LiDAR Quality Assurance (QA) Final Report
Sub-Project 2: South Central Nebraska
Nebraska/Kansas LiDAR
January 13, 2010

Submitted to:
USDA-NRCS-Nebraska/
U.S. Army Corps of Engineers

Prepared by:
Dewberry
Fairfax, VA

Table of Contents

Executive Summary 3
QA Report 5
1 Introduction 5
2 Completeness of Deliverables 6
2.1 LiDAR Inventory 6
3 LiDAR Quantitative Assessment 6
3.1 Statistical Analysis 7
3.1.1 ASPRS Classification Scheme 8
3.1.2 Pulse Return Analysis 8
3.2 Vertical Accuracy Assessment 8
3.2.1 Methodology 10
4 LiDAR Qualitative Analysis 12
4.1 Protocol 12
4.2 Quality Report 13
4.2.1 Artifacts 13
4.2.2 Divots 14
4.2.3 Misclassification 15
4.2.4 Flight Line Overlap Noise 15
5 Conclusion 16
6 Appendix A – Minor Issue Images 17
6.1 Artifacts 17
6.2 Divots 32
6.3 Flight Line Noise 34
6.4 Misclassification 38

Executive Summary

Reference: U.S. Army Corps of Engineers Contract W912P9-08-D-0507

The following quality assurance report documents Dewberry's review of the Sub-project 2 (South Central Nebraska) LiDAR data produced by Merrick & Company under subcontract to Optimal Geomatics for the U.S. Army Corps of Engineers. The project area consists of 1,613 tiles of LiDAR data in LAS format. The LiDAR data was acquired between January and April of 2009. Each tile contains LAS 1.1 point cloud data classified into four ASPRS classes (class 1 = unclassified; class 2 = ground; class 7 = Low point/noise; class 9 = water only in the area overlapping Sub-project 1). The data was reviewed quantitatively for statistical and accuracy errors, as well as qualitatively for classification and visual anomalies. Overall the LiDAR data was determined to be of good quality.

Completeness: According to the requirements of the contract, the LiDAR data was to contain point cloud data with multiple returns per pulse and with an intensity value recorded for each point. Dewberry verified that all 1,613 LAS tiles were of the proper size (each 5,000 m x 5,000 m) and contained multiple returns with intensity values recorded for each point. All the data was delivered in the correct file format and projected to the Universal Transverse Mercator coordinate system, Zone 14 North in meters with NAD83 datum. The vertical coordinate system is NAVD88 with elevation in meters. The location of the sub-project area in relation to the project boundary is illustrated in Figure 1.

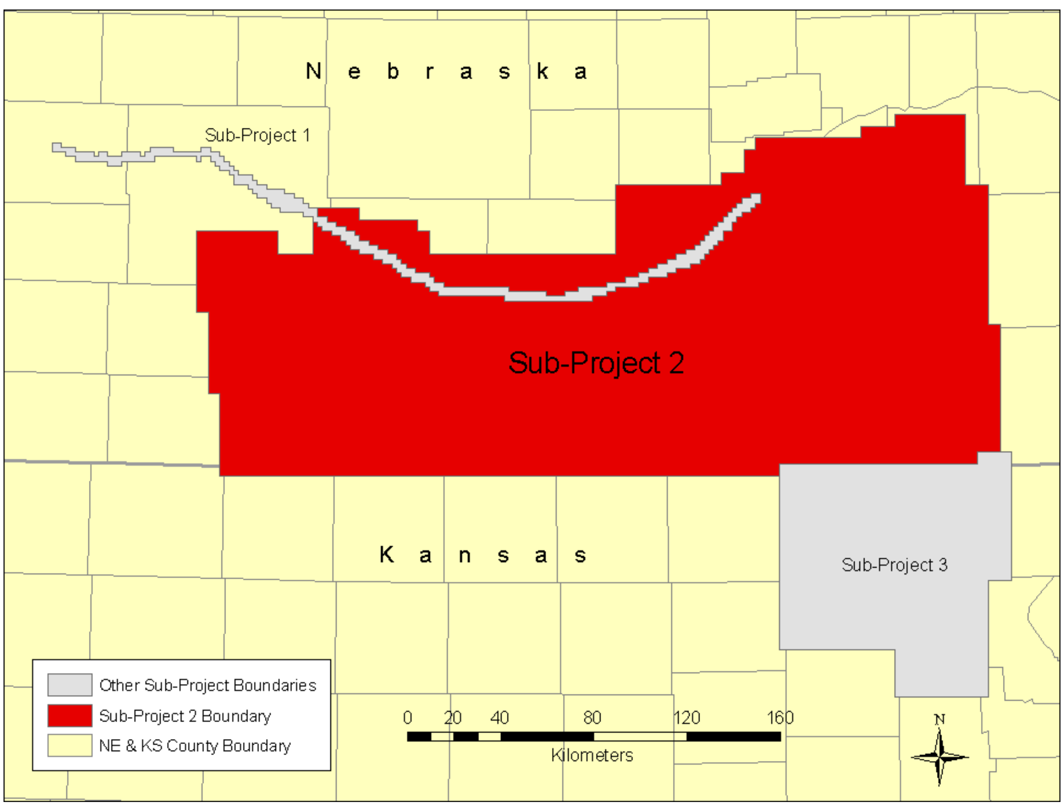


Figure 1: NE-KS project boundary with Sub-project 2 highlighted

Quantitative Analysis: Using checkpoints provided by USDA-NRCS-Nebraska, Dewberry tested the $RMSE_Z$ per FEMA/NSSDA and NDEP/ASPRS specifications. Checkpoints were provided in four land cover categories (open terrain, vegetation, forest, and urban). Table 1 shows the accuracy scores in open terrain at the 95% confidence level using the FEMA/NSSDA methodology ($RMSE_Z$ x 1.9600), and Table 2 shows the accuracy assessment scores in each land cover category measured at the 95th percentile (NDEP/ASPRS methodology).

Table 1: Vertical accuracy assessment summary (FEMA/ASPRS methodology)

Criterion	Checkpoints Used	Accuracy Specification	Results Achieved
$RMSE_Z$	1,276	0.185 m	0.157 m
FVA (open terrain)	746	0.363 m	0.320 m

Table 2: Vertical accuracy assessment summary (NDEP/ASPRS methodology)

Criterion	Checkpoints Used	Accuracy Specification	Results Achieved
Consolidated	1,273	0.363 m	0.290 m
Fundamental (open terrain)	746	0.363 m	0.320 m
Supplemental (open terrain)	746	0.363 m	0.290 m
Supplemental (vegetation)	507	0.363 m	0.290 m
Supplemental (forest)	10	0.363 m	0.164 m
Supplemental (urban)	13	0.363 m	0.257 m

- **Tested 0.157 meters $RMSE_Z$ (FEMA/NSSDA methodology)**
- **Tested 0.320 meters fundamental vertical accuracy at 95% confidence level in Open Terrain (FEMA/NSSDA and NDEP/ASPRS methodologies)**
- **Tested 0.290 meters consolidated vertical accuracy at 95th percentile in all land cover categories (NDEP/ASPRS methodology)**
- **Tested 0.290 meters supplemental vertical accuracy at 95th percentile in Open Terrain category (NDEP/ASPRS methodology)**
- **Tested 0.290 meters supplemental vertical accuracy at 95th percentile in Vegetation category (NDEP/ASPRS methodology)**
- **Tested 0.164 meters supplemental vertical accuracy at 95th percentile in Forest category (NDEP/ASPRS methodology)**
- **Tested 0.257 meters supplemental vertical accuracy at 95th percentile in Urban category (NDEP/ASPRS methodology)**

Qualitative Analysis: Dewberry visually inspected 50% of the data. No remote-sensing data voids were found and the data is free of major systematic errors. The cleanliness of the bare earth model meets expectations; minor errors were found in less than 2% of the data, including artifacts left in the ground classification, small divots and misclassifications. Noise in the flight line overlap areas is present throughout the project area, but is within the allowable tolerance. All of the remaining errors are minor and should not affect the usability of the data.

QA Report

1 Introduction

The following definitions are provided to distinguish between steps taken by Dewberry, as prime contractor, to provide Quality Assurance (QA) of the LiDAR data produced by Merrick, and steps taken by Merrick, as data producer, to perform Quality Control (QC) of the data that it provides to Dewberry. Collectively, this QA/QC process ensures that the LiDAR data delivered to USDA-NRCS-Nebraska and the Corps of Engineers are accurate, usable, and in conformance with the deliverables specified in the Scope of Work. These definitions are taken from the DEM Quality Assessment chapter of the 2nd edition of “Digital Elevation Model Technologies and Applications: The DEM Users Manual,” published by the American Society for Photogrammetry and Remote Sensing (ASPRS), 2007:

> **Quality Assurance (QA)** — Steps taken: (1) to ensure the end client receives the quality products it pays for, consistent with the Scope of Work, and/or (2) to ensure an organization’s Quality Program works effectively. Quality Programs include quality control procedures for specific products as well as overall Quality Plans that typically mandate an organization’s communication procedures, document and data control procedures, quality audit procedures, and training programs necessary for delivery of quality products and services.
>
> **Quality Control (QC)** — Steps taken by data producers to ensure delivery of products that satisfy standards, guidelines and specifications identified in the Scope of Work. These steps typically include production flow charts with built-in procedures to ensure quality at each step of the work flow, in-process quality reviews, and/or final quality inspections prior to delivery of products to a client.

Dewberry’s role is to provide overall project management as well as quality management that include QA of the data including a completeness validation of the LiDAR masspoints, vertical accuracy assessment and reporting, and a qualitative review of the derived bare earth surface.

First, the completeness verification is conducted at a project scale. It consists of a file inventory and a validation of conformity to format, projection, and georeference specifications. At this point Dewberry also ensures that the data adequately covers the project area. The LiDAR data review begins with the computation of general statistics over all fields per file, followed by an analysis of the results to identify anomalies, especially in the elevation fields and LAS class fields.

The quantitative analysis addresses the quality of the data based on absolute accuracy of a limited collection of discrete checkpoint survey measurements. Although only a small amount of points are actually tested through the quantitative assessment, 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 surrounding LiDAR measurements as acquisition conditions remain similar between points and from one flight line to the next.

To fully address the LiDAR data for overall accuracy and quality, a manual qualitative review for anomalies and artifacts is conducted on each tile. This includes creating pseudo-image products such as 3-dimensional models. The QA analyst uses multiple images and overlays to find potential errors in the data as well as areas where the data meets and exceeds expectations.

Three fundamental questions are addressed during Dewberry's QA process:

- Was the data complete?
- Did the LiDAR system perform to specifications?
- Did the ground classification process yield desirable results for the intended bare-earth terrain product?

Under the referenced task order, LiDAR data was acquired for 14,446 square miles in South Central Nebraska (Sub-project 2). All quality assurance processes and results are given in the following sections.

2 Completeness of Deliverables

Dewberry reviews the inventory of the data delivered by validating the format, projection, and georeferencing. LAS files were delivered in tiles that adhere to the project boundary and the specified 5,000 meter x 5,000 meter tile schema. Each LAS file was verified to be projected according to the project specifications in the horizontal projection UTM 14 North (NAD83) and the vertical datum NAVD88, with horizontal and vertical units in meters.

2.1 LiDAR Inventory

Dewberry received 1,613 LiDAR files covering Sub-project 2. They are in the correct format and projection:

- LAS version: 1.1
- Point data format: 1
- Projection set in the header:
    - NAD_1983_UTM_Zone_14N;
    - Horizontal unit: meters;
    - NAVD88 – Geoid03;
    - Vertical unit: meters

Each record includes the following fields (among others):

- X, Y, Z coordinates
- Flight line data
- Intensity value
- Return number, number of returns, scan direction, edge of flight line, scan angle
- Classification
    - Class 1 – unclassified
    - Class 2 – ground
    - Class 7 – low point/noise, overlap
    - Class 9 – water (Only for area overlapping Sub-project 1)
- GPS time (this is expressed in second of the week; note that the date of collection will be given in the metadata file because the date contained in the header is the file creation date according to the LAS standard).

3 LiDAR Quantitative Assessment

Dewberry utilizes several tools to evaluate each LAS tile for completeness, conformity to project specifications, and geospatial accuracy. An automated script is used to validate the header of each tile against the project specifications, as illustrated in section 3.1.1.

3.1 Statistical Analysis

To verify the content of the data and validate the data integrity, a statistical analysis was performed on each tile. This process allows Dewberry to statistically review 100% of the data at a macro level to identify any gross outliers. The statistical analysis consists of first extracting the header information and then reading the actual records and computing the number of points, minimum, maximum, and mean elevation for each class. Minimum and maximum for other relevant variables are also evaluated.

Each tile was queried to extract the number of LiDAR points. With a nominal point spacing of 1.4 meters, the number of points per tile should be approximately 13 million. The mean in Sub-project 1 is approximately 16.7 million, which is more dense than expected. All tiles are within the anticipated size range except for those on the edge of the project boundary (Figure 2).

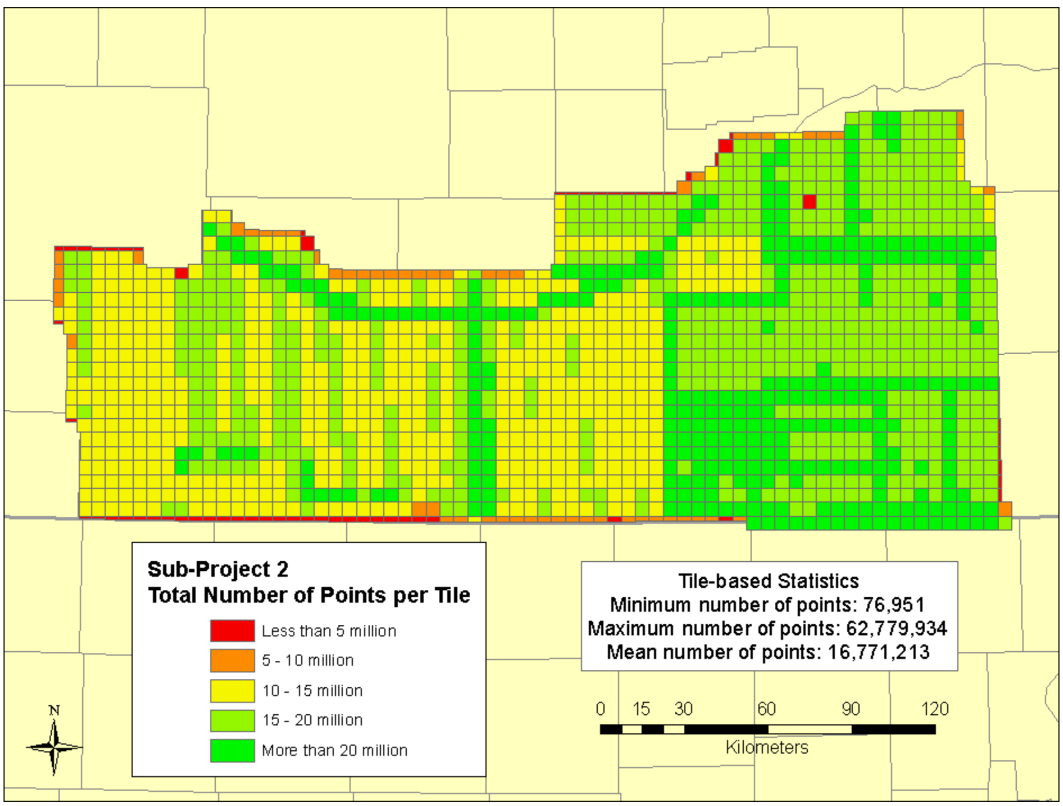


Figure 2: Number of points per tile.

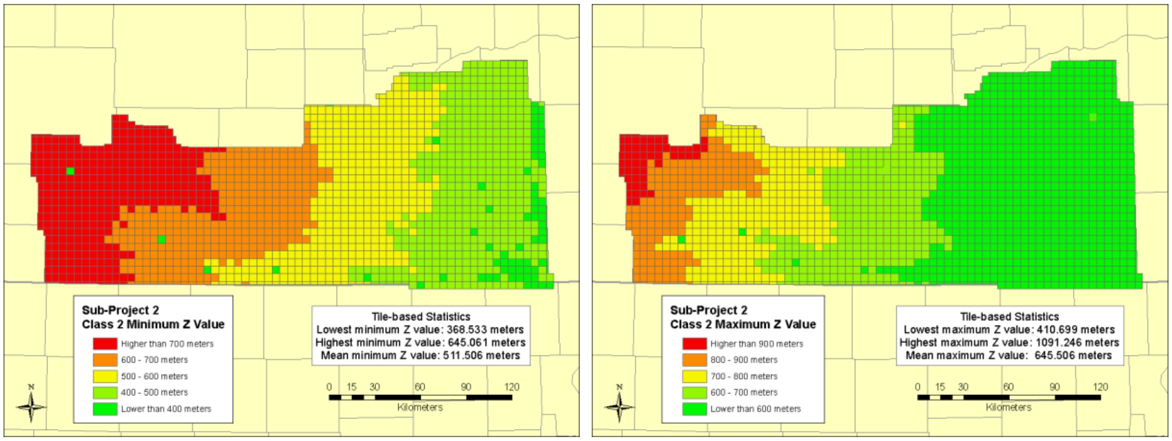


Figure 3: Minimum and maximum elevation by tile for ground points (class 2)

3.1.1 ASPRS Classification Scheme

According to the contract requirements, the LiDAR data were to be delivered in LAS format with each point classified according to a five-class ASPRS scheme:

- Class 1 – Unclassified
- Class 2 – Ground
- Class 7 – Low point and noise
- Class 9 – Water
- Class 12 – Overlap

The Sub-project 2 dataset was delivered with four classes (1, 2, 7 and 9) with class 7 combined to include low points, noise and overlap. Class 9 (water) was only included in Sub-project Areas 8 and 9 because those areas overlap with Sub-project 1 (Platte River Channel) and the Sub-project 1 breaklines were used to define the water classification. Merrick utilizes overlap points in the ground classification to increase the clarity, but if they begin to cause over-densification in the ground (evidenced by noise), those points are classified into class 7.

3.1.2 Pulse Return Analysis

According to the contract requirements, the LiDAR data was to be collected using a sensor with the ability to collect multiple echoes per laser pulse, with a minimum of first, last and one intermediate return. The sensors used for this project met that requirement, returning data with up to four total returns per pulse.

3.2 Vertical Accuracy Assessment

Typically for this type of data collection, a ground truth survey is conducted following the *FEMA Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial Mapping and Surveying* which is based on the NSSDA specifications. This methodology utilizes a minimum of 20 points for each of the predominant land cover types (i.e. open terrain, vegetation, urban, etc.) for a minimum of three land cover classes.

Dewberry uses photographs of each checkpoint to classify it as accurately as possible, but in some cases the land cover has changed between the time of LiDAR collection and the time of the checkpoint survey or documentation. Some checkpoints are located on farmland and are classified as vegetation, but because the LiDAR was collected in winter, there was little or no vegetation surrounding the checkpoint at the time of collection. This means that the checkpoint may be closer to open terrain than vegetation. Since there were several months between the time of collection and the time that the checkpoints were photographed, the vegetation on the land has changed.

The Nebraska Partners elected to use pre-existing survey points for LiDAR accuracy testing. 1,532 checkpoints were made available by USDA-NRCS-Nebraska for assessment by Dewberry. Of these 1,532 points, 1,276 were used in the final assessment after it was determined that 256 points were not suitable for analysis. Checkpoints are deemed unsuitable for analysis when they are determined to be located on a surface that is not ground, such as a bridge, culvert or other man-made feature. Checkpoints may also be invalidated if they are located on terrain with an incline greater than 20 degrees, or if the ground has been disturbed between the time of checkpoint measurement and the LiDAR collection, such as burial or relocation of the point due to land development. The photo in Figure 4 shows a checkpoint surveyed on the edge of a bridge, which is a feature that is removed from the surface model when conducting the accuracy assessment.

Figure 4: Checkpoint "Spring Cr. Br." located on a bridge

Figure 5 shows the point distribution across the South Central Nebraska. The checkpoints are well distributed across the project area.

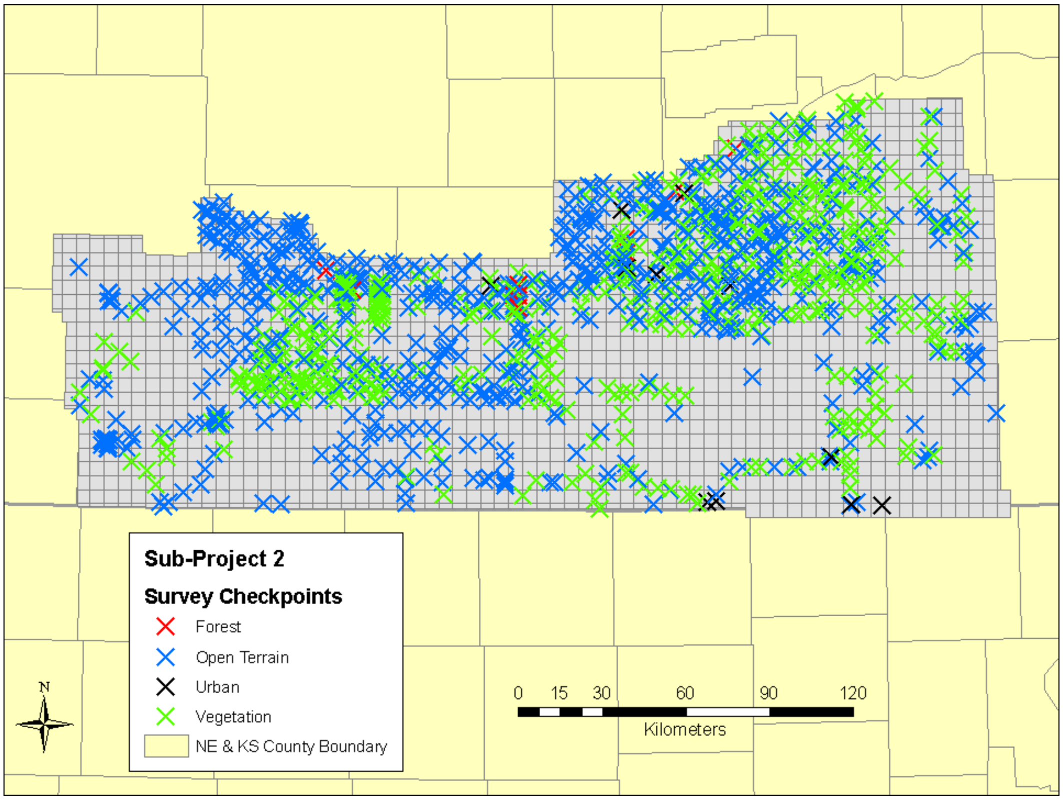


Figure 5: Sub-project 2 survey checkpoints provided by USDA-NRCS-Nebraska

3.2.1 Methodology

The vertical accuracy assessment compares the measured survey checkpoint elevations with those of the TIN as generated from the bare-earth LiDAR. The X/Y locations of the survey checkpoints are overlaid on the TIN and the interpolated Z values of the LiDAR are recorded. These interpolated Z values are then compared with the survey checkpoint Z values and this difference represents the amount of error between the measurements. Once all the Z values are recorded, the Root Mean Square Error (RMSE) is calculated and the vertical accuracy scores are interpolated from the RMSE value. The RMSE equals the square root of the average of the set of squared differences between the dataset coordinate values and the coordinate values from the survey checkpoints

The first method of evaluating vertical accuracy uses the FEMA specification which follows the methodology set forth by the National Standard for Spatial Data Accuracy. The accuracy is reported at the 95% confidence level using the Root Mean Square Error (RMSE) which is valid when errors follow a normal distribution. By this method, vertical accuracy at the 95% confidence level equals $RMSE_Z$ x 1.9600.

The second method of testing vertical accuracy, endorsed by the National Digital Elevation Program (NDEP) and American Society for Photogrammetry and Remote Sensing (ASPRS) uses the same (RMSEz x 1.9600) method in open terrain only; an alternative method uses the 95th percentile to report vertical accuracy in each of the other land cover categories (defined as Supplemental Vertical Accuracy – SVA) and all land cover categories combined (defined as

Consolidated Vertical Accuracy – CVA). The 95th percentile method is used when vertical errors may not follow a normal error distribution, as in vegetated terrain.

The Fundamental Vertical Accuracy (FVA) is calculated in the same way when implementing FEMA/NSSDA and NDEP/ASPRS methodologies; both methods utilize the 95% confidence level ($RMSE_Z$ x 1.9600) in open terrain where there is no reason for LiDAR errors to depart from a normal error distribution.

The following tables and graphs outline the vertical accuracy and the statistics of the associated errors as computed by the different methods. Table 3 shows the results of the Sub-project 2 dataset calculated with the FEMA/NSSDA methodology; vertical accuracy at the 95% confidence level equals the RMSE x 1.9600. By this method, the fundamental vertical accuracy equals the RMSE (0.163 m x 1.9600), or 0.320 m (32.0 cm). This means that 95% of the surveyed points have an absolute delta Z of less than or equal to 0.320 m.

Table 3: Final statistics for Sub-project 2 using FEMA/NSSDA processes.

100 % of Totals	RMSE (m) Spec=0.185 m	Mean (m)	Median (m)	Skew	Std Dev (m)	# of Points	Min (m)	Max (m)
Consolidated	0.157	0.013	0.015	0.500	0.156	1,276	-0.906	1.681
Open Terrain	0.163	0.001	0.007	0.651	0.163	746	-0.906	1.681
Vegetation	0.148	0.029	0.028	0.318	0.145	507	-0.436	0.878
Forest	0.108	0.051	0.041	-0.906	0.101	10	-0.164	0.164
Urban	0.144	0.045	0.009	0.427	0.143	13	-0.154	0.285

Table 4 shows the results of the Sub-project 2 dataset calculated with the NDEP/ASPRS process. The Consolidated Vertical Accuracy (CVA) at the 95th percentile is 0.290 m, which is within the accuracy requirement. The supplemental vertical accuracy, where each land cover type is tested independently, is within specifications for all land cover types.

Table 4: Final statistics for Sub-project 2 using NDEP/ASPRS processes.

Land Cover Category	# of Points	FVA — Fundamental Vertical Accuracy (RMSEz x 1.9600) Spec=0.363 m	CVA — Consolidated Vertical Accuracy (95th Percentile) Spec=0.363 m	SVA — Supplemental Vertical Accuracy (95th Percentile) Target=0.363 m
Consolidated	1,276		0.290	
Open Terrain	746	0.320		0.290
Vegetation	507			0.290
Forest	10			0.164
Urban	13			0.257

Figure 6 illustrates the distribution of the elevation differences between the LiDAR data and the surveyed checkpoints. The checkpoints are evenly distributed between positive and negative elevation error values.

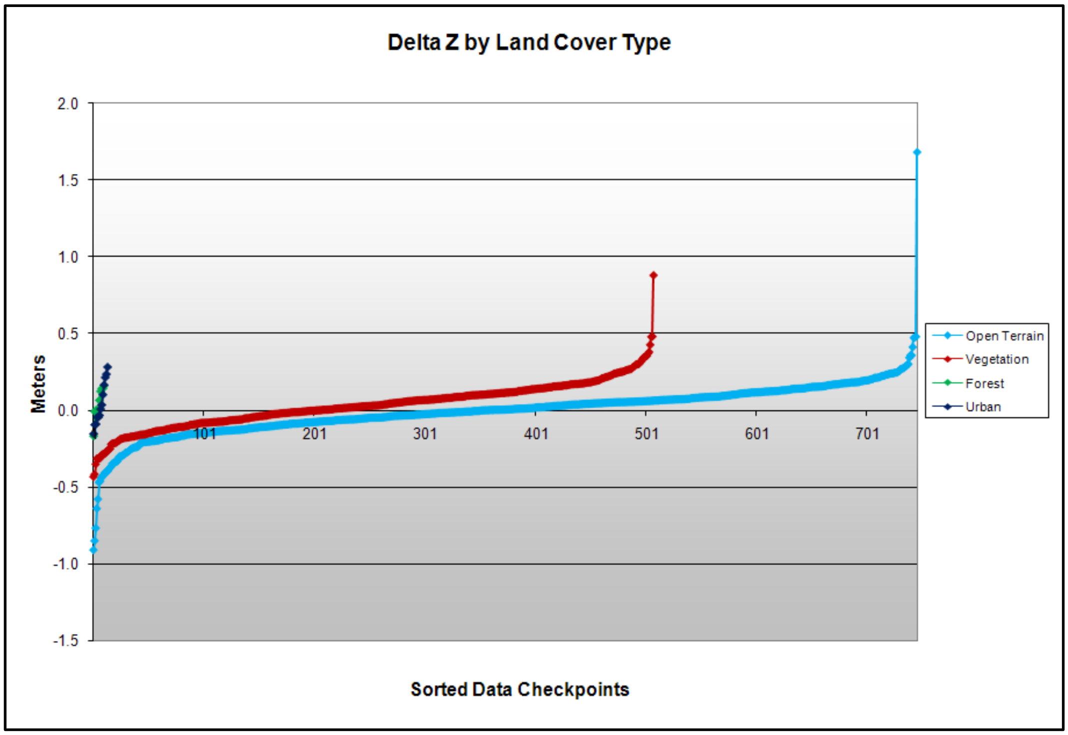


Figure 6: Checkpoint distribution sorted by error value (delta Z)

Given the good results throughout the dataset, Dewberry is confident that the data meets the accuracy requirements. Compared with the 0.363 m specification for vertical accuracy at the 95% confidence level, equivalent to 2-foot contours, the dataset passes by all methods of accuracy assessment.

4 LiDAR Qualitative Analysis

4.1 Protocol

The goal of Dewberry's qualitative review is to assess the continuity and the level of cleanliness of the bare earth product. Each LiDAR tile is expected to meet the following acceptance criteria:

- The point density is homogenous and sufficient to meet the user's needs;
- The ground points have been correctly classified (no man-made structures or vegetation remains, no gaps except over water bodies);
- The ground surface model exhibits a correct definition (no aggressive classification, no over-smoothing, no inconsistency in the post-processing);
- No obvious anomalies due to sensor malfunction or systematic processing artifacts are present (data voids, large spikes/divots, ridges between flight lines/tiles, cornrows, etc);
- 90% of artifacts classified, 95% of outliers, 95% of the vegetation, 98% of the buildings.

Dewberry analysts, experienced in evaluating LiDAR data, performed a visual inspection of 100% of the bare earth data using digital elevation models (DEMs). The DEMs are built by first creating a fishnet grid of the LiDAR masspoints with a grid distance of 2x the full point cloud resolution. Next, a triangulated irregular network (TIN) is built based on this gridded DEM and displayed as a 3D surface. A shaded relief effect (hillshade) was applied which enhances 3D rendering. The software used for visualization allows the user to navigate, zoom and rotate models, as well as display density and elevation information with an adaptive color coding in order to better identify anomalies.

One of the variables established when creating the models is the threshold for missing data. For each individual triangle, the point density information is stored; if it meets the threshold, the corresponding surface will be displayed in green, if not it will be displayed in red (Figure 7).

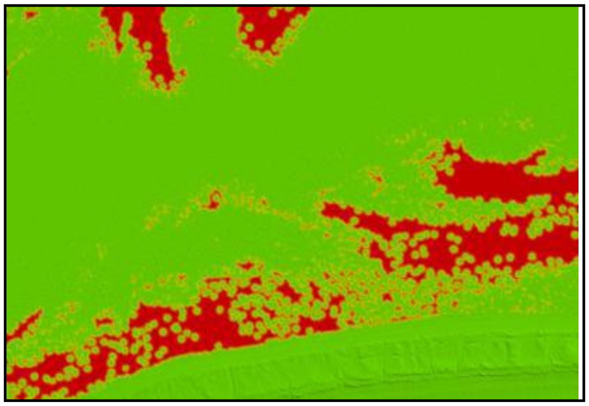


Figure 7: Stock example of low point density (red areas)

Please note that if this density model is created with ground points only, low density areas are expected where buildings, water, and/or heavy vegetation were classified out of the ground. Dewberry did not identify any areas of poor LiDAR penetration at the extent illustrated by the sample figure above. The LiDAR was collected to meet the 1.4 m nominal point spacing and therefore maintained sufficient density throughout the sub-project area.

The section below discusses some of the minor anomalies that Dewberry discovered while reviewing the data. These issues are included to make the end-user aware of the unique characteristics of the data; overall the LiDAR is accurate and free of collection and processing errors.

4.2 Quality Report

Dewberry's qualitative review consists of a micro-level review of 100% of the tiles. There is no automated toolset more effective than the manual inspection by a GIS analyst to find errors in automated processing of LiDAR data. Dewberry analysts inspected the data for processing anomalies, classification errors, and artifacts remaining in the ground classification. The following issues represent small anomalies in the data that generally do not create problems when conducting geographic and hydrographic analysis, but the user should be aware of their existence.

4.2.1 Artifacts

While reviewing the dataset, several buildings were found classified as ground. There is a 2% allowance for building artifacts; therefore these errors do not need to be reprocessed. Figure 8 shows the building remaining in the ground classification. The image on the right shows the full point cloud colored by intensity and the model on the left shows the ground classification colored by elevation. The profile graph shows the elevation difference between the full point cloud and ground. Please see section 6.1 for screenshot thumbnails.

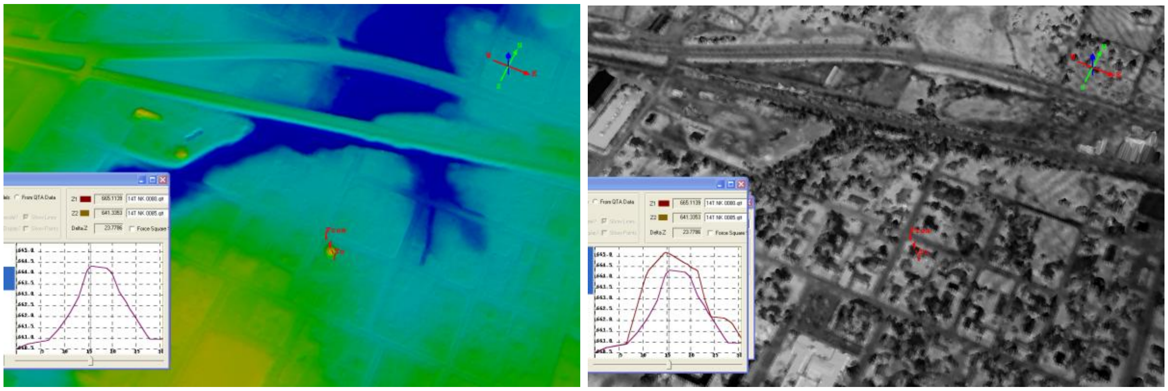


Figure 8: tile 14T NK 0080 showing part of a building remaining in the ground surface

Dewberry also identified several cases of vegetation remaining in the ground classification. There is a 5% allowance for vegetation in the project area so these errors do not need to be reprocessed. Figure 9 shows the full point cloud colored by intensity on the right and the ground classification colored by elevation on the left. The profile graph shows the height of the artifact in the ground model. Please see section 6.1 for screenshot thumbnails.

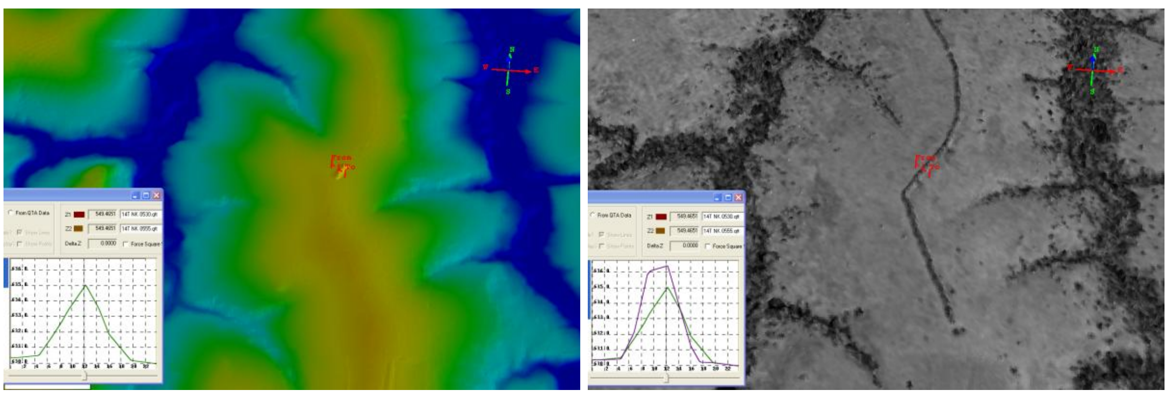


Figure 9: tile 14S NK 0525 showing vegetation in the ground surface

4.2.2 Divots

Spikes and divots are points in the dataset that are classified as ground, but are not part of the true ground surface. Spikes could be remnants of trees, buildings, etc that did not get completely removed from the ground, and divots are generally points with errors in GPS time and/or elevation. Spikes and divots must be removed from the final dataset, but Dewberry identified several small divots in the dataset that do not need to be reclassified, because they do not fall far below the ground surface and should not affect the usability of the ground model. Figure 10 shows a divot in the ground model. Please see section 6.2 for screenshot thumbnails.

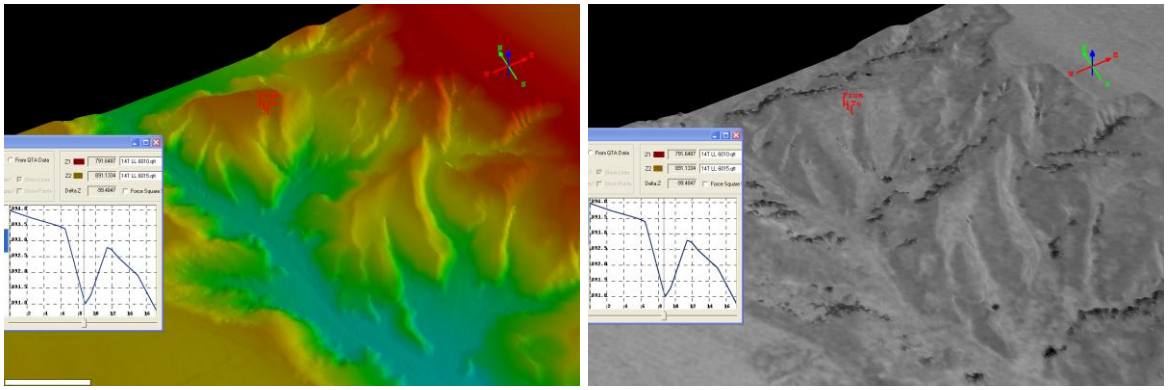


Figure 10: tile 14T LL 6015 showing a 2 meter divot in the ground surface

4.2.3 Misclassification

Dewberry identified one small area of misclassification that does not need to be corrected. It covers a very small area and is not near any significant drainage features. Figure 11 shows the misclassification; the image on the left shows the ground density model and the image on the right shows the full point cloud intensity. Please see section 6.4 for screenshot thumbnails.

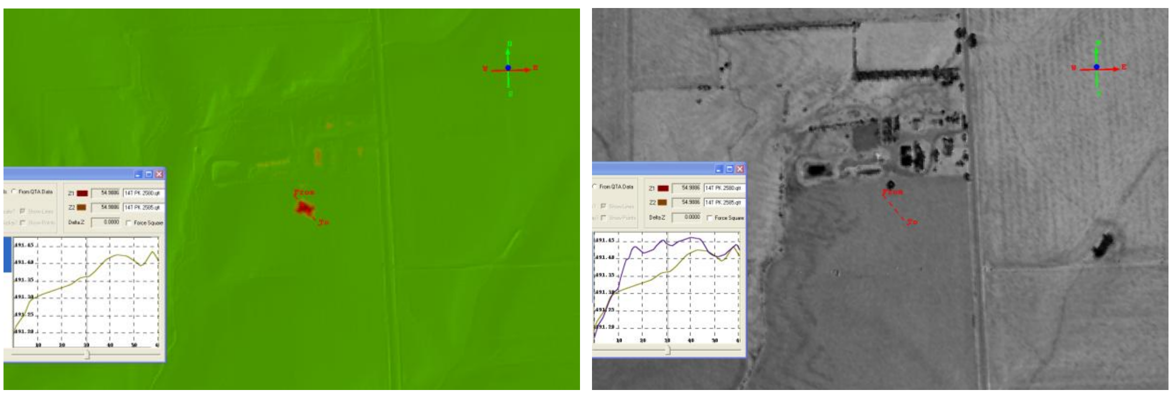


Figure 11: tile 14T PK 2590 showing a misclassification of ground points

4.2.4 Flight Line Overlap Noise

Noise due to small elevation differences between flight lines is a minor error found throughout the dataset. In areas where two or more flight lines overlap, the ground model appears more rough (noisy), as illustrated in Figure 12. All the noisy areas had elevation differences between flight lines of less than 20cm, which is relatively minor and should not affect the usability of the data. Please see section 6.3 for screenshot thumbnails.

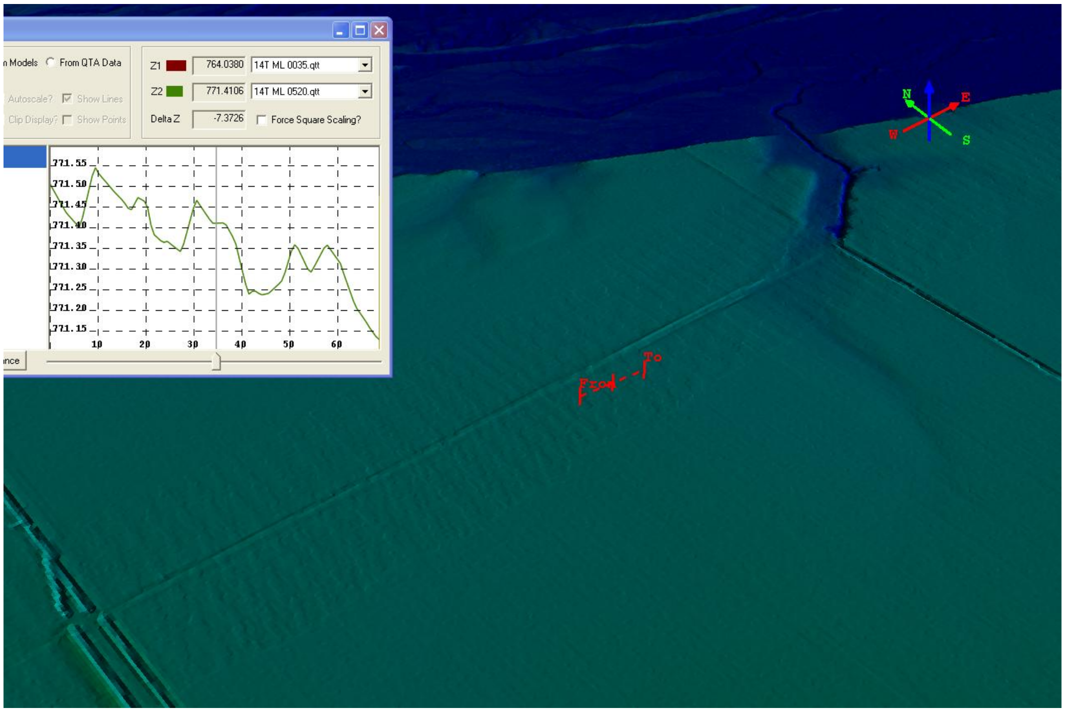


Figure 12: tile 14T ML 0520 showing noise in the flight line overlap area

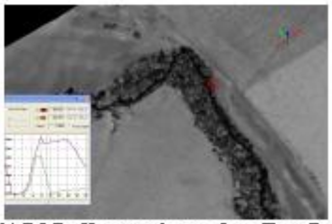
5 Conclusion

Dewberry has completed an extensive quantitative and qualitative assessment of the LiDAR for Sub-project 2, South Central Nebraska. Overall the data is of good quality and meets the minimum specifications for absolute and relative accuracy. The Nebraska Partners provided a sufficient number of checkpoints to conduct a vertical accuracy assessment and the LiDAR data passed in all three land cover categories. The qualitative review did not find any major anomalies in the data; several small issues have been identified and described in this report, but there are no issues that require reprocessing. Dewberry issues acceptance for this data with no further corrections necessary. Any additional editing to this dataset will not result in significant improvements. The LiDAR data are of good quality and will be useful for geographic and hydrographic modeling.

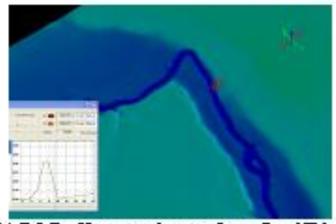
6 Appendix A – Minor Issue Images

6.1 Artifacts

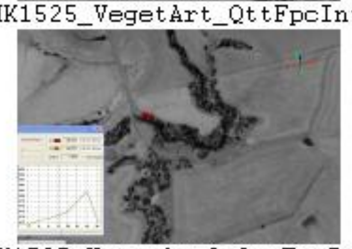
Artifacts



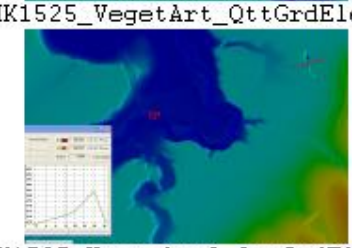
14SMK1525_VegetArt_QttFpcInt.bmp



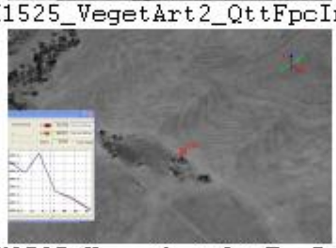
14SMK1525_VegetArt_QttGrdElev.bmp



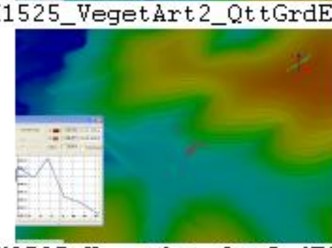
14SMK1525_VegetArt2_QttFpcInt.bmp



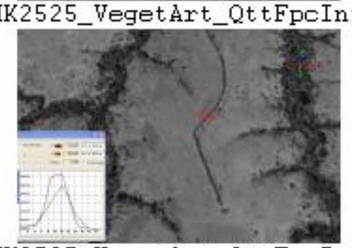
14SMK1525_VegetArt2_QttGrdElev.bmp



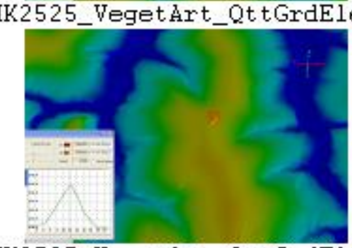
14SMK2525_VegetArt_QttFpcInt.bmp



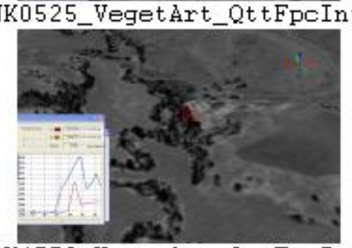
14SMK2525_VegetArt_QttGrdElev.bmp



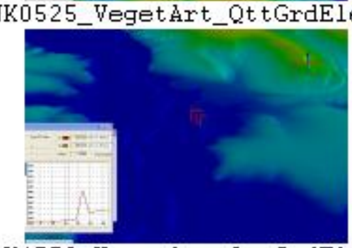
14SNK0525_VegetArt_QttFpcInt.bmp



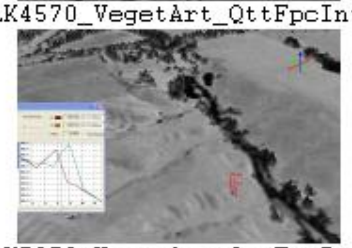
14SNK0525_VegetArt_QttGrdElev.bmp



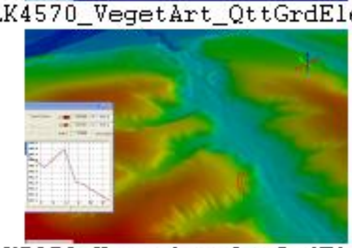
14TLK4570_VegetArt_QttFpcInt.bmp



14TLK4570_VegetArt_QttGrdElev.bmp

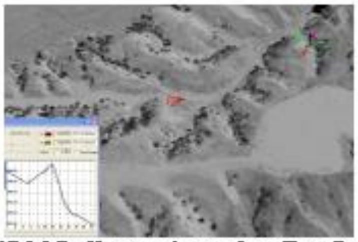


14TLK5050_VegetArt_QttFpcInt.bmp

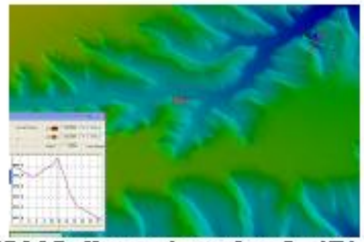


14TLK5050_VegetArt_QttGrdElev.bmp

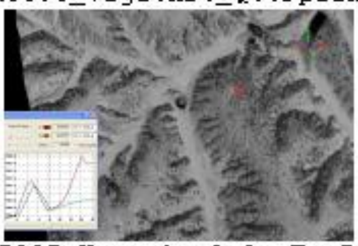
Artifacts



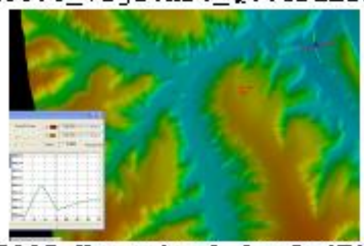
14TLK5095_VegetArt_QttFpcInt.bmp



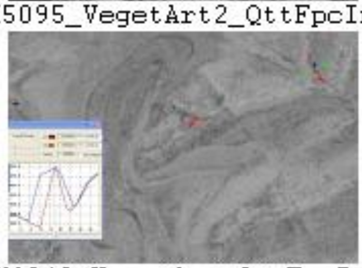
14TLK5095_VegetArt_QttGrdElev.bmp



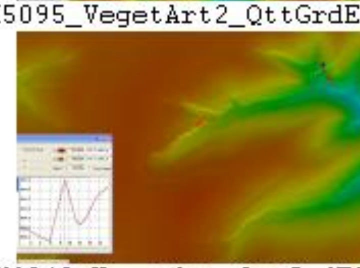
14TLK5095_VegetArt2_QttFpcInt.bmp



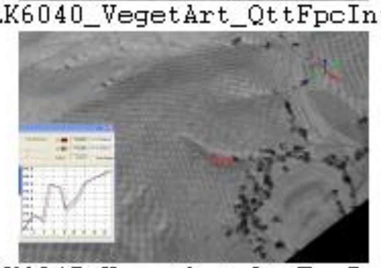
14TLK5095_VegetArt2_QttGrdElev.bmp



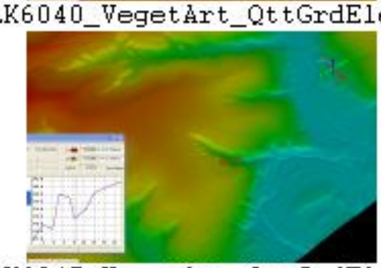
14TLK6040_VegetArt_QttFpcInt.bmp



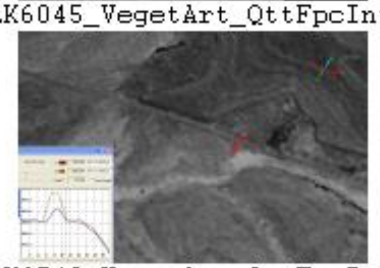
14TLK6040_VegetArt_QttGrdElev.bmp



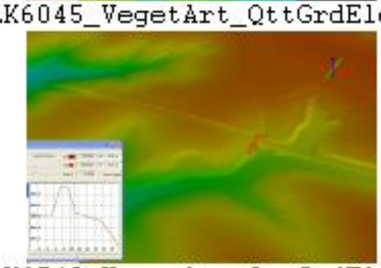
14TLK6045_VegetArt_QttFpcInt.bmp



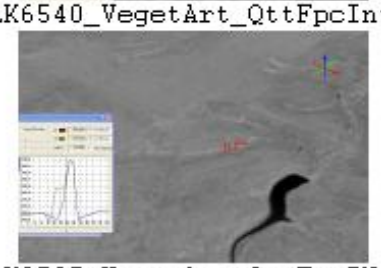
14TLK6045_VegetArt_QttGrdElev.bmp



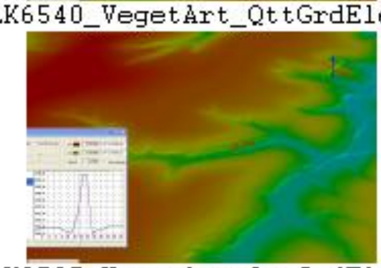
14TLK6540_VegetArt_QttFpcInt.bmp



14TLK6540_VegetArt_QttGrdElev.bmp

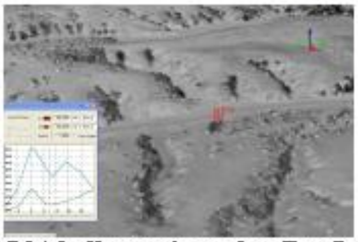


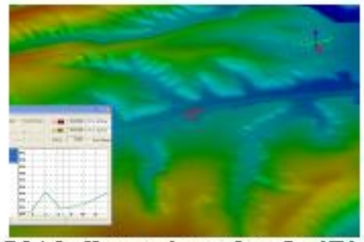
14TLK9535_VegetArt_QttFpcINt.bmp

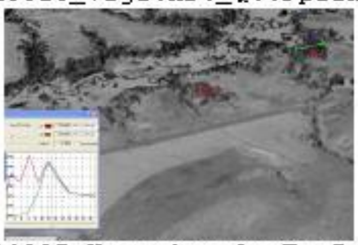


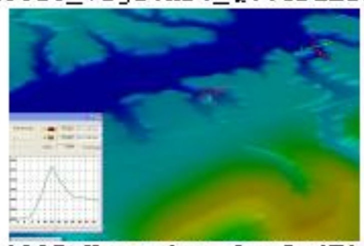
14TLK9535_VegetArt_QttGrdElev.bmp

Artifacts

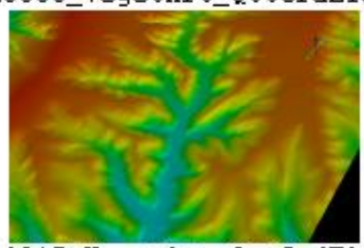

14TLL5010_VegetArt_QttFpcInt.bmp

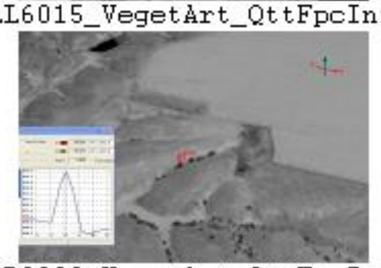

14TLL5010_VegetArt_QttGrdElev.bmp

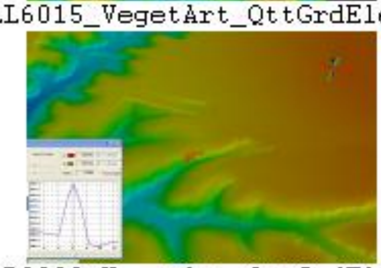

14TLL6005_VegetArt_QttFpcInt.bmp

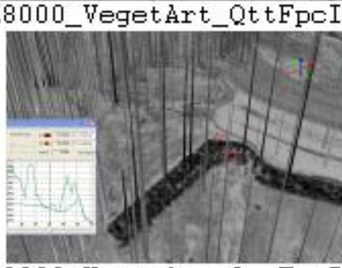

14TLL6005_VegetArt_QttGrdElev.bmp

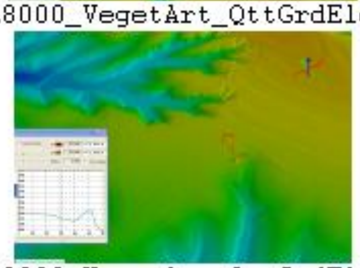

14TLL6015_VegetArt_QttFpcInt.bmp

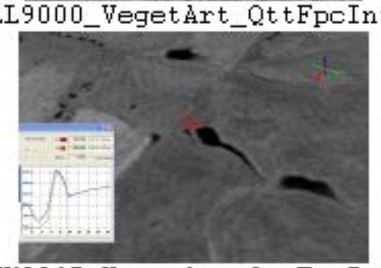

14TLL6015_VegetArt_QttGrdElev.bmp

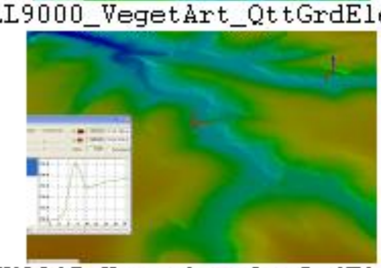

14TLL8000_VegetArt_QttFpcInt.bmp


14TLL8000_VegetArt_QttGrdElev.bmp

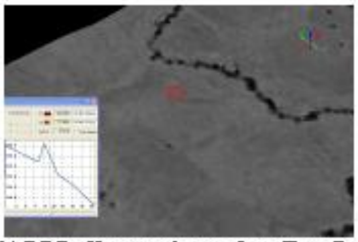

14TLL9000_VegetArt_QttFpcInt.bmp


14TLL9000_VegetArt_QttGrdElev.bmp

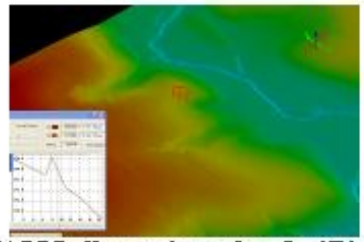

14TMK0065_VegetArt_QttFpcInt.bmp


14TMK0065_VegetArt_QttGrdElev.bmp

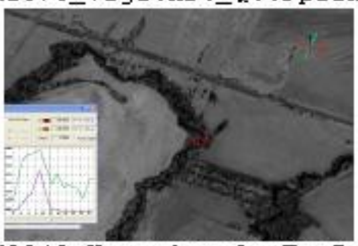
Artifacts



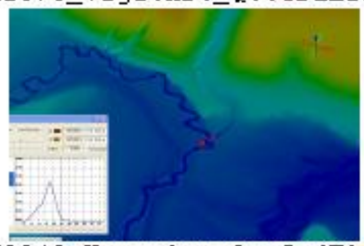
14TMK1575_VegetArt_QttFpcInt.bmp



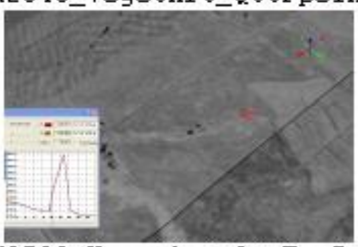
14TMK1575_VegetArt_QttGrdElev.bmp



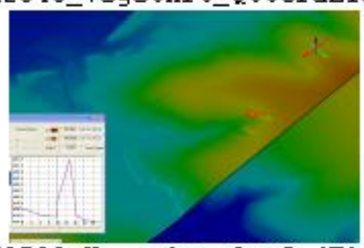
14TMK2040_VegetArt_QttFpcInt.bmp



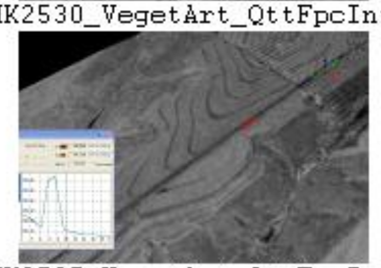
14TMK2040_VegetArt_QttGrdElev.bmp



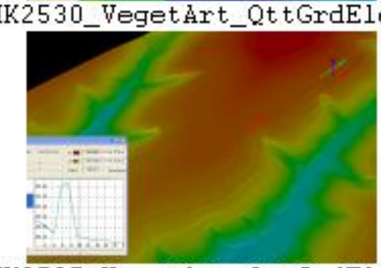
14TMK2530_VegetArt_QttFpcInt.bmp



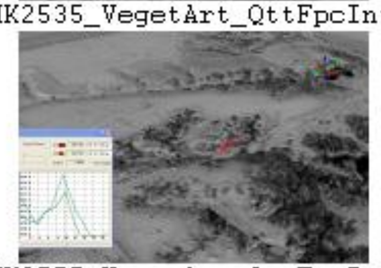
14TMK2530_VegetArt_QttGrdElev.bmp



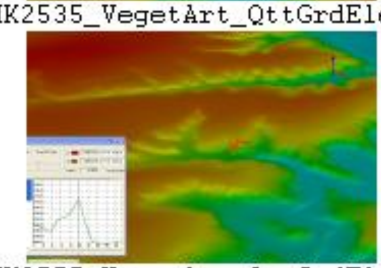
14TMK2535_VegetArt_QttFpcInt.bmp



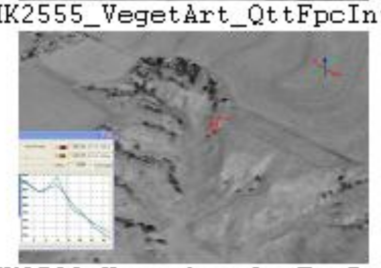
14TMK2535_VegetArt_QttGrdElev.bmp



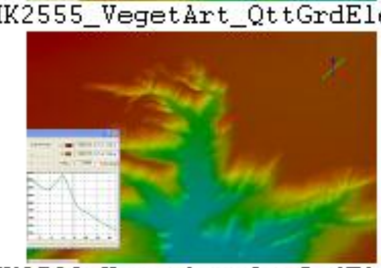
14TMK2555_VegetArt_QttFpcInt.bmp



14TMK2555_VegetArt_QttGrdElev.bmp

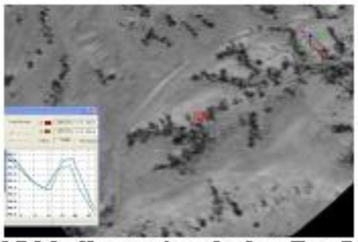


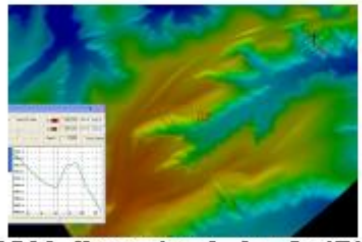
14TMK2590_VegetArt_QttFpcInt.bmp

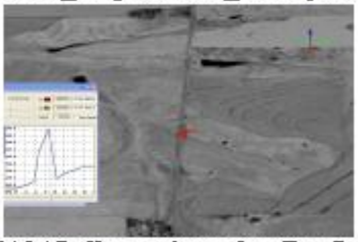


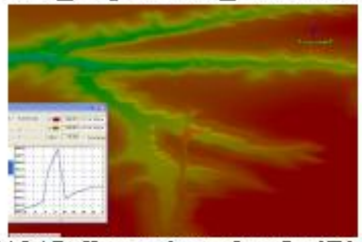
14TMK2590_VegetArt_QttGrdElev.bmp

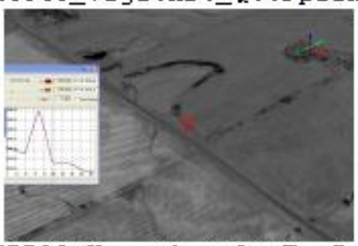
Artifacts

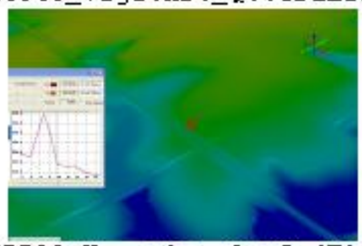

14TMK2590_VegetArt2_QttFpcInt.bmp

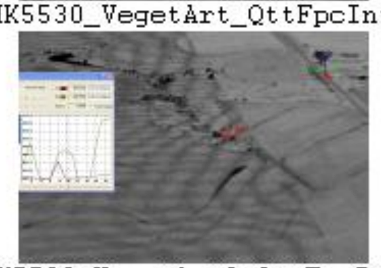

14TMK2590_VegetArt2_QttGrdElev.bmp

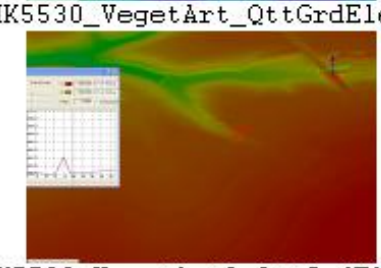

14TMK4045_VegetArt_QttFpcInt.bmp

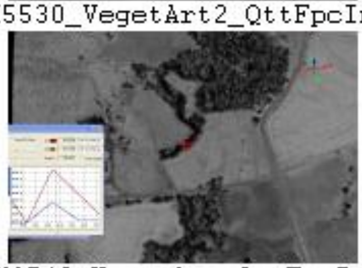

14TMK4045_VegetArt_QttGrdElev.bmp

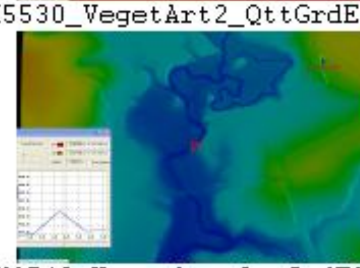

14TMK5530_VegetArt_QttFpcInt.bmp

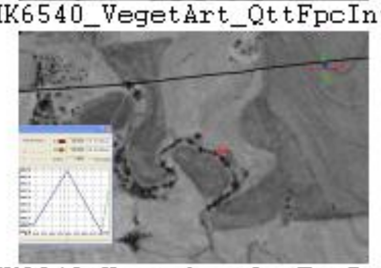

14TMK5530_VegetArt_QttGrdElev.bmp

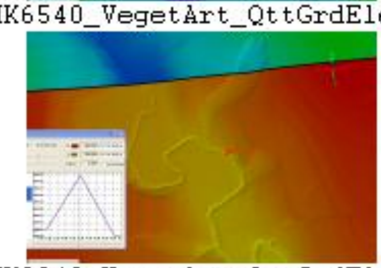

14TMK5530_VegetArt2_QttFpcInt.bmp


14TMK5530_VegetArt2_QttGrdElev.bmp

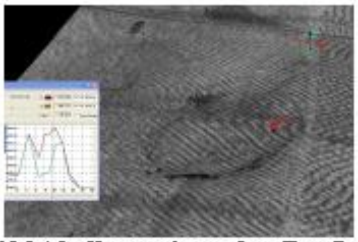

14TMK6540_VegetArt_QttFpcInt.bmp


14TMK6540_VegetArt_QttGrdElev.bmp

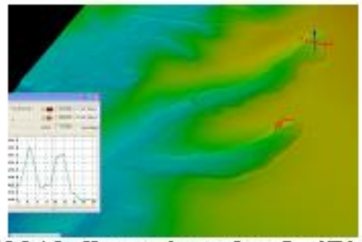

14TMK8040_VegetArt_QttFpcInt.bmp


14TMK8040_VegetArt_QttGrdElev.bmp

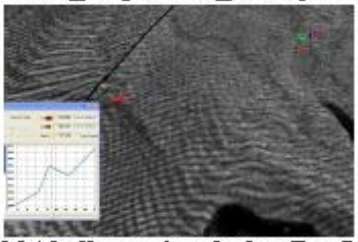
Artifacts



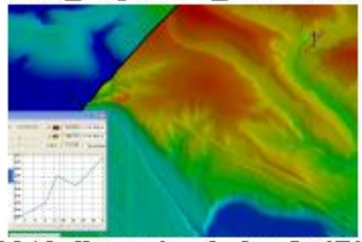
14TMK9040_VegetArt_QttFpcInt.bmp



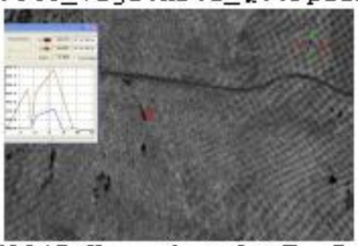
14TMK9040_VegetArt_QttGrdElev.bmp



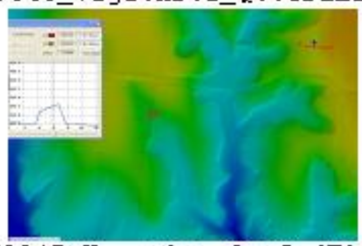
14TMK9040_VegetArt2_QttFpcInt.bmp



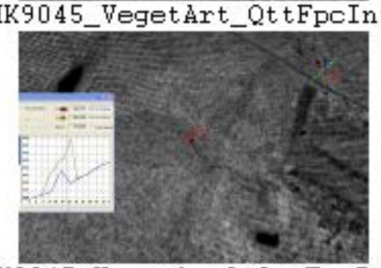
14TMK9040_VegetArt2_QttGrdElev.bmp



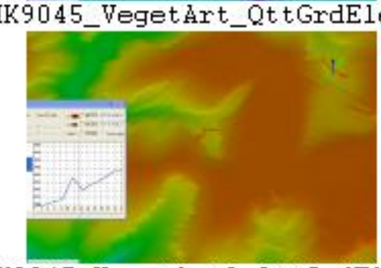
14TMK9045_VegetArt_QttFpcInt.bmp



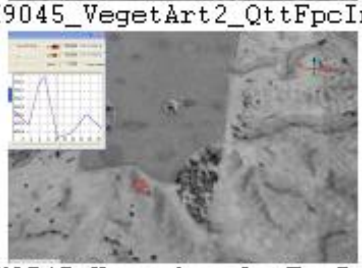
14TMK9045_VegetArt_QttGrdElev.bmp



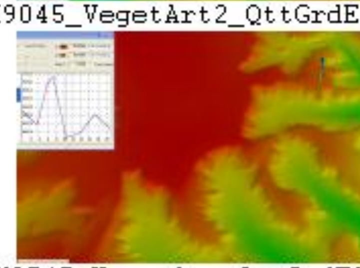
14TMK9045_VegetArt2_QttFpcInt.bmp



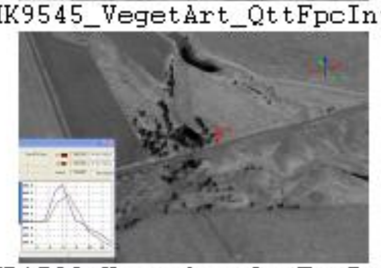
14TMK9045_VegetArt2_QttGrdElev.bmp



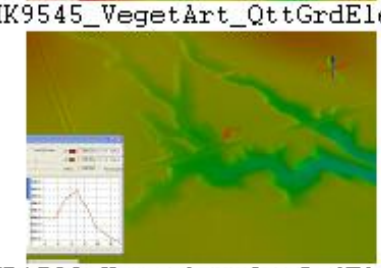
14TMK9545_VegetArt_QttFpcInt.bmp



14TMK9545_VegetArt_QttGrdElev.bmp

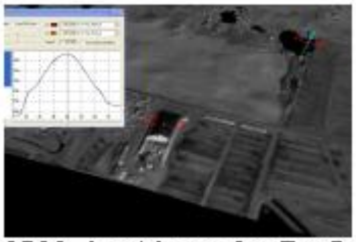


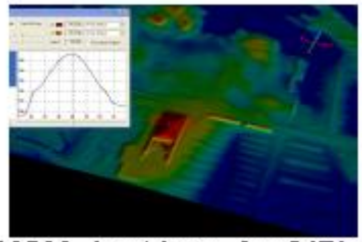
14TML1500_VegetArt_QttFpcInt.bmp

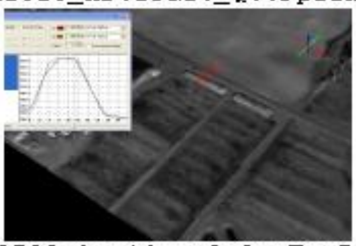


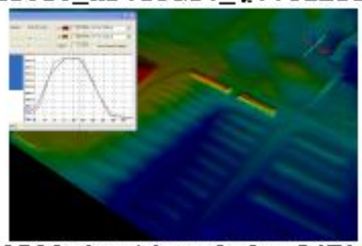
14TML1500_VegetArt_QttGrdElev.bmp

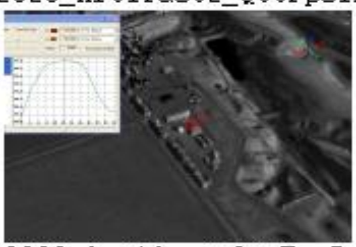
Artifacts

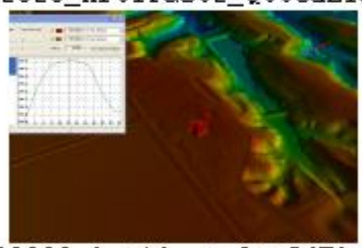

14TML2520_Artifact_QttFpcInt.bmp

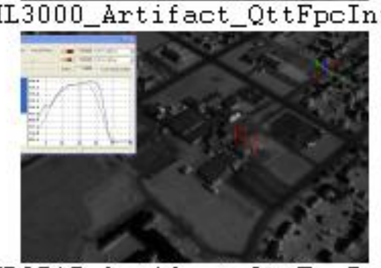

14TML2520_Artifact_QttGdElev.bmp

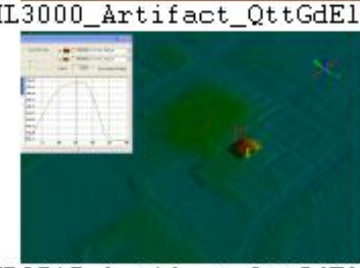

14TML2520_Artifact2_QttFpcInt.bmp

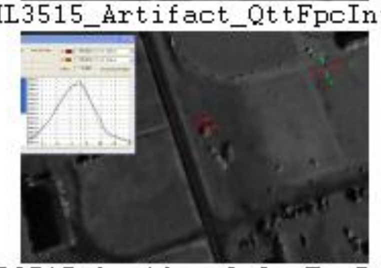

14TML2520_Artifact2_QttGdElev.bmp

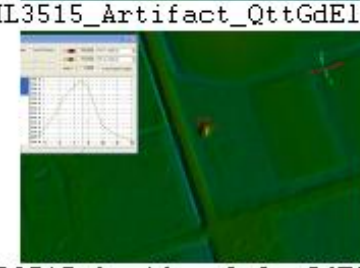

14TML3000_Artifact_QttFpcInt.bmp

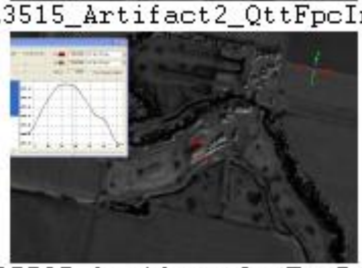

14TML3000_Artifact_QttGdElev.bmp

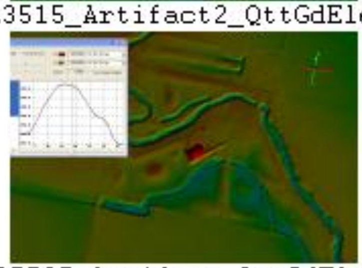

14TML3515_Artifact_QttFpcInt.bmp


14TML3515_Artifact_QttGdElev.bmp

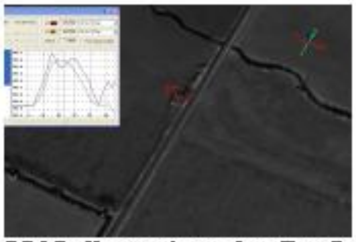

14TML3515_Artifact2_QttFpcInt.bmp

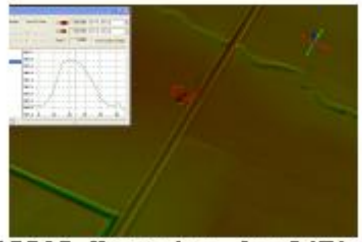

14TML3515_Artifact2_QttGdElev.bmp

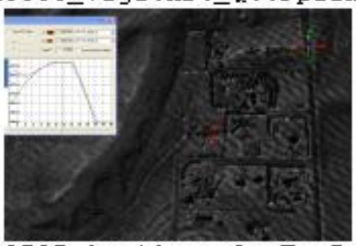

14TML5505_Artifact_QttFpcInt.bmp

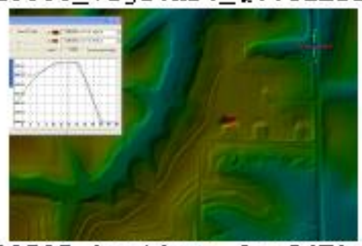

14TML5505_Artifact_QttGdElev.bmp

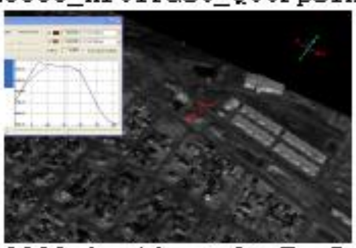
Artifacts

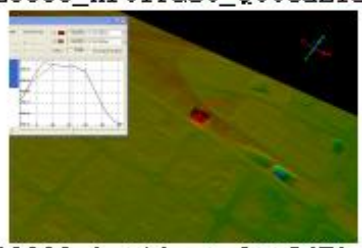

14TML5505_VegetArt_QttFpcInt.bmp

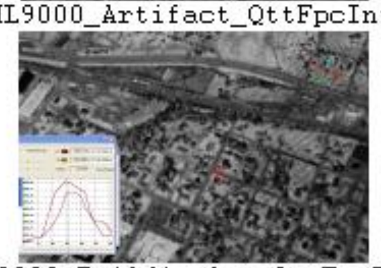

14TML5505_VegetArt_QttGdElev.bmp

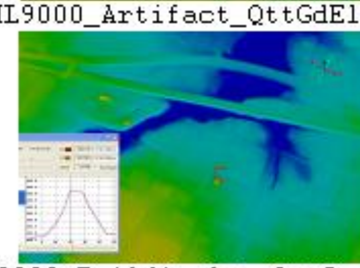

14TML8505_Artifact_QttFpcInt.bmp

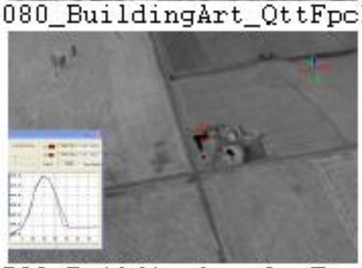

14TML8505_Artifact_QttGdElev.bmp

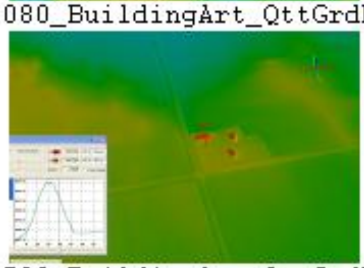

14TML9000_Artifact_QttFpcInt.bmp

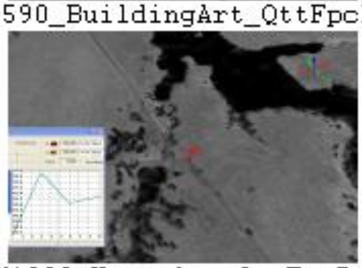

14TML9000_Artifact_QttGdElev.bmp

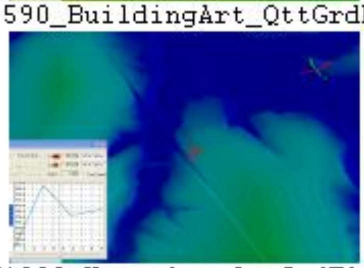

14TNK0080_BuildingArt_QttFpcInt.bmp


14TNK0080_BuildingArt_QttGrdElev.bm

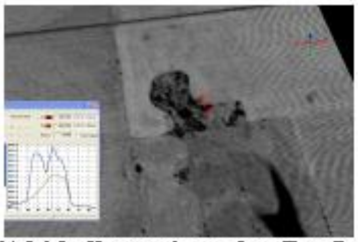

14TNK0590_BuildingArt_QttFpcInt.bmp


14TNK0590_BuildingArt_QttGrdElev.bm

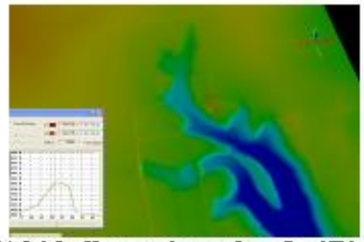

14TNK1030_VegetArt_QttFpcInt.bmp


14TNK1030_VegetArt_QttGrdElev.bmp

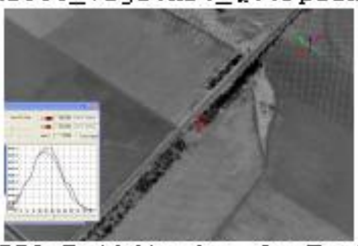
Artifacts



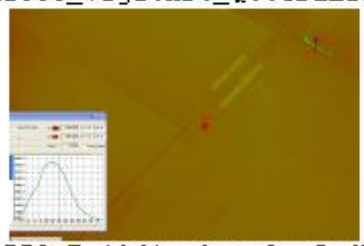
14TNK1060_VegetArt_QttFpcInt.bmp



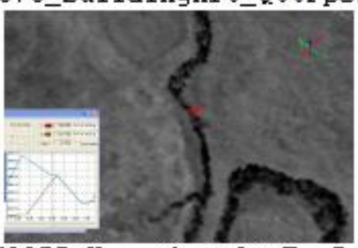
14TNK1060_VegetArt_QttGrdElev.bmp



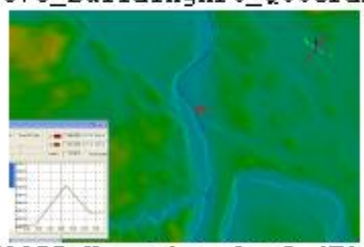
14TNK1570_BuildingArt_QttFpcInt.bmp



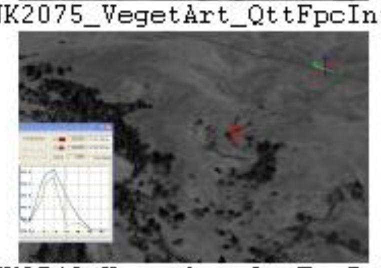
14TNK1570_BuildingArt_QttGrdElev.bm



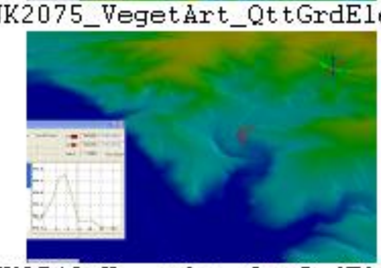
14TNK2075_VegetArt_QttFpcInt.bmp



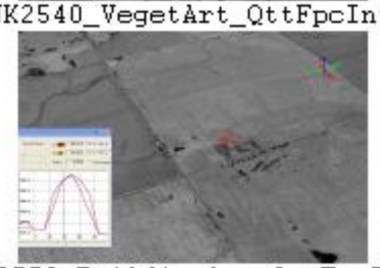
14TNK2075_VegetArt_QttGrdElev.bmp



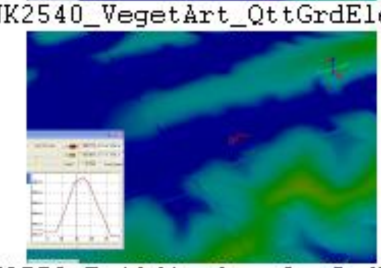
14TNK2540_VegetArt_QttFpcInt.bmp



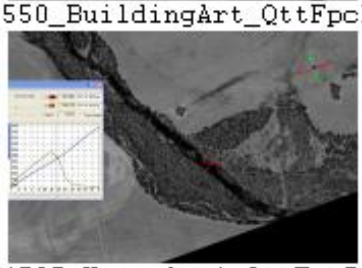
14TNK2540_VegetArt_QttGrdElev.bmp



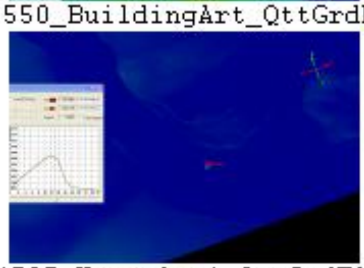
14TNK3550_BuildingArt_QttFpcInt.bmp



14TNK3550_BuildingArt_QttGrdElev.bm

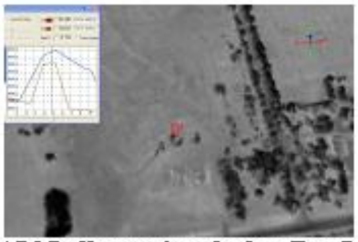


14TNK4535_VegetArt1_QttFpcInt.bmp

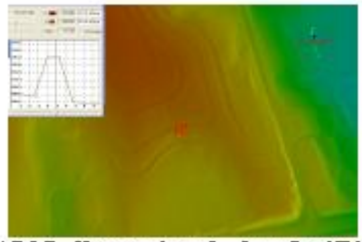


14TNK4535_VegetArt1_QttGrdElev.bmp

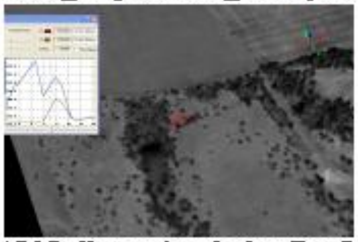
Artifacts



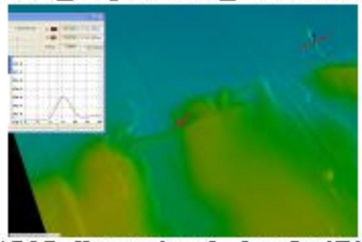
14TNK4535_VegetArt2_QttFpcInt.bmp



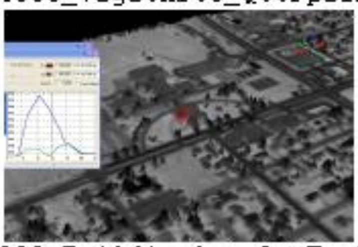
14TNK4535_VegetArt2_QttGrdElev.bmp



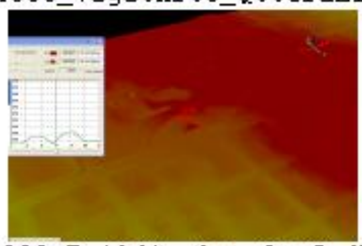
14TNK4535_VegetArt3_QttFpcInt.bmp



14TNK4535_VegetArt3_QttGrdElev.bmp

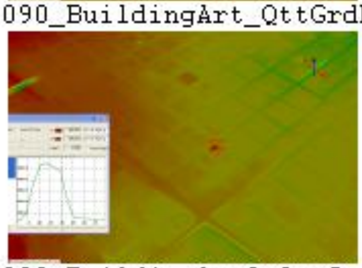


14TNK5090_BuildingArt_QttFpcInt.bmp

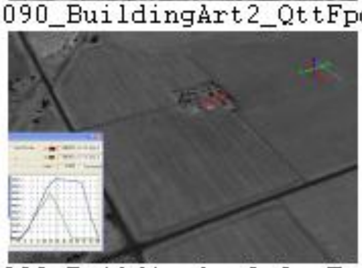


14TNK5090_BuildingArt_QttGrdElev.bm

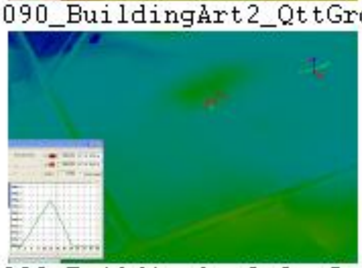
14TNK5090_BuildingArt2_QttFpcInt.bm



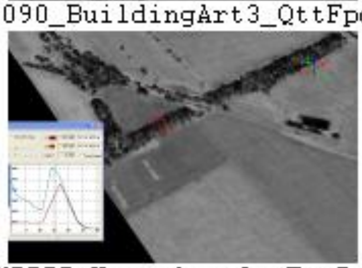
14TNK5090_BuildingArt2_QttGrdElev.b



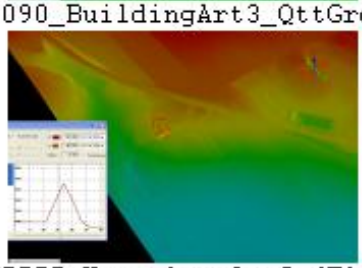
14TNK5090_BuildingArt3_QttFpcInt.bm



14TNK5090_BuildingArt3_QttGrdElev.b

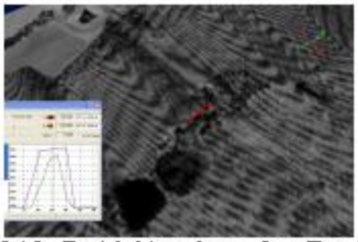


14TNK5575_VegetArt_QttFpcInt.bmp

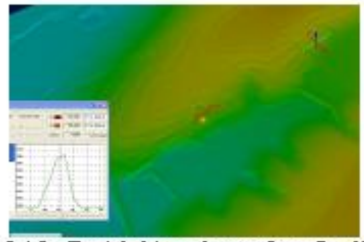


14TNK5575_VegetArt_QttGrdElev.bmp

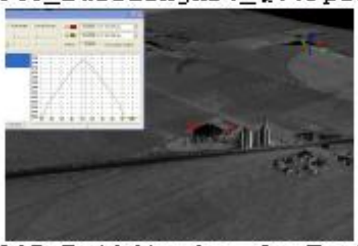
Artifacts



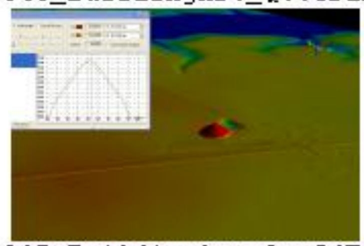
14TNK6040_BuildingArt_QttFpcInt.bmp



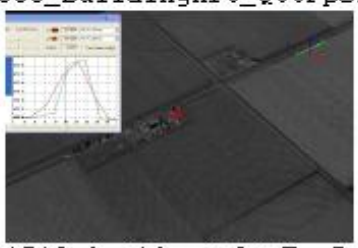
14TNK6040_BuildingArt_QttGrdElev.bm



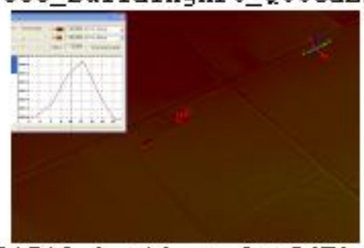
14TNK9065_BuildingArt_QttFpcInt.bmp



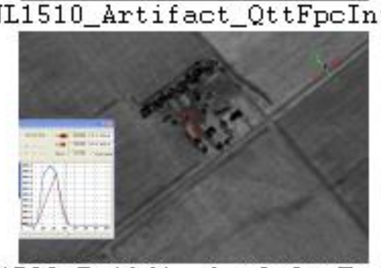
14TNK9065_BuildingArt_QttGdElev.bmp



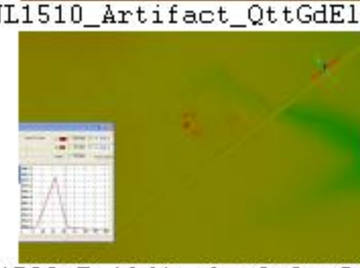
14TNL1510_Artifact_QttFpcInt.bmp



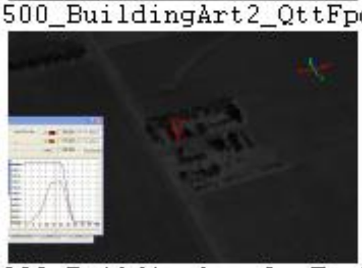
14TNL1510_Artifact_QttGdElev.bmp



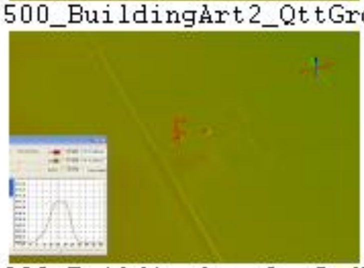
14TNL4500_BuildingArt2_QttFpcInt.bm



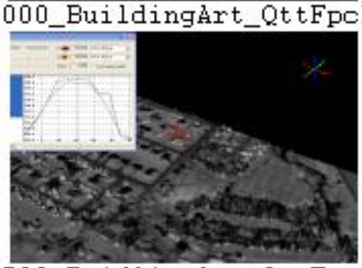
14TNL4500_BuildingArt2_QttGrdElev.b



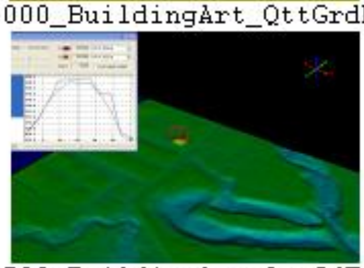
14TNL6000_BuildingArt_QttFpcInt.bmp



14TNL6000_BuildingArt_QttGrdElev.bm

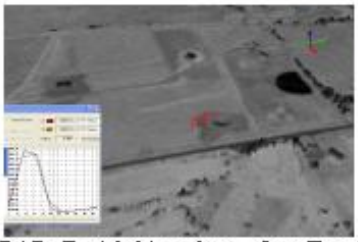


14TNL8520_BuidlingArt_QttFpcInt.bmp

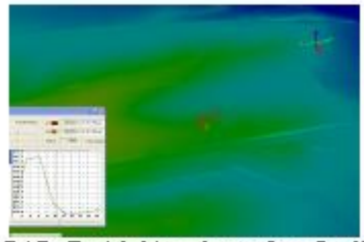


14TNL8520_BuildingArt_QttGdElev.bmp

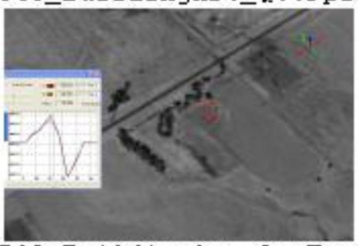
Artifacts



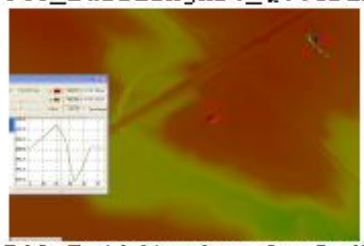
14TPK1545_BuildingArt_QttFpcInt.bmp



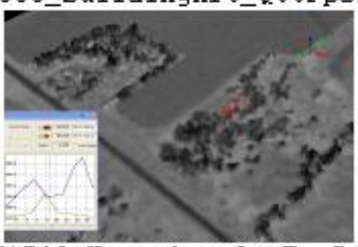
14TPK1545_BuildingArt_QttGrdElev.bm



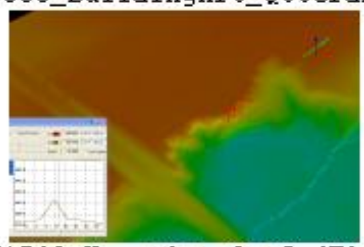
14TPK1560_BuildingArt_QttFpcInt.bmp



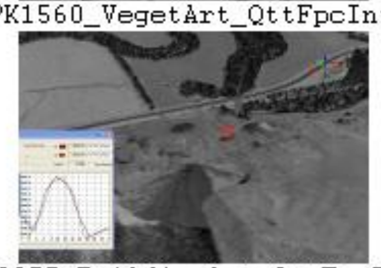
14TPK1560_BuildingArt_QttGrdElev.bm



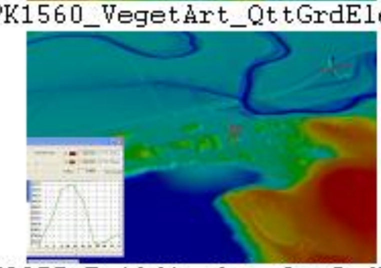
14TPK1560_VegetArt_QttFpcInt.bmp



14TPK1560_VegetArt_QttGrdElev.bmp

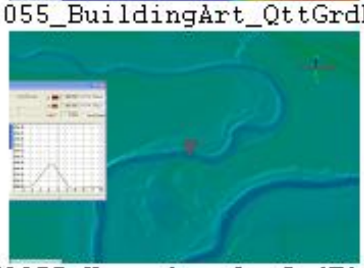


14TPK2055_BuildingArt_QttFpcInt.bmp

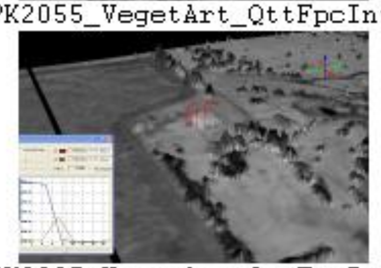


14TPK2055_BuildingArt_QttGrdElev.bm

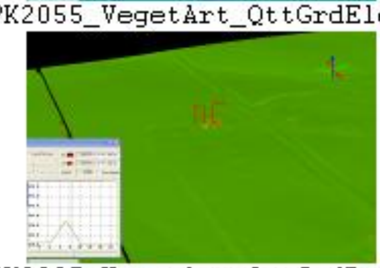
14TPK2055_VegetArt_QttFpcInt.bmp



14TPK2055_VegetArt_QttGrdElev.bmp

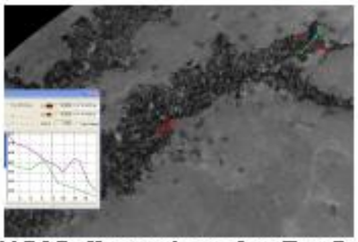


14TPK3095_VegetArt_QttFpcInt.bmp

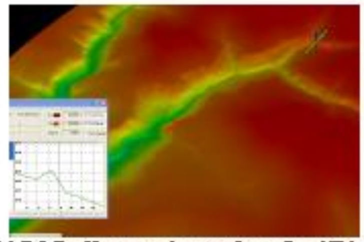


14TPK3095_VegetArt_QttGrdDens.bmp

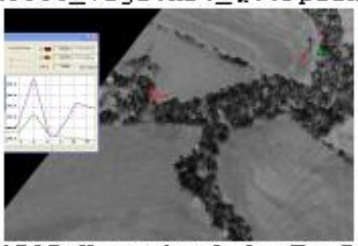
Artifacts



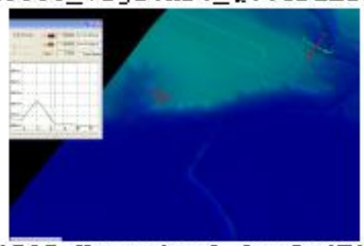
14TPK6535_VegetArt_QttFpcInt.bmp



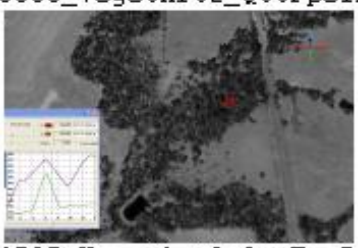
14TPK6535_VegetArt_QttGrdElev.bmp



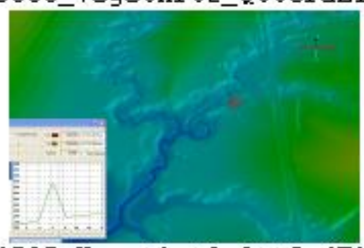
14TPK6535_VegetArt2_QttFpcInt.bmp



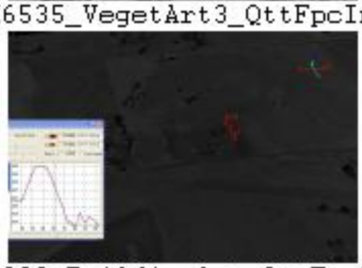
14TPK6535_VegetArt2_QttGrdElev.bmp



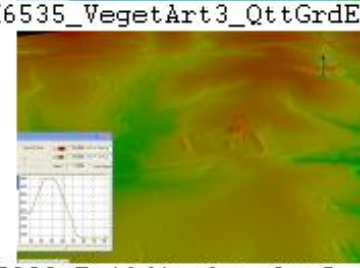
14TPK6535_VegetArt3_QttFpcInt.bmp



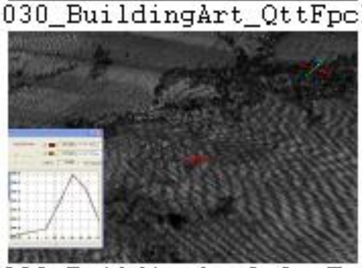
14TPK6535_VegetArt3_QttGrdElev.bmp



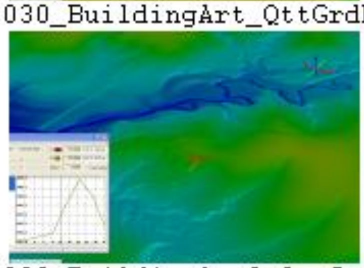
14TPK7030_BuildingArt_QttFpcInt.bmp



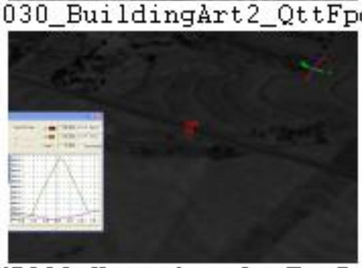
14TPK7030_BuildingArt_QttGrdElev.bm



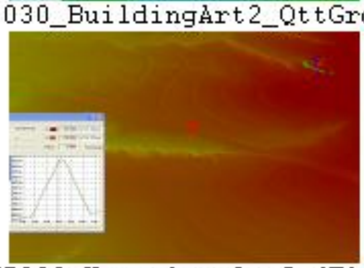
14TPK7030_BuildingArt2_QttFpcInt.bm



14TPK7030_BuildingArt2_QttGrdElev.b

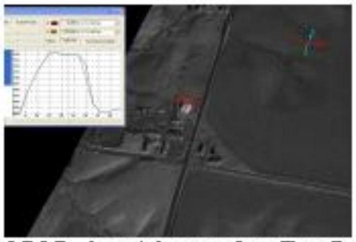


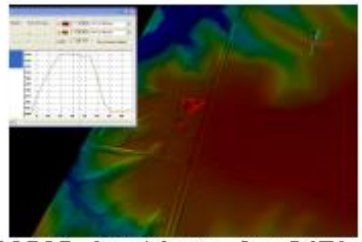
14TPK7030_VegetArt_QttFpcInt.bmp

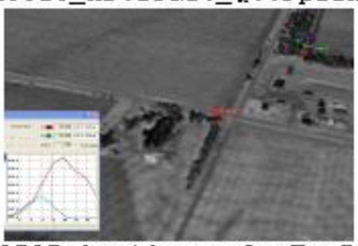


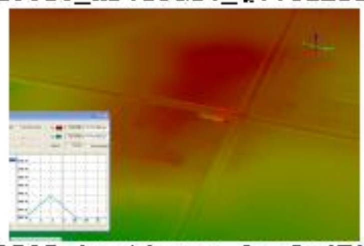
14TPK7030_VegetArt_QttGrdElev.bmp

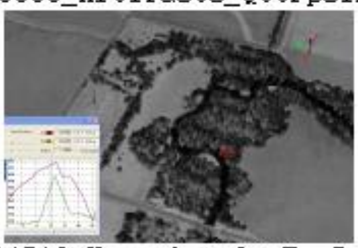
Artifacts

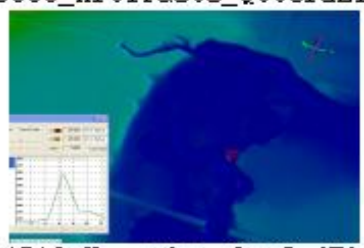

14TPL0525_Artifact_QttFpcInt.bmp

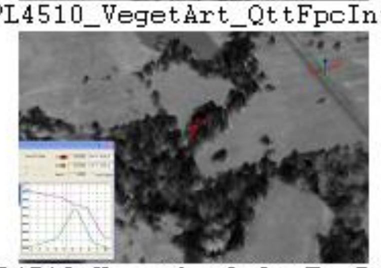

14TPL0525_Artifact_QttGdElev.bmp

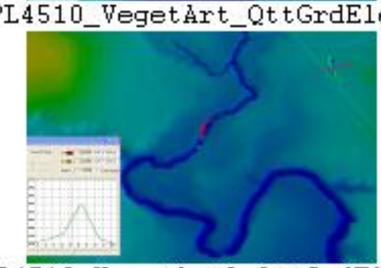

14TPL0535_Artifacts_QttFpcInt.bmp

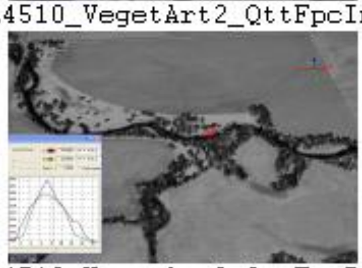

14TPL0535_Artifacts_QttGrdElev.bmp

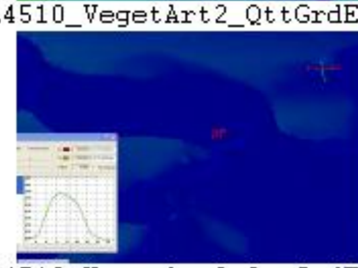

14TPL4510_VegetArt_QttFpcInt.bmp

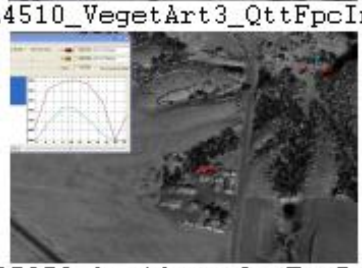

14TPL4510_VegetArt_QttGrdElev.bmp

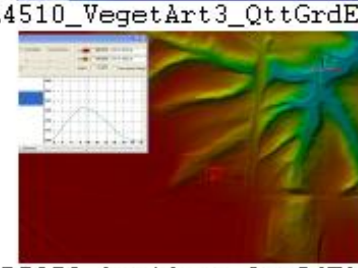

14TPL4510_VegetArt2_QttFpcInt.bmp


14TPL4510_VegetArt2_QttGrdElev.bmp

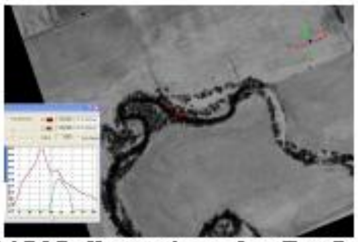

14TPL4510_VegetArt3_QttFpcInt.bmp


14TPL4510_VegetArt3_QttGrdElev.bmp

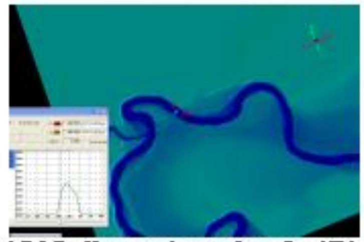

14TPL5070_Artifact_QttFpcInt.bmp


14TPL5070_Artifact_QttGdElev.bmp

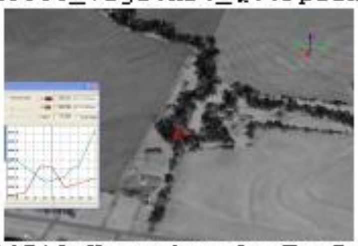
Artifacts



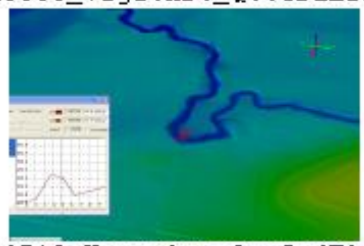
14TPL6505_VegetArt_QttFpcInt.bmp



14TPL6505_VegetArt_QttGrdElev.bmp

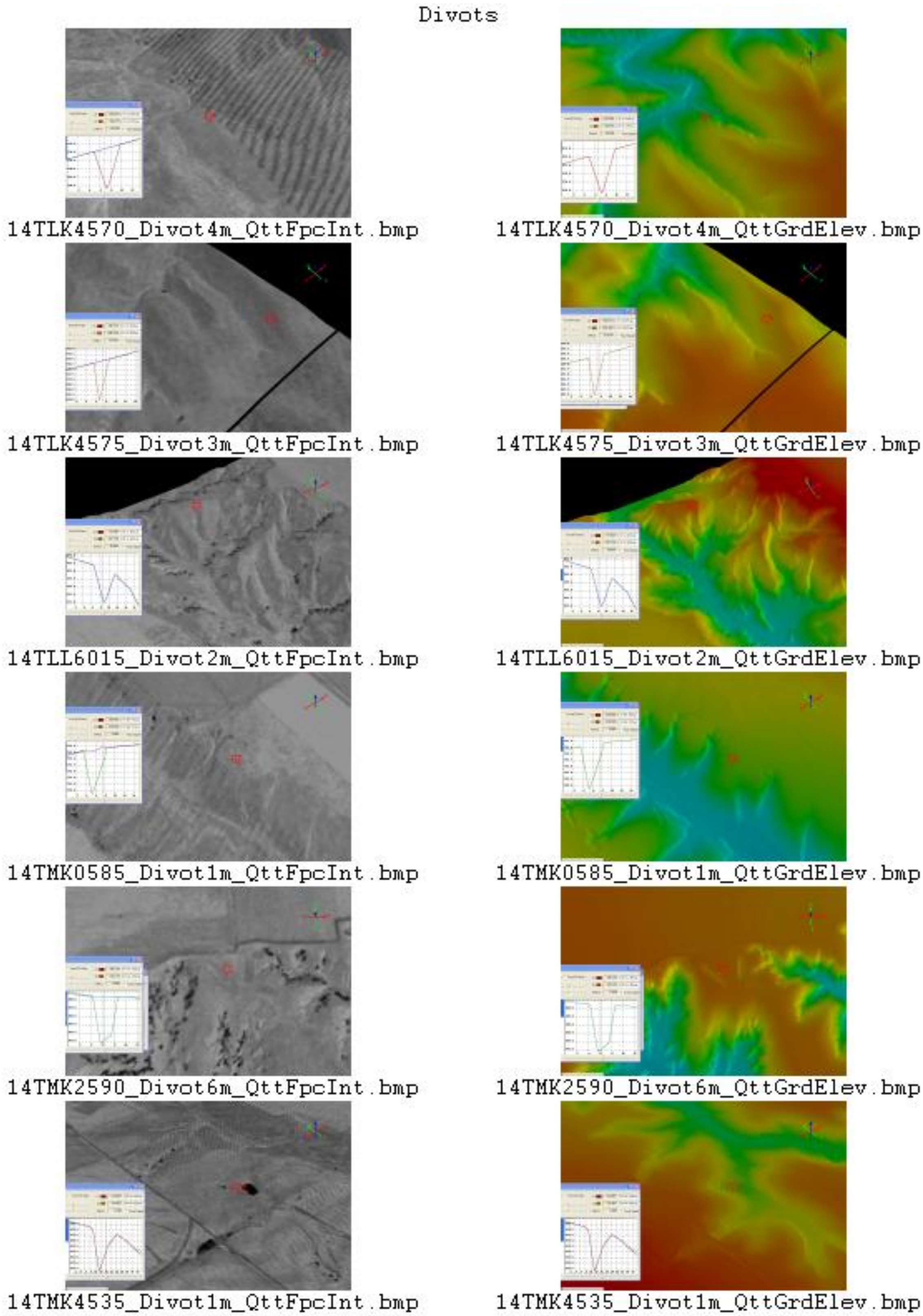


14TPL6510_VegetArt_QttFpcInt.bmp

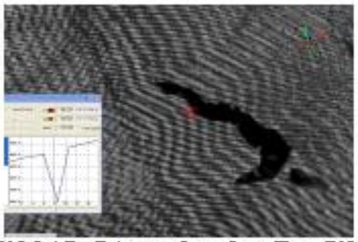


14TPL6510_VegetArt_QttGrdElev.bmp

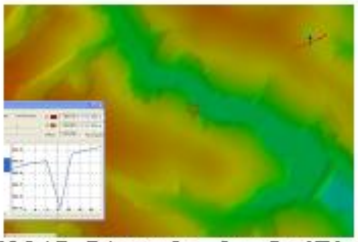
6.2 Divots


Divots
14TLK4570_Divot4m_QttFpcInt.bmp
14TLK4570_Divot4m_QttGrdElev.bmp
14TLK4575_Divot3m_QttFpcInt.bmp
14TLK4575_Divot3m_QttGrdElev.bmp
14TLL6015_Divot2m_QttFpcInt.bmp
14TLL6015_Divot2m_QttGrdElev.bmp
14TMK0585_Divot1m_QttFpcInt.bmp
14TMK0585_Divot1m_QttGrdElev.bmp
14TMK2590_Divot6m_QttFpcInt.bmp
14TMK2590_Divot6m_QttGrdElev.bmp
14TMK4535_Divot1m_QttFpcInt.bmp
14TMK4535_Divot1m_QttGrdElev.bmp

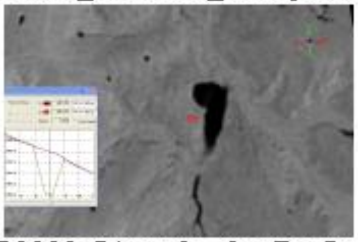
Divots



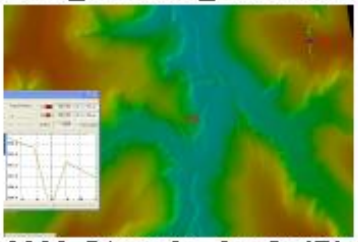
14TMK9045_Divot2m_QttFpcINt.bmp



14TMK9045_Divot2m_QttGrdElev.bmp

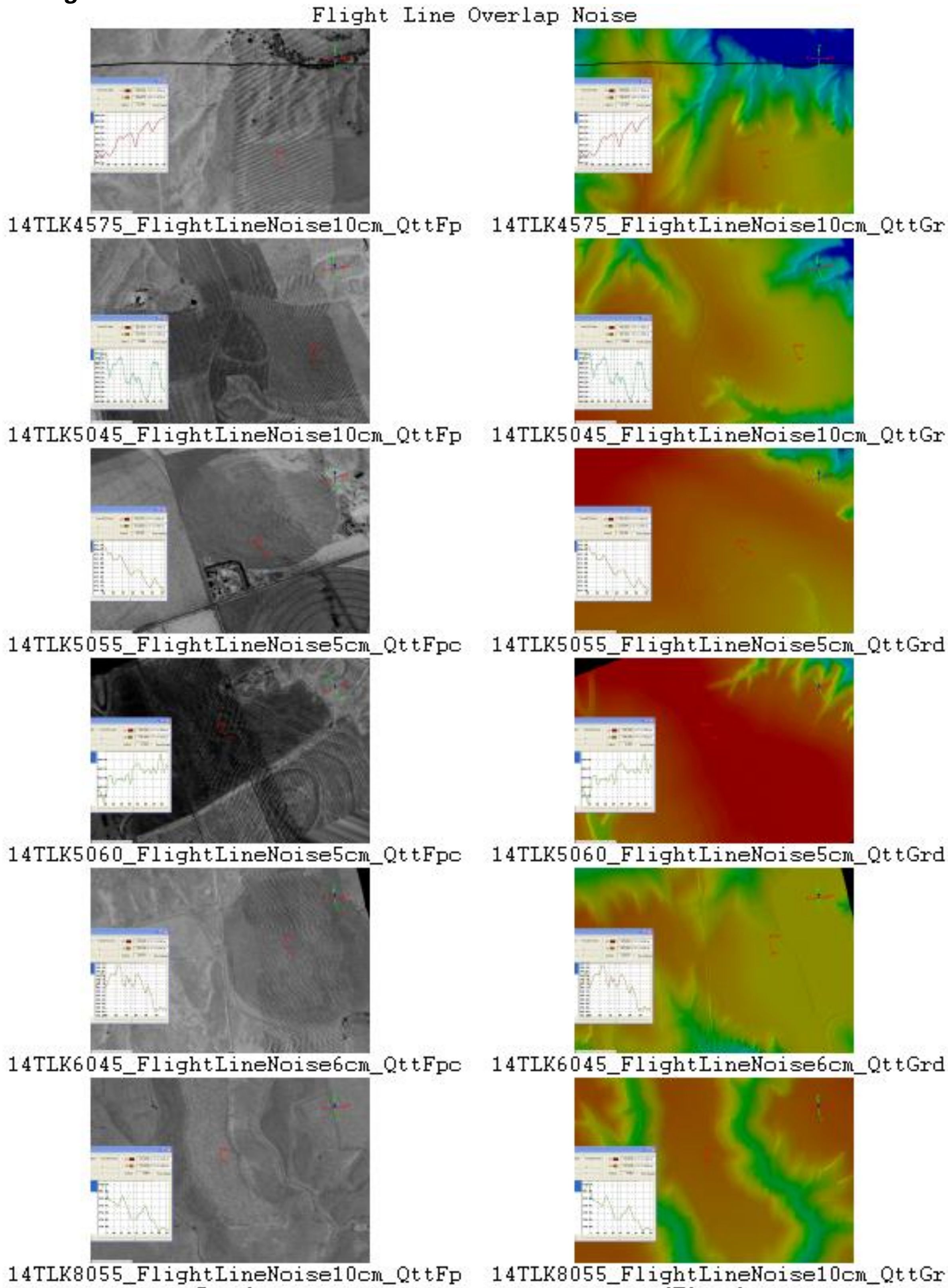


14TML2000_Divot2m_QttFpcInt.bmp

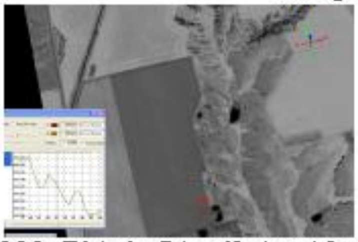


14TML2000_Divot2m_QttGrdElev.bmp

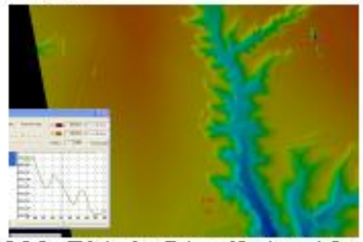
6.3 Flight Line Noise



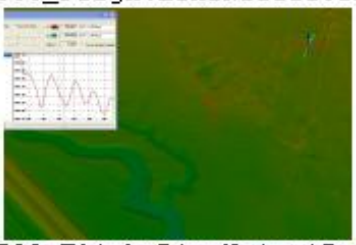
Flight Line Overlap Noise



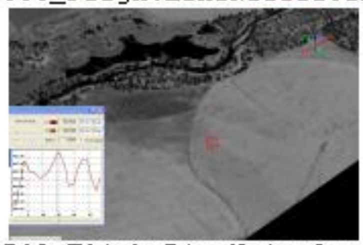
14TLL8000_FlightLineNoise10cm_QttFp



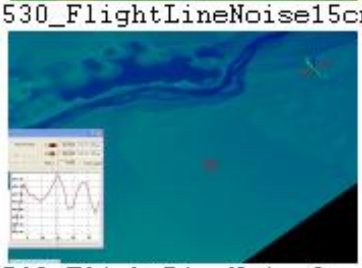
14TLL8000_FlightLineNoise10cm_QttGr



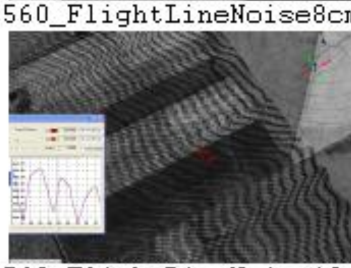
14TLL9530_FlightLineNoise15cm_QttGd



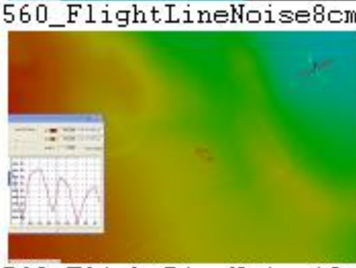
14TMK1560_FlightLineNoise8cm_QttFpc



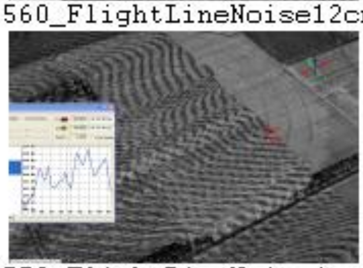
14TMK1560_FlightLineNoise8cm_QttGrd



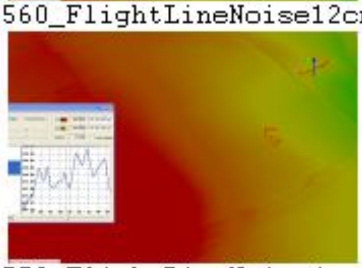
14TMK9560_FlightLineNoise12cm_QttFp



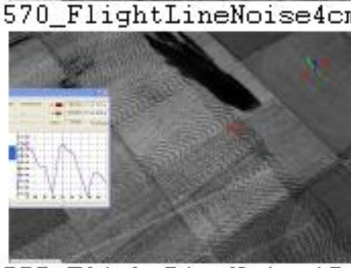
14TMK9560_FlightLineNoise12cm_QttGr



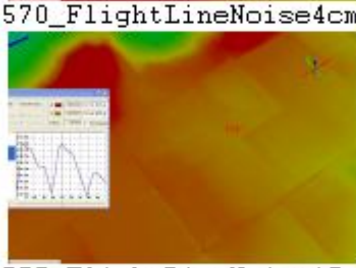
14TMK9570_FlightLineNoise4cm_QttFpc



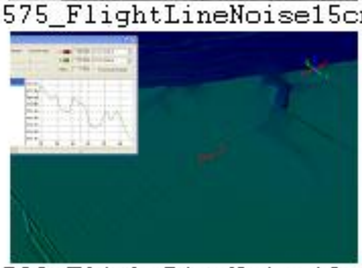
14TMK9570_FlightLineNoise4cm_QttGrd



14TMK9575_FlightLineNoise15cm_QttFp

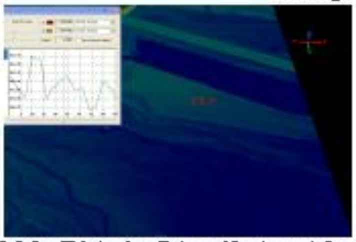


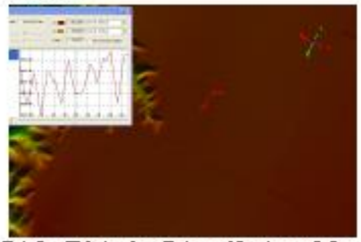
14TMK9575_FlightLineNoise15cm_QttGr

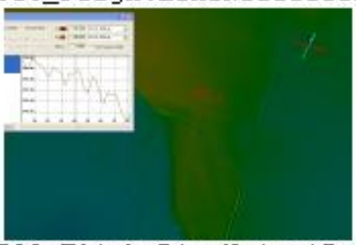


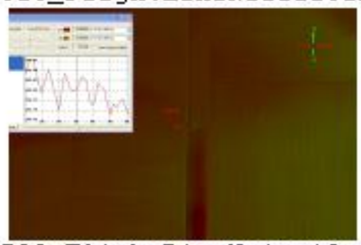
14TML0520_FlightLineNoise12cm_QttGd

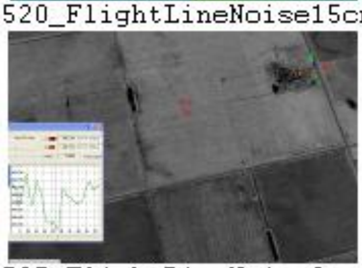
Flight Line Overlap Noise

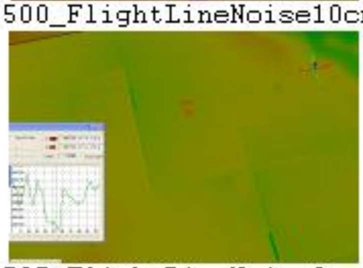

14TML1020_FlightLineNoise12cm_QttGd

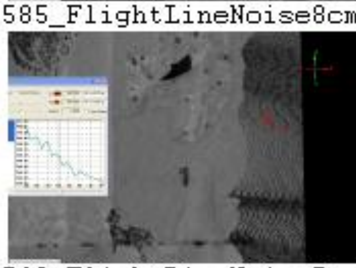

14TML1510_FlightLineNoise20cm_QttGd

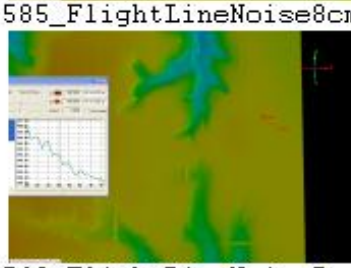

14TML2520_FlightLineNoise15cm_QttGd

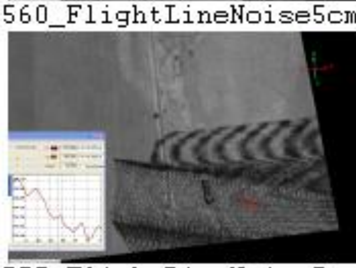

14TML9500_FlightLineNoise10cm_QttGd

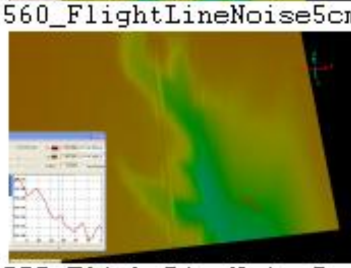

14TNK0585_FlightLineNoise8cm_QttFpc

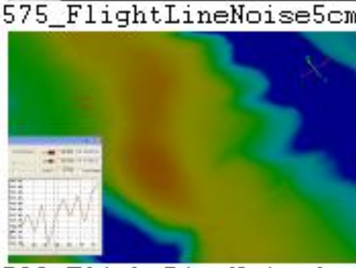

14TNK0585_FlightLineNoise8cm_QttGrd

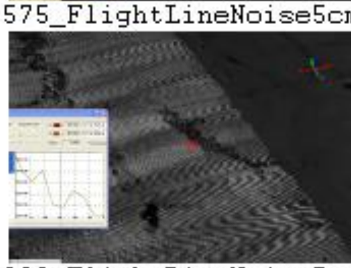

14TNK5560_FlightLineNoise5cm_QttFpc


14TNK5560_FlightLineNoise5cm_QttGrd

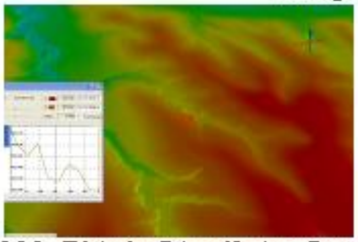

14TNK5575_FlightLineNoise5cm_QttFpc


14TNK5575_FlightLineNoise5cm_QttGrd

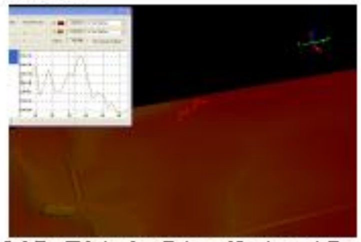

14TNK5580_FlightLineNoise6cm_QttGrd


14TNK6030_FlightLineNoise5cm_QttFpc

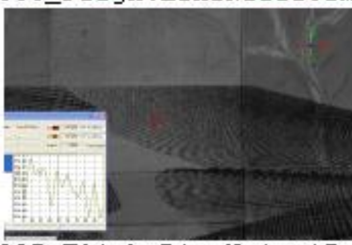
Flight Line Overlap Noise



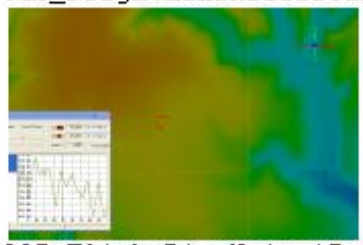
14TNK6030_FlightLineNoise5cm_QttGrd



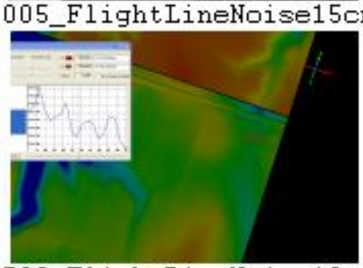
14TNK9065_FlightLineNoise15cm_QttGd



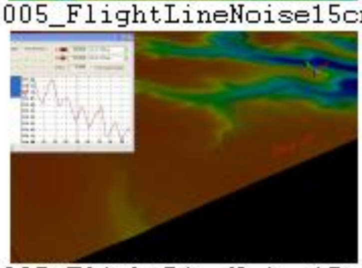
14TNL6005_FlightLineNoise15cm_QttFp



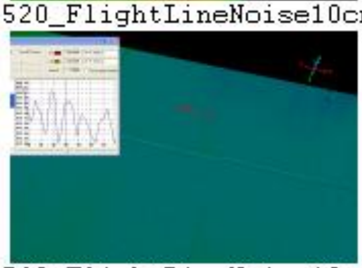
14TNL6005_FlightLineNoise15cm_QttGr



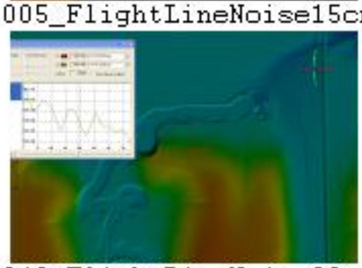
14TNL6520_FlightLineNoise10cm_QttGd



14TNL7005_FlightLineNoise15cm_QttGd

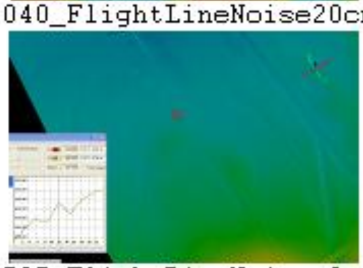


14TNL9560_FlightLineNoise12cm_QttGd

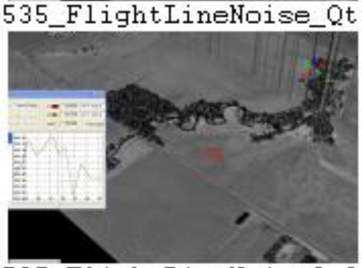


14TPL0040_FlightLineNoise20cm_QttGd

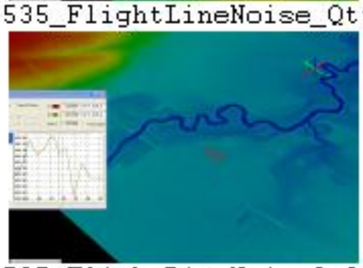
14TPL4535_FlightLineNoise_QttFpcInt



14TPL4535_FlightLineNoise_QttGrdEle



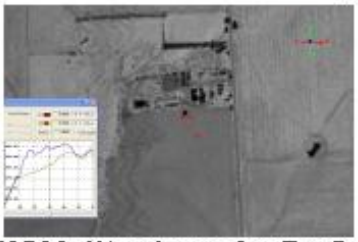
14TPL4535_FlightLineNoise2_QttFpcIn



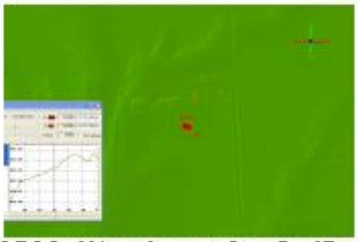
14TPL4535_FlightLineNoise2_QttGrdEl

6.4 Misclassification

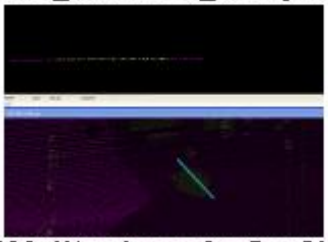
Misclassification



14TPK2590_Misclass_QttFpcInt.bmp



14TPK2590_Misclass_QttGrdDens.bmp



14TPK2590_Misclass_QttLasClass.bmp