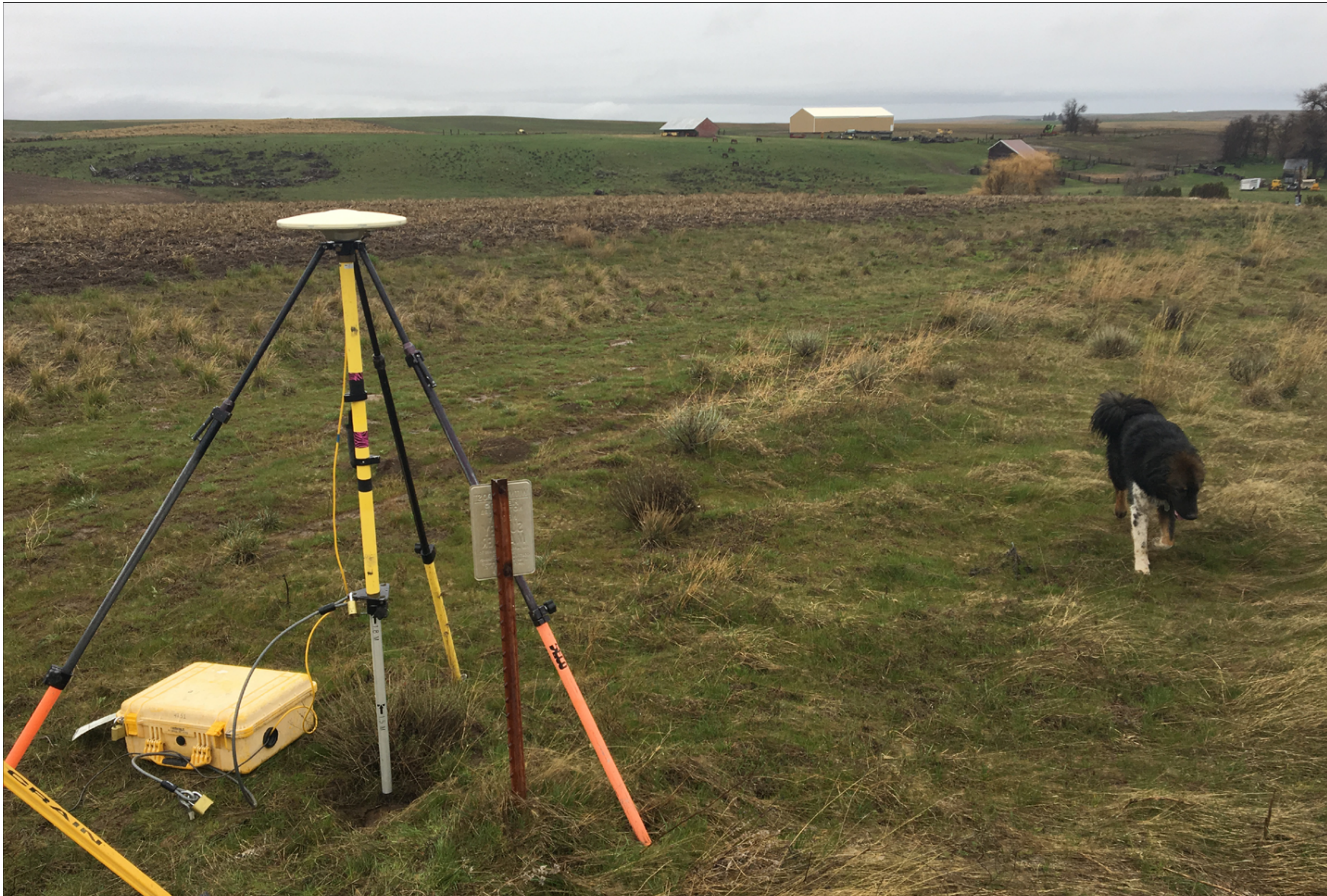
2017 OLC Grass Valley

July 28, 2017



Data collected for:
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Project Overview

QSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data describing the Oregon LiDAR Consortium's (OLC) Grass Valley Study Area. The Grass Valley TAF (total area flown) shown in Figure 1 encompasses 228,146 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.

LiDAR data acquisition occurred between April 22 and May 4, 2017. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter. Final products are listed on page three.

QSI acquires and processes data in the most current, NGS-approved datums and geoid. For Grass Valley, all final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC),[1] using the NAD83 (2011) horizontal datum and the NAVD88 (Geoid 12B) vertical datum, with units in International feet.

Table 1: Grass Valley delivery details

OLC Grass Valley	
Acquisition Dates	April 22 - May 4, 2017*
Area of Interest	219,888 acres
Total Area Flown	228,146 acres
Projection	OGIC Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12B)
Units	International Feet

*See page four for specific acquisition dates.

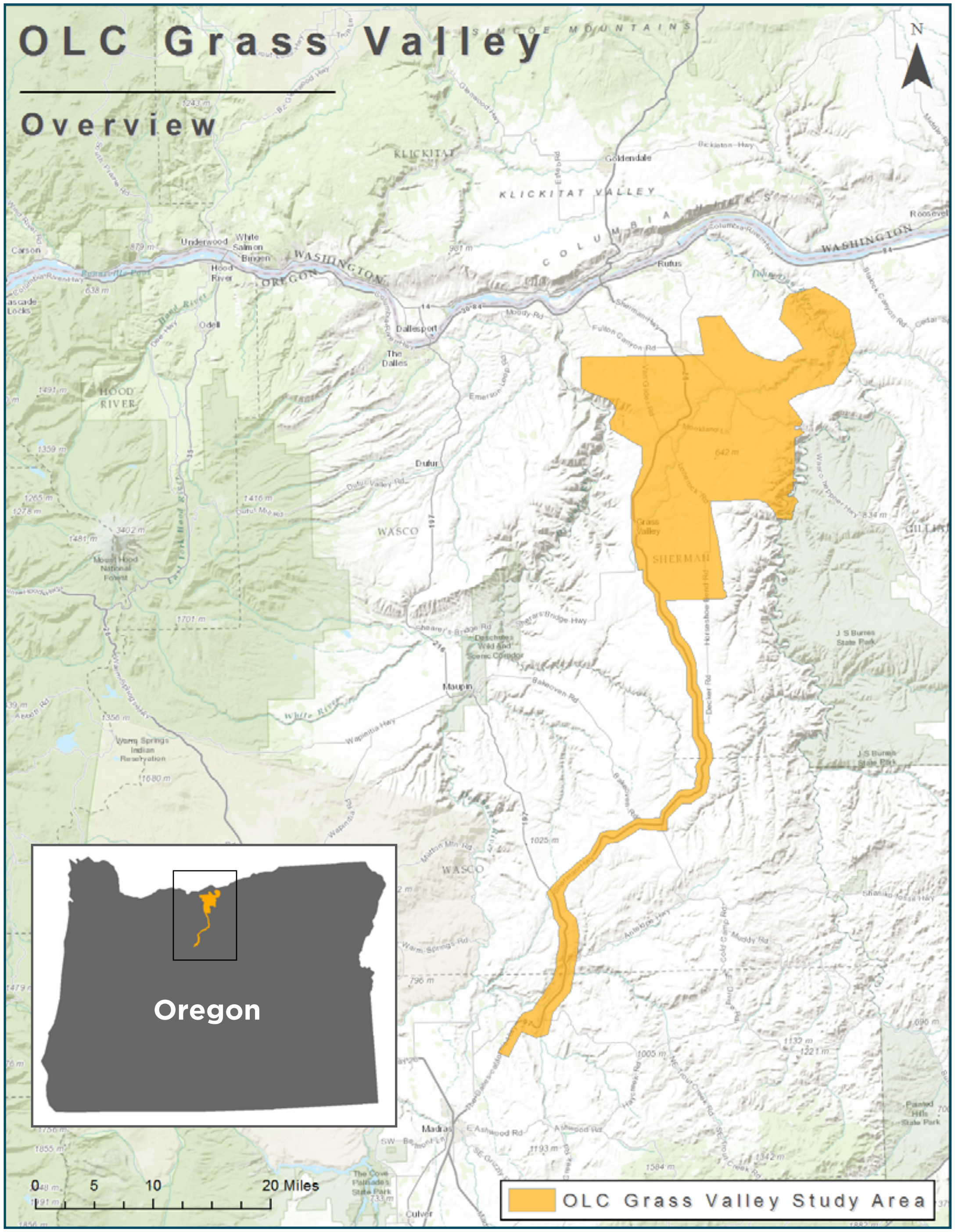

Figure 1: OLC Grass Valley study area

1 http://www.oregon.gov/DAS/EISPD/GEO/pages/coordination/projections/projections.aspx

Deliverable Products

Table 2: Products delivered for Grass Valley study area.

Grass Valley Projection: OGIC Lambert Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12B) Units: International Feet	
Points	LAS v 1.2 tiled by 0.75 minute USGS quadrangles • Default (1) and ground (2) classified points • RGB color extracted from NAIP imagery • Intensities
Rasters	3 foot ESRI GRID tiled by 7.5 minute USGS quadrangles • Bare earth model • Highest hit model 1.5 foot GeoTiffs tiled by 7.5 minute USGS quadrangles • Intensity images
Vectors	Shapefiles (*.shp) • Data extent (BAOI) • BAOI tile index of 0.75 minute USGS quadrangles • BAOI tile index of 7.5 minute USGS quadrangles • Ground control points (used to assess accuracy) • Ground survey points • Monuments • Acquisition flightlines
Metadata	• FGDC compliant metadata for all data products

Aerial Acquisition

LiDAR Survey

The LiDAR survey utilized a Leica ALS 80 sensor mounted in a Cessna Grand Caravan. For system settings, please see Table 3. These settings are developed to yield points with an average native density of greater than eight pulses per square meter over terrestrial surfaces.

The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions of terrain, land cover, and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60 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 data set.

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

Table 3: OLC Grass Valley acquisition specifications

OLC Grass Valley Acquisition	
Sensors Deployed	Leica ALS 80
Aircraft	Cessna Grand Caravan
Survey Altitude (AGL)	1,500 m
Pulse Rate	369.2 kHz
Pulse Mode	Multi (MPiA)
Field of View (FOV)	30°
Scan Rate	58.4 Hz
Overlap	100% overlap with 60% sidelap

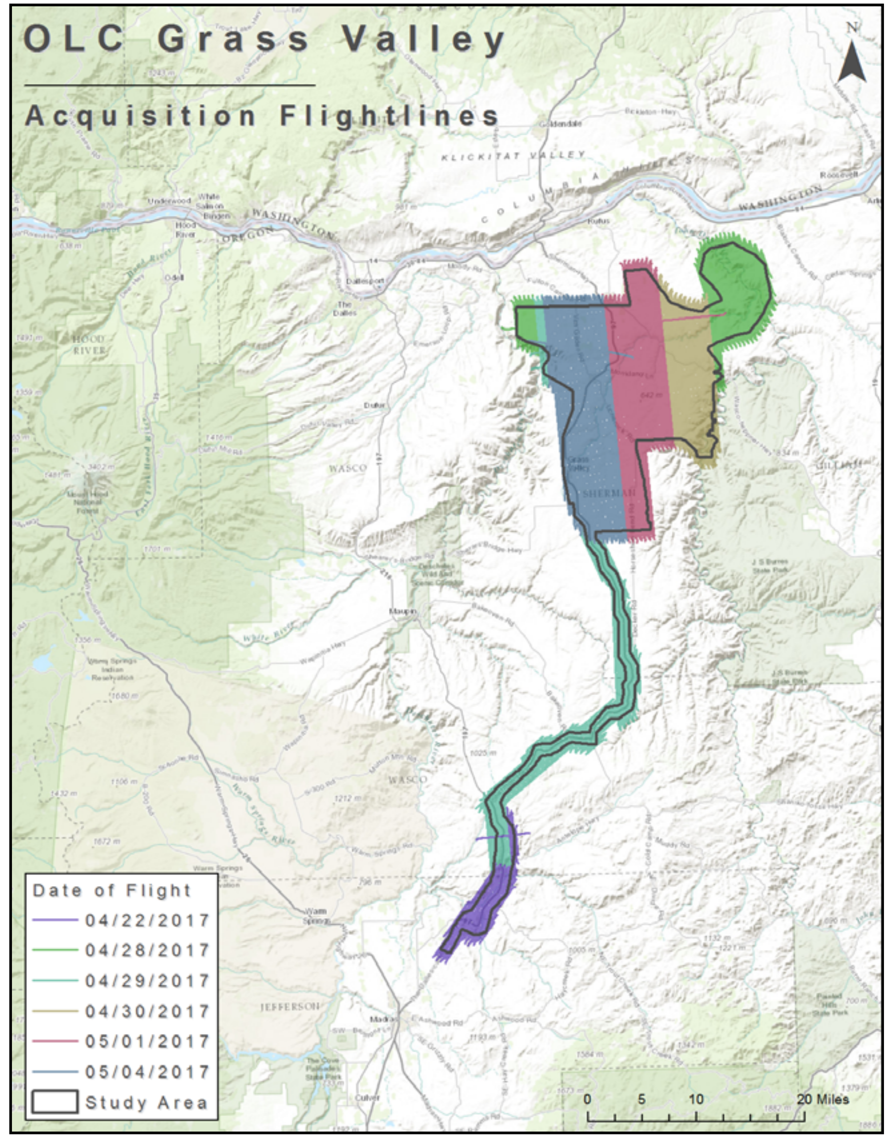

Figure 2: OLC Grass Valley acquisition specifications

Ground Survey

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

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas. Rover surveys for GCP and GSP collection were conducted with Trimble R8 and R10 GNSS receivers. Additionally, four permanent static GNSS stations from the Oregon Real-Time GNSS Network (ORGN; http://theorgn.net) were utilized for flight support and collection of GCPs and GSPs. See Table 5 for specifications of equipment used.

Monumentation

The spatial configuration of ground survey monuments provided redundant control within 20 nautical miles of the mission areas for LiDAR flights. Monuments and ORGN stations were also used for collection of ground control points and ground survey points using real time kinematic (RTK), post processed kinematic (PPK), and fast static (FS) survey techniques. Monument and ORGN station locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GCP/GSP coverage. New monumentation was set using 5/8" x 30" rebar topped with stamped 2-1/2" aluminum caps. QSI's professional land surveyor, Evon Silvia (OR PLS #81104) 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. Table 4 provides the list of monuments used in the Grass Valley study area.

Methodology

Ground control points and ground survey points were collected using real time kinematic (RTK), post-processed kinematic (PPK), and fast static (FS) survey techniques. For RTK surveys, a base receiver was positioned at a nearby monument to broadcast a kinematic correction to a roving receiver; for PPK and FS surveys, however, these corrections were post-processed. RTK and PPK surveys recorded observations for a minimum of five seconds, while FS surveys recorded observations for up to fifteen minutes on each GCP/GSP in order to support longer baselines for post-processing. All GCP and GSP measurements were 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 were requred to 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, GCP and GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GCPs and GSPs were taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GCPs and 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.

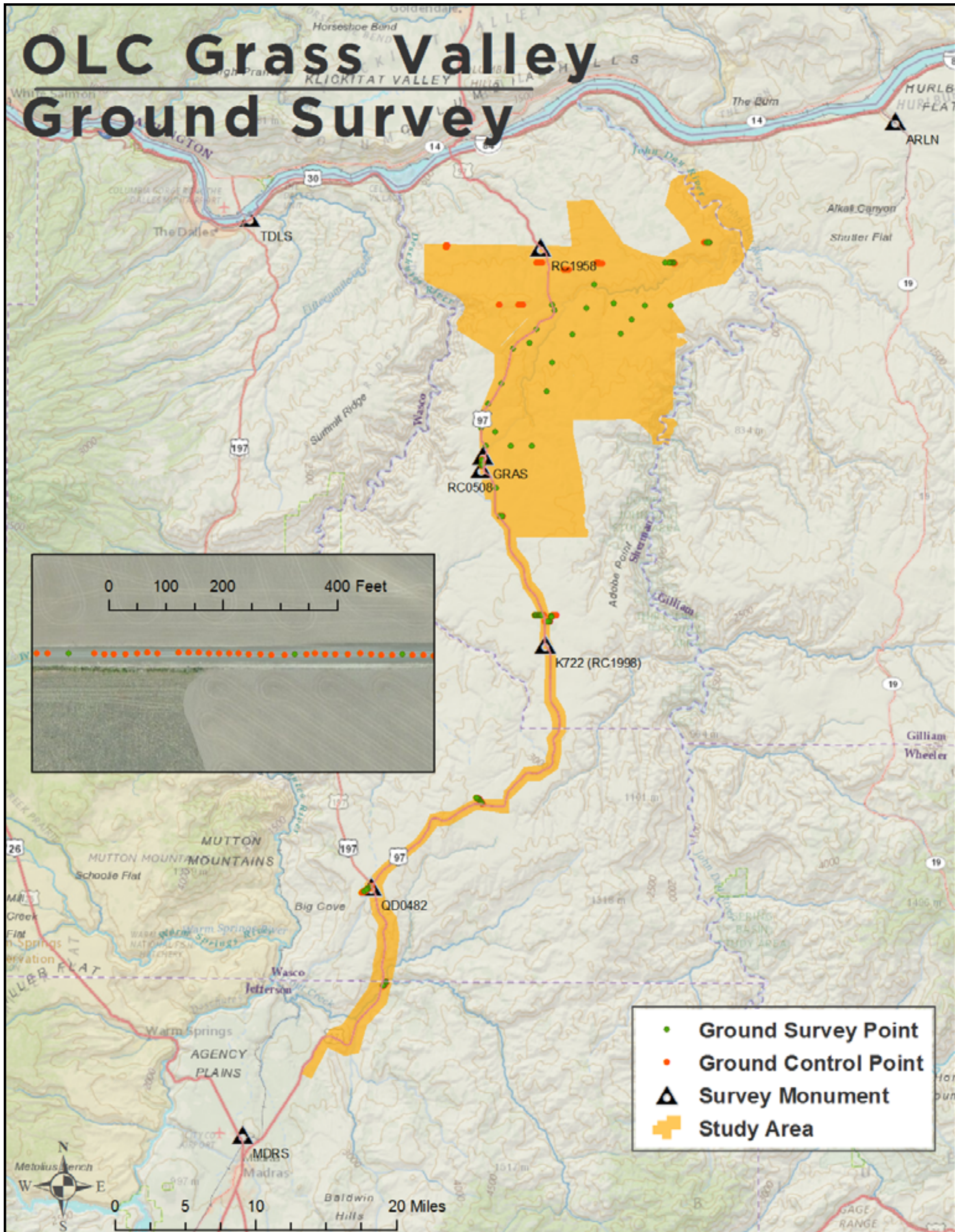

Figure 3: Grass Valley study area ground control

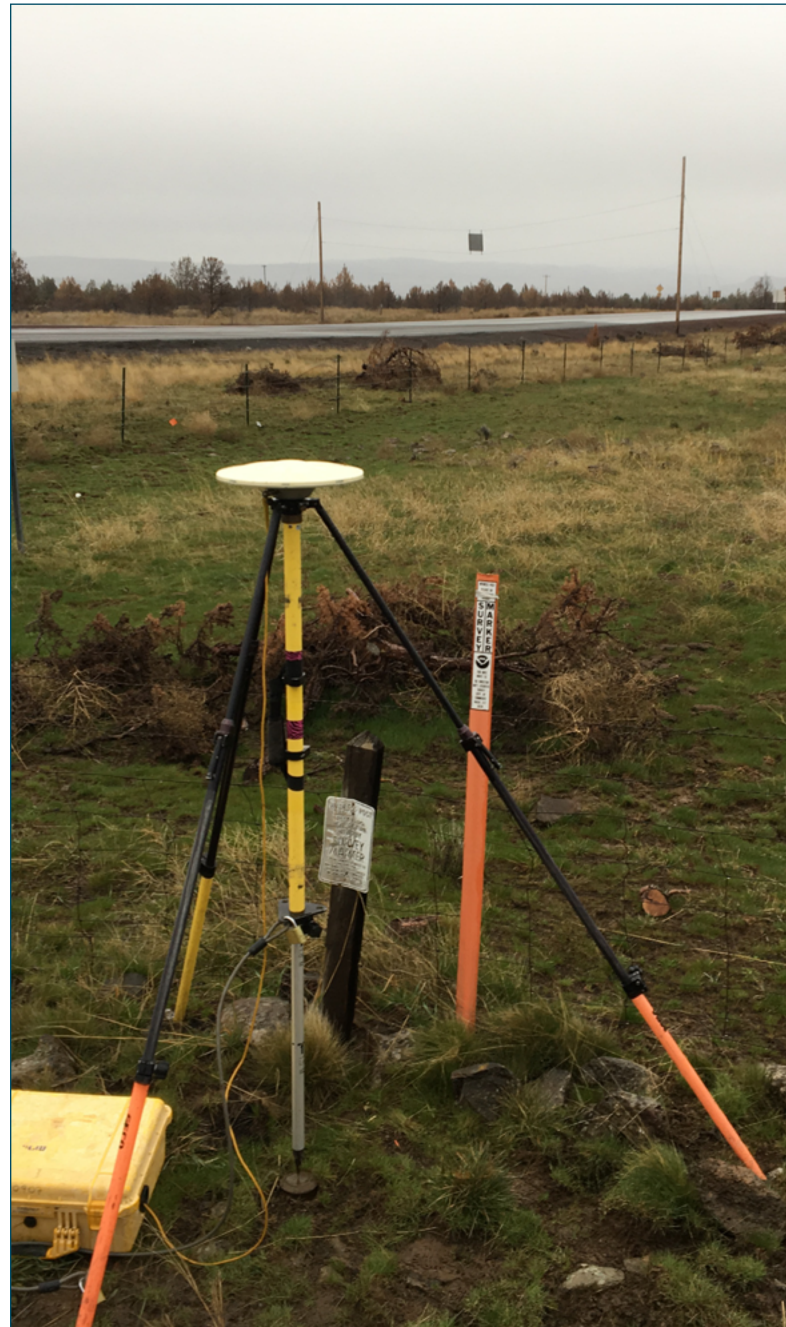

Figure 4: QD0482 monument

Figure 5: Zephyr GNSS Geodetic Model 2 antenna set up over QD0482 monument

Table 4: Grass Valley monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12B

	PID	Latitude	Longitude	Ellipsoid Height (m)	Orthometric Height (m)
QSI Monuments	K722	45° 10' 14.14714"	-120° 41' 44.33077"	796.320	817.142
	QD0482	44° 55' 13.39314"	-120° 56' 47.47985"	962.138	983.148
	RC0508	45° 21' 02.35258"	-120° 47' 20.61736"	688.062	709.078
	RC1958	45° 34' 43.16298"	-120° 42' 12.38152"	408.617	429.946
Oregon Real-Time GNSS Network	TDLS	45° 36' 27.74446"	-121° 07' 46.16461"	26.928	48.410
	ARLN	45° 42' 29.52532"	-120° 10' 59.71154"	120.812	142.429
	GRAS	45° 21' 51.87542"	-120° 47' 14.62113"	677.871	698.904
	MDRS	44° 39' 50.49280"	-121° 07' 49.44945"	736.344	757.736

Table 5: 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 GNSS	Integrated Antenna	TRMR8_GNSS	Rover
Trimble R10 GNSS	Integrated Antenna	TRM_R10	Rover

Table 6: Monument accuracy

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	2 cm
St Dev Z	2 cm

LiDAR Accuracy Assessments

Relative Accuracy

Relative vertical 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, reported in Table 7 are based on the comparison of 257 full and partial flightlines and over 23 billion sample points.

Table 7: Relative accuracy

Relative Accuracy Calibration Results		
Project Average	0.036 m	0.117 ft
Median Relative Accuracy	0.033 m	0.109 ft
1σ Relative Accuracy	0.038 m	0.126 ft
2σ Relative Accuracy	0.049 m	0.161 ft
Flightlines	257	
Sample points	23,864,694,533	

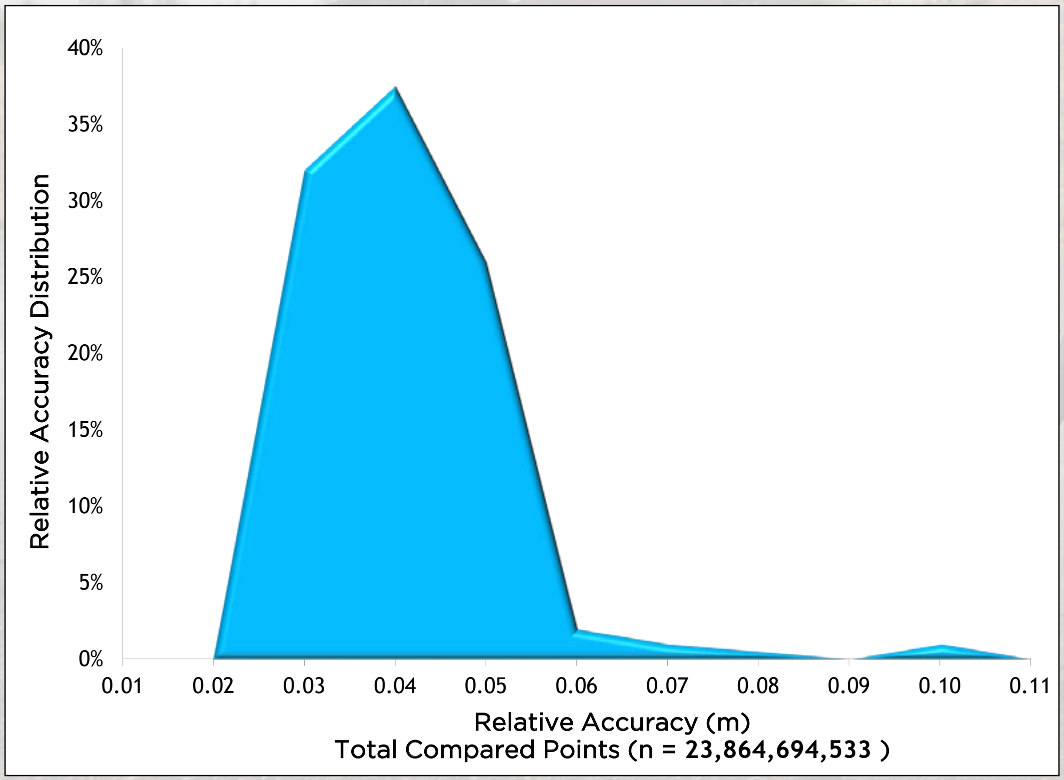

Figure 6: Relative accuracy based on 257 flightlines.

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 Positional Accuracy Standards for Digital Geospatial Data V1.0 (ASPRS, 2014). The statistical model compares known reserved ground survey points (GSPs) to the ground model, triangulated from the neighboring laser points. 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 Grass Valley study area, a total of 1,694 ground control points were collected and used for calibration of the LiDAR data. An additional 121 reserved ground survey points were collected for independent verification, resulting in a non-vegetated vertical accuracy (NVA) of 0.070 meters, or 0.231 feet.

Table 8: Vertical accuracy results

Non-vegetated Vertical Accuracy	Tested against TIN	
Sample Size (n)	121 Reserved Ground Survey Points	
Vertical Accuracy at 95% confidence level (RMSE*1.96)	0.070 m	0.231 m
Root Mean Square Error	0.036 m	0.118 ft
Standard Deviation	0.033 m	0.108 ft
Minimum Deviation	-0.092 m	-0.302 ft
Maximum Deviation	0.105 m	0.344 ft

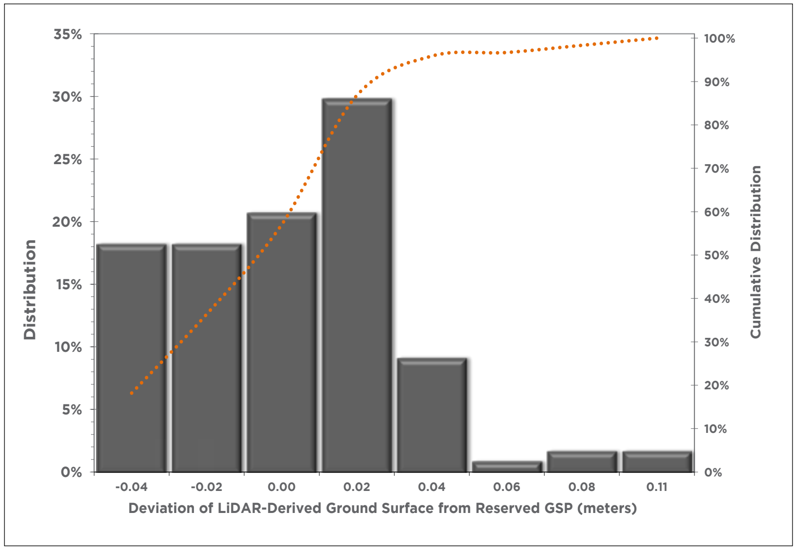

Figure 7: Vertical accuracy distribution

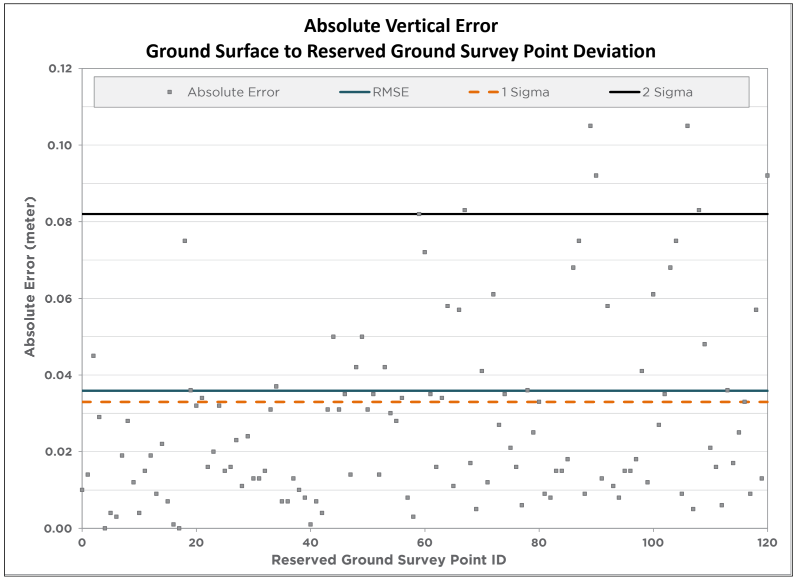

Figure 8: Reserved ground survey point absolute error

Density

Pulse Density

Final pulse density is calculated after processing and is a measure of first returns per sampled area. 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. Densities are reported for the entire study area.

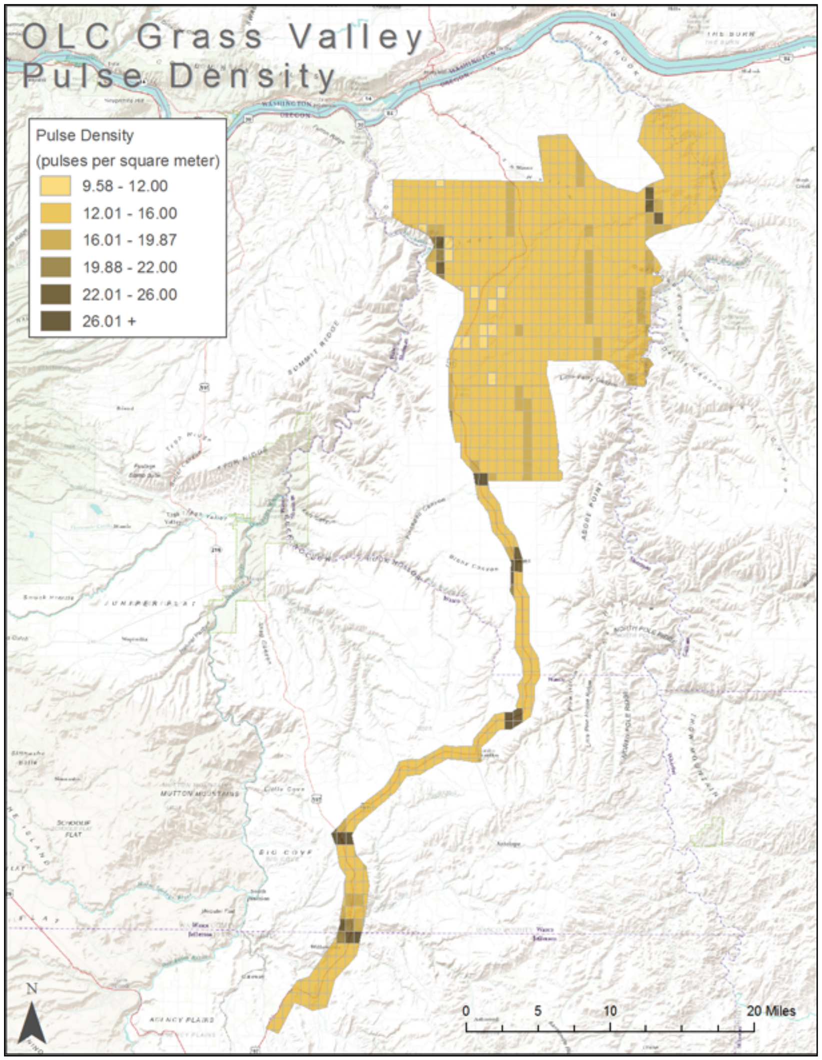

Table 9: Average pulse density

Average Pulse Density	pulses per square meter	pulses per square foot
	14.29	1.33

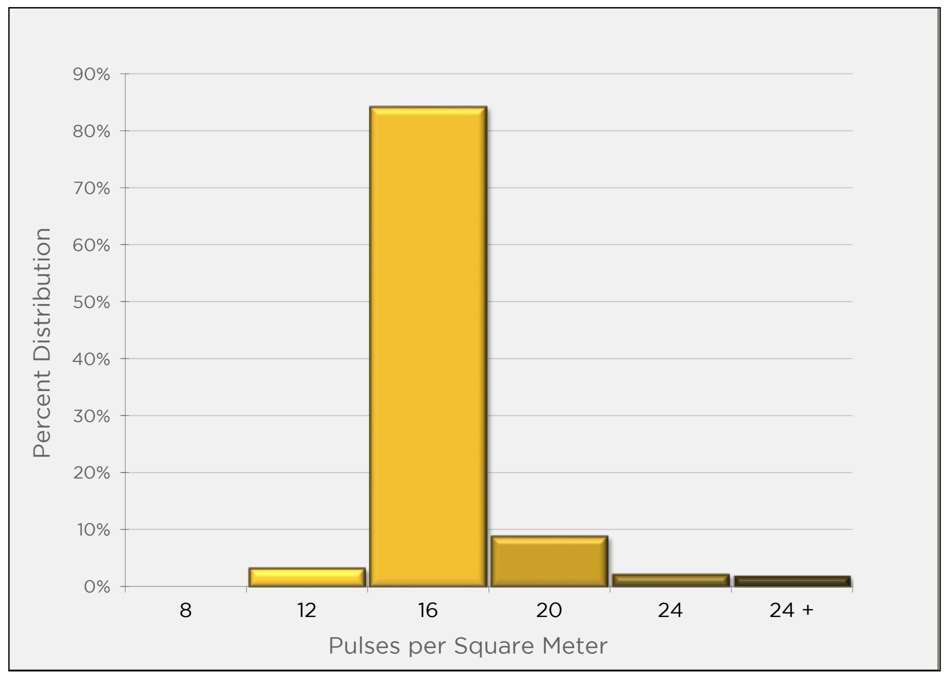

Figure 9: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).

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. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density in Table 10 is a measure of ground-classified point data for the entire study area.

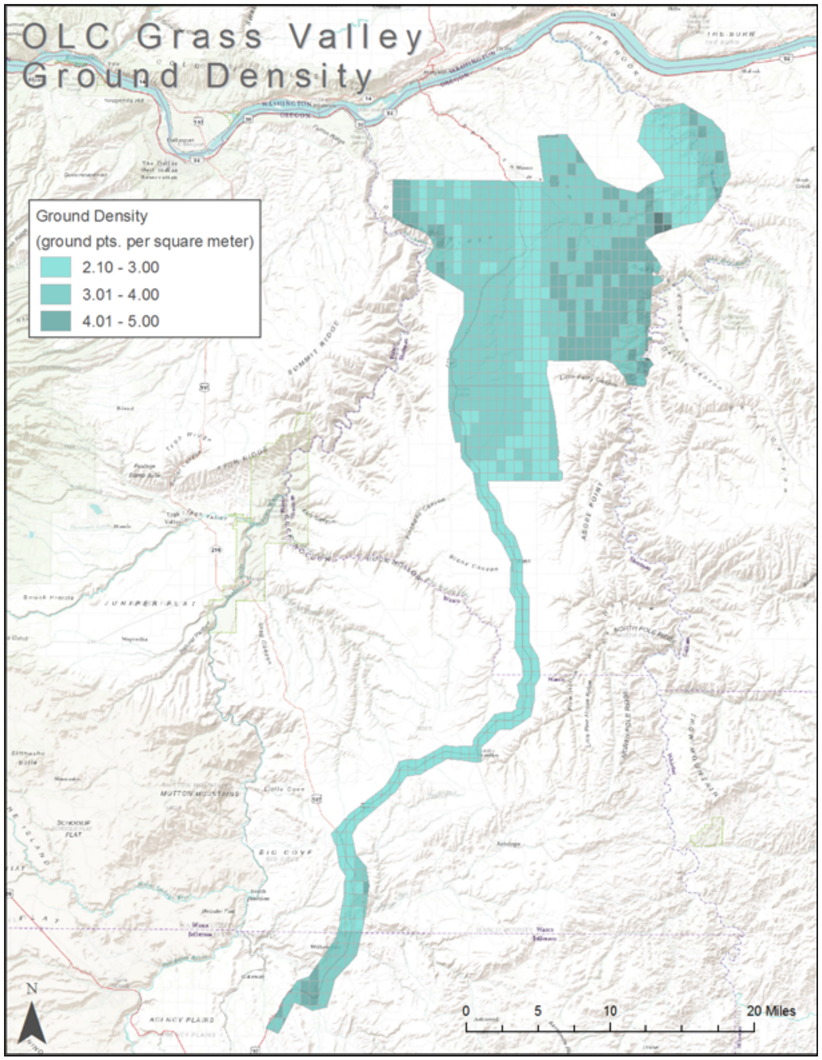

Table 10: Average ground density

Average Ground Density	points per square meter	points per square foot
	3.31	0.31

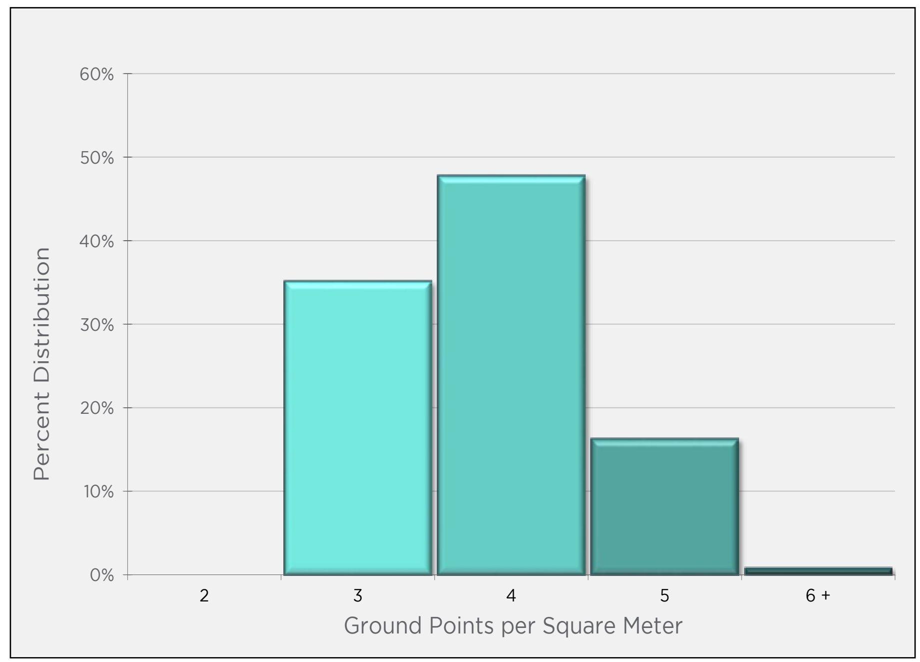

Figure 10: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).

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Appendix A : PLS Certification

Quantum Spatial, Inc. provided LiDAR services for the OLC Grass Valley project as described in this report.

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

July 28, 2017

John English, GISP
Project Manager
Quantum Spatial, Inc.

I, Evon P. Silvia, PLS, being duly registered as a Professional Land Surveyor in and by the state of Oregon, hereby certify that the methodologies, static GNSS occupations used during airborne flights, and ground survey point collection were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between March 22 and May 1, 2017.

Accuracy statistics shown in the Accuracy Section of this Report have been reviewed by me and found to meet the "National Standard for Spatial Data Accuracy".

July 28, 2017

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