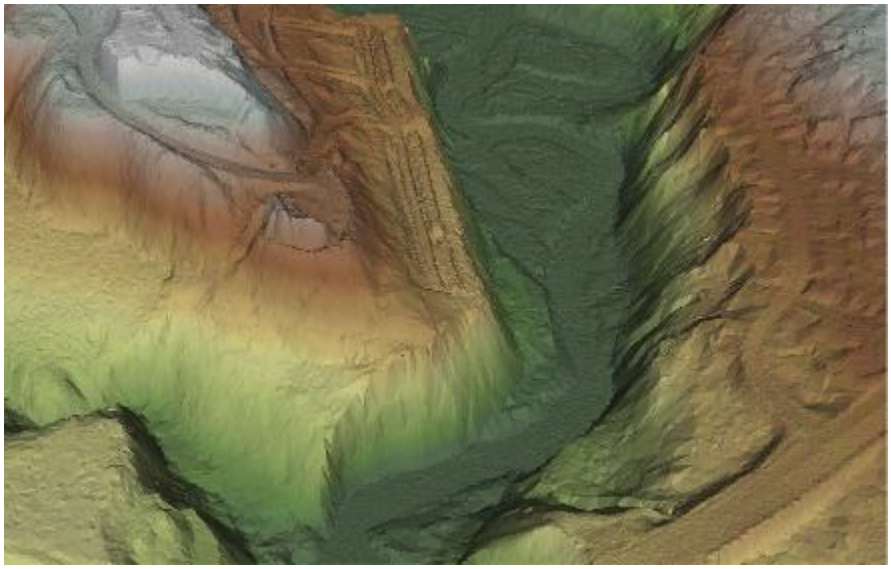
FEMA

Risk Mapping, Assessment, and Planning
(Risk MAP) Fiscal Year 2011

Elevation Data Quality Assurance Report for Anchorage, Alaska December 30, 2011



Submitted to:

Federal Emergency Management Agency, Region 10
Department of Homeland Security
Federal Regional Center
20700 44th Avenue W
Suite 400
Lynwood, WA 98036

Prepared by:

STARR
Strategic Alliance for Risk Reduction
Raleigh, NC

Anchorage Alaska Independent Quality Assurance Report
Table of Contents

TABLES

FIGURES

1.0 EXECUTIVE SUMMARY

Under FEMA task order HSFE10-11-J-00076 STARR has completed elevation data acquisition for Anchorage, Alaska. The goal of this project is to create a classified bare-earth digital terrain dataset with a vertical accuracy Root Mean Square Error of 18.5cm capable of supporting 2 foot contours.

2.0 OVERVIEW

STARR partner Greenhorne and O'Mara performed an independent quality assurance review on the All Return Point Cloud and Bare Earth datasets. This validates the quality of LiDAR data for use in Risk MAP projects that support the National Flood Insurance Program. This document summarizes the review process and results for Anchorage Alaska.

2.1 Project Requirements

The following table summarizes the project requirements for data acquisition based upon the agreed upon scope of work under FEMA task order HSFE10-11-J-00076.

Table 17 LiDAR Project Requirements

FEMA Region 10 Anchorage, Alaska LiDAR Acquisition	
Collection/Processing Area	79 square miles
Breaklines Required	No
Specification Level	Highest
Nominal Pulse Spacing	1 m
DEM Post Spacing	2 m DEM with 2 ft. contour accuracy
Vertical Accuracy, 95% Confidence Level FVA/CVA	24.5 cm/ 36.3 cm
Coordinate System	UTM Zone 6N
Horizontal Datum and Linear Units	NAD 83 Meters
Vertical Datum and Linear Units	NAVD 88 US Survey Foot

2.2 Guidelines and Specifications

All quality assurance activities completed for this project are in accordance with guidelines and specifications identified below.

Table 18 Guidance and QA Activities Matrix

	FEMA PM 61	USGS LiDAR Base Spec v13	ASPRS LAS v1.2	FEMA Appendix A	FEMA Appendix M
Vendor Submittal	X	X	X		X
Macro Review	X	X		X	
Micro Review	X	X	X	X	
Vertical Accuracy	X	X		X	X

Links to guidelines and specifications used in this report:

1. Federal Emergency Management Agency, Procedure Memorandum No. 61 - Standards for Lidar and Other High Quality Digital Topography, http://www.fema.gov/library/viewRecord.do?id=4345
2. U.S. Geological Survey National Geospatial Program, LiDAR Guidelines and Base Specification, Version 13-ILMF 2010, http://lidar.cr.usgs.gov/USGS-NGP%20Lidar%20Guidelines%20and%20Base%20Specification%20v13%28ILMF%29.pdf
3. American Society for Photogrammetry and Remote Sensing, LAS v1.2, http://www.asprs.org/a/society/committees/standards/asprs_las_format_v12.pdf
4. Federal Emergency Management Agency, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying [includes guidance on Light Detection and Ranging Systems (LIDAR)] http://www.fema.gov/library/file;jsessionid=1E39C93AF9CD18EE125B3DFCA5A874B8.Worker2Library?type=publishedFile&file=frm__gsaa.pdf&fileid=2daefcd0-df08-11e0-9bf5-001cc4568fb6
5. Federal Emergency Management Agency, Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix M: data Capture Standards http://www.fema.gov/library/file;jsessionid=1E39C93AF9CD18EE125B3DFCA5A874B8.Worker2Library?type=publishedFile&file=frm__gsam.pdf&fileid=cf85c9b0-df0f-11e0-9bf5-001cc4568fb6

3.0 LIDAR DATA REVIEW

Greenhorne & O'Mara, Inc. utilizes commercial software and proprietary scripts/applications to review LiDAR data. These tools, combined with guidelines and specifications, are incorporated into a standardized quality assurance workflow. The following table summarizes software and proprietary scripts/applications used in the review.

Table 19 Software used in quality assurance review

ESRI ArcGIS ArcInfo	LiDAR Data Processing
ESRI 3D Analyst Extension	Visual Analysis of LiDAR Data
ESRI Spatial Analyst Extension	Grid Analysis for LiDAR Data
LP360 ArcMap Extension	Visual Analysis of LiDAR Data
SIS Topo Analyst	Vertical Accuracy Quality Assurance
Proprietary Scripts/Applications	Working with LAS files

3.1 Quality Assurance Process

The following workflow was implemented for performing the independent quality assurance review for LiDAR data. Vendor submitted deliverables are reviewed and confirmed before the data reviews are imitated.

3.1.1 Macro Level Data Review

These review activities are completed for 100% of the All Returns Point Cloud and Bare Earth LiDAR data.

1. LiDAR Coverage and Completeness
2. LAS Header Review
3. Data Voids
4. Point Density

3.1.2 Micro Level Data Review

These review activities are completed for 5% of the All Returns Point Cloud and 10% of the Bare Earth LiDAR data.

5% Point Cloud

1. Scan lines
2. Overlap percentage
3. Visual review for outliers, blunders, anomalies, etc.
4. Tile edge matching

10% Bare Earth

1. Correct classification
2. Spikes, divots, and other anomalies
3. Artifacts/Structures
4. Channel geometry of streams and drainage features
5. Dense vegetation and open water voids
6. Tile edge matching

3.2 Vendor Submittal Verification

In order to begin a quality assurance review all relevant project information must be submitted for review. The following deliverables are necessary to complete the LiDAR review.

1. Descriptive Project Information
    a. Metadata and FEMA Compliance Form
    b. Pre-flight operations report
    c. Post-flight report
        i. GPS Base Station Shapefile
        ii. Project Coverage Shapefile
        iii. As-Flown Trajectories and Calibration line Shapefiles
        iv. Flight Logs
2. Survey Data
    a. Metadata and FEMA Compliance Form
    b. Ground Control
        i. Accuracy Report
        ii. Image Chips and Survey Pictures
        iii. Spatial Data (Shapefile, kml/kmz, and csv containing coordinates)
        iv. Final Report and Final Coordinates
    c. FVA/CVA
        i. Accuracy Report
        ii. Image Chips and Survey Pictures
        iii. Spatial Data (Shapefile, kml/kmz, and csv containing coordinates)
        iv. Final Report and Final Coordinates
        v. Vertical Accuracy Testing Results
3. Raw Point Cloud LiDAR
    a. All Returns Swath Data
        i. LAS v1.2 or v1.3 files
            1. No file greater than 2GB
        ii. Swath Index Shapefile
            1. Includes Calibration and Cross-Ties
4. Post Processed LiDAR
    a. Bare-Earth Data
        i. Tiled LAS v1.2 or v1.3 files
        ii. Tile Index Shapefile

The following tables confirm that the data provided for independent quality assurance is complete and meets the requirements documented in the task order scope of work.

Table 20 LiDAR Data Requirements

Coordinate System	**Projection Zone**
☒ UTM ☐ State Plane ☐ Geographic	UTM: 6N State Plane:
Horizontal Datum	**Horizontal Units**
☐ NAD 27 ☒ NAD 83 (default) ☐ Other	☐ US Survey Foot ☒ Meters ☐ Other
Vertical Datum	**Vertical Units**
☐ NAVD 29 ☒ NAVD 88 (default) ☐ Other	☒ US Survey Foot ☐ Meters ☐ Other
LiDAR Description	**Data Format**
☒ All Returns ☒ Bare Earth ☐ Other	☒ LAS v1.0-3 ☐ LAS v1.4 ☐ Ascii ☐ Other

Flood Risk and Terrain Slope Vertical Accuracy 95% Confidence Level FVA/CVA		
Specification Level	Vertical Accuracy	LiDAR Nominal Pulse Spacing
☒ Highest ☐ High ☐ Medium ☐ Low	☒ 24.5cm/36.3cm ☐ 49cm/72.6cm ☐ 98cm/145cm ☐ 147cm/218cm	☒ ≤ 1.0 meters ☐ ≤ 2.0 meters ☐ ≤ 3.5 meters ☐ ≤ 5.0 meters

Equivalent Contour Accuracy			
Contour Accuracy	Specification Level	RMSEz	NSSDA Accuracy 95% confidence level SVA (target) CVA (mandatory)
☒ 2 foot	☒ Highest	☒ 0.61 ft or 18.5 cm	☒ 1.19 ft or 36.3 cm
☐ 4 foot	☐ High	☐ 1.22 ft or 37.1 cm	☐ 2.38 ft or 72.6 cm
☐ 8 foot	☐ Medium	☐ 2.43 ft or 73.9 cm	☐ 4.77 ft or 1.45 m
☐ 12 foot	☐ Low	☐ 3.65 ft or 1.11m	☐ 7.15 ft or 2.18 m

Optional Deliverables	
DEMs	Breaklines
☐ ESRI Float GRID ☐ ESRI Integer GRID	☐ Hydrologically-Conditioned
☐ Ascii ☐ Floating Point (.flt)	☐ Hydrologically-Enforced
☐ ERDAS Imagine ☐ Other	☐ 3D Polyline ☐ 3D Polygon ☐ Other

Table 21 LiDAR Submittal Checklist

Project Name: Anchorage, Alaska		Date Delivered: 11/21/2011
Acquisition: Aerometric, Inc.		Survey: Compass Data, Inc.
Post Processing: Aerometric, Inc.		Breaklines: N/A | Topographic Products: N/A
Acquisition/Processing Point of Contact: Name: Jason Mann Mailing Address: 2014 Merrill Field Drive Anchorage, AK 99501 Phone Number: 907-272-4495 Email: jmann@aerometric.com		Survey Point of Contact: Name: Philipp Hummel Mailing Address:12353 E. Easter Ave, Suite 200, Centennial, CO 80112 Phone Number: 303-627-4058 Email: phummel@compassdatainc.com
Dataset	Included	Comments
Descriptive Project Information		
Metadata	Y	
Compliance Form	Y	
Pre-Flight Report	Y	
Post Flight Report	Y	
GPS Base Station Shapefile	Y	
Project Coverage Shapefile	Y	
As-Flown Trajectories	Y	
Final Flight Lines	Y	
Flight Logs	Y	
Survey Data		
Metadata	Y	
Compliance Form	Y	
Ground Control		
Accuracy Report	Y	
Image Chips	Y	
Survey Pictures	Y	
Shapefile and Final Coords	Y	
Final Report	Y	
FVA/CVA		
Accuracy Report	Y	
Image Chips	Y	
Survey Pictures	Y	
Shapefile and Final Coords	Y	
Final Report	Y	
Testing Results	Y	
Raw Point Cloud LiDAR		
LAS v1.2 or 1.3 Files < 2GB	Y	
Swath Index	Y	
Post Processed LiDAR		
LAS Files v1.2 or 1.3	Y	
LAS Tile Index	Y	

3.3 Data Acquisition and Ground Survey

Data acquisition and ground survey reports were provided and checked for compliance with guidelines and specifications.

Table 22 General acquisition requirements

Item Reviewed	Pass/Fail
Leaf-off conditions required	Pass
Area shall be free of snow and of flood condition with rivers remaining in their channels and near average heights	Pass
Extraneous environmental conditions such as rain, fog, or smoke shall be avoided	Pass

3.3.1 Pre-Flight Report

The pre-flight operations and planning report was submitted to Greenhorne & O'Mara, Inc. in July 2011 for review.

Table 23 Pre-Flight Operations Checklist

Project: Anchorage, Alaska	Vendor: Aerometric, Inc.	
Date Received: 7/11/11	Date Reviewed: 11/16/11	
Items Reviewed	Pass/Fail	Comments
Planned flight lines (sufficient coverage, spacing, length)	Pass	
Planned flight line Shapefile	Pass	
Planned GPS stations	Pass	
Planned Ground Control	Pass	
Calibration Plans	Pass	
Vendor Quality Procedures	Pass	
LiDAR sensor scan set – scan angle, sidelap, design pulse	Pass	
Aircraft utilizes ABGPS	Pass	
Sensor supports project design pulse density	Pass	
Type of aircraft – supports project design parameters	Pass	
Reflight procedure – tracking, documenting, processing	Pass	
Project design supports accuracy requirements of project	Pass	
Project design accounts for land cover and terrain types	Pass	
Notes:		

3.3.2 Ground Control Survey Report

The ground control survey report was submitted to Greenhorne & O'Mara, Inc. in November 2011 for review.

Table 24 Ground Survey Checklist

Project: Anchorage, Alaska	Vendor: Compass Data, Inc.	
Date Received: 11/18/11	Date Reviewed: 11/18/11	
Items Reviewed	Pass/Fail	Comments
Survey is referenced to NGS control monuments in the NSRS using appropriate horizontal and vertical control	Pass	
Base station locations are the "best" horizontal (second order or better) and vertical (third order or better) available and have a stability of "C" or better	Pass	
New control conforms to the Standards and Specifications for Geodetic Control Networks (1984), FGCC	Pass	
Primary control monuments established with GPS meet or exceed NOS NGS-58 "Guidelines for Establishing GPS-Derived Ellipsoidal Heights (Standards: 2 cm and 5 cm)" using the appropriate and latest geoid model and should be monumented to maintain stability and reoccupation if necessary	Pass	
Ground control stations meet local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically	Pass	
Supporting documentation submitted such as processing reports, minimally and constrained 3-D least squares adjustment, pictures, of the stations, etc.	Pass	
Notes:		

3.3.3 Post-Flight Report

The post-flight report was submitted to Greenhorne & O'Mara, Inc. in November 2011 for review.

Table 25 Post-Flight Report Checklist

Project: Anchorage, Alaska	Vendor: Aerometric, Inc.	
Date Received: 11/23/11	Date Reviewed:11/28/11	
Items Reviewed	Pass/Fail	Comments
GPS Base Station Information		
Name	Pass	
Latitude/Longitude Coordinates	Pass	
Heights	Pass	
Maximum PDOP	Pass	PDOP plots included
Location Map	Pass	
Correct Shapefile	Pass	
GPS/IMU		
GPS quality - Max horizontal variance (cm)	Pass	PDOP Plots
GPS quality - Max vertical variance (cm)	Pass	PDOP Plots
Notes on GPS Quality	Pass	Derived from Plots
GPS Separation Plot	Pass	
GPS Altitude Plot	Pass	
PDOP Plot	Pass	
GPS Distance From Base Stations Plot	Pass	
Coverage		
Verification of Area of Interest Coverage	Pass	
Correct Shapefile	Pass	
Flights		
Final Flight Lines	Pass	
Calibration Lines	Pass	
As-Flown Trajectories	Pass	
Correct Shapefiles	Pass	
Control		
Ground Control and Base Station Layout	Pass	
Correct Shapefile	Pass	
Data Verification and Quality Control		
Verification Process Documented	Pass	
Quality Control Procedures Documented	Pass	
Notes:		

3.3.4 Flight Logs

The flight logs were submitted to Greenhorne & O'Mara, Inc. in November 2011 for review as an appendix to the post-flight report.

Table 26 Flight Log Checklist

Project: Anchorage, Alaska	Vendor: Aerometric, Inc.	
Date Received: 11/23/11 and 11/29/11	Date Reviewed:11/29/11	
Items Reviewed	Pass/Fail	Comments
Job Number and Name	Pass	
Lift Number	Pass	
Block or Area of Interest Designator	Pass	
Date	Pass	
Aircraft Type	Pass	In the report
Aircraft Tail Number	Pass	
Pilot Name	Pass	
Operator Name	Pass	
Airport of Operations	Pass	Anchorage
GPS Base Station Names	Pass	
Flight Line Number	Pass	
Flight Line Direction	Pass	
Flight Line Start	Pass	
Flight Line Stop	Pass	
Flight Line Altitude	Pass	
Flight Line Scan Angle	Pass	
Flight Line Scan Rate	Pass	In the report
Flight Line Speed	Pass	In the report
Flight Line Conditions	Pass	In the report
Flight Line Comments	Pass	In the report
AGC Switch Settings	N/A	
Laser Pulse Rate Settings	Pass	
Mirror Rate Settings	Pass	
Field of View Settings	Pass	
Settings Comments	Pass	
Notes: Original Flight Log and Condensed Flight Log for each mission were provided.		

3.4 Macro Review Results

Activity 1: LiDAR Coverage and Completeness

The Anchorage, Alaska collection area is composed of 4 areas of interest. Each area was tested to insure both the Point Cloud and Bare Earth datasets meet project coverage requirements. All Project area AOIs meet project LiDAR coverage expectations.

Figure 14 Anchorage, Alaska LiDAR Areas of Interest

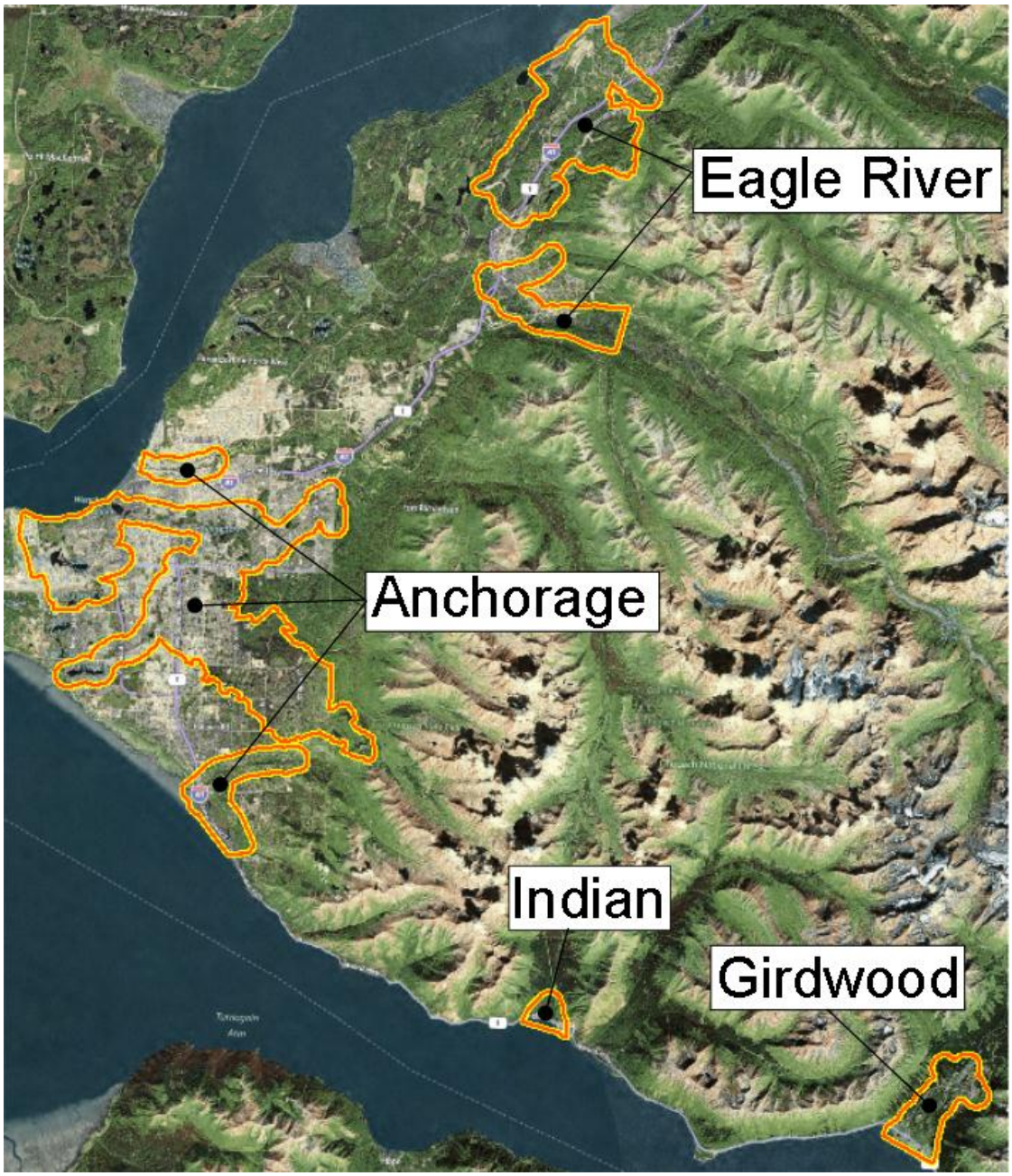


Figure 15 Area 1 Anchorage, Alaska

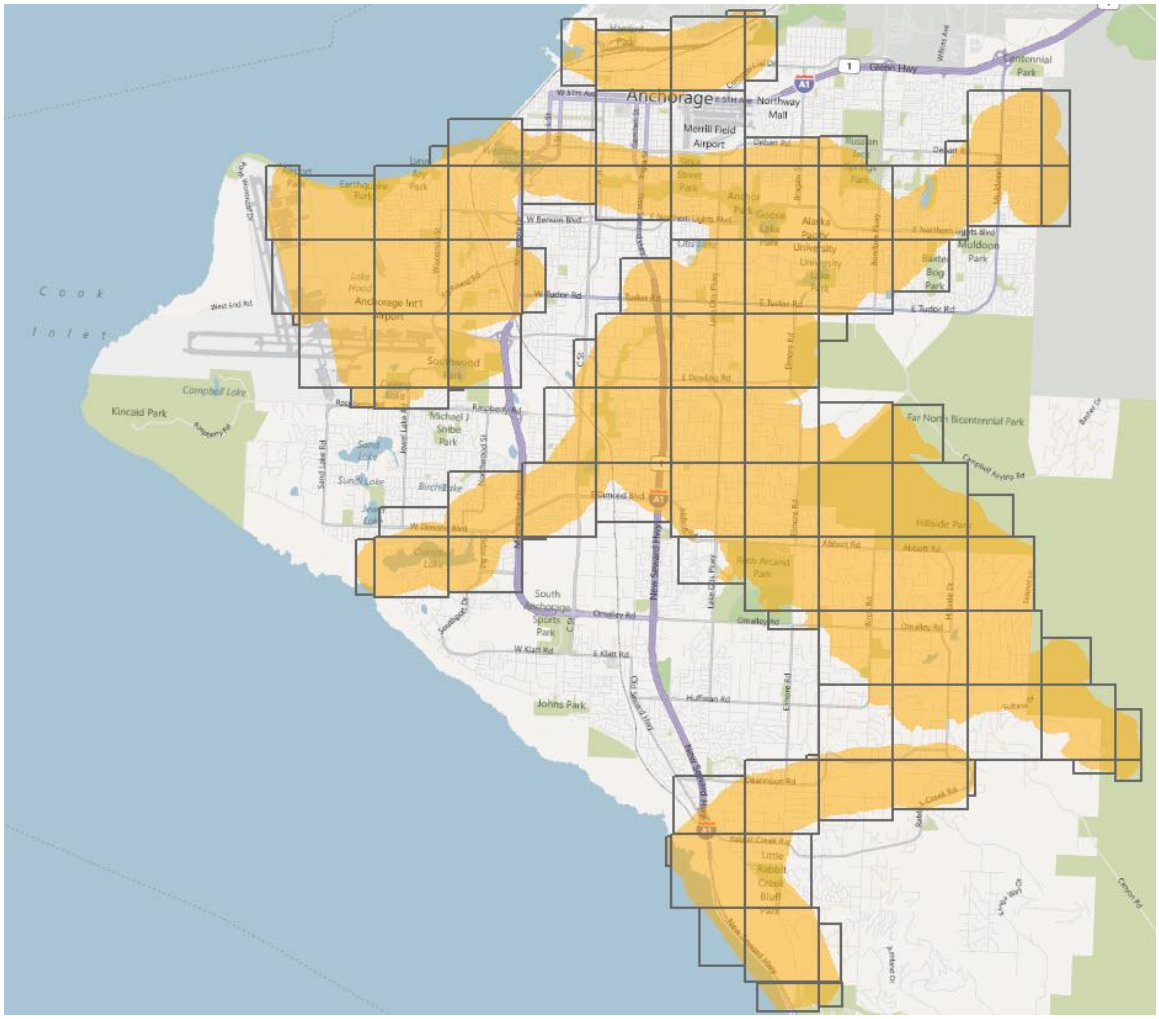


Figure 16 Area 2 Eagle River, Alaska

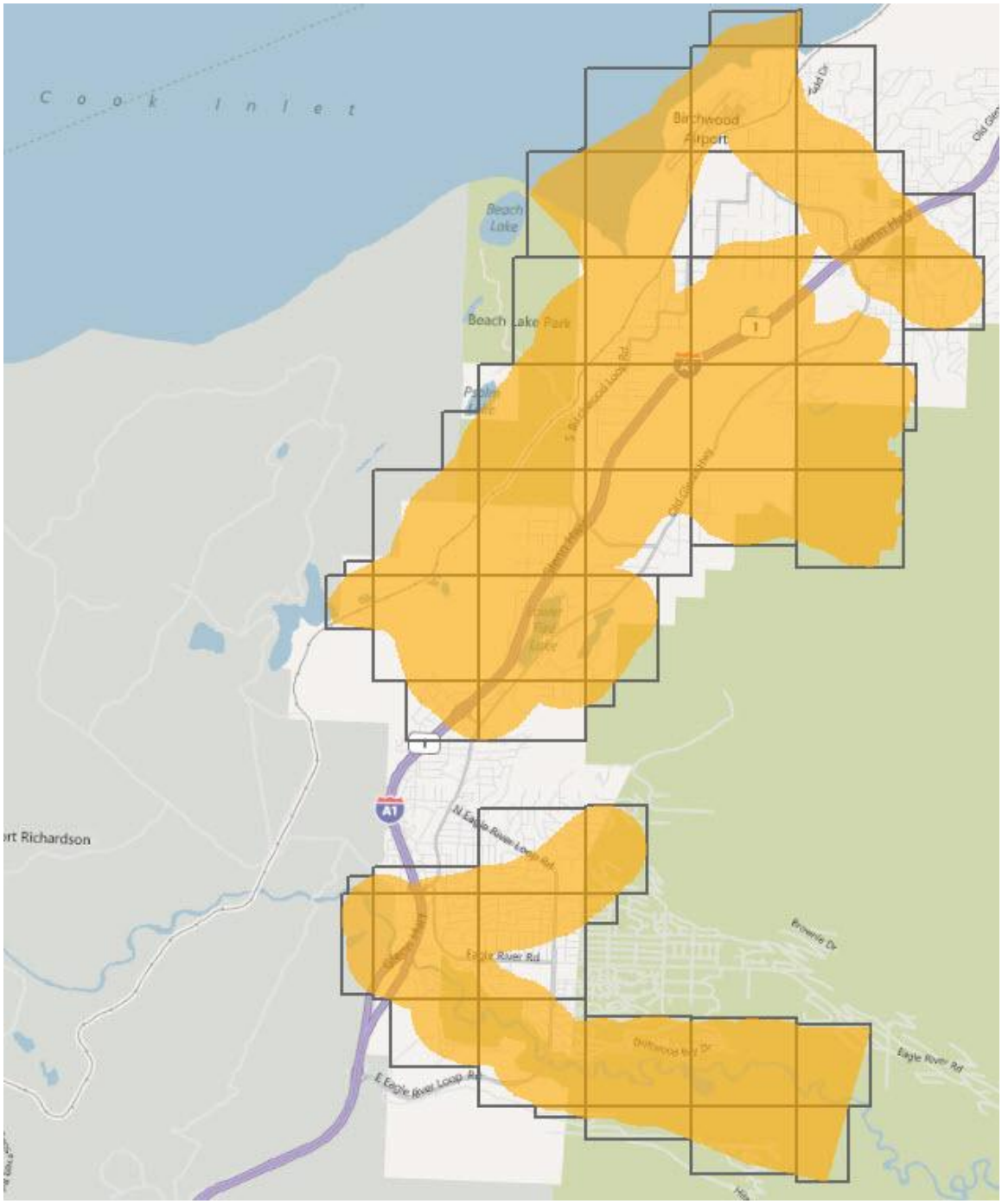


Figure 17 Area 3 Indian, Alaska

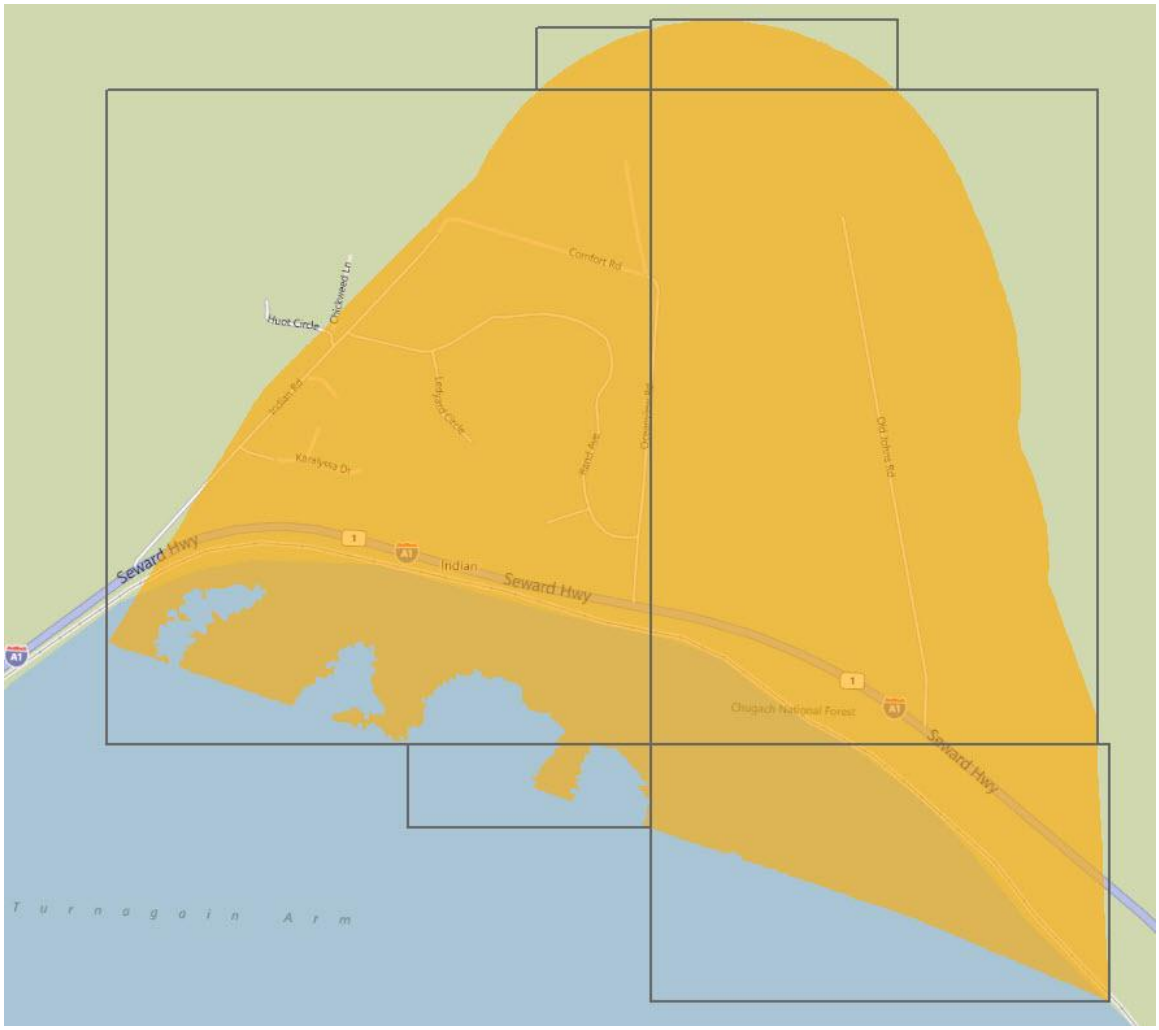
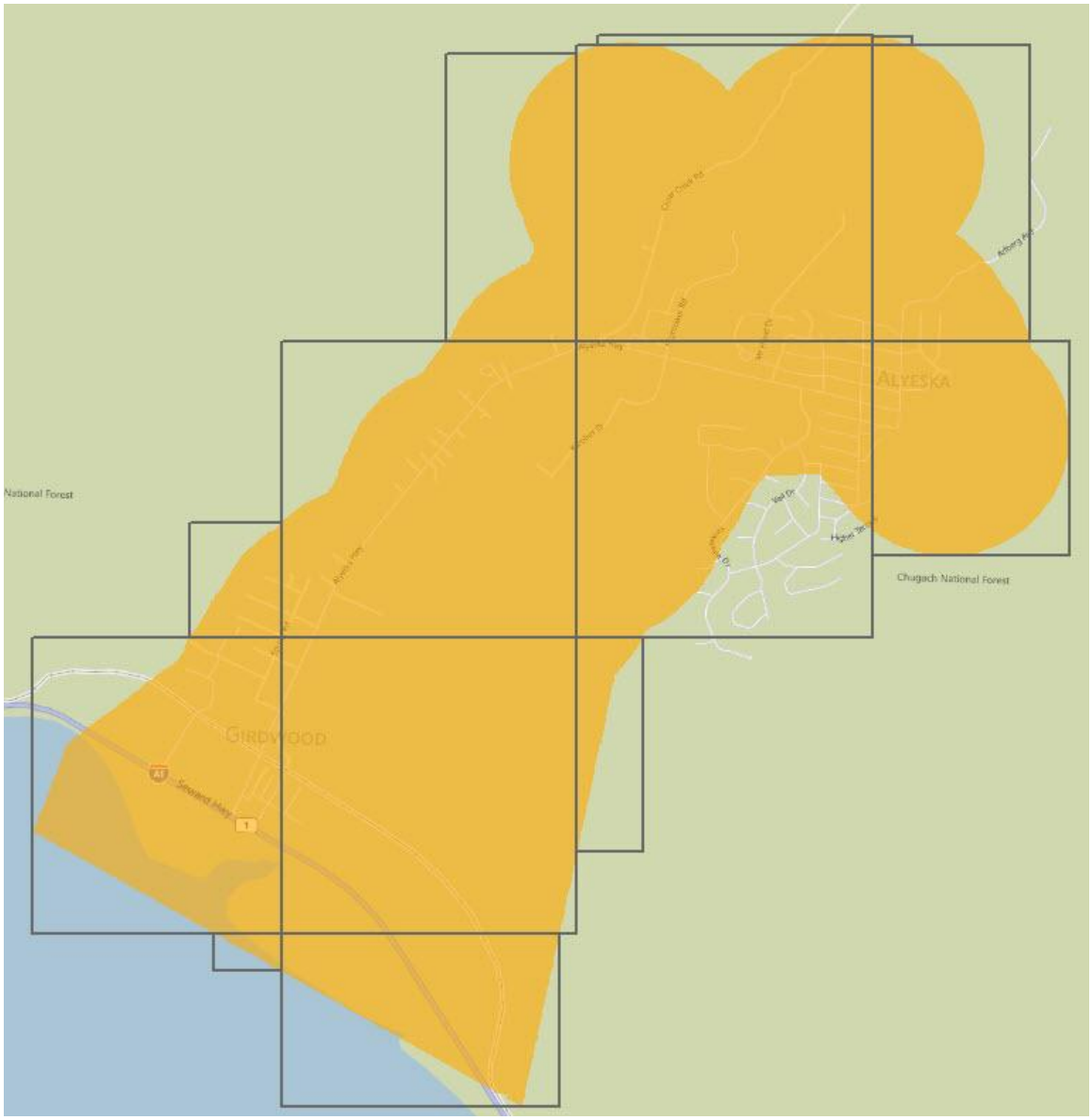


Figure 18 Area 4 Girdwood, Alaska



Activity 2: LAS Header Review Results

Point Cloud and Bare Earth LAS files were run through a LAS header parser to check the Variable length records, point information, returns, GPS timestamps, classification, intensity values, etc.

Table 27 LAS Header Review Results

Date: Wednesday November 30, 2011	
Point Cloud LAS Files Reviewed: 176	Bare Earth LAS Files Reviewed: 176
General Information	
LAS Version (version 1.2 or 1.3)	PASS
Horizontal Datum (NAD 1983)	PASS
Projection (UTM or Stateplane with correct Zone)	PASS
Horizonatl Units (Meters or US Survey Feet)	PASS
Vertical Datum (NAVD 1988)	PASS
Vertical Units (Meters or US Survey Feet)	PASS
LAS Header Contents	
file signature (Should be LASF)	PASS
file source ID: (Should match swath or 0 for tiles)	PASS
system identifier (Should be Sensor Hardware, matches metadata process step for collection)	PASS
generating software (Should be the software package used to create file, matches metadata process step for data processing)	PASS
point data format (1,3,4, or 5)	PASS
number of point records greater than zero	PASS
number of points by return (has at least 3 returns)	PASS
number of points by return equals number of point records	PASS
scale factor x y z (has 2 decimal places)	PASS
offset x y z (should be 0, 0, 0)	PASS
min x y z (xy greater than 0, xy is also used to check file name)	PASS
max x y z (xy greater than 0, z range is reasonable)	PASS
intensity (Must be included))	PASS
edge_of_flight_line (Must be included and be equal to 0 or 1)	PASS
scan_direction_flag (Must be included and be equal to 0 or 1)	PASS
number_of_returns_of_given_pulse (Must be included and have at least 3 returns)	PASS
return_number Must be included and match returns of pulse value)	PASS
classification (Must be included. 1 for Raw Point Cloud or 1, 2, 7, 8, 11 for classified data)	PASS
scan_angle_rank (Must be included. Nadir field of view value must not be greater than 34 degrees)	PASS
gps_time (Must be included and have precision to make unique)	PASS

Activity 3: Data Void Results

From section 1.5 of the USGS LiDAR Guidelines and Base Specification version 13:

> Data Voids [areas => $(4*NPS)^2$, measured using 1st-returns only] within a single swath (tile) are not acceptable, except:
>
> - where caused by water bodies
> - where caused by areas of low near infra-red (NIR) reflectivity such as asphalt or composition roofing
> - where appropriately filled-in by another swath

To insure the LiDAR data provided is in compliance with this specification Point Cloud LAS files were tested using an ESRI Geoprocessing model. This model uses the density grid created by the proceeding activity. The no data values from the intensity grid are extracted and converted to a polygon feature class. These polygons are dissolved to aggregate the void areas. The area is calculated and compared to the $(4*NPS)^2$ value (16 square meters). If an area is determined to be => the void tolerance it is retained, all values less than the tolerance are deleted. Each area is then reviewed using intensity grids, orthos, and other reference datasets to determine if they are acceptable. All areas were found to be in compliance with the USGS specification.

Figure 19 Anchorage Area Void Example

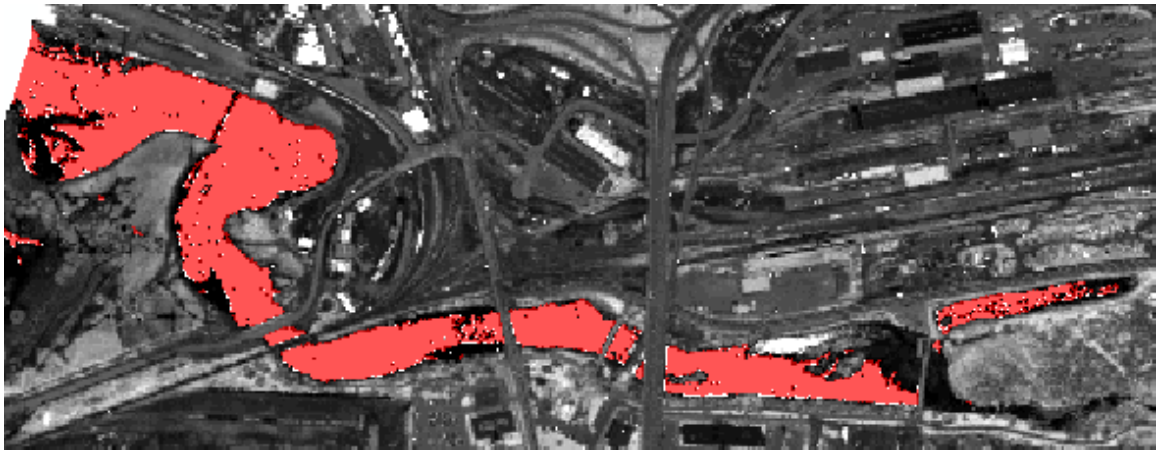


Figure 20 Eagle River Area Void Example

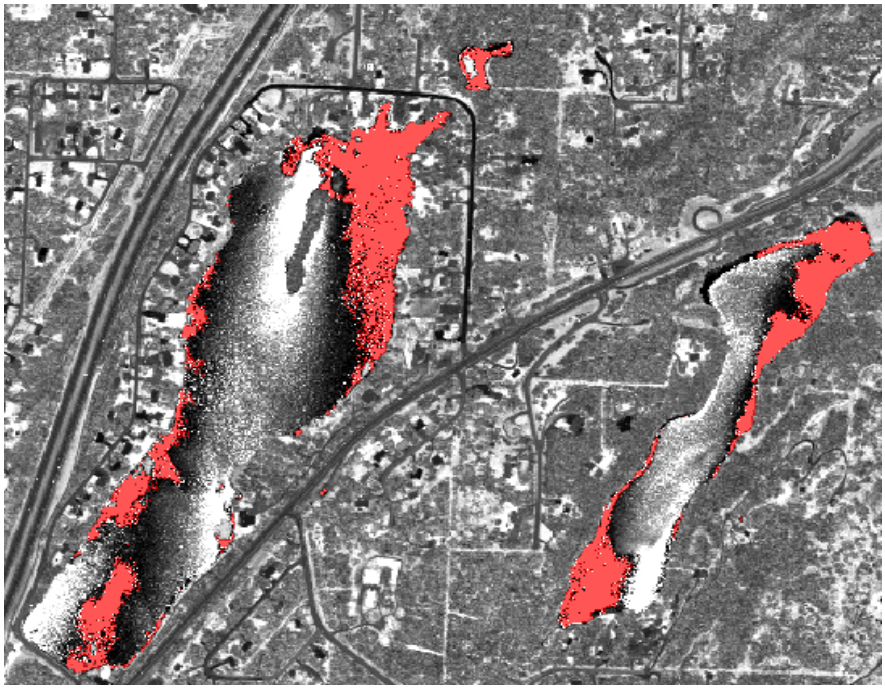


Figure 21 Girdwood Area Void Example

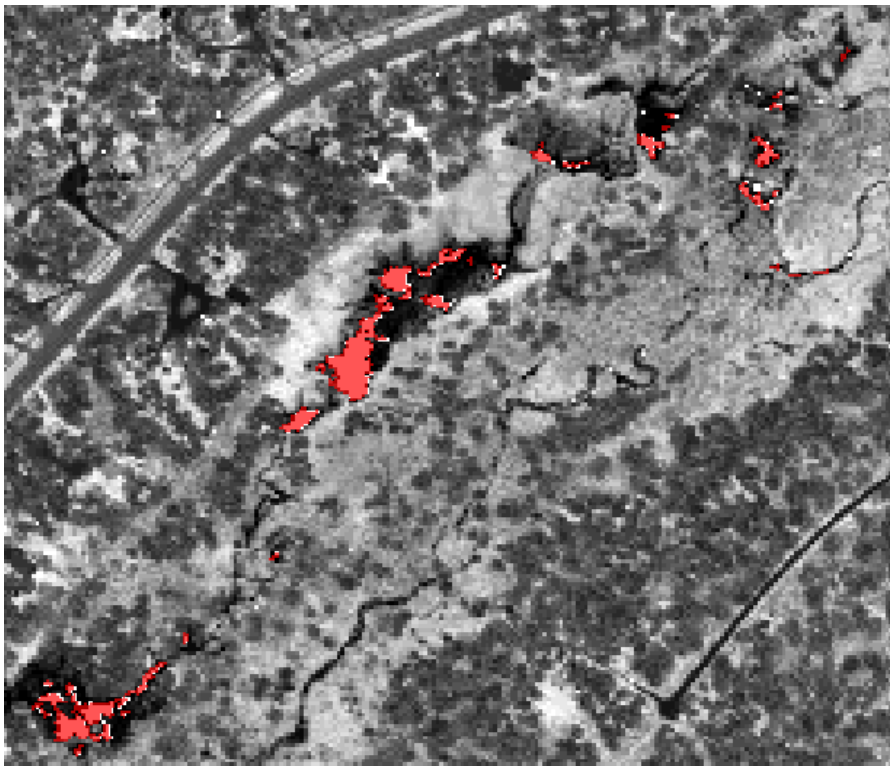
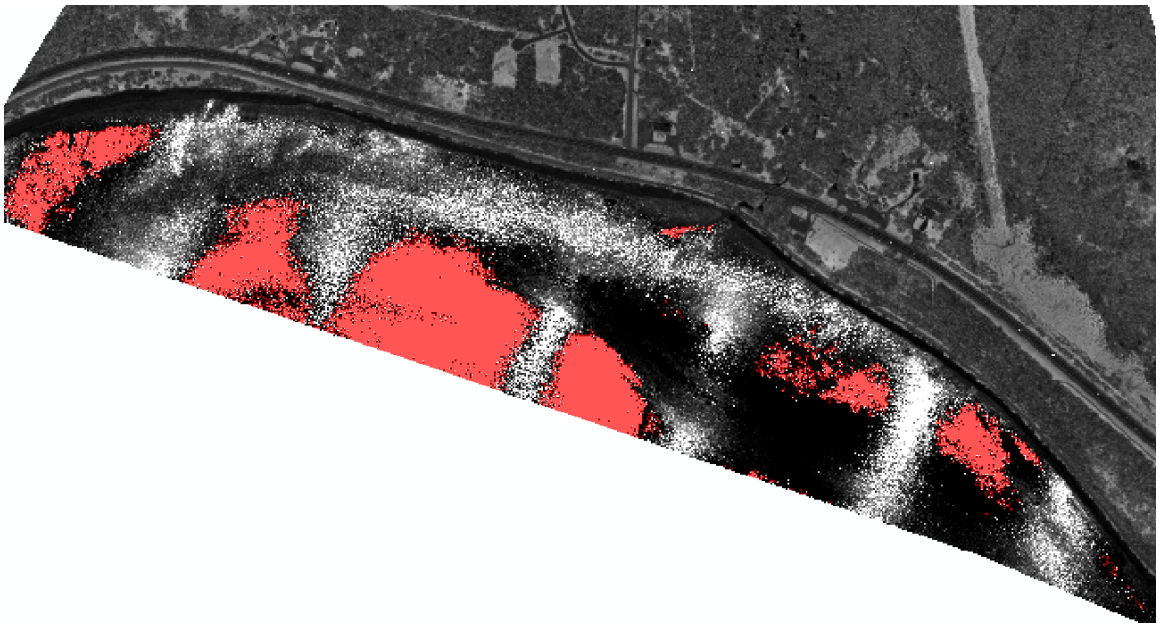


Figure 22 Indian Area Void Example



Activity 4: Point Density Results

From section 1.6 of the USGS LiDAR Guidelines and Base Specification version 13:

> The spatial distribution of geometrically usable points is expected to be uniform and free from clustering. In order to ensure uniform densities throughout the dataset:
>
> - A regular grid, with cell size equal to the design NPS*2 will be laid over the data.
> - At least 90% of the cells in the grid shall contain at least 1 lidar point.
> - Assessment to be made against single swath, first return data located within the geometrically usable center portion (typically ~90%) of each swath(tile).

To insure the LiDAR data provided is in compliance with this specification Point Cloud and LAS files were tested by creating a raster with a cell size of 2 meters (NPS=1) for each tile as well as the larger areas of interest. All areas were found to be in compliance with the USGS specification. The table below summarizes the results. Area units are in square meters.

Date: November 30, 2011	
Anchorage Area of Interest	
103 Point Cloud LAS Files Tested	PASS
103 Bare Earth LAS Files Tested	PASS
Total Area: 29854880 No Data Area: 177791 Percent of Cells with LiDAR: 99.4%	PASS
Eagle River Area of Interest	
53 Point Cloud LAS Files Tested	PASS
53 Bare Earth LAS Files Tested	PASS
Total Area: 14734571 No Data Area: 44447 Percent of Cells with LiDAR: 99.7%	PASS
Indian Area of Interest	
6 Point Cloud LAS Files Tested	PASS
6 Bare Earth LAS Files Tested	PASS
Total Area: 756994 No Data Area: 39370 Percent of Cells with LiDAR: 94.8%	PASS
Girdwood Area of Interest	
14 Point Cloud LAS Files Tested	PASS
14 Bare Earth LAS Files Tested	PASS
Total Area: 3146362 No Data Area: 6987 Percent of Cells with LiDAR: 99.8%	PASS

3.5 Micro Review Results

Task 1: 5% Point Cloud Review

Figure 23 Point Cloud Tiles Reviewed

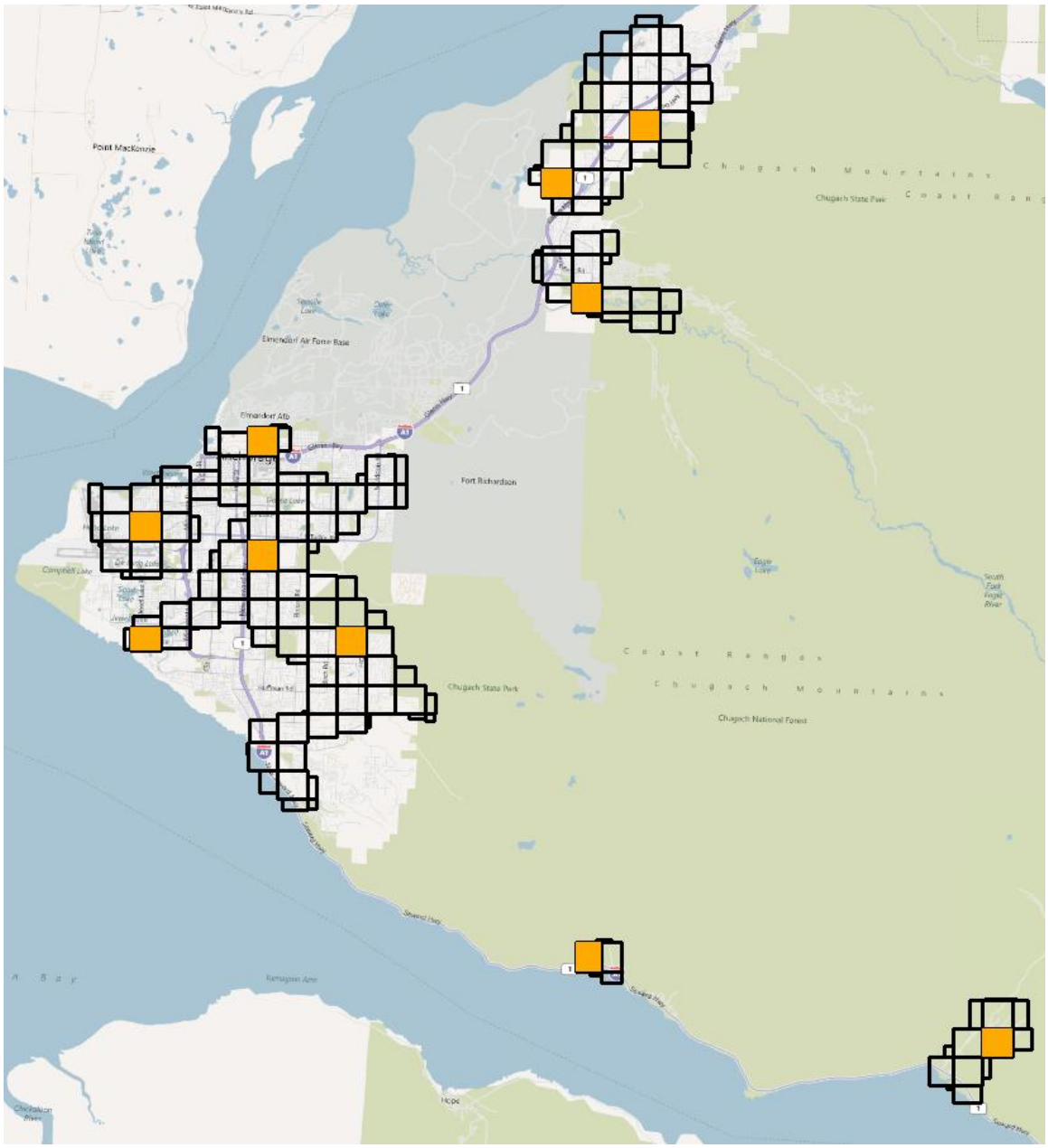


Table 28 5% Point Cloud Review Results

Point Cloud LAS Tiles Reviewed				
Tile Name	Scan Lines	Overlap	Visual Anomalies	Tile Edge Matching
03406780.las	PASS	PASS	PASS	PASS
03406786.las	PASS	PASS	PASS	PASS
03466784.las	PASS	PASS	PASS	PASS
03466790.las	PASS	PASS	PASS	PASS
03516780.las	PASS	PASS	PASS	PASS
03616804.las	PASS	PASS	PASS	PASS
03636763.las	PASS	PASS	PASS	PASS
03636798.las	PASS	PASS	PASS	PASS
03666807.las	PASS	PASS	PASS	PASS
03846759.las	PASS	PASS	PASS	PASS

Task 2: 10% Bare Earth Review

Figure 24 Bare Earth Tiles Reviewed

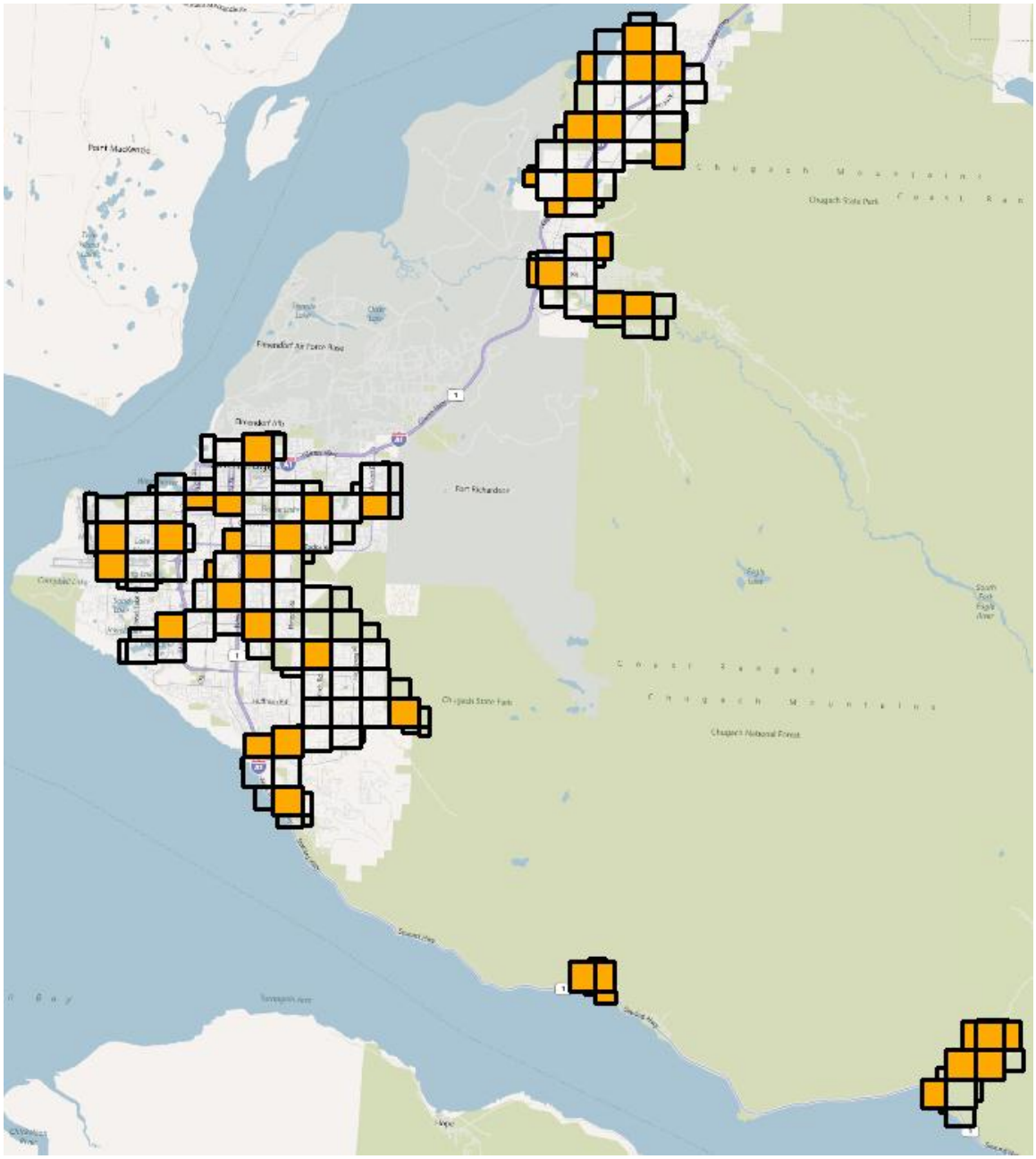


Table 29 10% Bare Earth Review Results

Point Cloud LAS Tiles Reviewed						
Tile Name	Classification	Anomalies	Artifacts and Structures	Drainage Features	Open Water Voids	Tile Edge Matching
03636763.las	PASS	PASS	PASS	PASS	PASS	PASS
03646762.las	PASS	PASS	PASS	PASS	PASS	PASS
03646763.las	PASS	PASS	PASS	PASS	PASS	PASS
03646765.las	PASS	PASS	PASS	PASS	PASS	PASS
03816757.las	PASS	PASS	PASS	PASS	PASS	PASS
03826759.las	PASS	PASS	PASS	PASS	PASS	PASS
03826760.las	PASS	PASS	PASS	PASS	PASS	PASS
03846759.las	PASS	PASS	PASS	PASS	PASS	PASS
03846760.las	PASS	PASS	PASS	PASS	PASS	PASS
03856760.las	PASS	PASS	PASS	PASS	PASS	PASS
03606799.las	PASS	PASS	PASS	PASS	PASS	PASS
03606804.las	PASS	PASS	PASS	PASS	PASS	PASS
03616799.las	PASS	PASS	PASS	PASS	PASS	PASS
03616802.las	PASS	PASS	PASS	PASS	PASS	PASS
03636804.las	PASS	PASS	PASS	PASS	PASS	PASS
03636807.las	PASS	PASS	PASS	PASS	PASS	PASS
03636810.las	PASS	PASS	PASS	PASS	PASS	PASS
03646798.las	PASS	PASS	PASS	PASS	PASS	PASS
03646801.las	PASS	PASS	PASS	PASS	PASS	PASS
03646807.las	PASS	PASS	PASS	PASS	PASS	PASS
03666798.las	PASS	PASS	PASS	PASS	PASS	PASS
03666810.las	PASS	PASS	PASS	PASS	PASS	PASS
03666811.las	PASS	PASS	PASS	PASS	PASS	PASS
03676805.las	PASS	PASS	PASS	PASS	PASS	PASS
03676810.las	PASS	PASS	PASS	PASS	PASS	PASS
03396784.las	PASS	PASS	PASS	PASS	PASS	PASS
03396786.las	PASS	PASS	PASS	PASS	PASS	PASS
03426781.las	PASS	PASS	PASS	PASS	PASS	PASS
03426786.las	PASS	PASS	PASS	PASS	PASS	PASS
03436784.las	PASS	PASS	PASS	PASS	PASS	PASS
03436787.las	PASS	PASS	PASS	PASS	PASS	PASS
03456783.las	PASS	PASS	PASS	PASS	PASS	PASS
03456786.las	PASS	PASS	PASS	PASS	PASS	PASS
03456787.las	PASS	PASS	PASS	PASS	PASS	PASS
03466775.las	PASS	PASS	PASS	PASS	PASS	PASS
03466781.las	PASS	PASS	PASS	PASS	PASS	PASS
03466784.las	PASS	PASS	PASS	PASS	PASS	PASS
03466790.las	PASS	PASS	PASS	PASS	PASS	PASS
03486772.las	PASS	PASS	PASS	PASS	PASS	PASS
03486775.las	PASS	PASS	PASS	PASS	PASS	PASS

03486786.las	PASS	PASS	PASS	PASS	PASS	PASS
03496780.las	PASS	PASS	PASS	PASS	PASS	PASS
03496787.las	PASS	PASS	PASS	PASS	PASS	PASS
03526787.las	PASS	PASS	PASS	PASS	PASS	PASS
03546777.las	PASS	PASS	PASS	PASS	PASS	PASS

4.0 VERTICAL ACCURACY VERIFICATION

Fundamental Vertical Accuracy (FVA) checkpoints are located only in open terrain, where there is a high probability that the sensor will have detected the ground surface without influence from surrounding vegetation and/or buildings. Checkpoints are located on flat or uniformly sloping terrain and at least five (5) meters away from a change in slope. Checkpoints are located randomly across the acquisition area. At least 20 FVA points were collected for each test.

Consolidated Vertical Accuracy (CVA) checkpoints are collected randomly across different land use types using the ASPRS NSSDA land cover types. The points are located in flat areas with no substantial elevation breaks within a five meter radius. The CVA assessment incorporates a representative sample of the FVA assessment points into the dataset to save on the total number of points collected. CVA points were not collected for any land class comprising less that 10% of the total project area; this may have resulted in less than 4 land classes being collected in a particular area. At least 15 CVA points were collected and 5 FVA points used, for a total of at least 20 points for the CVA testing. All points were collected at three times the accuracy of the surface being checked. Thus to check a 24.5cm surface the points were collected accurate to 8cm.

Tests were conducted when processing by the LiDAR vendor was complete and points were called for. The surveyor provided the point coordinates in an excel spreadsheet to the LiDAR vendor. The LiDAR vendor found the corresponding elevation from a surface created from the LiDAR points, filled in the spreadsheet and returned it to the surveyor who compared the elevation of the LiDAR data with that of the accuracy check point, calculated the difference and reported their findings both in terms of $RMSE_z$ and at the 95% confidence level (computed as $RMSE_z$ x 1.9600). LiDAR datasets passing the quality control checks were delivered to STARR for quality assurance approval.

The vertical accuracy requirements based on flood risk and terrain slope are met with 0.19’ (5.9 cm) and 1.01’ (31.8 cm) for both FVA and CVA testing. The mandatory requirements for the highest specification for vertical accuracy, 95% confidence levels are for FVA < 0.80’ (24.5 cm) and CVA < 1.19’ (36.3 cm).

Independent review of submitted FVA and CVA survey data with vendor provided LAS files. Survey data points containing field collected GPS elevation values were buffered by 10 meters. LiDAR points contained within the buffered areas are selected and used to create a TIN. The TIN facet z value closest to the x and y control point location is compared to the height of the survey point. The height difference is evaluated statistically and compared to the submitted FVA and CVA testing results to insure the vertical accuracy meets project expectations.

Table 30 Control Point Comparison with LiDAR

GCPID	Northing	Easting	GPSNAVD88	LAS Z	Z_Diff
ANC300	6805139.388	363701.072	372.777	372.919777	-0.1428
ANC301	6810947.55	367810.027	174.045	174.07446	-0.0295
ANC302	6807938.451	364653.858	205.365	205.477917	-0.1129
ANC303	6800982.827	364089.91	622.024	622.064369	-0.0404
ANC304	6799629.167	362266.854	278.738	278.87918	-0.1412
ANC305	6798899.781	365318.83	403.967	404.002513	-0.0355
ANC306	6790840.322	346505.059	50.731	50.628808	0.1022
ANC307	6788848.855	344834.585	40.048	39.967805	0.0802
ANC308	6787729.375	351793.464	223.561	223.506385	0.0546
ANC309	6787207.486	341817.768	72.404	72.460514	-0.0565
ANC310	6783945.261	348265.004	170.255	170.185456	0.0695
ANC311	6783122.936	345361.566	90.116	90.128088	-0.0121
ANC312	6781311.728	342241.7	44.619	44.577489	0.0415
ANC313	6781171.708	350224.055	402.009	402.004891	0.0041
ANC314	6778305.514	353899.517	1515.737	1515.939318	-0.2023
ANC315	6776234.611	350814.296	825.716	825.747051	-0.0311
ANC316	6775712.817	348782.786	361.398	361.45634	-0.0583
ANC317	6773585.754	348980.196	136.891	136.740147	0.1509
ANC318	6764711.342	364025.857	290.178	290.213533	-0.0355
ANC319	6764413.002	363773.43	217.034	217.009168	0.0248
ANC320	6763829.455	364460.168	62.188	62.274441	-0.0864
ANC321	6764006.125	363808.17	49.373	49.52498	-0.152
ANC322	6760633.098	385642.342	204.045	204.10477	-0.0598
ANC323	6760430.6	384451.432	119.546	119.535716	0.0103
ANC324	6759228.981	382766.775	89.884	89.863964	0.02
ANC401	6806602.707	364286.116	271.362	272.144435	-0.7824
ANC402	6798498.2	363902.233	348.718	349.202558	-0.4846
ANC403	6787371.206	348859.545	160.45	160.927358	-0.4774
ANC404	6763694.32	364803.483	42.436	43.0054	-0.5694
ANC405	6758400.736	381878.085	25.701	26.560708	-0.8597
ANC701	6812322.634	367018.405	61.438	60.957657	0.4803
ANC702	6807919.861	366567.07	365.44	366.309432	-0.8694
ANC703	6803780.383	362512.513	277.177	277.447825	-0.2708
ANC704	6801843.379	364689.816	1002.786	1003.222168	-0.4362
ANC705	6797434.86	367202.614	490.319	489.565624	0.7534
ANC706	6797433.908	367183.03	501.553	502.07391	-0.5209
ANC707	6799174.542	363951.822	434.392	435.148055	-0.7561
ANC708	6788822.163	343131.747	97.318	97.432323	-0.1143
ANC709	6781309.456	341079.367	37.432	37.208645	0.2234
ANC710	6781341.202	341073.849	39.533	39.998074	-0.4651
ANC711	6775545.045	347511.244	142.537	142.71921	-0.1822
ANC712	6764039.078	364293.074	88.276	88.744138	-0.4681
ANC713	6764380.3	363985.809	168.428	169.30598	-0.878
ANC714	6778279.929	353877.284	1515.637	1516.44834	-0.8113
ANC716	6759774.16	383060.216	144.902	143.748484	1.1535
ANC715	6758520.902	382390.038	88.935	87.149182	1.7858
ANC801	6811532.308	368427.37	316.041	316.081023	-0.04
ANC802	6801127.445	362235.975	319.248	319.266026	-0.018
ANC803	6789289.867	352943.385	254.54	254.467394	0.0726
ANC804	6786400.76	345825.378	129.503	129.490244	0.0128
ANC805	6758118.714	382373.718	31.885	31.868409	0.0166

Table 31 FVA Testing Results

Fundamental Vertical Accuracy Summary Statistics Units: US Survey Feet	
Minimum DZ:	-1.781
Maximum DZ:	0.956
Mean DZ:	0.088
Mean Magnitude DZ:	0.54
Number Observations:	51
Standard Deviation DZ:	0.463
RMSE Z:	0.467
95% Confidence Level Z:	0.915

Figure 25 FVA Histogram

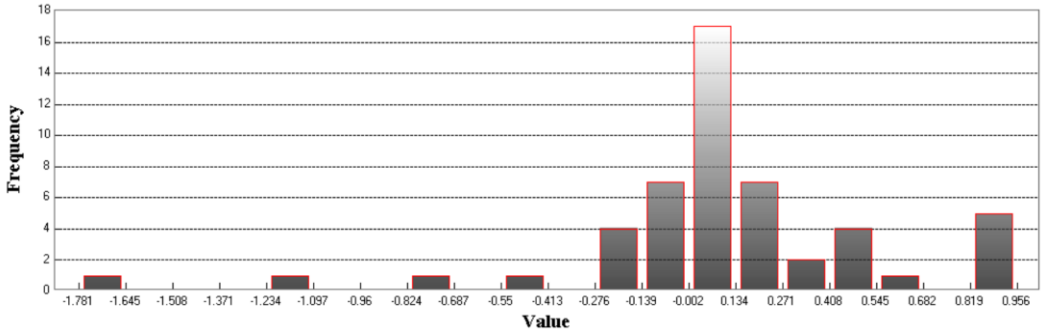
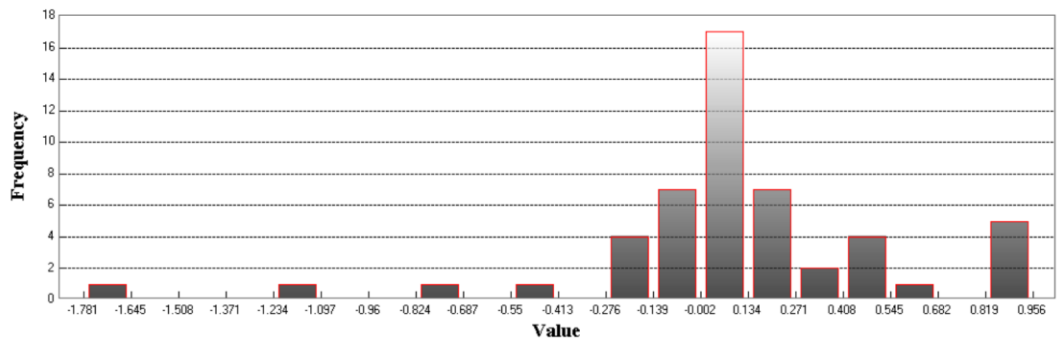


Table 32 CVA Testing Results

Consolidated Vertical Accuracy Summary Statistics Units: US Survey Feet	
Minimum DZ:	-1.781
Maximum DZ:	0.956
Mean DZ:	0.088
Mean Magnitude DZ:	0.54
Number Observations:	51
Standard Deviation DZ:	0.463
RMSE Z:	0.467
95% Confidence Level Z:	1.035

Figure 26CVA Histogram



5.0 CONCLUSIONS

Based upon the submittal verification, acquisition reports, macro/micro reviews and vertical accuracy confirmation reviews, the Anchorage, Alaska dataset meets all applicable project specifications defined in FEMA task order HSFE10-11-J-00076 dated July 15, 2011. This data meets and exceeds all project requirements for FEMA Risk MAP elevation acquisition and can be used in flood risk analysis.

Table 33 Credits

LiDAR Procurement	FEMA
Acquisition and Processing	STARR partner Aerometric, Inc.
Ground Control and FVA/CVA survey	STARR partner Compass Data, Inc.
Quality Assurance and Delivery	STARR partner Greenhorne & O'Mara, Inc.

Approvals

QA Team Lead: James L. Huffines **Date: 12/30/2011**