Lidar Quality Assurance and Quality Control Report for Inland Okaloosa County, Florida

National Oceanic and Atmospheric Administration (NOAA)
Coastal Services Center

NOAA Coastal Services Center
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September 2008

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Executive Summary

Lidar data for Okaloosa County, Florida, were collected in winter 2008 and reviewed for accuracy and quality by the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. The data were collected with a nominal point spacing of approximately 1.5 meters or better and have a fundamental vertical accuracy of 12 centimeters (cm) (bare earth) and a consolidated vertical accuracy of 13.5 cm (all land cover types). Qualitative aspects of the data such as flight line match and feature/vegetation classification were reviewed, and the data met, and in most cases exceeded, quality specifications and expectations.

Accuracy testing by the NOAA Coastal Services Center indicates that the lidar data meet the accuracy specified in the statement of work.

- Using Federal Geographic Data Committee (FGDC), Federal Emergency Management Agency (FEMA), National Digital Elevation Program (NDEP), and American Society for Photogrammetry and Remote Sensing (ASPRS) methodology: **Tested 12 cm vertical accuracy at 95% confidence level in open terrain.**
- Using NDEP and ASPRS methodology: **Tested 13.5 cm vertical accuracy at 95% confidence level in all land cover categories combined.**
- Using FGDC and FEMA methodology: **Tested 13.7 cm vertical accuracy at 95% confidence level in all land cover categories combined.**

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Okaloosa County, Florida

Introduction

This report consists of two separate sections. The first is the vertical accuracy assessment of the lidar data for Okaloosa County, Florida, and the second is the qualitative assessment of the lidar and the accompanying digital elevation models (DEMs). The data were collected by Fugro-EarthData in February, 2008, for the Northwest Florida Water Management District and the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. The data were processed to classify points as bare earth, water (surface), or unclassified (e.g., vegetation, houses). The bare earth elevations were used to create a DEM that will support, among other applications, Federal Emergency Management Agency (FEMA) flood mapping activities within the State of Florida. The lidar data were reviewed to make certain that they met the accuracy specified in the statement of work (Appendix A), were free of questionable artifacts, and provided a usable data set for multiple types of projects, including flood mapping. The data collection covered the inland areas of Okaloosa County with a small strip of the coastal area at the western county boundary (Figure 1). Data collection information is contained in the acquisition reports (Appendix B). No terrestrial or hydrographic breaklines were generated in this delivery.

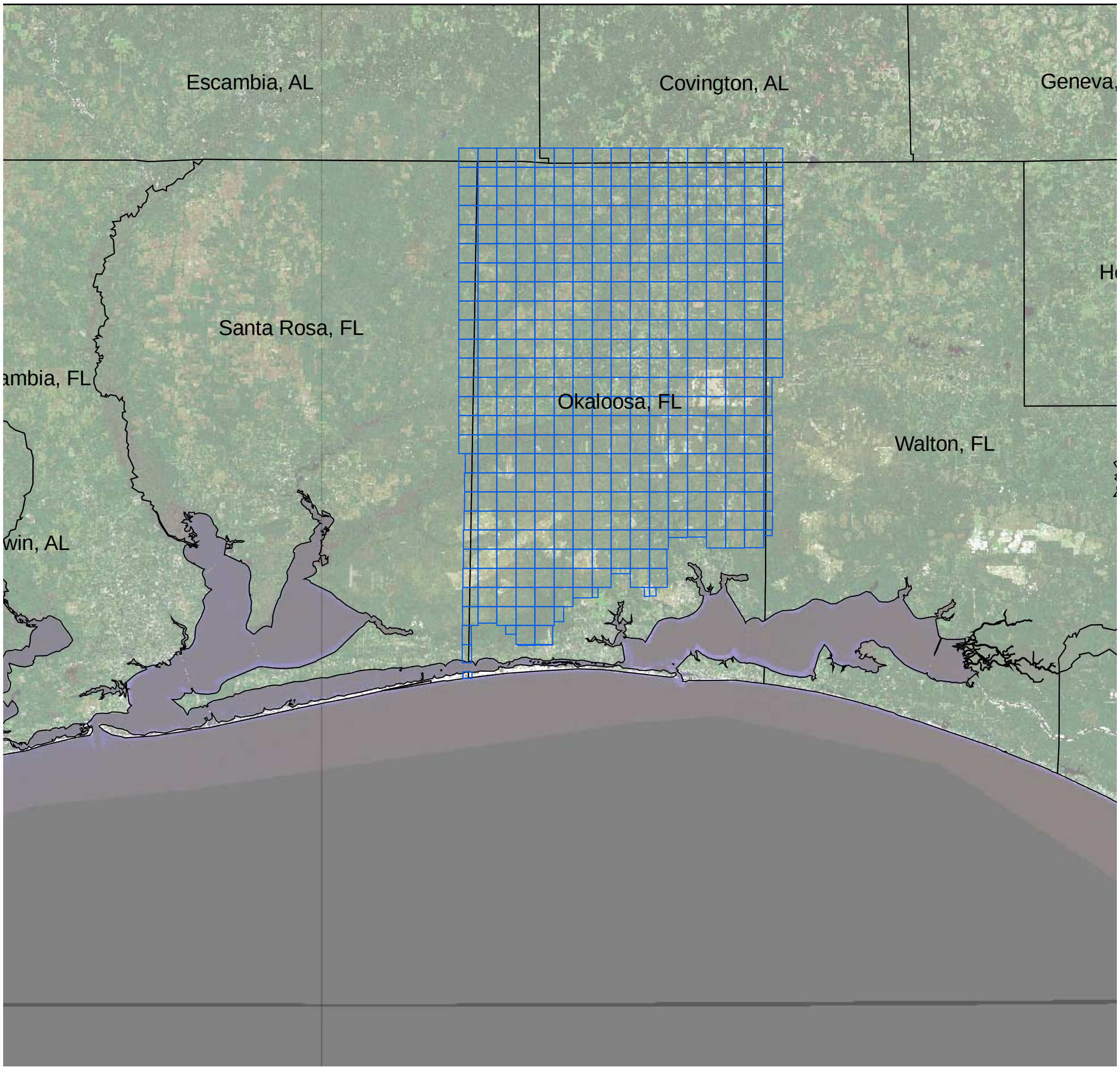

Figure 1. Data Collection Area and Tile Layout in Okaloosa County, Florida

Vertical Accuracy Assessment Report

Background: Data Standards

Data standards for topographic data have become more stringent in response to the increased-resolution data sets being generated by private industry, advances in technology, and the data's widespread application and use. Four primary documents have helped define the process of measuring, reporting, and defining the accuracy of Okaloosa County lidar elevation data. *Guidelines for Digital Elevation Data* (NDEP, 2004), "ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data" (ASPRS, 2004), and "National Standard for Spatial Data Accuracy" (FGDC, 1998) provide guidance and formulas for determining elevation data accuracy. "Guidance for Aerial Mapping and Surveying" by the Federal Emergency Management Agency (FEMA, 2003) draws on these other data-standard documents and includes a definition of what types of data are needed for some specific flood-mapping applications.

The specific requirements for the data being reviewed are provided below (Table 1). These requirements are meant to define how well the actual terrain was measured in 1) open areas and 2) obscured or vegetated areas. Several measures, $\text{Accuracy}_{z,}$ and the consolidated and supplemental accuracies, are used to assess these two important aspects.

Accuracy$_z$ is the 95% confidence level of the data (i.e., 95% of the data meets or exceeds the specified vertical Accuracy_z) and relates to the data accuracy in areas without trees; thus, this is an overall measure of the quality of the data collection process and adjustment for flight parameters. The fundamental vertical accuracy (FVA) statistic is the same thing as Accuracy_z; it is a FEMA-specific term. These measures are calculated using the root mean square error (RMSE) of the data points and are dependent on the data errors being normally distributed; the formula (RMSE x 1.96) follows guidance provided by the FGDC (1998). For this data set, the goal was to achieve a 15 centimeter (cm) RMSE or Accuracy_z of 29.4 cm, which is a tighter accuracy specification than the FEMA specification (FVA of 36.3 cm).

The supplemental and consolidated vertical accuracies are 95th percentile confidence statistics. In this case, the values provide a measure of how well the lidar penetrated the tree or shrub canopy, and how well the vegetation, structures, and other nonground features have been removed (processed), while still providing enough information about the ground surface in their vicinity to accurately portray the terrain. These "obscured" data are not normally distributed, since there are many different types of vegetation/features, and therefore the calculation of the value is done graphically. FEMA guidance (FEMA, 2003) suggests that for coastal areas (relatively flat) the supplemental vertical accuracy (SVA) and consolidated vertical accuracy (CVA) values be 36.3 cm or better. These are suggested values and, while not dictating the acceptance of the data, provide some additional guidance for their use.

Table 1. NOAA Coastal Services Center (Blue) and FEMA (Green) Accuracy Requirements from Statement of Work

Vertical Accuracy Criteria	NOAA/FEMA Measures of Acceptability
$RMSE_z$ = National Standard for Spatial Data Accuracy (FGDC, 1998) vertical accuracy statistic at 68% confidence level	15 cm in open terrain only
$Accuracy_z$ = National Standard for Spatial Data Accuracy (FGDC, 1998) vertical accuracy statistic at the 95% confidence level = $RMSE_z$ x 1.9600	29.4 cm (15 cm $RMSE_z$ x 1.9600) in open terrain only
Fundamental vertical accuracy (FVA) in open terrain only = 95% confidence level	36.3 cm (18.5 cm $RMSE_z$ x 1.9600) for open terrain only
Supplemental vertical accuracy (SVA) in individual land cover categories = 95% confidence level	36.3 cm (based on 95th percentile per category; this is a target value only, not mandatory)
Consolidated vertical accuracy (CVA) in all land cover categories combined = 95% confidence level	36.3 cm (based on combined 95th percentile)

There are ongoing discussions on whether the values for non–bare earth points (e.g., forest, scrub-shrub) should be calculated using RMSE x 1.96 or the 95th-percentile-confidence-level techniques. FEMA and National Standard for Spatial Data Accuracy (FGDC, 1998) guidance specify that RMSE x 1.96 should be used; ASPRS and NDEP guidance specify that the 95th percentile should be used. We provide values using both techniques for future reference; however, the acceptability measures in Table 1 are being used as the criteria for the validation of the data set.

Ground Control Point Collection

Ground control points (GCPs) were collected to measure the difference between ground elevations and lidar elevations. The points were collected by personnel from the NOAA Coastal Services Center and National Geodetic Survey during the spring of 2008. Documentation of the point collection is provided in Appendix D. Two separate types of point collection techniques were used depending on site location and surrounding geodetic control. Temporary benchmarks (TBM) were surveyed using static Differential Global Positioning System (DGPS) techniques in areas that lacked or had only a single National Geodetic Survey (NGS) monument (Benchmark). The GPS positions were corrected using continuously operating reference system (CORS) data and, in many cases, local rover data captured concurrently on NGS benchmarks. GPS data were collected and tested at 2 to 5 centimeter accuracy.

Total station measurements were then shot from the TBMs and NGS Benchmarks to collect GCPs in multiple land covers. The data were primarily shot from NGS 1st order benchmarks using the TBMs established with GPS as backsights for angular measure only. The total station data were collected with a micro-prism to minimize error. The accuracy of the points collected with the total station is estimated, based on tests to backsights, to be less than 1 centimeter and is associated primarily with operator error. In general, the surveyed points are judged to have accuracies that are approximately five times better than the target RMSE of the lidar collection (15 cm).

There were 20 "test sites" where points representing the target land covers were collected (Figure 2). The northern two-thirds were chosen in locations near benchmarks so that cross-checks could be made to pre-existing data. The southern third were located on Eglin Air Force Base and had few surveyed monuments available. At each site (Figure 3) the surveyed points were grouped into one of five different land cover categories, and photographs of each point were taken to provide information on its specific land cover aspects. The five land cover categories are 1) bare earth, 2) urban, 3) forest, 4) scrub/shrub, and 5) weeds and crops. These groups were used to compute errors across the spectrum of different land covers.

The five different land cover types did not always occur within each test site; at some sites more than one point per land cover type was collected and at others less than one point per land cover was collected. A total of 176 points were collected; 164 were used in the accuracy calculation and 12 were used for cross-checks. The accuracy points include 50 points in open terrain, 33 points in weeds and crops, 23 points in scrub/shrub, 29 points in forest, and 29 points in built-up or urban land covers.

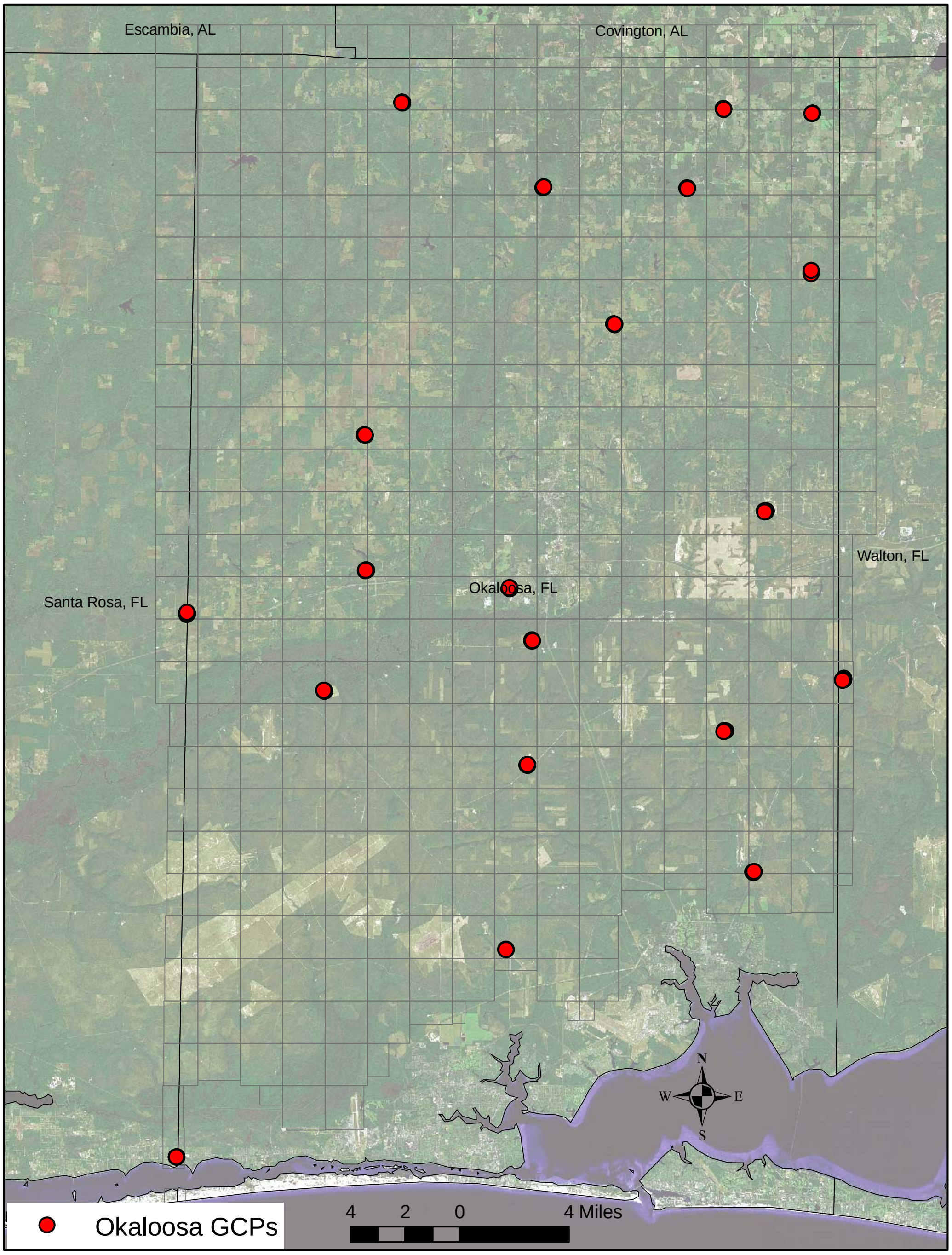

Figure 2. Ground Control Point Locations and Tile Layout for Okaloosa Lidar Data

Figure 3. Example "Site" with Yellow Markers (NGS Benchmark and TBM) as Control and Orange Markers as GCPs

Vertical Accuracy Tests

To test the vertical accuracy of the lidar data, the NOAA Coastal Services Center employs an automated program that first queries the (bare earth) lidar points surrounding the GCPs and then creates a digital terrain model (DTM) from a triangulated irregular network (TIN) surface of the lidar points. This DTM is then used to assign each surveyed point a lidar-generated elevation along with other local terrain information (Figure 4). The difference between the surveyed and lidar elevation (dz) was taken as the error. From these errors and land cover groupings, the various statistics were computed (Accuracy$_z$, FVA, SVA, CVA) using the guidance documents.

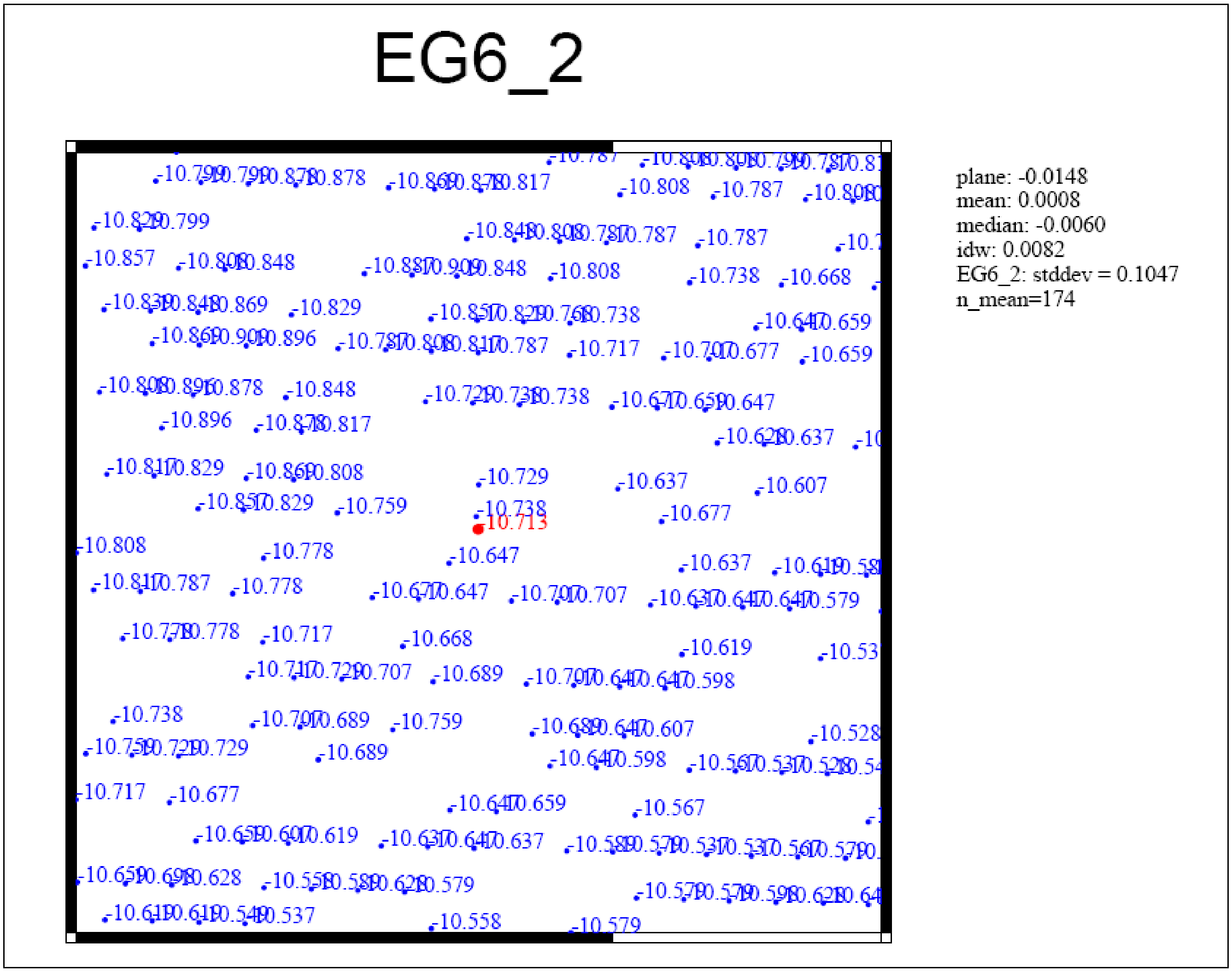

Figure 4. Example of the NOAA Coastal Services Center Accuracy Assessment Tool for Point EG6_2; The Box is 10 meters x 10 meters

Results

The overall accuracy within each land cover was similar and well within the specified RMSE of 15 cm (Figure 5). The critical pass or fail results are highlighted (bolded text) in

Table 2; all the values are in centimeters. The values were consistent using both measures of accuracy, RMSE x 1.96 and 95th percentile; the scrub-shrub category was the one notable exception, with a large difference between the RMSE and 95% percentile values. For the most part, use of either technique to report the data accuracy is probably within the resolution of the techniques to gather survey data (i.e., ~3 cm). The results meet and exceed all the specifications in the statement of work (SOW; Appendix A).

Table 2. Ground Control Point Values

Land Cover Type	No. of Points	RMSE (cm)	Accuracy$_z$ or FVA (1.96 x RMSE) (cm)	Consolidated Vertical Accuracy, CVA (95th percentile) (cm)	Supplemental Vertical Accuracy, SVA (95th percentile) (cm)
Total Combined (all points)	164	7.0	13.7	**13.5**	
Open Terrain	50	6.1	**12.0**		12.1
Weeds/Crops	33	9.0	17.6		15.4
Scrub/Shrub	23	7.5	14.7		11.4
Forest	29	7.4	14.5		13.5
Built-up/Urban	29	5.3	10.4		9.4

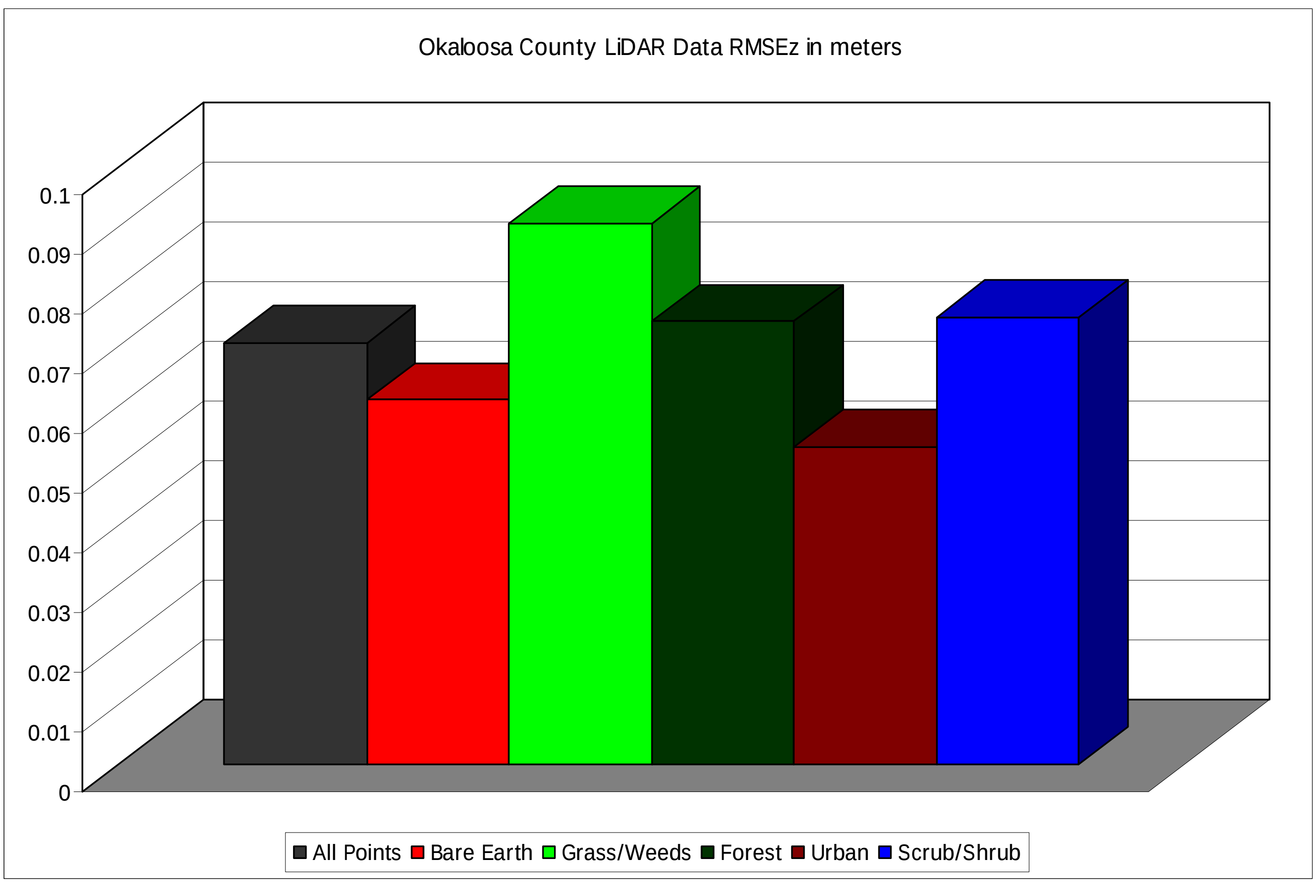

Figure 5. Graph of RMSE Values for the Various Land Covers

The error values for each land cover type show a fairly normal trend, a trend that would approximate a straight trend line in the graph, with few outliers (Figure 6). The overall error is very low, so any deviations from the “normal” distribution are clearly visible, the two with slight variations are Grass/Weeds and Forest. These are minor deviations and in fact, only two points from the entire data set were above the target RMSE value which is more than 2 times lower than the acceptable FVA value.

The mean of the data (Table 3) is slightly negative and may be a result of processing as opposed to point collection. The smooth aspect of the data (see qualitative section) may remove some of the small surface features with positive relief and thus impart a slightly low surface trend.

Skewness (an argument for not using the RMSE x 1.96 methods to determine $Accuracy_z$) is below 0.5 for all classes and, as the results highlight, the difference between the two methods is minimal. Likewise the standard deviation is also very nearly the same as the RMSE value.

Given that the largest error within the 164 points easily met the 95% accuracy requirement, it stands that this data set is very consistent throughout the land covers and can be used with confidence in all types of settings. In practical terms, a large fraction of the data is within 5 cm of the surveyed ground elevation (Figure 6, Figure 7, and Table 3), and applications requiring this level of accuracy can, in most cases, be supported by the data.

There are certain environments where this is less applicable, including heavily vegetated areas or those with a high level of undergrowth, such as swamp forests. Additionally, while the data for relatively flat areas are highly accurate (the GCPs are collected in areas with low slopes), areas with more complex terrain (i.e., road cuts, high slopes) will likely have lower specific accuracies. Additional guidance for these areas is provided in the qualitative review portion of the report.

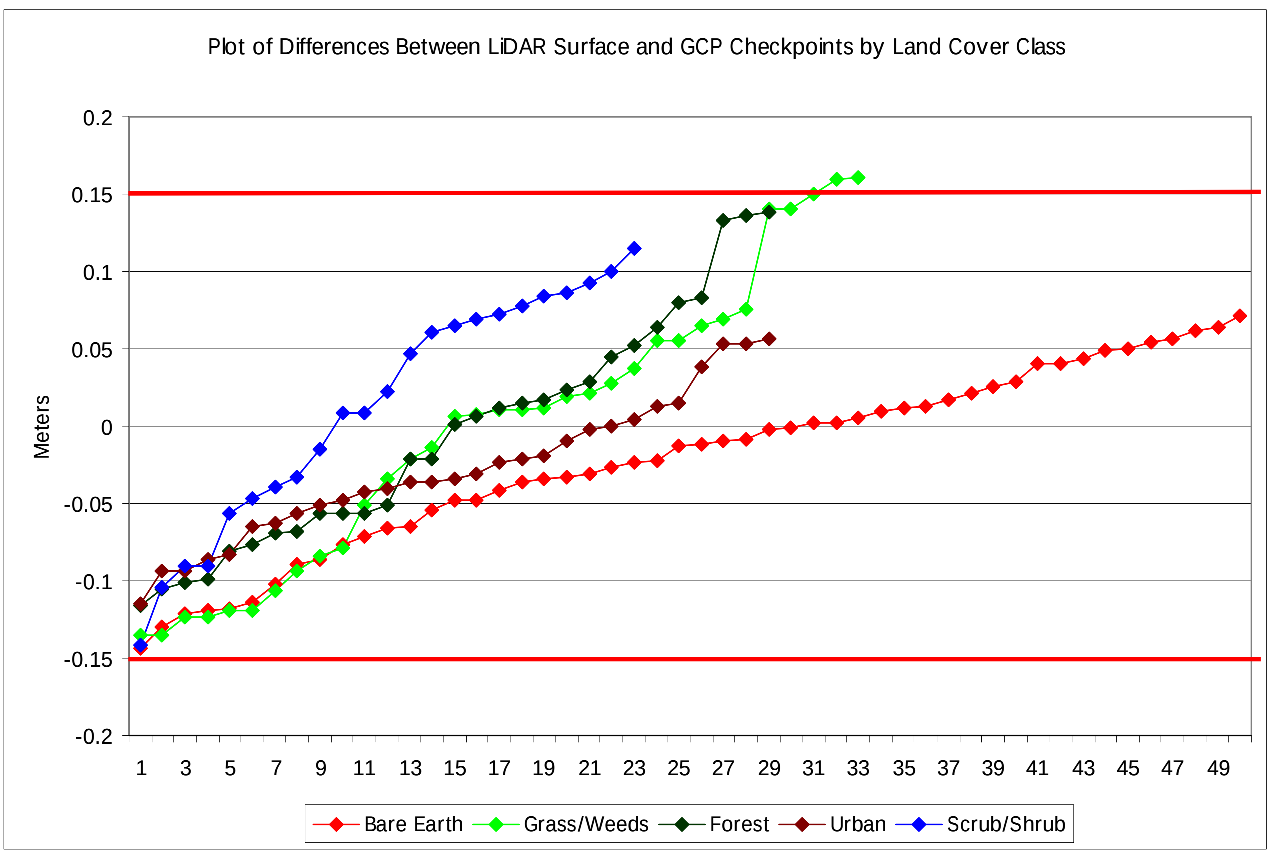

Figure 6. Sorted Check-Point Values; Red Lines Are Maximum RMSE Values from SOW

Table 3. Point Statistics

Point Class	RMSE (m)	Mean (m)	Median (m)	Skew	Std Dev (m)	n	Max (m)	Min (m)
Total	0.071	-0.011	-0.011	0.22	0.070	164	0.161	-0.144
bare earth	0.061	-0.022	-0.012	-0.38	0.058	50	0.071	-0.144
grass/weeds	0.090	0.000	0.011	0.16	0.092	33	0.161	-0.135
forest	0.074	-0.005	0.001	0.40	0.075	29	0.138	-0.116
urban	0.053	-0.028	-0.034	0.19	0.046	29	0.056	-0.115
scrub/shrub	0.075	0.013	0.022	-0.50	0.075	23	0.115	-0.141

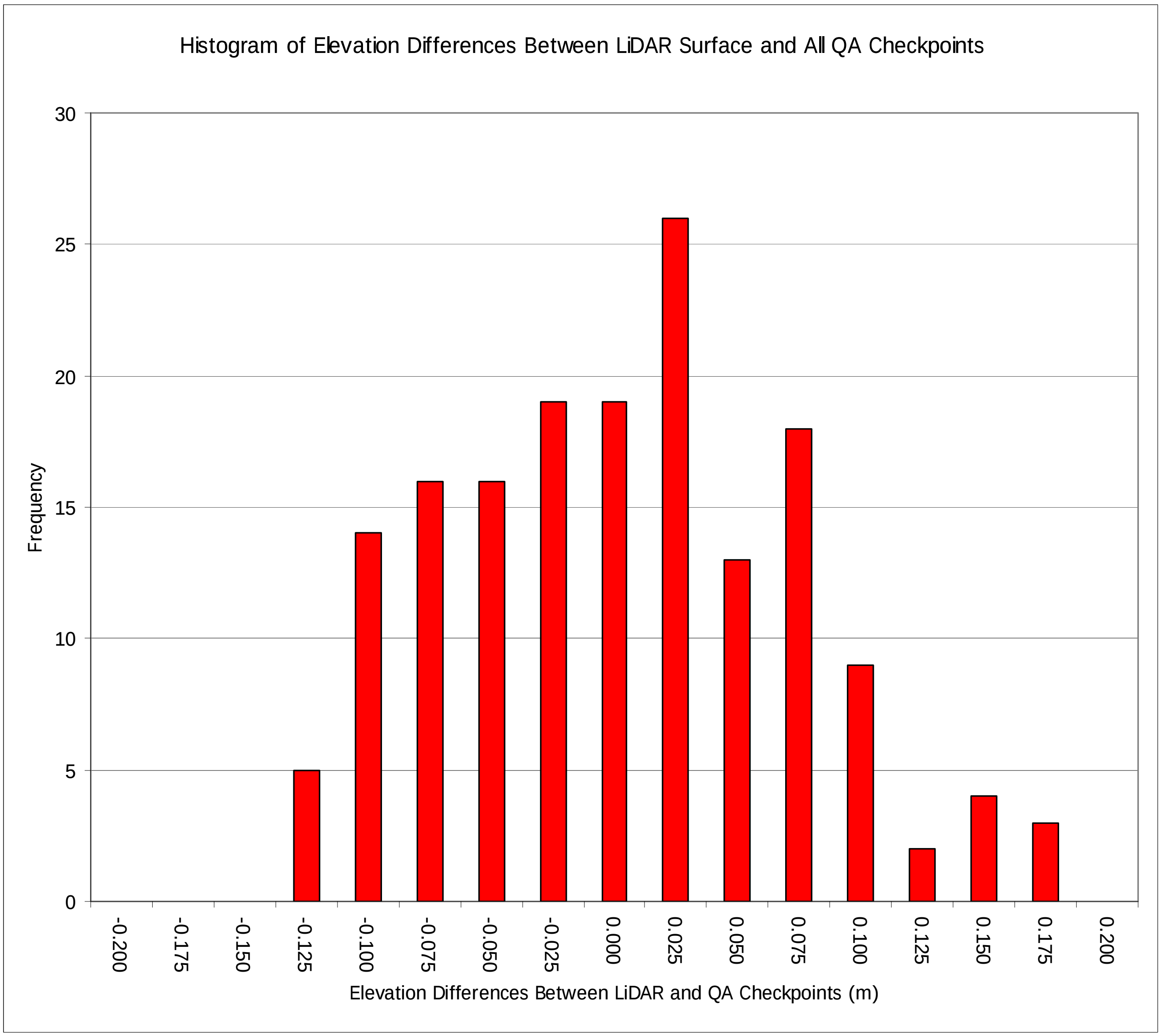

Figure 7. Error Histogram of All Ground Control Points (GCPs)

Fundamental and Consolidated Vertical Accuracy (FVA and CVA)

The data passed the FVA and CVA measures specified in the statement of work (SOW) (Table 1,

Table 2). The measured FVA is 12.0 cm (29.4 cm, NOAA Coastal Services Center specification; 36.3 cm, FEMA specification) and the CVA is 13.5 cm (36.3 cm, FEMA specification). None of the 164 points fell outside of the FEMA 36.3 cm specification (Figure 6). The data met and exceeded the FVA and CVA specifications.

Supplemental Vertical Accuracy (SVA)

All the land cover categories easily passed the 36.3 cm SVA target using the 95th percentile method (

Table 2). The lack of divergent values between the classes is not taken to be a result of non-vigorous GCP selection. Points were chosen in areas where it appeared lidar data for the bare earth could reasonably be assumed to exist; it was not the goal to test the ability of lidar to penetrate the forest canopy. The abundant coverage of points in forests and other vegetated land categories, and hence the high level of supplemental accuracy, is likely a result of the leaf-off collection conditions and an aggressive bare earth algorithm (see 'Qualitative Assessment" section). In all land covers, the data met and exceeded the SVA targets.

Spatial Accuracy Trends

An aspect of remote sensing data collected with GPS is the spatial correlation of the error across the collection area, and is associated with the changing quality of positional information (i.e., changes in PDOP, or positional dilution of precision, and distance to base stations). To define this variation, the accuracies of each point were normalized (divided) against the RMSE of its associated land cover classification. The mean of the normalized values was then generated for each "test site" to produce a relative site error. A site error of about 1.0 would approximate the RMSE of the overall data set. The average site error was computed and mapped, and a mathematical surface (trend surface) was created to highlight any systematic variation (Figure 8). An increase in relative error toward the east is the most notable trend. The specific cause is not known, but the flightlines were run north-south, so there was a notable time of day difference between the west, middle, and eastern portion of the collection area. The higher trend in the northwest portion of the county is poorly constrained by the data and should be assessed accordingly.

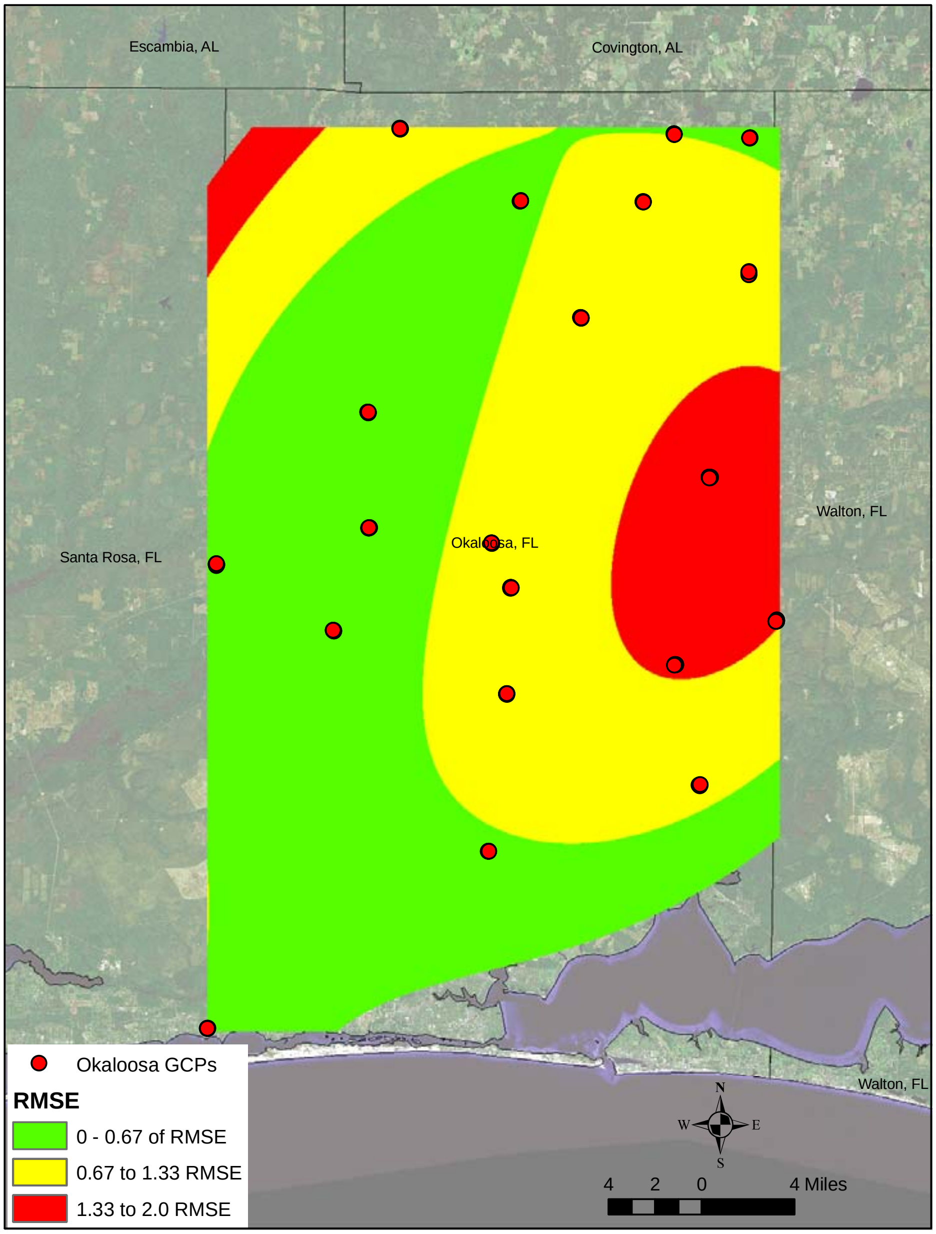

Figure 8. Error Trends in Okaloosa County from Lowest (Green) to Highest (Red) Relative Error

Accuracy Assessment Summary

Accuracy testing by the NOAA Coastal Services Center indicates that the lidar data meet the accuracy specified in the statement of work.

- Using Federal Geographic Data Committee (FGDC), Federal Emergency Management Agency (FEMA), National Digital Elevation Program (NDEP), and American Society for Photogrammetry and Remote Sensing (ASPRS) methodology: **Tested 12 cm vertical accuracy at 95% confidence level in open terrain.**
- Using NDEP and ASPRS methodology: **Tested 13.5 cm vertical accuracy at 95% confidence level in all land cover categories combined.**
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Qualitative Assessment of Okaloosa County Lidar

The qualitative assessment of the Okaloosa County lidar consisted of three procedures. First, the point data (LAS files) were checked for macro issues (i.e., general data and format), and second they were checked for micro issues (i.e., accuracy and feature processing). Third, the digital elevation models (DEMs) were inspected for both macro and micro issues (Figure 9). These analyses were performed on the first data delivery, with the highlighted issues documented in an interim report that was sent to Fugro-EarthData to guide them in data review and data correction. Fugro-EarthData addressed all the highlighted issues to the satisfaction of the NOAA Coastal Services Center's quality assurance (QA) team. The existence of site-specific issues in the data is possible, however, since each tile was not reviewed at the micro level. Examples of the specific noted problems are provided to guide future users on the potential issues associated with the data set. That said, the data were of a very high quality and should have widespread utility.

The LAS files were checked for macro issues such as the existence of data within each file, correct projection, correct file name, specified data classification followed, acceptable point density, return information provided, intensity values included, and the data delivered in an acceptable format. This is, in essence, an integrity check to see that all the files were received and were not corrupted. This procedure was used to test 100% of the files. The LAS files were then checked for micro issues that included 1) reviewing of the classifications, 2) checking that data from different flight lines matched, 3) assessing high frequency noise such as corn rows, 4) reviewing of artifact removal, 5) checking that high or low values were either removed or classified, and 6) assessing the level of point smoothing. This type of review was carried out for approximately 30% of the tiles (Figure 10).

The DEM files were reviewed separately. These DEM products will likely be used more by the partners (Northwest Florida Water Management District) than by the NOAA Coastal Services Center. DEM files were checked for micro issues in a manner similar to the LAS files. A total of 43% of the DEM tiles were reviewed.

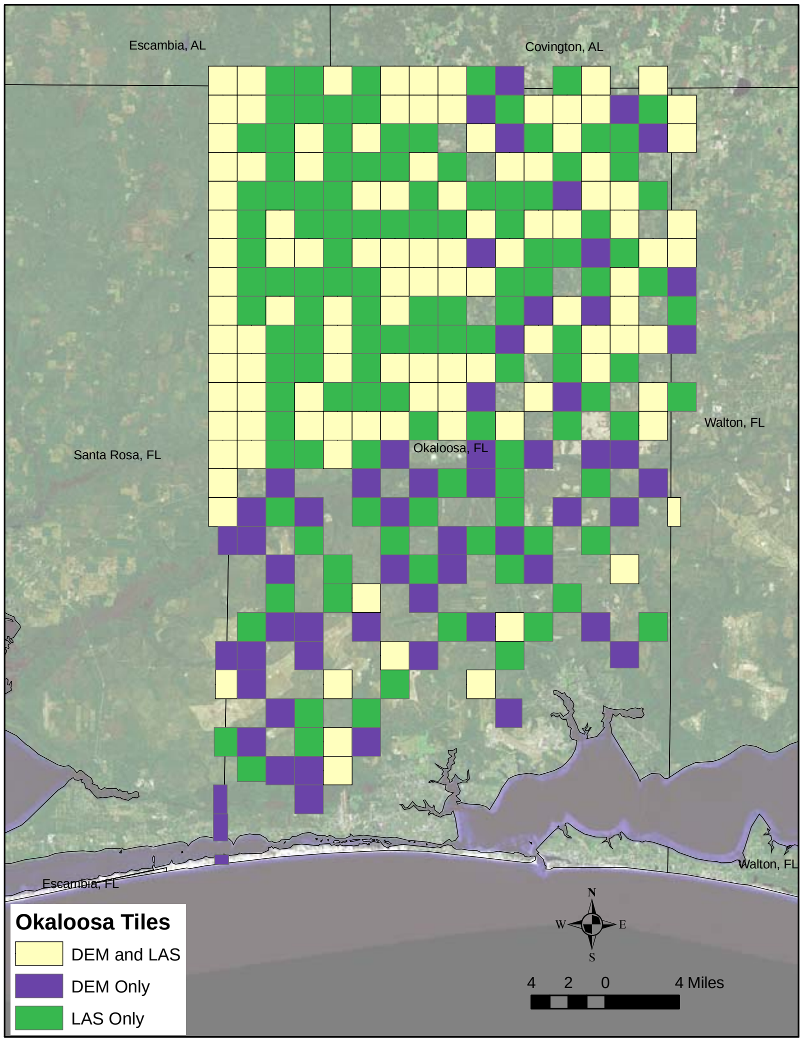

Figure 9. Okaloosa Tiles Reviewed

Quality Assurance Procedures

The files were reviewed using several software packages and techniques. The macro reviews were primarily carried out using PointVue software, which is a native 3D point-only viewing program. Here the projection and datum, classifications, outliers, intensity, and data format were checked. To assess the point density and classification, a program developed by the NOAA Coastal Services Center was run to count the number of “ground” points within a specific cell size (5 meter pixel).

The micro reviews were primarily performed with the LASEdit program. Data irregularities were examined using triangulated irregular network (TIN) surfaces generated from the points (primarily those classified as bare earth), as well as 3D views and profiles of varying widths.

The DEM files were reviewed using the Global Mapper and ArcMap programs. The tiles were reviewed for surface features both visually and with corresponding DOQQ (Digital Ortho Quarter Quad) and Google Earth images for reference. A DEM mosaic was also generated from the reviewed tiles for cross-checking data agreement between adjacent tiles.

Overview of LAS Evaluation

All the tiles (413 tiles) were checked at a macro level and 30% at the micro level of review (Figure 10). The data were, in almost all cases, very clean of artifacts, corn rows, and flight line mismatch problems. There were very few issues. The issue most often noted was a tendency to over-aggressively remove points from the “ground” classification (Figure 11). This created potential problems with low point densities in heavily vegetated areas and also in removing small-scale features and smoothing steep slopes. The aggressive point classification did, however, result in a smooth data set with few pits and spikes, producing visually pleasing contours (Figure 12). It is understood that there are inherent tradeoffs between the different ground classification strategies (e.g., aesthetic vs. highly detailed), and the advantages and disadvantages of each will depend on the ultimate use of the data.

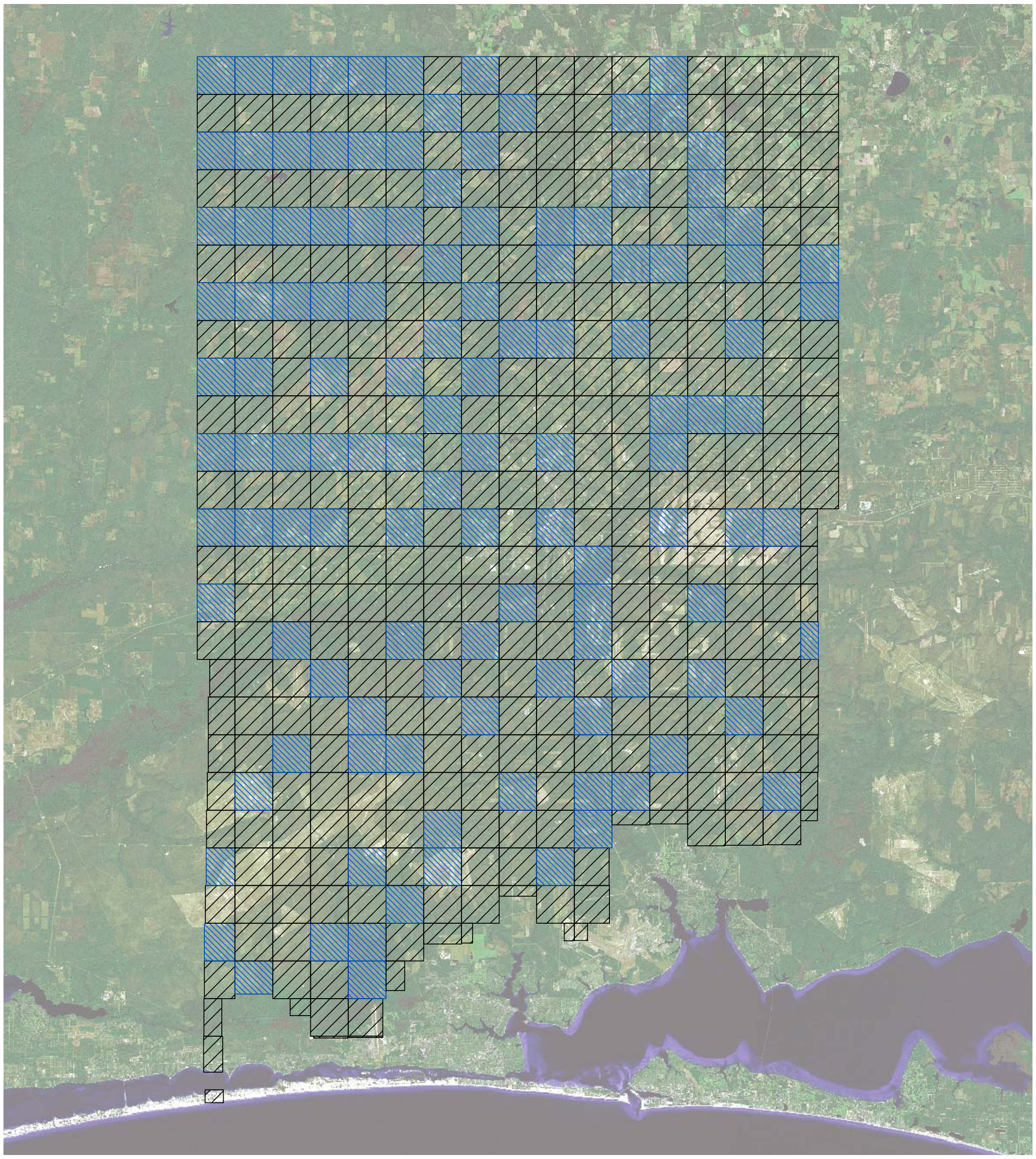

Figure 10. LAS Files Reviewed: All Had Macro Reviews; Blue Were Reviewed for Micro Issues

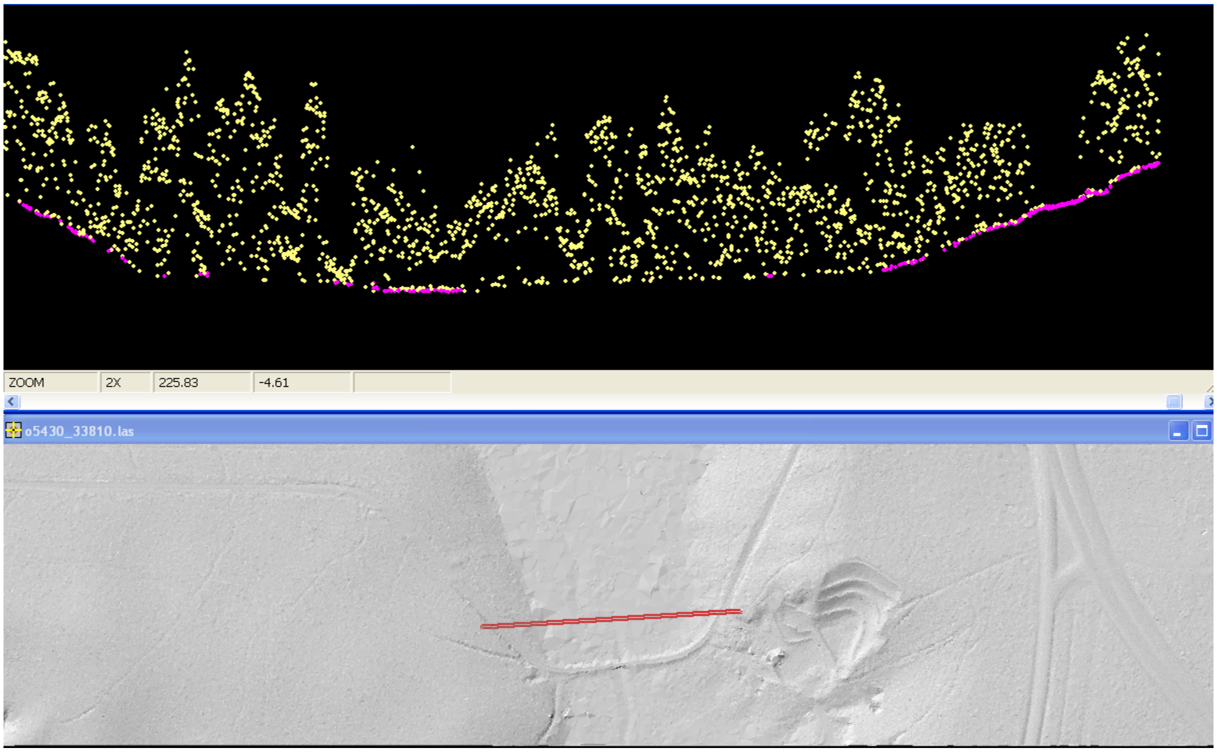

Figure 11. Aggressive Point Removal: Pink Points Are Ground; Yellow Are Unclassified

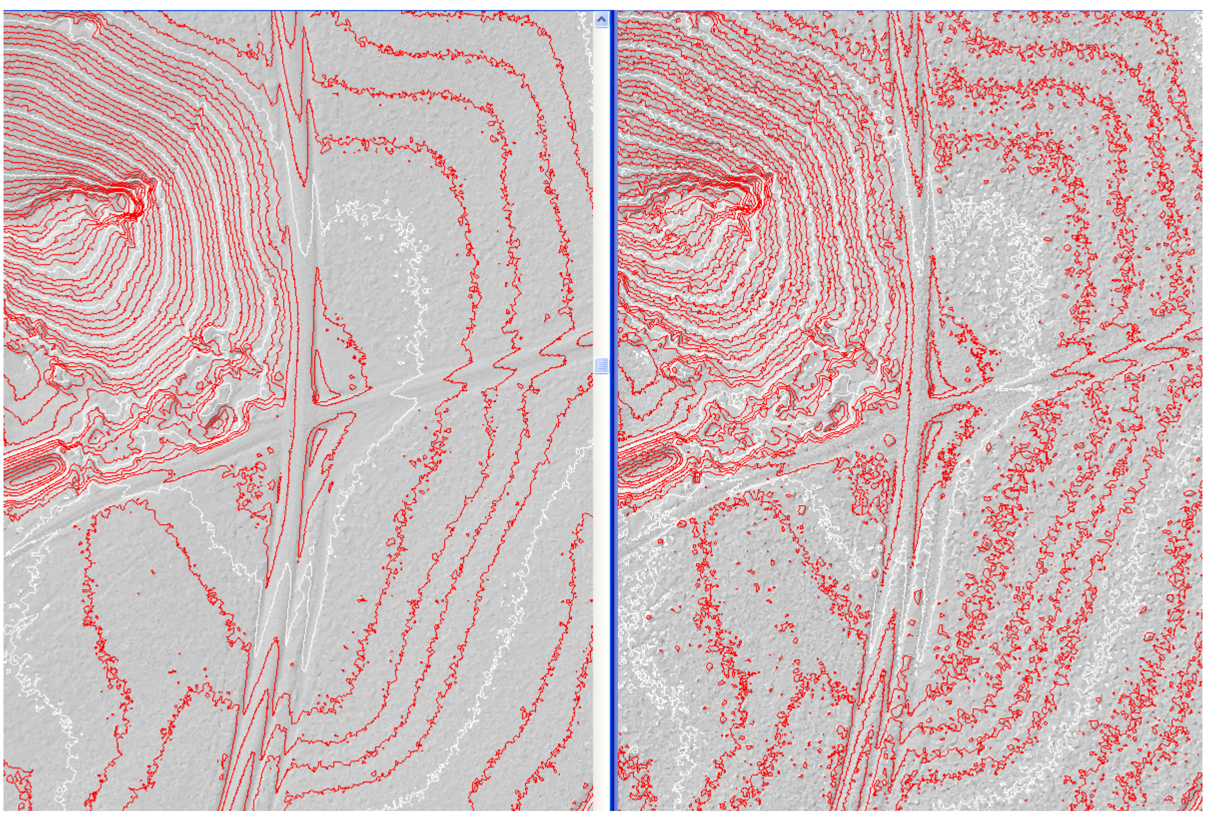

Figure 12. Two-Foot Contour Comparison in Buffer Areas between the Present Okaloosa Data Set (left) and Adjacent Data Set (Right) From Neighboring County.

LAS Quality Assurance Results

Macro Review

The results of the macro review confirmed that the data were complete and uncorrupted. The points were classified using the specified classes: vegetation and non-bare earth features were classified as "1," bare earth classified as "2," and water classified as "9." There were essentially no files noted with elevation values out of range; the noted high points fell on towers and were all classified as "unclassified."

Point densities were checked using a custom program to count points in user-defined grids. The program can count classified points as well as overall points (i.e., ground vs. all points). The data were "gridded" into 5-meter pixels and, in this case, represent point counts of bare earth points in each pixel (Figure 13). Areas with low point counts are mainly coincident with swamp forests, where vegetation is dense, and not with processing blunders. One small processing issue highlighted with the point count maps was remedied. Subtle variations in point densities also depicted changes in processing algorithms (Figure 14). The small inconsistencies were subsequently reviewed and additional processing performed.

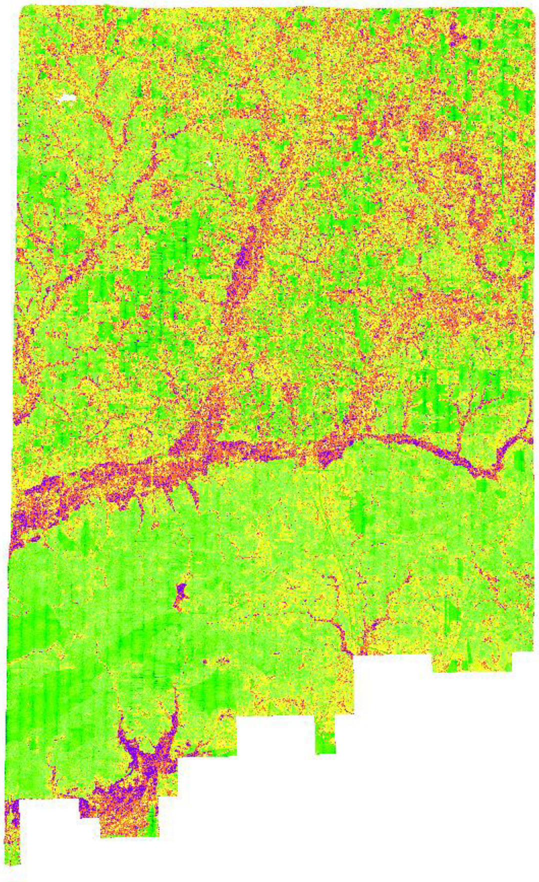

Figure 13. Point Density Map: Low Values Are Dark Red; High Values Are Green

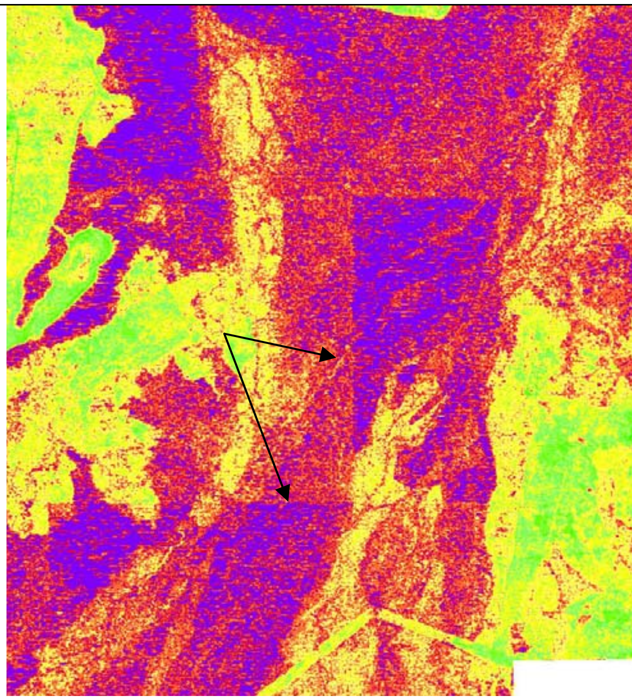

Figure 14. Areas with Slight Variation in Bare Earth Point Density

Micro Review

Overall, the LAS files were very clean of artifacts, and very few qualitative issues were noted. This is consistent with the high quality of the data documented in the accuracy assessment. Some tile-specific issues were noticed, but for the most part these were relatively minor. Of the 125 LAS tiles reviewed in depth, 35 had minor areas for review and 11 had potential issues (Figure 15).

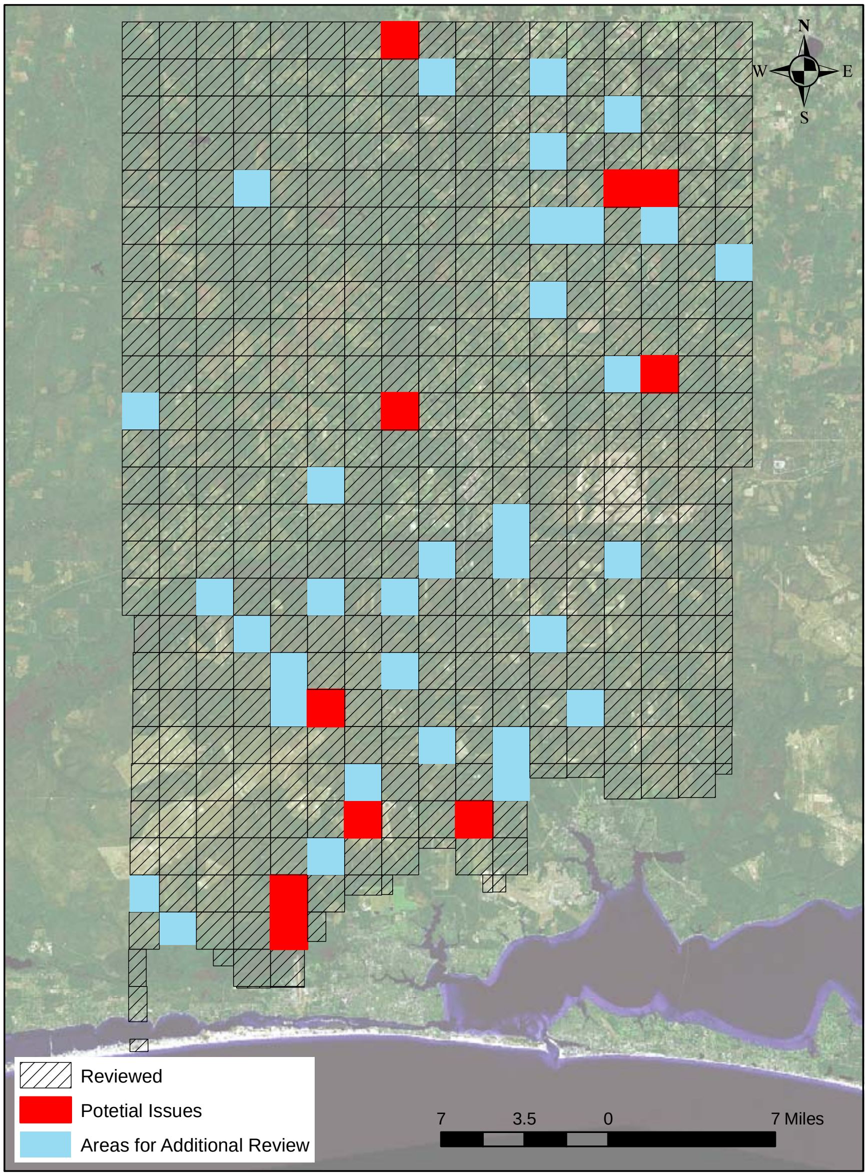

Figure 15. Tiles Flagged with Potential Issues

These issues were generally minor, difficult to find, and for the most part related to removal of points as opposed to having notable artifacts. Over-smoothing is a bit harder to assess than poor feature removal since the reviewer has to make inferences on what is not shown. This is where point density patterns and reviewing based on point classification are helpful. Slopes and road banks where the primary areas where over-aggressive point classification was judged to be potentially problematic (Figure 16 and Figure 17).

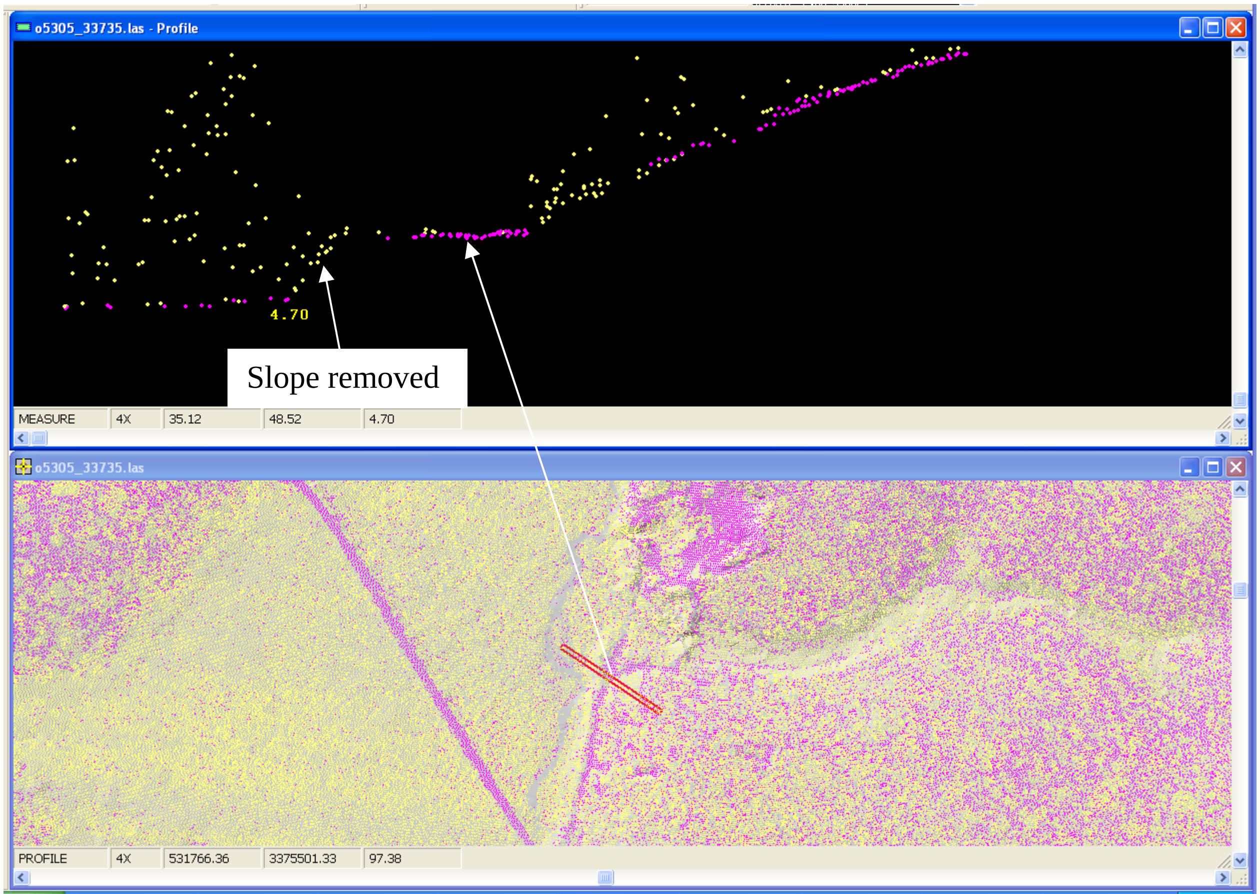

Figure 16. Potential Over-Smoothing Steep Slope: Yellow Points Are Unclassified

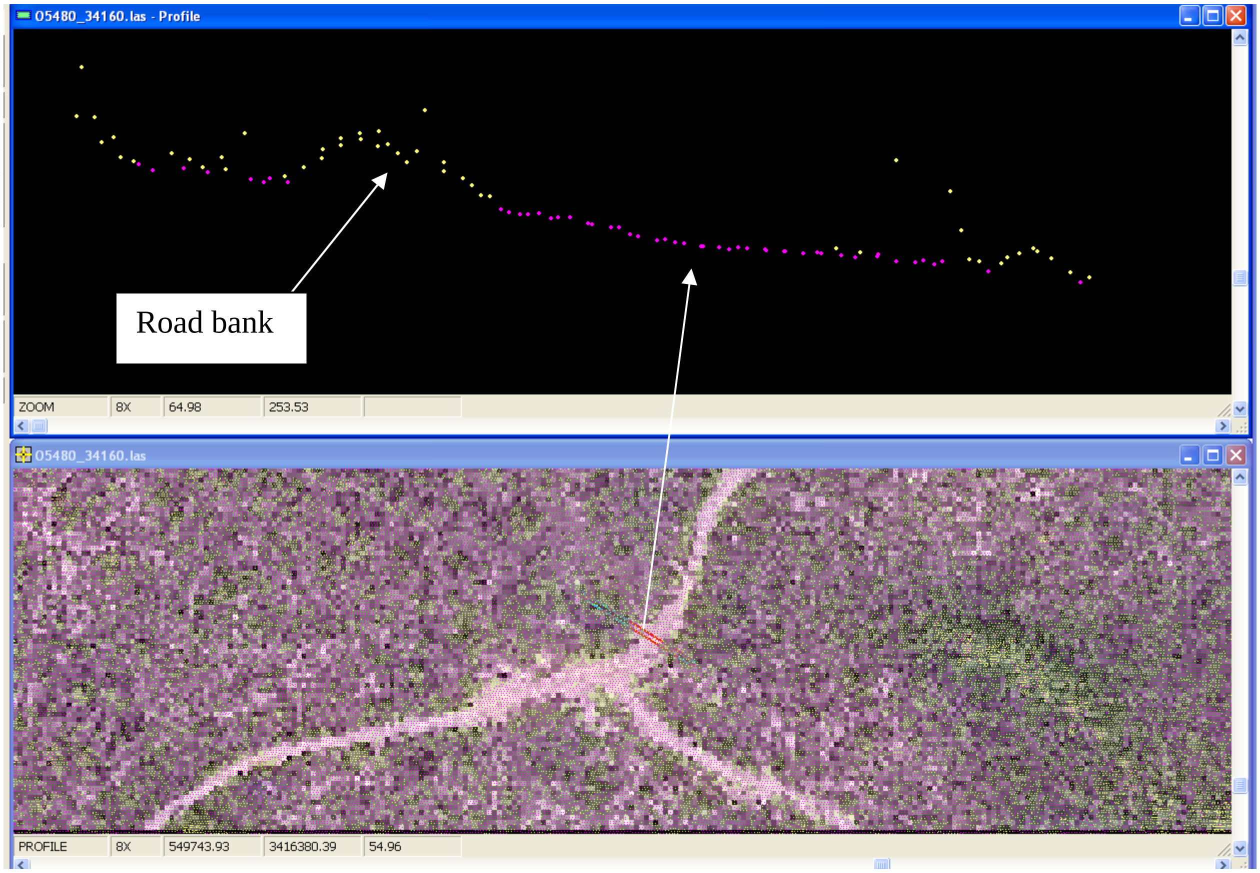

Figure 17. Example of Potential Road Bank or Elevated Shoulder Being Removed: Yellow Points Are Unclassified

Low point densities were also noted in swamp forests, which are heavily canopied. These areas generally have low relief and may or may not benefit from increased point densities. There appeared, however, to be room for additional ground point classification without appreciable increases in data noise (Figure 18). That said, the increase in ground resolution may not be advantageous in the extremely flat terrain. The existence of data voids, defined by FEMA (2003, Page A-41) as two times the DEM posting, which is 2 meters, may require some attention. Nothing was apparent to preclude interpolation in the low density (void) areas, but additional review may be warranted on a site-specific basis.

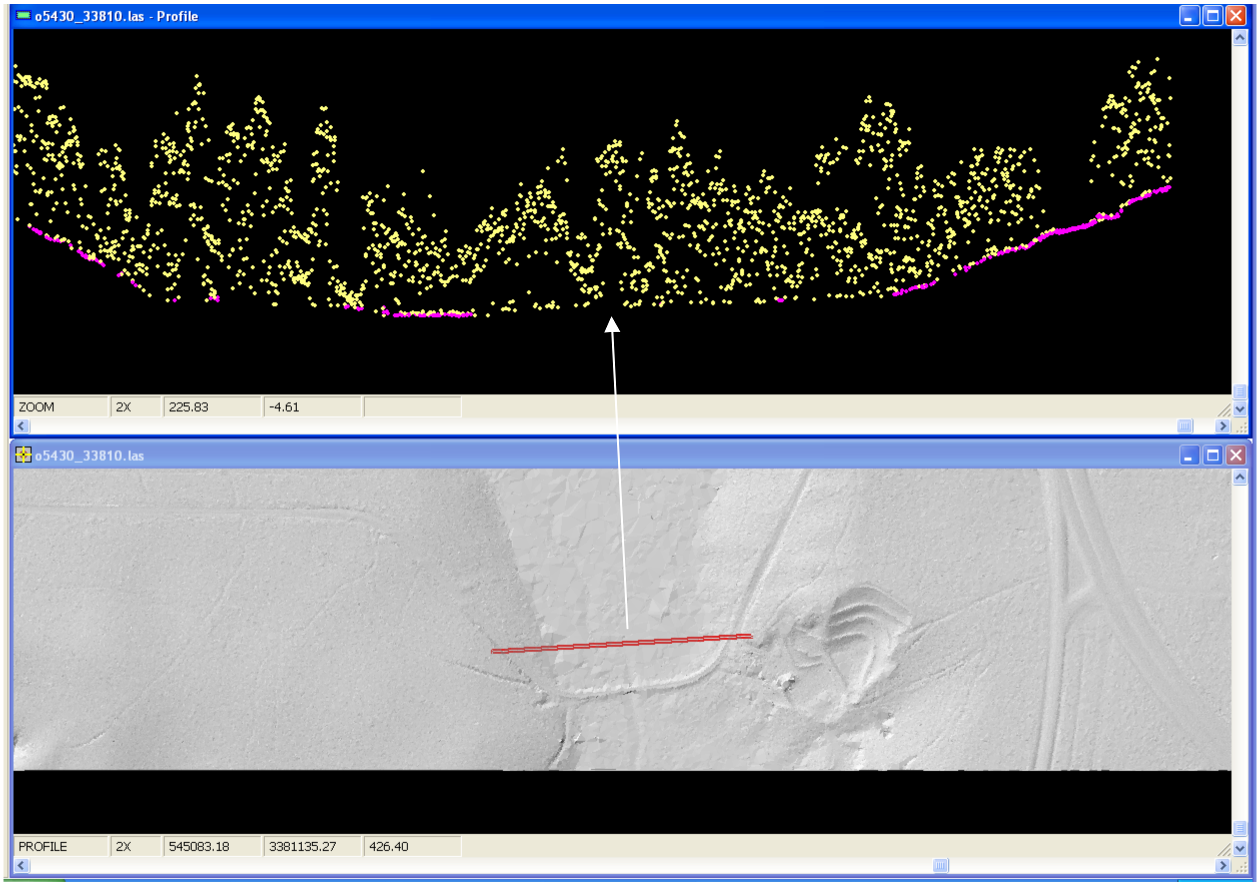

Figure 18. Aggressive Point Removal in Swamp Forest: Yellow Points Are Unclassified

There were a few instances where it appeared that slightly different algorithms were run to classify points as bare earth; where these different processes intersected, there was a slight variation in ground "texture," although elevations did not seem to be affected (Figure 19). The large-scale instances were noted in the point density maps and the specific tiles returned for reprocessing. There appear to be some areas where smaller or localized variations occur and are probably resident in multiple tiles (Figure 20).

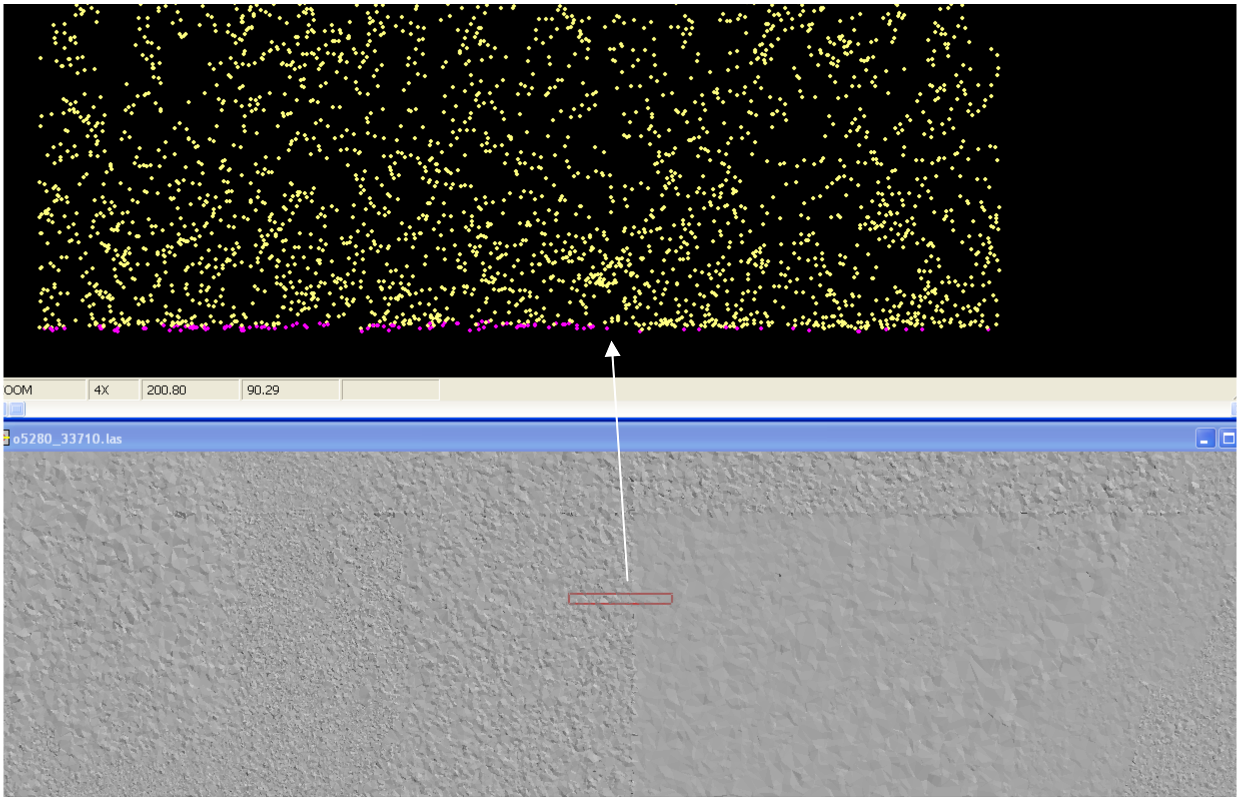

Figure 19. Slight Texture Variation in Forested Area from Apparent Changes in Processing Routines: Yellow Points Are Unclassified

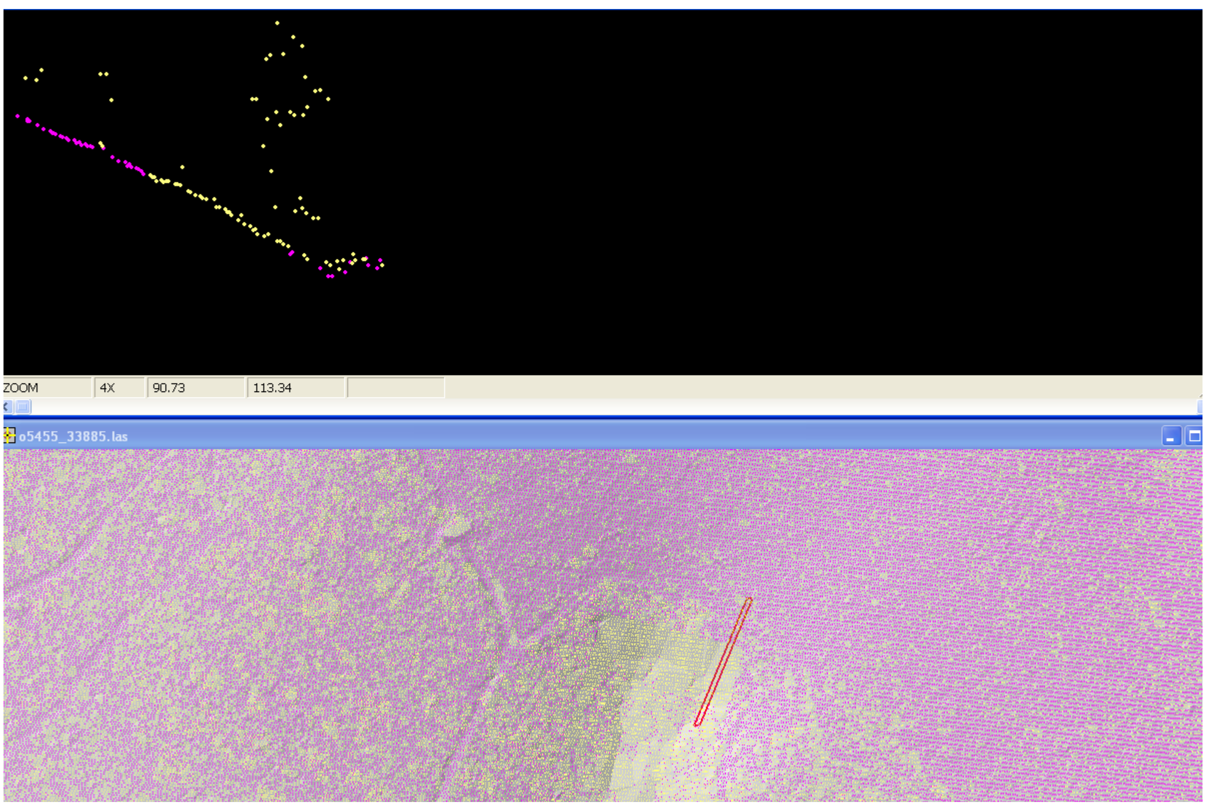

Figure 20. Variable Processing Area

Flight line offsets, which have been commonly found in previous data sets, were notably absent in this data set. There were slight cases, but rarely were any offsets greater than 10 cm, which is well within the accuracy specifications of the data.

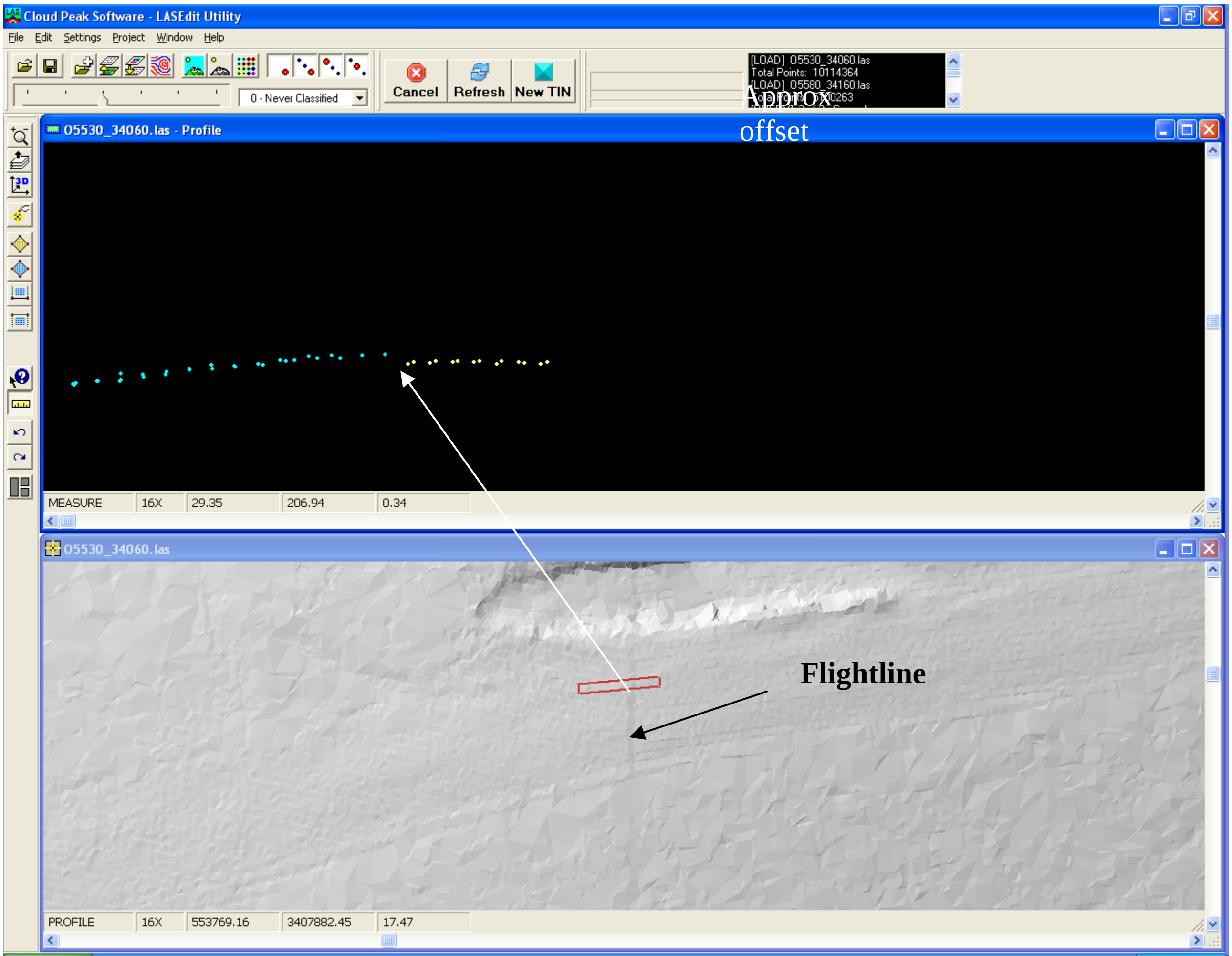

Figure 21. Example of a Flight Line Error (10 cm), One of the Few Found

Digital Elevation Models (DEMs)

The DEM QA results followed the LAS reviews; the DEMs from Okaloosa County were, overall, very clean. The tiles chosen for review (177) were randomly selected from a total of 413 tiles and represent approximately 43% of all tiles (Figure 22). Of the 177 tiles reviewed, only 30 were returned to the vendor for re-evaluation. These tiles were flagged for minor issues including possible nonremoval of structures and data processing inconsistencies. The flagged tiles were submitted to Fugro-EarthData for review. Fugro-EarthData reviewed and corrected these issues to the satisfaction of the QA team. Because the review did not include every tile, examples are being provided to users as a guide to potential problems that may be encountered.

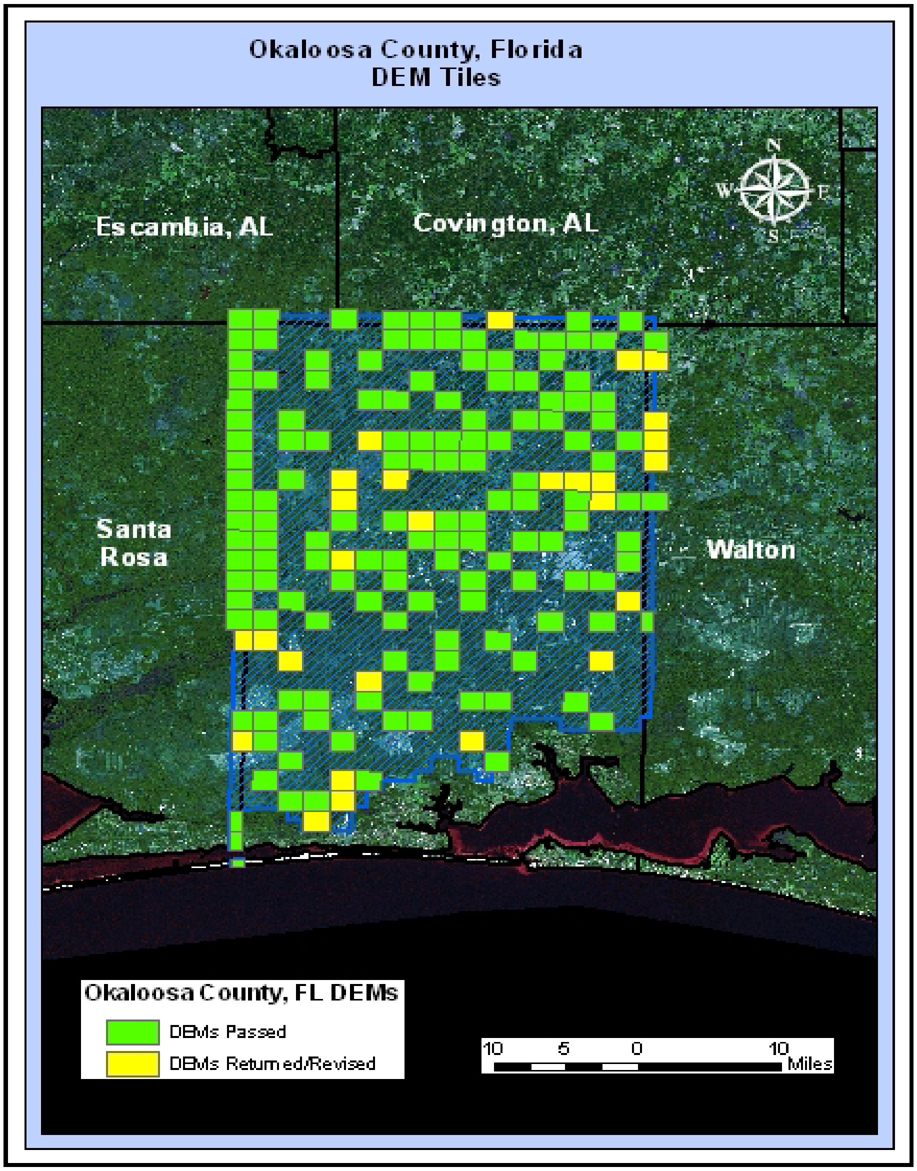

Figure 22. DEMs Reviewed and the Results of the Reviews

Process

Each DEM was checked using the Global Mapper software program with Flash Earth and Google Earth images for reference. The DEM tiles were

1. Checked for consistency;
2. Examined for tile edge match with neighboring tiles and match of features across tiles;
3. Checked for flight line match, artifacts, water boundaries, shoreline and road match, and bridge, building, and vegetation removal;
4. Checked for vertical accuracy to verify correct export from LAS files.

The tiles were reviewed initially to highlight any potential problems and then reviewed by a second reviewer to cross-check the issues. The list of tiles with issues was sent to Fugro-EarthData. Some of the issues included small localized artifacts, incomplete structure removal, and processing inconsistencies. In most cases, the professional opinion determined the artifacts to indeed be ground features. The vendor resolved the other issues to the satisfaction of the QA team. The following figures (Figure 23, Figure 24, Figure 25, Figure 26, and Figure 27) are examples of the minor issues that were found. The overall quality of the data set can be highlighted by the fact that only 17% of the total tiles reviewed were flagged for re-evaluation. The DEMs have been accepted as a very good data set.

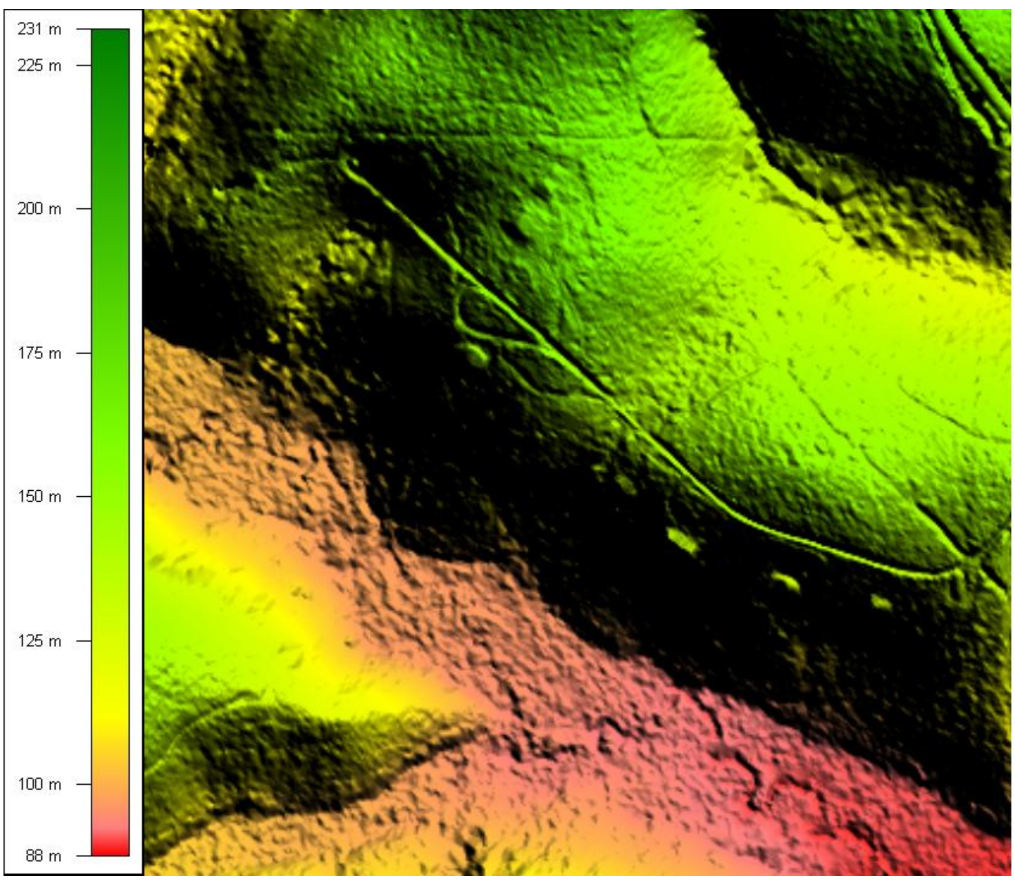

Figure 23. Potential Artifacts: Turned Out to Be House Terraces

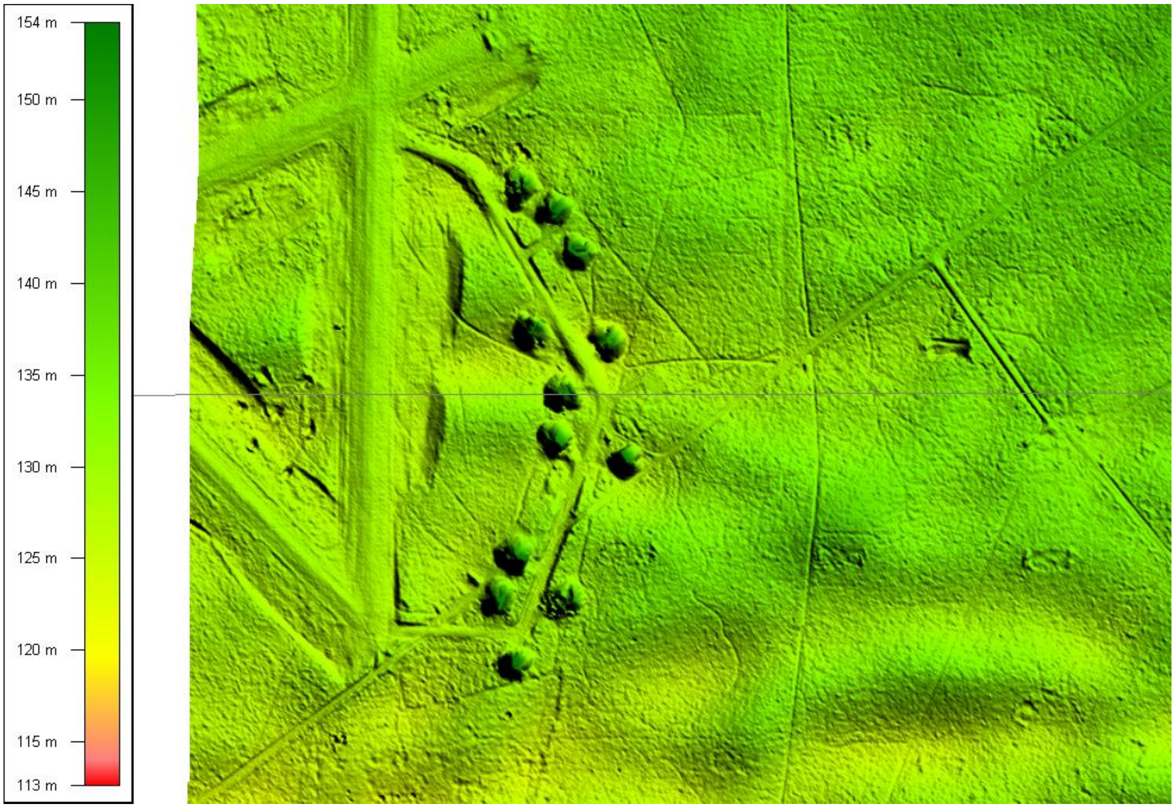

Figure 24. Structures Not Removed: Turned Out to Be Platforms of Structures and Were Removed

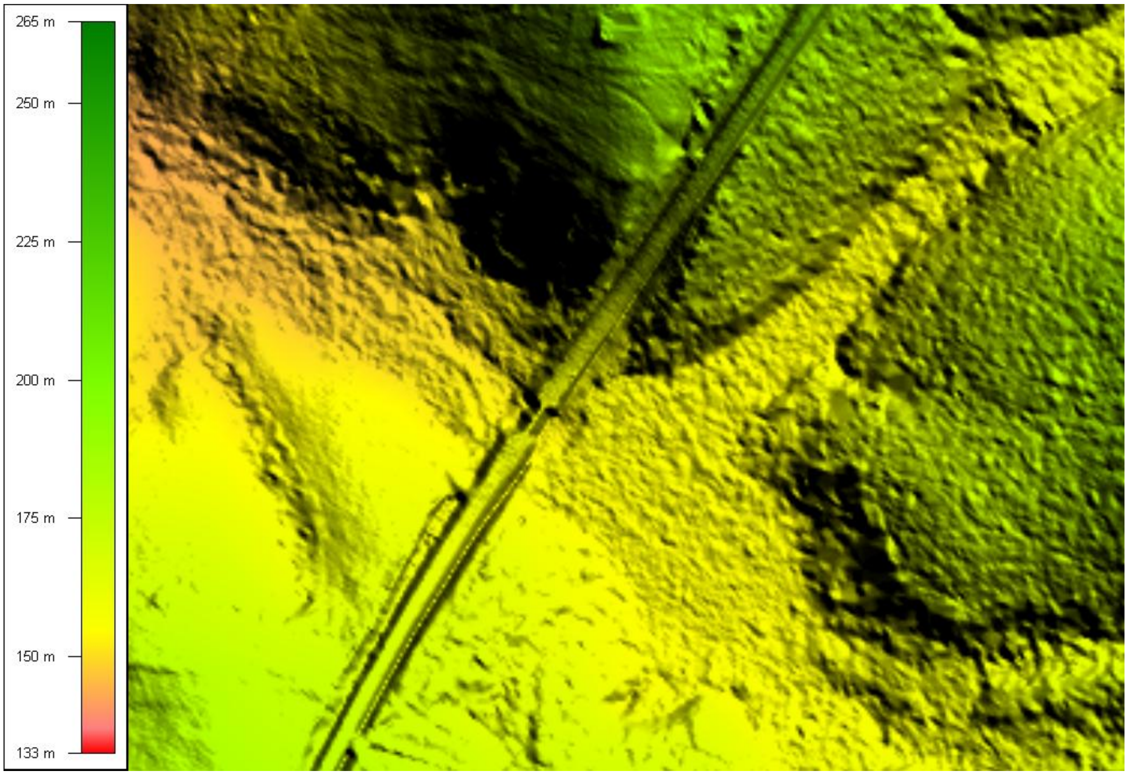

Figure 25. Incomplete Bridge Removal: Bridge Was Subsequently Completely Removed

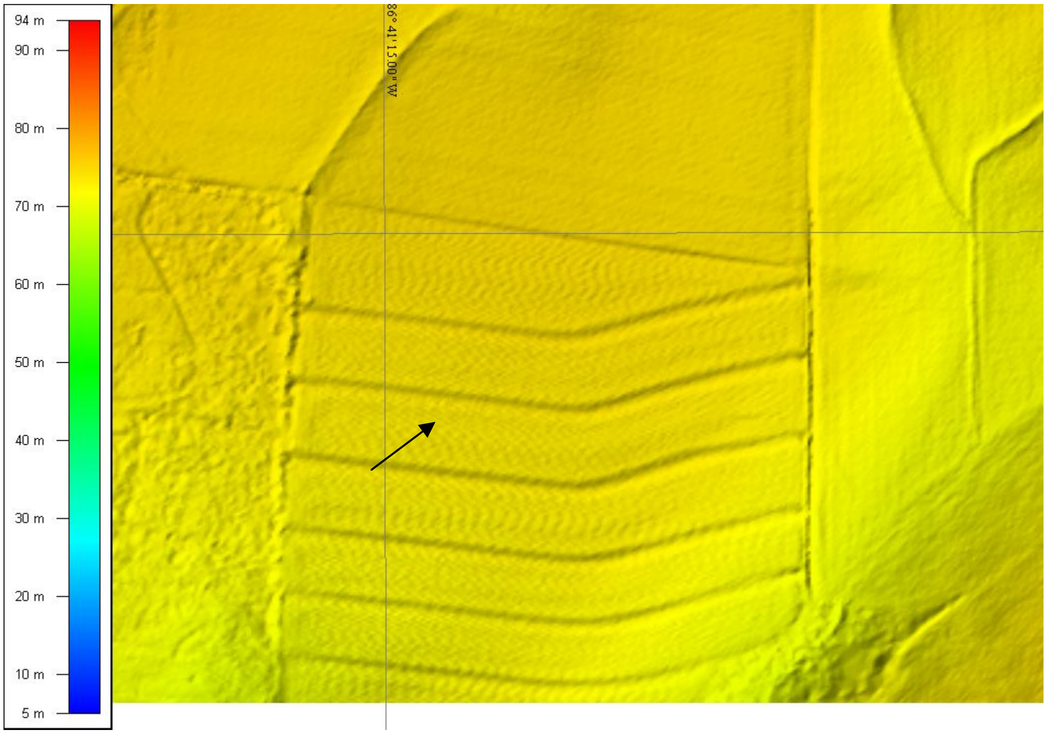

Figure 26. Ripples in Field: Appeared to Be Processing Issue but Was Plow Pattern

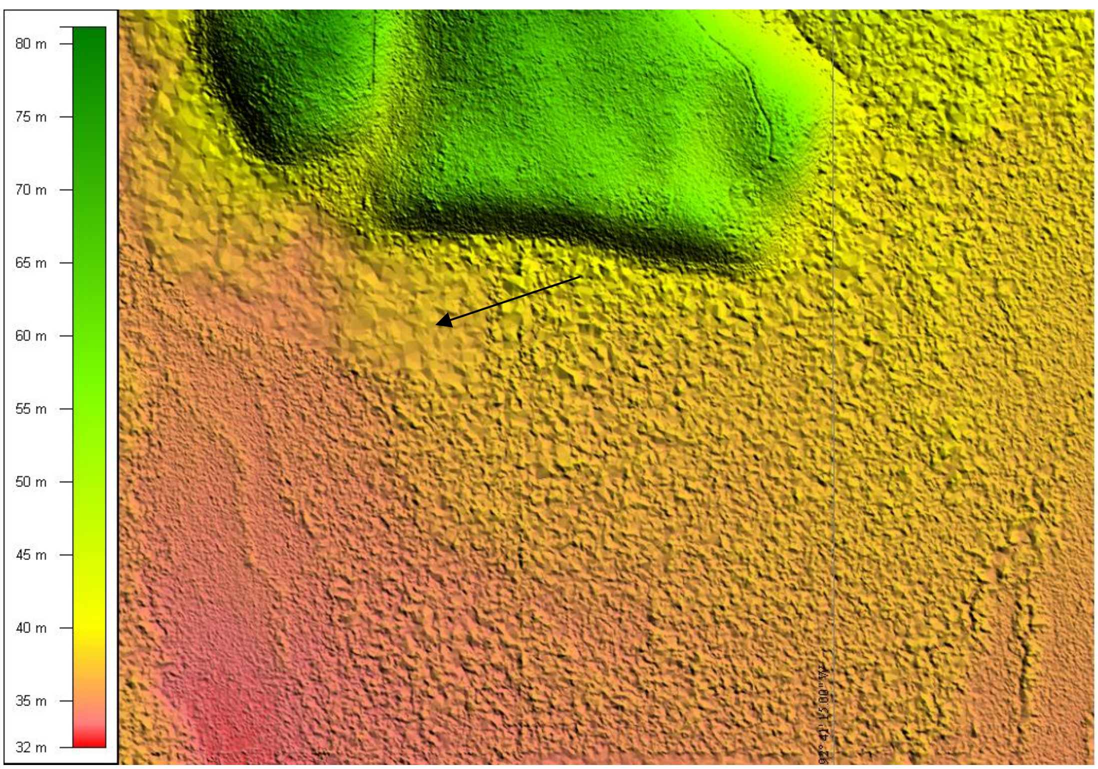

Figure 27. Inconsistent Processing: Remedied but Still May Occur in Some Areas

The DEMs were provided in ESRI GRID format with a 2-meter pixel size. The grids were tiled with no buffer (i.e., they abut one another). Therefore, if the data are not used in the native UTM projection, or the data are reprojected, there may be some slight data void issues between tiles.

When used in the native projection, however, there was good edge match between tiles. In only a few cases could the tile edges be discerned, and in profile there was no obvious data mismatch signature.

DEM Accuracy

A cross-check of the DEM data was performed in the native units to establish that no processing errors had occurred during creation of the DEM products. One hundred and five points were tested and represent all classes; the mean was -0.01 ft and the standard deviation was 0.26 ft (8 cm), which very nearly approximates the RMSE value calculated for the CVA (see Accuracy Assessment). This agreement indicates that the data were correctly gridded.

Conclusions

The data are, in all respects, of very high quality. The minor issues found with the lidar and DEM data either have been corrected or were deemed trivial to the performance of the data for the expected uses. The data collected in both open areas and in areas requiring processing (i.e., classification) have significantly higher accuracies than called for in the statement of work. The data can be used consistently over the collection area in applications where vertical accuracies of approximately 30 cm (1 foot) are required, even though the data were collected for 2-foot contours.

The one noted caveat of the data set is that it is a smooth product and may lack small feature resolution. Areas where this was noted include road cuts and forested hillsides. Customized classification routines may help to ‘bring out’ some additional resolution in these areas.

The accuracy of the data was tested using 164 known points spread over the collection area as ground control. The lidar data were compared to the known points and the following results were calculated.

- Using Federal Geographic Data Committee (FGDC), Federal Emergency Management Agency (FEMA), National Digital Elevation Program (NDEP), and American Society for Photogrammetry and Remote Sensing (ASPRS) methodology: **Tested 12 cm vertical accuracy at 95% confidence level in open terrain.**
- Using NDEP and ASPRS methodology: **Tested 13.5 cm vertical accuracy at 95% confidence level in all land cover categories combined.**
- Using FGDC and FEMA methodology: **Tested 13.7 cm vertical accuracy at 95% confidence level in all land cover categories combined.**

References

American Society for Photogrammetry and Remote Sensing (ASPRS). 2004. "ASPRS Guidelines: Vertical Accuracy Reporting for Lidar Data." American Society for Photogrammetry and Remote Sensing. Accessed November 2007 at *www.asprs.org/society/committees/lidar/Downloads/Vertical_Accuracy_Reporting_for_Lidar_Data.pdf*.

Federal Emergency Management Agency (FEMA). 2003. "Guidance for Aerial Mapping and Surveying." Appendix A in *Guidelines and Specifications for Flood Hazard Mapping Partners*. Federal Emergency Management Agency. Accessed November 2007 at *www.fema.gov/plan/prevent/fhm/dl_cgs.shtm*.

Federal Geographic Data Committee (FGDC). 1998. "National Standard for Spatial Data Accuracy." Part 3 of *Geospatial Positioning Accuracy Standards*. FGDC-STD-007.3-1998. Federal Geographic Data Committee. Accessed November 2007 at *www.fgdc.gov/standards/projects/FGDC-standards-projects/accuracy/part3/chapter3*.

National Digital Elevation Program (NDEP). 2004. *Guidelines for Digital Elevation Data: Version 1.0*. National Digital Elevation Program. Accessed November 2007 at *www.ndep.gov/NDEP_Elevation_Guidelines_Ver1_10May2004.pdf*.

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Appendices

Appendix A – Statement of Work

Appendix B – Lidar Data Collection Report

Appendix C – Point Data and Calculations

Appendix D – Ground Control Point Collection

Appendix A

Statement of Work

Coastal Services Center
National Ocean Service
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

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STATEMENT OF WORK

Okaloosa County Florida Lidar

July 2007

Table of Contents

List of Acronyms

ASPRS .... American Society of Photogrammetry and Remote Sensing
CO .... Contracting Officer
COR .... Contracting Officer's Representative
CRS .... Coastal Remote Sensing
CSC .... Coastal Services Center
DEM .... Digital Elevation Model
DTM .... Digital Terrain Model
FGDC .... Federal Geographic Data Committee
LIDAR .... Light Detection and Ranging
NAD .... North American Datum
NAVD .... North American Vertical Datum
NGA .... National Geo-spatial Intelligence Agency
NOAA .... National Oceanic and Atmospheric Administration
NSSDA .... National Standard for Spatial Data Accuracy
NWFWMD .... Northwest Florida Water Management District
QA .... Quality Assurance
QC .... Quality Control
RMSE .... Root Mean Square Error
SOW .... Statement of Work

1 Overview

This Statement of Work (SOW) has been developed by the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center (referred to as the Center) to collect and deliver topographic elevation point data derived from multiple return light detection and ranging (lidar) measurements for areas in coastal northwest Florida, specifically Okaloosa County. The Center is partnering with the Northwest Florida Water Management District (NWFWMD) in this project. Data are intended for use in coastal management decision making, including applications such as flood plain mapping. This SOW provides specific information needed by commercial contractors to respond by submitting a technical proposal, a firm fixed price cost proposal, and a timeline detailing how the required products will be produced and delivered for the geographic areas under consideration.

2 Background

The mission of the Center is to support the environmental, social, and economic well being of the coast by linking people, information, and technology. NWFWMD's mission is to protect and manage the water resources of northwest Florida in a sustainable manner for the continued welfare of its residents and natural systems. The data produced from this SOW are intended to support the local Coastal Zone Managers in their decision-making processes. This data will be used for flood plain mapping and other coastal management applications.

3 Requirements

The Contractor shall provide topographic elevation data for the designated areas of Figure 1 as described in this SOW. Data collection, processing, accuracy assessment , and delivery shall be accomplished in accordance with the following specifications. The contractor shall provide all necessary labor, equipment, material, software, and supplies to satisfactorily complete the SOW.

3.1 Data Coverage

The project area shall be Okaloosa County, Florida, with a one-kilometer buffer around the north, east, and west edges of the county. The total area is estimated to cover approximately 2665 km^2, but should be verified by the contractor. The cost proposal shall be broken out into three areas as shown in figure 1. The contractor can assume for pricing that they will all be flown together. An ESRI shapefile of the project area with the buffer will be provided upon request.

3.2 Data Collection and Delivery

- The Contractor shall deliver the Lidar multiple-return points for the specified area(s) in the LAS 1.1 data format. All returns shall be delivered (including vegetation, buildings, etc) with the exception of obvious error points. The LAS file public header block shall include all required fields according to the March 2005 LAS 1.1 specification. The LAS file shall also include the mandatory GeoKey DirectoryTag variable length header. The Point Data Record Format 1 shall be used and the intensity field shall be required. At a minimum, returns shall be classified for ground (2) and water (9) according to the American Society of Photogrammetry and Remote Sensing (ASPRS) LAS format classification table. If the GPS time is stored as seconds of the GPS week, the Point Source ID field must be filled out for each record and a separate table relating the IDs to acquisition dates must be provided. This is to allow determination of the time on a point by point basis.
- Nominal point spacing for the Lidar mass points shall be 1.5 meters. **The contractor shall also provide an additional cost option for a 1 meter nominal point spacing.**
- Acquisition shall be during a leaf off condition, typically late December through early March for this area.
- The LAS points and DEM grids shall be tiled into 2500 meter by 2500 meter tiles on even boundaries for UTM zone 16 North. Naming shall indicate the lower left corner of the tile and the scheme shall be Oxxxx_yyyyy where 'O' stands for Okaloosa, 'xxxx' is the first 4 digits of the UTM eastings (e.g. the tile with westernmost eastings of 517500 will have 'xxxx' equal to 5175), and 'yyyyy' is the first 5 digits of the northings (e.g. the tile with southernmost northing of 33600000 will have 'yyyyy' of 33600).
- The Contractor shall collect and deliver all point data referenced to the North American Datum of 1983 (NAD83) and the Geodetic Reference System of 1980 (GRS80). Horizontal units shall be in UTM, zone 16 north, meters. Vertical units shall be in orthometric NAVD88 feet using the latest GEOID model (GEOID03).
- A bare-earth gridded DEM / DTM shall be created and shall meet or exceed FEMA flood plain mapping specifications. Vertical datum for the gridded product shall be the North American Vertical Datum of 1988 (NAVD88) and horizontal datum shall be NAD83. The data shall be in ESRI grid format and projected to UTM zone 16 with horizontal units of meters. Grid spacing shall be 2 meters. Vertical units shall be feet. The tiling scheme for the grids will be provided by the government.

- Base stations for GPS surveys shall be based on first or second order survey control stations that are part of the National Geodetic Survey's Spatial Reference System. In the event no suitable control is available, new control stations will have to be established using NGS-58 Guidelines for Establishing GPS- Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm). New control stations will be sufficiently monumented to hold their position.
- Lidar data accuracy determination shall employ the National Standard for Spatial Data Accuracy (NSSDA). When compared to GPS survey grade points in generally flat non-vegetated areas, at least 95% of the positions shall have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm if errors were normally distributed). Horizontal accuracy shall be 1 meter RMSE or better. Additionally, the Consolidated Vertical Accuracy (computed using NDEP and ASPRS methodology) shall meet FEMA guidelines (36.3 cm) for the generation of 2 foot contours.
- Lidar data from different flight lines shall be consistent across flight lines, *i.e.*, there is minimal vertical offset within the noise level of the LiDAR system (typically 5 -10 cm) between adjacent flightlines.
- Spatial coverage prior to vegetation editing shall be continuous in the designated geographic areas. Lidar data gaps between adjacent flight lines larger than two meters will not be acceptable.
- Data delivery shall be by removable hard drive supporting USB 2.0 standards. The hard drive(s) will not be returned by the government.
- The Contractor shall deliver the x,y,z (latitude, longitude, elevation) data from the checkpoints used for quality control as well as the control points used to control the LiDAR flight missions. Points shall be delivered in ASCII format on the same media used for the elevation data delivery. The control and check points shall be delivered with sufficient detail regarding collection to allow the Government to tie into the same survey network of control points for an independent survey.
- Delivered elevation data shall become the property of the Government and will be shared with the public. The contractor shall retain the ability to use and distribute the data as they see fit.

If the contractor believes other delivery formats and/or mechanisms will serve the government's needs in a more efficient manner, the contractor is encouraged to propose alternatives.

3.3 Classification system

The contractor shall use the point classification system endorsed by the ASPRS for the LAS format. Ground shall be assigned a classification value of two (2), water shall be nine (9), and points that were examined but not classified as one of the ASPRS classes shall have a class value of one (1).

3.4 Records and Metadata

The contractor shall document all delivered data and data products (including options if exercised) according to Executive Order 12906 (http://www.fgdc.gov/policyandplanning/executive_order/) for the whole of the project in one metadata product. Specifically, the contractor shall deliver for all data and data products, metadata records which detail all flight lines, flight dates and times, datums, reprojections, resampling algorithms, processing steps, field records, and any other pertinent information. The metadata records shall conform to the Content Standards for Digital Geospatial Metadata (FGDC-STD-001-1998) as published on May 1, 2000, by the Federal Geographic Data Committee (FGDC) or to any format that supersedes it as determined by the FGDC (http://www.fgdc.gov/metadata/csdgm/). Profiles and extensions to the standard that have been endorsed by the FGDC shall be used if they are applicable to the data or data products. The metadata records shall contain any and all elements, including those that are considered optional, wherever applicable to the data or data product. The metadata record shall contain sufficient detail to ensure the data or data product can be fully understood for future use and for posterity. The metadata records shall be delivered free of errors in both content and format as determined by the metadata parser (mp) program developed by the United States Geological Survey or an equivalent. The metadata records will be subject to review and approval prior to final acceptance by the Government.

3.5 Kickoff Meetings

The contractor shall participate in a teleconference kickoff meeting with the NOAA Coastal Services Center and NWFWMD within 30 days of contract award unless otherwise agreed upon by NOAA/NWFWMD and the contractor. This meeting will serve as an information exchange and planning meeting for future activities such as delivery of government furnished equipment (GFE) and field trips. The contractor shall prepare an agenda for this meeting and issue meeting minutes within 7 days after the meeting.

3.6 Contractor Coordination

Communication and coordination between both the contractor and the Government is considered vital to the satisfactory accomplishment of this SOW. The Contractor shall expect periodic interaction with the Government to ensure clear understanding of the anticipated products and satisfactory progress in the delivery of products.

The contractor shall submit monthly progress reports to the Government summarizing progress made and problems encountered. After submittal of each of these reports the contractor shall schedule a conference call with the government to discuss the progress of the project and any issues that need to be addressed. The contractor shall prepare and distribute an agenda for the call and shall distribute the meeting minutes within 5 days of the conclusion of the call.

3.7 Deliverables

This section contains the complete list of deliverables associated with this project. Each deliverable must include a proposed measure of acceptability. All submitted plans shall be of sufficient detail so that the Government can verify that the contractor has a thorough understanding of the requirements of this SOW. The contractor shall also complete the attached spreadsheet with a percentage of the overall task order that each deliverable represents and the proposed due date for each deliverable. This data will be used to track performance and for approval of invoices. The contractor may propose additional deliverables/ milestones in their technical proposal if they determine they are required. The following project deliverables are required:

1 Work Plan – in some instances, the technical proposal may be accepted as the work plan. The work plan should include but is not limited to; potential base station locations, horizontal and vertical accuracy of the base stations, projected maximum baseline length for airborne trajectories, prior calibration reports, process to perform daily calibration checks, flight acquisition etc. The plan shall be in Microsoft Word format and **shall** include the major milestones and deliverables shown in **Gantt chart format**.
2 Flight path map and plan of LiDAR collecting aircraft.
3 Quality Control Plan – including detailed discussion of accuracy assessment methods/plan or other means of proving contract specifications have been met in Microsoft Word format.
4 Project schedule to include dates for all deliverables
5 Monthly progress report in a Microsoft Word, Excel or Project format on the 7th day of the month. In some cases a more appropriate regularly scheduled reporting timetable may be substituted contingent on agreement by all parties.
6 Final Report – The report shall summarize the project and provide the quality control evaluation showing that the project deliverables meet the contract specifications. The report shall be in Microsoft Word format.
7 FGDC-compliant metadata for all data sets per the project requirements
8 Digital elevation data sets per the requirements of section 3.2. These include:
   - Multiple-return classified mass point data in LAS format with nominal 1.5 meter spacing (or 1 meter dependent on which cost option is exercised).
   - Bare-earth DEM/DTM meeting or exceeding FEMA flood plain mapping specifications. The DEM shall be in ESRI grid format and represent a continuous surface (no holes).QA/QC validation data

3.8 Product Delivery Schedule Guidance

The contractor shall propose a product delivery schedule in their technical proposal. As a guideline, the government does not expect delivery to require more than six-months from time of leaf off acquisition.

3.9 Product Delivery Addresses

The deliverables listed above shall be delivered to the COR at the following address. Technical questions shall be addressed to the Technical POC.

NOAA COR
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
Attn: Dennis Hall
(843) 740-1323
Dennis.Hall@noaa.gov

NOAA Technical POC
NOAA Coastal Services Center
2234 South Hobson Avenue
Charleston, SC 29405
Attn: Kirk Waters
(843) 740-1227
Kirk.Waters@noaa.gov

NWFWMD POC
Northwest Florida Water Management District
81 Water Management Drive
Havana, Florida 32333
Attn: Ron Bartel
(850) 539-5999
Ron.Bartel@nwfwmd.state.fl.us

4 Figures and Maps

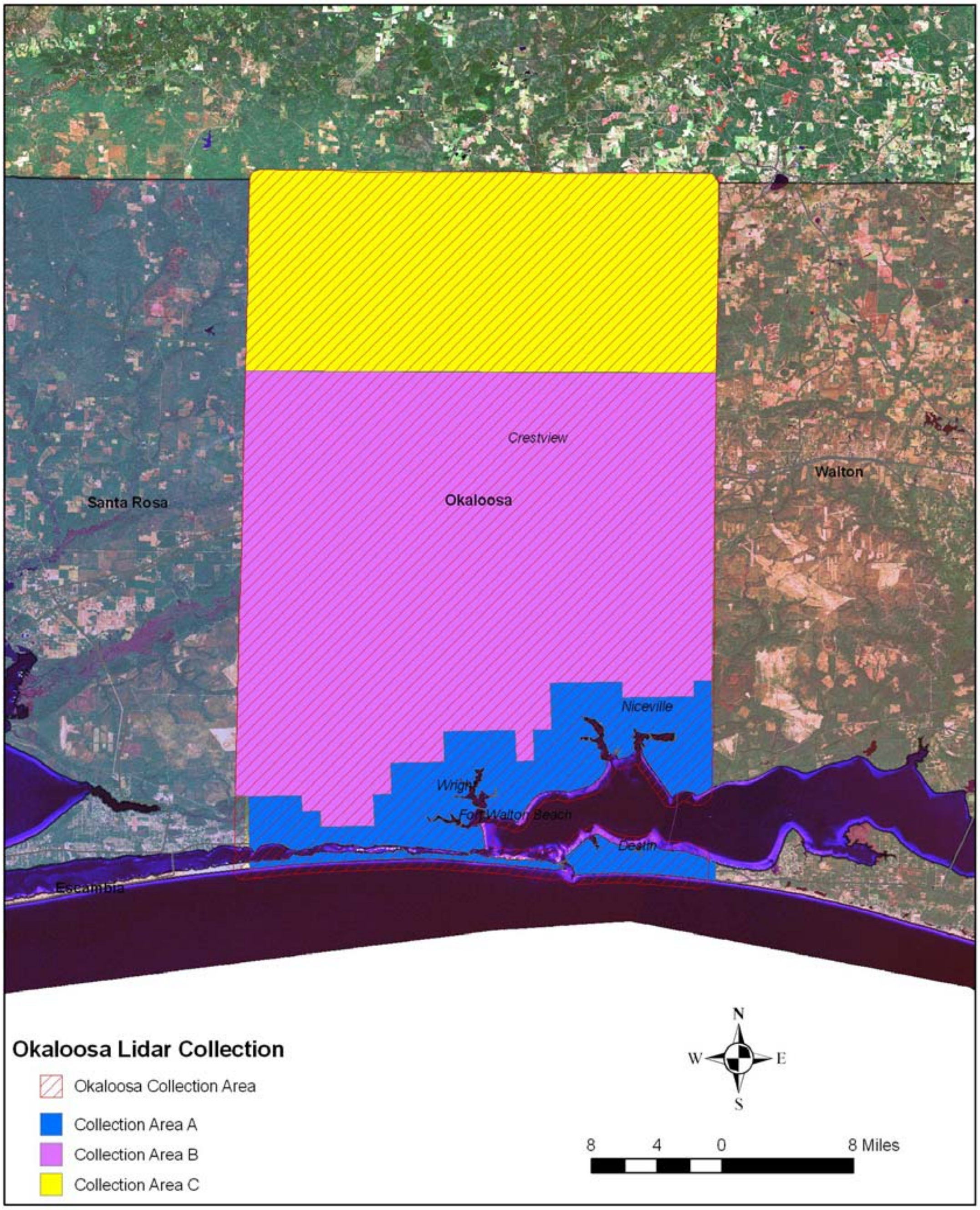


Figure 1. Map showing the area for LiDAR collection covering Okaloosa County, Florida.

Appendix B:

Lidar Data Collection Report

Turning Spatial Data into Knowledge

Coastal Services Center
National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Final Report for Okaloosa County Florida Lidar

NOAA Coastal Services Center
Contract EA133C-05-RP-1058
Task Order 11

OKALOOSA COUNTY FLORIDA LIDAR
Final Report

1. PROJECT OVERVIEW

In response to the Statement of Work (SOW) prepared by the NOAA Coastal Services Center for Okaloosa County Florida Lidar, the Fugro EarthData team acquired, processed, and delivered lidar and lidar-derived products for the following geographic region of Okaloosa County, Florida (Figure 1). Project boundary is denoted by the red polygon and represents approximately 874 square miles of Okaloosa County. The project delivery layout is denoted by the black, superimposed grid and consists of 5,000' x 5,000' tiles.

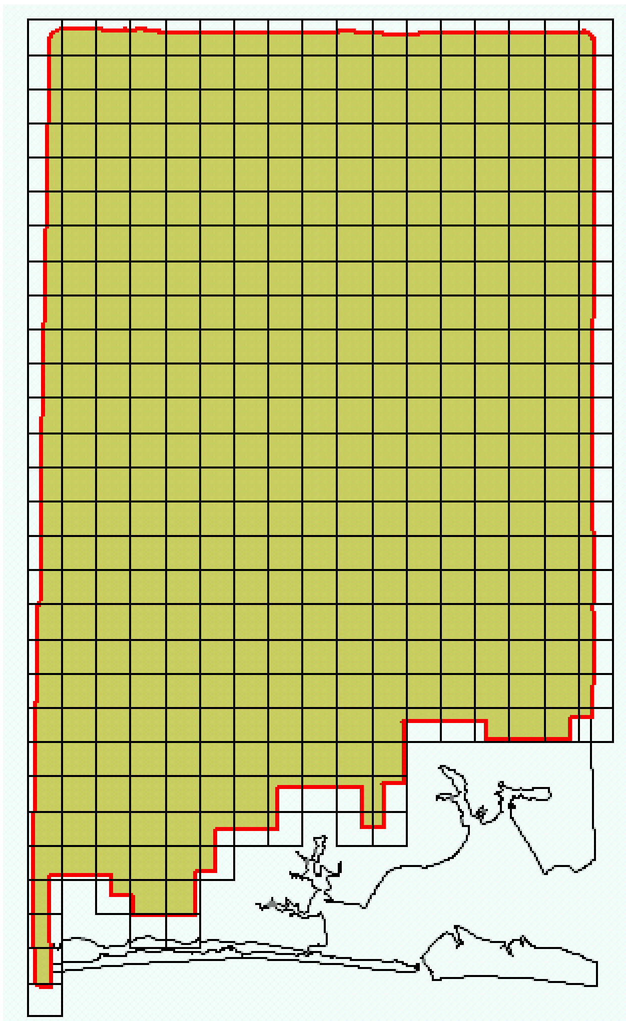


Figure 1

1.1. Project deliverables

- Project work plan
- Quality control plan
- Project schedule
- Monthly progress reports in Word format
- Final report
- FGDC-complient metadata for all data sets
- Digital elevation sets:
  - Multiple-return masspoint (all-returns) data in LAS format (with points classified)
  - Bare-earth DEM/DTM in ESRI grid format.

1.2. Project Reference System

All point data is referenced to the North American Datum of 1983 (NAD83) and the Geodetic Reference System of 1980 (GRS80). Horizontal units are in UTM, zone 16 north, meters. Vertical units are in orthometric NAVD88 feet using the latest GEOID model (GEOID03).

Vertical datum for the gridded product is the North American Vertical Datum of 1988 (NAVD88) and the horizontal datum was NAD83. The gridded data is in ESRI grid format and projected to UTM zone 16 with horizontal units of meters.

1.3. Naming Convention

Naming convention for the deliverable tiles indicates the lower left corner of the tile and the scheme is Oxxxx_yyyyy where 'O' stands for Okaloosa, 'xxxx' is the first 4 digits of the UTM eastings (e.g. the tile with westernmost eastings of 517500 has 'xxxx' equal to 5175), and 'yyyyy' is the first 5 digits of the northings (e.g. the tile with southernmost northing of 33600000 has 'yyyyy' of 33600).

1.4. Reports & Documents

The following documents were produced/delivered in support of the project:

- Project Work Plan (including schedule)
- Quality Control Plan
- Aerial Acquisition Report (consisting of flight logs, QC documents, and GPS plots)
- FGDC-compliant metadata
- Quality Control Evaluation (included in Appendix A of this report)
- Ground Survey Report

1.5. Lidar Specification

Nominal point spacing for the Lidar mass points is 1.5 meters. Lidar multiple-return points for the specified area(s) were delivered in the LAS 1.1 data format. All returns were delivered (including vegetation, buildings, etc) with the exception of obvious error points. The LAS file public header blocks include all required fields according to the March 2005 LAS 1.1 specification. The LAS files also include the mandatory GeoKey DirectoryTag variable length header. The Point Data Record Format 1 was used and the intensity field was incorporated. The returns were classified for ground (2) and water (9) according to the American Society of Photogrammetry and Remote Sensing (ASPRS) LAS format classification table.

1.6. Accuracy Specification

The accuracy specification for this project was based on the NSSDA standard and FEMA guidelines. That is, the Lidar data accuracy determination employed the National Standard for Spatial Data Accuracy (NSSDA). When compared to GPS survey grade points in generally flat non-vegetated areas, at least 95% of the positions have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm if errors were normally distributed). Horizontal accuracy is 1 meter RMSE or better. Additionally, the Consolidated Vertical Accuracy (computed using NDEP and ASPRS methodology) meets FEMA guidelines (36.3 cm) for the generation of 2 foot contours.

Conformance to the accuracy specifications was verified by a comparison of ground survey points collected for QC purposes against the lidar terrain points. These results are outlined in the attached Appendix A document.

2. PROJECT EXECUTION

2.2 Data acquisition

EarthData International, Inc. collected ALS-50-derived LiDAR over Okaloosa County, Florida with a 1.5m, nominal post spacing using a Cessna 310 aircraft. The collection for the entire project area was accomplished in one day on February 10, 2008. The collection was performed by Fugro EarthData using a Leica ALS50-II MPiA LiDAR system, serial number ALS039, including an inertial measuring unit (IMU) and a dual frequency GPS receiver.
This project required 3 lifts of flight lines to be collected. The lines were flown at an average of 6,000 feet above mean terrain using a pulse rate of 122,500 pulses per second. Lidar data was collected prior to the emergence of deciduous foliage; particularly undergrowth and shrubs that line stream channels. Data was only collected when environmental conditions meet the criteria specified. To be specific, the following conditions existed prior to launch of the aircraft:

- Low Vegetation period (leaf off)

- Streams and rivers were within their normal banks
- The project area was cloud-free below the design altitude for the mission
- The area was free of smoke or haze

2.2.1 Description of the Laser Scanning System

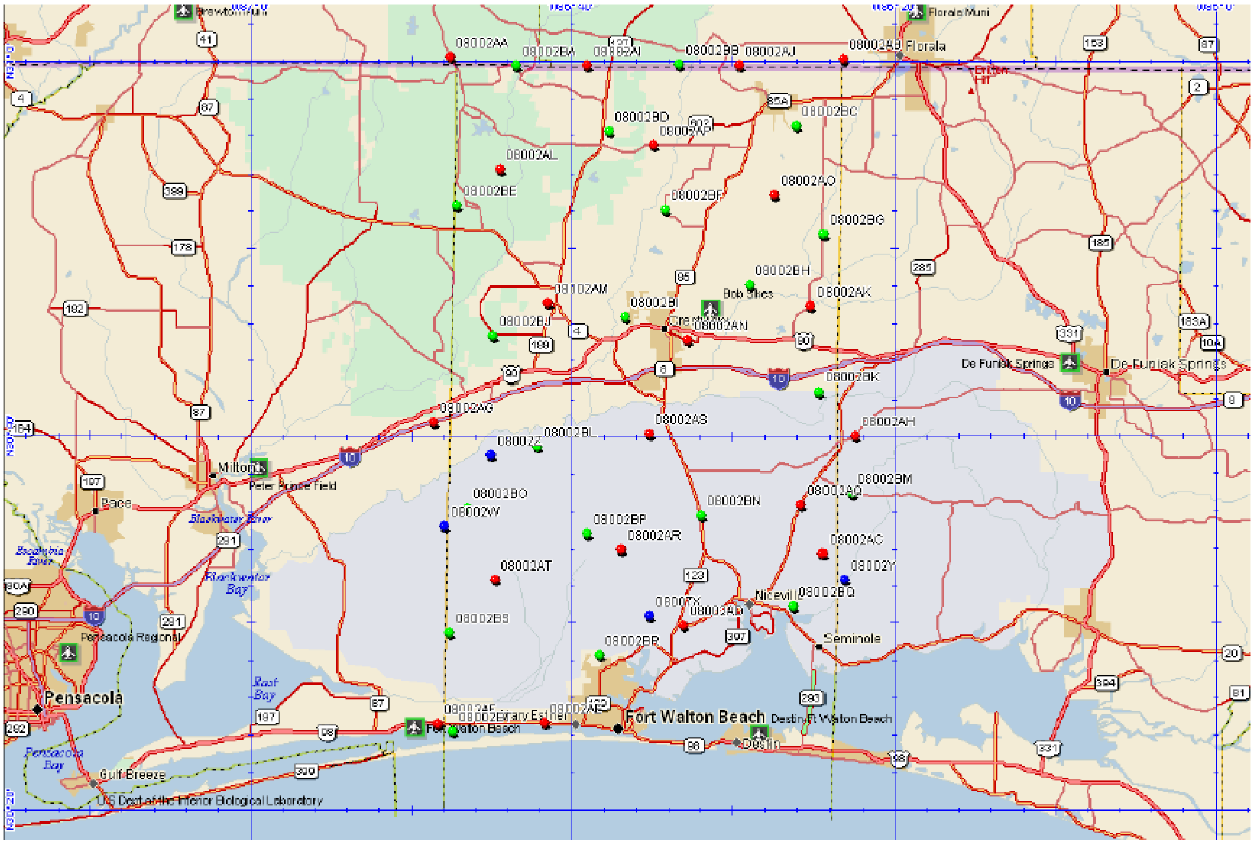
For this project, Fugro EarthData used the **Leica ALS50-II MPiA** (Multiple Pulse in the Air) laser scanning measurement system. The ALS50-II MPiA System is capable of recording three range points, and three intensity values for each emitted laser pulse. The ALS50-II MPiA is a state-of-the-art LIDAR sensor with the following operational specifications:

- Variable field of view from 10° to 75° (Field of view and altitude combination allow variable swath widths)
- Up-to 150 kHz laser pulse rate
- Altitude capability of 200 metes to 6000 metres AGL (above ground level)

The LIDAR system has a wide operational window and can be operated at night, to facilitate data acquisition in high traffic areas where daytime flight restrictions may be imposed. For larger projects two aircrews may be used to maximize daily acquisition, allowing LIDAR acquisition to be completed using a single aircraft.

2.2.2 GPS and Ground Survey

Terrasurv Inc., was tasked with establishing ground control for the project. The ground control for project was to meet accuracy requirements for compilation of 2 foot contours (0.06 m). The map below in figure 1 shows the locations of the 20 ground control points (A series, red) and 20 QC points (B series, green), as well as four extra control points (blue):



The Global Positioning System (GPS) was used in a static differential mode to establish the control network. The surveyed points consisted of a flat open area (grass, dirt, asphalt), and were not marked by permanent means.

All survey control was provided in the North American Datum of 1983 (NAD83) and the geodetic Reference System of 1980 (GRS80). Horizontal units shall be in UTM, Zone 16 North in meters. Vertical units shall be in orthometric NAVD88 feet using the latest GEOID model.

Upon completion of survey services, a surveyor's report was submitted to NOAA CSC in PDF format.

2.2.3 Verification of data usability

All acquired lidar data underwent a ***preliminary*** review to assure that complete coverage was obtained and that there were no gaps between flight lines before the flight crews left the project site. Once back in the office, the data was run through a complete iteration of processing to ensure that it was complete, uncorrupted and that the entire project area had been covered without gaps between flight lines. There were essentially three steps to this processing.

- **GPS/IMU Processing**

  Airborne GPS and IMU data was immediately processed using the airport GPS base station data, which is available to the flight crew upon landing the plane. This ensured the integrity of all the mission data. These results were also used to perform the initial lidar system calibration test described below.

- **System Calibration**

  EarthData always conducts a boresight/calibration determination for every lidar mission. The boresight determination process was used to model and measure the outputs of the inertial measurement unit (IMU) and the lidar instrument, as previously stated for this project. The flight crew developed a calibration test field at the chosen airport. The goal of the boresight was to determine the level of compensation that needed to be applied to the dataset to remove systematic distortion in the initial processing. The following are the steps included in the boresight determination:

  Step1 At the start of each acquisition mission, lidar data was acquired over a test field that had been set up near the airport using the specific parameters of the project design. The area was covered by three overlapping flight lines. Two parallel lines covered the area in opposing directions with 100% overlap; the third line crossed perpendicular to the two principal lines.

  Step 2 The vertical data from the 2 lines overlapping by 100% were processed using ESRI ArcView to color code differences in the elevation values of identical points in each of the lines to determine if there was any roll, in the lidar/IMU system. The perpendicular line was used to detect bowing or warping in the lidar sensor that can occur within each swath.

  Step 3 The technician recorded the measurements of the boresight determination and calculated any offsets that needed to be applied to the data during the initial processing.

  Step 4 During processing, the known ground control was used to adjust the lidar surface to the actual datum of the project.

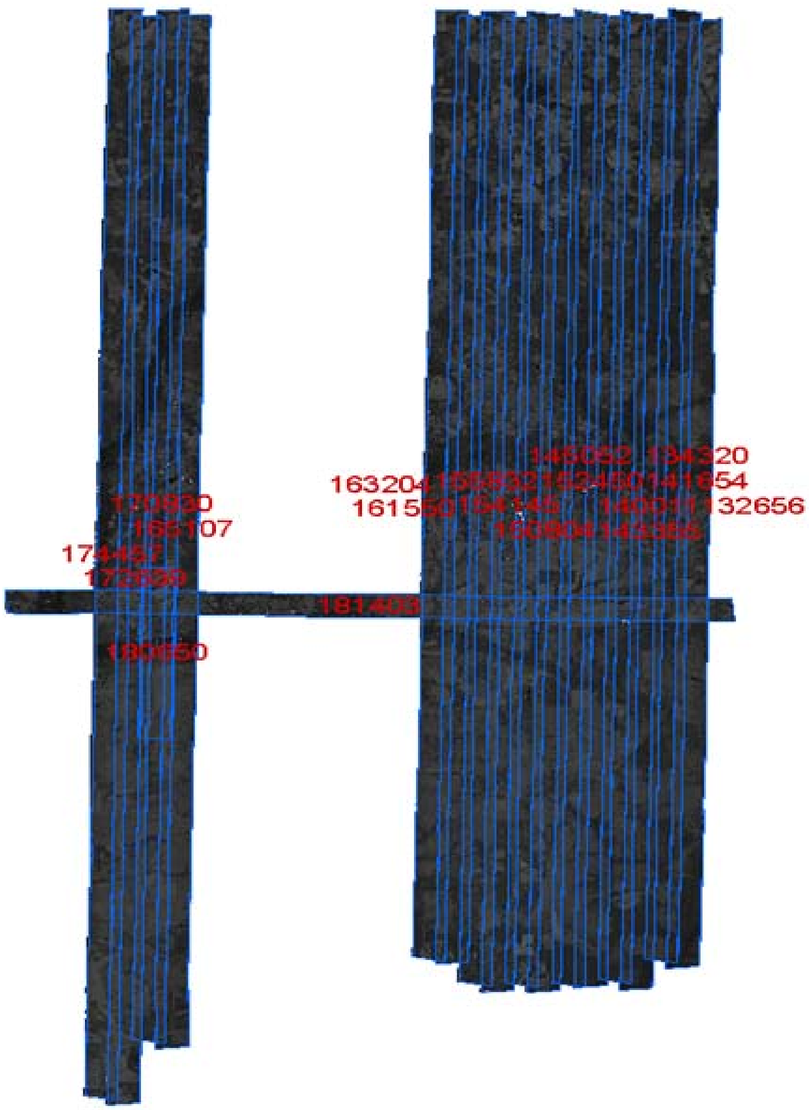
- **Verification of coverage**

Once the calibration site data was processed and reported for a particular mission, it was archived until full lidar processing production began for the project area. Because the lidar processing to produce the deliverables may occur after the aircrews have demobilized, it was critical that before final archiving of the mission data, it be run once through the process that reduces raw lidar data to XYZ points. This was the only way to ensure that all of the mission data is complete and that there were no gaps in the coverage between flight lines or around the project boundaries.

The coverage for each lidar mission was mapped to the project collection areas (project boundaries) as the last step in verification of data usability. The following images show the results of the coverage checks for this project:

Lift 1

Lift 1 was collected on Feb. 10, 2008. The LIDAR data was reviewed by Fugro EarthData for coverage and gross anomalies.

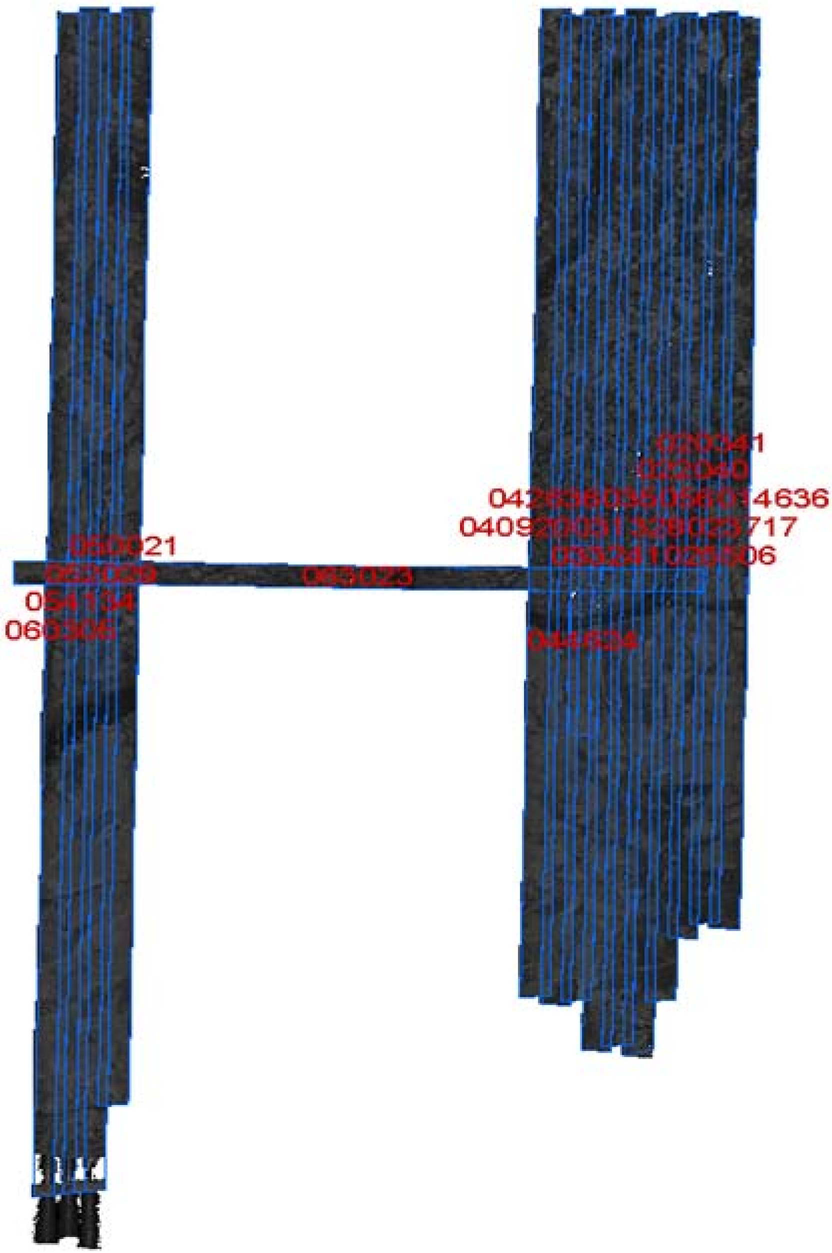


Lift 2

Lift 2 was collected on Feb. 10, 2008. The LIDAR data was reviewed by Fugro EarthData for coverage and gross anomalies.

Lift 3

Lift 3 was collected on Feb. 10, 2008. The LIDAR data was reviewed by Fugro EarthData for coverage and gross anomalies.



2.3 LIDAR data processing

The data processing involved 8 key steps in the flow of production for generating the final deliverables. These steps were:

- Pre-processing (boresight/calibration of data)
- Classification of first-pulse
- Classification of last-pulse
- Automated filtering (post processing)
- Manual filtering (post-processing)
- Data transformation

Quality control steps were incorporated throughout each step and are described in the following sections and illustrated in the process flowcharts located in **Section 3**.

2.3.1 Pre-processing and calibration

Pre-processing is the reduction of raw lidar, IMU, and GPS data into XYZ points. This is a hardware-specific, vendor-proprietary process. Data pre-processing algorithms use the sensor's complex set of electronic timing signals to compute ranges or distances to a reflective surface. The ranges must be combined with positional information from the GPS/IMU system to orient those ranges in 3D space and to produce XYZ points. As with any such electronic measuring system, systematic errors can be introduced from a variety of internal and external sources – instrument timing errors, effects of the atmosphere, initialization errors and so on. The correct procedure for diagnosing systematic errors is through the system calibration procedure described under **Section 2.2.5** of this document, within the System Calibration bullet.

At the conclusion of the system calibration, each flight mission has been archived with a unique set of calibration parameters using the most optimally located GPS base station for that mission. At the beginning of pre-processing, the entire flight mission is processed using this established calibration solution. All lidar pre-processing will utilize geographic curvilinear coordinates (latitude/longitude) and ellipsoid heights.

The technician performs a visual inspection of the data to verify that the flight lines overlap correctly and that there are no voids and that the data covers the project limits. The technician selects a series of areas in the data set to be inspected where adjacent flight lines overlay. These overlapping areas are merged and a routine is run to detect and color code differences in elevation values. The technician reviews the display on-screen and locates areas that contain systematic errors or distortions that are introduced by the lidar sensor.

At this point, the project cross flight lines, flown perpendicular to all mission flight lines, are used to detect and eliminate any lingering systematic errors in the preprocessed data. Ensuring consistency between overlapping and crossing flight lines constitutes quality control for the preprocessing phase. Systematic distortions highlighted in this process are removed and the data is re-checked. Correction and adjustment can involve application of angular deflection or compensation for systematic effects in the data sets.

Parameters used in pre-processing and the results of quality control checks were archived in the project database for future reference. The overlapping pre-processed data was merged and clipped into a seamless coverage for DTM production in the given area of interest.

2.3.2 Automated filtering

The algorithm for filtering the data points was developed by EarthData and was designed specifically to automate the filtering process. The algorithm has the ability to process large amounts of elevation point data in batch mode. Conceptually, the goal of automated processing is to remove as many artifacts as possible automatically, thereby reducing the amount of manual editing that is required to produce a lidar derived bare earth surface.

2.3.2.1 The automated process

Automated lidar filtering depends on mathematical filters to evaluate the lidar return data, removing points that are most likely to be non-bare earth points. Parameters were set in the software to control the size of the filter neighborhood and the aggressiveness with which it removed points that appeared to be mathematically above the bare earth surface. The filter settings were optimized for the particular terrain type and land cover apparent within a given flight line.

This initial processing run re-classified 95 – 98% of points falling on vegetation. The algorithm also re-classified the points falling on the edges of hard features including structures, elevated roadways and bridges.

Once the automated filtering was completed, the files were run through a visual inspection to ensure that the filtering was not too aggressive or not aggressive enough. In cases where the filtering was too aggressive and important terrain features had been filtered out, the data was either run through a different filter or was corrected during the manual filtering process.

2.3.3 Interactive filtering

Vegetation and artifacts remaining after automatic data post-processing were removed manually through interactive editing. The data was re-processed interactively to re-classify the remaining points falling on vegetation and points falling on other above ground structures.

Software visualization tools enabled the analyst to quickly scan through a deliverable sector, identify areas where additional points or artifacts needed to be removed and reclassified them in the database. The surface was then redrawn allowing the analyst to immediately see the result of the edit and make further corrections, including ‘undoing’ previous steps if necessary. Removed points were stored in the database where they may be retrieved at a later date, if required. The final result of interactive data post-processing was the bare earth digital elevation model (DTM) deliverable covering the project area.

2.4 Quality control

During the life of a project, attention to quality control is of the utmost importance to EarthData. EarthData implemented stringent quality measures designed to eliminate human error and identify systematic errors immediately upon their occurrence. Another important measure of quality control is the correction culture that EarthData works by. Correction culture is defined by procedures in each process, project management, and project requirements. From the level of the technicians to the Project Managers, procedures in each process dictated the action to be taken when errors were encountered. This included actions and decisions made to correct minor errors at the technician level, to larger errors that may impact project schedule or quality.

Each member of the team was expected to know and understand the specifications of the project, schedule, and quality steps. Kick-off meetings were held during which every team member assigned to the project was involved in discussing the scope of work for the project and the scheduling requirements. Progress on projects was monitored in a formal manner during weekly production meetings, and informally during the course of the week by constant monitoring by the project mangers. Detailed quality control steps in the processing follow in **Section 2.4.1.**

2.4.1 Processing quality control

2.4.1.1 Data evaluation

In the data evaluation step, a project or block of strips was examined for collection errors (excessive noise), preprocessing errors (gaps, slivers, missing data and steps) and AVR (Automated Vegetation Removal) errors (misclassified banks) and any other anomalies that were unique to the dataset. During the data evaluation step, the general terrain (flat, hilly, steep, swampy) and land cover (forested, agricultural, urban) was also assessed. This allowed the technicians to set up classification parameters during the manual filtering that closely match the terrain type. In order to ensure that the manual filtering process was effective and that no rework occured, the output from the automated processing was checked thoroughly, utilizing a visual check of the data.

2.2.1.1 Manual filtering – Hillshade checks

Hillshade images simulate the appearance of terrain surface, combining shading and coloration to indicate the elevation, slope and aspect (direction of slope) of the terrain in an artificial view of the landscape. Creating a hill shade image from points that have been classified as bare earth provides a view of the data that is useful in detecting errors in the bare earth product. Hill shades are especially useful in detecting points that would actually have been returns from vegetation that protrude above the surface of the surrounding terrain. Hill shades were used both during the manual filtering process, and by the technician at the end of filtering a strip for a personal QC check. Each strip was then submitted for a peer review. Hillshades were generated using ESRI ArcView software.

2.2.1.2 Peer Review

Because there are so many steps involved in the filtering process and due to the subjective nature of the task, the peer review offers the opportunity for yet another review of not only the data, but also of the editors' skills and editing abilities. Thus, the peer review becomes part of a process that promotes conformity among the filtering technicians and in the final product and ensures that the editing process produces a dataset that is edited completely and correctly. Every tile of data was subjected to review by peers during the QC process.

2.2.1.3 QC and tile / sheet edge matching

Another step of the QC process was for the final product to be consistent in quality across the breadth of the project.

Each group or number of strips in a project was assigned to a lead technician who was responsible for the quality of the block. The lead technician spent time on the front end exploring the strips in the block and making recommendations to the manual filtering technicians based on the content (terrain types). Once strips in the block completed the peer review process, they were checked over by the lead technician and were either approved or sent back to the editors for further edits. Once all strips in a given block were QC'ed, The lead technician then edge matched all the strips to ensure that there was conformity across the block between strips and between completed, adjoining blocks of strips.

2.2.1.4 Final delivery Quality Control

The Project Manager for the project was responsible for conducting a final overview QC of all deliverables leaving the department. A review of the lead technician's QC, file management procedures, and delivery format and coverage were all checked a final time before a deliverable was sent out. Reporting of deliveries and submitting any QC reports was the direct responsibility of the Project Manager.

2.2.1.5 Generation of ESRI Lidar Grid

The team used COTS for the production of lidar-derived grids in ESRI grid format. Once the bare-earth tiles for the entire project area were QC'ed, they were imported into Terrascan to produce the initial grid. This process was executed in batch.

Once the initial, 2 meter grid output from Terrascan, the technician checked the tiles to ensure that the grid spacing met specifications and to check for coverage. Once the data was checked, the tiles were then imported into ESRI AcrMap and converted into an ESRI-compatible format.

2.2.2 Reference Systems and Transformations

On completion of the quality control checks, all acceptable data was transformed into the final coordinate system: *North American Datum of 1983 (NAD83) and the Geodetic Reference System of 1980 (GRS80).* Horizontal units were in UTM, zone 16 north, meters. Vertical units were in orthometric NAVD88 feet using the latest GEOID model (GEOID03)

2.3 Accuracy Statement

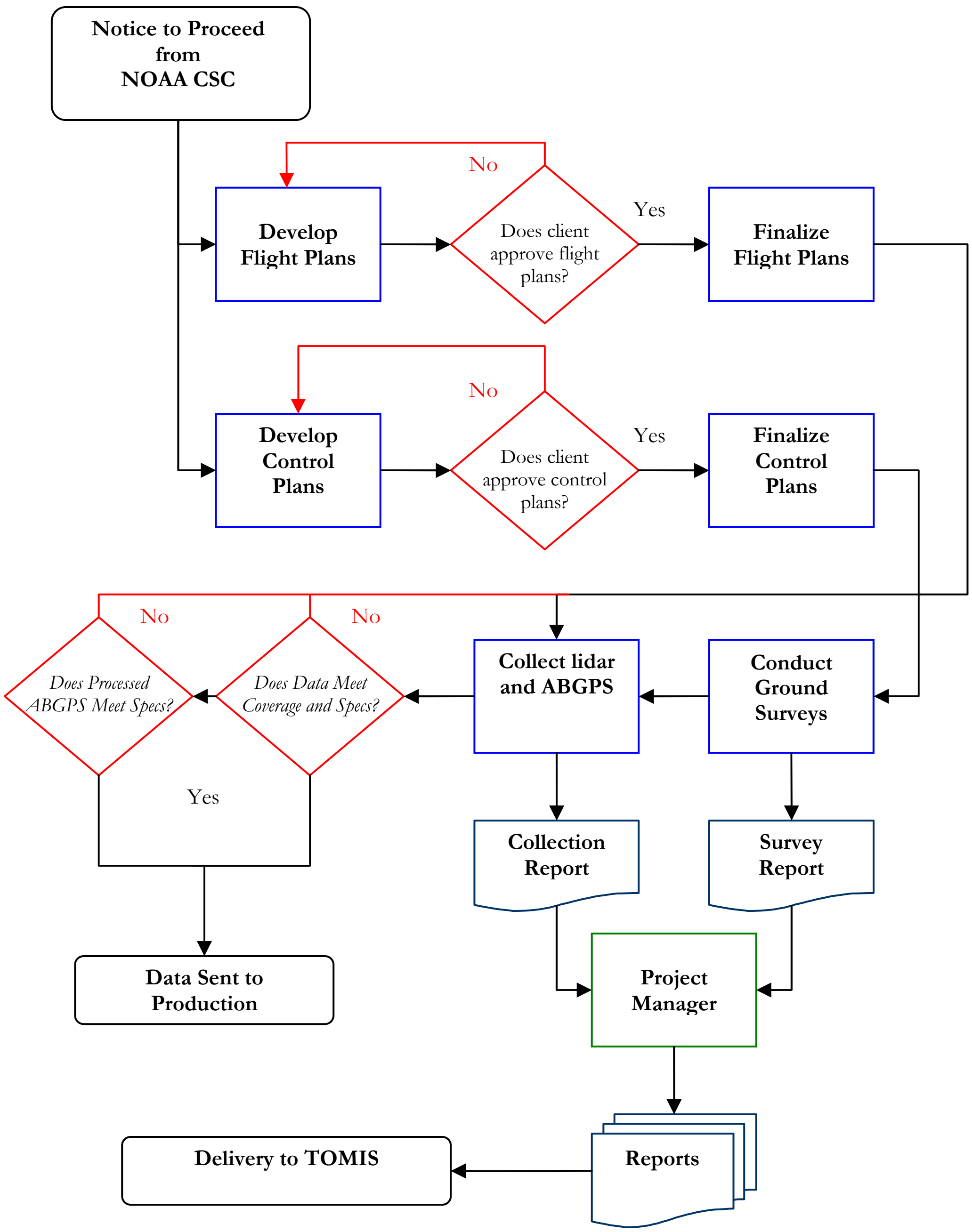
The elevation data meets or exceeds the following accuracy specification:

- When compared to GPS survey grade points in generally flat non-vegetated areas, at least 95% of the positions have an error less than or equal to 29.4 cm (equivalent to root mean square error of 15 cm if errors were normally distributed). Horizontal accuracy is 1 meter RMSE or better. Additionally, the Consolidated Vertical Accuracy (computed using NDEP and ASPRS methodology) meets FEMA guidelines (36.3 cm) for the generation of 2 foot contours.

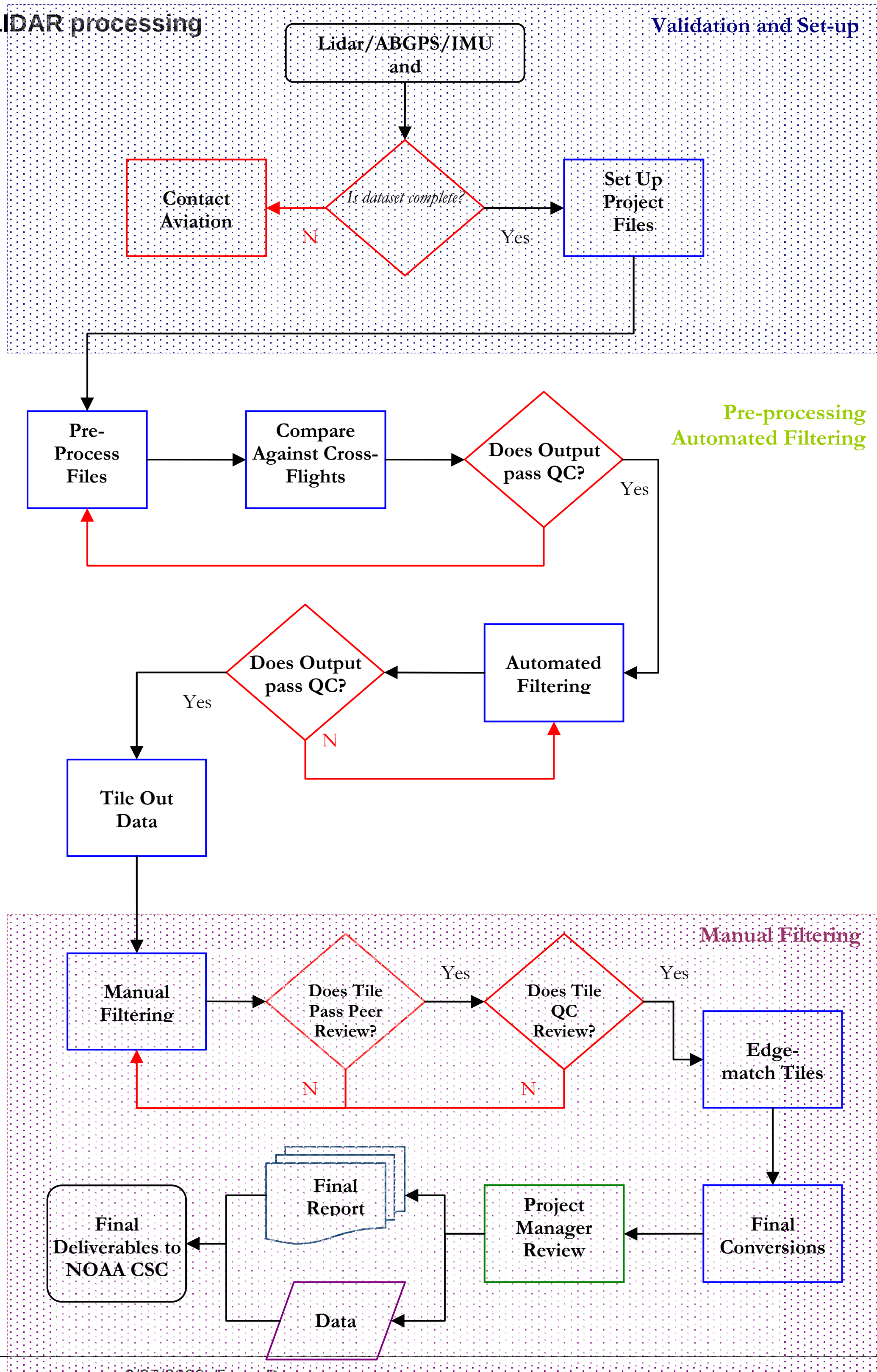
3 Process flowcharts

The following flow charts outline the lidar process flow used for this project.

Data acquisition



3.2.1 LIDAR processing



Appendix C

Ground Control Point Data and Calculations

pt_id	land cover	longitude	latitude	gcp_z	lidar_z	lidar-gcp	abs lidar-gcp
P296A	bare earth	-86.52867923	30.85248625	55.914	55.954256	0.040256	0.040256
P296_1	bare earth	-86.52846222	30.85255712	55.94	56.001898	0.061898	0.061898
P296_2	urban	-86.52848271	30.85230827	56.281	56.334548	0.053548	0.053548
P296_3	grass/weeds	-86.5281112	30.8523714	56.13	56.289253	0.159253	0.159253
P296_4	scrub/shrub	-86.52806299	30.85204663	56.121	56.221529	0.100529	0.100529
P296_5	forest	-86.52805175	30.85197043	56.246	56.290403	0.044403	0.044403
P296_6	bare earth	-86.52791279	30.85220631	56.49	56.543796	0.053796	0.053796
P296_7	urban	-86.52802217	30.85228986	56.534	56.589879	0.055879	0.055879
P049A	bare earth	-86.48284219	30.92439609	57.93	57.951473	0.021473	0.021473
P049_1	urban	-86.48291891	30.92428557	58.169	58.126975	-0.042025	0.042025
P049_2	forest	-86.48311968	30.9244641	57.806	57.724657	-0.081343	0.081343
P049_3	forest	-86.48309941	30.92450039	57.723	57.775567	0.052567	0.052567
P049_4	bare earth	-86.48271901	30.92452548	57.879	57.866175	-0.012825	0.012825
P049_5	urban	-86.4826046	30.92444272	58.226	58.192025	-0.033975	0.033975
P049_6	grass/weeds	-86.48264509	30.92417208	57.789	57.800075	0.011075	0.011075
P057_2	urban	-86.5932739	30.71185013	15.134	15.04788	-0.08612	0.08612
P057_3	bare earth	-86.59342507	30.71194478	14.749	14.671941	-0.077059	0.077059
P057_4	grass/weeds	-86.59333928	30.7122315	18.472	18.353253	-0.118747	0.118747
P057_5	scrub/shrub	-86.59336699	30.71238638	19.508	19.417604	-0.090396	0.090396
P057_6	forest	-86.59362826	30.71233233	18.317	18.26032	-0.05668	0.05668
P040A	bare earth	-86.68179903	30.7220261	31.296	31.30573	0.00973	0.00973
P040_1	bare earth	-86.68179862	30.72202604	31.294	31.305977	0.011977	0.011977
P040_2	scrub/shrub	-86.68207099	30.72169234	31.529	31.59377	0.06477	0.06477
P040_3	grass/weeds	-86.68223389	30.72167259	31.664	31.804306	0.140306	0.140306
P040_4	bare earth	-86.68236632	30.72190113	31.276	31.33959	0.06359	0.06359
P040_5	urban	-86.68143569	30.72193557	31.982	31.997262	0.015262	0.015262
P040_6	forest	-86.68198141	30.72178901	31.323	31.459249	0.136249	0.136249
P040_7	urban	-86.68204341	30.72198322	32.139	32.143752	0.004752	0.004752
E168A	bare earth	-86.79227073	30.69929341	26.333	26.29643	-0.03657	0.03657
E168_1	bare earth	-86.79227093	30.69929315	26.327	26.295895	-0.031105	0.031105
E168_2	bare earth	-86.79190854	30.69923669	26.614	26.58787	-0.02613	0.02613
E168_3	urban	-86.7918425	30.69912173	27.171	27.119939	-0.051061	0.051061
E168_4	bare earth	-86.79235664	30.69874212	26.119	26.071574	-0.047426	0.047426
E168_5	forest	-86.79239304	30.69857565	26.094	26.025213	-0.068787	0.068787
E168_6	scrub/shrub	-86.79254335	30.69939861	26.189	26.197895	0.008895	0.008895
E168_7	forest	-86.79255303	30.69949044	26.192	26.192568	0.000568	0.000568
E168_8	grass/weeds	-86.79234148	30.69972167	26.144	26.130223	-0.013777	0.013777
E168_9	scrub/shrub	-86.79223396	30.69973541	26.212	26.17274	-0.03926	0.03926
U084A	bare earth	-86.68216395	30.79352482	46.951	46.942632	-0.008368	0.008368
U084_1	bare earth	-86.68216382	30.79352459	46.939	46.940991	0.001991	0.001991
U084_2	forest	-86.68221516	30.79364878	46.9	46.91217	0.01217	0.01217
U084_3	urban	-86.68209546	30.79370856	46.981	46.978525	-0.002475	0.002475
U084_4	grass/weeds	-86.68262405	30.79403655	46.564	46.591973	0.027973	0.027973
U084_5	scrub/shrub	-86.6828029	30.79402763	45.88	45.95184	0.07184	0.07184
U084_6	bare earth	-86.68227833	30.79400956	46.861	46.873452	0.012452	0.012452
SH01	bare earth	-86.65863246	30.97029085	32.691	32.762081	0.071081	0.071081
SH01A	bare earth	-86.65893295	30.9706068	33.341	33.384307	0.043307	0.043307
SH01_1	urban	-86.65865286	30.97048852	33.593	33.631168	0.038168	0.038168
SH01_2	grass/weeds	-86.65865485	30.97068863	33.151	33.219754	0.068754	0.068754
SH01_3	forest	-86.65853998	30.97078302	32.585	32.717744	0.132744	0.132744
SH01_4	urban	-86.65831342	30.97047832	33.043	33.006613	-0.036387	0.036387
SH01_5	bare earth	-86.65854371	30.97049932	33.313	33.35307	0.04007	0.04007
SH01_6	grass/weeds	-86.65896802	30.97071007	33.011	33.087061	0.076061	0.076061
SH01_7	scrub/shrub	-86.65882554	30.97090657	33.071	33.163883	0.092883	0.092883
SH01_8	bare earth	-86.65893307	30.97060696	33.327	33.383262	0.056262	0.056262
P047A	bare earth	-86.57147715	30.92540905	20.796	20.8456	0.0496	0.0496
P047_1	urban	-86.57178911	30.9252679	20.77	20.75084	-0.01916	0.01916
P047_2	grass/weeds	-86.57204058	30.92518124	20.912	21.072908	0.160908	0.160908
P047_3	bare earth	-86.57200146	30.92504787	20.989	20.987895	-0.001105	0.001105
P047_4	forest	-86.57156374	30.92517106	20.955	20.969637	0.014637	0.014637
P047_5	bare earth	-86.57148633	30.92547785	20.834	20.859311	0.025311	0.025311
P047_6	bare earth	-86.57147638	30.92540902	20.796	20.844783	0.048783	0.048783
P066_1	urban	-86.40553737	30.96393433	59.846	59.824766	-0.021234	0.021234
P066_2	forest	-86.40530799	30.96400434	60.388	60.337012	-0.050988	0.050988
P066_3	grass/weeds	-86.40517686	30.96412349	60.432	60.410335	-0.021665	0.021665
P066_4	scrub/shrub	-86.4053002	30.96386558	60.363	60.477942	0.114942	0.114942
P066_5	urban	-86.40548417	30.9637578	60.107	60.059383	-0.047617	0.047617
P066_6	bare earth	-86.40561719	30.9639123	59.688	59.665158	-0.022842	0.022842

LH01A	urban	-86.4600714	30.9663338	61.003	60.979174	-0.023826	0.023826
LH01_1	bare earth	-86.46015647	30.96620064	60.726	60.685	-0.041	0.041
LH01_2	urban	-86.46026082	30.96650258	61.361	61.329671	-0.031329	0.031329
LH01_3	urban	-86.46005299	30.96665803	61.325	61.284893	-0.040107	0.040107
LH01_4	forest	-86.46023181	30.96678689	61.532	61.464413	-0.067587	0.067587
LH01_5	grass/weeds	-86.46051219	30.96673956	62.273	62.327805	0.054805	0.054805
LH01_6	bare earth	-86.46011405	30.96657824	61.455	61.407237	-0.047763	0.047763
LH01_7	urban	-86.46007098	30.96633217	61.003	60.967207	-0.035793	0.035793
P031_2	bare earth	-86.79941867	30.41016493	-22.282	-22.280111	0.001889	0.001889
P031_3	forest	-86.7994749	30.41022849	-21.989	-21.982836	0.006164	0.006164
P031_4	urban	-86.79954998	30.41012205	-21.93	-21.876989	0.053011	0.053011
P031_5	scrub/shrub	-86.79916512	30.41007418	-22.767	-22.706673	0.060327	0.060327
P031_6	grass/weeds	-86.79921077	30.41001403	-22.742	-22.591957	0.150043	0.150043
P031_7	bare earth	-86.79919639	30.41017595	-22.652	-22.66182	-0.00982	0.00982
P031_8	scrub/shrub	-86.79912144	30.41025552	-22.602	-22.518026	0.083974	0.083974
P031_9	urban	-86.79936111	30.41014745	-22.273	-22.282584	-0.009584	0.009584
SPUR_1	grass/weeds	-86.43632033	30.75272145	42.511	42.404273	-0.106727	0.106727
SPUR_2	urban	-86.43606979	30.75259311	42.843	42.786221	-0.056779	0.056779
SPUR_3	scrub/shrub	-86.43593781	30.7526126	42.627	42.486001	-0.140999	0.140999
SPUR_4	bare earth	-86.43557916	30.75267332	42.476	42.354226	-0.121774	0.121774
SPUR_5	forest	-86.4349601	30.75260575	42.215	42.194091	-0.020909	0.020909
SPUR_6	bare earth	-86.4353391	30.75237706	42.264	42.150632	-0.113368	0.113368
SPUR_7	grass/weeds	-86.43533959	30.75222587	42.241	42.106374	-0.134626	0.134626
SPUR_8	urban	-86.43605754	30.75205335	42.183	42.118431	-0.064569	0.064569
P063_1	urban	-86.40666278	30.87967269	36.668	36.604964	-0.063036	0.063036
P063_2	grass/weeds	-86.40657324	30.87946392	35.917	35.823027	-0.093973	0.093973
P063_3	scrub/shrub	-86.4064592	30.87906029	35.786	35.738776	-0.047224	0.047224
P063_4	bare earth	-86.4065917	30.87871409	35.387	35.308396	-0.078604	0.078604
P063_5	urban	-86.40671955	30.87868824	35.4	35.316852	-0.083148	0.083148
P063_6	forest	-86.40655261	30.88056843	37.467	37.350684	-0.116316	0.116316
P063_7	bare earth	-86.40660226	30.8804421	37.313	37.259237	-0.053763	0.053763
EG2A	bare earth	-86.46111445	30.63581357	40.121	40.002409	-0.118591	0.118591
EG2_1	bare earth	-86.46134164	30.63575983	40.392	40.262545	-0.129455	0.129455
EG2_2	grass/weeds	-86.46153652	30.63591983	40.349	40.214371	-0.134629	0.134629
EG2_3	forest	-86.46168096	30.63594551	40.467	40.365406	-0.101594	0.101594
EG2_4	scrub/shrub	-86.46087813	30.63595822	39.458	39.35325	-0.10475	0.10475
EG2_5	bare earth	-86.46071507	30.63576713	39.683	39.539038	-0.143962	0.143962
EG2_6	grass/weeds	-86.4611088	30.63566125	40.351	40.227072	-0.123928	0.123928
EG2_7	forest	-86.4618178	30.63546068	40.527	40.505307	-0.021693	0.021693
EG3	bare earth	-86.38812523	30.66271276	35.951	35.849042	-0.101958	0.101958
EG3A	bare earth	-86.38785474	30.66309857	36.176	36.110411	-0.065589	0.065589
EG3_1	bare earth	-86.38796065	30.66265603	36.377	36.257879	-0.119121	0.119121
EG3_2	forest	-86.38778896	30.6626313	36.753	36.654089	-0.098911	0.098911
EG3_3	forest	-86.38780857	30.66281021	36.397	36.291663	-0.105337	0.105337
EG3_4	bare earth	-86.38776851	30.66331284	36.279	36.214551	-0.064449	0.064449
EG3_5	forest	-86.38774705	30.66344655	36.42	36.34327	-0.07673	0.07673
EG3_6	urban	-86.38779163	30.66302667	36.44	36.32478	-0.11522	0.11522
EG3_7	scrub/shrub	-86.38862527	30.66257571	35.862	35.931518	0.069518	0.069518
EG3_8	scrub/shrub	-86.38862064	30.66240621	36.02	36.042036	0.022036	0.022036
EG4	bare earth	-86.44386377	30.56086156	16.713	16.718414	0.005414	0.005414
EG4A	bare earth	-86.44405679	30.56069081	16.779	16.707845	-0.071155	0.071155
EG4_1	urban	-86.4439051	30.5607067	16.916	16.929218	0.013218	0.013218
EG4_2	bare earth	-86.44413199	30.5606568	16.711	16.739682	0.028682	0.028682
EG4_3	forest	-86.44448169	30.56067748	16.37	16.434258	0.064258	0.064258
EG4_5	grass/weeds	-86.44396552	30.56041229	16.452	16.507218	0.055218	0.055218
EG4_6	scrub/shrub	-86.44399201	30.56026012	16.571	16.657591	0.086591	0.086591
EG4_7	forest	-86.44355184	30.56078646	17.097	17.235424	0.138424	0.138424
EG4_8	scrub/shrub	-86.44370059	30.56101715	16.725	16.824464	0.099464	0.099464
EG5	grass/weeds	-86.58301704	30.61806931	42.857	42.773348	-0.083652	0.083652
EG5A	grass/weeds	-86.58295408	30.61835358	43.338	43.287117	-0.050883	0.050883
EG5_1	bare earth	-86.58283698	30.61797237	42.913	42.823917	-0.089083	0.089083
EG5_2	forest	-86.58281231	30.61785537	42.551	42.494383	-0.056617	0.056617
EG5_3	scrub/shrub	-86.58306125	30.61793447	42.683	42.592045	-0.090955	0.090955
EG5_4	grass/weeds	-86.58316082	30.61798751	42.616	42.492938	-0.123062	0.123062
EG5_5	urban	-86.58288286	30.61813034	43.102	43.008234	-0.093766	0.093766
EG5_6	forest	-86.5827039	30.61824379	43.575	43.518177	-0.056823	0.056823
EG5_7	urban	-86.58278833	30.61835681	43.477	43.383269	-0.093731	0.093731
EG5_8	bare earth	-86.58306218	30.61819731	43.052	42.965486	-0.086514	0.086514
EG5_9	grass/weeds	-86.58295434	30.61834971	43.38	43.301676	-0.078324	0.078324
EG1	bare earth	-86.59633682	30.52019183	5.616	5.632641	0.016641	0.016641

EG1_1	grass/weeds	-86.59657566	30.52001982	5.408	5.42708	0.01908	0.01908
EG1_2	forest	-86.59663184	30.52004588	5.54	5.56336	0.02336	0.02336
EG1_3	urban	-86.59645224	30.51999413	5.775	5.774471	-0.000529	0.000529
EG1_4	scrub/shrub	-86.59666895	30.52006686	5.61	5.553136	-0.056864	0.056864
EG1_5	forest	-86.59630676	30.51996468	5.262	5.345121	0.083121	0.083121
EG1_6	bare earth	-86.59639313	30.51995787	5.707	5.694965	-0.012035	0.012035
EG6A	grass/weeds	-86.70805588	30.6581863	-11.053	-11.087062	-0.034062	0.034062
EG6_1	grass/weeds	-86.70802075	30.65803501	-10.998	-10.986701	0.011299	0.011299
EG6_2	scrub/shrub	-86.70809001	30.65789328	-10.713	-10.727827	-0.014827	0.014827
EG6_3	bare earth	-86.70798006	30.65778024	-10.729	-10.731192	-0.002192	0.002192
EG6_4	bare earth	-86.70781993	30.65772834	-10.386	-10.408889	-0.022889	0.022889
EG6_5	forest	-86.70759653	30.65767754	-10.381	-10.352063	0.028937	0.028937
EG6_6	forest	-86.70749748	30.6575529	-10.133	-10.115972	0.017028	0.017028
EG6_7	scrub/shrub	-86.70773427	30.65785991	-10.721	-10.64373	0.07727	0.07727
EG6_8	grass/weeds	-86.70779735	30.65806868	-11.056	-11.049	0.007	0.007
EG6_9	grass/weeds	-86.7080557	30.65818627	-11.093	-11.086836	0.006164	0.006164
EG7A	grass/weeds	-86.57941724	30.68424682	-2.697	-2.611537	0.085463	0.085463
EG7_1	forest	-86.57984717	30.68411894	-1.149	-1.069524	0.079476	0.079476
EG7_2	scrub/shrub	-86.57992812	30.68437454	-1.759	-1.750853	0.008147	0.008147
EG7_3	grass/weeds	-86.57974893	30.68446024	-2.576	-2.511249	0.064751	0.064751
EG7_4	bare earth	-86.57977471	30.68459811	-2.765	-2.798	-0.033	0.033
EG7_5	grass/weeds	-86.57951101	30.68404755	-1.762	-1.725049	0.036951	0.036951
EG7_6	scrub/shrub	-86.57986302	30.68389972	-0.465	-0.498054	-0.033054	0.033054
EG7_7	bare earth	-86.5798002	30.68403883	-1.263	-1.296692	-0.033692	0.033692
EG7_8	scrub/shrub	-86.57955382	30.68430251	-2.548	-2.500979	0.047021	0.047021
EG7_9	grass/weeds	-86.57941711	30.68424686	-2.634	-2.612652	0.021348	0.021348

Appendix D

Ground Control Point Data Collection

MILESTONE

GPS and Survey Points; Okaloosa County, FL

IMSG/PSGS Project Lead
Keil Schmid

IMSG/PSGS Project Team
Brian Hadley
Rebecca Mataosky

April 14, 2008

I. M. Systems Group, Inc.

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Government Services

The data provided include GPS and survey points (Total Station) collected during March 2 to March 6, 2008 by Keil Schmid, Brian Hadley, and Rebecca Mataosky in Okaloosa County Florida. The data were collected for lidar QA purposes with a target accuracy of +/- 5 cm or better.

GPS data was collected with Thales ZMAX receivers collecting at 2 second intervals. The data were processed using both the National Geodetic Survey OPUS RS (Online Positioning User Service Rapid Static) service and with GNSS software. The OPUS RS solutions used up to nine CORS sites for each correction, but lacked the local control, GPS occupation of NGS benchmarks, used during collection. The GNSS solution used up to three CORS sites and included local NGS benchmark occupations. There was good agreement between the processed elevations using the two solutions when local benchmarks were used. This provided confidence in the OPUS RS solutions. In areas where local benchmark control was not available (Eglin Air Force Base) the difference between solutions was not as good. In these cases the OPUS RS solutions were used exclusively.

Total station points were collected from either known NGS benchmarks or from the OPUS RS locations. The backsights locations (not elevations) were collected using either the GNSS or OPUS RS solutions. Backsight GPS elevations were checked using the total station to assess the local accuracy of the survey. Accuracies were within the +/- 5 cm. All data was processed in NAD83, UTM zone 16N projection with elevations in heights above the GRS80 Ellipsoid.

The following data include:

1. QA/QC points and photo #’s
2. Final GPS Control Points

QA/QC points and photo #'s

Sample Point ID	Eastings (m)	Northings (m)	Ellipsoid Heights (m)	Land Cover	Picture ID	Picture Direction	Sample Date	Sample Method	Notes	County
EG1	538727.885	3376498.391	5.616	Bare Earth	730	Not to N	3/3/2008	GPS		Okaloosa
EG1A	538710.989	3376479.963	5.464	NA		Not to N	3/3/2008	GPS		Okaloosa
EG1_1	538705.038	3376479.248	5.408	Grass/Weeds	731	Not to N	3/3/2008	TS		Okaloosa
EG1_2	538699.638	3376482.116	5.54	Forest	732	Not to N	3/3/2008	TS		Okaloosa
EG1_3	538716.889	3376476.443	5.775	Urban	733	North	3/3/2008	TS		Okaloosa
EG1_4	538696.069	3376484.429	5.61	Scrub/Shrub	734	Not to N	3/3/2008	TS		Okaloosa
EG1_5	538730.859	3376473.229	5.262	Forest	735	North	3/3/2008	TS		Okaloosa
EG1_6	538722.575	3376472.445	5.707	Bare Earth	736	North	3/3/2008	TS		Okaloosa
EG1_7	538710.975	3376479.941	5.524	NA	737	North	3/3/2008	TS	Check of BS	Okaloosa
EG2	551620.622	3389354.279	40.431	NA	684	Not to N	3/3/2008	GPS	OPUS RS; Total Station	Okaloosa
EG2A	551640.121	3389365.819	40.121	Bare Earth	685	North	3/3/2008	GPS	OPUS RS; BS	Okaloosa
EG2_1	551618.378	3389359.759	40.392	Bare Earth	687	North	3/3/2008	TS		Okaloosa
EG2_2	551599.618	3389377.401	40.349	Grass/Weeds	688	North	3/3/2008	TS		Okaloosa
EG2_3	551585.763	3389380.18	40.467	Forest	689	North	3/3/2008	TS		Okaloosa
EG2_4	551662.691	3389381.957	39.458	Scrub/Shrub	690	North	3/3/2008	TS		Okaloosa
EG2_5	551678.418	3389360.856	39.683	Bare Earth	691	North	3/3/2008	TS		Okaloosa
EG2_6	551640.744	3389348.941	40.351	Grass/Weeds	692	North	3/3/2008	TS		Okaloosa
EG2_7	551572.907	3389326.388	40.527	Forest	693	Not to N	3/3/2008	TS		Okaloosa
EG3	558618.396	3392382.64	35.951	Bare Earth	694	North	3/3/2008	GPS	OPUS RS; Total Station	Okaloosa
EG3A	558644.077	3392425.537	36.176	Bare Earth	695	North	3/3/2008	GPS	OPUS RS; BS	Okaloosa
EG3_1	558634.198	3392376.439	36.377	Bare Earth	697	North	3/3/2008	TS		Okaloosa
EG3_2	558650.661	3392373.787	36.753	Forest	698	Not to N	3/3/2008	TS		Okaloosa
EG3_3	558648.674	3392393.604	36.397	Forest	700	North	3/3/2008	TS		Okaloosa
EG3_4	558652.209	3392449.328	36.279	Bare Earth	701	North	3/3/2008	TS		Okaloosa
EG3_5	558654.184	3392464.157	36.42	Forest	703	North	3/3/2008	TS		Okaloosa
EG3_6	558650.167	3392417.602	36.44	Urban	704	North	3/3/2008	TS		Okaloosa
EG3_7	558570.574	3392367.191	35.862	Scrub/Shrub	706	Not to N	3/3/2008	TS		Okaloosa
EG3_8	558571.119	3392348.409	36.02	Scrub/Shrub	707	Not to N	3/3/2008	TS		Okaloosa
EG4	553334.278	3381067.629	16.733	Bare Earth	708	North	3/3/2008	GPS	OPUS RS; Total Station	Okaloosa
EG4A	553315.86	3381048.615	16.779	Bare Earth	709	North	3/3/2008	GPS	OPUS RS; BS	Okaloosa
EG4_1	553330.399	3381050.447	16.936	Urban	710	North	3/3/2008	TS		Okaloosa
EG4_2	553308.667	3381044.81	16.731	Bare Earth	711	North	3/3/2008	TS		Okaloosa
EG4_3	553275.118	3381046.937	16.39	Forest	712	North	3/3/2008	TS		Okaloosa
EG4_4	553329.443	3381018.603	17.177	NA (BM)	713	North	3/3/2008	TS	Check of BS	Okaloosa
EG4_5	553324.765	3381017.792	16.472	Grass/Weeds	714	North	3/3/2008	TS		Okaloosa
EG4_6	553322.308	3381000.916	16.591	Scrub/Shrub	715	North	3/3/2008	TS		Okaloosa
EG4_7	553364.234	3381059.454	17.117	Forest	716	North	3/3/2008	TS		Okaloosa
EG4_8	553349.842	3381084.948	16.745	Scrub/Shrub	717	North	3/3/2008	TS		Okaloosa

EG5	539965.662	3387349.74	42.857	Grass/Weeds	718	North	3/3/2008	GPS	OPUS RS; Total Station	Okaloosa
EG5A	539971.58	3387381.266	43.338	Grass/Weeds	719	North	3/3/2008	GPS	OPUS RS; BS	Okaloosa
EG5_1	539982.96	3387339.062	42.913	Bare Earth	721	North	3/3/2008	TS		Okaloosa
EG5_2	539985.373	3387326.104	42.551	Forest	722	Not to North	3/3/2008	TS		Okaloosa
EG5_3	539961.48	3387334.782	42.683	Scrub/Shrub	723	North	3/3/2008	TS		Okaloosa
EG5_4	539951.915	3387340.624	42.616	Grass/Weeds	724	North	3/3/2008	TS		Okaloosa
EG5_5	539978.498	3387356.551	43.102	Urban	725	North	3/3/2008	TS	White plastic	Okaloosa
EG5_6	539995.604	3387369.188	43.575	Forest	726	North	3/3/2008	TS	Redid, branch	Okaloosa
EG5_7	539987.465	3387381.683	43.477	Urban	727	North	3/3/2008	TS	White plastic	Okaloosa
EG5_8	539961.283	3387363.909	43.052	Bare Earth	728	North	3/3/2008	TS		Okaloosa
EG5_9	539971.557	3387380.837	43.38	Grass/Weeds	729	North	3/3/2008	TS	Check of BS	Okaloosa
EG6	527984.244	3391746.464	-11.066		738		3/4/2008	GPS	OPUS RS; Total Station	Okaloosa
EG6A	527969.73	3391757.728	-11.053	Grass/Weeds	739		3/4/2008	GPS	OPUS RS; BS	Okaloosa
EG6_1	527973.139	3391740.971	-10.998	Grass/Weeds	741	North	3/4/2008	TS		Okaloosa
EG6_2	527966.545	3391725.247	-10.713	Scrub/Shrub	742	North	3/4/2008	TS		Okaloosa
EG6_3	527977.111	3391712.747	-10.729	Bare Earth	743	North	3/4/2008	TS		Okaloosa
EG6_4	527992.467	3391707.036	-10.386	Bare Earth	744	North	3/4/2008	TS		Okaloosa
EG6_5	528013.885	3391701.462	-10.381	Forest	745	Not to North	3/4/2008	TS		Okaloosa
EG6_6	528023.411	3391687.674	-10.133	Forest	746	Not to North	3/4/2008	TS	Deeper forest	Okaloosa
EG6_7	528000.636	3391721.638	-10.721	Scrub/Shrub	747	North	3/4/2008	TS		Okaloosa
EG6_8	527994.533	3391744.758	-11.056	Grass/Weeds	748	North	3/4/2008	TS		Okaloosa
EG6_9	527969.747	3391757.725	-11.093	Grass/Weeds	749	Not to North	3/4/2008	TS	Check of BS	Okaloosa
EG7	540257.459	3394679.167	-1.996		750		3/4/2008	GPS	OPUS RS; Total Station	Okaloosa
EG7A	540283.242	3394684.855	-2.697	Grass/Weeds	751		3/4/2008	GPS	OPUS RS; BS	Okaloosa
EG7_1	540242.116	3394670.53	-1.212	Forest	753	Not to North	3/4/2008	TS	Corrected	Okaloosa
EG7_2	540234.256	3394698.826	-1.822	Scrub	754	Not to North	3/4/2008	TS	Corrected	Okaloosa
EG7_3	540251.384	3394708.388	-2.639	Grass/Weeds	755	North	3/4/2008	TS	Corrected	Okaloosa
EG7_4	540248.857	3394723.658	-2.828	Bare Earth	756	North	3/4/2008	TS	Corrected	Okaloosa
EG7_5	540274.343	3394662.738	-1.825	Grass/Weeds	757	North	3/4/2008	TS	Corrected	Okaloosa
EG7_6	540240.689	3394646.23	-0.528	Scrub/Shrub	758	North	3/4/2008	TS	Corrected	Okaloosa
EG7_7	540246.648	3394661.668	-1.326	Bare Earth	759	North	3/4/2008	TS	Corrected	Okaloosa
EG7_8	540270.137	3394690.978	-2.611	Scrub/Shrub	760	North	3/4/2008	TS	Corrected	Okaloosa
EG7_9	540283.254	3394684.86	-2.697	Grass/Weeds	761	North	3/4/2008	TS	Check of BS; Corrected	Okaloosa
P296A	545064.494	3413348.947	55.914	Bare Earth	763	North	3/4/2008	GPS		Okaloosa
P296_1	545085.21	3413356.889	55.94	Bare Earth	764	North	3/4/2008	TS		Okaloosa
P296_2	545083.368	3413329.302	56.281	Urban	765	North	3/4/2008	TS		Okaloosa
P296_3	545118.86	3413336.448	56.13	Grass/Weeds	766	North	3/4/2008	TS		Okaloosa
P296_4	545123.621	3413300.476	56.121	Scrub/Shrub	767	Not to North	3/4/2008	TS		Okaloosa
P296_5	545124.732	3413292.035	56.246	Forest	768	Not to North	3/4/2008	TS		Okaloosa
P296_6	545137.908	3413318.233	56.49	Bare Earth	769	Not to North	3/4/2008	TS	Brian had to reshoot	Okaloosa
P296_7	545127.41	3413327.448	56.534	Urban	770	North	3/4/2008	TS		Okaloosa

P049A	549410.246	3421337.769	57.93	Bare Earth	772	North	3/4/2008	GPS		Okaloosa
P049_1	549402.973	3421325.487	58.169	Urban	773	North	3/4/2008	TS		Okaloosa
P049_2	549383.699	3421345.183	57.806	Forest	774	North	3/4/2008	TS		Okaloosa
P049_3	549385.617	3421349.214	57.723	Forest	775	Not to North	3/4/2008	TS	Deeper forest	Okaloosa
P049_4	549421.949	3421352.164	57.879	Bare Earth	776	North	3/4/2008	TS		Okaloosa
P049_5	549432.922	3421343.042	58.226	Urban	777	North	3/4/2008	TS		Okaloosa
P049_6	549429.193	3421313.03	57.789	Grass/Weeds	778	North	3/4/2008	TS		Okaloosa
P057_1	538983.654	3397752.419	15.564	NA	779	North	3/5/2008	TS	Check of BS: P057	Okaloosa
P057_2	538944.959	3397739	15.134	Urban	780	North	3/5/2008	TS		Okaloosa
P057_3	538930.446	3397749.437	14.749	Bare Earth	781	North	3/5/2008	TS		Okaloosa
P057_4	538938.546	3397781.241	18.472	Grass/Weeds	782	North	3/5/2008	TS		Okaloosa
P057_5	538935.83	3397798.396	19.508	Scrub/Shrub	783	North	3/5/2008	TS		Okaloosa
P057_6	538910.835	3397792.315	18.317	Forest	784	North	3/5/2008	TS		Okaloosa
P040A	530465.228	3398839.325	31.296	Bare Earth		North	3/2/2008	GPS	GNSS	Okaloosa
P040_1	530465.267	3398839.318	31.294	Bare Earth			3/5/2008	TS	Check to BS	Okaloosa
P040_2	530439.294	3398802.263	31.529	Scrub/Shrub	786	Not to North	3/5/2008	TS		Okaloosa
P040_3	530423.704	3398800.031	31.664	Grass/Weeds	787	Not to North	3/5/2008	TS		Okaloosa
P040_4	530410.953	3398825.322	31.276	Bare Earth	788	North	3/5/2008	TS		Okaloosa
P040_5	530500.043	3398829.391	31.982	Urban	789	North	3/5/2008	TS		Okaloosa
P040_6	530447.841	3398813.001	31.323	Forest	790	North	3/5/2008	TS		Okaloosa
P040_7	530441.844	3398834.506	32.139	Urban	791	North	3/5/2008	TS		Okaloosa
E168A	519893.072	3396295.277	26.333	Bare Earth		North	3/2/2008	GPS	GNSS	Okaloosa
E168_1	519893.053	3396295.248	26.327	Bare Earth		North	3/5/2008	TS	Check of BS	Okaloosa
E168_2	519927.769	3396289.055	26.614	Bare Earth	792	North	3/5/2008	TS		Okaloosa
E168_3	519934.117	3396276.327	27.171	Urban	793	North	3/5/2008	TS		Okaloosa
E168_4	519884.958	3396234.167	26.119	Bare Earth	794	North	3/5/2008	TS		Okaloosa
E168_5	519881.506	3396215.713	26.094	Forest	795	Not to North	3/5/2008	TS		Okaloosa
E168_6	519866.943	3396306.887	26.189	Scrub/Shrub	796	Not to North	3/5/2008	TS		Okaloosa
E168_7	519865.997	3396317.062	26.192	Forest	797	Not to North	3/5/2008	TS		Okaloosa
E168_8	519886.209	3396342.724	26.144	Grass/Weeds	798	North	3/5/2008	TS		Okaloosa
E168_9	519896.503	3396344.266	26.212	Scrub/Shrub	799	North	3/5/2008	TS		Okaloosa
U084A	530407.81	3406762.841	46.951	Bare Earth		North	3/2/2008	GPS	OPUS RS	Okaloosa
U084_1	530407.823	3406762.816	46.939	Bare Earth		North	3/5/2008	TS	Check of BS	Okaloosa
U084_2	530402.872	3406776.565	46.9	Forest	800	North	3/5/2008	TS		Okaloosa
U084_3	530414.305	3406783.223	46.981	Urban	801	North	3/5/2008	TS		Okaloosa
U084_4	530363.631	3406819.428	46.564	Grass/Weeds	802	North	3/5/2008	TS		Okaloosa
U084_5	530346.523	3406818.391	45.88	Scrub/Shrub	803	North	3/5/2008	TS		Okaloosa
U084_6	530396.715	3406816.531	46.861	Bare Earth	804	North	3/5/2008	TS		Okaloosa

SH01	532599.205	3426359.395	32.691	Bare Earth	806	North	3/5/2008	GPS	OPUS RS Total Station	Okaloosa
SH01A	532570.402	3426394.323	33.341	Bare Earth	807	North	3/5/2008	GPS	OPUS RS (incrased time)	Okaloosa
SH01_1	532597.189	3426381.296	33.593	Urban	808	Not to North	3/5/2008	TS		Okaloosa
SH01_2	532596.931	3426403.473	33.151	Grass/Weeds	809	Not to North	3/5/2008	TS		Okaloosa
SH01_3	532607.869	3426413.967	32.585	Forest	810	Not to North	3/5/2008	TS		Okaloosa
SH01_4	532629.608	3426380.265	33.043	Urban	811	North	3/5/2008	TS		Okaloosa
SH01_5	532607.609	3426382.525	33.313	Bare Earth	812	North	3/5/2008	TS		Okaloosa
SH01_6	532567.018	3426405.757	33.011	Grass/Weeds	813	North	3/5/2008	TS		Okaloosa
SH01_7	532580.557	3426427.576	33.071	Scrub/Shrub	814	North	3/5/2008	TS		Okaloosa
SH01_8	532570.39	3426394.34	33.327	Bare Earth	815	North	3/5/2008	TS	Check of BS	Okaloosa
P047A	540941.378	3421414.115	20.765	Bare Earth	816	North	3/5/2008	GPS	GNSS	Okaloosa
P047_1	540911.633	3421398.357	20.77	Urban	817	North	3/5/2008	TS		Okaloosa
P047_2	540887.644	3421388.661	20.912	Grass/Weeds	818	North	3/5/2008	TS	Perfect grass & weeds	Okaloosa
P047_3	540891.439	3421373.894	20.989	Bare Earth	819	North	3/5/2008	TS	Keil thinks see tracks	Okaloosa
P047_4	540933.207	3421387.707	20.955	Forest	820	North	3/5/2008	TS		Okaloosa
P047_5	540940.472	3421421.736	20.834	Bare Earth	821	North	3/5/2008	TS		Okaloosa
P047_6	540941.452	3421414.112	20.796	Bare Earth	822	North	3/5/2008	TS	Blackmon, Check of BS	Okaloosa
P066A	556768.6	3425761.24	59.862	Urban		North	3/5/2008	GPS	Culvet Top/Not For QA use	Okaloosa
P066_1	556772.836	3425756.495	59.846	Urban	824	North	3/5/2008	TS		Okaloosa
P066_2	556794.701	3425764.371	60.388	Forest	825	North	3/5/2008	TS		Okaloosa
P066_3	556807.154	3425777.643	60.432	Grass/Weeds	826	North	3/5/2008	TS		Okaloosa
P066_4	556795.527	3425748.997	60.363	Scrub/Shrub	827	Not to North	3/5/2008	TS		Okaloosa
P066_5	556778.021	3425736.958	60.107	Urban	828	North	3/5/2008	TS		Okaloosa
P066_6	556765.226	3425754.013	59.688	Bare Earth	829	North	3/5/2008	TS		Okaloosa
P066_7	556768.604	3425761.188	59.862	Urban	830	North	3/5/2008	TS	Check of BS, culvert	Okaloosa
LH01A	551563.318	3425995.894	61.003	Urban	831	North	3/5/2008	GPS	OPUS RS	Okaloosa
LH01_1	551555.265	3425981.096	60.726	Bare Earth	832	North	3/5/2008	TS	Corrected	Okaloosa
LH01_2	551545.137	3426014.511	61.361	Urban	833	North	3/5/2028	TS	Corrected	Okaloosa
LH01_3	551564.902	3426031.835	61.325	Urban	834	North	3/5/2008	TS	Corrected	Okaloosa
LH01_4	551547.755	3426046.034	61.532	Forest	835	North	3/5/2008	TS	Corrected	Okaloosa
LH01_5	551521.004	3426040.659	62.273	Grass/Weeds	836	North	3/5/2008	TS	Corrected	Okaloosa
LH01_6	551559.114	3426022.964	61.455	Bare Earth	837	North	3/5/2008	TS	Corrected	Okaloosa
LH01_7	551563.359	3425995.713	61.003	Urban	838	North	3/5/2008	TS	Check of BS; Drain	Okaloosa
P031_1	519253.113	3364208.681	-22.77	Control Only	840	Not to North	3/6/2008	TS	Check of BS	Okaloosa
P031_2	519265.574	3364253.441	-22.28	Bare Earth	841	Not to North	3/6/2008	TS		Okaloosa
P031_3	519260.161	3364260.475	-21.99	Forest	842	Not to North	3/6/2008	TS		Okaloosa
P031_4	519252.971	3364248.666	-21.93	Urban	843	Not to North	3/6/2008	TS		Okaloosa
P031_5	519289.945	3364243.427	-22.77	Scrub/Shrub	844	Not to North	3/6/2008	TS		Okaloosa
P031_6	519285.573	3364236.754	-22.74	Grass/Weeds	845	Not to North	3/6/2008	TS		Okaloosa
P031_7	519286.922	3364254.7	-22.65	Bare Earth	846	Not to North	3/6/2008	TS		Okaloosa
P031_8	519294.105	3364263.53	-22.60	Scrub/Shrub	847	Not to North	3/6/2008	TS		Okaloosa
P031_9	519271.106	3364251.513	-22.27	Urban	848	Not to North	3/6/2008	TS		Okaloosa

SPUR_1	553951.053	3402333.488	42.51	Grass/Weeds	850	Not to North	3/6/2008	TS		Okaloosa
SPUR_2	553975.105	3402319.386	42.84	Urban	851	North	3/6/2008	TS		Okaloosa
SPUR_3	553987.726	3402321.609	42.63	Scrub/Shrub	852	North	3/6/2008	TS		Okaloosa
SPUR_4	554022.02	3402328.511	42.48	Bare Earth	853	North	3/6/2008	TS		Okaloosa
SPUR_5	554081.31	3402321.322	42.22	Forest	854	North	3/6/2008	TS		Okaloosa
SPUR_6	554045.163	3402295.795	42.26	Bare Earth	855	North	3/6/2008	TS		Okaloosa
SPUR_7	554045.2	3402279.039	42.24	Grass/Weeds	856	North	3/6/2008	TS		Okaloosa
SPUR_8	553976.578	3402259.573	42.18	Urban	857	Not to North	3/6/2008	TS		Okaloosa
P063_1	556715.05	3416417.491	36.67	Urban	859	Not to North	3/6/2008	TS		Okaloosa
P063_2	556723.732	3416394.399	35.92	Grass/Weeds	860	North	3/6/2008	TS		Okaloosa
P063_3	556734.871	3416349.725	35.79	Scrub/Shrub	861	Not to North	3/6/2008	TS		Okaloosa
P063_4	556722.409	3416311.29	35.39	Bare Earth	862	North	3/6/2008	TS		Okaloosa
P063_5	556710.203	3416308.36	35.40	Urban	863	North	3/6/2008	TS		Okaloosa
P063_6	556725.053	3416516.818	37.47	Forest	864	North	3/6/2008	TS		Okaloosa
P064_7	556720.382	3416502.793	37.31	Bare Earth	865	North	3/6/2008	TS		Okaloosa
Walton County - Eglin Air Base										
WC01	568760.621	3375936.139	-4.44	Bare Earth	890	North	3/6/2008	GPS		Walton
WC01A	568779.842	3375919.07	-4.58	Bare Earth		North	3/6/2008	GPS		Walton
WC01_1	568769.204	3375954.984	-4.53	Bare Earth	891	North	3/6/2008	TS		Walton
WC01_2	568790.117	3375952.032	-4.53	Forest	892	Not to North	3/6/2008	TS		Walton
WC01_3	568781.73	3375938.401	-4.47	Bare Earth	893	North	3/6/2008	TS		Walton
WC01_4	568825.148	3375928.706	-4.42	Bare Earth	894	North	3/6/2008	TS		Walton
WC01_5	568905.107	3375912.569	-4.15	Forest	895	North	3/6/2008	TS		Walton
WC01_6	568937.125	3375920.357	-4.29	Bare Earth		North	3/6/2008	TS		Walton
WC01_7	568982.923	3375914.73	-4.09	Forest	896	North	3/6/2008	TS		Walton
WC01_8	568776.701	3375903.147	-4.46	Grass/Weeds	897	North	3/6/2008	TS	Not real good weeds	Walton
WC01_9	568777.068	3375886.849	-4.29	Forest	898	North	3/6/2008	TS		Walton
WC01_10	568755.266	3375893.153	-4.59	Bare Earth	899	North	3/6/2008	TS		Walton
WC01_11	568744.658	3375849.881	-4.65	Bare Earth	900	North	3/6/2008	TS		Walton
WC01_12	568735.858	3375806.222	-4.90	Bare Earth	901	North	3/6/2008	TS		Walton
WC01_13	568752.489	3375916.816	-4.59	Scrub/Shrub	902	North	3/6/2008	TS		Walton
WC01_14	568749.25	3375922.209	-4.64	Grass/Weeds	903	North	3/6/2008	TS	Not real good weeds	Walton
WC01_15	568735.617	3375936.448	-4.56	Bare Earth	904	North	3/6/2008	TS		Walton
WC01_16	568779.84	3375919.085	-4.54	Bare Earth	905	North	3/6/2008	TS	Check of BS	Walton

Final GPS Control Points

	GNSS				OPUS				
	Easting	Northing	Elev (ellip)		Easting	Northing	Elev (ellip)	ELEV (ave)	ELEV (diff)
168A	519893.072	3396295.247	26.333	168A				26.33	0.00
296A	545064.494	3413348.947	55.914	296A	545064.539	3413348.918	55.878	55.90	0.04
E168	519907.184	3396316.882	26.526	E168				26.53	0.00
EG01	538727.881	3376498.362	5.527	EG01	538727.8845	3376498.391	5.6155	5.57	0.09
EG02	551620.632	3389354.249	40.298	EG02	551620.622	3389354.279	40.431	40.36	0.13
EG03	558618.409	3392382.63	35.81	EG03	558618.396	3392382.64	35.951	35.88	0.14
EG04	553334.295	3381067.612	16.68	EG04	553334.278	3381067.629	16.713	16.70	0.03
EG05	539965.649	3387349.711	42.739	EG05	539965.662	3387349.74	42.857	42.80	0.12
EG06	527984.22	3391746.443	-11.142	EG06	527984.244	3391746.464	-11.066	-11.10	0.08
EG07	540257.445	3394679.146	-2.09	EG07	540257.459	3394679.167	-1.996	-2.04	0.09
EG1A	538710.991	3376479.937	5.412	EG1A	538710.9885	3376479.963	5.464	5.44	0.05
EG2A	551640.142	3389365.801	39.993	EG2A	551640.121	3389365.819	40.121	40.06	0.13
EG3A	558644.092	3392425.526	36.073	EG3A	558644.077	3392425.537	36.176	36.12	0.10
EG4A	553315.879	3381048.591	16.645	EG4A	553315.86	3381048.615	16.779	16.71	0.13
EG5A	539971.568	3387381.237	43.254	EG5A	539971.58	3387381.266	43.338	43.30	0.08
EG6A	527969.704	3391757.703	-11.17	EG6A	527969.73	3391757.728	-11.053	-11.11	0.12
EG7A	540283.229	3394684.842	-2.737	EG7A	540283.242	3394684.855	-2.697	-2.72	0.04
LH01	551588.365	3426005.386	60.947	LH01				60.95	0.00
LH1A	551563.318	3425995.894	61.003	LH1A	551563.39	3425995.719	61.003	61.00	0.00
P031	519281.028	3364241.372	-22.687	P031				-22.69	0.00
P040	530437.114	3398848.367	30.802	P040				30.80	0.00
P047	540899.348	3421415.924	20.56	P047	540899.398	3421415.89	20.551	20.56	0.01
P049	549434.412	3421320.797	57.574	P049				57.57	0.00
P057	538983.665	3397752.422	15.564	P057	538983.935	3397752.559	15.502	15.53	0.06
P066	556765.994	3425734.525	59.618	P066	556766.01	3425734.472	59.654	59.64	0.04
P296	545088.696	3413344.147	56.143	P296	545088.726	3413344.108	56.151	56.15	0.01
P31A	519253.126	3364208.696	-22.769	P31A	519253.131	3364208.717	-22.762	-22.77	0.01
P40A	530465.228	3398839.325	31.296	P40A				31.30	0.00
P47A	540941.378	3421414.115	20.765	P47A	540941.427	3421414.073	20.745	20.76	0.02
P49A	549410.246	3421337.769	57.93	P49A				57.93	0.00
P57B	538956.491	3397743.423	15.1	P57B	538956.76	3397743.563	15.026	15.06	0.07
P66A	556768.6	3425761.24	59.871	P66A	556768.617	3425761.194	59.902	59.89	0.03
SH01	532599.155	3426359.414	32.598	SH01	532599.205	3426359.395	32.691	32.64	0.09
SH1A	532570.36	3426394.335	33.233	SH1A	532570.402	3426394.323	33.341	33.29	0.11
U84_	530389.165	3406800.742	46.808	U84_				46.81	0.00
U84A	530407.775	3406762.858	46.954	U84A	530407.81	3406762.841	46.951	46.95	0.00
WC01	568760.64	3375936.119	-4.518	WC01	568760.621	3375936.139	-4.444	-4.48	0.07
WC1A	568779.859	3375919.063	-4.596	WC1A	568779.842	3375919.07	-4.579	-4.59	0.02

All values in meters; UTM Zone 16; GRS80 Ellipsoid