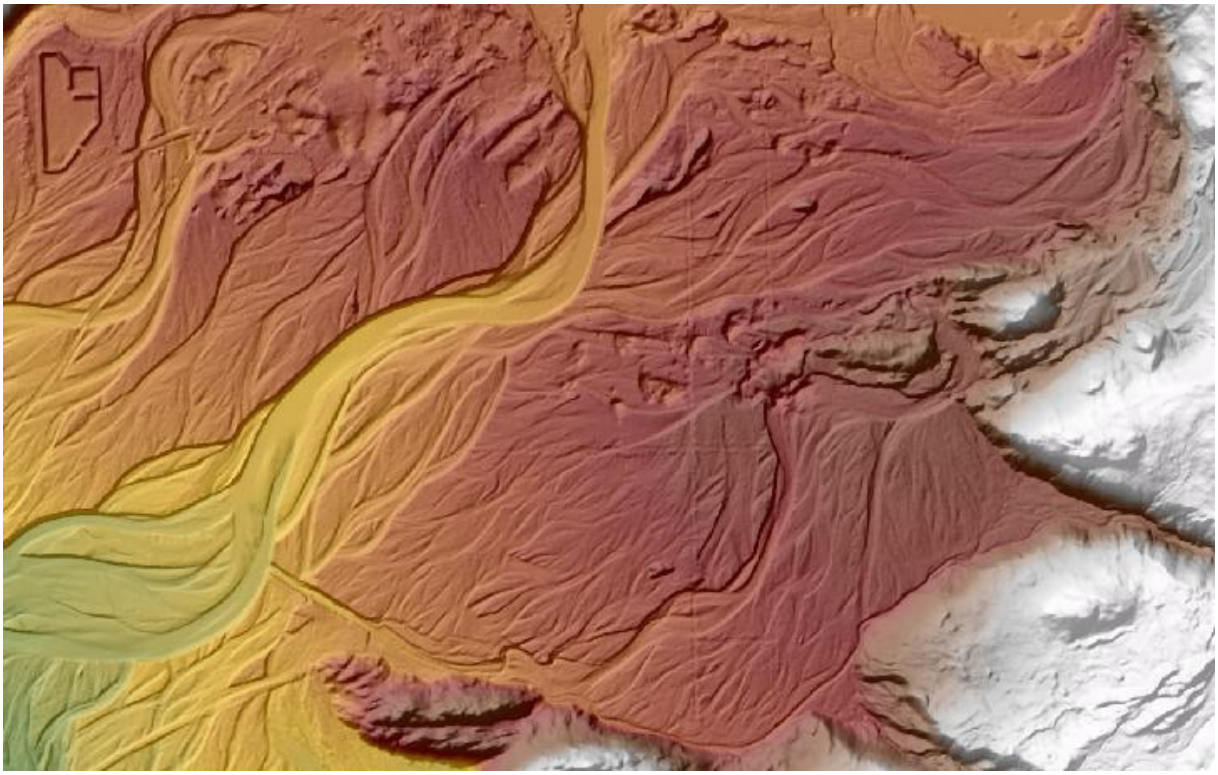
Elevation Data Quality Assurance Report
Valdez, Alaska
November 13, 2012



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

Contents

1. Executive Summary

Under FEMA task order HSFEHQ-10-J-0006 STARR has completed elevation data acquisition for Valdez, 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. 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 Valdez, Alaska.

Table 1 LiDAR Project Requirements

FEMA Region 10 Valdez, Alaska LiDAR Acquisition	
Collection/Processing Area	31 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 Meters

Table 2 QA Activity and Guideline and Specifications Matrix

QA Activity	PM 61	USGS LiDAR Base Spec v13	ASPRS LAS v1.2	Appendix A	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

3. 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 3 Software/Tools used in Quality Assurance Review

Software/Tools	QA Process
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 Vendor Submittal

All project data has been delivered and is accounted for. The completed Vendor Submittal Quality Assurance checklists are included with the QA Forms delivered with this document.

3.2 Macro Data Review

The macro review is conducted on the full all return and fully classified point cloud datasets. The purpose of this review is to determine whether the dataset was produced in a manner consistent with requirements set forth in the FEMA procedural memorandum. The individual review components are discussed in the following sections.

3.2.1 LiDAR Coverage and Completeness

All LiDAR data collected for the Valdez, Alaska covers the area of interest with a 100m buffer and has an area of approximately 31 square miles (See Figure 1). All LiDAR tiles are accounted for and the project datasets have the correct projection and datum information.

3.2.2 LAS Header Review

All LAS files submitted for review have header information that is compliant with ASPRS LAS specifications version 1.2 and 1.3.

The completed LAS Header Quality Assurance checklist is included with the QA Forms delivered with this document.

3.2.3 Point Density

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).

The percentage of cells with counts greater than or equal to one were found to be in compliance with the USGS specification of 90% (See Figure 2).

3.2.4 Data Voids

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

All areas were found to be in compliance with the USGS specification. The review confirmed that the data voids occur in legitimate hydro areas. Data void examples are included with QA forms delivered with this document.

3.3 Micro Data Review

The following macro reviews were completed on 5% of both the all return and the fully classified point cloud datasets. Tiles selected for review were chosen throughout the project area with a focus on areas of urban development and hydrographic significance (See Figure 3).

- Scan lines removed from bare earth
- Excessive Noise in bare earth
- Elevation Steps
- Gaps/Voids
- Edge matching between tiles
- Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)
- Proper definition of roads and drainage patterns
- "Over-smoothed" areas during filtering
- Corn Row Effects
- Mounds and Divots
- Other anomalies

All tiles reviewed meet project requirements for classified LiDAR data and can be used for floodplain mapping activities. The completed Micro Data Review Quality Assurance checklist is included with the QA Forms delivered with this document.

4. Vertical Accuracy Verification

An independent review and verification of submitted FVA and CVA survey data with vendor provided LAS files was completed to insure reported vertical accuracy is correct. 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. All FVA and CVA survey data submitted for this

project has been confirmed to meet project requirements. The report delivered with this document summarizes the results of this assessment.

5. Conclusions

Based upon the submittal verification, acquisition reports, macro/micro reviews and vertical accuracy confirmation, the Valdez, Alaska dataset meets all applicable project specifications defined in FEMA task order HSFEHQ-10-J-0006 dated July 15, 2011. This data meets all project requirements for FEMA Risk MAP elevation acquisition and can be used for flood risk analysis.

Approvals

QA Team Lead: **James L. Huffines Date: 11/13/2012**

6. References

Links to guidelines and specifications used in production of the LiDAR datasets:

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

Figure 1 LiDAR Coverage

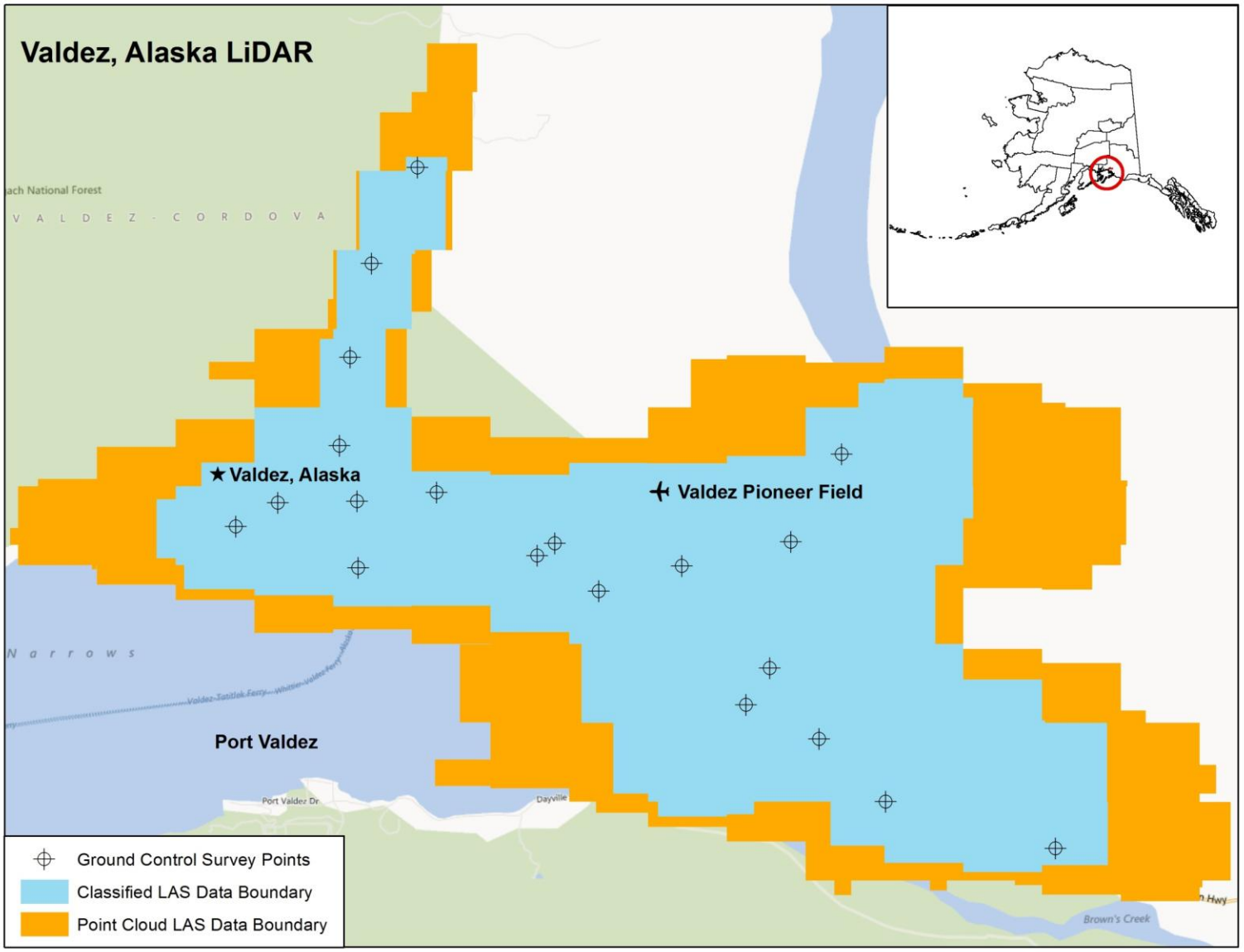


Figure 2 LiDAR Point Density and Distribution

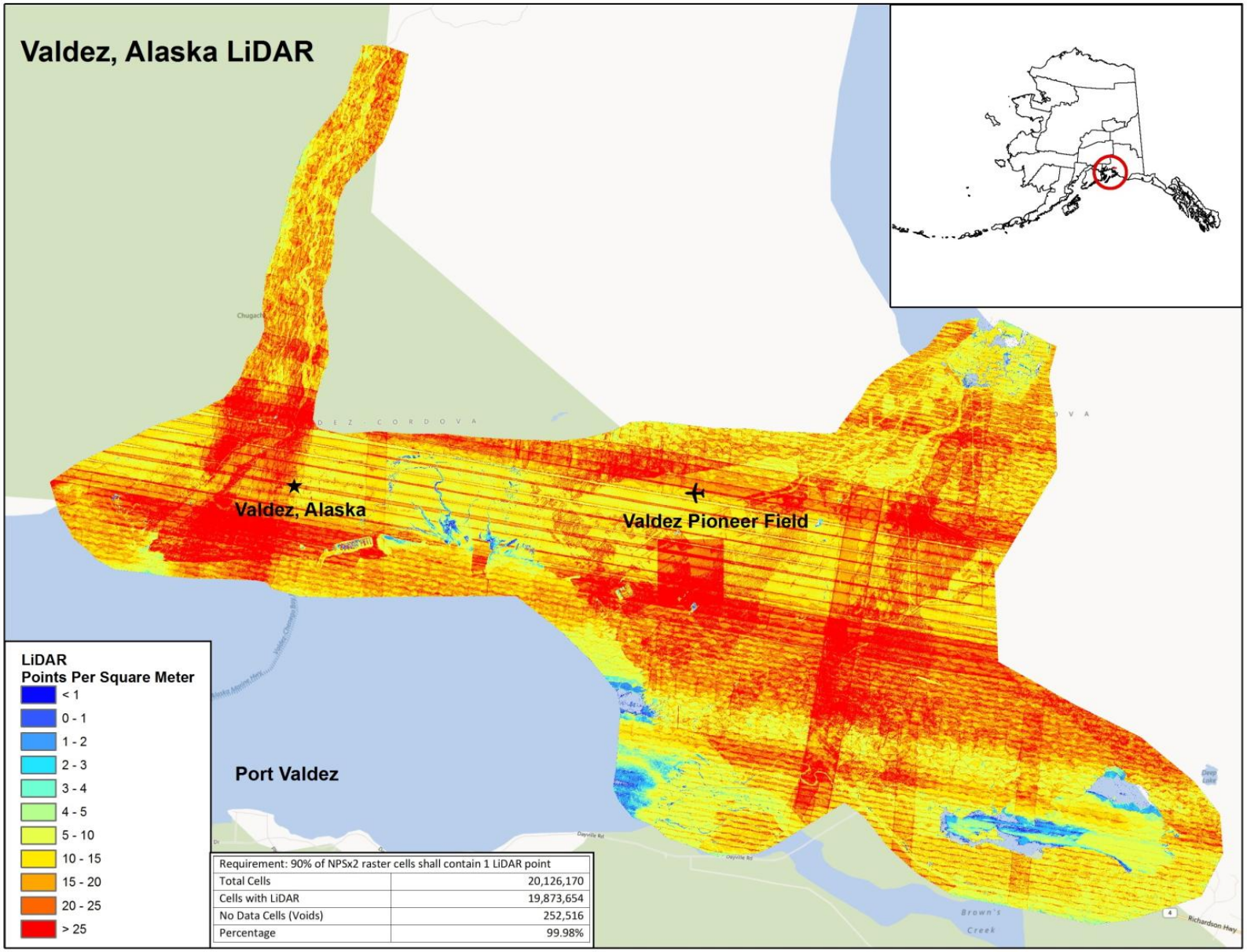
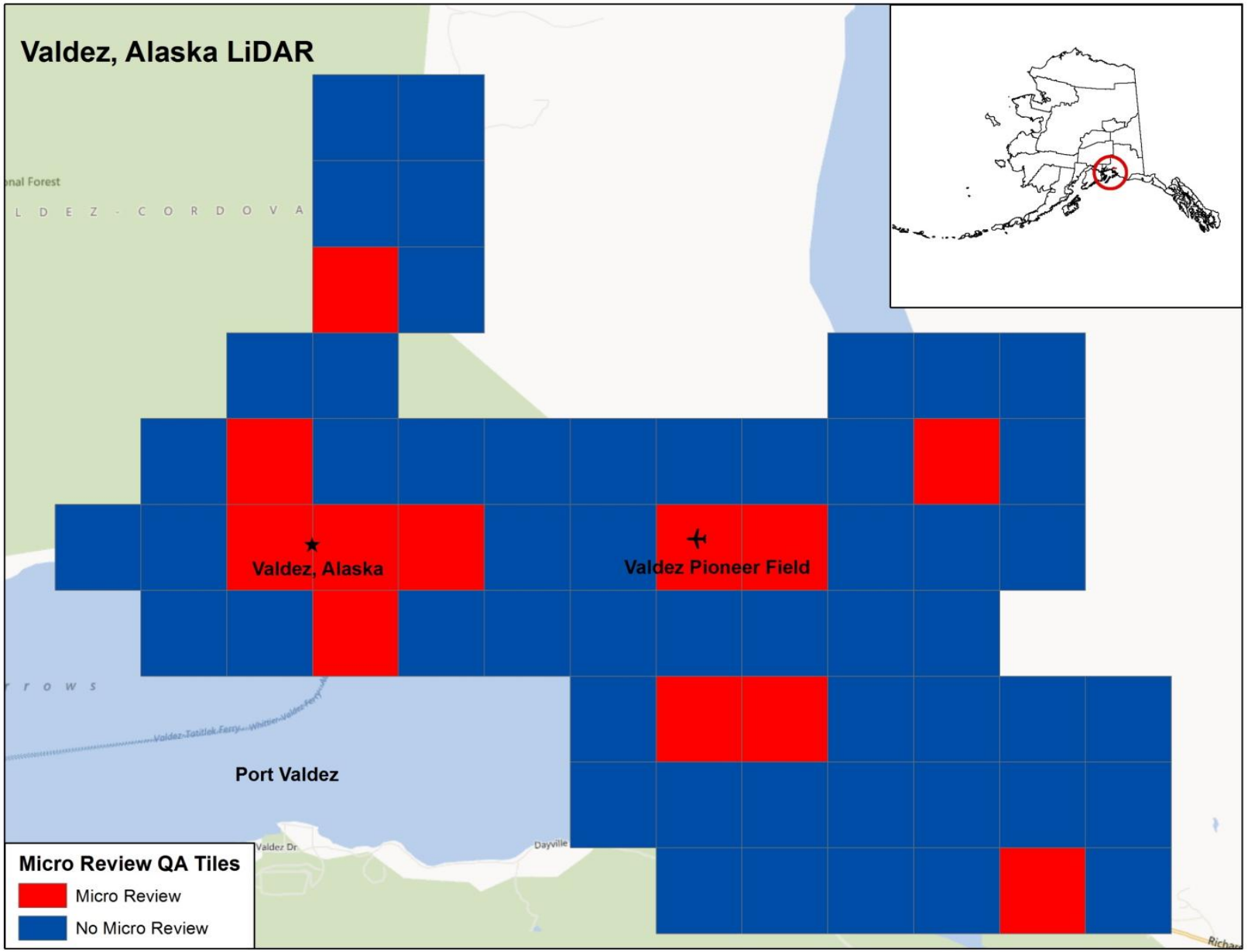


Figure 3 LiDAR Micro Review Tiles



Quality Assurance Forms

Project Summary

Table 1 Project Information

Project Name	Prince William Sound Valdez, Alaska
Project Area	31.08 Square Miles
LiDAR Acquisition Date(s)	September 21 and 26, 2011, October 18 and 28, 2011 and June 18 2012
LAS Version	1.2
LAS Point Data Format	1
Projection	UTM Zone 6N
Horizontal Datum	NAD83 Meters
Vertical Datum	NAVD88 Feet
Consistent Classification	Y

Table 2 Point Classification

Classification	Point Count	Density
ASPRS Class 1 Unclassified	1,302,733,064	16.18 ppsm
ASPRS Class 2 Ground	144,636,224	1.80 ppsm
ASPRS Class 7 Low Point (noise)	37,471	0 ppsm
ASPRS Class 8 Model Key-point (mass point)	22,401,372	0.28 ppsm
All Classifications	1,469,808,131	18.26 ppsm

Table 3 Point Return Summary

Point Return	Return Count
Return 1	1,200,135,697
Return 2	242,771,508
Return 3	24,448,163
Return 4	2,381,970

Table 4 Spatial Distribution

Requirement: 90% of NPSx2 raster cells shall contain 1 LiDAR point	
Total Cells	20,126,170
Cells with LiDAR	19,873,654
No Data Cells (Voids)	252,516
Percentage	99.98%

Raw Point Cloud Vendor Submittal Checklist		Project: Prince William Sound-Valdez, AK
Vendor: Aerometric LiDAR, Compass Data Survey		**Reviewed By: Myra Hupfeld-Cousineau**
Section: Descriptive Project Information		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Metadata – Project	Y	
Compliance Form – Survey	Y	
Compliance Form – LiDAR	Y	
Flight Reports – Pre-flight	Y	
Flight Reports – Post-flight	Y	
Base Station Point Shapefile	Y	
Flight Lines As Flown Trajectories Polyline Shapefile	Y	
Flight Lines Calibration Polyline Shapefile	Y	INCLUDED WITH TRAJECTORY SHAPEFILE
Flight Lines Planned Flight Lines Polyline Shapefile	Y	
Section: Survey Data		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Ground Control – Accuracy Report		
Ground Control – Shapefile and Final Coordinates	Y	
Ground Control – Final Report	Y	
Vertical Accuracy – FVA Accuracy Report	Y	
Vertical Accuracy – Shapefile and Final Coordinates	Y	
Vertical Accuracy – FVA Accuracy Final Report	Y	
Vertical Accuracy – FVA Accuracy Testing Results	Y	
Section: Raw Point Cloud LiDAR		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Project Area Coverage (100m Buffer) Polygon Shapefile	Y	
LiDAR Swath – LAS v1.2 or v1.3 < 2GB	NA	RAW DATA DELIVERED IN TILE FORMAT
LiDAR Swath – Project Swath Index Polygon Shapefile	Y	
LiDAR Tiles – LAS v1.2 or v1.3	Y	

Classified Point Cloud Vendor Submittal Checklist		**Project: Prince William Sound – Valdez, AK**
Vendor: Aerometric LiDAR, Compass Data Survey		**Reviewed By: Myra Hupfeld-Cousineau**
Section: Descriptive Project Information		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Metadata – Project	Y	
Compliance Form – Survey	Y	
Compliance Form – LiDAR Post Processing	Y	
Section: Survey Data		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Vertical Accuracy – FVA/CVA Accuracy Report	Y	
Vertical Accuracy – Shapefile and Final Coordinates	Y	
Vertical Accuracy – FVA/CVA Accuracy Final Report	Y	
Vertical Accuracy – FVA/CVA Accuracy Testing Results	Y	
Section: Classified Point Cloud LiDAR		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Project Area Coverage (100m Buffer) Polygon Shapefile	Y	
LiDAR Tiles – LAS v1.2 or v1.3	Y	
LiDAR Tiles – Project Tile Index Polygon Shapefile	Y	

Pre-flight Aerial Calibration Report Checklist		**Project: Prince William Sound-Valdez, AK**
Vendor: AEROMETRIC		**Reviewed By: Myra Hupfeld-Cousineau**
Section: Main		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Planned flight lines (sufficient coverage, spacing, length)	Y	
Planned flight line Shapefile	Y	
Planned GPS stations	Y	
Planned Ground Control	Y	
Calibration Plans	Y	
Vendor Quality Procedures	Y	
LiDAR sensor scan set – scan angle, sidelap, design pulse	Y	
Aircraft utilizes ABGPS	Y	
Sensor supports project design pulse density	Y	
Type of aircraft – supports project design parameters	Y	
Re-flight procedure – tracking, documenting, processing	Y	
Project design supports accuracy requirements of project	Y	
Project design accounts for land cover and terrain types	Y	

Post-flight Aerial Acquisition and Calibration Report Checklist		Project: Prince William Sound –Valdez, AK
Vendor: AEROMETRIC		**Reviewed By: Myra Hupfeld-Cousineau**
Section: Flight Logs		**Date: 16OCT2012**
Item	**Included**	**Comments**
Flight logs – Job #/name	Y	
Flight logs – Lift #	Y	
Flight logs – Block or AOI	Y	
Flight logs – Date	Y	
Flight logs – Aircraft type	NA	CONTAINED IN REPORT
Flight logs – Aircraft tail #	Y	
Flight logs – Lines – #	Y	
Flight logs – Lines – direction	Y	
Flight logs – Lines – start/stop	Y	
Flight logs – Lines – altitude	Y	
Flight logs – Lines – scan angle	Y	
Flight logs – Lines – speed	Y	
Flight logs – Conditions	Y	
Flight logs – Comments	Y	
Flight logs – Pilot name	Y	
Flight logs – Operator name	Y	
Flight logs – Automatic Gain Control switch setting	NA	NOT USED IN COLLECTION
Flight logs – Laser pulse rate	Y	CONTAINED IN REPORT
Flight logs – Mirror rate	Y	CONTAINED IN REPORT
Flight logs – Field of view	N	
Flight logs – Airport of operations	Y	CONTAINED IN REPORT
Flight logs – GPS base stations names or numbers	Y	CONTAINED IN REPORT

Section: GPS Base station		
Item	**Included**	**Comments**
GPS base station – names	Y	
GPS base station – lat/longs	Y	
GPS base station – heights	Y	
GPS base station – map	Y	
GPS base station – Base height (Ellipsoidal meters)	Y	
GPS base station – Max PDOP	Y	
GPS base station – Map of locations	Y	
Section: GPS/IMU Quality		
GPS quality – Max Horizontal GPS Variance (cm)	Y	
GPS quality – Max Vertical GPS Variance (cm)	Y	
GPS quality – separation plot	Y	
GPS quality – altitude plot	Y	
GPS quality – PDOP plot	Y	
Plot of GPS distance from base station/s	Y	
Notes on GPS quality (High, Good, etc.)	N	
Section: Data Verification and Quality Control		
Description of data verification and QC process	Y	
Results of verification and QC process steps		
Section: Spatial Data		
Base Station Point Shapefile	Y	
Ground Control Point Shapefile	Y	
Project Area Coverage (100m Buffer) Polygon Shapefile	Y	
Flight Lines As Flown Trajectories Polyline Shapefile	Y	
Flight Lines Calibration Polyline Shapefile	Y	INCLUDED WITH FLIGHT LINES
Flight Lines Planned Flight Lines Polyline Shapefile	Y	
Project Swath Index Polygon Shapefile	Y	
Project Tile Index Polygon Shapefile	Y	

Survey Data Checklist		Project: Prince William Sound-Valdez, AK
Vendor: Compass Data		**Reviewed By: Myra Hupfeld-Cousineau**
Section: Main		**Date: 16OCT2012**
Item	**Included (Y/N)**	**Comments**
Survey is referenced to NGS control monuments in the NSRS using appropriate horizontal and vertical control	Y	
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	Y	
New control conforms to the Standards and Specifications for Geodetic Control Networks (1984), FGCC	Y	
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	Y	
Ground control stations meet local network accuracy at the 95% accuracy level of 2 cm horizontally and vertically	Y	
Supporting documentation submitted such as processing reports, minimally and constrained 3-D least squares adjustment, pictures of the stations, etc.	Y	
Description of process used to test the points	Y	
A graphic depicting the spatial distribution of the ground survey points	Y	
FVA checkpoints must exist in the project area	Y	
FVA checkpoints as open area	Y	
SVA for up to three significant land cover categories	Y	
SVA checkpoints must exist in the area where bare-earth processing occurred	Y	
An analysis of checkpoints that have errors exceeding the 95th percentile in SVA and CVA calculations	NA	
Descriptive statistics and RMSE in FVA and/or CVA calculations.	Y	

spatial information solutions
one research boulevard, suite 105
starkville, mississippi 39759
http://www.spatialis.com

topo analyst™

LiDAR Accuracy Assessment Summary

LC Type	# of Points	FVA	SVA	CVA
LAS				
ALL	39			1.169
OPEN	19	0.924		
GRASS	5		0.741	
URBAN	5		0.390	
FOREST	10		0.901	
Total	39			

Units: US Survey Feet

spatial information solutions
one research boulevard, suite 105
starkville, mississippi 39759
http://www.spatialis.com

topo analyst™

Coordinates and Offsets of Analyzed Locations

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
1)	☑	VAL301					
			544331.574	6772534.676	26.811	NaN	26.784
					NaN	-0.027	OPEN
2)	☑	VAL302					
			542630.469	6773750.028	27.9	NaN	27.908
					NaN	0.008	OPEN
3)	☑	VAL303					
			540930.491	6773819.374	13.222	NaN	12.858
					NaN	-0.363	OPEN
4)	☑	VAL304					
			539431.437	6775716.924	9.921	NaN	8.533
					NaN	-1.388	OPEN
5)	☑	VAL305					
			542021.398	6776399.232	93.893	NaN	94.348
					NaN	0.454	OPEN
6)	☑	VAL306					
			541308.306	6777122.914	88.224	NaN	88.314
					NaN	0.09	OPEN
7)	☑	VAL307					
			539653.477	6776934.429	38.569	NaN	38.885
					NaN	0.316	OPEN

Coordinates and Offsets of Analyzed Locations (Continued)

		ID					
			Survey X	Survey Y	Z1	Z DEM	Z LAS
					ΔZ DEM	ΔZ LAS	LC Type
8)	☑	VAL308					
			542871.599	6778492.823	176.72	NaN	176.727
					NaN	0.007	OPEN
9)	☑	VAL309					
			544581.58	6779624.414	232.54	NaN	232.64
					NaN	0.1	OPEN
10)	☑	VAL311					
			535550.644	6777935.135	21.463	NaN	21.671
					NaN	0.208	OPEN
11)	☑	VAL312					
			534998.89	6777217.08	18.067	NaN	18.396
					NaN	0.329	OPEN
12)	☑	VAL313					
			533891.468	6777793.857	53.411	NaN	53.672
					NaN	0.26	OPEN
13)	☑	VAL314					
			533044.696	6778084.303	49.832	NaN	49.871
					NaN	0.039	OPEN
14)	☑	VAL315					
			532686.282	6777773.994	32.063	NaN	32.315
					NaN	0.252	OPEN

Coordinates and Offsets of Analyzed Locations (Continued)

	ID					
		Survey X	Survey Y	Z1	Z DEM	Z LAS
				ΔZ DEM	ΔZ LAS	LC Type
15)	VAL316					
		532478.398	6777115.589	78.9	NaN	77.731
				NaN	-1.169	OPEN
16)	VAL317					
		534117.592	6778506.43	99.943	NaN	100.341
				NaN	0.398	OPEN
17)	VAL318					
		534227.482	6779170.79	165.648	NaN	165.585
				NaN	-0.063	OPEN
18)	VAL319					
		534354.328	6780995.913	214.361	NaN	214.516
				NaN	0.155	OPEN
19)	VAL320					
		535238.66	6783573.485	336.833	NaN	336.883
				NaN	0.05	OPEN
20)	VAL401					
		545350.394	6771691.691	55.849	NaN	56.459
				NaN	0.61	GRASS
21)	VAL402					
		541425.35	6774992.771	47.663	NaN	47.943
				NaN	0.28	GRASS

Coordinates and Offsets of Analyzed Locations (Continued)

	ID					
		Survey X	Survey Y	Z1	Z DEM	Z LAS
				ΔZ DEM	ΔZ LAS	LC Type
22)	VAL403					
		544190.729	6779400.879	238.134	NaN	238.874
				NaN	0.741	GRASS
23)	VAL404					
		534492.764	6777164.626	28.946	NaN	28.78
				NaN	-0.167	GRASS
24)	VAL405					
		532807.082	6778065.808	42.749	NaN	43.072
				NaN	0.323	GRASS
25)	VAL801					
		533948.995	6778227.988	74.146	NaN	74.378
				NaN	0.232	URBAN
26)	VAL802					
		535008.821	6777427.791	20.141	NaN	20.531
				NaN	0.39	URBAN
27)	VAL803					
		534996.709	6778220.807	36.699	NaN	36.785
				NaN	0.086	URBAN
28)	VAL804					
		540622.904	6776823.312	60.81	NaN	60.95
				NaN	0.141	URBAN

Coordinates and Offsets of Analyzed Locations (Continued)

	ID					
		Survey X	Survey Y	Z1	Z DEM	Z LAS
				ΔZ DEM	ΔZ LAS	LC Type
29)	VAL805					
		542962.109	6774021.414	39.107	NaN	39.104
				NaN	-0.003	URBAN
30)	VAL701					
		542658.621	6773790.469	27.227	NaN	27.796
				NaN	0.568	FOREST
31)	VAL702					
		543792.321	6772498.311	32.644	NaN	33.545
				NaN	0.901	FOREST
32)	VAL703					
		541915.316	6774357.034	33.651	NaN	34.031
				NaN	0.38	FOREST
33)	VAL704					
		541165.385	6775799.004	51.072	NaN	51.755
				NaN	0.683	FOREST
34)	VAL705					
		543688.221	6779145.947	238.898	NaN	239.081
				NaN	0.183	FOREST
35)	VAL706					
		538925.391	6777498.526	26.21	NaN	27.03
				NaN	0.82	FOREST

Coordinates and Offsets of Analyzed Locations (Continued)

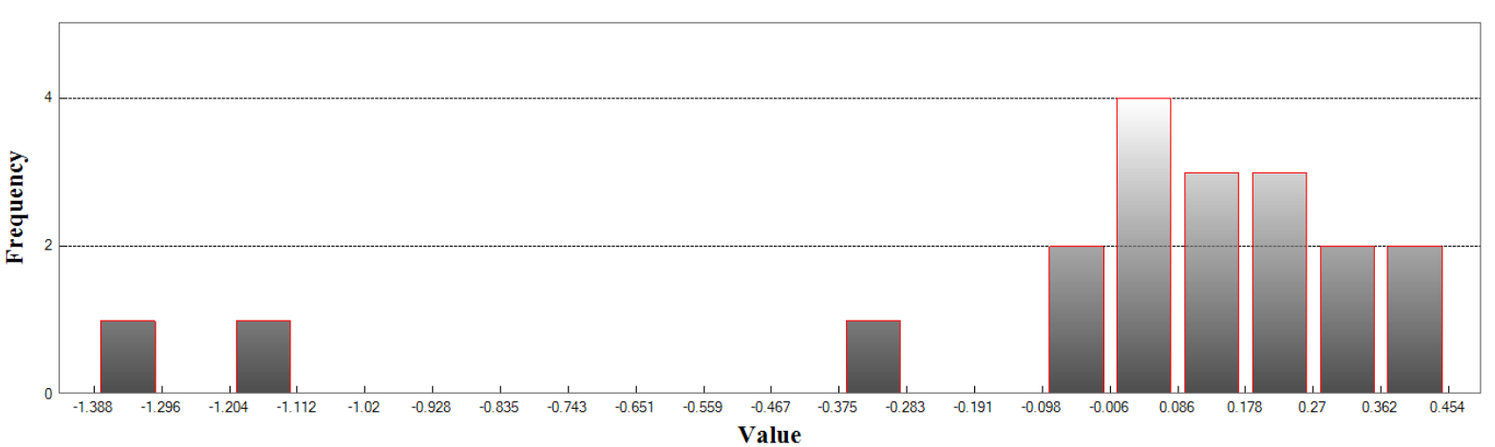
	ID					
		Survey X	Survey Y	Z1	Z DEM	Z LAS
				ΔZ DEM	ΔZ LAS	LC Type
36)	VAL707					
		533527.618	6777497.225	40.787	NaN	41.403
				NaN	0.616	FOREST
37)	VAL708					
		534324.42	6778703.632	100.278	NaN	99.987
				NaN	-0.291	FOREST
38)	VAL709					
		534317.631	6780239.261	141.389	NaN	141.935
				NaN	0.546	FOREST
39)	VAL710					
		534473.061	6781627.22	278.084	NaN	278.736
				NaN	0.652	FOREST

LAS

Fundamental Vertical Accuracy

LandCover Type: OPEN
Minimum DZ: -1.388
Maximum DZ: 0.454
Mean DZ: -0.018
Mean Magnitude DZ: 0.547
Number Observations: 19
Standard Deviation DZ: 0.484
RMSE Z: 0.471
95% Confidence Level Z: 0.924
Units: US Survey Feet

Histogram



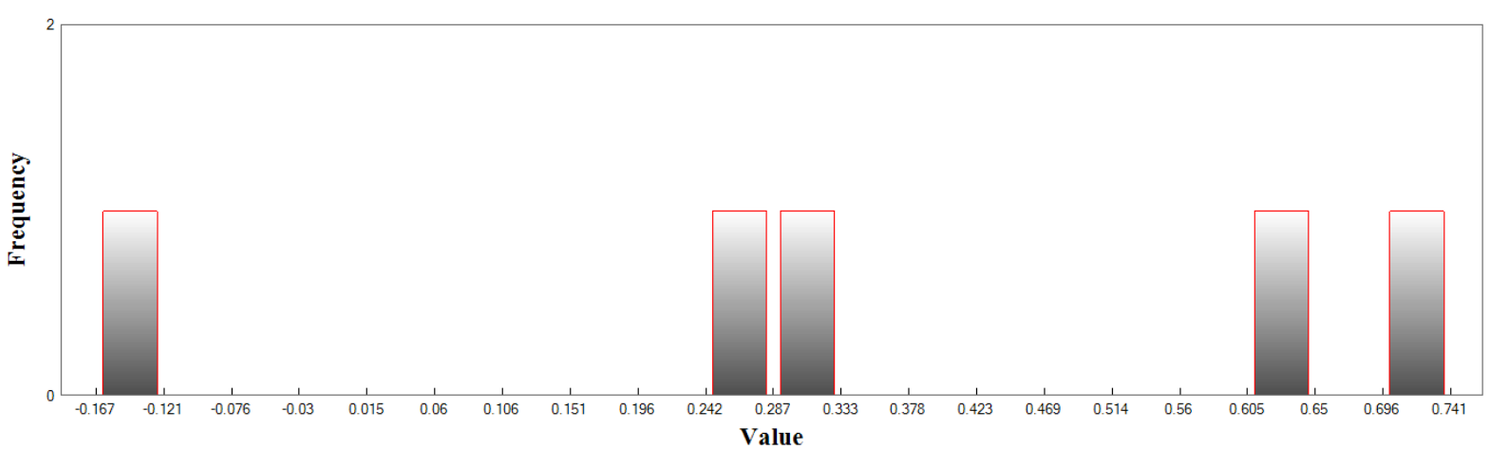
Min: -1.388
Max: 0.454
Number Of Bins: 20
Bin Interval: 0.092

LAS (Continued)

Supplemental Vertical Accuracy

LandCover Type: GRASS
Minimum DZ: -0.167
Maximum DZ: 0.741
Mean DZ: 0.357
Mean Magnitude DZ: 0.651
Number Observations: 5
Standard Deviation DZ: 0.351
RMSE Z: 0.476
95th Percentile: 0.741
Units: US Survey Feet

Histogram



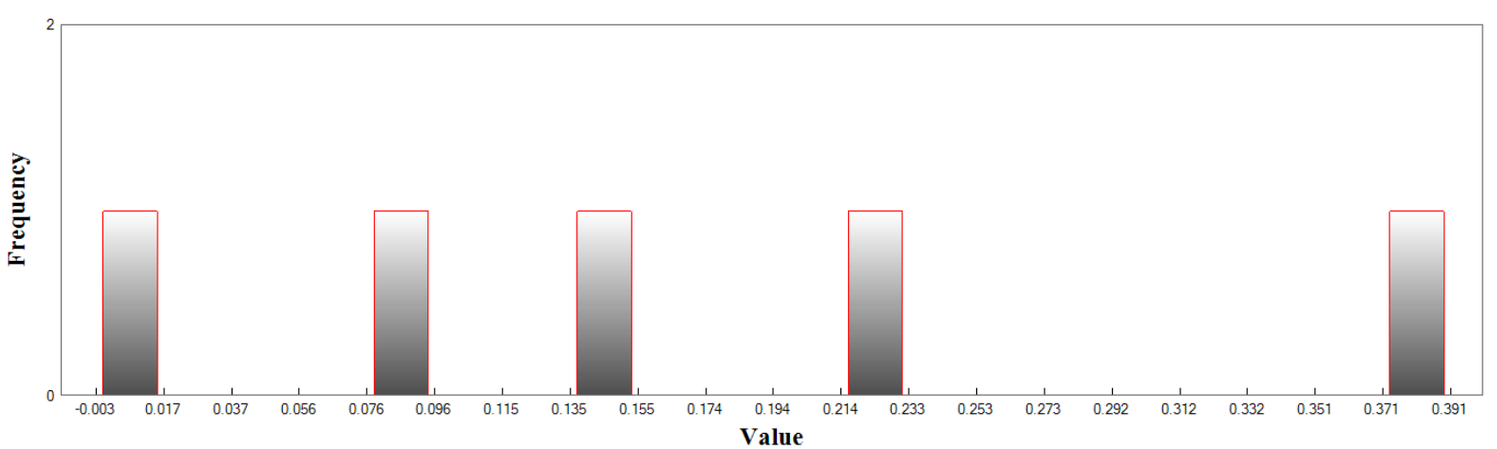
Min: -0.167
Max: 0.741
Number Of Bins: 20
Bin Interval: 0.045

LAS (Continued)

Supplemental Vertical Accuracy

LandCover Type: URBAN
Minimum DZ: -0.003
Maximum DZ: 0.39
Mean DZ: 0.169
Mean Magnitude DZ: 0.413
Number Observations: 5
Standard Deviation DZ: 0.15
RMSE Z: 0.216
95th Percentile: 0.39
Units: US Survey Feet

Histogram



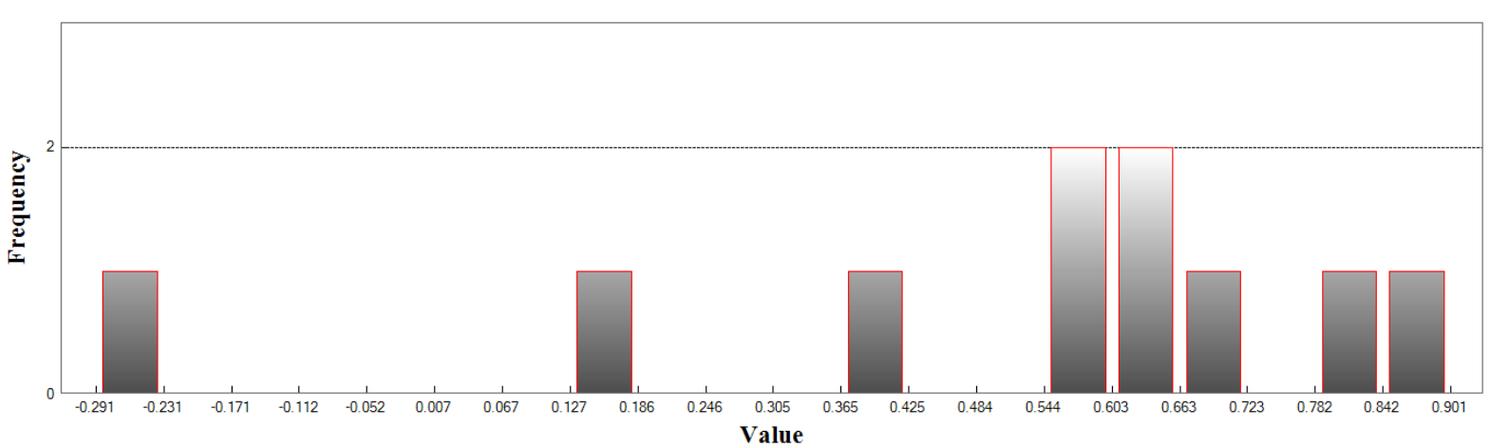
Min: -0.003
Max: 0.39
Number Of Bins: 20
Bin Interval: 0.02

LAS (Continued)

Supplemental Vertical Accuracy

LandCover Type: FOREST
Minimum DZ: -0.291
Maximum DZ: 0.901
Mean DZ: 0.506
Mean Magnitude DZ: 0.751
Number Observations: 10
Standard Deviation DZ: 0.346
RMSE Z: 0.603
95th Percentile: 0.901
Units: US Survey Feet

Histogram



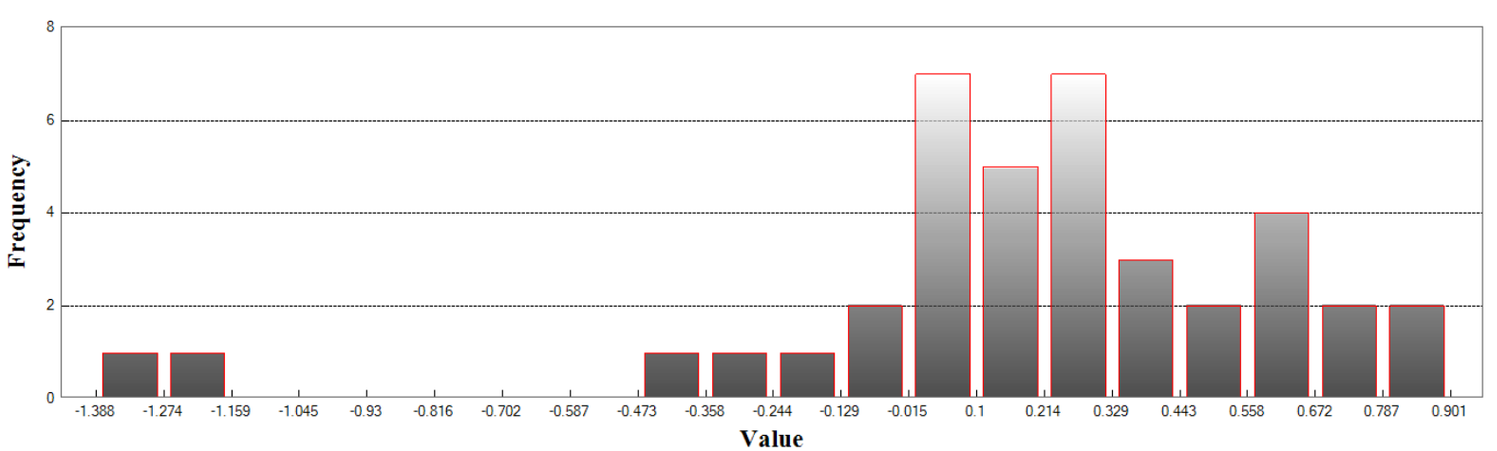
Min: -0.291
Max: 0.901
Number Of Bins: 20
Bin Interval: 0.06

LAS (Continued)

Consolidated Vertical Accuracy

LandCover Type: ALL
Minimum DZ: -1.388
Maximum DZ: 0.901
Mean DZ: 0.188
Mean Magnitude DZ: 0.605
Number Observations: 39
Standard Deviation DZ: 0.454
RMSE Z: 0.486
95th Percentile: 1.169
Units: US Survey Feet

Histogram



Min: -1.388
Max: 0.901
Number Of Bins: 20
Bin Interval: 0.114

LAS Header Checklist		Project: Prince William Sound-Valdez, AK
Vendor: Aerometric		**Reviewed By: Myra Hupfeld-Cousineau**
Files Reviewed: All 98 LAS files		
Section: Public Block		**Date: 10OCT2012**
Item	**Included**	**Comments**
File Signature ("LASF")	Y	
File Source ID	Y	Zero means an ID has not been assigned
Global Encoding	Y	Encoded as 0 has not been assigned
Version Major\Minor	Y	Version 1.2
System Identifier	Y	
Generating Software	Y	
Header Size	Y	
Offset to point data	Y	
Number of Variable Length Records	Y	5 in LAS file
Point Data Format ID (0-99 for spec)	Y	Format 1
Point Data Record Length	Y	
Number of point records	Y	
Number of points by return	Y	5 returns
X, Y, and Z scale factor	Y	
X, Y, and Z offset	Y	
X, Y, and Z Max	Y	Z values as US Survey Foot
X, Y, and Z Min	Y	Z values as US Survey Foot
Any field in the Public Header Block that is not required and is not used must be zero filled.	Y	

Required Public Block Item Definitions:

File Signature - The file signature must contain the four characters "LASF", and it is required by the LAS specification.
File Source ID (Flight Line Number if this file was derived from an original flight line) - This field should be set to a value between 1 and 65,535, inclusive. A value of zero (0) is interpreted to mean that an ID has not been assigned. In this case, processing software is free to assign any valid number. Note that this scheme allows a LIDAR project to contain up to 65,535 unique sources. A source can be considered an original flight line or it can be the result of merge and/or extract operations. All of the sources are the results of processing and are not based on the flight line number.
Global Encoding - This is a bit field used to indicate certain global properties about the file. The meaning of GPS Time in the Point Records 0 (not set) -> GPS time in the point record fields is GPS Week Time (the same as previous versions of LAS) 1 (set) -> GPS Time is standard GPS Time (satellite GPS Time) minus 1 x 109 . The offset moves the time back to near zero to improve floating point resolution.

Version Major\Minor - The version number consists of a major and minor field. The major and minor fields combine to form the number that indicates the format number of the current specification itself.
System Identifier - files often result from extraction, merging or modifying existing data files. Values should include: String identifying hardware ("ALS50"), "MERGE", "MODIFICATION", "EXTRACTION", "TRANSFORMATION", "OTHER" or a string up to 32 characters identifying the operation.
Generating Software – provides a mechanism for specifying which generating software package and version was used during LAS file creation (e.g. "TerraScan V-10.8", "REALM V-4.2" and etc.).
Header Size - The size, in bytes, of the Public Header Block itself
Offset to point data - The actual number of bytes from the beginning of the file to the first field of the first point record data field. This data offset must be updated if any software adds data from the Public Header Block or adds/removes data to/from the Variable Length Records.
Number of Variable Length Records - This field contains the current number of Variable Length Records. This number must be updated if the number of Variable Length Records changes at any time.
Point Data Format ID - The point data format ID corresponds to the point data record format type. LAS 1.2 define types 0, 1, 2 and 3.
Point Data Record Length - The size, in bytes, of the Point Data Record
Number of point records – The total number of point records within the file
Number of points by return - This field contains an array of the total point records per return. The first unsigned long value will be the total number of records from the first return, and the second contains the total number for return two, and so forth up to five returns.
X, Y, and Z scale factor - The scale factor fields contain a double floating point value that is used to scale the corresponding X, Y, and Z long values within the point records. The corresponding X, Y, and Z scale factor must be multiplied by the X, Y, or Z point record value to get the actual X, Y, or Z coordinate. For example, if the X, Y, and Z coordinates are intended to have two decimal point values, then each scale factor will contain the number 0.01.
X, Y, and Z offset - The offset fields should be used to set the overall offset for the point records. In general these numbers will be zero, but for certain cases the resolution of the point data may not be large enough for a given projection system. However, it should always be assumed that these numbers are used. So to scale a given X from the point record, take the point record X multiplied by the X scale factor, and then add the X offset. (Xcoordinate = (Xrecord * Xscale) + Xoffset, Ycoordinate = (Yrecord * Yscale) + Yoffset, Zcoordinate = (Zrecord * Zscale) + Zoffset)
Max and Min X, Y, and Z - The max and min data fields are the actual unscaled extents of the LAS point file data, specified in the coordinate system of the LAS data.

LAS Header Checklist		
Section: Variable Length Records		**Date: 10OCT2012**
Item	**Included (Y/N)**	**Comments**
GeoKeyDirectoryTag	Y	
User ID 'LASF_Projection'	Y	
Record ID: 34735	Y	
Length after Header	Y	
'GeoTiff Projection Keys'	Y	

Required Variable Length Record Definitions:

Georeferencing Information - Georeferencing for the LAS format will use the same robust mechanism that was developed for the GeoTIFF standard. The variable length header records section will contain the same data that would be contained in the GeoTIFF key tags of a TIFF file. Since LAS is not a raster format and each point contains its own absolute location information, only 3 of the 6 GeoTIFF tags are necessary. The GeoKeyDirectoryTag (34735), GeoDoubleParamsTag (34736), and GeoASCIIParamsTag (34737) records are used. Only the GeoKeyDirectoryTag record is required. The GeoDoubleParamsTag and GeoASCIIParamsTag records may or may not be present, depending on the content of the GeoKeyDirectoryTag record.
GeoKeyDirectoryTag Record (mandatory) - User ID: LASF_Projection, Record ID: 34735. This record contains the key values that define the coordinate system.
GeoDoubleParamsTag Record (Optional) - User ID: LASF_Projection, Record ID: 34736. This record is simply an array of doubles that contain values referenced by tag sets in the GeoKeyDirectoryTag record.
GeoAsciiParamsTag Record (Optional) - User ID: LASF_Projection, Record ID: 34737. This record is simply an array of ASCII data. It contains many strings separated by null terminator characters which are referenced by position from data in the GeoKeyDirectoryTag record.

LAS Header Checklist		
Section: Point Data Record		**Date: 10OCT2012**
Item	**Included (Y/N)**	**Comments**
Point record format 1,3,4, or 5	Y	
X, Y, Z	Y	
Intensity	Y	
Edge of Flight Line	Y	
Scan Direction Flag	Y	
Return Number	Y	
Number of Returns (given pulse)	Y	
Classification	Y	1, 2, 7, and 8
Scan Angle Rank (-90 to +90)	Y	-13 to 14
Point Source ID	Y	
GPS Time	Y	

Required Point Data Record Definitions:

X, Y, and Z – The X, Y, and Z values are stored as long integers. The X, Y, and Z values are used in conjunction with the scale values and the offset values to determine the coordinate for each point as described in the Public Header Block section.
Intensity – The integer representation of the pulse return magnitude
Edge of Flight Line – The Edge of Flight Line data bit has a value of 1 only when the point is at the end of a scan. It is the last point on a given scan line before it changes direction.
Scan Direction Flag – denotes the direction at which the scanner mirror was traveling at the time of the output pulse. A bit value of 1 is a positive scan direction, and a bit value of 0 is a negative scan direction (where positive scan direction is a scan moving from the left side of the in-track direction to the right side and negative the opposite).
Return Number – The Return Number is the pulse return number for a given output pulse. A given output laser pulse can have many returns, and they must be marked in sequence of return. The first return will have a Return Number of one, the second a Return Number of two, and so on up to five returns.
Number of Returns (for this emitted pulse) – The Number of Returns is the total number of returns for a given pulse. For example, a laser data point may be return two (Return Number) within a total number of five returns.
Scan Angle Rank – The Scan Angle Rank is a signed one-byte number with a valid range from -90 to +90. The Scan Angle Rank is the angle (rounded to the nearest integer in the absolute value sense) at which the laser point was output from the laser system including the roll of the aircraft. The scan angle is within 1 degree of accuracy from +90 to –90 degrees. The scan angle is an angle based on 0 degrees being nadir, and –90 degrees to the left side of the aircraft in the direction of flight.

Point Source ID – This value indicates the file from which this point originated. Valid values for this field are 1 to 65,535 inclusive with zero being used for a special case discussed below. The numerical value corresponds to the File Source ID from which this point originated. Zero is reserved as a convenience to system implementers. A Point Source ID of zero implies that this point originated in this file. This implies that processing software should set the Point Source ID equal to the File Source ID of the file containing this point at some time during processing.
GPS Time – The GPS Time is the double floating point time tag value at which the point was acquired. It is GPS Week Time if the Global Encoding low bit is clear and POSIX Time if the Global Encoding low bit is set (see Global Encoding in the Public Header Block description).

Classification – Standard set of ASPRS classifications

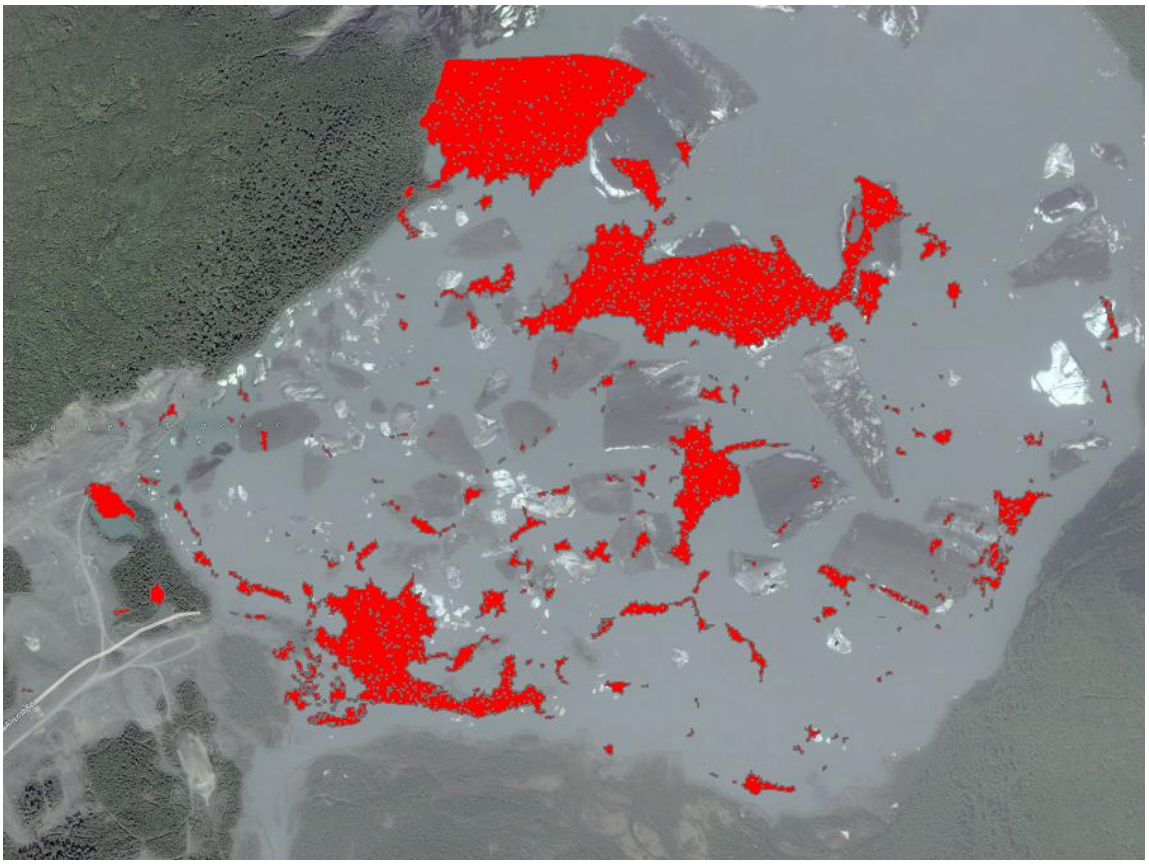
Classification Value	**Definition**
0	Created, Never Classified
1	Unclassified
2	Ground
3	Low Vegetation
4	Medium Vegetation
5	High Vegetation
6	Building
7	Low Point (noise)
8	Model Key-point (mass point)
9	Water
10	Ignored Ground (breakline proximity)
11	Withheld if Withheld bit is not implemented in processing software
12	Overlap (Should not be included)
13-31	Reserved for ASPRS Definition

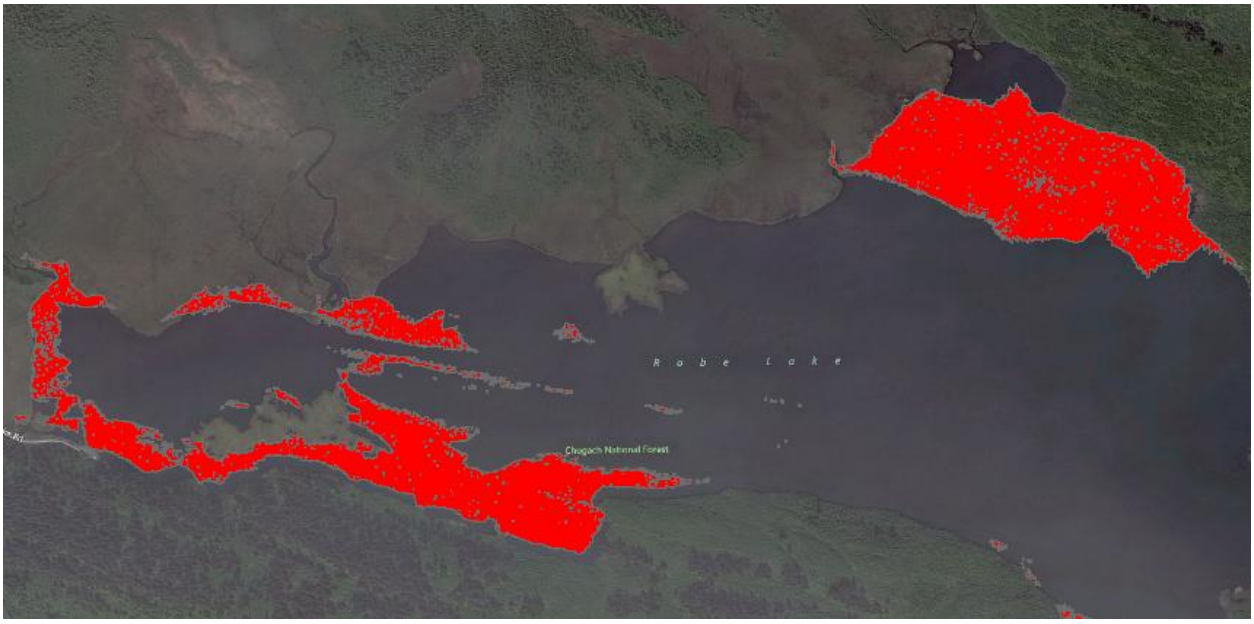
Classified LAS Data Checklist	Project: Valdez, Alaska
Vendor: Aerometric	**Reviewed By: JLH**

Section: Collection		**Date: 18OCT2012**
Item	**P/F/NA**	**Comments**
Cloud and fog free	P	
Snow free	P	
No unusual flooding	P	
Leaf-off conditions ground penetration adequate to produce a 3m NED	P	
Full Project Coverage Area buffered by 100 meters	P	
Multiple Discrete Returns (Minimum 3 per pulse)	P	4 returns
Intensity values for each return	P	
Nominal Pulse Spacing (NPS) of 1-2 meters	P	1.44 ppsm
Data Voids (Areas => (4xNPS) squared, measured using 1st-returns only)	P	
90% of NPSx2 cells raster shall contain 1 LiDAR point	P	99.94%
NAD83 or NAD83 HARN and NAVD88 (US Survey Feet or Meters)	P	NAD83 Meters, NAVD88 US Survey Foot
UTM or State Plane (US Survey Feet or Meters)	P	UTM 6
Point classification is to be consistent across the entire project.	P	
Single non-overlapped topologically correct polygon tiling scheme	P	
Tiles must have same coordinate system of LiDAR data	P	
Tiled deliverables without overlap and edge-match seamlessly and without gaps in both horizontal and vertical	P	

Section: 5-10% Visual Check		
Item	**P/F/NA**	**Comments**
Scan and profile	P	
Excessive Noise	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
“Over-smoothed” areas during filtering	P	
Corn Row Effects	P	

Valdez, Alaska Data Void Examples




Robe Lake
Chugach National Forest

STARR

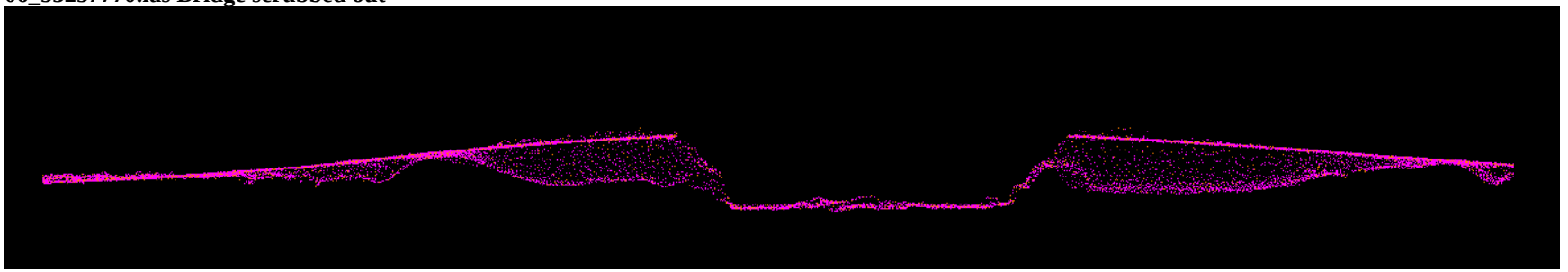
FEMA Region X
Valdez Alaska LiDAR Dataset

Classified LiDAR Micro Review

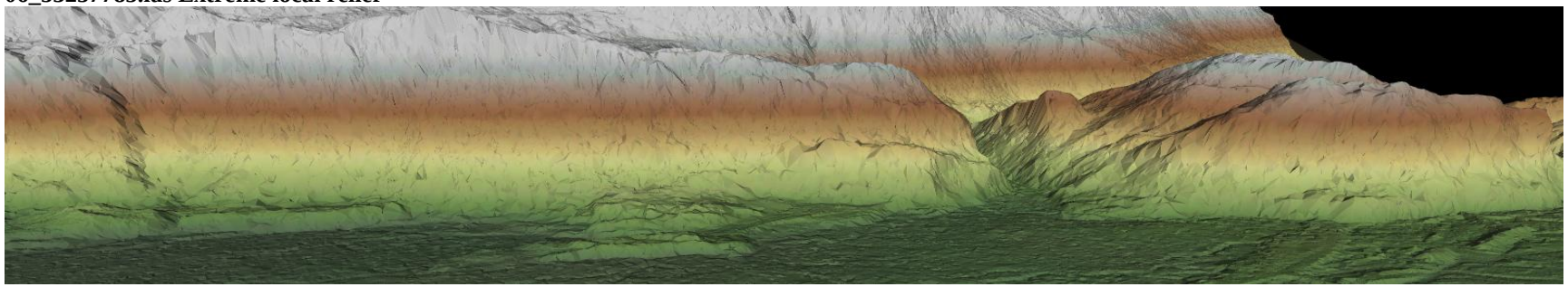
Quality Assurance Forms
11/13/2012

Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_53257770.las, 06_53257785.las, 06_53407755.las, 06_53407770.las, and 06_53557770.las		**Date: 31OCT2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	

06_53257770.las Bridge scrubbed out

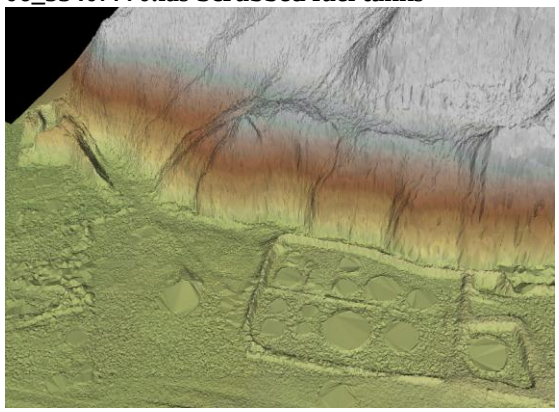


06_53257785.las Extreme local relief

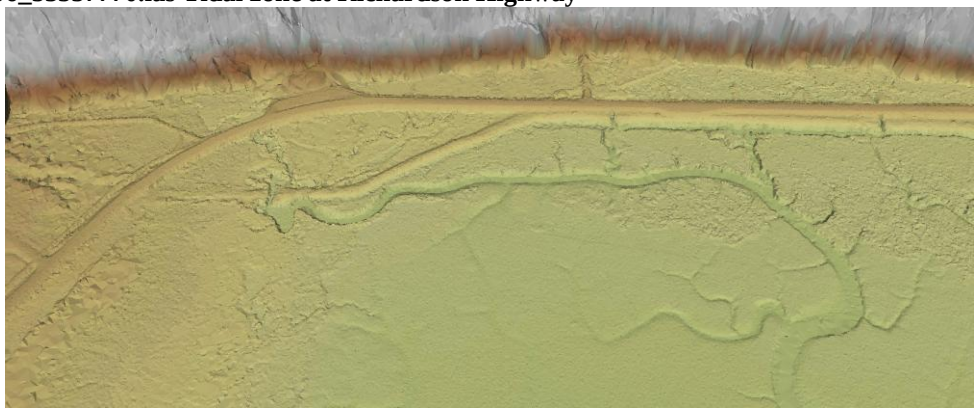


06_53407755.las Entrance to Valdez Harbor

06_53407770.las Scrubbed fuel tanks

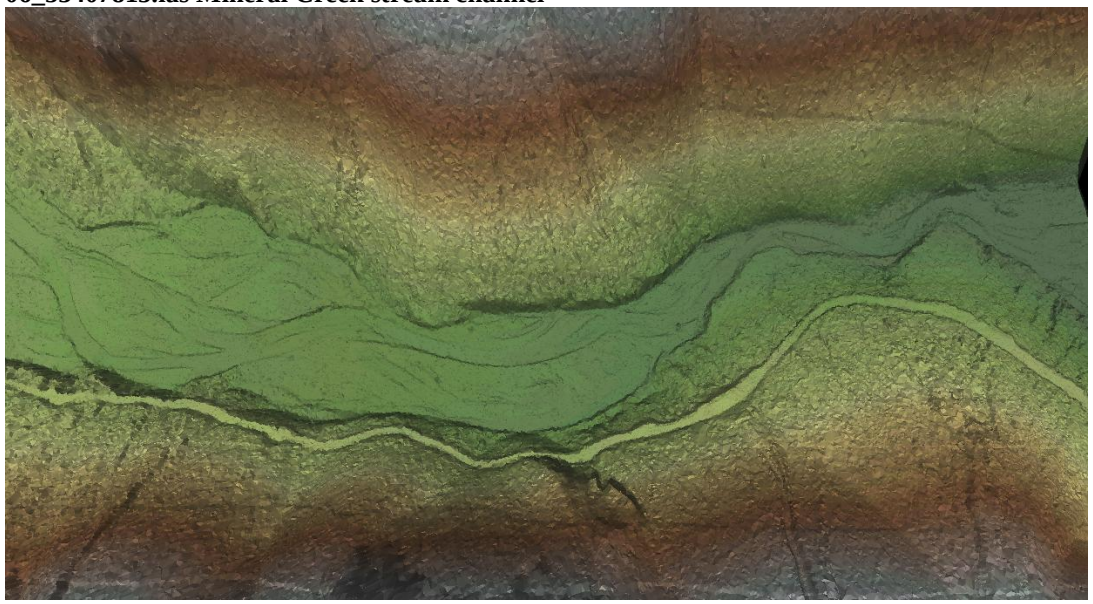


06_53557770.las Tidal zone at Richardson Highway



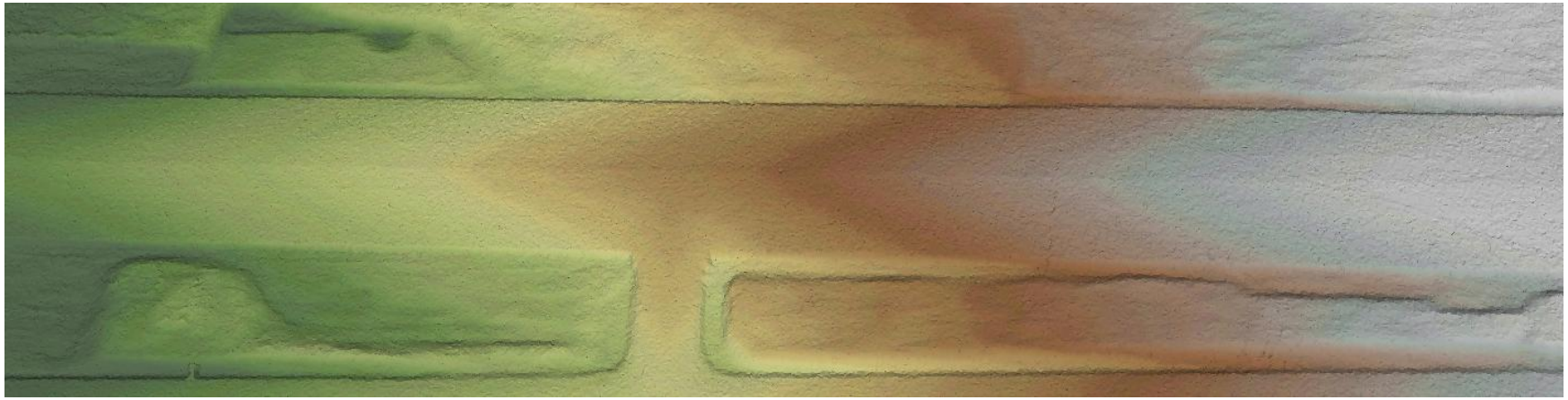
Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_53407815.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	

06_53407815.las Mineral Creek stream channel



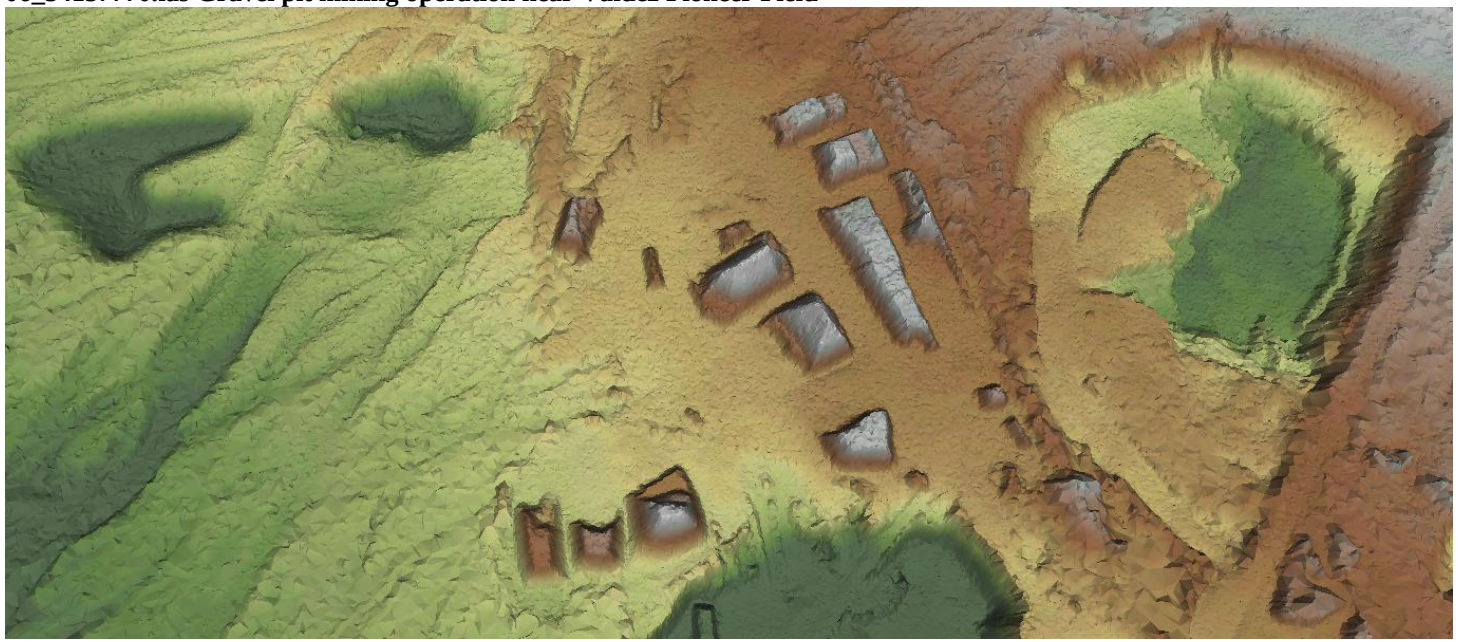
Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54007770.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Extremely Dense Point Cloud

06_54007770.las Valdez Pioneer Field bare earth



Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54157770.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Extremely Dense Point Cloud

06_54157770.las Gravel pit mining operation near Valdez Pioneer Field

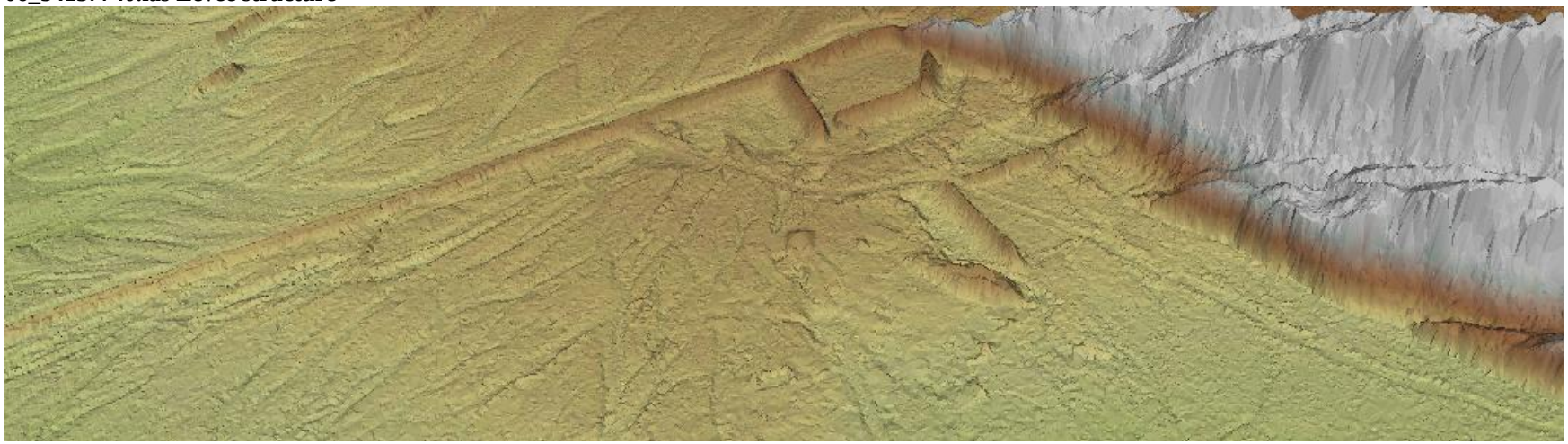


Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54007740.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Extremely Dense Point Cloud

06_54007740.las Bridge scrubbed out of bare earth and alluvial fan

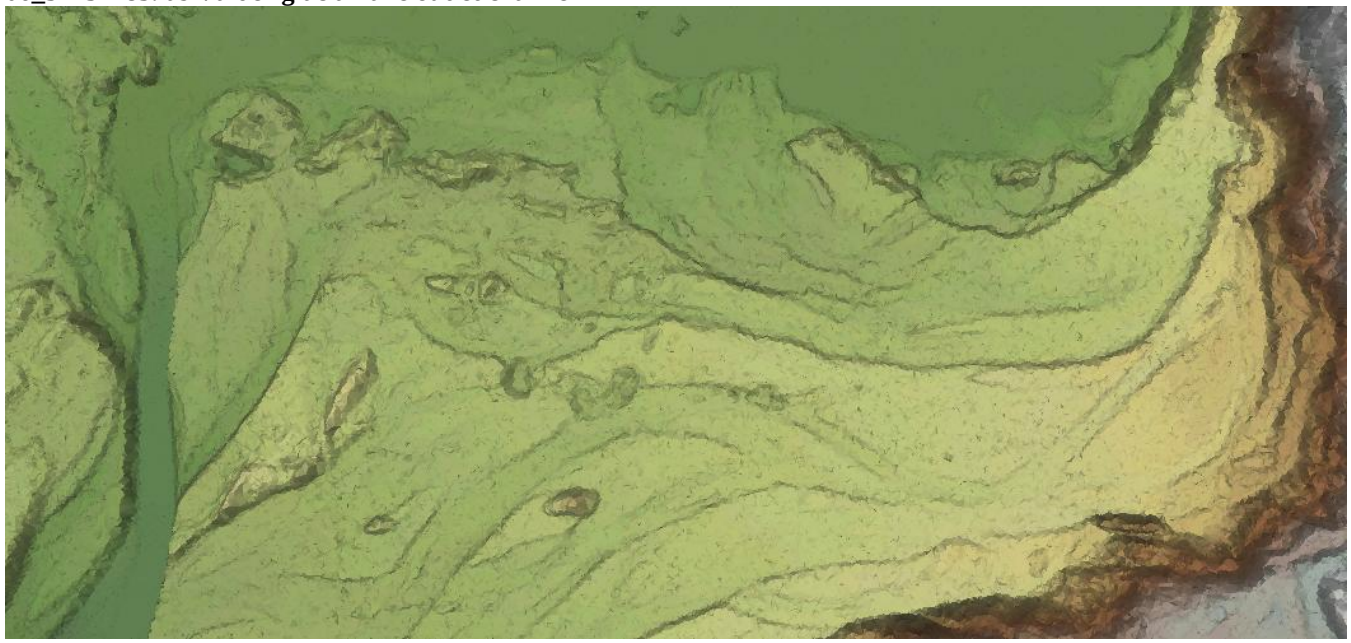
Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54157740.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Extremely Dense Point Cloud

06_54157740.las Levee structure



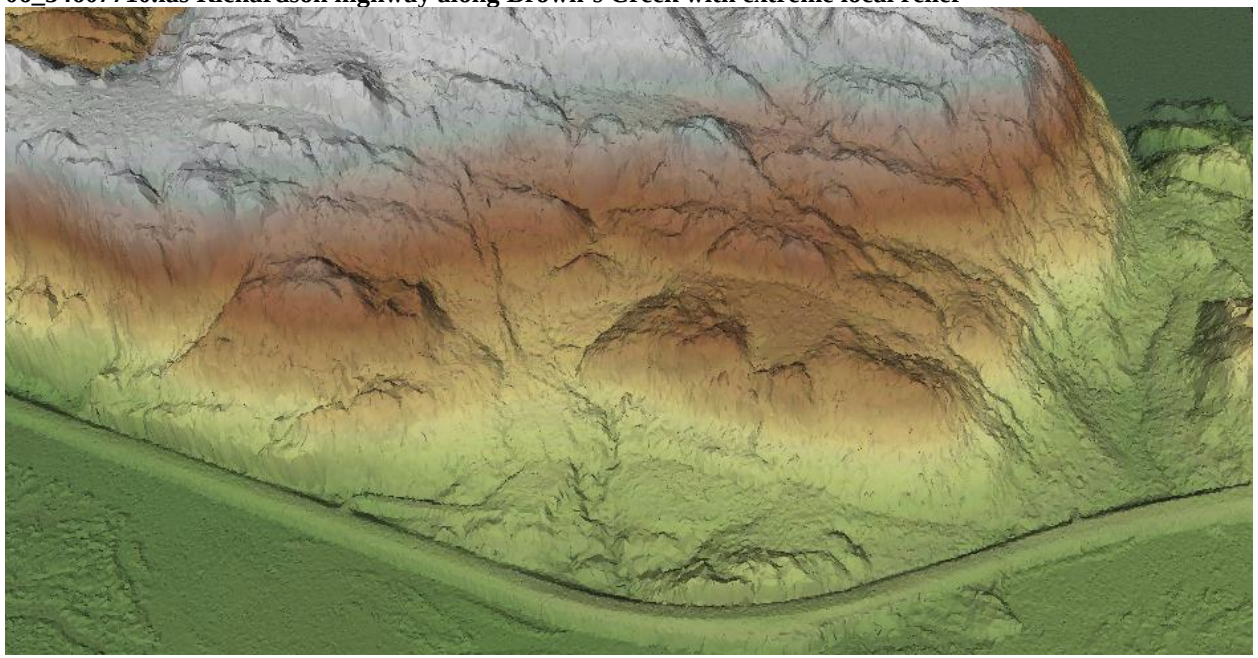
Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54457785.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	Extremely Dense Point Cloud

06_54457785.las Valdez glacial lake outlet channel



Classified Point Cloud Data Visual Checklist		Project: Valdez Alaska
Vendor: Aerometric		**Reviewed By: JLH**
LAS File: 06_54607710.las		**Date: 01NOV2012**
Item	**P/F/NA**	**Comments**
Scanlines removed from bare earth	P	
Excessive Noise in bare earth	P	
Elevation Steps	P	
Gaps/Voids	P	
Edge matching between tiles	P	
Artifacts have been removed from bare earth (vegetation, buildings, bridges, etc.)	P	
Proper definition of roads and drainage patterns	P	
"Over-smoothed" areas during filtering	P	
Corn Row Effects	P	
Mounds and Divots	P	
Other anomalies	NA	

06_54607710.las Richardson highway along Brown's Creek with extreme local relief



FEMA Final Deliverable Checklist		Project: Valdez, Alaska	Date:07NOV2012
Guidance: FEMA PM61 and G&S Appendix M 2011		Reviewed By: JLH	
Section: FEMA DCS Compliance			
Item	**P/F/NA**	**Comments**	
Folder Structure	P		
Correspondence	P	Transmittals to FEMA	
General			
Metadata (txt and xml)	P		
Correct naming convention (12345C_Terrain_metadata)	P		
Correct title and case number			
Purpose clearly describes floodplain mapping intention	P		
Bounding Coordinates match LAS tile index	P		
Place Keyword matches metadata naming convention	P		
Process Steps describes the LAS classifications	P		
All items listed in lineage are included in deliverable	P		
Process step matches the LAS classifications	P		
Projection information is correct	P		
Distribution information is correct	P		
Contact information is correct	P	FEMA Representative	
Project Narrative			
Purpose clearly describes floodplain mapping intention	P		
Text describes the LAS classifications	P		
Text includes spatial reference	P		
Text includes vertical accuracy test results	P		
Text includes scope of work	P		
Text includes MIP location	P		
LiDAR Compliance Form	P		
Survey Compliance Form	P		
Supplemental Data			
Survey Data and Vertical Accuracy Test Results	P		
LiDAR Collection Area	P		
QA Report and supporting documentation	P		
Pre and Post Flight Reports and supporting data	P		
LiDAR Project Tile Index			
All tiles listed in tile index are accounted for and have correct names	P		
Index does not have gaps or overlapping tiles	P		
Spatial reference is correct	P		

FEMA Final Deliverable Checklist		Project: Valdez, Alaska	Date:13NOV2012
Guidance: FEMA PM61 and G&S Appendix M 2011		Reviewed By: JLH	
Section: FEMA DCS Compliance Continued			
Item	**P/F/NA**	**Comments**	
Folder Structure	P		
Source			
Raw Point Cloud Data	P		
All tiles are present and accounted for	P		
Include tile index with all tiles included with correct names	P		
Index does not have gaps or overlapping tiles	P		
Spatial reference is correct	P		
Classified Point Cloud Data			
All tiles are present and accounted for	P		
Include tile index with all tiles included with correct names	P		
Index does not have gaps or overlapping tiles	P		
Spatial reference is correct	P		
Final			
Bare Earth DEM			
Vertical units correct	P	NAVD88 Linear US Survey Foot	
Tiled Erdas imagine files or other image format useable	P		
Project area in geotif format or other image format useable	P		
Spatial reference is correct	P	NAD83 UTM 6N Linear Meters	
Breaklines			
File is complete and covers project area	NA		
Spatial reference is correct	NA		
Contours			
Cartographic contours useable	P		
Analysis contours useable	P		
Vertical units correct	P		
Spatial reference is correct	P		
TIN			
Vertical units correct	P	NAVD88 Linear US Survey Foot	
ESRI Terrain useable	P		
Spatial reference is correct	P	NAD83 UTM 6N Linear Meters	