Appendix G: LiDAR Qualitative Assessment Report

References:
B _ Part 3: *National Standard for Spatial Data Accuracy (NSSDA)*, “Geospatial Positioning Accuracy Standards,” published by the Federal Geographic Data Committee (FGDC), 1998
C _ Appendix A, *Guidance for Aerial Mapping and Surveying*, “Guidelines and Specifications for Flood Hazard Mapping Partners,” published by the Federal Emergency Management Agency (FEMA), April 2003
D _ *Guidelines for Digital Elevation Data*, Version 1.0, published by the National Digital Elevation Program (NDEP), May 10, 2004
E _ *ASPRS Guidelines, Vertical Accuracy Reporting for LiDARData*, published by the American Society for Photogrammetry and Remote Sensing (ASPRS), May 24, 2004

Qualitative Assessment

The PDS qualitative assessment utilizes a combination of statistical analysis and interpretative methodology to assess the quality of the data for a bare-earth digital terrain model (DTM). This process looks for anomalies in the data and also identifies areas where man-made structures or vegetation points may not have been classified properly to produce a bare-earth model. Overall the data are of good quality and should satisfy most users for an accurate bare-earth elevation data product.

Overview

Within this review of the LiDAR data, two fundamental questions were addressed:

- Did the LiDAR system perform to specifications?
- Did the vegetation removal process yield desirable results for the intended bare-earth terrain product?

Mapping standards today address the quality of data by quantitative methods. If the data are tested and found to be within the desired accuracy standard, then the data set is typically accepted. Now with the proliferation of LiDAR, new issues arise due to the vast amount of data. Unlike photogrammetry where point spacing can be eight meters or more, LiDAR point spacing for this project is two meters or less. The end result is that millions of elevation points are measured to a level of accuracy previously unseen for elevation technologies, and vegetated areas are measured that would be nearly impossible to survey by other means. The downside is that with millions of points, the data set is statistically bound to have some errors both in the measurement process and in the vegetation removal process.

As previously stated, the quantitative analysis addresses the quality of the data based on absolute accuracy. This accuracy is directly tied to the comparison of the discreet measurement of the survey checkpoints and that of the interpolated value within the three closest LiDAR points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the LiDAR data is actually tested. However there is an increased level of confidence with LiDAR data due to the relative accuracy. This relative accuracy in turn is based on how well one LiDAR point "fits" in comparison to the next contiguous LiDAR measurement. Once the absolute and relative accuracy has been ascertained, the next stage is to address the cleanliness of the data for a bare-earth DTM.

By using survey checkpoints to compare the data, the absolute accuracy is verified, but this also allows us to understand if the vegetation removal process was performed correctly. To reiterate the quantitative approach, if the LiDAR operated correctly in open terrain areas, then it most likely operated correctly in the vegetated areas. This does not mean that the bare-earth was measured, but that the elevations surveyed are most likely accurate (including elevations of treetops, rooftops, etc.). In the event that the LiDAR pulse filtered through the vegetation and was able to measure the true surface (as well as measurements on the surrounding vegetation) then the level of accuracy of the vegetation removal process can be tested as a by-product.

To fully address the data for overall accuracy and quality, the level of cleanliness is paramount. Since there are currently no effective automated testing procedures to measure cleanliness, PDS employs a combination of statistical and visualization process. This includes creating pseudo image products such as LiDAR orthos produced from the intensity returns, Triangular Irregular Network (TIN)'s, Digital Elevation Models (DEM) and 3-dimensional models. By creating multiple images and using overlay techniques, not only can potential errors be found, but we can also find where the data meets and exceeds expectations. This report will present representative examples where the LiDAR and post processing had issues as well as examples of where the LiDAR performed well.

Analysis

Process

PDS utilizes GeoCue Software Products as the primary geospatial process management system. GeoCue is a three tier multi-user architecture that uses .NET technology from Microsoft. .NET provides the real-time notification system that provides users with up-to-the second project status, regardless of who makes changes to project entities. GeoCue uses database technology for sorting project metadata. PDS uses Microsoft SQL Server as the database of choice.

The PDS qualitative assessment process flow incorporates the following reviews
Statistical Analysis- A statistical analysis routine is run on the .LAS files upon receipt to verify that the .las files meet project specifications. This routine checks for the presence of Variable Length Records, verifies .las classifications, verifies header records for min/max x,y,z, and parses the .las point file to confirm min/max x,y,z matches the header records. These statistics are run on the all return point data set as well as the bare-earth point data set for every deliverable tile.
Spatial Reference Checks- The .las files are imported into the GeoCue processing environment. As part of the URS process workflow the GeoCue import produces a minimum bounding polygon for each data file. This minimum bounding polygon is one of the tools used in conjunction with the statistical analysis to verify spatial reference integrity.
Data Void/ Gap Checks-
The imported .las files are used to create LiDAR "Orthos". The LiDAR "Orthos" are one of the tools used to verify data coverage.
The standard QA process flow uses Data Point Elevation and LiDAR pulse return intensity returns. The intensity returns are used as delivered with no normalization. For North Bay the

final product is a 1 foot pixel produced from the All Return Data Set. The maximum density area allowed to generate the pixel is 16 feet. This product is produced to review the lidar collection to verify data density and to review Data Gaps/Data Voids. It is also used as a reference image during the artifact checks. It is not intended as a final product.

North Bay met the density requirement. In addition, the intensity return was very good for this particular collection.

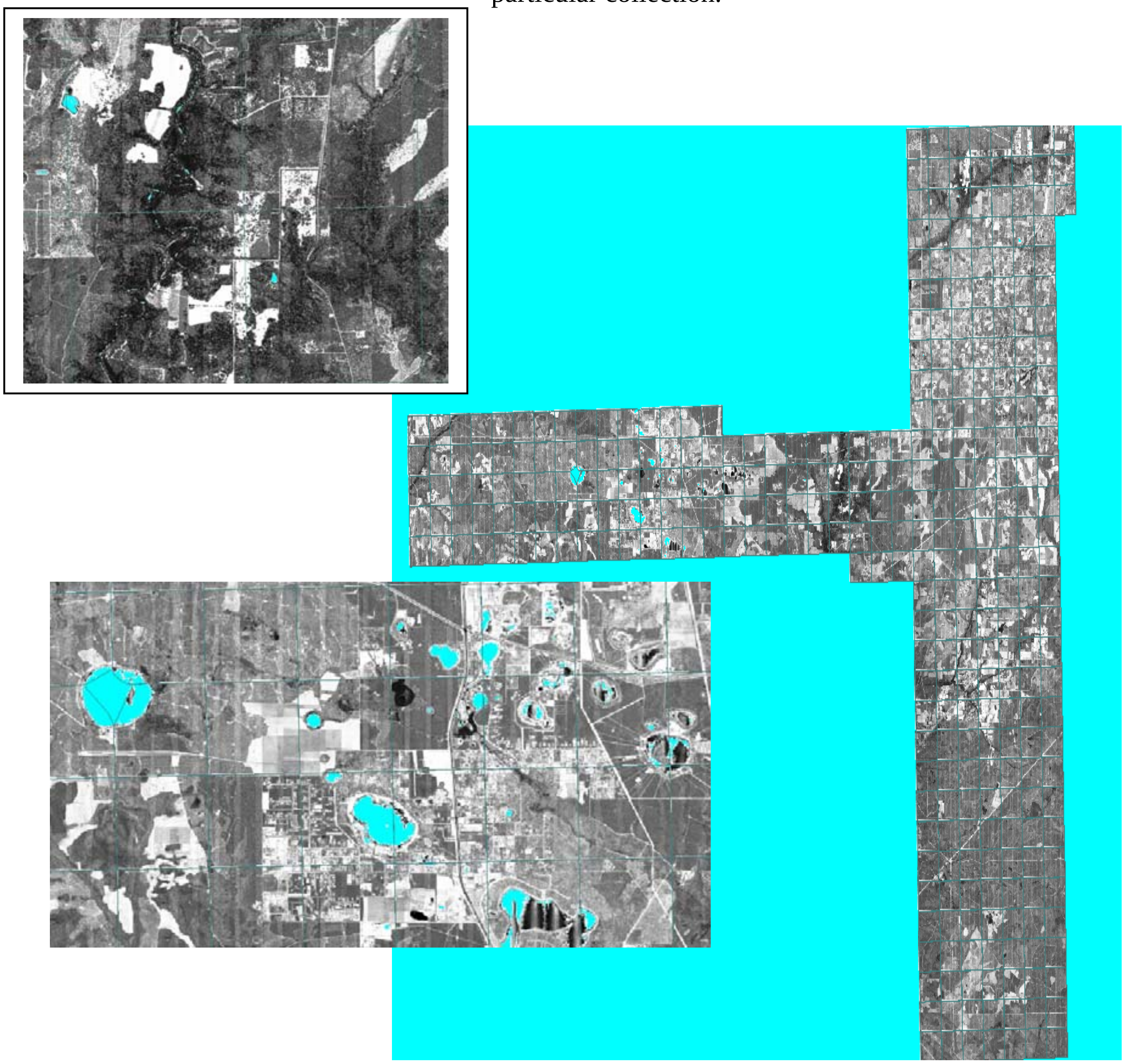
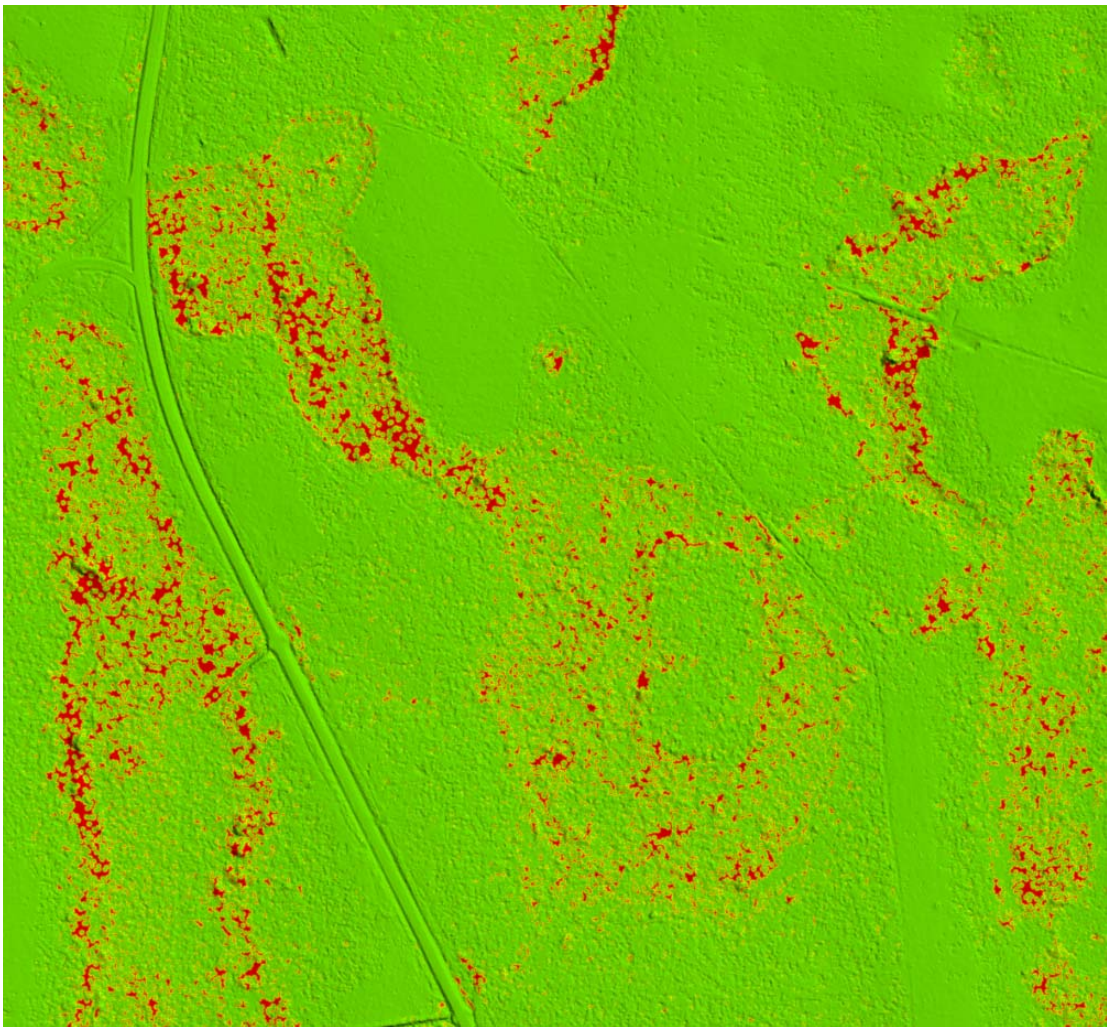


Figure A: Screenshot of Lidar Orthos in GeoCue. Zoom areas are examples of a legitimate Data Void caused by Ponds in the Terrain.

Initial Data Verification: PDS performs an initial 10% random check of the data delivery by looking at each tile individually in great detail utilizing TIN surfaces and profiles. If the data set passes the 10 % the tiles continue through the process work flow where every tile is reviewed. If the data set fails the 10% check it is normally due to a systematic process error and the data set is rejected.

Data Density/Elevation checks: The .las files are used to produce a Digital Elevation Model. These DEMs are produced using the software package QT Modeler which produces a 3-

dimensional data model. This data model is created from the Class 2 ground points using the project density deliverable requirement for unobscured areas. The QC for North Bay was done at the most stringent data density requirement. For the FDEM project this requirement was that Lidar Point Cloud data meet a maximum post spacing of 4 ft in unobscured areas for random point data. Model statistics were produced characterized by density as well as elevation. This data model is created from class 2 ground points and models statistics are characterized by density, scale, intensity as well as elevation. The low confidence area polygons are referenced with the density grids to ensure that all low confidence areas are properly identified with a low confidence area polygon. Again, these products are produced for Quality Assessment purposes



Zoom of area with dense vegetation. Density grids were created at a 4 foot cell size using a green to red color ramp. Green areas indicate that the grid meets the 4 foot specification.
Yellow to Red indicates that the 4 foot specification is not met.

Figure B. example 4 foot Density Grids produced for North- Bay County Florida .

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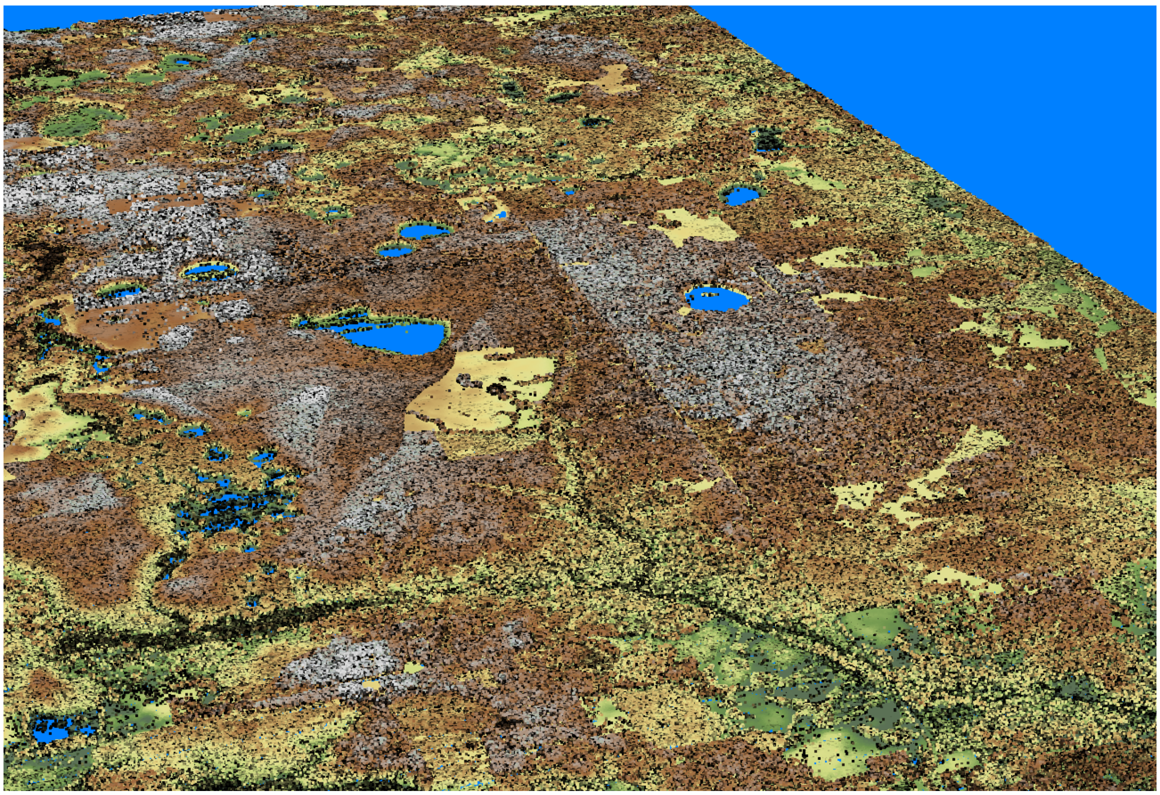
Artifact Anomaly Checks. The final step is to review every tile for anomalies that may exist in the bare-earth terrain surface. Items that are checked include, but are not limited to: buildings, bridges, vegetation and water points classified as Class 2 points and elevation "steps" that may occur in the overlap between adjacent flight lines.

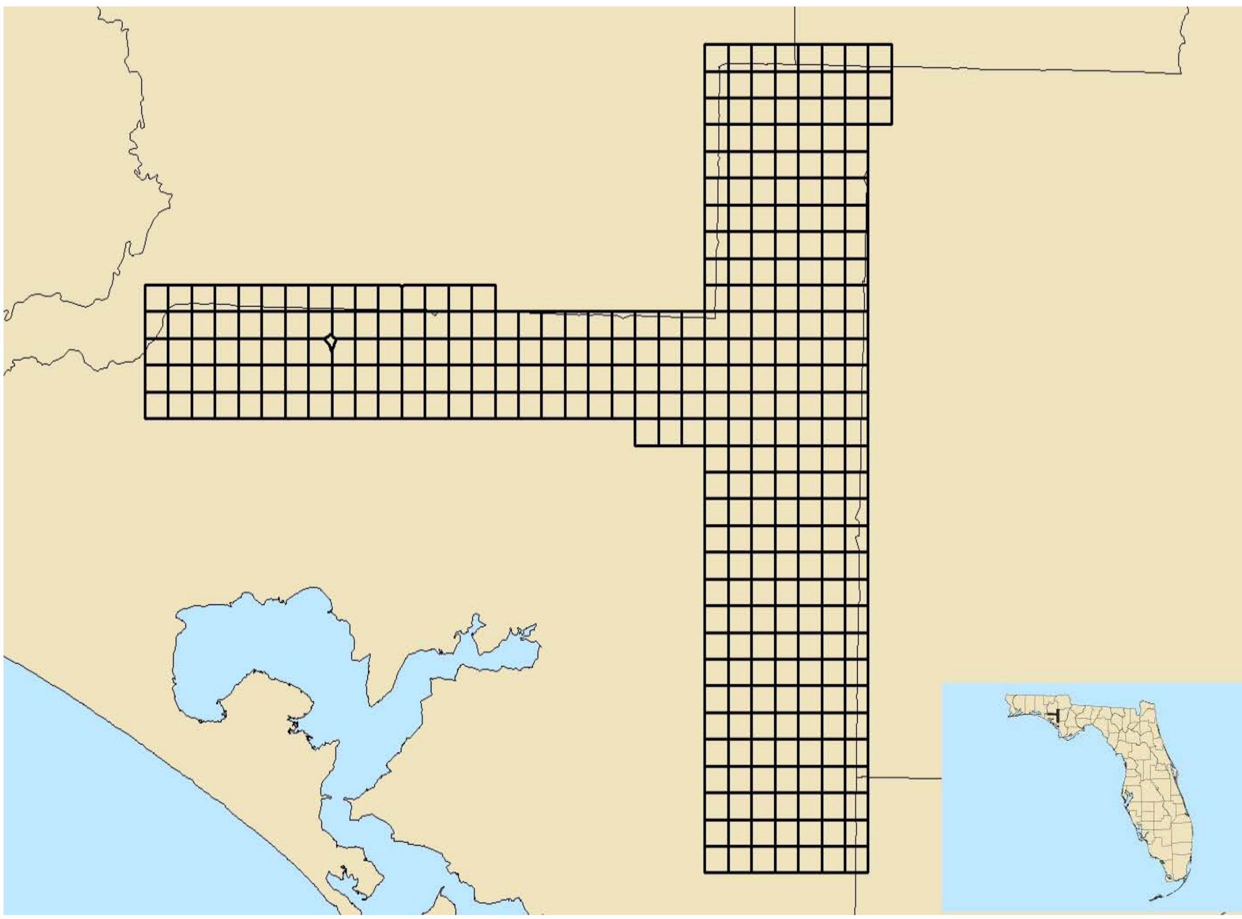
Issues Found

North Bay County Florida is characterized by heavy vegetation, marshes and swamp areas. There are no urban areas and there is one state forest.



The concern with this lidar collection for the final product is that the lidar would penetrate through the vegetation to produce the contract specifications for open terrain. Because of the heavy vegetation, defined low confidence areas will become critical due to the deliverable requirement for topography (Contours). In general the ground data set was noisy in what is defined as low confidence areas or areas of significant heavy vegetation. This is not considered a data failure but for the purposes of this project should be reported. There is a fine line in the decision making process of which points to classify as ground. By removing points from the ground classification due to heavy vegetation there is risk of oversmoothing or "flattening" the ground surface which can have a greater impact than leaving points to maintain the ground surface model. In addition, due to the lack of significant elevation changes in the physical terrain there are places where is no visible break in the terrain between the ground surface and what in traditional mapping would be considered a hard breakline feature, for example roads. Because the project includes the collection of breaklines this will be compensated for in the road breakline collection. The lidar data contained sporadic issues such as artifacts or small anomalies which is typical of any lidar dataset. However one issue that is scattered throughout the dataset occurs in the areas where flightlines are joined by a defining a seam line. This join appears visibly significant is some areas. This is partially due to the stringent QC surface model produced but in some cases there are steps in the elevation. Given the physical characteristics of the terrain in this area, the dataset meets the project specifications. The low confidence area polygons and breakline acquisition is an important delivable.

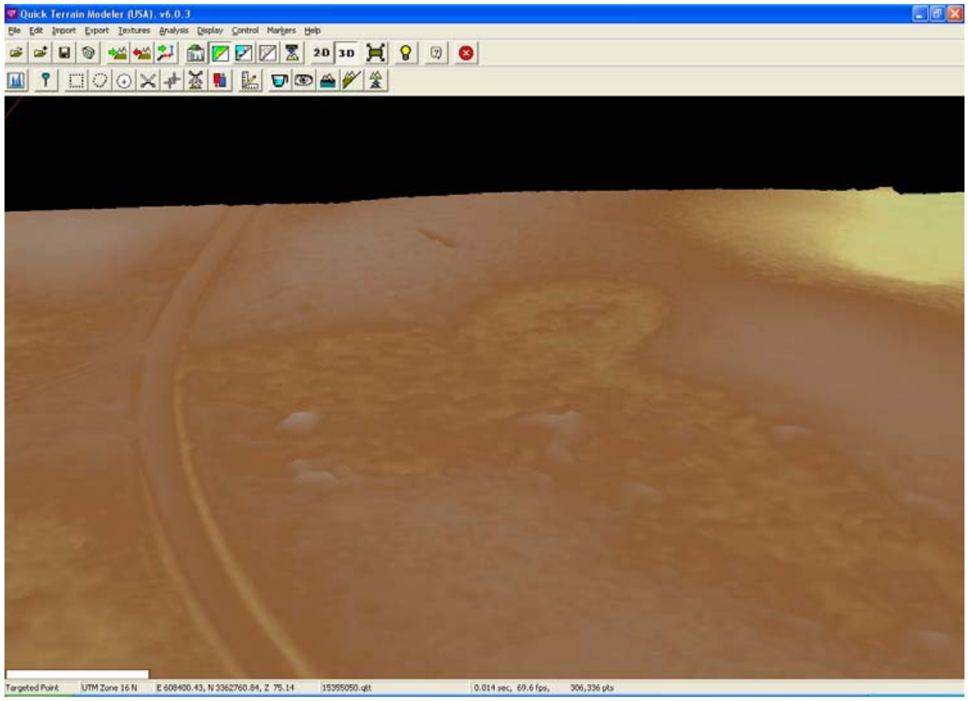
North Bay County Existing LiDAR Data Tiles included in this .LAS Quality Report



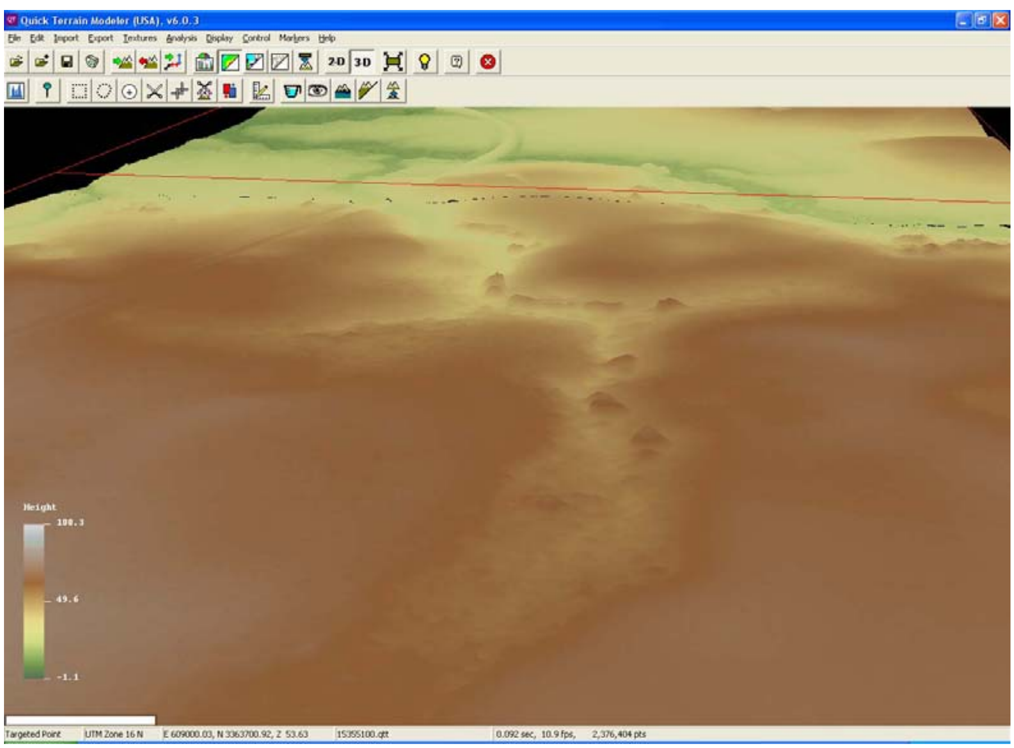
North Bay County, FL Tile Layout

Examples of issues:

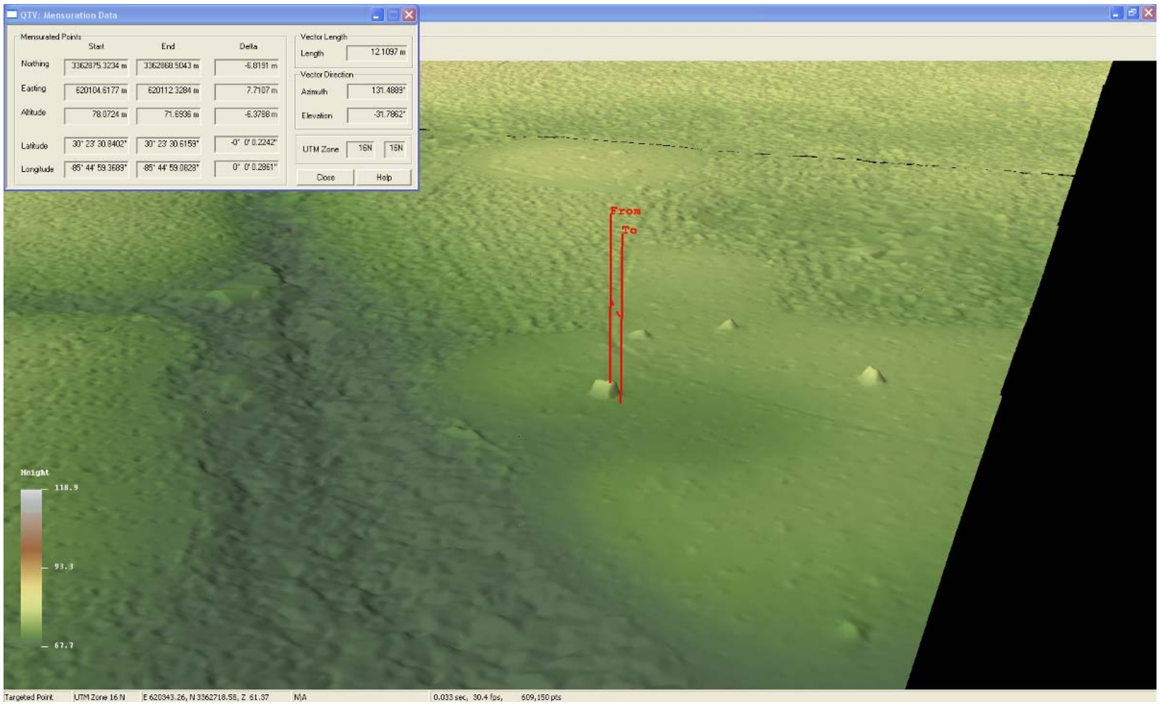
Irregular high points in low confidence areas



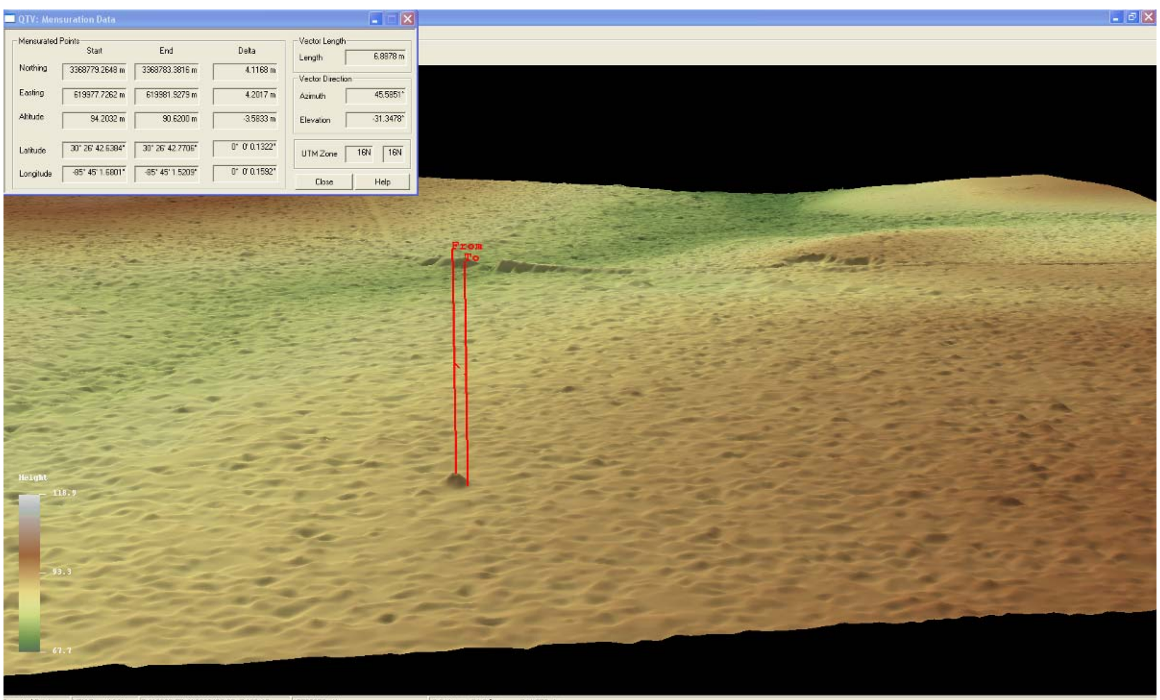
15355050: Irregular High points in Low Confidence area



15355100

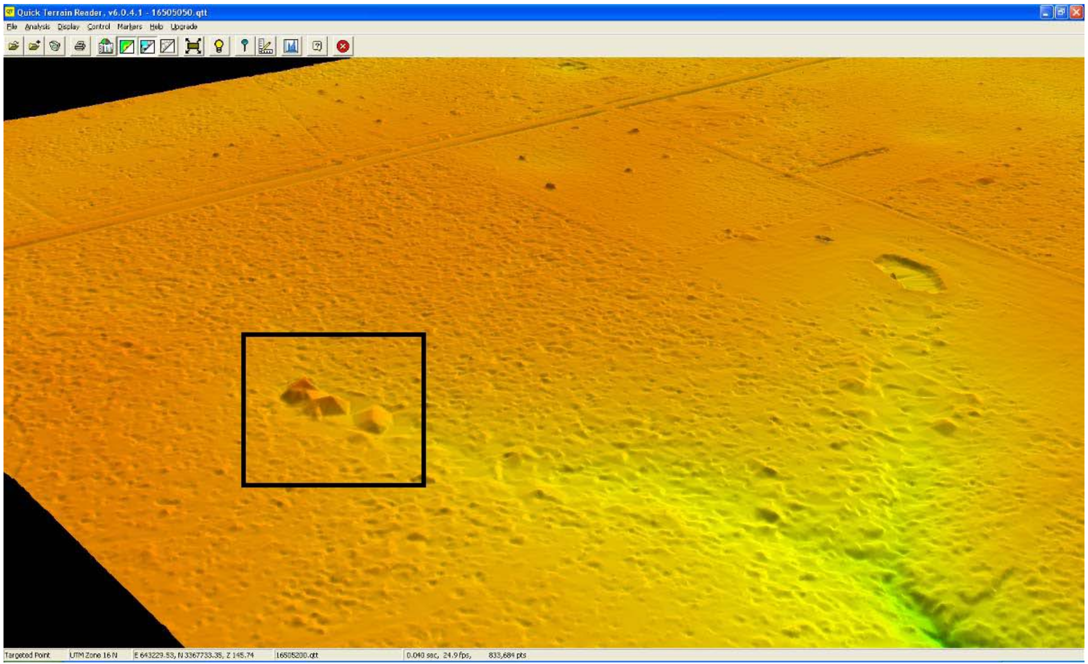


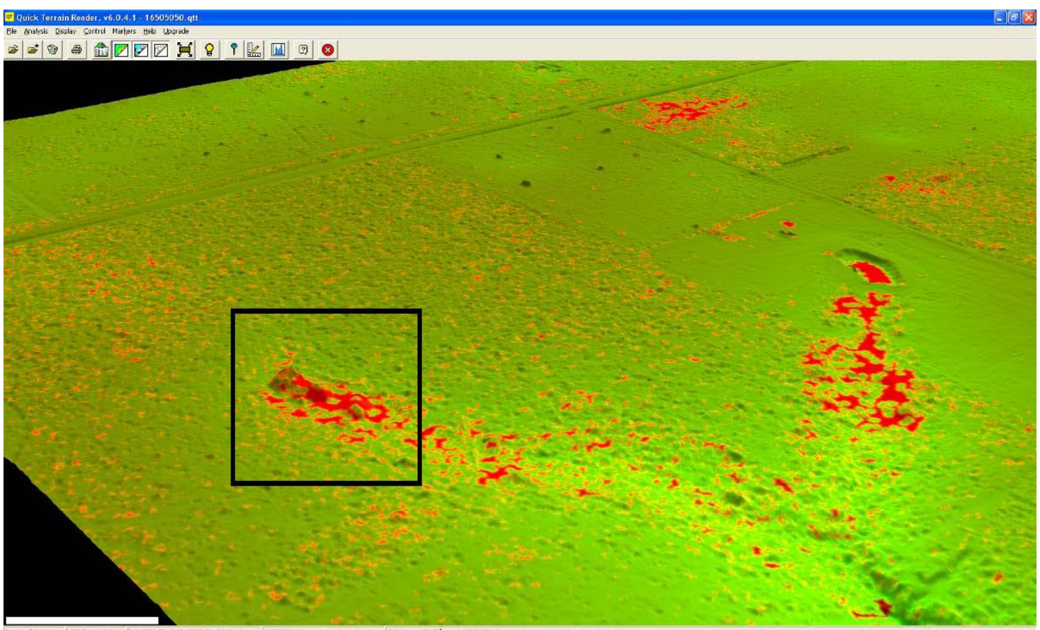
15705050: Elevation difference of 6.4 meters (21 feet)



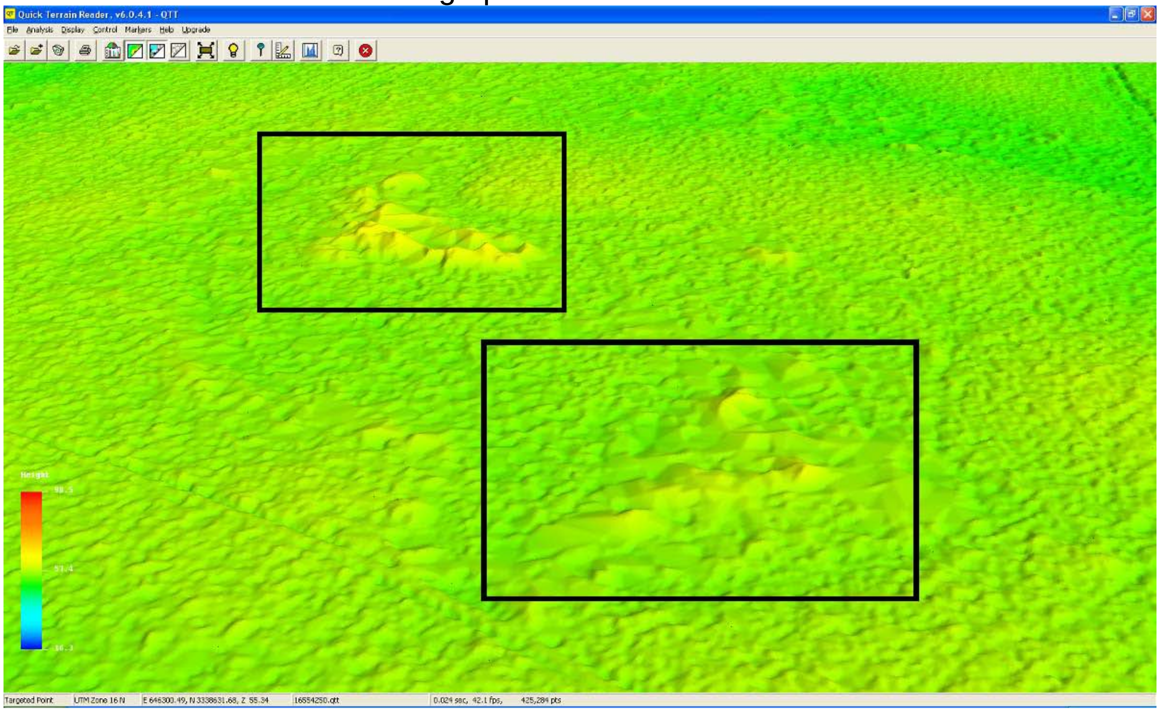
15705250: Elevation difference of 3.6 meters (11.8 feet)

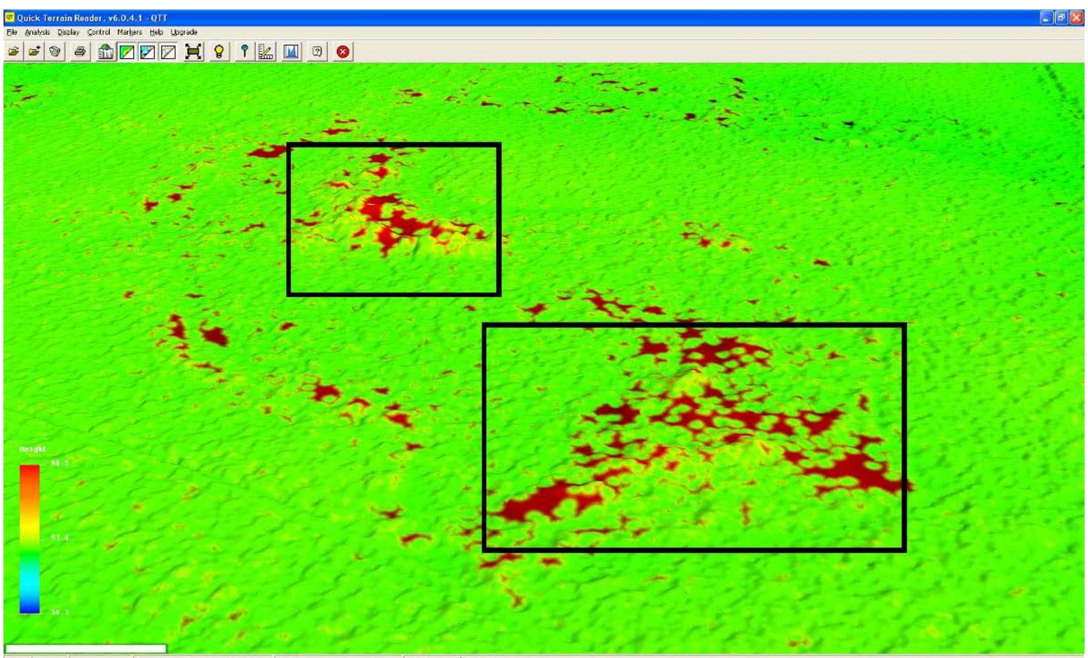
16505200: High points in low confidence area



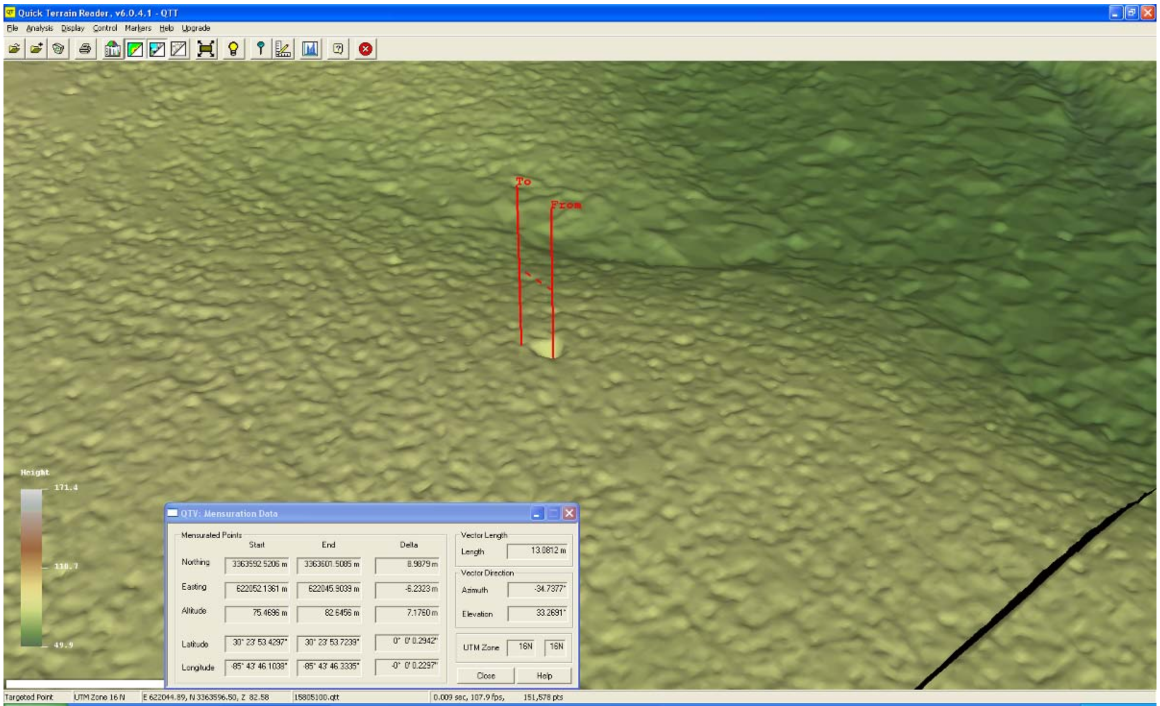


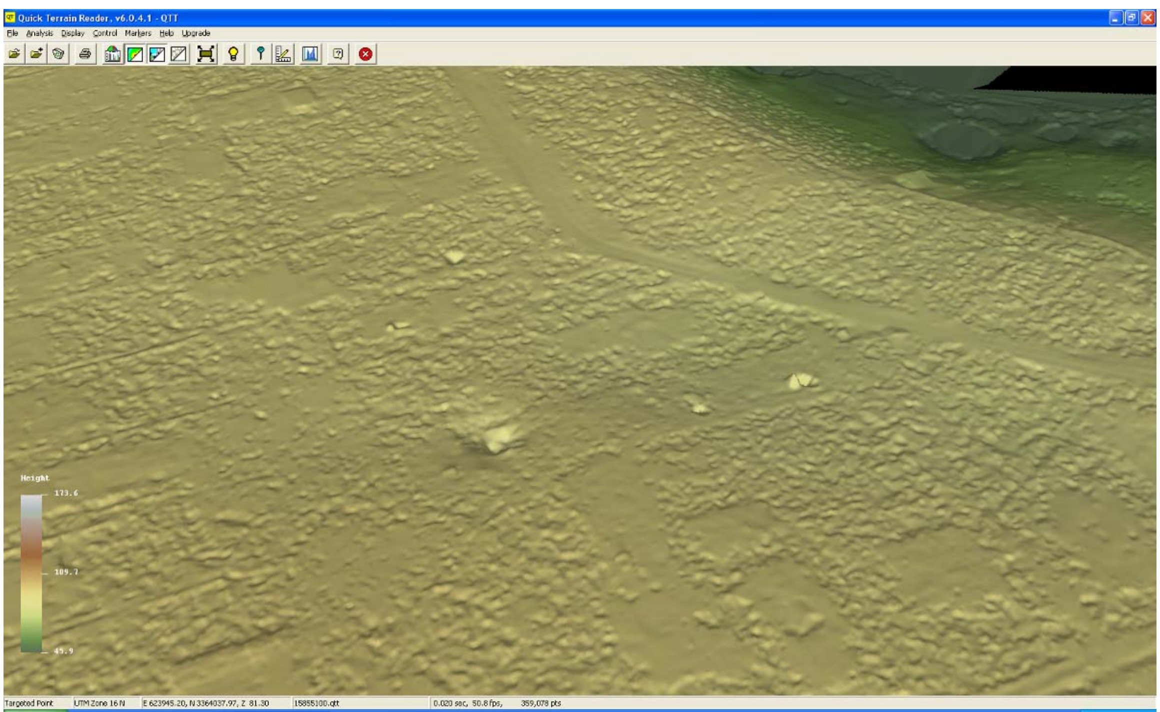
16554250: High points in low confidence areas





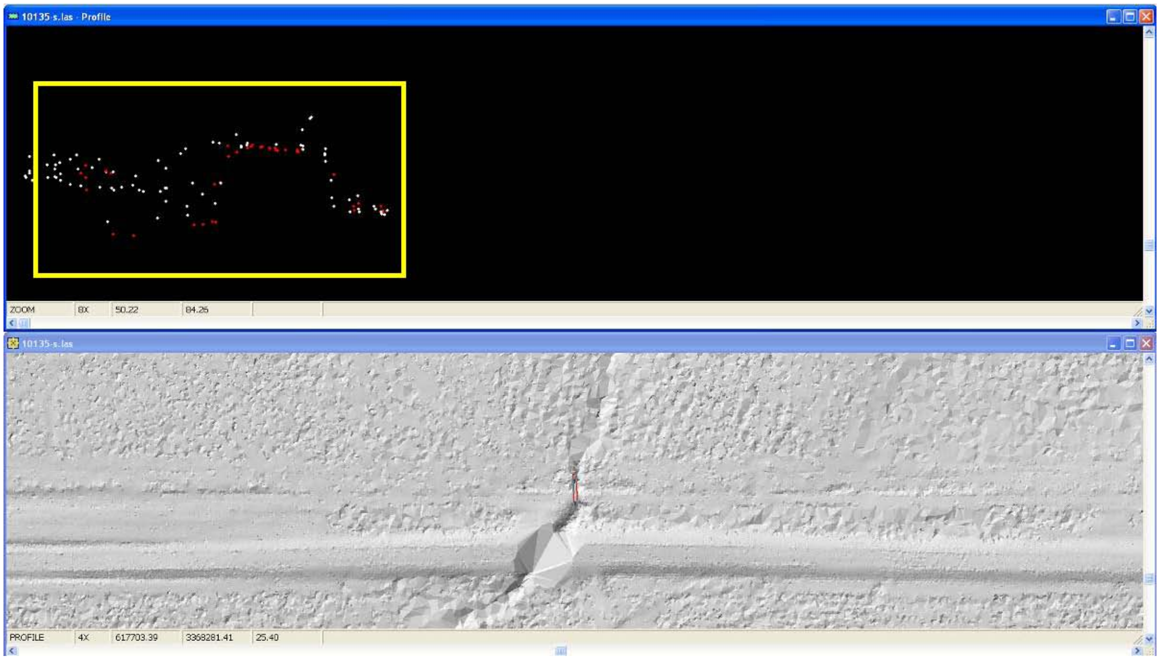
15805100: Irregular low point; Elevation difference of 7.2 meters (23.6 feet)

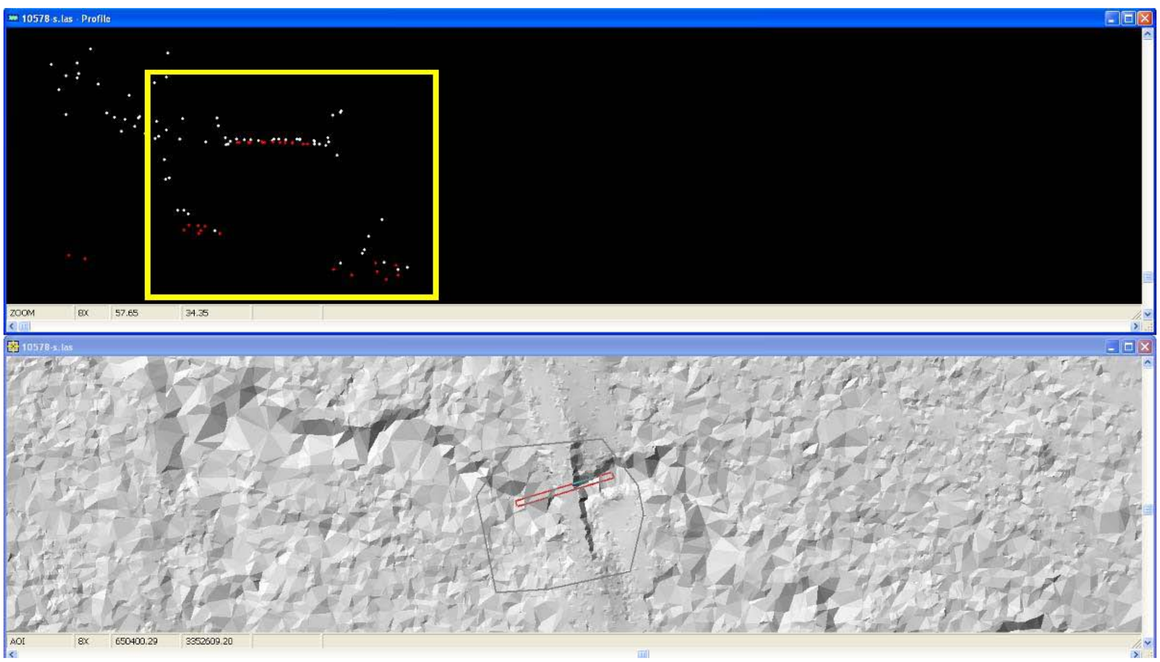




15855100: Irregular low point

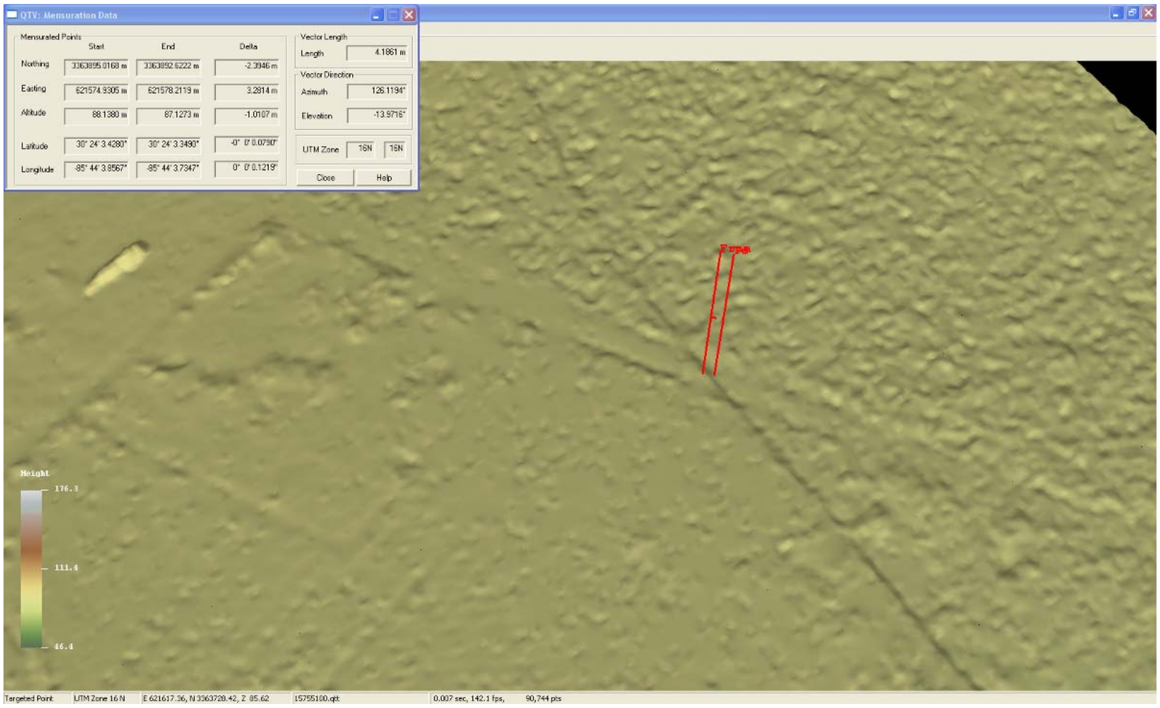
47664: Classification examples

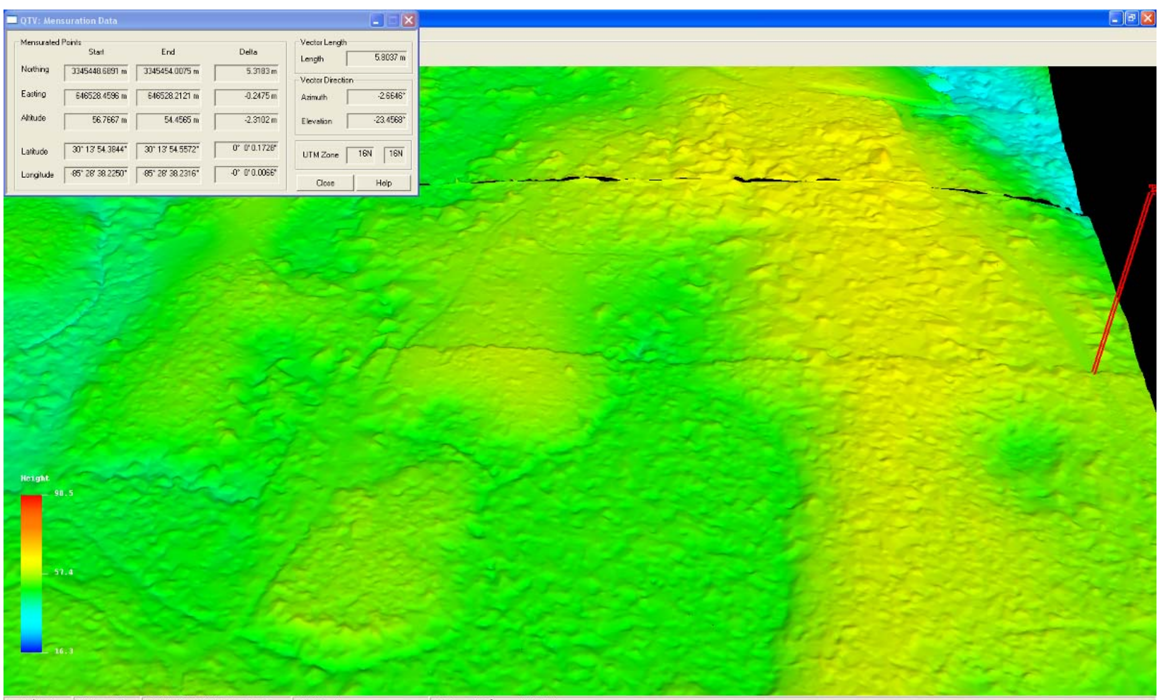




53625: Classification example

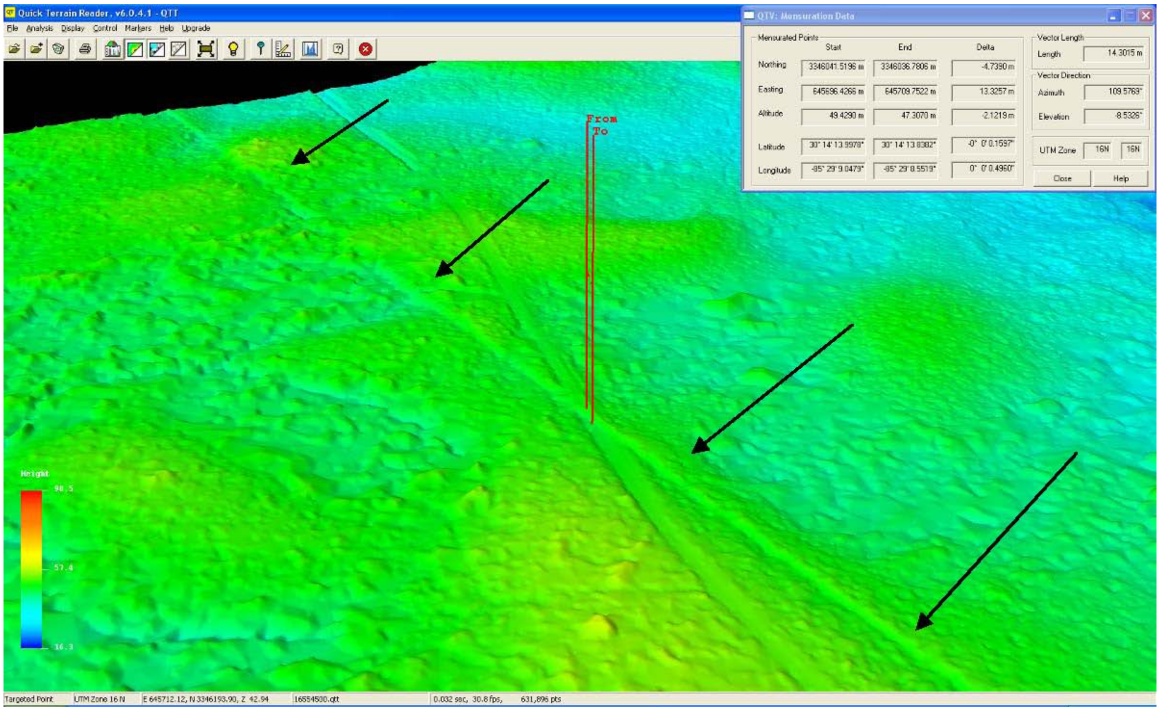
15755100: Flightline step visible on road; Elevation difference of 1.01 meters (3.3 feet)

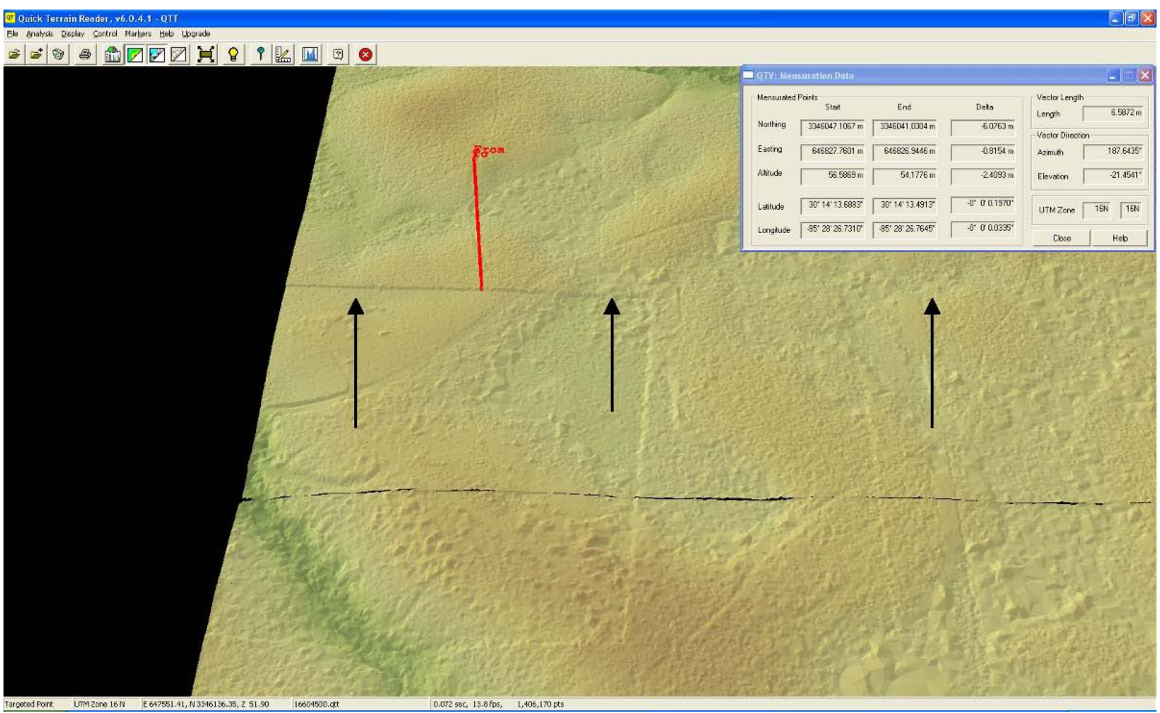




16554450: Flightline step visible on road; Elevation difference of 2.31 meters (7.6 feet)

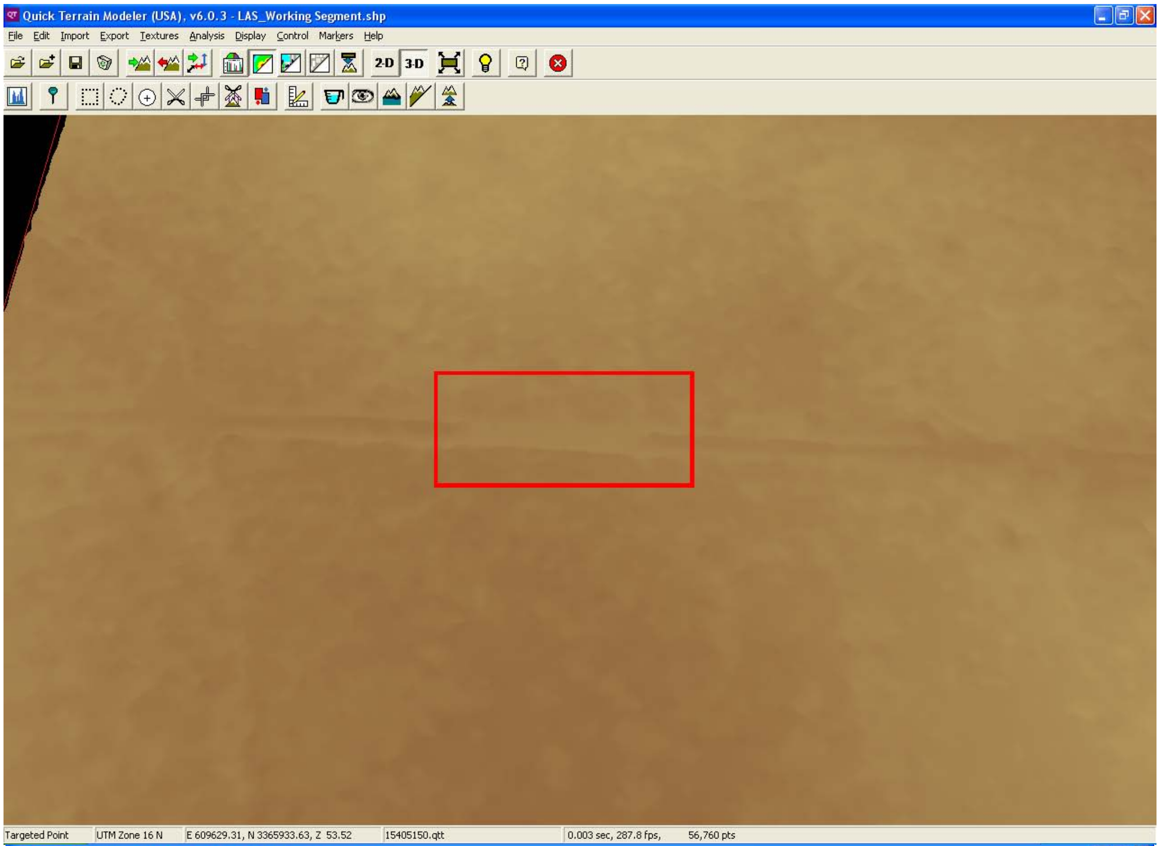
16554450: 2.12 Meter flightline step; (approximately 7 feet)

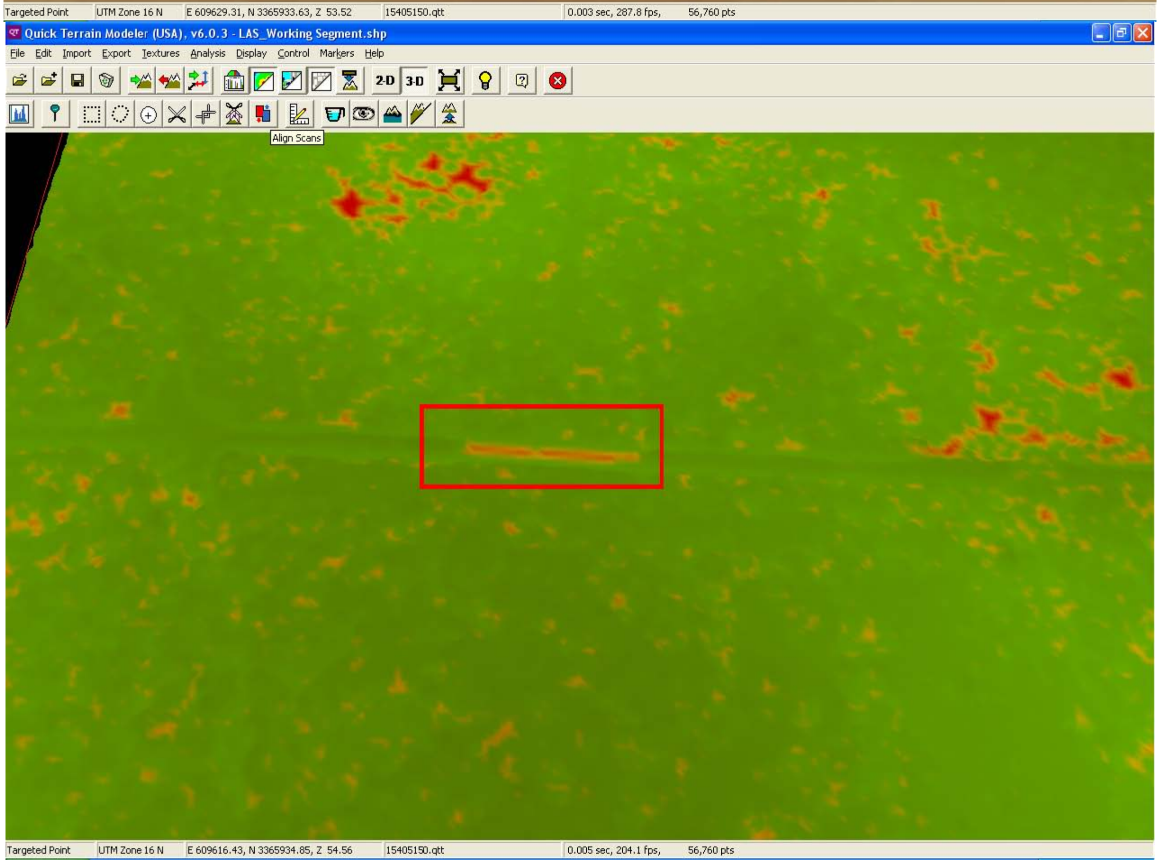




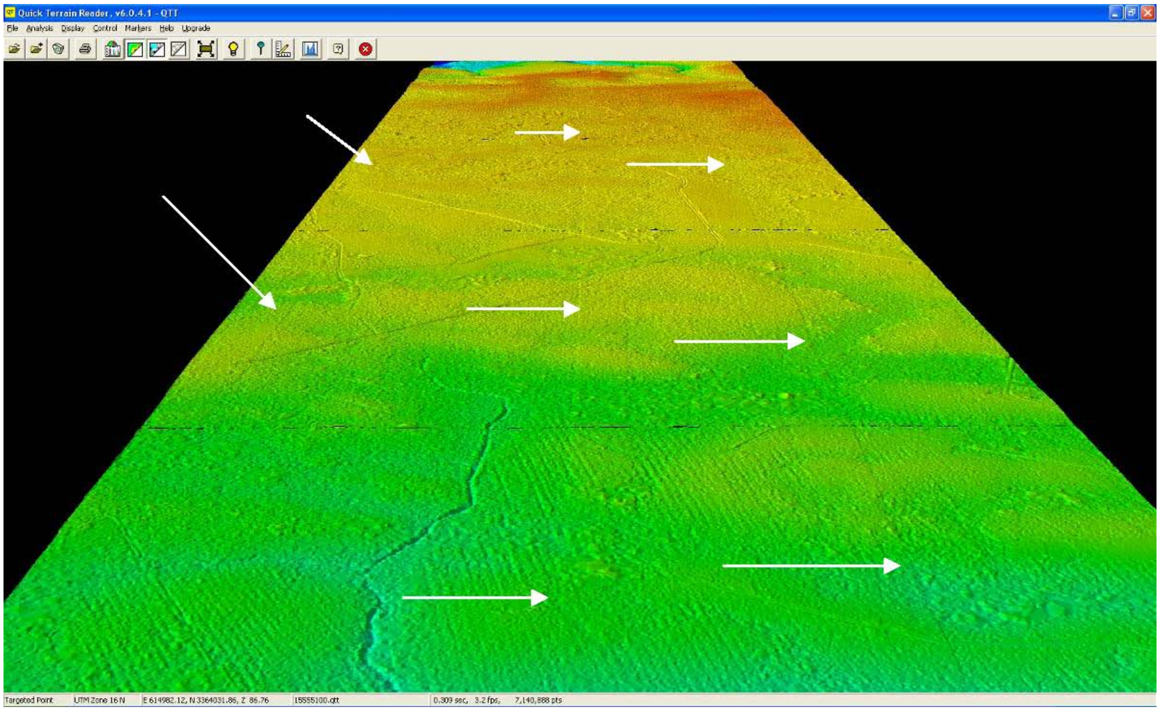
16604500: 2.41 Meter flightline step; (approximately 7.9 feet)

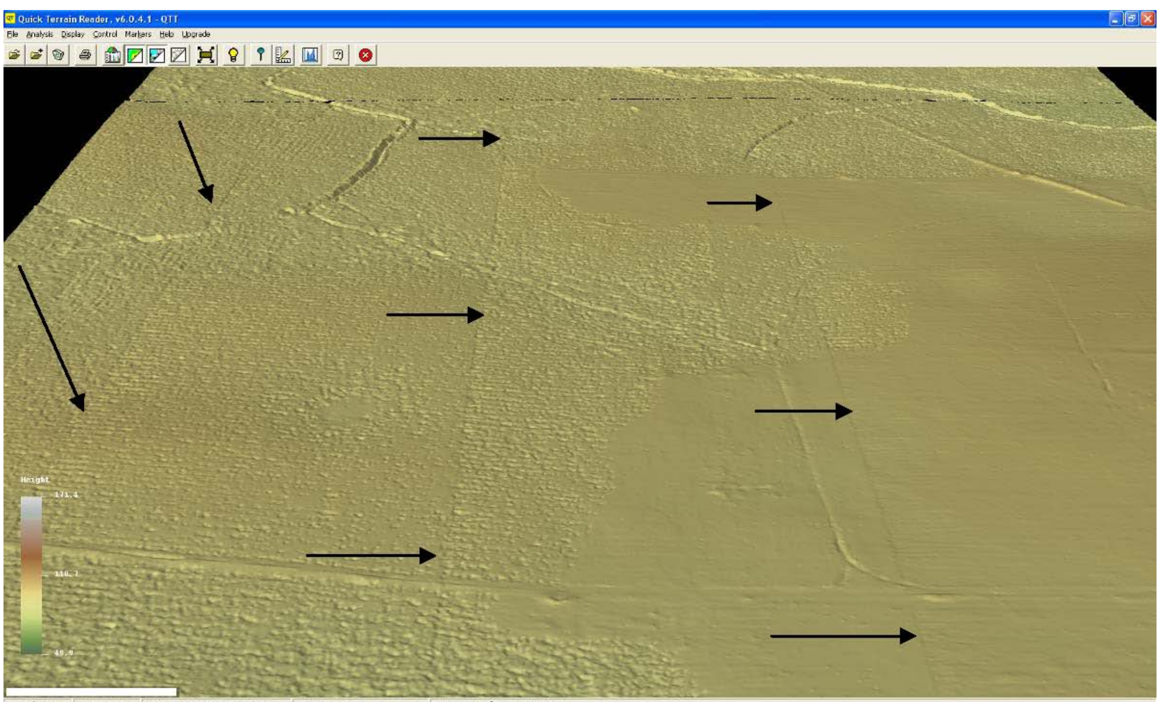
15355050: Points on road removed





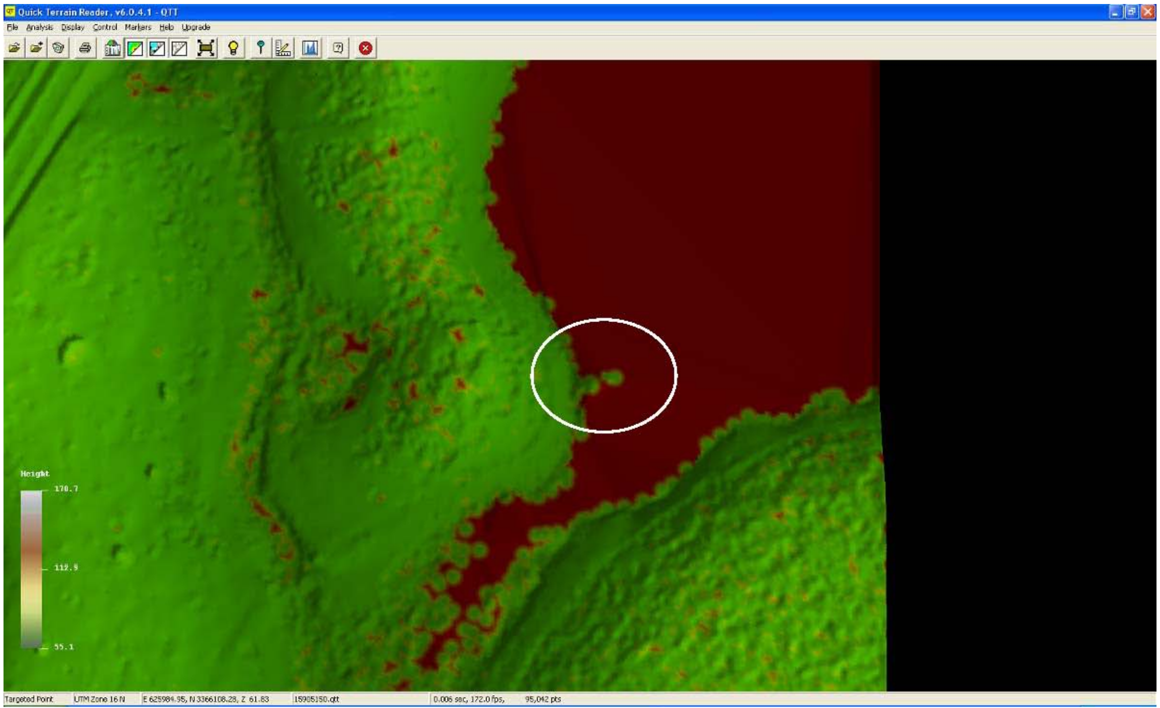
15555100: Flightlines visible on terrain model

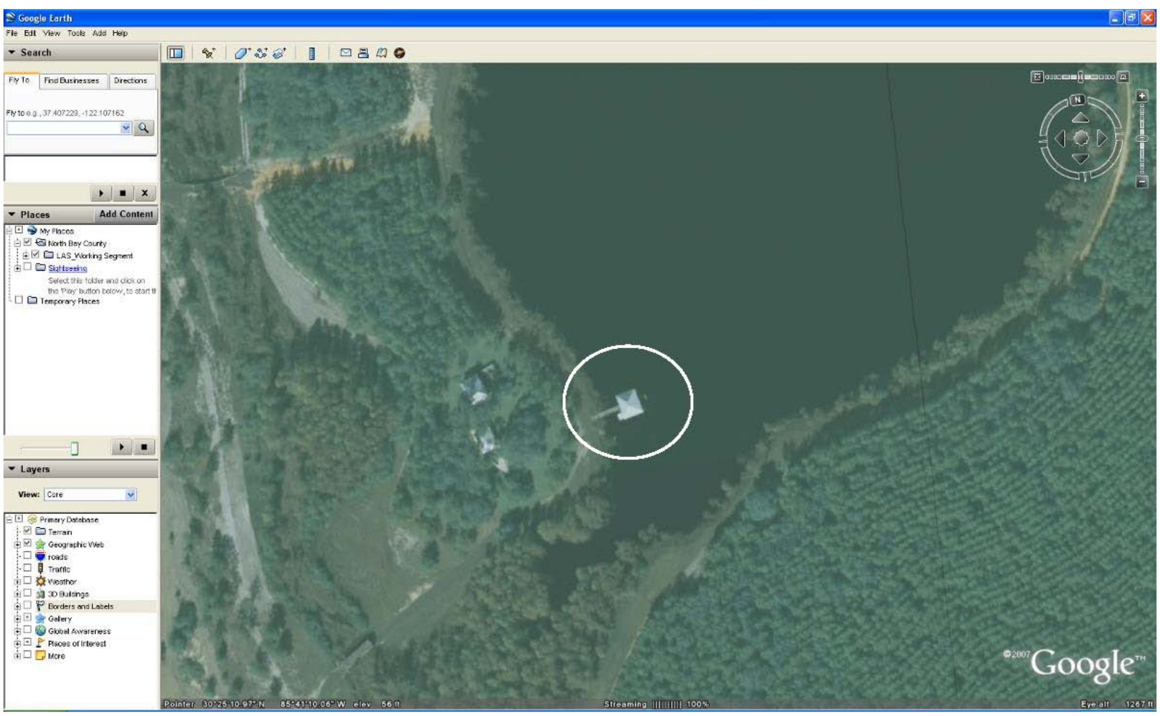


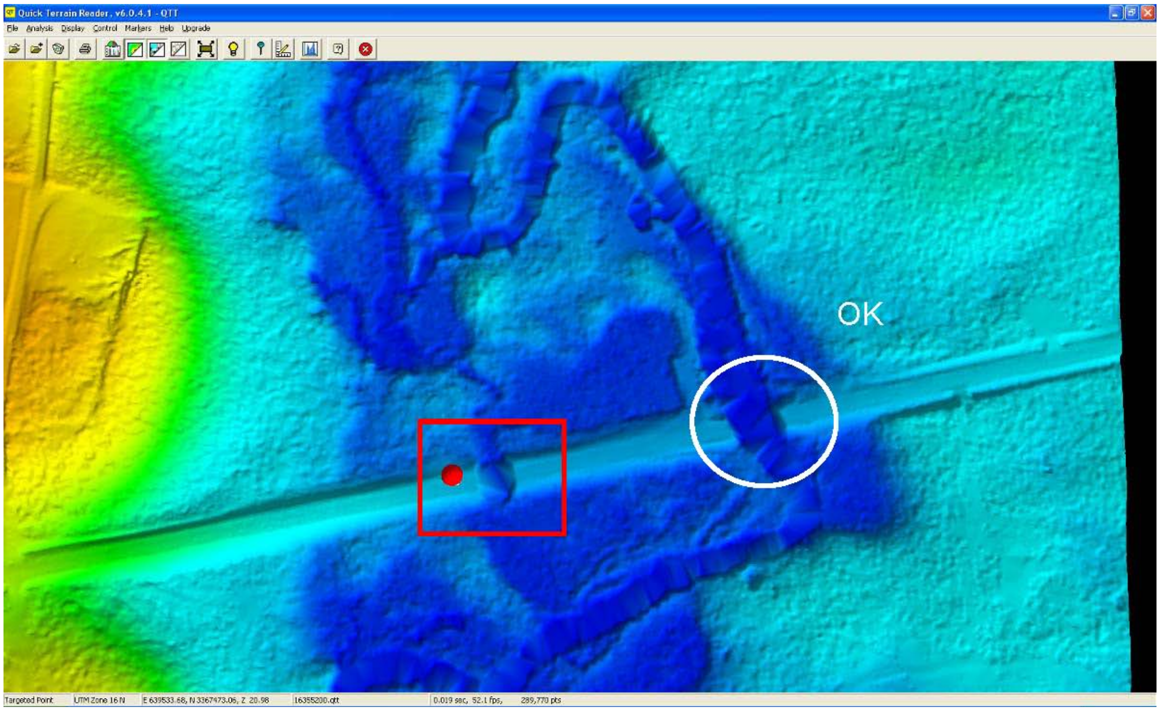


15805150: Flightlines visible on terrain model

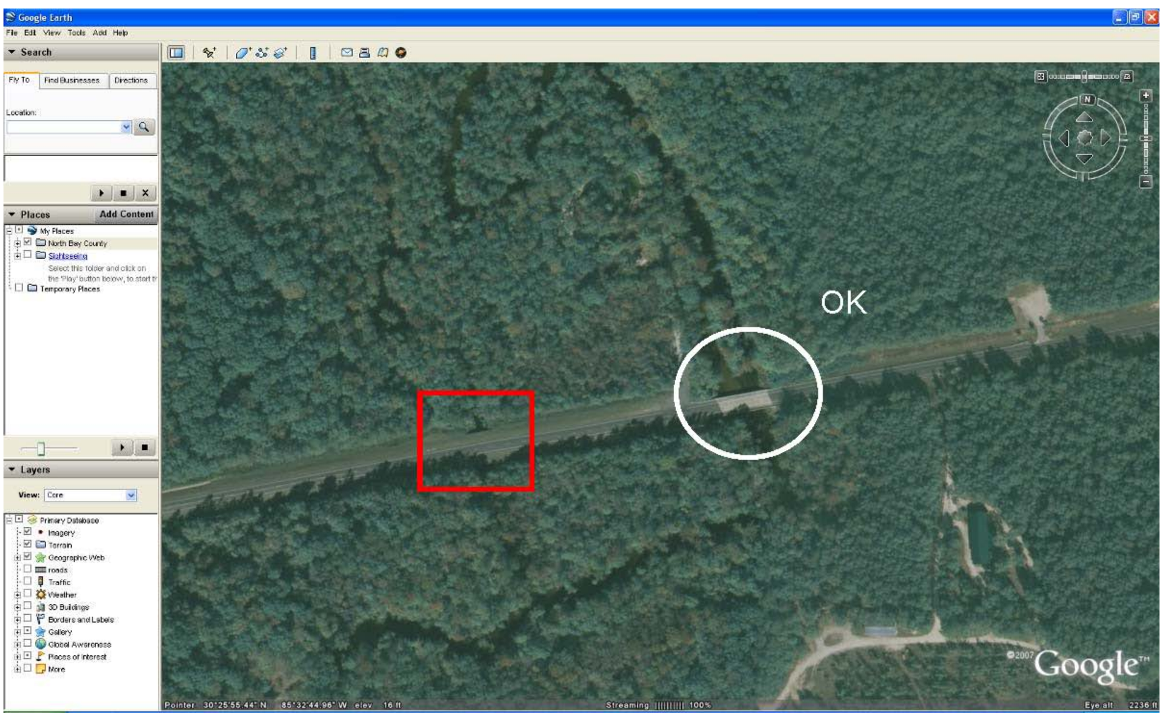
15905150: Pier not removed



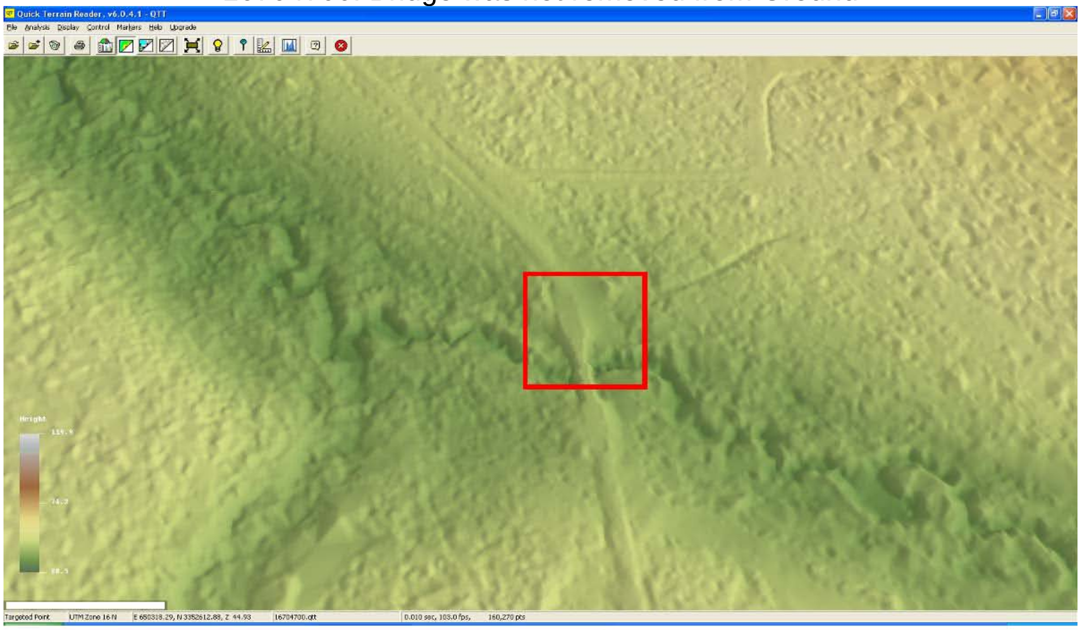


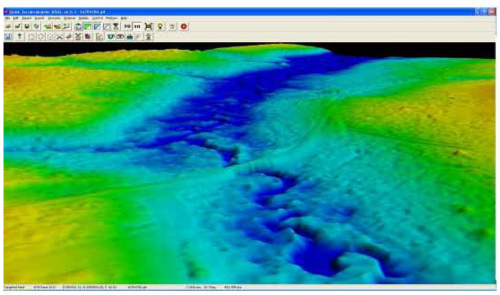


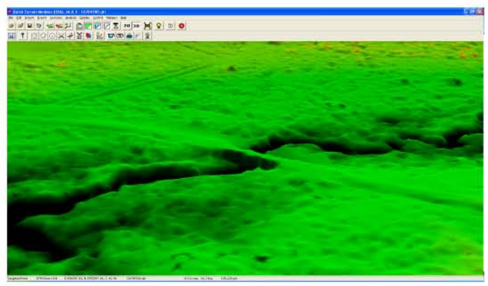
16355200: There are some discrepancies as to when culverts were removed

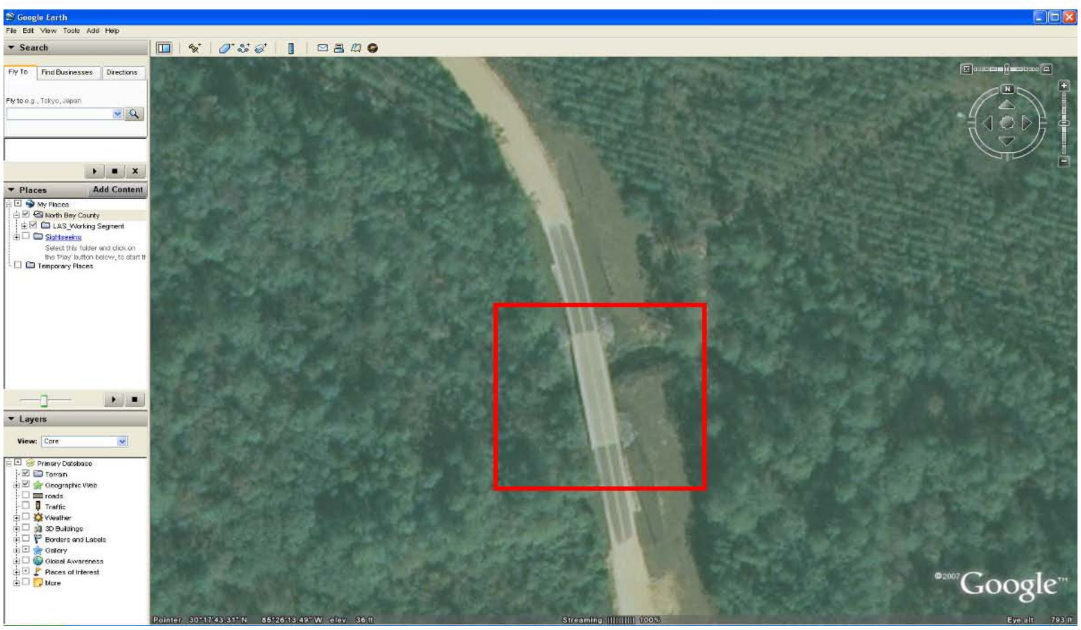


16704700: Bridge was not removed from Ground

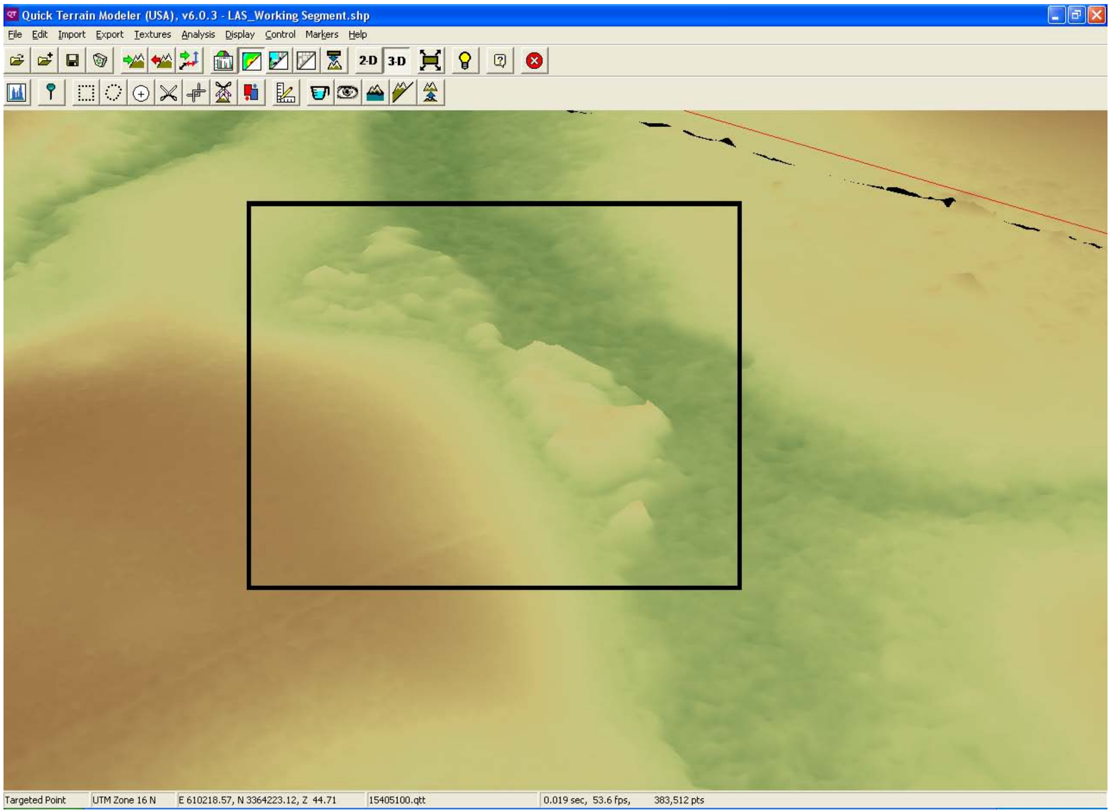




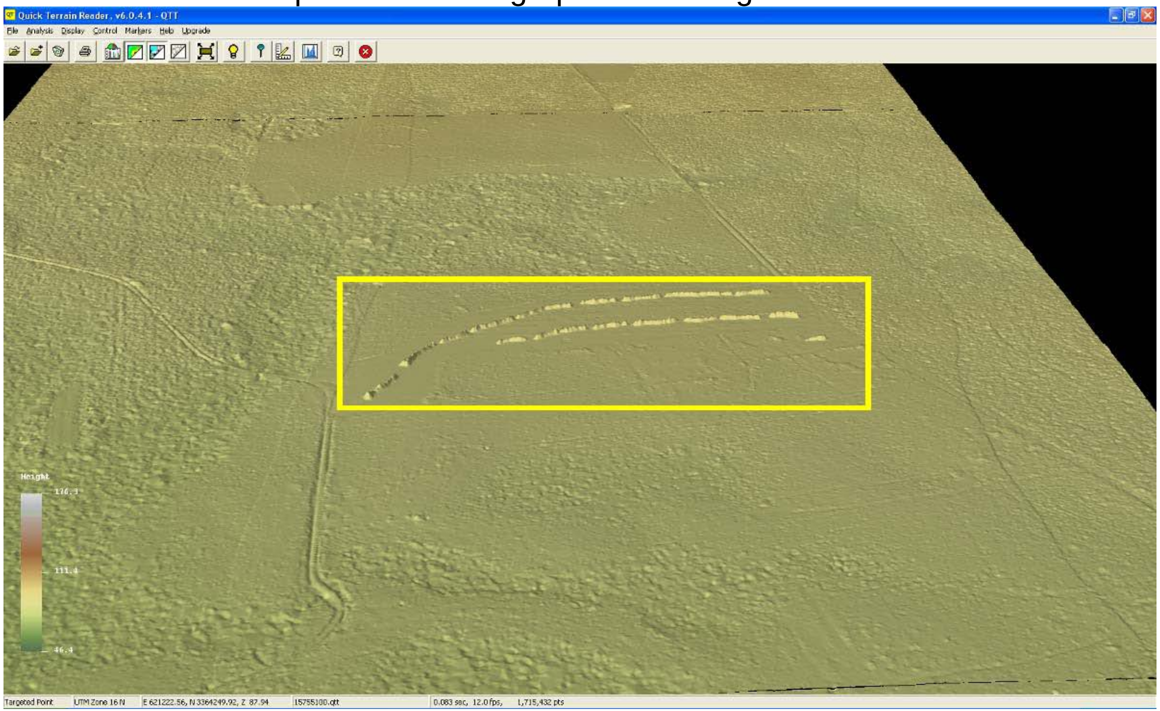


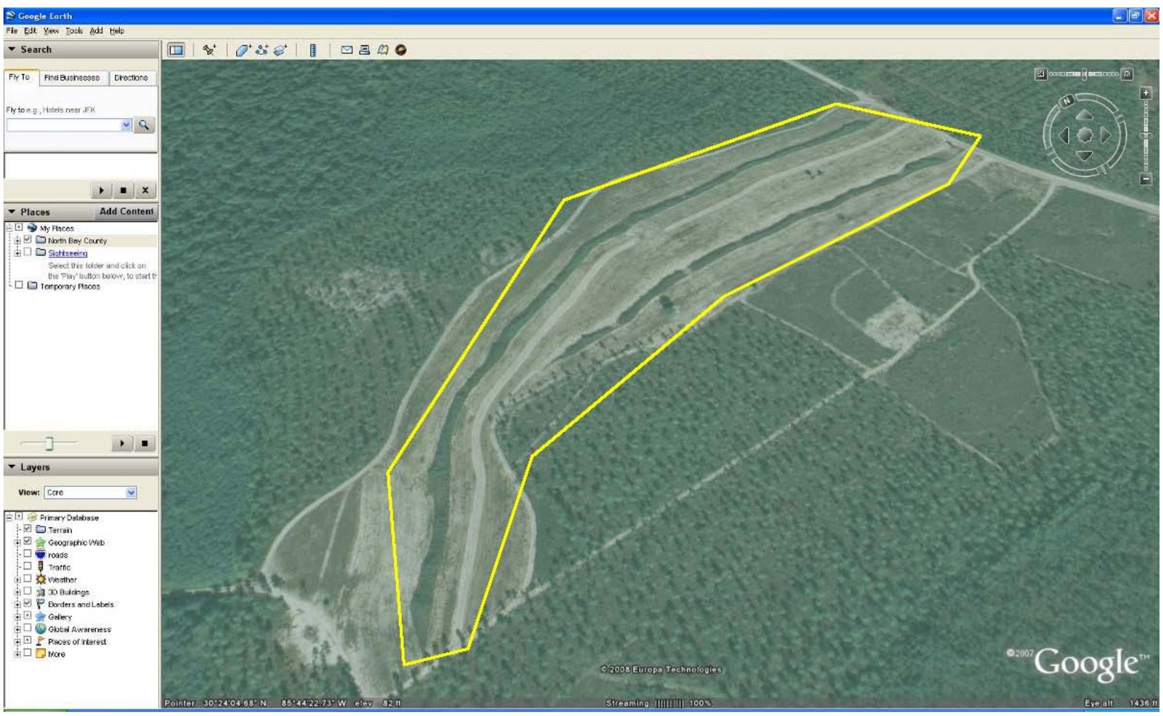


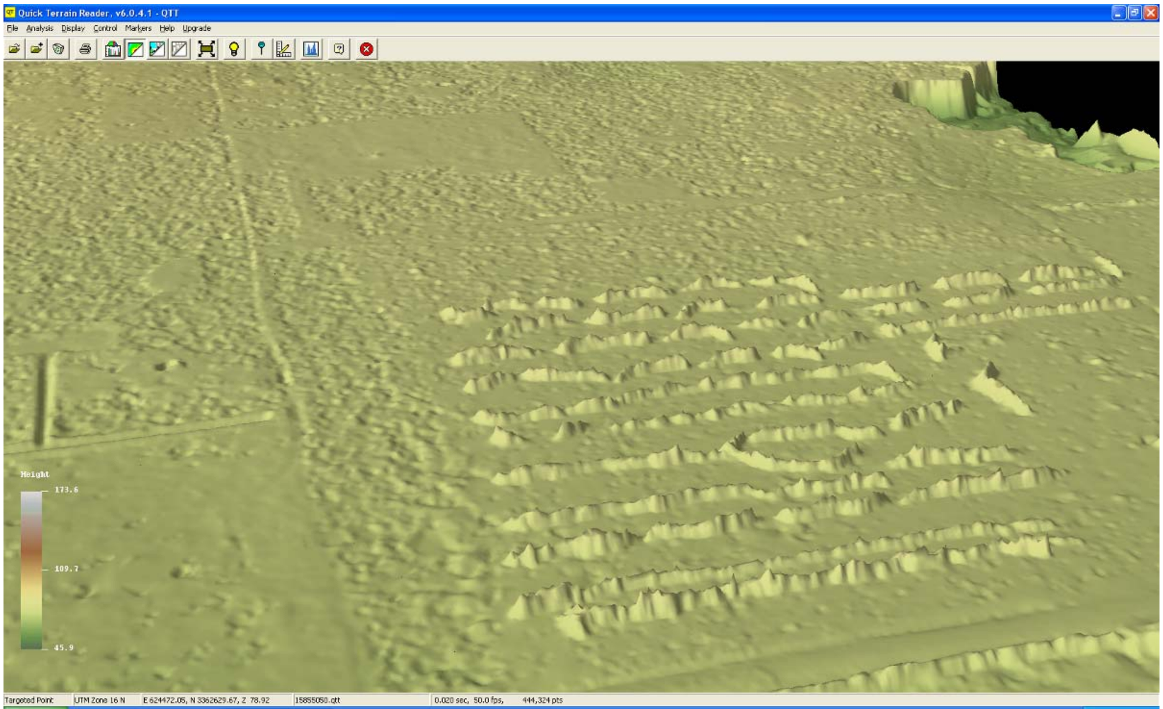
15405100: Irregular high-terrain in floodplain



15755100: possible tree high-points left in ground classification







Ground classification 15855050: Terrain inconsistent in plowed fields

16005200: Irregular Terrain surrounding open field