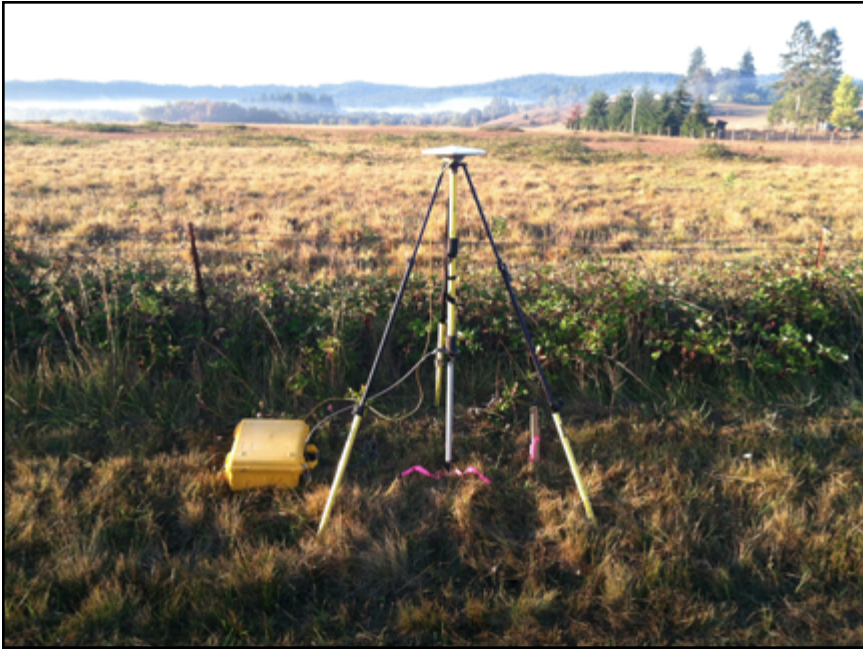# OLC Lane County: Delivery 1

Base station set up over control "LANE 19" and WSI survey cap.

Data collected for:
Oregon Department of Geology and Mineral Industries

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Prepared by:
WSI

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Contents

Trimble base station set up over LANE_13 monument in Delivery Area One.

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radio Metric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area One, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,245,900 acres. Delivery Area One encompasses 71,034 acres.
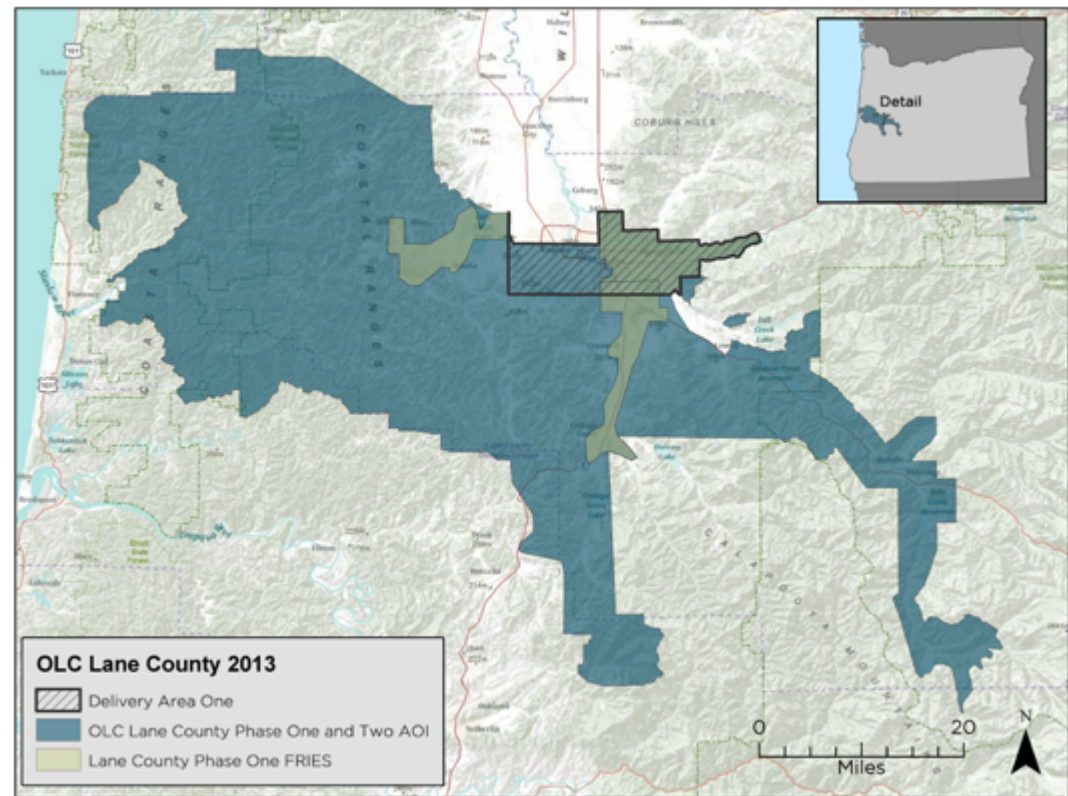
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Delivery Area One data collection occurred between September 7, 2013 and September 14, 2013. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5-foot intensity rasters, 3-inch orthophotos, ground density rasters, study area vector shapes, and corresponding statistical data. Final deliverables are projected in Oregon Lambert, endorsed by the Oregon Geographic Information Council (OGIC).[1]

1 http://www.oregon.gov/DAS/EISPD/GEO/pages/coordi-nation/projections/projections.aspx

Study Area

OLC Lane County AOI Data Delivered December 30, 2013	
Acquisition Dates	September 7-14, 2013
Delivery Area One Area of Interest	69,286.5 acres
Delivery Area One Total Area Flown	71,034 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 NAVD88 (Geoid 12A)
Units	International Feet

OLC Lane County 2013
- Delivery Area One
- OLC Lane County Phase One and Two AOI
- Lane County Phase One FRIES

Aerial Acquisition
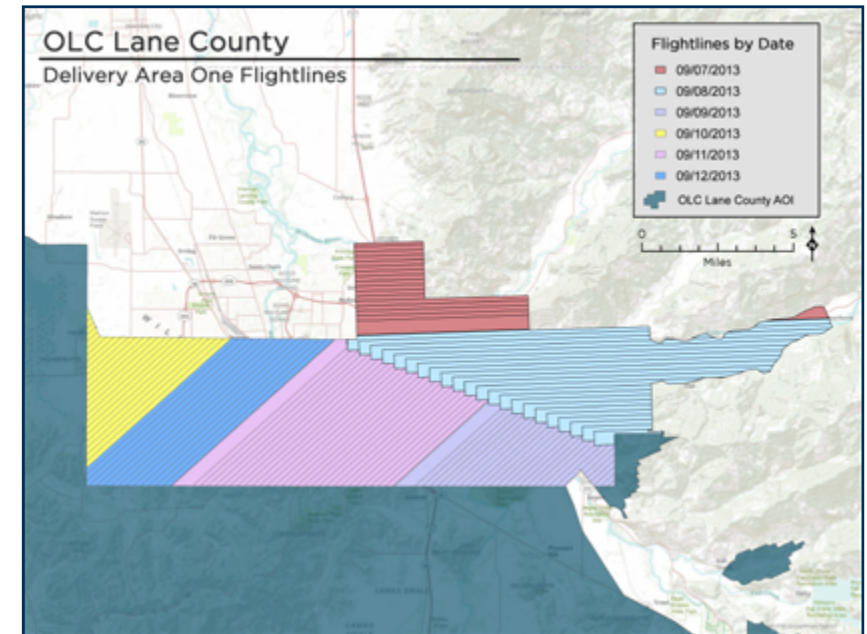

Cessna Caravan

LiDAR Survey

The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 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, 330 flightlines provide coverage of the study area.
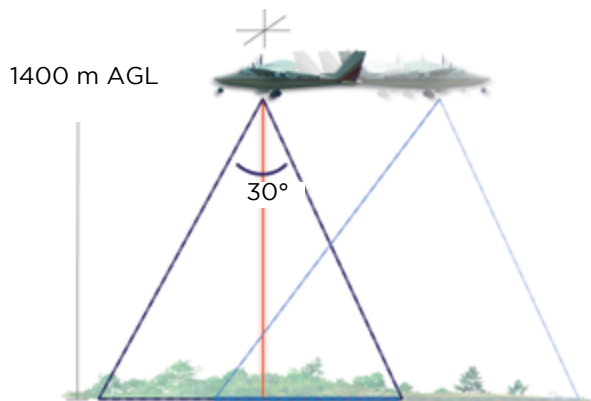
Project Flightlines

1400 m AGL
30°

| Lane County Acquisition Specs	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper-PA
Survey Altitude (AGL)	1400 m
Pulse Rate	190-198 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

Aerial Acquisition

Photography

The photography or Four-Band Radio Metric Image Enhanced Survey (FRIES) utilized an UltraCam Eagle 260 megapixel camera mounted in a Cessna 208B Caravan. The UltraCam Eagle is an 80 mm, 260 megapixel large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and contains a fully integrated UltraNav flight management system with a POS-AV 510 IMU embedded within the body of the camera unit.

The Eagle was designed with high efficiency, high resolution, and high accuracy in mind. With a physical pixel size of 5.2 microns, the Eagle captures a 6.5 cm ground sample distance (GSD) at a flying height of 1,000 meters AGL. This sensor size of the camera is 20,010 x 13,080 pixels in size, which allows for total ground coverage of 1300 x 850 meters within a single captured image frame at 1,000 meters AGL. This large footprint coupled with a fast frame rate (1.8 seconds per frame) allows for highly efficient acquisition. The precise integrated UltraNav system is accurate enough for direct georeferencing in many applications.

The UltraCam Eagle simultaneously collects panchromatic and multispectral (RGB, NIR) imagery in 14 bit format. The spectral sensitivity of the panchromatic charged coupled device (CCD) array ranges from 400-720 nm, with 16,000 grey values per pixel. Four separate 27 mm lenses collect red (590-720 nm), green (490-660 nm), blue (410-590 nm) and near infrared (690-990 nm) light. Panchromatic lenses collect high resolution imagery by illuminating nine CCD arrays, writing nine raw image files. RGB and NIR lenses collect lower resolution imagery, written as four individual raw image files. Level 2 images are created by stitching together raw image data from the nine panchromatic CCDs, and ultimately combined with the multispectral image data to yield Level 3 pan-sharpened TIFFs in either 8 bit format.
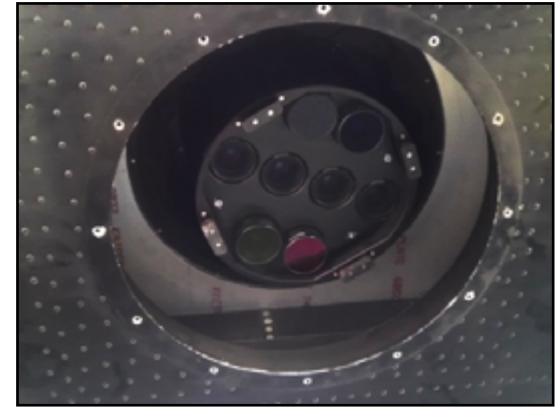
Above: UltraCam Eagle lens configuration as viewed from the Cessna Caravan.

Above: A Cessna Grand Caravan 208B was employed in the collection of all orthoimagery.

Below: UltraCam Eagle installed in the aircraft.

Orthophoto Processing

Within the UltraMap software suite, raw acquired images are radiometrically and geometrically corrected using the camera's calibration files and output as Level 2 images. The resulting radiometry is then manually edited to ensure each image has the appropriate tone, no pixels are clipped, and to blend each image with its neighbors. Once radiometry has been edited, separate RGBI and Panchromatic images are blended together to form single level 3 pan-sharpened 4 band TIFF images.

The kinematic GPS positional data is post-processed in office, using static monument coordinates from base stations that were occupied for a minimum of 6 hours, and were running during the time of acquisition. Photo position and orientation are calculated by linking the time of image capture, the corresponding aircraft position and attitude, and the smoothed best estimate of trajectory (SBET) data in POSPacMMS, and outputting an initial Exterior Orientations (EO) file.

The EO file is combined with level 3 TIFFs within the Inpho software suite to place the images frames spatially. Aerial triangulation is performed to tie the image frames to each other, and to align them with surveyed ground control coordinates. A point cloud ground model is generated from the image frames by finding matching pixels between images and calculating the coordinates of each extracted point. Triangulated image frames are then draped onto a DEM, derived from the extracted point cloud and orthorectified. Individual orthorectified tiffs are blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista. The 4-Band image mosaic is tiled to create a useable GeoTIFF raster product.

The 4-band GeoTIFF format allows for flexibility in image analysis and display. By adjusting the image band setup to display the near infrared spectral band as red (this display is known as color-infrared), vegetation stands out extremely vividly in the orthophoto mosaic.

Digital Orthophotography Survey Specifications	
Aircraft	Cessna 208-B Grand Caravan
Sensor	UltraCam Eagle
Altitude	1,846 m AGL
GPS Satellite Constellation	6
GPS PDOP	3.0
GPS Baselines	≤ 13nm
Image	8-bit GeoTIFF
Along Track Overlap	60%
Spectral Bands	Red, Green, Blue, NIR
Resolution	3 in. pixel size

**Below:** Trimble R7 set up over Lane_19

Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over three monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify daily variance. Multiple sessions were processed over the same monument to confirm antenna height measurements and reported position accuracy.

Instrumentation

For this study area all Global Navigation Satellite System (GNSS) survey work utilizes a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points. The Trimble GPS R8 unit is used primarily for real time kinematic (RTK) work but can also be used as a static receiver. For RTK data, the collector begins recording after remaining stationary for five seconds then calculating the pseudo range position from at least three epochs with the relative error under 1.5 centimeters horizontal and 2.0 centimeters vertical. All GPS measurements are made with dual frequency L1-L2 receivers with carrier-phase correction.

Monumentation

Existing and established survey benchmarks serve as control points during LiDAR acquisition, including those previously set by WSI. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own monuments. These monuments are spaced at a minimum of one mile 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, Inc. Control." Three new monuments were established and occupied for the Lane County study area (see Monument table at bottom right).
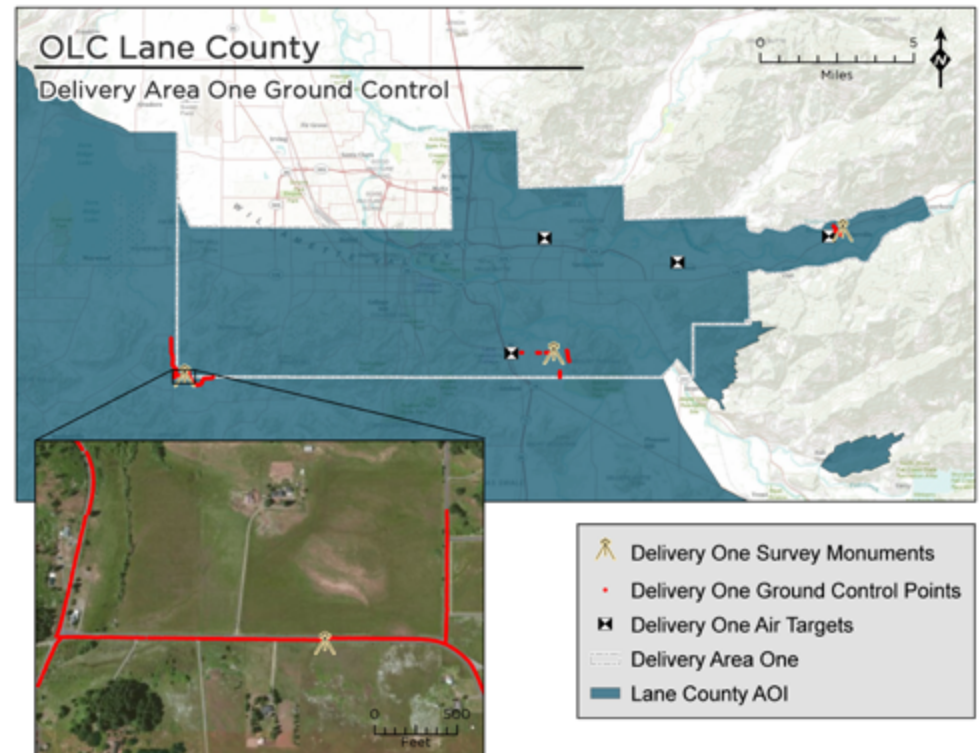
Monuments			
	Datum NAD 83 (2011)		GRS 80
Name	Latitude	Longitute	Ellipsoid Height (m)
LANE_11	44° 04' 08.74341"	-122° 48' 06.59661"	161.587
LANE_13	44° 00' 41.08475"	-122° 59' 27.48519"	119.047
LANE_19	44° 00' 01.44296"	-123° 13' 56.62771"	104.781

Methodology

Each aircraft is assigned a ground crew member with two R7 receivers and an R8 receiver. The ground crew vehicles are equipped with standard field survey supplies and equipment including safety materials. All control points are observed for a minimum of two survey sessions lasting no fewer than two hours. At the beginning of every session the tripod and antenna are reset, resulting in two independent instrument heights and data files. Data are collected at a rate of one hertz, using a 10 degree mask on the antenna.

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

The ground crew uploads the GPS data to the Dropbox website on a daily basis to be returned to the office for Professional Land Surveyor (PLS) oversight, Quality Assurance/Quality Control (QA/QC) review, and processing. OPUS processing triangulates the monument position using three CORS stations resulting in a fully adjusted position. Blue Marble Geographics Desktop v.2.5.0 is used to convert the geodetic positions from the OPUS reports. After multiple days of data have been collected at each monument, accuracy and error ellipses are calculated. This information leads to a rating of the monument based on FGDC-STD-007.2-1998 Part 2 at the 95 percent confidence level (see monument accuracy table).

All RTK measurements are made during periods with a Position Dilution of Precision (PDOP) of less than 3.0 and in view of at least six satellites by the stationary reference and roving receiver. RTK positions are collected on 20 percent of the flight lines and on bare earth locations such as paved, gravel or stable dirt roads, and other locations where the ground is clearly visible (and is likely to remain visible) from the sky during the data acquisition and RTK measurement period(s). In order to facilitate comparisons with LiDAR survey points, RTK measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. RTK points are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations.

Ground professional collecting RTK

Multiple differential GPS units are used in the ground based real-time kinematic portion of the survey. To collect accurate ground surveyed points, a GPS base unit is set up over monuments to broadcast a kinematic correction to a roving GPS unit. The ground crew uses a roving unit to receive radio-relayed kinematic corrected positions from the base unit. This RTK survey allows precise location measurement (≤1.5 centimeters).

WSI collected 1,189 RTK points and utilized 3 new monuments.
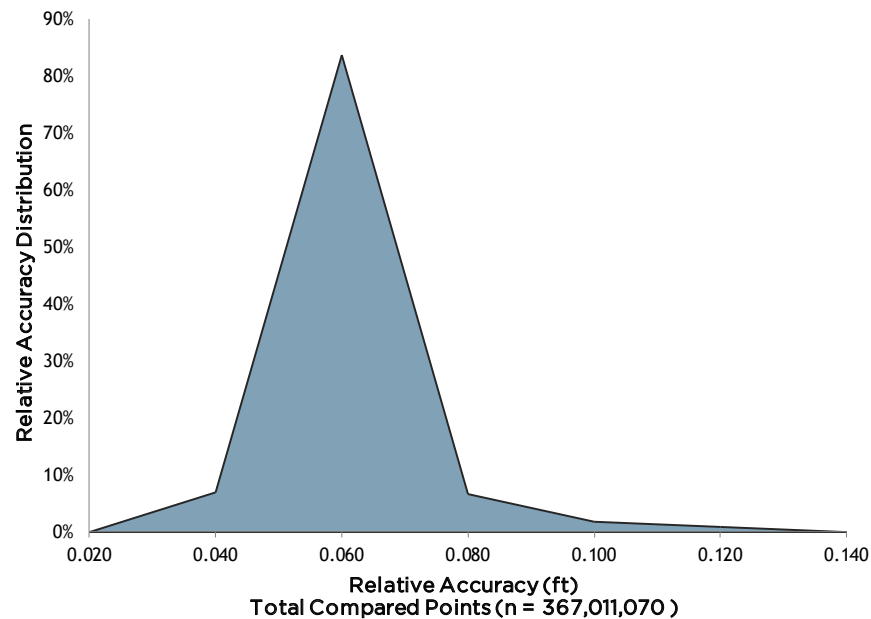

LiDAR Accuracy

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 330 flightlines and over 367 million points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results N = 330 flightlines	
Project Average	0.05 ft. (0.02 m)
Median Relative Accuracy	0.05 ft. (0.02 m)
1σ Relative Accuracy	0.05 ft. (0.02 m)
2σ Relative Accuracy	0.07 ft. (0.02 m)

Relative Accuracy Distribution

Relative Accuracy (ft)
Total Compared Points (n = 367,011,070)

R7 Receiver

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 check points to the closest laser point. 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 95th percentile. For the Lane County Delivery 1 study area, 1,189 RTK points were collected.

For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed to the right.
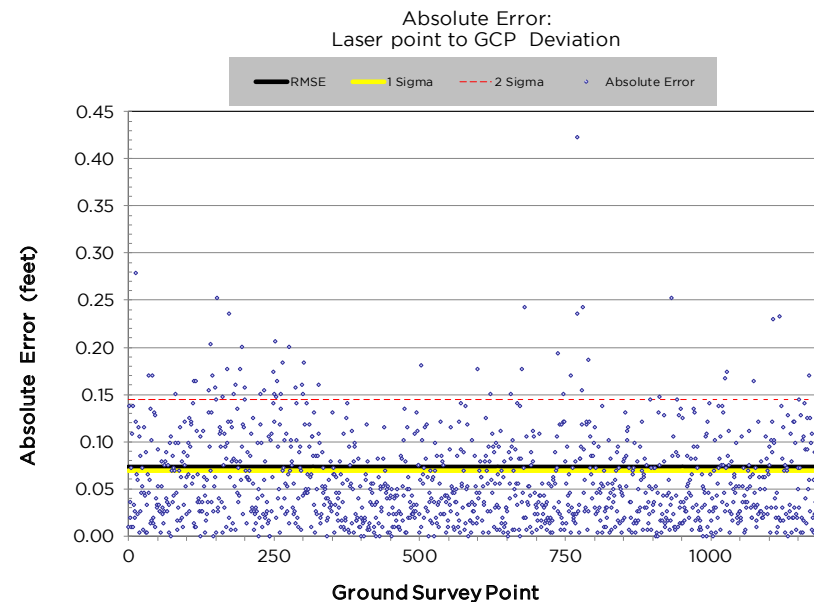
Vertical Accuracy Results	
Sample Size (n)	1,189
Root Mean Square Error	0.07 ft. (0.02 m)
1 Standard Deviation	0.07 ft. (0.02 m)
2 Standard Deviation	0.14 ft. (0.04 m)
Average Deviation	0.06 ft. (0.02 m)
Minimum Deviation	-0.28 ft. (-0.09 m)
Maximum Deviation	0.42 ft. (0.13 m)

Vertical Accuracy Distribution

GCP Absolute Error

Absolute Error:
Laser point to GCP Deviation
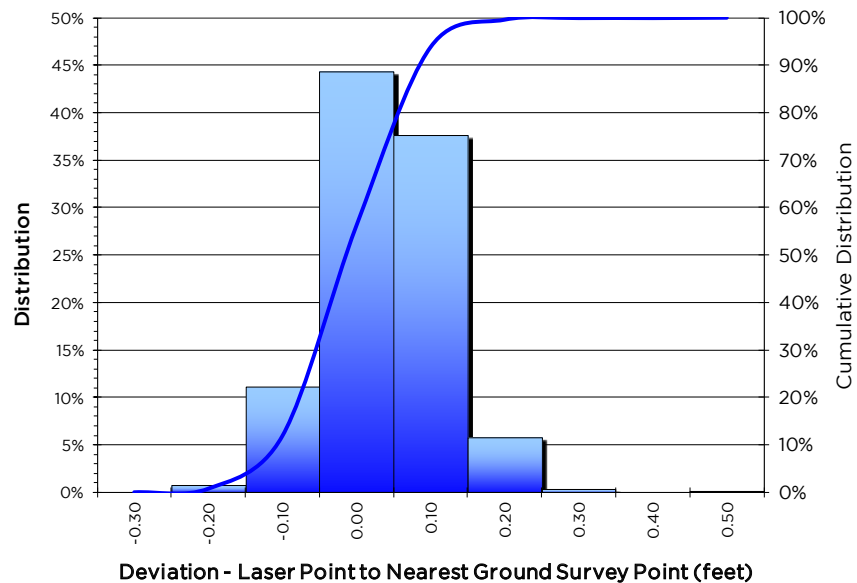
Horizontal Offset Accuracy Assessment

The flightline horizontal offset tool provided by Weyerhaeuser was set to look at 200 meter windows within each tile to find horizontal offsets between flightlines. The maximum elevation of the flightline tool was set at 2000 meters to assure all points were included in the horizontal accuracy calculations. This process is usually performed during the initial calibration stages of the data; for this project however, the tool was provided and run after the data had been finalized and delivered to the primary client as it is not included in the primary contracted scope of work.

Initial horizontal offsets were calculated from the dx and dy values from the spread-sheet created by the flightline tool. The data set was then consolidated to give the average offsets for each flightline, as any adjustments made to the data would be based on adjusting entire flightlines. Flightlines with offsets greater than 30 centi-meter were explored on a tile by tile basis to determine the cause and repairability of the offset. The 30 centimeter threshold for inspection was based upon a 1,400 meter AGL flightplan.

Results

Utilizing the Weyerhaeuser horizontal offset tool, one flightline contained within the OLC Lane County project Delivery Area One was found to have a horizontal offset above 30 centimeters, necessitating inspection. The offset was found at the very edge of flightline. It has been observed that in these cases where offsets are found at flightline edge, buildings that are further towards nadir showed no such offset. With this being the case, attempts to fix the flightlines in question could potentially have resulted in even larger offsets to the areas close to nadir. The decision was made to leave the flightline as originally calibrated. The complete results can be found in the attached document "OLC Lane County Delivery One Horizontal Accuracy Assess-ment".
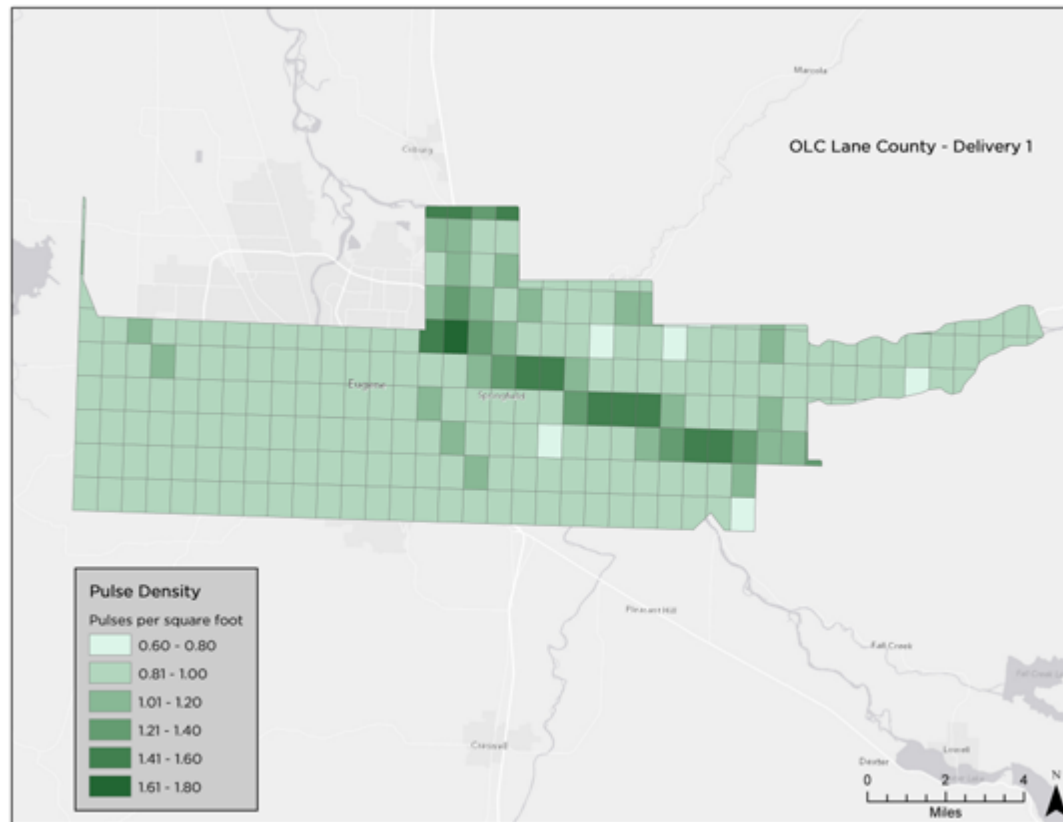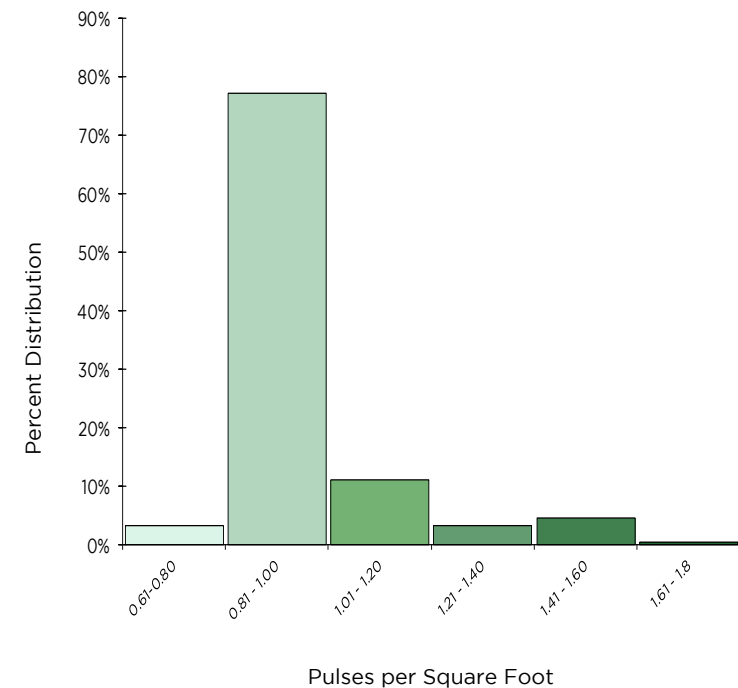
Density

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.

Pulse Density	pulses per square meter	pulses per square foot
	10.15	0.94

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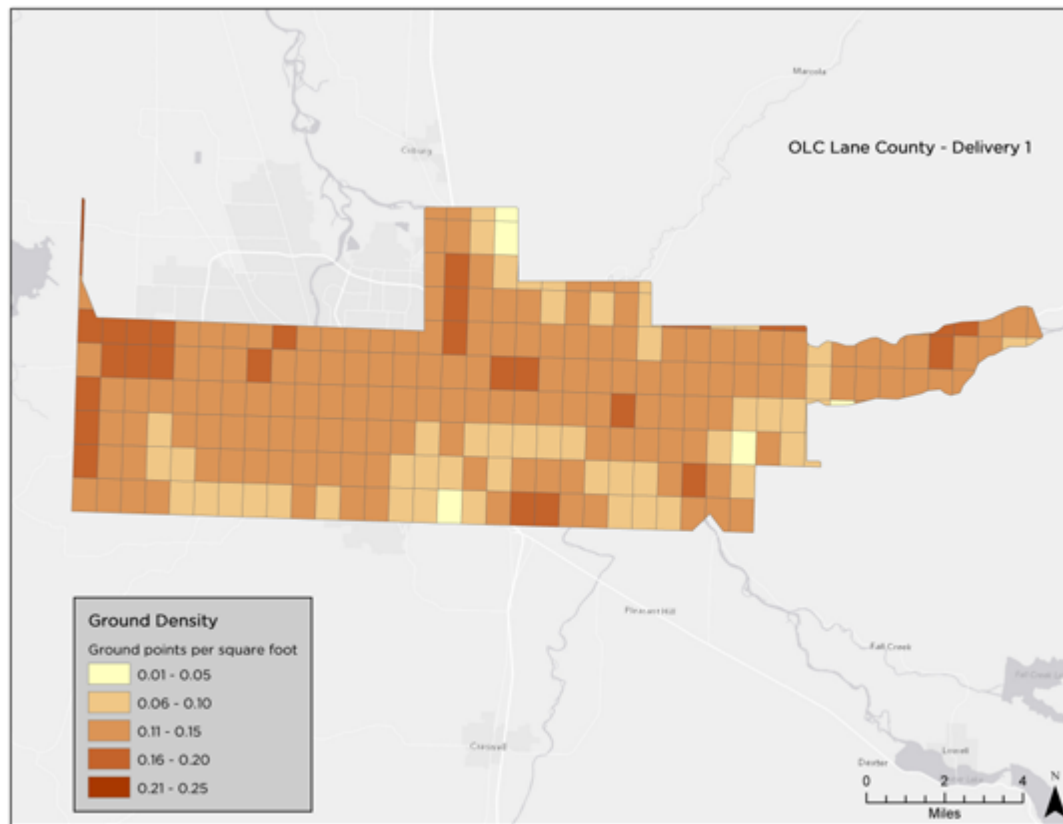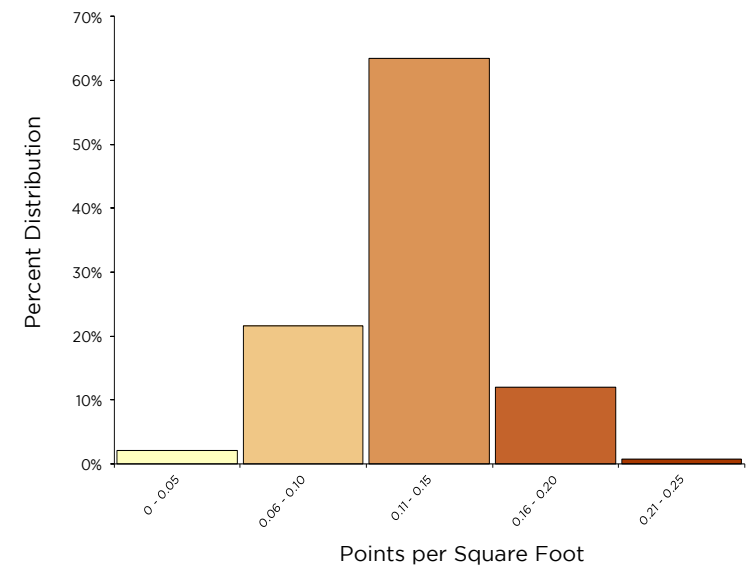

Pulse Density Distribution

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	points per square meter	points per square foot
	1.26	0.12

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

OLC Lane County - Delivery 1

Ground Density
Ground points per square foot
- 0.01 - 0.05
- 0.06 - 0.10
- 0.11 - 0.15
- 0.16 - 0.20
- 0.21 - 0.25

Ground Density Distribution

Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. 18 check points, distributed evenly across the total acquired area, were generated on surface features such as painted road lines and fixed high-contrast objects on the ground surface. They were then compared against check points identified from the LiDAR intensity images. The accuracy of the final mosaic was calculated in relation to the LiDAR-derived check points and is listed below.

Above: Example of co-registration of color images with LiDAR intensity images. **Below:** Examples of permanent air targets located within Lane County project area

 Orthophoto horizontal accuracy results

Orthophoto Horizontal Accuracy (n=18)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.169	0.554
1 Sigma	0.168	0.552
2 Sigma	0.328	1.075

PLS Certificate

WSI provided LiDAR and Orthometric Photo Services for OLC's Lane County project as described in this report.

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

_____

Matthew Boyd
Principle
WSI

I, Christopher W. Brown, 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 and Orthometric Photo project, and that Static GPS occupations on the Base Stations during airborne flights and RTK survey on hard-surface, Air-Targets and GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between September 7, 2013 and September 14, 2013.

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".

_____

Christopher W. Brown, PLS Oregon & Washington
WSI
Portland, OR 97204

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Selected Imagery

Orthophotos: **Top Left:** Main Street Bridge, Springfield, Oregon. **Top Right:** McKenzie View Drive, south of Coburg, Oregon.**Bottom Left:** Kellogg Road, Springfield, Oregon **Bottom Right:** Island Park along the Willamette River, Springfield, Oregon.