OLC Okanogan FEMA

Data collected for:

Department of Geology and Mineral Industries

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Prepared by:

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Project Overview

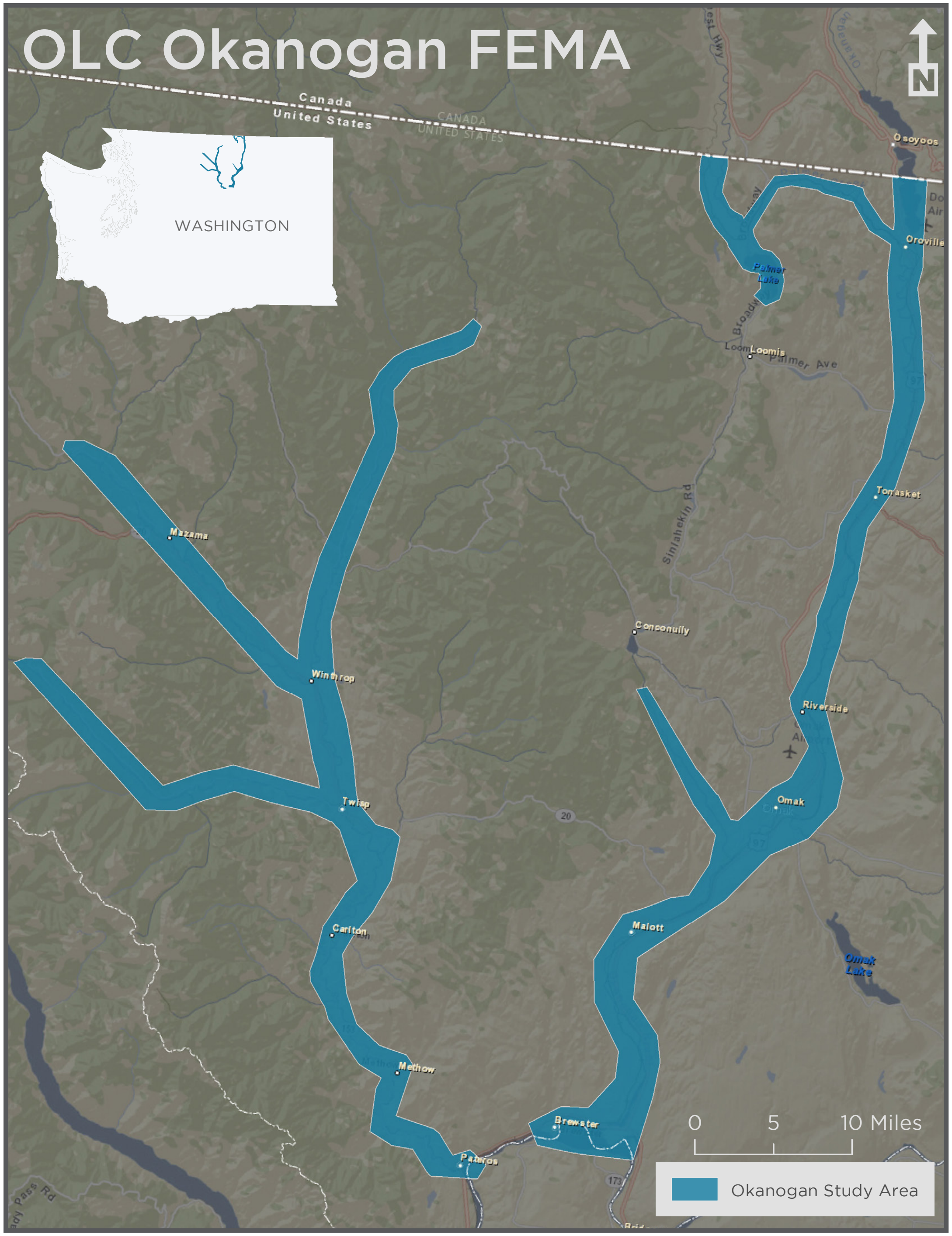
Quantum Spatial has collected Light Detection and Ranging (LiDAR) data for the Oregon LiDAR Consortium (OLC) Okanogan FEMA study area. This study area is located in northern Washington.

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 June, 2015 QSI employed remote-sensing lasers in order to obtain a total area flown of 263,839 acres. Sensor parameters 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 and bare earth ground models, 0.5-meter intensity rasters, one-meter density rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in UTM 11.

OLC Okanogan FEMA	
LiDAR Acquisition Dates	6/19/2015 - 7/10/2015
Area of Interest	246,400 acres
Data Extent	263,839 acres
Projection	Universal Transverse Mercator (UTM 11)
Horizontal Datum	NAD83(2011)
Vertical Datum	NAVD88 (Geoid 12A) Epoch 2010.00
Units	meters
Delivery Date	2/16/2016



Aerial Acquisition

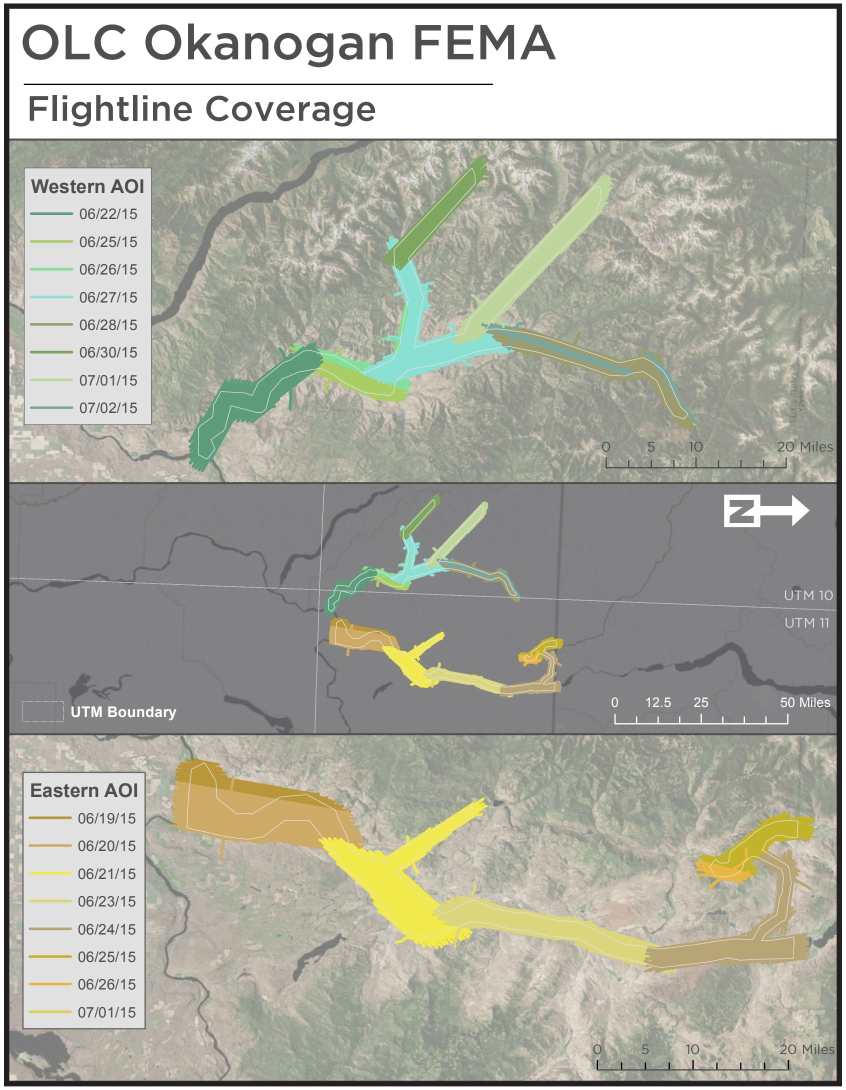
LiDAR Survey

The LiDAR survey occurred between June 19, 2015 and July 10, 2015, utilizing a Leica ALS70 mounted in a Cessna Grand Caravan and a Cessna Mini 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).

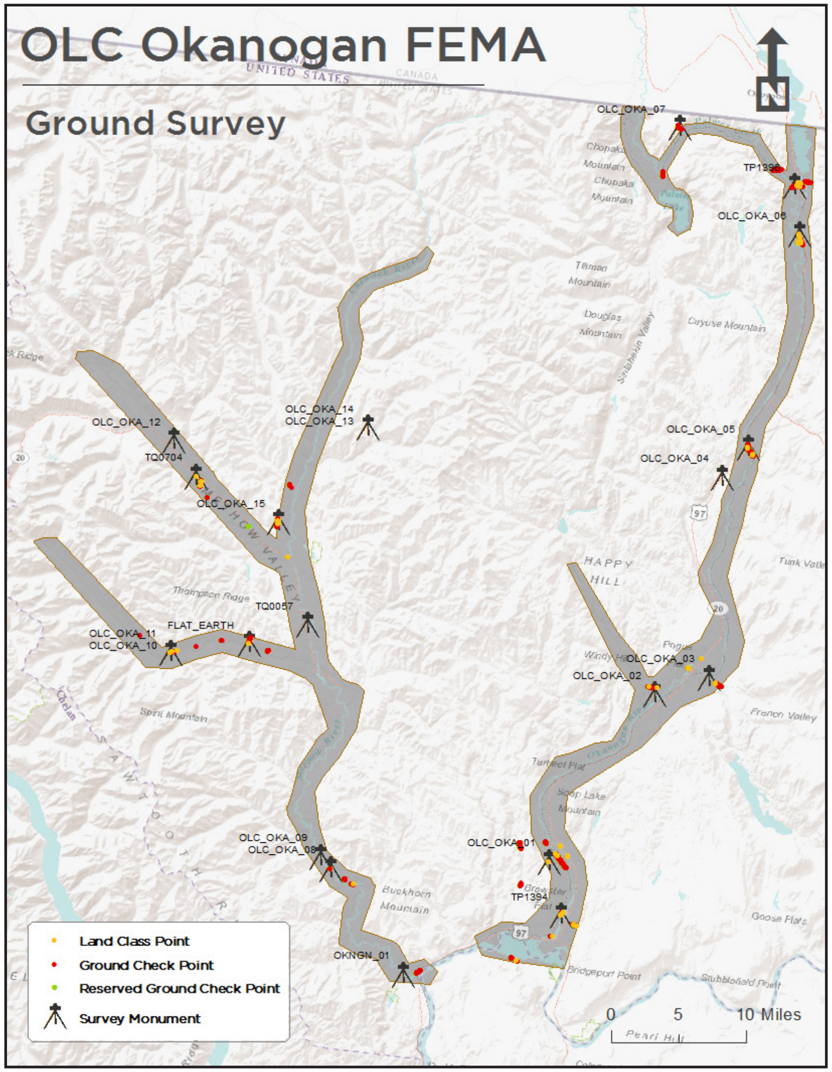
The LiDAR sensor operators constantly monitored the data collection settings during acquisition of the data, including pulse rate, power setting, scan rate, gain, field of view, and pulse mode. For each flight, the crew performed airborne calibration maneuvers designed to improve the calibration results 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 Okanogan FEMA LiDAR Acquisition Specs	
Sensor	Leica ALS70
Aircraft	Cessna Grand Caravan & Cessna Mini Caravan
Acquisition Date Range	6/19/2015 - 7/10/2015
Coverage	100% Overlap with 60% Sidelap
Field of View (FOV)	30 degrees
Targeted Pulse Density	≥8 PPSM
Pulse Rate	198 kHz
Speed	110 kts



Project Flightlines

Ground Survey



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

Ground control surveys, including monumentation, 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 21 monuments for the OLC Okanogan 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 (WA PLS #48755) 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.

Ground survey map of the 2015 OLC Okanogan FEMA study area.

	PID	Lattitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
UTM 10	FLAT_EARTH	48° 22’ 51.17352”	-120° 13’ 51.88530”	592.904	610.643
	OLC_OKA_10	48° 21’ 40.43399”	-120° 21’ 16.25816”	791.952	809.469
	OLC_OKA_11	48° 21’ 40.36492”	-120° 21’ 16.71213”	792.801	810.317
	OLC_OKA_12	48° 35’ 12.41301”	-120° 23’ 31.60924”	620.010	637.283
	OLC_OKA_13	48° 37’ 34.08572”	-120° 05’ 01.97091”	1219.141	1236.302
	OLC_OKA_14	48° 37’ 33.53762”	-120° 05’ 01.46445”	1215.950	1233.111
	OLC_OKA_15	48° 30’ 50.12527”	-120° 12’ 30.86053”	736.016	753.661
	TQ0057	48° 24’ 30.54308”	-120° 08’ 31.07705”	516.391	534.265
	TQ0704	48° 33’ 07.32623”	-120° 20’ 57.47351”	589.637	607.007
UTM 11	OKNGN_01	48° 02’ 56.14867”	-119° 55’ 23.67477”	225.981	245.061
	OLC_OKA_01	48° 11’ 13.14906”	-119° 42’ 42.82818”	357.299	376.446
	OLC_OKA_02	48° 22’ 40.06588”	-119° 34’ 25.71603”	338.108	356.901
	OLC_OKA_03	48° 24’ 05.64974”	-119° 29’ 26.65622”	299.275	317.946
	OLC_OKA_04	48° 36’ 59.84642”	-119° 30’ 16.21754”	298.306	316.499
	OLC_OKA_05	48° 39’ 05.45764”	-119° 28’ 06.18888”	266.626	284.773
	OLC_OKA_06	48° 53’ 05.74534”	-119° 25’ 27.24539”	269.544	287.508
	OLC_OKA_07	48° 59’ 02.70302”	-119° 38’ 16.21218”	378.250	395.996
	OLC_OKA_08	48° 09’ 07.09362”	-120° 03’ 32.07134”	361.153	379.643
	OLC_OKA_09	48° 09’ 48.47005”	-120° 04’ 36.65585”	364.257	382.674
	TP1394	48° 07’ 51.03042”	-119° 40’ 57.70671”	237.010	256.309
	TP1396	48° 56’ 08.92812”	-119° 26’ 26.22222”	265.828	283.801

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) 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.

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. Field images showing examples of land cover types are shown below as well.

BRUSHLAND land cover within the OLC Okanogan study area.

URBAN land cover within the OLC Okanogan study area.

TALL GRASS land cover within the OLC Okanogan study area.

FORESTED land cover within the OLC Okanogan study area.

Field surveyor collecting land class RTK points.

Land cover descriptions of check points taken for the OLC Okanogan study area.

Land Cover Type	Land Cover Code	Description
Brushland	BRUSHLAND	Brush lands and short trees
Urban	URBAN	Urban areas
Tall Grass	TALL GRASS	Areas dominated by tall grass
Forested	FOREST	Forested areas

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

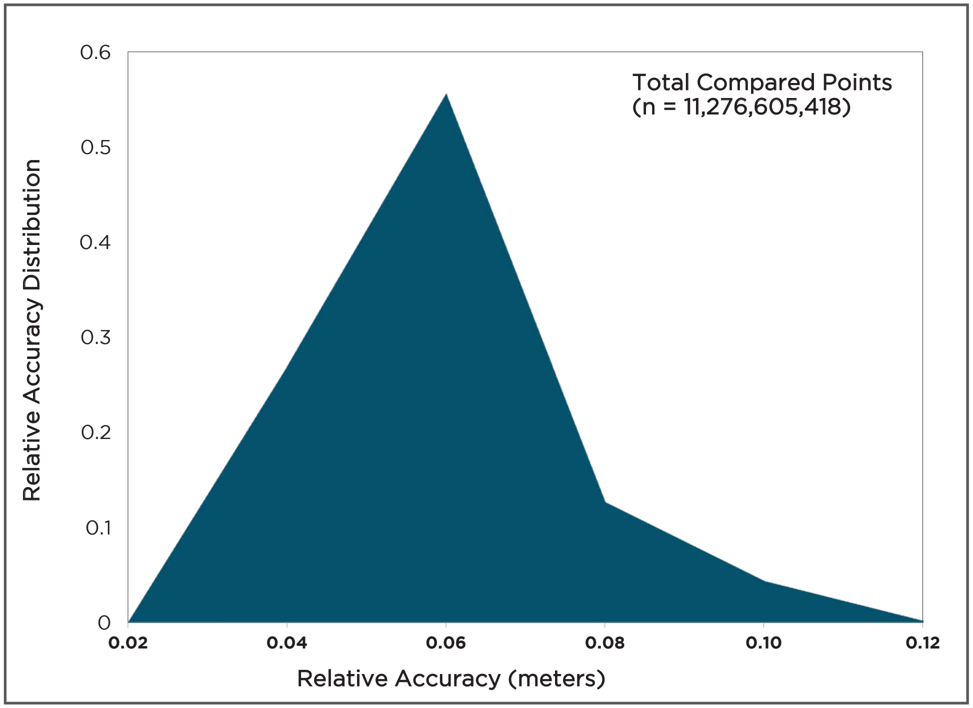
Accuracy

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 408 flightlines and 11,276,605,418 LiDAR points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Sample	n = 408 flightlines
Project Average	0.490 m 0.159 ft.
Median Relative Accuracy	0.044 m 0.145 ft.
1σ Relative Accuracy	0.049 m 0.161 ft.
2σ Relative Accuracy	0.080m 0.261 ft.



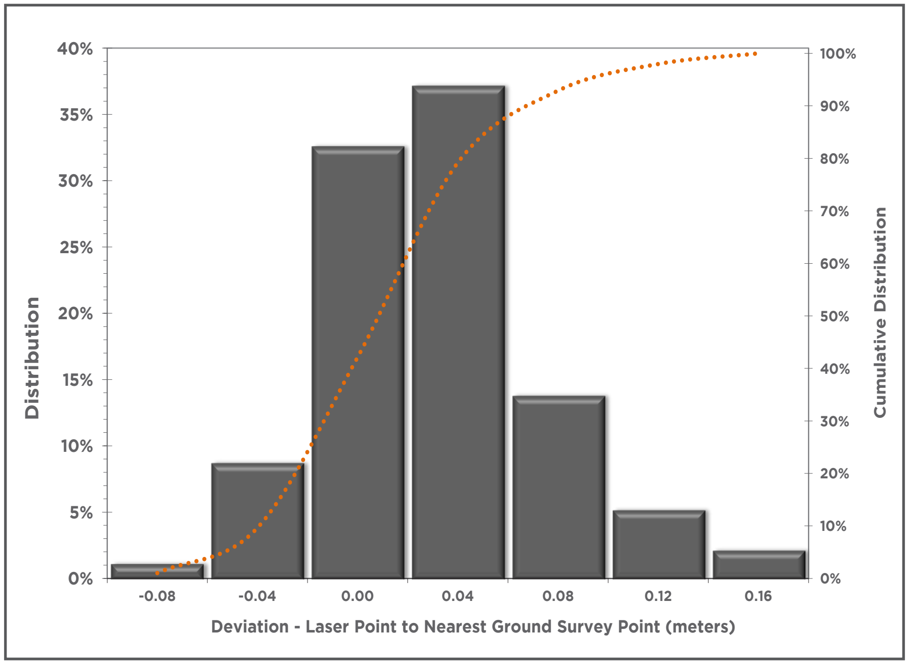
Vertical Accuracy

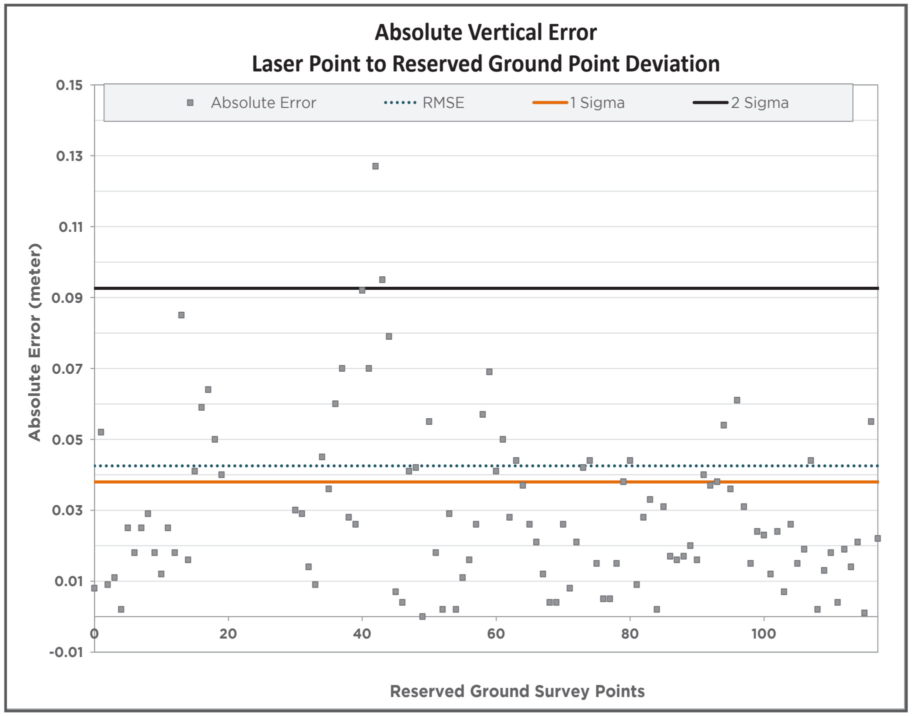
Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known ground survey points (GSPs) to 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 Okanogan FEMA study area, a total of 2,673 GSPs were collected. An additional 197 reserved ground survey points were collected for independent verification, resulting in a fundamental vertical accuracy (FVA) of 0.083 meters.

Vertical Accuracy Results	Hard Surface
Sample Size (n)	n = 197 GSPs
FVA (RMSE*1.96)	0.083 m (0.273 ft.)
Root Mean Square Error	0.043 m (0.139 ft.)
1 Standard Deviation	0.038 m (0.125 ft.)
2 Standard Deviations	0.093 m (0.304 ft.)
Average Deviation	0.034 m (0.0112 ft.)
Minimum Deviation	-0.092 m (-0.302 ft.)
Maximum Deviation	0.150 m (0.492 ft.)

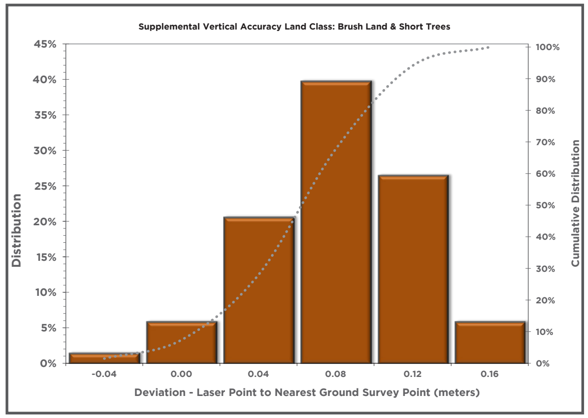
Vertical Accuracy Distribution

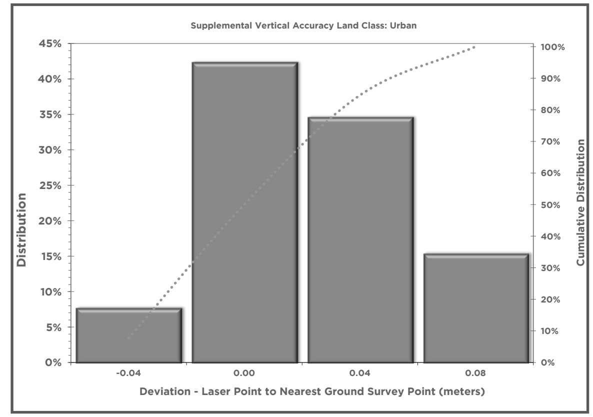


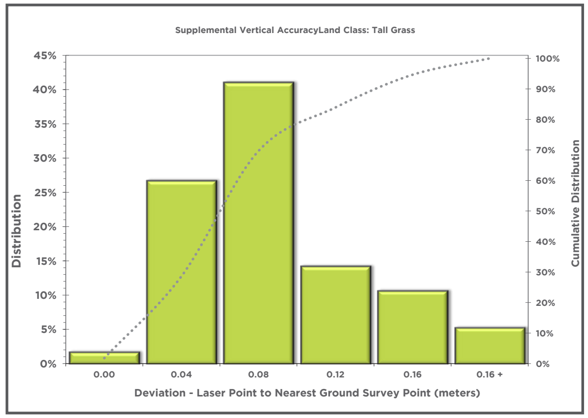


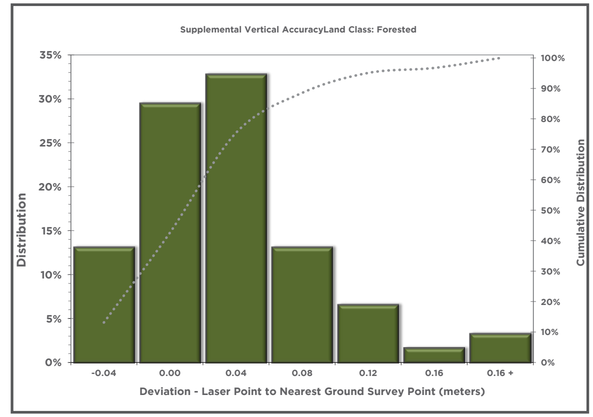
Supplemental and Consolidated Vertical Accuracies

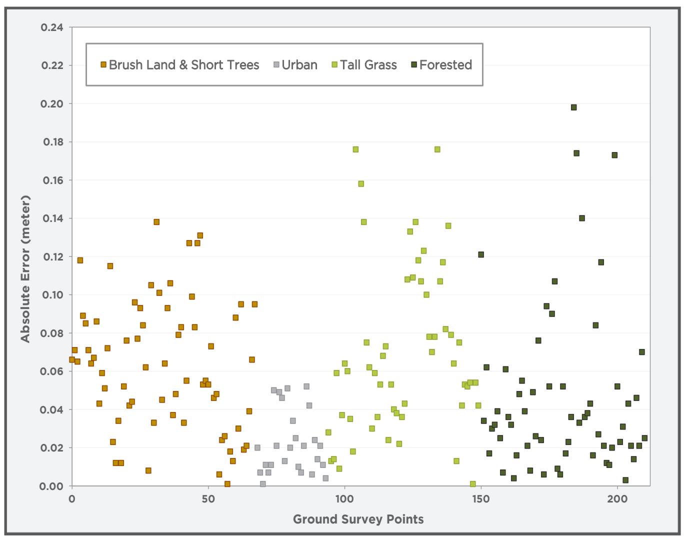
QSI also assessed absolute vertical accuracy for the OLC Okanogan FEMA study area, using Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) reporting. SVA compares known ground survey point data within individual land cover class categories to the triangulated ground surface 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.











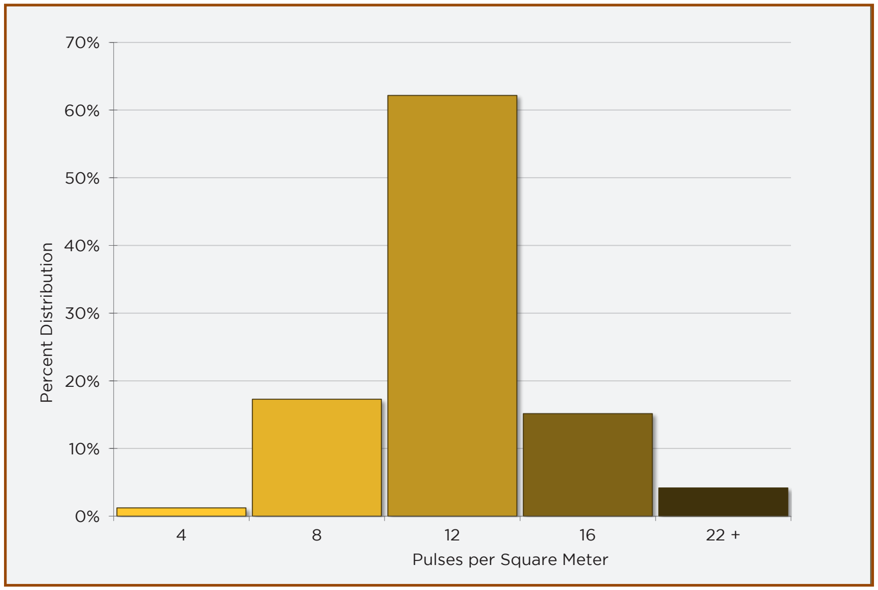
Vertical Accuracy Results	SVA				CVA
	Brushland & Short Trees	Urban	Tall Grass	Forested	All Land Cover Classes
Sample Size	n = 68	n = 26	n = 56	n = 61	n = 211
1 Standard Deviation	0.079 m 0.258 ft.	0.023 m 0.076 ft.	0.078 m 0.256 ft.	0.046 m 0.152 ft.	0.065 m 0.212 ft.
2 Standard Deviations	0.124 m 0.406 ft.	0.051 m 0.167 ft.	0.163 m 0.533 ft.	0.140 m 0.459 ft.	0.137 m 0.449 ft.
Average Deviation	0.063 m 0.207 ft.	0.022 m 0.073 ft.	0.074 m 0.241 ft.	0.047 m 0.153 ft.	0.056 m 0.184 ft.
Minimum Deviation	-0.048 m -0.157 ft.	-0.052 m -0.171 ft.	-0.001 m -0.003 ft.	-0.173 m -0.568 ft.	-0.173 m -0.568 ft.
Maximum Deviation	0.138 m 0.453 ft.	0.051 m 0.167 ft.	0.286 m 0.938 ft.	0.198 m 0.650 ft.	0.286 m 0.938 ft.

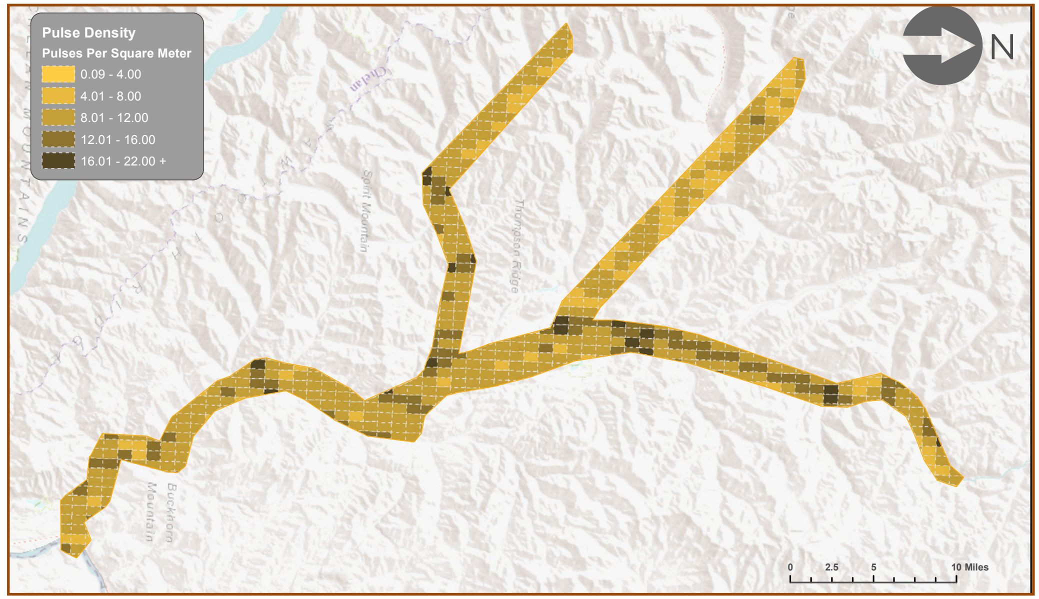
Pulse Density

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.

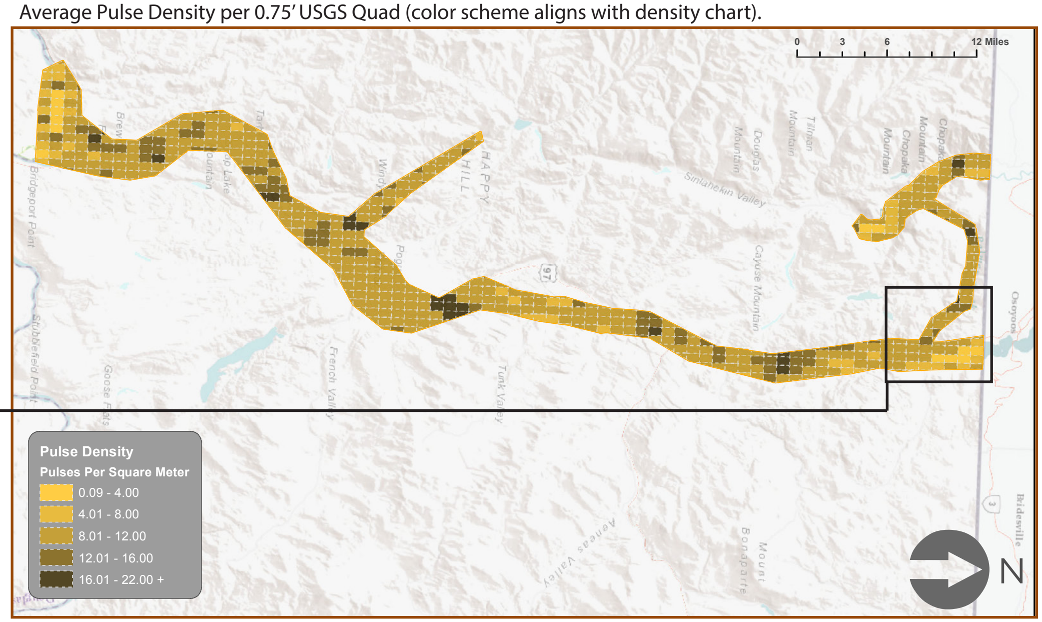
Average Point Densities			
Pulses per square meter	Pulses per square foot	Ground points per square meter	Ground points per square foot
10.03	0.93	2.21	0.21

Pulse Density Distribution

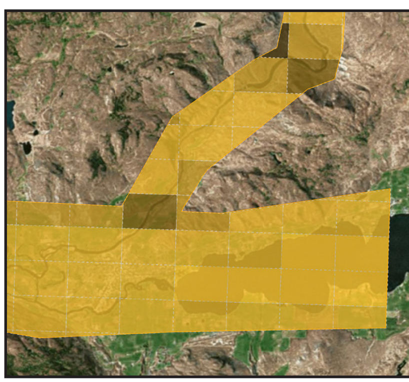




Above and below:
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart).



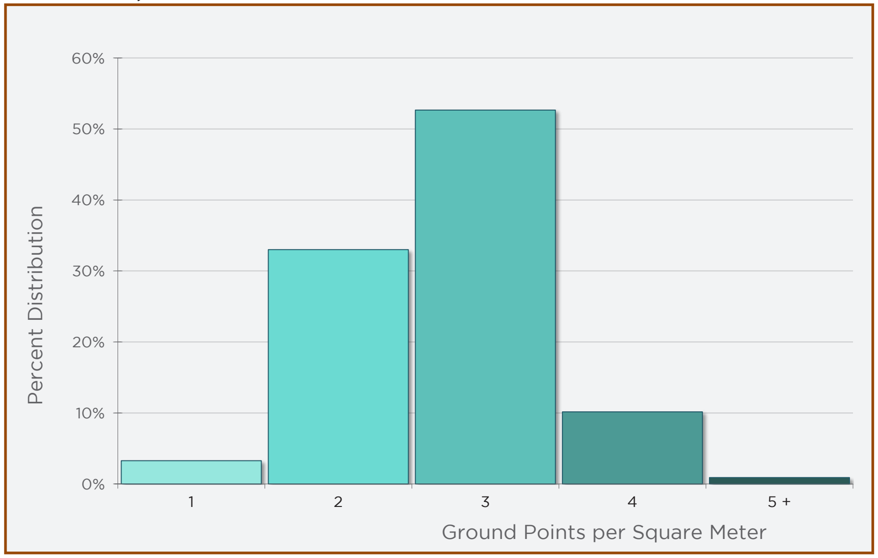
Right:
Due to the absorption of light by water, aquatic surfaces may return fewer LiDAR pulses than the laser originally emitted. The image to the right demonstrates such an area, with low pulse density values corresponding to water bodies.

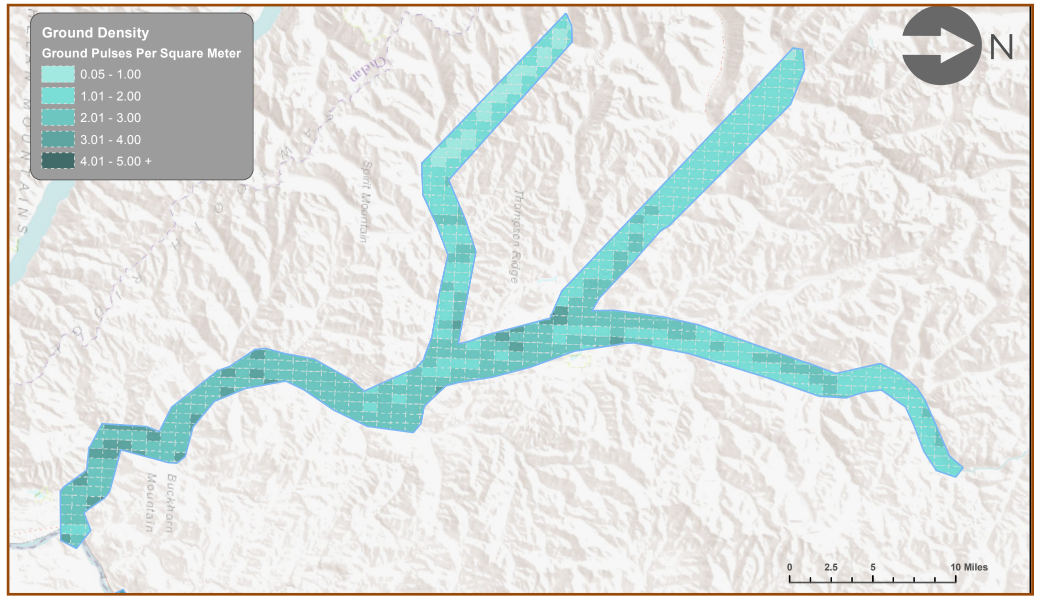


Ground Density

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.

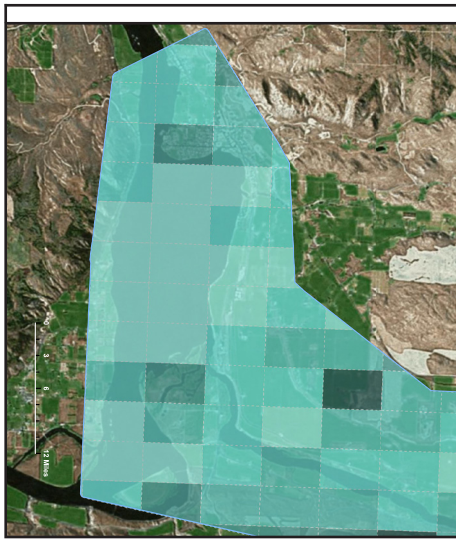
Ground Density Distribution

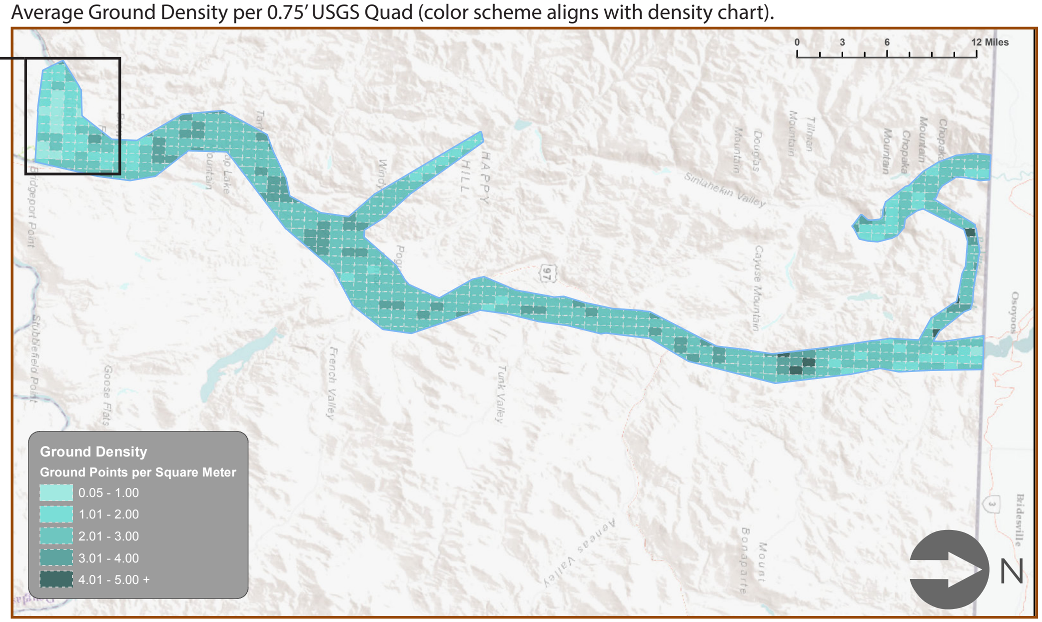




Above and below:
Average Ground Density per 0.75' USGS Quad (color scheme aligns with density chart).

Right:
Due to the absorption of light by water, aquatic surfaces may return fewer LiDAR pulses than the laser originally emitted. The image to the right demonstrates such an area, with low ground density values corresponding to water bodies.





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Appendix
PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for the OLC Okanogan FEMA lidar survey, 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.

2/16/2016

John English
Project Manager
WSI, a Quantum Spatial Company

I, Christopher Glantz, being duly registered as a Professional Land Surveyor in the state of Washington, 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 June 18, 2015 and July 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".

02/14/2016

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

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