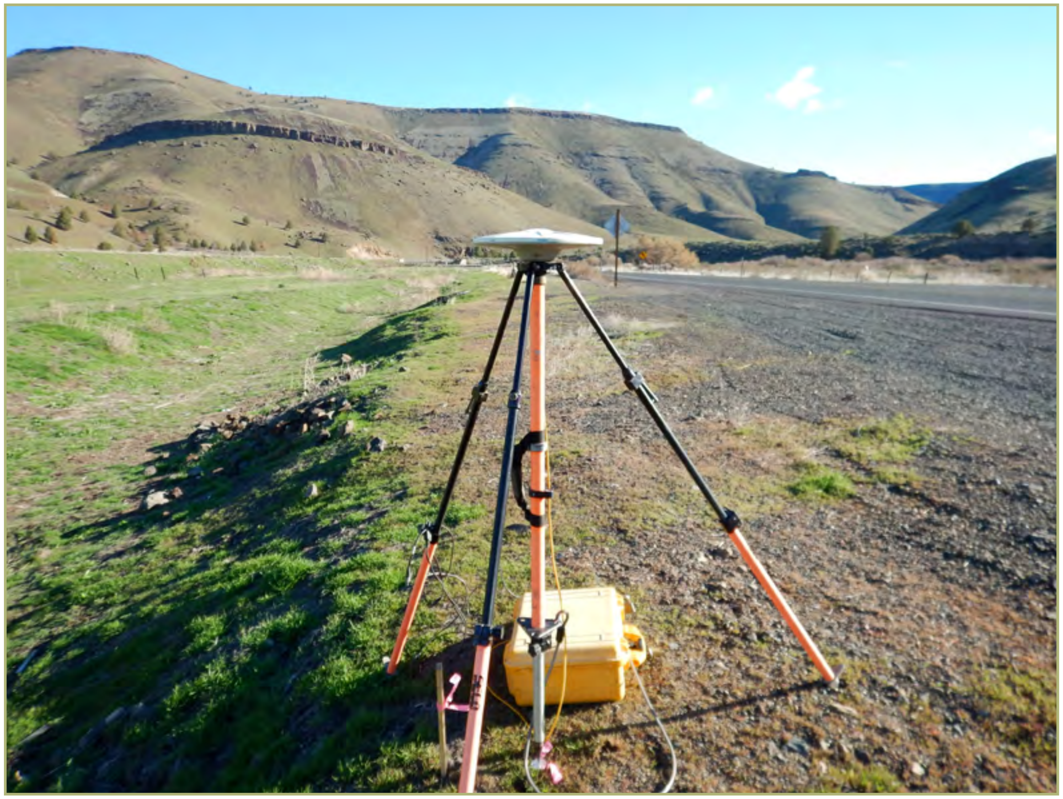
OLC Lower Malheur Study Area

August 4, 2015



Trimble R7 (left)
QSI established monument OLC_MAL_02
(above)

Data collected for:
Oregon 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

517 SW 2nd Street
Suite 400
Corvallis, OR 97333
phone: (541) 752-1204
fax: (541) 752-3770

Contents

Project Overview

QSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data describing the Oregon LiDAR Consortium's (OLC) Lower Malheur Study Area. The OLC Lower Malheur area of interest (AOI) shown in Figure 1 encompasses 176,640 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 occured from March 21, 2015 - April 9, 2015. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products are listed in page 2.

QSI acquires and processes data in the most current, NGS-approved datumsand geoid. For OLC Lower Malheur, 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 12A) vertical datum, with units in International feet.

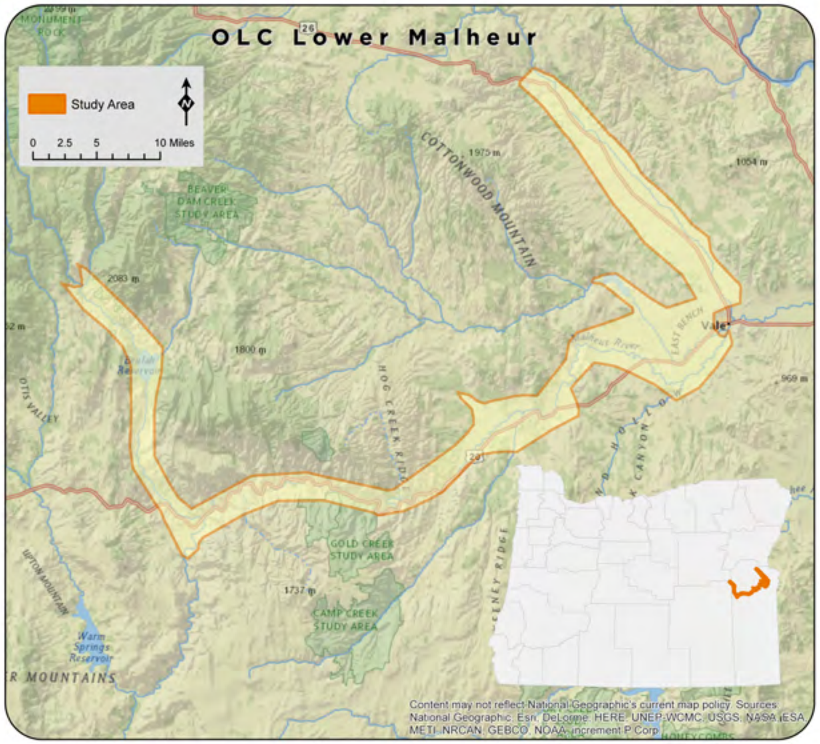


Figure 1: OLC Lower Malheur study area location

Table 1: OLC Lower Malheur delivery details

OLC Lower Malheur	
Acquisition Dates	March 21, 2015 - April 9, 2015
Area of Interest	176,640 acres
Projection	OGIC
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

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

Deliverable Products

Table 2: Products delivered for OLC Lower Malheur site

OLC Lower Malheur Projection: OGIC Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12A) Units: International Feet	
Points	LAS v 1.2 • Default and ground classfied points • RGB color extracted from NAIP imagery • Intensities
Rasters	3 foot ESRI GRID tile by 7.5 minute USGS quad • Bare Earth Model • Highest Hit Model • LiDAR ground density images 1.5 foot Meter GeoTiffs by 1/100th USGS quad • Intensity Images
Vectors	Shapefiles (*.shp) • Data extent (TAF) • Area of interest (AOI) • LiDAR Tile Index by 1/100th (.075 minute) USGS quad • DEM Tile Index • Flight Trajectory • Reserved ground survey points • Non-reserved ground survey points • Monuments
Metadata	• FGDC compliant metadata for all data products

Aerial Acquisition

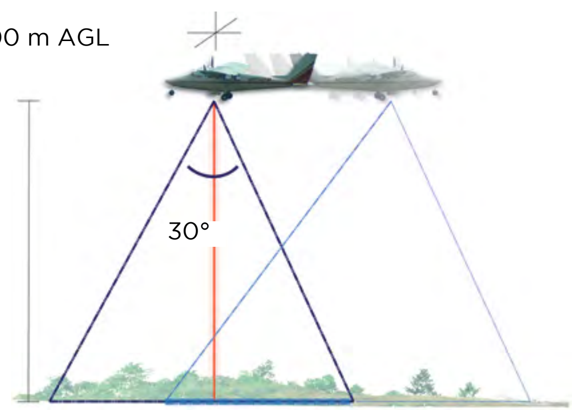
Cessna Caravan

LiDAR Survey

The LiDAR survey utilized Leica ALS70 sensor mounted in a Cessna Caravan 208-B. The systems were programmed to emit single pulses at a rate of 198 kilohertz and flown at 1400 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 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 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, 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). As illustrated in the accompanying map, 530 full and partial flightlines provide coverage of the study area.



OLC Lower Malheur	
Sensors Deployed	Leica ALS70
Aircraft	Cessna Grand Caravan 208-B
Survey Altitude (AGL)	1400 m
Pulse Rate	198 kHz
Pulse Mode	Single (SPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 65% sidelap
Pulse Emission Density	≥ 8 pulses per square meter

Table 3: OLC Lower Malheur aquisition specifications

Ground Survey

Ground control surveys and ground survey points (GSPs) were collected 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 and orthoimagery products.

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R8 GNSS receivers. See table 6 for specifications of equipment used.

Monumentation

Existing and newly established survey benchmarks serve as control points during LiDAR acquisition. Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, QSI produces monuments, 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 "Watershed Sciences." Table 4 provides the list of monuments used in the OLC Lower Malheur study area.

Delivery Area One Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
OLC_MAL_02	44° 06′ 45.59394″	-117° 22′ 04.51774″	721.525	739.471
OLC_MAL_03	44° 07′ 37.85944″	-117° 23′ 13.12362″	723.863	741.786
OLC_MAL_04	43° 58′ 57.07878″	-117° 18′ 35.34090″	727.106	745.164
OLC_MAL_05	43° 58′ 56.82339″	-117° 20′ 42.65722″	751.796	769.877
OLC_MAL_06	43° 51′ 15.06534″	-117° 34′ 47.35489″	753.919	771.992
OLC_MAL_07	43° 52′ 58.10107″	-117° 37′ 32.33493″	783.926	801.988
OLC_MAL_08	43° 51′ 21.96287″	-117° 36′ 23.77952″	746.879	764.954
OLC_MAL_09	43° 47′ 16.92080″	-118° 00′ 26.62437″	859.840	878.007
OLC_MAL_10	43° 46′ 26.39616″	-118° 01′ 38.03778″	872.024	890.242
OLC_MAL_11	43° 56′ 54.89644″	-118° 08′ 18.98105″	1025.427	1043.431
OLC_MAL_12	43° 55′ 58.63166″	-118° 08′ 22.89005″	1007.402	1025.420

Table 4: OLC Lower Malheur monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A

Methodology

To correct the continuously recorded aircraft position, QSI concurrently conducts multiple static GNSS ground surveys over each monument. All control monuments are observed for a minimum of two survey sessions, each lasting no fewer than two hours. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna. The static GPS data are then triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS) for precise positioning.

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; for PPK surveys, however, these corrections are post-processed. 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.

Table 5: Monument accuracy

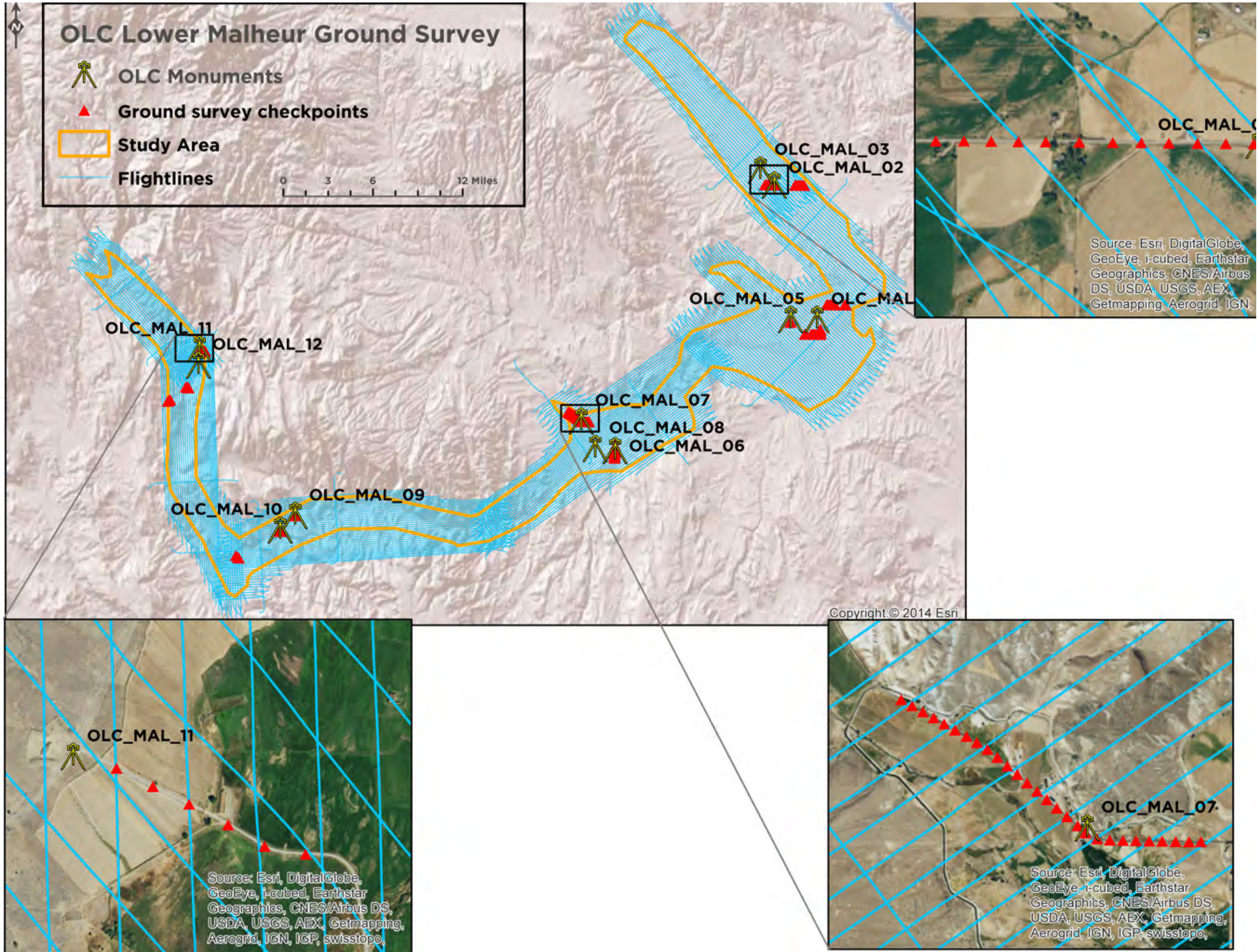
Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.020 m
St Dev z	0.050 m

Ground professional collecting RTK

Table 6: 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

Figure 2: OLC Lower Malheur study area ground control



LiDAR Accuracy Assessments

The accuracy of the LiDAR data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

Relative Accuracy

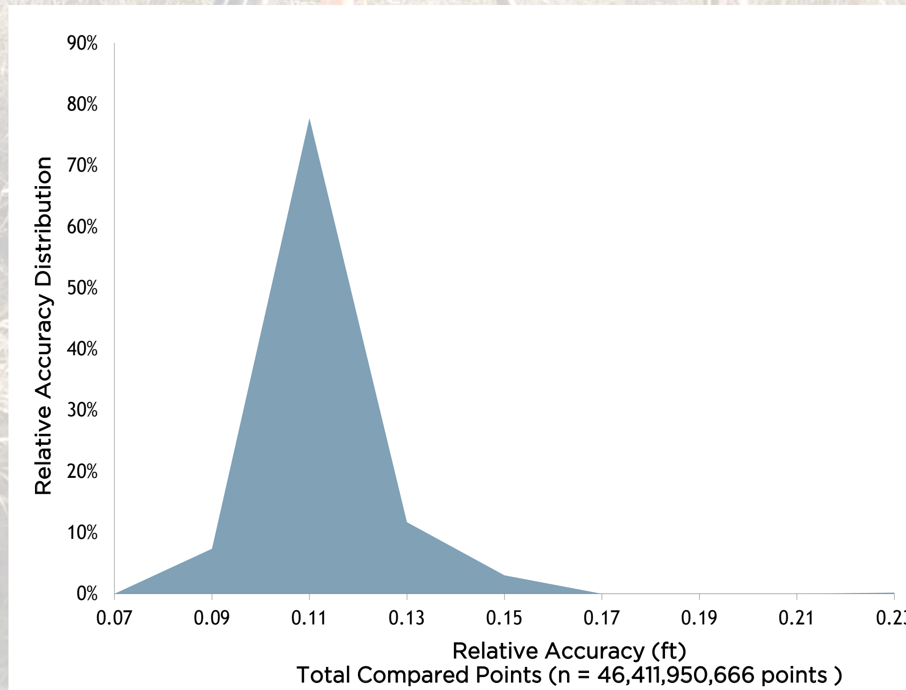
Relative vertical accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping aream. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence 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 530 full and partial flightlines and over 46 billion points.

Table 7: Relative accuracy

Relative Accuracy Calibration Results N = 530 flightlines	
Project Average	0.102 ft. (0.0311 m)
Median Relative Accuracy	0.100 ft. (0.0305 m)
1σ Relative Accuracy	0.104 ft. (0.318 m)
2σ Relative Accuracy	0.123 ft. (0.0378 m)

Figure 3: Relative Accuracy distribution



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 RTK ground check point data collected on open, bare earth surfaces with slopes <20° to the triangulated surface generaged by LiDAR points. 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 95% confidence interval For the OLC Lower Malheur study area, 122 GSPs were withheld from the calibration and post-processing of the LiDAR data, resulting in a fundamental vertical accuracy of 0.11 feet (0.042 meters). Histogram and absolute deviation statistics are displayed for the data being delivered in Figure 4 and Figure 5.

Table 8: Vertical accuracy

Vertical Accuracy Results	
Sample Size (n)	122 Ground survey points
FVA (RMSE*1.96)	0.11 ft. (0.042 m)
Root Mean Square Error	0.070 ft. (0.021 m)
1 Standard Deviation	0.072 ft. (0.022 m)
2 Standard Deviation	0.12 ft. (0.038 m)
Average Deviation	0.058 ft. (-0.018 m)
Minimum Deviation	-0.19 ft. (-0.059 m)
Maximum Deviation	0.17 ft. (0.053 m)

Figure 4: Vertical Accuracy distribution

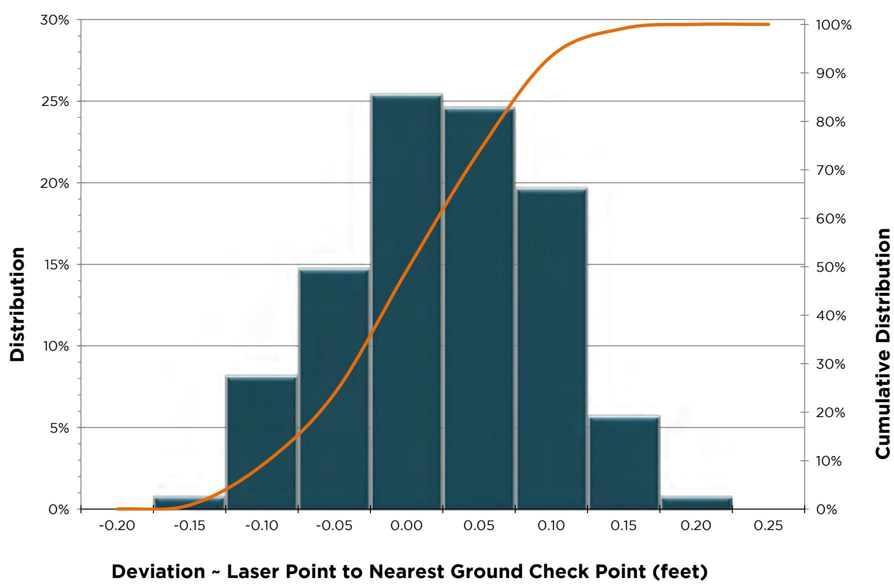
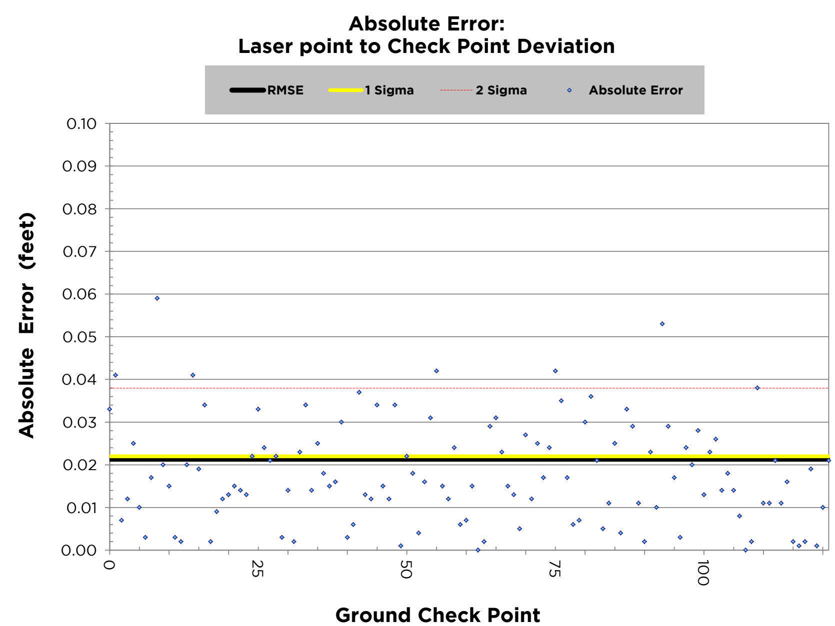


Figure 5: GSP absolute error



Density

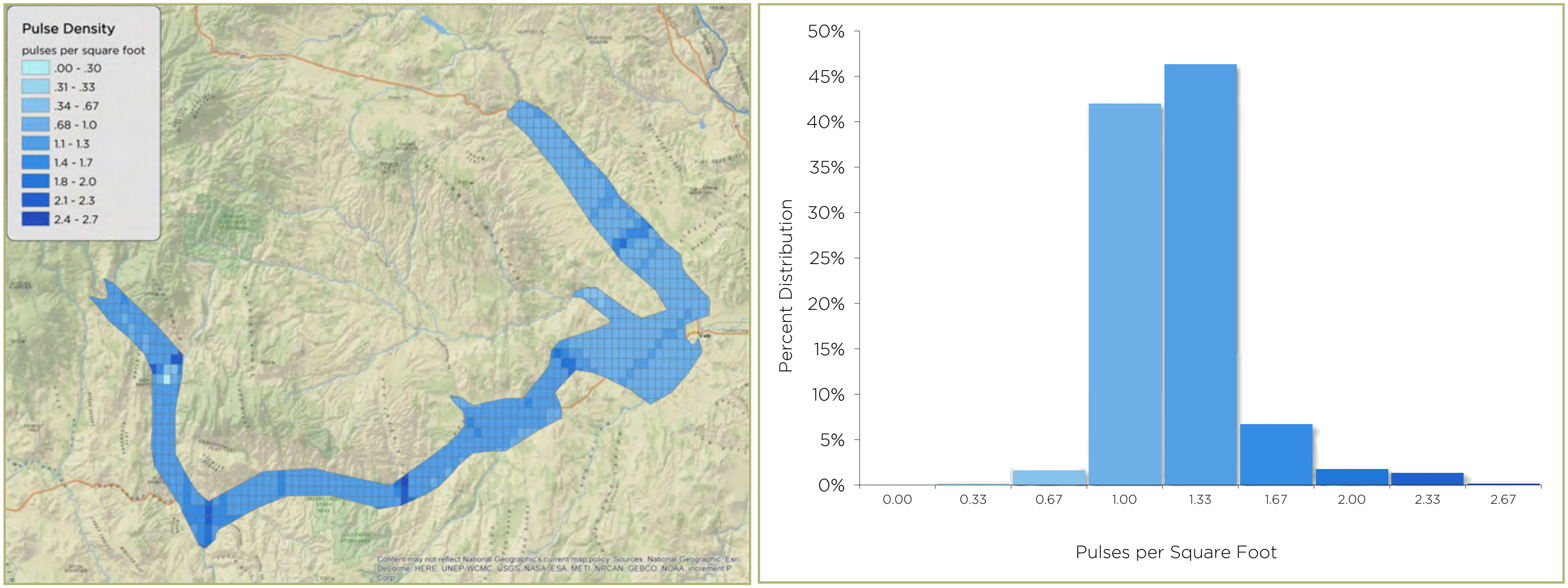
Pulse Density

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 and ground-classified laser point density. Densities are reported for the delivery area.

Table 9: Average pulse density

Average Pulse Density	pulses per square meter	pulses per square foot
	11.56	1.07

Figure 6: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).



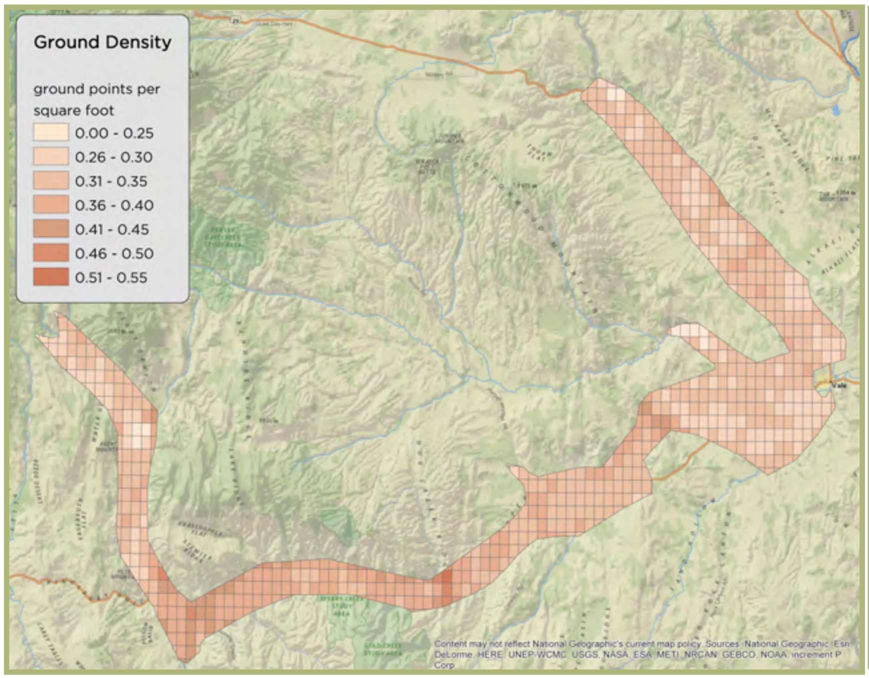
Ground Density

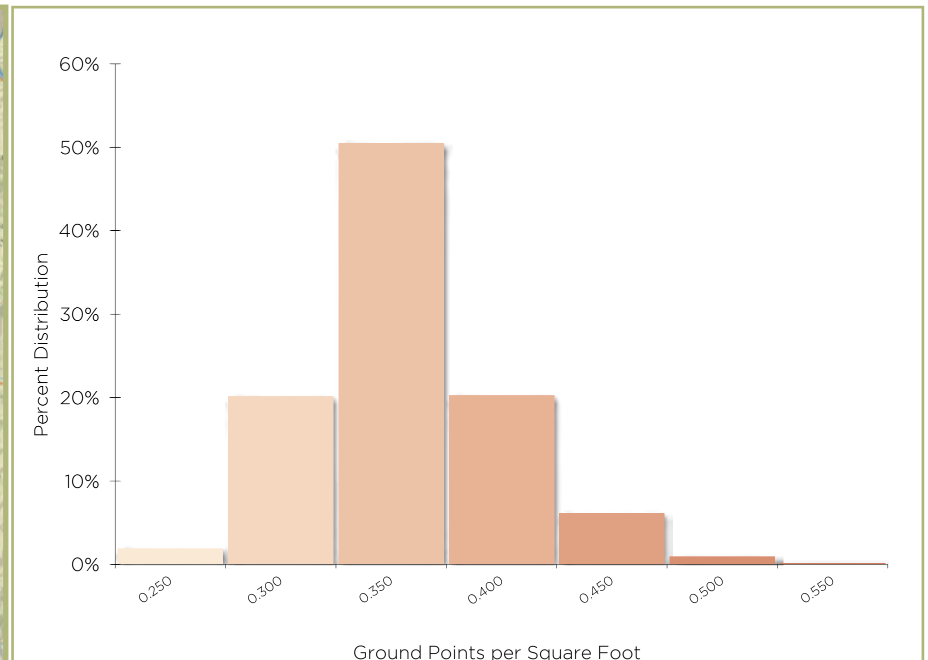
Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries. The classifications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

Table 10: Average ground density

	points per square meter	points per square foot
Ground Density	3.55	0.33

Figure 7: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).





[Page Intentionally Blank]

Appendix A : PLS Certification

WSI provided LiDAR Services for OLC Lower Malheur 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.

_____________________________ August 4th, 2015

John English
Project Manager
WSI, a Quantum Spatial Company

I, Christopher Glantz, being duly registered as a Professional Land Surveyor in the state of Oregon, 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 March 21, 2015 and April 9, 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".

_____________________________ August 4, 2015

Christopher Glantz, PLS
Land Surveyor
WSI, a Quantum Spatial Company

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648

RENEWS: 6/30/2017