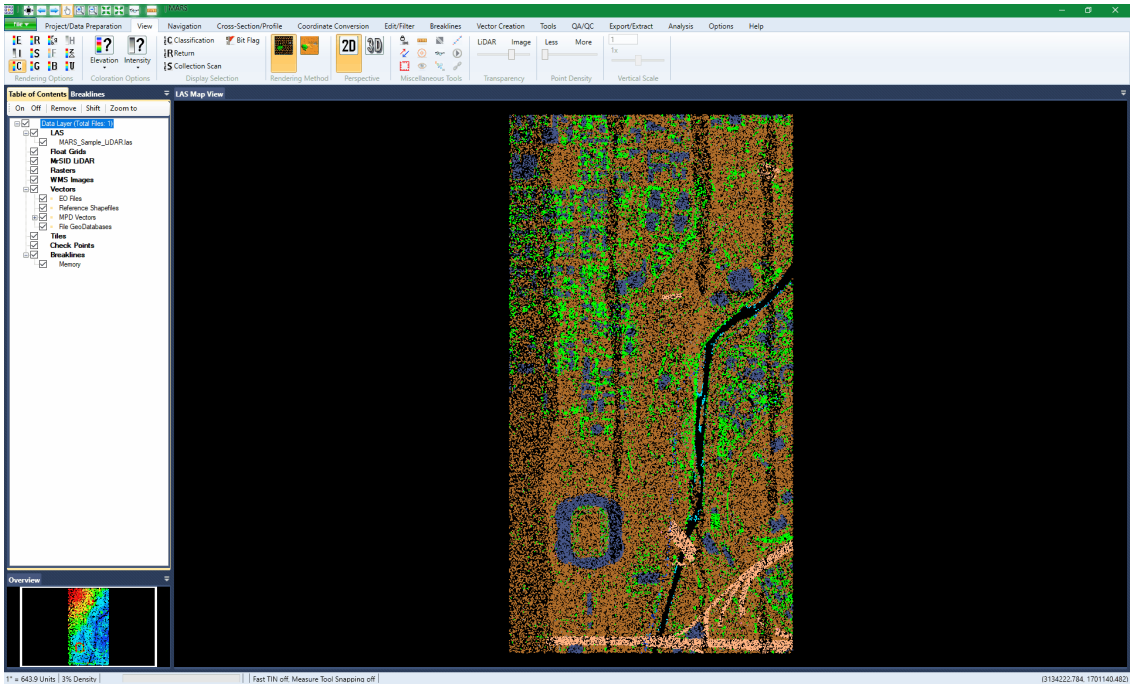
Color by Intensity[888]: Displays LiDAR points colored by intensity value. In a 16-bit scale, a value of 0 is shown as black; a value of 65535 is shown as white. To view more information about rendering LiDAR data by intensity, please visit the sections on data viewing by Intensity[888], Gray-scale Only[895] intensity, Color Extremes[892] intensity, or Equalizing[893] intensity.

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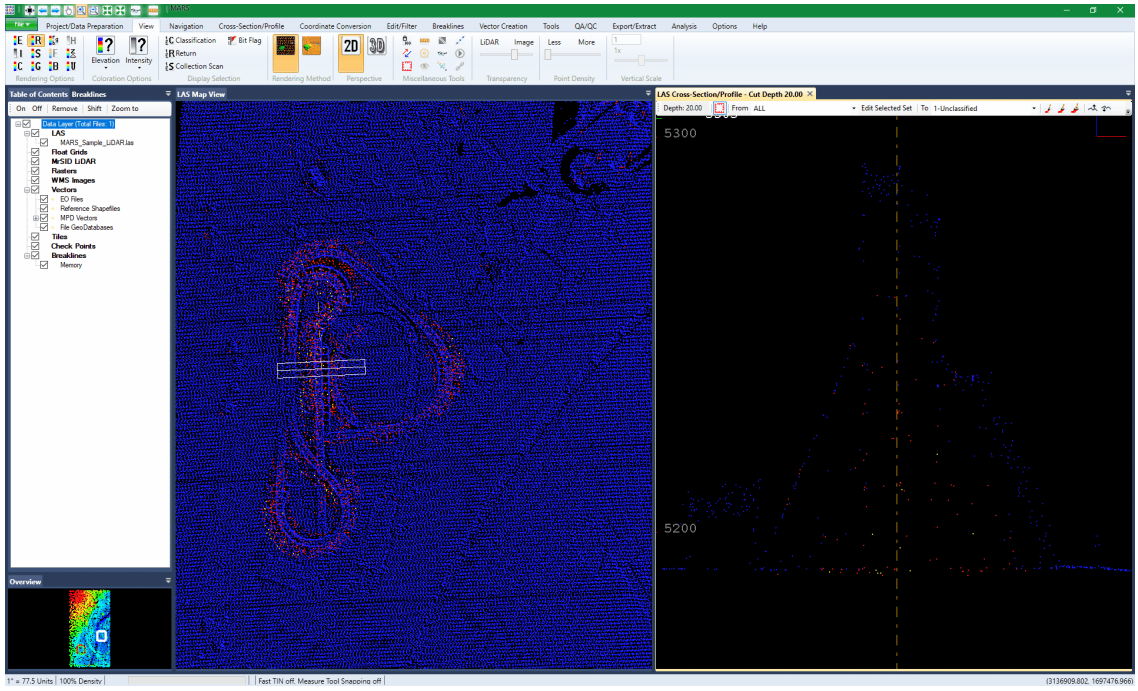
Color by Classification 846: Displays LiDAR points colored by classification. To view more information about rendering LiDAR data by classification, please visit the section on data viewing by Classification 846.

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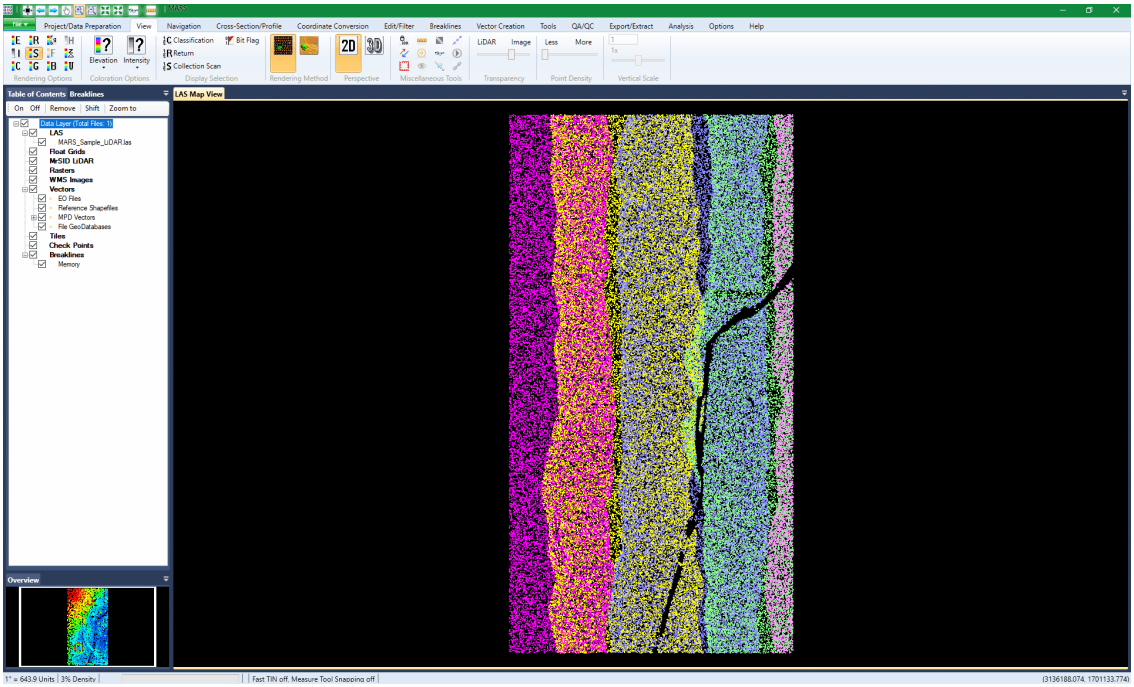
Color by Return [862]: Displays LiDAR points rendered by return value. In a dataset with discrete return values, like the one seen below, returns are colored dark blue to indicate a single return or 1st of many returns, red to indicate the 2nd of many returns, yellow to indicate the 3rd of many returns, and green to indicate the 4th of many returns. To view more information about coloring LiDAR data by return, please visit the section on data viewing by Return [862].

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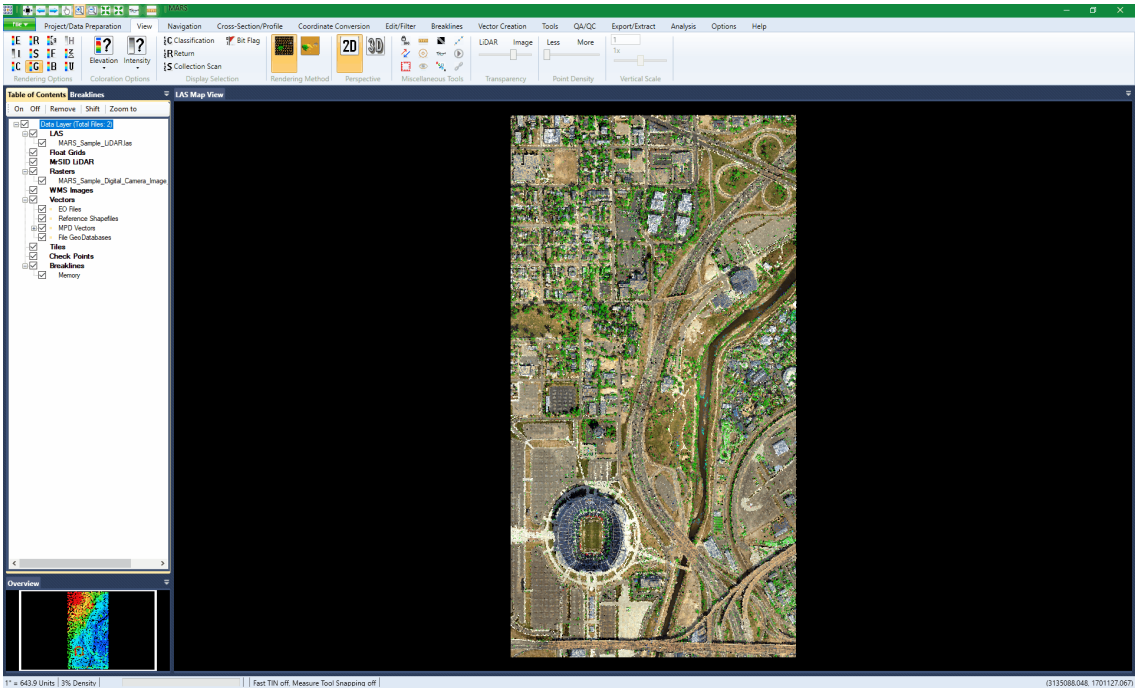
Color by Collection Scan[850]**:** Displays LiDAR points rendered by collection scan. To view more information about coloring LiDAR data by collection scan, please visit the section on data viewing by Collection Scan[850].

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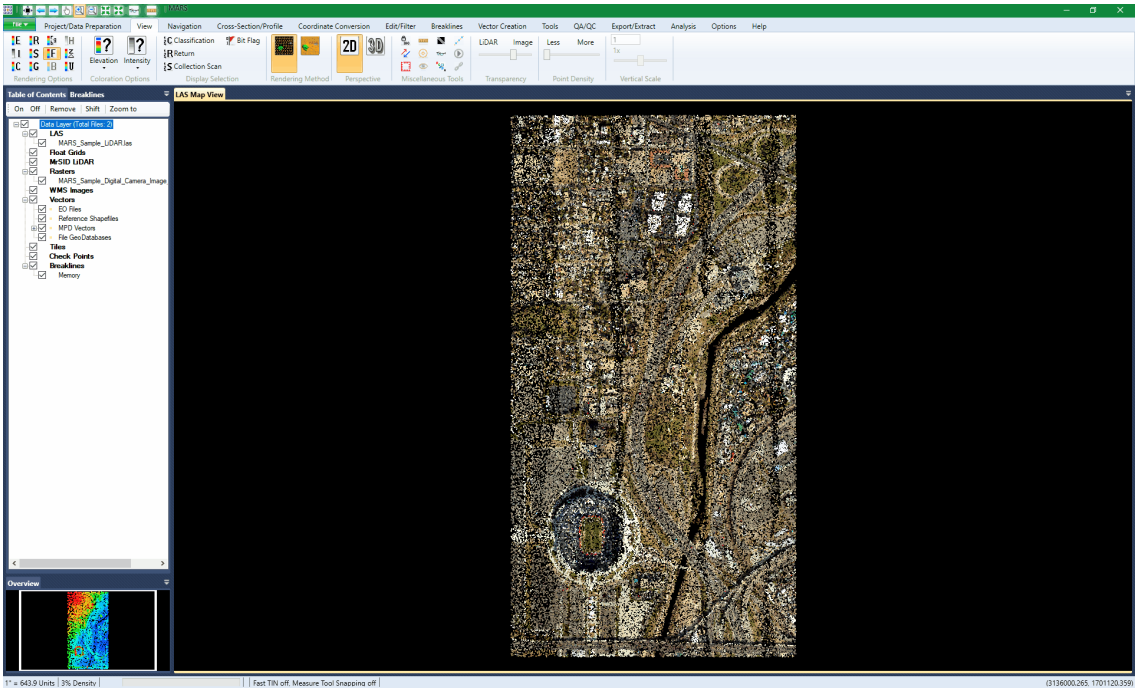
Color by Ground Color: Displays the user-specified ground class(es) using the RGB values of loaded imagery, both in point and TIN display modes. All other points are rendered by their classification values. This tool works in both 2D View and 3D View modes. To view more information about rendering ground-classed LiDAR data by imagery, please visit the section on data viewing by Ground Color.

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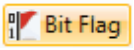


Color by Imagery (Fusion): In point rendering mode, this tool colors each LiDAR point with the RGB value of the geographically corresponding pixel of the loaded image. In TIN mode, the imagery is draped over the TIN for higher resolution display. This tool is only available for use in the LAS Map View window and will not function in the Cross-Section/Profile window. To view more information about rendering LiDAR data by imagery, please visit the section on data viewing by Fusion.

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NOTE: The remaining rendering options are explained in the View Tab 192 Help Topic.



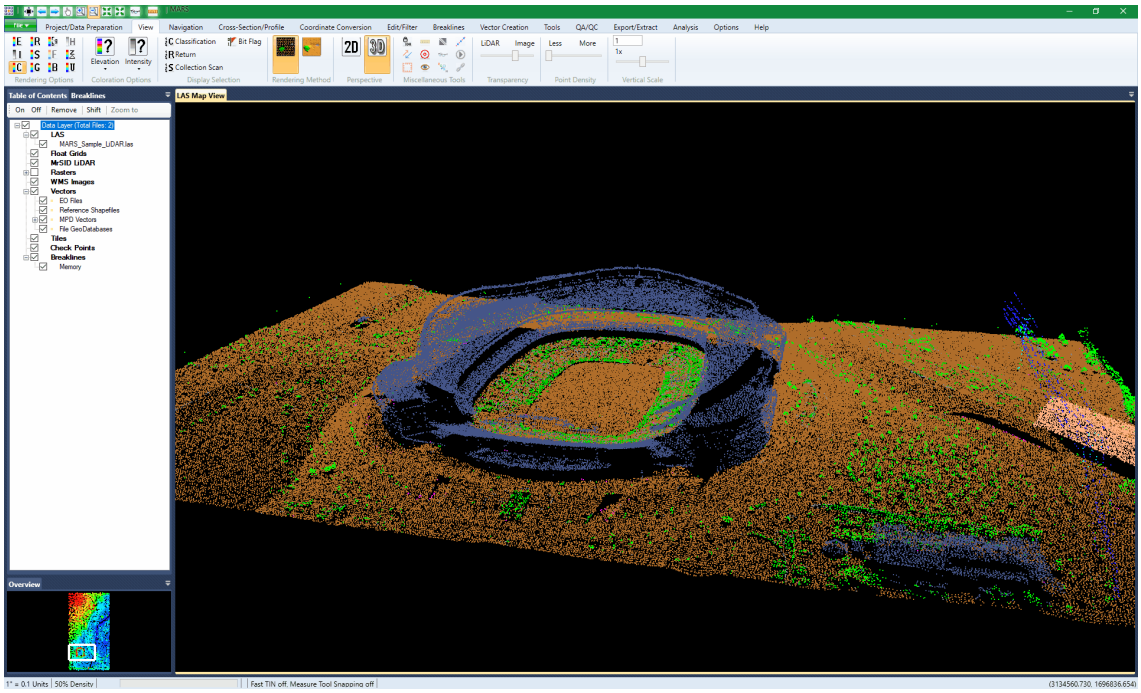
Bit Flag: The 'Bit Flag Display Settings' interface allows for LiDAR point rendering to be controlled by the point-level status of several bit flags: Synthetic, Model Key-point, Withheld, Overlap (also referred to as 'Overage'), Edge of Collection Scan, Scanner Channel, and Scan Direction. See the 'Bit Flag' topic in the View Tab 192 section of the Help file for more information.



Points: Displays LiDAR data as points (point cloud). Viewing the data by points is the fastest way to navigate through the data.

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The point cloud may also be viewed in 3D or 'perspective' view by clicking the **'Perspective'**  button. Click the **'Orthographic'**  button to return to 2D view.



 **TIN:** Displays LiDAR data as a TINned surface. A TIN (Triangulated Irregular Network) is generated on the fly and, thus, slows down data navigation. It is recommended to switch to point mode by choosing the **'Points'**  button before trying to navigate around the project or when viewing a large extent.

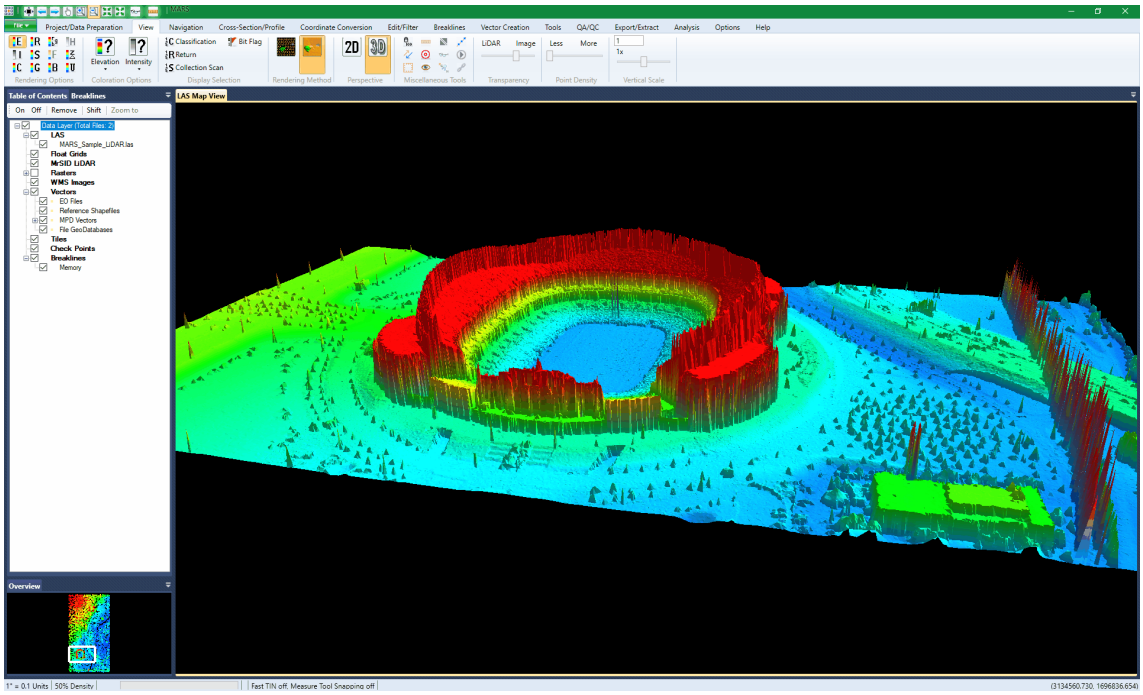
The TIN view may also be viewed in 3D or 'perspective' view by clicking the **'Perspective'**

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button. Click the **'Orthographic'** 

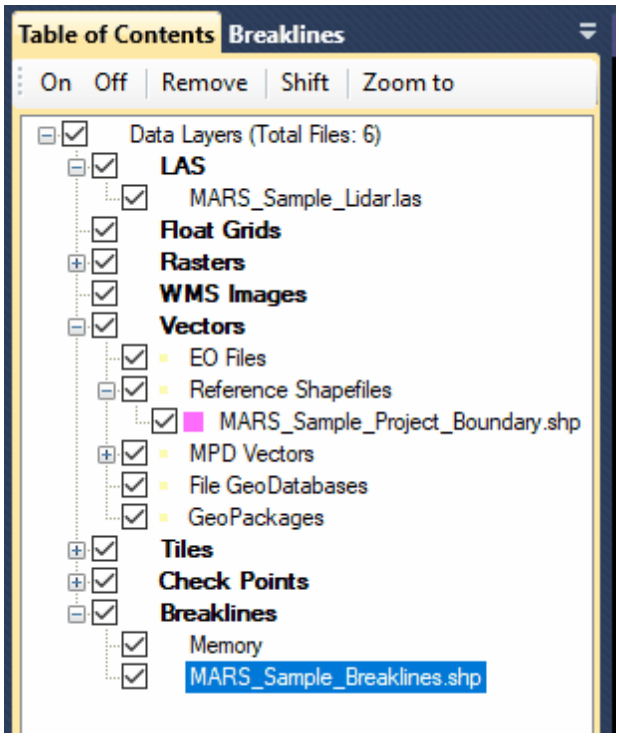
button to return to 2D view.



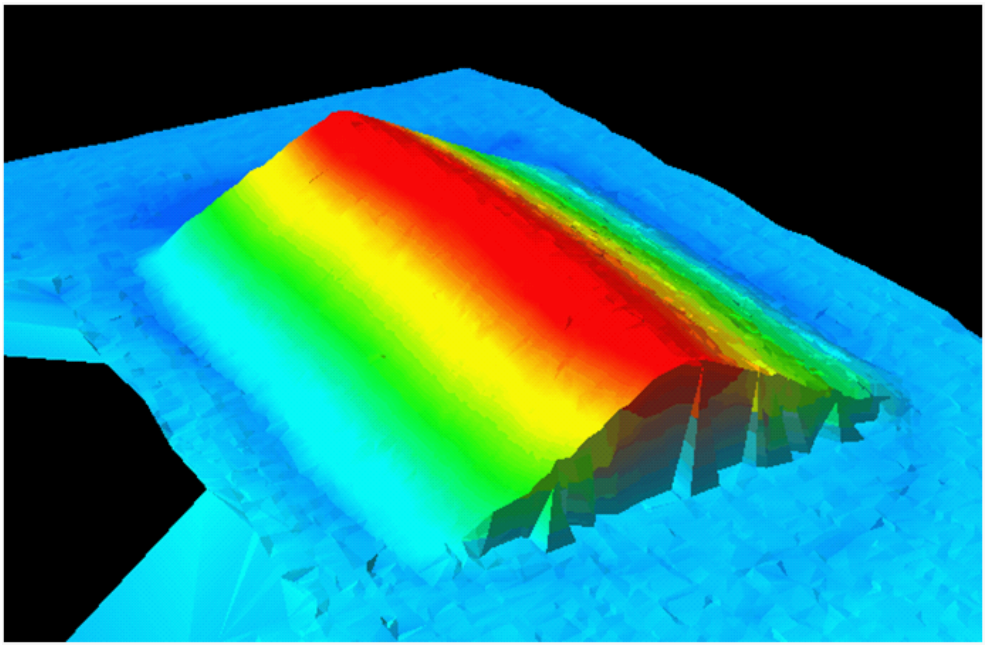
3D breaklines are a surface-refining feature in MARS®. TIN rendering will only respect 3D breaklines (breaklines with a Z-value) - 2D breaklines will not be recognized by TIN even if they have an elevation attribute. Breaklines added with the 'Reference Breaklines' option (covering a previously-edited area, for example) will also be respected. If a breakline file is loaded in MARS® as a reference file, the file will be shown in neon green in the Table of Contents (see below).

A neon green line indicates a polyline breakline reference file; a neon green box indicates a polygon reference file.

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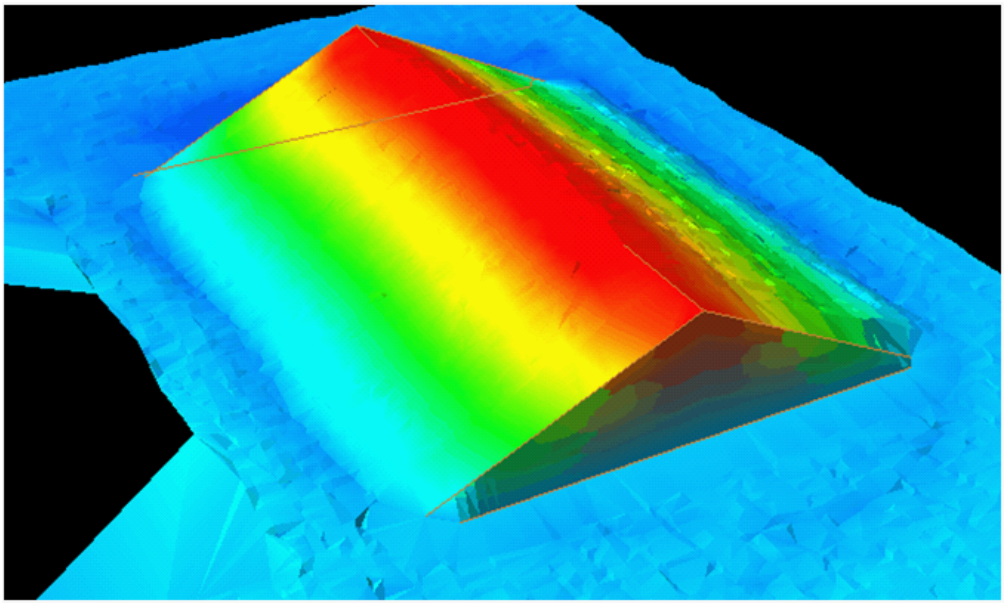
Below is an example of an area which needs to be corrected with a breakline. The side of this building should move smoothly from the roof to the ground without any jagged edges.



This next example is the same area, but with a 3D breakline loaded. The breakline has made

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the TIN respect the edge of the building and has produced a nice, smooth edge of the building down to the ground.



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8.4 Cross-Sections and Profiles

Cross-Sections and Profiles

Merrick Advanced Remote Sensing (MARS®) Software

The cross-section/profile tools will work with both LiDAR data and breakline data. The cross-section/profile tools are useful in evaluating data for calibration (collection scan/mission alignment) and obtaining measurements from elevation data. This tool first allows the user to see a 'cross-section' through the data. A cross-section has more 'depth' than a profile, which is only a linear cut through the data. Once the data has been cross-sectioned, the **'Place Cross-Section Line'**  button or

the **'Place Adjustable Cross-Section Line'**  button may be used to view a cut through a TIN. Cross-sections and profiles can also be exported. LiDAR point display may be toggled off in the LAS Map View without affecting the point display in the Cross-Section/Profile view.

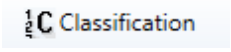
There are two ways of cross-sectioning data. The cross-section/profile tools are found on the Cross-Section/Profile Tab 240.

 **Place Cross-Section Line:** The place cross-section line requires the user to select only the length of the cut and the tool will default the cut depth to the value set in the 'Default cut area depth.' section of the 'Miscellaneous Options' interface on the Options Tab 519. This tool requires two left mouse clicks during use: one for the start and one for the end of the cut.

 **Place Adjustable Cross-Section Line:** The place adjustable cross-section line tool requires the user to select the length and depth of the cut. This tool requires three mouse clicks for use: one for the start of the cut, one for the end of the cut, and one to define the depth of the cut.

Either profile tool will open a new window with the user-defined area displayed. The default placement of this new window will be to the right of the LAS Map View window. The position can be modified by going to 'Arrange Cross-Section/Profile window' section of the 'Miscellaneous Options' interface on the Options Tab 519 and selecting either the **'Horizontally'** or **'Vertically'** radio button.

To use the cross-section/profile tools, follow these steps:

1. Click the **'View Classification'**  button on the View Tab 192 to display

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the 'Classifications Display Settings' dialog. Turn classes on and off by checking and unchecking them as desired, then click **'OK'**. To view the points in the cross-section/profile window by class, click at the top of the cross-section/profile window to ensure it is the active window. Then choose the 'Color by Classification'  button. The same can be done for the LAS Map View window by clicking at the top of the window, then selecting the 'Color by Classification' button.

2. Zoom to any tile with the left mouse button by double-clicking anywhere inside the tile. The display will zoom to the extents of that particular tile.

3. Click the **'Place Cross-Section Line'**  button on the Cross-Section/Profile Tab 240 to activate the tool and open a Cross-Section/Profile window. By default, the cross-section/profile window will be displayed to the right of the LAS Map View window as the active window. To place a new cross-section line, click the left mouse button once to designate the origin of the cut area, then click the mouse a second time in the desired end location of the cut area.

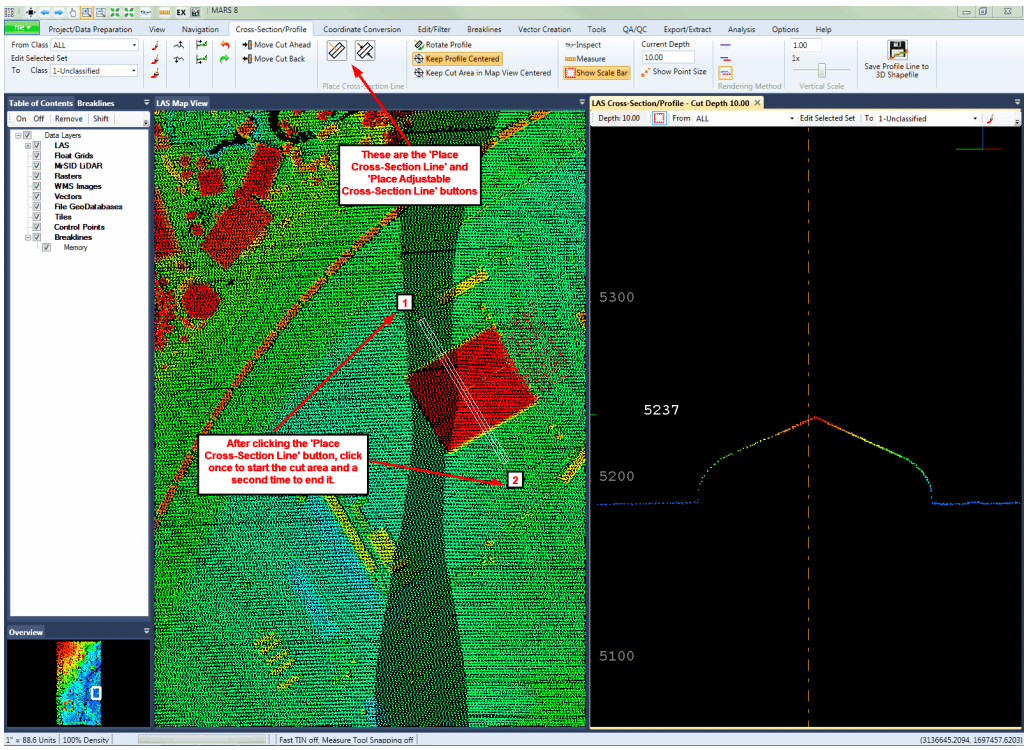
-OR-

4. Click the **'Place Adjustable Cross-Section Line'**  button on the Cross-Section/Profile Tab 240 to activate the tool and open a Cross-Section/Profile window. By default, the Cross-Section/Profile window will be displayed to the right of the LAS Map View window as the active window. To place a new cross-section/profile line with a user-defined cut depth, click the left mouse button once to designate the origin of the desired cut area, then click the mouse a second time in the desired end location of the cut area. Finally, move the mouse to expand or contract the depth of the cut area, and click the left mouse button a third time to

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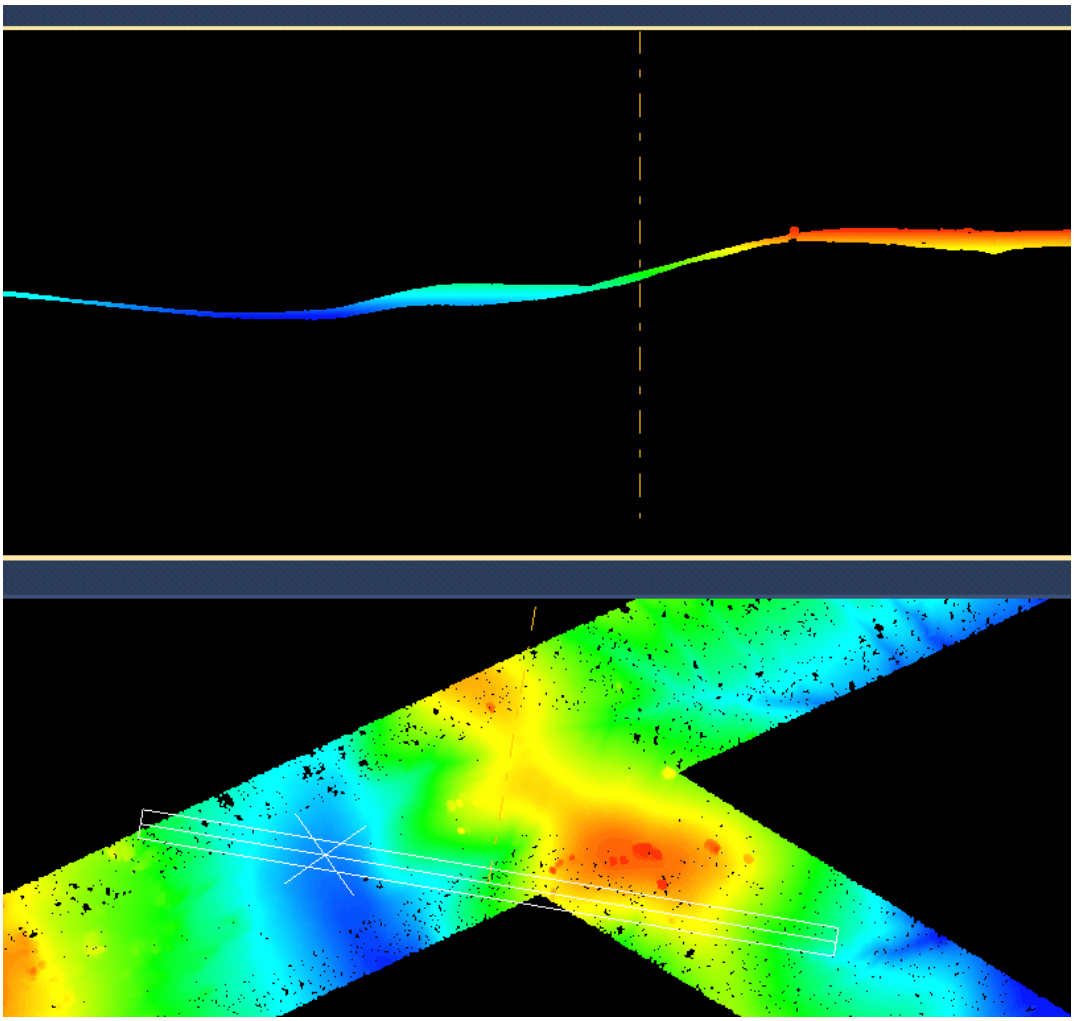
set that depth.

After either type of cross-section/profile has been created, it can be moved by dragging it in the LAS Map View window, by using the arrow keys on the keyboard, by using the mouse scroll wheel, or by clicking the 'Move Cut Ahead/Back' buttons.



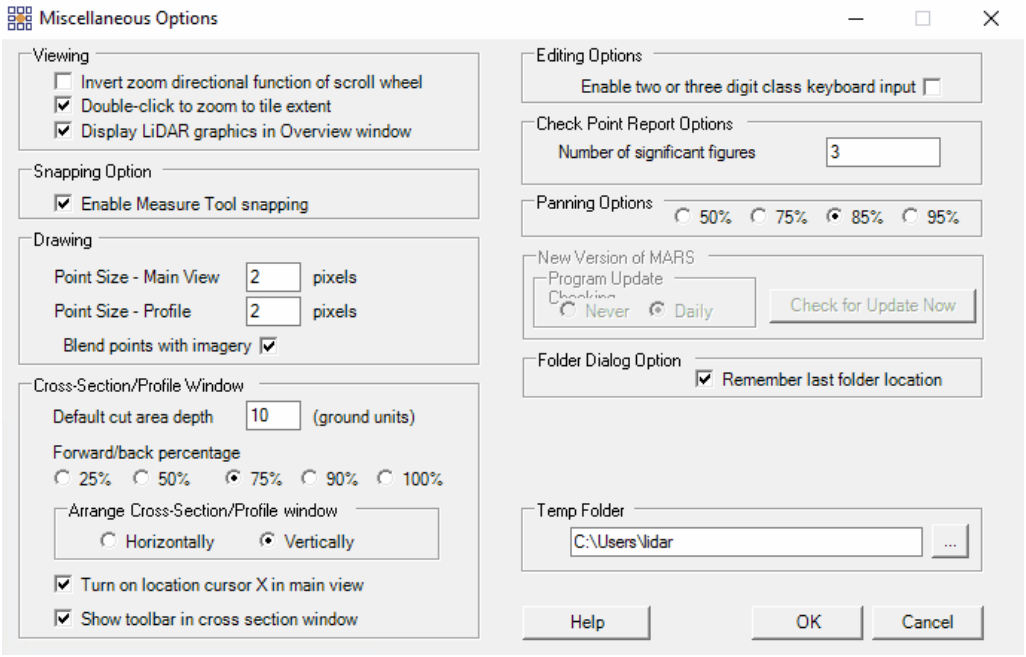
5. Note that as the cursor is moved in the Cross-Section/Profile window, a white 'X' symbol will move in sync within the cross-section/profile cut area box in the LAS Map View window. This aids the user in determining what areas of the data are being observed at any given time. This tool may be disabled by going to the 'Miscellaneous Options' interface on the Options Tab 519.

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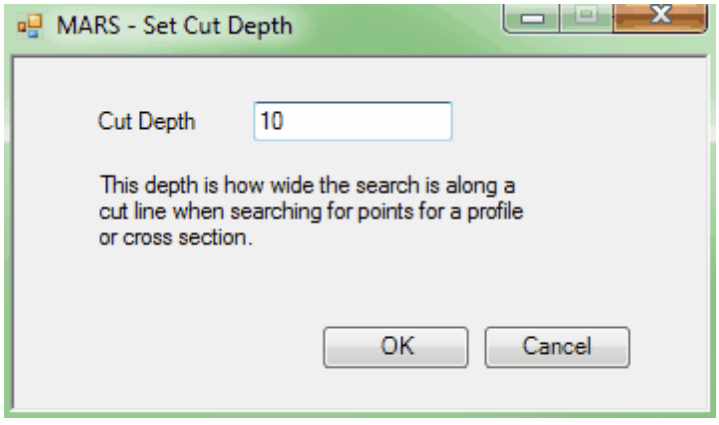
6. In the Cross-Section/Profile window, MARS® defaults to the rendering method called 'Cross-Section' and has a cut depth of ten (10) units when using the 'Place Cross-Section Line' tool. The default Cross-Section/Profile window depth is defined in the 'Cross-Section/ Profile Window' section of the 'Miscellaneous Options' dialog. Click the **'Miscellaneous'** button on the Options Tab[519] to bring up this dialog or use the keyboard accelerator **'D'** on the keyboard. This dialog also allows the user to define the arrangement of the Cross-Section/Profile window (horizontally or vertically), and the forward\backward step percentages when moving with the keyboard arrow keys or the 'Move Cut Ahead/Back' buttons.

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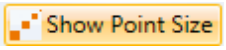


7. Activate the Cross-Section/Profile Tab[240], and go through the following tools with the created cross-section/profile.

a. To change the depth of the cut in the Cross-Section/Profile window without redefining the area, enter a new value in the 'Current Depth' text box on the tab. The current value will also be displayed on the Cross-Section/Profile window tab. Any change will take affect immediately in both windows. Using the shortcut key **'D'** on the keyboard will bring up the following interface where the value can also be changed:



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b. To modify the proportional sizes of the LiDAR points in the Cross-Section/Profile window, click the **'Show Point Size'** 

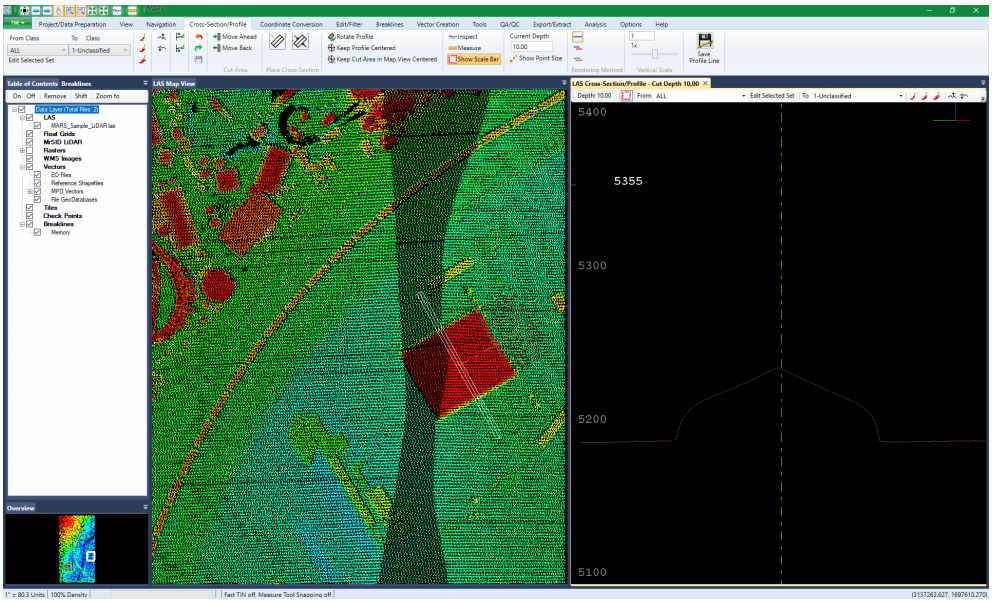
button. This action will cause the points closest to the user to be displayed slightly larger, while those points at the back of the cross-section/profile cut will be displayed smaller.

c. To combine the points in the Cross-Section/Profile view across all included collection scans, click the **'Profile Combined'**  button. Using this tool in combination with the **'Color by Classification'** 

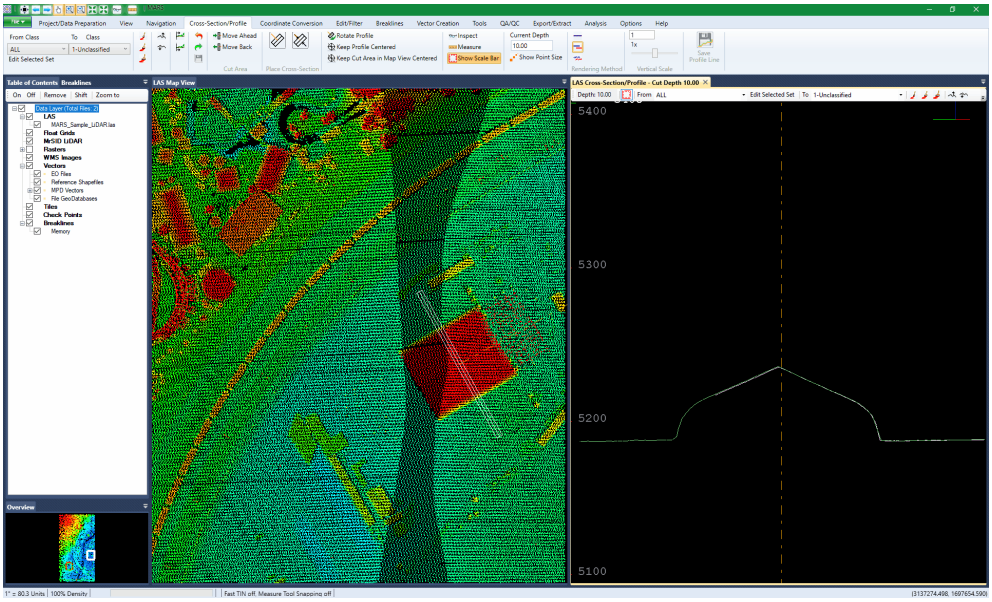
rendering style allows the user to assess which data classifications are included in the profile line. When data in the Cross-Section/Profile window is rendered using 'Profile Combined' the **'Save Profile Line'** 

option is available. This tool allows the user to save the profile line shown in the Cross-Section/Profile window as a 3D shapefile or a CSV file of XYZ values. When the output is a shapefile, it can then be loaded into MARS® as a reference shapefile and viewed in the LAS Map View window (2D 835 or 3D 837 views).

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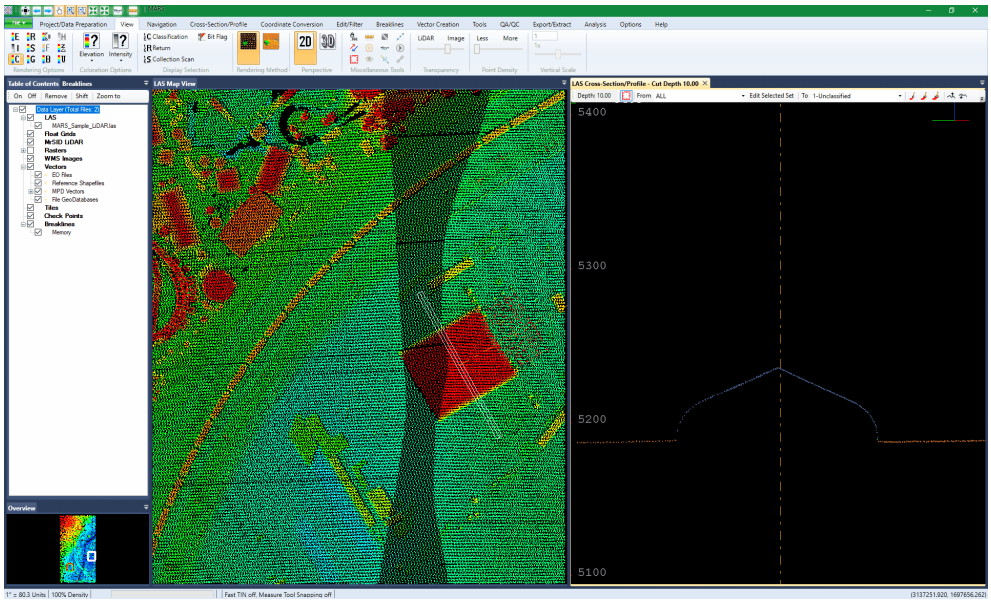


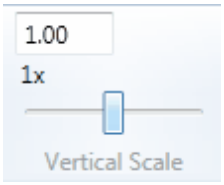
d. To render the LiDAR data in the Cross-Section/Profile view by collection scan, click the **'Profile by Collection Scan'** button on the Cross-Section/Profile Tab 240. This will create one line per collection scan in the Cross-Section/Profile window, and is very useful for determining the data's collection scan-to-collection scan alignment. Typically, the user can quickly assess the data quality by comparing the profile alignment of each collection scan.



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e. Turn the profile display back to a cross-section of points by using the **'Cross Section'** button.



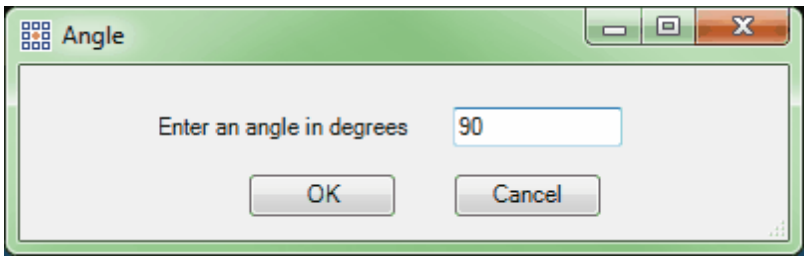
f. To exaggerate (or de-exaggerate) the scaling of the Cross-Section/Profile window display, the user can drag the **'Vertical Scale'** 

slider bar or type in the desired scale in the text box. Click the **'1x'** button to return the scale to its normal state. This tool is normally used to evaluate the ground control (check) points in relation to the classified LiDAR ground points. To see more information concerning the vertical scale slider bar, please see the Cross-Section/Profile Tab 240 or Cross-Section/Profile Window 146 sections.

8. To rotate the cross-section/profile area shown in the Cross-Section/Profile window, click

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the **'Rotate Profile'** button. This tool allows the user to rotate the cut area a specified number of degrees from its current position. 90 degrees is the default value, but any numerical value may be entered. Entering a negative value (i.e., -90 degrees) will cause the cut area to rotate in a counter-clockwise direction. Select 'OK' to see the results in both the LAS Map View window and the Cross-Section/Profile window. This tool can also be invoked by using the keyboard accelerator **'R'** on the keyboard while the cross-section/profile window is active. Small changes in rotation can be made by scrolling the mouse wheel or using the left and right arrows on the keyboard.



9. To exit the Cross-Section/Profile display, click the (close) button on the right side of the window tab, and the LAS Map View window will maximize to fill the vacated area.

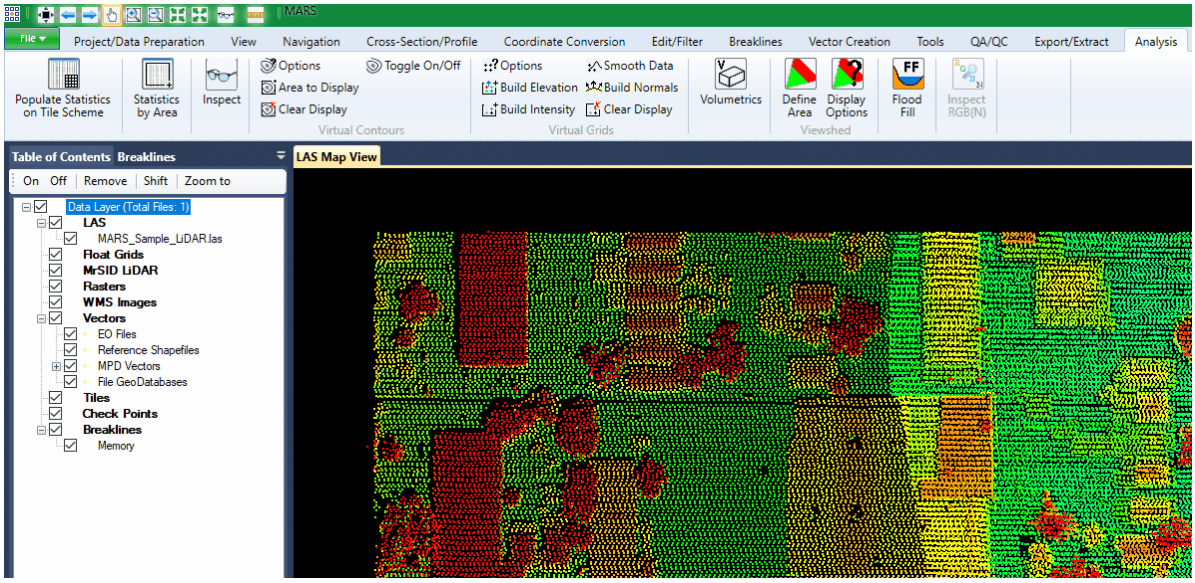
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8.5 Viewing and Generating Contours

Viewing and Generating Contours

Merrick Advanced Remote Sensing (MARS®) Software

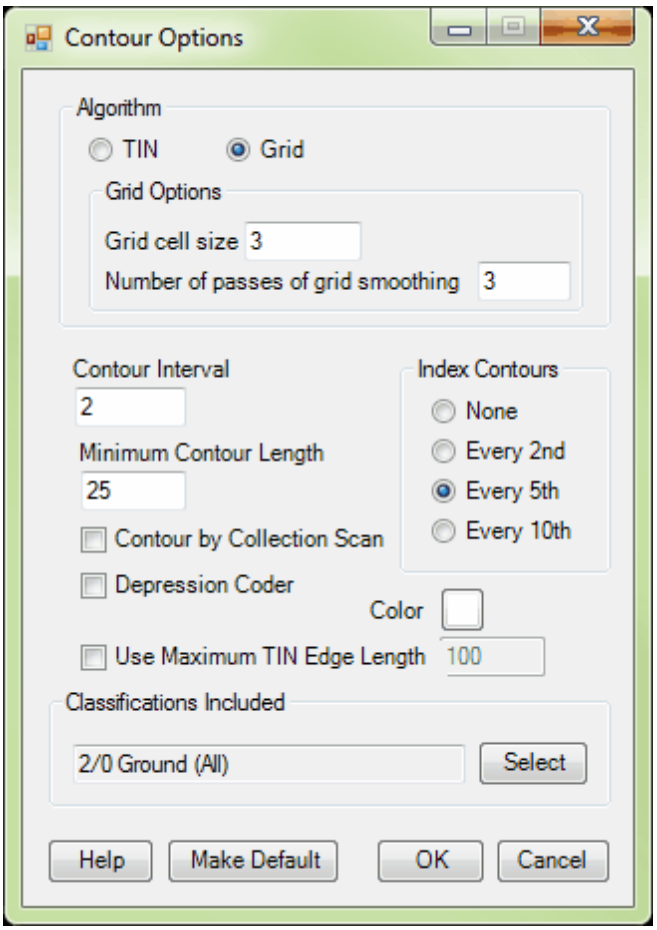
The virtual contour tools are found on the Analysis Tab 489. In this tutorial the user will learn how to display contours and export them to shapefiles. Contours will respect breaklines created in a project and breaklines loaded as reference files (if Fast TIN is unchecked in the 'Performance Options' on the Options Tab 519). Contours may also be created with only breaklines loaded - LAS data does not need to be loaded.



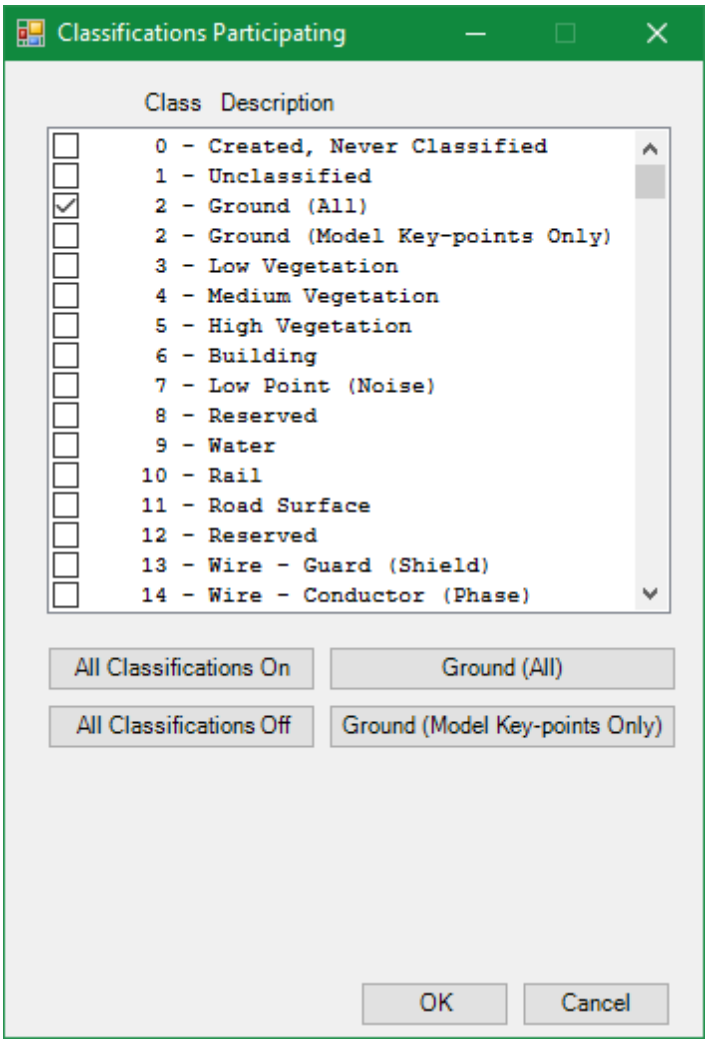
1. Make sure the Denver Sample Data (or other LAS data) is loaded. On the Project/Data Preparation Tab 162, click the top half of the '**Add LAS Files**' button, then navigate to **C:\MARS\Sample_Data\MARS_Sample_LiDAR.las** and click '**Open**'). Click the **'Options'** Options button on the Analysis Tab 489 and the following dialog will appear. This dialog can be used to define contours that are created from a TIN or a virtual Grid. If the 'Grid' option is used, then the user may further specify the grid cell size and the number of times the grid smoothing algorithm is run. The option to create a virtual grid inside the contour options function allows the user to create a smooth grid file which, in turn, will create aesthetically pleasing and smooth contour lines. The RAM-based virtual grid also allows for quicker processing. There are also options to specify the contour interval, the frequency of index contours, the minimum contour length, the color in which the contours

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are displayed, the data classification(s) used to create contours, and whether or not contours are generated by collection scan. The **'Depression Coder'** check box should be checked when the user would like to uniquely symbolize depression contours. The **'Use Maximum TIN Edge Length'** option allows the user to set a maximum TIN triangle edge length to be used in generating contours, thereby ignoring areas where LiDAR ground data may be too sparse to create accurate contours. Enter the following settings into the dialog and select **'OK'**. (To see more about the Contour Options settings, please see the Analysis Tab 489 topic.)

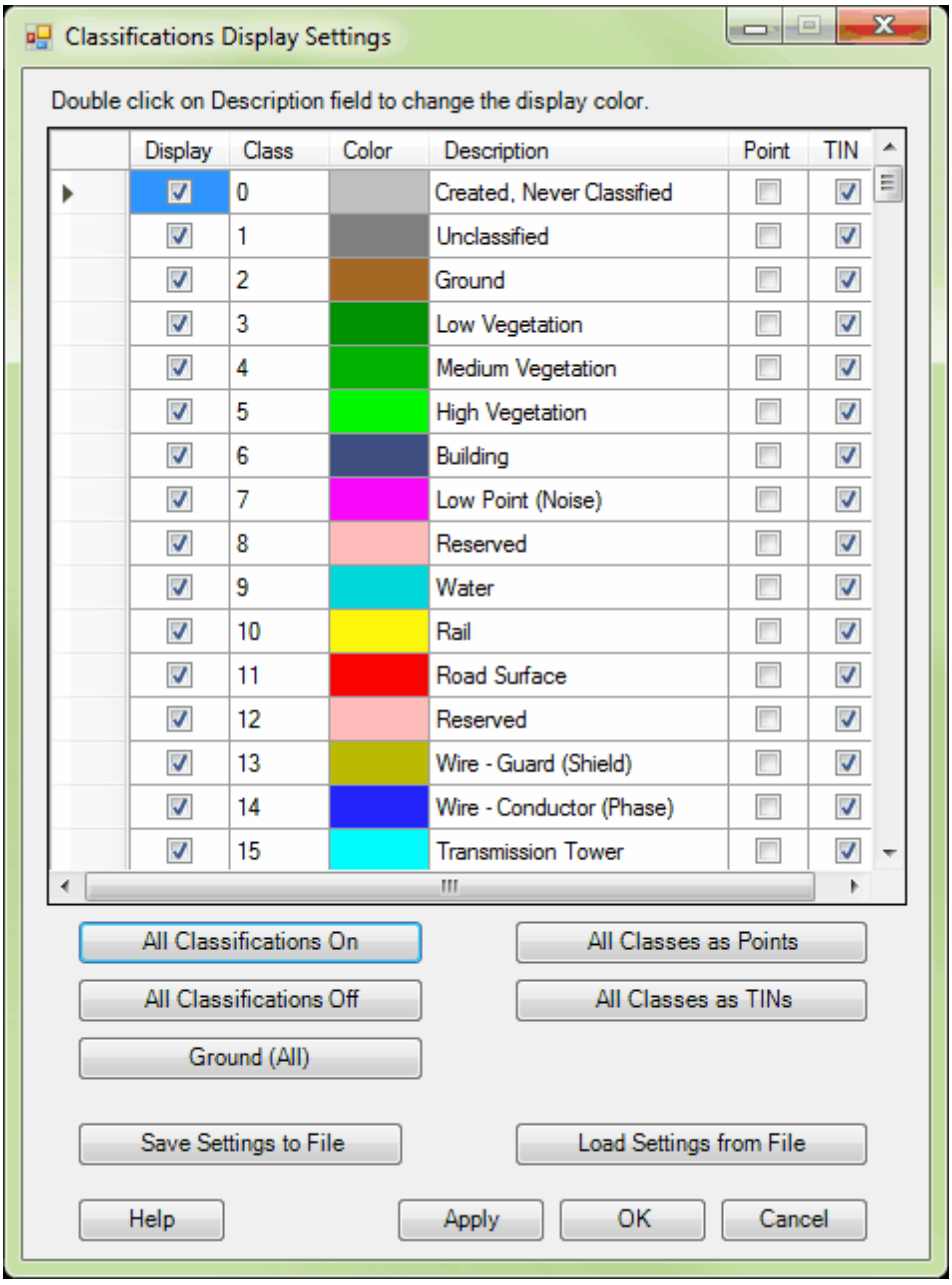


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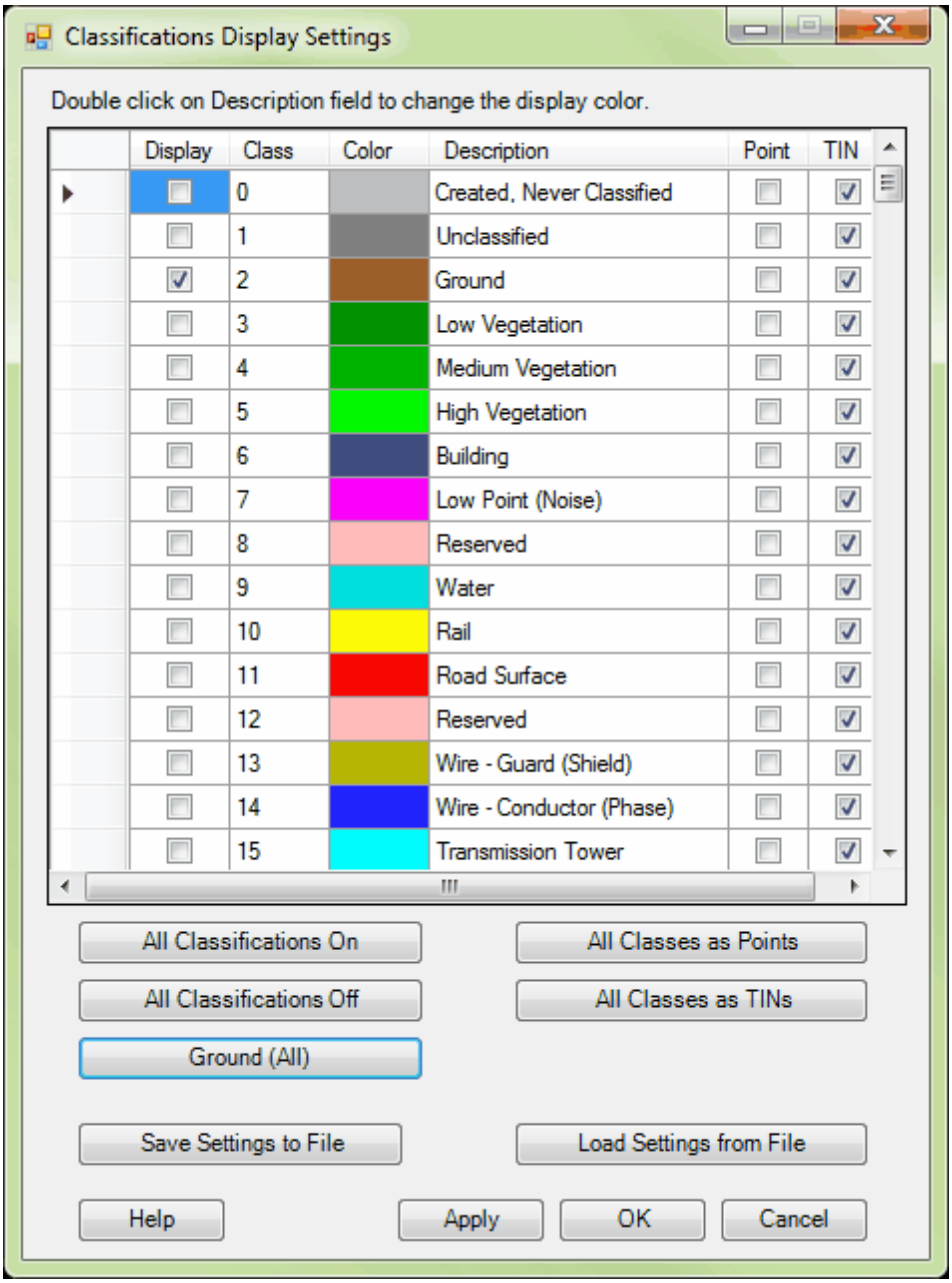


2. Open the **'Classification Display Settings'** Classification interface on the View Tab 192, and click the **'Ground (All)'** button. Notice that this turns on for display only Class 2 -- Ground (including any ground points flagged as Model Key-points). Click **'OK'**.

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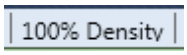
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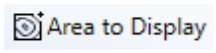


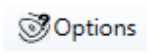
3. Ensure that the dataset is being viewed by classification by selecting the **'Color by Classification'** button on the View Tab[192]. Now zoom into an area in the sample dataset by using the **'Zoom In'** Zoom In Window tool. MARS® will not show virtual contours unless the user is zoomed in far enough to

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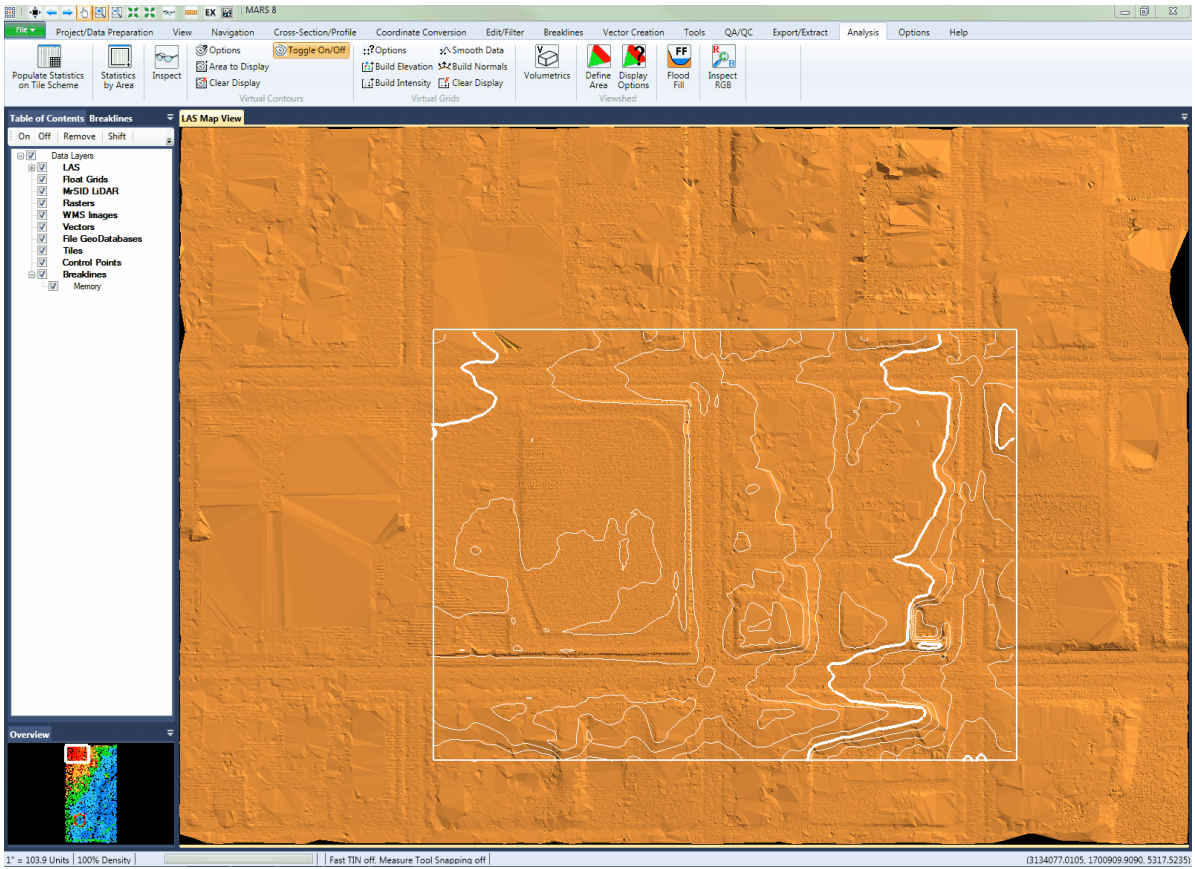
show 100% of the LiDAR points, or has enabled the 'Lock to view 100%' button on the View Tab 192. To see the density percentage, check the area of the status bar at the bottom of the LAS Map View window immediately to the right of the scale display.



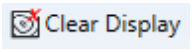
TIN the surface by clicking the  button on the View Tab. Click the **'Area to Display'** 

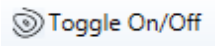
button and drag a box over an area to see the contours. The virtual contours may be viewed in 2D View 835 or 3D View 837. Click the **'Options'** 

button again, change some of the settings and click on **'OK'**. The new settings will be automatically applied to the contour display.



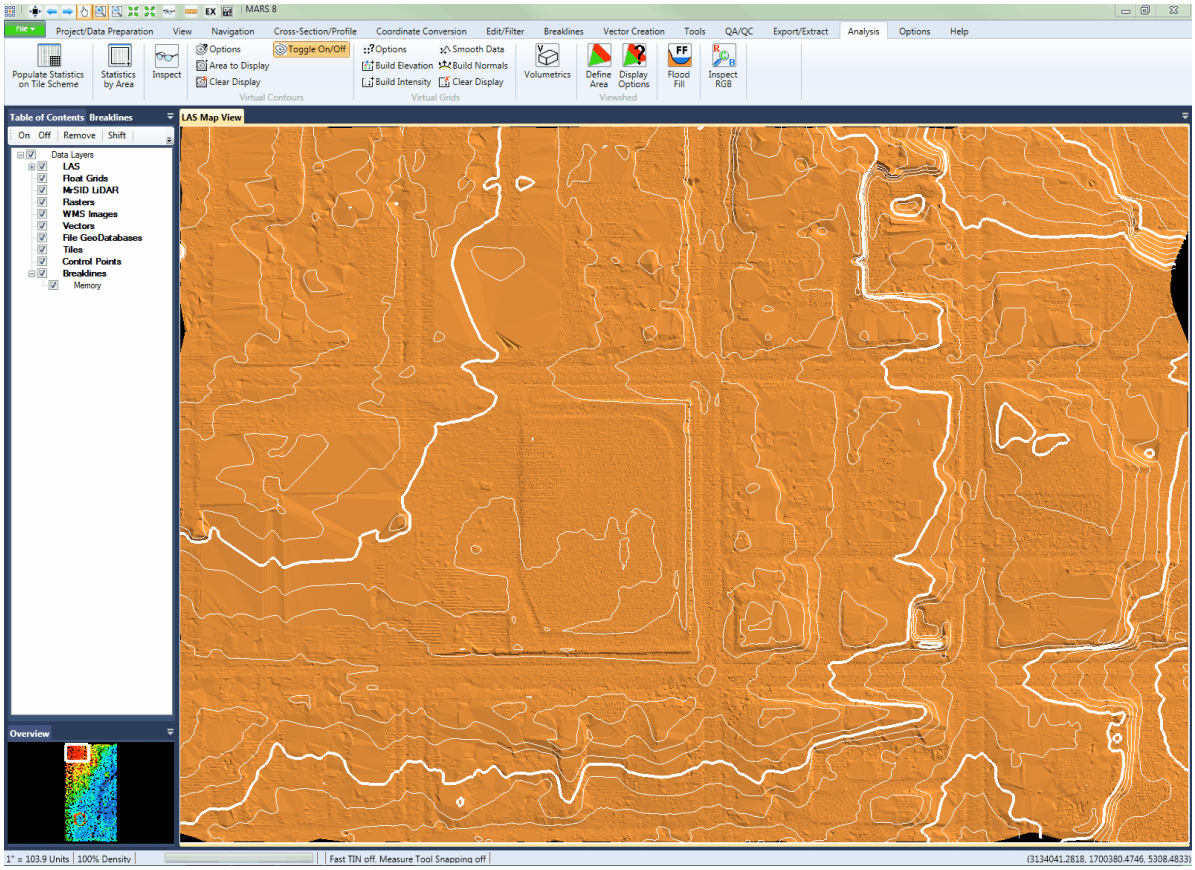
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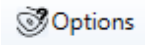
4. Now remove the contours by using the **'Clear Display'** 

button. Once contours are cleared, select the **'Toggle On/Off'** 

button at the same view extent and notice that contours are drawn over all visible data rather than a specified area. By changing the contour options again and clicking **'OK'** the changes will be applied immediately to the data.

Note: It is not recommended to use the 'Toggle On/Off' tool when panning over large amounts of data as contours are created 'on the fly,' and production of a large amount of contours may slow down navigation. The software will attempt to calculate contours for all data in the extent at any time when the 'Toggle On/Off' tool is enabled. It is much faster to pan to the chosen area with the contours turned off, and then re-create the contours when the pan and/or zoom operation is complete.

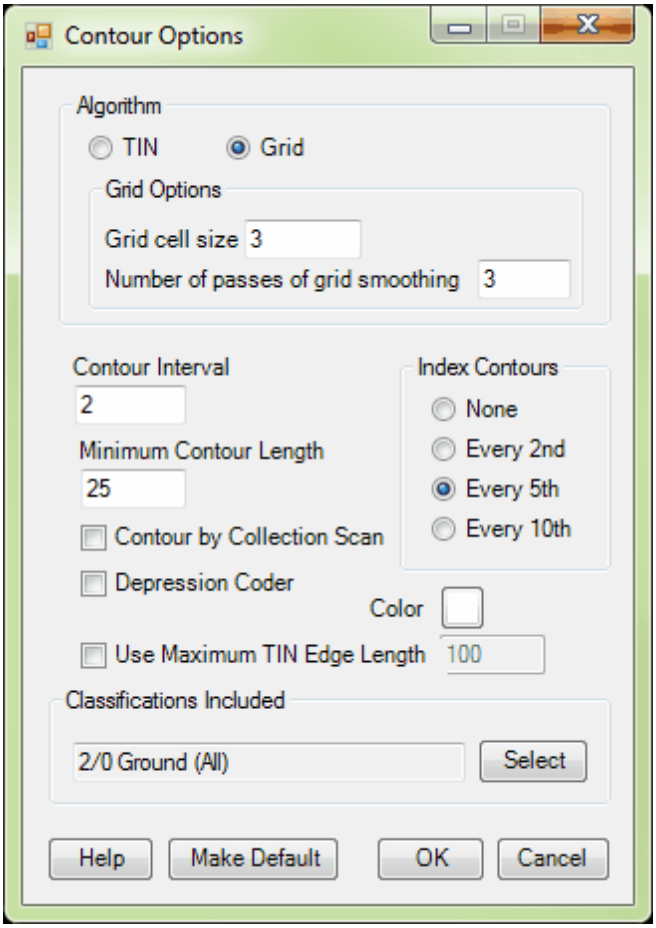


5. Click the **'Options'** 

button and select the **'Contour by Collection Scan'** check box,

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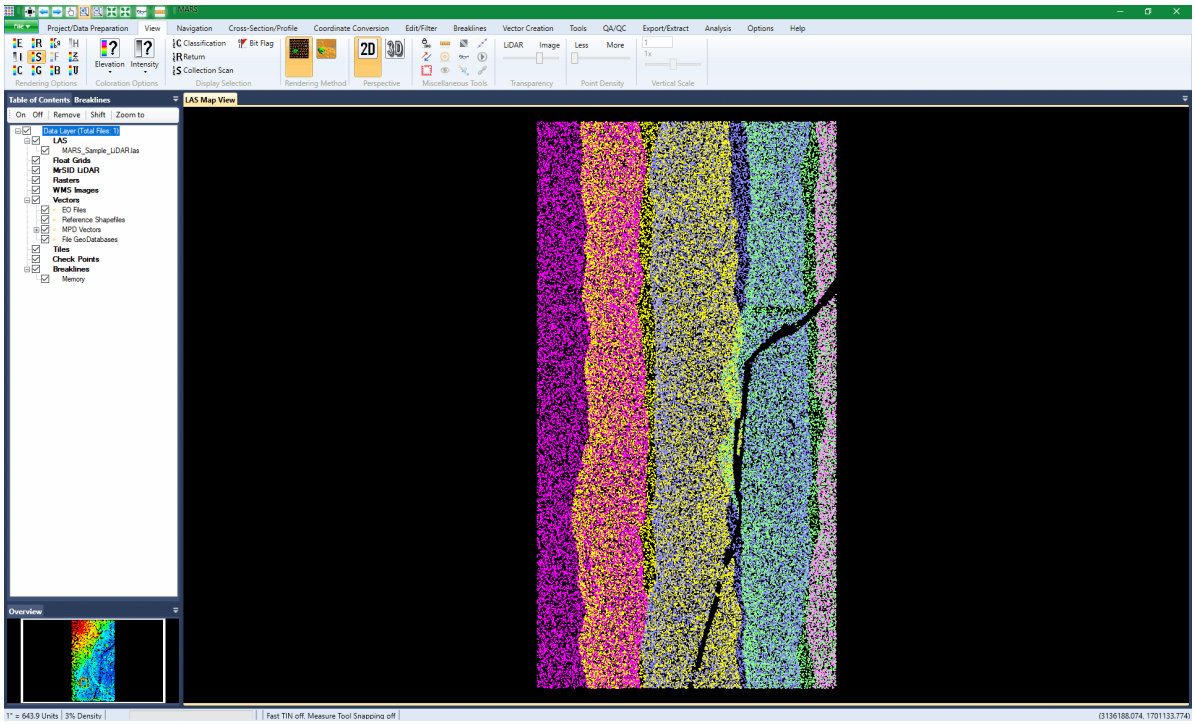
then click **'OK'** ***(this option is not available with an Evaluation license)***.



The LAS Map View will update automatically to display the contours color-coded by collection scan. In this example there are four overlapping collection scans: yellow, purple, green, and magenta.

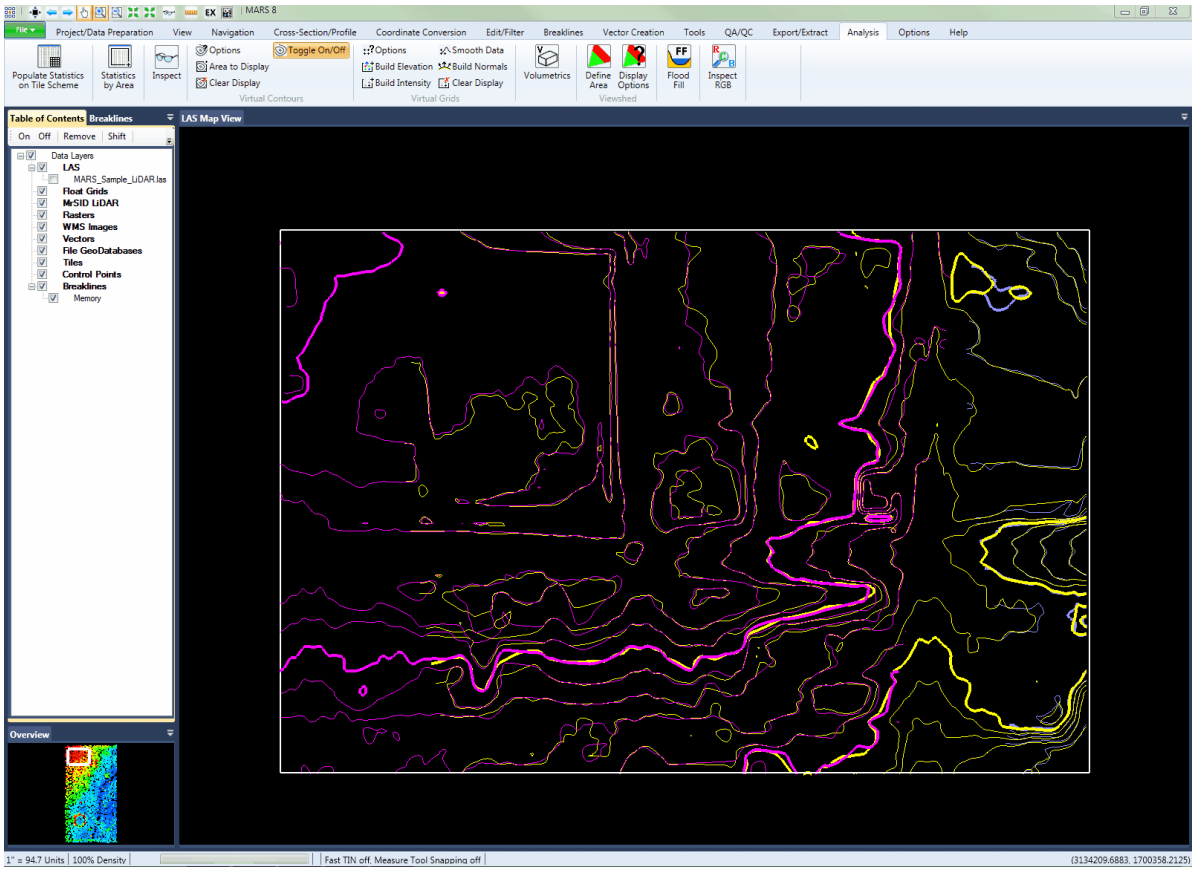
Note: This must be performed over an area with overlapping collection scans (as in the example below) for the difference in contouring to be visible.

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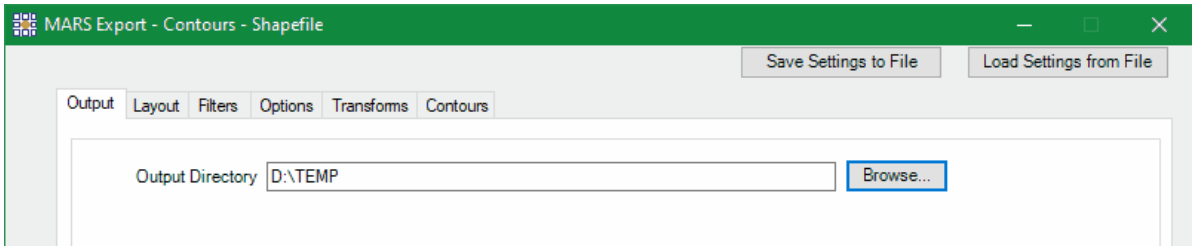
The contours can be more easily seen if the LiDAR data is unchecked in the Table of Contents.

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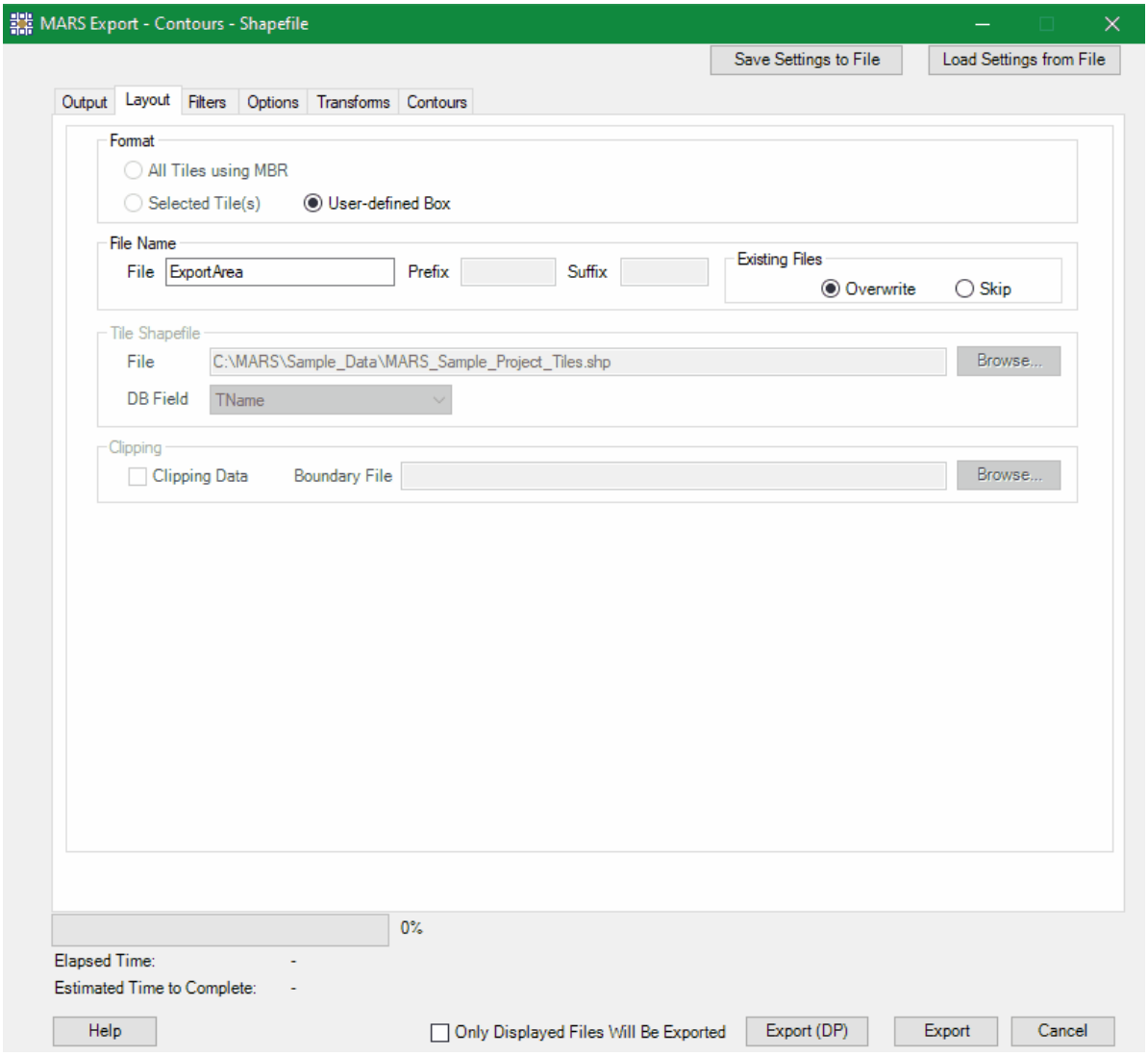
6. Contours can also be exported as polyline shapefiles. Change the contour options settings as described above until the desired combination is found. These settings should be used in **Step 10**, below. Select the **'Export Area'** 

tool on the Export/Extract Tab[461] and drag a box over the area to be exported. From the drop-down list that appears, select 'Contours - Shapefile' and click 'OK'. The following Export dialog will appear. Browse to or type in the directory where the file is to be exported in the **'Output Directory'** box.



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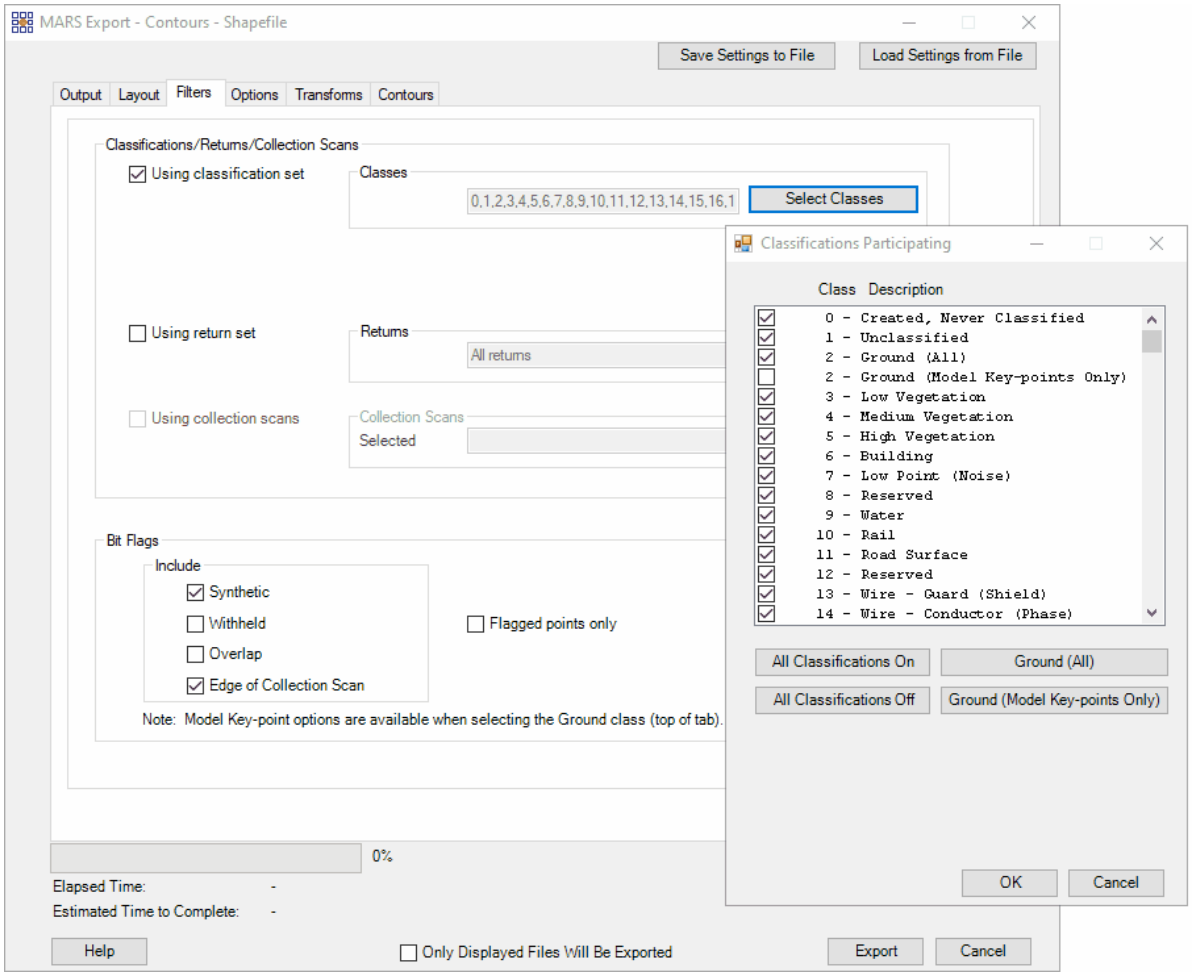
7. Next select the **'Layout'** tab, and give the contour shapefile a name - this is done in the **'File Name'** section. The default name is 'ExportArea' but can be modified. Notice that **'User-Defined Box'** is the only layout format available. This is because the area was defined by the user. Make sure to specify whether existing files in the output directory should be overwritten or skipped if the file name already exists.



8. Click on the **'Filters'** tab. Click the **'Select Classes'** button to change which classes will be included in creating the contour export. To export contours of the bare earth, click the **'Ground (All)'** button and

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all classes will be turned off except for 'Class 2 -- Ground (All)'. Click **'OK'**, then make sure the **'Using classification set'** option is checked to include the class(es) just specified.



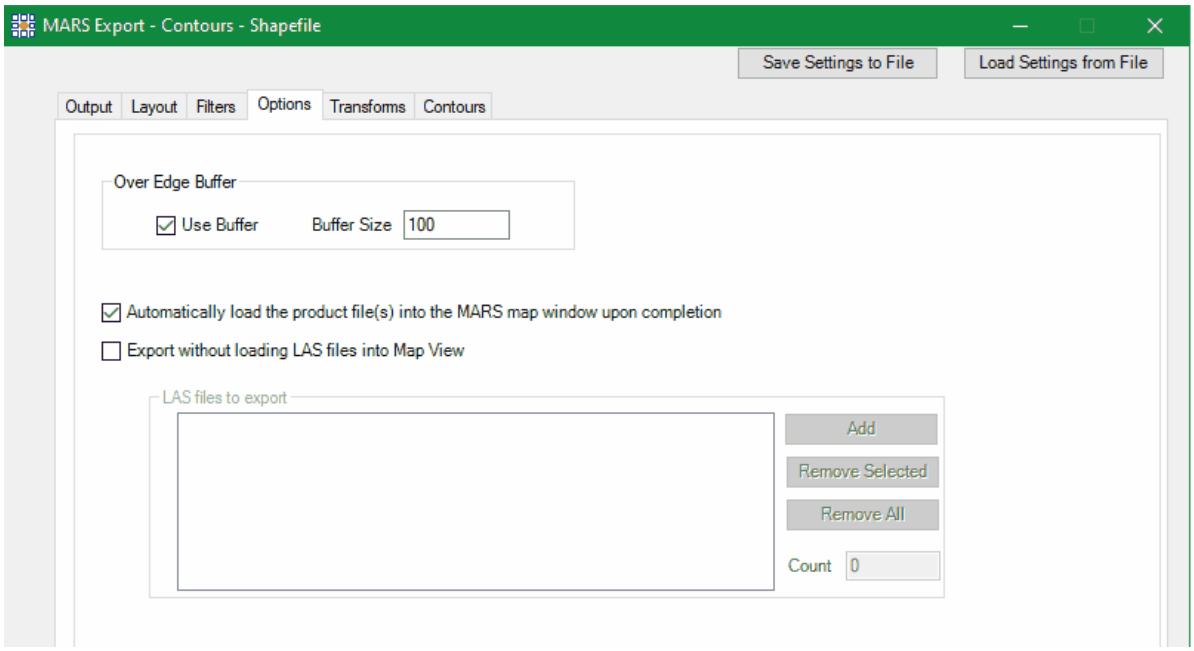
The specific returns and/or collection scans to be included in the export can also be defined. By default, all returns and all collection scans are used. For any other configuration, make sure the **'Using return set'** and/or 'Using collection scans' boxes are checked and click on the **'Select Returns'** and/or 'Select Collection Scans' buttons as needed to make selections.

9. Next, go to the **'Options'** tab. A buffer (in project units) can be set here if desired - this will extend the area to be exported beyond the user-defined box. To set a buffer, check the box next to 'Use

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Buffer' and enter the size of the buffer needed around the data. To export contours without a buffer, leave the box unchecked.

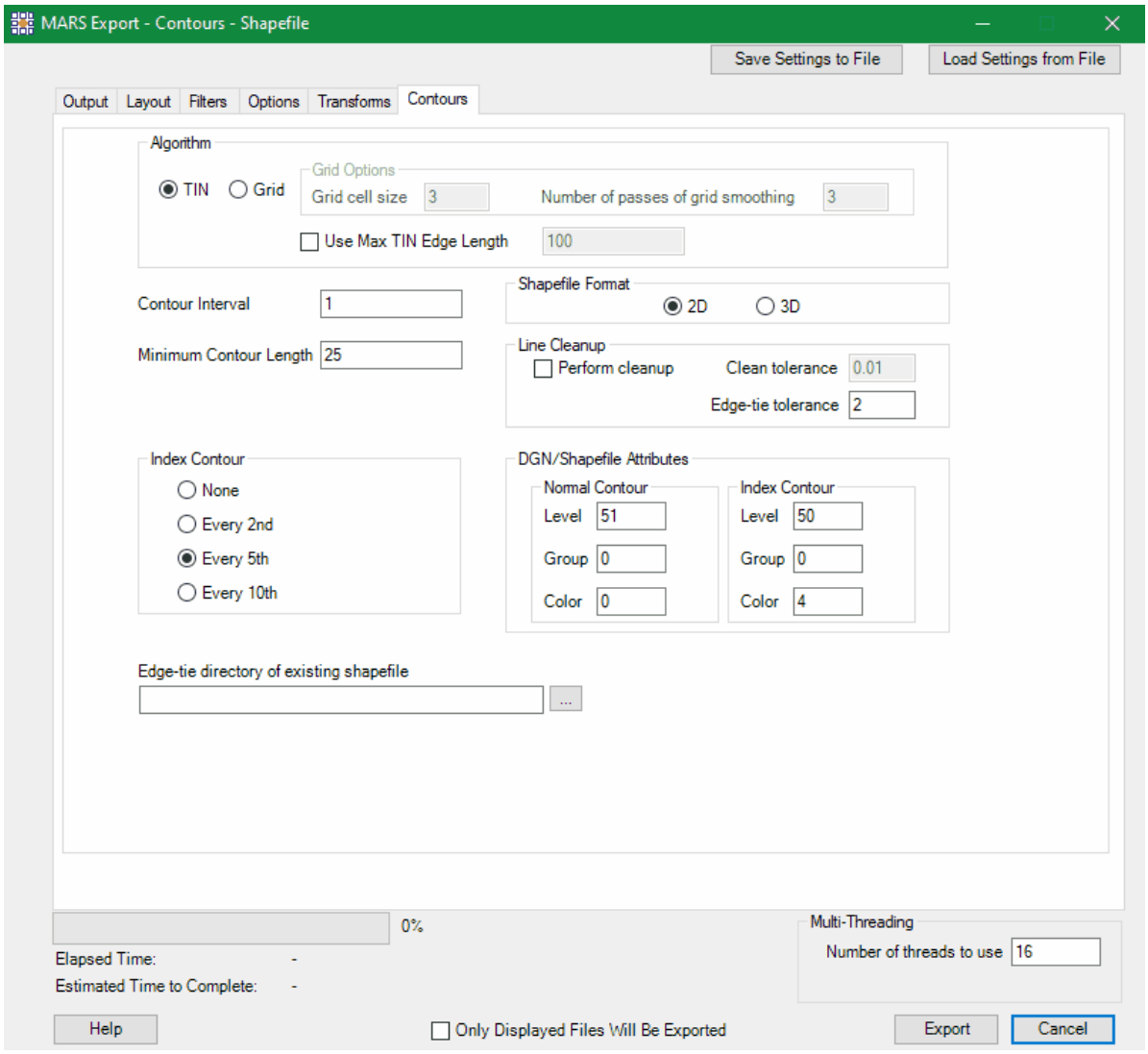
There is also an option to load the newly-exported data immediately after the export is completed. To do this, check the 'Automatically load the product file(s) into the MARS® map window upon completion' box.



10. Finally, go the **'Contours'** tab. Make sure the 'Every 5th' option is chosen for the 'Index Contour' setting for this example. Also, uncheck the 'Perform cleanup' box.

By default, the contours will export as a 2D shapefile. To export to a 3D shapefile, make sure the '3D' radio button is checked. Click the **'Export'** button at the bottom of the interface. The file will now be exported to the specified output directory. When contour shapefiles are exported, a *.prj (projection definition file) is created if the projection information is known for the source LAS data. Please see the Contours Tab 806 topic for more on these settings.

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11. If the option to load data upon export was not checked in step 9, add the exported contour file into MARS® by clicking on the **'Add Reference Shapefiles'** button on the Project/Data Preparation Tab 162 and browsing to the shapefile to be added. In the Table of Contents 67 'Vectors' layer, right-click on the newly added contour shapefile and choose **'Properties'**. Make the shapefile lines thicker or change their color to make the contours more visible. Contours can be labeled for elevation by checking the '**Display Label**' box, choosing '**ELV**' from the '**DB Field for Labeling**' drop-down box, and choosing a '**Font Size**.' labeling will be in the same color as the contour lines. Click '**OK**' to apply these properties. Make sure the **'Vectors'** layer and entry boxes are checked on in the 'Table of

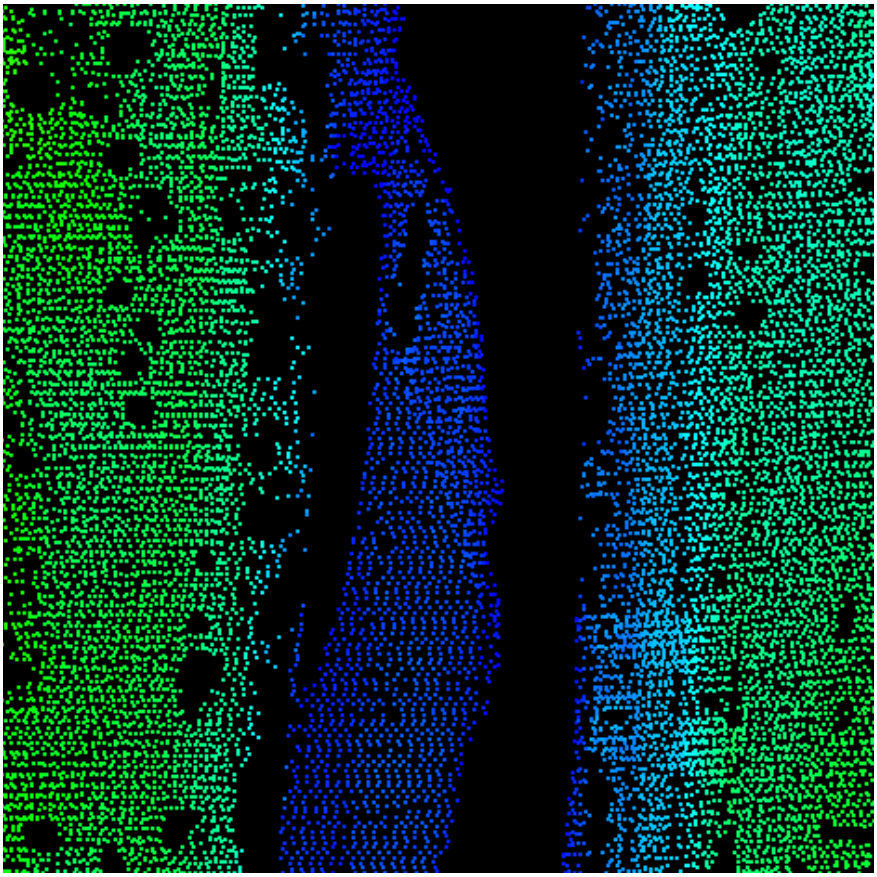
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Contents' so that the new shapefile can be seen.

Using 3D Breakline Shapefiles to generate Contours

It is also possible to create contours (virtual or exported) using breaklines - both 3D and 2D breaklines may be used. The use of breakline shapefiles to create contour lines can result in quicker production of more precise and aesthetically pleasing contour lines.

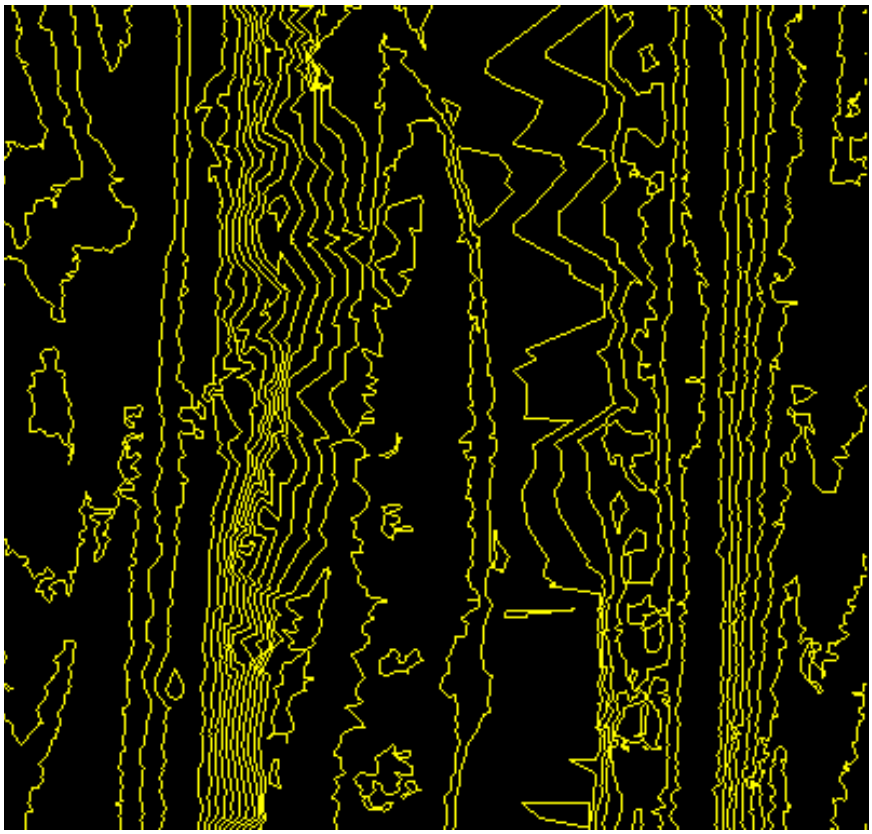
The example below shows only model key-points in an area where contours are to be created around a river. There is no breakline shapefile loaded.



In the example below, contours have been created using the parameters for the above screen shot. The

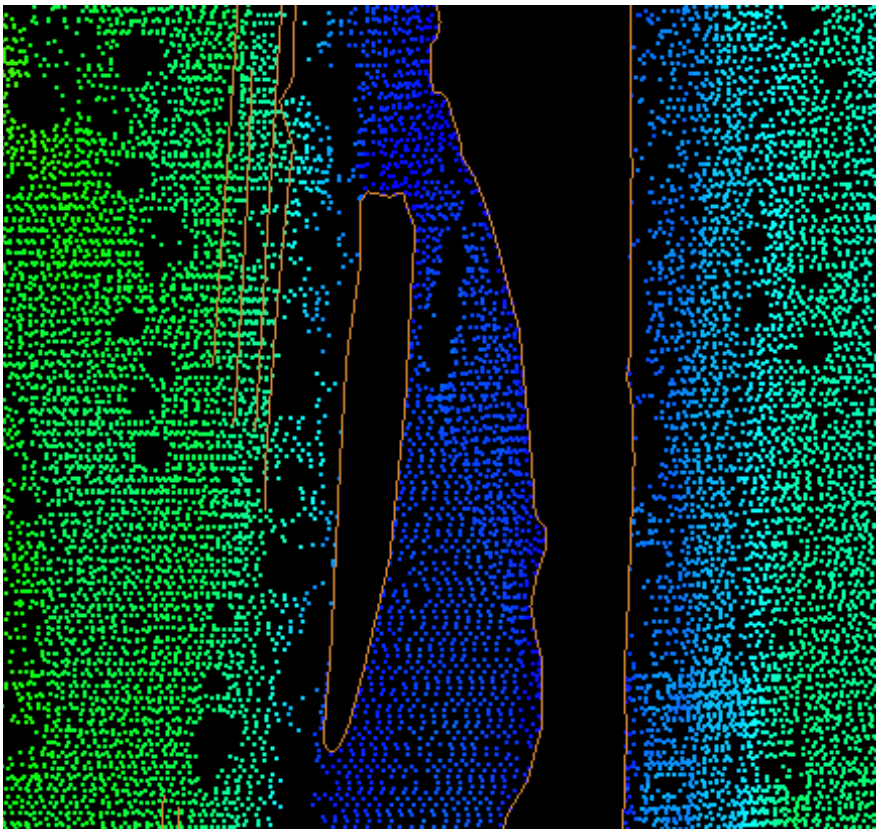
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contours lines are cutting back and forth through the water.



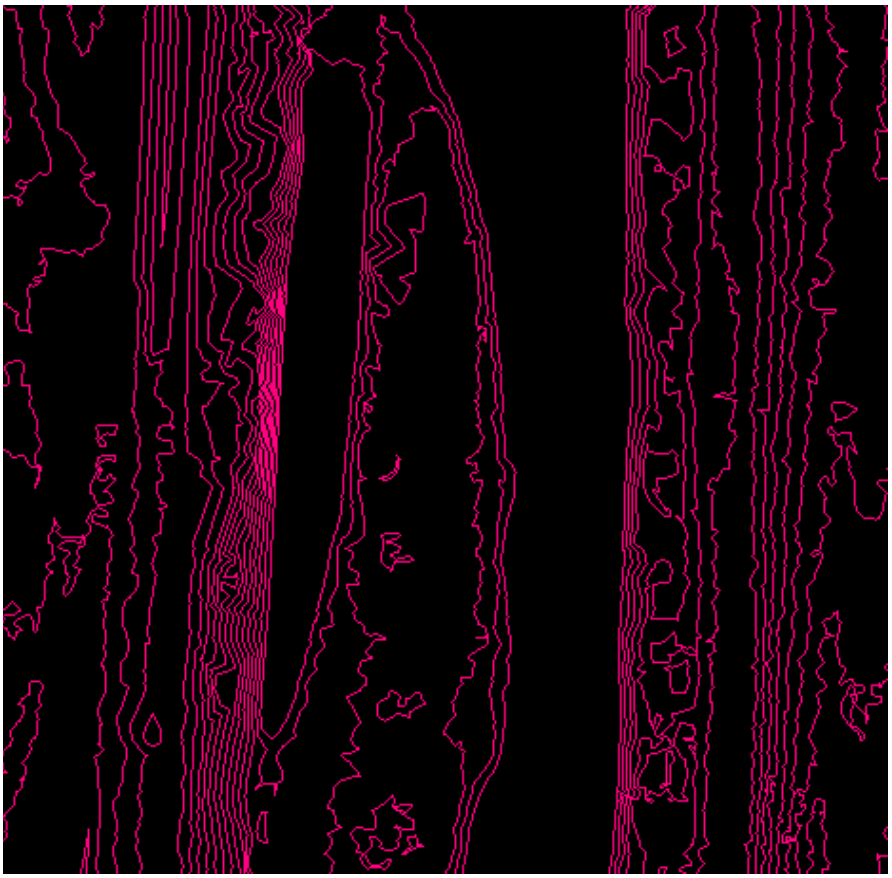
In this example, the same area is used to create contours, but a breakline shapefile has also been loaded and can be seen in orange.

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The result is contours that 'respect' the breaklines and do not enter the water.

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8.6 Manually Editing LiDAR Data

Manually Editing LiDAR Data

Merrick Advanced Remote Sensing (MARS®) Software

The hand filter (or manual editing) step is used to clean up any of the mis-classified features left by automatic filtering. It is important that the automatic filter performs as effectively as possible in extracting the bare earth surface or any other features to reduce the amount of hand filter work.

Depending on the automatic filter parameters it is typical to see errors on large buildings, mountain tops, bridges, swamps, and canopy jumps where there is little ground penetration. To view and modify these anomalies MARS® has a variety of display and hand-editing tools to quickly repair the surface.

The MARS® Display & Editing tools include:

1. Reclassification tools

- **a) Source Classification**
- **b) Target Classification**
- **c) Paint Brushes**
- **d) Edit Place Polygon**
- **e) Edit Selected Polygons**
- **f) Edit Line String Above (Cross-Section/Profile window only)**
- **g) Edit Line String Below (Cross-Section/Profile window only)**
- **h) Edit Scrape Above (Cross-Section/Profile window only)**
- **i) Edit Scrape Below (Cross-Section/Profile window only)**

2. View and Color by:

- **a) Elevation (color cycles)**
- **b) Intensity**
- **c) Classification**
- **d) Collection Scan**
- **e) Return**
- **f) Fusion**
- **g) Ground Color**

3. Creating Contours on the fly

4. 2D & 3D Views

5. View by Cross-Section/Profile View

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6. Inspect Tool

7. Viewing Specific Classifications

8. View by Points/TIN

9. Coverage Tracking *(available with Production license only)*:

a) Start Coverage Tracking

b) Stop Coverage Tracking

c) Save Tracking to Shapefile

10. Undo and Redo buttons

Hand Filter Procedure:

- **Performance Options:** Due to LAS datasets becoming increasingly larger in file size (frequently surpassing the available RAM in a computer) as well as the possibility of lost work caused by an unexpected shutdown of MARS prior to a save operation, the 'Cache points into available RAM' option ('Options' tab, 'Performance' button) has been disabled. LAS data will be read from disk and 'live' edit changes (such as hand filtering) are committed to disk as soon as they occur. Additionally, with newer, faster hard drives such as SSD, the performance difference between disk-based and RAM-based operations is constantly shrinking.

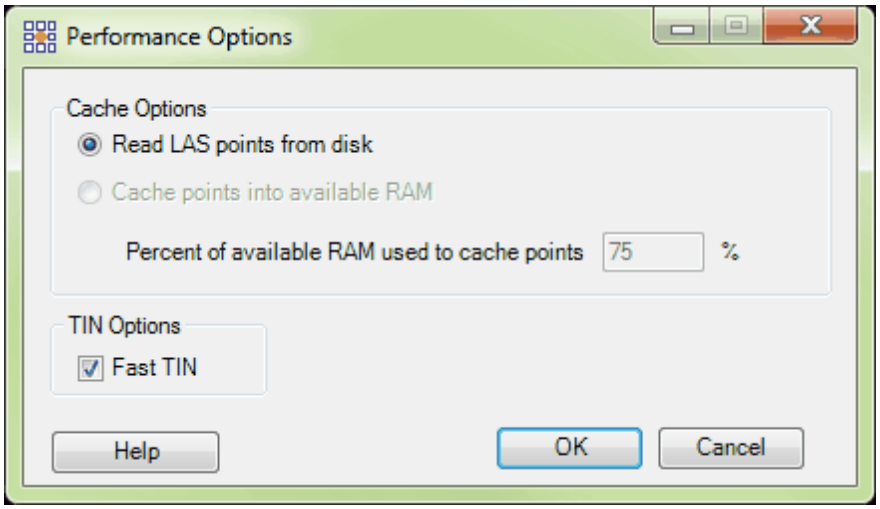
  ✓ **Read LAS points from disk:** Allows practically unlimited amounts of LAS data (tested beyond 1 Terabyte) to be loaded by reading the points directly from disk - either a local (internal or external) disk, or a network drive location. Changes made to the LAS files are automatically saved.

  ✓ **Fast TIN:** This option allows the user to improve the display performance of MARS® over small areas of data when panning and zooming with TIN rendering enabled. This tool will speed up the display performance of LiDAR data only and is intended for hand filtering purposes.

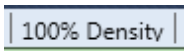
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Breaklines will NOT be respected while the 'Fast TIN' option is selected and it should NOT be used for ANY functions involving breaklines. The shortcut key combination for toggling Fast TIN is 'Ctrl-T.'

.

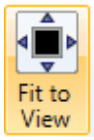


Lock to view 100%: This tool is intended for hand editing purposes and can be found on the View Tab[192]. The user should activate this tool while hand editing to be sure they are editing at 100% density of points. Note that in 3D View, the point density must be at (or locked to) 100% before the paint brush tools will be available. The percentage shown on the Status Bar[158] tells the user the percentage of points which are currently being displayed. This number will be locked at 100% regardless of window extent when the user activates the 'Lock to view 100%' tool.
Please see the screen shot below as an example. The screen shot below shows the user viewing point density at 100%:

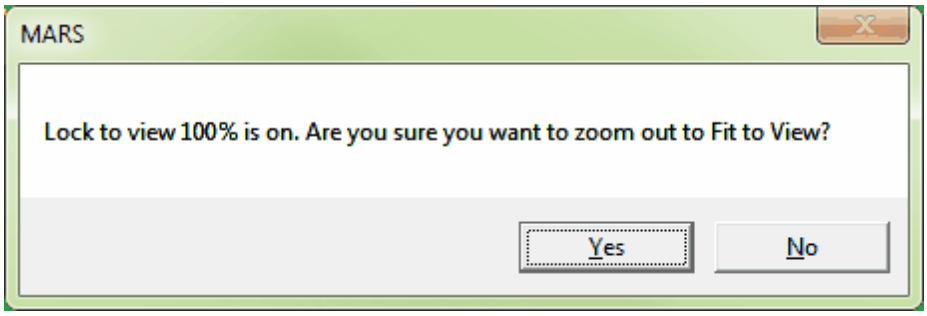


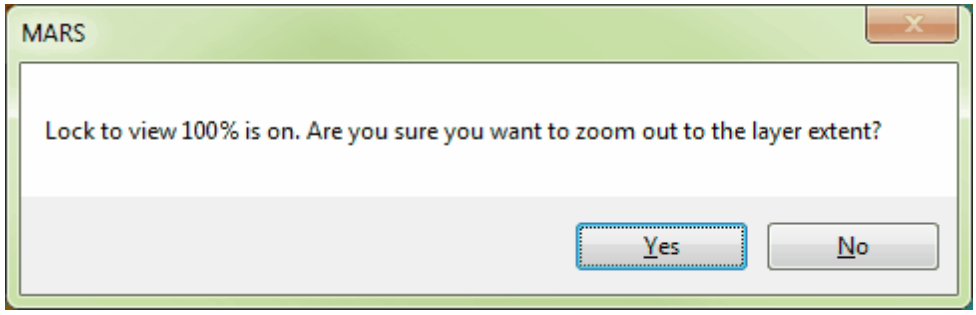
In 2D View, hand editing should ONLY be done when the user is viewing points at 100% density. It is easy for the editor to zoom in/out or lose/gain point density frequently throughout the hand editing process by navigating around the project, and this tool allows the editor to lock the point density of the display at 100%. To use this tool, zoom into the data to 100% density and then click on the 'Lock to

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view 100%' button. If the user attempts to zoom out to the full extent of the loaded data using the 'Fit to View' button 

, or to zoom to a layer in the Table of Contents while this tool is activated, confirmation prompts will appear as shown below.





If the user answers 'No' to either prompt, MARS® will return to the LAS Map View window at the current extent and the 'Lock to view 100%' tool will remain active. If 'Yes' is chosen, the user will be able to zoom out with the 'Lock to view 100%' tool still active, but display performance will be affected. Another purpose of the above prompt is to prevent a crash. MARS® will attempt to display whatever extent is requested at 100% density when either prompt is answered 'Yes', but this may lead to a program crash on less-powerful computers.

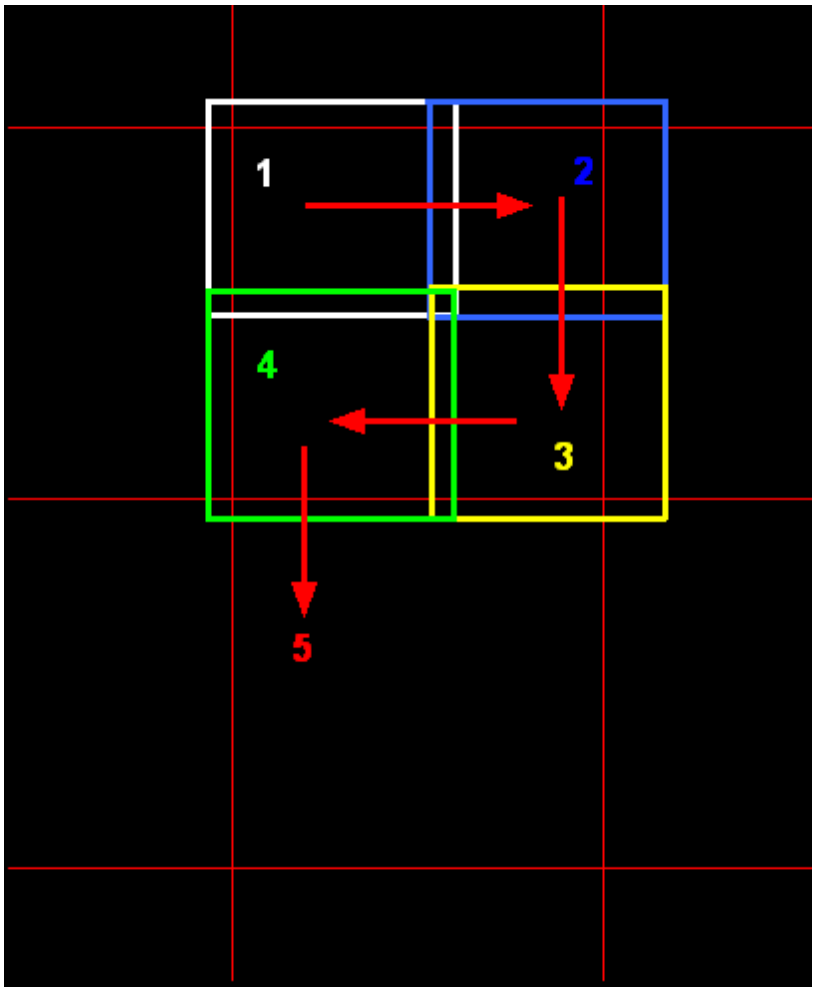
Systematic Editing:

A shapefile of the tile layout should be loaded to make sure that the editor is not 'wandering' in each tile. It is important to follow a systematic path across the LiDAR data when hand filtering to be

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thorough and efficient in finding and correcting errors.

Example: One good approach is scrolling and panning in MARS® using a strict series of four movements. The arrows describe the motion for moving around each tile. Each tile is edited in quadrants. Starting at the upper left (1), this example shows the editor moving to the upper right (2), then moving down to the lower right (3), and finally moving left to the lower left (4). Each color in the screen shot below denotes a separate movement over a tile to edit it. When the tile is completely edited, the editor will move down, restarting the process in the upper left corner of the tile below (5).



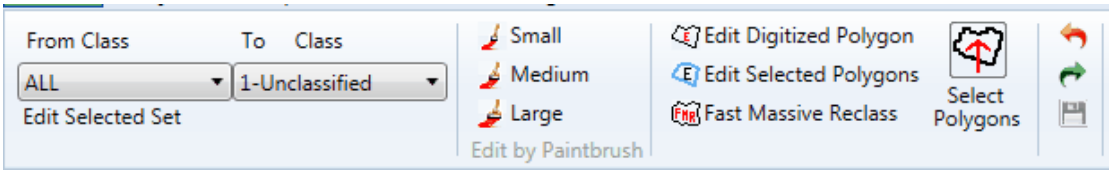
1.) Reclassification Tools

The Edit/Filter Tab 270, Cross-Section/Profile Window 146, and (optional) Cross-Section/Profile

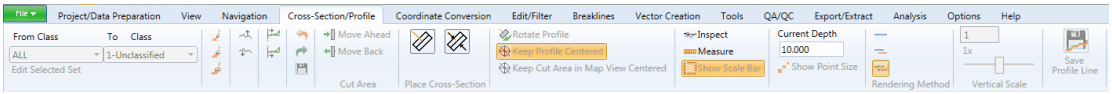
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window toolbar are the locations for manual reclassification tools. The purpose of each tool will be explained in this section of the tutorial.

Edit/Filter Tab manual editing tools:



Cross-Section/Profile tab manual editing tools:



Optional Cross-Section/Profile window edit toolbar:

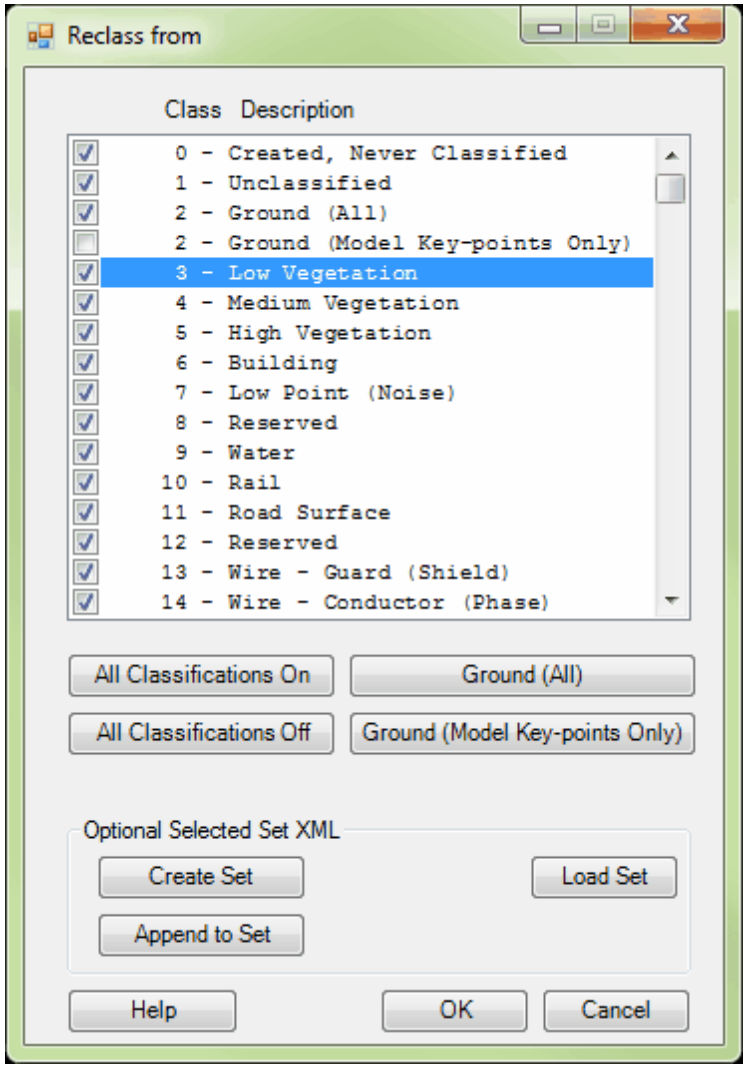


a) The **'From Class'** tool allows the user to specify which points, when selected, will be reclassified to a specified target classification. The user may choose '**ALL**', a pre-defined group of classes by choosing '**- Selected -**', or choose any one individual classification from the drop-down list provided. Choosing '**ALL**' or a single class by number (for example, 1 - Unclassified) does not affect the class choices that may have been made using the '**Edit Selected Set**' button.

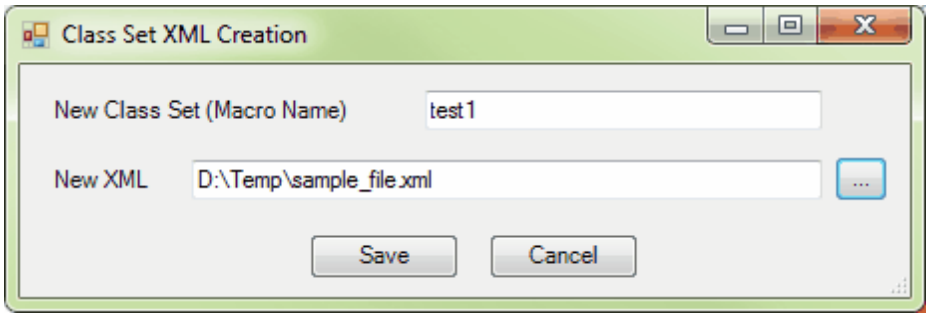
When clicking '**Edit Selected Set**', the '**Reclass from**' window that appears has options for saving and loading user-defined sets of classes for later use. To use these features: **1.** Pick the desired classes by checking/unchecking the boxes as appropriate. **2.** Click the '**Create Set**' button and enter a set name **(Macro Name)** and file name - use the browse button  to navigate to the output folder. Click '

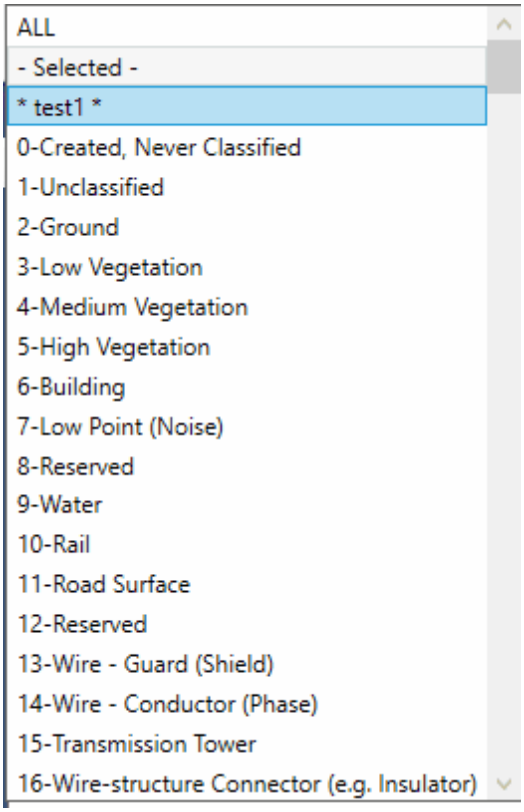
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Save' after making all entries. **3.** To use this set in either the current MARS® session or a later one, click the '**Load Set**' button and navigate to the saved XML file, then click '**OK**' on the '**Reclass from**' window. Click on the arrow at the right side of the '**From Class**' drop-down list and choose the set name created in step 2. It will be listed near the top between the '**- Selected -**' and '**0-Created, Never Classified**' entries. The class choices in the saved set are independent of any classes chosen using the '**Edit Selected Set**' button.



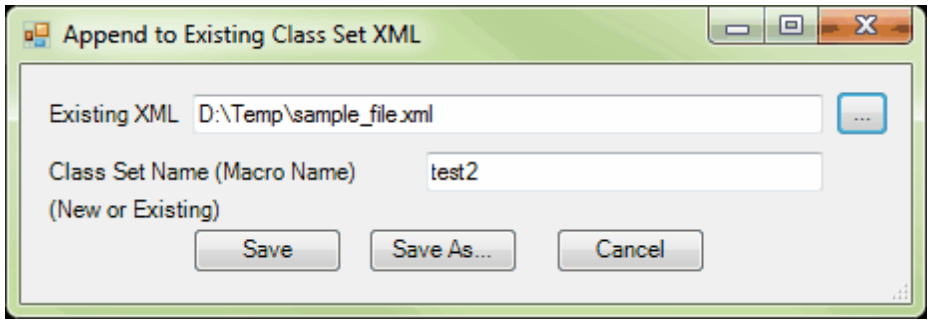
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4. To modify an existing XML file, click the 'Edit Selected Set' button on the Cross-Section/Profile ribbon or the toolbar, check the boxes for all the desired classes (not just the new ones) in the 'Reclass From' window, and click the '**Append to Set**' button. Navigate to an existing XML and enter a new or existing class set (macro) name - new if creating a different class set, or existing if updating a previously created one. Click '**Save**' to overwrite the existing XML file or '**Save As...**' to create a new XML file. To use the newly modified set of classes follow step 3, above.

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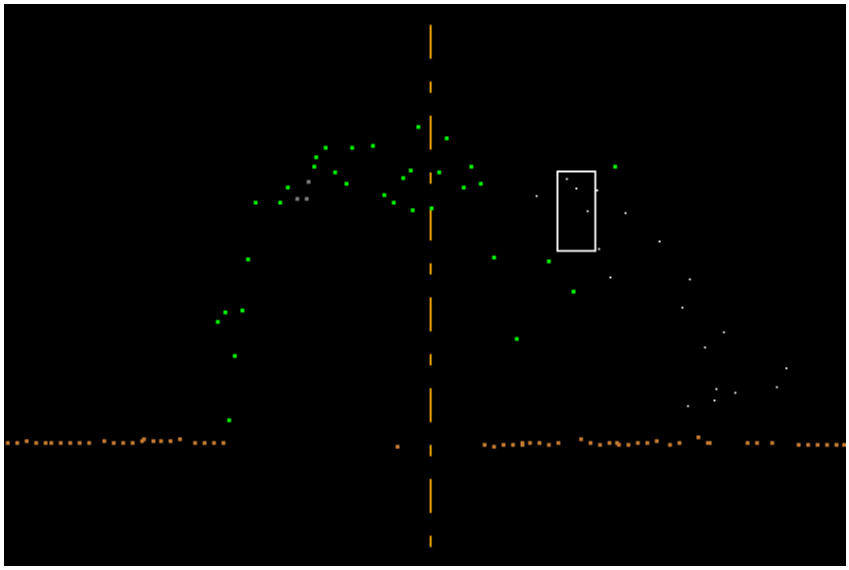
b) The **'To Class'** tool allows the user to specify which classification the selected points will be reclassified to. The user may choose any one individual classification from the drop-down list provided.

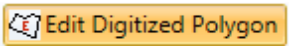
c) **Paint Brush** tools allow the user to select visible points using three different sized brush strokes: small  , medium  , and large  . Points may be edited in 2D or 3D view in the LAS Map View window, or in the Cross-Section/Profile window. Points are selected by clicking or dragging the cursor box over them. To make edits in 3D the user must be either zoomed in to 100% point density or have the 'Lock to view 100%' button toggled on - the paint brush buttons will not be available otherwise. Once points have been selected using a brush, they will be immediately reclassed and saved while in 2D View, based on the settings of the **'From Class'** and **'To Class'** drop-downs. In the Cross-Section/Profile window, they can be reclassed after selection by one of two methods: by setting the From classification and the To classifications to the proper settings and tapping the *space bar* (or *Enter key*) once the points are selected, or by selecting the class number from the *keypad* while the points are selected. The default setting in MARS® is to allow reclassification based only on the first digit which limits the re-classification options to classes 0-9. To reclass using a two or three digit class number, please see the Options Tab 519

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section concerning the Miscellaneous Options button.

In the screen shot below, the large paint brush has selected the above-ground points to the right of the tool. Selected points appear smaller and in white.

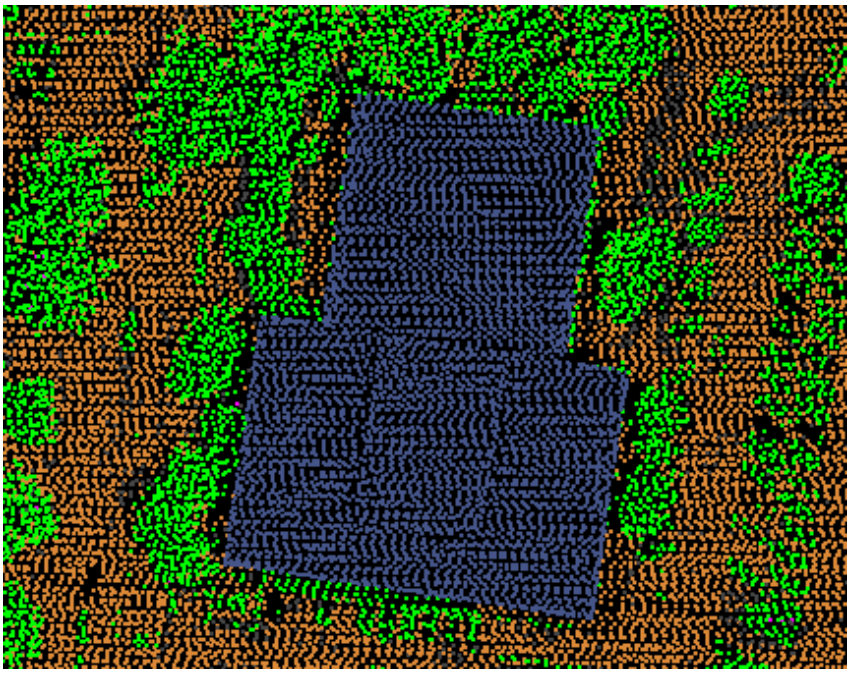


d) The **Edit Digitized Polygon** tool 

is used to reclass visible points within a custom shaped polygonal area that the user defines. *This tool will only work in the LAS Map View window in 2D View mode!* To create a polygon to use for reclassification, click on the 'Edit Digitized Polygon' button and draw a polygon in the LAS Map View window by left-clicking for each vertex. Then right-click the mouse to finish the polygon and re-class the points inside, based on the settings of the 'From Class' and 'To Class' drop-downs.

In the example below, the user has classified a building using the Edit Digitize Polygon tool. These points have been classified as Class 6: Building.

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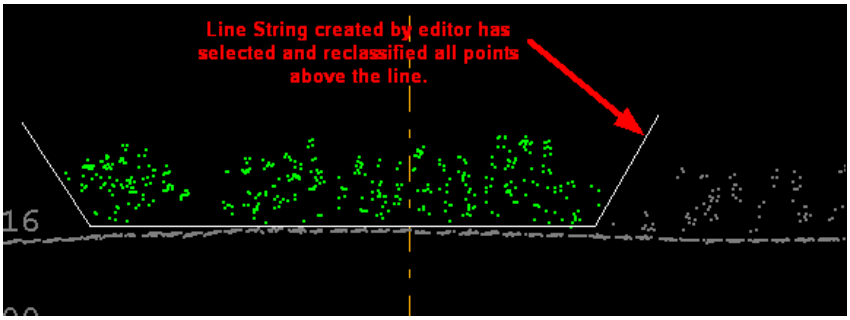
e) The **Edit Selected Polygons** tool 

is functional if the user has a pre-existing polygon shapefile (*.shp) loaded as a Reference Shapefile, and has selected one or more polygons using the 'Select Polygons' button. Visible points within any selected polygons will be reclassed, based on the settings of the 'From Class' and 'To Class' drop-downs. *This tool will only work in the LAS Map View window in 2D View mode!* An example use of this tool would be to reclass points at known building locations.

f) The **Edit Line String Above** tool  is a user-placed edit line which will reclassify all the visible points which fall above that line. *This tool can ONLY be used in the Cross-Section/Profile window.* Once the proper points are selected, they can be reclassed by using either the *space bar* (or *Enter key*), or by typing the number of the desired target class into the *keypad*.

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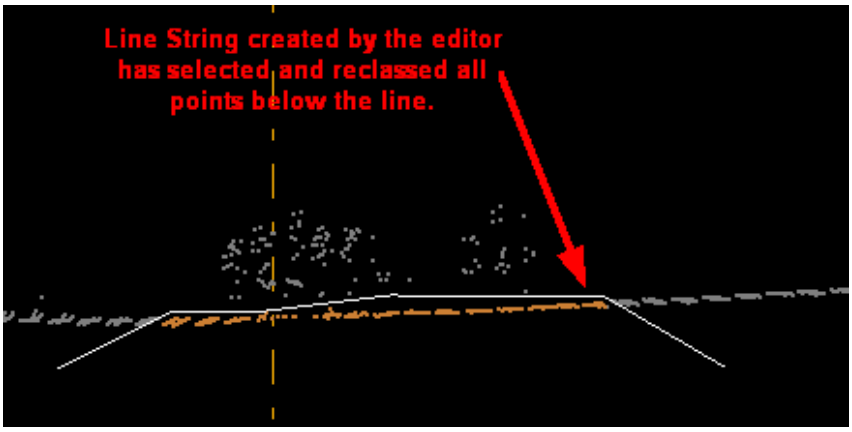
In the example below, the editor has specified (using the source and target classification drop-downs) that ALL selected points will be reclassified to Class 5: High Vegetation points. The editor has drawn an edit line, and all visible points above this line have been successfully reclassed.



g) The **Edit Line String Below** tool is a user-placed edit line which will reclassify all the visible points which fall below that line. *This tool can ONLY be used in the Cross-Section/Profile window.* Once the proper points are selected, they can be reclassed by using either the *space bar* (or *Enter key*), or by typing the number of the desired target class into the *keypad*.

In the example below, the editor has specified (using the source and target classification drop-downs) that ALL selected points will be reclassified to Class 2: Ground points. The editor has drawn an edit line, and all visible points below this line have been successfully reclassed.

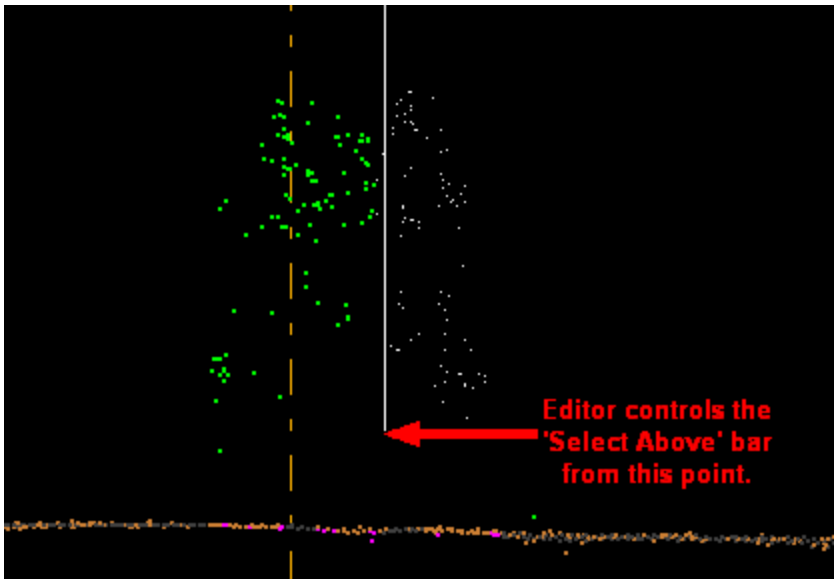
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h) The **Edit Scrape Above** tool  is similar to the 'Edit Line String Above' tool, but works with a different method of selecting points. *This tool can ONLY be used in the Cross-Section/Profile window.* Rather than selecting points above a horizontally drawn line, this tool appears as a vertical line that selects visible points as it is dragged over them. Once the proper points are selected, they can be reclassed by using either the *space bar* (or *Enter key*), or by typing the number of the desired target class into the *keypad*.

In the example below, the 'Edit Scrape Above' tool has been dragged over a section of points and has selected everything which lies above the start point of the tool.

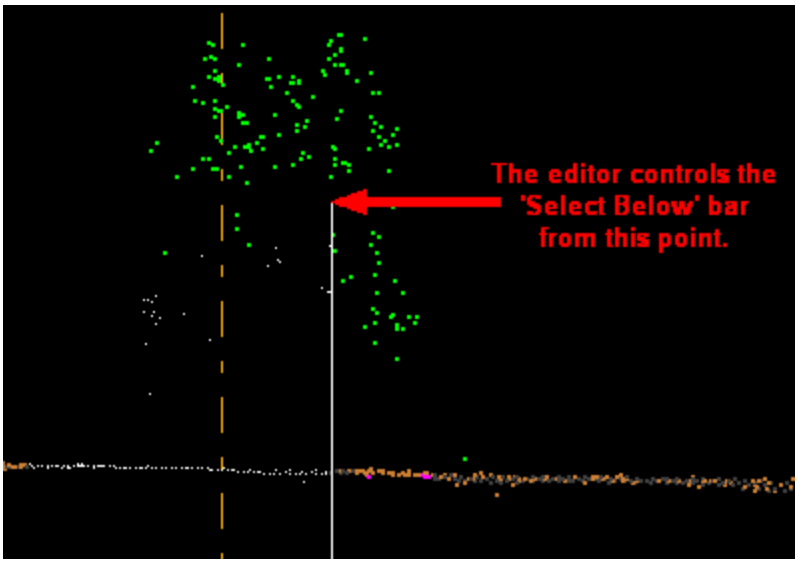
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i) The **Edit Scrape Below** tool  is similar to the 'Edit Line String Below' tool, but works with a different method of selecting points. *This tool can ONLY be used in the Cross-Section/Profile window.* Rather than selecting points below a horizontally drawn line, this tool appears as a vertical line that selects visible points as it is dragged over them. Once the proper points are selected, they can be reclassed by using either the *space bar* (or *Enter key*), or by typing the number of the desired target class into the *keypad*.

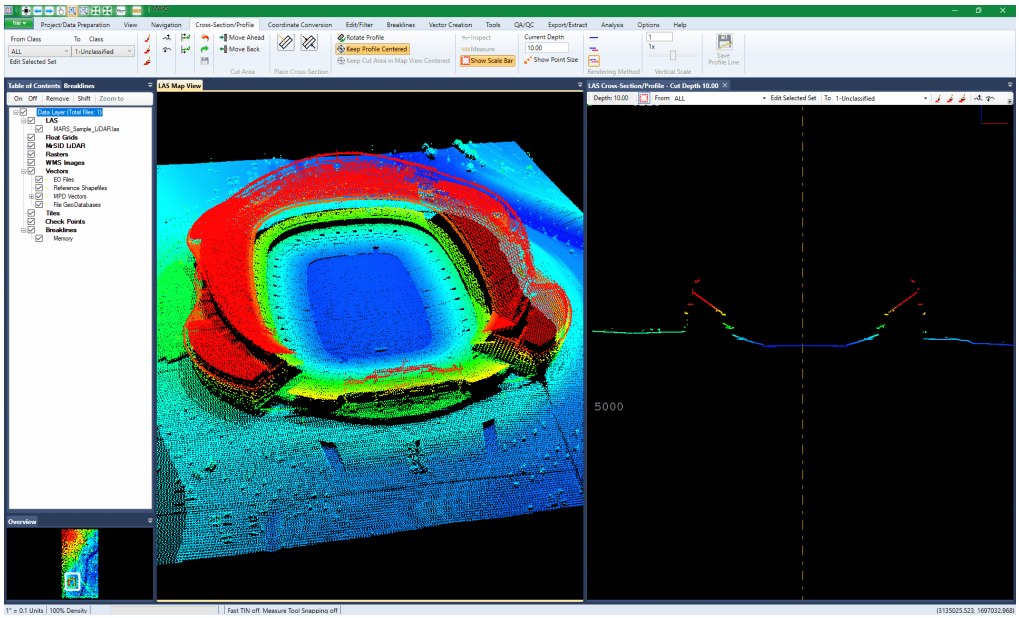
In the example below, the 'Edit Scrape Below' tool has been dragged over a section of points and has selected everything which lies below the start point of the tool.

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2) View and Color by (buttons for these next seven methods can be found on the View Tab 192):

a) **Elevation (color cycles):** Viewing the LiDAR data by elevation. For more information, please see the section on Elevation 878.



Elevation color cycles can also be adjusted. If a hand editor wanted to get a better

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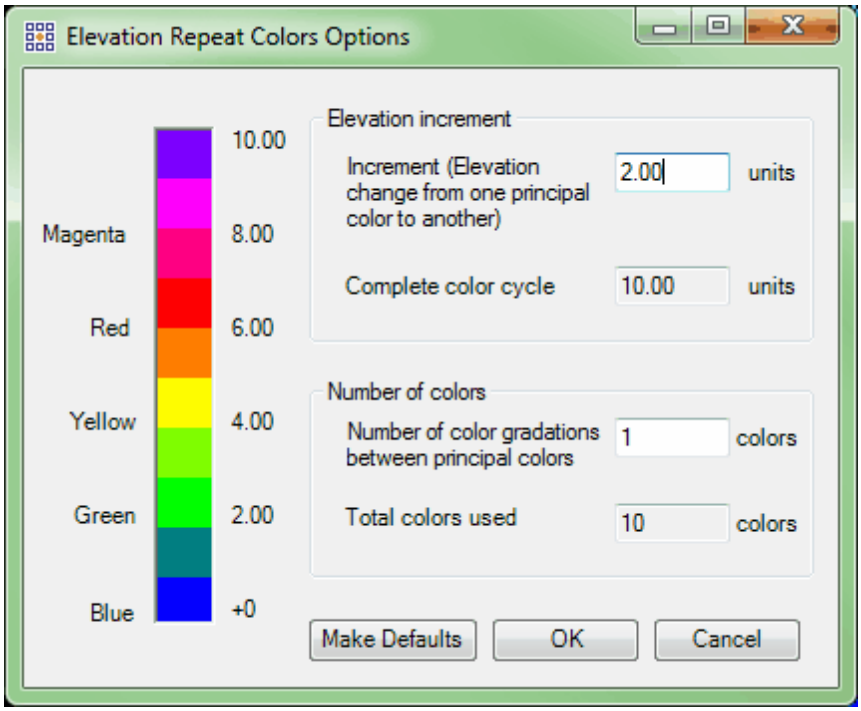
understanding of the elevation changes in an area, the color cycle per unit interval could be changed to help show elevation changes which may interest an editor.

The amount of elevation gain between color changes controls the accuracy with which the hand editor can see changes. The more accuracy that is necessary, the narrower the elevation gain between color changes should be. A final product with a 1-foot contour needs smaller-increment color 'cycling' than a 2-foot contour.

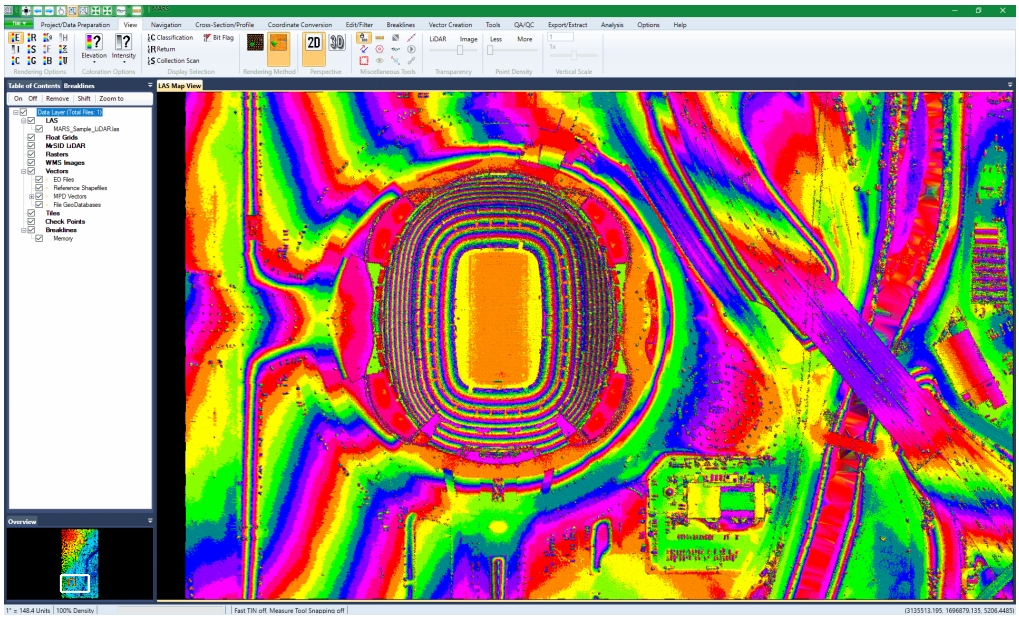
Sudden changes in color tell the hand editor where there may be surface anomalies. With larger elevation gains per color, fewer sudden color changes occur and less hand editing will take place. Controlling the amount of viewable surface errors by 'cycling' colors at different rates affects the accuracy and time necessary to hand-edit a project.

To bring up the color cycle options window, press **'Z'** on the keyboard, or click the **'Coloration Options | Elevation'** button on the View Tab 192 and choose the **'Repeat'** option.

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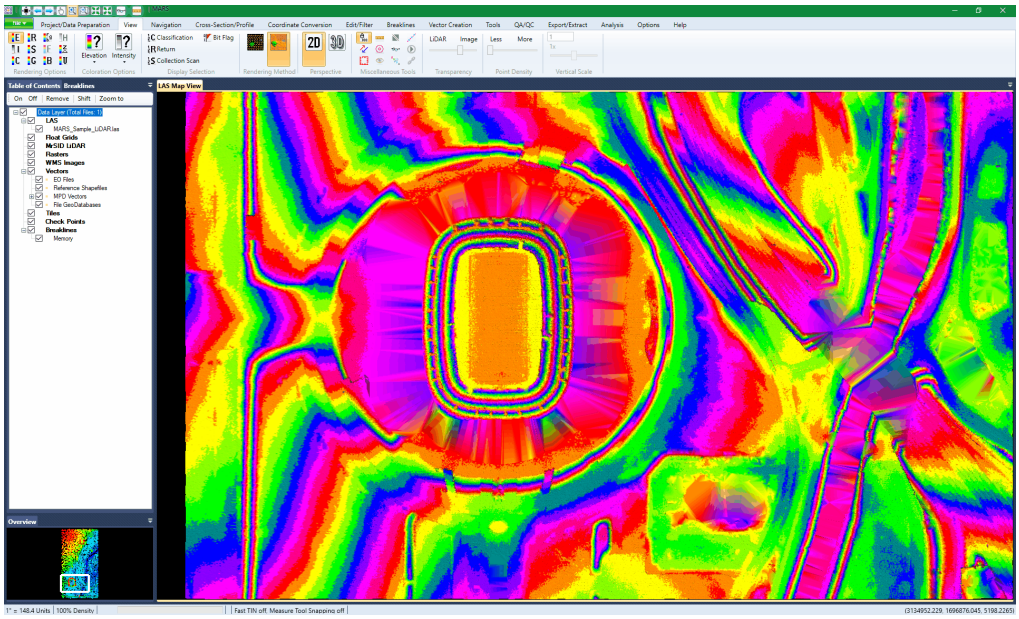
Example: The colors in this image are changing once every 2 feet. The color 'cycle' is 10 feet. The image is very 'busy' because all data classifications are on.



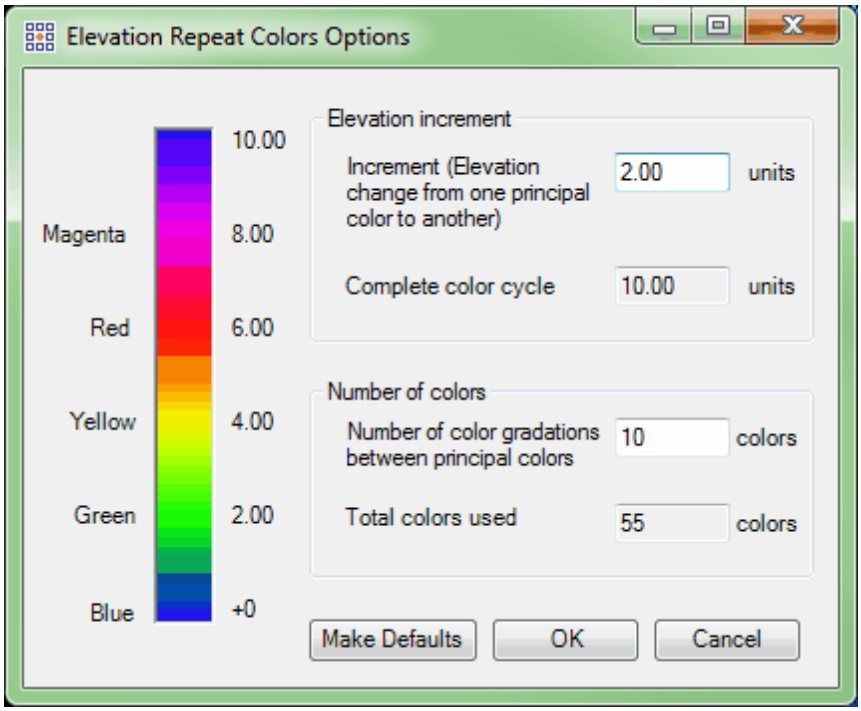
Example: The colors in this image are changing once every 2 feet as in the example before. The color 'cycle' is still 10 feet. All of the classifications have been turned off,

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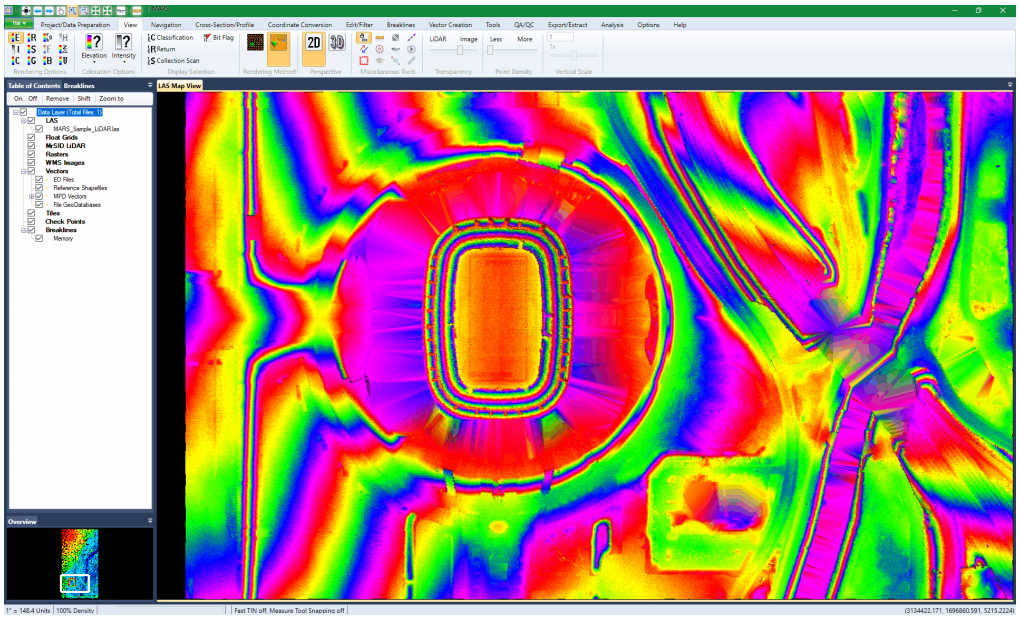
except for Class 2 - Ground (final ground surface classification).



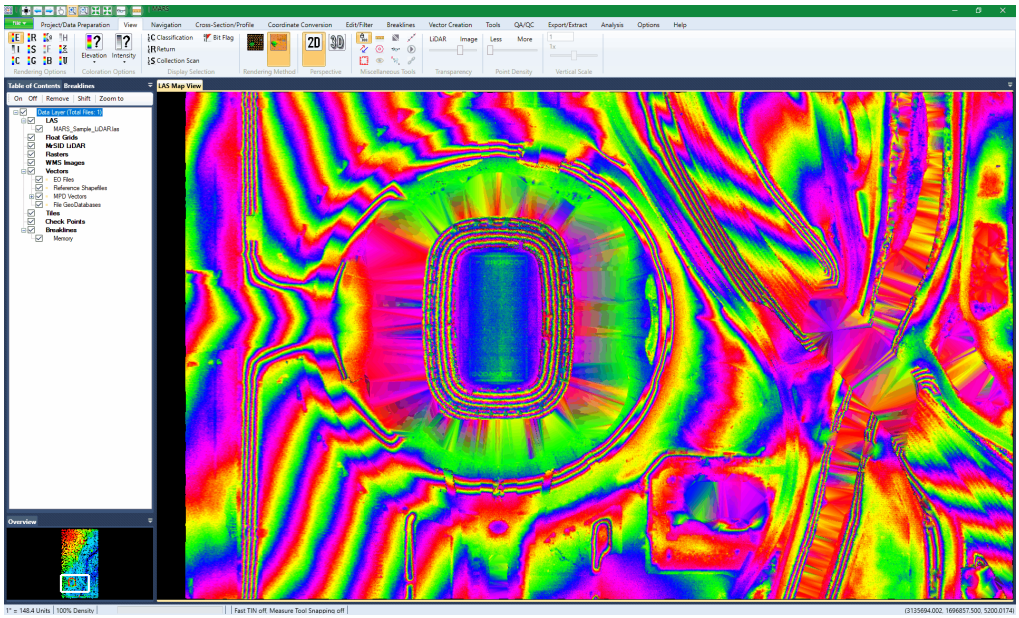
Example: The colors have been modified to smooth the abrupt changes between elevations. This is controlled by the 'Number of Color Gradation' option. In this case, the 'Number of Color Gradations' has been changed from 1 to 10.



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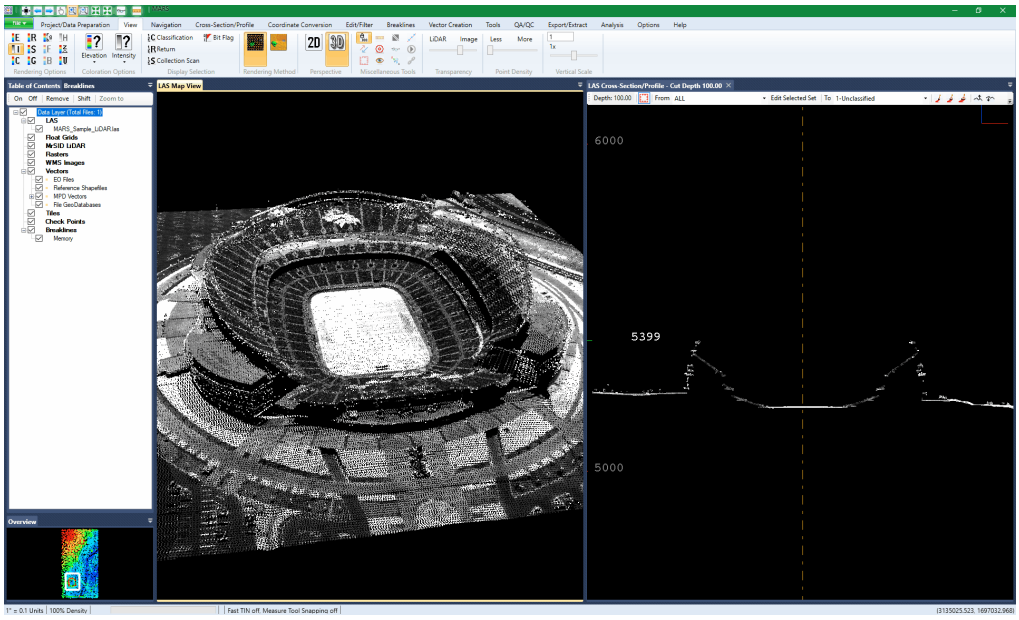


Example: If the color 'cycle' elevation increment is decreased from 2 feet to 1 foot the amount of sudden color changes that may need to be checked by the hand editor starts to increase.

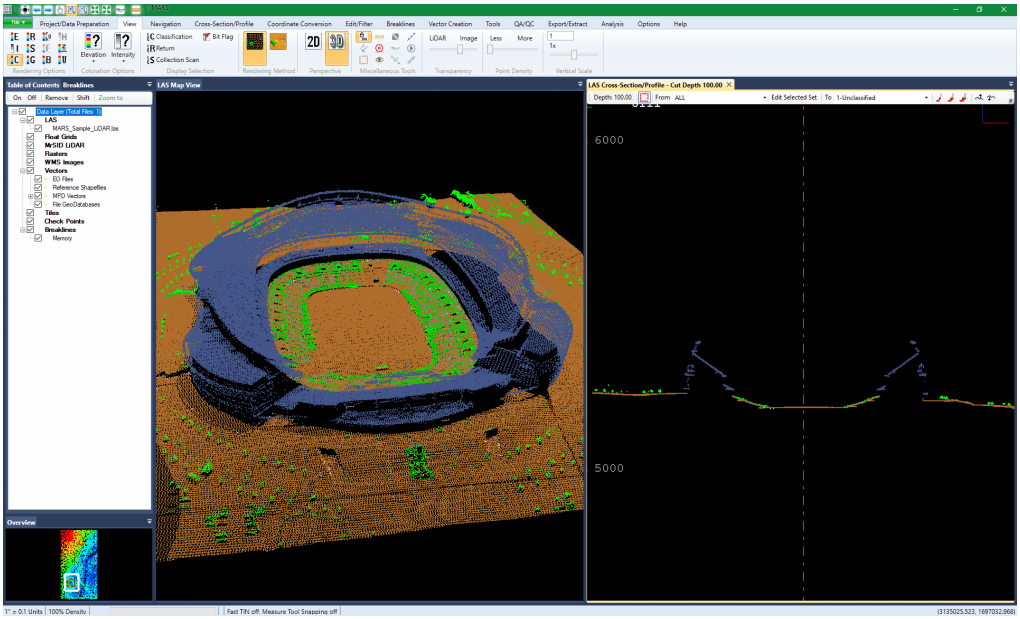


b) **Intensity:** Viewing the LiDAR data by its intensity values (ranging from 0-65535). For more information, please see the section on Intensity 888.

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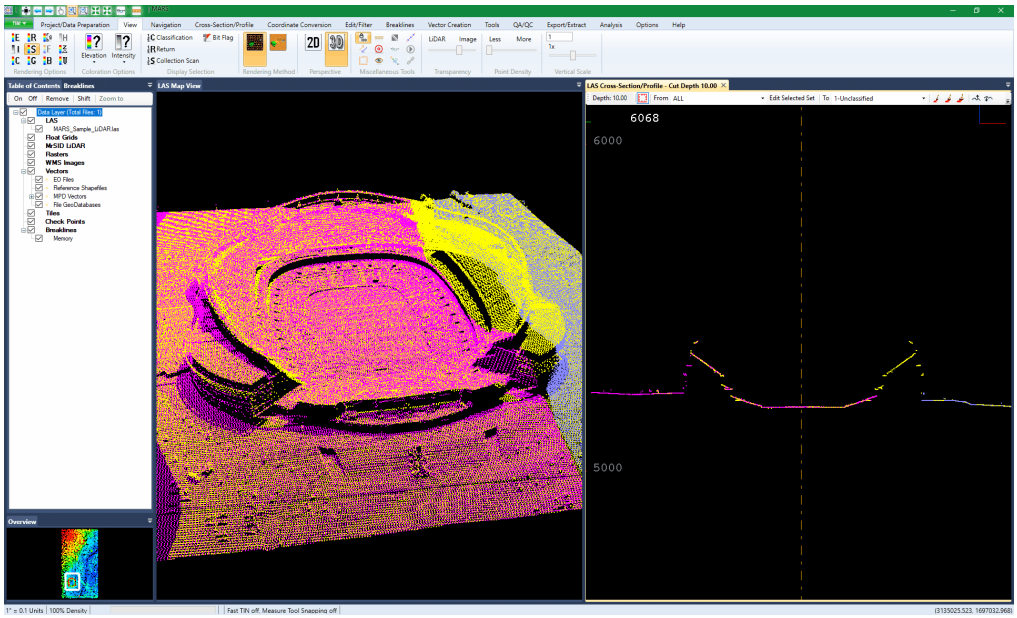


c) **Classification:** Viewing the LiDAR data by its classification. For more information, please see the section on Classification[846].

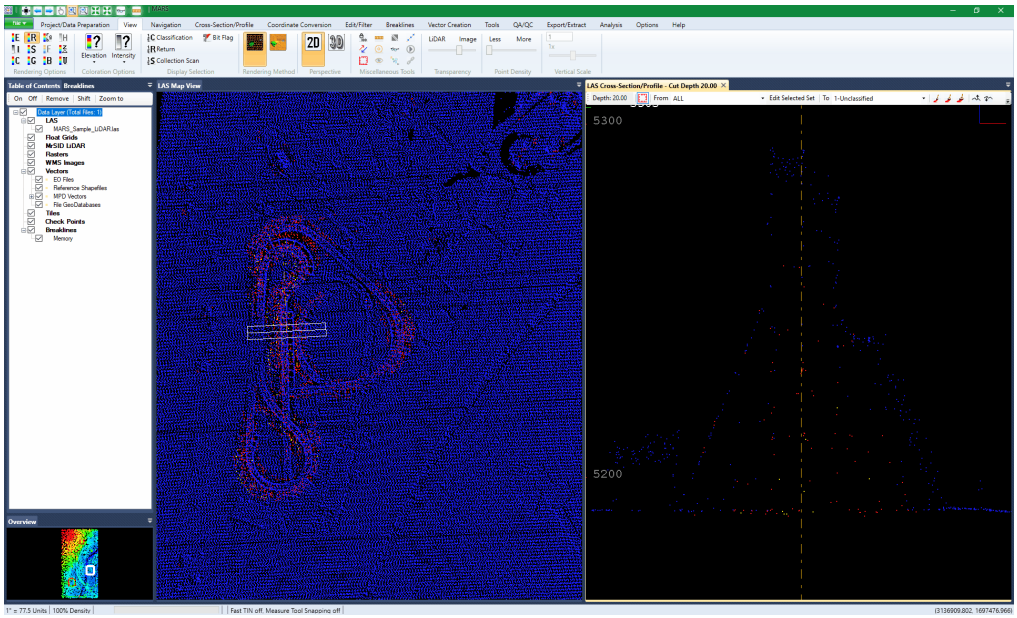


d) **Collection Scan:** Viewing the LiDAR data by collection scan. There are three separate collection scans in this image: magenta, yellow, and blue. For more information, please see the section on Collection Scan[850] data.

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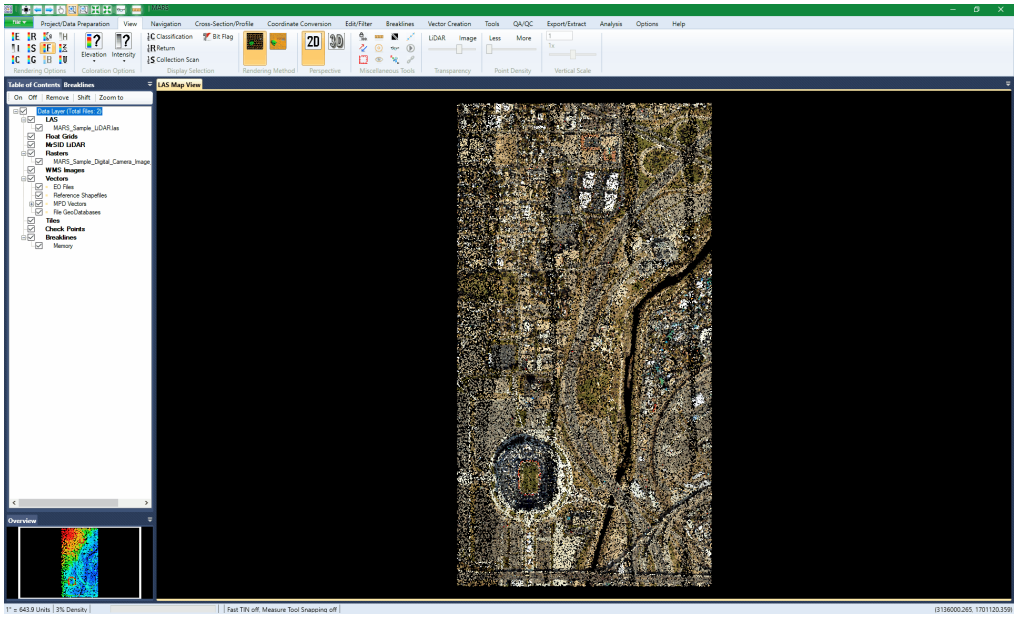
e) **Return:** Viewing the LiDAR data by return value. The returns are colored dark blue to indicate single return, red to indicate the 2nd of 2 returns, yellow to indicate the 3rd of 3 returns, and green to indicate the 4th of 4 returns. For more information, please see the Return 862 section.



f) **Fusion:** Displays the LiDAR data fused with the RGB imagery values. This tool only

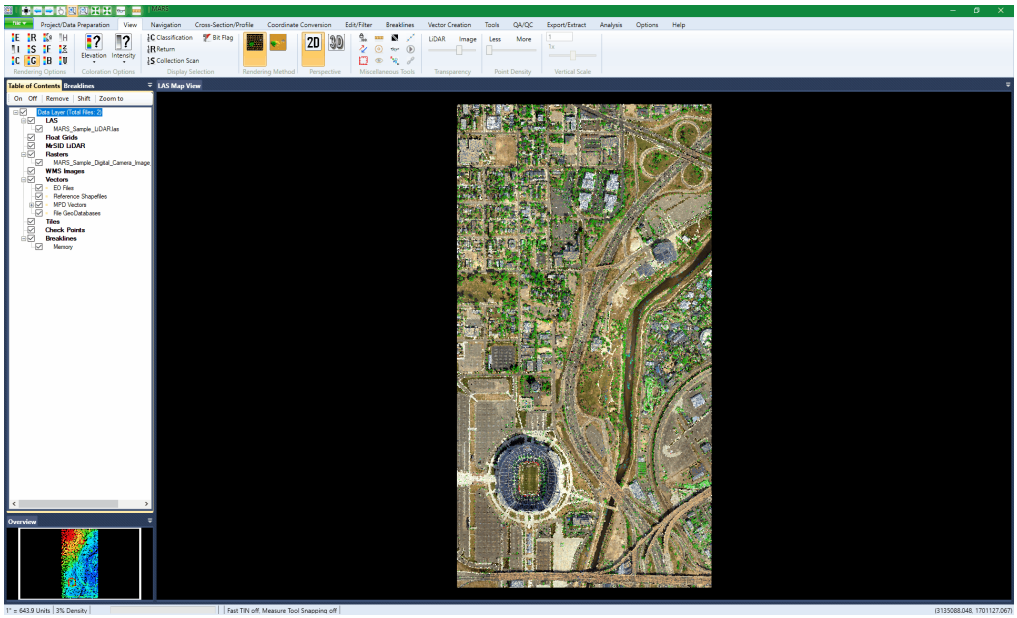
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works in the LAS Map View window and will not function in the Cross-Section/Profile window. For more information, please see the Fusion 853 section.

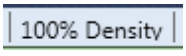


g) **Ground Color:** Displays the user-specified ground class(es) using the RGB values of loaded imagery - all other points are rendered by their classification values. This tool only works in the LAS Map View window and will not function in the Cross-Section/Profile window. For more information, please see the Ground Color 856 section.

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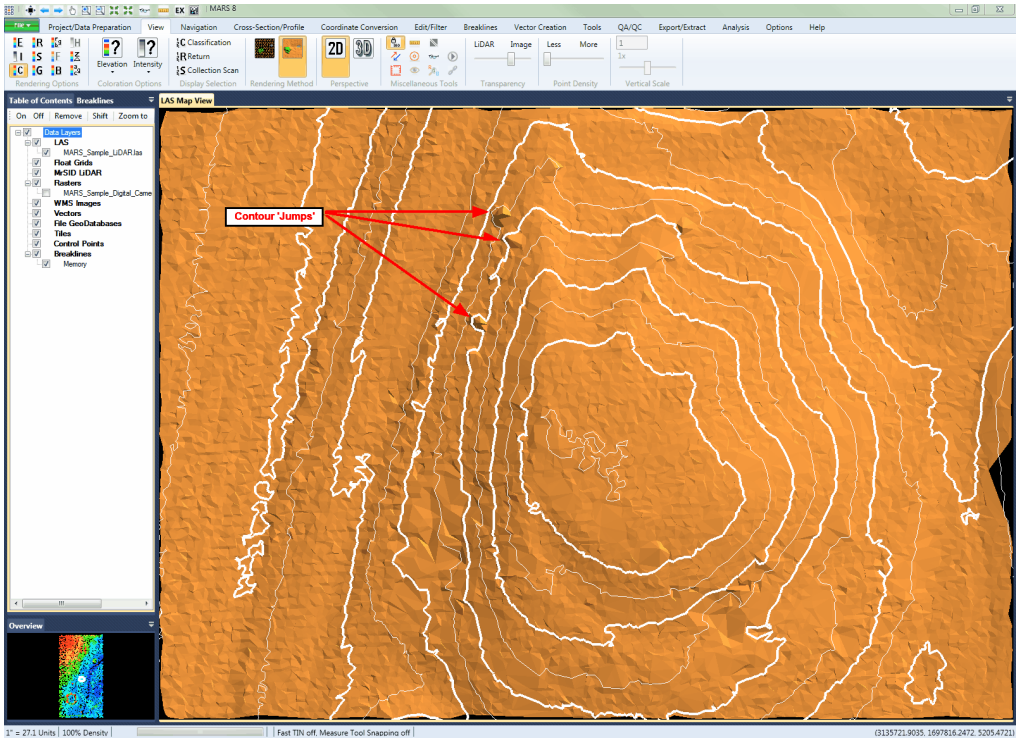
3) **Creating Contours on the fly:** Contours are generated virtually inside the LiDAR data 'on the fly', meaning that contours are only generated within the LAS Map View window extent and not for the project as a whole. The virtual contour buttons can be found on the Analysis Tab 489. Contours can only be created if the user is zoomed in far enough to show 100% of the LiDAR points, or has enabled the 'Lock to view 100%' button  on the View Tab 192. To see the density percentage, check the left side of the Status Bar 158.



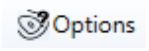
Contours help to support the placement of breaklines as well as helping an editor more accurately reclassify data during hand filtering. Most importantly, contours can help find 'contour jumps'. These jumps are typically found in places where surface anomalies are found and usually need manual reclassification to fix an auto-filter error. To learn more about virtual contours and the MARS® tools associated with them, please see the previous tutorial on Viewing and Generating Contours 1806.

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Example: 2-foot contours are drawn on a 'Ground' (Class 2) TIN. Notice the contours 'jumping' at the red arrows. The contour jumps are caused by misclassified data.

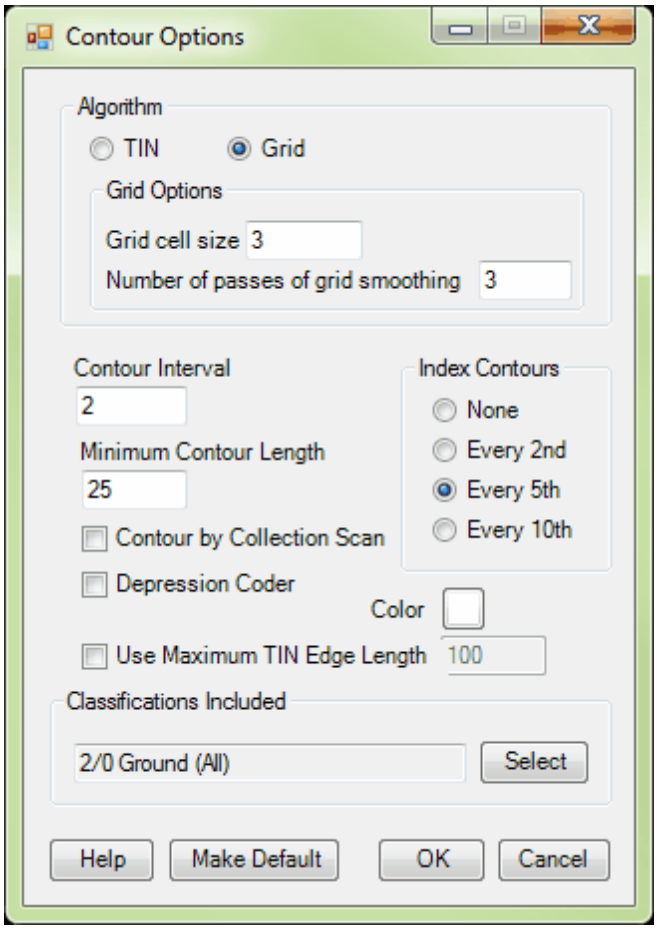


MARS® can contour at different contour intervals and on any classifications. *(Note: It is not recommended to show contours when displaying large amounts of data, as contours are created 'on the fly' and rendering of a large area of contours may slow down navigation.)*

Example: The Contour Options interface. Bring this up by clicking the **'Options'** 

button.

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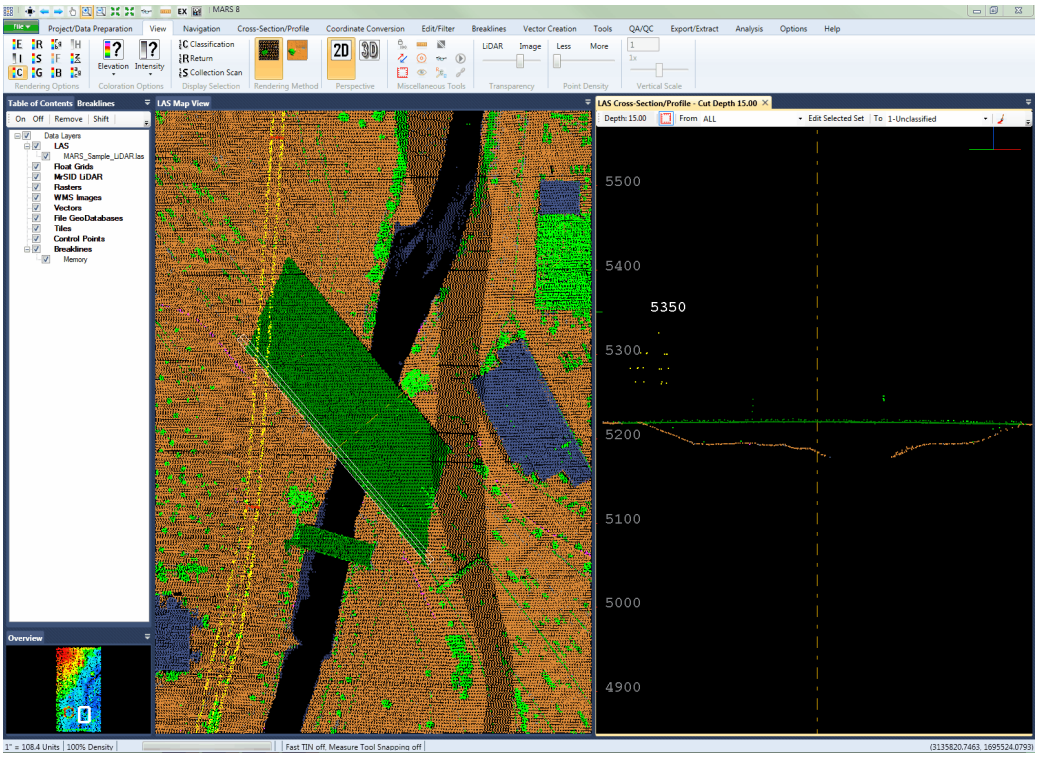


4) **2D and 3D Views:** Typical manual editing is done in 2D View[835] in the LAS Map View window, and/or in the Cross-Section/Profile window. Occasionally, it is useful to look at the point data in 3D View[837] to get another perspective in the particular location that is being edited. These two perspective buttons can be found on the View Tab[192]. LiDAR points can be viewed in 3D from the LAS Map View window. *Visible points may be edited while in 3D mode, and the Undo and Redo buttons on the Edit/Filter Tab[270] function in 3D editing.* Most editing should be completed in 2D mode, but if the editor is having difficulty understanding where the ground surface is, 3D mode can be a useful tool that allows the viewer to 'fly' around the data and reclass or edit specific points. **Note that the data must be viewed at (or locked to) 100% point density before the paint brush tools will be available for 3D editing.** 100% point density is highly recommended for

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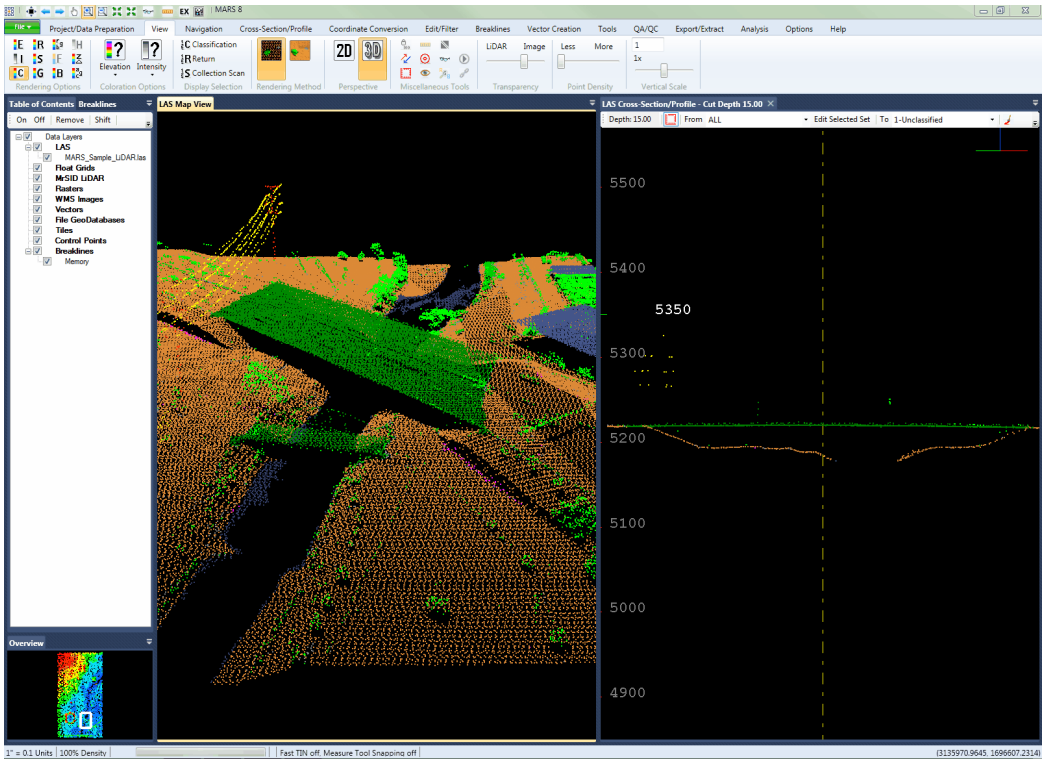
editing in 2D mode - if all points are not shown the user may possibly edit data which is not visible at a lesser density.

a) Example: What is ground and what is canopy? From the top view (2D in the LAS Map View window) it may be difficult to determine, but with the cross-section/profiling tool it is easy to see that the canopy (dark green) points in the center of the LAS Map View window represent a bridge.

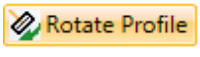


b) Example: What is ground and what is canopy? A quick 3D rotation in the LAS Map View window gives the editor better understanding of where the bridges are.

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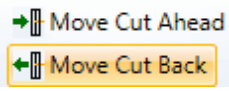


5) **View by Cross-Section/Profile View:** The cross-section/profile window is useful for helping to analyze the point data and reclassify it only where it is needed. MARS® has two cross-section/profiling tools.

a) The **'Place Cross-Section Line'** tool  is a 2-point tool where the first mouse click defines the start of the cross-section/profile line and the second click determines the length of the line. This tool is set at a fixed default depth for more rapid cuts. The length and depth of the cross-section/profile is represented by three white lines with a perpendicular dashed orange line showing which way the cross-section/profile view window is facing. The user can rotate the cut area by selecting the left or right directional arrow on the keyboard, or by rolling the mouse wheel in either direction. There is also a **'Rotate Profile'** tool 

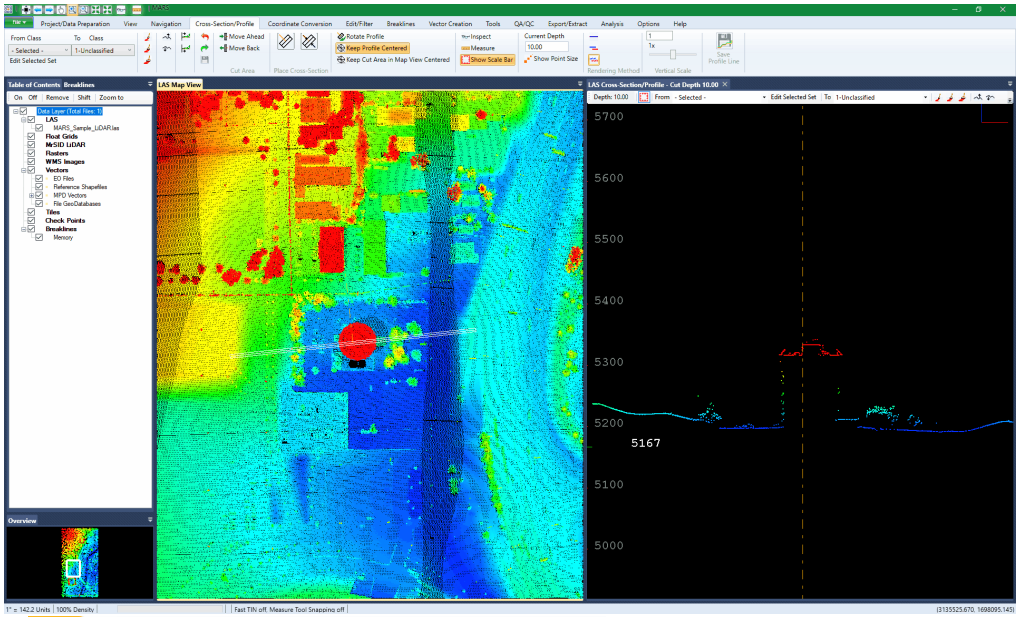
on the Cross-Section/Profile Tab 240 that allows a specific number of degrees of rotation to be

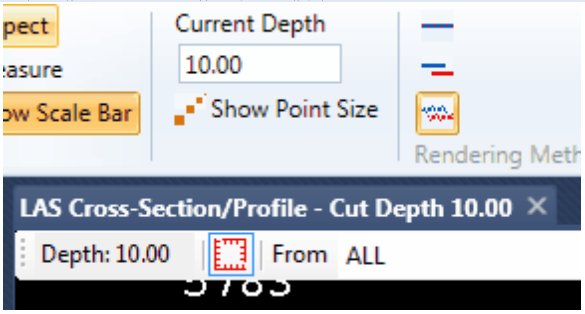
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entered (positive or negative) with respect to the current position. The cut area can be moved by selecting the up (ahead) or down (back) arrow on the keyboard, or by using the **'Move Cut Ahead/Back'** buttons 

on the Cross-Section/Profile tab. More details on navigating in the Cross-Section/Profile window are available in the Cross-Section/Profile 816 topic.

In the example below, the cross-section/profile window is showing a cut area depth of 10 units. Note the density of the points in the cross-section/profile (right) window.

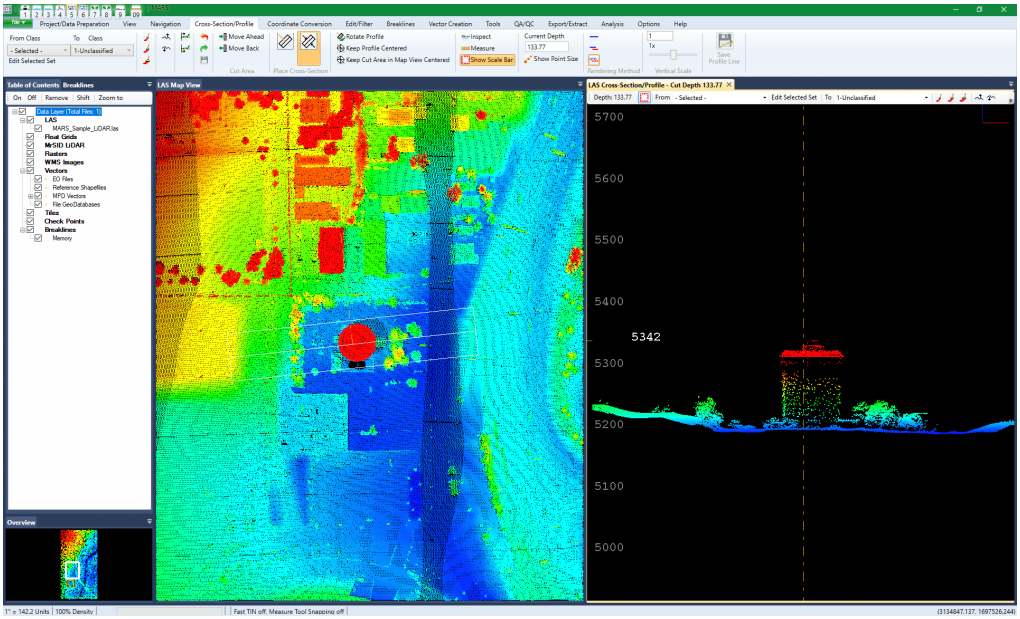


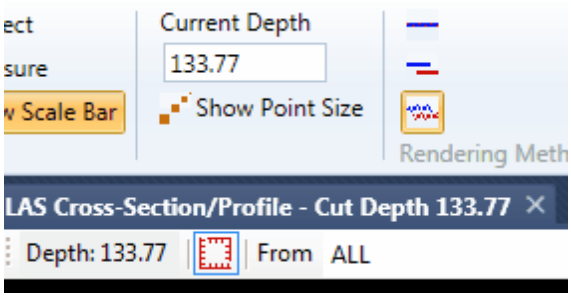


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b) The **'Place Adjustable Cross-Section Line'** tool  is a 3-point tool where the first mouse click defines the start of the cross-section/profile line, the second click determines the length of the line, and the third click specifies the depth of the cut area. The cut area is represented with the same symbology as in the **'Place Cross-Section/Profile Line'** tool. Navigation is handled the same way as well.

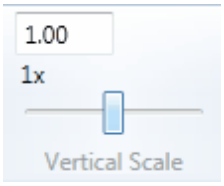
In the example below, the cross-section/profile window is showing a cut area depth of 133.77 units. Note the increased density of the points in the cross-section/profile (right) window.





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c) **Cross-Section/Profile Tab**[240]**:** When either of the above tools are selected, the Cross-Section/Profile window opens and the tools become active. The majority of tools on this tab are specifically designed for use ONLY inside the Cross-Section/Profile window. To learn more about the functions of the tools on this tab, please view the Cross-Section/Profile Tab[240] section of this help document.

d) The **Vertical Scale Slider** tool 

on the Cross-Section/Profile tab allows the user to exaggerate the vertical display (with respect to horizontal) of the points in view. (The similar-functioning vertical scale slider on the View Tab[192] can be used in the LAS Map View window in 3D View[837].) This can be used to find a more exact/refined point selection with the various editing tools. Slide the bar to adjust the scale or type the scale into the scale text box above the **'1x'** button. The minimum value is 0.01 and the maximum is 100. The vertical scale slider can be reset to the normal 1:1 (vertical to horizontal) ratio by selecting the **'1x'** button. This slider is synchronized with the vertical scale slider on the optional Cross-Section/Profile Window[146] toolbar.

6.) The **Inspect**  tool (2D view or Cross-Section/Profile view) can be helpful when editing. This tool can be found on the View Tab[192], the Cross-Section/Profile Tab[240], the Analysis Tab[489], or the Quick Access Toolbar[65]. After selecting the tool, click on a LiDAR point for which more information is needed. The chosen point will flash twice and then remain highlighted in white at a larger symbol size to identify itself. The information provided by this tool includes: parent file path and point source ID (PSID), X coordinate, Y coordinate, Z coordinate, timestamp, intensity value, data classification, bit

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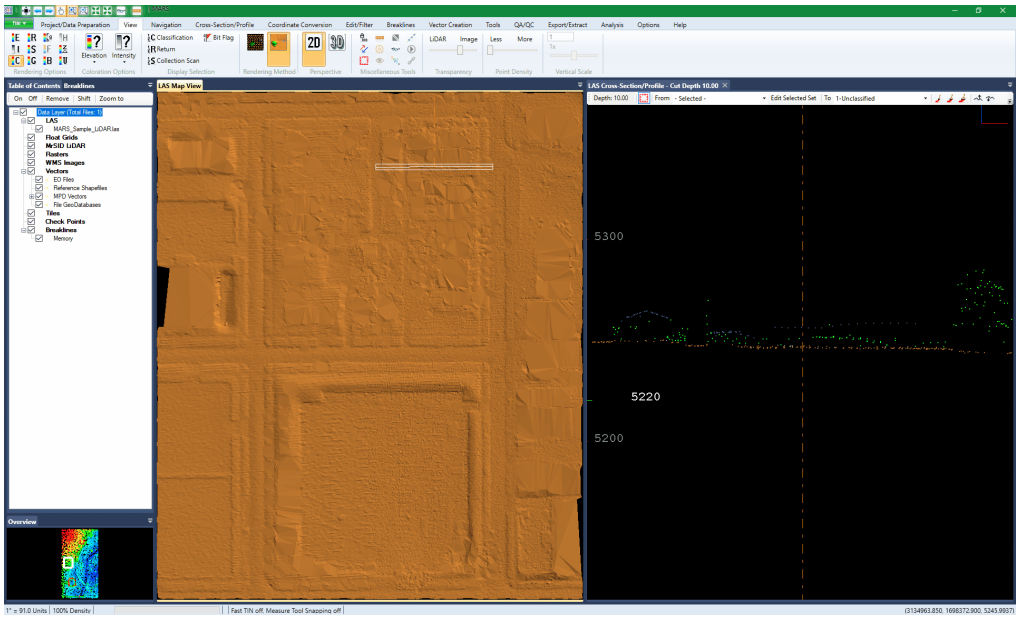
flag status, return number, file position, user data (often AGC values), scan angle and scan angle rank (from nadir), scan direction flag, edge of collection scan, scanner channel flag, and red/green/blue and (optionally) infrared color values if present. The **'Inspect'** tool also works in the Cross-Section/Profile window, on virtual contour lines, check points, and reference shapefile features including breaklines. When the **'Inspect'** tool is enabled, hold down **'Ctrl'** on the keyboard and click on any virtual contour or shapefile feature. A properties window will appear displaying the details of the feature selected. It is possible to copy information from the properties window. Note that for LiDAR data, some fields are dependent on the data collected, the post-processing software used, and the LAS version and PDRF. To dismiss the **'Inspect'** tool, right-click the mouse.

7.) Viewing Specific Classifications: When editing, it is sometimes helpful to view only certain classifications and minimize the 'clutter' of points to only those needed for easier viewing. Classifications can be turned on and off individually. When using the Cross-Section/Profile window, the classifications selections in the LAS Map View window and the Cross-Section/Profile window are independent of each other. For example. the user can view all of the data classifications in the Cross-Section/Profile window and only the 'Ground' (Class 2) in the LAS Map View window. A selection interface will allow the user to modify each view individually.

Example: Only the ground classification is displayed and TINned in the left (LAS map) view. In the right (cross-section/profile) window, the data is shown in point mode with building, canopy, and ground visible.

-

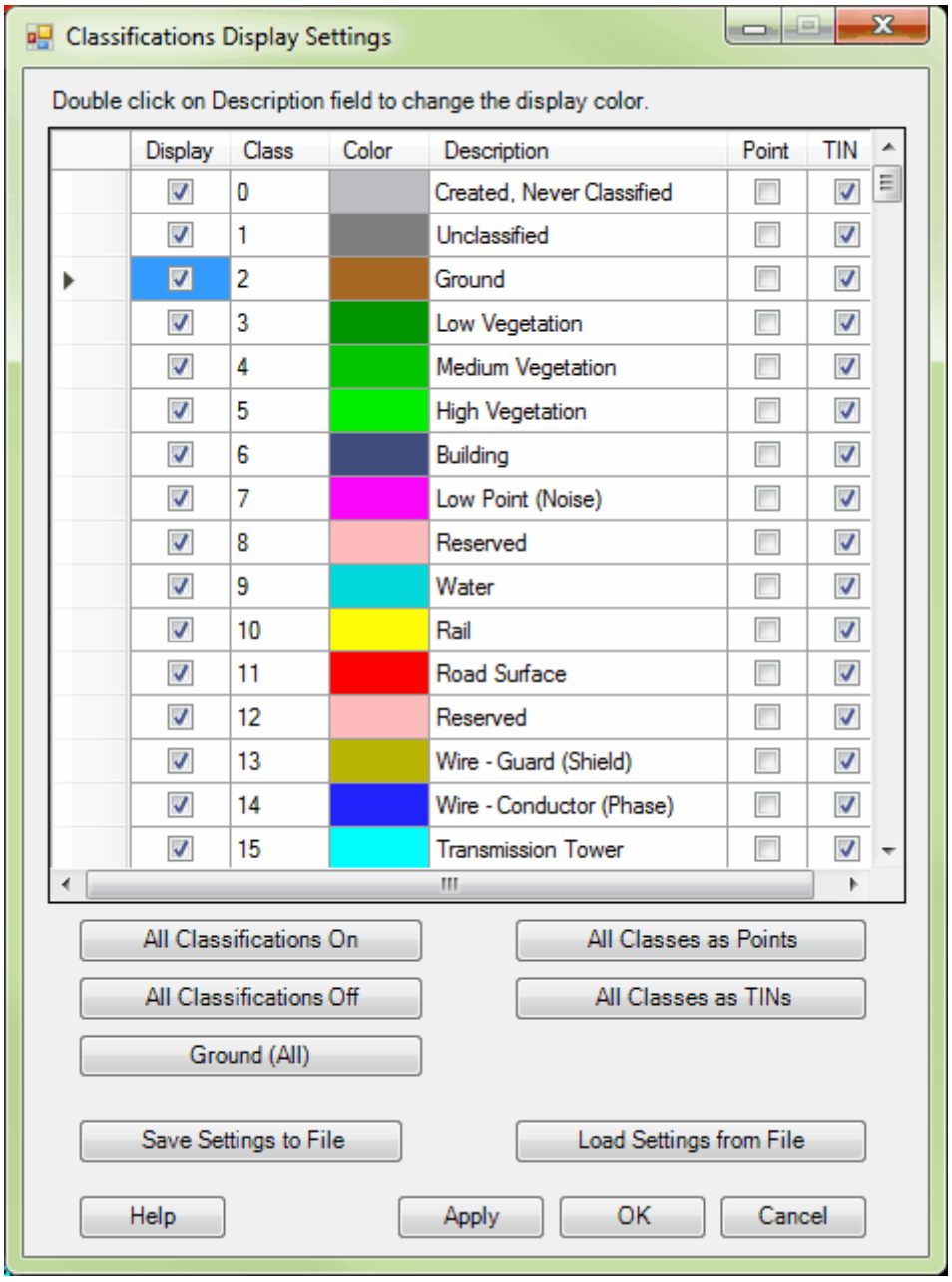
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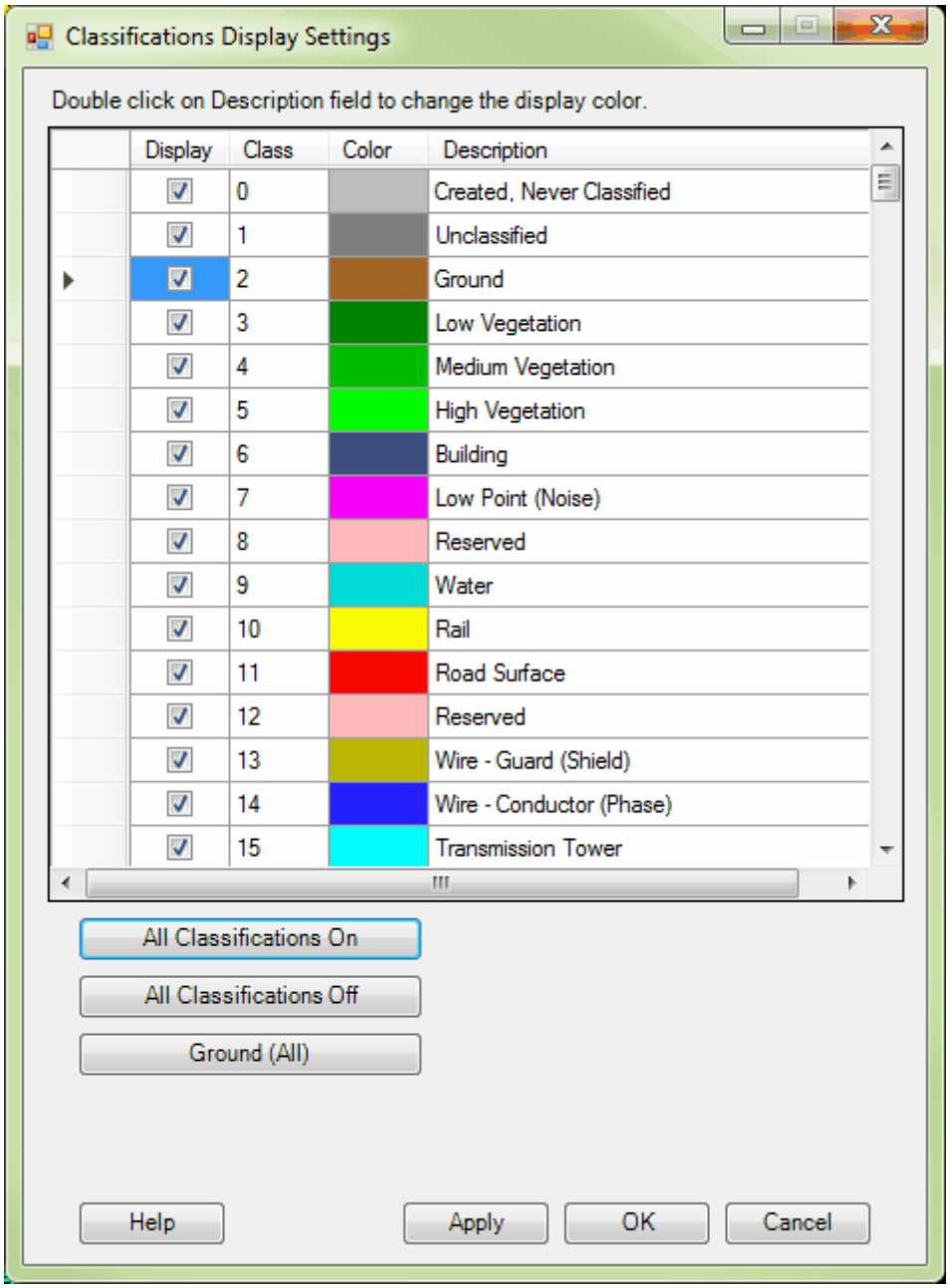
Example: The Classifications Display Settings interface for the LAS Map View window.

The Classifications Display Settings interface for the Cross-Section/Profile window.

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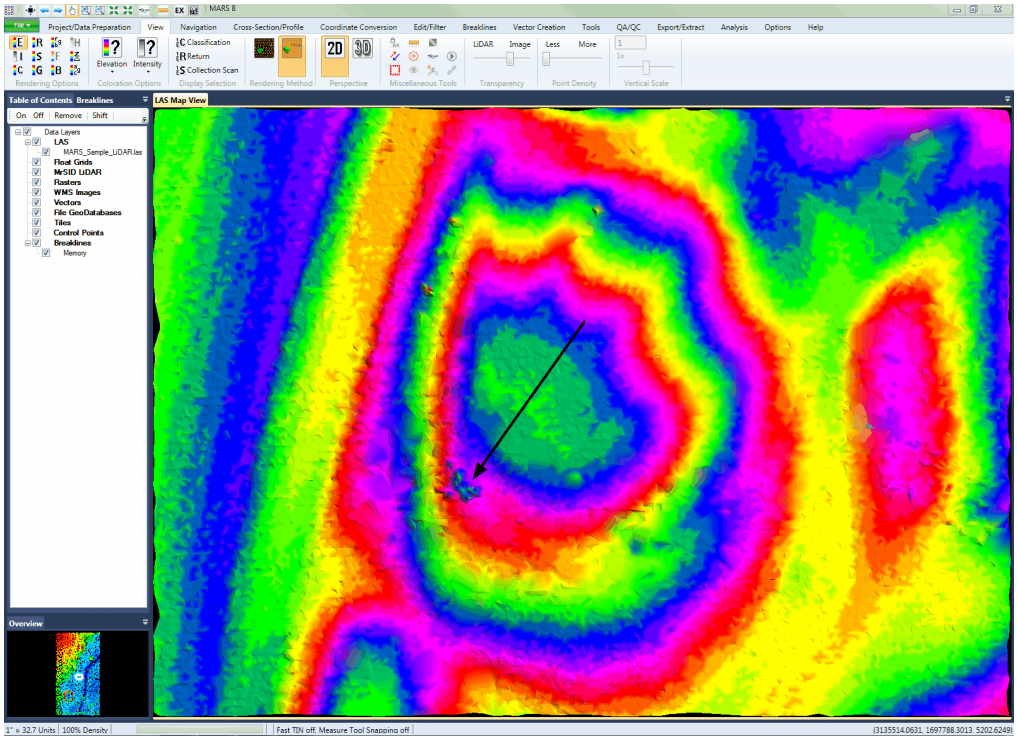


8.) Viewing by Points/TIN: These tools, located on the View Tab[192], allow the user to switch between viewing the data in the LAS Map View window as individual points or as a Triangulated Irregular Network (TIN). The TIN is hill-shaded for easy viewing. Switching between these rendering methods is critical in finding areas that need manual editing. The TIN viewing mode regenerates every

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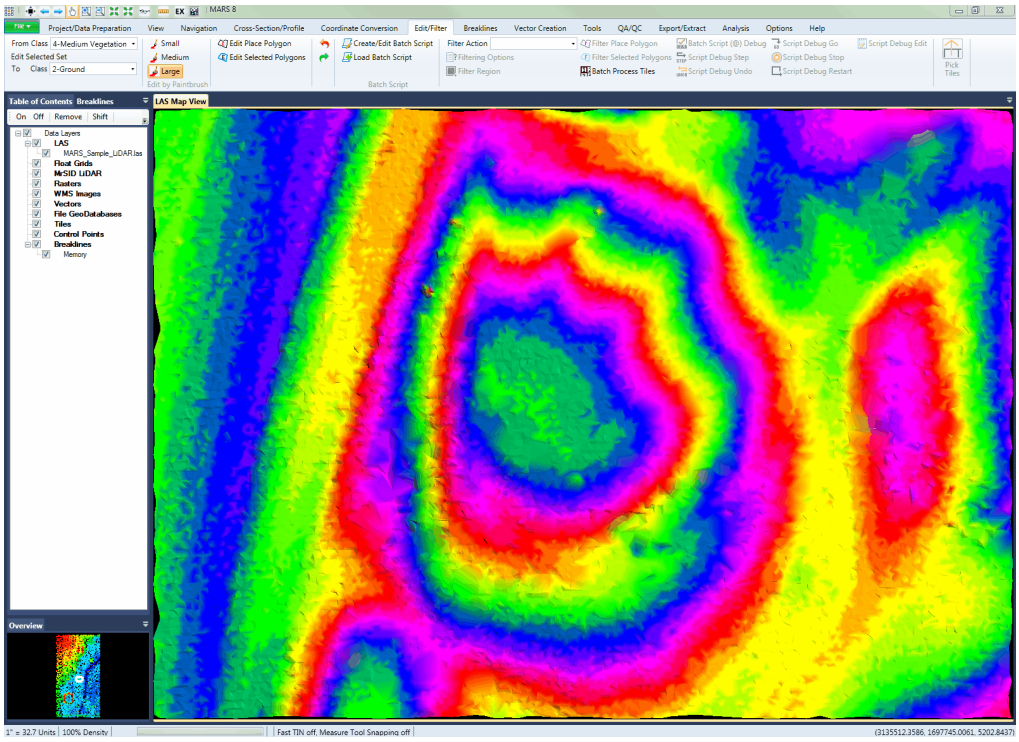
time the LAS Map View window is changed or points are edited/reclassed. Some computers, depending on the amount of RAM available, may perform slower in TIN viewing mode, so switching to Points view before moving around in the data may help speed up panning and zooming.

Example: The data is TINned and is colored by elevation. Using the TIN mode, the areas with sudden color changes are apparent at the black arrow. These 'jumps' in the TINned data show anomalies or errors in classification which need to be corrected manually.



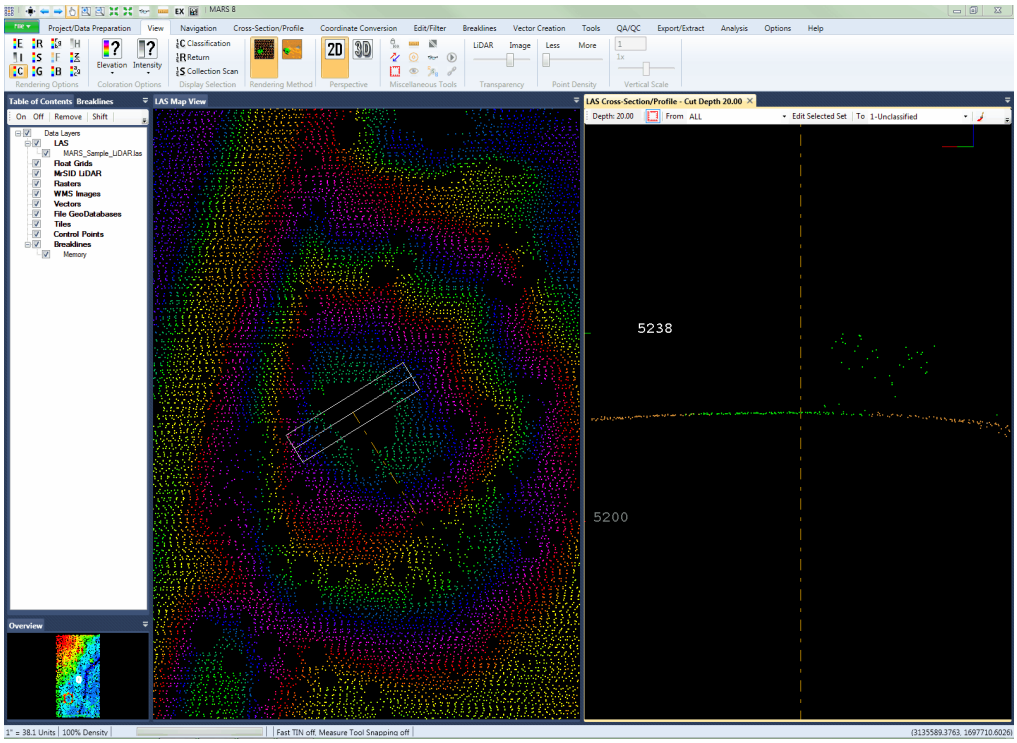
Example: The 'repairs' are made to the surface. MARS® automatically refreshes the LAS Map View every time data is reclassified.

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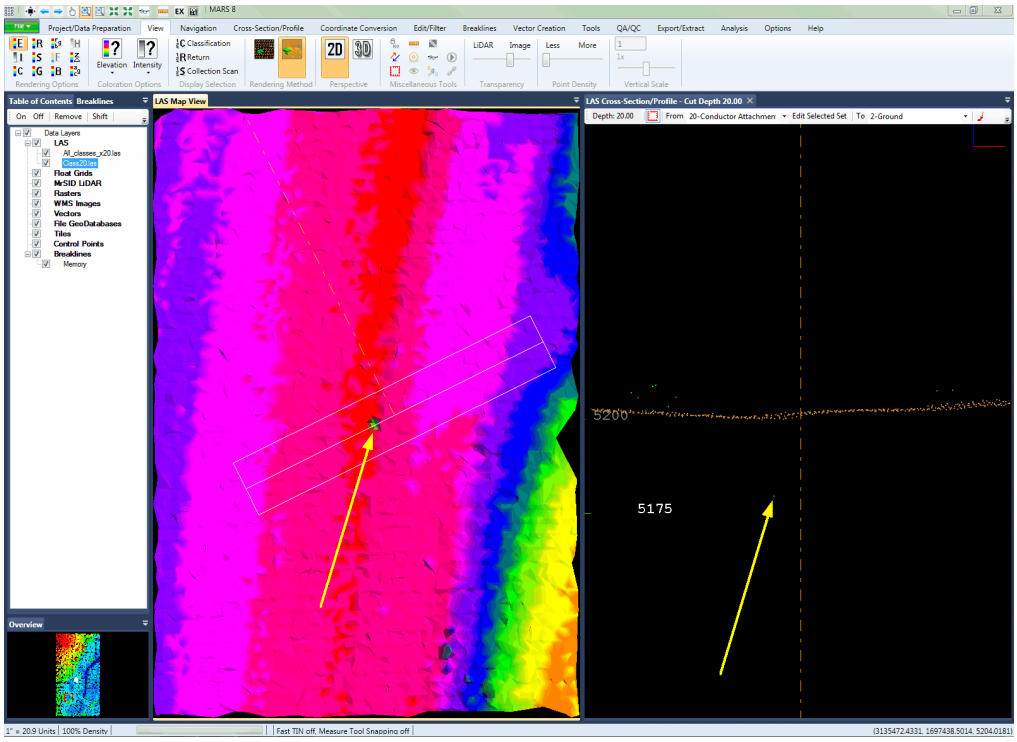
Example: This example shows the LiDAR in Point view. Although the user cannot see individual point errors as would be visible in TIN mode, large areas of 'no data' values which may be due to an over-zealous auto-filter can be seen. In this example, the top of a small hill was mis-classified as canopy in the auto-filter process. This will require manual editing to fix.

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Example: The TIN view helps spot hard to find points that were mis-classified in the auto-filter process. The hill-shading effect in TIN mode makes the data easier to view. In the example below it is apparent that a point (located by the yellow arrows) classified as ground is sitting far below the rest of the ground surface. In Point rendering mode, this error would have been difficult to catch.

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9.) Coverage Tracking ***(available with Production license only)*****:** The Coverage Tracking tools (on the QA/QC Tab[458]) are intended to make a polygon shapefile noting where the user has been in the project. This helps to document which areas of a project have been edited. For example, when going into coverage check, the user would be able to distinguish what areas have been checked versus not checked. These tools work like a recorder in that the user is capable of starting recording, leaving the tool running while performing coverage checks to record movement, and then stopping recording. The user may also save the recorded data for later reference.



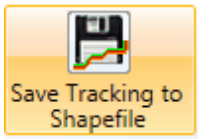
Start Coverage Tracking: Use this tool when coverage checking, editing, or during any other activity where it is useful for the user to track movements across the project. Clicking the 'Start Recording' button will start the process of recording

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the user's movements across the data.



Stop Coverage Tracking: Select this button to stop the recording process. At this time, the user's movements across a project will no longer be noted in the shapefile created when the tracking path is saved.



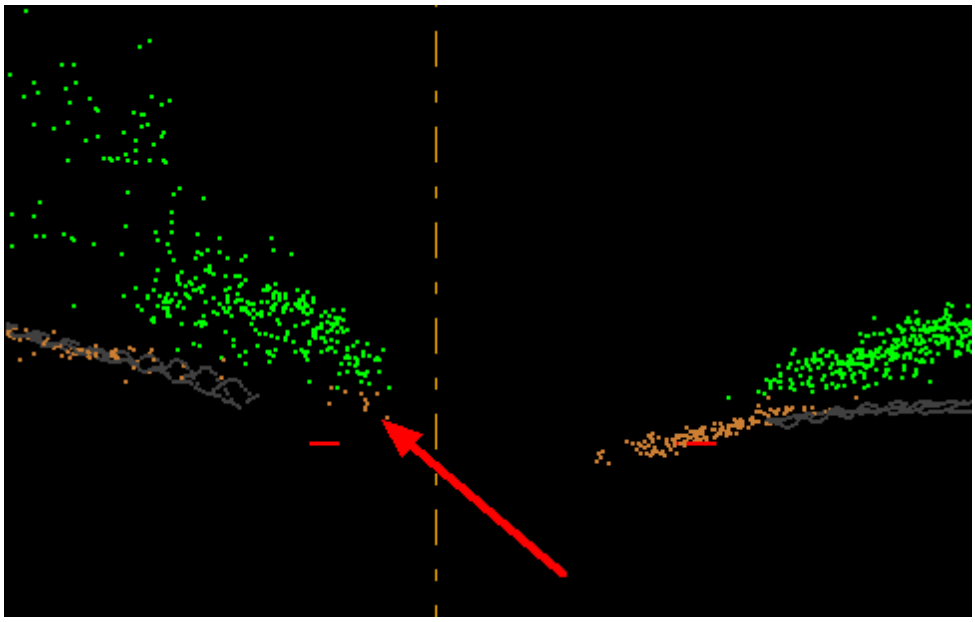
Save Tracking to Shapefile: When the user has started and stopped a recording tracking the movements across a project, the recording can then be saved as a polygon shapefile. This shapefile will show the areas which the user has visited. This can be useful in double-checking that a project area has been fully examined.

10.) Undo and Redo Tools: If a reclassification is done in error, an undo button is available. The undo button can be helpful when complex and confusing areas are being hand edited. An attempt can be made to reclassify data and if the attempt fails, click the undo button and try the reclassification again.

Example: The **'Undo'**  button and the **'Redo'**  button.

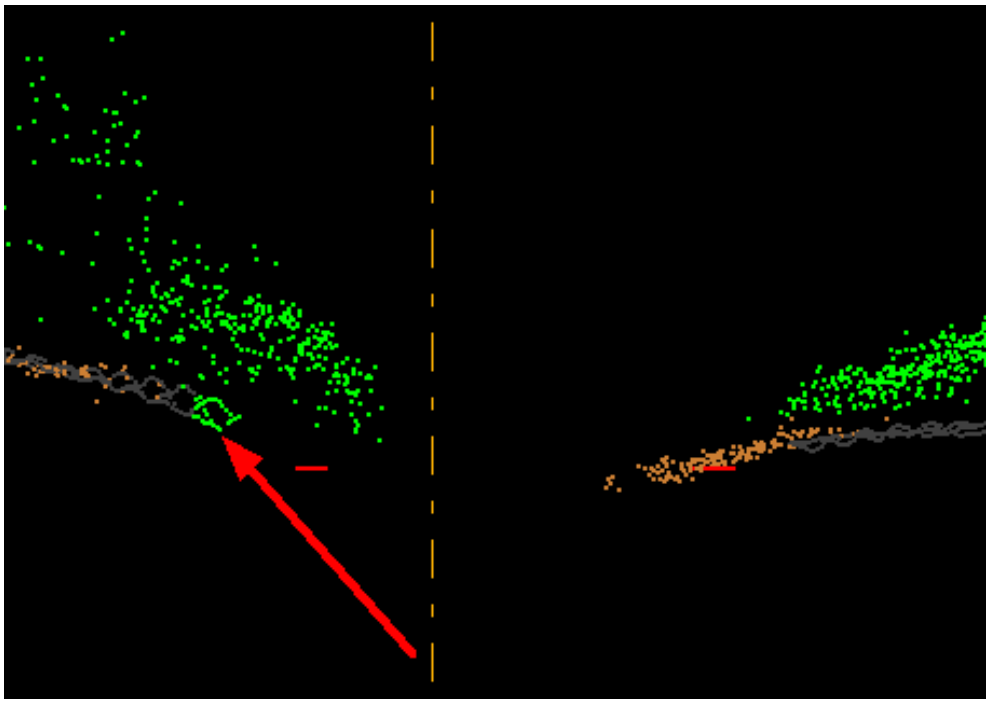
In this first example, a bit of vegetation next to a river has been incorrectly classified as ground.

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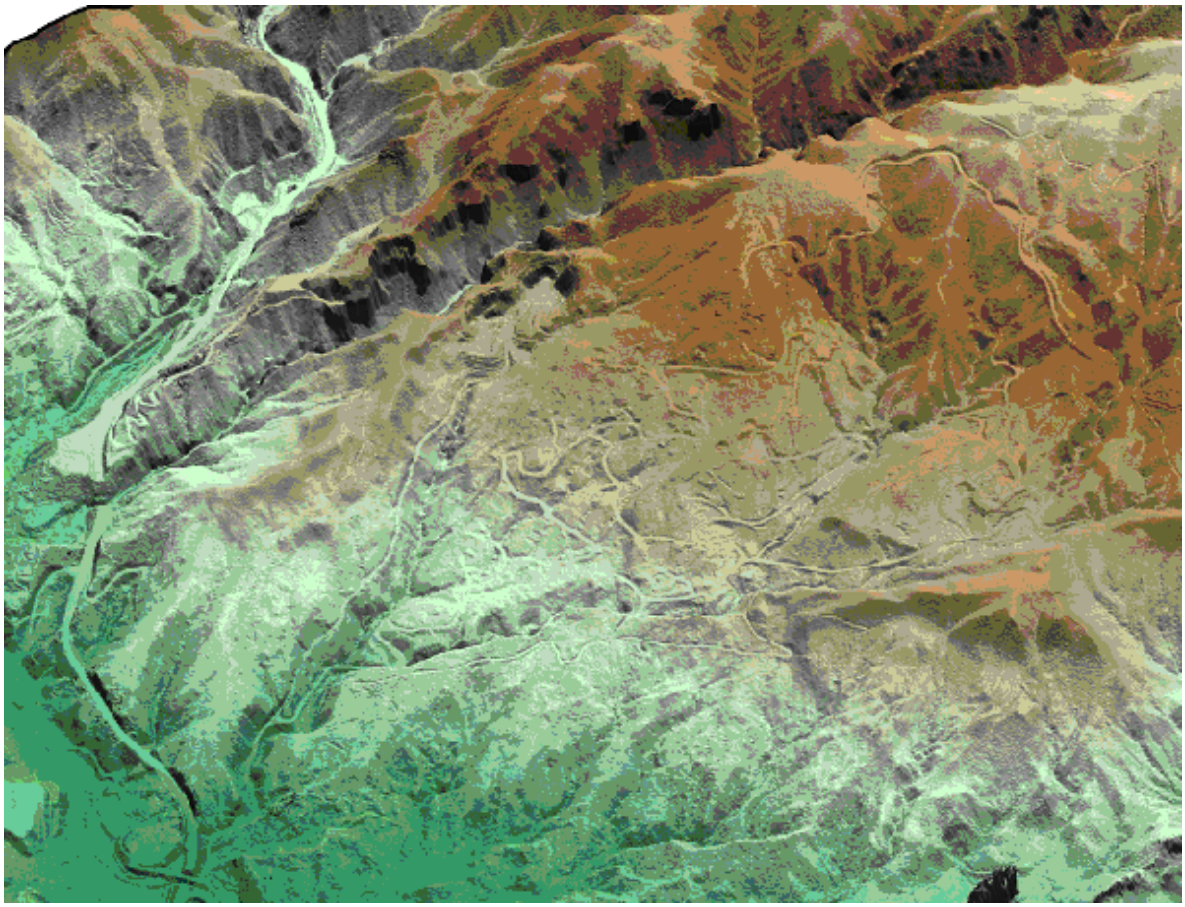
In the next example, the misclassified ground point has been changed to vegetation. However, the editor has made a mistake and has accidentally classified the ground below the vegetation as vegetation. By clicking on the ***'Undo'***  *button, this mistake is easily reversed and the point classifications that were changed to vegetation will go back to their original ground value as if the edit was never made. To reverse an 'undo' action, click on the* ***'Redo'***  *button and the edit that was made will reappear. These buttons appear on the Edit/Filter Tab 270, the Cross-Section/Profile Tab 240, and the optional Cross-Section/Profile 146 toolbar.*

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The final product is a high-quality 'Bare Earth Model Surface'. Type I errors have been repaired: bridges have been removed and canopy anomalies have been fixed. Cliffs and road-side retaining walls have been checked for missing points needing reclassification.

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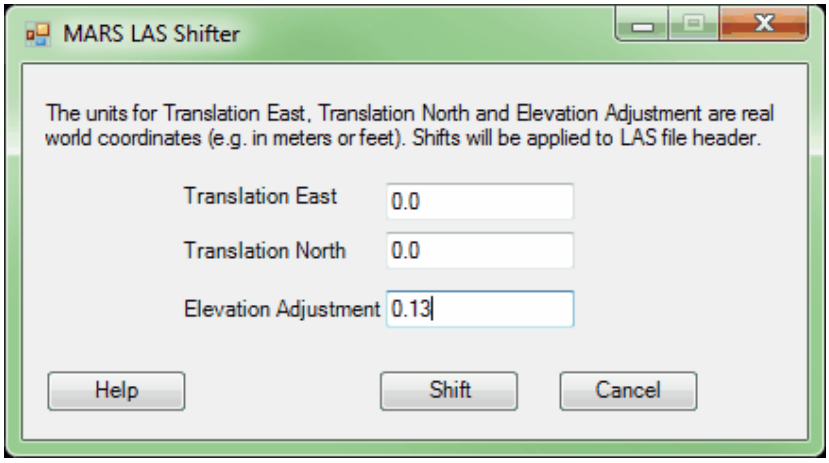
When all the hand editing is done for a project, run a Check Point Report 1224 as a final step to validate the accuracy of the surface.

If hand editing has shifted the average Z error of the project as a whole, it may be necessary to shift the LiDAR surface to fit the photo ID control. Some projects do not need an elevation shift, others will.

Example: Using a global project shifter to shift all the LAS files in an entire project. This sort of shift can be done after hand editing is finished and a Check Point Report has been run to determine the average Z (elevation) error in a project. To use this shifting tool, go to the Coordinate Conversion Tab 254 and click the **'XYZ Shift'** button. Enter the elevation, or Z, error into the 'Elevation Adjustment' text box to correct the Z error. **** NOTE: If multiple shifts are applied to a single project, the**

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effect is cumulative. Each shift is applied to the existing XYZ offset in the header.



After the elevation shift (if needed) is complete, the project is ready for delivery. Raw contours are exported for the soft copy edit process. New sets of LAS files are created for the client. The client LAS contains only the ground (class 2) and canopy (class 5) classifications. The Check Point Report is given to the client to validate the accuracy standards of the surface.

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8.7 Using Float Grids

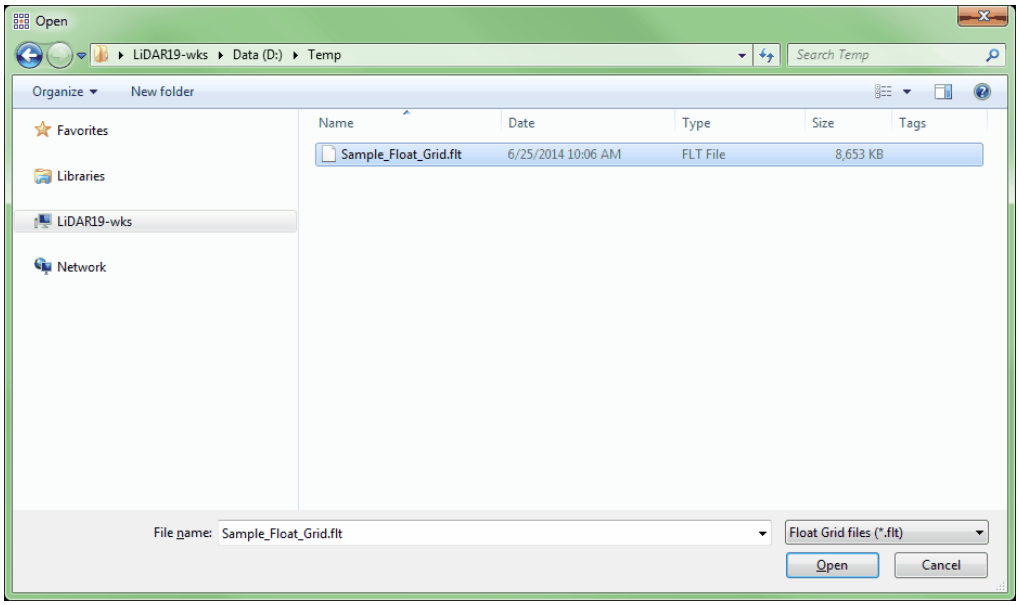
Using Float Grids

Merrick Advanced Remote Sensing (MARS®) Software

There are three ways to display/use Float Grids in MARS®. The user may 1) view a float grid (*.flt file) colored by hillshade on the fly, 2) create a hillshade raster from a float grid (*.flt) file, or 3) export an LAS file to a hillshade raster or image (this option allows the user to bypass creating a gridded, elevation float grid file and still create an image or raster file showing hillshade).

1) View a Float Grid Colored by Hillshade: In order to view a float grid colored by hillshade, a float grid must first be loaded to MARS®. For more instructions on loading a float grid, please see the information below. To see the gridded, elevation float grid colored by hillshade, click on the **'Color by Hillshade'** button on the View Tab 192 once data has been loaded. This tool only becomes available when a gridded, elevation float grid has been loaded into MARS®. This tool may be used to view a float grid in 3D View 837.

To load a float grid to MARS®, click the **'Add Float Grid'** button on the Project/Data Preparation Tab 162. Navigate to the float grid (*.flt) to be loaded and select it. Choose **'Open'**.

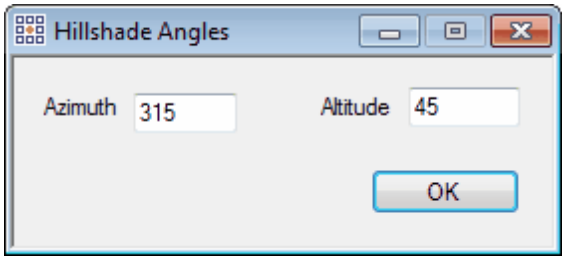


The loaded float grid can now be seen in the table of contents. Please visit the 'Float Grids' layer 82 link for more information about using float grid files inside the table of contents.

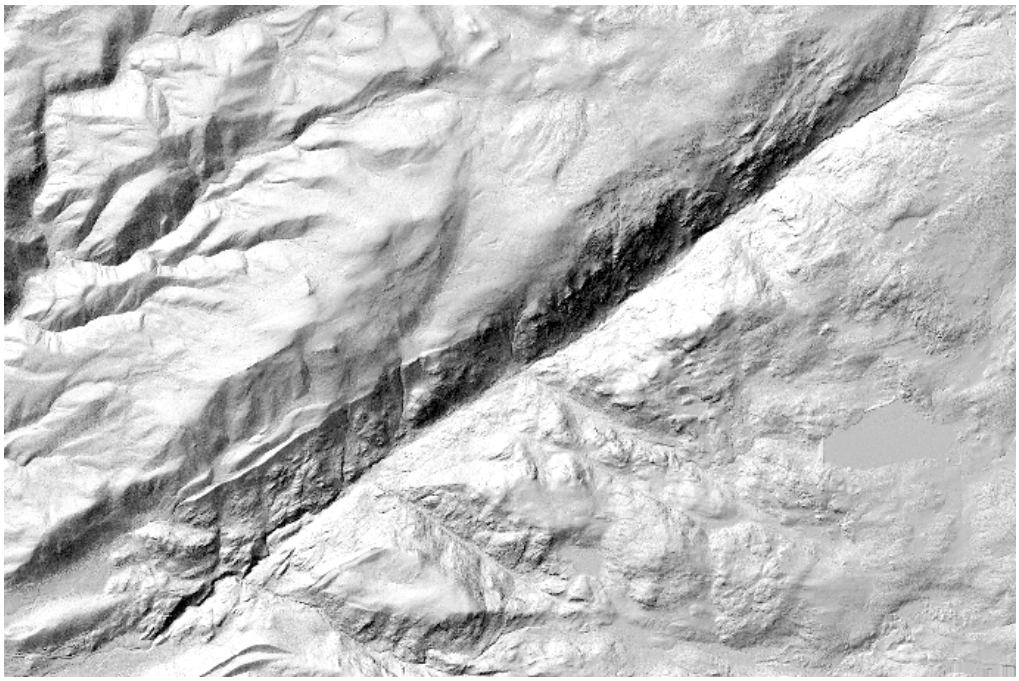
Once a gridded, elevation float grid (*.flt) is loaded into MARS®, the Color by Hillshade

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 tool may be applied to the data. Click on the Color by Hillshade button, choose the desired sun angle settings, and a hillshade will be calculated and displayed. Because the hillshade is being calculated and displayed 'on the fly,' display can sometimes be slow. The resulting display can also be viewed in 3D. **Please note that loaded LAS files will not function with the Color by Hillshade tool. Only gridded, elevation float grids (*.flt) will work with this tool.**



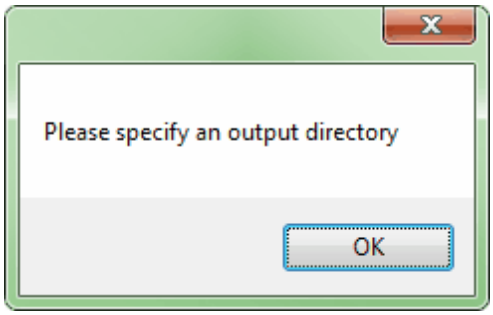
The screen shot below shows a gridded, elevation float grid colored by Hillshade.



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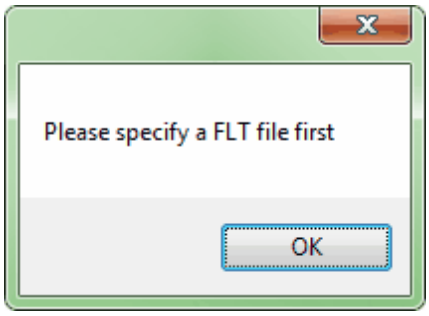
2) Elevation Float Grid to Hillshade: This tool can be found on the Tools Tab 389 as part of the 'Format Conversion' button. This tool allows the user to create a hillshade image or raster from a gridded, elevation float grid (*.flt). This tool inputs a float grid and is capable of outputting a JPEG 2000 file, BMP file, IMG file, or float grid file. It is important to understand that the output file created by this tool is an image or raster. It is meant to display quickly, similar to the performance of a compressed .ecw file. Because the resulting file is an image or raster file, this type of file will only work in 2D View 835 and CANNOT be seen in 3D.

- **Output folder:** Click on the **'...'** button and navigate to or key in an output folder for the finished image or raster product. There must be an output folder specified to use this tool. If the user does not designate an output folder, the following prompt will appear:

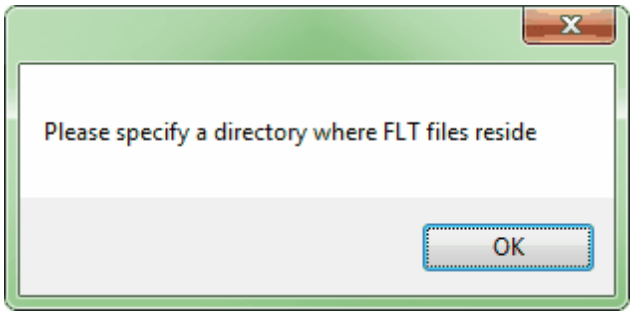


- **FLT File:** By clicking on the corresponding **'...'** button, the user may navigate to a single input *.flt file. This is the file that will be used to create an image or raster. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'FLT File' is not specified and the user attempts to click on the corresponding **'Convert'** button, the following prompt will appear:

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- **Folder to Process:** By clicking on the corresponding **'...'** button, the user may navigate to a folder. Every *.flt file inside the specified folder will be converted to an image or raster if this option is chosen. Either the 'FLT File' specification or the 'Folder to Process specification' must be filled to use this tool. If the 'Folder to Process' is not specified and the user attempts to click on the corresponding **'Convert'** button, the following prompt will appear:

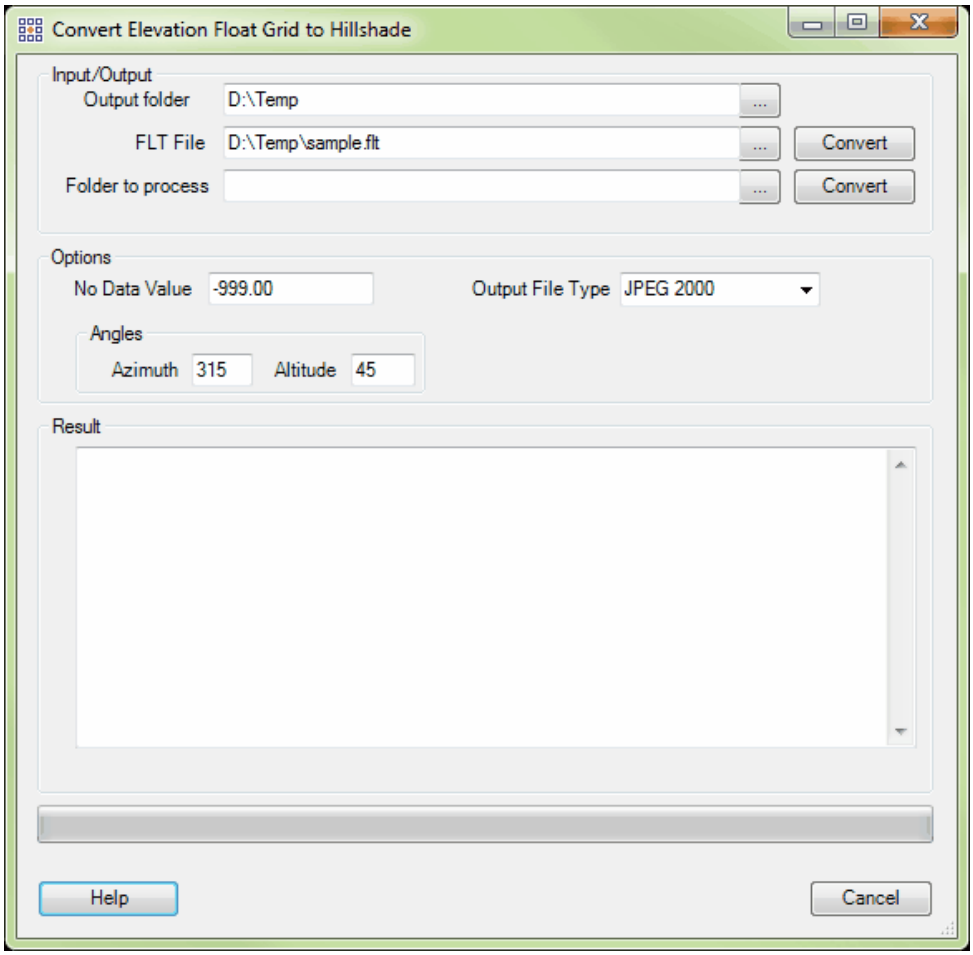


- **No Data Value:** If there is a data void in the data set (no information within the cell), a 'No Data' value is assigned. Cells with null values will be given a default value of -999.00 unless otherwise specified. Enter an integer in the text box for the No Data Value if another value is preferred. *Note: Water does not reflect LiDAR points, so water should be considered a No Data area.*
- **Output File Type:** The user may specify here which type of product the tool should output. The user may choose from outputting a JPEG 2000 file, float grid, IMG file, or BMP file. Click on the drop-down to display the choices.
- **Result:** The 'Result' text box will show the user the processing of the tool. When

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the file has been converted, the result text box will display that the specified *.flt file(s) were processed.

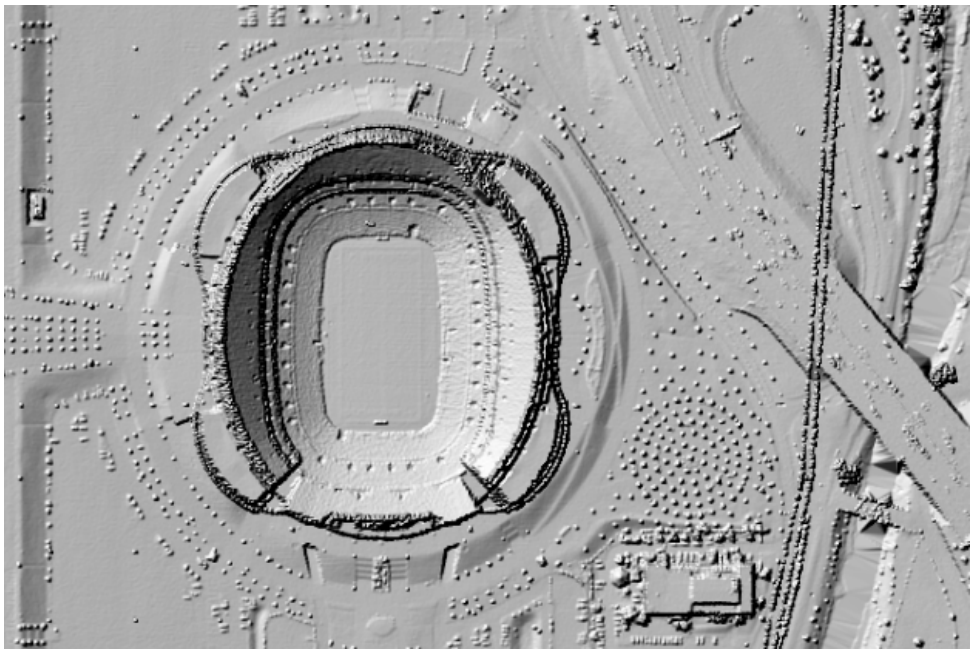
The example below shows the 'Convert Elevation Float Grid to Hillshade' window:



After the conversion has taken place, go to the specified output directory and load the resulting image or raster file into MARS®. The file will be renamed with the same name as the float grid file which was the input *.flt along with '_Hillshade' appended to the end of the file name. For example, the 'sample.flt' file which was the input *.flt in the example above was output as a JPEG 2000 file and named 'sample_Hillshade.jp2'. Load the newly converted file into MARS® to view it.

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Below is a sample of the newly created 'sample_Hillshade' JPEG 2000 file. Because the resulting file is an image file, panning and moving around the data is much quicker than using the corresponding float grid with hillshade created 'on the fly'.



3) Exporting LAS Data to Create a Float Grid or Hillshade JPEG 2000 image:

For a description of the **'Export'** 

or **'Export Area'** 

tools, please see the Data Export[658] section of the help. If the user wishes to export the entire project which is loaded into MARS®, use the **'Export'** tool. To export a particular area of a project, please use the **'Export Area'** tool and drag a box over the desired area. In either case the export interface appears the same, so use the following screen shots to aid in exporting a Float Grid or Hillshade image.

- **Exporting LAS data to create an elevation float grid:**

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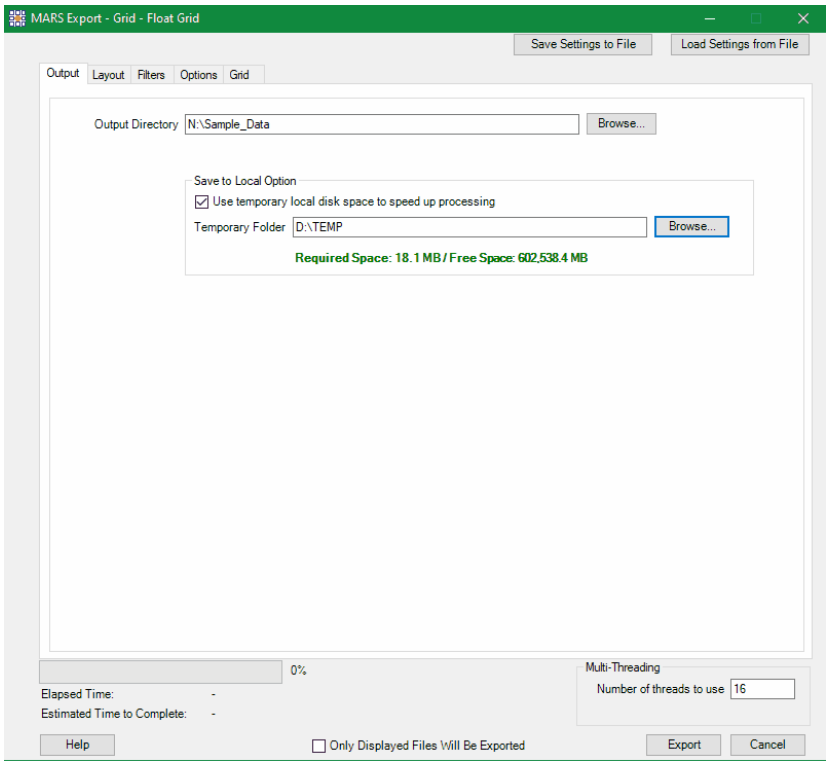
1) Start by loading the LAS data to be used for the float grid creation. For more information on loading LAS data, please see the LAS Files 74 section of the Help Topics.

2) When data has been loaded, choose the **'Export'** 

or **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears. Select 'Grid - Float Grid' from the list.

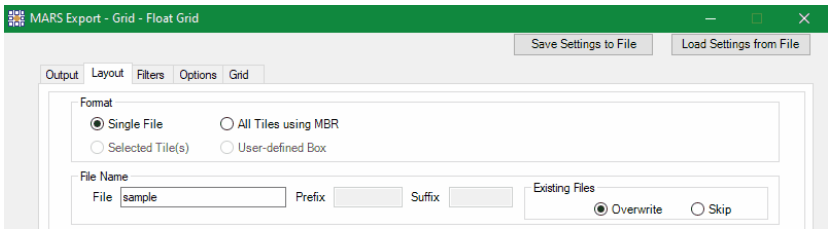
3) When the export interface appears, specify an output directory. The output directory will be the folder to which the final float grid (*.flt) product can be found after processing is complete.



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4) The **'Save to Local Option'** on the 'Output' tab is available to improve performance when the 'Output Directory' is a network location. To use this option, check the box and browse to a 'Temporary Folder' location with sufficient free space. The 'Temporary Folder' specified WILL NOT be the output folder (final destination of the float grid produced), and will be cleared when the export is complete. ***NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

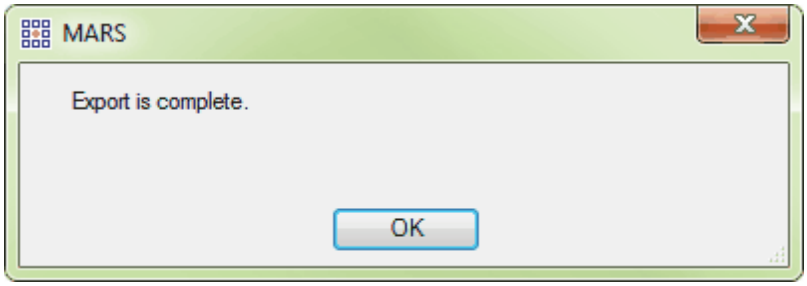
5) Under the **'Layout'** tab in the Export interface, specify a file name in the **'File'** text box for the float grid to be exported.



6) If any other parameters need to be set for export, please make those entries in the rest of the tabs located on the export interface (see Data Export 658).

7) When all the settings have been made, click the **'Export'** button at the bottom of the interface to export the file.

8) When the export is complete, the following message will appear.



9) To see the newly created elevation float grid, click the **'Add Float Grid'**

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button on the Project/Data Preparation Tab 162. Navigate to the designated output folder and load the *.flt file. Once loaded, the float grid will appear in the table of contents. To see more information concerning the use of float grids in the table of contents, please visit the Float Grids 82 section of the help file. Float grids may be viewed in 2D View 835 or 3D View 837.

- **Exporting LAS data to create a Hillshade JPEG 2000 image:**

  1) Start by loading the LAS data which will be needed to create an image. For more information on loading LAS data, please see the LAS Files 74 section of the help file.

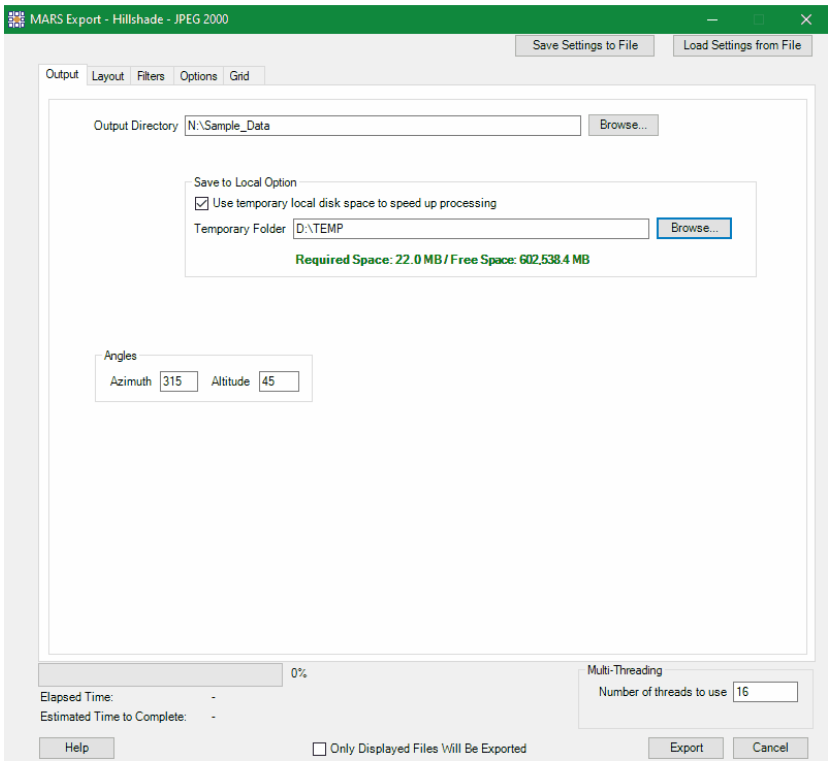
  2) When data has been loaded, choose the **'Export'** 

or **'Export Area'** 

button to see the drop-down list of export types. 'Export Area' requires that a drag box be created first before the drop-down list appears. Select 'Hillshade - JPEG 2000' from the list.

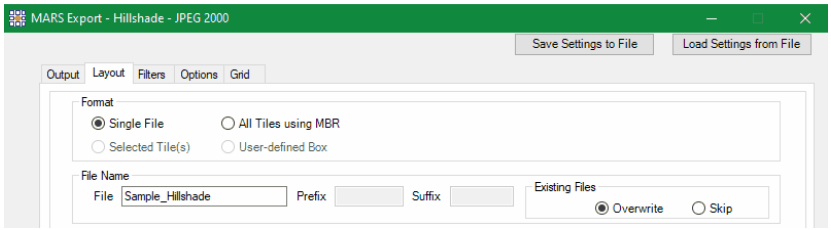
  3) When the export interface appears, specify an output directory. The output directory will be the folder in which the final JPEG 2000 (*.jp2) product can be found after processing is complete.

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4) The **'Save to Local Option'** on the 'Output' tab is available to improve performance when the 'Output Directory' is a network location. To use this option, check the box and browse to a 'Temporary Folder' location with sufficient free space. The 'Temporary Folder' specified WILL NOT be the output folder (final destination of the float grid produced), and will be cleared when the export is complete. ***NOTE: Most versions of Windows prohibit an application's output of files to the root directory of drives. It is strongly recommended that an actual folder be used for this option.***

5) Under the **'Layout'** tab in the Export interface, specify a file name in the **'File'** text box for the JPEG 2000 file to be exported.

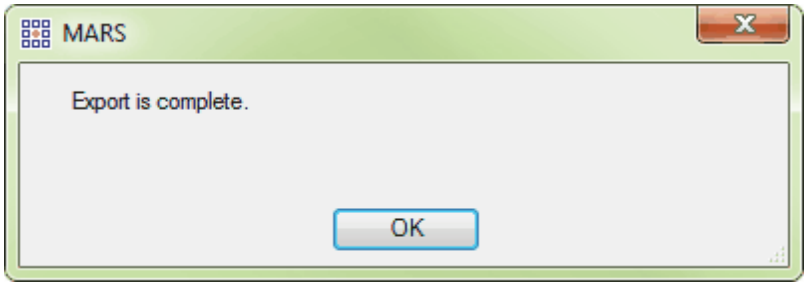


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6) If any other parameters need to be set for export, please make those entries in the rest of the tabs located on the export interface (see Data Export 658).

7) When all the settings have been made, click the **'Export'** button at the bottom of the interface to export the file.

8) When the export is complete, the following message will appear.



9) To see the newly created JPEG 2000 hillshade raster, click on the **'Add Images'** button on the Project/Data Preparation Tab 162. Make sure the **'Files of type: JPEG 2000'** is selected at the bottom of the 'Open' interface. Navigate to the output folder designated earlier in the process and load the *.jp2 file. An image file (raster) such as a JPEG 2000 renders much faster when using the pan, zoom in, or zoom out features than a float grid file. Once loaded, the image can be found in the table of contents. To see more information concerning the use of rasters, or images, in the table of contents please visit the Raster Files 86 section of the help file. This resulting image may be viewed only in 2D View 835.

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9 Reference Information

9.1 LAS File Specifications

LAS File Specifications

Merrick Advanced Remote Sensing (MARS®) Software

The **American Society for Photogrammetry and Remote Sensing** (ASPRS) is responsible for developing and updating the specifications to be followed when writing files in the binary LAS format. This helps ensure that all laser point cloud files using the LAS extension (*.las) will be readable across the various software platforms used to display, query, and edit LiDAR data.

For more information on the current LAS specification (LAS 1.4) as well as past specifications going back to 2003, please use this link to the ASPRS LAS File Format website.

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9.2 Additional WMS Resources

Additional WMS Resources

Merrick Advanced Remote Sensing (MARS®) Software

Some additional resources for WMS imagery are listed here. Although no guarantee is made about the working status of these sources, these URLs were functional at the time this help file was compiled. This list may be revised from time to time (without prior notice) as new WMS sources are identified or

previously existing ones are dropped by their host.

NOTE: Merrick neither hosts nor maintains any WMS (Web Map Service) image layer sources and is therefore not responsible for the completeness, accuracy, or frequency of updates of any WMS sources that may be accessed from within the MARS® program.

USGS (U.S. Geological Survey) Framework WMS: http://frameworkwfs.usgs.gov/framework/wms/wms.cgi

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9.3 Link to Google Earth info



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9.4 Keyboard Accelerators



Many functions in MARS® support keyboard shortcuts which speed manipulation and use of the

application. The following lists contain all of the application's keyboard accelerators:

Keyboard Accelerator for the Help File:

F1	Open the Help Topics document for MARS®.

Common Keyboard Accelerators:

Ctrl-N	New MARS® project (.mpd file).
Ctrl-O	Open MARS® project (.mpd file). Does not open any other type of file.
Ctrl-S	Save MARS® project (.mpd file).
Q	Activate 'Pan' tool.
+	Zoom in by a fixed amount (25%). Applies to both '+' on keyboard and on number keypad.
-	Zoom out by a fixed amount (25%). Applies to both '-' on keyboard and on number keypad.
Esc	Exit out of any open dialog box.
L	Toggle 'Lock to view 100%' tool on/off.
T	Toggle between viewing points and viewing a TIN surface.
X	Toggle on/off LiDAR points.
O	Toggle on/off orthophotography (imagery).
C	Toggle on/off contour lines.
S	Toggle on/off shapefiles.
M	Toggle 'Measure' tool on/off. To dismiss the 'Measure' tool and return to 'Pan' mode, press the 'Esc' key.
I	Toggle 'Inspect' tool on/off. To dismiss the 'Inspect' tool and return to 'Pan' mode, right-click the mouse.
Ctrl-A	Allow display of all LiDAR point classifications.
Ctrl-K	Allow display of only the model key-points (Class 2 with MKP bit flag set to 'On').
Ctrl-G	Allow display of only the ground point classification (2).
Ctrl-E	Color points or TIN by elevation.

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Ctrl-I	Color points or TIN by intensity.
Ctrl-C	Color points or TIN by classification.
Ctrl-R	Color points or TIN by return.
Ctrl-L	Color points or TIN by collection scan.
Ctrl-J	Color points or TIN by RGB values.
Ctrl-F	Color points or TIN by imagery RGB values (Color by Imagery Fusion).
Ctrl-D	Copy the X, Y (and Z, if available) coordinate values shown at the right side of the Status Bar to the Windows clipboard, based on the current cursor location.
Ctrl-T	Toggle Fast TIN on/off.
Ctrl-Z	When using 2D drawing tools on 'Vector Creation' tab, allow undo of last vertex or last point placed (depending on tool being used). Also, undo last vertex drawn when creating a polygon with the 'Filter Digitized Polygon' tool.
Z	Open the 'Elevation Repeat Colors Options' interface.

Keyboard Accelerators for Cross-Section/Profile View Manipulation *(these options are only available when the Cross-Section/Profile window is open and selected)*

W	Activate 'Place Adjustable Cross-Section Line' tool.
D	Set Depth of the cross-section/profile area.
Up Arrow (⬆)	Move the cross-section/profile area forward.
Down Arrow (⬇)	Move the cross-section/profile area backward.
Right Arrow (➡)	Rotate the cross-section/profile area clockwise.
Left Arrow (⬅)	Rotate the cross-section/profile area counter-clockwise.
Underscore (_)	In the Cross-Section/Profile window, toggle between 'Cross-Section' and 'Profile by Collection Scan' views.
Ctrl-A	Allow display of all LiDAR point

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	classifications.
Ctrl-K	Allow display of only the model key-points (Class 2 with MKP bit flag set to 'On').
Ctrl-G	Allow display of only the ground point classification (2).
Ctrl-E	Color points or TIN by elevation.
Ctrl-I	Color points or TIN by intensity.
Ctrl-C	Color points or TIN by classification.
Ctrl-R	Color points or TIN by return.
Ctrl-L	Color points or TIN by collection scan.
R	Activate the 'Rotate Profile' window and allow the user to rotate the cross-section/profile area a specified number of degrees.

Keyboard Accelerators for Point Editing in the LAS Map View Window

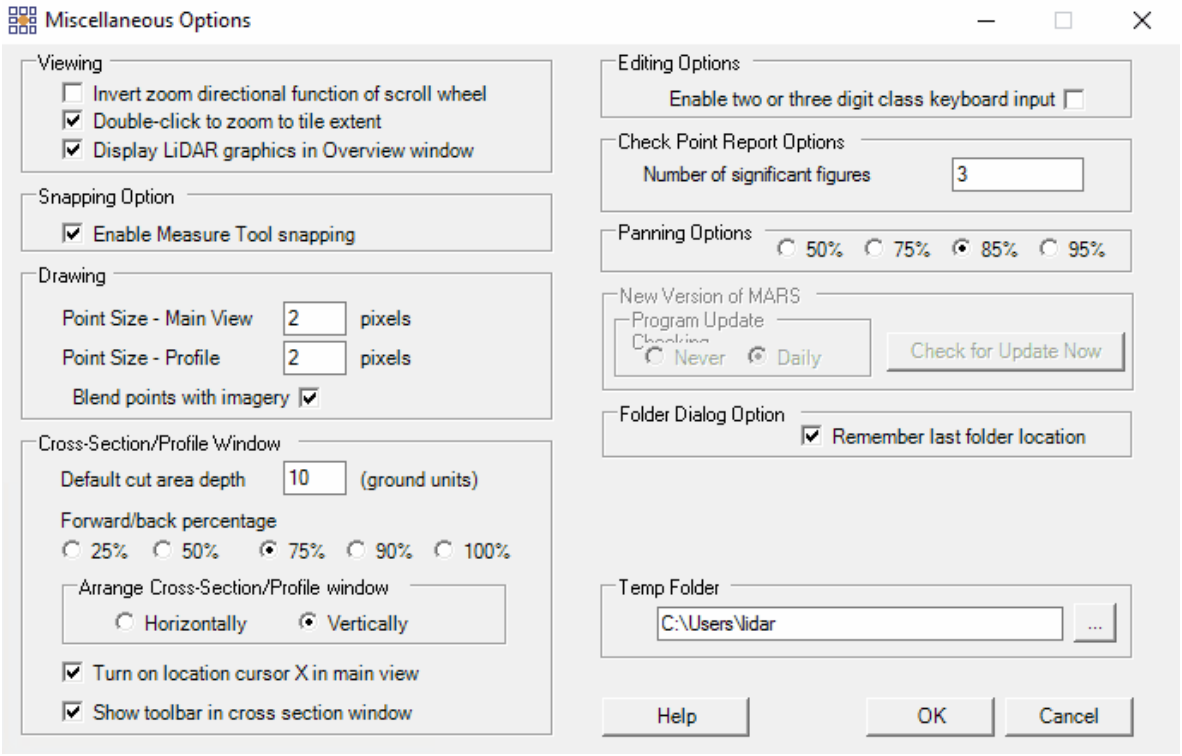
0-9	Modify the currently selected points to the new classification indicated by the number key pressed. For example, the '5' key modifies selected points to the point classification 'High Vegetation'.
G	Activate the 'Edit Place Polygon' tool, which selects all points within the boundary of the user's manually defined polygon.
Space	Modify the currently selected points to the last target classification used. For example, if the last classification edited had a value of 6, pressing the space bar will modify the *currently* selected points to the same target classification - 6.
U	Unselect all currently selected points.
Ctrl-H	Allow display of only classification (8).
Ctrl-M	Allow display of only the ground point classification (2) and the ignored ground classification (20).
Ctrl-P	Activate small paintbrush tool for selecting points.
P	Activate medium paintbrush tool for selecting points.
Shift-P	Activate large paintbrush tool for selecting points.
E	Activate 'Filter Region' tool.
N	Re-use the last polygon created with the 'Filter Digitized Polygon' tool
Esc	Leave the current editing mode.
Ctrl-Z	Undo the last edit step.

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Ctrl-Y	Redo an edit step.
Z	Open the 'Elevation Repeat Colors Options' interface.
Ctrl-⬆	Pan up, using the extent percentage selected in Miscellaneous Options | Panning Options.
Ctrl-⬇	Pan down, using the extent percentage selected in Miscellaneous Options | Panning Options.
Ctrl-⬅	Pan left, using the extent percentage selected in Miscellaneous Options | Panning Options.
Ctrl-➡	Pan right, using the extent percentage selected in Miscellaneous Options | Panning Options.

To enter a number for any class (0-9, 10-99, or 100-255), go to the '**Options Tab**' and click the ' **Miscellaneous**' button. In the upper-right corner of this window is the 'Editing Options' section. Check the box labeled **'Enable two or three digit class keyboard input'**. If LiDAR data contains classes with 2 or 3 digits (e.g., Class 14 or Class 122), this option can be useful during editing. Simply enter the 2- or 3-digit class, choose 'Enter' on the keyboard, and any LiDAR points highlighted will be changed to that classification. Single-digit class values can also be applied while the 'Enable two or three digit class keyboard input' option is checked by choosing 'Enter' on the keyboard after the single number is entered. The points will then be reclassified. When the 'Enable two or three digit class keyboard input' option is unchecked, points selected cannot be reclassified to 2- or 3-digit classes because as soon as one number is entered (interpreted by MARS® as a 1-digit class) the points are automatically reclassified *without* hitting the 'Enter' key. For example, the user can select LiDAR points needing to be reclassified and enter '15' if that is the intended target class. Without the 'Enable two or three digit class keyboard input' option checked, the points selected will be reclassified to Class 1 because this was the first number entered on the keyboard to reclassify data. See the upper-right of the 'Miscellaneous Options' window below. See the 'Miscellaneous Options' window below.

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Keyboard Accelerators for Point Editing in the Cross-Section/Profile Window

0-9	Modify the currently selected points to the new classification indicated by the number key pressed. For example, the '5' key modifies selected points to the point classification 'High Vegetation'.
Space	Modify the currently selected points to the last target classification used. For example, if the last classification edited had a value of 6, then pressing the space bar will modify the *currently* selected points to the same target classification, 6.
U	Unselect all the currently selected points.
/	Activate the 'Edit Scrape Above' tool.
?	Activate the 'Edit Scrape Below' tool.
S	Activate the 'Line String Above' tool, which selects all points above the user's manually defined line string.
Shift-S	Activate the 'Line String Below' tool, which selects all points below the user's manually defined line string.
Ctrl-P	Activate the small paintbrush tool for selecting points.
P	Activate the medium paintbrush tool for selecting points.
Shift-P	Activate the large paintbrush tool for selecting points.
E	Activate 'Filter Region' tool.

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Esc	Leave the current editing mode.
Ctrl-Z	Undo the last edit step.
Ctrl-Y	Redo an edit step.
D	Open the 'Set Cut Depth' window to adjust the cut area depth of the cross-section/ profile tool.
Z	Open the 'Elevation Repeat Colors Options' interface.
R	Activate the 'Rotate Profile' window and allow the user to rotate the cross-section/ profile area a specified number of degrees.

Keyboard Accelerators for Breakline Editing in the LAS Map View Window

Esc	Leave the current editing mode or dialog window.
Shift-Mouse Click	Holding down the shift key while compiling breaklines will cause the breakline to snap to the user-designated point. The point to which the breakline will be snapped will be determined by the feature drop-down code list. Choose either: 'startendvertex', 'vertex', 'nearestpoint', or 'midpoint'.
Ctrl-Mouse Click	Ctrl-Click on a breakline the first time will collect that breakline's Z-value, and Ctrl-Click a second time will transfer that collected Z-value to a new breakline point that is currently being compiled.
A	When pressed and released during breakline collection, begins the creation of an arc (splined curve) in the breakline. The next two left-clicks will be the center and endpoint of the arc, respectively.
B	Toggle on/off the auto-pan mode.
V	Toggle on/off the auto-pan edge markers.
Alt	Holding the 'Alt' key down while in collection mode will allow the user to pan across the data when auto-pan is turned off. The cursor will temporarily turn from collection tool to pan tool while the 'Alt' key is pressed.
Ctrl-B	Toggle display of breaklines on/off.
Ctrl-M	Allow display of only the ground point classification (2) and the ignored ground classification (20).
Ctrl-T	Toggle Fast TIN mode on/off.
Ctrl-Z	Undo last vertex drawn when placing a breakline.
Shift-B	Quick save of breaklines without confirmation (when path/name has previously been established).

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9.5 Glossary of Terms

Glossary of Terms and Acronyms

Merrick Advanced Remote Sensing (MARS®) Software

AGL - ***A***bove ***G***round ***L***evel

AGPS - ***A***irborne ***G***lobal ***P***ositioning ***S***ystem

ANPD - ***A***ggregate ***N***ominal ***P***ulse ***D***ensity

ANPS - ***A***ggregate ***N***ominal ***P***ulse ***S***pacing

AOI - ***A***rea ***o***f ***I***nterest

Artifacts - Any feature, whether man-made or system-made, that unintentionally exists in a digital elevation model. Buildings, trees, towers, telephone poles or other elevated features should be removed when depicting a DEM of the bare-earth terrain.

ASPRS - ***A***merican ***S***ociety for ***P***hotogrammetry and ***R***emote ***S***ensing

Bare Earth - (sometimes referred to as bald earth) Digital elevation data of the terrain, free from vegetation, buildings, and other man-made structures. Bare earth data may be modeled as a DEM or a DTM.

Boresighting - A LiDAR calibration process that corrects for attitude offsets (pitch, roll, and yaw or heading in an aircraft setup) affecting the position of the LiDAR sensor, measurement biases in the sensor itself, and atmospheric conditions during the mission, using a known reference surface.

Breakline - A linear feature that describes a change in continuity of a surface. Breaklines are typically captured along road edges and hydrographic features to assist with the accurate depiction of contours.

Calibration - Procedures used to identify systematic errors in hardware and software so that the errors can be corrected in preparation for data collection activities.

Collection Scan - a file of LiDAR points output from a laser scanner. Also known as a swath, or a flight line if from an airborne sensor.

Confidence level - The probability that errors are within a defined range of values.

Contour - A line connecting points of equal elevation.

Contour interval - The difference in Z-value (elevation) between adjacent contours.

Datum - Any quantity or set of quantities that may serve as a basis for calculation of other quantities.

Datum, Horizontal - A geodetic datum specifying the coordinate system to which horizontal control points are referenced.

Datum, Vertical - A set of fundamental elevations to which other elevations are referred.

DEM (***D***igital ***E***levation ***M***odel) - An acronym used as a generic term for digital topographic data. Also referred to as bare-earth elevations at regularly spaced intervals.

DGN - Bentley MicroStation design file format.

DSM (***D***igital ***S***urface ***M***odel) - Elevation dataset containing accurate X, Y, and Z coordinates of all the LiDAR system returns. A DSM contains all of the topographic, planimetric, and vegetative information of the area.

DTED (***D***igital ***T***errain ***E***levation ***D***ata) - Standard elevation datasets of the National Geospatial-intelligence Agency (NGA), similar to USGS DEMs.

DTM (***D***igital ***T***errain ***M***odel) - Similar to a DEM but incorporates significant topographic features on the land as well as masspoints and breaklines that are irregularly spaced to better characterize the shape of the terrain.

Elevation - The height above a specific vertical reference.

Ellipsoid - The Earth's ellipsoid is a biaxial ellipsoid of revolution (defined by its major axis 'a' and its minor axis 'b') obtained by rotating an ellipse about its minor (shorter) axis.

FGDC - ***F***ederal ***G***eographic ***D***ata ***C***ommittee

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FOV (***F***ield ***o***f ***V***iew) - The usable area of a LiDAR sensor's pulse pattern.

Geoid - The geoid is the imaginary surface where the oceans would seek mean sea level if allowed to continue into all land areas so as to encircle the earth. The geoid undulates up and down with local variations in the mass and density of the earth.

Grid - A geographic data model that represents information as an array of equally sized square cells. Grids are the most common structures used for modeling terrain and bathymetric surfaces.

GSD - *G*round ***S***ample ***D***istance (also referred to as NPS - Nominal Pulse Spacing

Horizontal accuracy - Positional accuracy of a dataset with respect to a horizontal datum.

Horizontal error - Magnitude of the displacement of a feature's recorded horizontal position in a dataset from its true accurate position, as measured radially and not resolved into X and Y.

Horizontal post spacing - The smallest distance between two discrete points that can be explicitly represented in a gridded elevation dataset.

Hydro-enforcement - The removal of elevations from the tops of selected drainage structures (bridges and culverts) in a DEM, TIN or topographic dataset to depict the terrain under those structures.

IMU (***I***nertial ***M***easurement ***U***nit) - Technology that computes the roll, pitch, yaw, and heading of a moving object, for example a LiDAR sensor or an aerial camera mounted on an aircraft.

Interpolation - The estimation of Z-values at a point with X/Y coordinates, based on the known Z-values of surrounding points.

LiDAR (***Li***ght ***D***etection ***A***nd ***R***anging) - A technology that employs an airborne scanning laser range finder to produce accurate topographic surveys and store other information about struck targets. Also known as ALSM (Airborne Laser Swath Mapping).

LiDAR Intensity - The strength of the returning light pulse being observed. Intensity readings can be used to produce raster image files that have the appearance of a photographic image.

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Sometimes described as reflectance.

LiDAR Pulse Rate - The number of light pulses emitted per second in a scanning array, reported in kilohertz (kHz). Pulse rates for various sensors typically range from 85,000 (85 kHz) to 500,000+ (500 kHz).

LiDAR Returns - The number of signals received back at the sensor per pulse. Some LiDAR sensors are capable of receiving up to eight returns per pulse. Typically, the first and last returns are most commonly used for mapping applications. The first return measures the first object struck. The last return ***usually*** represents the ground unless an obstruction (dense tree, car, building) obscures penetration to the ground.

Mass points - Irregularly spaced points, each with an X/Y location and a Z-value, used to form a TIN.

NDEP - ***N***ational ***D***igital ***E***levation ***P***rogram

NSSDA - ***N***ational ***S***tandard for ***S***patial ***D***ata ***A***ccuracy

PDOP (***P***osition ***D***ilution ***o***f ***P***recision) **-** Measure of the geometrical strength of the GPS satellite configuration.

Point cloud - A point cloud elevation file is generally a raw data file containing three-dimensional (3D) point samples, i.e. discrete X/Y points with elevations.

Point density - the number of LiDAR points per square horizontal unit.

Positional accuracy - The accuracy of the position of features, including horizontal and/or vertical positions.

Post spacing - The Z-values at regularly spaced intervals of a grid. The post spacing is usually specified in units of whole feet or meters.

Profile (aka cross-section) - A vertical view of a surface derived by sampling surface values along a specified line. In USGS DEMs, profiles are the basic building blocks of an elevation grid and are defined as one-dimensional arrays, i.e., arrays of n columns by 1 row, where n is the length of the profile.

RTK (***R***eal-***T***ime ***K***inematic) - A process or system used in surveying in which a GPS base station re-

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broadcasts signals to mobile receivers with very little accuracy loss.

Resolution - Related to the horizontal post spacing and the vertical precision. Also defined as the size of the smallest feature that can be represented in a surface or image.

RMSE (***R***oot ***M***ean ***S***quare ***E***rror) **-** The square root of the mean (average) of squared errors for a sample.

Slope - The measure of change in Z-value over distance, expressed either in degrees or as a percentage.

Surface - A 3D geographic feature represented by computer models built from uniformly or non-uniformly spaced points with X/Y coordinates and Z-values.

TIN (***T***riangulated ***I***rregular ***N***etwork) - A set of adjacent, non-overlapping triangles generated from irregularly spaced points with X, Y, and Z coordinate values.

USGS - ***U***nited ***S***tates ***G***eological ***S***urvey, the federal agency responsible for establishing and maintaining the Lidar Base Specifications used for many lidar product deliveries.

Vertical accuracy - Measure of the positional accuracy of a dataset with respect to a specified vertical datum.

Vertical error - The displacement of a feature's recorded elevation in a dataset from its true or more accurate elevation.

Voids (aka holidays) - Portions of a digital elevation dataset where no elevation data are available.

Well-defined point - A point that represents a feature for which the horizontal position is known to a high degree of accuracy with respect to the geodetic datum.

WKT (***W***ell-***K***nown ***T***ext) - A protocol for storing coordinate reference system information.

X-coordinate - The distance along the X-axis from the origin of a 2D or 3D Cartesian coordinate system.

Y-coordinate - The distance along the Y-axis from the origin of a 2D or 3D Cartesian coordinate system.

Z-coordinate - The distance along the Z-axis from the origin of a 3D Cartesian coordinate system.

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The elevation or height above the vertical datum.

Z-values - The elevations of the 3D surface above the vertical datum at designated X/Y locations.

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