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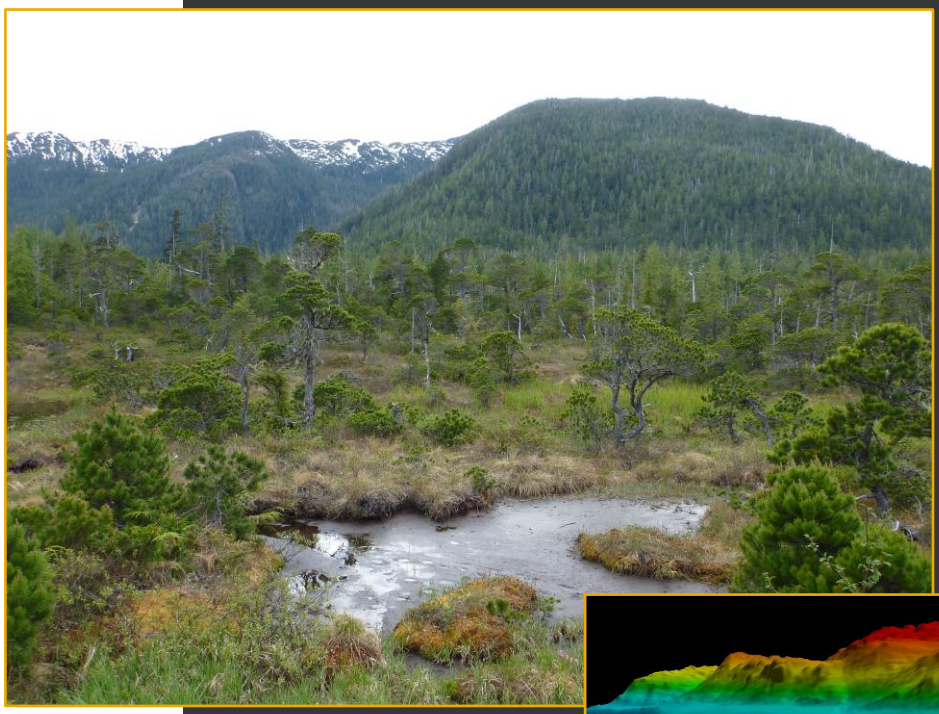

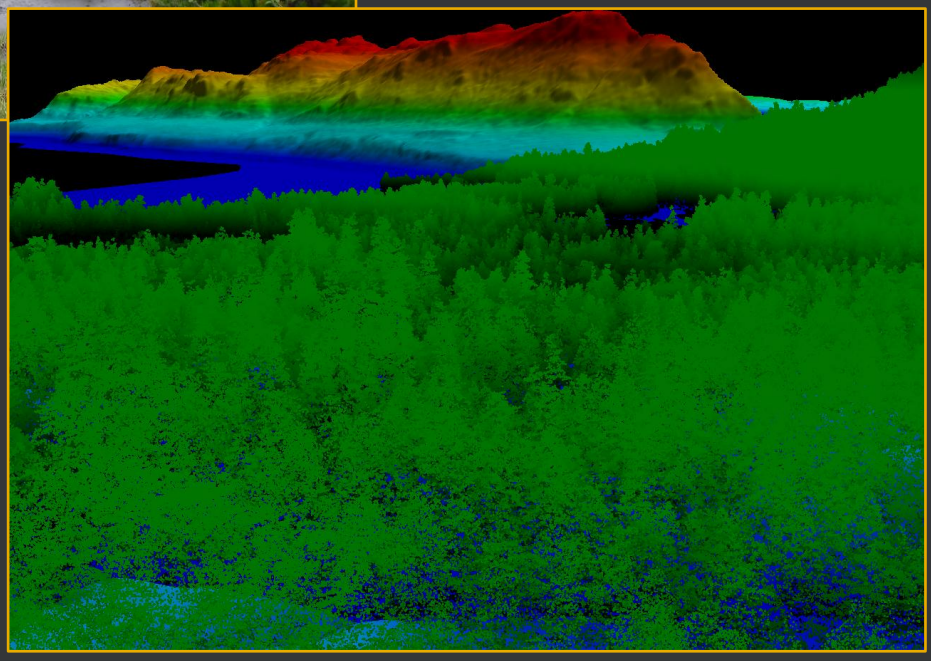

6130410 Vallenar Bay LiDAR

Processing and QA / QC Report

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Introduction

The University of Alaska Fairbanks, Geographic Information Network of Alaska (UAF/GINA) provided Aero-Metric, Inc. (AeroMetric) and Watershed Sciences, Inc. (WSI) with detailed specifications for this project in the spring of 2013. Planning and acquisition of airborne LiDAR data was carried out by WSI in early May of 2013. Acquired swaths are illustrated in Figure 1 below. For further details please refer to the acquisition report included in this delivery.

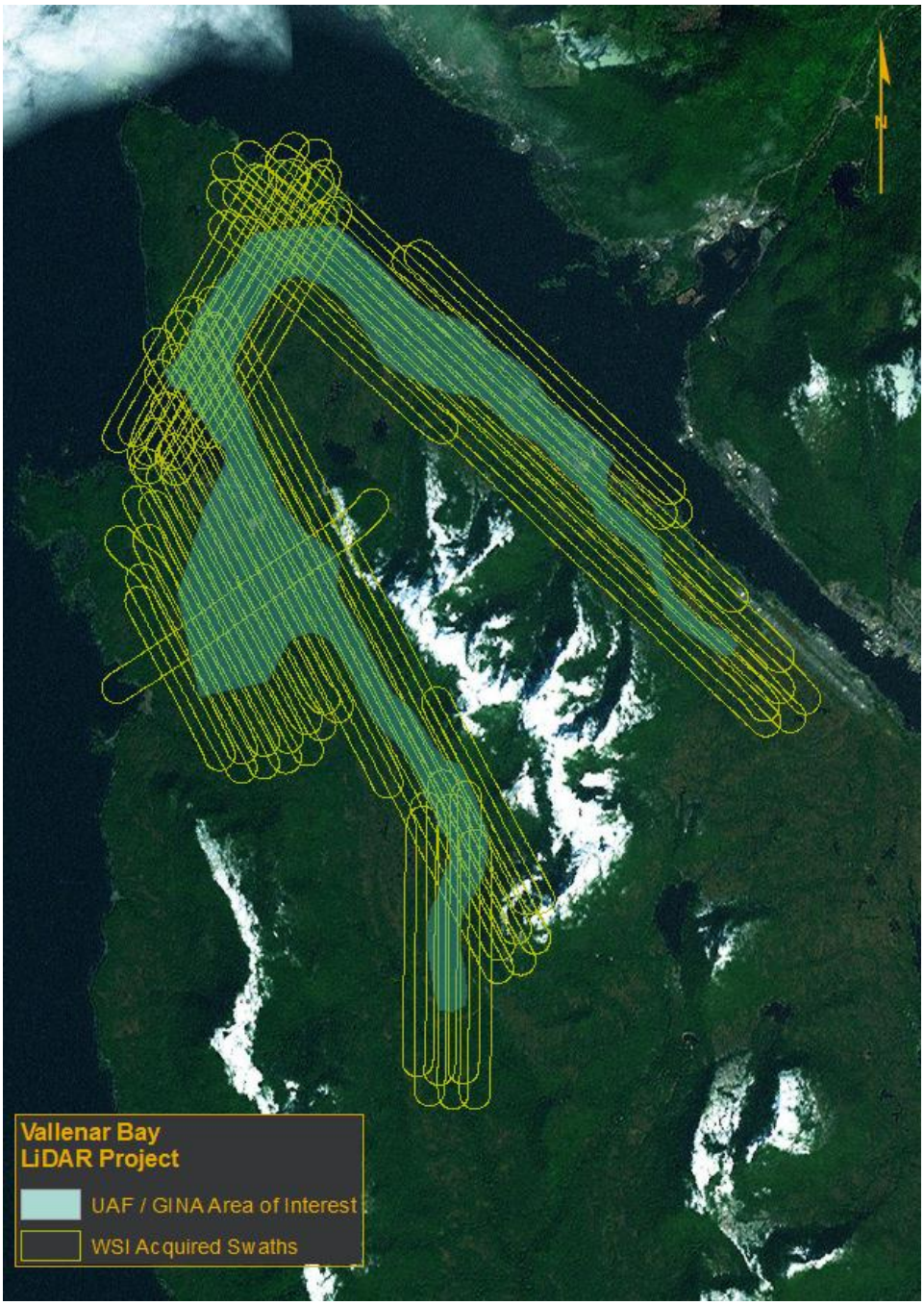

Figure 1 - Vallenar Bay LiDAR Acquisition

WSI Processing

Point Cloud Calibration

The WSI processing staff utilizes a suite of automated and manual tools to process the acquired LiDAR data. Front end processing consists of GPS control computations, smoothed best-estimated trajectory (SBET) calculation, and point cloud generation. Proprietary software is used to normalize the 8-bit intensity values taking into account auto gain control, atmospherics, and the angle of incidence.

The geometric relationships between overlapping and perpendicular swaths are analyzed to identify deviations in systematic attitude parameters. The automated calibration routines within TerraSolid's TerraMatch were used to solve for misalignment offsets (roll, pitch, and heading) and mirror scale. The final calibration step evaluates and corrects for vertical differences between adjacent flight lines to optimize relative accuracy of the data.

Data Classification

LiDAR point cloud classification is carried out using a combination of automated and manual techniques within TerraSolid's TerraScan suite. During this process WSI considers both the terrain in the area of interest and the intended application of the data. This allows for custom tailored methodologies to maximize workflow efficiency.

For this project, WSI classified ground, vegetation, buildings, bridges, and water. Fully classified point cloud files were provided to AeroMetric for review and use in product development. Files were formatted as LAS v. 1.2 with Adjusted GPS timestamps. Table 1 outlines the classes utilized for Vallenar Bay.

Table 1 – LAS Classification Schema for Vallenar Bay

Class Number	Name	Description
1	Unclassified	Objects not appropriate for any other class (cars, man-made non-building objects, etc.)
2	Ground	Bare Earth as determined through manual and automated routines
3	Low Vegetation	Vegetation within 12" of ground surface
4	Medium Vegetation	Vegetation greater than 12" but less than 36" above ground surface
5	High Vegetation	Vegetation greater than 36" above ground surface
6	Buildings	Permanent man-made structures
7	Noise	Returns associated with common errors such as bird strikes or erroneous last returns
8	Model Keypoints	Points selected at ~20' intervals from the ground class to use in contour generation
9	Water	Permanent water bodies
10	Breakline Proximity	Points Within1.5 US Feet of Breaklines on Land Side
14	Bridge Decks	Points on surface of bridge features

Preliminary QC Measures

Prior to delivery to AeroMetric, WSI evaluated the Vallenar Bay LiDAR data to verify that project specifications were being met. This included assessing the relative and absolute accuracies of the data, to ensure internal consistency of the survey and external consistency with control respectively.

Overall point density was assessed for the entire project and local point densities were assessed for 100 meter cells covering the area of interest. In both cases the minimum 8 points per square meter density was met by first-return points.

AeroMetric QA/QC

Upon receiving calibrated, classified LiDAR point cloud data from WSI, AeroMetric completed the following evaluations to verify that the Vallenar Bay project specifications were fully adhered to. All assessments detailed below were made using a minimum 30 meter buffer of the area of interest provided by UAF/GINA.

Data Completeness

Verification of point cloud completeness consists of two main components. First the point cloud data is reviewed to confirm the absence of voids. This is through the examination of intensity imagery and density grids.

The imagery can be used to identify clouds or other obstructions when present; the density grids provide a visual reference for areas where returns have thinned. In both cases raster data sets show NODATA where LiDAR points are lacking entirely.

The second completeness check is evaluating the first-return density of the data set. The Vallenar Bay project specifications called for a design pulse density of 8 points per square meter. Average first return density for the project area was calculated to be 10.5 points per square meter. First return densities as calculated for 30 meter cells are shown in Figure 2.

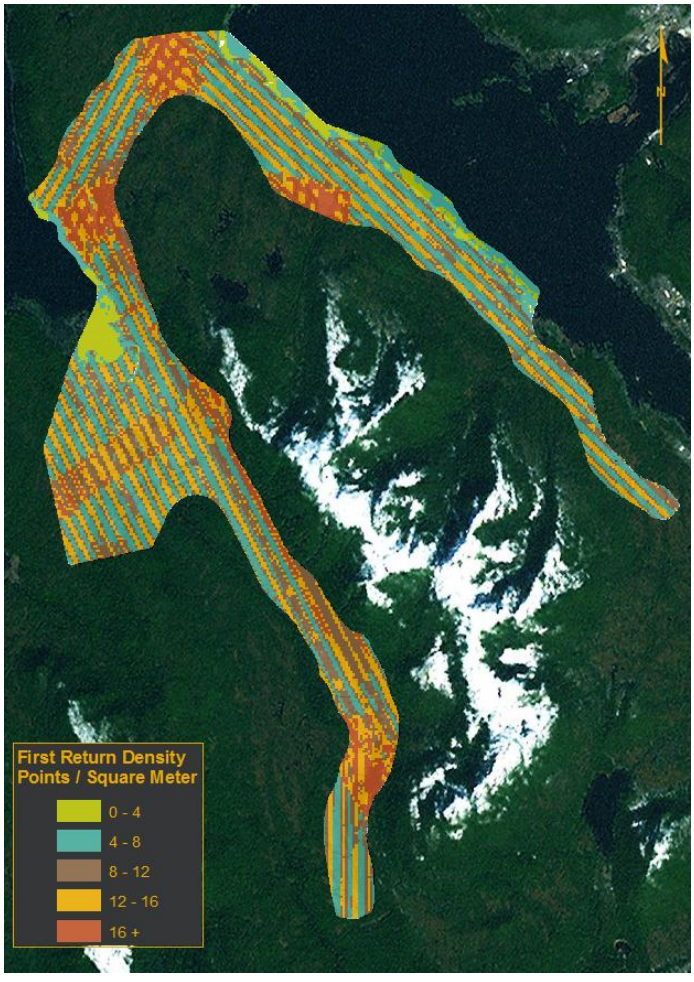

Figure 2 - Point Density of 30 meter Cells

Relative Accuracy Assessment

Relative accuracy is assessed to determine the internal consistency of a LiDAR data set. This is done through statistical analysis of laser ranges within individual swaths, as well as the relationships between multiple adjacent swaths.

Range Reproducibility

The specifications for Vallenar Bay called for a 5 centimeter or less RMSE of range reproducibility within individual swaths. This was tested by selecting two classified bridges within the project area and analyzing each swath of data that covered them.

A total of four point sets were used in this analysis: two swaths per bridge. Orthogonal regression was used to compute the least-squares best fit plane to each set of points. The results of this analysis are listed in Table 2; further details available in the 'Range_Reproducibility' directory included in this delivery.

Table 2 - Range Reproducibility Results

Flight Line	Surface	RMSE (meters)
5	Test Bridge 01	0.039
6	Test Bridge 01	0.033
7	Test Bridge 02	0.026
8	Test Bridge 02	0.025

Horizontal Accuracy

The stated requirement for horizontal reproducibility was ≤ 40 centimeters RMSE for the project as a whole. Computing the horizontal accuracy of a LiDAR point cloud directly is the topic of research, and presently there exists no standardized method for doing so. It is therefore common to rely on the stated sensor capabilities as published by the manufacturers.

Figure 3 is taken from Leica Geosystems' product specifications for the ALS60, the sensor model utilized on this project. This graph shows that horizontal accuracy is expected to be less than 20 centimeters at the 1 sigma level for a flying height of 900 meters, the height this data was collected at.

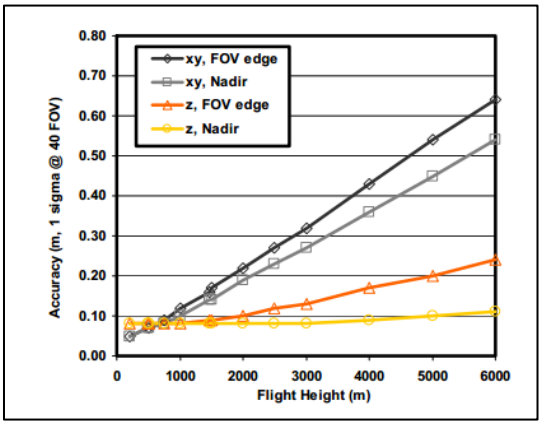

Figure 3 - Leica ALS60 Accuracies

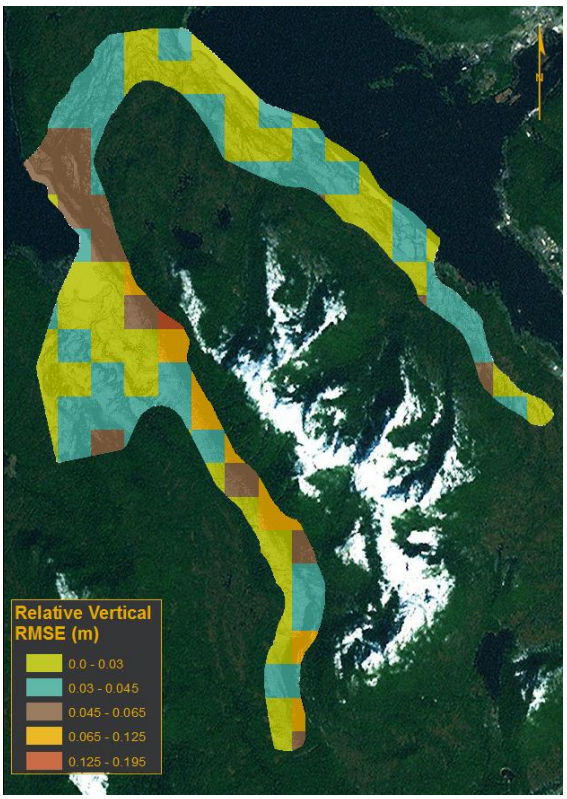

Figure 4 - Project Wide Relative Accuracies

Intra-Survey Reproducibility

The project specifications for Vallenar Bay required intra-survey reproducibility to have a vertical RMSE of no greater than 10 centimeters. Intra-survey reproducibility is a measure of agreement between swaths where they overlap. This is calculated by comparing bare-earth point elevations to those of overlapping flight lines. For the entire project area the overall RMSE from these calculations was 0.05 meters.

Furthermore, it was stated that any 500 x 500 meter area within the project area have a vertical RMSE of ≤ 20 centimeters on near-horizontal surfaces. Figure 4 shows 500 meter cells covering the project area with their respective relative RMSE values. Note that RMSE values tend to be higher in areas of more extreme terrain; however none of the areas exceed 20 centimeters.

Absolute Accuracy Assessment

Absolute accuracy is assessed to determine the consistency between a LiDAR data set and an external control source of higher accuracy, typically in the form of ground-surveyed check points. The Vallenar Bay absolute accuracy requirement as stated in the project specifications is a vertical RMSE of no greater than 15 centimeters as evaluated in open areas with slopes less than 20 degrees.

It is common practice within the LiDAR industry to test and report vertical accuracy in accordance with the methodology put forward by the National Digital Elevation Program (NDEP) in 2004. Notable organizations that have adopted these standards into their own include ASPRS and USGS.

Using these guidelines the Fundamental Vertical Accuracy (FVA) is computed using check points in open, relatively moderate terrain. Additionally, the Supplemental Vertical Accuracy (SVA) of various land cover categories (mixed brush, tall trees, etc.) is computed using check points collected within each respective category. Finally, the Consolidated Vertical Accuracy (CVA) is computed using all check points from the FVA and SVA tests.

As the FVA is computed using check points in open, moderate terrain, it is assumed that for a well calibrated LiDAR data set, the errors will conform to a normal distribution. As a result, NDEP calls for reporting the FVA as $RMSE_z$ * 1.96 to obtain the accuracy at the 95% confidence interval per the National Standard for Spatial Data Accuracy (NSSDA).

Since the check points utilized in the computation of any SVA values are often in regions where LiDAR data is prone to greater variation in error (denser vegetation, swampy terrain, etc.), a normal distribution is not expected. Therefore the NDEP recommends reporting SVA and the subsequent CVA values at the 95th percentile. Table 3 contains the computed FVA, CVA, and SVA values for this project. Point listings and full statistical results are available in the 'Vertical_Accuracy' directory included in this delivery.

Table 3 – Vertical Accuracy Results

Category	Number of Points	Accuracy (meters)	Method
FVA	634	0.084	RMSE * 1.96
Open - Logged	27	0.20	95th Percentile
Tall Grass	22	0.34	95th Percentile
Mixed Brush	27	0.19	95th Percentile
Mature Trees	29	0.14	95th Percentile
Small Trees	23	0.55	95th Percentile
CVA	762	0.14	95th Percentile

Deliverable Production

Deliverable Tiling Scheme

Once it has been fully verified that the LiDAR point cloud data was collected, calibrated, and classified to meet project specifications, final products are generated. Figure 5 shows the tiling scheme utilized for all deliverables generated for the Gravina to Vallenar Bay corridor.

The tiling scheme is comprised of 4000 x 4000 US Survey Foot tiles, set on even intervals relative to the Alaska State Plane Zone 1 origin. Tiles are named sequentially beginning in the northwest and progressing to the southeast.

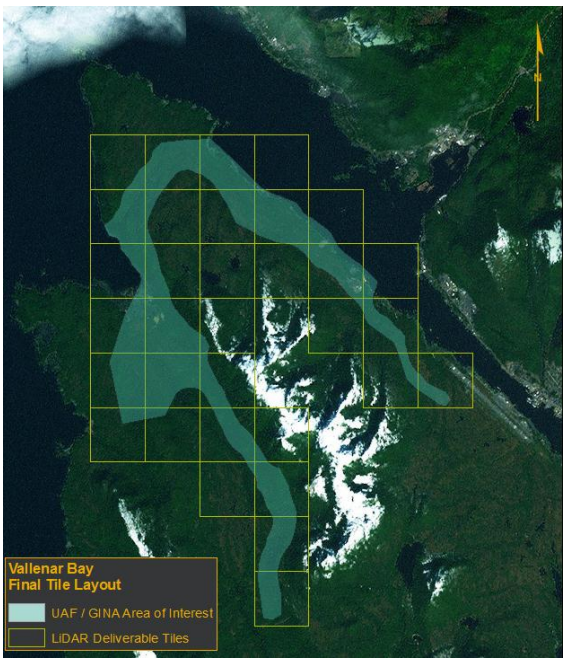

Figure 5 - Final Tile Layout

Spatial Reference

LiDAR data was horizontally tied to the NGS CORS network through the use of OPUS derived positions in the GPS processing phase. Vertically the data is tied to NAVD88 through the application of undulation values from the published GEOID12A model to the ellipsoid heights computed using processed GPS and range data. Table 4 outlines the final spatial reference parameters.

Table 4 – Deliverable Spatial Reference

Horizontal Datum	NAD83 (2011) Epoch 2010.0
Coordinate System	Alaska State Plane Zone 1
Vertical Datum	NAVD88
Geoid Model	GEOID12A
Units	US Survey Feet

Final Products

Final deliverable products were generated using a variety of industry standard and proprietary tools. Table 5 outlines the products included in this delivery.

Table 5 – Deliverable Product Listing

Product	Resolution	Format	Notes
Bare Earth Digital Elevation Models	2 feet	GeoTIFF	
Unclassified Point Cloud	N/A	LAS 1.2	All points in Class 0
Classified Point Cloud	N/A	LAS 1.2	See Table 1 for Classes
Intensity Images	2 feet	GeoTIFF	
Civil 3D Surfaces	N/A	Civil 3D 2012 / LandXML 1.2	ASCII Point files used included with drawings
AOI / Tile Index	N/A	ESRI Shapefile	As Approved by UAF / GINA
Metadata	N/A	FGDC Compliant XML	
Project Reports	N/A	PDF / Other	Acquisition, Survey, and Processing Reports with Supplemental Files