SURVEY & PROCESSING REPORT

FOR

FY15 TOPO-BATHY LIDAR, ELWHA RIVER, WA

Prepared by:

GEOMATICS DATA SOLUTIONS

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On Behalf of:

WOOLPERT
DESIGN | GEOSPATIAL | INFRASTRUCTURE

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TABLE OF CONTENTS

1. INTRODUCTION

Geomatics Data Solutions (GDS), Inc. was sub-contracted by Woolpert, Inc. to conduct a topo-bathy lidar survey of the Elwha River near Port Angeles, Washington as part of task order G15PD01145, under USGS contract G10PC00057. The scope of services included acquisition, processing and deliverables. Task order G15PD01145 also includes a topo lidar only QL2 survey of the river to be conducted in Spring 2016. The topo only QL2 survey is not discussed here and a separate report will be provided, once acquired.

This report presents the methods used for topo-bathy data acquisition, processing, QC analysis and deliverable creation. Final products delivered to USGS included LAS files by flight line and by tile, bare-earth digital elevation models, intensity images, ortho-rectified imagery mosaics, associated metadata and this report.

1.1. Survey Area

The survey area for the topo-bathy portion of the task order covers the lower mouth of the Elwha River and along the Eastern Coast from where the Elwha River opens into the Salish Sea (Figure 1). The survey area provided was buffered 120m for acquisition and delivery.

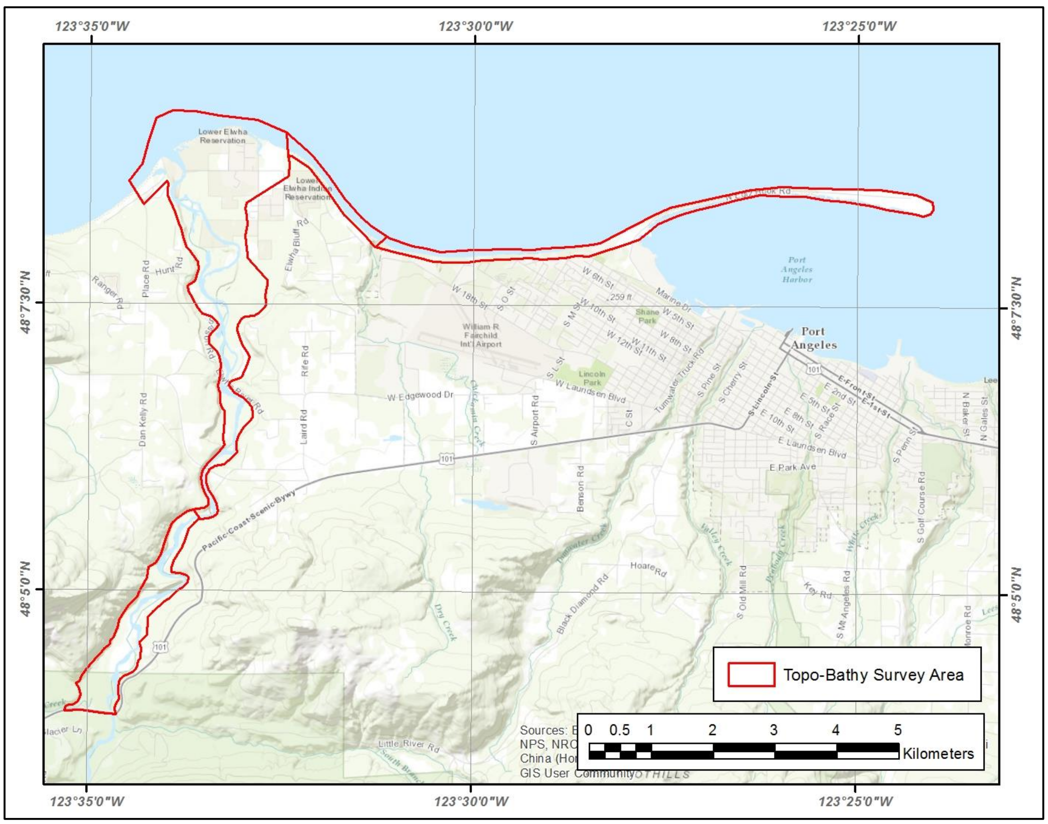

Figure 1: Overview of Survey Area

2. DATA ACQUISITION

All lidar data were acquired using a Chiroptera II (CHII) sensor owned and operated by GDS. The sensor was mounted in a Leica PAV100 gyro-stabilized mount integrated with a NovAtel SPAN GNSS and LCI-100C IMU. Real time navigation and GNSS/IMU data logging was provided by Leica FlightPro software. Lidar data were logged on the Airborne Hydrography, AB (AHAB) operator console.

The aircraft was mobilized and a calibration flight was conducted at Scappoose Airport, WA on 26 September, 2015. Project data were acquired in 2 flights: one on 28 September, 2015 and a second on 29 September, 2015.

2.1. Mobilization

The CHII sensor was installed in a Cessna 404 (N475RC) aircraft provided by Woolpert (Figure 2). A sensor calibration flight was carried out over the Scappoose airport on 26 September, 2015. The aircraft then transited to the survey site the following day, after data verification.

Figure 2: Mobilized Aircraft

2.1.1. Aircraft Offset Survey

Physical mounting offsets between the GNSS antenna, IMU and gyro-stabilized mount were determined through a combination of manual measurements and iterative processing in NovAtel Inertial Explorer software.

Manual measurements were taken from the GNSS antenna to the reference point on the IMU CHII sensor. These are then added to the known offset between the IMU reference point and the rotation center of the gyro-stabilized mount to calculate the preliminary offset between the GNSS antenna and sensor reference point. This preliminary value was then used to seed the post-processing software which, through an iterative computation, uses the dynamic accelerations and rotations during flight to refine the offsets. Once the solution converges, the final offsets are entered into the flight management software and used in subsequent post-processing of the GNSS/IMU data for final trajectories.

Final offsets, shown in the Leica reference frame, are presented in Table 1.

Table 1: Aircraft Offsets

Lever Arm	X (forward)	Y (right)	Z (down)
Reference to GNSS Antenna L1 Phase Center	0.005 m	-0.008 m	-1.307 m
Reference to IMU	-0.004 m	-0.006 m	-0.324 m
Reference to IMU Rotation	0 °	0 °	90 °

2.2. Calibration

Field calibration of the CHII system is carried out to eliminate systematic errors by calculating corrections for boresight errors, scanner angle errors, remaining IMU angle errors and any necessary internal timing errors. In order to verify or compute the field calibration, the following lines are flown (Figure 3):

a. 2 x Line A over mixed terrain with flat or gentle slopes and features such as peaked roof buildings (1 x each direction)
b. 1 x Line B offset +50% from Line A in one direction
c. 1 x Line C offset -50% from Line A in the same direction as Line B

d. 2 x Line D orthogonal to previous lines (1 x each direction)

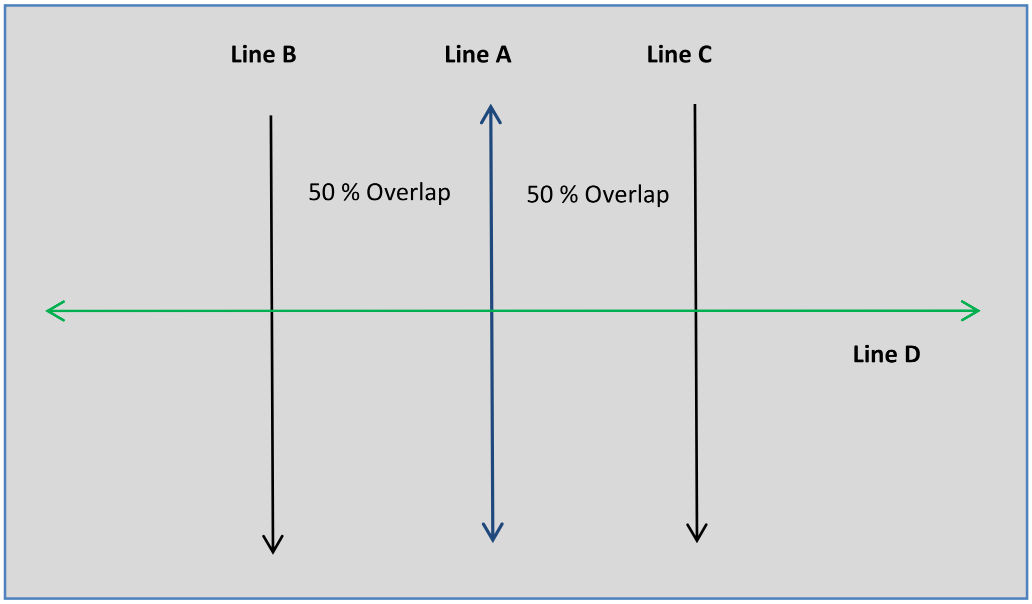

Figure 3: Schematic of CHII Calibration Lines

A set of calibration lines were acquired at 1000m, 500m, and 400m altitude. All sets of lines are used to calibrate and verify the topographic lidar, while the 500m and 400m lines are used for the bathymetric lidar.

Calibration values are calculated using the automatic calibration routine within the Leica Lidar Survey Studio (LSS) software. This utility first identifies patches (areas) of gentle slope within the overlap region of all the lines to use for calibration. Patch selection prevents areas of vegetation, side of cars or buildings, from being used in the calibration process. Next, the utility compares the front side and back side of the elliptical scan within the same line, as well as comparing all lines to each other, to identify suitable calibration parameters such that data within the patches match. The procedure is iterative and continues until the best possible solution is computed.

Calibration of the topo laser was done using the 1000m altitude lines together. Calibration of the shallow channel was then done (independently from the topo laser), using data from 500m and 400m altitude together.

At each step of the calibration process, quality assurance is conducted to ensure values being calculated are valid. This is done using the Leica LSS Quality Control Utility. Two types of checks are done; firstly the front scan is compared to the back scan for every line. In this case we expect the average error to be small (1 to 2 cm). Then a single line is chosen as a baseline and is compared to every other line. Again we would expect the average errors to be small. In addition, the data is visually reviewed. In particular, features are studied to ensure lines from different directions show structures in the same position, in other words, verifying horizontal accuracy is maintained. These tests all provide assurance of relative accuracy.

Ground truth is not used within the automatic calibration routine, however ground truth can be used to verify absolute accuracy.

For this project, calibration lines were acquired over the runway and surrounding area at Scappoose Airport. Ground truth data over the area was acquired by GDS using post-processed kinematic (PPK) survey techniques.

Results from the calibration verification checks are provided in Table 2 below. Results are good and indicate that calibration was successful.

Table 2: Calibration QA Results

Test		Topo 1000m	Topo 500m	Topo 400m	Bathy 500m	Bathy 400m
Front to Back Scan Comparison	Average Error (m)	0.0192	0.0124	0.0078	0.0230	0.0165
	Std. Dev. of Error	0.0050	0.0032	0.0014	0.0026	0.0026
Line to Line Comparison	Average Error (m)	0.0197	0.0119	0.0242	0.0205	0.0245
	Std. Dev. of Error	0.0094	0.0049	0.0077	0.0035	0.0064

A comparison to the ground truth was also conducted. Results presented below show data is within required accuracy specifications.

Table 3: Calibration Ground Truth Comparisons

	Topo 1000m	Topo 500m	Topo 400m	Bathy 500m	Bathy 400m
Average dz (m)	-0.0209	-0.0027	-0.0019	0.0061	0.0085
Root mean square (m)	0.0292	0.0126	0.0164	0.0244	0.0238
Standard Deviation (m)	0.0204	0.0123	0.0163	0.0236	0.0222

2.3. Survey Operations

Port Angeles Airport was used as the base of operations for survey. The majority of the survey area was acquired on 28 September, 2015. After field review, a small gap was discovered in the topo lidar data, and a single flight line was acquired to fill the gap on 29 September, 2015. Airborne collection logs are provided in Appendix A. Flown survey lines are shown in Figure 4.

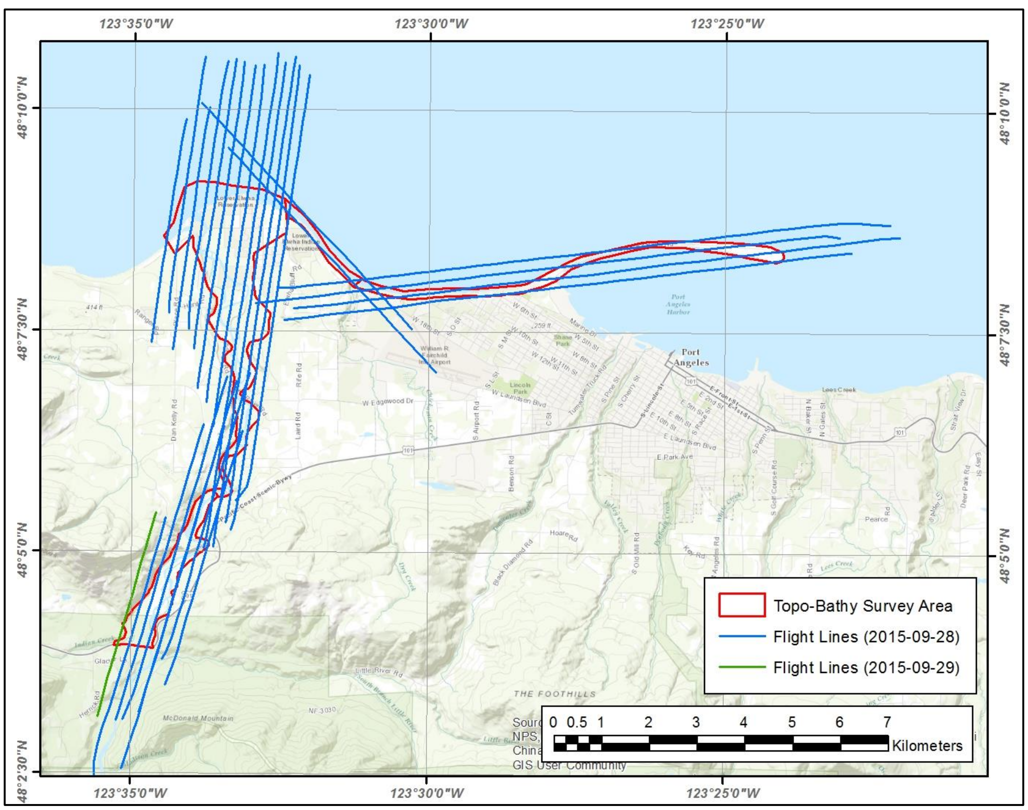

Figure 4: Flight Lines Acquired

A GNSS base stations was set up over NGS control point AC5475 at the Port Angeles airport for both survey flights. The NGS Datasheet for AC5475 is provided in Appendix B.

For the topo only part of this task order, data is required to be collected when the tide level at the NOAA tide gauge at Port Angeles, WA (9444090) is less than 0.4m above MLLW. Although not a requirement for the topo-bathy part of the task order, data were acquired close to low tide. During acquisition verified water level data ranged from 0.355m to 1.206m above MLLW.

2.3.1. THE CHIROPTERA II

All lidar data were acquired using a Chiroptera II (CHII) sensor. The CHII is the latest generation topographic and bathymetric lidar sensor commercially available. The system provides denser data than previous traditional bathymetric lidar systems. It is unique in its ability to acquire bathymetric lidar, topographic lidar and 4-band digital camera imagery simultaneously.

The CHII provided 35 kHz shallow bathymetric data and 300 kHz topographic data for this topo-bathy collect. 4-band 80 MP digital camera imagery was also collected simultaneously with the sensor's RCD-30 camera.

The bathymetric and topographic lasers are independent and do not share an optical chain or receivers, so they are optimized for their specific function. As with any bathymetric lidar, maximum depth penetration is a function of water clarity and seabed reflectivity. While the Chiroptera was designed to penetrate to 1.5 times the secchi depth, past projects have shown consistent penetration greater than 1.7 times the secchi depth, offering the best bathymetric penetration among competing shallow water sensors.

Both the topographic and bathymetric sub-systems use a palmer scanner to produce an elliptical scan pattern of laser points with a degree of incidence ranging from +/-14° (front and back) to +/-20° (sides), providing a 40° field of view. This has the benefit of providing multiple look angles on a single pass and helps to eliminate shadowing effects. This can be of particular use in urban areas, where all sides of a building are illuminated, or for bathymetric features such as the sides of narrow water channels, or features on the seafloor such as smaller objects and wrecks.

The bathymetric laser is a diode pumped class 4 laser which operates in the green spectrum. Full waveform data is acquired for every pulse. The topographic laser operates in the infra-red spectrum at 1064nm. Up to 4 returns per pulse are acquired from each lidar.

For this project, the flight parameters shown in Table 4 were used to provide 100% coverage.

Table 4: CHII Survey Parameters

Topo PRF (kHz)	300
Topo Points per m^2	11
Bathy PRF (kHz)	35
Bathy Points per m^2	1.29
Swath Width (m)	280
Flight Line Sidelap (%)	15
Altitude (m)	400
Survey Speed (knots)	125

The Chiroptera II system includes a NovAtel SPAN GNSS system with an LCI-100C IMU for aircraft position and orientation. Flight lines are shown on a pilots display, and the aircraft is controlled by the pilots at all times. Information from the IMU are also used in real-time by the PAV100 gyro-stabilized mount to compensate for deviations in pitch and roll. Aircraft bank angles were restricted to 20º to avoid any potential GPS dropouts. No flights were planned if the PDOP was expected to go above 3.0.

Data were monitored for quality during acquisition using the Operators Console running on the AHAB collection computer. The operator monitored system status of the scanners and receivers, waveforms, camera images, data coverage, flight lines and the health of the navigation system.

All data were recorded to a removable solid state hard disk. At the end of the flight the hard disk was removed and taken to the field office where data was copied on to backup disks for transmittal back to the main processing office. Data was reviewed daily in the field for quality and coverage.

2.3.2. Positioning

Position and orientation data were acquired in the aircraft using a NovAtel SPAN with LCI-100C IMU. All data were post-processed using NovAtel Inertial Explorer software to provide a tightly-coupled kinematic position and orientation solution.

For every flight, a GNSS base station was set-up to serve as a control point, collecting raw dual frequency observables at 2Hz. Base station data were uploaded to the NGS's Online Positioning Users Service (OPUS) to verify coordinates of the control point. Published control was used for processing. Table 5 shows the control points used for base stations during the survey.

Table 5: GNSS Base Stations

Survey Area	Control Point	Source	Latitude	Longitude
Calibration – Scappoose, WA	1S4-D	NGS	45° 46' 38.95702''N	122° 51' 45.17290"W
Survey – Elwha, WA	AC5475	NGS	48° 07' 30.75981"N	123° 30' 08.01501"W

3. DATA PROCESSING

An overview of GDS's established CHII processing workflow is presented in Figure 5. Initial data coverage analysis and quality checks to ensure there were no potential system issues were carried out in the field prior to demobilization of the sensor. Final processing was conducted in GDS's offices.

In general, data were initially processed in Leica's Lidar Survey Studio (LSS) using final processed trajectory information. LAS files from LSS were then imported to a Terrascan project where spatial algorithms were used to remove noise and classify bare earth/ground. Manual review was conducted in both Terrascan and LP360 prior to product creation.

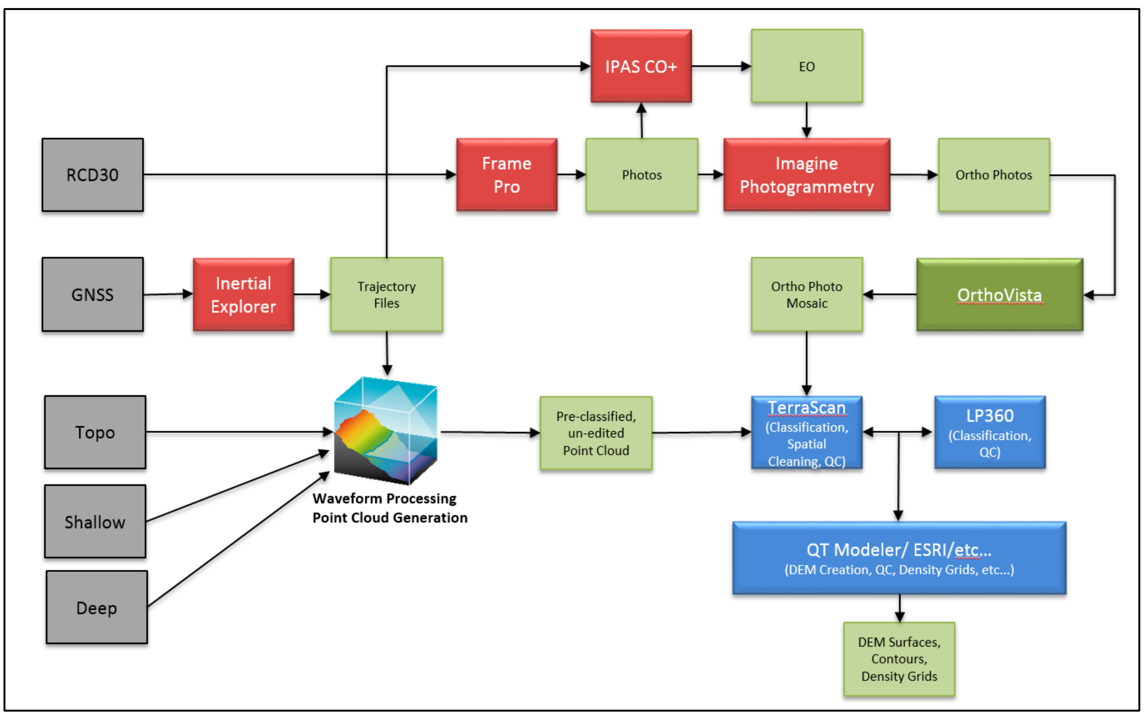

Figure 5: Overview of Processing Work Flow

3.1. Position

Final trajectory data were post processed in NovAtel Inertial Explorer. Base station data were converted to GPB format and imported with aircraft GNSS and IMU data. Lever arms, shown in the NovAtel reference frame, are presented in Table 6. Inertial Explorer accounts for the fixed offset between the reference point and IMU and uses a multi-pass algorithm to compute a tightly-coupled solution.

Table 6: Inertial Explorer Offsets

Lever Arm	X (right)	Y (forward)	Z (up)
Reference to GNSS Antenna L1 Phase Center	-0.003 m	0.009 m	0.983 m
Reference to IMU Rotation	0 °	180 °	0 °

3.2. Imagery

Imagery data collected with the RCD30 camera were extracted from the raw compressed airborne format to 8-bit RGBN TIFF images using Leica's FramePro software.

Leica's IPAS CO+ was used to finalize the camera calibration. It uses orthogonal lines flown in both directions over an area containing buildings and features. In this case, orthogonal lines from the calibration flight over Scappoose Airport were used. IPAS CO+ has an automated point matching (APM) feature that identifies the same point in overlapping images and automatically iterates to compute final misalignment and principal point offset (PPO) parameters, which are provided in the table below.

Table 7: RCD30 Camera Misalignment and PPO Parameters

Parameter	X	Y	Z
Lever Arms (m)	0.000	-0.115	0.166
Rotation (deg)	0 °	0 °	90 °
Misalignment (deg)	-0.0688 °	-0.0730 °	0.1338 °
PPO (mm)	0.0705	-0.0143	N/A

IPAS CO+ was then used along with the final camera calibration file and the final GNSS/IMU trajectory file to export valid exterior orientation (EO) parameters for each image.

The TIFF images and the EO files were used by LSS when processing the lidar data, to colorize lidar points that overlapped the imagery with RGB values. The color values are valid for the flight time of each pulse. Where no images overlapped the lidar data, lidar points still remain but are not colored.

A digital terrain model was created from all the valid lidar data at 25cm resolution for orthorectification. All RGBN TIFF images exported from FramePro were rectified in ERDAS IMAGINE Photogrammetry, using the 25cm DTM and the EO files created by IPAS CO+. No additional Aerial Triangulation was conducted. Individually rectified images were used to create a 10cm resolution color balanced mosaic in OrthoVista. Final 4-band RGBN mosaic images were created for each project tile in 8-bit geotiff format.

3.3. Lidar

3.3.1. Raw Data Processing

Lidar processing was conducted using the Leica Lidar Survey Studio (LSS) software. Calibration information, along with processed trajectory information were combined with the raw laser data to create an accurately georeferenced lidar point cloud for the entire survey in LAS v1.2 format. All points from the topographic and bathymetric laser include 16-bit intensity values.

During this LSS processing stage, an automatic land/water discrimination is made for the bathymetric waveforms. This allows the bathymetric (green) pulses over water to be automatically refracted for the pulse hitting the water surface and travelling through the water column, producing the correct depth. Another advantage of the automatic land/water discrimination is that it permits calculation of an accurate water surface over smaller areas, allowing simple bathymetric processing of smaller, narrower streams and drainage channels. Sloping water surfaces are also handled correctly.

Prior to processing the hydrographer can adjust waveform sensitivity settings dependent on the environment encountered and enter a value for the refraction index to be used for bathymetry. The index of refraction is an indication of the water type. For example if the water was salty and a value for fresh water was used, the depth could be incorrect by as much as 5cm (dependent on depth).

In the field, default waveform sensitivity settings were used for processing. In order to determine the optimal waveform sensitivity settings for final processing, sample areas were selected and processed with multiple different settings, to iteratively converge on the best possible settings. This is done by reviewing the processed point cloud and waveforms within the sample areas. A sample waveform is provided in Figure 6, while a sample LSS editing screen is provided in Figure 7. Settings affect which waveform peaks are classified as valid seabed, and which peaks are classified as noise. Optimal settings strike a balance between the amount of valid data that is classified as seabed bottom, and the amount of noise that is incorrectly classified due to peaks in the waveforms. Ideally all valid data is selected, while only a small amount of noise remains to be edited out. Once optimal threshold settings were chosen, these were used for the entire project.

It is important to note that all digitized waveform peaks are available to be reviewed by the hydrographer; both valid seabed bottom and peaks classed as noise. This allows the hydrographer to review data during Terrascan and LP360 editing for objects that may have been potentially misclassified as noise.

LSS processing produced LAS files in 1.2 format. Although LSS is capable of producing and working with LAS 1.4, many third party systems are not. Therefore, LAS 1.2 was used as the processing format for this project.

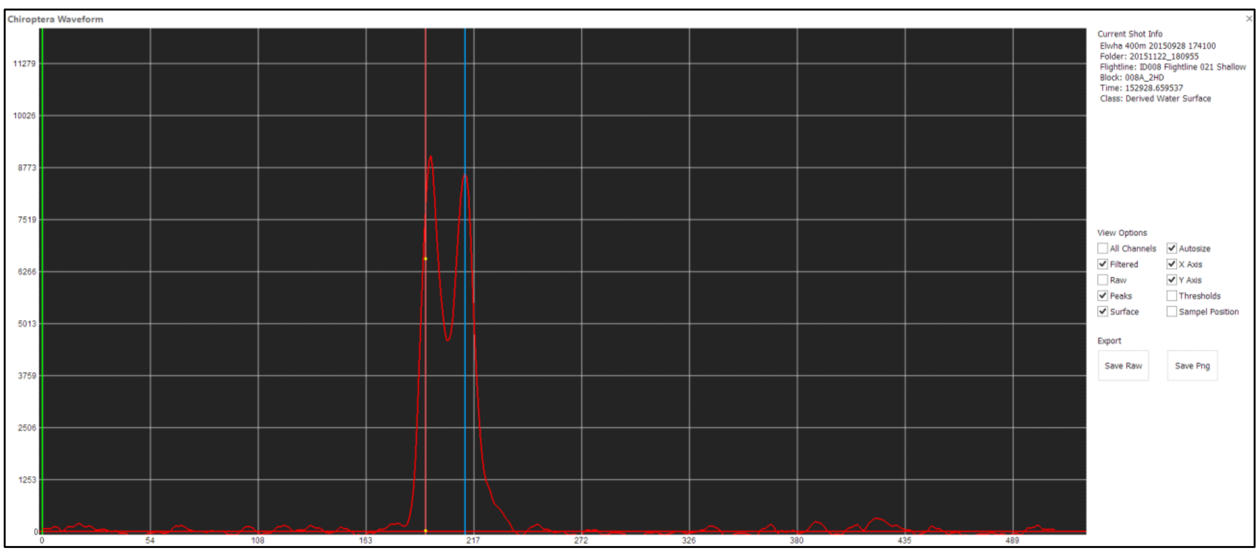

Figure 6: Sample Waveform in Shallow Water

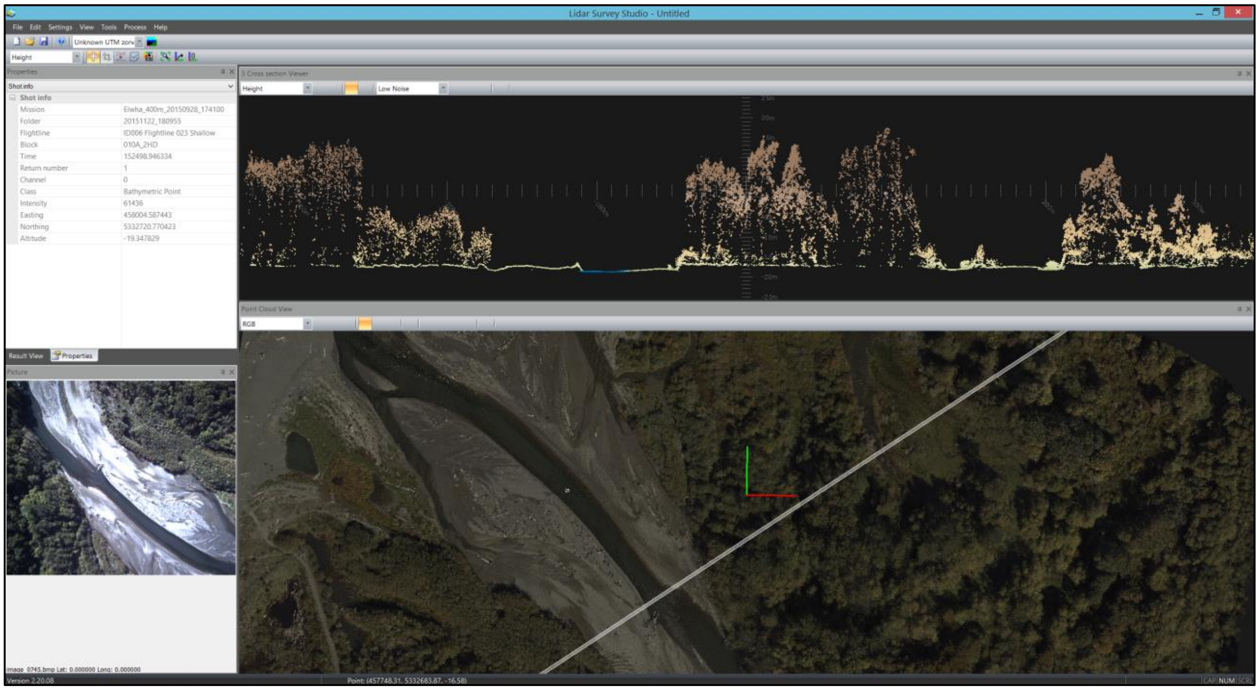

Figure 7: Sample LSS Processing Screen

Once the files were created, the points were colorized within LSS using the RCD30 images extracted from FramePro, as described in Section 3.2.

Additional QC steps were then performed in LSS prior to import to Terrascan. First, the derived water surface was reviewed to ensure a water surface was correctly calculated for all channels and pools. Small scattered areas with invalid water surface results were identified along the river. In these cases, the derived water surface, which is used for computation of the depth, were higher than the actual raw water surface returns. Data were re-processed using slightly different water surface setting parameters to ensure the derived water surface and raw water surface points aligned, to improve data accuracy. Spot checks were also made on the data to ensure the front and back of the scans remained in alignment and no calibration or system issues were apparent prior to further data editing in Terrascan.

Processing Logs are provided in Appendix C, indicating the calibration files used and processing session that data were output too.

LSS stores data in multiple LAS files for a single flight line. Each file corresponds to a single .dat file from the raw airborne data. GDS merged these multiple files into a single file per flight line and moved data into a standard class definition in preparation for data editing.

3.3.2. Lidar Data Editing

After data were processed in LSS and the data integrity reviewed, data were organized into tiles within a Terrascan project. Tile layout was supplied by Woolpert from the FY14 Elwha River project. Data classification and spatial algorithms were applied in Terrasolid's Terrascan software. Customized spatial algorithms, such as isolated points and low point filters, were run to remove gross fliers in the topographic data, and to identify bare earth/ground in the topographic data. In addition, spatial algorithms were run to remove any low noise in the bathymetric data.

Due to the complexity of the riverine environment, all data were reviewed manually to reclassify any valid bathy points incorrectly identified by the automated routines in LSS as invalid, and vice versa. In addition any topo ground points remaining over the water were reclassified to correct the ground representation. Manual editing was conducted both in Terrascan and LP360. Steps for manual editing included:

- Remove any topo ground or unclassified data from the water surface

- Remove any invalid topo ground points – typically from overhanging vegetation along the river banks.
- Review bathymetry in cross section along the river and shoreline.
    - Reclass suitable data to bathy ground (Class 22).
    - Remove any noise in the bathy ground class, usually from the water surface.
- Reclass suitable data to topo ground – typically from large boulders in the river or along rocky shoreline.
- Classify Bridge Decks

A final QC of the topo and riverbed ground classes was conducted in LP360 and QT Modeler before classified LAS files were exported for delivery.

4. QUALITY CONTROL

Quality control is carried out through every phase of the project. Several checks were used to ensure data integrity and quality was maintained.

- **Calibration** – This is fundamental to data accuracy. Calibration is discussed in detail in Section 2.2.
- **Online Checks** – The airborne operator monitored system status of the scanners and receivers, waveforms, camera images, data coverage, flight lines and health of the navigation system during data acquisition. Acquisition notes are maintained during data acquisition. They not only track lines acquired, but also any relevant information on weather or water clarity, instances when sensor issues occur and so on. These logs are a valuable resource during processing.
- **Positioning** - Aircraft bank angles were restricted to 20° to avoid any potential GPS dropouts. No flights were planned if the PDOP was expected to go above 3.0.
- **GNSS Base Station Checks** – GNSS Base Station coordinates were computed using OPUS to check the validity of published coordinates.
- **Comparison to Adjacent Lines** – Throughout data processing, adjacent survey lines of data are compared during editing to ensure there are no data busts, or system artifacts. Overlap analyses were conducted as part of the relative accuracy checks. Method and results are provided in Section 4.3.2.
- **Comparison to Check Points** – Check point data collected by GDS at Scappoose Airport was used to perform system quality checks after installation and calibration. This is described in Section 2.2, with results presented in Table 3. In addition, check points acquired by Woolpert for the FY14 Elwha River lidar survey were used for comparison to the point cloud and DEM in the survey area. This method and results is described below, in Sections 4.3 and 4.4.

4.1. DATA VOIDS

Data voids were assessed by creating a grid using first returns only. A data void is considered to be any area greater than or equal to 4(ANPS^2) according to the National Geospatial Program (NGP) Lidar Base Specification, Version 1.2.

The topo-bathy collect was designed around the bathymetry collection, and therefore does not fall into one of the usual NGP Quality Level categories. The topographic lidar data acquired as part of the topo-bathy collection was designed to have a Nominal Pulse Density (NPD) of 11 points per square meter, exceeding QL2 requirements. The bathymetric portion of the data was designed at a NPD of 1.29 points per square meter.

Due to the elliptical scan pattern used in the Chiroptera II nominal pulse spacing (NPS) is higher across track than along track. As designed for this topo-bathy project, the topo NPS is 0.18m across track and 0.5m along track. This provides an overall NPD of > 11 pts/m^2 for topo. In order to assess data voids and spatial distribution of data (Section 4.2) a NPS of 0.5m was used for topo, since this still exceeds the QL2 requirements. Therefore a 1m resolution grid was used to assess data voids.

Acceptable voids exist over the Elwha River, Salish Sea and other small bodies of water such as stream channels. Any remaining voids from the first return analyses occur in small areas of ground between high vegetation. In these cases, the ground location is not reached by the first pulse return due to the angle of incidence of the lidar pulse and the vegetation. In most cases these voids are filled by subsequent pulse returns after penetrating the vegetation (Figure 8). Any remaining voids in the data are demonstrated during the clustering analysis, described in Section 4.2.

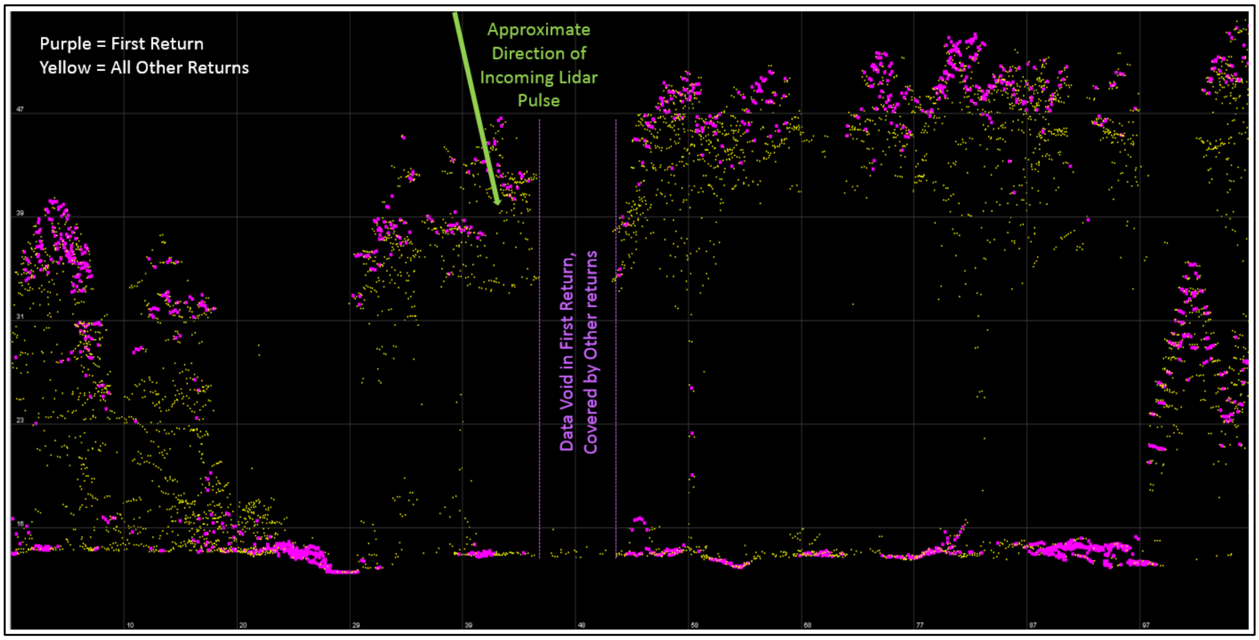

Figure 8: Data Voids in First Return Covered by Other Returns

For bathymetry, the NPS for the project is 0.88m. Data voids may be caused in bathy lidar for a variety of valid reasons, such as turbid water, low seabed reflectivity, or areas of white water which cannot be penetrated. Data voids were not computed for the bathymetry, however clustering analysis was conducted, and is described in the following section. In general bathymetry coverage was achieved for the majority of the survey area. Gaps in coverage occurred in areas of rapids within the river, and deeper areas offshore where the laser reached extinction depth. Design extinction depth for the Chiroptera II is D_{max}=2.2/k, which is approximately 1.5 times the secchi depth. Depths of approximately 10m were achieved in the Salish Sea.

4.2. Spatial Distribution / Clustering

Clustering was assessed by creating a regular grid with a resolution of 2*ANPS (Aggregate Nominal Pulse Spacing) for each individual swath in Applied Imagery's QT Modeler. A "no fill" grid creation method was used to ensure gaps were represented correctly. Parameters used for analysis are presented in Table 8. The specification requires that 90% of the cells in the grid should contain at least 1 lidar point.

Table 8: Parameters Used for Clustering Analyses

	Topo	Bathy
NPS (m)	0.5	0.88
ANPS (m)	0.5	0.88
Grid Resolution (2*ANPS)	1	1.76
Points Used	First return	Valid Seabed Returns and Water Surface Returns

For topo lidar data, acceptable voids such as the river and Salish Sea, were removed or masked out of the analysis in ArcGIS. Analysis in ArcGIS indicated that 97.55% of the required survey area (excluding acceptable voids) contained at least one lidar point, meeting the requirement. Results for individual swaths are presented in Table 9.

Bathy analysis was conducted only on areas along the shoreline of the Salish Sea where bathy data existed across entire swaths. Analysis was not conducted on the river itself, as only slim partial sections of each swath were available along the river. Analysis in ArcGIS indicated that 99.12% of the required survey area contained at least one bathy lidar point. Results for individual swaths are presented in Table 9.

Table 9: Percentage of Grid Cells with ≥ 1 Lidar Point

Swath	Topo	Bathy
50	99.12%	N/A
60	98.83%	N/A
70	98.59%	N/A
80	97.02%	N/A
90	97.94%	N/A
100	95.66%	N/A
200	99.49%	99.93%
210	99.04%	99.94%
220	97.72%	100.00%
230	98.27%	99.95%
240	98.04%	99.98%
250	98.01%	99.48%
260	98.74%	98.41%
270	98.56%	97.28%
280	96.68%	99.19%
290	97.17%	100.00%
300	97.58%	98.40%
310	97.22%	98.61%
320	96.30%	97.38%
330	96.20%	N/A
340	97.78%	N/A
350	98.61%	N/A
360	97.78%	N/A
370	97.97%	N/A
371	96.23%	N/A
380	94.38%	N/A
390	95.00%	N/A
Average	97.55%	99.12%

4.3. Relative Vertical Accuracy

Relative vertical accuracy was checked within a swath and for overlap consistency between swaths.

4.3.1. Within Swaths (Smooth Surface Repeatability)

Smooth surface repeatability was assessed for three areas within the survey limits (Figure 9). Flat areas were selected where lidar data consisted of single returns in non-vegetated areas. The DeltaZ of points from a single swath was calculated for all cells within a regular grid at a resolution of 2*ANPS (Aggregate Nominal Pulse Spacing); in this case 1m for topo data. Results are provided in Table 10. All cells meet the accuracy requirement of ≤6cm.

Table 10: Relative Accuracy within Swaths

Location	Swath	Samples	Max DeltaZ (cm)	Mean DeltaZ (cm)	St. Dev (cm)
Parking Lot	280	218	5.7	3.3	0.9
Driveway	300	403	5.6	2.8	0.8
Airport	60	231	5.2	3.3	0.6

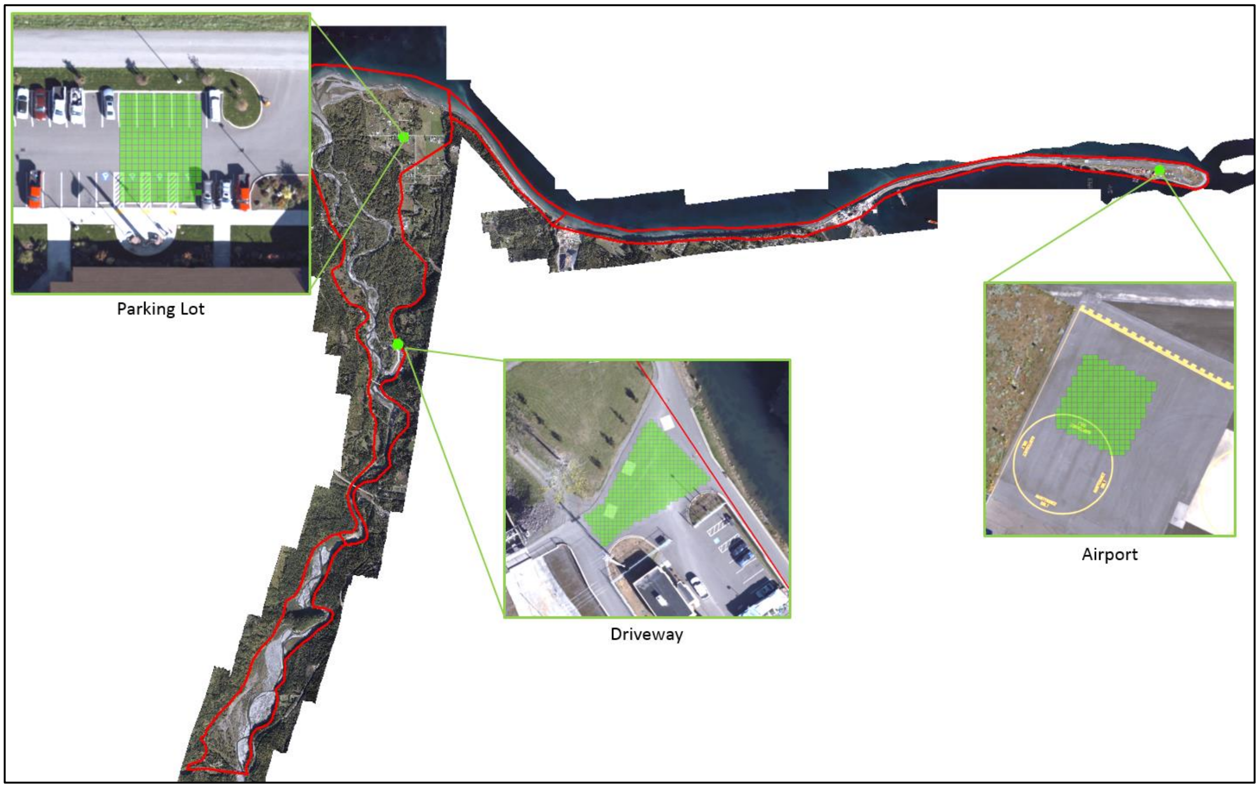

Figure 9: Smooth Surface Repeatability Locations and Grids (Green indicates ≤6cm)

4.3.2. Overlap Consistency (Between Adjacent Swaths)

Overlap consistency was computed by generating a DeltaZ raster for the project in LP360. The raster was generated at a resolution of 2*ANPS; 1m for topo data and 2m for bathy. Only non-vegetated areas with single returns were used for the topo analysis. All areas of valid seabed/riverbed returns (Class 22) were used for the bathy analysis.

The raster calculator in ArcGIS was used to compute the root mean square difference in Z (RMSDz) from the DeltaZ raster. Required RMSDz for the topo data is ≤8cm, with a maximum difference of ±16cm. Required RMSDz for bathy is ≤14.8cm, with a maximum difference of ±29.6cm. Results are presented in Table 11, below.

Table 11: Relative Accuracy between Swaths

	Topo	Bathy
RMSDz (cm)	4.3	6.8
Maximum Difference (cm)	186.1	91.5
Mean Delta Z (cm)	2.9	5.0
St Dev. Of Delta Z (cm)	3.2	4.5
No. of Comparison Cells	1,753,381	296,370
% of cells above required Maximum	0.86	0.30

RMSDz values for both the topo and the bathy are within specification. However the maximum differences of the topo and bathy data are high. This is largely due to slopes within the survey area. The survey area has large areas of steep terrain, including overhangs and cliffs present in the data (Figure 10, Figure 11).

The steep terrain affects the DeltaZ rasters. The average slope for DeltaZ values greater than 16cm in the topo data is 12.1 degrees. However the average slope for DeltaZ values less than the required maximum of 16cm is significantly lower at 4.3 degrees. This indicates that terrain slope is affecting the maximum difference values. In addition, only

0.86% of comparison cells have a value greater than 16cm. This information along with the overall RMSDz indicates the topo data between swaths is within specification.

Similarly for the bathy data, the average slope for DeltaZ values greater than the required 29.6cm is 12.5 degrees, while the average slope for DeltaZ values less than 29.6cm is 3.5 degrees. Again, this indicates that terrain slope is affecting the maximum difference values. Only 0.30% of comparison cells have a value greater than 29.6cm. This information along with the overall RMSDz indicates the bathy data between swaths is within specification.

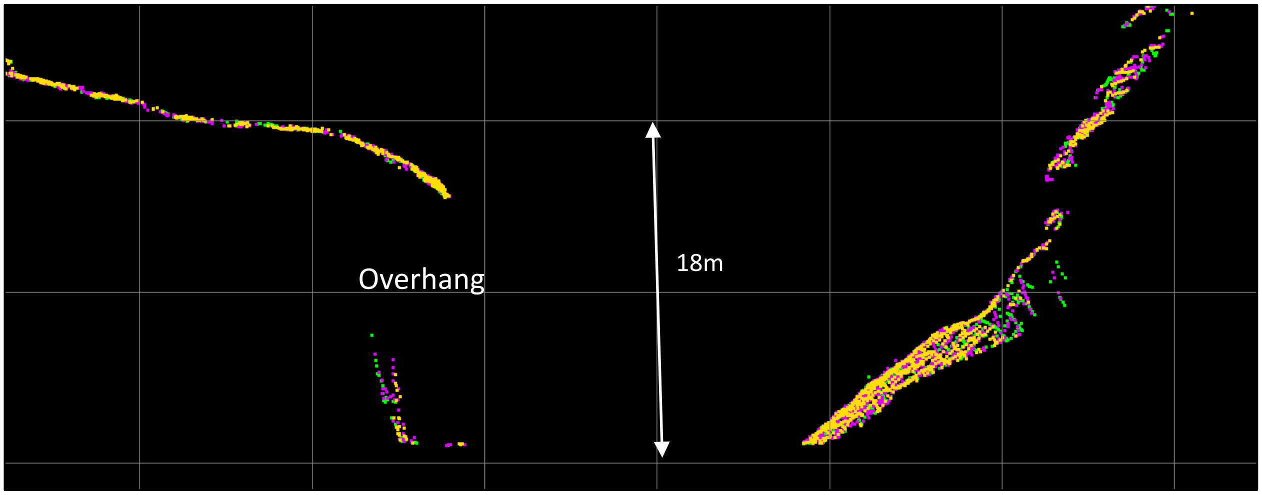

Figure 10: Overhanging Ground Points (Points Colored by Swath, Single Returns, Non-Vegetated Area)

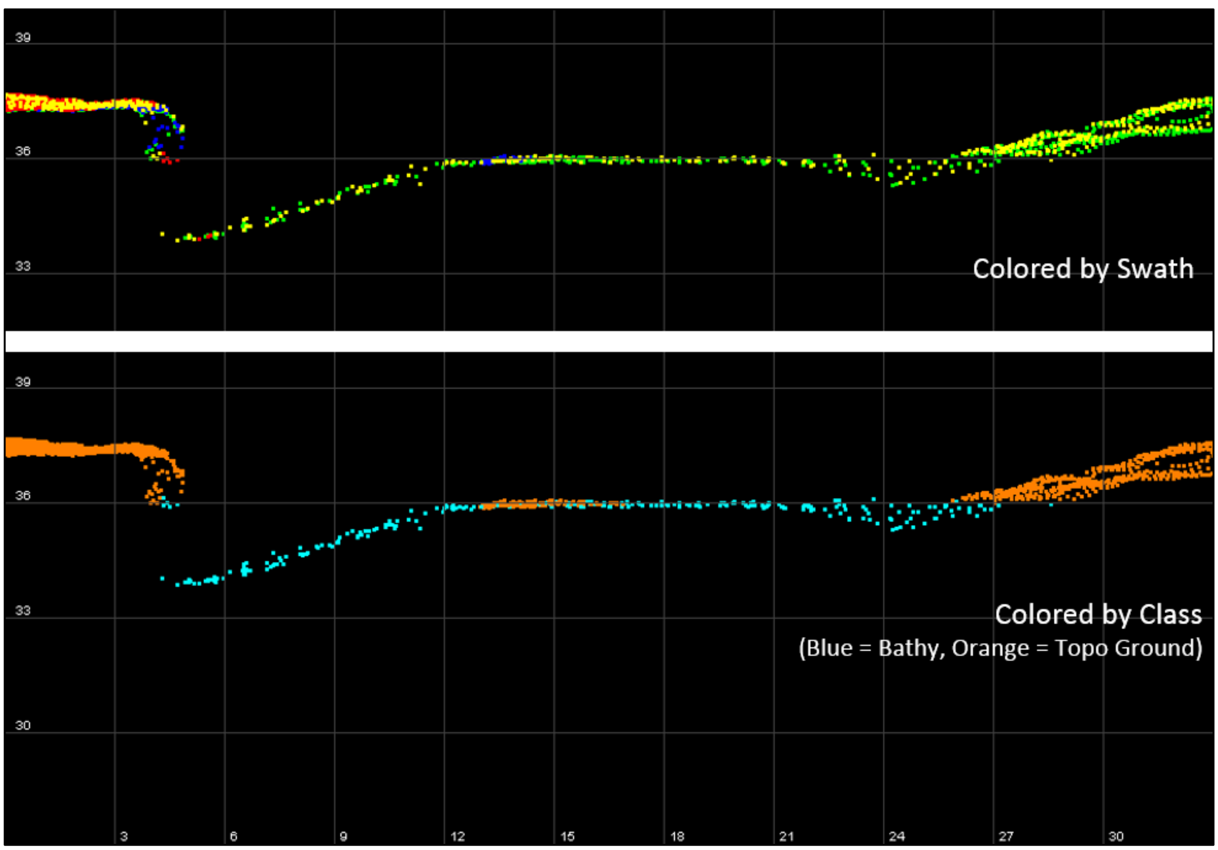

Figure 11: Overhanging /Steep Valid Bathy Points

4.4. Absolute Vertical Accuracy

Absolute vertical accuracy checks were carried out using check points acquired during the FY14 Elwha Topo Lidar survey. Check points were supplied to GDS by Woolpert. Check points were reviewed by GDS prior to use. Overall, very few checkpoints, only 14, were available within the survey area. Also, some checkpoints existed in areas where the ground cover had changed between the prior survey and this topo-bathy survey.

GDS assessed the check points available against the 4-band imagery mosaic created from the current survey. Check points were organized into valid NVA (Non-vegetated Vertical Accuracy) and VVA (Vegetated Vertical Accuracy) groups based on the existing ground conditions. These newly grouped NVA and VVA points were used for the absolute vertical accuracy checks. No check points or ground points were used to adjust the lidar data. 10 NVA points and 4 VVA points were available for analyses.

4.4.1. Point Cloud Accuracy

Absolute vertical accuracy for the topo lidar swath data was calculated by comparing the NVA check points against a TIN of the final lidar swath points in LP360. Required accuracy (ACCz) is ≤19.6cm at the 95% confidence level, with an RMSEz ≤10cm. Results are presented in Table 12.

Although the results meet the required accuracy specification using all the NVA points available, 2 points had higher values than the other 8 points. Vertical difference for these two points is 9.6cm and 11.4cm. These two points exist in an area susceptible to change over time at the back of the beach (Figure 12). Due to the time passed between check point collect and the topo-bathy lidar survey, accuracy results were also computed with these two points removed, and are presented as Pass 2.

Tested 0.066 meters vertical accuracy at 95 percent confidence level.

Table 12: Accuracy of Topo Lidar Point Cloud

	Pass 1	Pass 2	Required
RMSEz (cm)	5.6	3.4	≤10
ACCz (cm) at 95% Confidence	11	6.6	≤19.6
No. of Check Points Used	10	8	-

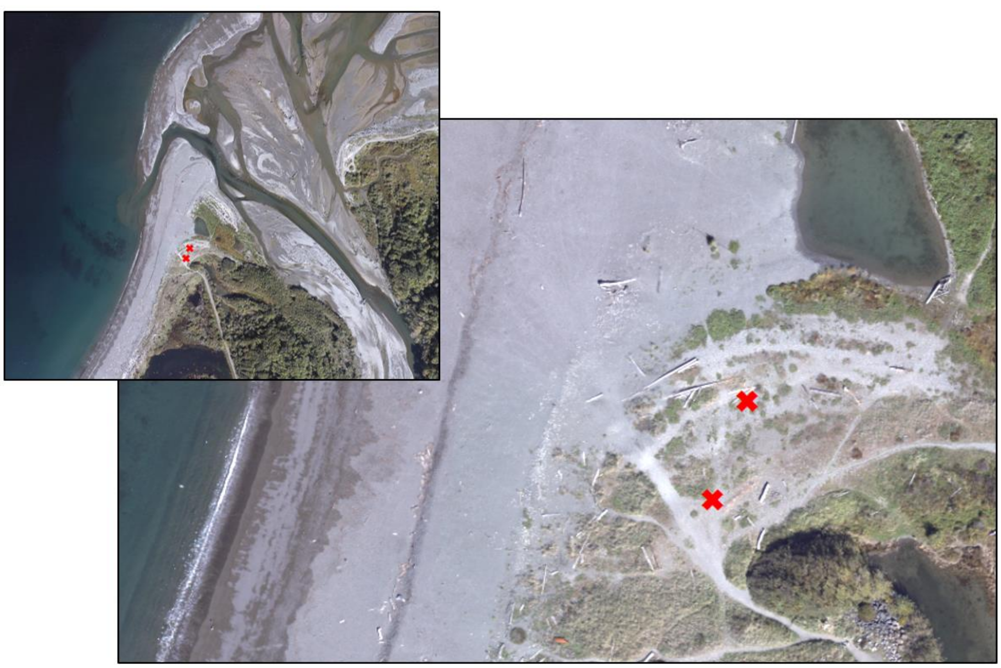

Figure 12: Location of 2 NVA check points with Higher Vertical Differences

4.4.2. DEM ACCURACY

The accuracy of the DEM was first assessed by comparing the NVA and VVA check points to the DEM in ArcGIS. The required RMSEz is ≤10cm, with a NVA of ≤19.6cm at the 95% confidence level. The required VVA is ≤29.4cm at the 95% percentile.

All data meets the required accuracy specifications, despite the low number of check points available.

Table 13: DEM Accuracy

	Pass 1	Pass 2	Required
RMSEz (cm)	5.9	4.0	≤10
NVA (cm) at 95% Confidence	11.6	7.9	≤19.6
VVA (cm) at 95th Percentile	6.8	6.8	≤29.4
No. of NVA Check Points Used	10	8	-
No. of VVA Check points Used	4	4	-

5. PRODUCTS

The tiling scheme used for the project was provided by Woolpert, having been used on prior Elwha River projects. Its follows US National Grid conventions for naming, and is shown in Figure 13. Each tile is 750m x 750m.

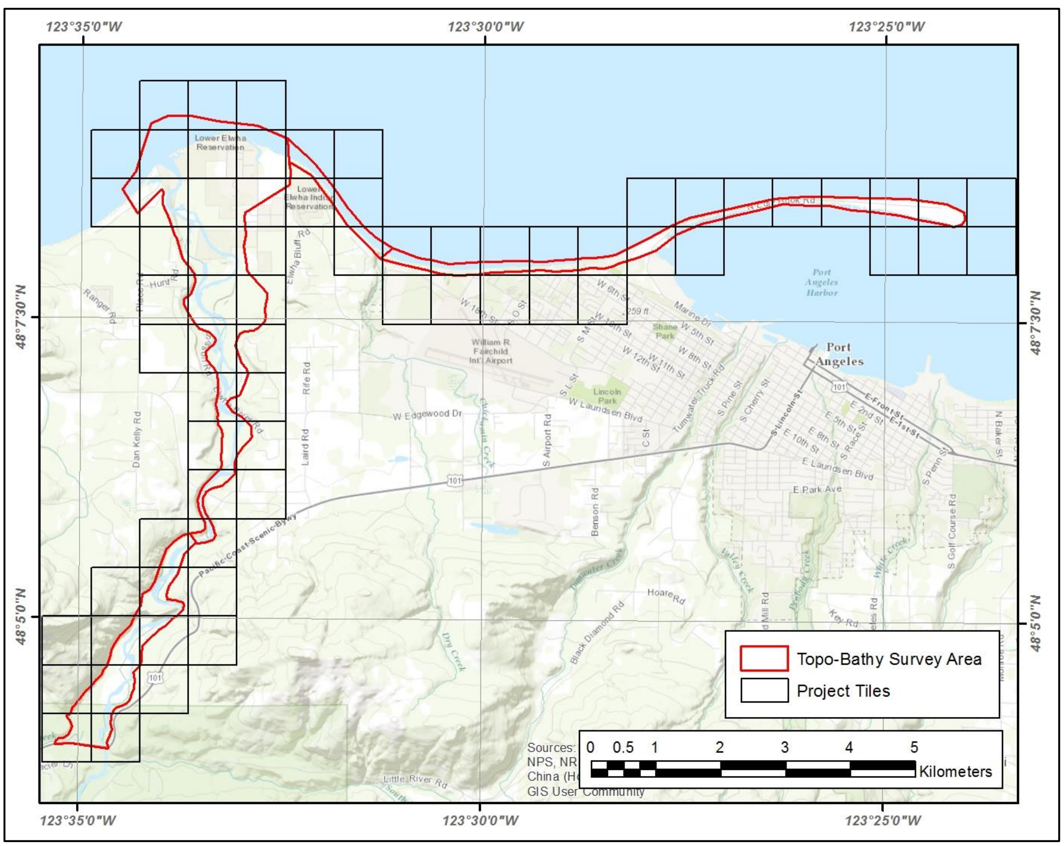

Figure 13: Project Tile Layout

5.1. POINT CLOUD DATA

Point cloud data is provided as LAS files in LAS 1.4 point Record 7 format.

The NOAA NGS VDatum tool was used to convert processed LAS files from the selected processing datum:

- Horizontal: NAD83 (2011), UTM Zone 10N, meters
- Vertical: NAD83 (2011), meters

to the project delivery datum using the Geoid 12A model:

- Horizontal: NAD83 (2011), UTM Zone 10N, meters
- Vertical: NAVD88, meters

The processing datum was selected for convenience when using many different software packages during the editing process. All final QC checks were conducted using the project delivery datum with NAVD88 elevations in meters.

Data were originally created from the Leica LSS software in LAS 1.2, Point Record Format 3. Prior to delivery, data were converted to LAS 1.4, Point Record Format 7 and then exported for delivery using SAFE FME software. LAS file classes delivered are shown in Table 14. In general LAS classes follow ASPRS guidelines for the LAS format, but additional classes are used to separate data from the bathy and topo lidar. There are multiple invalid bathy lidar classes. Each class indicates the automated algorithm in Leica's Lidar Survey Studio software that was used to generate or classify the point during initial point cloud creation. Rather than put all invalid or noise data from the bathy laser in to one noise class, the independent classes have been retained. It is important to note that all valid bathy lidar data is found in Class 22 (Bathy Ground/Seabed).

All LAS files contain 16bit intensity values and RGB point color values.

All remaining products were created from the final LAS files.

Table 14: LAS Classes

Class	Description	Comment
1	Topo Unclassified	
2	Topo Bare-Earth Ground	
7	Topo Low Noise	
9	Topo Water	
17	Bridge Decks	
18	Topo High Noise	
20	Invalid Bathy Unclassified	Not valid. Peak selected from waveform in LSS, but did not meet the user set thresholds for valid depth selection
22	Bathy Ground (Seabed)	
23	Invalid Shallow Depths	depths selected by shallow algorithm – not valid
24	Invalid TWE1	Created from the Turbid Water Enhancement Algorithm – not valid
25	Invalid TWE2	Created from the Turbid Water Enhancement Algorithm (lower confidence) – not valid
26	Invalid Submerged Object	Intermediate Returns below the water surface – not valid
27	Invalid Bathy Low Noise	Rejected by algorithm during initial LSS Point Cloud Computation – not valid
29	Bathy Water Surface	

5.2. RCD30 4-Band Imagery Mosaic

Image mosaic creation is described in Section 3.2. All RGBN TIFF images exported from FramePro were rectified in ERDAS IMAGINE Photogrammetry, using the 25cm DTM and the EO files created by Leica's IPAS CO+ software. Individually rectified images were used to create a 10cm resolution color balanced mosaic in OrthoVista. Final 4-band RGBN mosaic images were created for each project tile in 8-bit geotiff format.

5.3. Bare-Earth DEM

The project required 1m bare earth DEMs, without bridges and overpasses included in the model, to be delivered in the project tile structure.

A 1m DEM was generated using Applied Imagery's QT Modeler software. A single QT Modeler grid was created and exported as 32-bit floating point ERDAS .IMG format file. Data were then clipped to tiles using SAFE FME software.

Note that no break lines were used in creation of the DEMs. In addition hydro-flattening was not required for this project.

5.4. Intensity Images

All LAS files contain 16-bit intensity values. Applied Imagery's QT Modeler was used to generate 8-bit geotiffs of the intensity values for the entire project. Initially two intensity images were created: one from all the valid topo laser data, and one from all valid bathy laser data. Intensity between the two lasers is not normalized in the Chiroptera II hardware.

In order to improve consistency between the topo lidar and bathy lidar intensity values, a radiometric correction was performed on each individual image in InPho's OrthoVista software. Data were then exported using the project tile structure in 8-bit Geotiff format. Corresponding TFW files are also provided.

It should be noted that bathy laser data contains raw intensity values and has not been corrected for losses of the signal as it travels through the water column. In general terms this means the intensity will appear darker with depth.

5.5. FGDC Metadata

Validated FGDC metadata files in XML format were generated for the following products:

- Project
- Each Lift (Flight)
- Classified Point Cloud Tiles
- Imagery Tiles
- Bare-Earth DEM Tiles
- Intensity Tiles

Information within the metadata file explains the project data and process steps, also included within this report.

APPENDIX A : AIRBORNE ACQUISITION LOGS

FLIGHT LOG - CALIBRATION

PROJECT NAME:	*P2015.021 - Elwha River Bathy-Topo Lidar*	**DATE:**	*26 / September / 2015*
LOCATION / AREA:	*Port Angeles, WA / Blocks 01 to 04*	**BASE AIRPORT:**	*Scappoose (SPB)*
AIRCRAFT:	*Cessna 404 - N475RC*	**PILOT:**	*Dave S.*
SYSTEM:	*Chiroptera II*	**OPERATOR:**	*Dushan A.*
MISSION ID:	*CALIBRATION-SPB*	**CLOUDS:**	*Partly Cloudy*
BASE STATION:	*1S4D*	**WIND:**	*5kts*

ENGINE START:	*18:46*	**ENGINE OFF:**	*21:01*	**ENGINE TIME:**	*02:15*
GNSS START:	*18:52*	**GNSS START:**	*20:55*		
TAKEOFF:	*19:01*	**TOUCHDOWN:**	*20:50*	**AIR TIME**	*01:49*

FL #	START TIME	END TIME	TOPO PRF / POWER		BATHY POWER	REMARKS
	19:05:00					Dataset: 400m_20150926_190902
000_FL1	19:07:32	19:08:46	300	14	80	
001_FL2	19:12:13	19:13:38	300	14	80	
002_FL3	19:15:53	19:17:12	300	14	80	
003_FL4	19:19:10	19:20:23	300	14	80	
004_FL5	19:23:18	19:24:29	300	14	80	
005_FL6	19:29:08	19:30:20	300	14	80	
	19:31:00					Dataset: 500m_20150926_193502
000_FL1	19:33:32	19:34:49	400	19	90	
001_FL2	19:37:59	19:39:21	400	19	90	
002_FL3	19:41:44	19:42:54	400	19	90	
003_FL4	19:45:24	19:46:37	400	19	90	
004_FL5	19:49:29	19:50:39	400	19	90	
005_FL6	19:54:37	19:55:49	400	19	90	
	19:58:00					Dataset: 1000m_20150926_200200
000_FL1	20:00:30	20:02:06	250	36	150	
001_FL2	20:05:19	20:06:59	250	36	150	
002_FL3	20:09:52	20:11:29	250	36	150	
003_FL4	20:14:17	20:15:52	250	36	150	
004_FL5	20:18:42	20:20:12	250	36	150	
005_FL6	20:24:23	20:25:54	250	36	150	
						Topo Testing
	20:28:00					Dataset: 1500m_20150926_203223
000_FL1	20:30:53	20:32:50	160	61	-	
001_FL1	20:36:16	20:38:20	170	57	-	
002_FL1	20:41:05	20:43:10	180	56	-	

FlightLog_2015-09-26A.xlsx *Page | 1*

FLIGHT LOG

PROJECT NAME:	*P2015.021 - Elwha River Bathy-Topo Lidar*	**DATE:**	*28 / September / 2015*
LOCATION / AREA:	*Port Angeles, WA / Blocks 01 to 04*	**BASE AIRPORT:**	*Port Angeles (CLM)*
AIRCRAFT:	*Cessna 404 - N475RC*	**PILOT:**	*Dave S.*
SYSTEM:	*Chiroptera II*	**OPERATOR:**	*Dushan A.*
MISSION ID:	*P2015-021_ElwhaRiver_400m*	**CLOUDS:**	*Clear*
BASE STATION:	*AC5475*	**WIND:**	*5kts*

ENGINE START:	*15:32*	**ENGINE OFF:**	*19:31*	**ENGINE TIME:**	*03:59*
GNSS START:	*15:50*	**GNSS START:**	*19:26*		
TAKEOFF:	*16:02*	**TOUCHDOWN:**	*19:23*	**AIR TIME**	*03:21*

FL #	START TIME	END TIME	TOPO PRF / POWER		BATHY POWER	REMARKS
						Flightline numbering starts at FL5
	16:00:00					*Dataset: 20150928_160657 (BL01)*
000_FL5	*16:05:27*	*16:08:51*	*300*	*14*	*295*	*DNP*
001_FL6	*16:11:47*	*16:15:00*	*300*	*14*	*295*	*DNP*
002_FL7	*16:18:22*	*16:21:42*	*300*	*14*	*295*	*DNP*
	16:22:00					*Lost GNSS, reboot entire system*
	16:31:00					*System rebooted and running*
	16:33:00					*Initialise GNSS over AC5475*
	16:38:00					*Dataset: 20150928_164115 (BL01)*
000_FL5	*16:39:45*	*16:43:00*	*300*	*14*	*295*	
001_FL6	*16:46:11*	*16:49:46*	*300*	*14*	*295*	
002_FL7	*16:52:02*	*16:55:10*	*300*	*14*	*295*	
003_FL8	*16:58:01*	*17:01:17*	*300*	*14*	*295*	
	17:03:00					*Dataset: 20150928_164115 (BL02)*
004_FL9	*17:04:50*	*17:06:27*	*300*	*14*	*295*	
005_FL10	*17:09:17*	*17:10:59*	*300*	*14*	*295*	
	17:12:00					*Dataset: 20150928_164115 (BL03)*
006_FL32	*17:14:51*	*17:17:12*	*300*	*14*	*295*	
007_FL31	*17:21:34*	*17:24:03*	*300*	*14*	*295*	
	17:26:00					*Force Stop; reboot lidar system*
	17:30:00					*Dataset: 20150928_173220 (BL03)*
000_FL30	*17:30:50*	*17:33:22*	*300*	*14*	*295*	
	17:35:00					*Force Stop; reboot lidar system*
	17:38:00					*Dataset: 20150928_174100 (BL03)*
000_FL29	*17:39:30*	*17:42:05*	*300*	*14*	*295*	
001_FL28	*17:48:14*	*17:50:48*	*300*	*14*	*295*	
002_FL27	*17:56:57*	*17:58:50*	*300*	*14*	*295*	
003_FL26	*18:03:20*	*18:05:05*	*300*	*14*	*295*	
004_FL25	*18:09:32*	*18:11:13*	*300*	*14*	*295*	
005_FL24	*18:15:24*	*18:16:54*	*300*	*14*	*295*	

FlightLog_2015-09-28A.xlsx *Page | 1*

FLIGHT LOG

PROJECT NAME:	*P2015.021 - Elwha River Bathy-Topo Lidar*	**DATE:**	*28 / September / 2015*
LOCATION / AREA:	*Port Angeles, WA / Blocks 01 to 04*	**BASE AIRPORT:**	*Port Angeles (CLM)*
AIRCRAFT:	*Cessna 404 - N475RC*	**PILOT:**	*Dave S.*
SYSTEM:	*Chiroptera II*	**OPERATOR:**	*Dushan A.*
MISSION ID:	*P2015-021_ElwhaRiver_400m*	**CLOUDS:**	*Clear*
BASE STATION:	*AC5475*	**WIND:**	*5kts*

ENGINE START:	*15:32*	**ENGINE OFF:**	*19:31*	**ENGINE TIME:**	*03:59*
GNSS START:	*15:50*	**GNSS START:**	*19:26*		
TAKEOFF:	*16:02*	**TOUCHDOWN:**	*19:23*	**AIR TIME**	*03:21*

FL #	START TIME	END TIME	TOPO PRF / POWER		BATHY POWER	REMARKS
006_FL23	*18:20:49*	*18:22:12*	*300*	*14*	*295*	
007_FL22	*18:24:26*	*18:25:48*	*300*	*14*	*295*	
008_FL21	*18:28:05*	*18:29:28*	*300*	*14*	*295*	
009_FL20	*18:31:46*	*18:32:59*	*300*	*14*	*295*	
						Dataset: 20150928_174100 (BL04)
010_FL36	*18:35:02*	*18:36:52*	*300*	*14*	*295*	
011_FL37	*18:38:47*	*18:40:42*	*300*	*14*	*295*	*May have missed start of line*
012_FL38	*18:43:07*	*18:44:40*	*300*	*14*	*295*	
013_FL39	*18:47:39*	*18:49:04*	*300*	*14*	*295*	
014_FL35	*18:52:10*	*18:53:44*	*300*	*14*	*295*	
015_FL34	*18:55:47*	*18:57:09*	*300*	*14*	*295*	
016_FL37	*18:59:39*	*19:01:26*	*300*	*14*	*295*	*Refly FL37*
	19:02:00					*Force Stop; reboot lidar system*
	19:15:00					*lidar system not rebooting.*
	19:16:00					*Abort mission*
	19:28:00					*System running good on the ground*

FlightLog_2015-09-28A.xlsx *Page | 2*

FLIGHT LOG

PROJECT NAME:	*P2015.021 - Elwha River Bathy-Topo Lidar*	**DATE:**	*29 / September / 2015*
LOCATION / AREA:	*Port Angeles, WA / Block 04*	**BASE AIRPORT:**	*Port Angeles (CLM)*
AIRCRAFT:	*Cessna 404 - N475RC*	**PILOT:**	*Dave S.*
SYSTEM:	*Chiroptera II*	**OPERATOR:**	*Dushan A.*
MISSION ID:	*P2015-021_ElwhaRiver_400m*	**CLOUDS:**	*Clear*
BASE STATION:	*AC5475*	**WIND:**	*5kts*

ENGINE START:	*16:48*	**ENGINE OFF:**	*18:11*	**ENGINE TIME:**	*01:23*
GNSS START:	*16:52*	**GNSS START:**	*18:05*		
TAKEOFF:	*17:04*	**TOUCHDOWN:**	*18:03*	**AIR TIME**	*00:59*

FL #	START TIME	END TIME	TOPO PRF / POWER		BATHY POWER	REMARKS
	17:11:00					Lost GNSS, reboot entire system
	17:18:00					System rebooted and running
	17:20:00					Initialise GNSS over AC5475
	17:25:00					Dataset: 20150929_172724 (BL04)
000_FL33	17:25:54	17:26:10	300	14	295	DNP; Laser cutoff
001_FL33	17:26:27	17:26:44	300	14	295	DNP; Laser cutoff
002_FL33	17:36:51	17:38:04	300	14	295	
						Camera Calibration
						Mission: CALIBRATION-SPB_1000m
	17:45:00					Dataset: 20150929_174650
000_FL1	17:45:20	17:46:20	300	14	295	Topo data may not be good
001_FL2	17:49:15	17:50:15	250	36	295	
002_FL3	17:53:11	17:54:08	250	36	295	
003_FL4	17:57:00	17:57:57	250	36	295	

FlightLog_2015-09-29A.xlsx *Page | 1*

APPENDIX B : NGS DATASHEET

```
National Geodetic Survey,   Retrieval Date = SEPTEMBER 28, 2015
 AC5475 ***********************************************************************
 AC5475  PACS        -  This is a Primary Airport Control Station.
 AC5475  DESIGNATION -  CLALLAM CBL 150
 AC5475  PID         -  AC5475
 AC5475  STATE/COUNTY-  WA/CLALLAM
 AC5475  COUNTRY     -  US
 AC5475  USGS QUAD   -  ANGELES POINT (1978)
 AC5475
 AC5475                         *CURRENT SURVEY CONTROL
 AC5475  ______________________________________________________________________
 AC5475* NAD 83(2011) POSITION- 48 07 30.75981(N) 123 30 08.01501(W)   ADJUSTED
 AC5475* NAD 83(2011) ELLIP HT-    51.752 (meters)        (06/27/12)   ADJUSTED
 AC5475* NAD 83(2011) EPOCH   -  2010.00
 AC5475*  NAVD  88  <http://www.ngs.noaa.gov/datums/vertical/index.shtml#NAVD88>  ORTHO  HEIGHT  -
71.99  (meters)      236.2   (feet) GPS OBS
 AC5475  ______________________________________________________________________
 AC5475  NAVD 88 orthometric height was determined with an earlier geoid model
 AC5475  NAD 83(2011) X  - -2,354,367.915 (meters)                     COMP
 AC5475  NAD 83(2011) Y  - -3,556,761.609 (meters)                     COMP
 AC5475  NAD 83(2011) Z  -  4,726,219.463 (meters)                     COMP
 AC5475  LAPLACE CORR    -         -3.59  (seconds)                    DEFLEC12B
 AC5475  GEOID HEIGHT    -        -20.15  (meters)                     GEOID12B
 AC5475
 AC5475  Network accuracy estimates per FGDC Geospatial Positioning Accuracy
 AC5475  Standards:
 AC5475         FGDC (95% conf, cm)     Standard deviation (cm)     CorrNE
 AC5475            Horiz  Ellip           SD_N   SD_E   SD_h      (unitless)
 AC5475  -------------------------------------------------------------------
 AC5475  NETWORK    0.41   0.98           0.19   0.13   0.50     -0.01244677
 AC5475  -------------------------------------------------------------------
 AC5475  Click here <http://www.ngs.noaa.gov/cgi-bin/lna_ret.prl?PID=AC5475> for local accuracies
and other accuracy information.
 AC5475
 AC5475
 AC5475.This mark is at William R Fairchild Intl Airport (CLM)
 AC5475
 AC5475.The horizontal coordinates were established by GPS observations
 AC5475.and adjusted by the National Geodetic Survey in June 2012.
 AC5475
 AC5475.NAD 83(2011) refers to NAD 83 coordinates where the reference
 AC5475.frame has been affixed to the stable North American tectonic plate. See
 AC5475.NA2011 <http://www.ngs.noaa.gov/web/surveys/NA2011> for more information.
 AC5475
```

```
AC5475.The horizontal coordinates are valid at the epoch date displayed above
AC5475.which is a decimal equivalence of Year/Month/Day.
AC5475
AC5475.The orthometric height was determined by GPS observations and a
AC5475.high-resolution geoid model.
AC5475
AC5475.GPS derived orthometric heights for airport stations designated as
AC5475.PACS or SACS are published to 2 decimal places.  This maintains
AC5475.centimeter relative accuracy between the PACS and SACS.  It does
AC5475.not indicate centimeter accuracy relative to other marks which are
AC5475.part of the NAVD 88 network.
AC5475
AC5475.The X, Y, and Z were computed from the position and the ellipsoidal ht.
AC5475
AC5475.The Laplace correction was computed from DEFLEC12B derived deflections.
AC5475
AC5475.The ellipsoidal height was determined by GPS observations
AC5475.and is referenced to NAD 83.
AC5475
AC5475. The following values were computed from the NAD 83(2011) position.
AC5475
AC5475;                    North         East     Units Scale Factor Converg.
AC5475;SPC WA N     -   128,548.288   301,366.624   MT  0.99994226   -1 59 13.4
AC5475;SPC WA N     -   421,745.51    988,733.67   sFT  0.99994226   -1 59 13.4
AC5475;UTM  10      - 5,330,339.031   462,626.965   MT  0.99961716   -0 22 26.3
AC5475
AC5475!             -  Elev Factor  x  Scale Factor =   Combined Factor
AC5475!SPC WA N     -   0.99999189  x   0.99994226  =   0.99993415
AC5475!UTM  10      -   0.99999189  x   0.99961716  =   0.99960905
AC5475
AC5475|---------------------------------------------------------------------|
AC5475| PID    Reference Object                     Distance      Geod. Az  |
AC5475|                                                           dddmmss.s |
AC5475| AC5476 CLALLAM CBL 430                     279.974 METERS 14917     |
AC5475| AC5474 CLALLAM CBL 0                       149.961 METERS 32917     |
AC5475|---------------------------------------------------------------------|
AC5475
AC5475                          SUPERSEDED SURVEY CONTROL
AC5475
AC5475  NAD 83(2007)-  48 07 30.75884(N)    123 30 08.01704(W) AD(2007.00) 0
AC5475  ELLIP H (02/10/07)   51.764  (m)                       GP(2007.00)
AC5475  NAD 83(1998)-  48 07 30.75730(N)    123 30 08.01963(W) AD(       ) A
AC5475  ELLIP H (03/21/00)   51.757  (m)                       GP(       ) 3 2
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AC5475  NAD 83(1991)-  48 07 30.75498(N)    123 30 08.02106(W) AD(       ) B
AC5475  NAD 83(1998)-  48 07 30.75688(N)    123 30 08.02065(W) AD(       ) B
AC5475  ELLIP H (07/23/97)   51.782  (m)                       GP(       ) 3 1
AC5475  NAVD 88 (11/01/99)   71.99   (m)  GEOID99 model used   GPS OBS
AC5475  NAVD 88 (07/23/97)   71.92   (m)  GEOID96 model used   GPS OBS
AC5475
AC5475.Superseded values are not recommended for survey control.
AC5475
AC5475.NGS no longer adjusts projects to the NAD 27 or NGVD 29 datums.
AC5475.See file dsdata.txt  <http://www.ngs.noaa.gov/cgi-bin/ds_lookup.prl?Item=HOW_SUP_DET>to
determine how the superseded data were derived.
AC5475
AC5475_U.S. NATIONAL GRID SPATIAL ADDRESS: 10UDU6262630339(NAD 83)
AC5475
AC5475_MARKER: DQ = CALIBRATION BASE LINE DISK
AC5475_SETTING: 7 = SET IN TOP OF CONCRETE MONUMENT
AC5475_STAMPING: 150 1984
AC5475_MARK LOGO: NGS
AC5475_PROJECTION: FLUSH
AC5475_MAGNETIC: N = NO MAGNETIC MATERIAL
AC5475_STABILITY: C = MAY HOLD, BUT OF TYPE COMMONLY SUBJECT TO
AC5475+STABILITY: SURFACE MOTION
AC5475_SATELLITE: THE SITE LOCATION WAS REPORTED AS SUITABLE FOR
AC5475+SATELLITE: SATELLITE OBSERVATIONS - June 10, 2008
AC5475
AC5475  HISTORY     - Date     Condition        Report By
AC5475  HISTORY     - 1984     MONUMENTED       NGS
AC5475  HISTORY     - 19841010 GOOD             NGS
AC5475  HISTORY     - 19960810 GOOD             CHANCE
AC5475  HISTORY     - 19970912 GOOD             NGS
AC5475  HISTORY     - 19981010 GOOD             NGS
AC5475  HISTORY     - 20080610 GOOD             WHPACI
AC5475
AC5475                          STATION DESCRIPTION
AC5475
AC5475'DESCRIBED BY NATIONAL GEODETIC SURVEY 1984 (JLD)
AC5475'THE STATION IS LOCATED IN GRASS AREA NORTHEAST OF RUNWAY 13-31 AND
AC5475'SOUTHWEST OF ASPHALT ROAD (CLOSED TAXIWAY) , ABOUT 130 FT (39.6 M)
AC5475'NORTHEAST OF NORTHEAST EDGE OF OLD RUNWAY PAVEMENT AND 98 FT (29.9 M)
AC5475'SOUTHWEST OF CENTER OF ASPHALT ROAD.  THE STATION IS A NGS CALIBRATION
AC5475'BASE LINE DISK STAMPED 150 1984, SET IN THE TOP OF 30 INCH DIAMETER
AC5475'CONCRETE MONUMENT FLUSH WITH THE GROUND.
AC5475
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AC5475                          STATION RECOVERY (1984)
AC5475
AC5475'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1984 (CLN)
AC5475'THE BASE LINE IS LOCATED ABOUT 1.6 KM (1.0 MI) WEST OF PORT ANGELES,
AC5475'AT THE WILLIAM R. FAIRCHILD INTERNATIONAL AIRPORT AND SET NORTHEAST OF
AC5475'AND APPROXIMATELY PARALLEL TO THE MOST NORTHERN ONE OF TWO RUNWAYS AND
AC5475'LANDING STRIPS.
AC5475'
AC5475'TO REACH THE BASE LINE FROM THE FRONT ENTRANCE (SOUTH FACE) OF THE
AC5475'PASSENGER TERMINAL OF THE WILLIAM R. FAIRCHILD INTERNATIONAL AIRPORT,
AC5475'WHICH IS LOCATED ABOUT 1.6 KM (1.0 MI) WEST OF PORT ANGELES, GO WEST
AC5475'ALONG AN ASPHALT ROAD FOR 0.1 KM (0.05 MI) TO THE 1300 METER POINT ON
AC5475'THE RIGHT (THE 1300 METER POINT IS ABOUT 30.5 M (100.0 FT) NORTH OF
AC5475'THE CENTER OF THE ASPHALT ROAD). CONTINUE NORTHWEST ALONG A RAMP AREA
AC5475'AND THE MOST NORTHERN ONE OF TWO RUNWAYS AND LANDING STRIPS FOR 0.9 KM
AC5475'(0.55 MI) TO THE 430 METER POINT ON THE RIGHT.  CONTINUE NORTHWEST
AC5475'ALONG THE RUNWAY FOR 0.2 KM (0.15 MI) TO THE 150 METER POINT ON THE
AC5475'RIGHT.  CONTINUE NORTHWEST ALONG THE RUNWAY FOR 0.1 KM (0.05 MI) TO
AC5475'THE 0 METER POINT ON THE RIGHT.
AC5475'
AC5475'THE BASE LINE IS A NORTHWEST-SOUTHEAST LINE WITH THE 0 METER POINT ON
AC5475'THE NORTHWEST END.  IT CONSISTS OF THE 0, 150, 430 AND 1300 METER
AC5475'POINTS.  THERE IS A DISK SET 100 FEET NORTHWEST OF THE 0 METER POINT
AC5475'TO BE USED FOR TAPE CALIBRATON.  THE HORIZONTAL DISTANCES FROM THE 0
AC5475'METER POINT TO THE CENTER OF THE 100 FOOT TAPING DISK MEASURED 99.91
AC5475'FT (30.452 M) AND TO THE OFF-CENTERED PUNCH ON THE DISK MEASURED
AC5475'100.00 FT (30.480 M).
AC5475'
AC5475'THE 0, 150, AND 430 METER POINTS ARE SET IN A GRASS AREA INBETWEEN AN
AC5475'ASPHALT ROAD AND THE MOST NORTHERN RUNWAY OF THE AIRPORT.  THE 1300
AC5475'METER POINT IS SET JUST WEST OF THE TERMINAL AND MAIN HANGAR AREA AND
AC5475'JUST EAST OF A RAMP AREA.
AC5475'
AC5475'ALL THE DISKS ARE STANDARD NGS CALIBRATION BASE LINE DISKS STAMPED
AC5475'WITH THEIR BASE LINE DESIGNAITON AND THE YEAR 1984.
AC5475'
AC5475'THE 0 AND 150 METER POINT DISKS ARE SET IN THE TOP OF ROUND CONCRETE
AC5475'MONUMENTS WHICH MEASURE ABOUT 76 CM (30.0 IN) IN DIAMETER AND SET
AC5475'FLUSH WITH THE GROUND.  THE 430 METER POINT DISK IS SET IN THE TOP OF
AC5475'AN IRREGULAR MASS OF CONCRETE WHICH MEASURES ABOUT 127 CM (50.0 IN) IN
AC5475'DIAMETER AND SET FLUSH WITH THE GROUND.  THE 1300 METER POINT DISK IS
AC5475'SET IN THE TOP OF AN IRREGULAR MASS OF CONCRETE WHICH MEASURES ABOUT
AC5475'76 CM (30.0 IN) IN DIAMETER AND SET FLUSH WITH THE GROUND.
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AC5475'
AC5475'THE 100 FOOT POINT, 150 METER POINT, 430 METER POINT AND THE 1300
AC5475'METER POINT HAVE NGS WITNESS POSTS NEARBY.
AC5475'
AC5475'THE 150 METER POINT IS A STANDARD NGS DISK STAMPED---150 1984---, SET
AC5475'INTO THE TOP OF A ROUND CONCRETE MONUMENT 76 CM (30.0 IN) IN DIAMETER
AC5475'FLUSH WITH THE GROUND LOCATED ABOUT 39.6 M (130 FT) NNE FROM THE
AC5475'NORTHEAST EDGE OF THE RUNWAY AND 29.9 M (98.0 FT) SW FROM THE CENTER
AC5475'OF AN ASPHALT ROAD.
AC5475
AC5475                          STATION RECOVERY (1996)
AC5475
AC5475'RECOVERY NOTE BY JE CHANCE AND ASSOCIATES 1996 (KAL)
AC5475'STATION IS LOCATED ABOUT 22 MILES (35.4 KM) SOUTH OF VICTORIA B.C.,
AC5475'CANADA, 18.5 MILES (29.8 KM) WEST OF SEQUIM, IN PORT ANGELES, AT THE
AC5475'WILLIAM R FAIRCHILD INTERNATIONAL AIRPORT, GEORGE YOUNT - TEMPORARY
AC5475'AIRPORT ADMINISTRATOR, PHONE 360-417-3343  TO REACH THE STATION FROM
AC5475'THE JUNCTION OF NORTH LINCOLN STREET AND EAST FRONT STREET IN DOWNTOWN
AC5475'PORT ANGELES, PROCEED WEST ON EAST FRONT STREET (ALSO MARINE DRIVE)
AC5475'0.7 MILES (1.1 KM) TO JUNCTION WITH STATE HIGHWAY 117 (ALSO TUMWATER
AC5475'TRUCK RD) , TURN LEFT AND PROCEED SOUTH ON SH 117 1.1 MILES (1.8 KM)
AC5475'TO W LAURIDSEN BLVD, TURN RIGHT AND PROCEED WEST ON 1.15 MILES (1.85
AC5475'KM) TO L STREET, TURN RIGHT AND PROCEED NORTH ON L STREET 0.1 MILES
AC5475'(0.2 KM) TO AIRPORT ENTRANCE, TURN LEFT AND PROCEED WEST 0.75 MILES
AC5475'(1.21 KM) TO A SECURITY GATE. PROCEED SOUTH AND WEST THROUGH THE GATE
AC5475'0.05 MILES (0.08 KM) TO THE HANGAR AREA, TURN RIGHT AND PROCEED NORTH
AC5475'0.05 MILES (0.08 KM) TO TAXIWAY A, TURN RIGHT AND PROCEED EAST ON
AC5475'TAXIWAY A 0.05 MILES (0.08 KM) TO JCT TAXIWAY E, TURN LEFT AND PROCEED
AC5475'NORTHWEST A TOTAL OF 0.75 MILES (1.21 KM) ACROSS RUNWAY 8-26 ONTO
AC5475'TAXIWAY J TO THE END OF THE RUNWAY.  TURN RIGHT AND CROSS RUNWAY 13-31
AC5475'ONTO AN ABANDONED TAXIWAY, PROCEED 0.1 MILES (0.2 KM) TO THE BEGINNING
AC5475'OF THE BASELINE NEAR THE PERIMETER FENCE, TURN RIGHT AND PROCEED SOUTH
AC5475'ALONG THE FENCELINE 0.15 MILES (0.24 KM) TO THE POINT 20 M (65.6 FT)
AC5475'WEST OF THE FENCELINE PERPENDICULAR TO A PERSONNEL GATE IN THE
AC5475'FENCELINE  THE STATION IS A STANDARD NATIONAL GEODETIC SURVEY
AC5475'CALIBRATION BASELINE DISK SET IN THE TOP OF A ROUND CONCRETE MONUMENT,
AC5475'SET FLUSH WITH THE SURFACE.  THE STATION IS LOCATED 21.15 M (69.39 FT)
AC5475'SOUTHWEST OF THE CENTER OF THE PERSONNEL GATE, 86.35 M (283.30 FT)
AC5475'EAST OF THE 3RD RUNWAY LIGHT SE OF THE NW END OF THE RUNWAY, 67.45 M
AC5475'(221.29 FT) NORTHEAST OF THE 4TH RUNWAY LIGHT SE OF THE NW END OF THE
AC5475'RUNWAY.  150 M (492.1 FT) SOUTHEAST OF THE ZERO METER BASELINE
AC5475'MONUMENT, 41.0 M (134.5 FT) NORTHEAST OF THE NORTHEAST EDGE OF THE OLD
AC5475'RUNWAY  THE STATION IS DESIGNATED AS A PRIMARY AIRPORT CONTROL STATION
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AC5475'(PACS) - WASHINGTON ANA SURVEYS 1996
AC5475
AC5475                          STATION RECOVERY (1997)
AC5475
AC5475'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1997 (JTM)
AC5475'RECOVERED AS DESCRIBED.
AC5475
AC5475                          STATION RECOVERY (1998)
AC5475
AC5475'RECOVERY NOTE BY NATIONAL GEODETIC SURVEY 1998 (CSM)
AC5475'THE STATION IS LOCATED AT THE AIRPORT IN PORT ANGELES.  TO REACH FROM
AC5475'THE INTERSECTION OF SR 101 AND AIRPORT ROAD, ABOUT 1.5 MI (2.4 KM)
AC5475'WEST OF PORT ANGELES, GO NORTH ON AIRPORT ROAD FOR 0.75 MI (1.21 KM)
AC5475'TO A RIGHT HAND CURVE AND THEN SOUTH L STREET ON THE LEFT, TURN LRFT
AC5475'AND GO NORTH ON SOUTH L STREET FOR 0.05 MI (0.08 KM) TO THE ENTRANCE
AC5475'TO FAIRCHILD INTERNATIONAL AIRPORT, TURN LEFT AND GO WEST FOR 0.75 MI
AC5475'(1.21 KM) TO RITE BROTHERS AVIATION, PHONE 360-452-6226, WHERE
AC5475'PERMISSION TO ACCESS MARK AND A KEY MAY BE OBTAINED.  FROM THE L
AC5475'STREET FAIRCHILD AIRPORT ENTRANCE, CONTINUE NORTH FOR 0.3 MI (0.5 KM)
AC5475'ON SOUTH L STREET TO AN INTERSECTION, TURN LEFT AND GO WEST FOR 0.7 MI
AC5475'(1.1 KM) ON WEST 18TH STREET TO THE ENTRANCE OF THE AIRPORT INDUSTRIAL
AC5475'PARK ON THE LEFT, TURN LEFT AND GO SOUTH FOR 0.2 MI (0.3 KM) ON THE
AC5475'ENTRANCE ROAD TO A SIDE ROAD RIGHT.  TURN RIGHT AND GO WEST FOR 0.5 MI
AC5475'(0.8 KM) FOLLOWING A NORTH RIGHT-OF-WAY FENCE TO PEDESTRIAN GATE
AC5475'NUMBER 27 AND THE STATION ON THE LEFT.  IT IS, 32.5 M (106.6 FT) WEST
AC5475'OF THE 8TH FENCE POST EAST OF THE GATE, 21.1 M (69.2 FT) SOUTHWEST OF
AC5475'THE PEDESTRIAN GATE, 0.5 M (1.6 FT) NORTHEAST OF A WITNESS POST AND
AC5475'FLUSH WITH GROUND LEVEL.  NOTE -- THE KEY FOR GATE 27 IS TAGGED AS
AC5475'--EDM RANGE--.  DESCRIBED BY V.C.  PICZAK.
AC5475
AC5475                          STATION RECOVERY (2008)
AC5475
AC5475'RECOVERY NOTE BY W + H PACIFIC, INCORPORATED 2008 (MBE)
AC5475'RECOVERED AS DESCRIBED

*** retrieval complete.
Elapsed Time = 00:00:05
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APPENDIX C : PROCESSING LOGS

Project No. 2015.021
Client Woolpert / USGS
Location Port Angeles
Block Elwha River

GNSS BASE SUMMARY LOG

GEOMATICS DATA SOLUTIONS

GNSS Base		USED FOR PROCESSING												
Name	Project Name	Latitude				Longitude				Height (m)	XY Datum	Z Datum	Source	Description
1S4-D	1S4D	45	46	38.95702	45.77748806	122	51	45.17290	122.86254803	-5.795	NAD83(2011)	NAD83(2011)	NGS	
AC5475	AC5475	48	07	30.75981	48.12521106	123	30	8.01501	123.50222639	51.752	NAD83(2011)	NAD83(2011)	NGS	

Project No. 2015.021
Client Woolpert / USGS
Location Port Angeles
Block Elwha River

TRAJECTORY PROCESSING LOG

GEOMATICS DATA SOLUTIONS

Trajectory Project	Download Airborne Data	Create IE Project	Copy Data to IE Project Raw	Airborne Data imported	Base Data Imported	Base Station/ Receiver		Check Base Station Coord	Check Lever Arms	Process TC	Review QC Plots	Sep - East RMS	Sep - North RMS	Sep - Up RMS	Export LSSLeica	Solution Status	Comments
2015-09-26A	DA	DA	DA	DA	DA	1S4D	R10	DA	DA	DA	DA	0.004	0.005	0.009	-	Final	
2015-09-28A	DA	DA	DA	DA	DA	AC5475	R10	DA	DA	DA	DA	0.006	0.006	0.019	-	Final	Start@146090; End@156680
2015-09-29A	DA	DA	DA	DA	DA	AC5475	R10	DA	DA	DA	DA	0.006	0.007	0.033	DA	Final	Start@235172; End@238251

NOTES:

Project No. 2015.021
Client Woolpert / USGS
Location Port Angeles
Block Elwha River

RCD30 CALIBRATION LOG

GEOMATICS DATA SOLUTIONS

	FramePro				IPAS CO+					Estimate Misalignment												
RCD30 Dataset	Download RCD30 Data in FramePro	Run in Dataset in FramePro	Image Type Created	Bits	IPAS Solution	Camera File	PPO X (mm)	PPO Y (mm)	Camera File Status	APM	Run AT	Sigma0	PPA X (mm)	PPA Y (mm)	Misalign X (arcmin)	Misalign Y (arcmin)	Misalign Z (arcmin)	Misalign X RMS (arcmin)	Misalign Y RMS (arcmin)	Misalign Z RMS (arcmin)	Accept / Reject	Comments
2015-10-29A	DA	CL	RGB	8	2015-10-29A																	
2015-10-26A	DA	CL	RGB	8	2015-10-26A	IPAS_RCD30_82541	0	0	Initial	5x5	CL	6.4	-0.0048	0.0431	-0.60	-0.32	2.21	0.08	0.11	0.19	IPAS_RCD30_82541_r1	
						IPAS_RCD30_82541_r1	-0.0048	0.0431	Interim	As above	CL	6.5	-0.0048	0.0430	0.01	0	0.00	0.08	0.11	0.19	Reject - Same as above	
						IPAS_RCD30_82541_r1	-0.0048	0.0431	Interim	5x5	CL	6.3	-0.0060	0.0436	0	-0.02	-0.03	0.06	0.07	0.12	IPAS_RCD30_82541_r2	Remove Lines 5 and 6.
Export Geometry File 20151122-185913																						

NOTES:
0.1 arcmin = 1cm at 400m, 3cm at 1000m

Project No. 2015.021
Client Woolpert / USGS
Location Port Angeles
Block Elwha River

RCD30 PROCESSING LOG

	FramePro				IPAS CO+									LPS							OrthoVista	
RCD30 Dataset	Download in FramePro	Run in Dataset in FramePro	Image Type Created	Bits	IPAS Solution	Camera File	PPO X (mm)	PPO Y (mm)	Camera File Status	Output File (Output in LPS .dat and ASCII .txt)	Output Datum	Output Units	Output Geographic txt	Update EO .dat file paths	Create Block File	Set IO	Set EO	Import DTM	Ortho Calibration	Ortho rectification (10cm)	Mosaic (10cm)	Comments
2015-10-26A	DA	CL	RGB	8	2015-10-26A	20151122-185913	0	0	Final	EO_Cal_2015-09-26A	NAD83 (2011) / UTM10N	m	CL	CL	cal_2015-09-26A	5.2	CL	CL	CL	CL	N/A	Aprrox errors of 38cm from 1000m altitude - direct georeference
2015-10-28A	DA	CL	RGBN	8	2015-10-28A	20151122-185913	0	0	Final	EO_Elwha_2015-09-28A	NAD83 (2011) / UTM10N	m	CL	CL	2015-09-28a	5.2	CL	CL	CL	CL	CL	
2015-10-29A	DA	CL	RGBN	8	2015-10-29A	20151122-185913	0	0	Final	EO_Elwha_2015-09-29A	NAD83 (2011) / UTM10N	m	CL	CL	2015-09-29a	5.2	CL	CL	CL	CL	CL	

NOTES:

Project No. 2015.021
Client Woolpert / USGS
Location Port Angeles
Block Elwha River

LIDAR CALIBRATION LOG

Mission	Copied to Disk	Nav Session	Nav Type	Calibration File	Cal Type	Processing Parameters	Check Processing Parameters	Processing Session	Number of FL	Process Topo	Process Shallow	Process Deep	Export to FL SHP	Comments
Cal_SPB_1000m_20150926_200200	DA	2015-09-26A	Final	Cal_TS_r1_20150716	Initial	Processing_20150716_1000m_250PRF	CL	20151022_142035	6	6	-	-		
								Calibration_2015-10-25_11.08.49						1000m Topo Only
Cal_SPB_500m_20150926_193502	DA	2015-09-26A	Final	Cal_TS_r1_20150716	Initial	Processing_20150716_500m_400PRF	CL	20151022_171650	6	6	6	-		
Cal_SPB_400m_20150926_190902	DA	2015-09-26A	Final	Cal_TS_r1_20150716	Initial	Processing_20150716_400m_300PRF	CL	20151022_150504	6	6	6	-		
								Calibration_2015-10-25_14.19.36						500m and 400m Shallow
														UPDATED CAL VALUES
Cal_SPB_1000m_20150926_200200	DA	2015-09-26A	Final	Cal_TS_r0_20150926	Interim	Processing_20150716_1000m_250PRF	CL	20151103_145451	6	6	-	-		
Cal_SPB_500m_20150926_193502	DA	2015-09-26A	Final	Cal_TS_r0_20150926	Interim	Processing_20150716_500m_400PRF	CL	20151103_193437	6	6	6	-		
Cal_SPB_400m_20150926_190902	DA	2015-09-26A	Final	Cal_TS_r0_20150926	Interim	Processing_20150716_400m_300PRF	CL	20151103_174700	6	6	6	-		

NOTES:

Project No.	2015.021
Client	Woolpert / USGS
Location	Port Angeles
Block	Elwha River

LIDAR PROCESSING LOG

Mission	Copied to Disk	Nav Session	Nav Type	Calibration File	Cal Type	Processing Parameters	Check Processing Parameters	Processing Session	Number of FL	Process Topo	Process Shallow	Process Deep	Verify Derived Water Surface (Coverage and Height)	Review Submerged Data for any settings issues	Review shallow to Deep Channel	Colorizie in LSS	Export to FL SHP	Merge in FME	Comments
Elwha_400m_20150928_164115	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF	CL	20151105_180024	8	8	8	-	MC	MC	-				
Elwha_400m_20150928_173220	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF	CL	20151105_190045	1	1	1	-	MC	MC	-				
Elwha_400m_20150928_174100	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF	CL	20151107_142550	17	17	17	-	MC	MC	-				
Elwha_400m_20150929_172724	DA	2015-09-29A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF	CL	20151106_075613	3	1	1	-	MC	MC	-				
Elwha_400m_20150928_164115	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r2	MC	20151121_180551	8	8	8	-	MC	MC	-				
Elwha_400m_20150928_173220	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r2	MC	20151121_192841	1	1	1	-	MC	MC	-				
Elwha_400m_20150928_174100	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r2	MC	20151121_194225	17	17	17	-	MC	MC	-				
Elwha_400m_20150929_172724	DA	2015-09-29A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r2	MC	20151121_222657	3	1	1	-	MC	MC	-				
Elwha_400m_20150928_164115	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r3	MC	20151122_135108	8	8	8	-	MC	MC	-	CL		CL	
Elwha_400m_20150928_173220	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r3	MC	20151122_173539	1	1	1	-	MC	MC	-	CL		CL	
Elwha_400m_20150928_174100	DA	2015-09-28A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r3	MC	20151122_180955	17	17	17	-	MC	MC	-	CL		CL	
Elwha_400m_20150929_172724	DA	2015-09-29A	Final	Cal_TS_r0_20150926	Final	Proc_20150928_400m_300PRF_r3	MC	20151123_021723	3	1	1	-	MC	MC	-	CL		CL	

NOTES:
A composte dataset was produced from these sessions. The data processed with Proc_20150928_400m_300PRF_r3 parameters is the base session and data from the other were used when better.