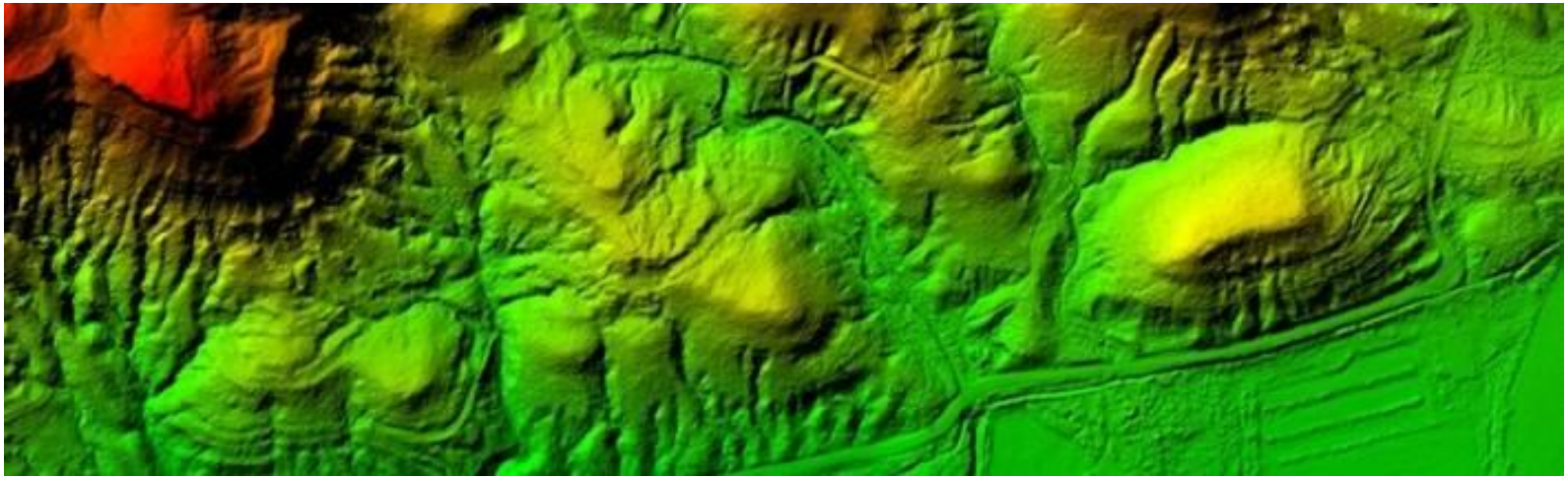
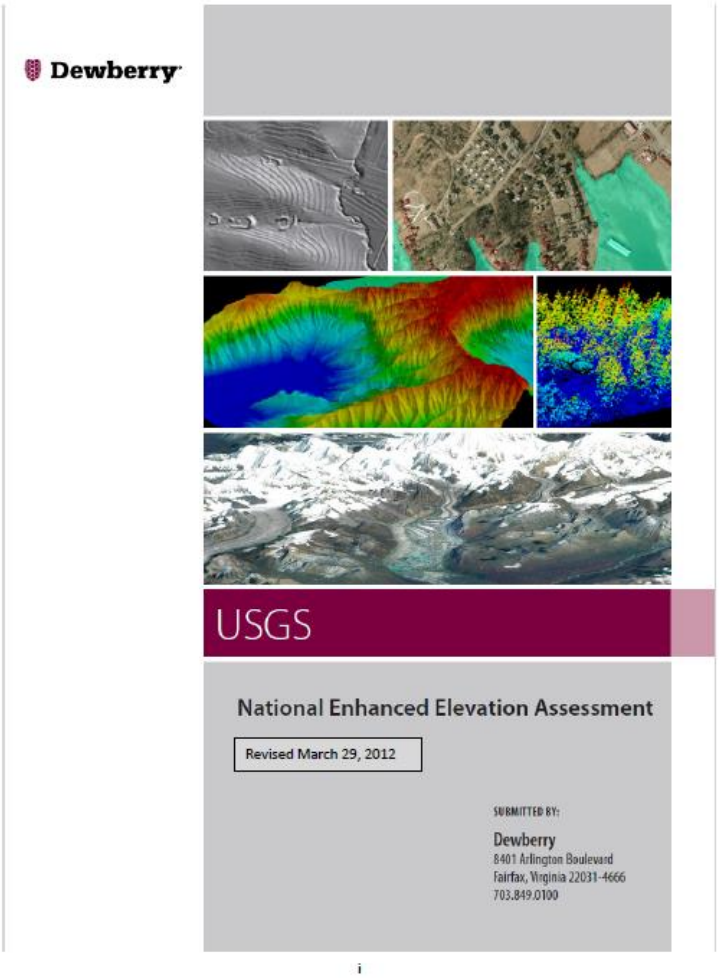
Dewberry



LARIAC4

Lidar Acceptance Criteria

3D Elevation Program (3DEP)



- Dewberry authored the National Enhanced Elevation Assessment that led to the 3DEP, based on nationwide QL2 lidar (LiDAR)
- We are a leading producer of QL2 lidar for USGS, FEMA, USACE and NOAA
- For LARIAC4, Dewberry will perform independent QA/QC of Pictometry's lidar to ensure compliance with specifications

Dewberry

Acceptance Criteria

- Based on the following documents:
  - USGS Lidar Base Specification Version 1.2, November 2014, as pertains to QL2 lidar
  - ASPRS Positional Accuracy Standards for Digital Geospatial Data (Edition 1, Version 1.0. – November, 2014)
  - LARIAC4 SOW which adds requirements for contour lines in addition to standard lidar deliverables required by USGS

Acceptance Criteria – Collection Requirements

Parameter	Requirement	Validation Approach
Nominal Pulse Spacing	Nominal Pulse Spacing (NPS) 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 ~90%) of each swath.	Dewberry will calculate the NPS of each swath using a QT Modeler script. The output of the script will be recorded and documented in the project report. The values will be reported as the NPS for single swaths and an ANPS for the final classified LAS in tile format.
Signal Returns	The laser system shall be configured to collect multiple echoes per pulse, with a minimum of a first return and a last return and at least one additional intermediate return. All returns captured during acquisition shall be delivered. Return number shall be recorded.	Dewberry will validate that system returns have been captured through the use of a custom python script that verifies the header information stored in the LAS file. The results of this validation will be documented in our project report.
GPS Times	Shall be recorded as Adjusted GPS Time, at a precision sufficient to allow unique timestamps for each return. Adjusted GPS Time is defined to be Standard (or satellite) GPS time minus $1*10^9$. See the LAS Specification for more detail	Dewberry will validate that adjusted GPS time as been recorded by running a custom python script that validates the header information. For this validation we will verify the GPS time as well as the global encoder bit which must be set properly for other software to recognize the time as adjusted GPS time.
Signal Strength	The signal strength (intensity) of each return pulse shall be recorded.	Dewberry will validate that the intensity of each pulse has been recorded properly through the use of an automated script. The results of this script will be documented in the project report.
Spatial Distribution	The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the data set: (a) A regular grid, with cell size equal to the design 2*NPS will be laid over the data, (b) At least 90% of the cells in the grid shall contain at least 1 lidar point.(c) Clustering will be tested against the 1st return only data of points located in the geometrically usable center part (typically 95%) of each swath.(d) Acceptable data voids identified elsewhere in this task order are excluded.	Dewberry will validate the spatial distribution of the points using a QT modeler script that divides the swath into a grid that is 2* the NPS (1.4 meters) and calculates the number of LiDAR returns in each cell. This creates a raster with the point counts for each cell as well as a value for the percentage of cells with at least one point. The graphical output along with the percentage will be documented in the project report.

Acceptance Criteria – Collection Requirements

Overlap	Flight line overlap is at the contractor's discretion, but is cautioned to be vigorous to ensure there are no data gaps between the usable portions of the swaths and to ensure the nominal pulse density (NPD) can be achieved. Collections in high relief terrain are expected to require greater overlap. Any data with gaps between the geometrically usable portions of the swaths will be rejected.	Dewberry will validate the overlap of the swath data to ensure sufficient coverage with no voids between swaths. This will be completed using GeoCue and TerraScan software. The output of the review will be included in the project report.
Data Voids	Data Voids [areas => 4(NPS^2), measured using 1^{st}-returns only] within a single swath are not acceptable, except: (a) where caused by water bodies. (b) Where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing. (c) where appropriately filled-in by another swath	Dewberry will validate the overlap of the swath data to ensure sufficient coverage with no voids between swaths. This will be completed using GeoCue and TerraScan software. The output of the review will be included in the project report.
Atmospheric Conditions	Cloud and fog-free between the aircraft and ground	Dewberry will validate the daily flight logs and status updates to ensure conditions on were suitable.
Ground Conditions	Snow free; No unusual flooding or inundation, except in cases where the goal of the collection is to map the inundation. Data shall be acquired to minimize the effects of variable water elevations within the project area. Contractor shall seek approval to acquire LiDAR data prior to 72 hours following a rain event of 0.5 inches or greater within the project area. LiDAR data shall not be acquired during high water events and/or recent rain events which may affect the resultant digital elevation model. If weather conditions and/or hydrologic conditions do not meet specified requirements, Contractor must receive customer approval before flying.	Dewberry will verify that ground conditions were suitable and will validate the weather as it existed during collection.
Vegetation Requirements	Leaf-off is preferred, however as numerous factors will affect vegetative condition at the time of any collection, the USGS National Geospatial Program (NGP) only requires that penetration to the ground must be adequate to produce an accurate and reliable bare-earth surface suitable for incorporation into the 1/9 (3-meter) NED	Dewberry will verify that the vegetation conditions were accepted based on the project plan and report submitted by TBD.

Acceptance Criteria – Accuracy

Description	Accuracy Requirement	Validation Approach
Non-Vegetated Vertical Accuracy (NVA)	≤10 cm RMSEz / ≤19.6cm at the 95% Confidence Level (LiDAR/DEM)	The validation will be performed using TerraScan/TerraModeler for the LiDAR validations and ArcGIS for the DEM validations. This will enable our analysts to quickly determine the differences between the LiDAR and checkpoints. The values are then input into a worksheet designed by Dewberry to quickly calculate all of the accuracy statistics. This validation will occur at: 1. The initial delivery of the calibrated swath data prior to any classification. This validation will be reported to USGS as part of the pilot deliverables. 2. At the completion of the project on the final classified LiDAR tiles and the DEM products. These results will be reported in the final project report along with other descriptive statistics.
Vegetated Vertical Accuracy (VVA)	≤29.4 cm at the 95th Percentile (LiDAR/DEM)	The validation will be performed using TerraScan/TerraModeler for the LiDAR validations and ArcGIS for the DEM validations. This will enable our analysts to quickly determine the differences between the LiDAR and checkpoints. The values are then input into a worksheet designed by Dewberry to quickly calculate all of the accuracy statistics. This validation will occur at: 1. At the completion of the pilot any points falling within the area will be calculated. These values will be reported in the pilot deliverables. 2. At the completion of the project on the final classified LiDAR tiles and the DEM products. These results will be reported in the final project report along with other descriptive statistics.
Relative Accuracy (between swaths)	≤8 cm RMSE with a maximum allowable difference of 16 cm.	Dewberry has designed a process to validate the relative accuracy between swaths that provides both a graphical representation of the relative accuracy in the form of DZ orthos as well as an actual RMSE value. The DZ orthos are generated in GeoCue and allows our analysts to quickly review 100% of the overlapping areas for anomalies in the relative accuracy. Once this is completed we run the LiDAR through a series of automated processes which are designed to identify areas that are free from vegetation and with minimal slope. These areas are then extracted and the difference values are exported for each cell. The final values are then processed in excel to determine the RMSE. The relative accuracy will be reported to USGS in the final report.
Relative Accuracy (within a single swath)	≤6 cm RMSE	Dewberry has designed a process to validate the relative accuracy within swaths that provides both a graphical representation of the relative accuracy in the form of a difference raster as well as an actual RMSE value. The difference raster is generated in QT Modeler allows our analysts to quickly review 100% of the LiDAR swaths for anomalies in the relative accuracy within the swath. Once this is completed we run the LiDAR through a series of automated processes which are designed to identify areas that are free from vegetation and with minimal slope. These areas are then extracted and the difference values are exported for each cell. The final values are then processed in excel to determine the RMSE. The relative accuracy within a swath will be reported to USGS in the final report.

Acceptance Criteria – Accuracy

- Dewberry also plans to test the horizontal accuracy of the Lidar data using the checkpoints collected in 2014.
  - The ability to assess the horizontal accuracy is largely dependent on the features being visible in the intensity imagery.
- Dewberry will use the guidance in the ASPRS Positional Accuracy Standards to calculate the horizontal accuracy.

Acceptance Criteria – LAS Deliverables

Requirement	Validation Approach
LAS Version 1.4	Dewberry will perform an evaluation of all LAS deliverables to ensure they are fully compliant with LAS v1.4 requirements. This is conducted using a custom python script that validates all LAS headers and records.
Point Record Format 6-10	Dewberry will perform an evaluation of all LAS deliverables to ensure the correct point record format has been set. This is conducted using a custom python script that validates all LAS headers and records.
Overlap (Overage) Bit/Withheld Bit	Dewberry will perform an evaluation of all LAS deliverables to ensure the correct bits have been set. This is conducted using a custom python script that validates all LAS headers and records. Additional verification will come from a visual review of the point cloud data to ensure that points with this bit set are displaying properly in TerraScan, LP360, and ArcGIS software.
Georeferencing Information in OGC WKT Format	Dewberry will verify the header information of all LAS files to ensure they are fully compliant with the WKT requirement in LAS v1.4. UTM Zones 14 and 15 will both be present in the project. Dewberry will verify that the correct projection has been set.
Adjusted GPS Time (correct global encoder bit)	Dewberry will perform an evaluation of all LAS deliverables to ensure the correct GPS time has been set along with the correct global encoder bit.. This is conducted using a custom python script that validates all LAS headers and records. An additional validation step will be to convert the adjusted GPS time to julian dates to ensure it aligns with the project.
Full Swaths	All swaths will be loaded into GeoCue and their extents will be reviewed to ensure full coverage of the project area.
Raw Point Cloud Data Classification (Class 0 - Withheld bit and overlap bit assigned)	Dewberry will perform an evaluation of all LAS deliverables to ensure they are fully compliant with LAS v1.4 requirements. This is conducted using a custom python script that validates all LAS headers and records.
Classified Point Cloud Data Classification (Class 1, 2, 7, 9, 10, 17, 18 - Withheld bit and Overlap bit assigned)	The classified LAS will undergo a full compliance validation at a macro level (1:25,000) and micro level only where issues in the DEM or macro review have been identified. This will validate that all files are classified accurately and consistently with the USGS requirements. An overview of the review along with the final results will be provided in the final project report.

Acceptance Criteria – Point Classification

- Class 0 – Raw point data never classified
- Class 1 – Processed, but unclassified
- Class 2 – Bare Earth
- Class 7 – Low Noise
- Class 9 – Water
- Class 10 – Ignored Ground (near a breakline)
- Class 17 – Bridge Decks
- Class 18 – High Noise

Acceptance Criteria – Breaklines

Feature	Collected	Capture Rules and Validation
Inland Ponds and Lakes	Yes	Water bodies greater than ¾ acres shall be captured as closed polygons with the water feature to the right. The compiler shall take care to ensure that the z-value remains consistent for all vertices placed on the water body. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. An Island within a Closed Water Body Feature that is 1 acre in size or greater will also have a "donut polygon" compiled. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water.
Inland Streams and Rivers	Yes	Capture features showing dual line (one on each side of the feature). Average width shall be greater than 50 feet to show as a double line. Each vertex placed should maintain vertical integrity. Generally both banks shall be collected to show consistent downhill flow. There are exceptions to this rule where a small branch or offshoot of the stream or river is present. The banks of the stream must be captured at the same elevation to ensure flatness of the water feature. If the elevation of the banks appears to be different see the task manager or PM for further guidance. Breaklines must be captured at or just below the elevations of the immediately surrounding terrain. Under no circumstances should a feature be elevated above the surrounding LiDAR points. Acceptable variance in the negative direction will be defined for each project individually. These instructions are only for docks or piers that follow the coastline or water's edge, not for docks or piers that extend perpendicular from the land into the water. If it can be reasonably determined where the edge of water most probably falls, beneath the dock or pier, then the edge of water will be collected at the elevation of the water where it can be directly measured. If there is a clearly-indicated headwall or bulkhead adjacent to the dock or pier and it is evident that the waterline is most probably adjacent to the headwall or bulkhead, then the water line will follow the headwall or bulkhead at the elevation of the water where it can be directly measured. If there is no clear indication of the location of the water's edge beneath the dock or pier, then the edge of water will follow the outer edge of the dock or pier as it is adjacent to the water, at the measured elevation of the water. Every effort should be made to avoid breaking a stream or river into segments. Dual line features shall break at road crossings (culverts). In areas where a bridge is present the dual line feature shall continue through the bridge. Islands: The double line stream shall be captured around an island if the island is greater than 0.5 acres. In this case a segmented polygon shall be used around the island in order to allow for the island feature to remain as a "hole" in the feature.

Acceptance Criteria – Breaklines

Bridge Polygons	Yes	All bridges within the project area shall be collected as a polygon feature. The extent of the bridge will be generated visually to determine the extents of the actual bridge deck. These polygons will be used to classify the bridge points (class 17) in the LAS files.
Under Bridge Saddle	Yes	In areas where the DEM produces a saddle under the bridge additional breaklines shall be collected to support the generation of the DEM. These breaklines shall be placed perpendicular to the bridge at the top and bottom of the embankment (at minimum). Vertices are to be placed in areas where the density of the ground points is sufficient to model the surface. One vertex should be placed on either side of the bridge and the elevations derived from the LiDAR surface.

Tidal waters, per USGS QL2 specifications

- As the DEM should represent as much ground as the collected data permits, lidar ground points shall not be removed for the sake of adjusting a shoreline inland to match another shoreline.
- Likewise, adjusting a shoreline outland will create an equally unacceptable area of unmeasured land in the DEM.
- It is recommended that, to the highest degree practical, collections be planned to minimize tidal differences at the land-water interface.

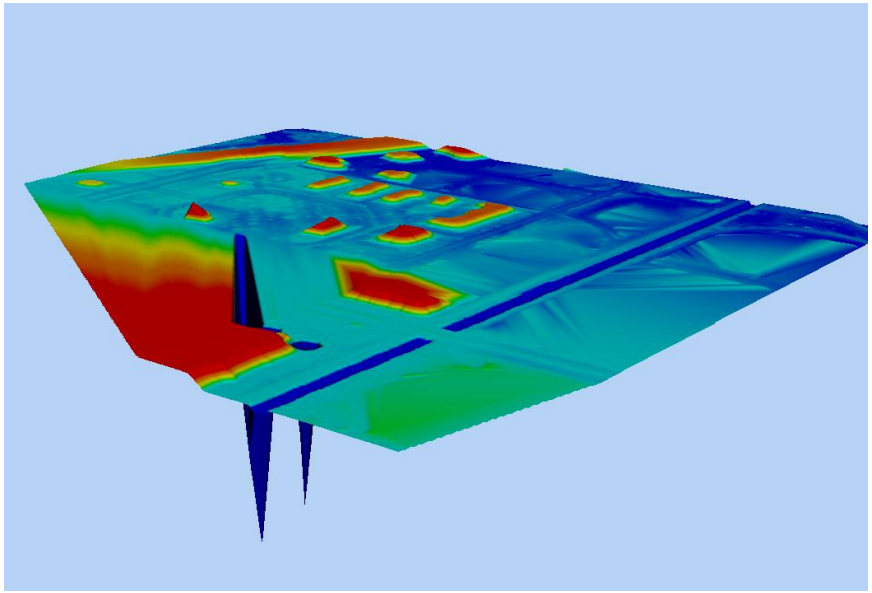
Acceptance Criteria – Derivative Products

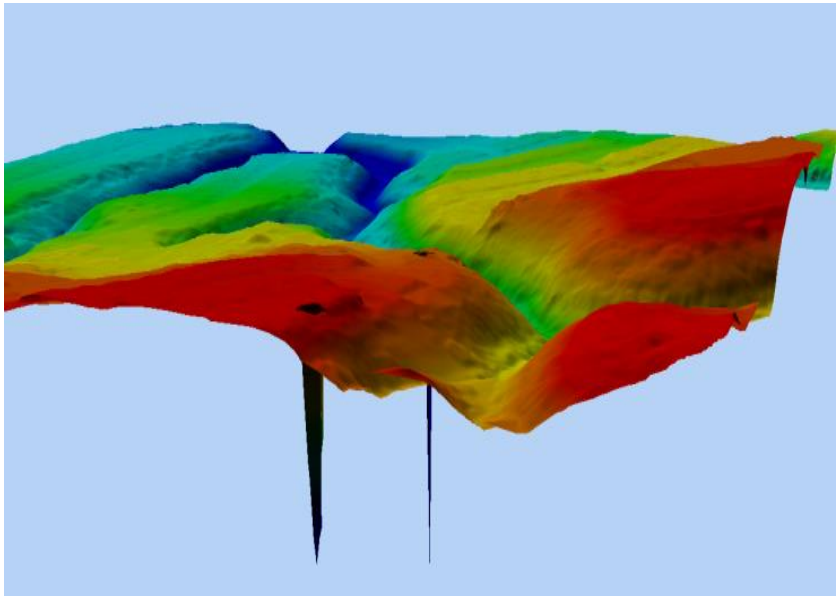
Product	Validation Methods
Hydro-Flattened DEM	Dewberry will review the DEM products in detail to ensure no artifacts or classification errors are present. The review will ensure that all bare earth DEM products meet the USGS v1.2 guidelines and are suitable for ingestion into the NED. 1. DEM will be created with a grid spacing of 1 meter. 2. 32-bit floating point raster format in ERDAS .img 3. All files must have the correct Georeferencing 4. Tiles shall not have any edge artifacts or mismatches. 5. Void areas will be coded as NoDATA 6. Depressions and Sinks are not to be filled
First Return DSM	Dewberry will review the DSM products to ensure they represent the first return surface free of major artifacts and noise (spikes and wells) 1. DSM will be created with a grid spacing of 1 meter. 2. 32-bit floating point raster format in ERDAS .img 3. All files must have the correct Georeferencing. 4. Tiled delivery without overlap, should not have any edge artifacts or mismatches.
Intensity Imagery	Dewberry will review the intensity imagery to ensure it matches the project tile scheme are created from the first return LiDAR. File format will be ERDAS .img.
Contours	Contours will be developed using the LiDAR ground and breaklines. Contours shall be at 1' intervals with Index, Intermediate, and depression contours present. Contours crossing through buildings shall be coded as hidden index or hidden intermediate. Contours will be free of topology errors related to overlapping or intersecting contours as well as dangles within the project boundary. Contours will snap between tiles throughout the project area. Contours crossing large rivers or streams should cross perpendicular to the stream and those crossing single line drains should show the direction of flow of the feature. Contours should not cross large waterbodies unless the surface elevation of the water is changing such as with certain reservoirs.

Acceptance Criteria – Derivative Products

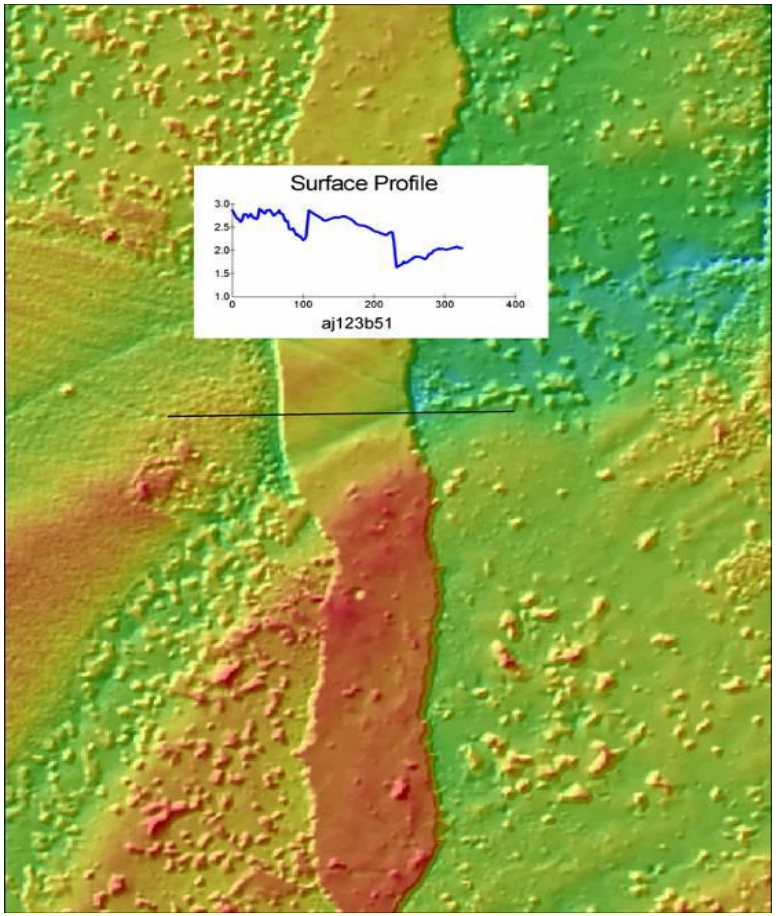
Metadata	Dewberry will validate metadata for all required deliverables. Some metadata is in the form of XML files while others is listed in TO as reports or additional files. A breakdown of the deliverables that Dewberry will review is as follows: 1. Collection Report detailing mission planning and flight logs (PDF Deliverable). 2. Survey Report detailing the collection of control and check points used for calibration and QA/QC (PDF Deliverable). 3. Processing Report detailing calibration, classification, and product generation procedures including methodology used (PDF Deliverable). 4. QA/QC Reports (detailing the analysis, accuracy assessment and validation of (PDF Deliverable): a. The point data (absolute, within swath, and between swath) b. The bare-earth surface (absolute) c. Other optional deliverables as appropriate 1. Calibration points and any validation points: All control and check points used to calibrate, control, process, and validate point data or any derivative products are to be delivered (Shapefile Deliverable). the lidar 2. Geo-referenced, digital spatial representation (shapefile) of the precise extents of each delivered dataset. This should reflect the extents of the actual lidar source or derived product data, exclusive of Triangular Irregular Network (TIN) artifacts or raster NODATA areas. A union of tile boundaries or minimum bounding rectangle is not acceptable. ESRI Polygon shapefile is preferred (Shapefile Deliverable). 3. Product metadata (FGDC compliant, XML format metadata). One file for each (XML Deliverable): a. Project b. Lift (note: this one per lift – not one per project) c. Tiled deliverable product group (classified point data, bare-earth DEMs, etc.). Metadata files for individual tiles are not required.

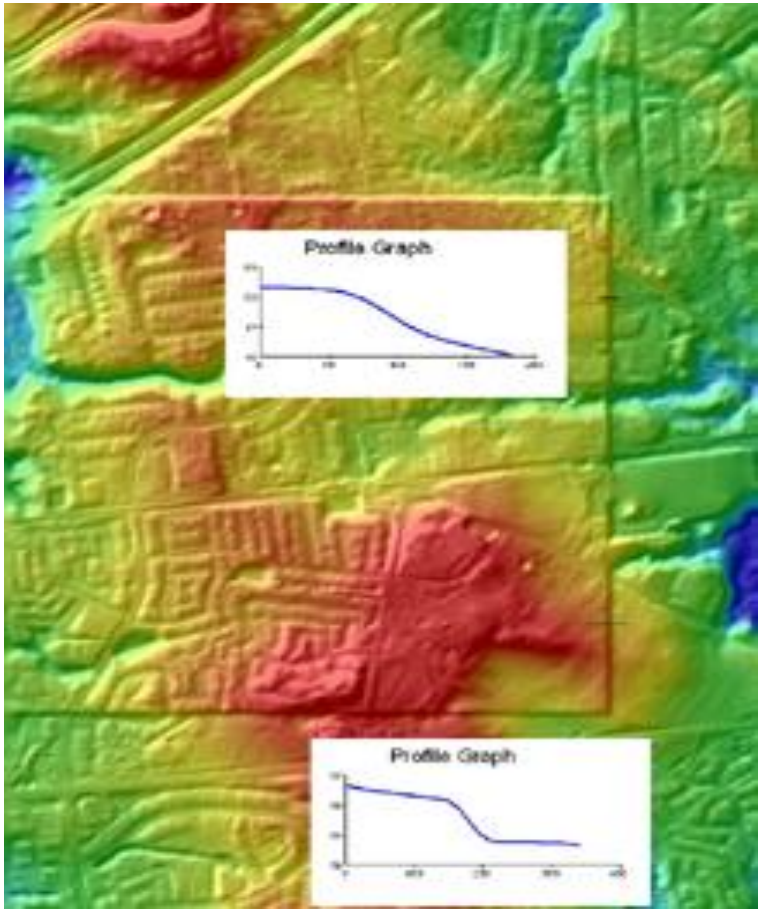
Examples of Errors – Spikes and divots





Examples of Errors – Systematic Errors





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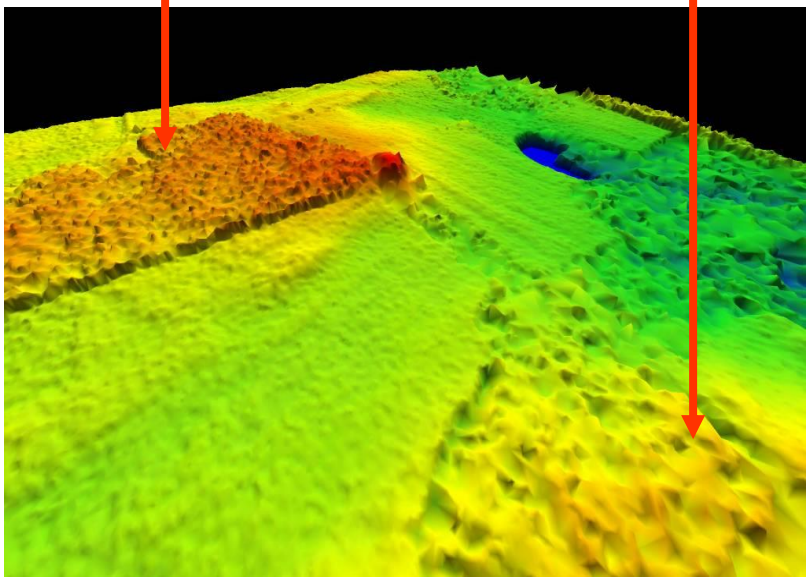
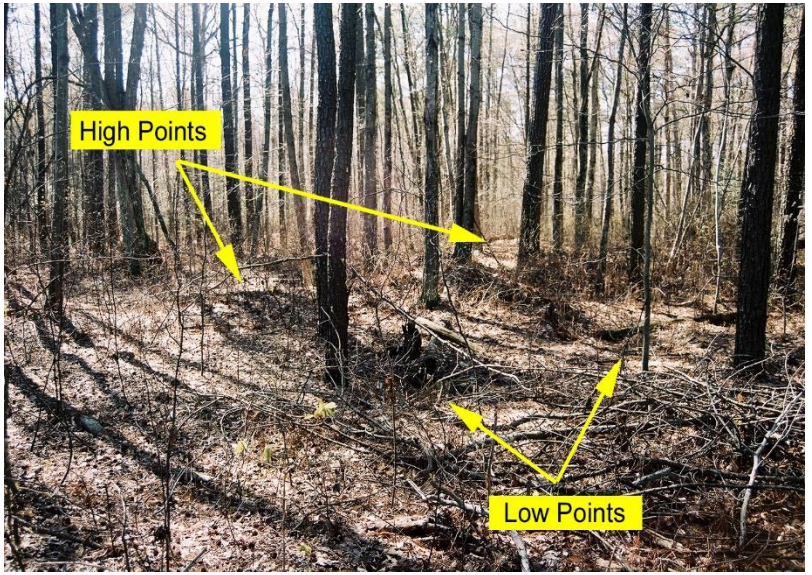
Examples of Errors – Classification Errors

Corn field

Why noisy?

Here's why





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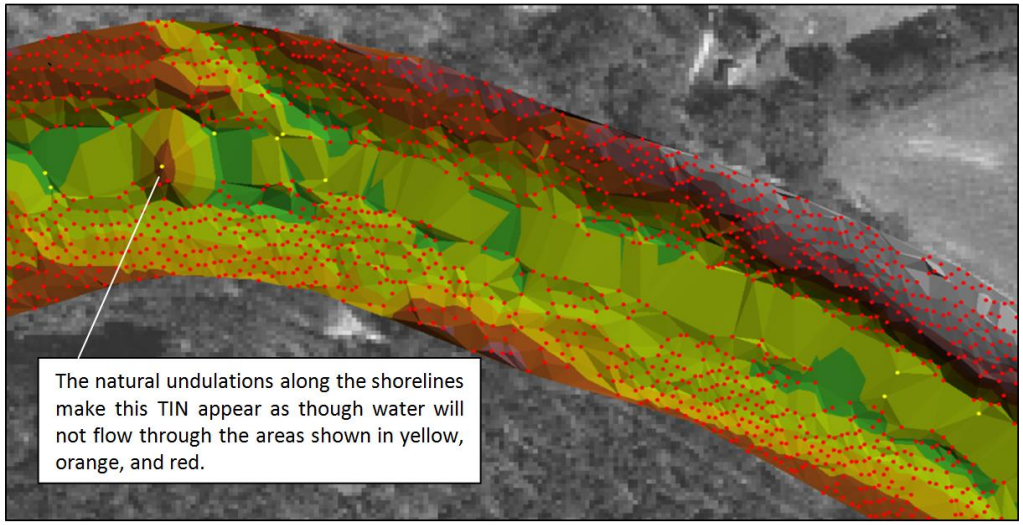
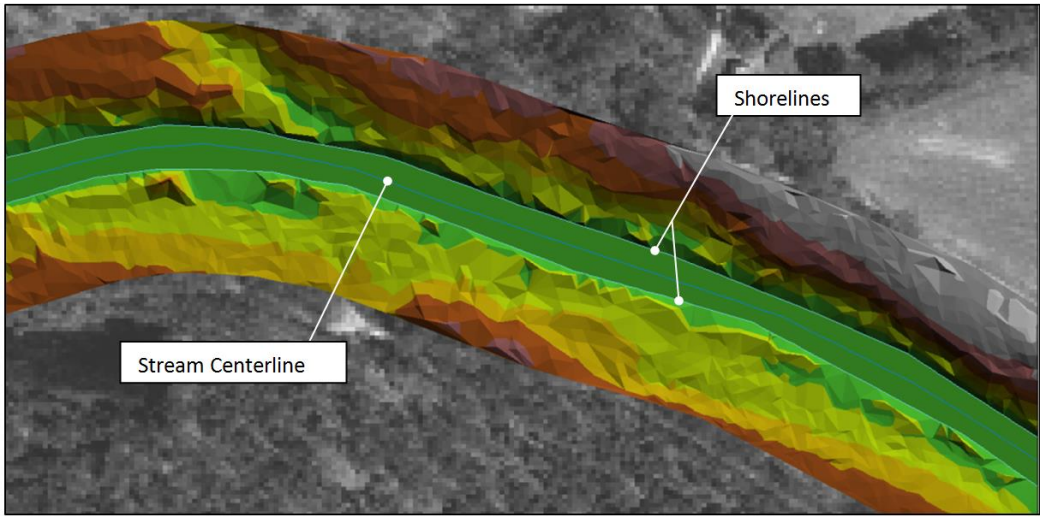
Hydro-enforcing a stream with breaklines



TINing



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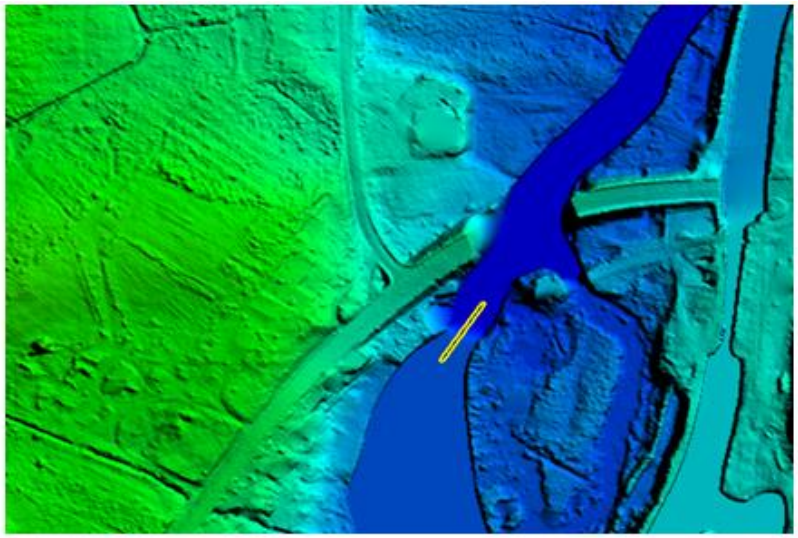
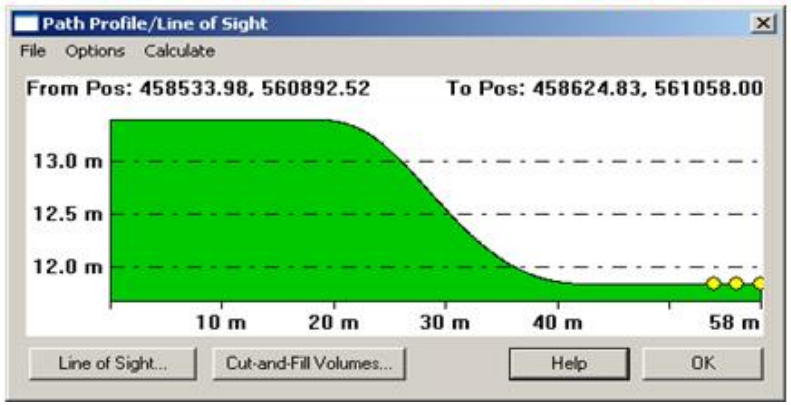
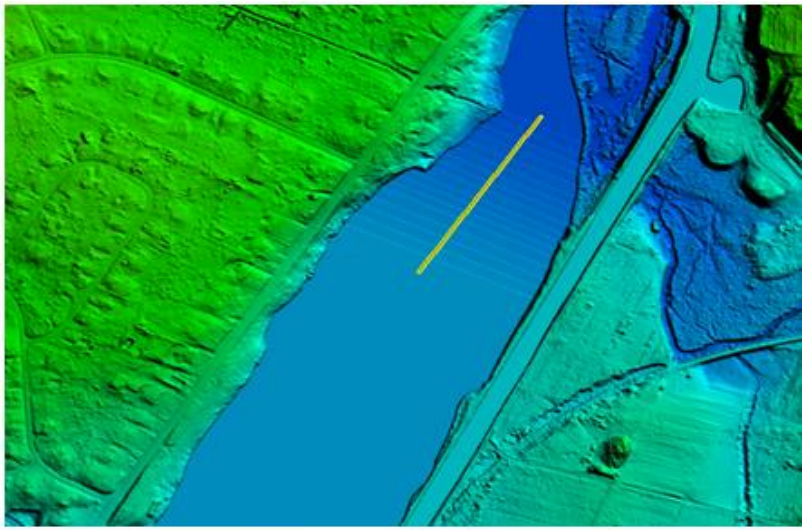
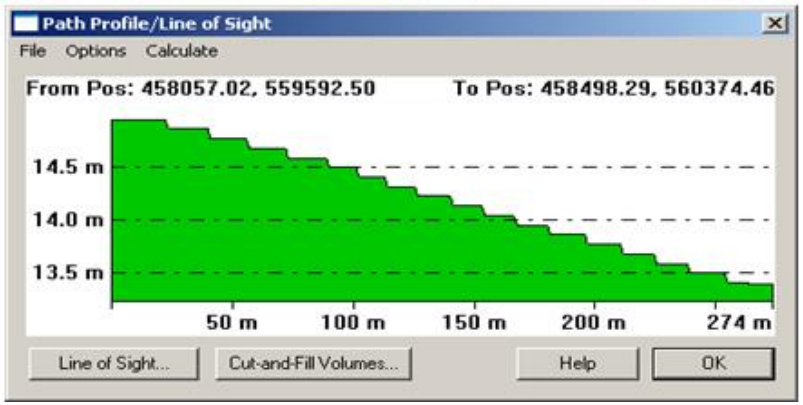
Hydro-flattening and hydro-enforcement









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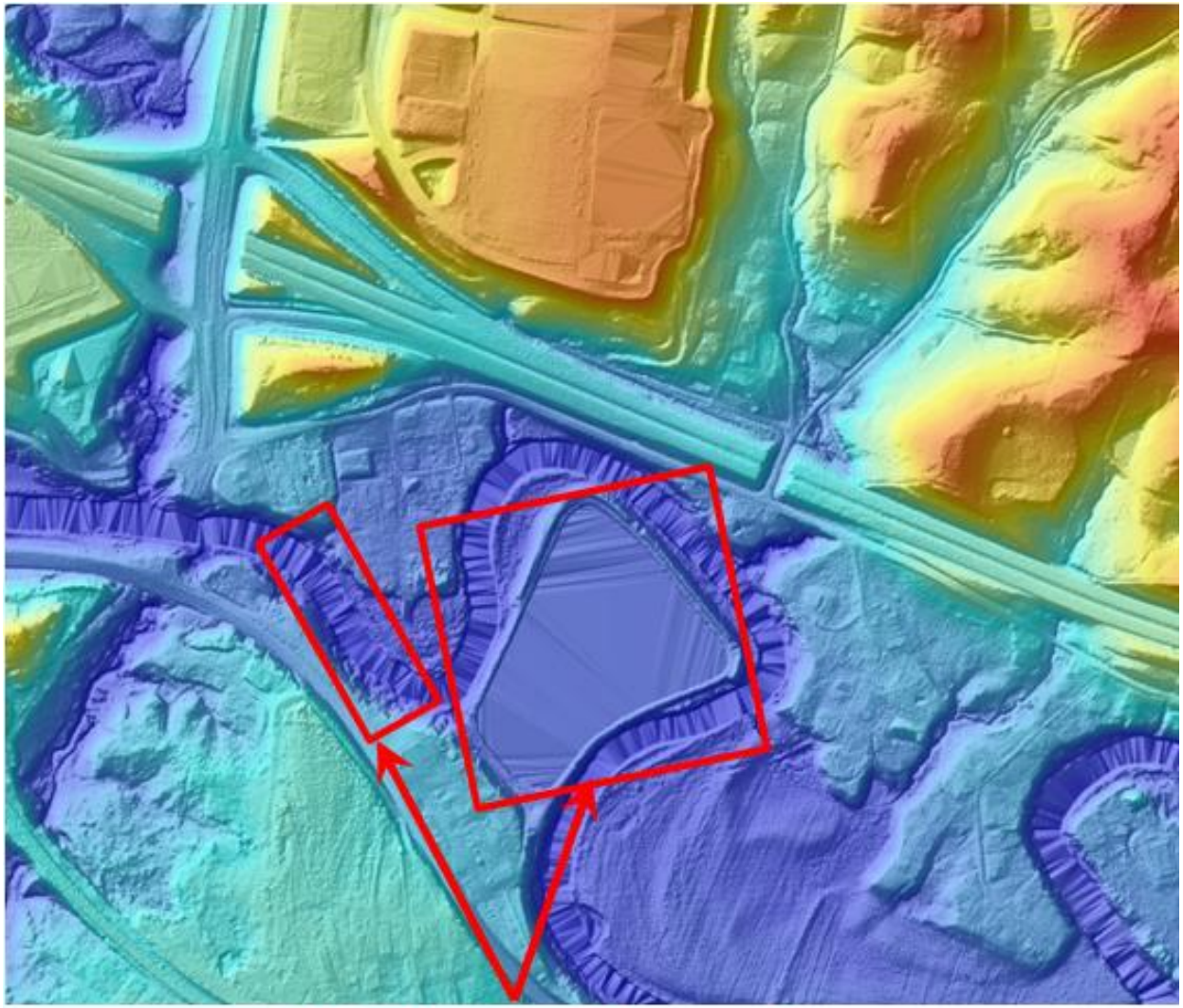
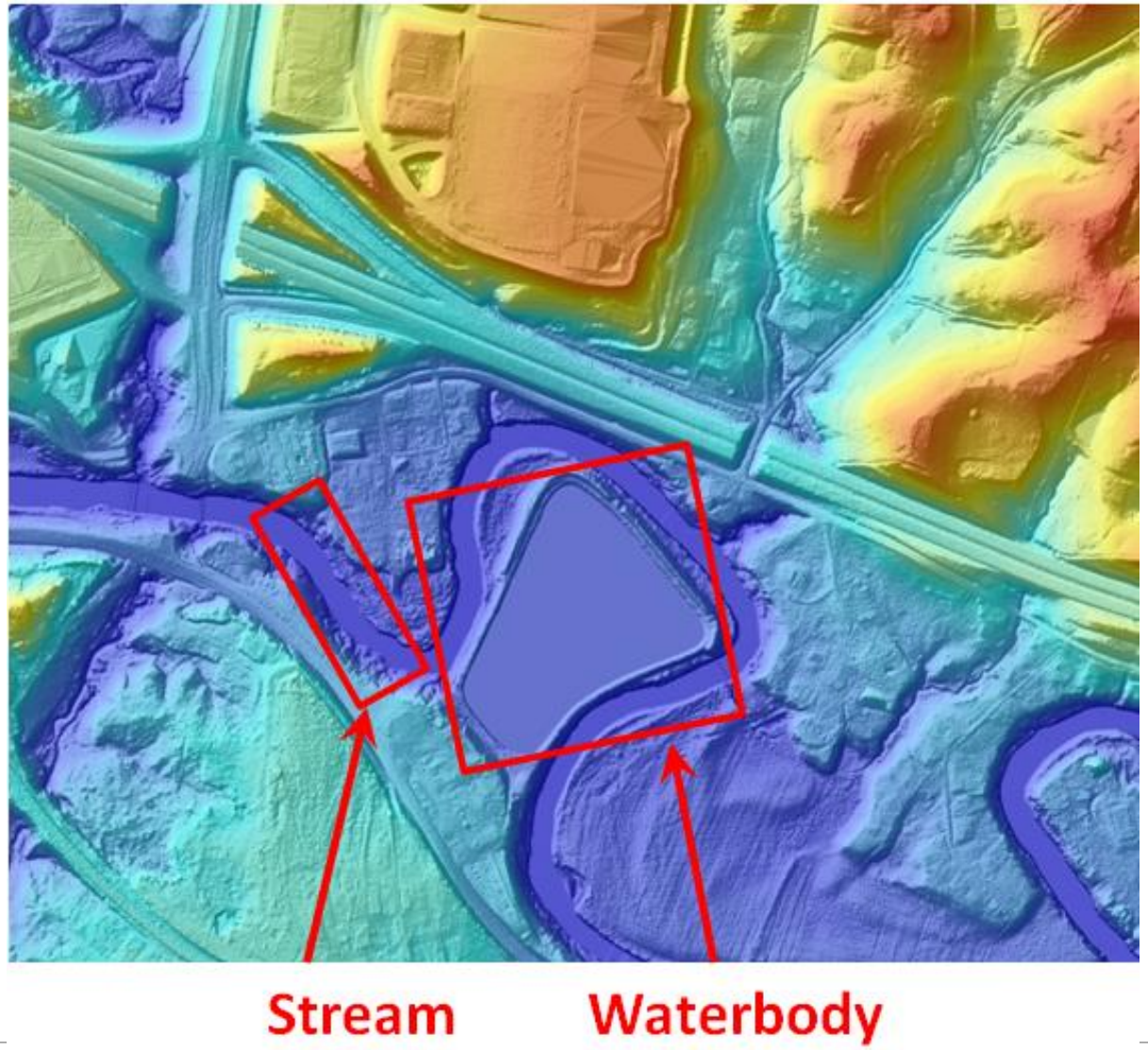
Lidar TINing of streams and lakes



TINning in Water Areas

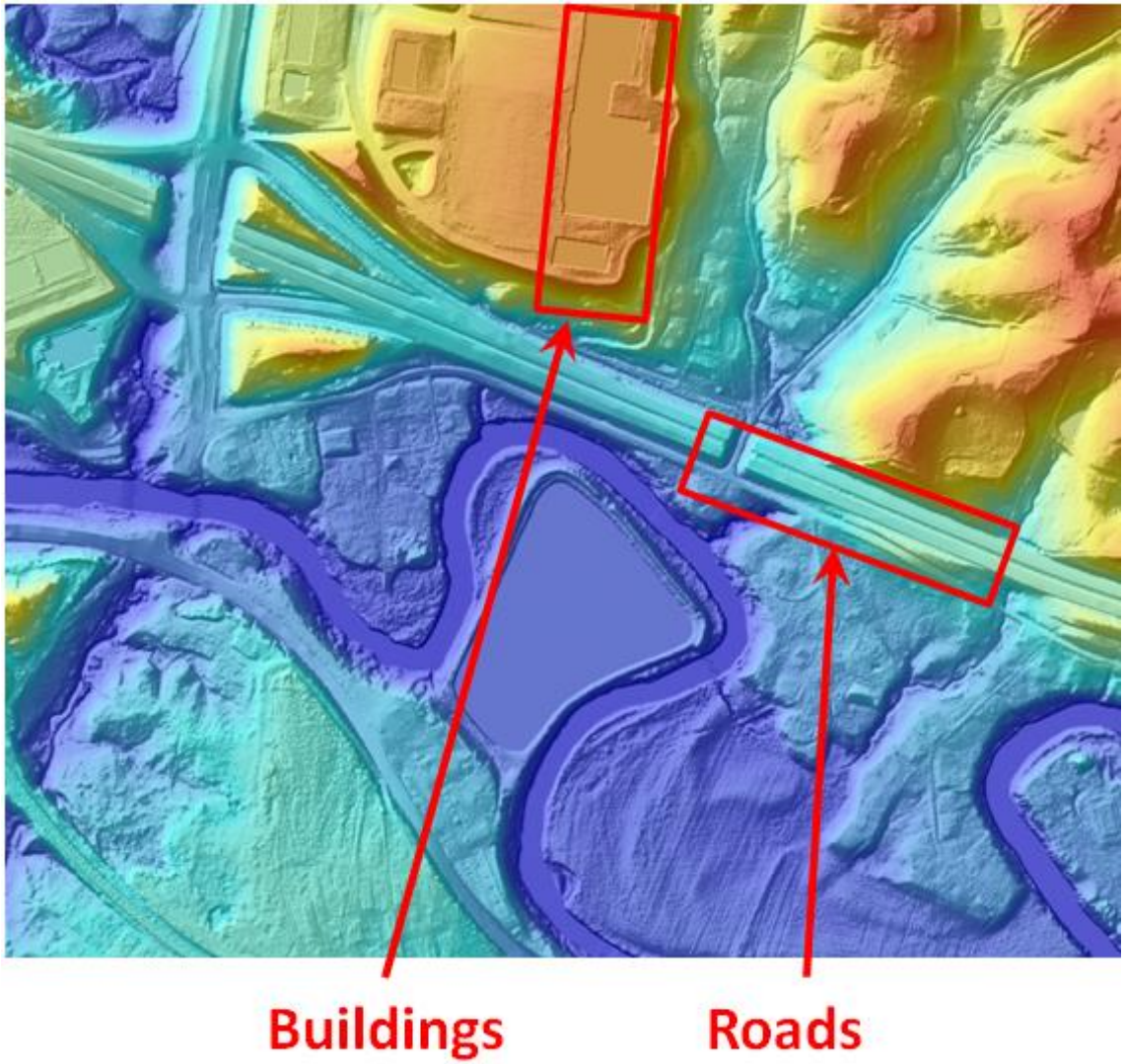
Breaklines are required for both hydro-flattening and hydro-enforcement

Hydro-flattening from shore to shore



Breaklines are required for hydro-flattening of streams and lakes so water levels are flat from shore to shore, and for hydro-enforcement of streams so water flows continuously downstream

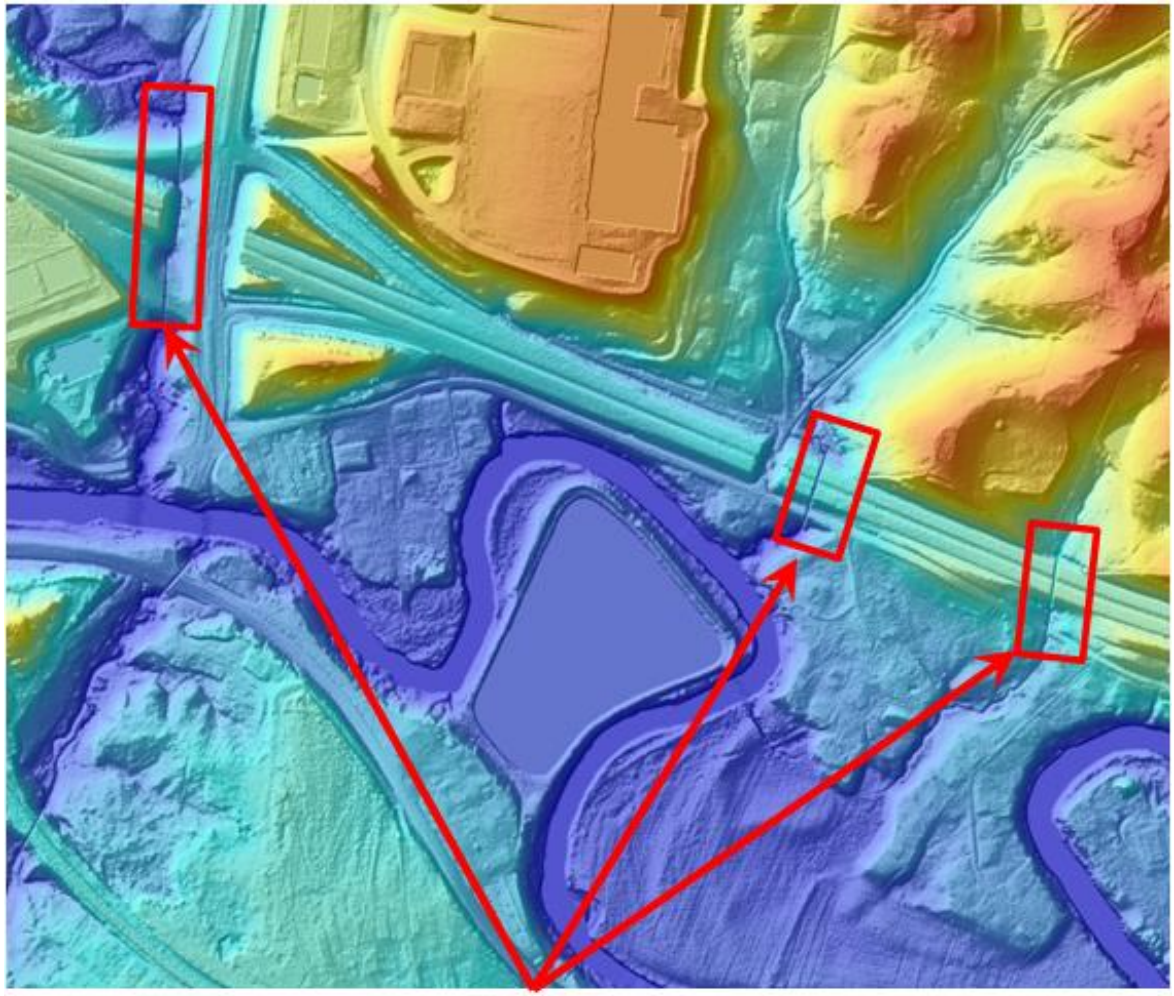
Breaklines for buildings and roads



Breaklines of building footprints are needed for hidden contours to pass through buildings at theoretical ground levels, rather than contouring over roofs.

Breaklines of some roads may be needed for contours to pass smoothly across and not meander.

Don’t cut culverts unless >30 ft



Culverts Cut Through Roads

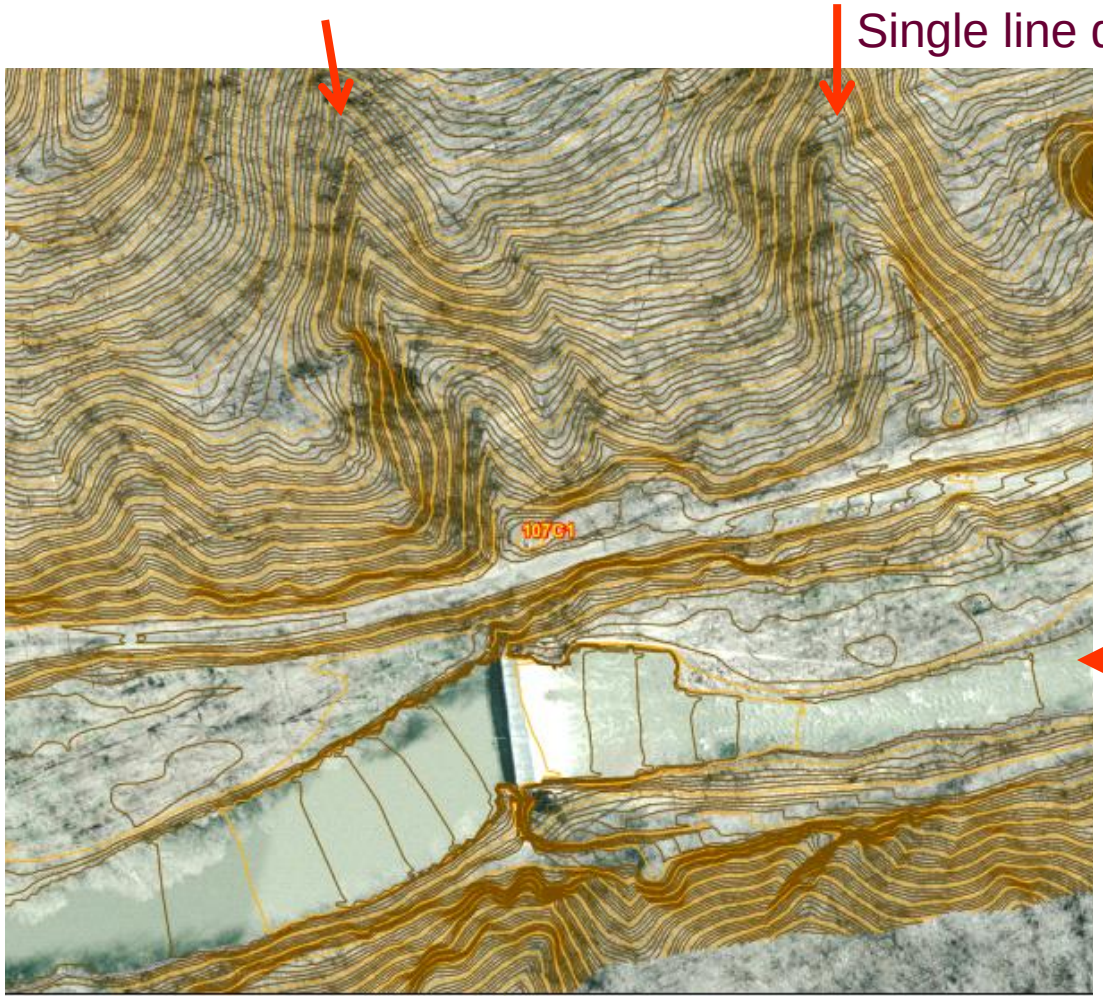
Bridges are always cut with breaklines , and elevations are placed in LAS class 17

Breaklines of concrete box culverts are cut only if large, normally longer than 30 feet

Hydro breaklines are normally not cut for small culverts such as the two shown on the right.

Good contours of drainage features

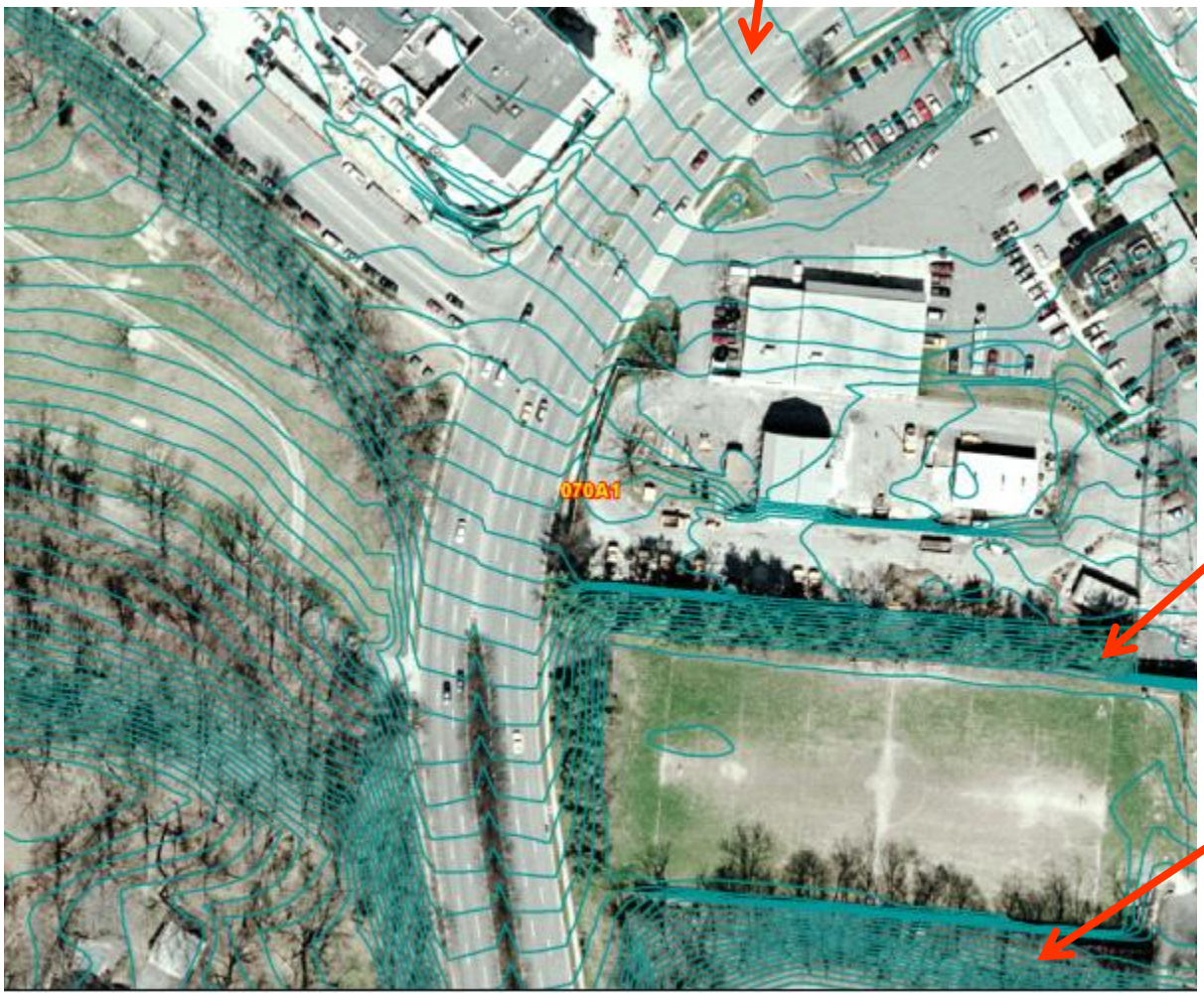
Contours are for humans



Dewberry

Good contours crossing roads and buildings

Breaklines smooth contours crossing roads

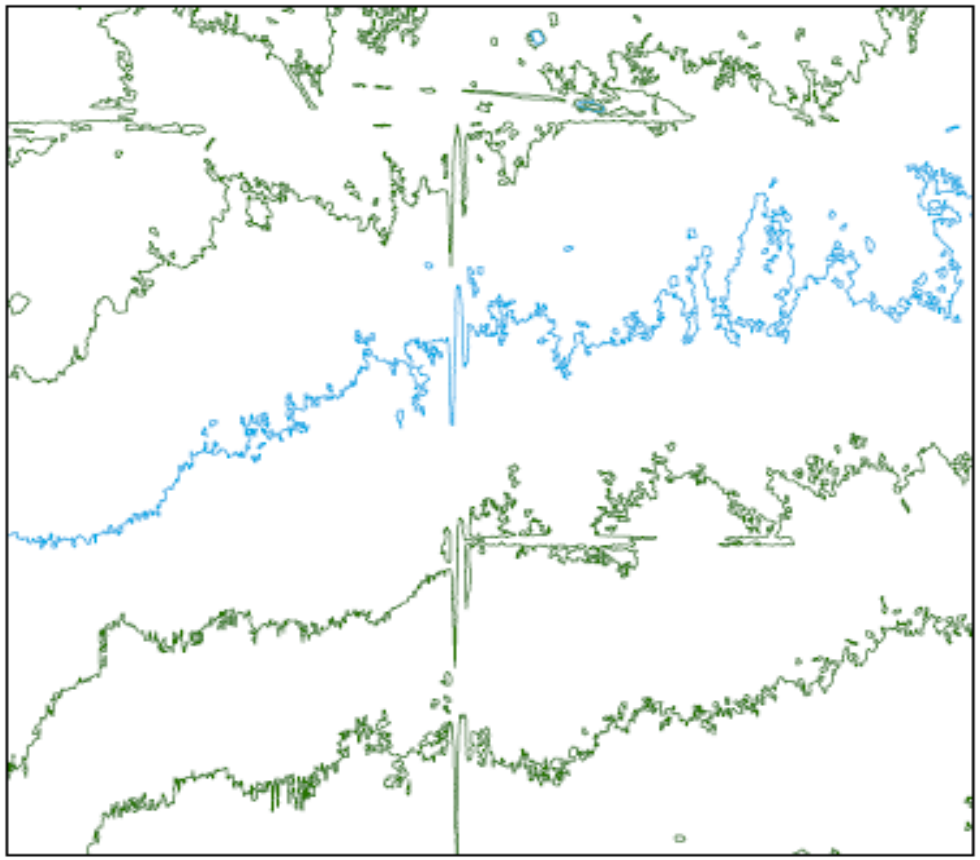


Humans must be able to see where terrain is steeper

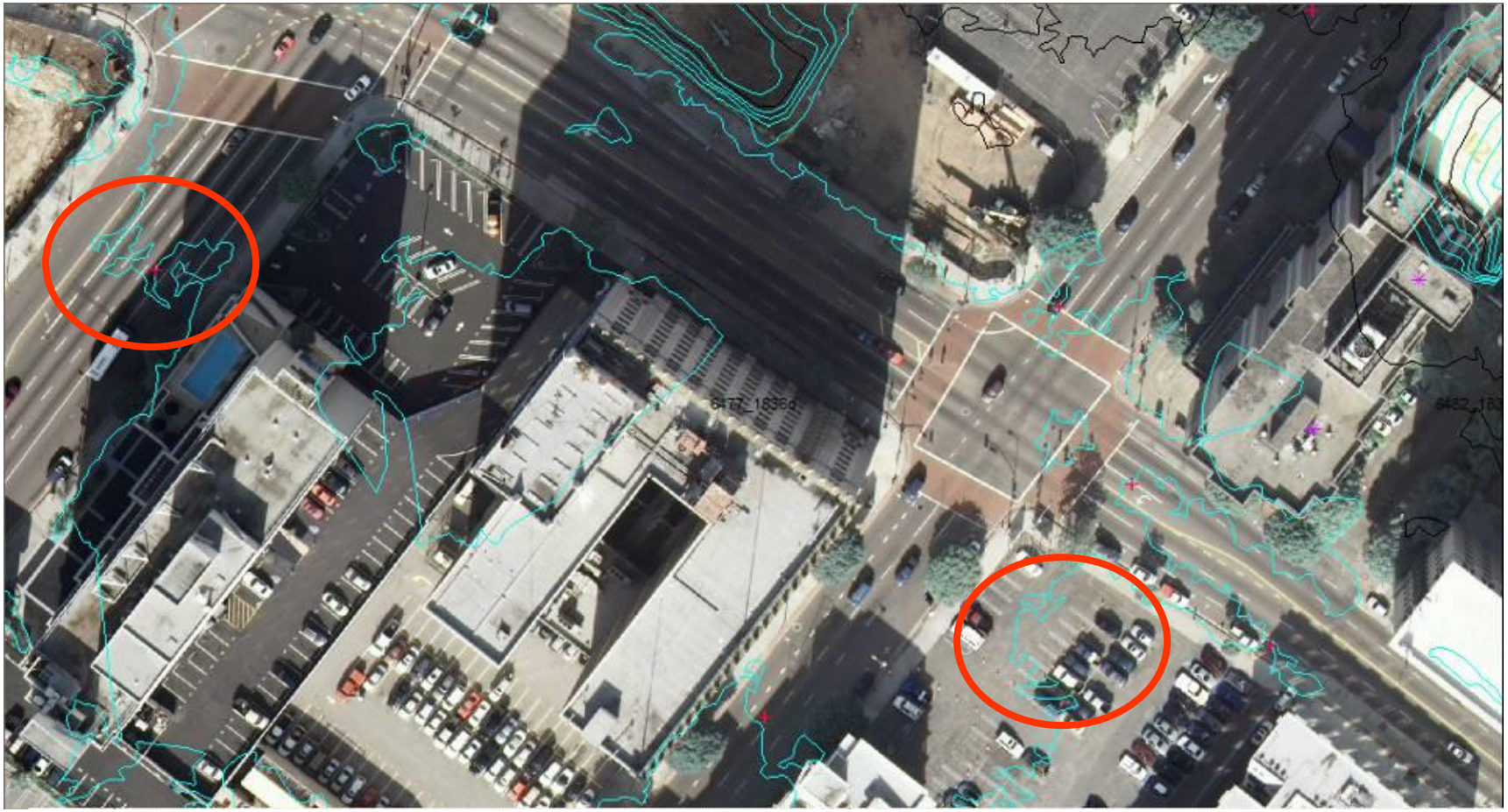
Steep hillsides; these are 2' contours

Noisy contours

- Contours generated directly from Lidar data can be noisy as a result of the variability in the point cloud itself
- LARIAC contours will be smoothed for better cartographic representation as shown in the previous two slides



Meandering contours should be minimized



Using Lidar Data

- Numerous software programs available to both visualize the Lidar and generate derivative products
  - ArcGIS – Introduced Lidar tools and the LAS dataset with version 10.1 with significant additions in versions 10.2 and 10.3 related to generating Lidar products such as digital elevation models and contours. Within ArcGIS you can view both the point cloud and on-the-fly representations of the surface.
  - Global Mapper – Introduced Lidar tools in version 16 with tools to view and edit the Lidar data as well as generate derivative products.
  - LP360 – Lidar specific program used to edit and generate products from Lidar point clouds

Using Lidar Data

- ENVI Lidar suite – Comprehensive tool set for viewing and editing lidar data.

- There are multiple other tools for viewing and analyzing lidar data.