# OLC Alaska FEMA Sitka

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October 6, 2014

Totem Park, Sitka, AK

Data collected for:

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# Contents



National Ocean Service Benchmark

# Project Overview

WSI, a Quantum Spatial Company, has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data of the Oregon LiDAR Consortium (OLC) Alaska FEMA Sitka Survey, for the Oregon Department of Geology and Mineral Industries (DOGAMI).

The OLC Alaska FEMA Sitka project area (AOI) encompasses approximately 7,200 acres. Total area flown (TAF) is approximately 9,245 acres.

The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

WSI acquired data from May 14 - May 22, 2014. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5 - foot intensity rasters, three foot ground density rasters, study area vector shapes, acquisition shapes including SBETs, Ground Control Points (hard surface and landclass), and GPS Monuments and corresponding statistical data, and. Final deliverables are projected in Alaska State Plane.

| OLC Alaska FEMA Sitka<br>Delivered<br>October 7, 2014 | |
|---|---|
| Acquisition Dates | May 14, 2014 - May 22, 2014 |
| Area of Interest | 7,199 Acres |
| Projection | Alaska State Plane |
| Datum: horizontal & vertical | NAD83<br>NAVD88 (Geoid 12A), MLLW Adjustment |
| Units | US Survey Feet |

Study Area

# Aerial Acquisition

## LiDAR Survey

The LiDAR survey utilized a Leica ALS70 sensor mounted in a Partenavia P.68. The system was programmed to emit a single pulse at a rate of 140 to 198 kilohertz, and flown at 1,500 meters above ground level (AGL), capturing a scan angle of +/-15 degrees from nadir (field of view equal to 30 degrees). These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The study area was surveyed with opposing flight line side-lap of greater than 65 percent with at least 100 percent overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernible laser returns were processed for the output dataset.

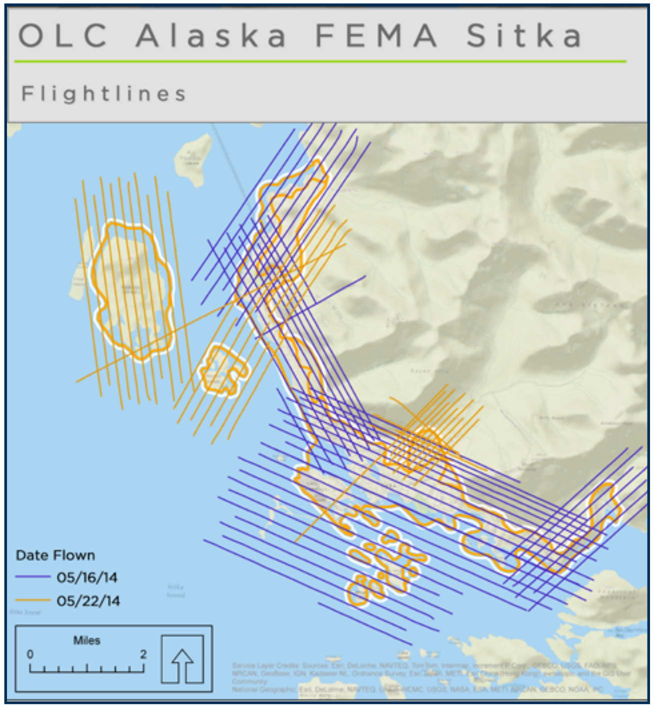
To solve for laser point position, an accurate description of aircraft position and attitude is vital. Aircraft position is described as x, y, and z and was measured twice per second (two hertz) by an onboard differential GPS unit. Aircraft attitude is described as pitch, roll, and yaw (heading) and was measured 200 times per second (200 hertz) from an onboard inertial measurement unit (IMU)

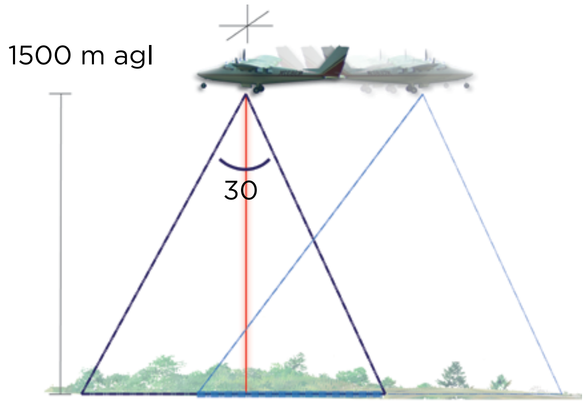
The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results during the data processing stage. They were also in constant communication with the ground crew to ensure proper ground GPS coverage for data quality.

The LiDAR coverage was completed with no data gaps or voids, barring non-reflective surfaces (e.g., open water, wet asphalt). All necessary measures were taken to acquire data under good conditions (e.g., minimum cloud decks) and in a manner (e.g., adherence to flight plans) that prevented the possibility of data gaps.

All WSI LIDAR systems are calibrated per the manufacturer and our own specifications, and tested by WSI for internal consistency for every mission using proprietary methods.

Project Flightlines




| Lane County Acquisition Specs | |
|---|---|
| Sensors Deployed | Leica ALS 70 |
| Aircraft | Partenavia P.68 |
| Survey Altitude (AGL) | 1500 m |
| Pulse Rate | 140-198 kHz |
| Pulse Mode | Single (SPiA) |
| Field of View (FOV) | 30° |
| Roll Compensated | Yes |
| Overlap | 100% overlap with 60% sidelap |
| Pulse Emission Density | ≥ 8 pulses per square meter |

# Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over four monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify daily variance. Multiple sessions were processed over the same monument to confirm antenna height measurements and reported position accuracy.

## Instrumentation

For this study area all Global Navigation Satellite System (GNSS) survey work utilizes a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points. The Trimble GNSS R8 unit is used primarily for real time kinematic (RTK) work but can also be used as a static receiver. For RTK data, the collector begins recording after remaining stationary for five seconds then calculating the pseudo range position from at least three epochs with the relative error under 1.5 centimeters horizontal and 2.0 centimeters vertical. All GPS measurements are made with dual frequency L1-L2 receivers with carrier-phase correction.

## Monumentation

Existing and established survey benchmarks serve as control points during LiDAR acquisition, including those previously set by WSI. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own monuments. These monuments are spaced at a minimum of one mile and every effort is made to keep them within the public right of way or on public lands. If monuments are necessary on private property, consent from the owner is required. All monumentation is done with 5/8" x 30" rebar topped with a two-inch diameter aluminum cap stamped "Quantum Spatial Control." Three new monuments were established and one National Oceans Service benchmark were occupied for the OLC Alaska FEMA Sitka study area (see Monument table at bottom right).


| Monuments | | | |
|---|---|---|---|
| | Datum NAD 83 (2011) | | GRS 80 |
| Name | Latitude | Longitute | Ellipsoid Height (m) |
| AK_FEMA_01 | 57 01 59.30322 | -135 14 58.02581 | 22.437 |
| AK_FEMA_02 | 57 07 36.01827 | -135 23 13.36327 | 10.558 |
| AK_FEMA_03 | 57 02 55.14533 | -135 20 52.30281 | 5.928 |
| 945_1600_N | 57 03 01.88013 | -135 20 19.65368 | 12.640 |

## Methodology

| Monument Accuracy | |
|---|---|
| FGDC-STD-007.2-1998 Rating | |
| St Dev NE | 0.010 m |
| St Dev z | 0.050 m |

Each aircraft is assigned a ground crew member with two R7 receivers and an R8 receiver. The ground crew vehicles are equipped with standard field survey supplies and equipment including safety materials. All control points are observed for a minimum of two survey sessions lasting no fewer than two hours. At the beginning of every session the tripod and antenna are reset, resulting in two independent instrument heights and data files. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna.

The ground crew uploads the GPS data to the Dropbox website on a daily basis to be returned to the office for Professional Land Surveyor (PLS) oversight, Quality Assurance/Quality Control (QA/QC) review, and processing. OPUS processing triangulates the monument position using three CORS stations resulting in a fully adjusted position. Blue Marble Geographics Calculator 2013 SP1 is used to convert the geodetic positions from the OPUS reports. After multiple days of data have been collected at each monument, accuracy and error ellipses are calculated. This information leads to a rating of the monument based on FGDC-STD-007.2-1998 Part 2 at the 95 percent confidence level (see monument accuracy table).

**WSI collected 317 hard surface GCP points and established three new monuments**

All Ground Check Point (GCP) measurements are made during periods with a Position Dilution of Precision (PDOP) of less than 3.0 and in view of at least six satellites by the stationary reference and roving receiver. For collecting GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK).GCP positions are collected on 20 percent of the flight lines and on bare earth locations such as paved, gravel or stable dirt roads, and other locations where the ground is clearly visible (and is likely to remain visible) from the sky during the data acquisition and RTK measurement period(s). In order to facilitate comparisons with LiDAR survey points, RTK measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. RTK points are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations.


Ground professional collecting RTK

Multiple differential GPS units are used in the ground based real-time kinematic portion of the survey. To collect accurate ground surveyed points, a GPS base unit is set up over monuments to broadcast a kinematic correction to a roving GPS unit. The ground crew uses a roving unit to receive radio-relayed kinematic corrected positions from the base unit. This RTK survey allows precise location measurement (≤1.5 centimeters).

# LiDAR Accuracy

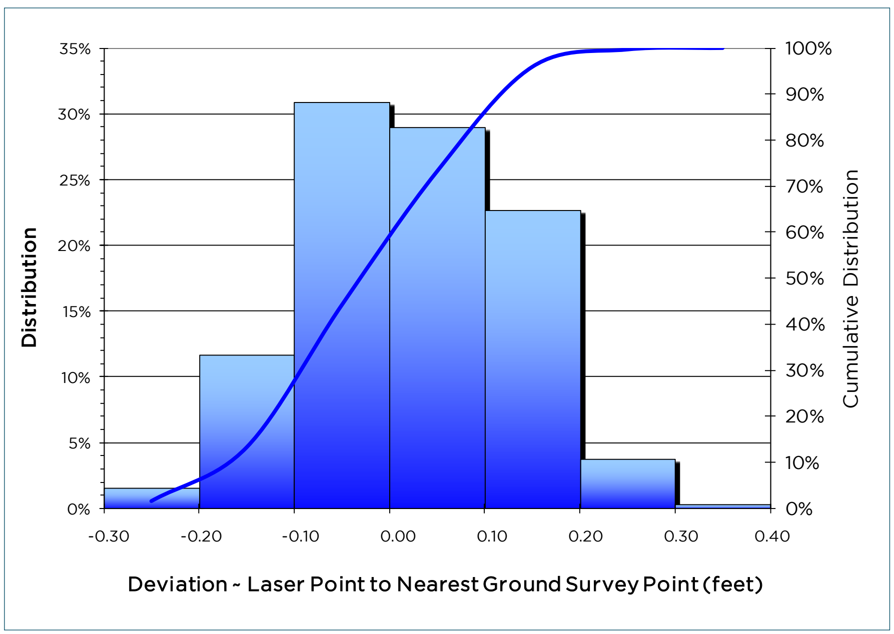
## Vertical Accuracy

Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known ground check points to the closest laser point. Vertical accuracy statistical analysis uses ground control points in open areas where the LiDAR system has a "very high probability" that the sensor will measure the ground surface and is evaluated at the 95th percentile. For the OLC Alaska FEMA Sitka study area 317 GCP points were collected. Statistics are calculated on the cumlative sum of all points collected for all deliveries.

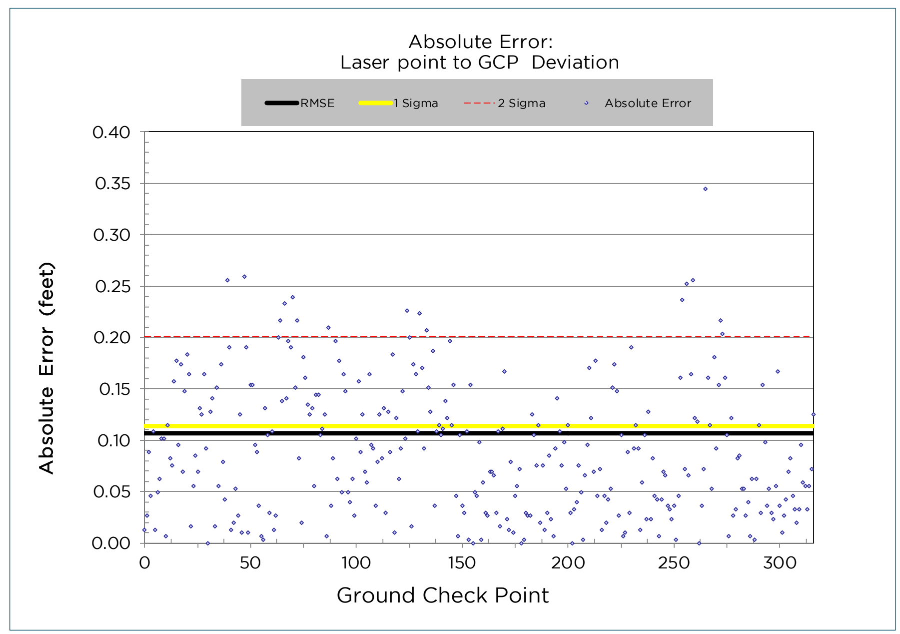
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

| Vertical Accuracy Results | |
|---|---|
| Sample Size (n) | 317 Ground check points |
| Root Mean Square Error | 0.11 ft. (0.03 m) |
| 1 Standard Deviation | 0.11 ft. (0.03 m) |
| 2 Standard Deviation | 0.20 ft. (0.06 m) |
| Average Deviation | 0.02 ft. (0.01 m) |
| Minimum Deviation | -0.26 ft. (-0.08 m) |
| Maximum Deviation | 0.34 ft. (0.11 m) |

Vertical Accuracy Distribution




GCP Absolute Error



## Land Class Cover Checkpoints

In addition to the hard-surface GCP data collection, checkpoints were also collected across the delivery area on four different land class cover types to provide Supplemental Vertical Accuracy (SVA) statistics in accordance with National Standard for Spatial Data Accuracy (NSSDA) guidelines and used the U.S. Geological Survey's Land Cover Institute's land cover class definitions as a guideline (USGS LCI).

The dominant land cover classes within the delivery area are listed to the right. The descriptions provide further detail regarding the actual vegetation. In order to further refine the USGS class standard for Grassland/Herbaceous, "above the knee" and "below the knee" were used as the defining line between tall grass and short grass.

A total of 34 individual land class checkpoints in five different land cover classes were collected.

| RMSE Landclass | |
|---|---|
| Shrub (1) | 0.00 ft. |
| Short Grass (13) | 0.49 ft. (0.15 m) |
| Tall Grass (11) | 0.51 ft. (0.12 m) |
| Forest (5) | 0.46 ft. (0.17 m) |
| Developed (4) | 0.10 ft. (0.04 m) |

| Land Cover Classification | |
|---|---|
| Shrub (1) | Areas characterized by natural or semi-natural woody vegetation with aerial stems, generally less than six meters tall, with individuals or clumps not touching to interlocking. Both evergreen and deciduous species of true shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions are included. |
| Grasslands/Herbaceous Short Grass (13) | Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing. Distinguished as below the knee in length. |
| Grasslands/Herbaceous Tall Grass (11) | Areas dominated by upland grasses and forbs. In rare cases, herbaceous cover is less than 25 percent, but exceeds the combined cover of the woody species present. These areas are not subject to intensive management, but they are often utilized for grazing. Distinguished as above the knee in length. |
| Forest (5) | Areas characterized by tree cover (natural or semi-natural woody vegetation, generally greater than 6 meters tall); tree canopy accounts for 25-100 percent of the cover. |
| Developed (4) | Areas characterized by a high percentage (30 percent or greater) of constructed materials (e.g., asphalt, concrete, buildings, etc.). |

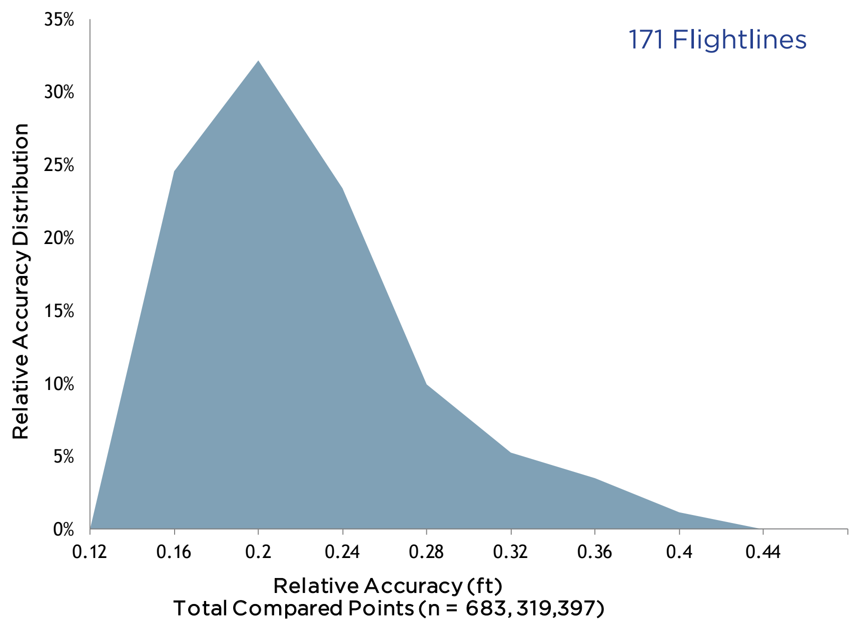
## Relative Accuracy

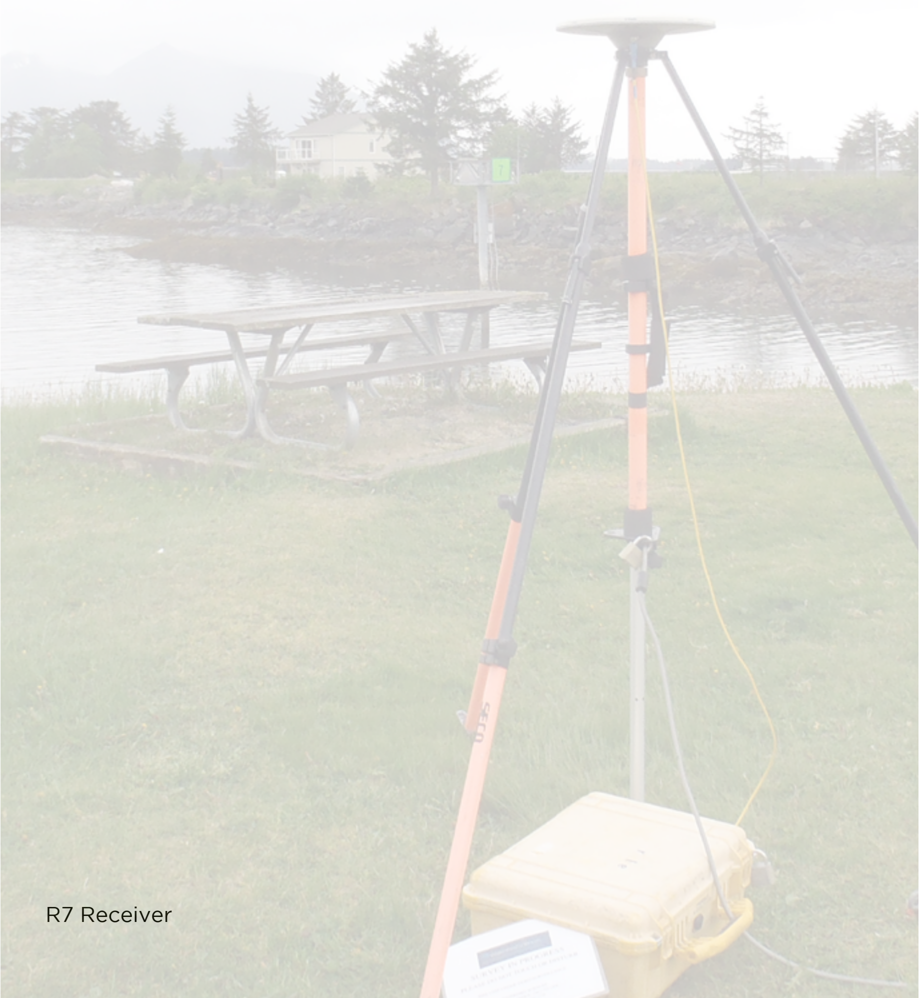
Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence is low (<10 centimeters). Internal consistency is affected by system attitude offsets (pitch, roll, and heading), mirror flex (scale), and GPS/IMU drift.

Relative accuracy statistics are based on the comparison of 171 flightlines and over 683 million points. Relative accuracy is reported for the whole study area.

| Relative Accuracy Calibration Results N = 171 flightlines | |
|---|---|
| Project Average | 0.20 ft. (0.06 m) |
| Median Relative Accuracy | 0.20 ft. (0.06 m) |
| 1σ Relative Accuracy | 0.22 ft. (0.07 m) |
| 2σ Relative Accuracy | 0.31 ft. (0.09 m) |

Relative Accuracy Distribution



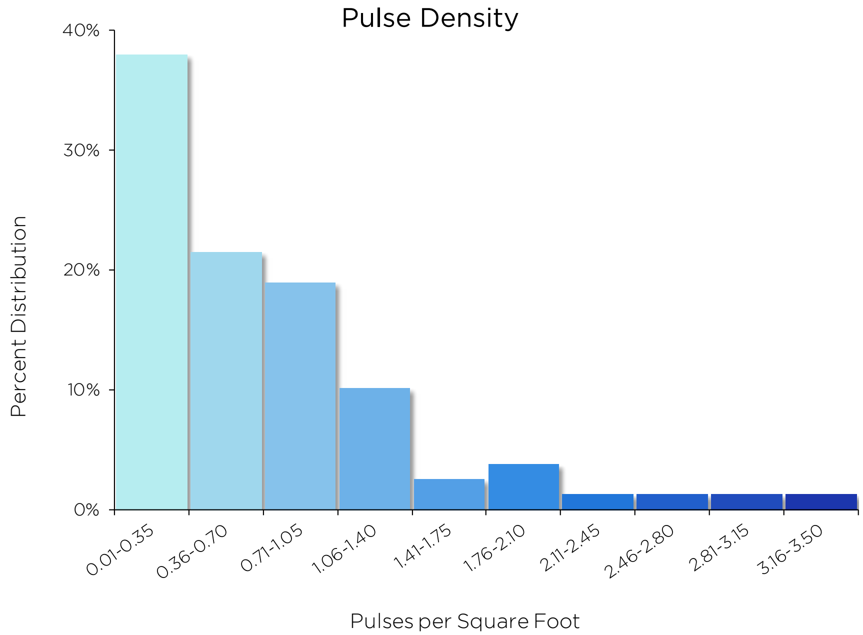
R7 Receiver

# Density

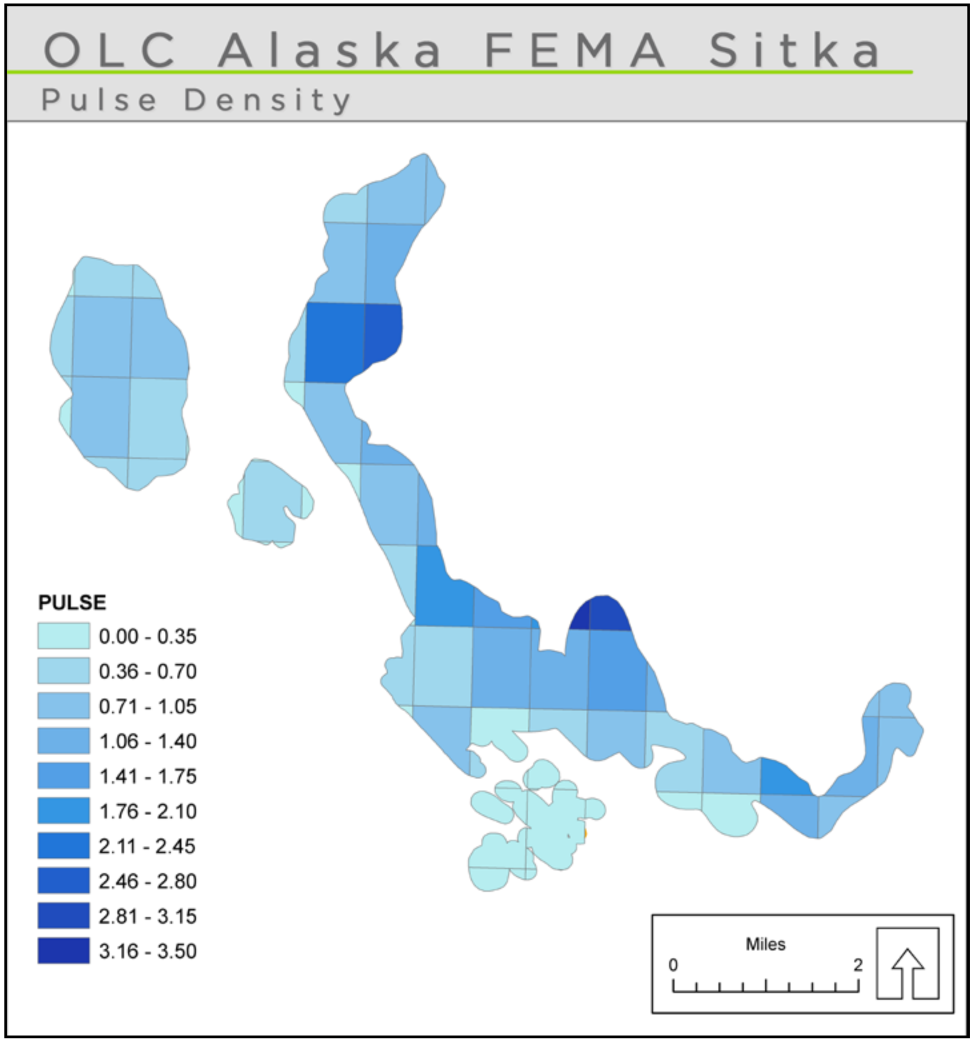
## Pulse Density

Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover, and water bodies. Density histograms and maps have been calculated based on first return laser pulse density and ground-classified laser point density. The native pulse density is the number of pulses emitted by the LiDAR system.

| Pulse Density | pulses per square meter | pulses per square foot |
|---|---|---|
| | 9.98 | 0.93 |



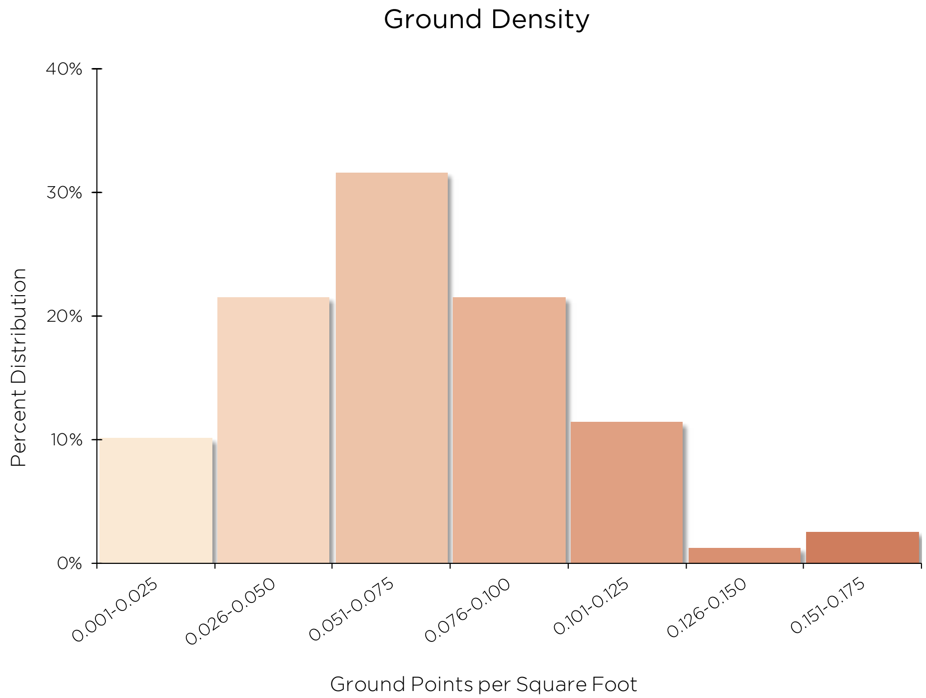

Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart).



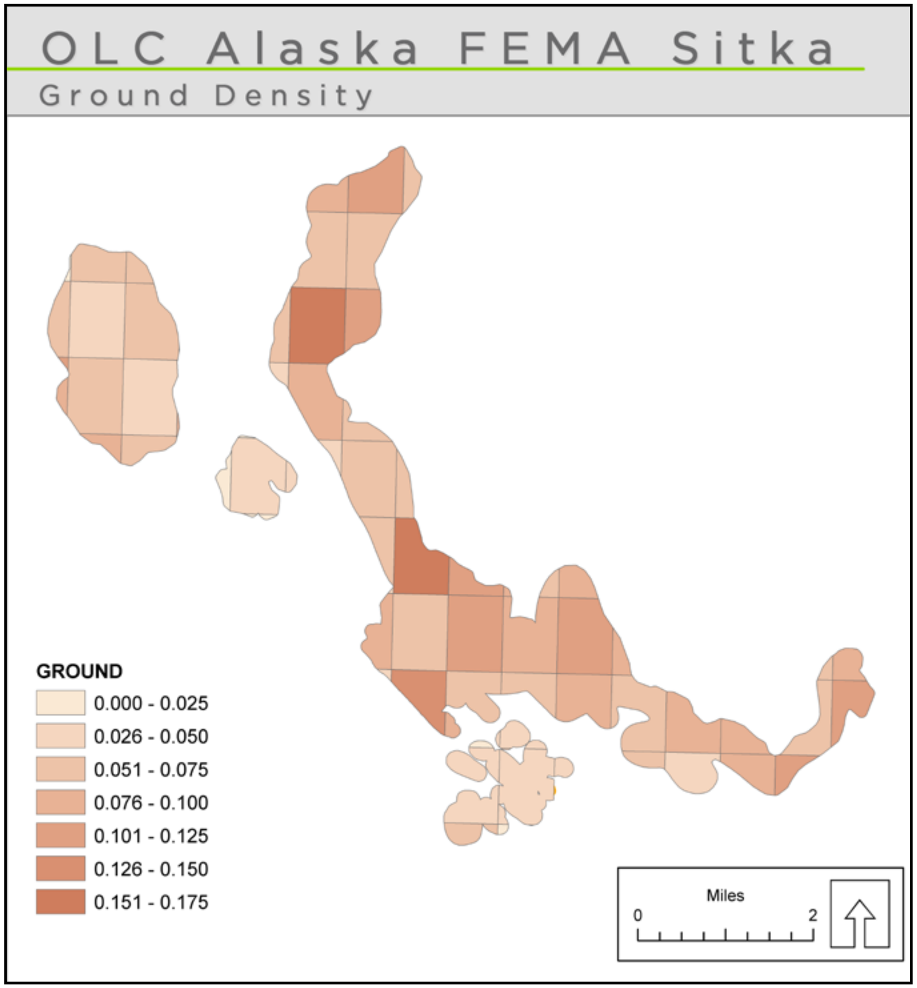
## Ground Density

Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries.

| Ground Density | points per square meter | points per square foot |
|---|---|---|
| | 0.82 | 0.08 |




Average Ground Density per 0.75' USGS Quad (color scheme aligns with density chart).



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# Appendix

**McCLINTOCK LAND ASSOCIATES INC.**
16942 N. Eagle River Loop Road
Eagle River, Alaska 99577

Chris Brown, PLS
Quantum Spatial, Inc.
421 SW 6th Ave, Suite 800
Portland, Oregon 97204

July 16, 2014

Re: Sitka LiDAR Control Points

Chris,

One of our lead surveyors Douglas Popham, PLS took your data and processed it independently. The below table displays the differences in our results. 'From' points are the result of MLA's processing, 'To' points are taken from Quantum's spreadsheet.

| From | To | Forward Azimuth | Ground Distance (m) | Delta Elev (m) |
|---|---|---|---|---|
| AKFEMA01 | Q-01 | 131°19'39.3960" | 0.008 | 0.013 |
| AKFEMA02 | Q-02 | 8°28'55.1474" | 0.016 | 0.046 |
| 945_1600_N | Q-1600 | 304°42'53.5009" | 0.002 | 0.001 (-) |

It appears that your surveyor conducted this survey by simply occupying your control points during flight operations and then submitted the data to OPUS to derive position on the points. Multiple days of observations were conducted with the results meaned to produce a final position. Flyers were rejected but the position is a result of meaned OPUS results. This is an accepted and adequate method.

As an independent check Doug took the next step of processing your data into a local network and comparing those results with your OPUS means. The network was constrained to the OPUS mean for AKFEMA03. This should provide a more precise set of positions.

This independent method confirms your results with the only possible issue being the delta elevation on point AKEMA02. If 5 centimeters is within your error budget then we can agree with your positions. Basically we can certify that we agree with your positions within 0.016 meters horizontally and 0.046 meters vertically.

Respectfully Submitted,

William McClintock, PLS

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Thank You