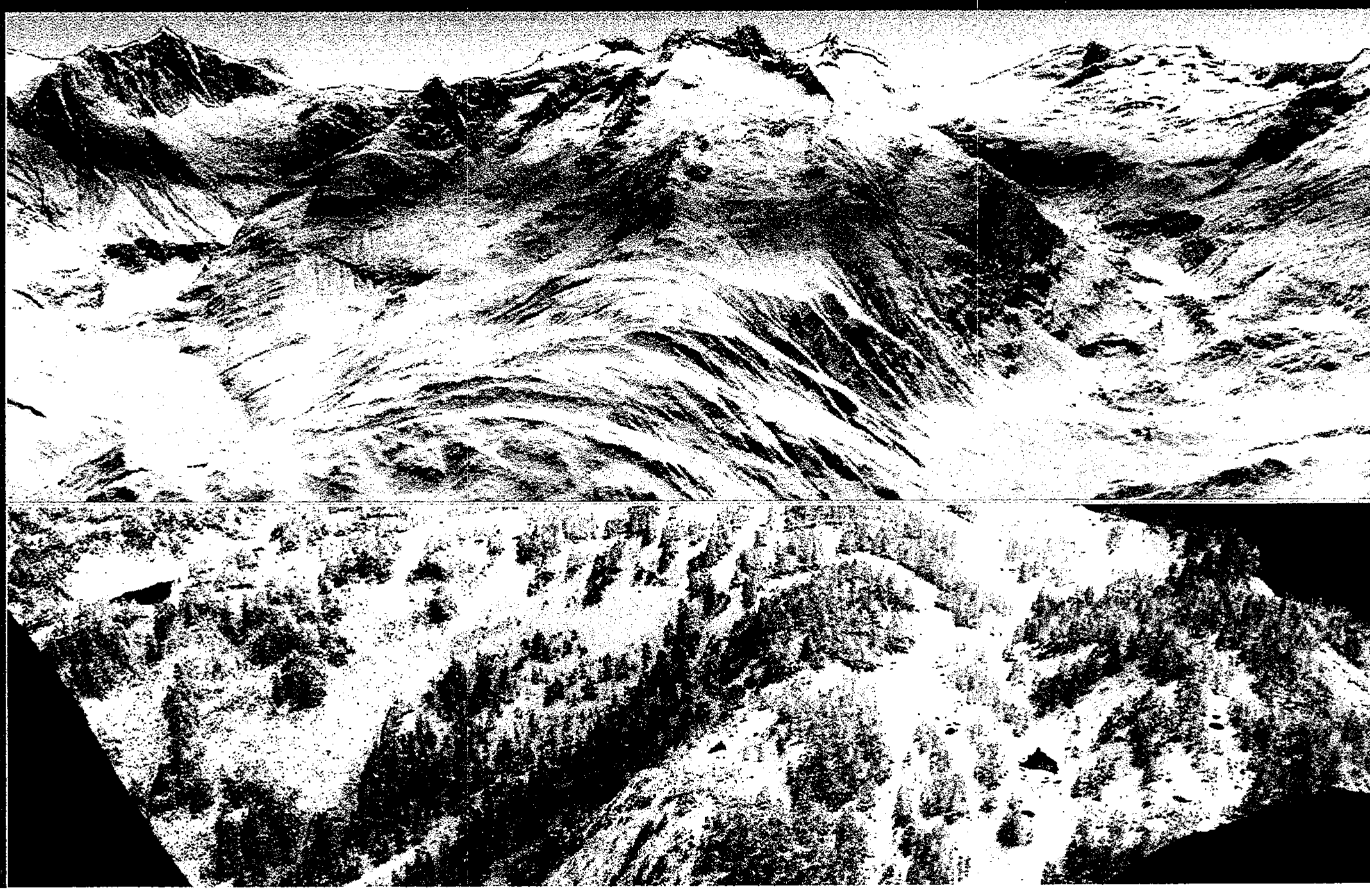
WSI Applied Remote Sensing and Analysis

FEBRUARY 8, 2013



Response to RFP #13-008

Procurement of Remotely Sensed Data

Prepared for:

City/Borough of Juneau, Alaska

Nicole Tragis, Purchasing Division
155 South Seward Street
Juneau, AK 99801

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WSI Applied Remote Sensing and Analysis

Letter of Transmittal

February 4, 2013

Nicole A. Tragis, Buyer
City/Borough of Juneau, Purchasing Division
155 South Seward St
Juneau, AK 99801

Dear Ms. Tragis,

In response to the Request for Proposals #13-008 issued on Dec. 21 2012, Watershed Sciences, Inc. (WSI) is pleased to submit this statement of qualifications and cost proposal for collecting remote sensing data (LiDAR & 4-band Orthophotography) for 142 square miles of priority areas of interest to the City and Borough of Juneau, Alaska.

Below we present an overview of our understanding of the project, approach to acquisition and processing to meet project specifications including QA/QC; our experience; contingency plans for the project; and a price proposal for the work. Data captured at our recommended settings exceeding project requirements (4-8 pulses/m^2 LiDAR and 15-30 cm orthophoto pixel resolution) will provide for a refined ground model and accompanying imagery for comprehensive management, planning and habitat mapping (streams, wetlands) efforts in the region.

WSI has collected high resolution LiDAR data in combination with aerial photography to provide the vital framework for natural resource management within temperate forest watersheds throughout the western U.S., including Alaska. We offer more operational and geospatial product experience in the terrain and conditions of the rugged West than any other remote sensing company, and have successfully accomplished, within contract timelines and budgets, some of the most challenging of remote sensing acquisition tasks there are. Our team is more than capable of meeting the RFP requirements and will exceed all resolution and accuracy specifications outlined.

WSI will be the prime contractor for the project providing all remote sensing data, quality control, and consulting. We will work with R&M Engineering (R&M) of Juneau, AK (whom qualifies as a Juneau proposer) for all survey work and PLS certification of geodetic control. We acknowledge receipt of the two addenda and have provided written verification below (page 2 of letter of transmittal).

Please do not hesitate to contact us should you have any questions regarding our qualifications or submittal. We look forward to hearing from you.

Sincerely,

Russell Faux

Russell Faux
Co-CEO, WSI
(Official Point of Contact to
Represent WSI and for Contract Negotiations)
517 SW 2nd St., Suite 400
Corvallis, OR 97333
541-752-1204

Applied
Remote Sensing
and Analysis

January 15, 2013

ADDENDUM #1 TO REQUEST FOR PROPOSAL #13-008

Procurement of Remotely Sensed Data

Information to bidders:

Please find attached questions and subsequent answers that were submitted prior and during the Pre Proposal Meeting on Friday January 11, 2013.

Receipt of this addendum should be acknowledged or your proposal may be considered non- responsive. Acknowledgment can be made by signing and faxing this addendum to (907) 586- 4561 prior to the RFP deadline, by returning the signed addendum to the Purchasing Division prior to the RFP deadline, or by including a signed copy with submitted proposal.

Nicole A Tragis

Nicole A Tragis, Buyer

Watershed Sciences, Inc. – WSI	Russell Faux	January 20, 2013
Company	Signature	Date

WSI Applied Remote Sensing and Analysis

January 31, 2013

ADDENDUM #2 TO REQUEST FOR PROPOSAL #13-008

Procurement of Remotely Sensed Data

REFER TO:
Section 2.10 Proposal Deliverables Specification and Cost Tables

Page 12 DELETE PAGE ENTIRELY

REPLACE WITH:

Attached REVISED, Section 2.10 Proposal Deliverables Specification and Cost Tables
Page 12

Receipt of this addendum should be acknowledged or your proposal may be considered non- responsive. Acknowledgment can be made by signing and faxing this addendum to (907) 586- 4561 prior to the RFP deadline, by returning the signed addendum to the Purchasing Division prior to the RFP deadline, or by including a signed copy with submitted proposal.

Nicole A Tragis

Nicole A Tragis, Buyer

Watershed Sciences, Inc. – WSI	Russell Faux	February 1, 2013
Company	Signature	Date

WSI Applied Remote Sensing and Analysis

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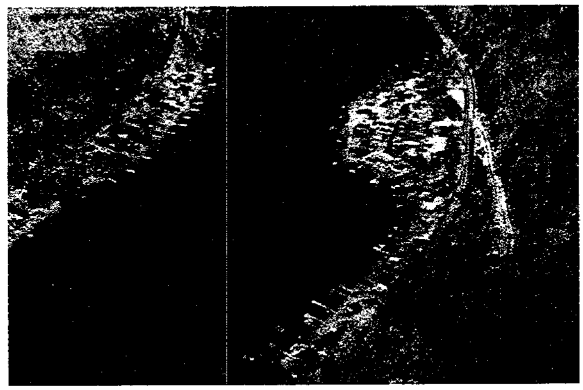
Cover: Bare earth DEM (top) and 3D LiDAR point cloud colored by NIR imagery (bottom), Heen Latinee Experimental Forest, Tongass National Forest, AK

1.0 Proposal Executive Summary

Watershed Sciences, Inc. (WSI) appreciates the opportunity to present a statement of qualifications and cost proposal to the **City and Borough of Juneau (CBJ)** for acquiring high resolution LiDAR data and concurrent 4-band orthoimagery in spring 2013 for three priority regions of interest for geospatial and habitat mapping in and around Juneau, Alaska. Below we present an overview of our understanding of project needs (and recommended resolution specifications); methodologies and approach to acquisition and processing; contingency planning; timetable; experience and methodologies for providing requested deliverables; a management plan for the CBJ project; a price proposal; and other supportive documentation. As requested, costs are presented as totals and per square mile for LiDAR and orthoimagery for Priority areas 1, 2 and 3, with an additional option for 3-band photography for each.

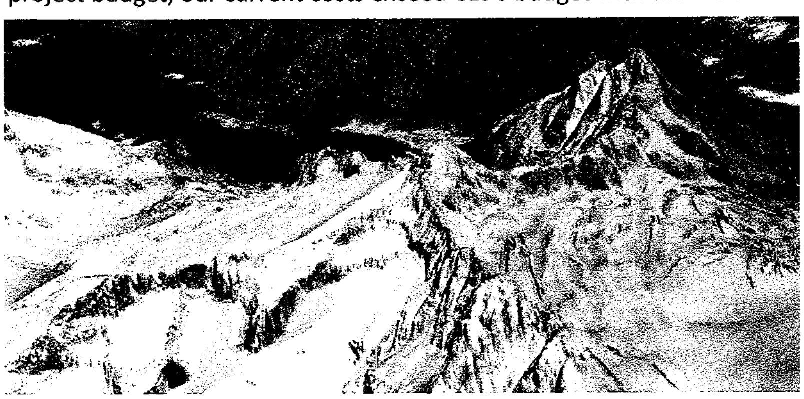


3D point cloud colored by elevation of lakeshore residences, shoreline roads, and surrounding forest in western WA, similar in configuration of landforms to Juneau, AK.

WSI will be the prime contractor for the project providing all remote sensing data, quality control, and consulting. We will work with R&M Engineering (R&M) of Juneau, AK for all survey work and PLS certification of geodetic control. As a local Juneau and SE Alaska firm, R&M has a proven track record for quality surveying and engineering services in the region. With extensive long term experience in SE Alaska and the project area itself, R&M is highly familiar with the terrain and conditions found in the CBJ.

The following provides a quick summary of key elements of our proposal:

- **Project specifications and deliverables**: WSI proposes collecting the Priority 1 areas of interest at a LiDAR pulse density specification of 8 pulses/m^2 and 4 pulses/m^2 for Priorities 2 & 3. Our corresponding recommendation for orthoimagery is 15 cm pixel resolution for Priority 1, and 30 cm pixel resolution for Priorities 2 & 3. These resolutions will allow for greater utility and will better match other high resolution datasets in Alaska. Specifications will support the generation of a 1m resolution bare earth DEM (hydroflattened) as well as CBJ-generated contour layers with 1-ft intervals in lowlands and 2-ft intervals in terrain/vegetation. Vertical accuracy (RMSE) of 12.5 cm will be met for all LiDAR products, and <1 m for all orthophotography.
- **Total project price proposal**: Efficient acquisition parameters, flight planning, ground operations, and processing methodologies will bring cost saving to the CBJ for this challenging and ambitious project while meeting or exceeding minimum specifications outlined in the RFP. Our total cost for the project with recommended specifications outlined above amounts to $333,871. While costs for the Priority 1 & 2 areas fall well within CBJ's project budget, our current costs exceed CBJ's budget with the inclusion of all four Priority 3 areas. An alternative cost calculated by lowering the Priority 2 & 3 LiDAR pulse density to the minimum 2 pulses/m^2 falls below the CBJ's projected $320,000 budget.



LiDAR and orthophoto-derived visualization from WSI data/imagery, Tongass National Forest, AK.

- **WSI experience**: WSI has unparalleled experience with high resolution airborne acquisitions in rugged terrain and locales with constrained flight windows. We have extensive experience with airborne acquisitions in Alaska, which include the AK Natural Gas Pipeline Project, Tongass National Forest, Mt. Spurr, and Whittier, AK remote sensing projects. Our high caliber datasets have set the bar for excellence in LiDAR and orthoimagery, and our client references will confirm timely delivery of products that exceed all requirements.
- **Quality assurance and quality control**: WSI's QA/QC methodologies are rigorous, thorough, iterative and integrative so that our clients receive nothing but the best. Second party QA/QC reviews have found WSI data and imagery to stand above and beyond all requirements for accuracy and quality.
- **Contingency planning**: WSI will implement an experience-based plan that will provide the highest probability of success for the LiDAR/Orthoimagery acquisition. Contingency responses to weather, lingering spring snowpack, lack of coinciding weather with low tide, and lack of clear days for imagery will include consideration of double crew configurations to compress required mission time; prioritization of difficult areas to take advantage of rare weather opportunities; and a focus on lower elevation areas earlier in the season. At all times, WSI will remain in close contact with the CBJ to discuss tradeoffs and contingencies. WSI is highly experienced in successfully collecting remote sensing data/imagery in the most challenging of locales in North America.
- **Completeness of coverage**: Our proposal provides a plan for acquisition of LiDAR and orthoimagery while meeting and/or exceeding specifications for all three Priority areas.
- **Juneau proposer preference**: while not the prime for this proposal, R&M Engineering qualifies for Juneau Proposer status.

2.0 Firm Profiles

Corporate Information

- S-Corp, est. 1999 (as LLC, converted S-Corp in 2004)
- CCR DUNS No: 078378242
- Alaska Business License: 946782
- Federal EIN ID #: 56-2428251
- Website: www.wsidata.com

WSI Watershed Sciences, Inc. (WSI) specializes in airborne remote sensing and analysis, including light detection and ranging (LiDAR), multi-spectral and hyperspectral imagery, thermal infrared (TIR), ground surveying, vegetation analysis, and water quality modeling. We have collected LiDAR and other remote sensing data throughout North America, and with our breadth of experience in remote regions including Alaska, we are familiar with the challenges of flight planning and ground surveying encountered in any study region.

WSI has distinguished itself by consistently providing ***research-quality airborne data*** with a focus on excellent mapping control and ground verification to support valuable analyses and inventory of landscape characteristics. We operate the most advanced LiDAR systems available on the market, featuring high pulse rates, dense spot-spacing, multiple returns per pulse (up to 4), and high relative and absolute accuracies. As such, we have a reputation among state and federal agencies, private industry, universities, and other research groups for delivering LiDAR data of high resolution (at least 4 points/m^2 multi-swath point density) and high accuracy (NSSDA $RMSE_z$ of less than 15 cm, usually less than 6 cm). We are known and appreciated by our client base for tailoring our data collection and delivery to the desired application of the data, and for maximizing the utility of the dataset among users.

3D LiDAR point cloud colored by NIR band orthoimagery, Upper Grande Ronde River Basin, OR

Our staff numbers over 100 and comprises a talented group of geographers, engineers, foresters, hydrologists, biologists, and landscape ecologists specializing in applied GIS and remote sensing applications. Through all phases of a project, from the flight planning and data acquisition to the final reporting and delivery of products, we adhere to techniques and practices that ensure our products meet or surpass industry standards and meet the client's needs. It is our strong-held philosophy to make sure our clients receive quality data with high utility, and we regularly recommend sensor specifications and methodologies that will ensure the delivery of such data. WSI has the capacity to complete large projects (over 1-million acres) yet is small enough to allow clients to work directly and personally with our technical staff.

Office Location	Address	Phone	Fax	Project Leader/ Email
Corvallis, OR	517 SW 2nd Street, Suite 400 Corvallis, OR 97333	(541) 752-1204	(541) 752-3770	Russell Faux faux@watershedsciences.com

R&M ENGINEERING INC. ENGINEERS • GEOLOGISTS • SURVEYORS

Corporate Information

- Established: 1975
- Alaska Business License: 045166
- EIN: 92-0103146
- Website: www.rmjuneau.com

R&M Engineering, Inc. (R&M) is an engineering and land surveying firm with over 30 years of experience in Juneau and Southeast Alaska. Specializing in civil, structural, geological engineering and land surveying services, the company has worked with various government agencies and private firms in SE Alaska for decades. R&M is comprised of 10 professionals (4 registered Professional Land Surveyors and 6 civil engineers), supported by an experienced technical staff of Survey Technicians, CAD Draftsmen, and administrative staff. The R&M team provides practical surveying and engineering expertise with long-term local knowledge of Juneau and the surrounding landscape.

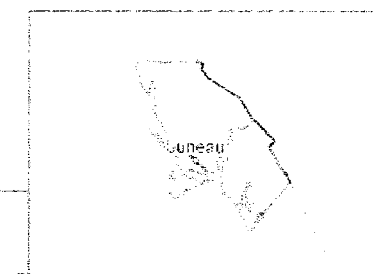
R&M has won awards for excellence in surveying in engineering from the American Society of Civil Engineers and the Alaska Society of Professional Engineers for Juneau's Calhoun Avenue Wall, the Delta Western Juneau Bulk Fuel Facility, and the Juneau Calhoun Avenue Viaduct Replacement projects. Multiple projects in SE Alaska have been featured and recognized for excellence at the Alaska Surveying and Mapping Conference. The company has a solid track record for the successful and efficient completion of projects on schedule within scope and below budget. R&M longtime clients have included the City/Borough of Juneau, Alaska Department of Transportation and various architectural firms. As part of the WSI team, R&M brings invaluable survey experience working in SE Alaska, including detailed knowledge of the landscape and regional weather patterns. With longterm residency in Juneau and provision of surveying services as requested under the RFP, R&M classifies as a Juneau proposer.

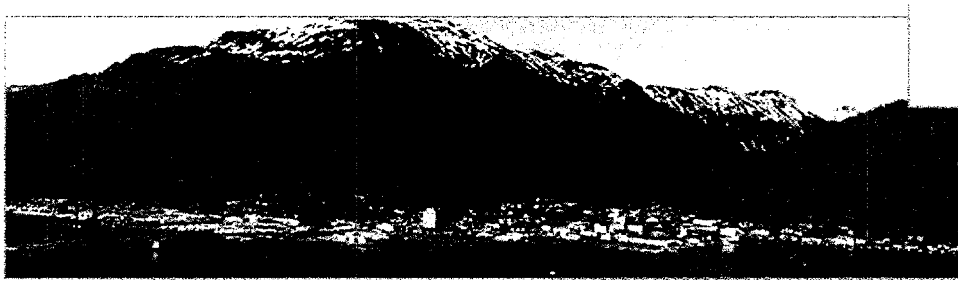
Office Location	Address	Phone	Fax	Project Leader/ Email
Juneau, AK	6205 Glacier Highway Juneau, AK 99801	(907) 780-6060	(907) 780- 4611	Mark Johnson mjohnson@rmjuneau.com

3.0 Project Understanding

The City and Borough of Juneau (CBJ) encompasses a diverse area known for its sharp elevation gradient (from sea level at downtown Juneau to 4,000 ft at the Juneau Icefield) and contrasting land forms influenced by tidal fluctuations (23 ft), watershed processes, and glacial change (retreating perennial ice). These characteristics pose a number of resource and planning issues for the CBJ related to watershed management and and characterization for streams and wetlands, tidal influences on coastal infrastructure, erosion/landslide/avalanche activity, hazard mitigation (tsunami inundation, fault detection), transportation planning, urban development, and environmental protection. The precipitation patterns for the CBJ - up to 90 inches, significant snowfall November-March, short dry spring window - also present considerable challenges when weighing how to conduct remote sensing acquisitions in this terrain-rich landscape.

Successful and timely capture of remote sensing data in such regions will require careful planning, strategy, and know-how, elements that WSI has mastered from working in similar landscapes in Alaska and the Pacific Northwest. Moreover, accurate and detailed information on topography and landscape elements within the CBJ will be crucial in making sound geospatial decisions in management, planning and habitat mapping for the Juneau project area. We will recommend that this level of information is best facilitated through resolutions for LiDAR and orthophotography on the higher end of the spectrum (4-8 pulses/m^2; 15-30 cm pixel size) to allow for robust spatial analyses.





City & Borough of Juneau, AK (above); Juneau, Alaska (left)

4.0 Methodology & Approach

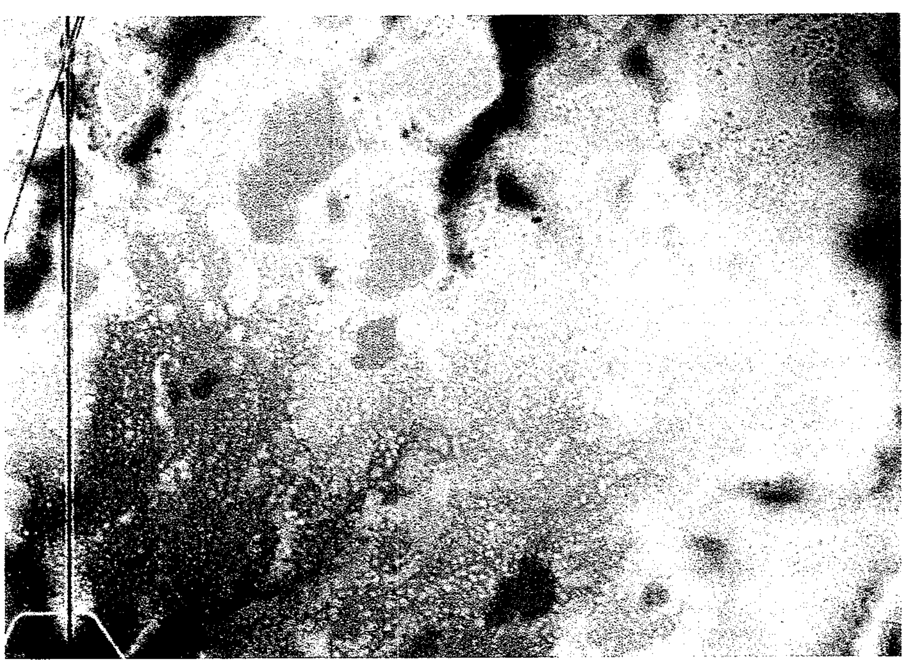
The following narrative provides an overview of our operational approach towards the successful collection of LiDAR and orthoimagery within the logistically challenging Juneau project area. We first provide an overview of our approach and recommendations for data and imagery resolutions to provide products that will achieve the application objectives of the CBJ. We follow with specifics on planned base of operations and logistics, LiDAR and 4 band imagery acquisitions methodology and approach, survey control and ground verification procedures, problem solving approaches/contingency plans, processing methodologies for requested products, and proposed project schedule and timeline identifying major tasks and milestones.

4.1 Operational Plan

Juneau Area of Interest & Recommended Data/Imagery Resolutions

Three areas of interest (AOIs) for LiDAR and 4 band orthoimagery collection are identified in the RFP (Figure 1). Priority 1 AOI (52,746 acres) is considered of highest priority, with an additional 38,494 acres in Priority 2 and 3 AOIs as budgets allow. City-requested and WSI-recommended data resolutions are provided below. To best meet the CBJ's objective, we propose collecting LiDAR data at 8 pulses/m^2 for the Priority 1 AOI which encompasses the more complex coastline and City of Juneau. This pulse density is a standard, research-grade specification for characterizing topography of streams and wetlands, and also matches that collected by WSI for the Alaska Department of Natural Resources (see **5.0 Experience & Methodology for Project Deliverables**, page 23). We also propose exceeding the requested 2 pulse/m^2 density specification for Priority 2 and 3 AOIs by collecting data at 4 pulses/m^2. This specification is considered the minimum high density resolution for landscapes in the PNW while still providing strength to capture important landscape elements (terrain breaks, floodplain terraces, wetland and channel topography) and to analyze data for various applications. Data collected at these pulse densities will also enable the generation of reliable 1m DEMs, and of desired contour layers with 1-ft intervals at low slope (< 20°) and 2-ft intervals in areas with more significant terrain (>20°) and vegetation. Orthophotography will be collected at 15 cm pixel resolution for Priority 1, and WSI will exceed the 60 cm pixel specification for Priority 2 and 3 AOIs to provide imagery that better aligns with the LiDAR resolution providing for more robust analyses of landscape features when data are fused.

		LiDAR Pulse Density		4 Band Orthoimagery Pixel Size	
Project Area	Sq Miles	Requested (Min Spec)	Recommended (WSI, Costs provided for)	Requested (Min Spec)	Recommended (WSI, Costs provided for)
Priority 1	82	5 – 10 pulses/m^2	**8 pulses/m^2**	15 cm	**15 cm**
Priority 2 & 3	60	2 pulses/m^2	**4 pulses/m^2**	60 cm	**30 cm**



½ m bare earth DEM derived from 10 pulses/m^2 LiDAR, Jepson Prairie wetlands, CA.

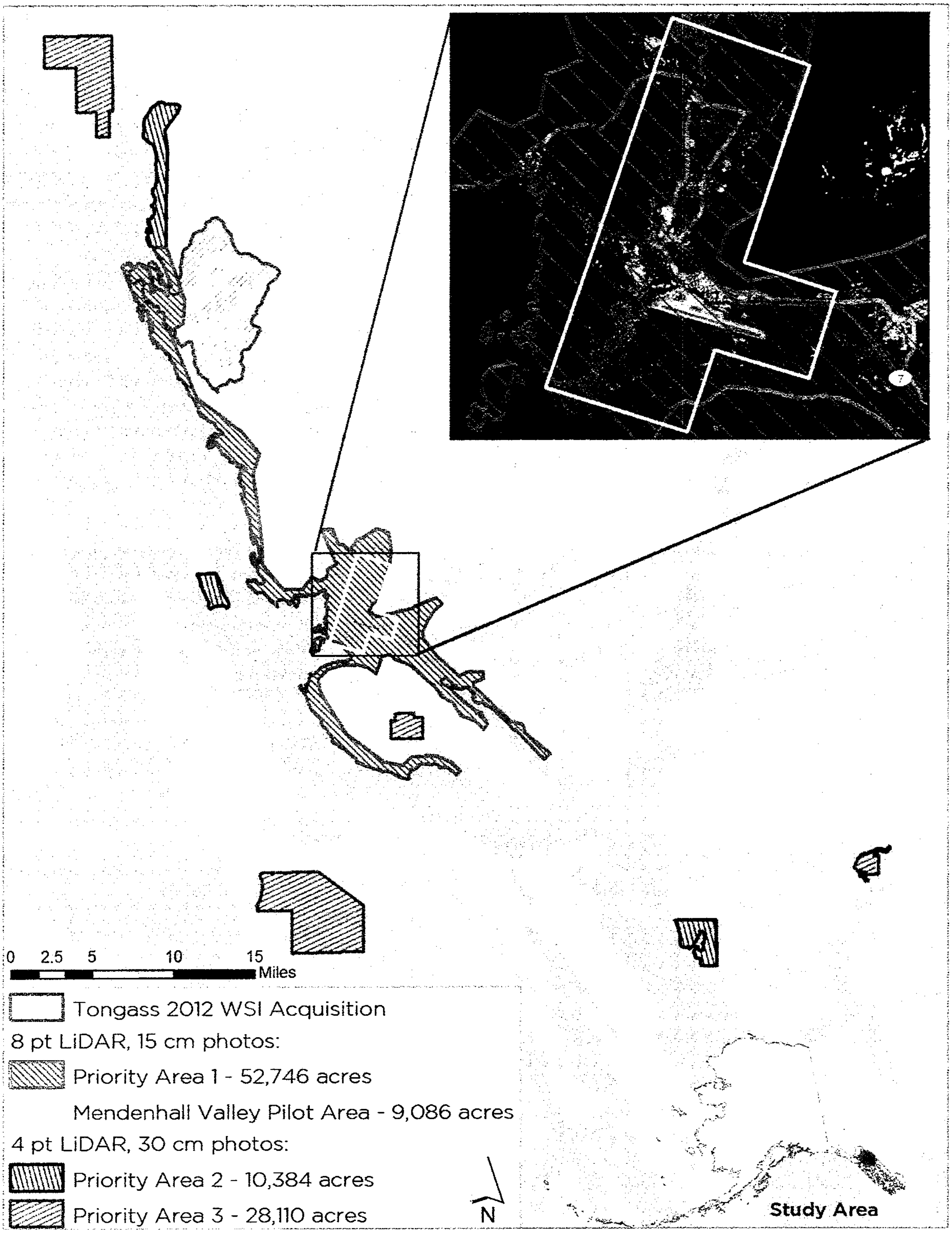


Figure 1. Map of Juneau study area outlining priority areas and recommended data & imagery resolutions.

ACQUISITION WORK PLAN

The airborne data acquisition is anticipated between late April and the end of May after snow has melted in lowlands of the project area (500-ft elevation). WSI will work with the CBJ to arrive upon a specific start date that meets the needs of the project. Once conditions are met, WSI will deploy one of its Cessna Caravans equipped with both a state-of-the-art LiDAR system and a large format 4-band camera to Juneau, AK. WSI will target acquisition of the LiDAR and orthophotos within as close a time frame as possible.

WSI recognizes that the weather in the region can be highly variable and requires flexibility and responsiveness during field operations. Through our experience on the Heen Latinee Experimental Forest and other Coastal Alaska projects, we recognize that being on site is critical to capitalize on very limited weather opportunities. WSI will deploy from Oregon on the first favorable weather opportunity arriving in Juneau, AK within one day. WSI has built contingency days into our budget to allow the aircraft to remain on site. In addition, we frequently double crew our aircraft (two crews per aircraft allowing for 2 full acquisition missions within a day) our aircraft to take advantage of flight days required to complete a project.

WSI pilot fueling our Cessna Caravan at Delta Junction, AK

WSI recognizes that weather and logistics may make it impractical to return to the study area during the 2013 season. We are highly experienced working under these conditions and have implemented near real-time quality control checks on the data while still in the field including processing of the GPS/IMU data and quick look analysis of the raw laser data. To ensure data collections are comprehensive, our survey and acquisition staff will evaluate data for QA/QC purposes and for near real-time detection of any system issues (see also **QA/QC Procedures to Ensure Product Quality**, page 35). Our Acquisition Manager will provide weekly status maps that graphically depict areas acquired and provide statistics relevant to the acquisition. This type of reporting is routine for all of our projects.

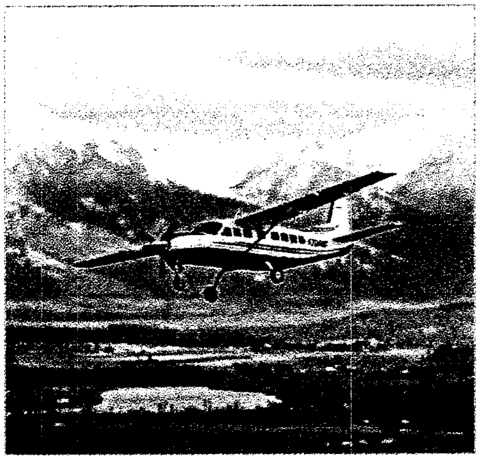
The physical layout of the Juneau Priority areas lends itself to a natural sequence for data collection. WSI's operational strategy will be as follows:

- WSI will deploy an aircraft equipped with a LiDAR sensor and 4-band camera to Juneau, AK when conditions meet data acquisition specifications. This will be done in close coordination with the CBJ.
- Priority 1 will be the primary focus for the LiDAR data and orthophoto collection targeting as feasible the low tide window for all nearshore areas (see below under **Low Tide Acquisition Approach**, page 9). WSI will continue to collect data and imagery as long as conditions permit. Field crews in coordination with our Acquisition Manager will select flight lines based on prevailing weather conditions.
- Whenever sky conditions are acceptable, WSI will fly imagery on all project areas.

WSI Applied Remote Sensing and Analysis

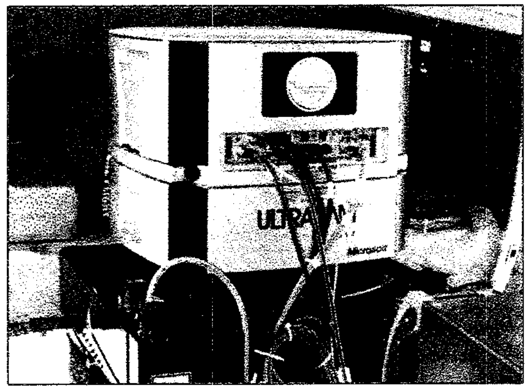
LiDAR Acquisition

LiDAR data will be acquired using one or more LiDAR systems (Leica ALS50 Phase II, ALS60, ALS70) comprised of a roll-compensated sensor with GPS/IMU and capable of emitting ≥150,000 laser pulses per second with multi-pulse in air (MPIA) capabilities (ALS60 = 200KHz; ALS70 = 500KHz). Calibration test flights are performed frequently to verify computation of lever arms and ultimately the relative and absolute accuracy of the system. Our state-of-the-art methodology includes flying opposing lines with ≥ 50% swath overlap to ensure laser penetration to the ground in variable terrain at multiple angles, and to negate laser shadowing. Prior to every mission, the GPS satellite constellation and PDOP values will be computed for the project area and used to plan particular mission times. Our LiDAR systems are GPS/GNSS capable and include "tightly coupled" GNSS-IMU technology. This allows for greater flight efficiencies by having a greater range of available satellites and by no longer requiring satellite lock during turns. Our GPS, IMU, and boresighted LiDAR systems result in line-to-line differences in points locations that are indiscernible. LiDAR coverage will be complete, with no data gaps or voids. A summary of specifications, sensor settings and flight conditions is provided below. Further detail for WSI acquisition equipment can be found under **WSI Acquisition Equipment** (page 17).



LiDAR Specifications	
Sensor	Leica ALS50, ALS60, ALS70
Multi-Swath Pulse Density	≥8 pulses/m^2 Priority 1 ≥4 pulses/m^2 Priority 2 & 3
Scan Angle	≤ 30° (+/-15° from Nadir)
Returns Collected Per Laser Pulse	Up to 4
Intensity Range	1-255
Laser Footprint Diameter on Ground	10-40 cm
Swath Overlap	50% side-lap (100% overlap)
Flight Line Direction	Opposing w/ Orthogonal Cross-Lines
Vertical RMSE (1σ), *bare earth slope <20°*	≤ 12.5 cm
Horizontal Accuracy (σ)	≤ 30 cm
Relative Accuracy (RMSE), between swaths	≤ 10 cm
Range reproducibility (RMSE), within swaths	≤ 5 cm
Collection conditions	Leaf off, no snow below 500 ft

4 Band Imagery



WSI will acquire aerial photography using an UltraCam (Eagle, XP or equivalent) large format mapping camera with project-specific along-track overlap and sidelap settings (60% forward overlap and ≥30% sidelap). The UltraCam is a frame-based digital sensor capable of simultaneous capture of red, green, blue, and NIR bands. Cameras are integrated with a GPS receiver and Inertial Measurement Unit (IMU) that streams aircraft position and attitude data (pitch, roll, and yaw) for direct computation of image external orientation (EO).

The sensor will be flown with flight parameters designed to capture imagery at 15 cm or 30 cm pixel resolution, depending on Priority project area. Overall flight tolerances will be set to industry standards to support engineering accuracies and orthophotography specifications, utilizing the most nadir portion of each image to minimize lean effects inherent with photography. Photos will be collected during peak sun angles for the day, under clear conditions with minimal cloud cover.

Aerial Photography Specifications	
Equipment	UltraCam Eagle or Equivalent (4 band or 3 band) RCD105 (for exclusive 3 band)
Data Format	R, B, G, NIR
Resolution	15 cm pixel Priority 1 30 cm pixel Priority 2 & 3
Target Wavelengths (UltraCam Eagle)	Blue: 400-600 Green: 480-660 Red: 590-720 NIR: 695-1000
Along Track (Vertical) Overlap	≥ 60%
Horizontal (Swath) Overlap	≥ 30%
Horizontal Accuracy	≤ ± 3 pixels RMSE (< 1 meter)
Side Boundary Areas Overlap	> 25%
Collection conditions	Leaf off, no snow below 500 ft, no fog or obstructing clouds, minimal shadowing concurrent with LiDAR

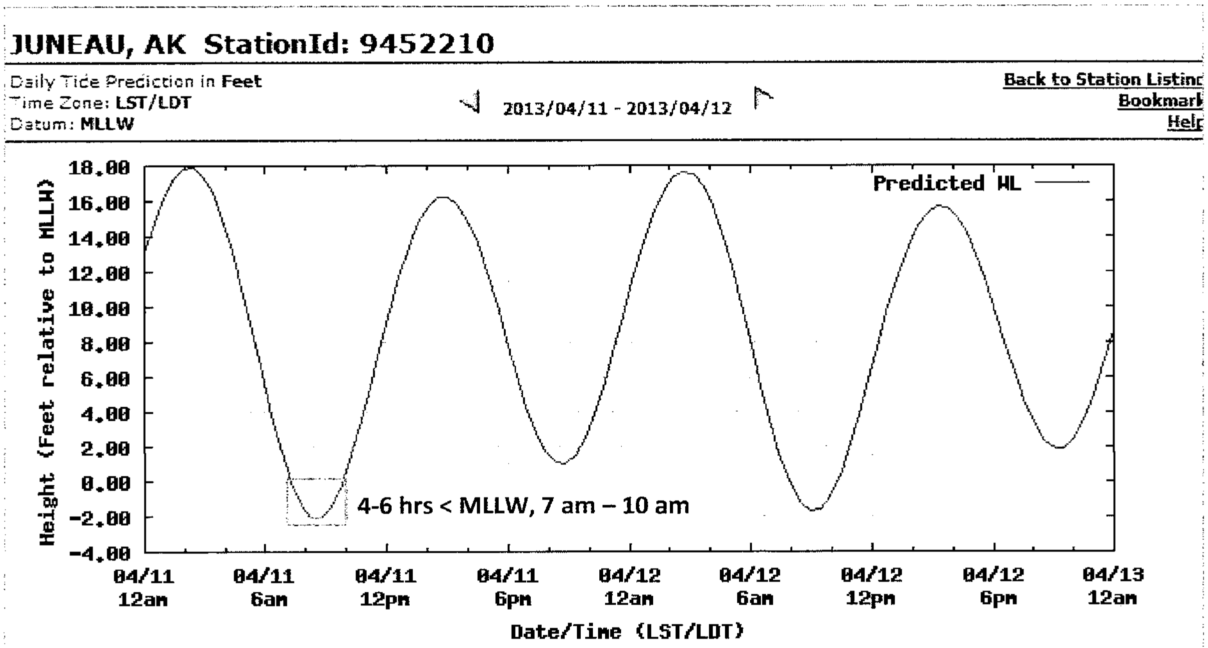
The 15 cm GSD specification within Priority 1 will provide for greater versatility in imagery applications and will support appropriate spatial accuracies (1"=50' scale) for public works and preliminary engineering applications for the City of Juneau and surrounding coastal areas. This high resolution will not be necessary (nor cost effective) in Priorities 2 and 3 where we assume that vegetation mapping will be a primary goal. Imagery acquired at 30 cm GSD will still provide imagery of superior clarity and resolution compared to other imagery available for the project area.

The collection of 3-band (natural color) orthophotography is also an option, for which we would use our UltraCam (using only 3 bands), or a Leica RCD 105 medium format digital camera.

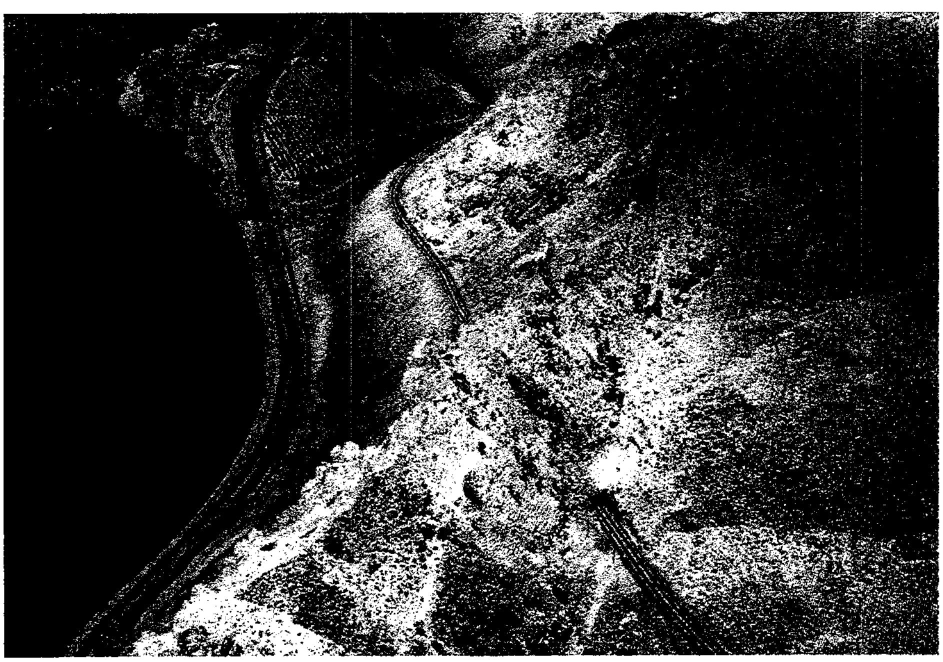
Low Tide Acquisition Approach

The CBJ has requested prioritization of acquisitions of coastal areas during the lowest tide conditions possible, preferably below mean lower low water (MLLW). Given the constrained windows of opportunity during April/May for flying during optimal conditions for both LiDAR and imagery within SE Alaska, the additional request to collect at low tide is ambitious. However, WSI has taken this additional request into consideration in our flight planning and field logistics to facilitate capturing data during low tide. During low tide events on and around April 11 and 27, projected daily time span for collecting during low tide amounts to 4-6 hours. Coastal flights will be coordinated to the extent possible during these time periods within the constraint of daily local weather patterns.

Planned flightlines are oriented parallel to the coast (Figure 2) which will enable efficiently flying coastal portions of each AOI while 'chasing the tide' either in or out. In addition, total daylight hours increase by two hours between April 1 (13:15 hours of daylight) and May 31 (17:45 hours) presenting increased opportunities for double crew logistical configuration to quickly capitalize on optimal conditions of weather, ground conditions and tide. While optimal weather conditions will take precedent in order to ensure collection of data and imagery within the spring 2013 timeframe, we will be poised as much as possible to align LiDAR and image collection during low tide windows.

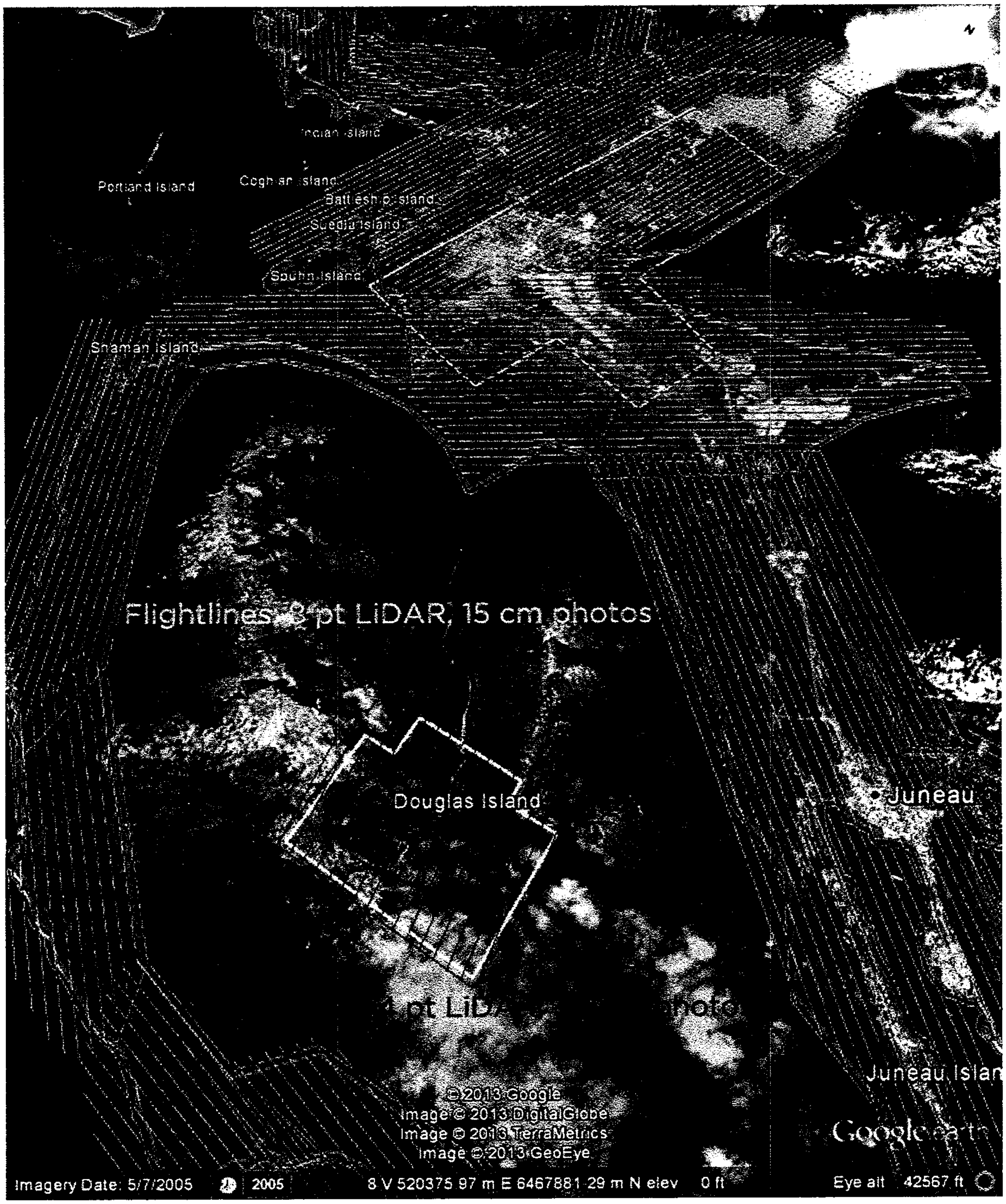


Example tide chart for April 11, 2013 in Juneau, Alaska showing acquisition time period (duration and time of day) during which time coastline will be exposed at a negative tide below MLLW. From: [*http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=9452210*](http://tidesandcurrents.noaa.gov/noaatidepredictions/NOAATidesFacade.jsp?Stationid=9452210)



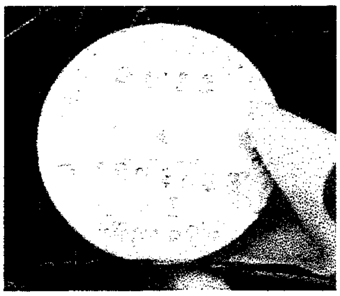
3D point cloud colored by elevation and textured by intensity, Wenatchee study area, east-central WA.

Figure 2. Portrayal of flight line orientation along coastline for Priority 1 AOI in Juneau, AK. Parallel alignment with the coastline facilitates efficient collection of data during low tide windows.

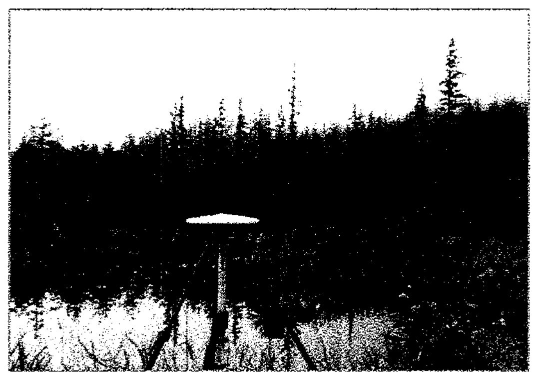


SURVEY CONTROL

Control Monuments: Our team will provide all necessary ground control for this project. All survey control will be accomplished in close collaboration among team members, with *R&M Engineering* of Juneau, AK responsible for all PLS oversight following Alaska statutes. R&M will certify and/or establish all survey monuments and will independently verify the accuracy of the data. R&M is an Alaskan firm with significant experience in geodetic survey, with on-the-ground knowledge of Juneau and the surrounding landscape. WSI and R&M will work with CBJ officials to gain access permission to any private property for survey control operations.



Simultaneous to the airborne LiDAR data collection missions, the WSI/R&M team will collect static (1 Hz recording frequency) survey data at monuments using dual-frequency L1-L2 DGPS base stations with carrier phase correction. Our team will use existing control whenever possible - we have identified **four NGS** (national geodetic control) monuments that potentially meet our criteria of currency, reasonable access, and GPS visibility. In addition, a **one-second CORS** (continually operating reference station) is located within the Priority 1 AOI (previously established control point from WSI's Tongass USFS LiDAR and Orthophoto Acquisition in 2012) and is central to the overall study area. WSI will utilize the CORS to the maximum extent possible including as a redundant control during the airborne data collection and in the computation of new control coordinates. Maximum baseline lengths between survey control and the aircraft GPS will not exceed 37 kilometers (20 nautical miles), as we have found from previous experience that relative accuracy is degraded when baseline lengths exceed **20 nautical** miles.



Our team proposes to have survey monument pairs strategically located within the study area that will provide for efficient baseline coverage, geospatial distribution of check points, and cost effectiveness for each of the priority areas (Figure 3). The survey control plan is as follows for each of the Priority Areas:

- <u>Priority 1</u>: A total of three control monument pairs will be used for the Priority 1 area. Maximum baseline lengths between the survey control and the aircraft GPS will not exceed **13 nautical miles.** Ground control will include NGS monuments (PID=AI4906, PID=AI4907) located at the Juneau Airport. We will establish two additional monument pairs to the north along the Glacier Highway (**P1A** and **P1B**). **P1A** provides survey control within baseline of all Priority 1 areas, and will provide a convenient location for collecting QA checkpoints. **P1B** is an existing WSI monument established for the 2012 Tongass USFS LiDAR acquisition. **P1B** provides a location for collecting QA check points on the far northern edge of the Priority 1 as well as a location for airborne control for Priority 2 & 3 AOIs located to the north.
- <u>Priority 2</u>: The two most northern blocks of priority 2 can be controlled using Priority 1 AOI's monument pairs. If Priority 2 is included, an additional monument pair (**P2A**) will be set near the end of Point Bishop Dupont Road. This monument will be used to control the LiDAR data collection for the Taku Harbor area. The baseline length will be extended to **16 nautical miles** for this area.
- <u>Priority 3</u>: The Priority 3 area contains four distinct blocks. The two northern blocks (Eagle Crest Ski Area and Lion's Head Mt./Kensington Mine) can be controlled using the Priority 1 area monuments. The southern areas (Hawk Inlet and Snettisham) will require one additional survey monument (**P3A**); however, the baseline length will be extended to **20 nautical miles** for this area as the cost to establish a monument closer to Snettisham will be prohibitively high (should the CBJ require, WSI can provide additional cost).

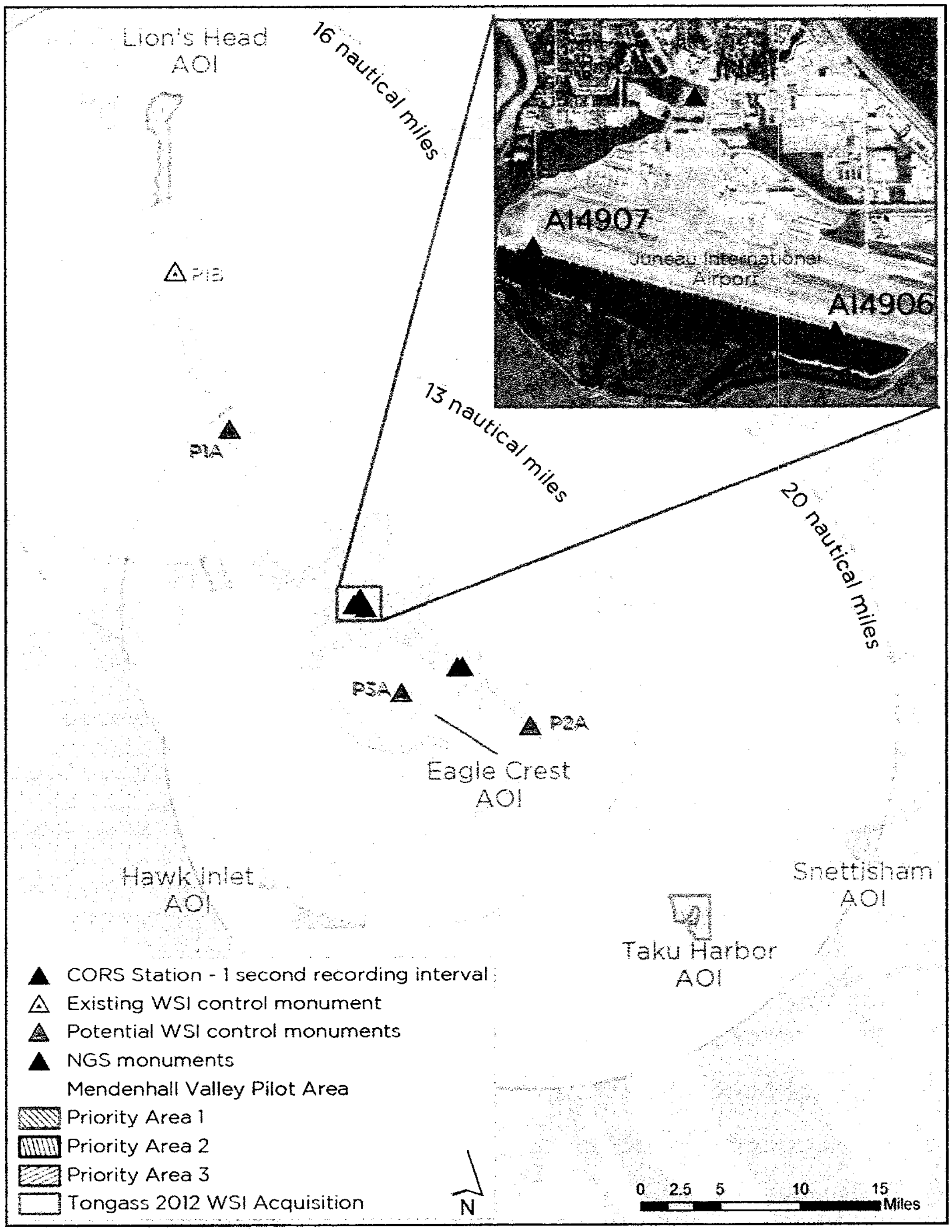
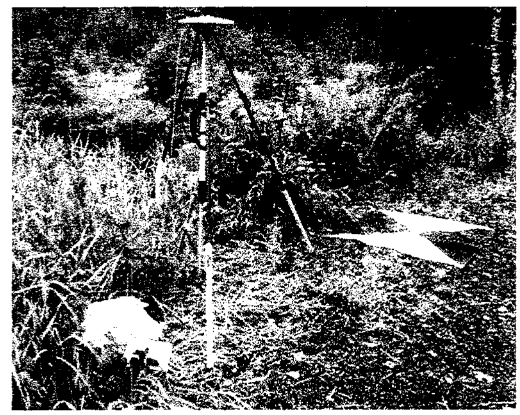


Figure 3. Map of anticipated survey control monuments including NGS (primary control) and anticipated potential new control points to be established and certified by R&M Engineering.

After the static GPS data have been collected, the files will be processed using the Online Positioning User Service (OPUS). Multiple sessions will be processed over the same monument to confirm antenna height measurements and reported OPUS position accuracy. In areas where existing control monuments do not meet the minimum criteria of currency, reasonable access, or GPS visibility, WSI will establish new vertical control monuments. Our project team will occupy each control for a minimum of two sessions (6+ hours, 4+ hours) to verify and update control coordinates. Each new mark will be located by tying to one or more NGS CORS by static GPS. As a minimum, two independent sessions, each at least 2 hours long, will be used for CORS less than 80 km distance; two independent sessions, each at least 4 hours in duration, will be used for CORS more than 80 km distance from bases. The identity and published positions of CORS to which new monument locations are tied will be documented in the Final Report.

For the orthophotography acquisition, aerial photo targets will be placed throughout the project area prior to photo acquisition to aid in both geo-spatially correcting the orthoimagery and in assessing final accuracy. Located within RTK range of the ground survey monuments, the targets will be secured with surveyor's nails and routinely checked for disturbance. Each target will be precisely located using five RTK points (four corner points and a center point). Air target points will be used as ground control points in aerial triangulation adjustments to ensure a high-quality fit between the imagery and survey control. Additional air target control points not used in aerial triangulation will be used as independent check points in assessing the absolute accuracy of final orthoimagery.



Ground Check Point Collection: To verify LiDAR point calibration, our field crew will collect ground check points (GCPs) using GPS-based real-time kinematic (RTK) survey techniques. For an RTK survey, the ground crew uses a roving unit to receive radio-relayed corrected positional coordinates for all ground points from a GPS base unit set up over the control sites identified in Figure 3 above. The roving unit records precise location measurements with an error (σ) of ≤ 1.5 cm relative to the base control. We will distribute a minimum of 300 ground check points (GCPs) within the Priority 1 AOI. Checkpoints will be acquired as feasible within the more remote and inaccessible Priority 2 and 3 AOIs. In areas with limited access, our team will collect airborne data and ground control checkpoints over a surrogate site within baseline of inaccessible sites during the same mission in order to validate the accuracy of the airborne LiDAR in these areas. Checkpoints will be clustered on open, bare earth surfaces with a level slope to aid in calibration and enable effective assessment of swath-to-swath reproducibility. In addition, R&M Engineering will collect a set of independent checkpoints (20-30) distributed throughout the study area to provide an independent assessment of accuracy. Techniques for establishing all ground check points will be outlined in the Final Report, including the identity, locations and position residuals of all GCPs used to evaluate survey accuracy.

	Summary of Ground Check Points
# Base Stations Used	Two per nmi radius
GPS PDOP During Acquisition	≤ 3.0; ≥ 9 satellites
Maximum GPS baseline length	≤ 13 nmi Priority 1; ≤ 16 nmi for Priority 2; ≤ 20 nmi for Priority 3
Roving unit recording precision (RMSE)	≤1.5 cm relative to base control
Check points (hard bare earth, level slope)	300+ points for Priority 1; as feasible/surrogate flight(s) for Priorities 2 & 3 20-30 independent checkpoints by R&M

CHALLENGES & CONTINGENCY PLAN

In the case of airborne remote sensing, the variability of weather poses the greatest risk to successful data acquisition. This is particularly true in Coastal Alaska where clear days can average as few as four per month and monthly percent possible sunshine averages only 39%[1]. In Juneau and surrounding areas, we understand that the data collection opportunities will be limited and we will implement an experienced-based plan that will provide the highest probability of success. This base plan provides for the aircraft to be on station during the data collection time frame and the flexibility of the acquisition team to acquire data in a logical sequence based on the Priorities provided by the CBJ.

WSI is committed to providing on-time data that meet or exceed specifications. However, WSI recognizes that even with a solid Operational Plan that weather in this region can restrict airborne data acquisition opportunities. In the event of contingency planning, WSI will use the following strategy to meet project specifications, deadlines, and deliverables:

Factor	Project Element Affected	Contingency
Worse than average weather in Juneau and surrounding areas during the data collection window	Meeting Deadlines	We frequently double crew our aircraft (double staff aircraft allowing for 2 full acquisition missions of 5-6 hrs duration per day) to take advantage of flight days required to complete a project. Our acquisition managers will monitor the weather conditions and deploy a second crew if/when conditions warrant.
Clouds and fog that persist in certain data acquisition blocks	Meeting Deadlines	Our Operations Plan allows the flexibility to prioritize flight lines in difficult areas to take advantage of rare weather windows. In some cases, we may implement lower altitude flight plans in order to "get under" persistent clouds in certain areas. These modifications typically increase data quality and exceed specifications.
Large spring snowpack that remains at the higher elevations (but below 500-ft) in the study area into the data acquisition seasons	Meeting Deadlines	This may results in abbreviated data collection window. We will focus on lower elevation areas first and then target higher elevation areas later in the season. WSI has the acquisition resources to either double crew or send a second laser to the project site in order to meet acquisition deadlines.
Low tide and weather opportunities do not coincide	Specifications	Possibly the most significant risk to meeting specifications is the low tide request in near shore areas. WSI will target near shore areas at low tide, but will prioritize weather opportunities over tidal constraints. If a near shore area is collected during high tide, we will make every opportunity to recollect during a subsequent low tide window. However, our first priority will be complete coverage of the project area.
No clear days for flying imagery	Deadlines/ Specifications	Our large format camera enables us to collect imagery over the full project area in a relatively short amount of time. However, if there are no optimal clear days for image collection, WSI will discuss options with the city including collection under sub-optimal conditions or redeployment under different conditions.

[1] from historic weather indicators in Juneau, AK - http://www.climate-zone.com/climate/united-states/alaska/juneau/

WSI has worked in some of the most difficult terrain in the western United States including Alaska. The following are a few examples of how good planning, flexibility, and persistence have helped us complete similarly difficult projects (see also **Expertise and Methodology for Project Deliverables,** page 23):

1. Alaska Proposal Natural Gas Pipeline: WSI was able to complete the 1.9M acre (2,100 mile) high-resolution LiDAR data acquisition within a 4-month time schedule due to both flexibility in field operations and good logistical planning. Prior to starting acquisition, WSI acquisition staff with cooperation from Alaska DNR identified the most difficult weather areas within the entire study area including Valdez, Thompson Pass, Isabelle Pass, Atigun Pass, and Prudhoe Bay/Dead Horse. WSI monitored weather and conditions daily in these areas and moved resources immediately based on changing conditions. In one instance, WSI moved our Caravan and crews from Bettles to Deadhorse within 12 hours to take advantage of a narrow weather opportunity.
2. Mt Spurr, Alaska: WSI was contracted to collect high-resolution LiDAR data on 37,000 acres on Mt. Spurr in Coastal Alaska in the summer of 2010. WSI was originally scheduled to fly in the July time frame, but lingering snow and poor weather pushed the schedule forward. WSI Acquisition Managers monitored weather patterns and ground observations daily in order to identify a favorable weather window. WSI was able to collect the Mt. Spurr project in the only flyable conditions during the July/August time frame. Due to the weather delays in acquisition, WSI accelerated data processing to provide deliverables within the original deliverable schedules. Data products exceeded all project specifications.
3. Big Island, Hawaii: In 2011, WSI was contracted to fly five project sites within Maui and Hawaii (Big Island). One of the Big Island sites had a persistent low cloud deck that precluded acquisition at the planned flight specification. In order to acquire these data on schedule, WSI modified the flight plan for a lower altitude (and hence higher point density). Although this cost WSI more flight time, we were able to complete the project on schedule with data that exceeded the original specifications.
4. Sun Valley, Idaho: WSI was contracted to fly the Sun Valley/Big Wood River during the late October time frame in order to capture low flow/leaf off conditions. However, when an early snow storm threatened the success of the project, WSI immediately doubled our acquisition crews completing 25 hours of data acquisition within two days. The LiDAR data acquisition was completed within hours of the arrival of snow which ended the fall acquisition season for this locale.
5. Heen Latinee, Tongass National Forest, Alaska: WSI completed acquisition of high resolution LiDAR and 4-band photos on the Heen Latinee Experimental Forest north of Juneau during the fall of 2012. WSI was able to deploy our aircraft to Juneau during a rare clear weather window in early October. The deliverables were provided before the end of the contract and met and/or exceeded all specifications. A subset of the LiDAR that was within in the CBJ was also delivered to the CBJ Engineering Department. The ultimate success of the project illustrates the power of persistence and our ability to deploy resources in relatively short notice. We also learned valuable lessons on how variable weather patterns are for Juneau and what it takes to successfully complete a project in this region.

WSI Acquisition Equipment

Function	(Number) Equipment Manufacturer - Description
Aircraft	(2) **Cessna 208B** (Grand Caravan) – owned (2) **Partenavia P-68** (Observer) – operate with long term lease (1) **Bell Long Ranger Helicopter** – operate with long term lease
Airborne Sensors	(1) **Leica ALS70 LiDAR** w/ 500KHz pulse rate with MPIA; Honeywell uIRS IMU (1) **Leica ALS60 LiDAR** w/ 200KHz pulse rate with MPIA; Honeywell uIRS IMU (2) **Leica ALS50 Phase II** LiDAR w/ 150KHz pulse rate with MPIA, one with full waveform digitizer. Litton LN200 IMU (1) **Optech Orion- C LiDAR** w/ 200KHz pulse rate. Litton LN200 IMU (1) **Microsoft UltraCam Eagle**, large format 4 band digital camera (2) **Leica RCD 105** 39 megapixel medium format true color digital cameras (1) **RED Epic 5K** Digital Cine Camera, 14 mp video at 120 fps at full 5K (1) **FLIR Systems SC6000 QWIP** thermal infrared sensor. SC6000 is a scientific grade sensor (8-9.2μm) with a pixel array of 640 x 512.
Geodetic, Ground Survey	(6) **Trimble R7 GPS** (12) **Trimble R7 GNSS Bases** (1) **Trimble R10 GNSS RTK Rover Kit** (4) **Trimble R8 GNSS RTK Rover Kit** (1) **Trimble R6 GNSS RTK Rover Kit** (4) **Pegasus-EX portable weather stations** – collect temperature, barometric pressure, wind speed, wind direction, relative humidity, and rainfall at multiple intervals (including one-minute).

Timetable

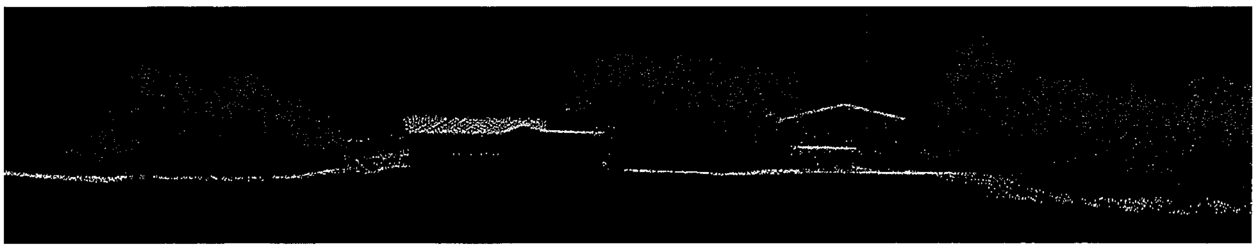
As stated in the RFP, an award is anticipated by March 15, 2013, with a project kick-off meeting anticipated shortly thereafter. The table below provides timelines for tasks and milestones, with anticipated review periods needed by the CBJ. WSI can provide all final data products within 3 months of acceptance of pilot area data, bringing anticipated project close to December 31, 2013. The timeline holds for any project scope (Priority AOIs 1; 1 and 2, or 1, 2 and 3) chosen by the CBJ.

Task & Milestones	Timeframe	Projected Dates for Completion
LiDAR and Orthoimagery Acquisitions	April 13 – May 15, 2013	April 13 – May 15, 2013
Pilot Area Delivery (9,086 acres)	Within 8 weeks post acquisition	June 13 – July 15, 2013
CBJ Review	*(Within 4 weeks of Delivery to CBJ)*	*(July 13 – Aug 15, 2013)*
Final Product Deliverables	Within 3 months of Pilot Area Acceptance by CBJ	November 15, 2013
CBJ Review	*(Within 6 weeks of Final Delivery to CBJ)*	*December 31, 2013*

4.2 Processing

LiDAR

Upon the LiDAR data's arrival to the office, WSI processing staff will initiate a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks include GPS control computations, kinematic corrections, calculation of laser point position, calibration for optimal relative and absolute accuracy, and classification of ground and non-ground points. Bare earth classification is accomplished using the automated ground modeling process with visual QA/QC inspection to identify any misclassifications. We will employ LiDAR ground model parameters appropriate for the project terrain and vegetation based on our past experience with Juneau and similar landscapes.



LiDAR cross section showing points classified as ground (brown), building (grey), and vegetation (green). Pulse density affects the ability to fully resolve features such as buildings with overhanging vegetation, and height classes of vegetation.

In greater detail, **LiDAR processing steps** include the following:

1. Kinematic corrections – resolve aircraft position data using kinematic aircraft GPS and static ground GPS data
2. SBET files – develop 'smoothed best estimate of trajectory' (SBET) file that blends post-processed aircraft position with attitude data. SBETs are used extensively for laser point processing.
3. Calculate laser point position – SBET position is associated to each laser point return time, scan angle, intensity, etc.
4. Create raw laser point cloud in LAS (ASPRS v 1.2) format
5. Convert to orthometric elevations (NAVD88) by applying appropriate Geoid model correction (see **Ellipsoidal & Orthometric Elevations** below, page 19).
6. Relative accuracy testing and calibration (see also **QA/QC Procedures to Ensure Product Quality**, page 35).
    a. Automated filter of erroneous points
    b. Classify ground points for individual flight lines
    c. Conduct automated line-to-line calibrations for system attitude parameters, mirror flex, and GPS/IMU drift
    d. Calculate calibrations on ground-classified points from paired flight lines with results applied to all points in a flight line. All flight lines are used for relative accuracy calibration.
7. Classify resulting calibrated data to ground (involving point cloud cleaning workflow; see also **QA/QC Procedures to Ensure Product Quality,** page 35) and other client designated ASPRS classifications
8. Assess statistical absolute accuracy via direct comparisons of ground classified points to ground RTK survey data
9. Generate bare earth models as triangulated surfaces
10. Generate highest hit models as a surface expression of all classified points (excluding noise and withheld classes)
11. Export surface models as GeoTIFFs at 1 meter pixel resolution
12. Perform quality control checks. Manually inspect for any anomalies including tiling artifacts, seam matching, etc. Review all metadata and final reporting for completeness and accuracy.

WSI's department technical leaders (calibration, QA/QC, and product development) will oversee all phases of data analysis including checks of quality and completeness, data compilation, and accuracy assessments. Key software includes Waypoint GPS, Trimble Business Center, IPAS TC, ALS Post Processing, ERDAS, TerraScan/TerraMatch/ TerraModeler of the TerraSolid software suite v.12, and proprietary WSI software developed for specific WSI workflow steps.

Ellipsoidal & Orthometric Elevations

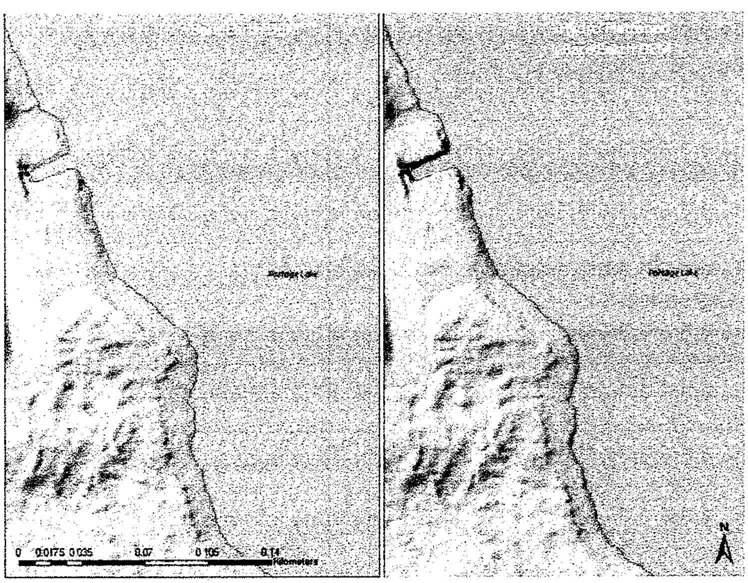
All products will be delivered with clearly documented metadata and referenced to standard NGS coordinate systems, including standard epoch dates. LAS files will be delivered in two versions with the following coordinate system specifications:

Point Cloud Version	Horizontal System	Horizontal Datum	Horizontal Units	Vertical Datum	Vertical Reference	Vertical Units
Orthometric	AKSP1	NAD83(CORS96) Epoch 2002.00	US Feet	NAVD88	GEOID2009	US Feet
Ellipsoidal	AKSP1	NAD83(CORS96) Epoch 2002.00	US Feet	GRS80	(Ellipsoid)	US Feet

Conversions to the orthometric elevations will be computed using the standard National Geodetic Survey (NGS, http://www.ngs.noaa.gov/) GEOID2009 definition, publicly available at http://www.ngs.noaa.gov/GEOID/USGG2009/. Generally, this process entails re-projecting a LiDAR point's UTM northing and easting into standard Latitude-Longitude coordinates. These coordinates are then used to look up and interpolate over the earth's surface an elevation correction using the geoid grid. This correction can then be used to convert between ellipsoidal and orthometric elevations at the given point. Various of-the-shelf software packages will be used to perform this operation, including IPAS TC, Blue Marble Desktop, and Trimble Business Center. Points in both datasets shall be shifted to a standard and uniform epoch date of January 1, 2002, using the Horizontal Time Dependent Positioning (HTDP) system developed by NGS and integrated into the Blue Marble Desktop software package. See more at http://www.ngs.noaa.gov/TOOLS/Htdp/Htdp.shtml.

Hydroflattening & Water's Edge Breaklines

The hydro-flattening process eliminates artifacts in the digital terrain model over water caused by both increased variability in ranges or dropouts in laser returns due to the low reflectivity of water. Significant water bodies and rivers anticipated to require the most attention for the hydro-flattened DEM for Juneau include Mendenhall Lake, Auke Lake, Mendenhall River, and the ocean channel at Juneau. Methodologies for hydro-flattening will include the following:



Lakes and other closed water bodies with a surface area >2 acres will be flattened to a consistent water level. For rivers > 30 m in average width, hydro-lines will follow the direction of flow (gradient to follow the immediate surrounding terrain) and will be flat and level from bank to bank and at or below immediately surrounding terrain. Streams will break at road crossings, but road fills will not be removed from the DEM. Bridges will be delineated and removed from the DEM.

Bare earth & hydro-flattened bare earth models, Whittier, AK

Along the shoreline, water levels will vary given changes in tide level over the course of the data collection, presenting discontinuities in the water's edge. These anomalies will be retained and variations in water surface elevation from tidal variations will not be removed. However, WSI will generate a pseudo-line (no elevation values) along the tidal shoreline to depict a best estimate of the water's edge at time of collection.

Hydro-flattening is performed through a combination of automated and manual detection and adjustment techniques designed to identify lake and river boundaries and water levels. Boundary polygons and polylines are developed using an algorithm which weighs LiDAR-derived slopes, intensities, and return densities to detect the water's edge. Edges are then manually reviewed and edited as necessary. Once hydrolines are developed, water body elevations are computed from the filtered LiDAR returns. The elevation of each water body is computed as 5 centimeters above the minimum elevation of filtered water surface cells within the polygon. This approach ensures that all spurious returns off the water surface (both artificially high and low) are excluded from water level assessment. Water's edge breaklines are then incorporated into the final terrain model and enforced as hard breaklines. The initial ground classified points falling within polygons or polylines are reclassified as water.

Optional Vegetation Classification

The RFP states that additional classification of the LiDAR point cloud into different vegetation types is desirable. This is a standard procedure within our workflow (incurring no additional cost). WSI will classify non-ground points into appropriate vegetation height classes (low, high) in collaboration with client needs and intended analyses. A first step in the data analysis will be to identify above-ground non-vegetation returns in order to exclude them from the vegetation classes. We will subset the above ground LiDAR returns as vegetation or non-vegetation by applying a series of automated routines on the LiDAR point cloud to identify buildings, vehicles, and power lines. If needed, a refinement of the classification will include an object-oriented approach using derived raster models (i.e. 1st return models, ground models, 1st return intensities, etc.) and existing spatial data layers (NAIP imagery) to identify non-vegetation features. The automated process will result in a high level of confidence in the vegetation classes. However, we do expect some level of commission from features such as small utility poles and fence lines that are difficult to distinguish from above ground vegetation.

LiDAR Deliverables

The following LiDAR deliverables will be provided for the Pilot Area (9,086 acres) and for full Juneau project scope. All deliverables will be provided on USB hard drives (2 copies).

Aircraft Trajectories (SBET files), *ASCII text & shapefile formats*

- Aircraft position (easting, northing, elevation) & attitude (heading, pitch, roll), and GPS time recorded at regular intervals of 1 second or less. May include additional attributes.

Points, *Las v 1.2 format*

- All Return Raw Point Cloud, provided in two versions (will include common set of timestamps as point identifiers):
    - Ellipsoidal elevations (WGS84)
    - Orthometric NAVD88 elevations (Geoid 09) with zero at MLLW for Juneau, AK
- Classified Point Cloud, as per the following LAS codes:

Juneau LiDAR Point Classification			
LAS code	Class	LAS code	Class
1	Processed, unclassified	6	Bridges
2	Bare earth	7	Noise
3	Low vegetation (< 2 m)	9	Water
5	High vegetation (> 2 m)	10	Ignored ground (proximate to breakline)

All Point files will include the following fields: X,Y,Z (to nearest 0.01 meter), Return Intensity, Return Number, Point Classification (for classified point cloud), Scan Angle, GPS time (Adjusted, time reported to nearest microsecond or better). Point families will be maintained.

Surface Models

- Hydro-flattened Bare-earth DEM, 1-meter resolution, *ESRI Grid format*
- Highest Hit DEM, 1-meter resolution, *ESRI Grid format*
- Intensity Images, ½ m resolution, *GeoTIFF format*

Vectors, *shapefile format*

- Hydro Breaklines
- Ground Control and Validation Check Points
- Flightlines, with plane locations at GPS second intervals
- Project Area Boundary
- Tiling Scheme

Coordinate System & Delineations

Projection	Alaska State Plane 1
Horizontal Datum	NAD83, U.S. Survey Feet
Vertical Datum	NAVD88 Geoid 09, U.S. Survey Feet
Tiling Delineations	TBD in coordination with CBJ GIS needs

Reporting

To include, at minimum:

- Acquisition information including mission planning and flight log information
- Survey control and checkpoints used in QA/QC
- Conversion process for ellipsoidal heights to orthometric heights (with zero elevation at MLLW for Juneau)
- Methodologies for calibration, point classification, validation, and deliverable production
- Results and Accuracy Assessments/QAQC reports, detailing resulting point density and relative & absolute accuracies
- FGDC-compliant Metadata for:
    - Raw LiDAR point cloud (ellipsoidal)
    - Classified Point Cloud (orthometric)
    - Bare Earth DEM, 1 m resolution, hydroflattened & Hydro Breaklines, including methodology for development
    - Ground control points
    - Flight-lines
    - Tiling delineation
    - Project Extent

MULTIBAND ORTHOIMAGERY

The collected digital photographs will go through the following processing steps to create final orthophoto products. Image radiometric values will be calibrated to specific gain and exposure settings associated with each capture. Calibrated images will be geometrically corrected for lens distortion, radiometrically adjusted, and saved in TIFF format. Photo position and orientation will be calculated by linking the time of image capture, the corresponding aircraft position and attitude (provided by the integrated IMU/GNSS system), and the post-processed smoothed best estimate of trajectory (SBET) data. Within LPS, automated aerial triangulation (AT) will be performed to tie images together and adjust the photo block to align with ground control. Adjusted images will be ortho-rectified using the LiDAR-derived ground model to remove displacement effects from topographic relief inherent in the imagery. Individual ortho-rectified TIFFs will be blended together into a seamless mosaic by correcting any remaining radiometric or intensity differences between images. Mosaic lines will be non-apparent by carefully blending and editing seam locations. Processing software used will include Microsoft's UltraMap software suite, POSPac MMS, and Inpho's OrthoVista.

4 band orthophotography of residential area alongside stream, Upper Grande Ronde River, OR.

All four bands (RGB and NIR) will be rectified, mosaicked and edited concurrently as one process. Color balancing and detailed mosaic edits will be primarily focused on the natural color imagery and will target best visual appearance of the RGB bands. Those edits will be applied automatically to the NIR band for consistent seamless mosaicking and appearance. Additional separate edits to optimize or customize the NIR band are not proposed. Adjustments to the NIR band are highly application-dependent and should be done on a case-by-case basis.

Orthoimagery Deliverables

For the Pilot Area (9,086 acres) and for full Juneau project scope, the following orthophotography deliverables will be provided. All deliverables will be provided on USB hard drives (2 copies).

Imagery

- Unrectified image frames
- Orthorectified 4 band Imagery Mosaic, *GeoTIFF format*
    - Pixels outside boundary set to no-data value

Vectors, *shapefile format*

- Project Area Boundary
- Photo Index (vector grid, centerpoints, flightlines)
- Photo Block Files

Reporting

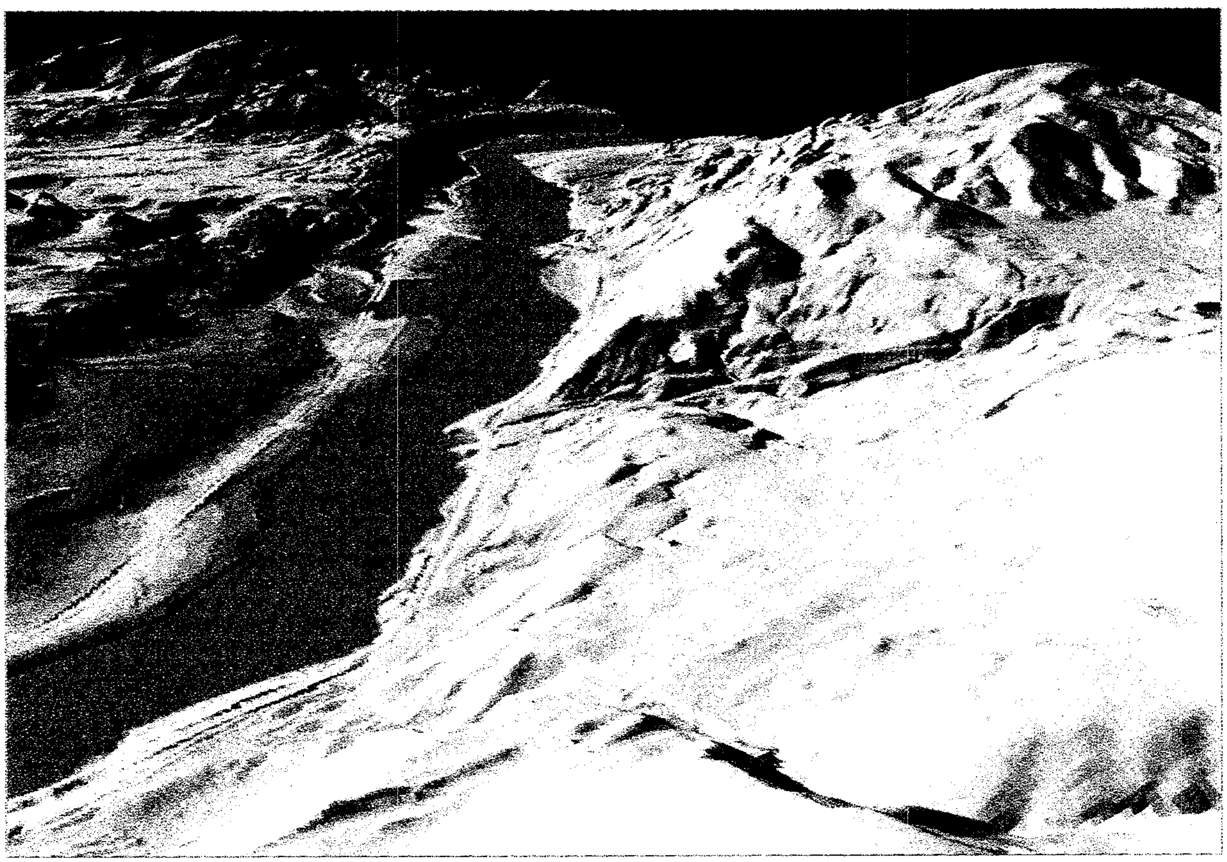
To include, at minimum:

- Acquisition information including mission planning and flight log information
- Survey control and targets used in QA/QC
- Results and Accuracy Assessments/QAQC reports, detailing horizontal accuracy evaluation and results
- FGDC-compliant Metadata for:
    - Flight-lines
    - Tiling delineation
    - Project Extent

Coordinate System & Delineations

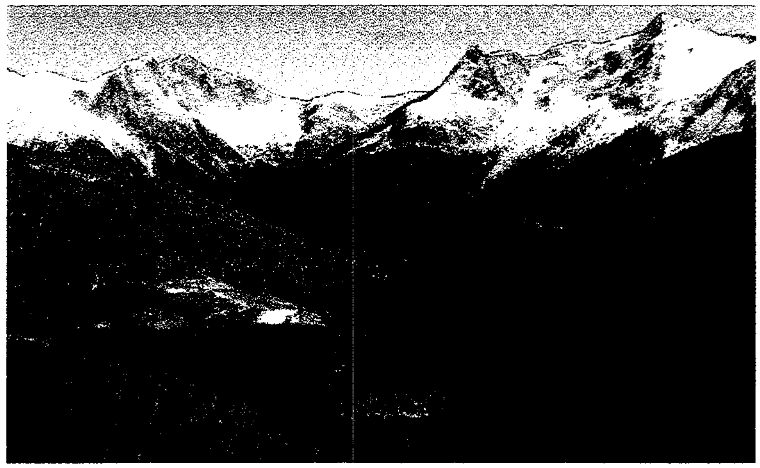
Projection	Alaska State Plane 1
Horizontal Datum	NAD83, U.S. Survey Feet
Tiling Delineations	TBD in coordination with CBJ GIS needs

LiDAR-derived DEM from ground classified points, 3D view looking North along Lake Entiat (Columbia River) past Chelan Falls (to left), Wenatchee Puget Sound LiDAR Consortium contract 2009.



5.0 Expertise & Methodology for Project Deliverables

WSI has been collecting high resolution LiDAR and orthophotography since 2005, with a focus on landscapes of the Pacific Northwest. In 2012 alone, WSI collected over 4 million acres of broad-area LiDAR for over 40 contracts, with the majority centered in the PNW including Alaska. Many of these included an orthophoto component to inform analyses with LiDAR and enable further photogrammetric evaluations. These projects varied in pulse density and resolution specifications; sensor settings; deliverables; and intended data applications. We have been delivering accurate high resolution LiDAR to clients in the PNW for over eight years, and have refined acquisition, processing and quality control methodologies to ensure deliverables meeting client needs and industry standards. Team member R&M Engineering has provided quality surveying services to SE Alaska clients including the CBJ for decades.



3D point cloud colored by orthophotography, Tongass National Forest near Juneau, AK

WSI offers exceptional knowledge of the Juneau project area; experience with SE Alaska remote sensing acquisitions; specialized experience and capabilities to provide the requested data products; an outstanding past performance record in the project region and elsewhere; and unique capabilities that are notable and make our company stand out. These strengths are summarized below.

WSI has collected remote sensing data in over 20 states and provinces in North America.

Strengths of WSI – R&M Team

CATEGORY	OVERVIEW
Knowledge of Juneau Landscape & Acquisition Conditions	✓ Understanding of the terrain, land cover types, and prevailing seasonal weather patterns characteristic of the Juneau project area and SE Alaska. ✓ Unparalleled experience in timely acquisitions within the challenging PNW landscape (weather and ground conditions), capturing data during appropriate timeframes for application of data. ✓ Tailored calibration and processing methodologies for the SE Alaska Landscape
Specialized Experience and Capabilities in Providing Requested Data Products	✓ State-of-the-art equipment, methodologies, and capabilities for LiDAR and orthoimagery acquisition, surveying services, and data/image processing. ✓ Expertise in the collection of remote sensing data to support potential applications desired by the CBJ, including contour generation, natural resource characterization and inventories, hazard management, urban planning/development, restoration planning and monitoring, forest inventory, engineering design, transportation planning, infrastructure assessment, disaster response, and many others. ✓ Reputation for producing research-grade remote sensing datasets.
Past Performance in SE Alaska and PNW	✓ Past project history and experience with the CBJ and Tongass National Forest (data collected at > 8 pulses/m^2). ✓ Successful acquisition and delivery of 2M acres of LiDAR for the AK natural gas pipeline corridor which included some of the most challenging and remote localities in the U.S. ✓ Excellent track record meeting budgets and schedules.
Unique Qualifications	✓ Intimate knowledge of the challenges of working in SE Alaska, with three recent formidable Alaska projects successfully completed by WSI (AK Pipeline, Tongass NF, and Whittier, AK) ✓ Focus on data collections following research consortium model (high resolution, standard specifications) which ensures state-wide data integrity, quality, cohesiveness, and across-the-board utility. ✓ Ensuring that newly acquired data match with older WSI data at the point level to create a near seamless elevation dataset. WSI will take care to match Tongass USFS LiDAR data with the new Juneau project area.

Below we summarize the methodologies and operational procedures WSI has developed to ensure that final deliverables are of the highest caliber. Methodologies and relevant project examples are provided for each requested section. Examples focus on relevant geographies, i.e., projects completed by WSI in Alaska, Washington, Idaho, and Montana. Project Contacts have been verified as available for comment during the proposal review period. While the product deliverables of high density LiDAR data, bare-earth DEM, Quality Assurance & Assessment, and FGCD-compliant Metadata are included in virtually each project outlined, project examples outlined for each were chosen to best represent each deliverable.

5.1 Acquisition of High Resolution LiDAR

WSI is intimately familiar and experienced with the collection and processing of high resolution LiDAR data. Since deploying our first LiDAR systems, WSI has been delivering accurate LiDAR at high pulse densities varying between 6 pulses (broad area acquisitions) to 25 or more pulses/m^2 (primarily full feature transmission line work) for over eight years. With our first LiDAR contracts in the Pacific Northwest where vegetation is structurally complex and diverse and terrain is highly variable, our early experimentation with pulse density quickly led us to the conclusion that 8 pulses/m^2 or greater is necessary in order to provide the full utility and accuracy of LiDAR models in this region. Through our years of service to the LiDAR community, WSI has been unyielding about the merits of high resolution LiDAR for a variety of applications (Evans et al 2009; Kane et al. 2013). This, along with the undeniable superiority of the data products that result, has been instrumental in the acceptance of the 8 pulses per m^2 specification as the standard adopted by the LiDAR research community as well as by state LiDAR consortiums. The Oregon LiDAR Consortium and Puget Sound LiDAR Consortium are two such groups (for which WSI is the sole LiDAR vendor) which have standardized the specifications for the collection of LiDAR data for public access and maximum utility. Consequently, we have collected high resolution LiDAR data over a widespread geographic area in North America, with millions of acres of land mapped in over 20 states or provinces. High resolution LiDAR of 8 pulses/m^2 or more has undeniably become WSI's hallmark within the industry.

WSI operational procedures for collecting accurate high resolution data include detailed flight planning and parameter settings including 50% overlap of flight lines, flight headings in coordination with terrain contours, terrain following, GPS/IMU/boresighting coordination resulting in indiscernible line-to-line differences in point locations, and careful scan angle/flight altitude configurations. These are tailored to the project landscape to ensure achieving and exceeding the nominal pulse density with 100% coverage. Processing methodologies include highly accurate calculations of laser point position using precise survey control and airborne GPS/IMU data, relative accuracy testing and tight line-to-line calibration, a combination of rigorous automated and manual point filtering procedures, and classification of the point cloud using in-house processing algorithms tailored for the particular study area/landscape through custom WSI processing R & D.

3D point cloud, looking north at the glacial lake at the head of Cowee Creek, Héen Latinee Experimental Forest, Tongass National Forest, AK.

The following examples illustrate our experience in collecting and delivering LiDAR at high pulse densities. The focus is on our operational and processing expertise for Alaska projects, but there are many more examples of high resolution data acquisitions accomplished by WSI in the Pacific Northwest (see **5.2 Bare Earth DEMs**) where the 8 pulses/m^2 standard was developed. Each of the below projects also serves as an example of WSI experience in generating **Bare Earth DEMs**, and in rigorous **QA/QC Procedures to Ensure Product Quality**.

Project Specifications

PROJECT SIZE: 35,292 acres

DATES OF SERVICE: Oct 2012 – Jan 2013

CUSTOMER: Alaska Dept. of Natural Resources

CUSTOMER POC: Rod Combellick, 907-451-5007, rod.combellick@alaska.gov

DELIVERABLES

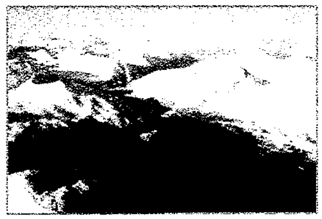
- Raw and Classified (to ground) Returns (LAS)
- Bare Earth DEM (hydroflattened) (1 m ESRI GRID)
- Highest Hit DEM (1 m ESRI GRID)
- Vegetation Model (1 m ESRI GRID)
- Intensity Images (1/2 m GeoTIFF)
- Water's Edge Breaklines (shapefile)
- FGDC-compliant Metadata

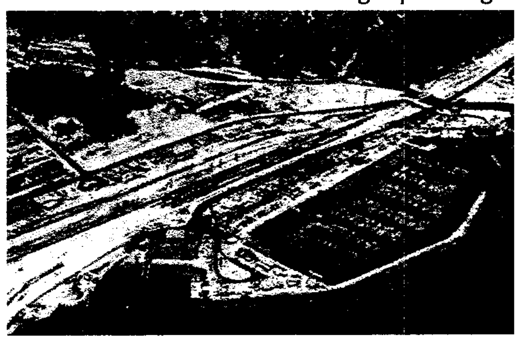
Top: Photo of Whittier and Passage Canal; bottom: 3D LiDAR point cloud colored by elevation of Whittier harbor.

WHITTIER, ALASKA

High Resolution LiDAR

High resolution data (13 pulses/m^2 below 1600 ft elevation; > 4 pulses/m^2 above 1600 ft) were collected for the town of Whittier and terrain surrounding Passage Canal to aid in analyses of topographic and geophysical properties of the area in relation to hazard mitigation (glacial and seismic relative to location of town). Challenges included collecting data during suitable flight conditions, and flight planning in extreme terrain. Data were successfully collected and delivered within contracted timeline and budget. Vertical RMSE was < 5 cm.





Project Specifications

PROJECT SIZE: 37,295 acres

DATES OF SERVICE: Fall 2010

CUSTOMER: Ormat

CUSTOMER POC: Patrick Walsh, 775.356.9029, ext 32268, pwalsh@ormat.com

DELIVERABLES

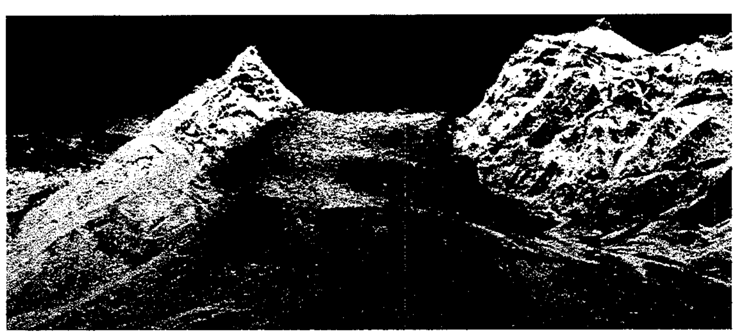
- All returns, Ground returns, Model Keypoints (LAS)
- Bare Earth DEM (hydroflattened) (1 m ESRI GRID)
- Highest Hit DEM (1 m ESRI GRID)
  Intensity Images (1/2 m GeoTIFF)
- FGDC-compliant Metadata

3D LiDAR point cloud of glacier at Mt. Spurr, AK

MT. SPURR & CHAKACHAMNA RIVER, AK

High Resolution LiDAR

WSI acquired high resolution (6 pulses/m^2) LiDAR data for the Chakachamna River and Mount Spurr study area west of Anchorage, AK. Project applications included gaining an understanding of fault patterns and neotectonic activity for hydro-geothermal exploration. Vertical accuracy was 7 cm RMSE. Challenges included flight planning around Mt. Spurr given the extreme elevation changes and weather variability in coastal Alaska. The data exceeded all accuracy specifications and was delivered within contracted timeline and budget.



Project Specifications

PROJECT SIZE: 2.0 million acres

DATES OF SERVICE: Sept 2010 – Feb 2012

CUSTOMER: Alaska Dept. of Natural Resources

CUSTOMER POC: Rod Combellick, 907-451-5007, rod.combellick@alaska.gov

DELIVERABLES

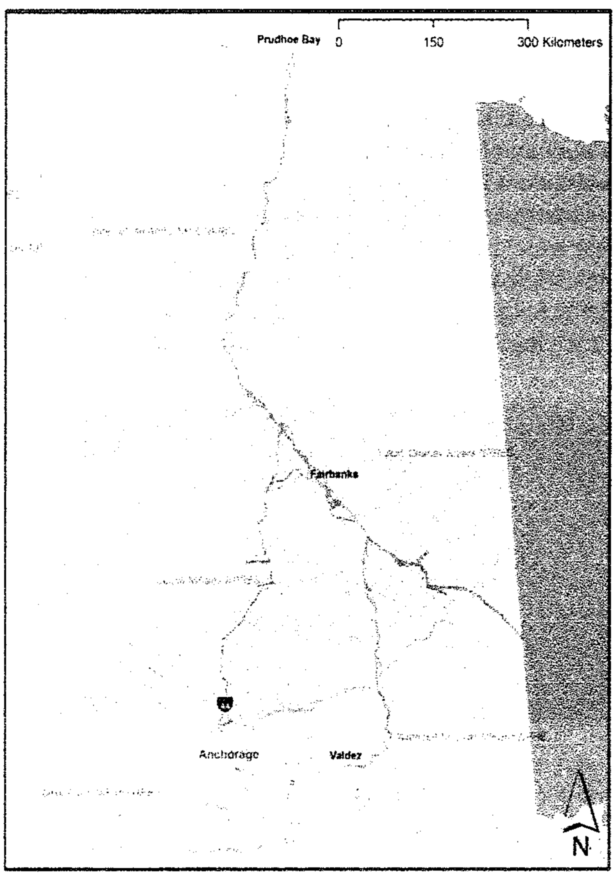
- SBET files (shapefile)
- Fully Classified Points (LAS)
- Hydroflattened Bare Earth DEM (1 m ESRI GRID)
- Highest Hit DEM (1 m ESRI GRID)
- Intensity Images (1/2 m GeoTIFF)
- Hydrographic Breaklines
- Lake Edge Boundaries
- 1-m Contours
- FGDC-compliant Metadata

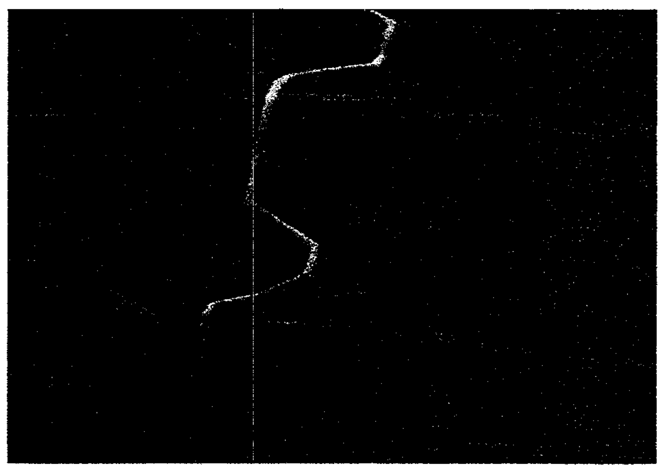
Bottom L: project scope (orange corridor); Bottom R: 3D LiDAR point clouds of pipeline coarse across terrain (top) and bridge across Gerstle River (bottom).

NATURAL GAS PIPELINE CORRIDOR, AK

High Resolution LiDAR

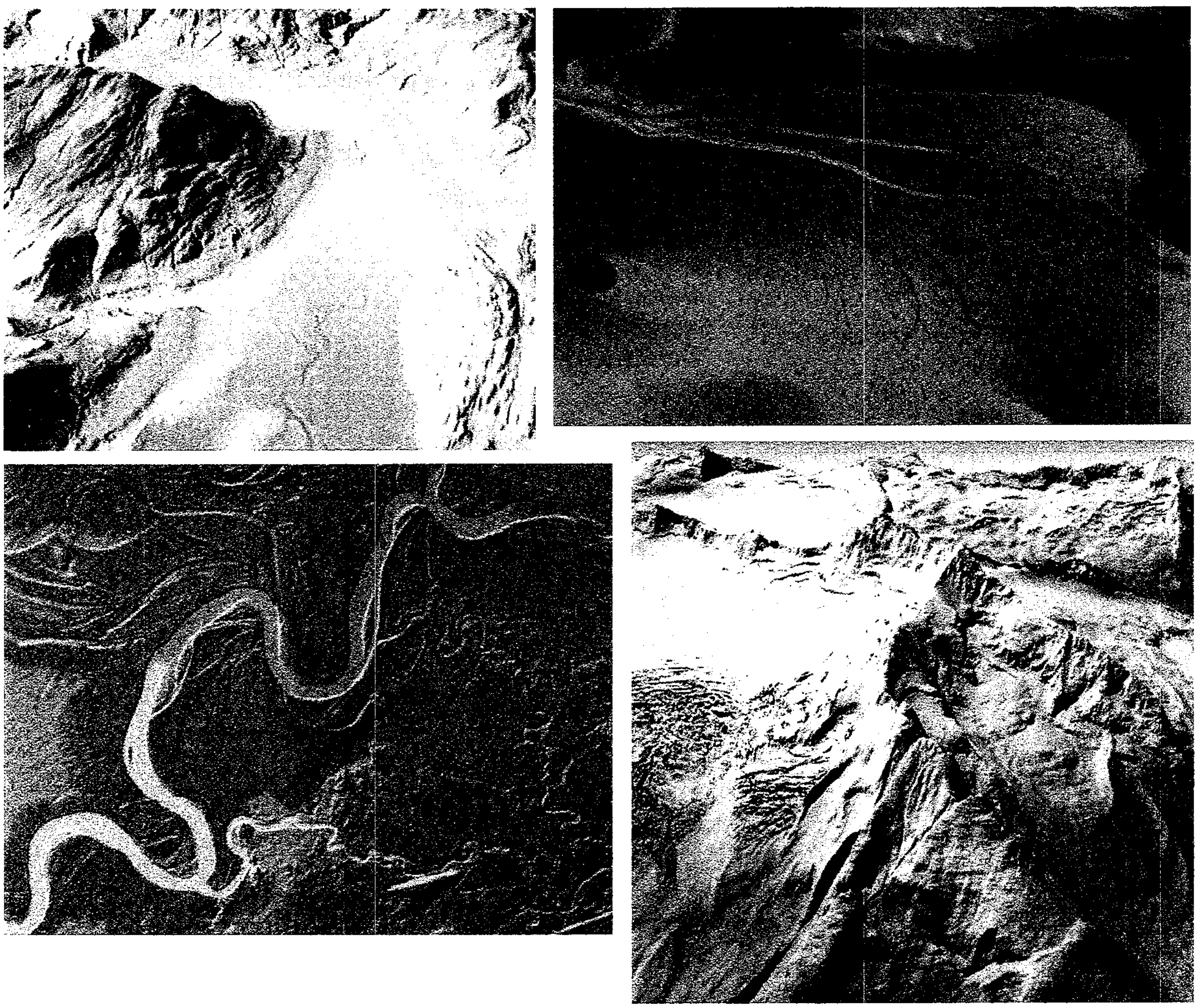
WSI acquired high resolution (8 pulses/m^2) LiDAR data along ~1,000 miles (2,050,430 acres) of planned pipeline corridor route spanning from Valdez and the Canadian/AK border to the North Slope. Project scope covered four significant mountain passes and two coastal zones, with > 500,000 acres north of the Arctic Circle. Despite the challenges of accomplishing flights in advance of inclement weather/snow at high elevation passes, and the logistical challenges of working in some of the most remote areas of the U.S., WSI successfully completed the acquisition and processing of deliverables within 1.5 years (fall 2010 – early 2012). This was an accomplishment unprecedented by any other remote sensing data provider for Alaska or elsewhere. Project applications included detection of faults and lineaments along the planned corridor path, and natural resource characterization and inventory. Vertical RMSE was <5.0 cm throughout the study area. Deliverables included full point classification, hydro-flattening of 1000s of small lakes, and generation of vegetation metrics. The data exceeded all accuracy specifications and was delivered within contracted timeline and budget.





5.2 Bare-earth DEM

Creation of a bare earth DEM is a key component of WSI's standard LiDAR product workflow, and it is a product of focus for the majority of our clients. For most LiDAR applications, the quality and accuracy of the ground model is of paramount importance. WSI operational procedures for collecting LiDAR to maximize ground modeling include maintaining 50% swath overlap (75% in high terrain) to ensure the laser penetrates to the ground in variable terrain at multiple angles, flying lines in opposing directions to facilitate calibration and relative accuracy testing, and terrain following and appropriate scan angle/altitude settings to ensure complete coverage. Processing methodologies for DEM generation include creating a triangulated surface between ground-classified points, exporting TINs as ArcInfo ASCII grids at the specified pixel resolution (typically 1 m for high resolution LiDAR), and then mosaicking the grid into a delineation/tiling system specified by the client. In the mosaicking process, WSI uses protocols to ensure there are no tile edge artifacts, and we take care to ensure pixels are snapped between raster models (bare earth, highest hit DEMs and intensity images) to a common origin of 0,0 (upper left corner of NW-most pixel). WSI's proprietary software (written in house) is used to ensure consistent model output criteria are met for each project.



Medley of bare earth DEMs illustrating derived ground models from WSI LiDAR surveys in Alaska and the Pacific NW – Top L: Héen Latinee Experimental Forest near Juneau, AK; Top R: Skagit River Estuary, WA during negative tide; Bottom L: Bear Creek, central AK; Bottom R: extreme terrain within Tongass National Forest near Juneau, AK.

WSI Applied Remote Sensing and Analysis

The following examples illustrate our experience with projects in which the ground model DEM was a focal product of interest to the client. Focus is on projects in the Pacific Northwest similar to the Juneau landscape. Each of these also serves as examples of WSI experience in **Acquisition of High Resolution LiDAR**, and in rigorous **QA/QC Procedures to Ensure Product Quality**.

Project Specifications

PROJECTS (recent relevant):
Jefferson & Clallam Counties – 42,038 acres for FEMA
Chehalis River – 234,000 acres for FEMA and WA DNR
Nooksack River – 35,000 acres (2009); 108,000 acres (2013) for Nooksack Tribe
Hoh Watershed – 167,000 acres for Hoh Tribe
Quinault River Basin – 221,000 acres for Quinault Tribe

DATES OF SERVICE: 2006 - present

CUSTOMER: Puget Sound LiDAR Consortium

CUSTOMER POC: Diana Martinez, 206-971-3052, dmartinez@psrc.org

DELIVERABLES

- SBET files (shapefile)
- All and ground returns (LAS and ASCII)
- Bare Earth DEM (1 m ESRI GRID)
- Highest Hit DEM (1 m ESRI GRID)
- Intensity Images (1/2 m GeoTIFF)
- Value-added deliverables, incl. 2-ft Contours, normalized intensities, stream network, vegetation analysis, hydrologic breaklines
- FGDC-compliant Metadata

Bare earth DEMs from various PSLC projects: Top R – Wenatchee, WA; Middle – Wenas Valley landslide at Hwy 410; Bottom – Nooksack River.

PUGET SOUND LIDAR CONSORTIUM, WA

High Resolution LiDAR

WSI is the sole vendor for the Puget Sound LiDAR Consortium (http://pugetsoundlidar.org/), currently holding our second 5-year PSLC contract after the 2012 competitive contract renewal process. Over 6 years, we have collected high resolution LiDAR data during leaf-off conditions for over 20 projects for a variety of end users and clients of the PSLC across the state of Washington. All data are collected at 8 pulses/m^2 and <30° field of view, with standard product deliverables including 1m resolution bare earth DEM. Project applications have been varied, but focus on topographic mapping and geophysical characterization (landslide potential, channel morphology and change, erosion potential). Data for all projects exceeded all accuracy specifications and was delivered within contracted timeline and budget.

WSI Applied Remote Sensing and Analysis

Project Specifications

PROJECT SIZE: 287,218 acres

DATES OF SERVICE: Fall 2007 – 2009; Fall 2012

CUSTOMER: National Park Service – Mount Rainier National Park

CUSTOMER POC: Darin Swinney, 360-569-6108, darin.swinney@nps.gov

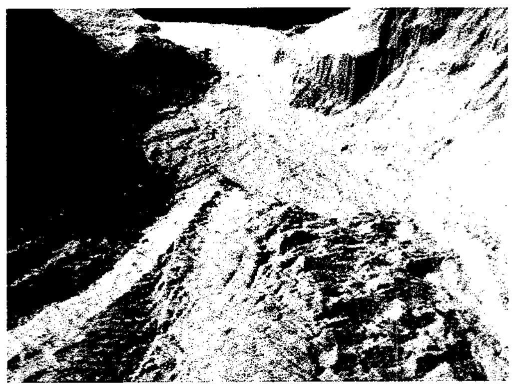
DELIVERABLES

- All & Ground Classified Points (LAS)
- Bare Earth DEM (1 m ESRI GRID)
- Highest Hit DEM (1 m ESRI GRID)
- Intensity Images (1/2 m GeoTIFF)

MOUNT RAINIER, NORTH CASCADES & NISQUALLY/CARBON RIVERS, WA

High Resolution LiDAR

Over a number of fall seasons, WSI acquired high resolution LiDAR data over portions of Mount Rainier and the Nisqually & Carbon River Valleys as well as the North Cascades National Park. Data were collected at high resolutions ranging from 5 to 17 pulses/m^2 among study areas. Project applications included characterizing channel morphology, geomorphology, landslide potential, and forest structure. RMSE values for vertical error ranged from 1.5 to 4 cm among project areas. The data exceeded all accuracy specifications and was delivered within contracted timelines and budgets.



Bare earth model colored by elevation looking north over the Carbon Glacier into the Carbon River, WA.

Project Specifications

PROJECT SIZE: ~60,000 acres

DATES OF SERVICE: spring – fall 2011

CUSTOMER: U.S. Geological Survey & The Nature Conservancy

CUSTOMER POC: Eric Grossman, 206-526-6282, ext. 334, egrossman@usgs.gov

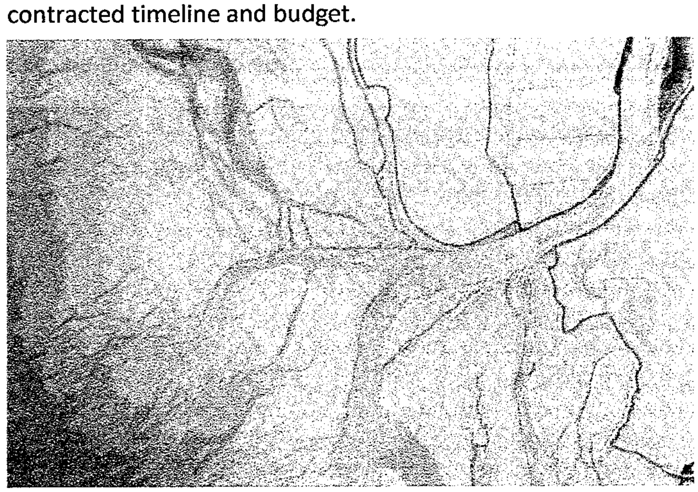
DELIVERABLES

- All Returns (LAS)
- Bare earth DEM (1 m, ESRI GRID)
- Highest hit DEM (1 m, ESRI GRID)
- Intensity images (1/2 m, GeoTIFF)
- FGDC-compliant Metadata

NORTHERN WASHINGTON ESTUARIES, WA

High Resolution LiDAR

WSI acquired high resolution LiDAR during extreme low tides (some during night) over three northern Washington estuaries (Skokomish, Stillaguamish, and Skagit) totaling over 60,000 acres. Data were collected at a nighttime negative tide to evaluate details of the tidal flats for intertidal channel restoration and management. Densities achieved varied from 9 to 12 pulses/m^2. Reported accuracies (1σ) were 2-4 cm (among estuaries) for absolute vertical accuracy. The data exceeded all accuracy specifications and was delivered within contracted timeline and budget.



Bare earth model colored by elevation, Stillaguamish River Estuary, WA

Project Specifications

PROJECT SIZE: 932,850 acres

DATES OF SERVICE: October 2010 – December 2011

CUSTOMER: Pierce County, WA

CUSTOMER POC: Ross Heasty, 253.798.6064 rheasty@co.pierce.wa.us

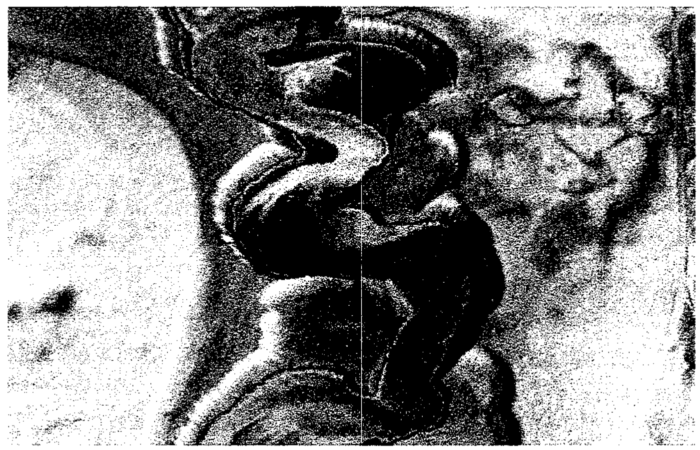
DELIVERABLES

- Raw Points (LAS)
- All returns, ground classified (LAS)
- Bare Earth DEM (3 ft, IMG)
- Hydroflattened Bare Earth DEM (3 ft IMG)
- Intensity Images (1.5 ft GeoTIFF)
- Hydrologic Breaklines (ESRI geodbase)
- FGDC-compliant Metadata

PIERCE COUNTY, WA

High Resolution LiDAR

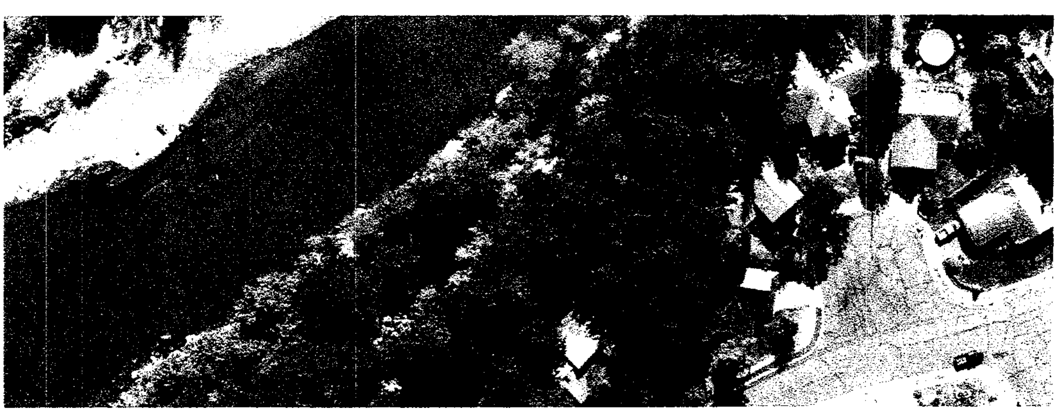
WSI acquired high resolution (8pulses/m^2) LiDAR data throughout Pierce County (large elevation gradient of coastal lowlands to Mt. Rainier) primarily during leaf-off conditions in fall 2010/winter 2011. The total requested LiDAR area of interest (AOI) was approximately 932,850acres. Project applications have included flood and landslide hazard mapping, natural resource assessments, and transportation/urban planning. Deliverables included hydrologic breaklines and hydro-flattened bare earth DEMs. Ground check points were collected in land cover classes to assess supplemental vertical accuracy (SVA). Vertical RMSE was <6.0 cm throughout. Data exceeded specifications and was delivered within contracted timeline and budget.



Bare earth DEM colored by elevation, looking northeast down the Mashell River near Eatonville, WA.

5.3 ORTHOIMAGERY

Co-acquired orthoimagery is a common request by WSI clients, used primarily to supplement analyses of LiDAR data for a number of applications, including engineering design, hydrologic analysis, urban planning, and evaluation of vegetation structure. WSI has been collecting orthoimagery (natural color and 4 band) to supplement LiDAR data for over eight years since deploying our first LiDAR systems. Orthoimagery has been an integral component of a number of recent WSI contracts. Imagery is directly geo-referenced using the LiDAR DEM, and a rigorous QA/QC workflow is followed to ensure consistent radiometry across the final mosaic. WSI specializes in imagery collected at high resolutions (small pixel size of 1-ft pixel resolution or better) coinciding with our high resolution LiDAR and providing for maximum utility in fusing data from multiple sensors. The following examples illustrate our experience in collecting and delivering 4 band orthoimagery. Each of the below projects also included collection of LiDAR data at high resolutions.



Natural color ortho-photography, Sandy River, OR.

Project Specifications

PROJECT SIZE: 30,863 acres

DATES OF SERVICE: Sept – Dec 2012

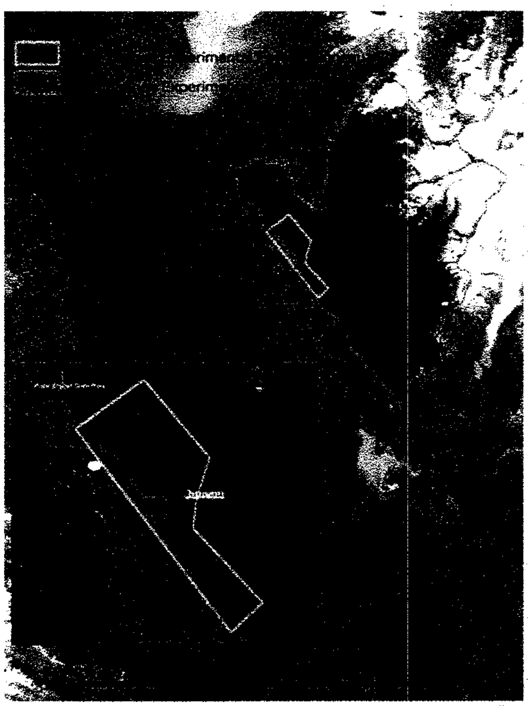
CUSTOMER: USDA Forest Service

CUSTOMER POC: Rick Edwards, 907-586-8801, rtedwards@fs.fed.us

DELIVERABLES

All returns and ground-classified returns (LAS and ASCII formats)
Bare Earth DEM (1 m ESRI GRID)
Highest Hit DEM (1 m ESRI GRID)
Canopy Height DEM (1m ESRI GRID)
Normalized Intensity Images (0.5 m GeoTIFF)
1/2 m Contours (.dxf format)
SBET files (shapefile format)
4 Band Orthorectified Image Mosaic (GeoTIFF)
FGDC-compliant Metadata

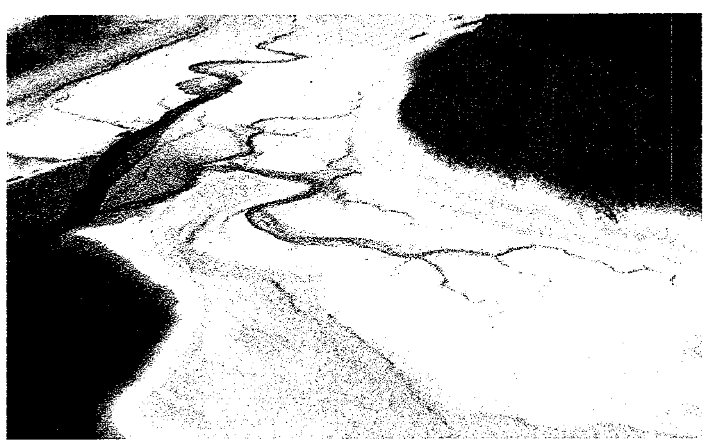
Right: 4 band/3 band swipe planar view of orthoimagery along coastline within Tongass NF AOI; Below: Area map of Experimental Forest and AOI for which LiDAR data were provided to the CBJ (yellow); Below R: Bare earth DEM, view of Cowee Meadow from Point Bridget



HÉEN LATINEE EXPERIMENTAL FOREST, TONGASS NATIONAL FOREST, AK

High Resolution LiDAR
4 Band Orthoimagery

WSI acquired high resolution (4 pulses/m^2) LiDAR data and 30 cm GSD 4 band orthophotos for the Heen Latinee Experimental Forest within the Tongass National Forest in SE Alaska. Project applications included assessments of topographic and geophysical properties of the study area to support planning and management efforts. Successful acquisition within a single season in this challenging temperate rainforest landscape was a significant achievement showing determination and excellent planning. Vertical accuracy was 3.6 cm RMSE. Horizontal accuracy for orthophotos was <56 cm. The data exceeded all accuracy specifications and was delivered within contracted timeline and budget. A subset of the LiDAR data was additionally provided to the CBJ (Engineering Department) on December 27, 2012 for a portion (1,368 acres) of the Experimental Forest AOI. The data exceeded all specifications and was delivered within contracted timeline and budget.



Applied Remote Sensing and Analysis

Project Specifications

PROJECT SIZE: 18,474 acres

DATES OF SERVICE: Fall 2009, 2011, 2012

CUSTOMER: Bureau of Reclamation (BOR IDIQ)

CUSTOMER POC: David J. Bandrowski (TRRP), 530.623.1811

DELIVERABLES

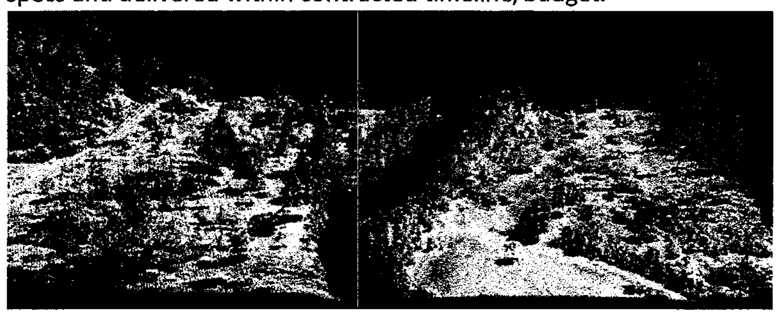
All returns w/ground class (LAS)
Intensity Images ½ m (GeoTIFF)
Imagery Mosaics (RGB, NIR) at 6 in resolution (GeoTIFF)
Site Boundary (shapefile)
Orthophoto Index
FGDC-compliant Metadata

3D LiDAR point cloud colored by NIR orthoimagery, Trinity River, CA.

TRINITY RIVER, CA

4 Band Orthoimagery
High Resolution LiDAR

WSI acquired high-resolution LiDAR data (6 pulses/m^2), true-color and 4 band digital orthophotos (15 cm GSD), and thermal infrared imagery on multiple occasions to support an ongoing river restoration program (Trinity River Restoration Program) funded by the Bureau of Reclamation and other natural resource agencies. In 2009, LiDAR data were integrated by Woolpert, Inc. with bathymetric data (EARRL) collected by the USGS. Achieved LiDAR pulse density was 6.67 – 8.67 points/m^2 between years, and an RMSE (1 standard deviation for vertical error) of <3.0 cm. Horizontal accuracy for orthophotos was 50 cm. Data exceeded specs and delivered within contracted timeline/budget.



Project Specifications

PROJECT SIZE: 13,925 acres

DATES OF SERVICE: Fall 2012

CUSTOMER: Woolpert, Inc. (for Bureau of Reclamation end user)

CUSTOMER POC: KC Kroll, 720-279-3796, kc.kroll@woolpert.com

DELIVERABLES

Native unrectified frames (TIFF)
Orthorectified frames (GeoTIFF)
Orthorectified mosaicked tiles (GeoTIFF)
Site Boundary (shapefile)
Orthophoto Index
FGDC-compliant Metadata

3D LiDAR point cloud colored by RGB (L) and NIR (R) orthoimaagery within the Upper Grande Ronde floodplain.

UPPER GRANDE RONDE RIVER, OR

4 Band Orthoimagery

WSI collected 4 band orthoimagery at 6 inch pixel resolution for a portion of the Upper Grand Ronde River in NE Oregon to support ongoing river restoration and monitoring efforts of the Bureau of Reclamation. High resolution (8 pulses/m^2) is under contract for acquisition in spring 2013. Horizontal accuracy for orthophotos < 1 ft. This acquisition was one of many conducted by WSI over the last 5 years within the Grande Ronde Basin, with acres captured with LiDAR and/or orthoimagery for this effort totaling ~200,000 acres. Data exceeded specs and delivered within contracted timeline/budget.

Project Specifications

PROJECT SIZE: 21,348 acres

DATES OF SERVICE: Aug - Nov 2012

CUSTOMER: Idaho Department of Lands

CUSTOMER POC: Joel Clark, 208-666-8633, jclark@idl.idaho.gov

DELIVERABLES

All returns (LAS format)
Bare Earth DEM (1 m ESRI GRID)
Highest Hit DEM (1 m ESRI GRID)
Normalized Highest Hit DEM (1 m ESRI GRID)
Normalized Veg DEM (1m ESRI GRID)
Intensity Images (1/2 m GeoTIFFs)
SBET files (shapefile format)
Roads, Streams, Tree Crown Points (shapefile)
4 Band Orthorectified Image Mosaic (GeoTIFF)

MIDDLE FORK EAST RIVER, ID

High Resolution LiDAR
4 Band Orthoimagery

WSI collected 4 band orthophotography at 15 cm pixel resolution and high resolution LiDAR at 12 pulses/m^2 for the Middle Fork East River research site in northern Idaho. Data were collected to aid the IDL in assessing the topographic & geophysical properties of the study area and to generate a suite of forest biometrics to support planning and development for forestry. Vertical accuracy (RMSE) was 4.6 cm. Horizontal accuracy for orthophotos was < 50 cm. Data exceeded specs and delivered within contracted timeline/budget.

Highest hit DEM colored by NIR imagery, NE corner of MFER area of interest.

5.4 QA/QC PROCEDURES TO ENSURE PRODUCT QUALITY

Through all phases of a project - from the flight planning and data acquisition to the final reporting and delivery of products – WSI adheres to techniques and practices that ensure our products meet or surpass industry standards and will meet the client's needs. For each project, we build quality control into the entire process through regular sensor calibration, detailed mission planning, thorough ground control, and a rigorous ground check point assessment of laser and photo accuracy. It is WSI's strong-held philosophy to make sure our clients receive quality data with high utility, and we regularly recommend sensor specifications and methodologies that will ensure the delivery of such data.

ACQUISITION QA/QC

LiDAR: Various parameters during the acquisition phase factor into final absolute accuracy obtained for a particular project. A number of measures are performed to ensure robust quality control during the acquisition phase. Laser point accuracy is largely a function of within-swath reproducibility (or conversely 'laser noise'), and swath-to-swath reproducibility (also 'relative accuracy'), or the consistency of elevations within and between acquisition flight lines. Operational and flight parameters are designed to minimize *laser noise* by flying low, optimizing laser power, targeting optimal GPS windows, and reducing scan angles. Typical laser noise evaluated over multiple projects completed by WSI has been approximately 2 cm. Relative accuracy is assessed and slight system pitch, roll, and yaw misalignments are corrected through automated sampling and calibration routines comparing elevation, slope and intensity values for the same area within two or more overlapping flight lines. To increase and evaluate *relative accuracy*, we will fly missions with >50% overlap between opposing flight lines, and fly one or more orthogonal flight lines over mission areas.

Our acquisition protocol of flying missions at 50% side-lap with terrain following to maintain consistent aircraft altitudes minimizes greatly the potential for data gaps related to both acquisition and laser shadowing of targets. Moreover, we take all necessary measures to acquire data under optimal conditions (e.g., minimum cloud decks) and in a manner (i.e., adherence to flight plans) that will prevent the possibility of data gaps. WSI survey and acquisition staff will immediately evaluate acquired data for QA/QC purposes and for near real-time detection of any system issues. Mission GPS/IMU data are run through Leica IPAS Pro to look for gaps in data collection. Point clouds from missions are immediately examined to evaluate pulse densities and identify any gaps in coverage, providing an opportunity for adjusting flight parameters and/or re-flying areas not meeting specification. Our rigorous acquisition QA/QC will ensure that the LiDAR coverage will be complete with no data gaps or voids, barring non-reflective surfaces (e.g., open water, wet asphalt, etc).

3D LiDAR point cloud colored by NIR imagery, Middle Fork East River, ID

Photography: In preparation for data collection, careful flight planning by acquisition staff ensures proper coverage of the survey site and a ground sample distance (GSD) appropriate for the targeted resolution. Factors such as satellite constellation availability and weather windows are considered. Any weather hazards and conditions affecting the flight are continuously monitored due to their impact on the daily success of airborne and ground operations. The flight window for photo collection will require peak sun angles and visibility free of clouds and fog. Weather conditions will be recorded and reported for all flight missions. During flight missions, operators monitor image collection to verify proper exposure settings, correct forward lap and side lap between images, and that images are free of fog and cloud shadow.

Processing QA/QC

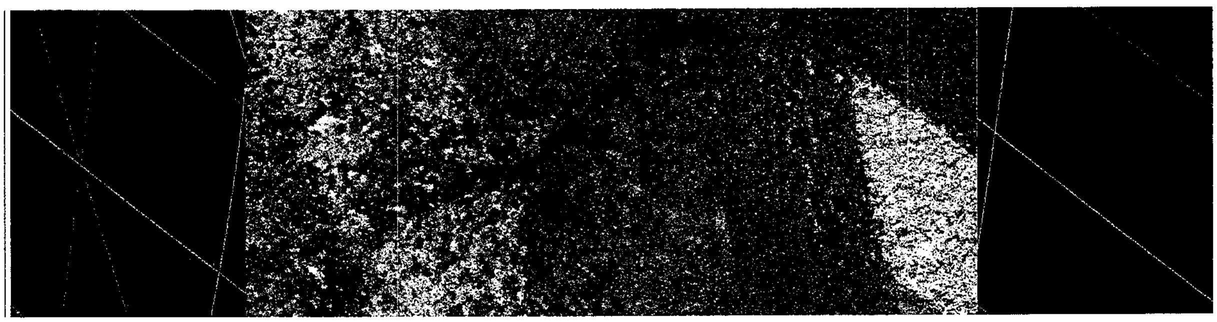
Data processing starts as soon as data are received from the field. The base station data, RTK check points, executed flight plans, and daily field reports are transferred to the office nightly and evaluated within a day of acquisition. The in-flight data are received in the office typically within 1-3 days of acquisition.

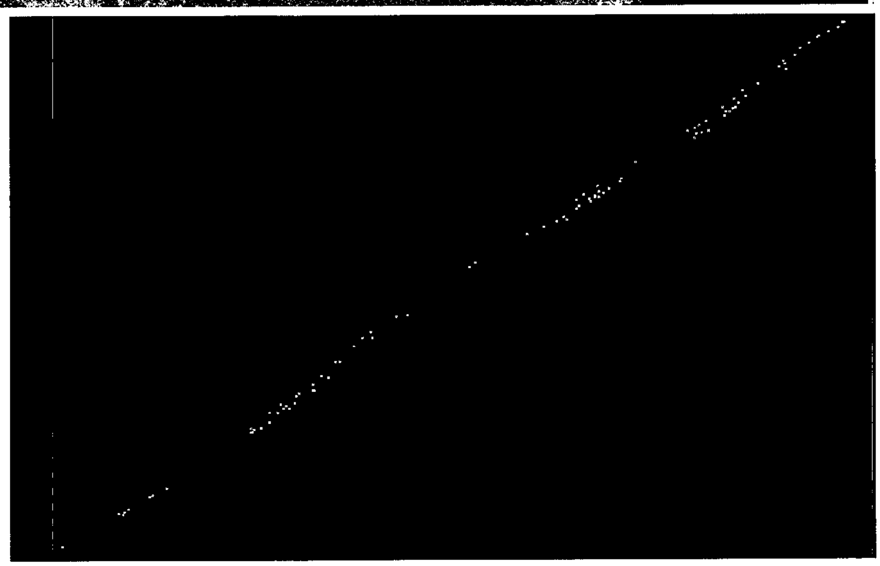
LiDAR

Calibration & Density Evaluation: WSI follows a stringent protocol for calibration of flight lines, both to ensure high relative and absolute accuracy, and to facilitate data consistency among missions. Calibration of the raw data begins with creating a Smoothed Best Estimate of Trajectory (SBET) file that blends post-processed aircraft position data (GPS) and orientation data (IMU) for each flight mission. The SBET is then used to associate position and orientation of each laser point based on time. An individual ground surface for each flightline of data is generated automatically and used to test relative accuracy (line-to-line). Automated line-to-line calibrations are then performed for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Once flight mission data have been corrected for relative accuracy, they are compared to RTK surveyed points on hard surfaces to assess absolute accuracy, and adjusted if necessary. A visual inspection is performed on a data subset concentrating on roofs and road edges where relative offsets are most visible. WSI is known for providing datasets with tight line-to-line calibrations and exceptionally high relative accuracy (as may be confirmed by QA/QC references below). Native (first return density) and ground classified densities are initially calculated in calibration to ensure acquisition of the AOI was completed to the nominal pulse density specified in the contract.

During every mission, the relative accuracy among flight lines is verified using ground check point data collected on hard, bare-earth surfaces within the study area. The relative accuracy is computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. When the LiDAR system is well calibrated, the swath-to-swath divergence is low (<10cm).

Acquisitions collected over the same area at different times (for example different projects adjacent to each other) will be matched using comparisons of RTK points collected with each acquisition as well as direct comparison of the LiDAR point clouds. When possible, the same established GPS monuments are used for each acquisition. For the City/Borough of Juneau LiDAR project, the survey control monument used for the 2012 Tongass National Forest Project will be used to facilitate matching new Juneau LiDAR data to the adjacent Tongass dataset.





In this example, points from different flight line swaths (shown above in planar view over one processing tile) are depicted with different colors (notice 50% overlap among flight line swaths). A well calibrated dataset shows indistinguishable offsets in vertical position (within tolerance of RMSE) among flight lines (Right).

***Point Processing and Product QA/QC*: Point d**ata go through multiple inspections to ensure the most representative models of the project area terrain and above-ground features are delivered. QA/QC results will be provided with each delivery; all results and corresponding reporting outlining quality control and verification methodologies will be included in metadata. The following provides greater detail on the measures we take to ensure our data meet required specifications for accuracy.

After data calibration and checks for nominal pulse density, point clouds are reviewed and "cleaned" by a team of interns and analysts. Each tile is visually examined in planar and cross sectional views to manually refine the ground model (filtering any remaining erroneous high and low points). Each tile is also evaluated for classification accuracy, depending on the needs of each project. After initial review of the point cloud, data are reviewed to ensure proper protocols were followed in the cleaning process. Revisions to classifications on the point cloud are made in this 2nd round of "cleaning". Native and ground densities are calculated after final classification. WSI guarantees there will be no avoidable misclassification of returns (no more than 2% error per square kilometer).

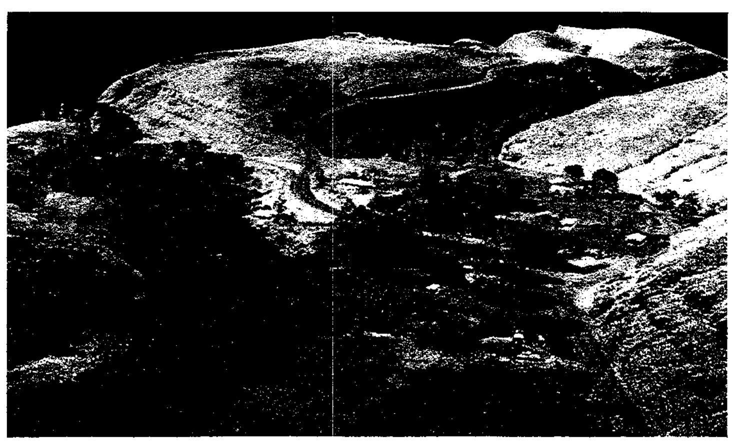
Upon classification of the point cloud to project specifications, specified deliverables (digital elevation/surface models including hydro-flattening, contours, intensity images, and others) are created. All products are run through an extensive QC process. Planar visual inspection of DEMs and DSMs are performed to ensure completed coverage of the contracted area with no tiling artifacts. Intensities are inspected for value and proper alignment. All raster datasets are loaded together to ensure proper pixel snapping, and all deliverable projections are confirmed. Metadata files for each deliverable are reviewed for accuracy and completeness.

To assess absolute accuracy, we use data from the ground survey conducted in the study area. Absolute accuracy assessments compare the x,y,z locations of known ground survey points to the triangulated ground surface generated from the LiDAR points. Accuracies are described as the mean and standard deviation (sigma~σ) of divergence from ground survey point coordinates. These statistics assume the error for x, y, and z are normally distributed, and therefore we also consider the skew and kurtosis of distributions when evaluating error statistics. All accuracy statistics ($RMSE_z$, $Accuracy_z$ - 1.96 σ, skewness/distribution, and percentile deviations) are reported in the Report of Survey.

Orthophoto QA/QC

Spatial Accuracy: Orthoimages are generated for the entire project area and rectified to the ground surface model derived from LiDAR data. Aerial-Triangulation (AT) is performed to guarantee a high-quality fit between imagery and survey control. The AT reveals any photogrammetric image fit issues should they be present within the photography or survey control, thus providing a good quality control check for both image and survey data sets. Collected air target points are precisely measured in soft copy workstations and used for ground control during the AT adjustment. Additional air target points will be included in the AT process, but not used in the adjustment. This will provide an independent check on the AT solution.

Absolute accuracy assessments compare known RTK ground survey points to derived orthophoto positions. RMSE values are reported for both ground control points and independent check points. The horizontal accuracy will also be measured in the final ortho-rectified image using both air targets and LiDAR check points (measurements taken from a LiDAR derived intensity image). These are typically high contrast ground surfaces such as road markings. Use of LiDAR check points ensures accurate co-registration between the LiDAR and orthophoto datasets. All accuracy statistics are documented in the final report to verify that the RFP specifications have been met.



3D LiDAR point cloud colored by natural (RGB) orthoimagery, Asotin River project area, WA

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Ortho-Rectification and Radiometry: The final mosaic of orthoimagery will not only be highly accurate, but will convey the highest aesthetics possible for the imagery collected. To ensure consistent radiometry across the final orthophoto mosaic and aesthetically pleasing imagery, the output mosaic will be inspected at a large scale for all image-to-image color adjustments and seam-line placement between images. Radiometric adjustments are made during the final mosaic process. Both automated and manual corrections are made for both groups of images and single images as needed to ensure smooth radiometric properties across the final mosaic. Any radiometrically unsuitable image pairings will be re-balanced and corrected, with seam replacement if necessary. The inspection also identifies any image stretching during the ortho-rectification process, as is possible in high relief areas; this issue can often be resolved drawing the seam from a more nadir image over the affected area.

Ortho-rectification of imagery to a ground DTM will result in some displacement of building rooftops, treetops, elevated power lines, and similar elevated features. Bridges and similar elevated roadway features (including major docks) are the exception. Elevated bridge decks and overpasses will be rectified and edited to their correct position for continuity with the roadway. Care will be taken in the mosaic process to minimize or eliminate mosaic lines that cut across other elevated features that cause a visual shift, with seam lines being edited where necessary. This visual inspection of seam placement ensures that the centermost portion of each frame was used and the proper image area was selected such that building lean does not obscure roads or any other key features. The edited seam lines are then used to create a high quality, tonally balanced mosaic covering the complete extent of the study area. The end result is a photo mosaic that includes the best detail from each image and is aesthetically pleasing with no compromise to the high level of accuracy necessary for the project's mapping purposes.

Our rigorous internal QA/QC processes can be verified through the performance of our data products in external review conducted by our clients or second-party quality control. We provide the following list of references each of whom has had direct experience with performing external quality control tests on WSI data. In addition, all references provided above can provide feedback on the quality of our internal QA/QC in ensuring the delivery of final accurate data products of the highest quality.

References for QA/QC and Resulting Quality of WSI Products

Name	Agency	Project	Elements	Phone	Email
Ralph Haugerud	USGS	Multiple PSLC and forest research projects	LiDAR	(206) 553-5542	rhaugerud@usgs.gov haugerud@u.washington.edu
Bill Conroy	USFS Boise, ID	Clearwater/Nez Perce National Forests	LiDAR	(208) 983-5154	wconroy@fs.fed.us
Ian Madin	Oregon LiDAR Consortium (OLC)	Multiple OLC projects	LiDAR, Spectral	(971) 673-1542	ian.madin@dogami.state.or.us
Diana Martinez	Puget Sound LiDAR Consortium (PSLC)	Multiple PSLC projects	LiDAR	(206) 971-3052	dmartinez@psrc.org
George McFadden	Bureau of Land Management	Panther Creek, OR forest research consortium	LiDAR, Spectral	(503) 808-6107	gmcfadde@blm.gov
Jacob Macdonald	U.S. Army Corps	Columbia Basin, Pacific NW	LiDAR	(503) 808-4844	jacob.macdonald@usace.army.mil

5.5 Fully Compliant FGDC Metadata

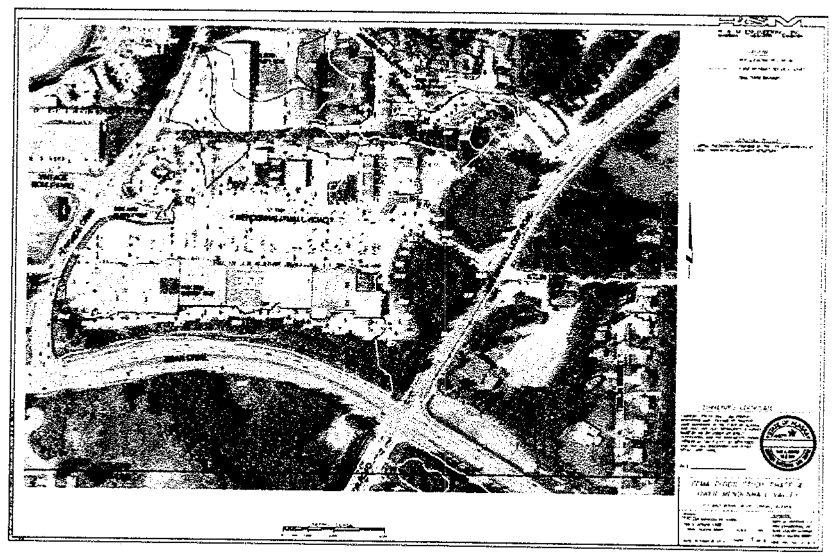
WSI provides FGDC-compliant metadata as a deliverable for all contracted projects (50+ projects per year). All metadata are created and edited in Arc10.1 using the FGDC CSDGM Metadata style which ensures FGDC standards are met. The FGDC CSDGM Metadata tool follows the FGDC *Content Standard for Digital Geospatial Metadata (CSDGM)* guidelines, allowing for exporting metadata in CSDGM XML format, and for validating metadata files using the CSDGM XML DTD. Samples of FGDC-compliant metadata files for two relevant projects are provided in section **7.0 FGDC Compliant Metadata Examples** (page 48).

5.6 R&M Engineering - Local Juneau Survey Experience

The CBJ is a long-time client of R&M Engineering and other firms have contracted R&M's for a number of local surveying and engineering projects. The following two projects provide representative examples and corresponding client references.

FEMA Flood Zone Boundary, Mendenhall Valley, AK: R&M was tasked to verify flood zone boundaries of FEMA's draft flood zone mapping for select areas of the Mendenhall Valley through retracement of spot elevations from 1989/1990 aerial mapping. Additional tasks performed during this survey included verification and limited ground truth GPS surveying of recent LIDAR mapping.

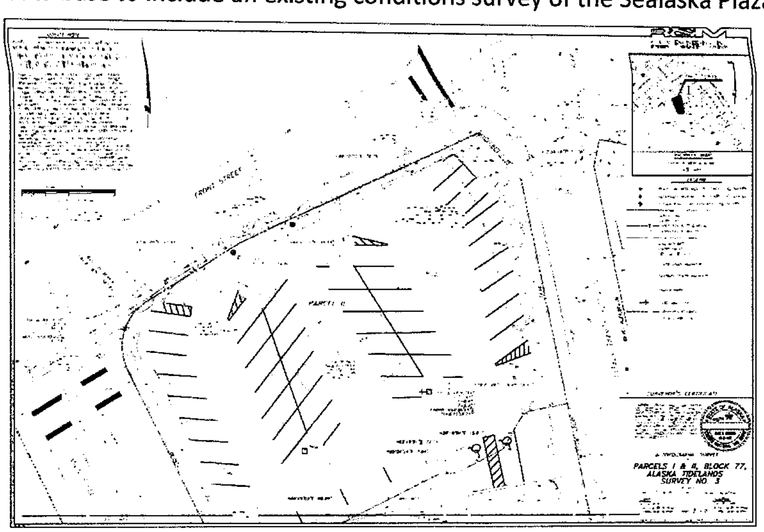
Client Reference: Eric Feldt, Planner, City & Borough of Juneau. Phone: 907-586-0764



R&M survey plan showing resultant revisions to flood zones, Mendenhall Valley, AK.

Existing Conditions Survey, Sealaska Plaza, downtown Juneau, AK: R&M was contracted to expand current survey data base to include an existing conditions survey of the Sealaska Plaza in downtown Juneau in order to facilitate planning and design of the complex's access, parking and infrastructure. This expansion survey supplemented a boundary and topographic survey of property located on adjacent Seward Street.

Client Reference: Paul Voelckers, President, MRV Architects. Phone: 907-586-1371



R&M survey plan for the Sealaska Plaza, Juneau, AK.

6.0 Management Plan

6.1 Management Workflow, Communication & Lines of Authority

Our overall management approach is to provide an integrated, multidisciplinary group of professionals with unsurpassed experience and qualifications that can meet the technical management elements of the CBJ Remote Sensing Project. WSI's team is highly qualified to manage and complete all aspects of this project to the extent necessary to guarantee complete, efficient, and timely delivery. All key personnel outlined for this project have prior experience with Alaska contracts and fully understand the objectives of the CBJ for this particular remote sensing project. The management plan below addresses our communication and coordination approach to successfully acquiring, processing, and delivering all LiDAR data and orthoimagery to the CBJ. An organizational chart is provided below, showing respective personnel, management teams, and channels of communication.

At WSI, projects flow from the acquisition team (who are responsible for flight planning, logistics and ground survey control) to data processing specialists (who calibrate data, perform LiDAR point classification, orthorectification, product development & feature extractions, and other custom tasks). Quality control is built into every aspect of this management workflow. Each team manager and specialist is responsible for the workflow within their specialty area, including all phases of data analysis, checks of quality and completeness, data compilation, and accuracy assessments. At each step in the production sequence, a technical lead will provide workflow reports, technical results, and schedule status to the Project Manager. In addition, weekly manager meetings focus on resource allocation, where necessary adjustments to computing and staff resources are made in order to ensure meeting a target delivery schedule.

Data Acquisition

Our team will coordinate all data acquisition aspects of this project to the extent necessary to guarantee complete, efficient, and timely acquisition. Resources (crews and aircraft) will be positioned in the Pacific Northwest during the acquisition timeframe to allow for the complete and successful collection of data during good weather opportunities.

Our Acquisition Team, consisting of the Project Manager, Acquisition Managers, and R&M AK Surveyor of Record will coordinate with the CBJ on priority areas and acquisition conditions. During the acquisition phase, we recommend scheduled conference calls between WSI and the CBJ to provide status updates, identify priorities, and discuss any issues (e.g., weather, etc.). Our acquisition managers will coordinate with R&M on refining and executing survey control work (anticipated as outlined above, page 12) to ensure it meets all project specifications for distribution within the chosen study area. In addition, WSI will coordinate with R&M on the timing and collection of independent QA/QC checkpoints. All ground data (base station and WSI RTK check points) will be uploaded to company servers nightly and evaluated in the office for validity and spatial coverage. This near real-time review of the ground survey data allows our Acquisition Managers to identify problems and direct ground operations. Our ground crews are experienced in safely and effectively conducting fieldwork in remote locations, including the successful collection of data at sites that require satellite phones for communication and remote transportation.

DATA PROCESSING AND DELIVERY

Our Processing Management Team, consisting of the Project Manager, Processing Resources Manager, Orthoimagery Lead, Calibration Lead, Product Development Lead, and Data Processing QA/QC Lead will oversee all phases of data analysis including checks of quality and completeness, data compilation, and accuracy assessments. All department leads will report weekly to the Project Manager to enable any adjustment to computing and staff resources to meet an agreed-upon delivery schedule.

In coordination with the CBJ, a GIS tiling scheme will be identified and created for the entire project area prior to the start of data processing. The tiling scheme is reviewed by project managers with special attention to potential boundary effects due to coordinate systems and projections. All deliveries will follow the tiling scheme so that any sequential deliveries to CBJ will fit seamlessly into the overall GIS project database.

Our Processing Resources Manager will assign qualified staff to oversee specific stages of the processing and product development. The Calibration Lead oversees all aspects of point cloud processing from calibration to initial point 'cleaning'. The Orthoimagery Lead will supervise all orthorectification, aero-triangulation, and accuracy assessments by trained image processing staff. The Product Development Lead will be assigned to overseeing implementation of water's edge breaklines (i.e. hydro-flattening) and development of raster based LiDAR deliverables (i.e. DEMs). Finally, under the supervision of the Data Processing QA/QC Lead, experienced analysts are assigned to each phase of quality assurance checks of the data prior to final delivery. Computing resources and staff are added as needed to meet the project schedule. While we have a standard production workflow for all projects, we also develop a custom work diagram for each project that addresses the specifications of product generation for each client. This client-centric workflow ensures all specialists understand the specific solutions, file types and formats, and data specifications for the client are acknowledged and correctly generated. Data processing methods are detailed in Section **4.2 Processing** (page 18) and **5.4 QA/QC Procedures to Ensure Product Quality** (page 35).

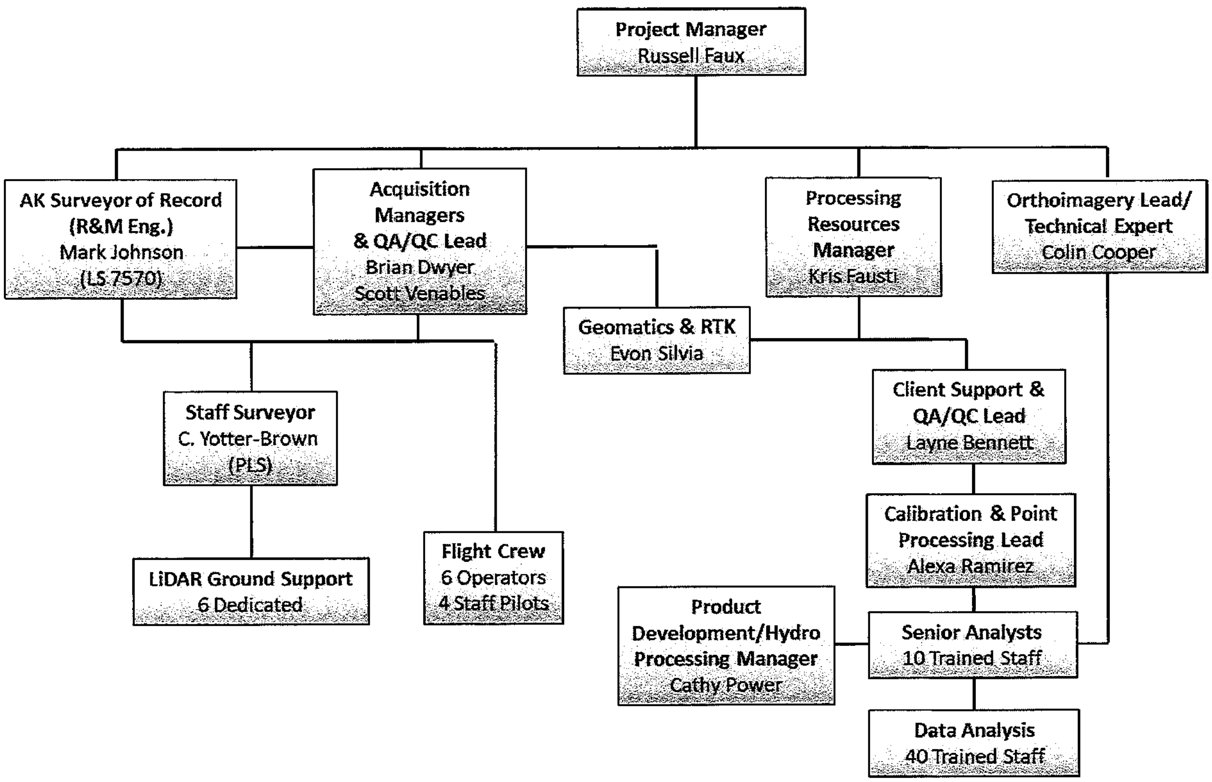
COMMUNICATION WITH THE CBJ

We believe in frequent, efficient communications with the client throughout the process in order to insure that all stakeholders are aware of project progress and any questions/issues can be addressed in a timely manner. Communication with the CBJ is built into each phase of the project. Our Acquisition Manager will provide weekly status maps that graphically depict areas acquired and provide statistics relevant to the acquisition. This type of reporting is routine for all of our projects. When the calibration and processing is underway, the Project Manager and/or Data Processing QA/QC Lead will be in direct contact with the CBJ on a regular basis until final product delivery. We utilize these meetings to discuss project status, schedule, and technical issues. We will also confirm document and file sharing and delivery. Action items are assigned according to meeting discussions and implemented into the workflow, contingency plan, etc.

Bare earth DEM derived from LiDAR ground points, Nisqually River, WA.

6.2 Organizational Chart

The following chart provides an overview of personnel filling the roles outlined above, and portrays channels of communication amongst WSI and R&M staff for the City/Borough of Juneau Remote Sensing Project. Lines of communication are multi-level, reflecting WSI's strategic integrative approach to quality control.



6.3 Project Team

Below we present a team roster with anticipated roles and qualifications of key staff who will be available and dedicated to the acquisition and processing of LiDAR data for the **City/Borough of Juneau Remote Sensing Project**. Profiles focus on specialized experience and capabilities with unique qualifications for performing the work for the CBJ project, with a focus on Alaska experience. Résumés for key staff are included in Appendix A (page 52).

Management

- **RUSSELL FAUX** - *Project Manager*, WSI: Mr. Faux will be the project manager and primary point of contact for the CBJ project, responsible for all top-level decision-making and accountable for the satisfactory completion of all work (level of authority). Mr. Faux will coordinate with the CBJ on project planning, scheduling, quality assurance, and progress reporting, and he will be readily available to the CBJ for all consultation needs. An engineer with an M.S. in Bioresource Engineering (Oregon State University) and a B.S. in Electrical Engineering (Penn State), Mr. Faux is a remote sensing specialist and research collaborator with over 20 years of experience in data acquisitions and analyses for airborne sensors including Light Detection and Ranging (near IR and green LiDAR), thermal infrared, and multispectral and hyperspectral imagery. He has embraced new technologies and innovative geospatial problem solving to shepherd WSI into the leading remote sensing data provider for research and engineering-grade applications. Mr. Faux has a solid track record (over 12 years) of project management experience that has required flexibility in project schedule and other unanticipated issues. He was the project manager for all prior Alaska projects including Alaska Natural Gas Pipeline Corridor, Whittier, Tongass National Forest, and Mt. Spurr (15 years as a principal with WSI).

Field Operations

- **MARK JOHNSON** – *Alaska Surveyor of Record* (Alaska PLS LS 7570), **R&M Engineering**: Mr. Johnson is the Corporate Secretary/Treasurer for R&M, and a land surveyor registered since 1988 for the State of Alaska. Mr. Johnson is a lifelong resident of SE Alaska, and brings significant local knowledge and expertise to the CBJ Remote Sensing Project. He will direct all survey work for this project including establishing the GPS ground control network, verification of data accuracy, and certification of data products. Mr. Johnson has over 30 years of experience working in both the land and engineering survey fields in SE Alaska, working for local, state and federal governments, and the private sector. Mr. Johnson attended the University of Alaska-Southeast, and has completed technical design and field surveys for a majority of subdivisions within SE Alaska, as well as numerous accretion and cadastral surveys.
- **CHRIS YOTTER-BROWN** - *Acquisition Survey Support*, WSI: Mr. Yotter-Brown is an experienced Professional Licensed Surveyor in Oregon and Washington. He has a B.S. in surveying from the Oregon Institute of Technology. Mr. Yotter-Brown will interface with acquisition managers, R&M surveyors, and ground crew teams on mapping control, flight support, and land survey techniques (2 years with WSI).

- **TRISTAN GOSSENS, BRIAN BUTLER** - *Survey Pilots;* WSI: Mr. Gossens and Mr. Butler both have substantial experience flying over challenging conditions in Alaska and the PNW. Professional flight experience: Gossens: 3,850 hrs/2,263 hrs AK ; Butler: >7,000 hrs/>500 hrs AK/BC Canada. (*Gossens: 3 years with WSI; Butler: 6 years with WSI)*
- **BRIAN DWYER** – *Acquisition Manager*, WSI: Mr. Dwyer has a B.S. in Geology (University of Wisconsin) and has over 10 years of experience in geosciences and hydrology. Mr. Dwyer is qualified to operate the cameras & LiDAR instruments as well as supervise field operations including flight planning, coordinating with other operators and ground survey crews, and verifying acquired data. Mr. Dwyer is instrumental in the installation and calibration of each of WSI's sensors and is extremely familiar with the management and coordination efforts required to successfully complete a project acquisition. A skilled mechanic, Brian brings extensive know-how and integrated solutions to technical challenges in acquisition including sensor installs, logistical coordination and legwork for remote acquisitions, flight planning, and field crew management for all remote sensing operations. (6 years with WSI).

- **SCOTT VENABLES** – *Acquisition Manager & QA/QC Lead*, WSI: Mr. Venables holds a degree in Fish and Wildlife Biology (Oregon State University) and has over 8 years of experience in hydrological studies. Mr. Venables is responsible for evaluating flight data for QA/QC purposes and for near real-time detection of any system issues. Other workflow responsibilities include resolving GPS kinematic corrections for aircraft position data, and developing smoothed best estimate of trajectory (SBET) files that blend post-processed aircraft position with attitude data. Mr. Venables was instrumental in the acquisition success of WSI Corvallis's Alaska Natural Gas Pipeline Corridor project. (6 years with WSI).

Processing

- **KRIS FAUSTI** – *Processing Resources Manager*, WSI: Ms. Fausti holds a degree in Environmental Sciences. She has prior experience managing large crews for multi-federal agency watershed management programs, and over 6 years working with LiDAR remote sensing for WSI. Ms. Fausti will provide all oversight on management of processing resources, ensuring that the CBJ project stays within budget and contract timelines (5 years with WSI).

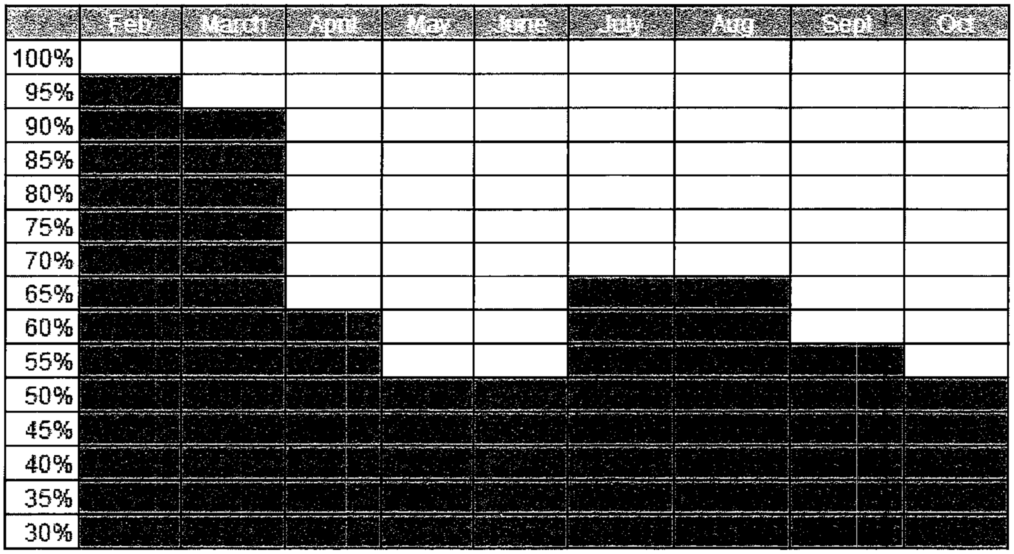
- **EVON SILVIA** – *Geomatics & RTK*, WSI: Mr. Silvia will oversee all RTK processing and geomatics (orthometric conversions and projections) operations for the CBJ project. Mr. Silvia holds M.S. and B.S. degrees in Civil Engineering (Oregon State Univ). Mr. Silvia will interface with R&M staff and Mr. Yotter-Brown on survey control data review and will provide any necessary technical programming support for processing of the LiDAR point cloud. (2 years with WSI).

- **COLIN COOPER** – *Orthophoto Department Lead, Remote Sensing Technical Expert*, WSI: Mr. Cooper has extensive experience working with raw LiDAR data and our processing workflow for various projects, including hydro-flattening, intensity normalization, and point feature coding. Mr. Cooper is also a specialist in spectral image processing (multispectral and thermal). Mr. Cooper has an M.S. in Geography/GIS (OSU) and a B.S. in Environmental Science (University of Delaware). He will manage the progress of the workflow for orthophotography and LiDAR products and provide direct technical assistance to analysts/image processors. (7 years with WSI).
- **ALEXA RAMIREZ** – *Calibration Lead*, WSI: Ms. Ramirez has broad experience in managing the processing workflow for a diversity of remote sensing contracts. She is an experienced LiDAR analyst with strong skills in managing multiple deliveries with attention paid to the necessary resources (computer, personnel) to keep multiple projects on task. She has extensive experience working with data from Alaska as she was the project lead for the Alaska Natural Gas Pipeline project. Her expertise and principal responsibility includes data calibration, working with Mr. Venables and Mr. Silvia on ensuring a smooth transition of newly acquired data into the processing workflow, and direct technical assistance to LiDAR analysts/processors. Ms. Ramirez holds an M.S. in Marine Science - Geological Oceanography (University of South Florida), and a B.S. in Earth and Ocean Science (Duke University) (4 years with WSI).
- **CATHY POWER** – *Hydro Analysis & Products Manager*, WSI: Ms. Power has broad experience in managing the processing workflow for value-added products used in hydrological modeling (hydroflattened and hydro-enforced products). She is an experienced LiDAR analyst with strong skills in project supervision and workflow oversight with attention paid to the necessary resources (computer, personnel) to keep multiple deliveries on task. Ms. Power will be responsible for applying hydro-breaklines to the LiDAR DEM for hydroflattening. Ms. Power holds a B.A. in Geography and International Studies (University of Oregon) (4 years with WSI).
- **LAYNE BENNETT** – *Data Processing QA/QC Lead/GIS Specialist*, WSI: Ms. Bennett serves as the lead manager responsible for client communication on project deliverables, and all final quality assurance review of data products. Her responsibilities include client support during and after project contracts and all project reporting. Ms. Bennett coordinates with all key managers and analysts throughout the life of a project and oversees all aspects of processing quality control. Ms. Bennett has been project lead on several Alaska projects, and has strong analytical and GIS skills. Ms. Bennett has a B.S. in Geology (Oregon State University) with a Certificate in GIS (4 years with WSI).

6.4 Current Workload

The figure below shows the current utilization of WSI aircraft, sensors, and processing resources through the next two quarters. Based on our current commitments, we will have LiDAR/orthophotography equipment and field staff available in the late April through mid-June time frame. All 4 of our wide-area mapping LiDAR systems are capable of meeting project specifications and at least one system will be available for this project.

Percent at Capacity for WSI Resources February – October 2013



6.5 Approach to Project Monitoring, Control, Risk Assessment & Management

In airborne remote sensing, project success is often defined by efficient field operations that produce high quality data. This will be acutely true for the **City/Borough of Juneau** project where the data collection season is relatively short and weather opportunities will be limited. Our management goal is ensure that the data collection is effective and that any problems (equipment or otherwise) are identified and acted on immediately. In order to achieve this goal, WSI has established a process that identifies unanticipated issues and defined paths for communicating and resolving problems through the management structure. All WSI managers have at least 5-years' experience following this process and the size and structure of WSI allows quick escalation and resolution of issues.

Project Monitoring & Control

Through years of experience, WSI has developed a robust tracking and reporting system that allows managers to monitor progress, identify potential problems, and take corrective measures. WSI will establish clear lines of communication with the City of Juneau, which allows both routine status reporting and escalation of problems. Status reporting is typically accomplished both via web based status maps and scheduled conference calls. **Figure 4** provides a general overview of WSI lines of communication, information flow, and frequency during the data collection. Our Acquisition Manager continuously monitors conditions and weather forecasts in the project area and makes decisions – in coordination with the Project Manager - regarding resource allocations, logistics, and predicting problems at the project level. As a minimum, the Acquisition Manager communicates with the Field Crew (*consisting of pilot, sensor operator, and GPS survey technician*) at least once a day on a scheduled phone conference call. Field crews submit all records, ground data, and sensor log files to the office via the internet daily. WSI utilizes several tools for monitoring the project including a custom built tool called Field Fusion Manager (FFM), which synthesizes all field data into a Google Earth (kmz) file that is easily accessed by both field staff and managers to monitor progress.

During an airborne mission, the sensor operator monitors system diagnostics and reports all potential issues in a field log and during the daily call with the Acquisition Manager. The sensor operator will perform quick look checks on the data in the field and also overnight (if possible) the data to one of our Oregon offices. Once in the office, the data are processed immediately to check for any indication of anomalies (i.e. potential sensor issues), data gaps, or other factors that may impact data quality. The calibration staff reports any concerns or issues to both Acquisition and Project Manager.

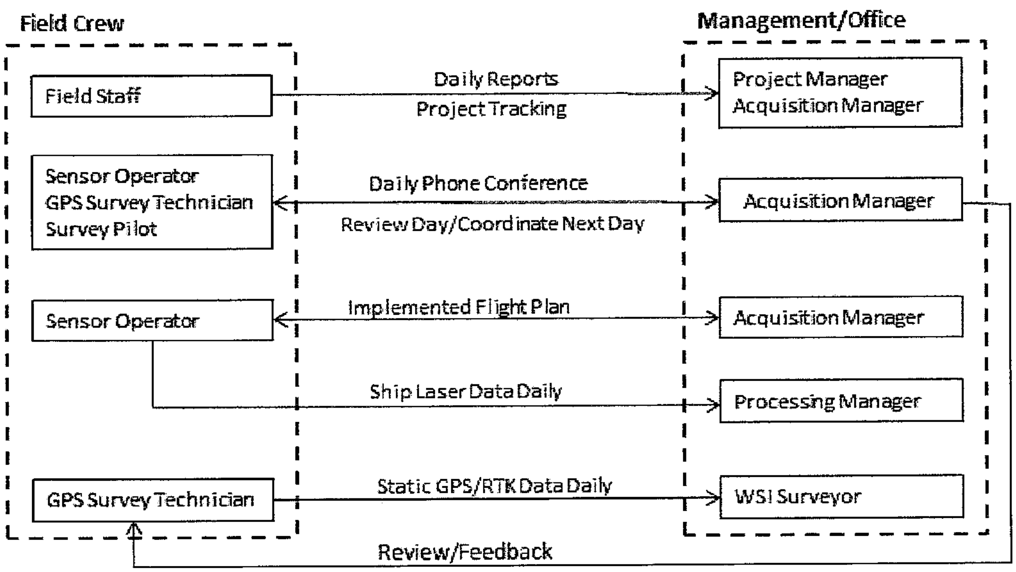


Figure 4 - WSI field reporting procedures, data transfer, and frequency.

Issue and Escalation Process

An issue may be identified at any stage during the life of the project, but is typically most time-sensitive during data collection. Our project monitoring and control process is designed specifically to identify critical issues as soon as they occur and to prevent undesirable impacts to the project. WSI has a direct line of communication between field staff, analysts, and the project manager. Consequently, escalation of issues to the correct decision-making levels happens quickly within the organization. Our approach is as follows:

1. Problem Identification: Field staff and analysts inform the Acquisition/Process Manager of all problems or potential issues regardless of severity or perceived importance. The Acquisition/Process manager resolves all routine (i.e. day-to-day) issues, but elevates all other issues to the Project Manager via direct meeting or email.
2. Analysis: The WSI Management Team will analyze the problem and determine action items and timelines. This analysis will prioritize the issue and determine the potential impact on schedule, resources, and overall project plan.
3. Corrective Action: The Management Team will identify corrective action(s) and identify potential or real impact on costs and schedule. The Management Team will consult with WSI principal-in-charge on corrective actions and resources required. The Project Manager is responsible implementing and tracking the corrective action to ensure successful implementation.
4. Escalation: Issues or potential problems are elevated based on results and prioritization from the WSI Management Team. If an issue potentially impacts project schedule, specifications, project execution, or other variable impacting project success, WSI will discuss the issue and proposed corrective actions to the CBJ via phone call with a follow up email documenting decisions and potential consequences.

WSI will follow its Project Management Plan (PMP) as described in this proposal. In the event of a WSI personnel or management change, the new manager will be introduced directly to the City's representative. If a project problem results in necessary changes to the PMP, then WSI will modify the PMP with the City's written approval.

WSI will seek to resolve any project problems or contractual disputes through open communication. WSI has traditionally established good communication and rapport with our clients. We have successfully resolved all project issues through proactive management and open communication.

Risk Assessment and Management

The following provides an identification of risks, probability, assessment, and steps to mitigate. The risks are separated into programmatic risks and general safety risks.

Risk	Impacts	Assessment	Mitigation Plan
Poor Weather	Schedule/Budget	The impact of weather is most pronounced in Alaska coastal areas. Prolonged bad weather can result in inactive field crews (budget) and delays in the schedule. The variability of weather is outside the control of the project team (probability = high)	• Monitor weather closely; consult with the City and R&M on local weather patterns. • Allocate additional resources during prolonged good weather windows.
Equipment Failure	Schedule/Budget/ Data Quality	LiDAR systems are high tech instruments that operate in harsh environments. System errors can be subtle and difficult to detect OR can be catastrophic. The Project Manager cannot control when a system may/may not fail, but can take steps to minimize the impact on the project. (probability = low)	• Reporting systems and quick look analysis are designed to catch system failures before they impact the project. • WSI owns 5 LiDAR systems. In the event of a failure we have enough resources to minimize the impact on acquisition schedule by deploying a different sensor • If a system error causes the data to be out of spec., WSI will refly the area or flight line
Operational Safety	Process Success	The Project Management team can minimize operational risks, but not eliminate them all together. WSI maintains and operates reliable aircraft that are suitable for this project and provides the proper equipment to the ground crews. (probability = low)	• Minimizes risks by providing the proper training and equipment to the field crews. • Field Crews follow established WSI Safety Protocols and Flight Operations Procedures.
Data Processing Anomalies	Delivery Schedule/Budget	WSI QA protocols are designed to ensure high quality data is received from the field. None-the-less data processing anomalies can still occur that can "slow" processing. (probability = low)	• Identify problem and assign technical resources. • Allocate additional processing staff or computational resources to offset any lost time due to delays during the work-flow.

7.0 FGDC Compliant Metadata Examples

WSI provides FGDC-compliant metadata as a deliverable for all contracted projects. **Appendix B** (page 58) provides samples of FGDC-compliant metadata (.txt format) for the following deliverables from two WSI representative projects in Alaska:

- Hydroflattened Bare Earth DEM, Alaska Natural Gas Pipeline Corridor, AK Department of Natural Resources
- Othoimagery, Héen Latinee Experimental Forest, Tongass National Forest, AK

8.0 PROPOSAL DELIVERABLE SPECIFICATION AND COST TABLES

Proposals shall include a completed version of the following tables. Please note these tables are informational only, and are not intended to be a statement of the proposed total cost of the project to the CBJ. For example, if appropriate, proposers may choose to exclude the cost of mobilization from these cost figures.

In Table 1, specify proposed nominal LiDAR first return point densities and unit costs for each priority area. In Table 2, for orthoimagery, specify the proposed pixel size, and list the proposed bands (and target wavelengths) for each priority area. In Table 3, specify the unit cost for RGB imagery at one and two foot pixel sizes for the project's priority areas. This RGB imagery is not a deliverable in this project, but this information will assist the CBJ with the evaluation of received proposals.

Note from WSI: Mobilization of the plane and crew are included in Priority 1 LiDAR costs. Costs are presented individually for each priority area in sequence, and thus differ from per unit cost calculations presented in section **10.0 Price Proposal of Total Project** (presented as cumulative costs).

Table 1

	Project Priority 1 Area (82 square miles)		Project Priority 2 Area (16 square miles)		Project Priority 3 Area (44 square miles)	
Product	Proposed first return point density (pts / sq m)	Unit Cost (per sq mile)	Proposed first return point density (pts / sq m)	Unit Cost (per sq mile)	Proposed first return point density (pts / sq m)	Unit Cost (per sq mile)
LiDAR	**8**	$1,918	**4**	$2,402	**4**	$1,013

Table 2

	Project Priority 1 Area (82 square miles)		Project Priority 2 Area (16 square miles)		Project Priority 3 Area (44 square miles)	
Product	Proposed pixel size and Proposed Bands	Unit Cost (per sq mile)	Proposed pixel size and Proposed Bands	Unit Cost (per sq mile)	Proposed pixel size and Proposed Bands	Unit Cost (per sq mile)
Ortho-imagery	**15 cm** Blue: 400-600 Green: 480-660 Red: 590-720 NIR: 695-1000	$732	**30 cm** Blue: 400-600 Green: 480-660 Red: 590-720 NIR: 695-1000	$760	**30 cm** Blue: 400-600 Green: 480-660 Red: 590-720 NIR: 695-1000	$448

Table 3

	Project Priority 1 Area (82 square		Project Priority 2 Area (16 square miles)		Project Priority 3 Area (44 square miles)	
Product	RGB 1 foot pixels	Unit Cost (per sq mile)	RGB 2 foot pixels	Unit Cost (per sq mile)	RGB 2 foot pixels	Unit Cost (per sq mile)
RGB Ortho-imagery	**1 foot**	$658	**2 foot**	$448	**2 foot**	$624

9.0 LICENSING AND DELIVERABLES & DERIVATIVES IN PUBLIC DOMAIN

Delivery of data for entry into the public domain is standard practice for WSI, and we fully support public dissemination of valuable data. We are the sole data provider for LiDAR and value-added products to two public consortiums in the Pacific Northwest: the Puget Sound LiDAR Consortium (PSLC) serving Washington State LiDAR procurements and the Oregon LiDAR Consortium (OLC), serving Oregon State.
Further information on Public Domain distribution through these consortiums as examples of approach to data dissemination can be found at:

- PSLC: http://pugetsoundlidar.ess.washington.edu/About_PSLC.htm#status
- OLC: http://www.oregongeology.org/sub/projects/olc/DOGAMI_Lidar_Distribution_Policy_FINAL_Jan2103.pdf

WSI will grant the CBJ rights to all deliverables and subsequent derivatives, as well as the rights to place deliverables and derivatives in the public domain.

10.0 PRICE PROPOSAL OF TOTAL PROJECT

The below table outlines cumulative costs for acquiring LiDAR and 4 band imagery for Priority Areas 1, 2 & 3. Costs for mobilization of the plane and crew, and for contingencies, are included in Priority 1 LiDAR costs. Total costs include all expenses related to data acquisition, processing of deliverables and reporting. Costs reflect the following specifications, as recommended in our proposal:

Priority 1: 8 pulses/m^2 LiDAR and 15 cm resolution orthoimagery
Priority 2 & 3: 4 pulses/m^2 LiDAR and 30 cm resolution orthoimagery

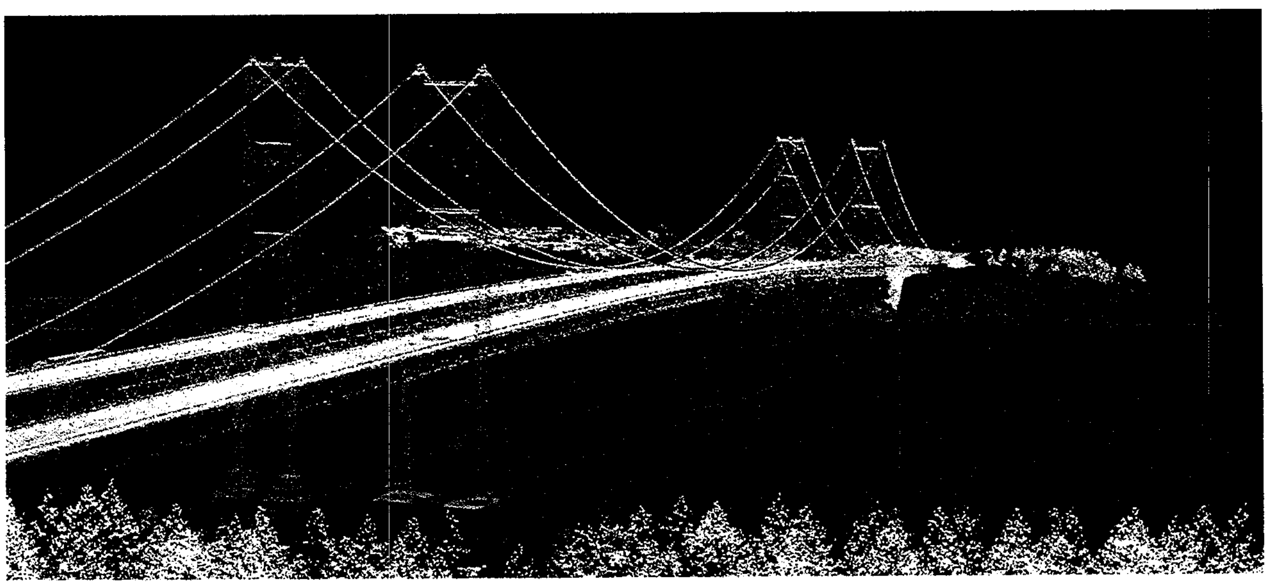
	LiDAR		4 Band Orthophotography		
Area	Total Cost	Per Unit ($/sq mile)	Total Cost	Per Unit ($/sq mile)	Total
Priority 1 (82 sq miles)	$158,052	$1,918	$60,342	$732	**$218,394**
Priority 1 & 2 (98 sq miles)	$197,019	$1,997	$72,667	$737	**$269,687**
Priority 1, 2 & 3 (142 sq miles)	$241,520	$1,694	$92,352	$648	**$333,871**

11.0 JUNEAU PROPOSER PREFERENCE

While WSI does not qualify as a Juneau Proposer, our team partner R&M Engineering meets the criteria outlined in City Ordinances 53.50.010 and 53.50.050. These criteria met by R&M (briefly paraphrased) include:

- Submission of bid (as subcontractor) under the name of business appearing on the bidder's City and Borough business registration (which is 'R&M Engineering, Inc.'
- Longterm residency in Juneau (>6 months prior to proposal deadline of 2/8/13)
- Provision of surveying services as requested under the RFP
- As of 2/8/13, R&M Engineering is in compliance with the registration and filing requirements for sales tax and business personal property tax
- As of 2/8/13, R&M Engineering is not delinquent in the payment of any taxes or associated penalties, interest, or fees, or any special assessments, owing to the CBJ

LiDAR point cloud colored by elevation, Tacoma Narrows Bridge, Washington.



12.0 Appendix A - Select Resumes

RUSSELL FAUX

Project Manager/Principal

Russell Faux founded Watershed Sciences, Inc. in the late 1990's and has developed the company into one of the premier airborne remote sensing companies in North America in a little over 1 decade. Mr. Faux is a remote sensing specialist and research collaborator with over 20 years of experience in data acquisitions and analyses for airborne sensors including Light Detection and Ranging (LiDAR), thermal infrared, and multispectral and hyperspectral imagery. Mr. Faux has embraced new technologies and innovative geospatial problem solving to shepherd the company into the leading LiDAR data provider for research and engineering-grade LiDAR applications. He has successfully managed and provided technical guidance on a range of remote sensing surveying and mapping projects across a number of landscape types in the United States for a variety of federal, state and private clients, some exceeding 2 million acres in size.

- ***Project Manager***
  - LiDAR and other remote sensing projects that include teaming relationships for survey and multiple sensor acquisitions.
  - Spectral remote sensing projects including thermal infrared, digital ortho-photography hydro-acoustics, and hyperspectral imagery.
- ***Education***
  - **M.S. Bioresource Engineering**, Oregon State University, Corvallis, OR, 1996
  - **B.S. Electrical Engineering**, Pennsylvania State University, University Park, PA, 1987
- ***Selected Professional Experience***
  - **President.** Watershed Sciences, Inc, Corvallis, OR (1999 – Present). Business Development and management of airborne remote sensing projects.
  - **Faculty Research Assistant.** Dept. of Forest Science, Oregon State University, Corvallis, OR (1997- 2001). Developed the application of airborne thermal infrared remote sensing to stream temperature, hydrologic analysis, and habitat monitoring
  - **GIS Specialist.** Agricultural Policy Research Unit, Lilongwe, Malawi, Africa (1996). Research of deforestation and agricultural diversification
  - **Electrical Engineer.** Aberdeen Proving Ground, MD (1988-1992). Test design and evaluation of airborne optical sensors and radar sub-systems. Member of technical test and evaluation team deployed to Southwest Asia.
- ***Selected Publications/Technical Papers***

Evans, J.S., A.T. Hudak, **R. Faux**, and A.M.S. Smith, *2009.* Discrete return LiDAR in natural resources: recommendations for project planning, data processing, and deliverables. *Remote Sensing* 1: 776-794.

Faux, R.N., J.M. Buffington, G. Whitley, S. Lanigan, and B. Roper. *2009.* Use of airborne LiDAR for determining channel cross-section characteristics and monitoring aquatic habitat in pacific Northwest rivers: A preliminary analysis. Proceedings of ASRPS Conference, PNAMP Special Session: Remote Sensing Applications for Aquatic Resource Monitoring, Portland, OR, Annual meeting April 2008.

Faux, R.N. and B.A. McIntosh. *2006.* Stream temperature assessment: Using thermal infrared remote sensing. *Conservation in Practice* 1(1): 38-41.

Torgersen, C.E., **R. Faux**, B.A. McIntosh, N. Poage, and D.J. Norton. *2001.* Airborne thermal remote sensing for water temperature assessment in rivers and streams. *Remote Sensing of Environment* 76(3): 386-398.

MARK JOHNSON

Alaska Surveyor of Record

EDUCATION:
University of Alaska Southeast (no degree)

Continuing Education: Over 100 hours in civil design and land surveying

REGISTRATION:
Registered Land Surveyor, Alaska, 1988 (LS 7570)

PROFESSIONAL AFFILIATIONS
American Congress of Surveying and Mapping

Alaska Society of Professional Land Surveyors

Since 1971, Mr. Johnson has worked in the surveying and engineering fields in Southeast Alaska, working with and/or for local state and federal governments and the private sector. His state service was in surveying and transportation engineering (roads and airfields), while his government service has been with utilities and computer science. His private sector work has incorporated all of these skills plus aerial photography, photogrammetric ground control and mapping. Mr. Johnson has completed technical design of a majority of subdivisions within Southeastern Alaska along with their field surveys. He has also conducted numerous accretion and cadastral surveys (original and retracement) throughout Southeastern Alaska.

Mr. Johnson has designed rural, urban and municipality street and utility projects throughout Southeast Alaska. In addition, he played a major role in both the civil and structural design and contract administration for a major water reservoir system within the Juneau Water Distribution System. He has also served as project manager and civil designer of numerous private subdivision developments entailing conceptual through contract issue of design plans. These projects typically include site mass grading and drainage, storm drainage, sewer collection and domestic water distribution systems, geotechnical investigation and analysis, subbase, base course and final surfacing sections. In many cases he has participated in off-site drainage impact studies.

Projects in which Mr. Johnson was the Surveyor of Record include the following:

- 2012 CBJ Docks & Harbors DH12-155 Lease Boundary Survey, Juneau, AK
- 2012 CBJ FEMA Flood map Comparisons, Phase 1-4, Juneau, AK
- 2012 CBJ Bayview Subdivision Topographic Survey, Juneau, AK
- 2012 CBJ Lower West Mendenhall Valley Sewer, Peterson Hill Survey
- 2011 City of Hoonah Contract Documents for Road Improvement project, Hoonah, AK
- 2011 Sealaska Plaza Site Topographic & Boundary Survey, Juneau, AK
- 2011 Johnson Youth Center Topographic and Construction Survey, Juneau, AK
- 2011 AEL&P Salmon Creek Dam Control Survey, Juneau, AK
- 2011 Municipality of Skagway Small Boat Harbor Improvements Topographic Survey, Skagway, AK
- 2011 CBJ ATS 1685 Auke Nu Cove Survey, Juneau, AK
- 2011 City of Hoonah Tract WA1 Subdivision Plat, Hoonah, AK
- 2011 CBJ Mt. Jumbo – Douglas Drainage Correction Survey, Juneau, AK
- 2011 Kensington Mine Paste Plant Survey, Juneau, AK
- 2011 Wrangell Airport Tower Road Topographic Survey, Wrangell, AK
- 2011 CBJ West Juneau Access Survey, Juneau, AK
- 2011 Russian Orthodox Church As-built, Topographic and Boundary Survey, Juneau, AK

CHRIS YOTTER-BROWN

Project Surveyor

- ***Licenses***
  - Oregon Professional Land Surveyor No. 60438
  - Washington Professional Land Surveyor 46328

- ***Company Project Lead***

  Survey planning & management for LiDAR acquisition throughout Oregon and Washington; provides survey support for projects in other states

- ***Education***

  B.S. Surveying, Oregon Institute of Technology, Klamath Falls, OR, 1999

- ***Selected Professional Experience***

  Mr. Yotter-Brown has 12 years of survey experience ranging from a field technician to Survey Manager.

  Project Surveyor. *Watershed Sciences, Inc., Portland, OR. 2010*
  - Responsibilities include oversight on mapping control, supervision and training of field crew, certification of mapping control monuments

  Project Surveyor. *Alcantar & Associates, LLC, Portland, OR. 2008-2010.*
  - Responsibilities include preparing Statements of Qualifications, Technical Proposals and Project Cost Estimates.
  - Prepare calculations and working maps for field crews on Construction Staking projects and provided a QA/QC review of field work prepared by others.

  Office Surveyor. *OTAK, Inc., Lake Oswego, Oregon. 2007-2008.*
  - Drafting maps for Topographical surveys, Condo Plat, ALTA and Records of Survey.
  - Provided cost estimates for projects for construction staking projects.

  Survey Manager. *Anderson Engineering and Surveying, Inc., Lakeview, OR. 2005-2006*
  - Worked on boundary, topographic, construction, cadastral and ALTA projects, performing the drafting, boundary resolution and calculations for the field crew.

  Survey Technician. *DeJarnatt Land Surveying, Inc., Bend, Oregon. 2000-2005.*
  - Drafted maps for Records of Survey, Property Line Adjustments, Partitions and Water Right Transfers.
  - Instrument operator for Boundary, Topographic, Construction and Cadastral surveys.

- ***Affiliations***

  Professional Land Surveyors of Oregon; Oregon Institute of Technology Alumni Northwest Chapter, Secretary

BRIAN DWYER

Acquisition Manager

- ***Company Project Lead***
  - LiDAR Acquisition, Planning, & Management, including recent projects:
    - Tongass National Forest (AK)
    - Whittier (AK)
    - Alaska Natural Gas Pipeline Corridor (AK)
    - Pierce County (WA)
    - Kittitas-Rattlesnake PSLC (WA)
    - Tahoe Lake Basin (CA)
    - Clearwater National Forest (ID)
    - Flathead Basin (MT)
    - Coronado National Forest (AZ)

- ***Education***

Post-Baccalaureate Coursework, Oregon State University, Corvallis, OR, 2000-2002
B.S. Psychology, with Minor in Geology, University of Wisconsin – Eau Claire, 1997

- ***Certifications***
  - CPR Certified, American Heart Association
  - Swift-water Rescue Certified, American Canoe Association

- ***Selected Professional Experience***

LiDAR Operator & Acquisition Manager, *Watershed Sciences, Inc., Corvallis, Oregon. October 2006-Present.*

- Responsibilities include Acquisition, Field Personnel Training, Planning & Management of LiDAR Missions
- Report to clients on status of active projects

Crew Leader, Hydrological Science Technician, *Aquatic and Riparian Effectiveness Management Program, Bureau of Land Management, Corvallis, Oregon. May 2003 - September 2006*

- Team leader (1 season) and crew member (3 seasons) responsible for collecting field data concerning watershed health throughout the Pacific Northwest.

Field Assistant, *Oregon State University, Geosciences Department. July – November 2002.*

- Collected and analyzed field data necessary to assess the geomorphic and ecological impacts of the removal of Marmot Dam on the Sandy River, Oregon.

Lab Assistant, *University of Wisconsin –Eau Claire, Department of Geology. Sept 1997 – June 1999*

- Member of 4-person laboratory team responsible for analyses of volcanic, sedimentary, and metamorphic rock from Southern British Columbia and Baja Mexico.

ALEXA RAMIREZ

Calibration Lead

+ ***Company Project Lead***

  Recent key projects:
  - Tongass National Forest (Alaska), LiDAR mapping
  - Whittier (Alaska), LiDAR mapping
  - Alaska Natural Gas Pipeline Corridor (Alaska), LiDAR mapping
  - Tahoe Lake Basin (California), LiDAR mapping
  - Nooksack River PSLC (WA), LiDAR mapping
  - Clearwater National Forest (ID), LiDAR mapping
  - Washington Estuaries (WA), LiDAR mapping

+ ***Education***

  M.S. Marine Science (Geological Oceanography), College of Marine Sciences, University of South Florida, 2008
  B.S. Earth and Ocean Science, Duke University, Durham, NC, 2005

+ ***Selected Professional Experience***

Technical Lead / Spatial Analyst – Watershed Sciences Inc (*Corvallis, OR*), 2008 - Present
Lead analyst on 13 projects, including multi-state, > million acre projects. Responsibilities include: calibration of LiDAR data; organizing and processing LiDAR data for dissemination to Project Leads; training Project Leads, Spatial Analysts, and Interns on project workflow and QA/QC. Processing manager of all duties involved in LiDAR processing, including processing LiDAR point data for error points; Creating and manipulating raster images of LiDAR data; Visually interpret accuracy and density information regarding the LiDAR data; Creating reference maps identifying study areas, locations of static stations, ground truth points, and relative location identifiers; Creating reports.

Graduate Assistant – University of South Florida (*St. Petersburg, FL*), Aug 2006 – July 2008
Used spatially referenced satellite imagery and LiDAR data to identify ideal sampling locations (patch reefs); Used boat, handheld GPS device, and SCUBA equipment to locate identified reefs; Acquired sediment and rubble samples from reef environments; Processed samples for grain size analysis and foraminiferal and sedimentary assemblages; Trained new students in identification of major symbiont-bearing foraminifers; Utilized statistical and graphical software to interpret data (PRIMER, ArcGIS, Surfer); Teacher's Assistant for Geological Oceanography graduate course; Participated in two separate week long geological cruises utilizing box core sampling, CTDs and multi-beam sonar equipment

Lab and Research Technician I – Virginia Institue of Marine Science (*Gloucester Point, VA*), May 2005 – October 2005
Conducted experiments on viability of seeds in seagrass restoration efforts; Supervised high-school interns; Assisted in long term seagrass bed and water quality monitoring in Chesapeake Bay

+ ***Skills***
  - Proficient in Microsoft Office Applications
  - Experience with ArcGIS software
  - Experience with Microstation software
  - Basic knowledge of Photoshop and ERDAS Imagine software

COLIN COOPER
Orthophotography/Technical Expert

+ ***Company Project Lead***
  Recent key projects:
  - Tongass National Forest (AK), Specrtal Image Processing
  - Trinity River (California), LiDAR and Specrtal Image Processing
  - Upper Grande Ronde River (Oregon), Spectral Image Processing
  - Pierce County (Washington), LiDAR mapping
  - Tahoe Lake Basin (California), LiDAR mapping
  - Flathead Basin (Montana) LiDAR mapping and Hydro-enforced DTM
  - Sprague River (Oregon) True-Color/TIR mapping

+ ***Education***

  M.S. Geography, Oregon State Univerity, Corvallis, OR, 2005
  Major in Geographic Information Science and Minor in Marine Resource Management
  B.S. Environmental Science, University of Delaware, Newark, DE, 2002
  Concentration in Geology and Minor in Geography

+ ***Selected Professional Experience***

  Remote Sensing Analyst – Watershed Sciences Inc (*Corvallis, OR*)
  Collect, process, and analyze remotely sensed data including LiDAR, TIR Imagery, and Aerial Photographs; Develop deliverable products and reports for clients ensuring quality, accuracy, and clarity of data

  Teaching Assistant – Oregon State University (*Corvallis, OR*)
  Instructed the laboratory sections of graduate level GIS courses including Advanced Applications in the Geosciences; Developed new lab exercises including GPS field components

  Research Asst. Catalogue of Oregon Marine and Coastal Information (*Corvallis, OR*)
  Created an ArcIMS website to search a coastal database online by spatial location

+ ***Software Proficiencies***
  - **GIS**- (ESRI v. 3.x-9.x), IDRISI, Imagine, ENVI, Freehand, Illustrator, Photoshop
  - **Image Processing**- Leica Photogrammetry Suite, ORIMA, OrthoVista,
  - **LiDAR processing**- Microstation w/ Terrascan and Terramodeler, Fusion
  - **Web**- ArcIMS, HTML, Flash, Dreamweaver, ASP, ArcXML, Google Maps API
  - **Programming**- JavaScript, Visual Basic, Fortran, and the Unix environment

+ ***Presentations***
  - **Cooper, C**. 2005. Building and sharing spatial metaphors for the Catalogue of Oregon Marine and Coastal Science. Invited presentation to the annual meeting of the Association of American Geographers (AAG), March 2005, Denver, CO.

13.0 APPENDIX B – WSI FGDC-COMPLIANT METADATA SAMPLES

METADATA FILE for
Hydroflattened Bare Earth DEM, Alaska Natural Gas Pipeline Corridor, AK Department of Natural Resources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The LiDAR data was collected between September 17th through September 22nd, 2010. The survey used the Leica ALS 60 system mounted in a Cessna Caravan 208. Near nadir scan angles were used to increase penetration of vegetation to ground surfaces. Ground level GPS and aircraft IMU were collected during the flight.

Leica sensor Instrument Parameters;
Beam diameter: 34 cm,
Pulse rate: 150 kHz,
Maximum returns: 4
Overlap: >60%
Laser power: 19%
Field of vew (FOV): 28°
Beam wavelenth: 1064 nm,
Frequency of GPS sampling: 2 Hz,
Frequency of IMU sampling: 200 Hz,
Swath width: 638m
AGL: 1,500 m
Average pulse density: 8</procdesc>
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<procdesc>**Processing.**
1. Flight lines and data were reviewed to ensure complete coverage of the study area and positional accuracy of the laser points.
2. Laser point return coordinates were computed using ALS Post Processor software and IPAS TC based on independent data from the LiDAR system, IMU, and aircraft.
3. The raw LiDAR file was assembled into flight lines per return with each point having an associated x, y, and z coordinate.
4. Visual inspection of swath to swath laser point consistencies within the study area were used to perform manual refinements of system alignment.
5. Custom algorithms were designed to evaluate points between adjacent flight lines. Automated system alignment was computed based upon randomly selected swath to swath accuracy measurements that consider elevation, slope, and intensities. Specifically, refinement in the combination of system pitch, roll and yaw offset parameters optimize internal consistency.
6. Noise (e.g., pits and birds) was filtered using ALS postprocessing software, based on known elevation ranges and included the removal of any cycle slips.
7. Using TerraScan and Microstation, ground classifications utilized custom settings appropriate to the study area.
8. The corrected and filtered return points were compared to the RTK ground survey points collected to verify the vertical accuracy.
9. Ground classified points were output as laser points, TINed and GRIDed surfaces with hydroflattening breaklines enforced. </procdesc>
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METADATA FILE for Othoimagery, Héen Latinee Experimental Forest, Tongass National Forest, AK


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<procdesc>**Acquisition. The Orthoimagery data was collected on October 26th, 2012. The survey utilized a Vexcel Ultracam, large format camera mounted in a Cessna 208B Caravan.**

Leica RCD 105 specifications:
1. Focal Length: 80 mm
2. Data Format: RGB, NIR
3. Pixel size: 5.2 micrometers
4. Image size: 20,010 x 13,080 pixels
5. FOV: 66 degrees x 46 degrees
6. Frame rate: 1.8 seconds (GPS triggered)

Digital Orthophotography Specifications
1. Spectral Bands: Red, Green, Blue, Near Infrared
2. Resolution: 30 cm pixel size
3. Along track overlap: Greater than or equal to 60 percent
4. Planned Height (AGL): 4300meters
5. GPS Baselines: 25 nm
6. GPS PDOP: Less than or equal to 3.0
7. GPS Satellite Constellation: Greater than or equal to 6
8. Image: 8-bit GeoTiff</procdesc>
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<procdesc>**Processing. 1. Resolve GPS kinematic corrections for the aircraft position data using kinematic aircraft GPS (collected at 2HS) and static ground GPS (1Hz) data collected over geodetic controls. 2. Develop a smooth best estimate trajectory (SBET) file that blends post-processed aircraft position with attitude data. Sensor heading, position, and attitude are calculated throughout the survey. 3. Create an exterior orientation file (EO) for each photo image with omega, phi, and kappa. 4. Convert Level 00 raw imagery data into geometrically corrected Level 02 image files. 5. Apply radiometric adjustments to Level 02 image files to create Level 03 Pan-sharpened TIFFs. 6. Apply EO to photos, measure ground control points and perform aerial triangulation. 7. Import DEM, orthorectify and clip triangulated photos to the specified area of interest. 8. Mosaic orthorectified imagery, blending seams between individual photos and correcting for radiometric differences between photos.**</procdesc>
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14.0 Appendix C – Alaska Business License

Alaska Business License # 946782

Alaska Department of Commerce, Community, and Economic Development
Division of Corporations, Business and Professional Licensing
P.O. Box 110806, Juneau, Alaska 99811-0806

This is to certify that

WATERSHED SCIENCES, INC

517 SW 2ND ST STE 400 CORVALLIS OR 97333

owned by

WATERSHED SCIENCES INCORPORATED

is licensed by the department to conduct business for the period

June 25, 2012 through December 31, 2013
for the following line of business:

54 - Professional, Scientific and Technical Services

This license shall not be taken as permission to do business in the state without having complied with the other requirements of the laws of the State or of the United States.

This license must be posted in a conspicuous place at the business location. It is not transferable or assignable.

Susan K. Bell
Commissioner