2016 OLC Canyon Creek

September 30, 2016

Data collected for:
Oregon Department of Geology and Mineral Industries

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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) Canyon Creek Study Area. The Canyon Creek area of interest (AOI) shown in Figure 1 encompasses 161,068 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 occured between June 7 and June 20, 2016. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter. Final products are listed in page 3.

QSI acquires and processes data in the most current, NGS-approved datums and geoid. For Upper Rogue, 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.

Table 1: OLC Canyon Creek delivery details

OLC Canyon Creek Data	
LiDAR Acquisition Dates	6/7/2016 - 6/20/2016
Area of Interest	161,068 acres
Bufered Area of Interest	166,052 acres
Projection	OGIC
Horizontal Datum Vertical Datum	NAD83 (2011) Epoch 2010.00 NAVD88 (Geoid 12A)
Units	International Feet

*See page four for specific acquisition dates.

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

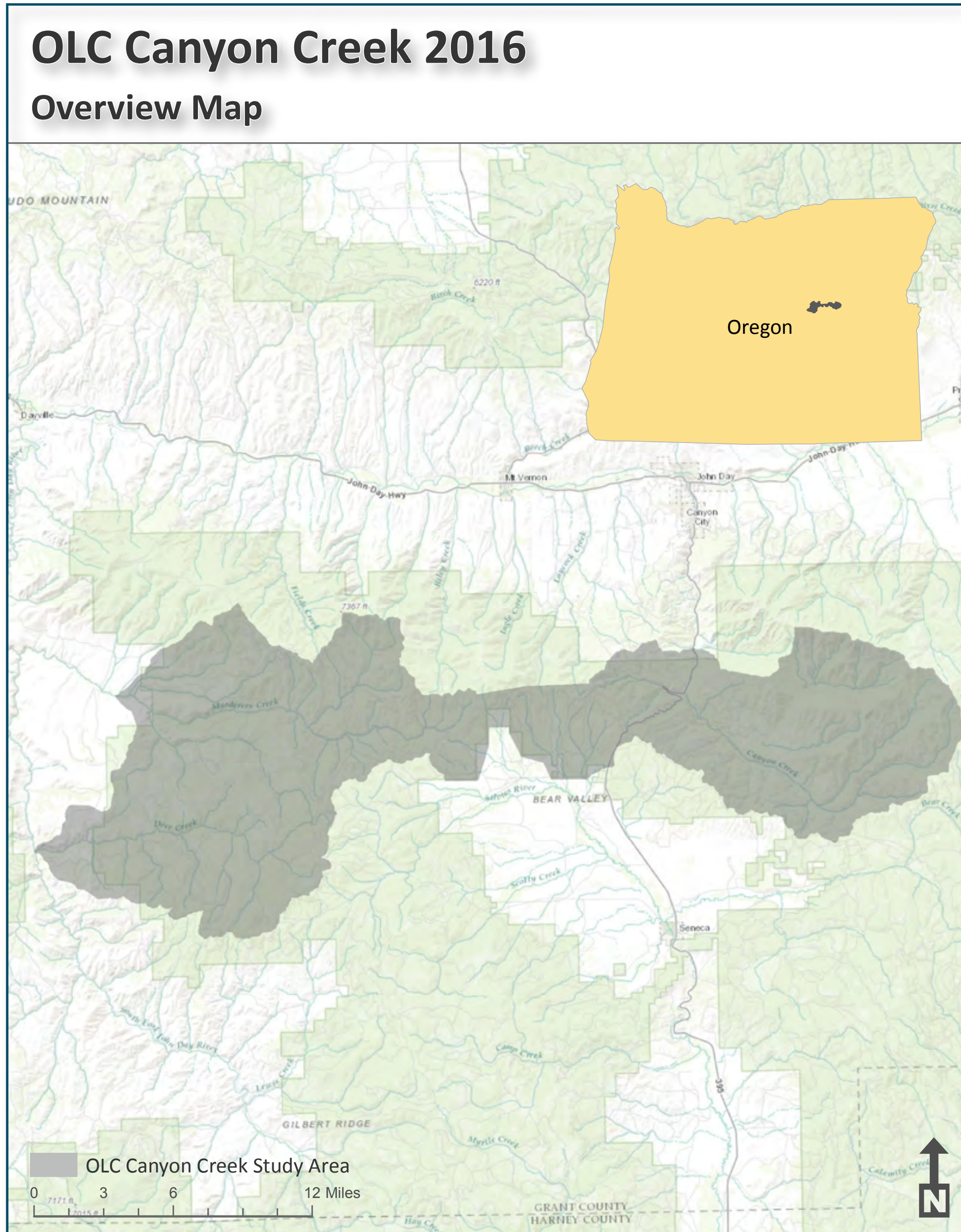


Figure 1: OLC Canyon Creek study area

Deliverable Products

Table 2: Products delivered for OLC Canyon Creek study area.

OLC Canyon Creek Projection: OGIC Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12A) Units: International Feet	
Points	LAS v 1.2 tiled by 0.075 minute USGS quadrangles • Default (1) and ground (2) • 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 • LiDAR ground density images 1.5 foot GeoTiffs tiled by 7.5 minute USGS quadrangles • Intensity images
Vectors	Shapefiles (*.shp) • Data extent (TAF) • TAF tile index of 0.075 minute USGS quadrangles • TAF tile index of 7.5 minute USGS quadrangles
Metadata	• FGDC compliant metadata for all data products
Projection: UTM Zone 11N Horizontal Datum: NAD83 (2011) Vertical Datum: NAVD88 (GEOID12A) Units: Meters	
Vectors	• Acquisition flightlines • Ground survey points • Monuments • Reserved ground survey points

Aerial Acquisition

LiDAR Survey

The LiDAR survey utilized a Leica ALS80 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 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).

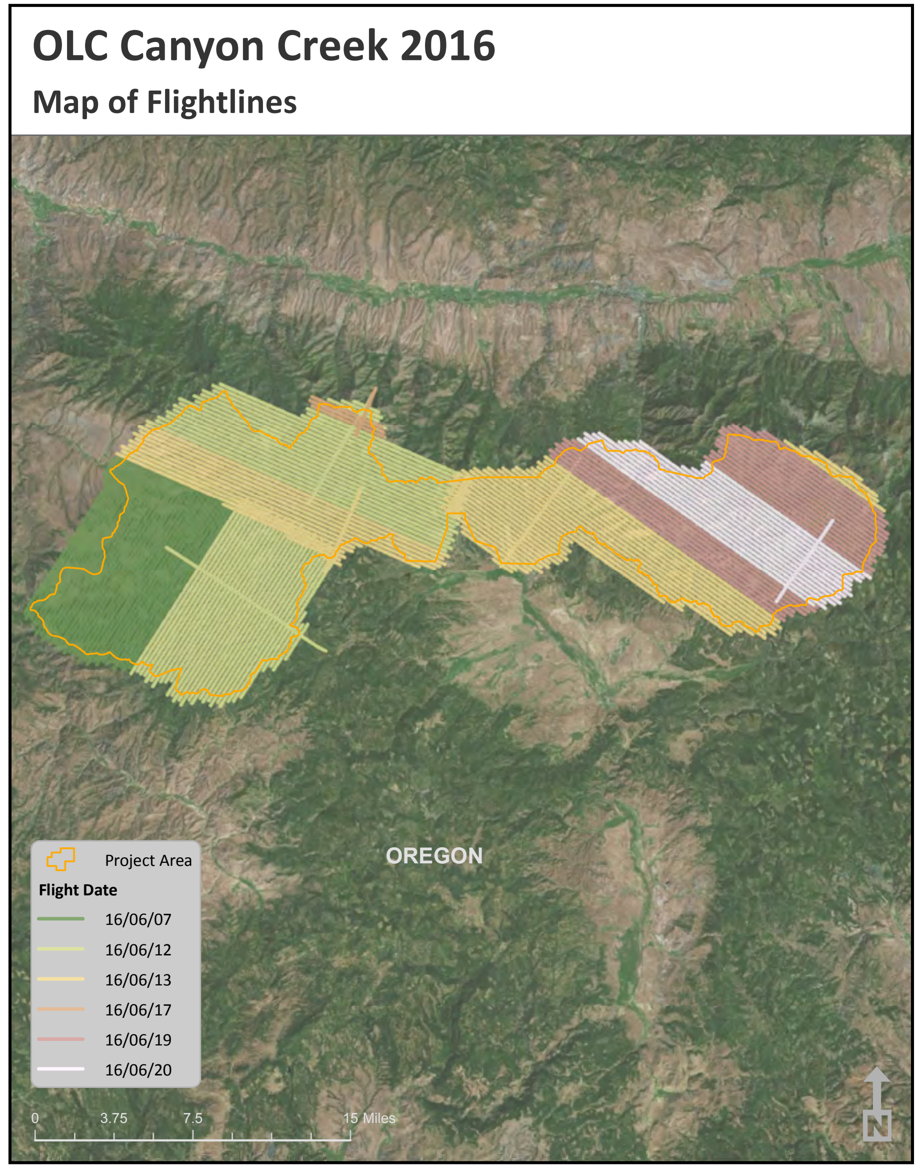


Figure 2: OLC Canyon Creek Acquisition Map

Table 3: OLC Canyon Creek acquisition specifications

OLC Canyon Creek	
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 kHz
Overlap	100% overlap with 60% sidelap

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.

Instrumentation

All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas. Rover surveys for GSP collection were conducted with Trimble R8 GNSS receivers. See Table 4 for specifications of equipment used.

Monumentation

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. New monumentation was set using 5/8" x 30" rebar topped with stamped 2-1/2" aluminum caps. QSI utilized three existing monuments and established one new monument for the OLC Canyon Creek project. 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 6 provides the list of monuments used in the OLC Canyon Creek study area.

Methodology

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 4: 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 R8 Model 2	TRMR8_GNSS	Rover

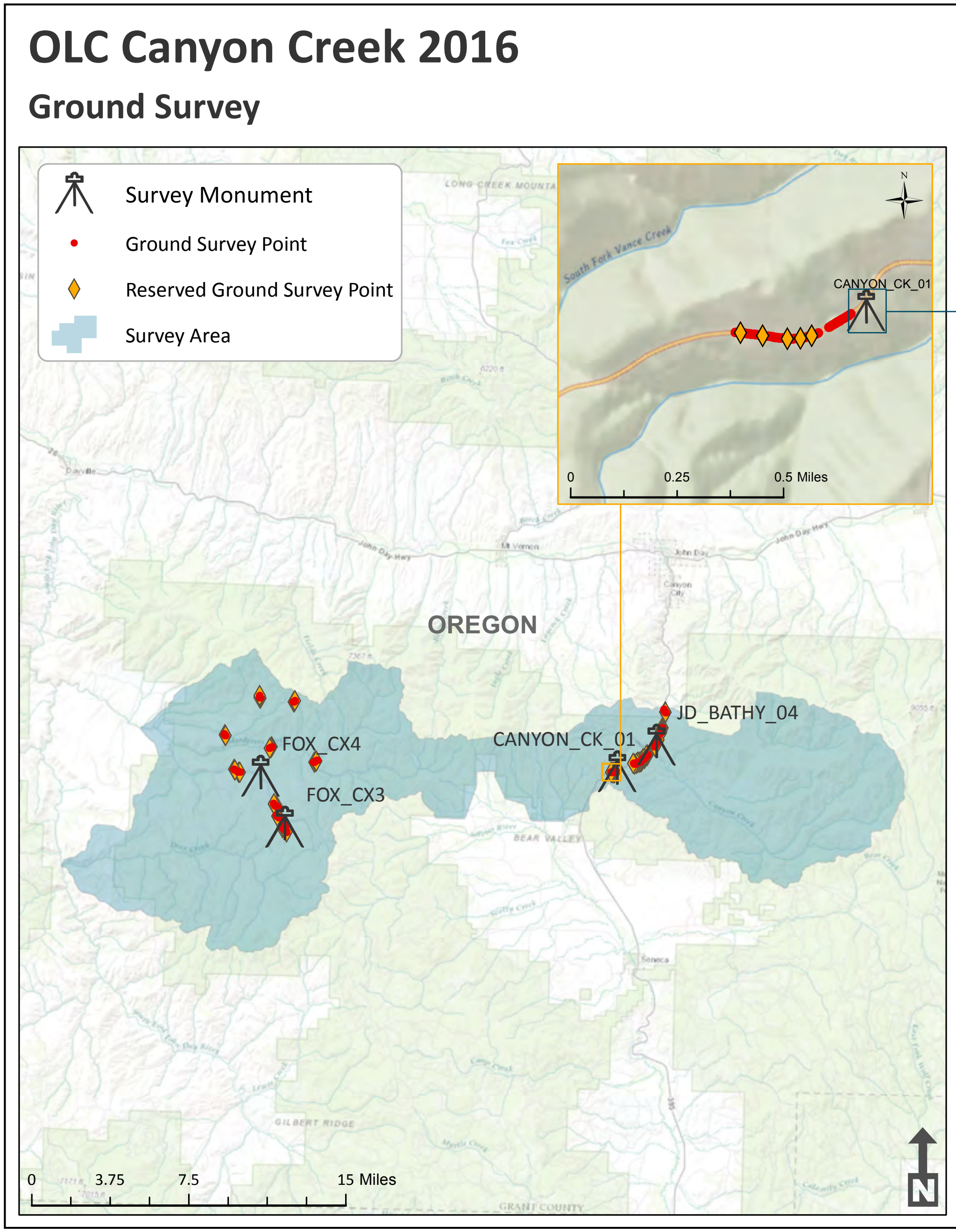


Figure 3: OLC Canyon Creek study area ground control

Table 5: Monument accuracy

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

Figure 4: CANYON_CR_01 monument

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
CANYON_CK_01	44° 16’ 03.83941”	-118° 59’ 46.80009”	1477.880	1495.913
FOX_CX3	44° 13’ 23.94980”	-119° 18’ 52.61851”	1409.174	1427.473
FOX_CX4	44° 15’ 29.26759”	-119° 20’ 22.44183”	1351.184	1369.482
JD_BATHY_04	44° 17’ 12.63576”	-118° 57’ 34.69074”	1159.512	1177.514

Table 6: OLC Canyon Creek monuments. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A

Figure 5: Monument set up over existing FOX_CX4 base station used in OLC Canyon Creek area ground survey

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 196 full and partial flightlines and over 5 billion sample points.

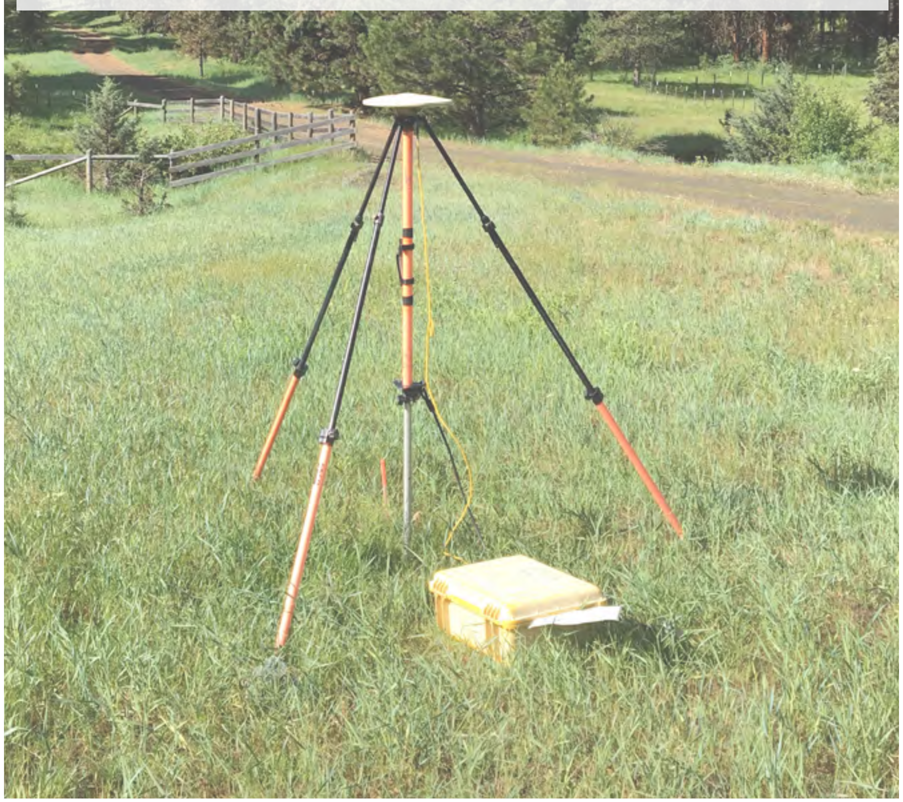


Table 7: Relative accuracy

Relative Accuracy Calibration Results		
Project Average	0.030 m	0.100 ft
Median Relative Accuracy	0.024 m	0.079 ft
1σ Relative Accuracy	0.036 m	0.118 ft
2σ Relative Accuracy	0.059 m	0.196 ft
Flightlines	196	
Sample points	5,357,404,900	

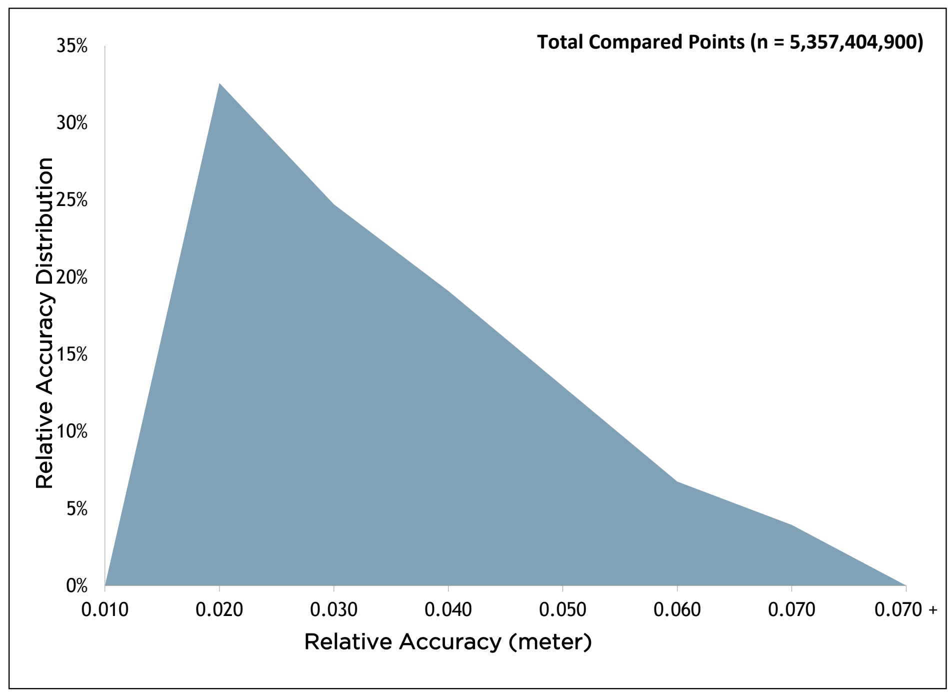


Figure 6: Relative accuracy based on 196 flightlines.

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 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 Canyon Creek study area, a total of 1,343 GSPs were collected and used for calibration of the LiDAR data. An additional 72 reserved ground survey points were collected for independent verification, resulting in a non-vegetated vertical accuracy (NVA) of 0.064 meters, or 0.211 feet.

Table 8: Vertical accuracy

Vertical Accuracy Results		
Sample Size (n)	72 Reserved Ground Survey Points	
NVA (RMSE*1.96)	0.064 m	0.211 ft
Root Mean Square Error	0.033 m	0.108 ft
1 Standard Deviation	0.039 m	0.128 ft
2 Standard Deviation	0.079 m	0.259 ft
Average Deviation	0.032 m	0.106 ft
Minimum Deviation	-0.095 m	-0.312 ft
Maximum Deviation	0.039 m	0.128 ft

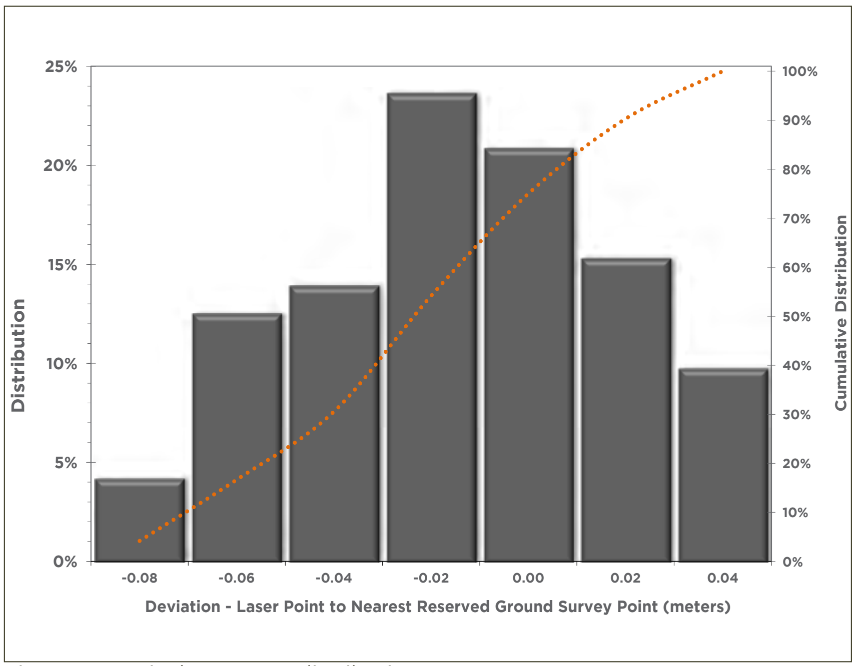


Figure 7: Vertical Accuracy distribution

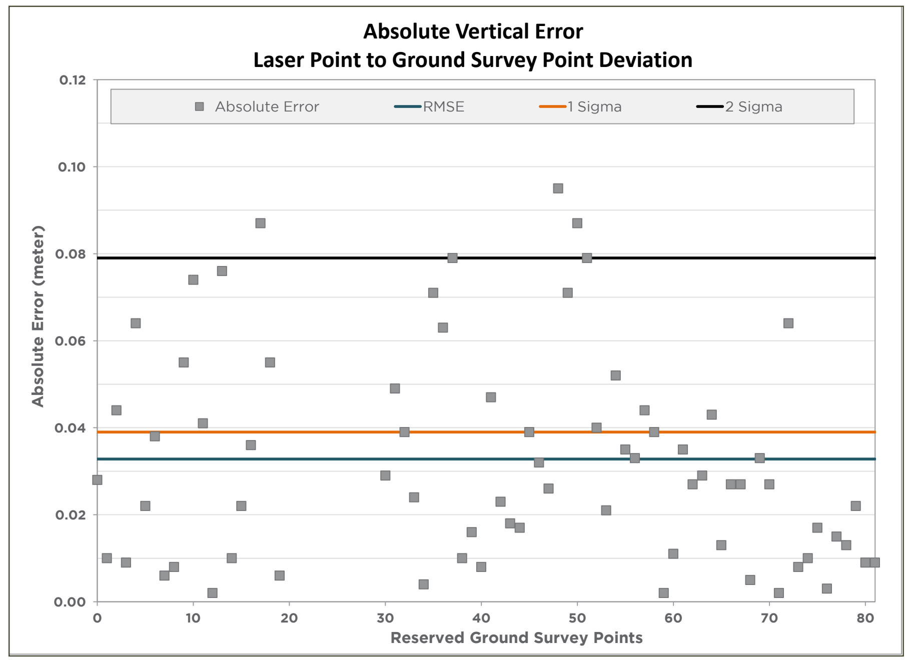


Figure 8: GSP absolute error

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. Densities are reported for the delivery area.

Average Pulse Density	pulses per square meter	pulses per square foot
	11.00	1.02

Table 9: Average pulse density

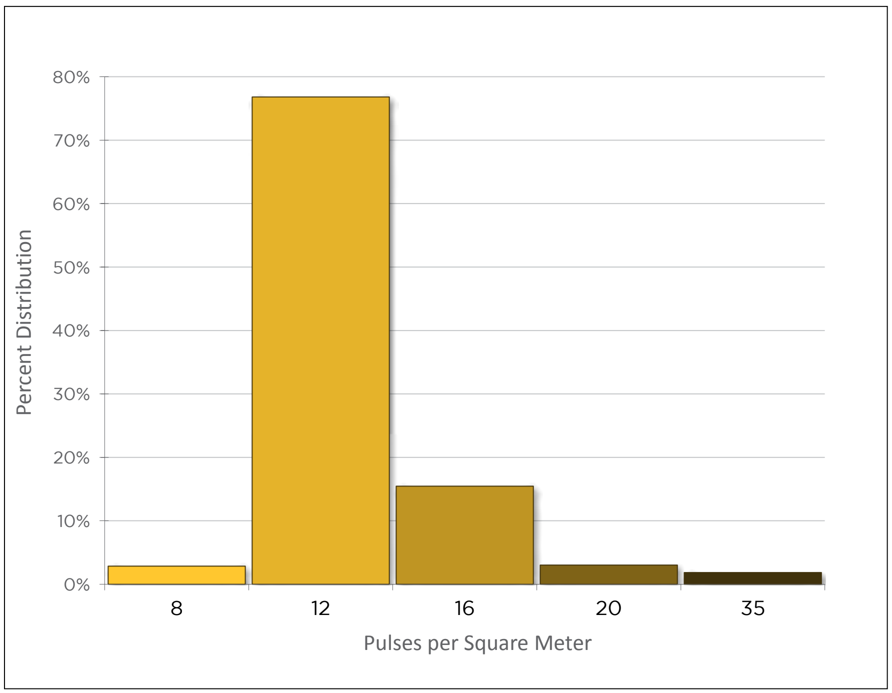
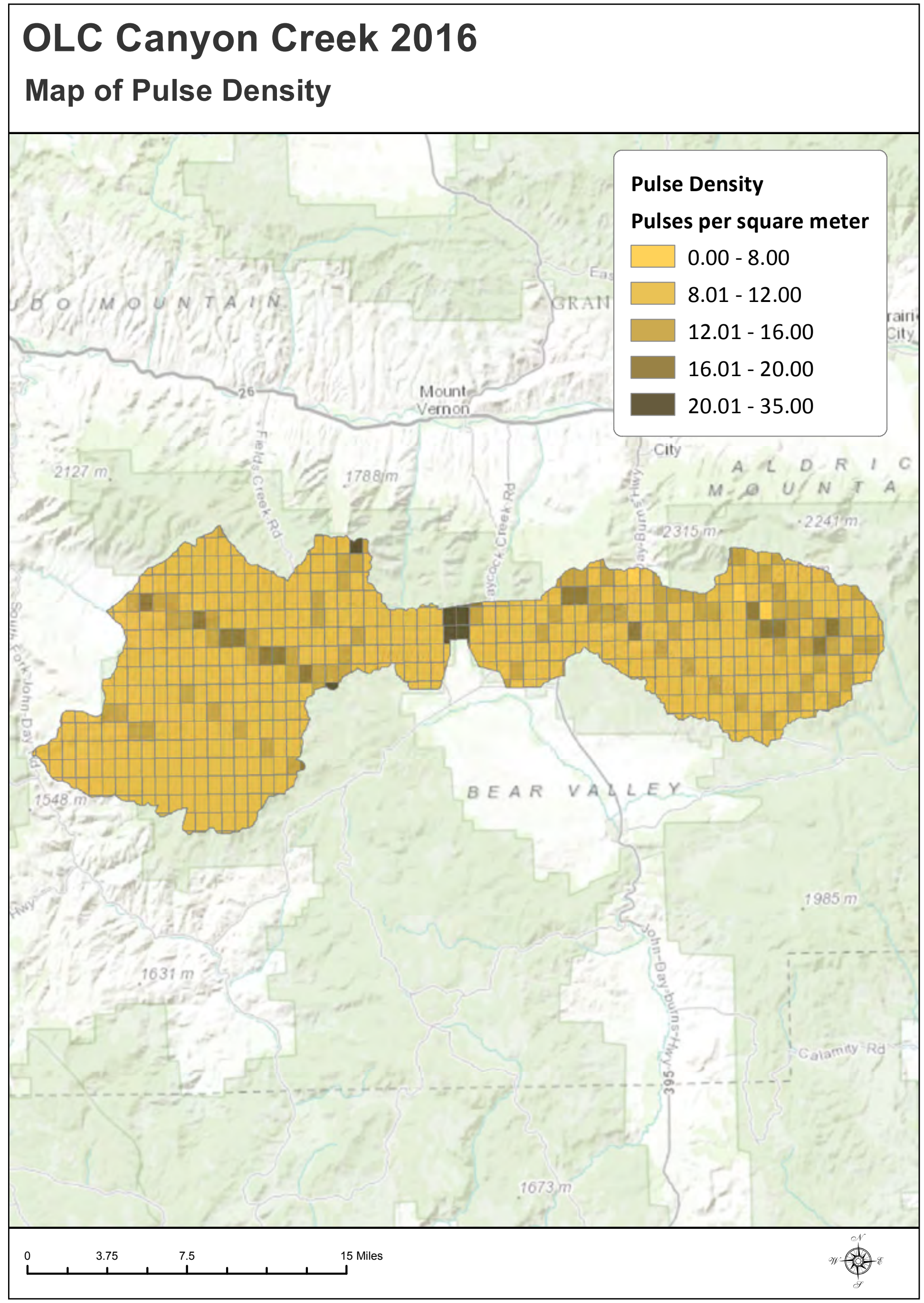


Figure 9: Average pulse density per 0.75' USGS Quad (color scheme aligns with density chart).



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 delivery area.

Average Ground Density	points per square meter	points per square foot
	2.45	0.23

Table 10: Average ground density

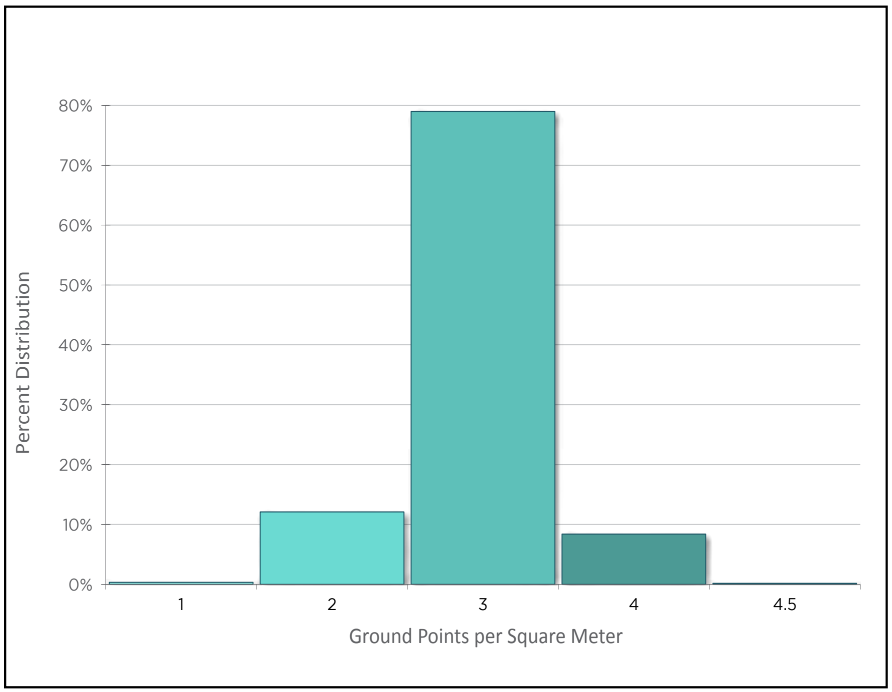
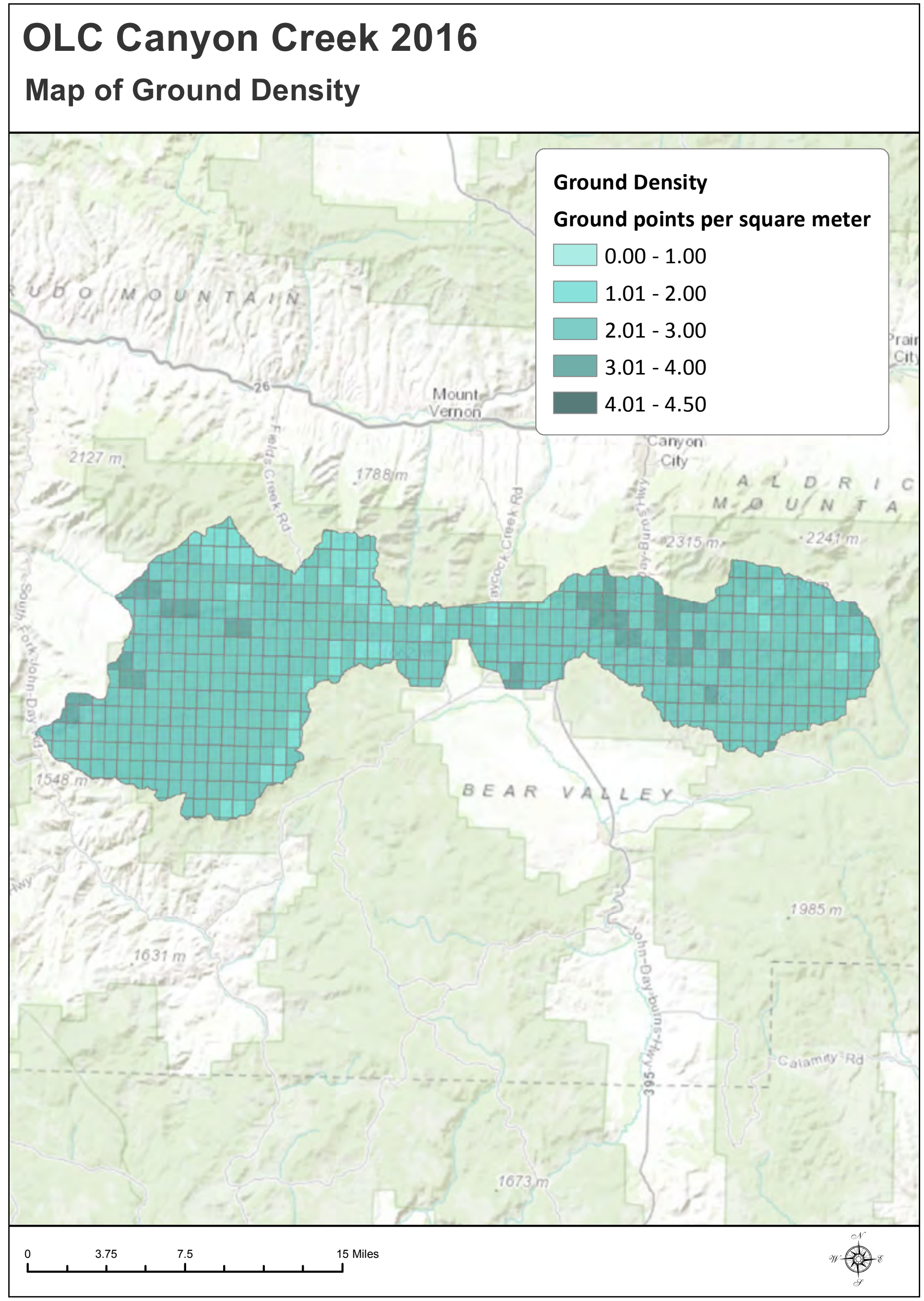


Figure 10: Average ground density per 0.75' USGS Quad (color scheme aligns with density chart).



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Appendix A : PLS Certification

Quantum Spatial, Inc. provided LiDAR services for the 2016 OLC Canyon Creek project as described in this report.

I, Evon P. Silvia, 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 June 7, 2016 and June 20, 2016.

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”.

Evon P. Silvia 2016.09.30 14:01:59 -07'00'

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