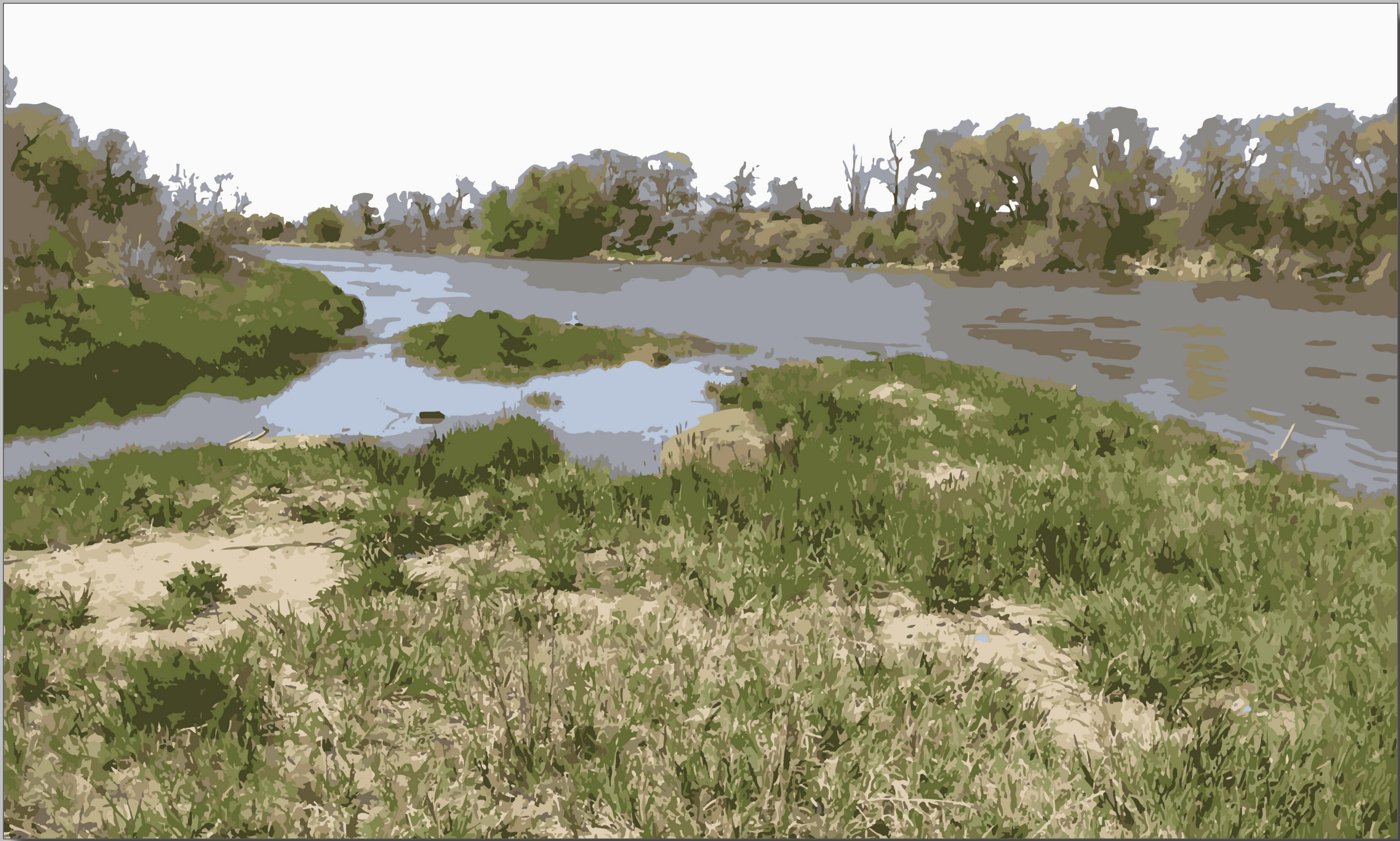
OLC Snake River FEMA



Data collected for:

Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:

Quantum Spatial

421 SW 6th Avenue
Suite 800
Portland, Oregon 97204
phone: (503) 505-5100
fax: (503) 546-6801

Contents

2 - Project Overview

3 - Aerial Acquisition

3 - LiDAR Survey

4 - Ground Survey

4 - Monumentation

5 - Ground Survey Points (GSPs)

5 - Land Cover Class

6 - Accuracy

6 - Relative Accuracy

7 - Vertical Accuracy

8 - Supplemental and Consolidated Vertical Accuracies

9 - Pulse Density

9 - Density

10 - Ground Density

12 - Appendix

12 - PLS Certification

LiDAR Acquisition Dates	4/22/2015 - 6/2/2015
Area of Interest	482,299 acres
Buffered Area of Interest	496,813 acres
Projection	Universal Transverse Mercator (UTM) 12
Horizontal Datum	NAD83 (2011)
Vertical Datum	NAVD88 (Geiod 12A) Epoch 2010.00
Units	meters

Project Overview

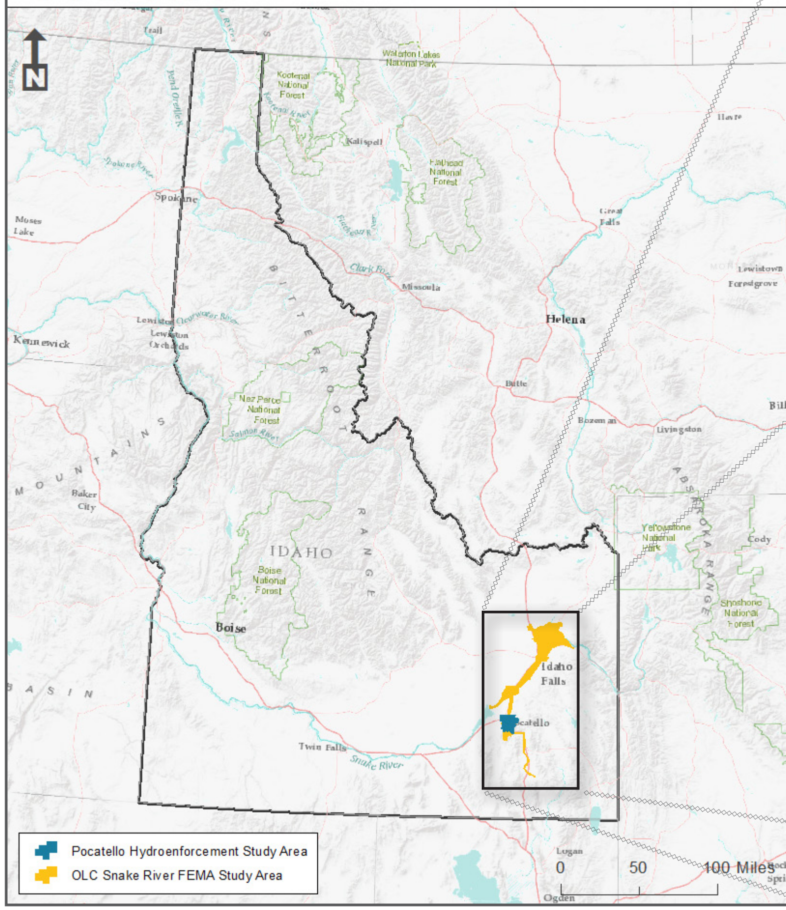
Quantum Spatial has collected Light Detection and Ranging (LiDAR) data for the Oregon LiDAR Consortium (OLC) Snake River FEMA study area. This study area is located in southeastern Idaho.

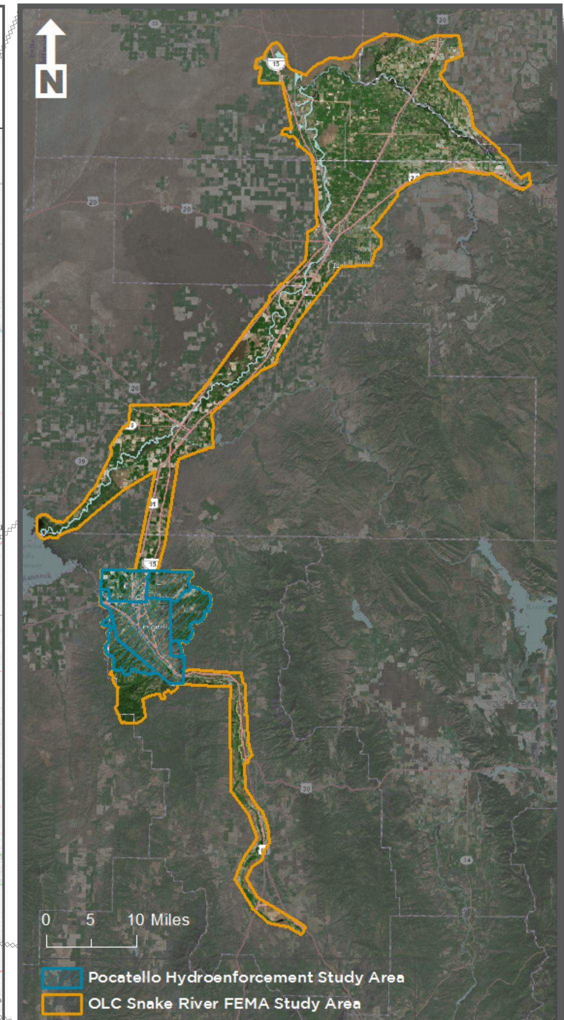
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

In April 2015 QSI employed remote-sensing lasers in order to obtain a total area flown of 496,813 acres. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products created include RGB extracted (from NAIP imagery) LiDAR point cloud data, one-meter digital elevation models of highest hit, bare earth (entire project area) and hydro-enforced bare earth (Pocatello study area only) ground models, 0.5-meter intensity rasters, one-meter ground density rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in UTM Zone 12.

OLC Snake River FEMA Overview





Aerial Acquisition

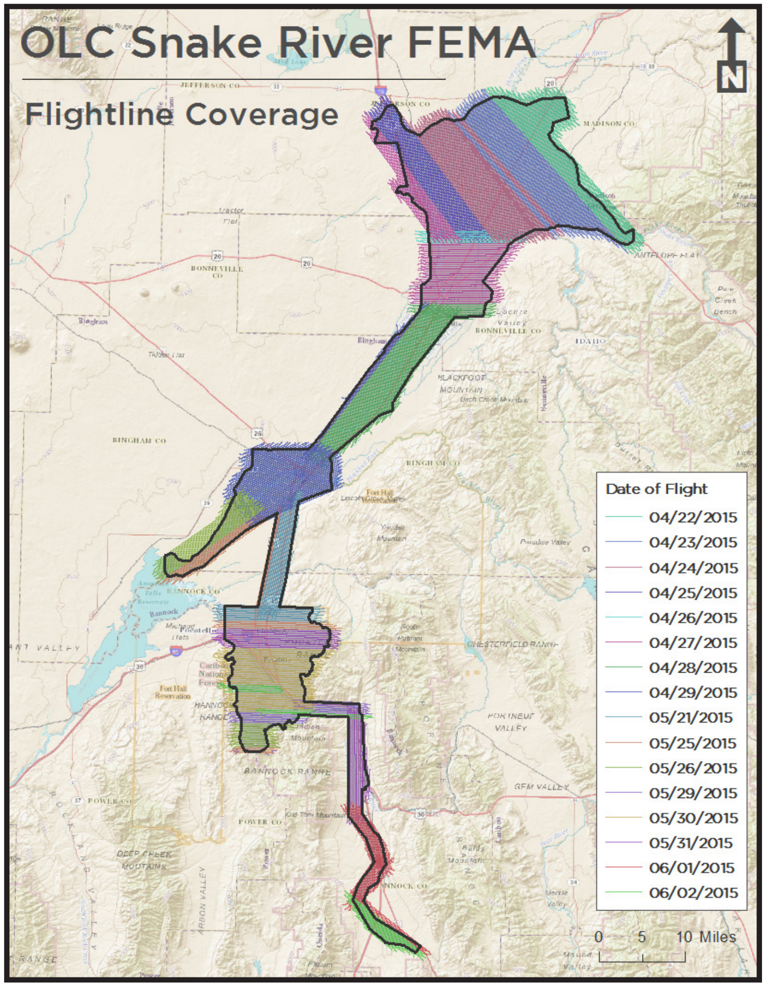
LiDAR Survey

The LiDAR survey occurred between April 22, 2015 and June 2, 1015 utilizing a Leica ALS70 mounted in a Cessna Grand Caravan. The systems were programmed to emit single pulses at around 198 kHz and flown at 1,400 m AGL, capturing a scan angle of 15 degrees from nadir. These settings were developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

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

OLC Snake River FEMA LiDAR Acquisition Specs	
Sensor	Leica ALS70
Aircraft	Cessna Grand Caravan
Acquisition Date Range	4/22/2015 - 6/2/2015
Coverage	100% Overlap with 60% Sidelap
Field of View (FOV)	30 degrees
Targeted Pulse Density	≥8 PPSM
Pulse Rate	198 kHz
Speed	110 kts
Target AGL	1,400 m
Laser Power	71%



Ground Survey

Ground control surveys, including monumentation, aerial targets, and ground survey points (GSPs) were conducted to support the airborne acquisition. Ground control data are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data products. See the table to the right for specifications of equipment used.

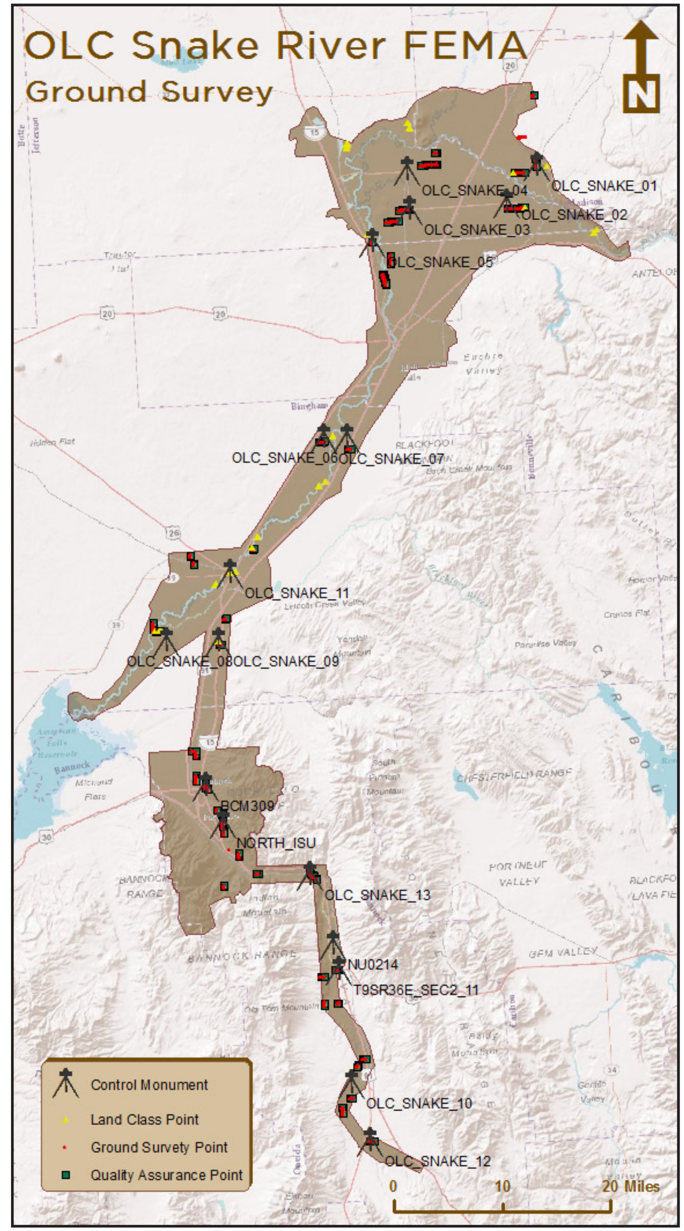
Monumentation

Ground control surveys, including monumentation and ground survey points (GSPs), were conducted to support the airborne acquisition. Ground control data were used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data.

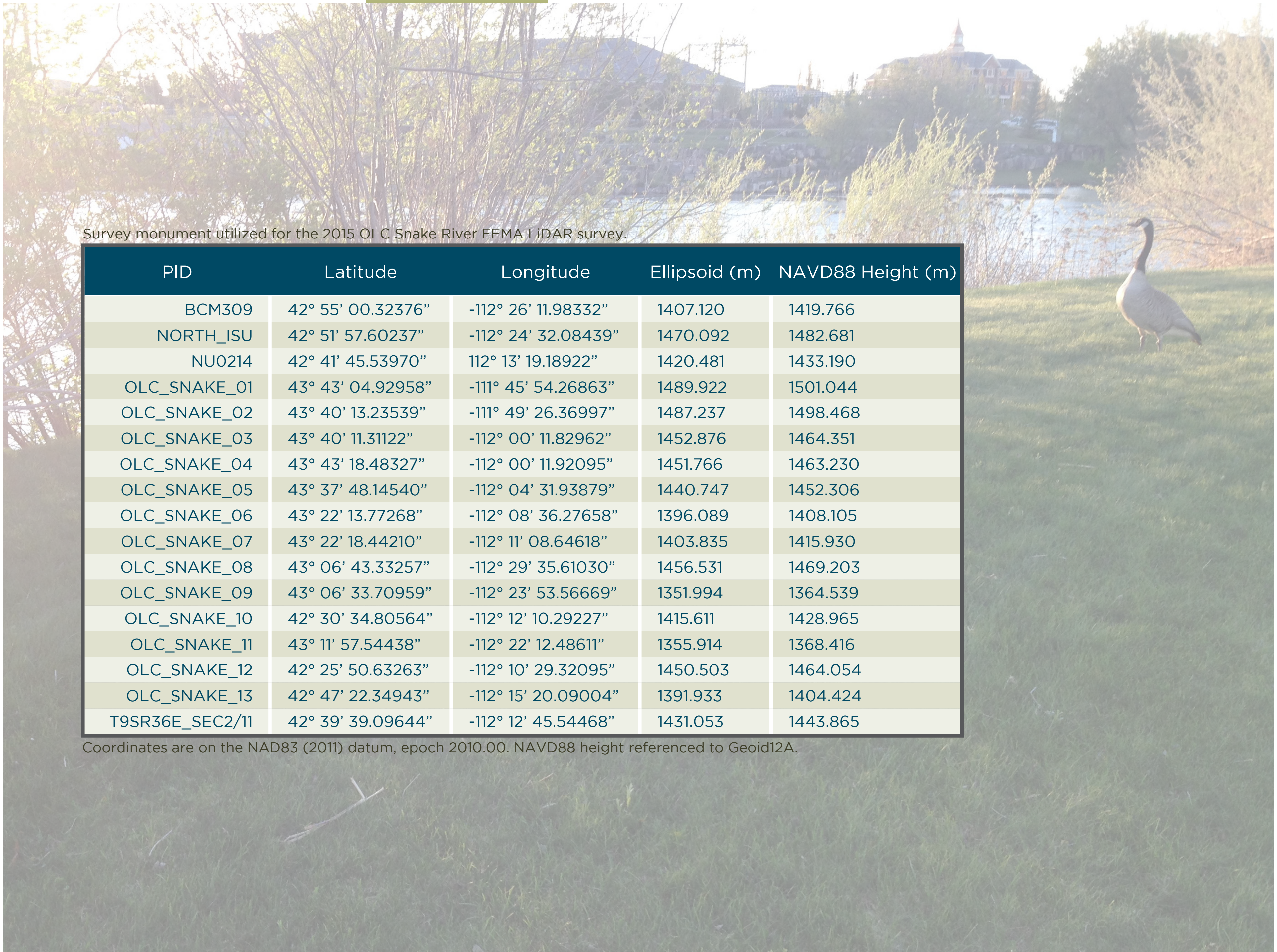
The spatial configuration of ground survey monuments provided redundant control within 13 nautical miles of the mission areas for LiDAR flights. Monuments were also used for collection of ground survey points using real time kinematic (RTK) and post processed kinematic (PPK) survey techninques. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. QSI utilized four existing monuments and established 13 new monuments for the OLC Snake River FEMA LiDAR project. New monumentation was set using 5/8” x 30” rebar topped with stamped 2-1/2” aluminum caps. QSI’s professional land surveyor, Christopher Glantz (ID PLS #16402) oversaw and certified the establishment of all monuments.

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each monument. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning. Multiple independent sessions over the same monument were processed to confirm antenna height measurements and to refine position accuracy. The table on the following page provides the list of monuments used.

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.02 m
St Dev z	0.05 m



Ground survey map of the OLC Snake River FEMA study area.



Survey monument utilized for the 2015 OLC Snake River FEMA LiDAR survey.

PID	Latitude	Longitude	Ellipsoid (m)	NAVD88 Height (m)
BCM309	42° 55’ 00.32376”	-112° 26’ 11.98332”	1407.120	1419.766
NORTH_ISU	42° 51’ 57.60237”	-112° 24’ 32.08439”	1470.092	1482.681
NU0214	42° 41’ 45.53970”	112° 13’ 19.18922”	1420.481	1433.190
OLC_SNAKE_01	43° 43’ 04.92958”	-111° 45’ 54.26863”	1489.922	1501.044
OLC_SNAKE_02	43° 40’ 13.23539”	-111° 49’ 26.36997”	1487.237	1498.468
OLC_SNAKE_03	43° 40’ 11.31122”	-112° 00’ 11.82962”	1452.876	1464.351
OLC_SNAKE_04	43° 43’ 18.48327”	-112° 00’ 11.92095”	1451.766	1463.230
OLC_SNAKE_05	43° 37’ 48.14540”	-112° 04’ 31.93879”	1440.747	1452.306
OLC_SNAKE_06	43° 22’ 13.77268”	-112° 08’ 36.27658”	1396.089	1408.105
OLC_SNAKE_07	43° 22’ 18.44210”	-112° 11’ 08.64618”	1403.835	1415.930
OLC_SNAKE_08	43° 06’ 43.33257”	-112° 29’ 35.61030”	1456.531	1469.203
OLC_SNAKE_09	43° 06’ 33.70959”	-112° 23’ 53.56669”	1351.994	1364.539
OLC_SNAKE_10	42° 30’ 34.80564”	-112° 12’ 10.29227”	1415.611	1428.965
OLC_SNAKE_11	43° 11’ 57.54438”	-112° 22’ 12.48611”	1355.914	1368.416
OLC_SNAKE_12	42° 25’ 50.63263”	-112° 10’ 29.32095”	1450.503	1464.054
OLC_SNAKE_13	42° 47’ 22.34943”	-112° 15’ 20.09004”	1391.933	1404.424
T9SR36E_SEC2/11	42° 39’ 39.09644”	-112° 12’ 45.54468”	1431.053	1443.865

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Ground Survey Points (GSPs)

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK) and post processed kinematic (PPK) survey techniques. For RTK surveys, a base receiver is positioned at a nearby monument to broadcast a kinematic correction to a roving receiver. All GSP measurements are made during periods with a Position Dilution of Precision (PDOP) no greater than 3.0 and in view of at least six satellites for both receivers. Relative errors for the position must be less than 1.5 centimeters horizontal and 2.0 centimeters vertical in order to be accepted. The PPK survey technique is similar to an RTK survey; a roving GPS unit is paired with a static GPS base station and deployed to collect true ground points, but a radio connection to the base need not be established. This potentially allows greater dispersion of ground data beyond the limit of radio communication, though no real-time correction is available. All geometry is identical to that of a real-time survey, but baselines are post-processes and point values are determined afterward using applicable software. Precision thresholds are equal to RTK thresholds and out-of-tolerance points are discarded.

In order to facilitate comparisons with high quality LiDAR data, GSP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GSPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GSPs were collected within as many flight lines as possible; however, the distribution depended on ground access constraints and may not be equitably distributed throughout the study area.

Land Cover Class

In addition to ground survey points, land cover class control points were collected throughout the study area. Individual accuracies were calculated for each land cover type to assess confidence in the LiDAR derived ground models across land cover classes. Land cover types and descriptions are shown in the table below.



Left to right: SHRUB, TALL GRASS, and FOREST land cover within the OLC Snake River FEMA study area.

Field surveyor collecting land class RTK points.

Land cover descriptions of check points taken for the OLC Snake River FEMA study area.

Land Cover Type	Land Cover Code	Description
Forest	FOREST	Areas dominated by forest
Shrub	SHRUB	Areas dominated by shrubs
Tall Grass	TALL GRASS	Areas dominated by tall grass

Ground survey instrumentation

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover

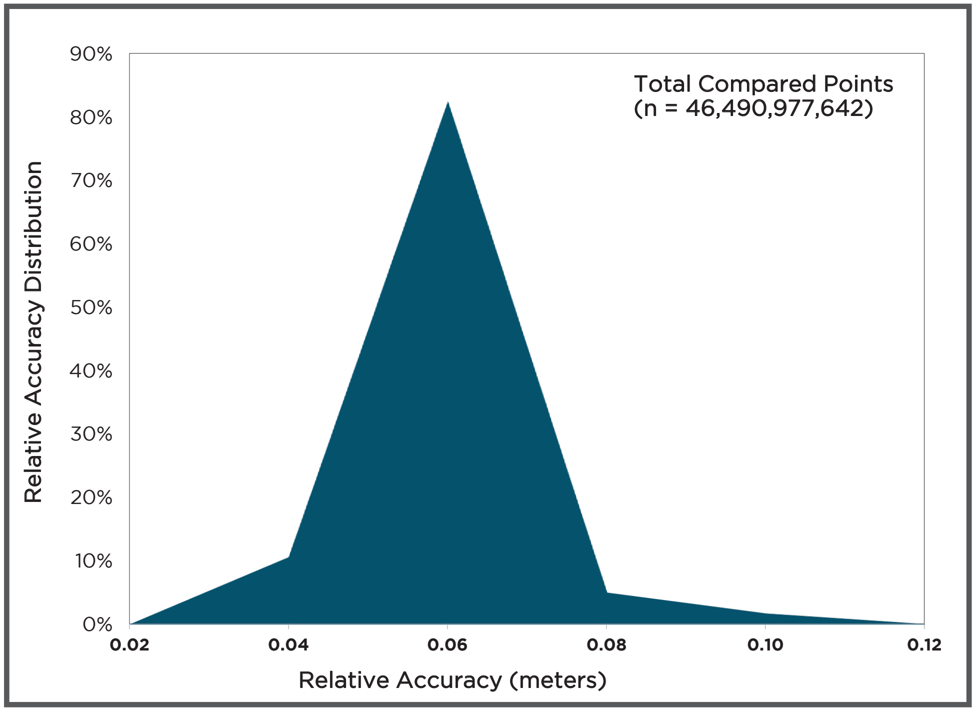
Accuracy

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 1,032 flightlines and over 46 billion LiDAR points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Flightlines	n = 1,032
LiDAR Points	n = 46,490,977,642
Project Average	0.051 m 0.168 ft.
Median Relative Accuracy	0.053 m 0.174 ft.
1σ Relative Accuracy	0.053 m 0.174 ft.
2σ Relative Accuracy	0.065 m 0.213 ft.



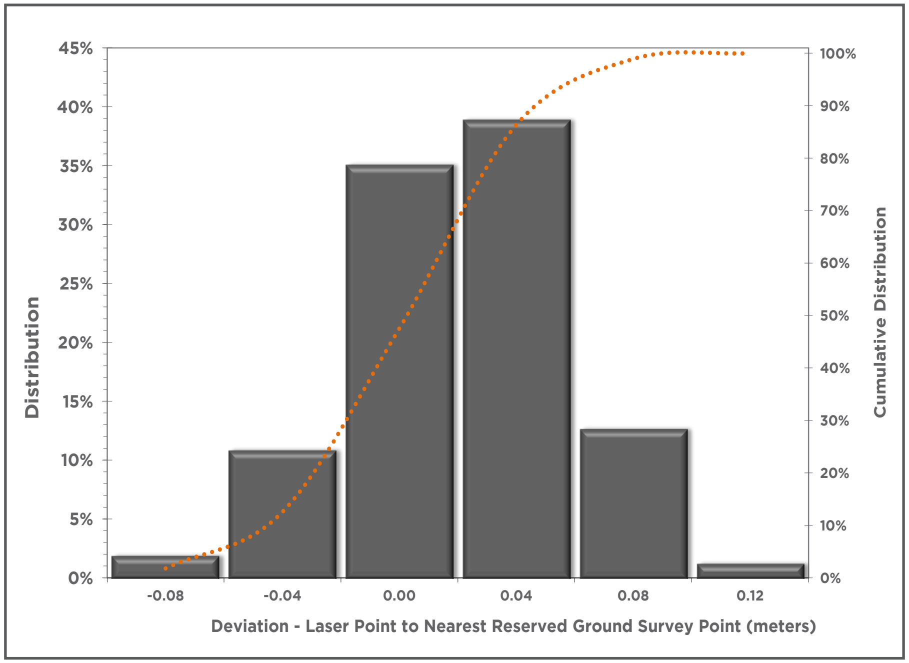
Vertical Accuracy

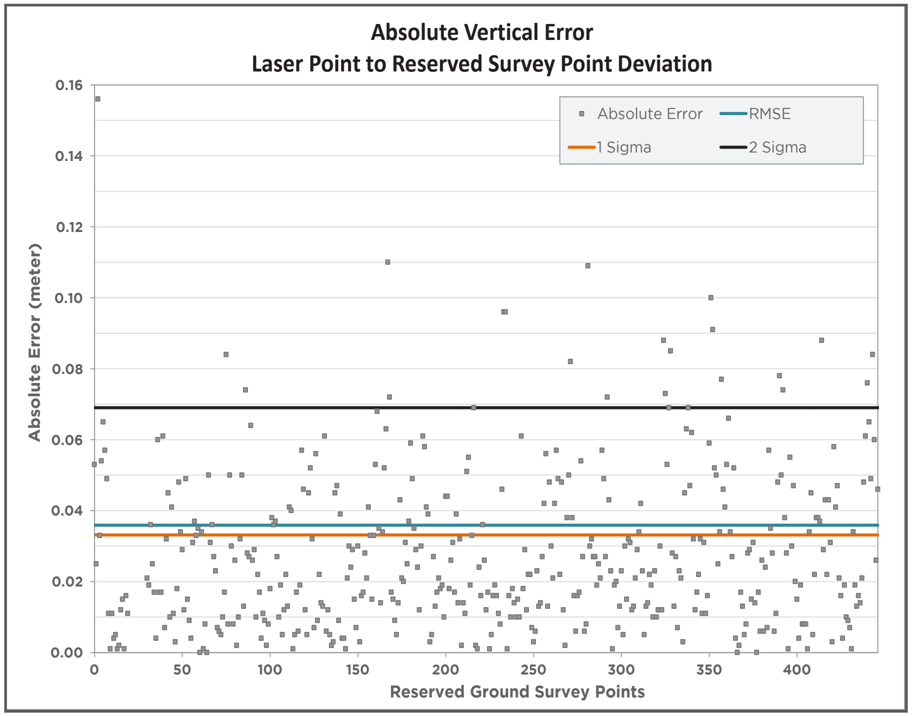
Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known ground survey points (GSPs) to the closest laser point. Vertical accuracy statistical analysis uses ground survey 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 Snake River FEMA study area, a total of 5,460 GSPs were collected. An additional 446 reserved ground survey points were collected for independent verification, resulting in a fundamental vertical accuracy (FVA) of 0.070 meters.

Vertical Accuracy Results	Hard Surface
Sample Size (n)	n = 446 GSPs
FVA (RMSE*1.96)	0.070 m (0.231 ft.)
Root Mean Square Error	0.036 m (0.118 ft.)
1 Standard Deviation	0.033 m (0.109 ft.)
2 Standard Deviations	0.069 m (0.226 ft.)
Average Deviation	0.028 m (0.093 ft.)
Minimum Deviation	-0.156 m (-0.512 ft.)
Maximum Deviation	0.100 m (0.328 ft.)

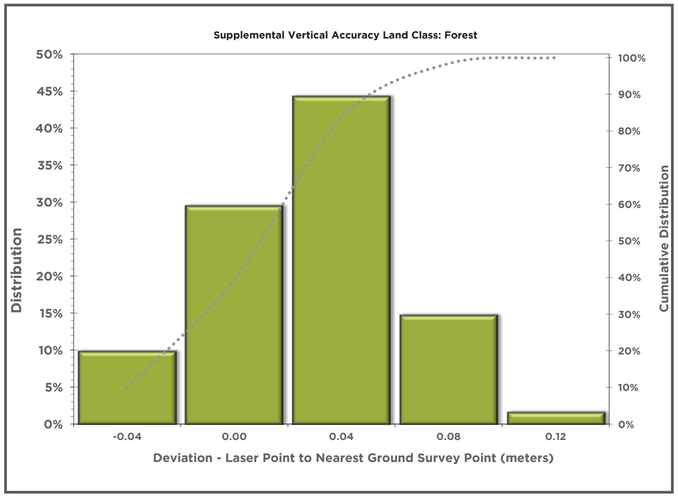
Vertical Accuracy Distribution

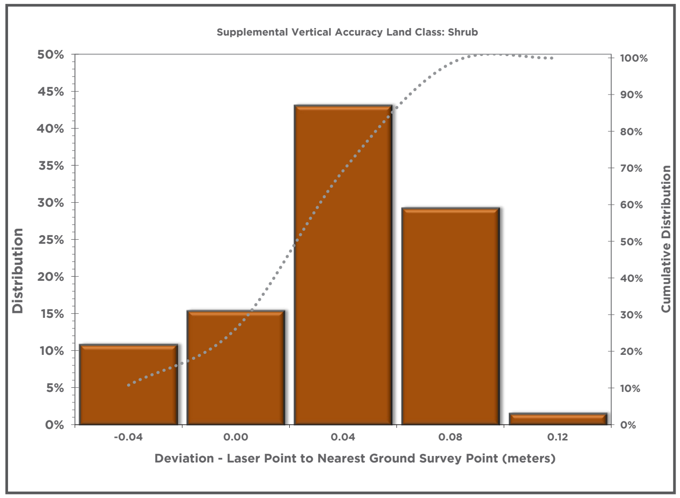


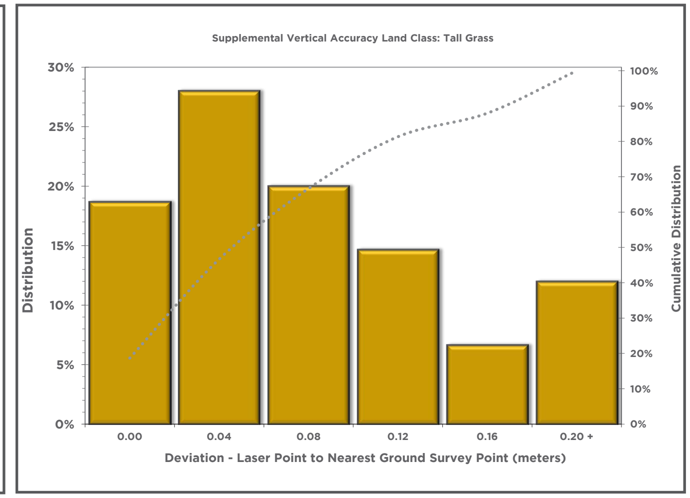


Supplemental and Consolidated Vertical Accuracies

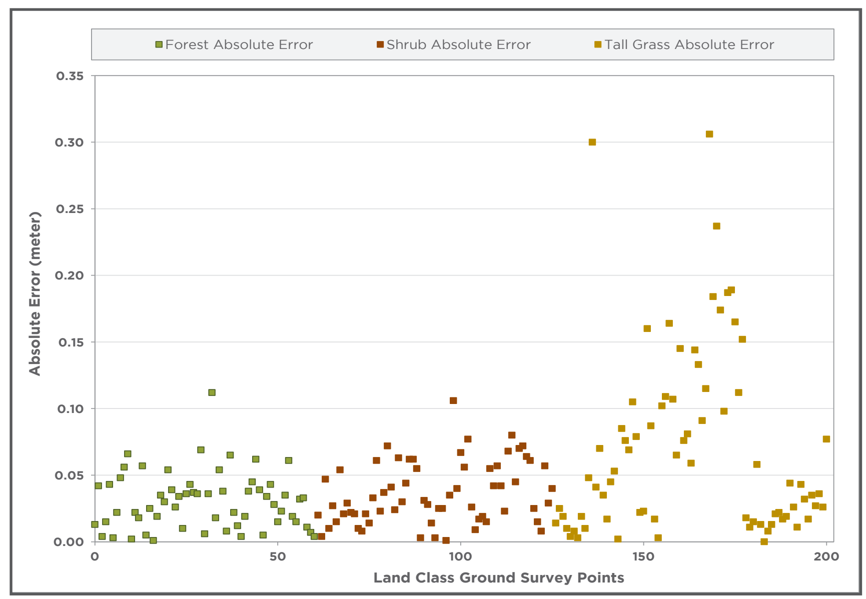
QSI also assessed absolute vertical accuracy for the OLC Snake River FEMA study area, using Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) reporting. SVA compares known ground survey point data within individual land cover class categories to the triangulated ground surface generated by the LiDAR points. CVA, rather, compares known ground survey points within all land cover classes to the triangulated ground surface generated by LiDAR points. SVA and CVA are measures of the accuracy of LiDAR point data in various land cover classes where the LiDAR system has a high probability of measuring the ground surface and is evaluated at the 95th percentile, as shown in the table below.







Vertical Accuracy Results	SVA			CVA
	Forest	Shrub	Tall Grass	All Land Cover Classes
Sample Size	n = 61	n = 65	n = 75	n = 201
1 Standard Deviation	0.037 m 0.122 ft.	0.045 m 0.147 ft.	0.080 m 0.263 ft.	0.048 m 0.157 ft.
2 Standard Deviations	0.065 m 0.213 ft.	0.072 m 0.236 ft.	0.188 m 0.615 ft.	0.152 m 0.499 ft.
Average Deviation	0.030 m 0.100 ft.	0.037 m 0.120 ft.	0.070 m 0.229 ft.	0.047 m 0.155 ft.
Minimum Deviation	-0.061 m -0.200 ft.	-0.062 m -0.203 ft.	-0.026 m -0.085 ft.	-0.062 m -0.203 ft.
Maximum Deviation	0.112 m 0.367 ft.	0.106 m 0.348 ft.	0.306 m 1.004 ft.	0.306 m 1.004 ft.



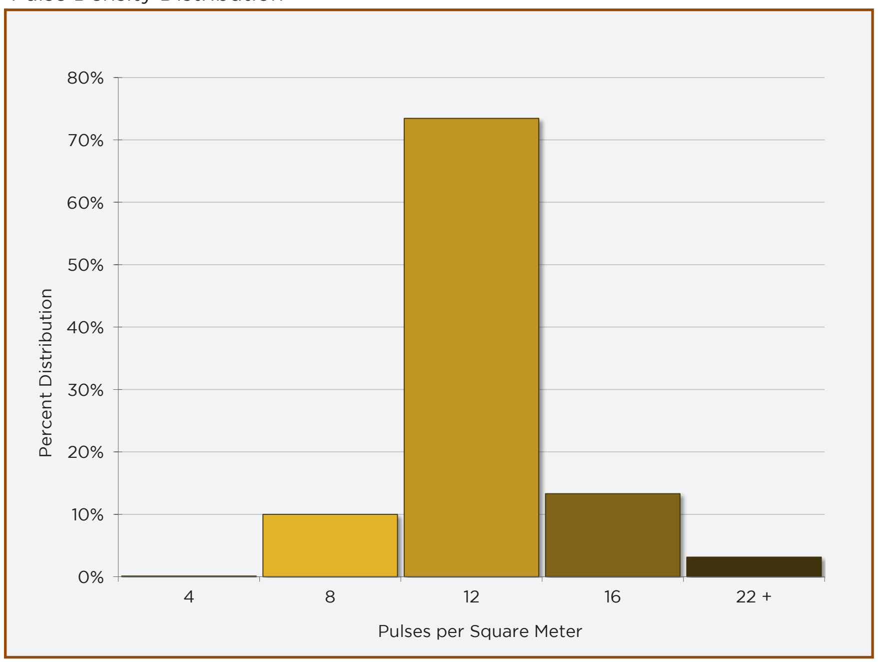
Density

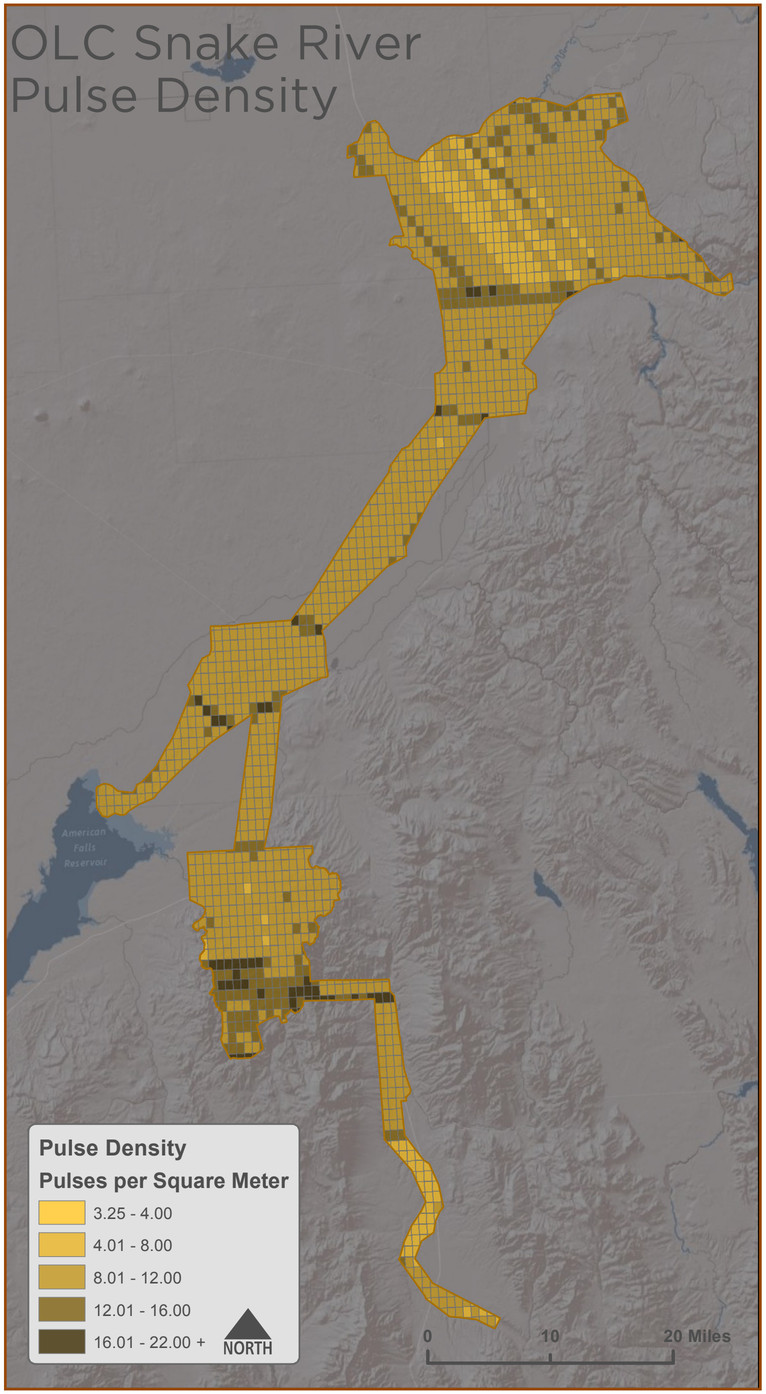
Pulse Density

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.

Average Point Densities			
Pulses per square meter	Pulses per square foot	Ground points per square meter	Ground points per square foot
10.49	0.97	2.27	0.21

Pulse Density Distribution



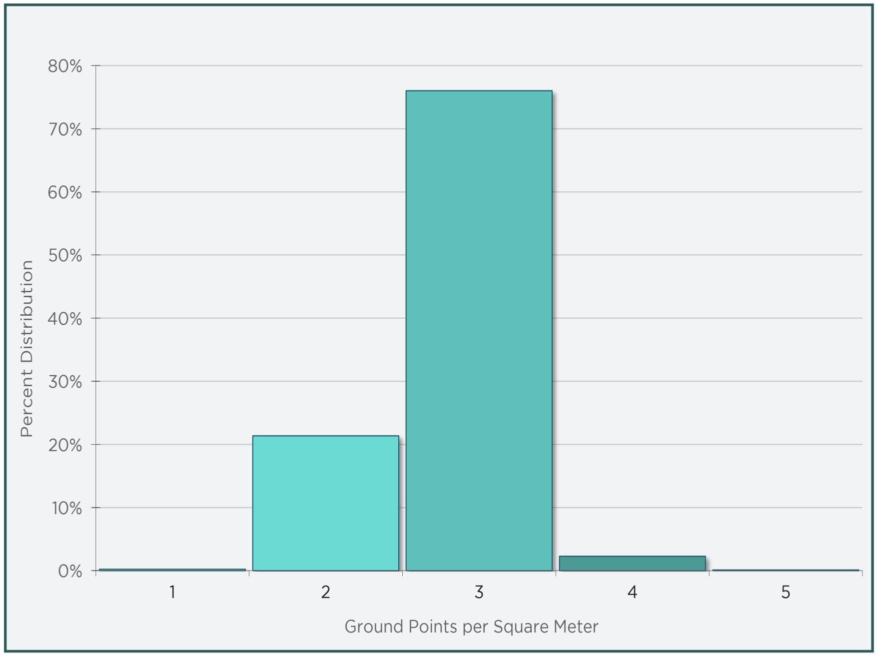


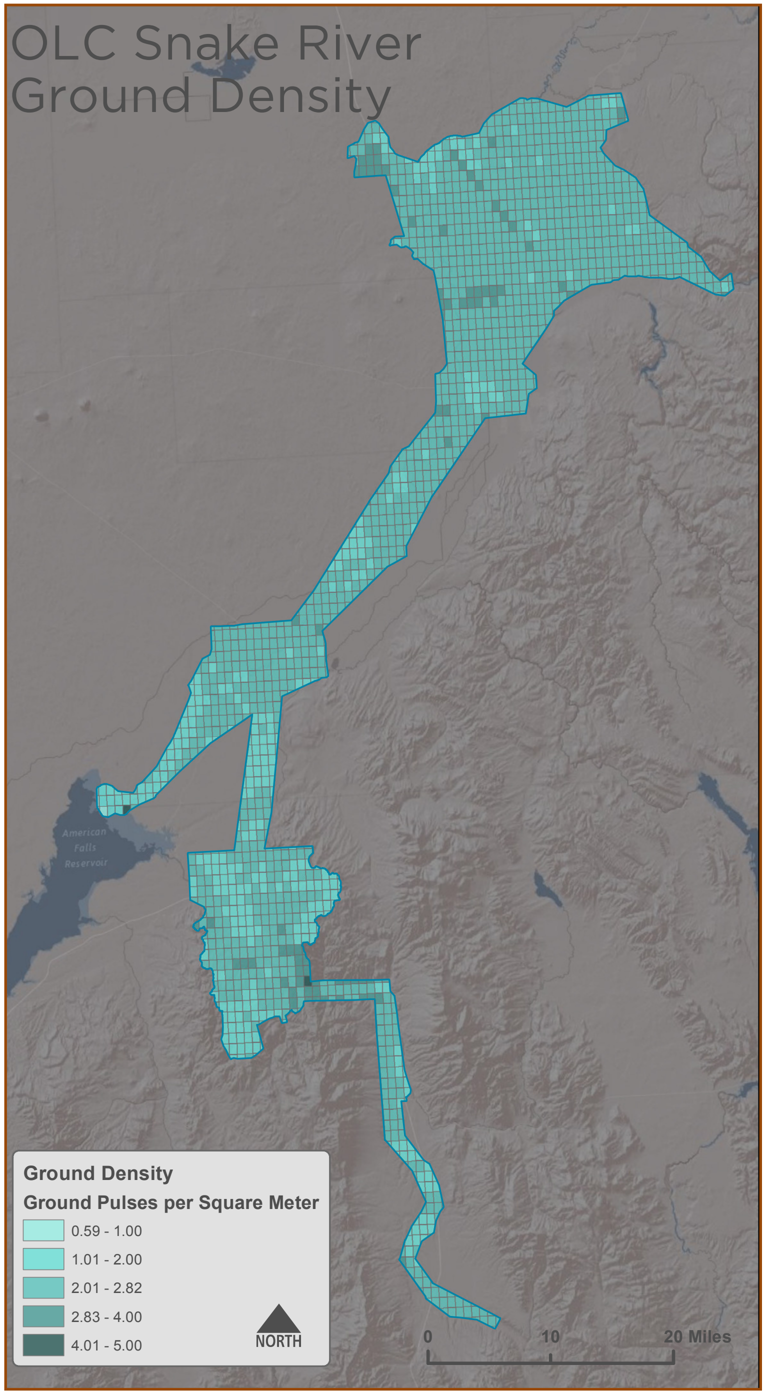
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart).

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 Distribution





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

Appendix
PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for OLC Snake River FEMA LiDAR project as described in this report.

I, John English, have reviewed the attached report for completeness and herby state that it is a complete and accurate report of this project.

02/19/2016

John English
Project Manager
WSI, a Quantum Spatial Company

I, Christopher Glantz, being duly registered as a Professional Land Surveyor in the state of Idaho, say that I hereby certify the methodologies and results of the attached LiDAR project, and that Static GNSS occupations on the Base Stations during airborne flights and RTK survey on hard-surface and GSP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between April 22, 2015 and June 2, 2015. Accuracy statistics shown in the Accuracy Section of this Report have been review by me and found to meet the "National Standard for Spatial Data Accuracy".

02/19/2016

Christopher Glantz, PLS
Land Survey Manager
WSI, a Quantum Spatial Company