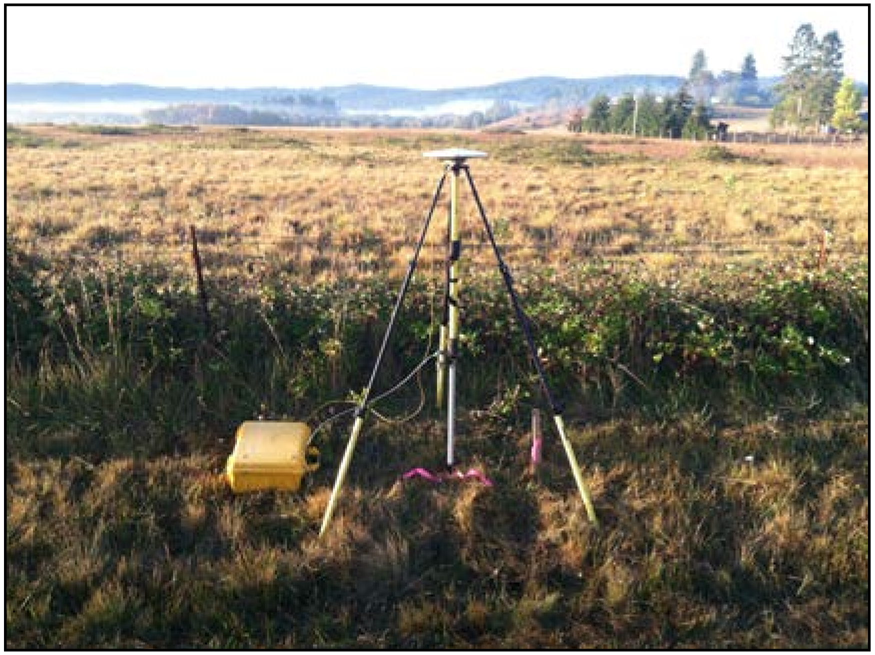
WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 1

December 30, 2013



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:
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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.

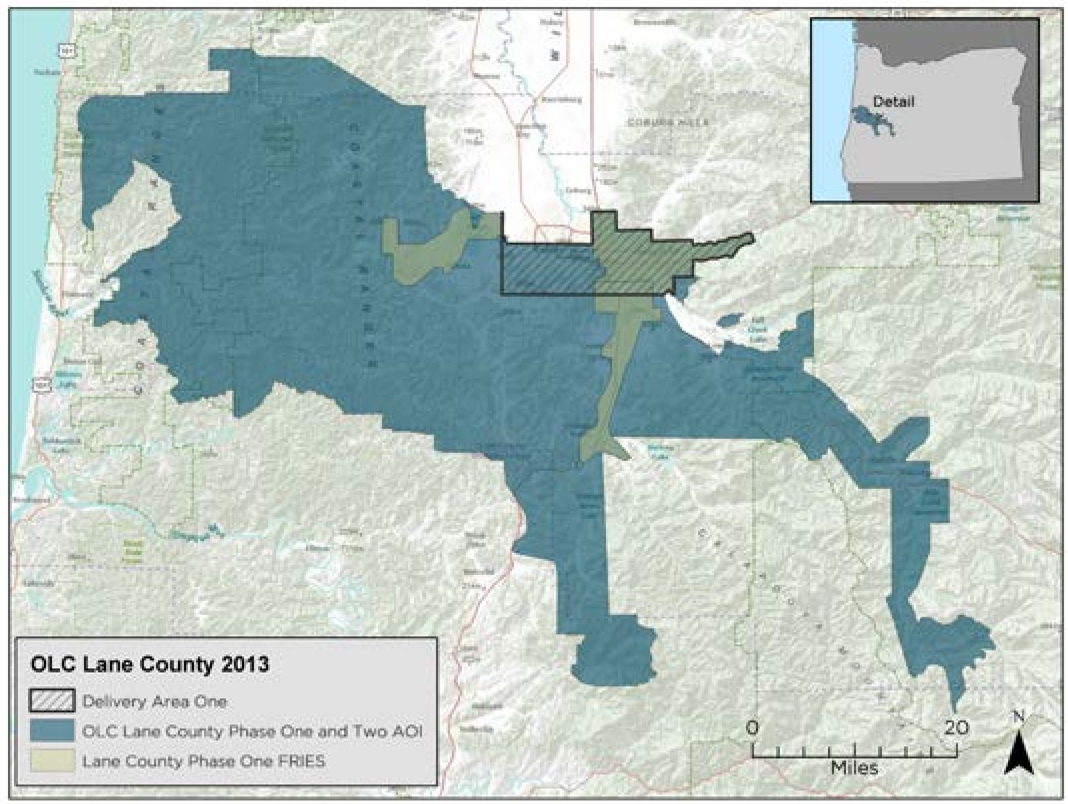
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

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, endoresed by the Oregon Geographic Information Council (OGIC).[1]

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

Study Area



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

Aerial Acquisition

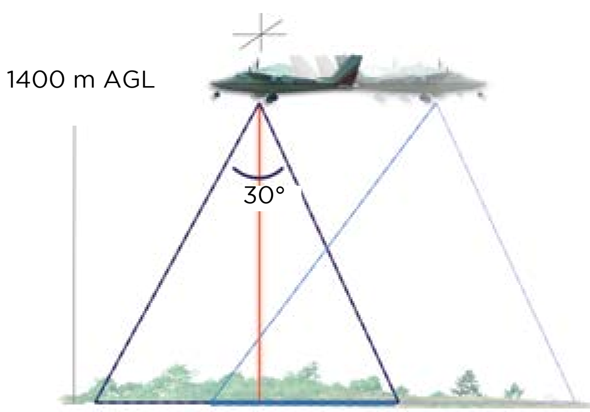
Cessna Caravan

LiDAR Survey

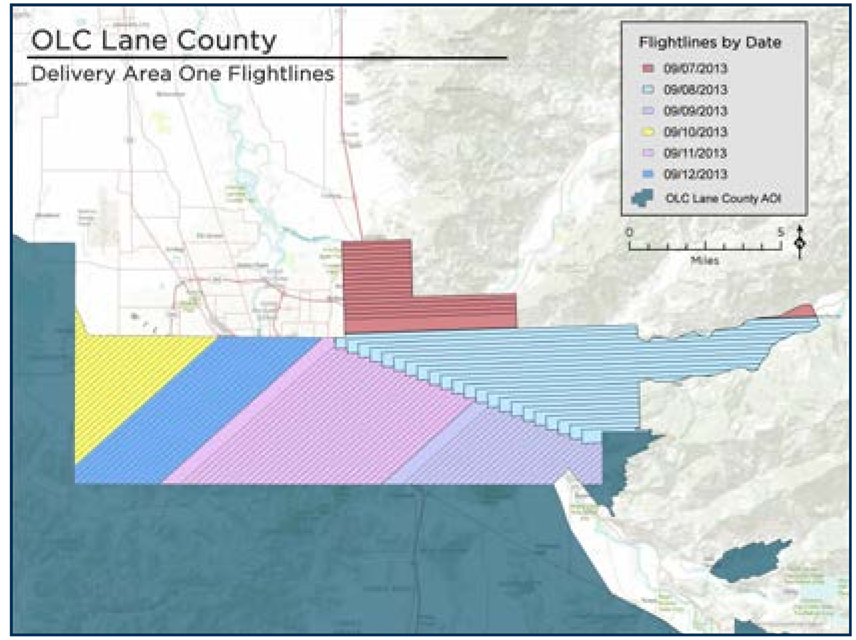
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters above ground level (AGL), capturing a scan angle of +/-15 degrees 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



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

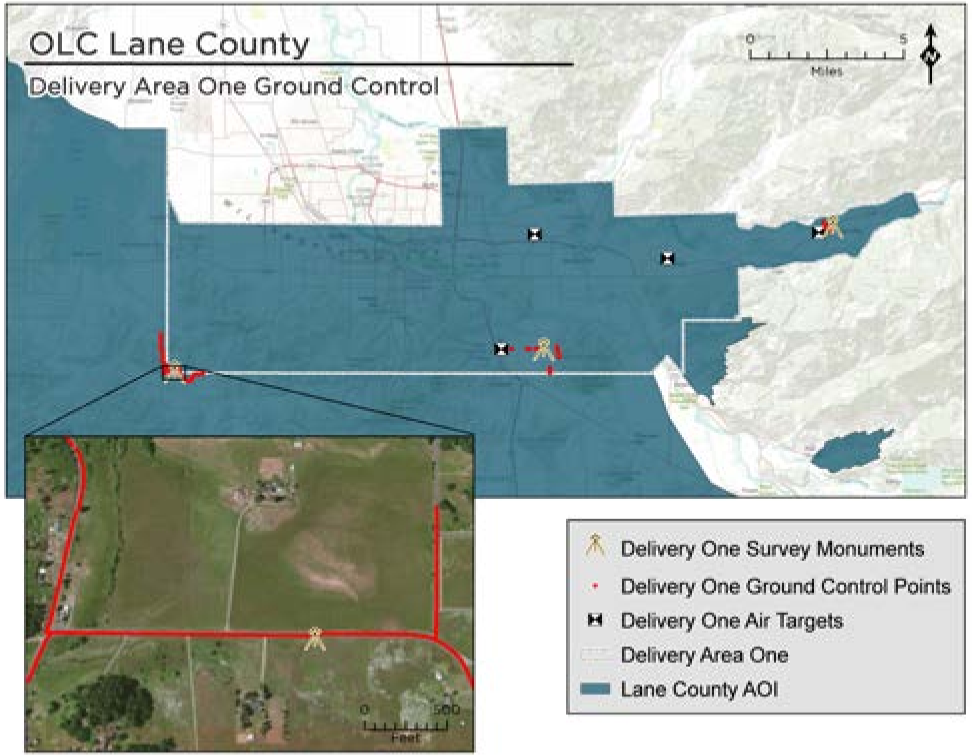
During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over three monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify 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).

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

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).

LiDAR Accuracy

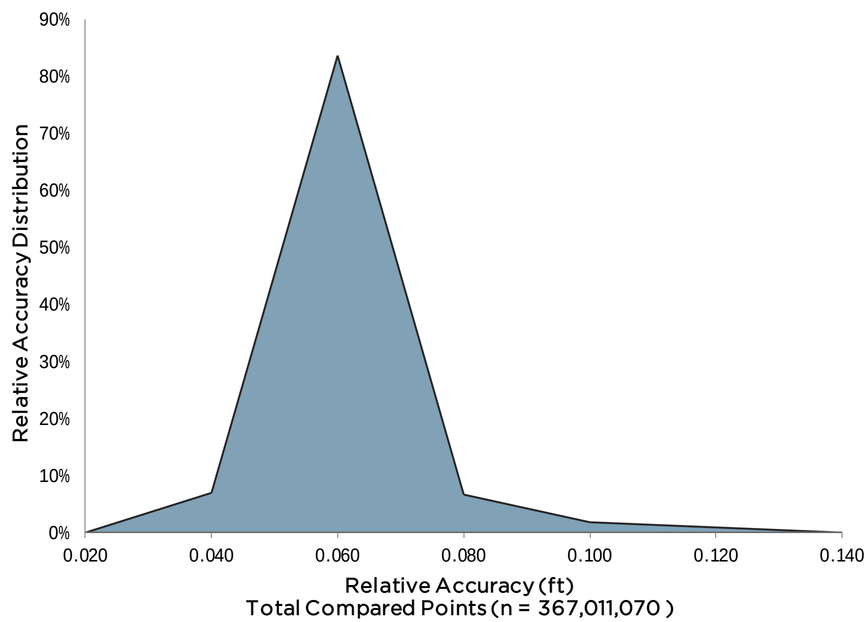
Relative Accuracy

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



R7 Receiver

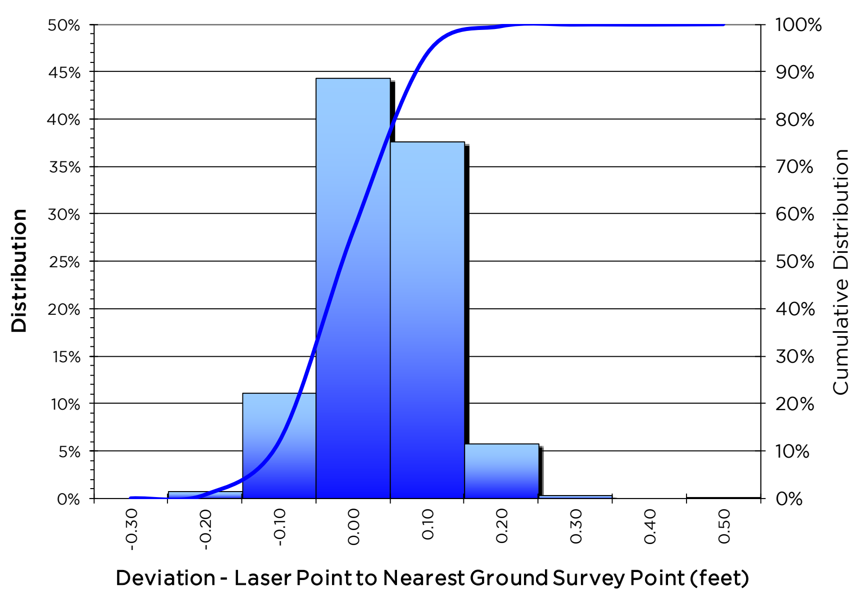
Vertical Accuracy

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.

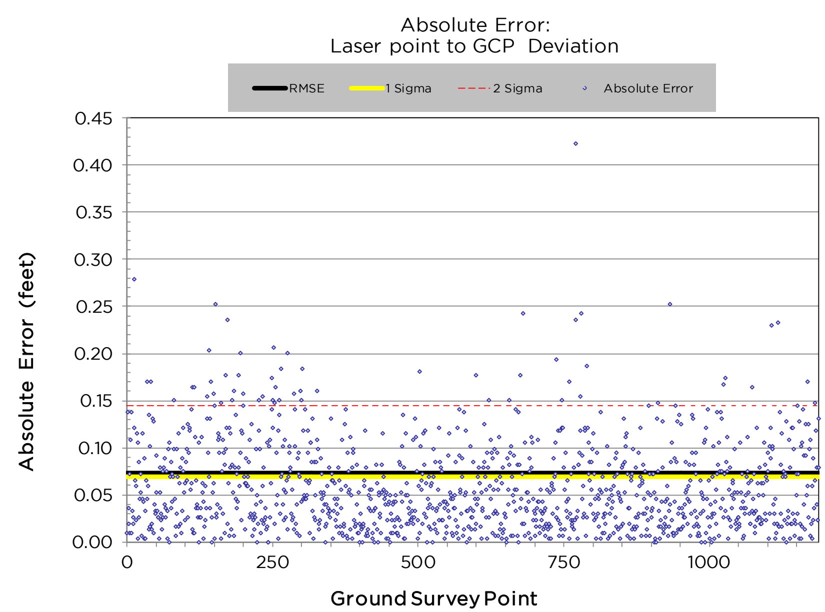
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation 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



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 spreadsheet 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 centimeter 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 Assessment".

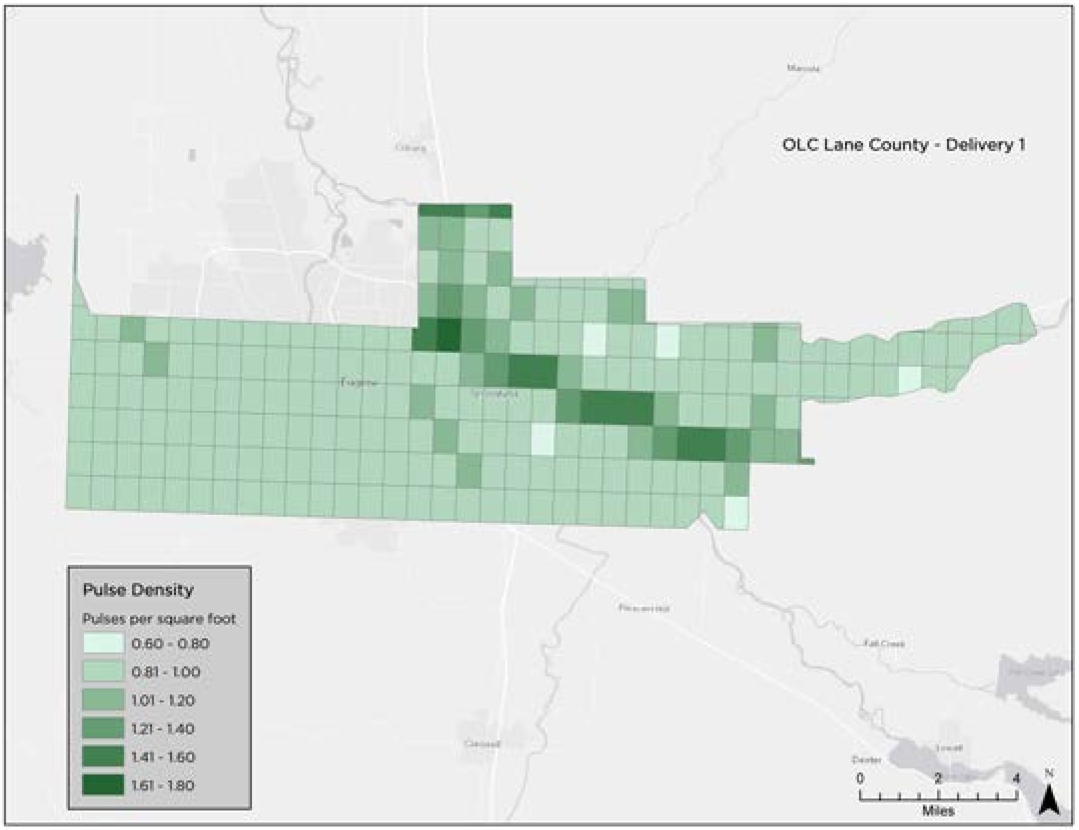
Density

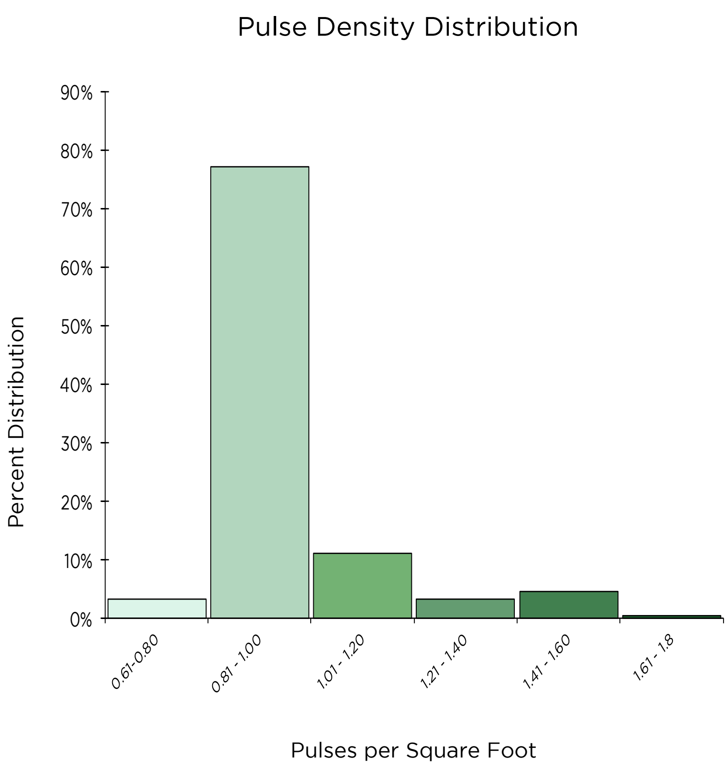
Pulse Density

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)



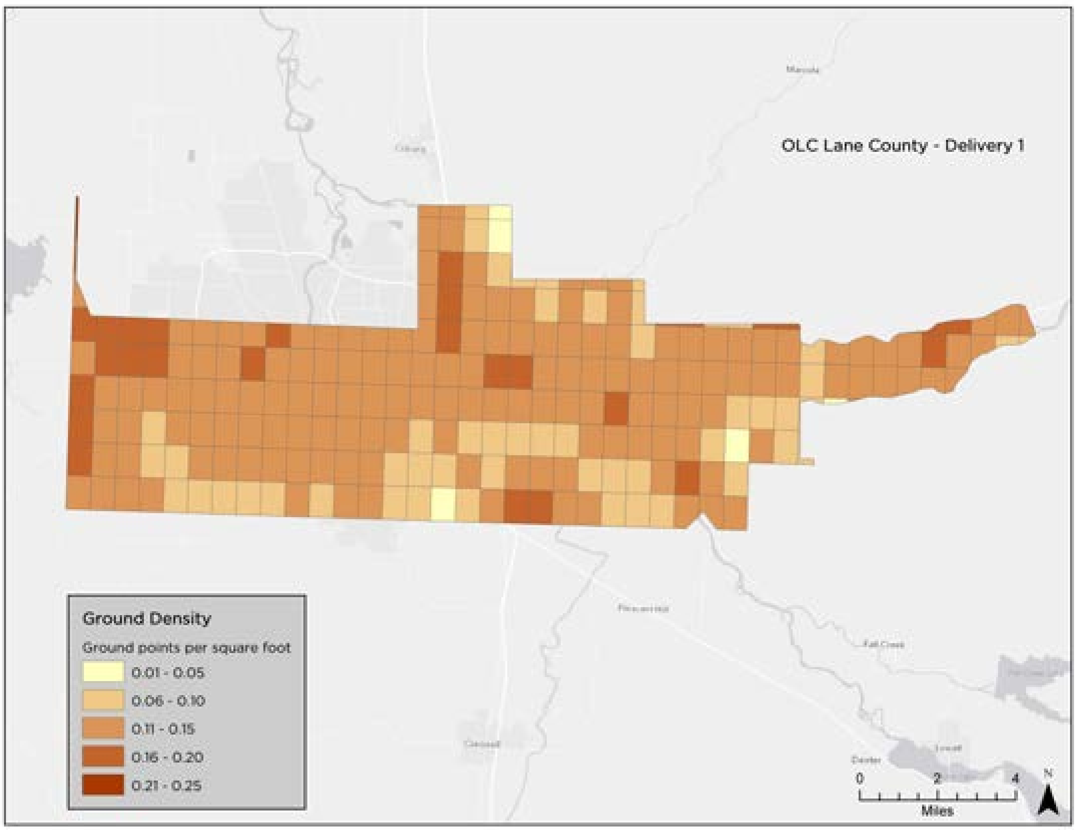


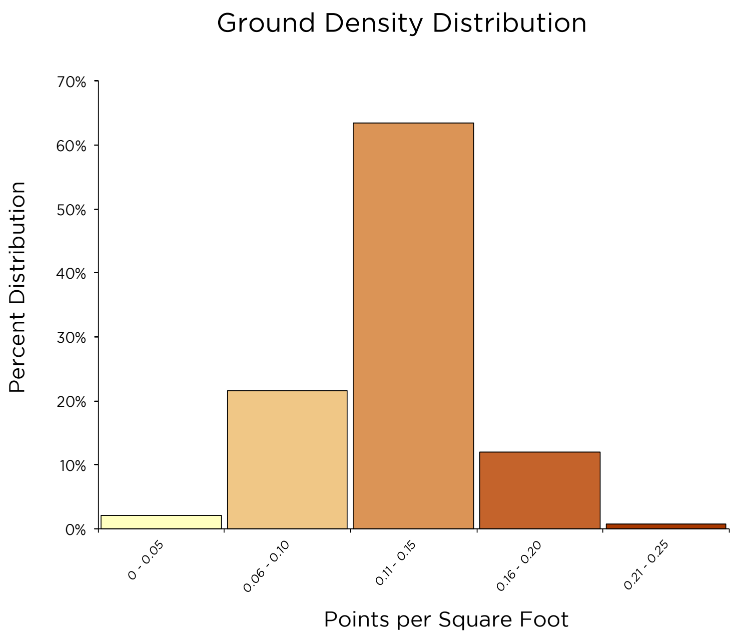
Ground Density

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)





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

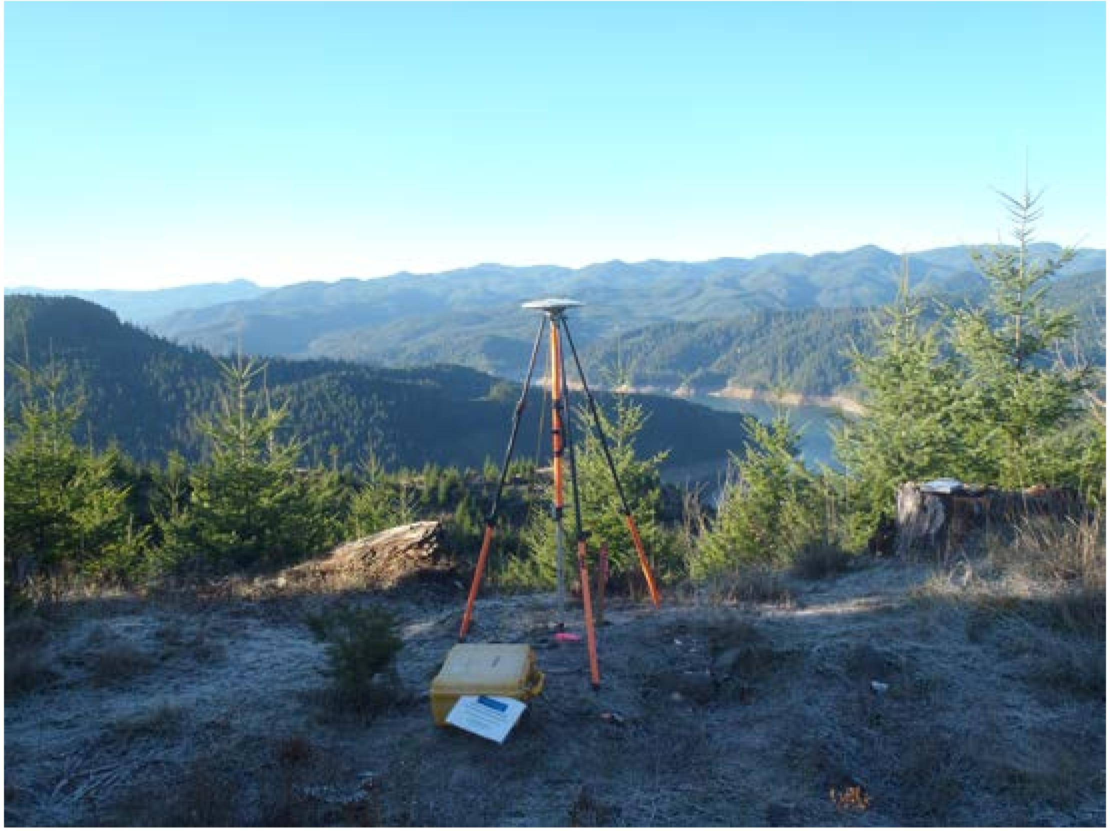
Selected Imagery

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.

WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 2

January 24, 2013



Base station set up over control "LANE 25"

Data collected for:
Oregon Department of Geology and Mineral Industries

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Prepared by:
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Contents

"Lane 24" survey cap

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 Two, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,611,890 acres. Delivery Area Two encompasses 58,509.9 acres.

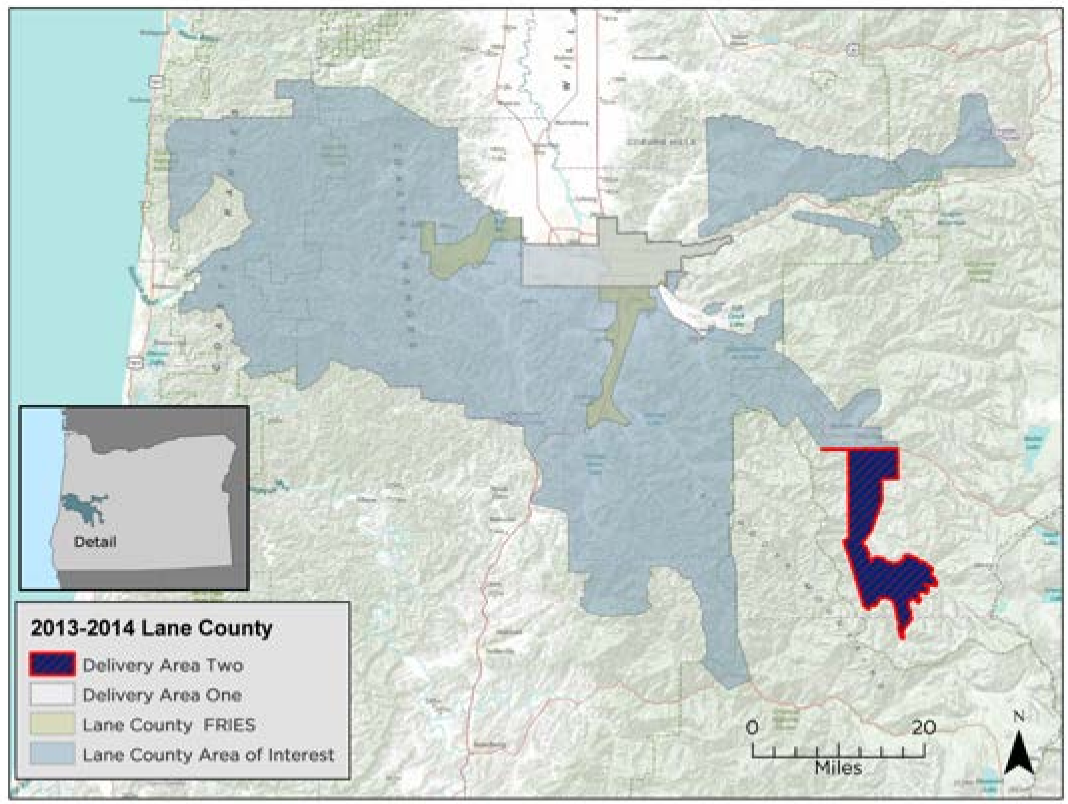
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Delivery Area Two data collection occurred between November 21, 2013 and December 5, 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]

OLC Lane County AOI Data Delivered January 24, 2014	
Acquisition Dates	November 21- December 5, 2013
Delivery Area Two Area of Interest	58,509.9 acres
Lane County 2013/2014 Area of Interest	1,611,890 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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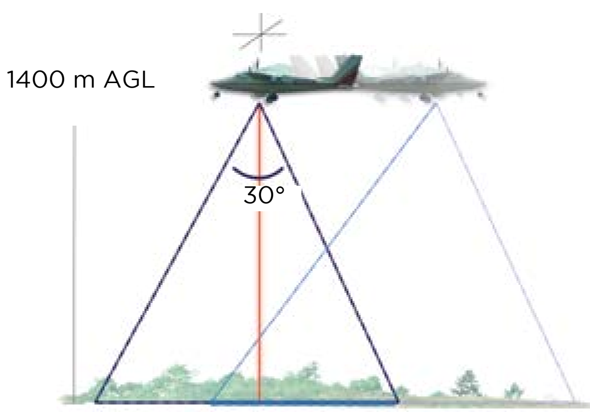
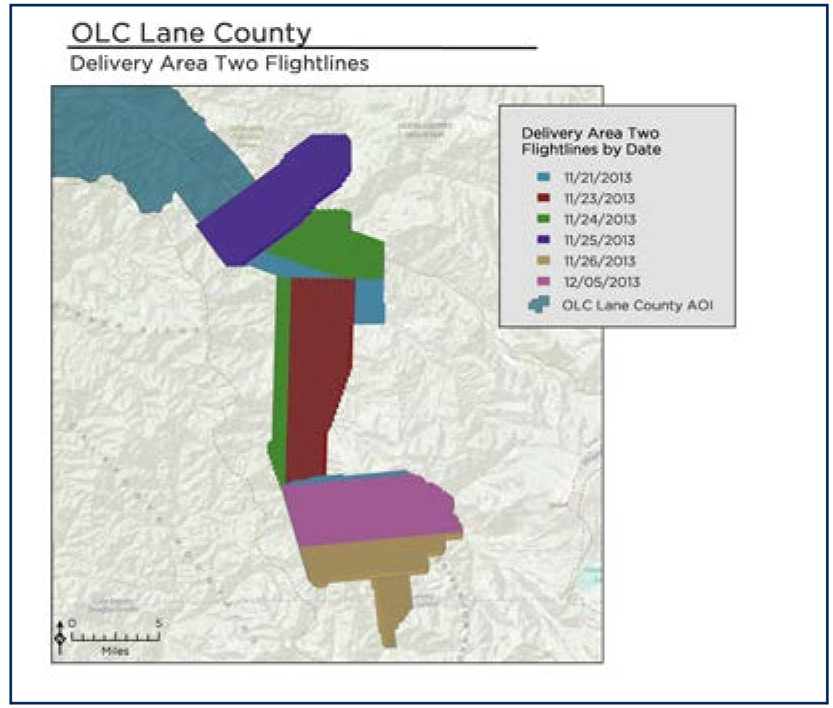


Project Flightlines



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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.

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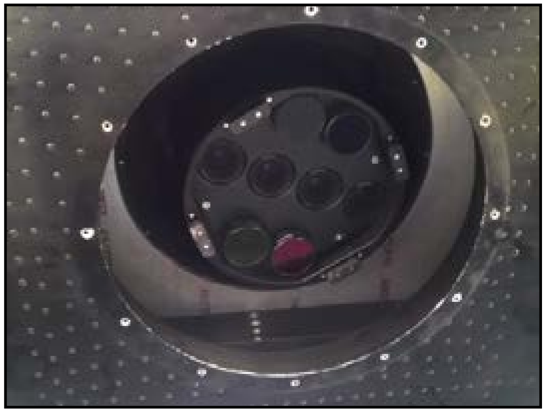
The Lane County Delivery Area Two portion of the project does not have any orthophotos, though FRIES are part of the project as a whole.



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.

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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

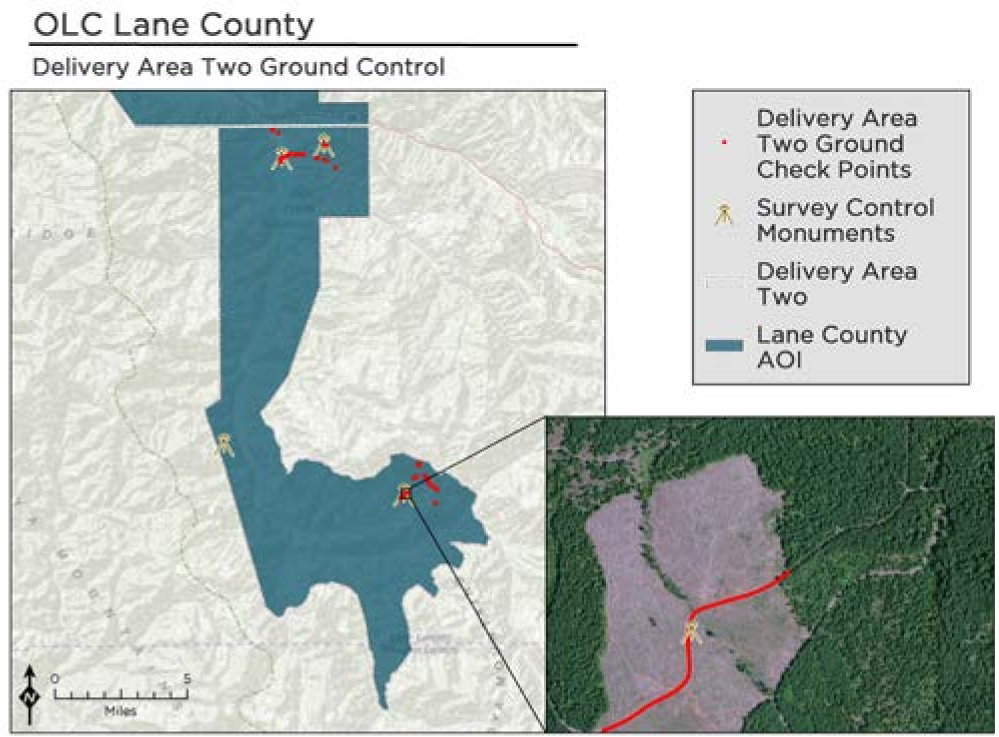
During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over three monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and using the Online Positioning User Service (OPUS) to quantify 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 GNSS 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_24	43° 42' 26.18996"	-122° 25' 40.56001"	450.794
LANE_25	43° 42' 51.38283"	-122° 23' 45.43363"	792.318
LANE_26	43° 33' 00.45694"	-122° 28' 22.66794"	815.341
LANE_27	43° 31' 20.08417"	-122° 20' 15.46234"	1080.075

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	0.010 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 Calculater 2013 SP1 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).

WSI collected 1,040 GCP points and established 4 new monuments for Delivery Area Two.

All Ground Check Point (GCP) 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. For collectiong GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). GCP 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).

LiDAR Accuracy

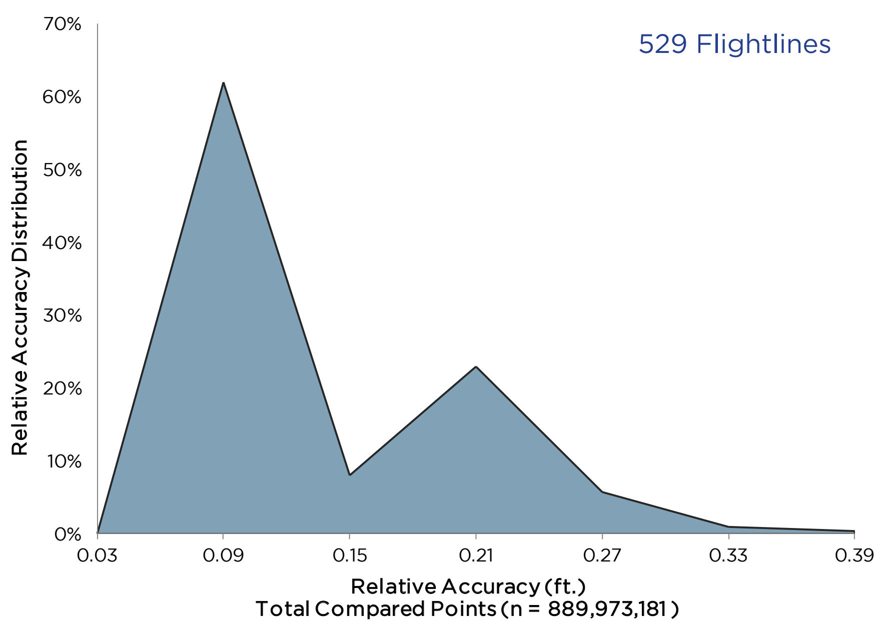
Relative Accuracy

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 523 flightlines (194 flightilnes from Delivery Area Two) and over 889 million points. Relative accuracy is reported for the delivered portions of the study area.

Relative Accuracy Calibration Results N = 523 flightlines	
Project Average	0.09 ft. (0.03 m)
Median Relative Accuracy	0.06 ft. (0.02 m)
1σ Relative Accuracy	0.14 ft. (0.04 m)
2σ Relative Accuracy	0.22 ft. (0.07m)

Relative Accuracy Distribution



R7 Receiver

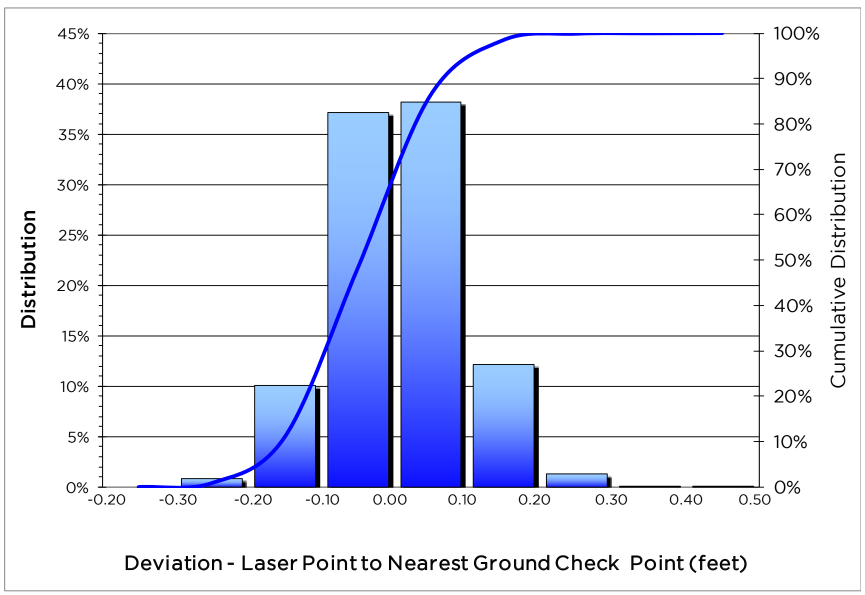
Vertical Accuracy

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 Two study area, 1,040 RTK points were collected. Statistics are calculated on the cumlative sum of all points collected for all deliveries.

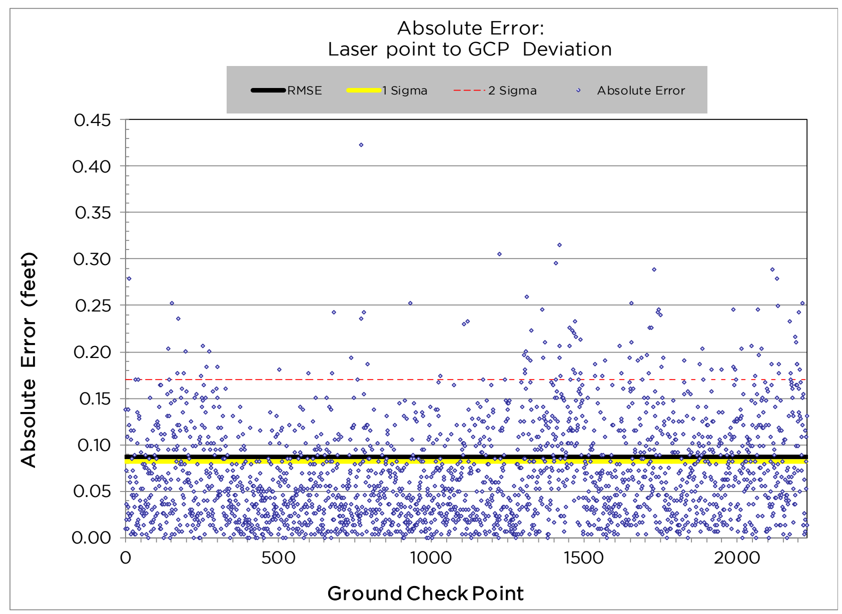
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed to the right.

Vertical Accuracy Results	
Sample Size (n)	2,229 Ground check points
Root Mean Square Error	0.09 ft. (0.03 m)
1 Standard Deviation	0.08 ft. (0.03 m)
2 Standard Deviation	0.17 ft. (0.05 m)
Average Deviation	0.00 ft. (0.00 m)
Minimum Deviation	-0.28 ft. (-0.09 m)
Maximum Deviation	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GCP Absolute Error



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 spreadsheet 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 centimeters 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

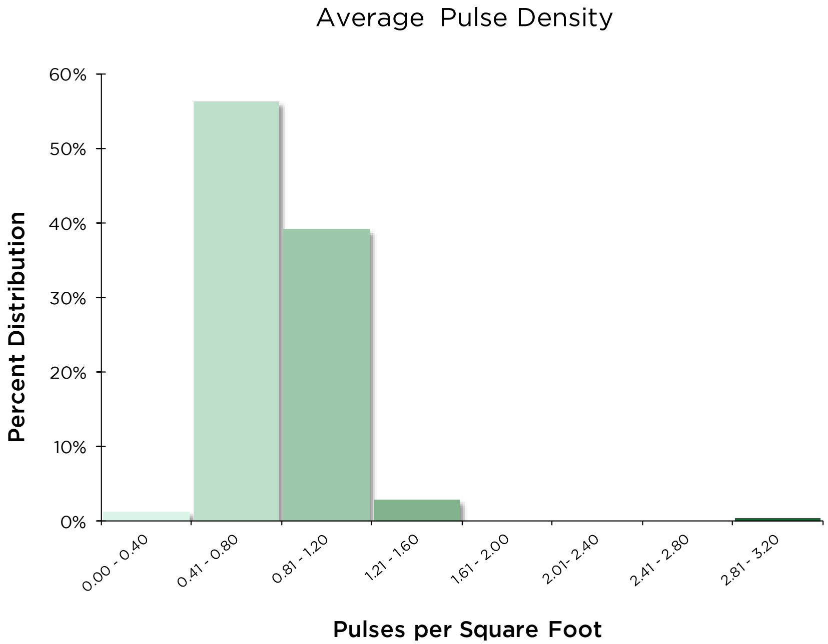
Utilizing the Weyerhaeuser horizontal offset tool, one flightline contained within the OLC Lane County project Delivery Area Two was found to have a horizontal offset above 30 centimeters, necessitating inspection. The offset was found at the very edge of flightline. It has been observed that in these 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 Two Horizontal Accuracy Assessment".

Density

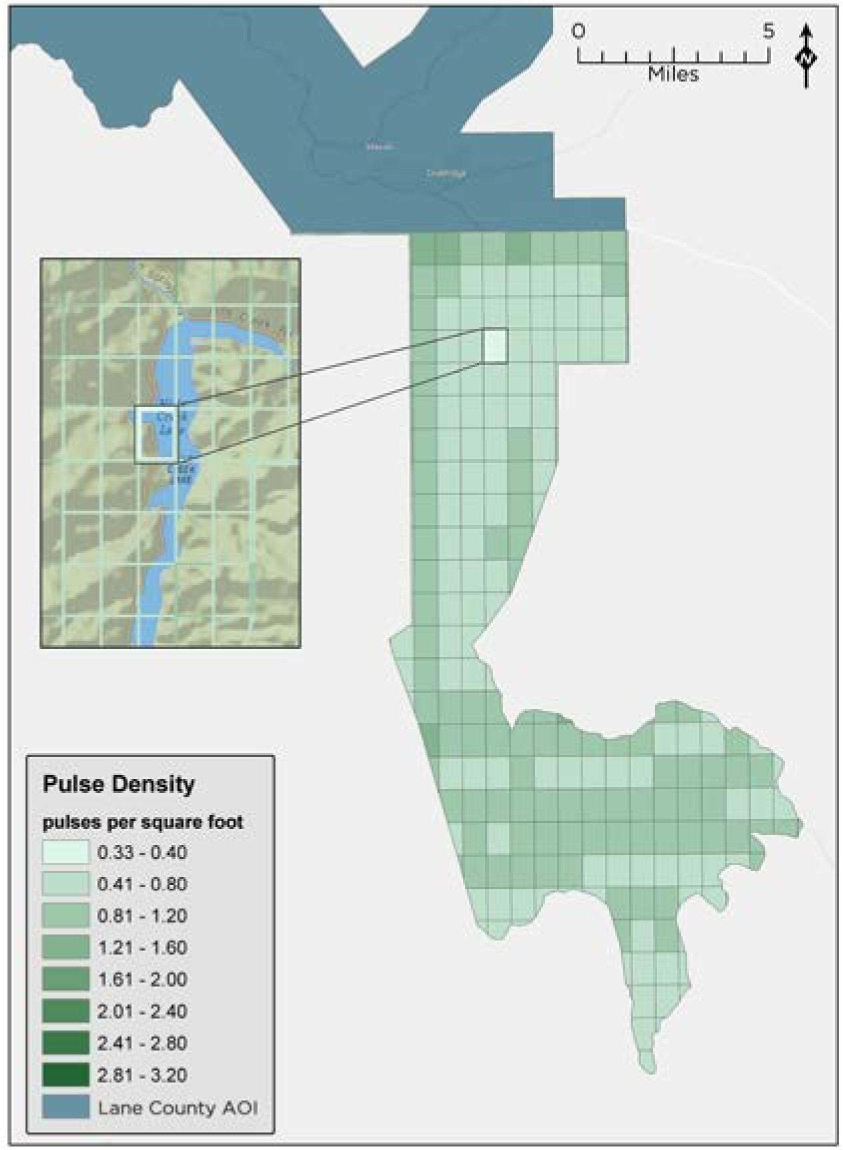
Pulse Density

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.

	pulses per square meter	pulses per square foot
Pulse Density	8.63	0.80



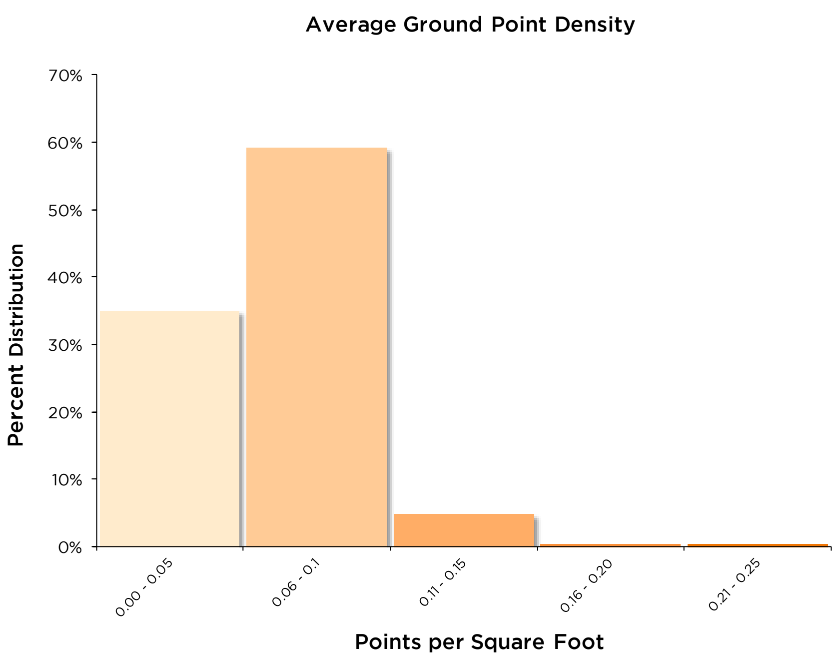
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart)



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.

Ground Density	points per square meter	points per square foot
	0.69	0.06



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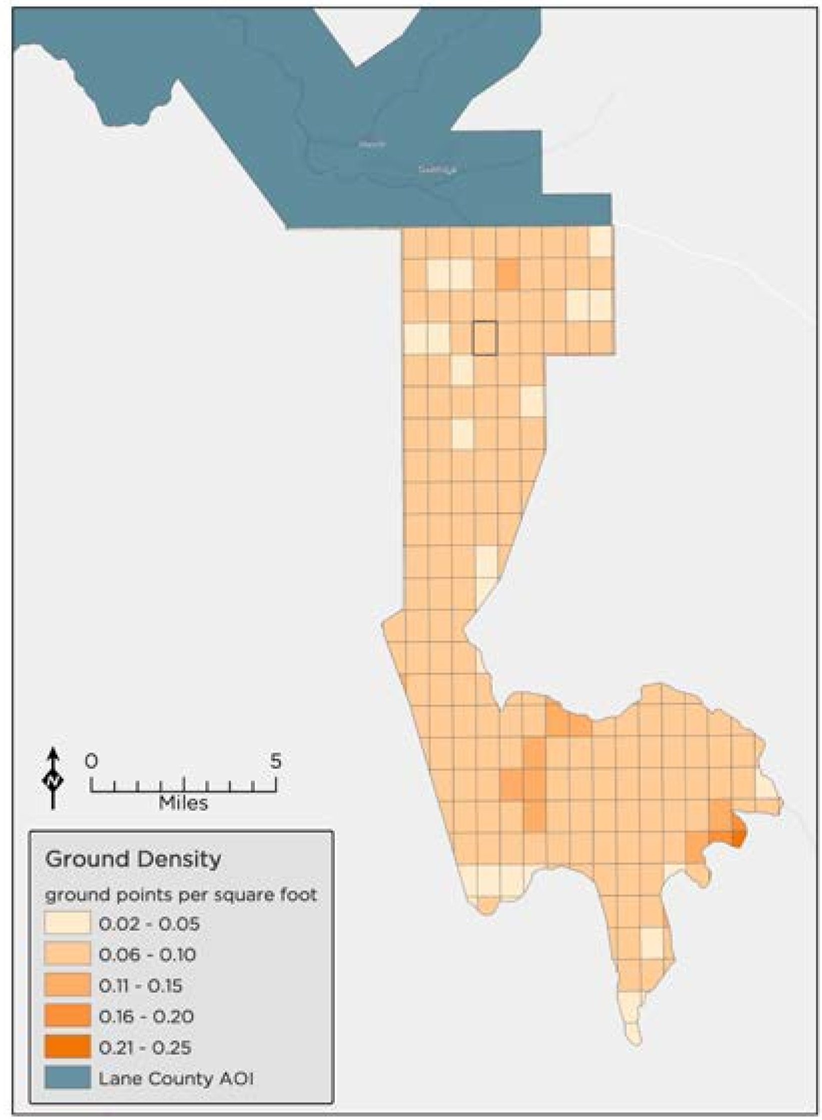


Orthophoto Accuracy

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.

Orthophotos are not in Delivery Area 2, though are part of the project. Assessment recorded here coincides with Delivery Area One, and will be updated as the project progresses.

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

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

Appendix

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 October 30, 2013 and December 5, 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".

REGISTERED
PROFESSIONAL
LAND SURVEYOR

1/24/2014

OREGON
JULY 13, 2004
CHRISTOPHER W. BROWN
60438LS

RENEWS: 12/31/2015

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

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, Spring-field, Oregon.

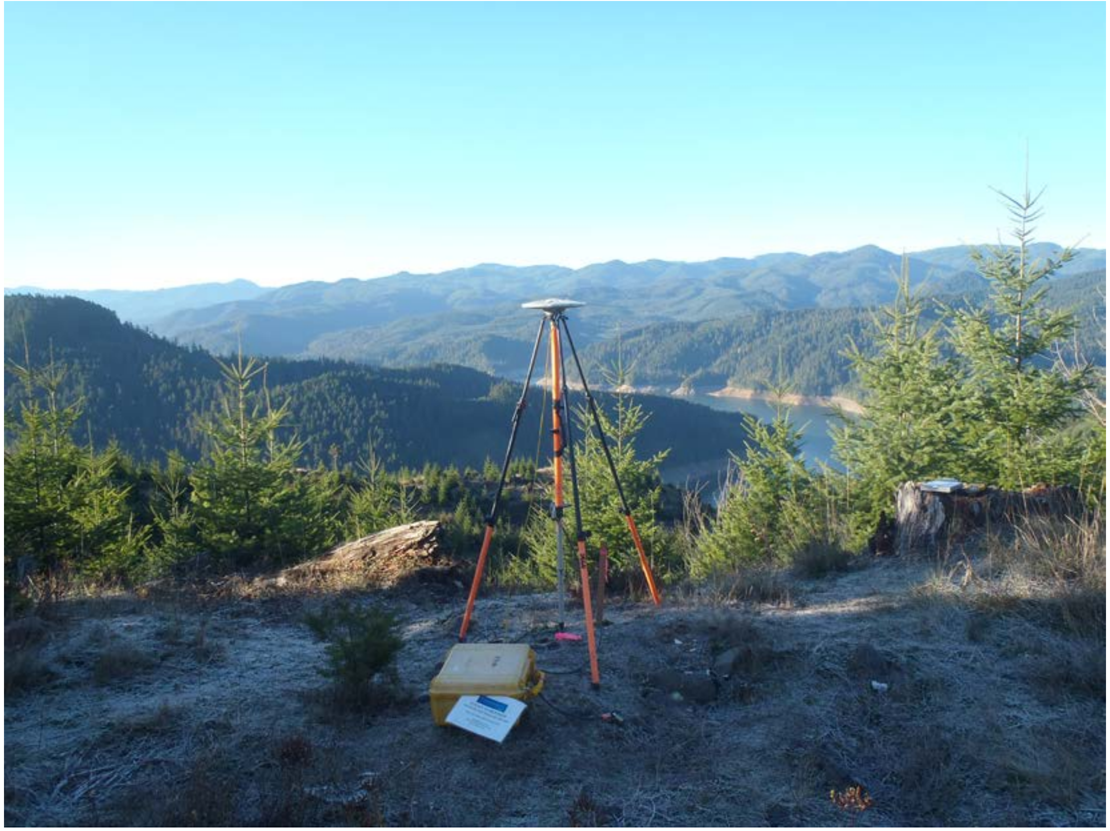
Highest Hit DEM of section of Delivery Area Two

Applied Remote Sensing and Analysis

OLC Lane County: Delivery 3

wsidata.com

March 24, 2014



Base station set up over control "LANE 25"

Data collected for:
Oregon Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:
WSI

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

"Lane 24" survey cap

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 Three, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,611,890 acres. Delivery Area Three encompasses 132,012 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. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

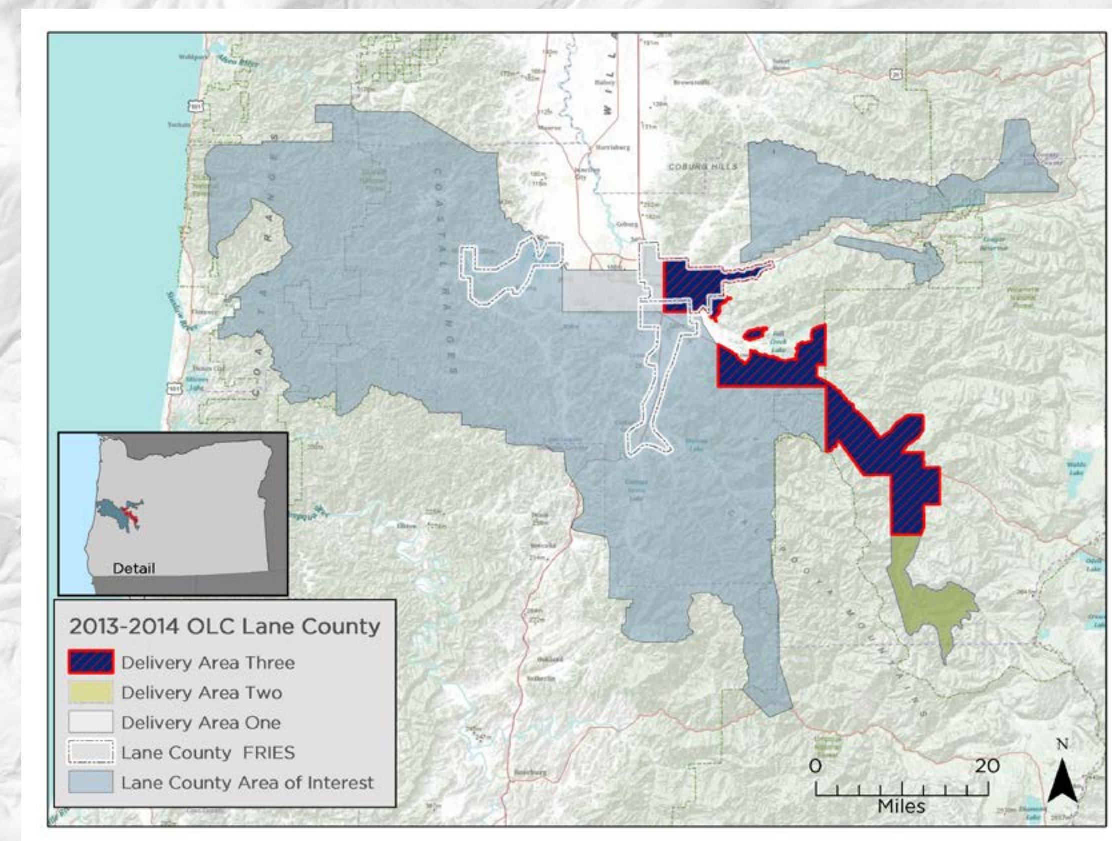
Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5-foot intensity rasters, 3-inch orthophotos, ground density rasters, study area vector shapes, and corresponding statistical data.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

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

OLC Lane County AOI Data Delivered January 24, 2014	
Acquisition Dates	September 7, 2013- January 25, 2014
Delivery Area Three Area of Interest	132,012 acres
Lane County 2013/2014 Area of Interest	1,611,264 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



Aerial Acquisition

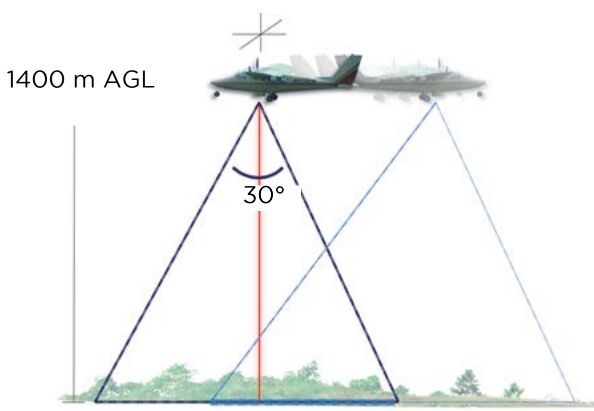
Cessna Caravan

LiDAR Survey

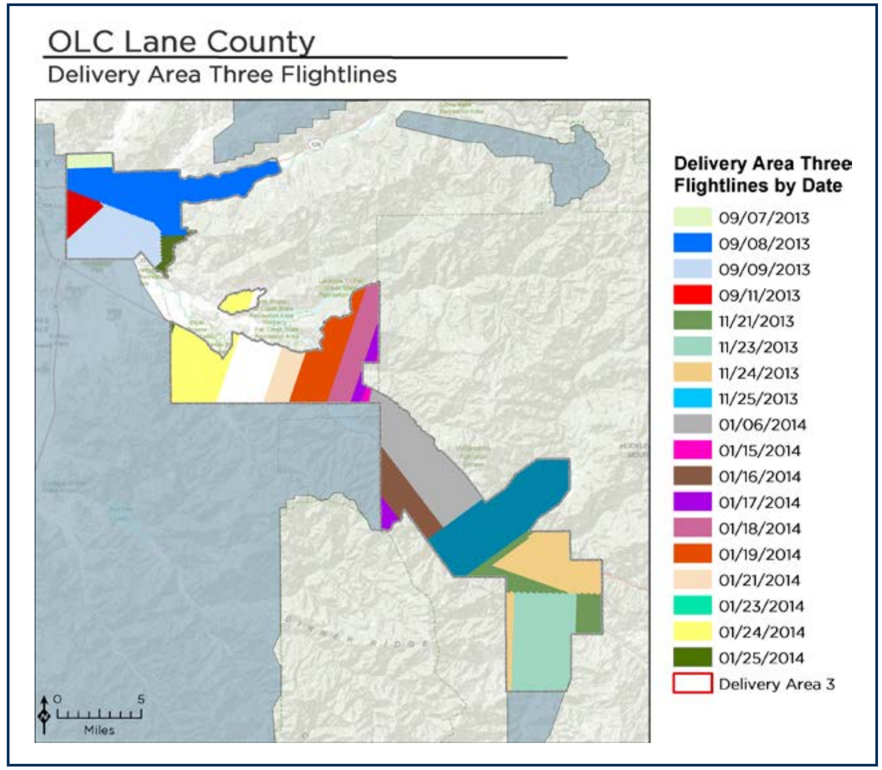
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-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, 572 flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper-PA
Survey Altitude (AGL)	1400 m / 900 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.

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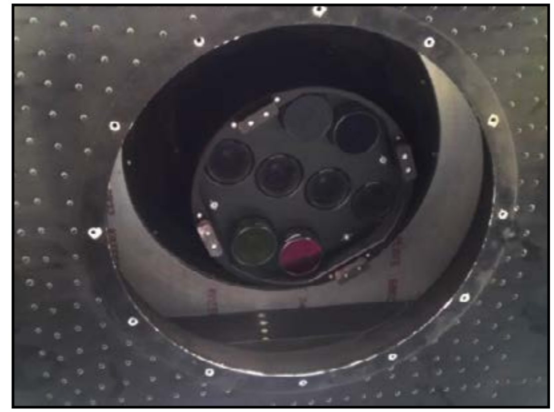

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The 4-band GeoTIFF format allows for flexibility in image analysis and display. By adjusting the image band setup to display the near infrared spectral band as red (this display is known as color-infrared), vegetation stands out extremely vividly in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

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Aircraft	Cessna 208-B Grand Caravan
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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

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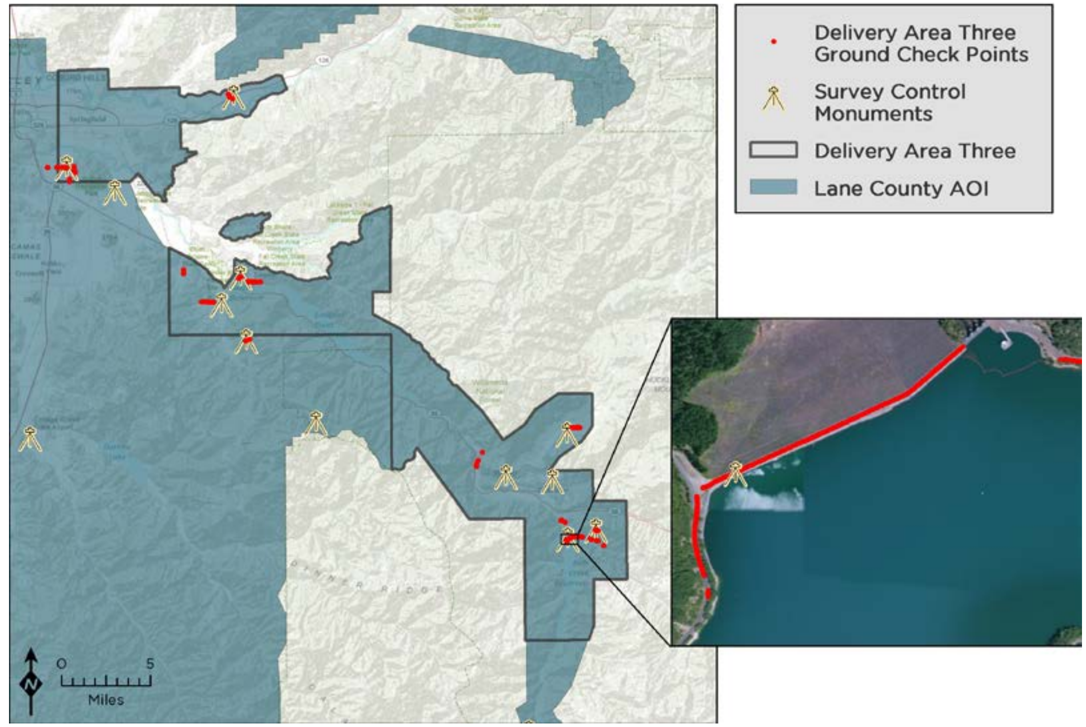
Monuments			
Name	Latitude	Longitude	Ellipse
	Datum NAD 83 (2011)		GRS 80
AI2001	43° 55' 19.20493"	-122°4 7' 41.08223"	195.963
LANE_11	44° 04' 08.74341"	-122° 48' 06.59661"	161.587
LANE_13	44° 00' 41.08475"	-122° 59' 27.48519"	119.047
LANE_15	43° 59' 28.97732"	-122° 56' 10.19436"	139.378
LANE_24	43° 42' 26.18996"	-122° 25' 40.56001"	450.794
LANE_25	43° 42' 51.38283"	-122° 23' 45.43363"	792.318
LANE_28	43° 53' 58.92454"	-122° 48' 59.17889"	194.478
LANE_29	43° 52' 12.08177"	-122° 47' 18.45224"	420.38
LANE_29A	43° 52' 12.08161"	-122° 47' 18.45256"	420.361
LANE_31	43° 45' 16.82389"	-122° 26' 41.15314"	492.053
LANE_32	43° 47' 33.82161"	-122° 25' 40.76291"	677.205
LANE_34	43° 45' 30.54400"	-122° 29' 48.47559"	308.081
LANE_35	43° 48' 11.57911"	-122° 42' 37.56859"	1041.596

OLC Lane County

Delivery Area Three Ground Control



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." Twelve new monuments were established and one NGS monument was occupied for the Lane County study area (see Monument table at bottom left).

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 Calculator 2013 SP1 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).

WSI collected 1,618 GCP points, established 12 new monuments and occupied one NGS monument for Delivery Area Three.

All Ground Check Point (GCP) 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. For collecting GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). GCP 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.

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).

Ground professional collecting RTK

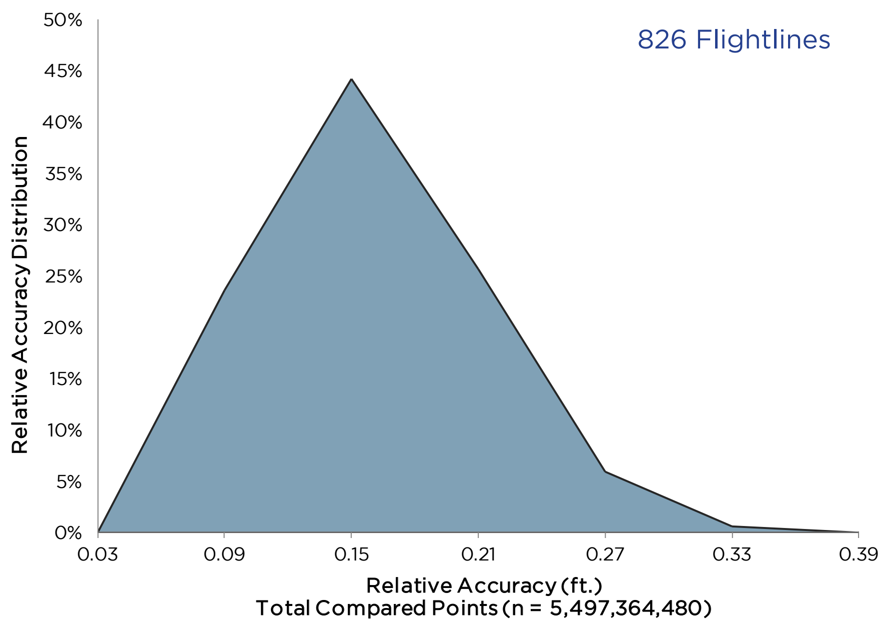
LiDAR Accuracy

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 826 flightlines (572 full and partial flightlines from Delivery Area Three) and over 5 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 1,095 flightlines	
Project Average	0.12 ft. (0.04 m)
Median Relative Accuracy	0.12 ft. (0.04 m)
1σ Relative Accuracy	0.15 ft. (0.05 m)
2σ Relative Accuracy	0.22 ft. (0.07m)

R7 Receiver

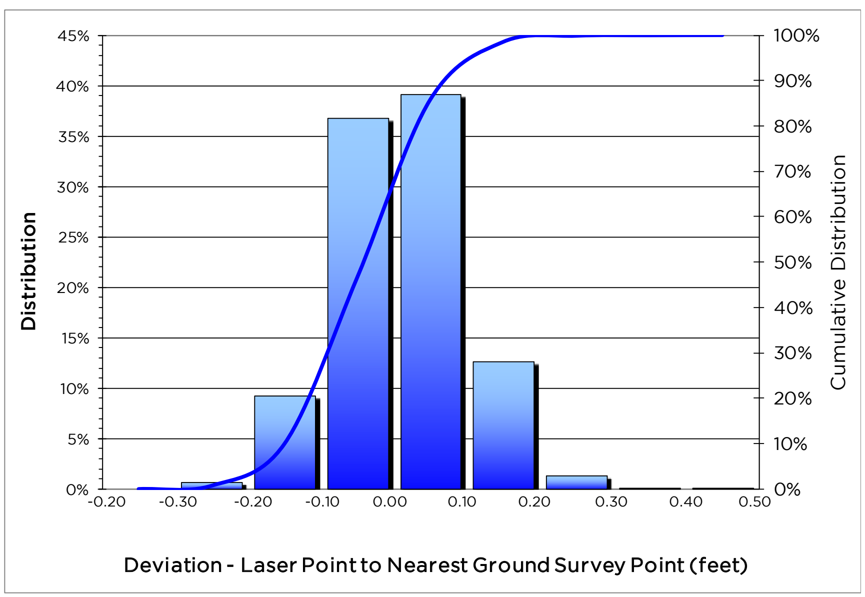
Vertical Accuracy

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 Three study area, 1,618 RTK points were collected. Statistics are calculated on the cumulative sum of all points collected for all deliveries.

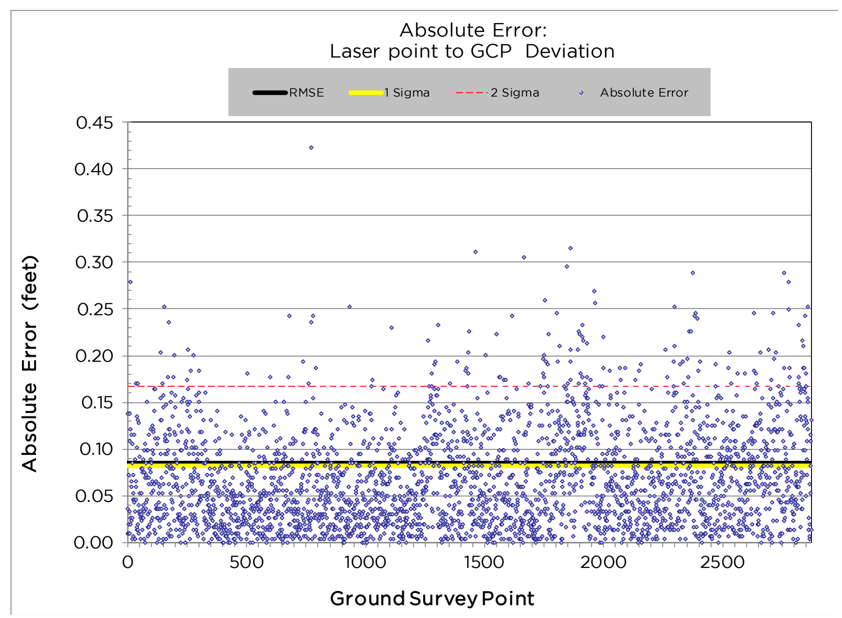
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results	
Sample Size (n)	2,874 Ground check points
Root Mean Square Error	0.09 ft. (0.03 m)
1 Standard Deviation	0.08 ft. (0.03 m)
2 Standard Deviation	0.17 ft. (0.05 m)
Average Deviation	0.01 ft. (0.00 m)
Minimum Deviation	-0.29 ft. (-0.09 m)
Maximum Deviation	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GCP Absolute Error

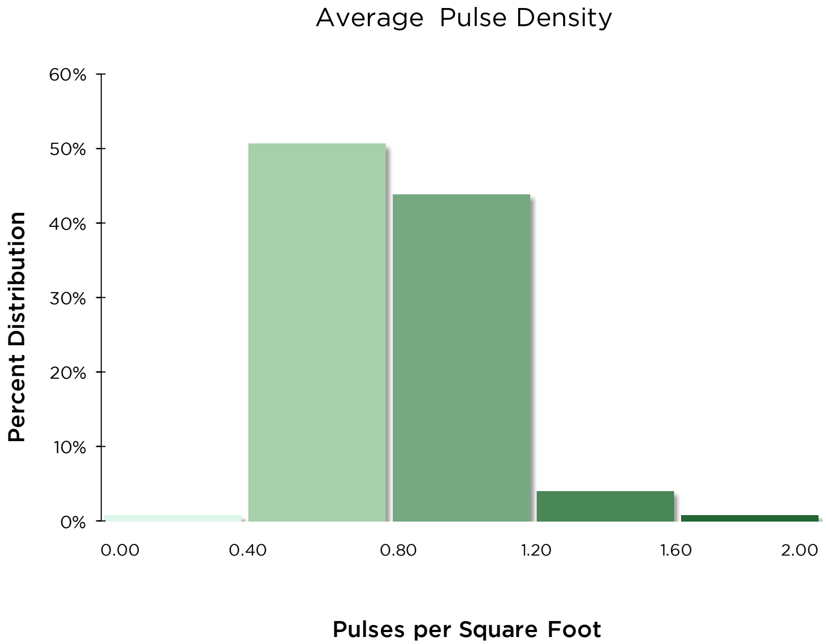


Density

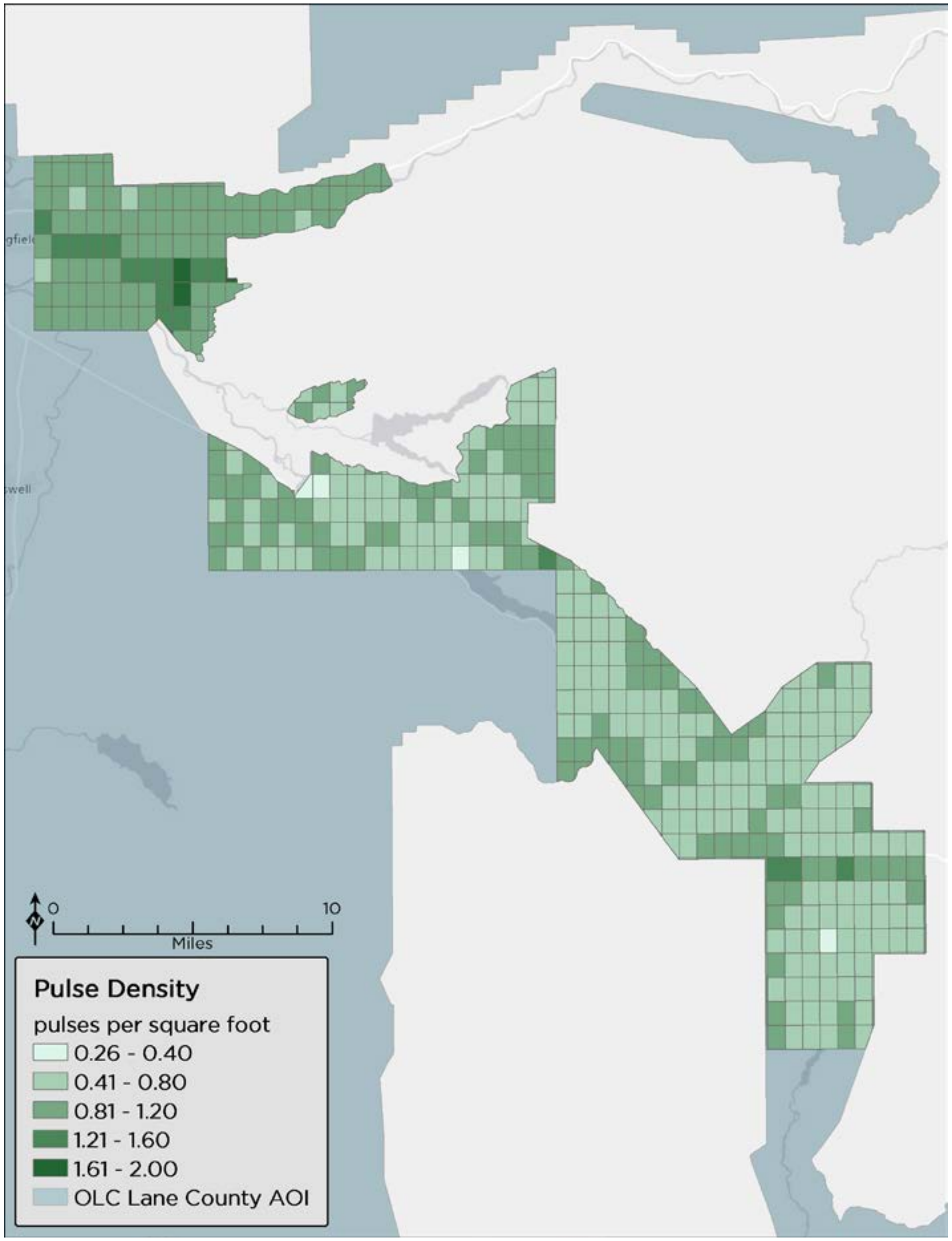
Pulse Density

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.

Pulse Density	pulses per square meter	pulses per square foot
	8.79	0.82



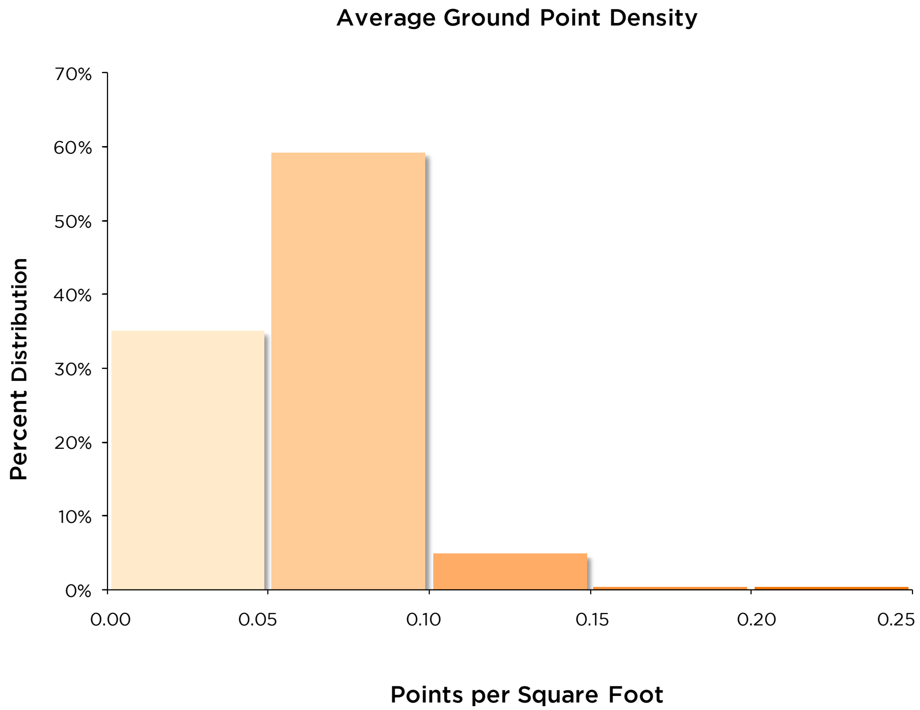
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart)



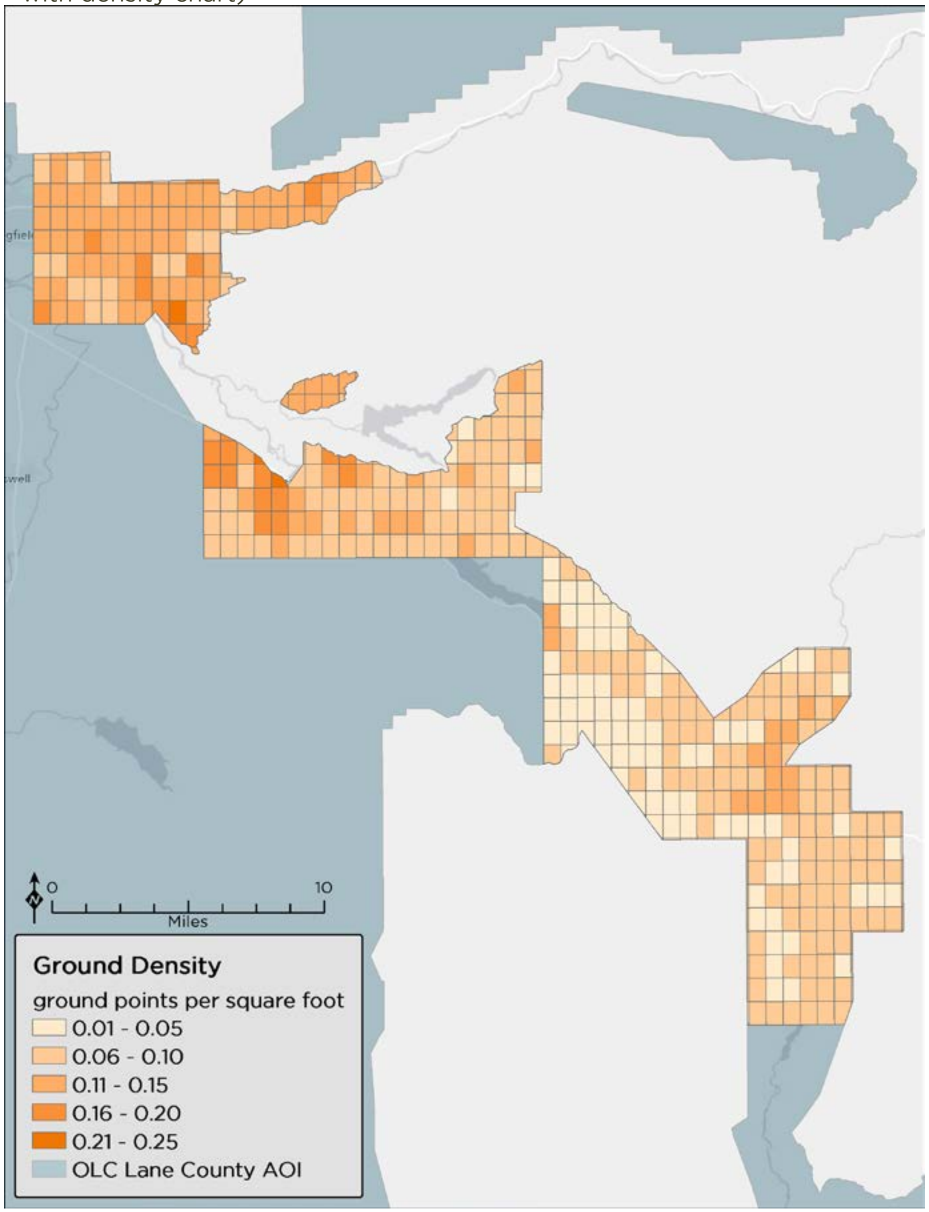
Ground Density

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 is a measure of ground-classified point data.

Ground Density	points per square meter	points per square foot
	0.91	0.08



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



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.

Orthophotos are not in Delivery Area 2, though are part of the project. Assessment recorded here coincides with Delivery Area One, and will be updated as the project progresses.

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

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Appendix

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 the Static GPS occupations on the Base Stations during airborne flights and RTK survey on hard-surface, and GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between September 27, 2013 and January 25, 2014.

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

REGISTERED
PROFESSIONAL
LAND SURVEYOR

3/24/2014

OREGON
JULY 13, 2004
CHRISTOPHER W. BROWN
60438LS

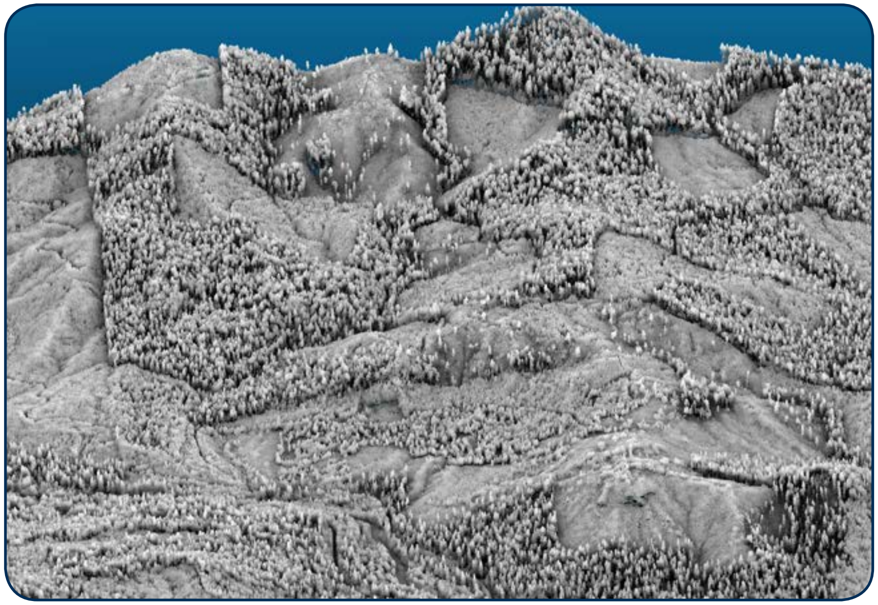
RENEWS: 12/31/2015

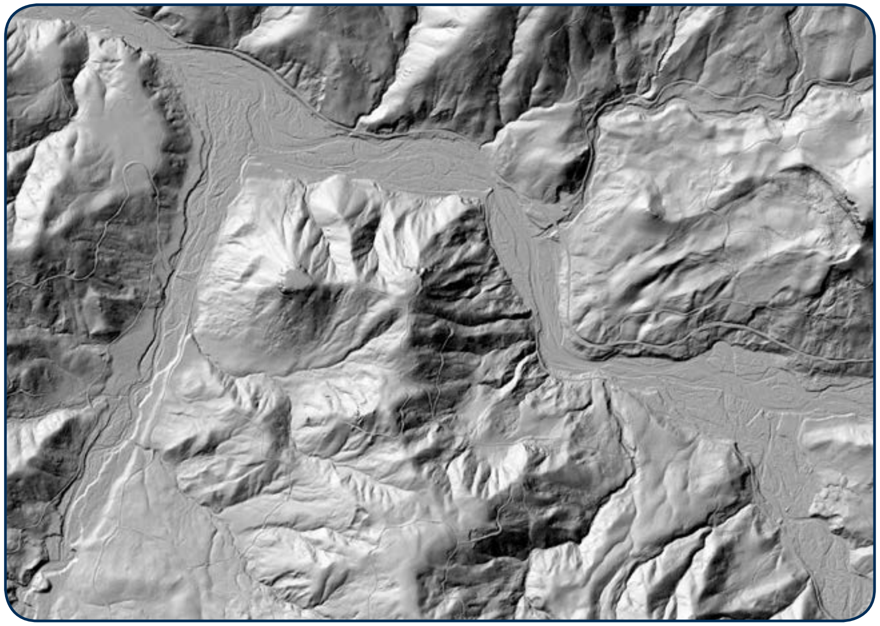
Selected Imagery

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.

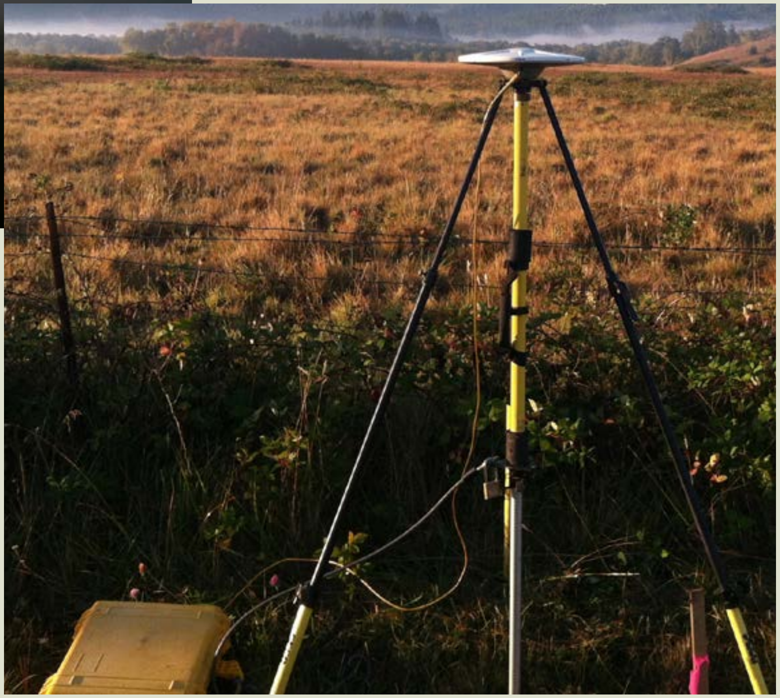
Highest Hit DEM of section of Delivery Area Two

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





OLC Lane County: Delivery 4



Data collected for:
Oregon Department of Geology and Mineral Industries

800 NE Oregon Street
Suite 965
Portland, OR 97232

Prepared by:
WSI

421 SW 6th Avenue
Suite 800
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fax: (541) 752-3770

Contents

"Lane 17" and "Lane 19" survey caps.

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 Four, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,611,890 acres. Delivery Area Four encompasses 100,733 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. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

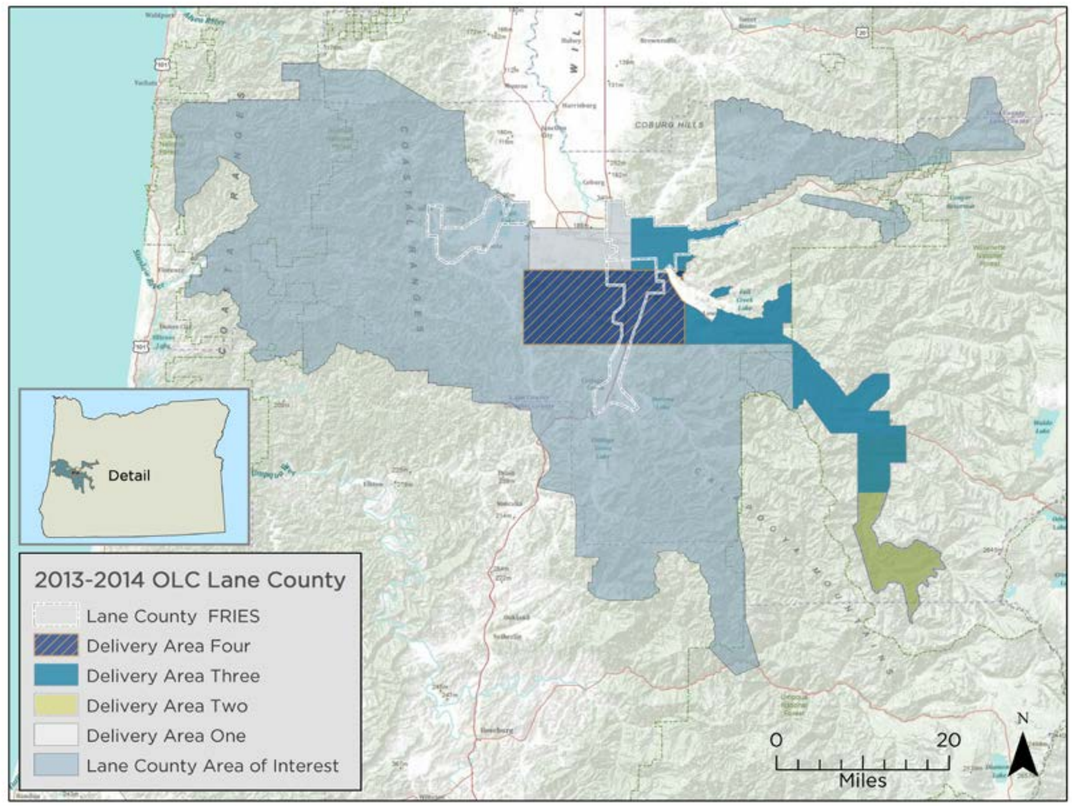
Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5-foot intensity rasters, 3-inch orthophotos, ground density rasters, study area vector shapes, and corresponding statistical data.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

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

OLC Lane County AOI Data Delivered July 11, 2014	
Acquisition Dates	September 7, 2013- April 11, 2014
Delivery Area Four Area of Interest	100,733 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



Aerial Acquisition

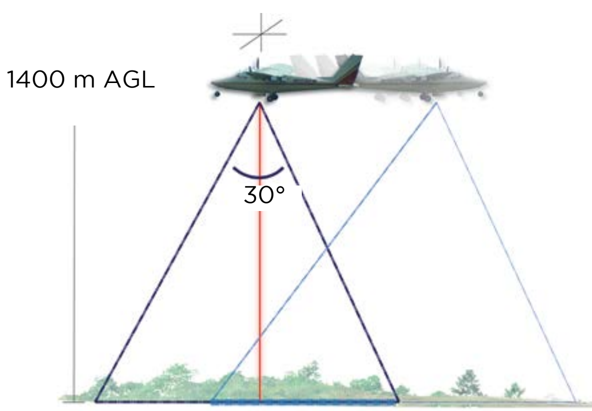
Cessna Caravan

LiDAR Survey

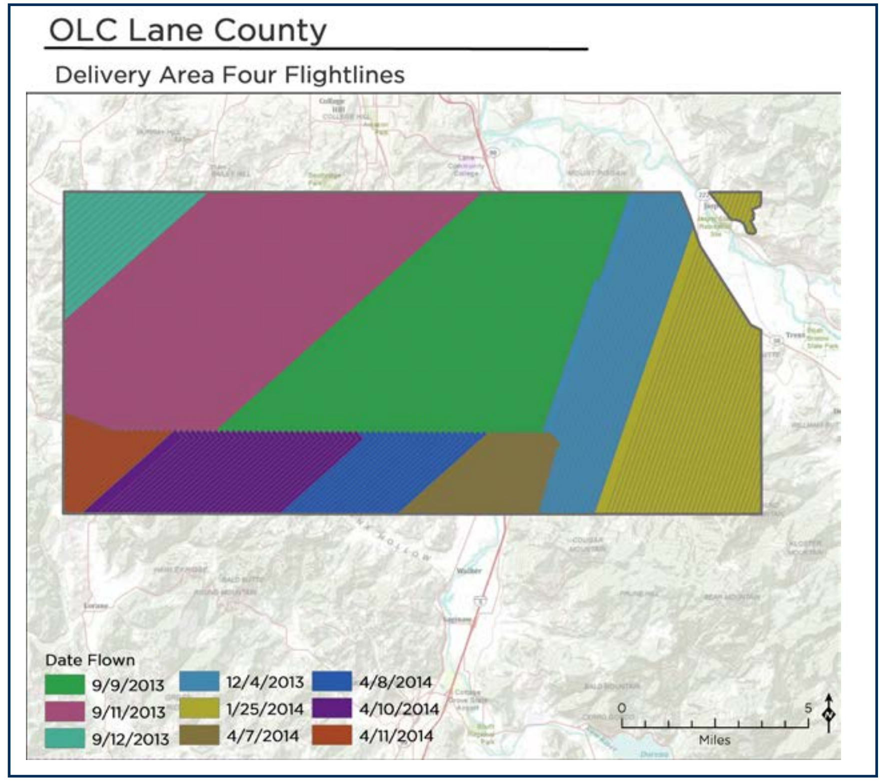
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-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, 572 flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper-PA
Survey Altitude (AGL)	1400 m / 900 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

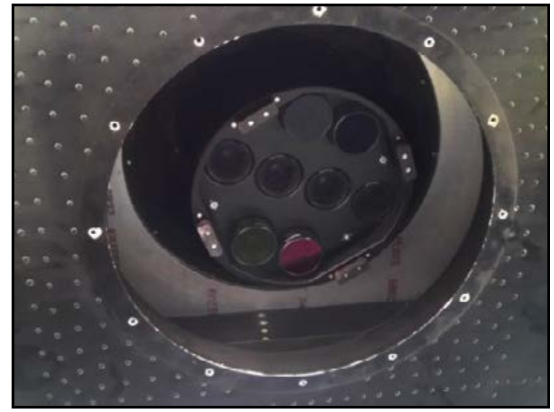
Aerial Acquisition

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 usable 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	≤ 13 nm
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

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

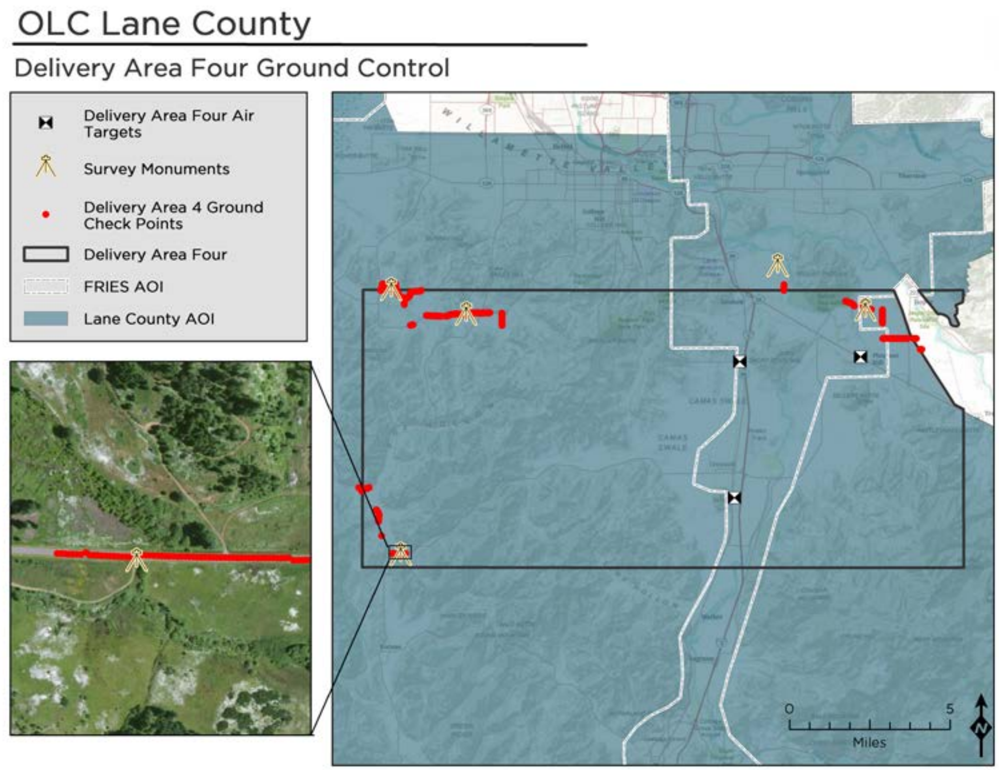
Examples of permanent air targets

Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over five 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 GNSS 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.



Monuments			
Name	Latitude	Longitude	Ellipse
	Datum NAD 83 (2011)		GRS 80
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LANE_17	43° 59’ 22.07068”	-123° 11’ 07.80197”	111.693
LANE_19	44° 00’ 01.44296”	-123° 13’ 56.62771”	104.781
LANE_22	43° 52’ 51.72856”	-122° -123 13 33.92296	194.478

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.” Twelve new monuments were established and one NGS monument was occupied for the Lane County study area (see Monument table at bottom left).

Methodology

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

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.

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WSI collected 2,173 GCPs, and established five new monuments for Delivery Area Four.

All Ground Check Point (GCP) 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. For collecting GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). GCP 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.

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).

Ground professional collecting RTK

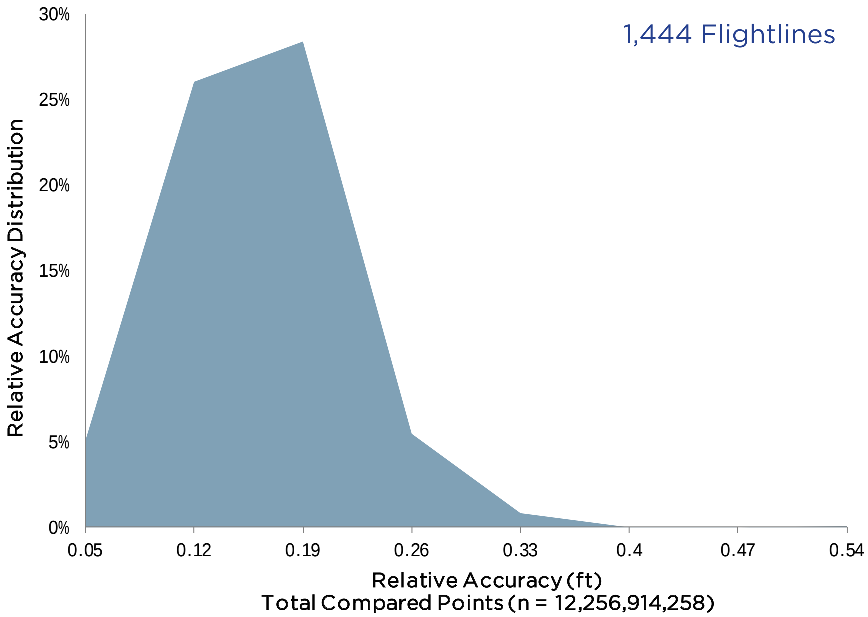
LiDAR Accuracy

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 1,444 full and partial flightlines (349 full and partial flightlines from Delivery Area Four) and over 12 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 1,444 flightlines	
Project Average	0.13 ft. (0.04 m)
Median Relative Accuracy	0.13 ft. (0.04 m)
1σ Relative Accuracy	0.15 ft. (0.05 m)
2σ Relative Accuracy	0.22 ft. (0.07 m)

R7 Receiver

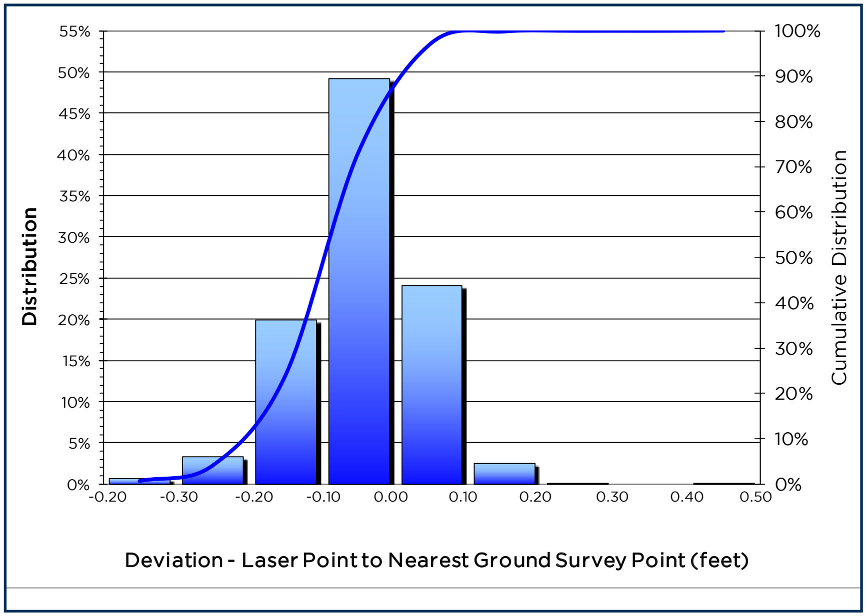
Vertical Accuracy

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 Four study area, 2,173 GCPs were collected. Statistics are shown for Delivery Area Four.

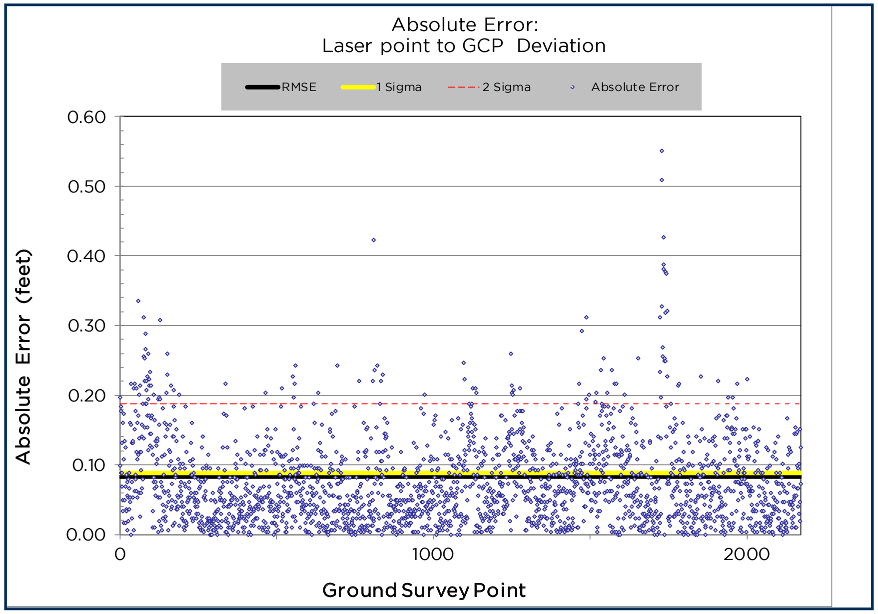
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results		
	Delivery Area Four	Cumulative
Sample Size (n)	2,173 Ground check points	4,455 Ground check points
Root Mean Square Error	0.08 ft. (0.03 m)	0.09 ft. (0.03 m)
1 Standard Deviation	0.09 ft. (0.03 m)	0.09 ft. (0.03 m)
2 Standard Deviation	0.19 ft. (0.06 m)	0.18 ft. (0.06 m)
Average Deviation	-0.01 ft. (0.00 m)	-0.02 ft. (0.00 m)
Minimum Deviation	-0.29 ft. (-0.09 m)	-0.55 ft. (-0.17 m)
Maximum Deviation	0.42 ft. (0.13 m)	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



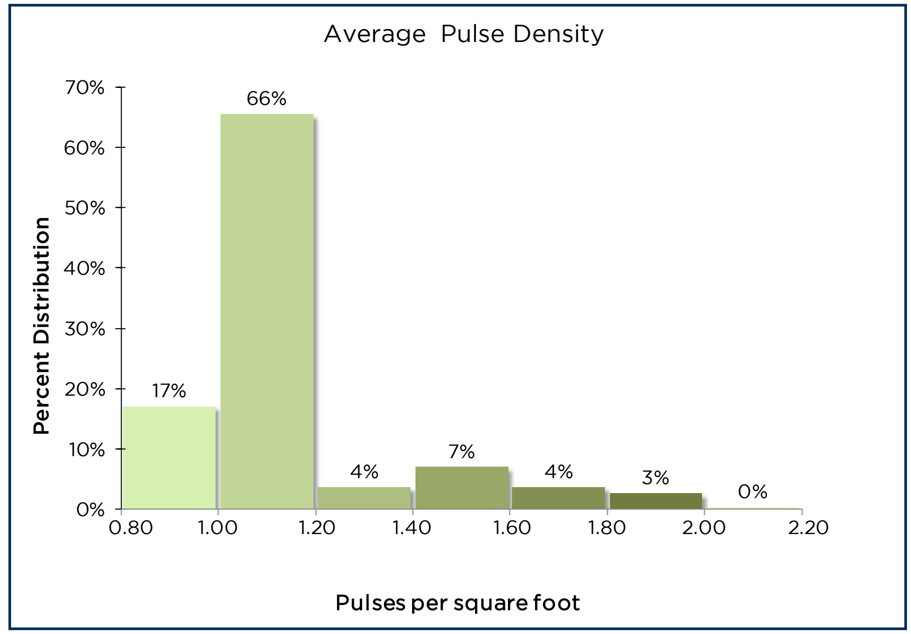
GCP Absolute Error



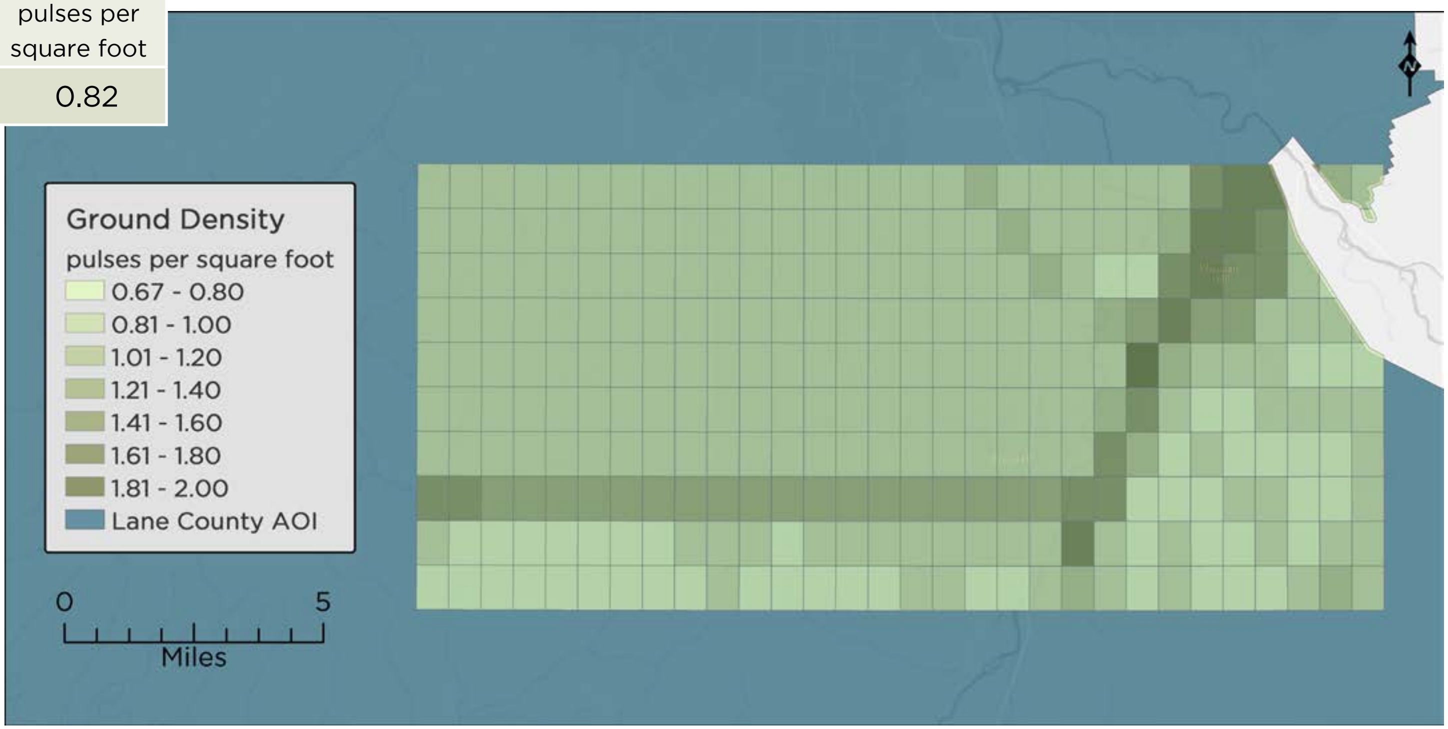
Density

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 delivery area.



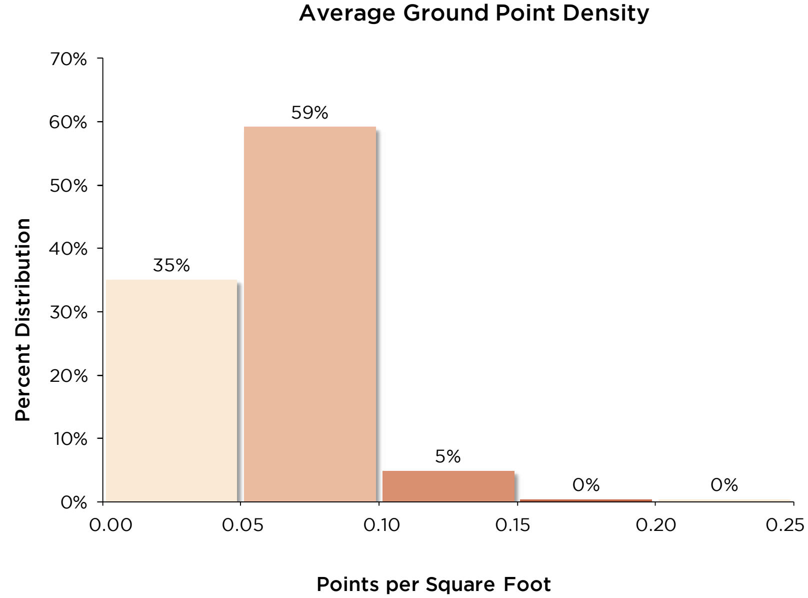
Average Pulse Density	pulses per square meter	pulses per square foot
	10.08	0.82



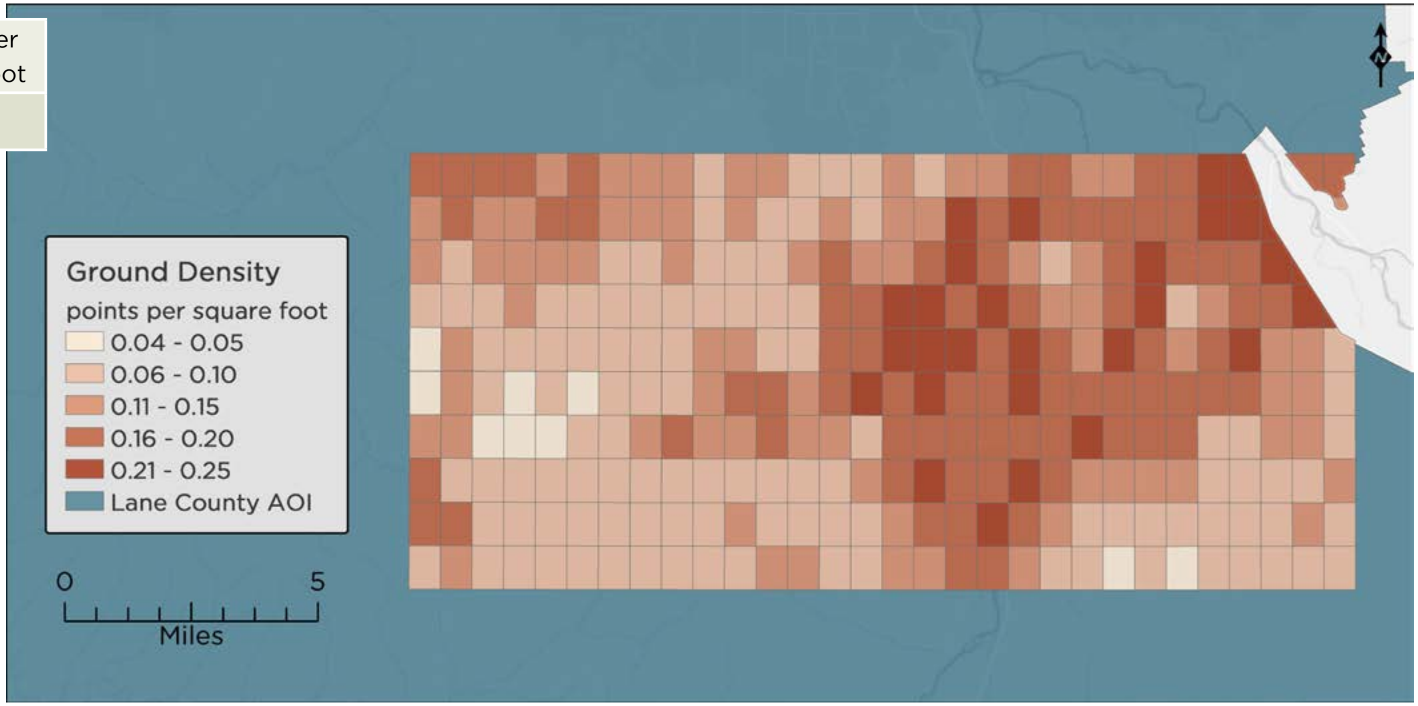
Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart)

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 is a measure of ground-classified point data for the delivery area.



Ground Density	points per square meter	points per square foot
	1.35	0.13



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

Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen check points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix

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
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 the Static GPS occupations on the Base Stations during airborne flights and RTK survey on hard-surface, and GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between September 7, 2013 and May 17, 2014.

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

REGISTERED PROFESSIONAL LAND SURVEYOR

7/11/2014

OREGON
JULY 13, 2004
CHRISTOPHER W. BROWN
60438LS

RENEWS: 12/31/2015

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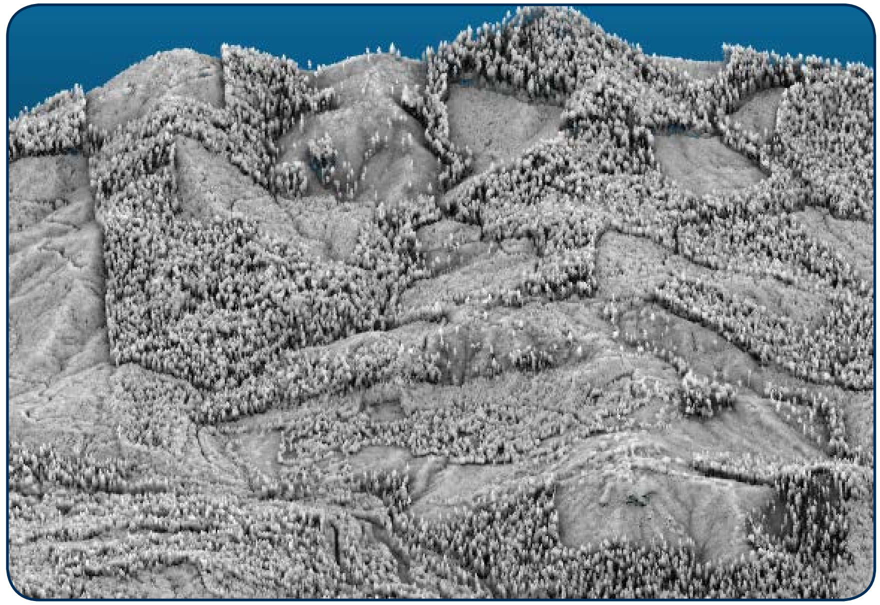
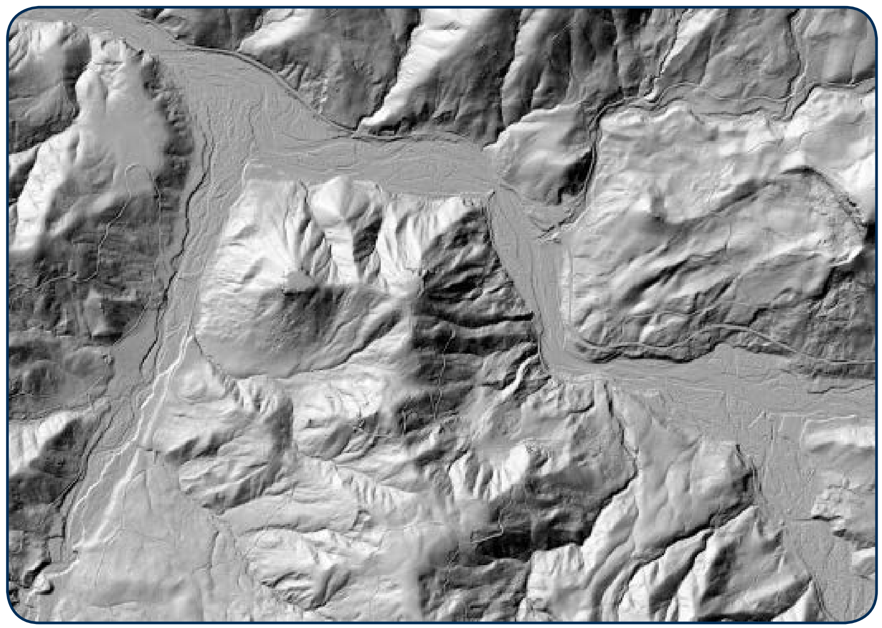
Selected Imagery

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.

Highest Hit DEM of section of Delivery Area Two

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 5

Data collected for:
Oregon Department of Geology and Mineral Industries

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Prepared by:
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Contents

“Lane 17” and “Lane 19” survey caps.

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 Five, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,640,978 acres. Delivery Area Five encompasses 68,155.1 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. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

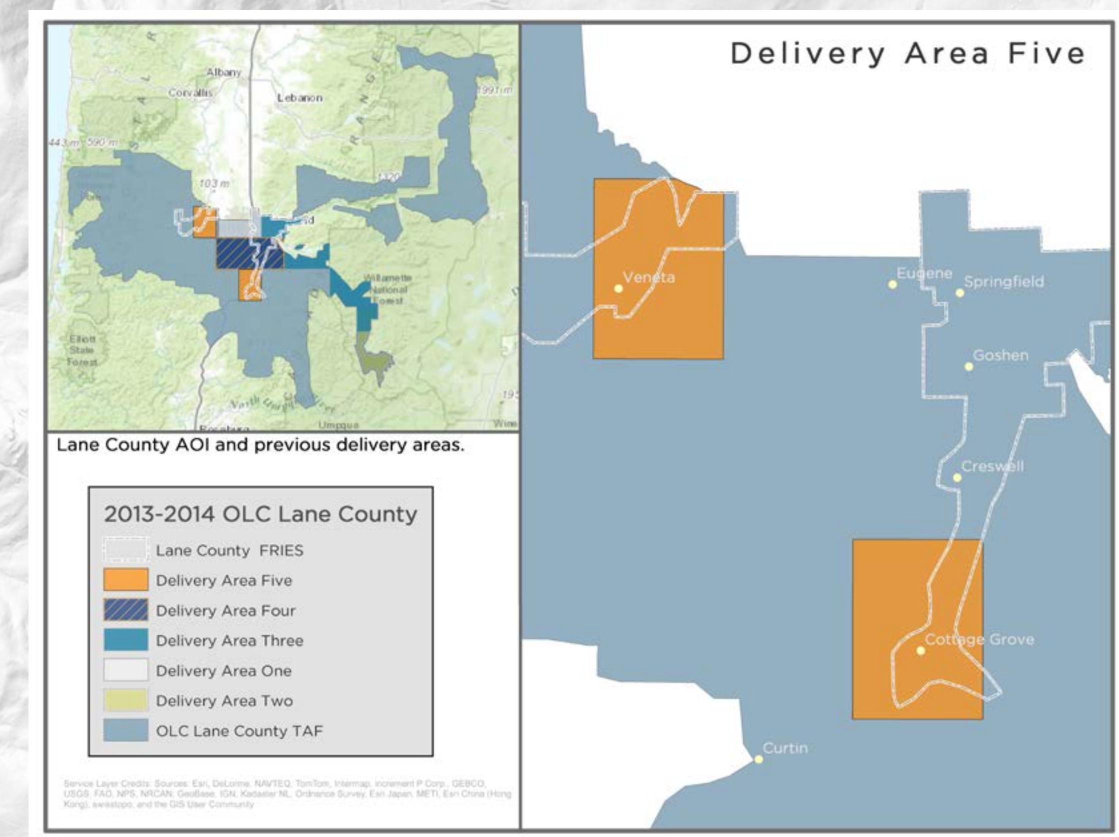
Final products created include LiDAR point cloud data, three-foot digital elevation models of bare earth ground model and highest-hit returns, 1.5-foot intensity rasters, 3-inch orthophotos, ground density rasters, study area vector shapes, and corresponding statistical data.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

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

OLC Lane County AOI Data Delivered November 18, 2014	
Acquisition Dates	September 10 - 13, 2013, November 27 - 28, 2013 December 4, 2013 January 25 - 26, 2014 April 7 - 8, 2014 June 4- 7, 2014
Delivery Area Five Area of Interest	68,155.1 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



Aerial Acquisition

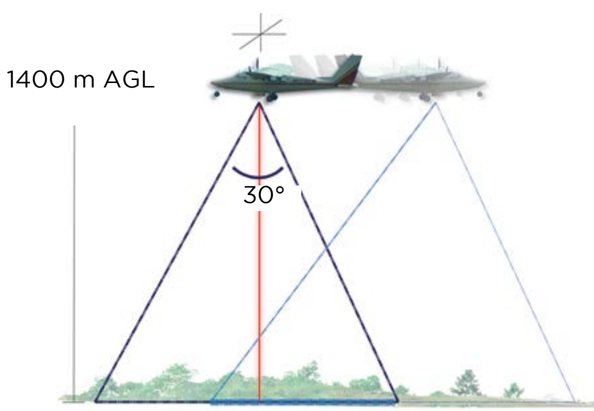
Cessna Caravan

LiDAR Survey

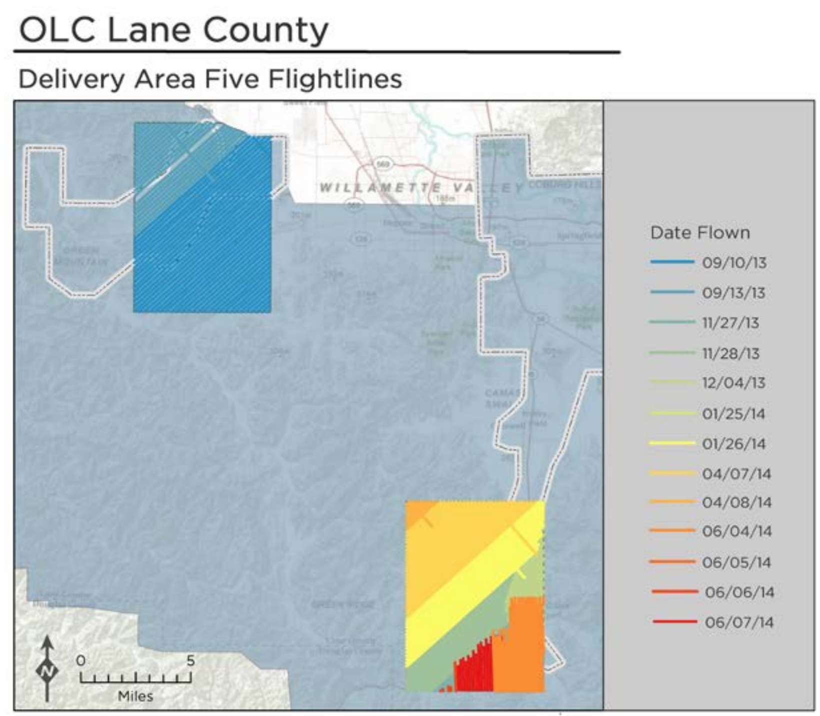
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz, and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-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, 572 flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper-PA
Survey Altitude (AGL)	1400 m / 900 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

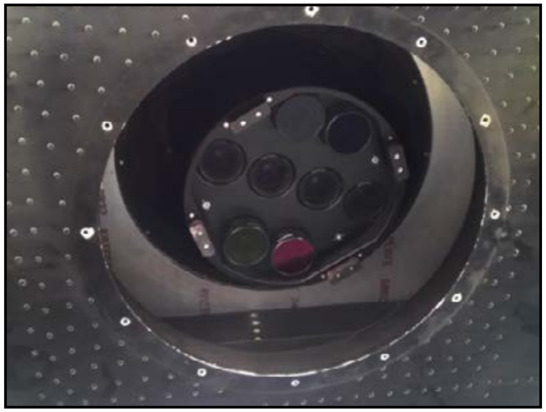
Aerial Acquisition

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 POSPac MMS, 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 usable 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	≤ 13 nm
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.

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

During the LiDAR survey, static (one hertz recording frequency) ground surveys were conducted over five 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

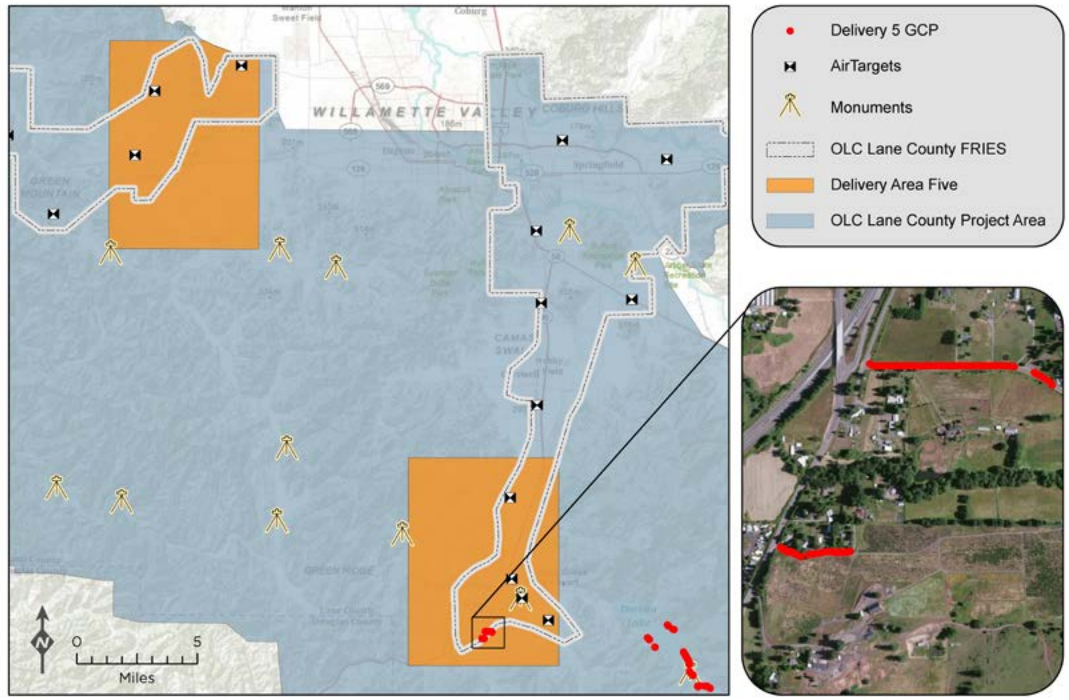
For this study area all Global Navigation Satellite System (GNSS) survey work utilizes a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points. The Trimble GNSS R8 unit is used primarily for real time kinematic (RTK) work but can also be used as a static receiver. 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.” One new monument was established and occupied for the Lane County study area. See Appendix B for a list of monuments placed within the whole OLC Lane County Study Area.

OLC Lane County

Delivery Area Five Ground Control



Methodology

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

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.

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 Calculator 2013 SP1 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 Ground Check Point (GCP) 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. For collecting GCPs, WSI uses two methods; Real Time Kinematic (RTK) and Post Processed Kinematic (PPK). GCP 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).

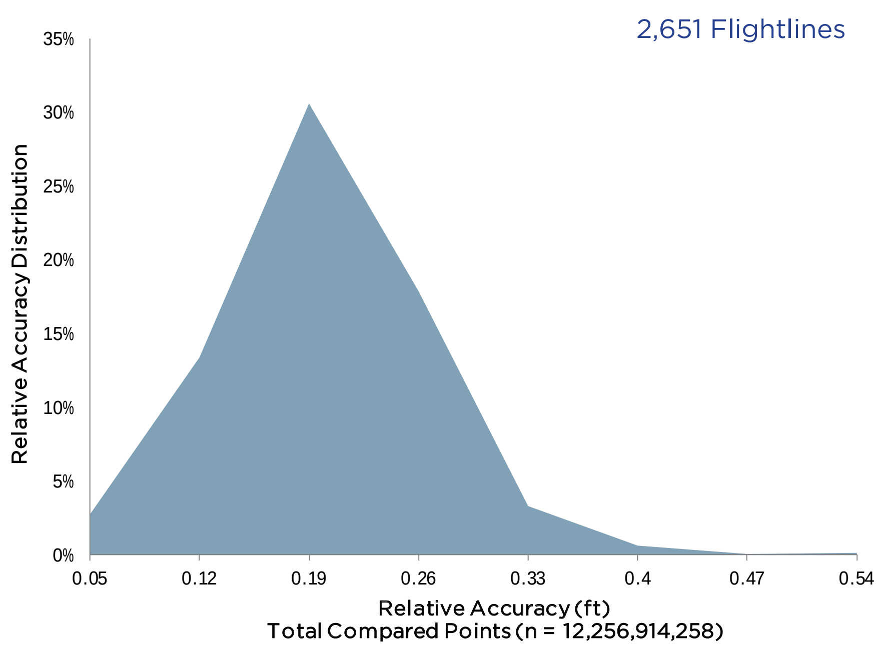
LiDAR Accuracy

Relative Accuracy

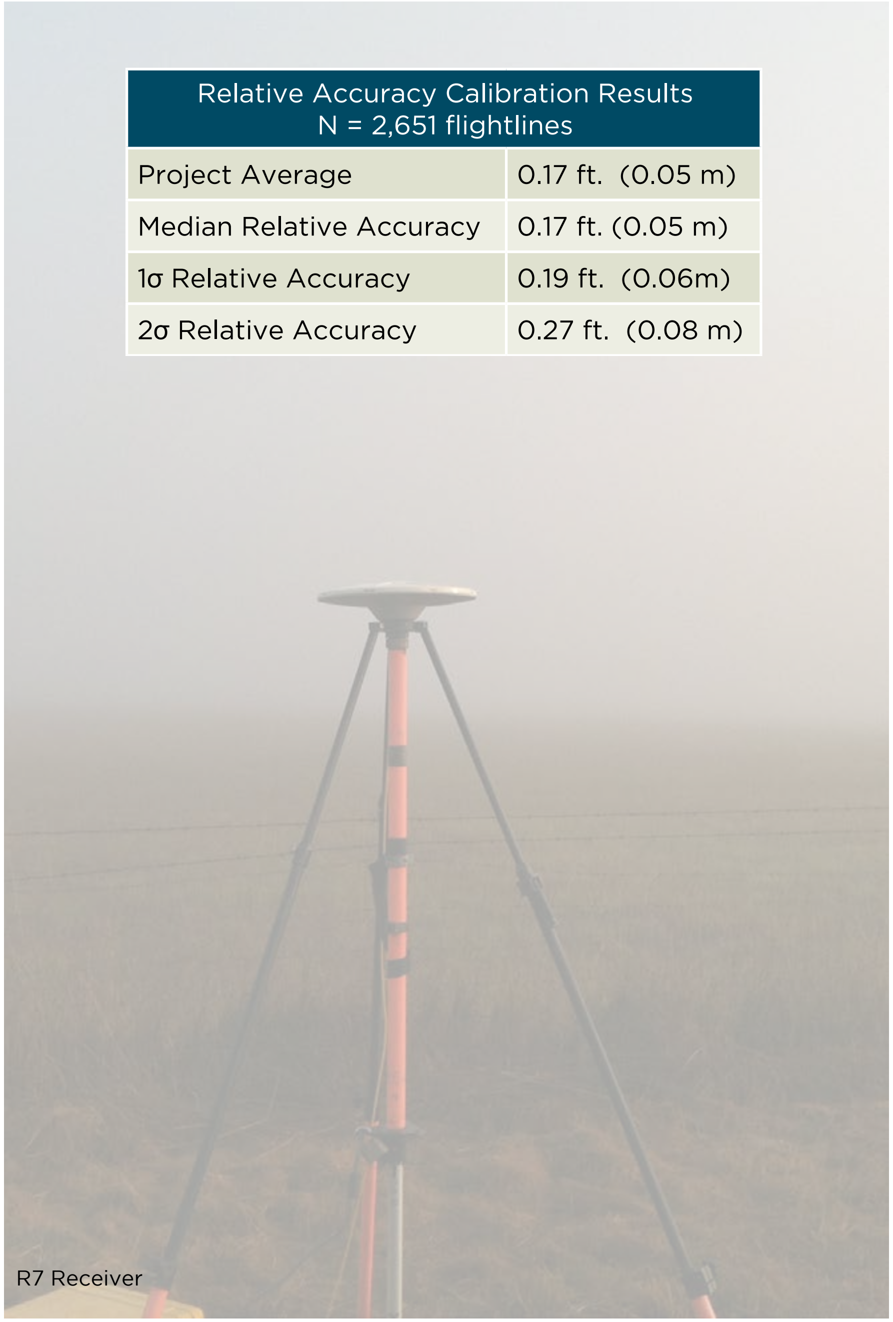
Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flightlines within an overlapping area. Divergence is most apparent when flightlines are opposing. When the LiDAR system is well calibrated the line to line divergence 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 2,651 full and partial flightlines (1,207 full and partial flightlines from Delivery Area Five) and over 12 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 2,651 flightlines	
Project Average	0.17 ft. (0.05 m)
Median Relative Accuracy	0.17 ft. (0.05 m)
1σ Relative Accuracy	0.19 ft. (0.06m)
2σ Relative Accuracy	0.27 ft. (0.08 m)



R7 Receiver

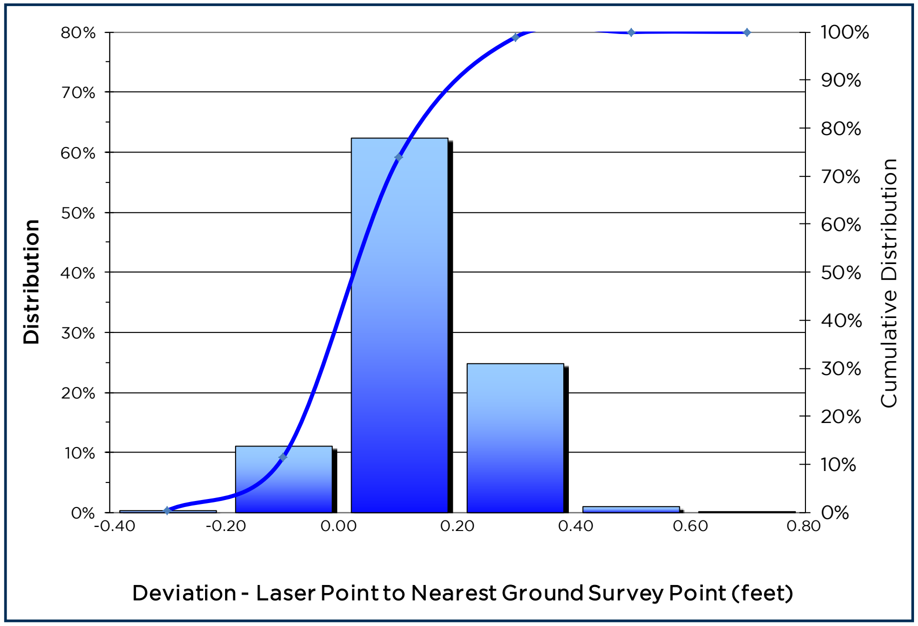
Vertical Accuracy

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 triangulated LiDAR surface. 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 Five study area, 2,607 GCPs were collected. Statistics are shown for Delivery Area Five.

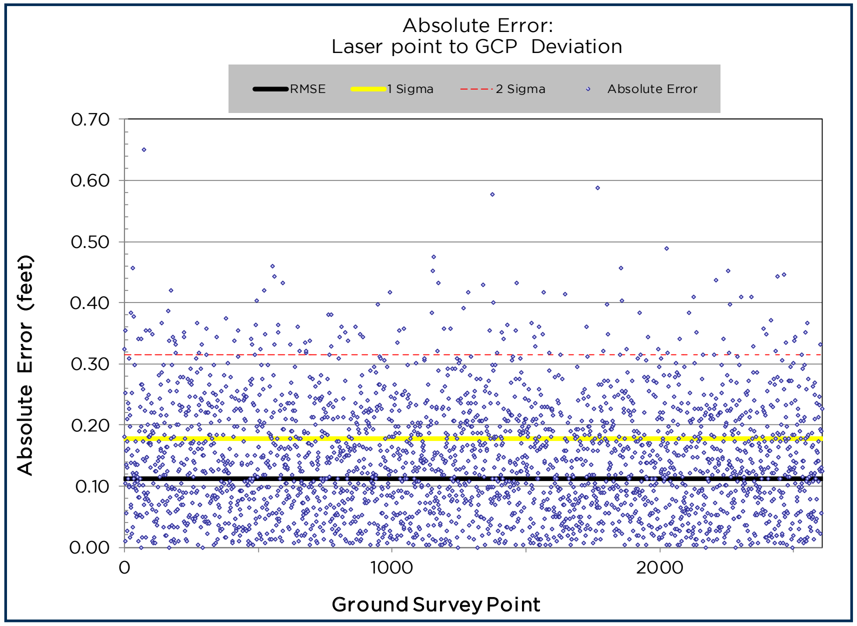
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results		
	Delivery Area Five	Cumulative
Sample Size (n)	2,607 Ground check points	7,062 Ground check points
Root Mean Square Error	0.11 ft. (0.03 m)	0.09 ft. (0.03 m)
1 Standard Deviation	0.18 ft. (0.05 m)	0.09 ft. (0.03 m)
2 Standard Deviation	0.31 ft. (0.10 m)	0.18 ft. (0.06 m)
Average Deviation	-0.13 ft. (0.04m)	-0.02 ft. (0.00 m)
Minimum Deviation	-0.37 ft. (-0.11 m)	-0.55 ft. (-0.17 m)
Maximum Deviation	0.65 ft. (0.20 m)	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GCP Absolute Error



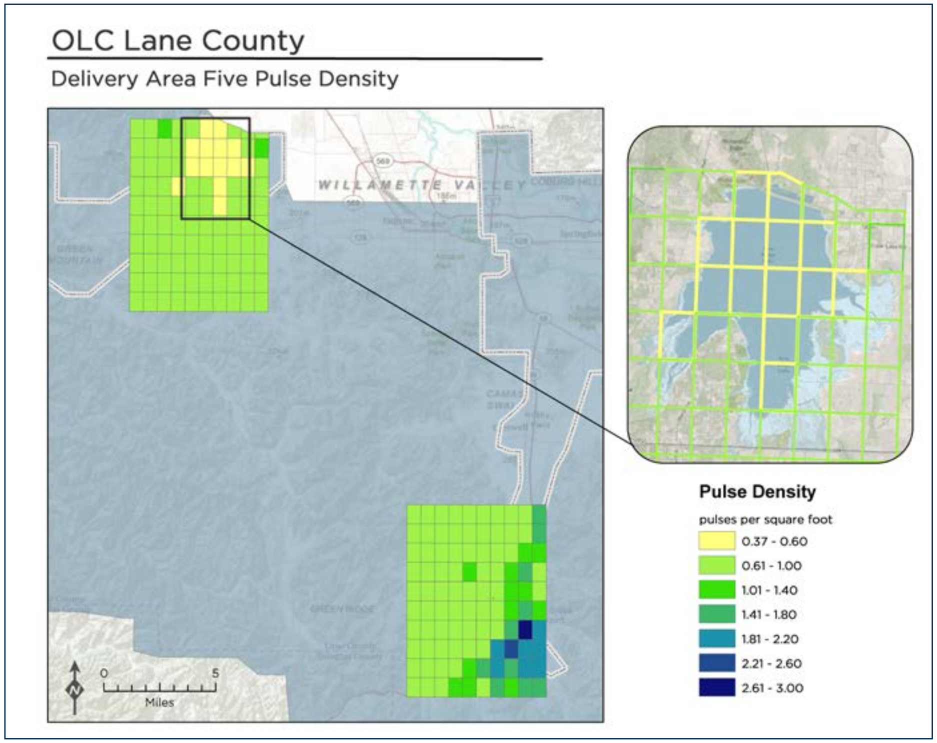
Density

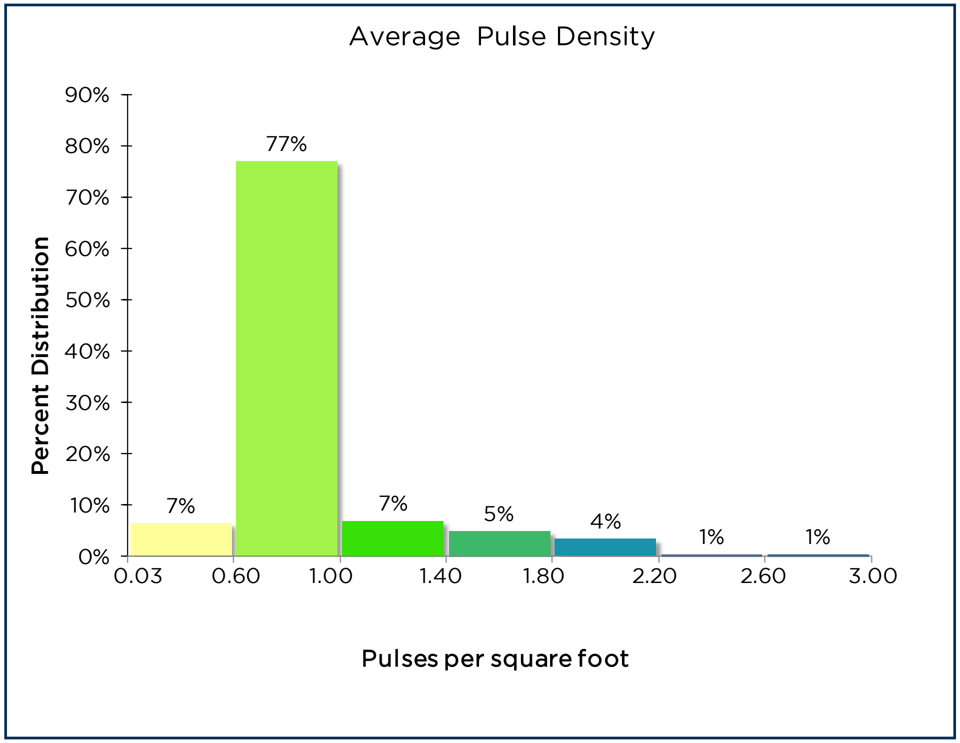
Pulse Density

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 delivery area.

Average Pulse Density	pulses per square meter	pulses per square foot
	9.90	0.92

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

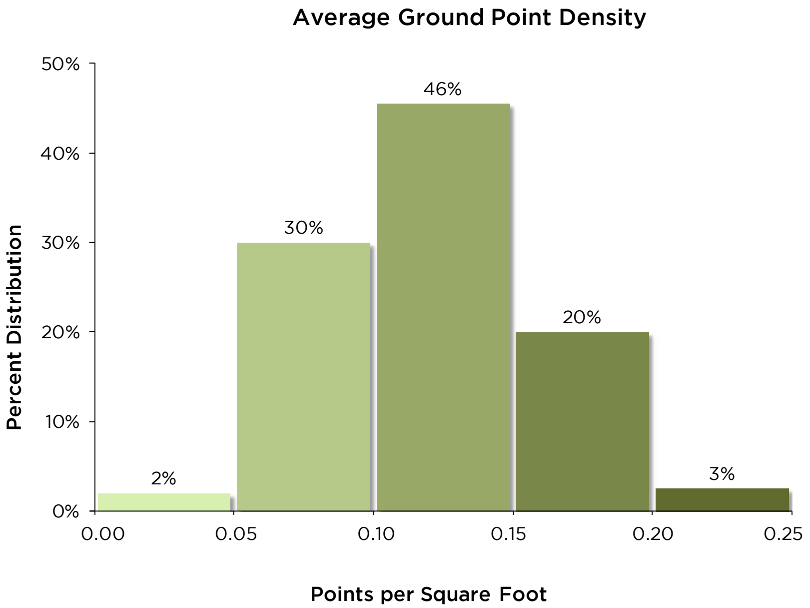




Ground Density

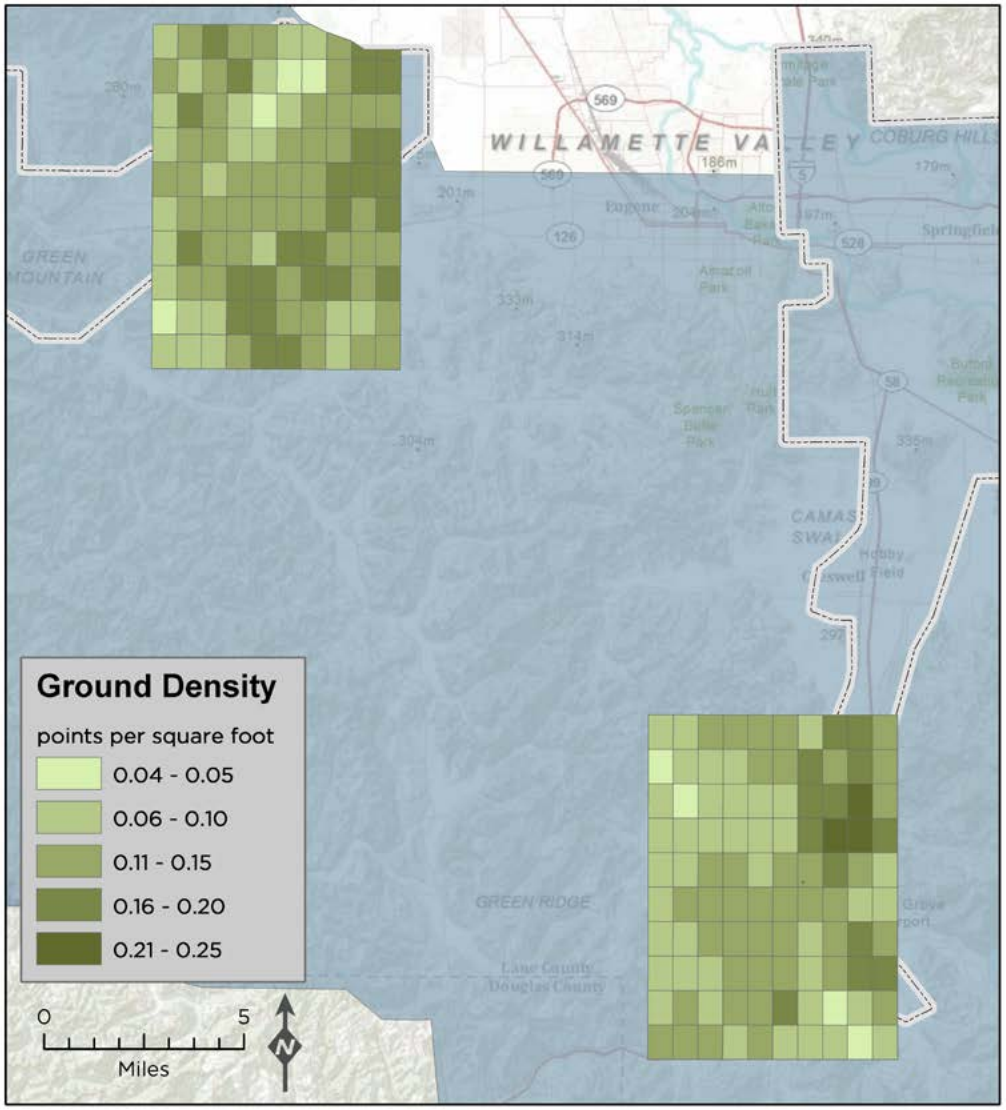
Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density is a measure of ground-classified point data for the delivery area.

Ground Density	points per square meter	points per square foot
	1.33	0.12



OLC Lane County

Delivery Area Five Ground Density



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

Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI provided LiDAR services for the OLC Lane County Delivery 5 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 September 3, 2013, and November 10, 2014.

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 11/17/2014

Evon P. Silvia, PLS Oregon
WSI, a Quantum Spatial Company
Corvallis, OR 97333

REGISTERED
PROFESSIONAL
LAND SURVEYOR

Evon P. Silvia

OREGON
JUNE 10, 2014
EVON P. SILVIA
81104LS

EXPIRES: 6/30/2014

Appendix B : GPS Monument Table

List of GPS monuments used in Lane County Survey Area.

Lane County GPS Monuments			
PID	Latitude	Longitude	Ellipse
LANE_01	44 13 34.22103	-123 55 25.99216	487.832
LANE_02	44 11 04.59366	-123 51 03.90195	104.844
LANE_05	44 16 43.86859	-124 02 41.13217	458.248
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_15	43 59 28.97732	-122 56 10.19436	139.378
AI1995	44 01 06.96543	-123 51 37.53642	-15.700
LANE_07	43 59 52.25896	-123 22 23.48186	143.322
LANE_09	44 04 26.42150	-123 30 21.24330	133.059
LANE_17	43 59 22.07068	-123 11 07.80197	111.693
LANE_19	44 00 01.44296	-123 13 56.62771	104.781
LANE_14	43 50 13.64839	-123 14 03.11154	175.699
LANE_16	43 49 45.78726	-123 07 47.74145	212.747
LANE_06	44 12 10.80761	-123 30 31.42667	196.503
LANE_08	44 08 23.10388	-123 35 55.56664	168.733
LANE_22	43 52 51.72856	-123 13 33.92296	147.785
LANE_23	43 47 25.93196	-123 01 54.25135	176.209
LANE_24	43 42 26.18996	-122 25 40.56001	450.794
LANE_25	43 42 51.38283	-122 23 45.43363	792.318
LANE_26	43 33 00.45694	-122 28 22.66794	815.341
LANE_27	43 31 20.08417	-122 20 15.46234	1080.075
LANE_30	43 37 14.50986	-123 05 19.83916	253.542
LANE_31	43 45 16.82389	-122 26 41.15314	492.053
LANE_32	43 47 33.82161	-122 25 40.76291	677.205
LANE_29	43 52 12.08177	-122 47 18.45224	420.380
LANE_28	43 53 58.92454	-122 48 59.17889	194.478

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipse
LANE_34	43 45 30.54400	-122 29 48.47559	308.081
LANE_29A	43 52 12.08161	-122 47 18.45256	420.361
AI2001	43 55 19.20493	-122 47 41.08223	195.963
LANE_35	43 48 11.57911	-122 42 37.56859	1041.596
LANE_36	43 50 54.28025	-123 21 47.73924	229.292
LANE_37	43 51 23.46541	-123 25 02.19196	197.776
LANE_20	43 53 27.38516	-123 28 30.83622	153.934
LANE_18	43 55 40.86962	-123 37 20.35729	178.186
LANE_38	43 58 54.14928	-123 41 53.55130	424.298
LANE_10	44 00 11.70302	-123 59 45.31927	-21.486
LANE_46	43 38 28.84405	-123 12 52.40829	104.565
LANE_47	43 35 46.97747	-123 15 08.04840	105.980
LANE_33	43 36 30.58173	-123 01 40.84386	471.540
RP_265+4988	43 25 06.36155	-123 09 01.37675	201.245
LANE_43	43 21 17.49608	-122 44 41.88280	524.594
LANE_39	43 42 19.93987	-122 57 05.04012	456.450
LANE_40	43 35 23.35579	-123 00 04.90380	479.127
LANE_41	43 44 45.10607	-122 53 27.75969	236.302
LANE_42	43 40 03.45665	-122 48 42.76721	311.004
LANE_49	43 41 54.47511	-122 46 16.97790	331.018
LANE_45	43 30 26.64379	-122 50 42.75367	1160.885
LANE_06	44 12 10.80764	-123 30 31.42667	196.522
LANE_12	44 05 44.71178	-123 43 49.91180	63.439
LANE_06A	44 14 32.55999	-123 24 47.48386	336.456
LANE_03	44 17 35.16542	-123 41 42.13047	69.602
LANE_51	44 05 39.63958	-122 47 04.98635	545.973

Lane County GPS Monuments

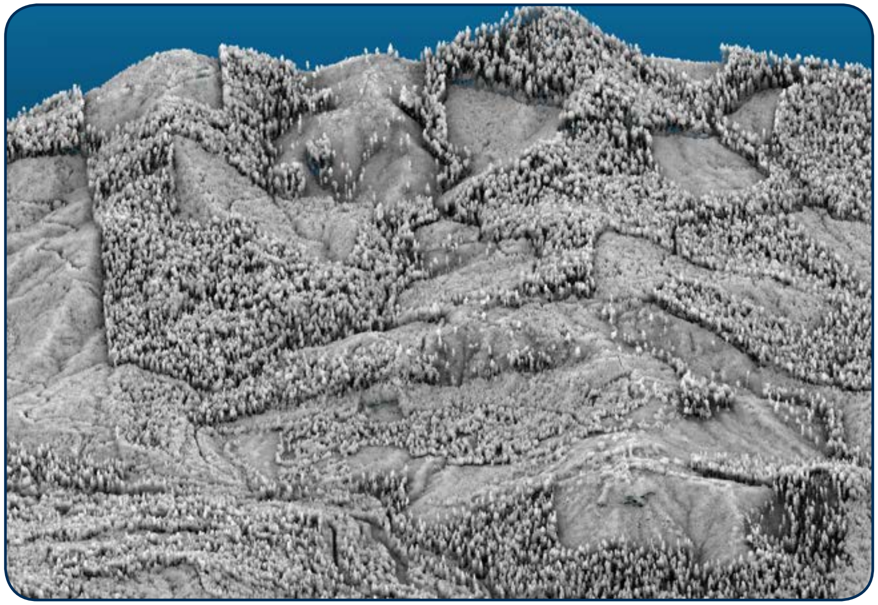
PID	Latitude	Longitude	Ellipse
AI1987	44 12 27.42931	-122 49 49.03656	157.321
LANE_04	44 19 30.86443	-123 39 58.03953	230.843
LANE_53	44 11 00.46734	-121 55 12.33453	1466.849
LANE_54	44 10 41.98041	-121 57 40.08010	1208.453
LANE_55	44 14 58.44023	-121 49 52.63978	1558.758
LANE_56	44 15 38.38604	-121 48 09.68817	1601.779
AJ8191	44 39 23.18028	-121 41 33.57573	1983.063
LANE_59	44 42 09.70199	-122 04 57.99867	497.773
LANE_69	44 42 36.07455	-122 06 34.98373	463.920
WRM_SP_01	44 39 22.75371	-121 41 33.13407	1981.876
LANE_57	44 25 19.90234	-121 51 23.67546	1434.237
LANE_58	44 26 11.01683	-121 56 36.51882	1117.648
LANE_63	44 15 13.30087	-122 07 55.02809	1377.917
LANE_64	44 13 05.95603	-122 06 13.58282	1482.944
LANE_67	44 09 58.41010	-122 40 34.96786	736.802
LANE_68	44 12 06.66895	-122 39 43.82798	699.408
LANE_60	44 40 38.57139	-121 54 04.98722	1281.918
LANE_70	44 07 45.63642	-122 26 24.72517	543.955
BLUE_RIV_04	44 19 45.50913	-122 06 01.51323	1412.718
LANE_71	44 10 24.58901	-122 32 25.77843	536.990
LANE_74	44 04 58.19343	-122 21 53.66019	715.086

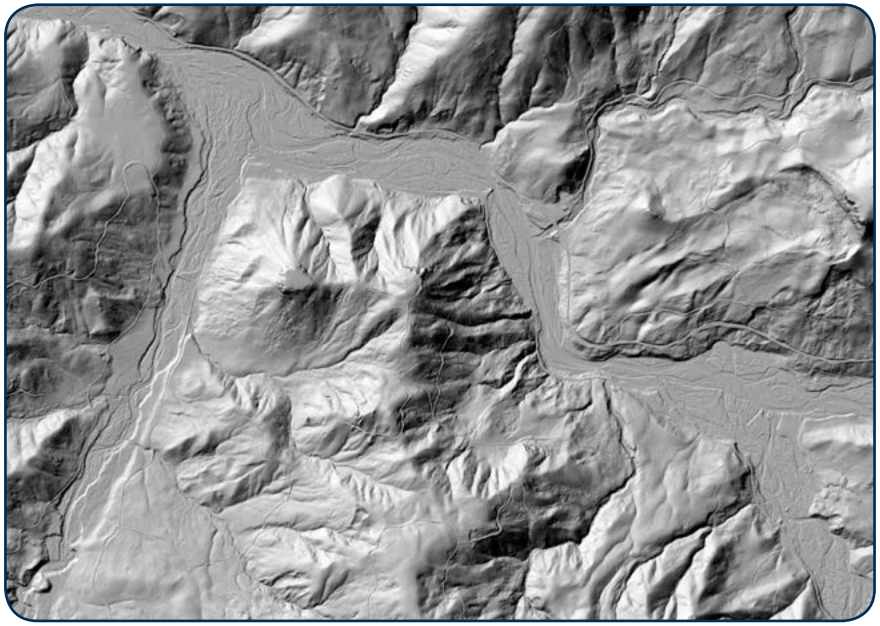
Appendix C : Selected Imagery

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, Spring-field, Oregon.

Highest Hit DEM of section of Delivery Area Two.

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 6

Data collected for:
Oregon Department of Geology and Mineral Industries

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Contents

Trimble R8 Reciever set up over GPS Monument "Lane_27," December 4, 2013.

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radiometric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Six, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,640,978 acres. Delivery Area Six encompasses 198,377 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.

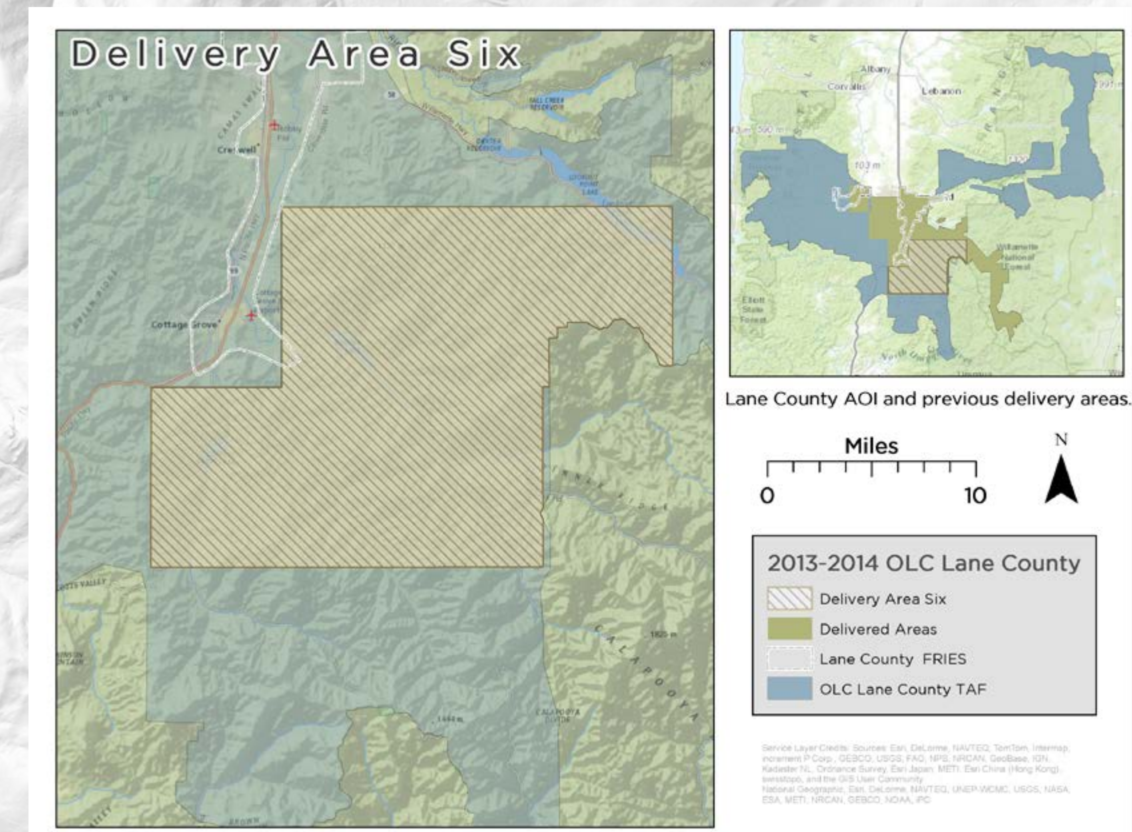
WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

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.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

OLC Lane County AOI Data Delivered December 19, 2014	
Acquisition Dates	November 27 - 28, 2013 December 4, 2013 January 6 - 26, 2014 June 4- 22, 2014 July 4-7, 2014
Delivery Area Six Area of Interest	198,377 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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

Aerial Acquisition

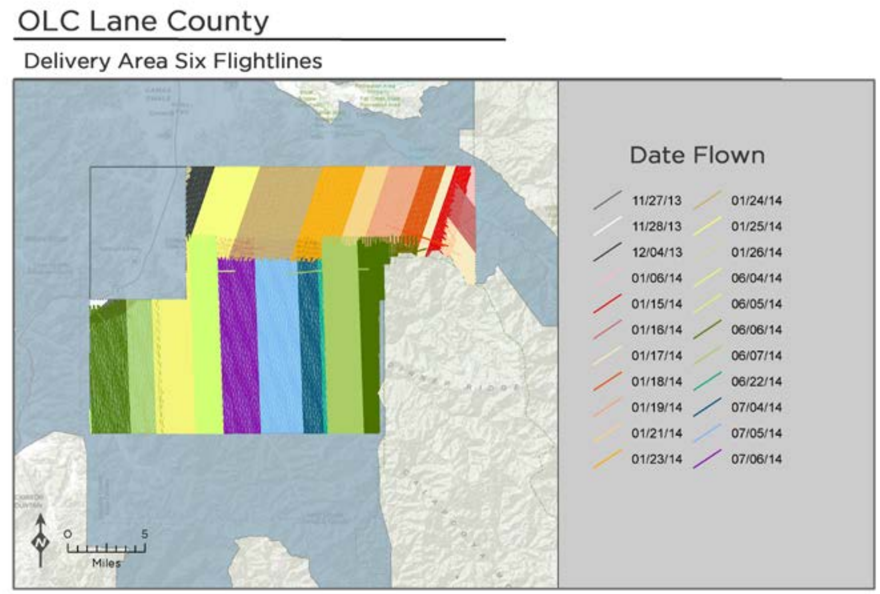
Cessna Caravan

LiDAR Survey

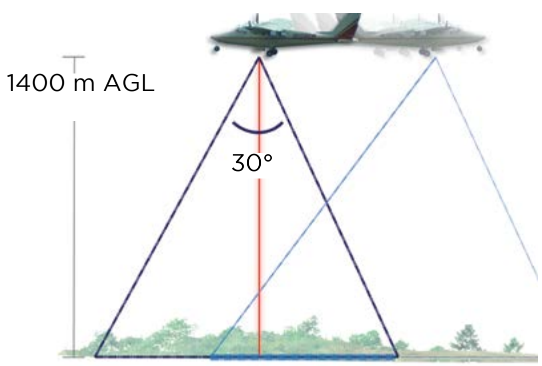
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-15 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, 553 flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper PA 31
Survey Altitude (AGL)	1400 m / 900 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

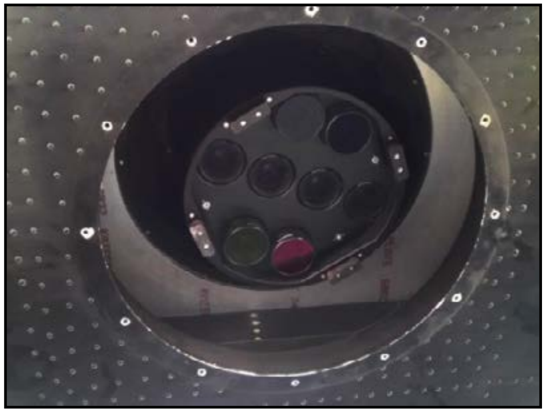
Aerial Acquisition

Photography

The photography or Four-Band Radiometric 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 POSPac MMS, 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 usable 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	≤ 13 nm
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_32".

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

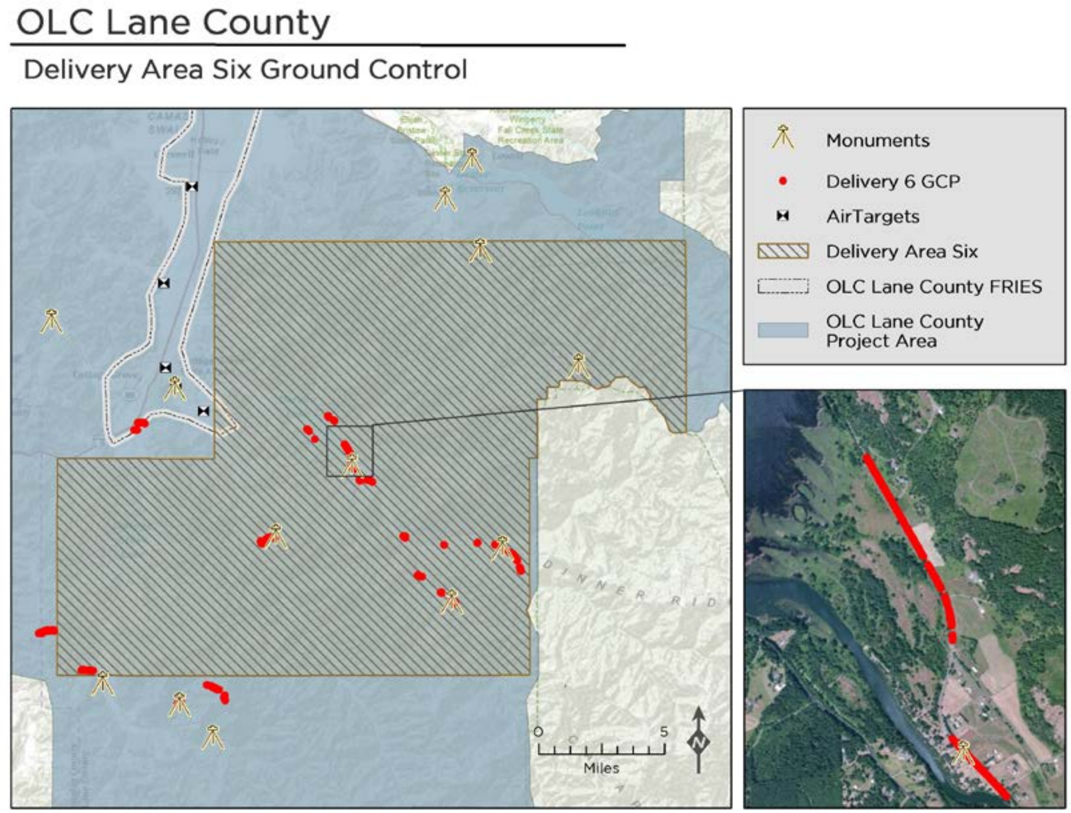
Ground control surveys, including monumentation, aerial targets, and ground check points (GCPs) were conducted to support the airborne acquisition. Ground control data are used to geospatially correct the aircraft positional coordinate data and to perform quality assurance checks on final LiDAR data and orthoimagery products. See the table below for specifications of equipment used.

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 GCP collection were conducted with Trimble R8 and Trimble R10 GNSS receivers.

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 GCP coverage. NGS benchmarks are preferred for control points; however, in the absence of NGS benchmarks, WSI produces our own 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, Inc. Control.” The table at right provides the list of monuments used in Delivery Area Six. See Appendix B for a complete list of monuments placed within the OLC Lane County 2014 Study Area.



Delivery Area Six Monuments			
PID	Latitude	Longitude	Ellipsoid Height (m)
LANE_29A	43° 52’ 12.08161”	-122° 47’ 18.45256”	420.361
LANE_35	43° 48’ 11.57911”	-122° 42’ 37.56859”	1041.596
LANE_39	43° 42’ 19.93987”	-122° 57’ 05.04012”	456.450
LANE_41	43° 44’ 45.10607”	-122° 53’ 27.75969”	236.302
LANE_42	43° 40’ 03.45665”	-122° 48’ 42.76721”	311.004
LANE_49	43° 41’ 54.47511”	-122° 46’ 16.97790”	331.018

Methodology

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

To correct the continuously recorded aircraft position, WSI 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 Check Points (GCPs) are collected using Real Time Kinematic (RTK), Post-Processed Kinematic (PPK), and Fast-Static (FS) 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 and FS surveys, however, these corrections are post-processed. All GCP 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, GCP measurements are not taken on highly reflective surfaces such as center line stripes or lane markings on roads. GCPs are taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs. GCPs 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.

Ground professional collecting RTK

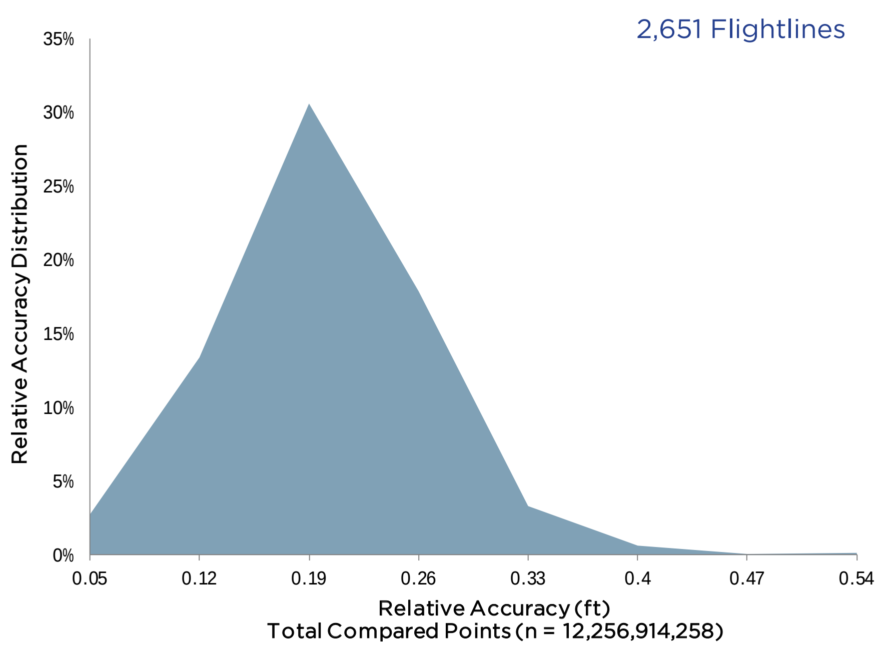
LiDAR Accuracy

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 2,651 full and partial flightlines (553 full and partial flightlines from Delivery Area Six) and over 12 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 2,651 flightlines	
Project Average	0.17 ft. (0.05 m)
Median Relative Accuracy	0.17 ft. (0.05 m)
1σ Relative Accuracy	0.19 ft. (0.06 m)
2σ Relative Accuracy	0.27 ft. (0.08 m)

R7 Receiver

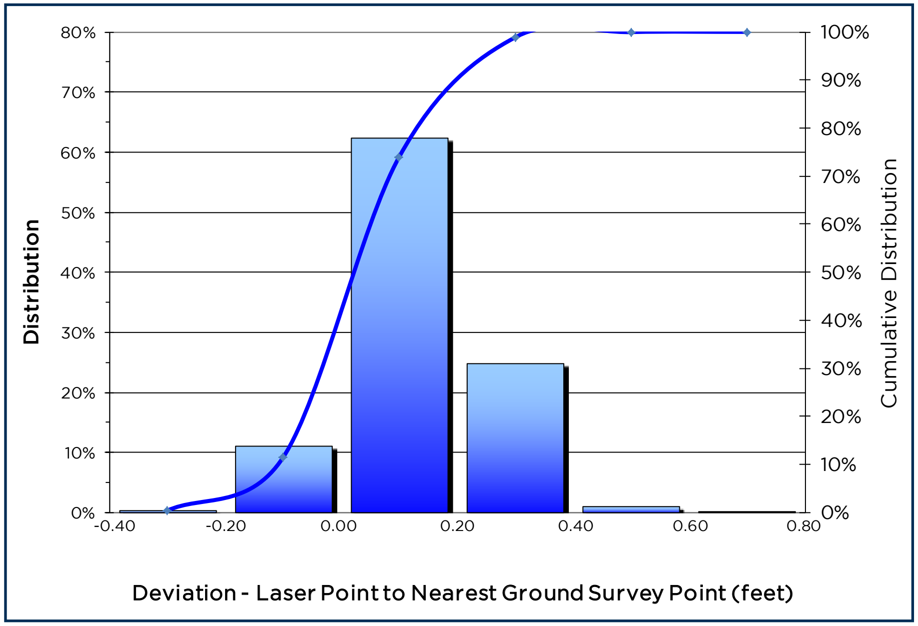
Vertical Accuracy

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 triangulated LiDAR surface. 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 six study area, 2,607 GCPs were collected. Statistics are shown for Delivery Area Six.

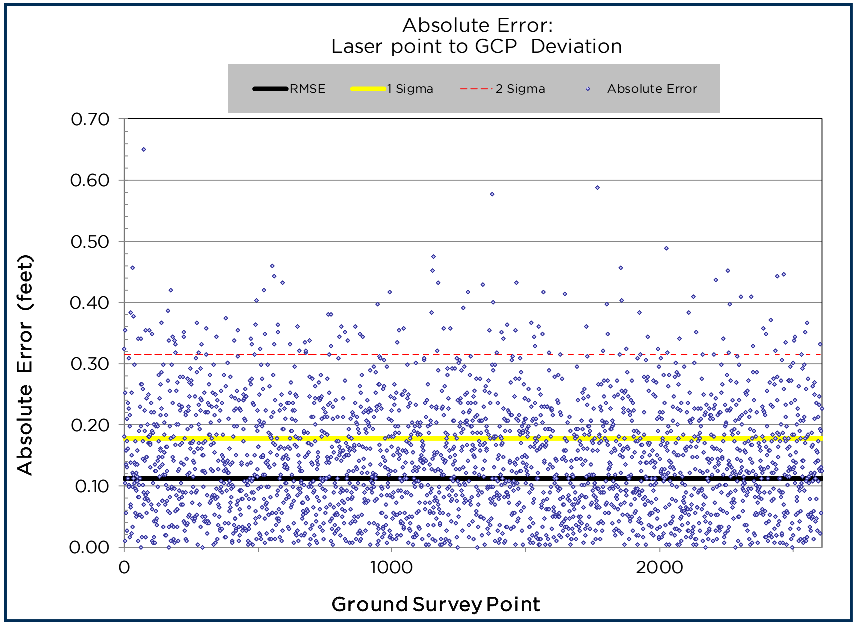
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results		
	Delivery Area Six	Cumulative
Sample Size (n)	2,607 Ground check points	7,062 Ground check points
Root Mean Square Error	0.11 ft. (0.03 m)	0.09 ft. (0.03 m)
1 Standard Deviation	0.18 ft. (0.05 m)	0.09 ft. (0.03 m)
2 Standard Deviation	0.31 ft. (0.10 m)	0.18 ft. (0.06 m)
Average Deviation	-0.13 ft. (0.04 m)	-0.02 ft. (0.00 m)
Minimum Deviation	-0.37 ft. (-0.11 m)	-0.55 ft. (-0.17 m)
Maximum Deviation	0.65 ft. (0.20 m)	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GCP Absolute Error



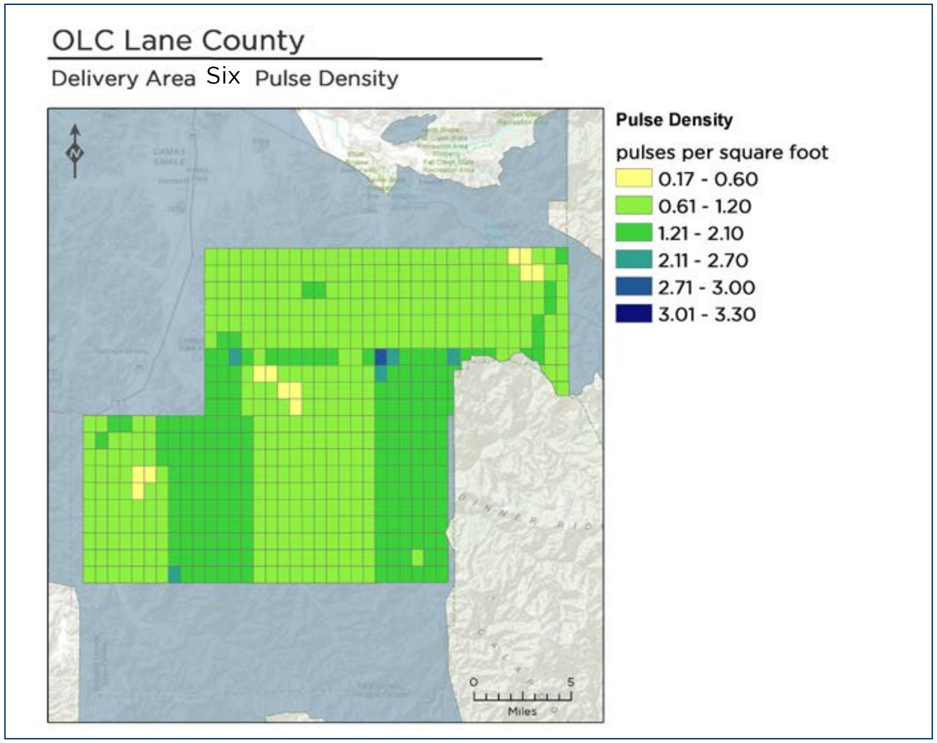
Density

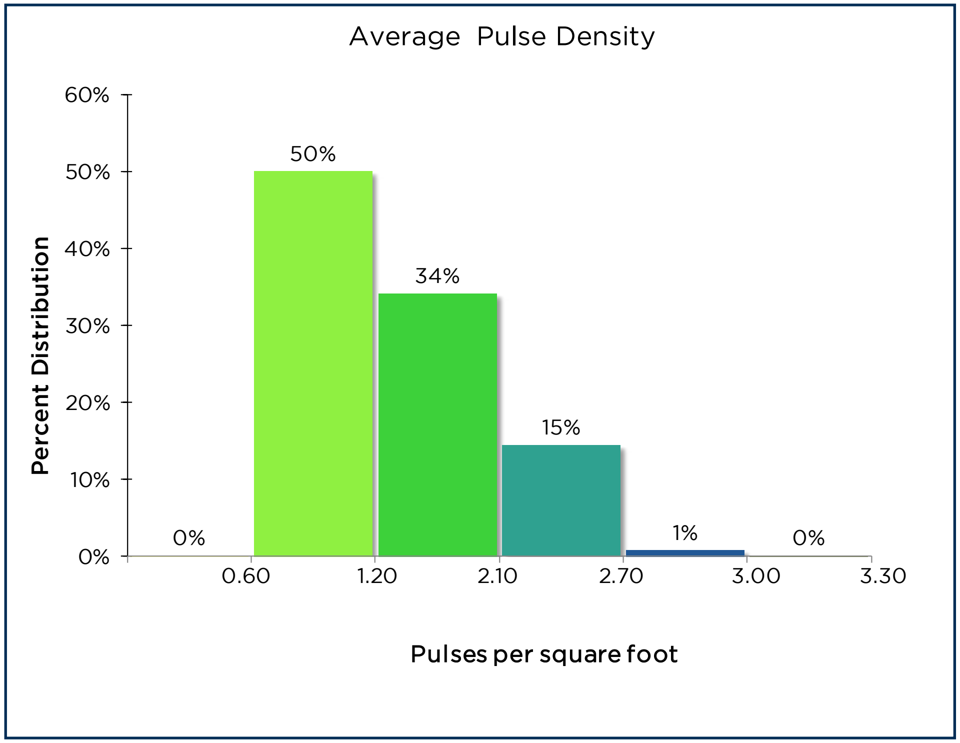
Pulse Density

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.

Average Pulse Density	pulses per square meter	pulses per square foot
	11.42	1.06

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



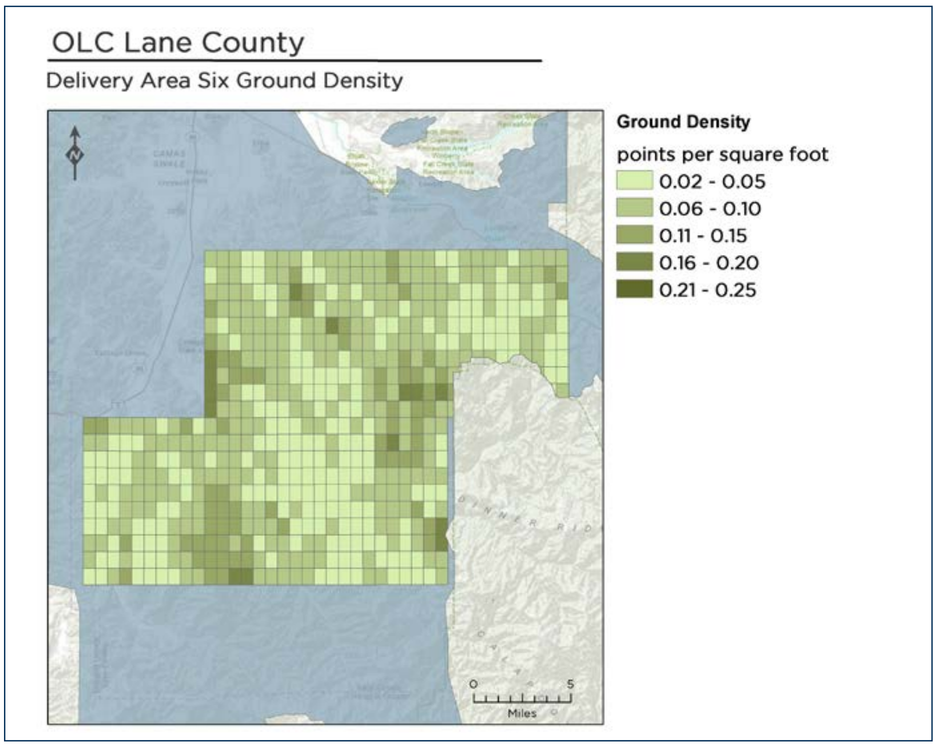


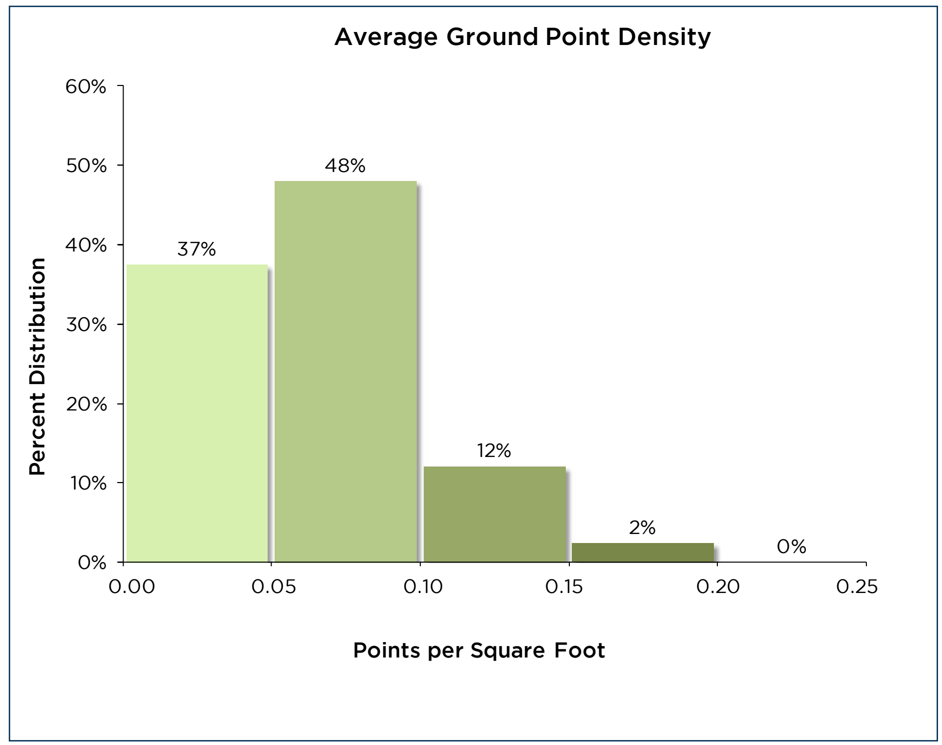
Ground Density

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 is a measure of ground-classified point data for the the delivery area.

Ground Density	points per square meter	points per square foot
	0.72	0.07

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





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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. Accuracy statistics are reported for the entire Lane County Orthophoto AOI.

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

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI provided LiDAR Services for OLC Lane County LiDAR project Delivery 6 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.

12/19/2014

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 GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between November 27, 2014 and July 7, 2014. 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".

12/18/2014

Christopher Glantz, PLS
Land Surveyor
WSI, a Quantum Spatial Company
Portland, OR 97204

REGISTERED
PROFESSIONAL
LAND SURVEYOR
OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648
RENEWS 6/30/2015

Appendix B : GPS Monument Table

List of GPS monuments used in Lane County Survey Area.

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)
LANE_01	44° 13’ 34.22103”	-123° 55’ 25.99216”	487.832
LANE_02	44° 11’ 04.59366”	-123° 51’ 03.90195”	104.844
LANE_05	44° 16’ 43.86859”	-124° 02’ 41.13217”	458.248
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_15	43° 59’ 28.97732”	-122° 56’ 10.19436”	139.378
AI1995	44° 01’ 06.96543”	-123° 51’ 37.53642”	-15.700
LANE_07	43° 59’ 52.25896”	-123° 22’ 23.48186”	143.322
LANE_09	44° 04’ 26.42150”	-123° 30’ 21.24330”	133.059
LANE_17	43° 59’ 22.07068”	-123° 11’ 07.80197”	111.693
LANE_19	44° 00’ 01.44296”	-123° 13’ 56.62771”	104.781
LANE_14	43° 50’ 13.64839”	-123° 14’ 03.11154”	175.699
LANE_16	43° 49’ 45.78726”	-123° 07’ 47.74145”	212.747
LANE_06	44° 12’ 10.80761”	-123° 30’ 31.42667”	196.503
LANE_08	44° 08’ 23.10388”	-123° 35’ 55.56664”	168.733
LANE_22	43° 52’ 51.72856”	-123° 13’ 33.92296”	147.785
LANE_23	43° 47’ 25.93196”	-123° 01’ 54.25135”	176.209
LANE_24	43° 42’ 26.18996”	-122° 25’ 40.56001”	450.794
LANE_25	43° 42’ 51.38283”	-122° 23’ 45.43363”	792.318
LANE_26	43° 33’ 00.45694”	-122° 28’ 22.66794”	815.341
LANE_27	43° 31’ 20.08417”	-122° 20’ 15.46234”	1080.075
LANE_30	43° 37’ 14.50986”	-123° 05’ 19.83916”	253.542
LANE_31	43° 45’ 16.82389”	-122° 26’ 41.15314”	492.053
LANE_32	43° 47’ 33.82161”	-122° 25’ 40.76291”	677.205
LANE_29	43° 52’ 12.08177”	-122° 47’ 18.45224”	420.380
LANE_28	43° 53’ 58.92454”	-122° 48’ 59.17889”	194.478

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)
LANE_34	43° 45' 30.54400"	-122° 29' 48.47559"	308.081
LANE_29A	43° 52' 12.08161"	-122° 47' 18.45256"	420.361
AI2001	43° 55' 19.20493"	-122° 47' 41.08223"	195.963
LANE_35	43° 48' 11.57911"	-122° 42' 37.56859"	1041.596
LANE_36	43° 50' 54.28025"	-123° 21' 47.73924"	229.292
LANE_37	43° 51' 23.46541"	-123° 25' 02.19196"	197.776
LANE_20	43° 53' 27.38516"	-123° 28' 30.83622"	153.934
LANE_18	43° 55' 40.86962"	-123° 37' 20.35729"	178.186
LANE_38	43° 58' 54.14928"	-123° 41' 53.55130"	424.298
LANE_10	44° 00' 11.70302"	-123° 59' 45.31927"	-21.486
LANE_46	43° 38' 28.84405"	-123° 12' 52.40829"	104.565
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980
LANE_33	43° 36' 30.58173"	-123° 01' 40.84386"	471.540
RP_265+4988	43° 25' 06.36155"	-123° 09' 01.37675"	201.245
LANE_43	43° 21' 17.49608"	-122° 44' 41.88280"	524.594
LANE_39	43° 42' 19.93987"	-122° 57' 05.04012"	456.450
LANE_40	43° 35' 23.35579"	-123° 00' 04.90380"	479.127
LANE_41	43° 44' 45.10607"	-122° 53' 27.75969"	236.302
LANE_42	43° 40' 03.45665"	-122° 48' 42.76721"	311.004
LANE_49	43° 41' 54.47511"	-122° 46' 16.97790"	331.018
LANE_45	43° 30' 26.64379"	-122° 50' 42.75367"	1160.885
LANE_06	44° 12' 10.80764"	-123° 30' 31.42667"	196.522
LANE_12	44° 05' 44.71178"	-123° 43' 49.91180"	63.439
LANE_06A	44° 14' 32.55999"	-123° 24' 47.48386"	336.456
LANE_03	44° 17' 35.16542"	-123° 41' 42.13047"	69.602
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973

Lane County GPS Monuments

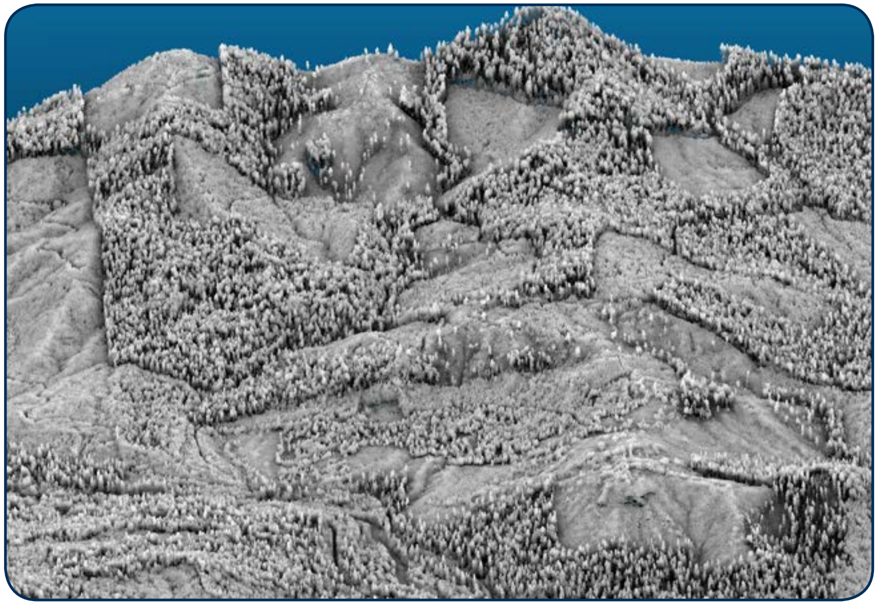
PID	Latitude	Longitude	Ellipsoid Height (m)
AI1987	44° 12’ 27.42931”	-122° 49’ 49.03656”	157.321
LANE_04	44° 19’ 30.86443”	-123° 39’ 58.03953”	230.843
LANE_53	44° 11’ 00.46734”	-121° 55’ 12.33453”	1466.849
LANE_54	44° 10’ 41.98041”	-121° 57’ 40.08010”	1208.453
LANE_55	44° 14’ 58.44023”	-121° 49’ 52.63978”	1558.758
LANE_56	44° 15’ 38.38604”	-121° 48’ 09.68817”	1601.779
AJ8191	44° 39’ 23.18028”	-121° 41’ 33.57573”	1983.063
LANE_59	44° 42’ 09.70199”	-122° 04’ 57.99867”	497.773
LANE_69	44° 42’ 36.07455”	-122° 06’ 34.98373”	463.920
WRM_SP_01	44° 39’ 22.75371”	-121° 41’ 33.13407”	1981.876
LANE_57	44° 25’ 19.90234”	-121° 51’ 23.67546”	1434.237
LANE_58	44° 26’ 11.01683”	-121° 56’ 36.51882”	1117.648
LANE_63	44° 15’ 13.30087”	-122° 07’ 55.02809”	1377.917
LANE_64	44° 13’ 05.95603”	-122° 06’ 13.58282”	1482.944
LANE_67	44° 09’ 58.41010”	-122° 40’ 34.96786”	736.802
LANE_68	44° 12’ 06.66895”	-122° 39’ 43.82798”	699.408
LANE_60	44° 40’ 38.57139”	-121° 54’ 04.98722”	1281.918
LANE_70	44° 07’ 45.63642”	-122° 26’ 24.72517”	543.955
BLUE_RIV_04	44° 19’ 45.50913”	-122° 06’ 01.51323”	1412.718
LANE_71	44° 10’ 24.58901”	-122° 32’ 25.77843”	536.990
LANE_74	44° 04’ 58.19343”	-122° 21’ 53.66019”	715.086

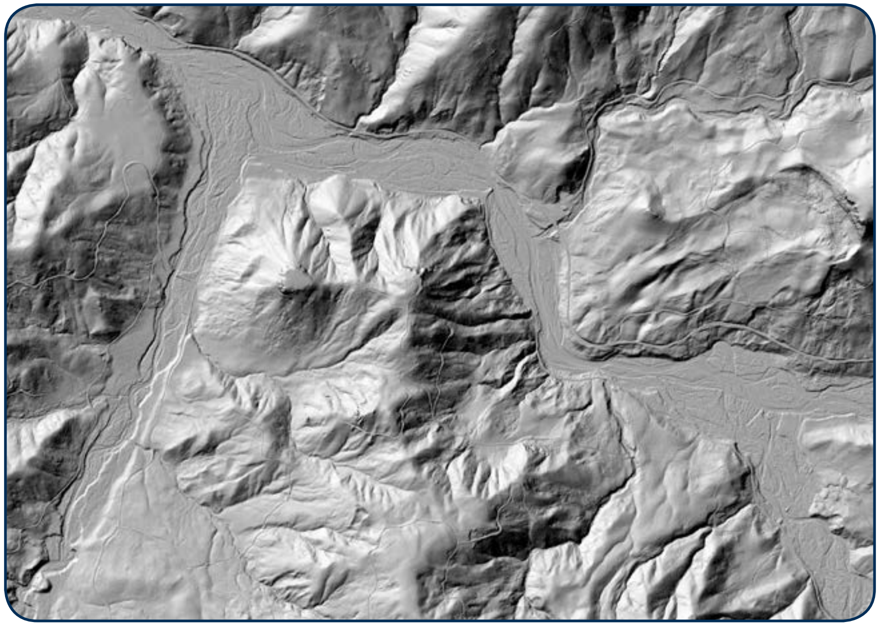
Appendix C : Selected Imagery

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.

Highest Hit DEM of section of Delivery Area Two.

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 7

January 16, 2015

Data collected for:
Oregon Department of Geology and Mineral Industries

800 NE Oregon Street
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Portland, OR 97232

Prepared by:
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Contents

GPS Monument "Lane_47"

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radiometric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Seven, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 1,640,978 acres. Delivery Area Seven encompasses 297,015 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.

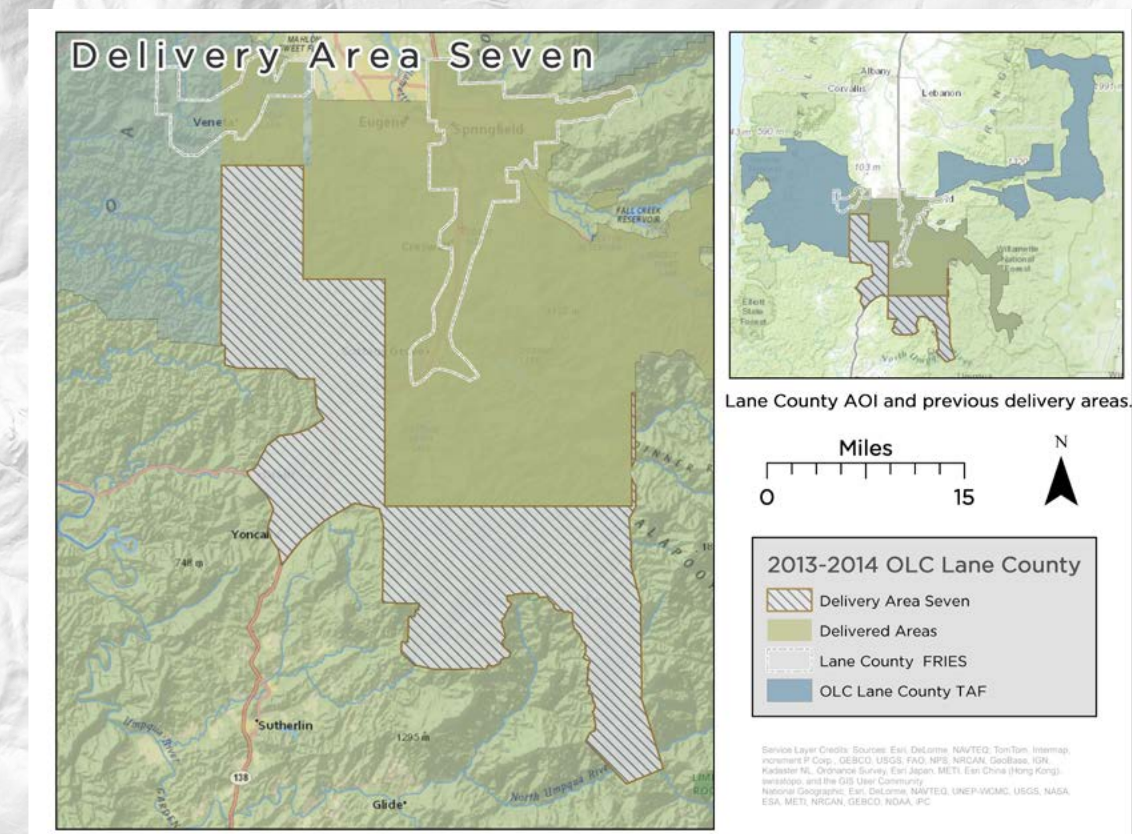
WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

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.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

OLC Lane County AOI Data Delivered January 16, 2015	
Acquisition Dates	September 10 - 12, 2013 November 27 - 28, 2013 January 26, 2014 April 7 - 29, 2014 June 3 - 22, 2014 July 4 - 6, 2014
Delivery Area Seven Area of Interest	297,015 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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

Aerial Acquisition

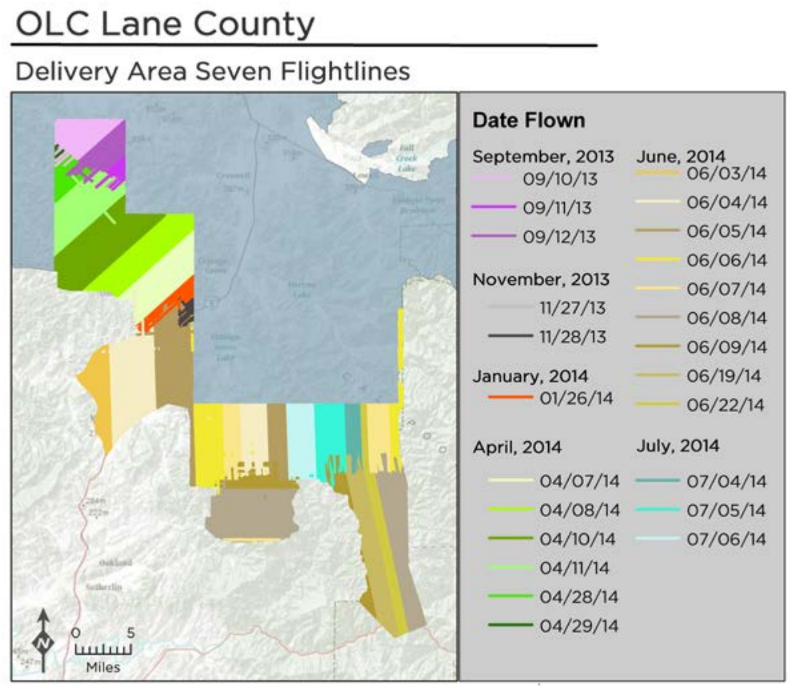
Cessna Caravan

LiDAR Survey

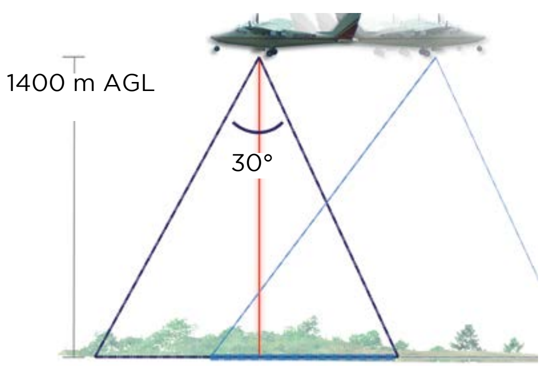
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-15 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, 795 full and partial flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper PA-31
Survey Altitude (AGL)	1400 m / 900 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

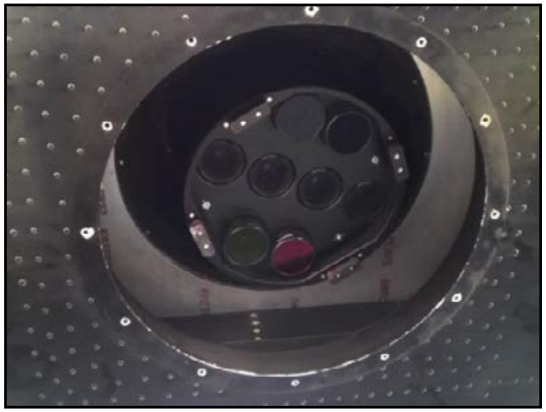
Aerial Acquisition

Photography

The photography or Four-Band Radiometric 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 POSPac MMS, 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 usable 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	≤ 13 nm
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_30”.

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

Ground control surveys, including monumentation, aerial targets, 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 and orthoimagery products.

Instrumentation

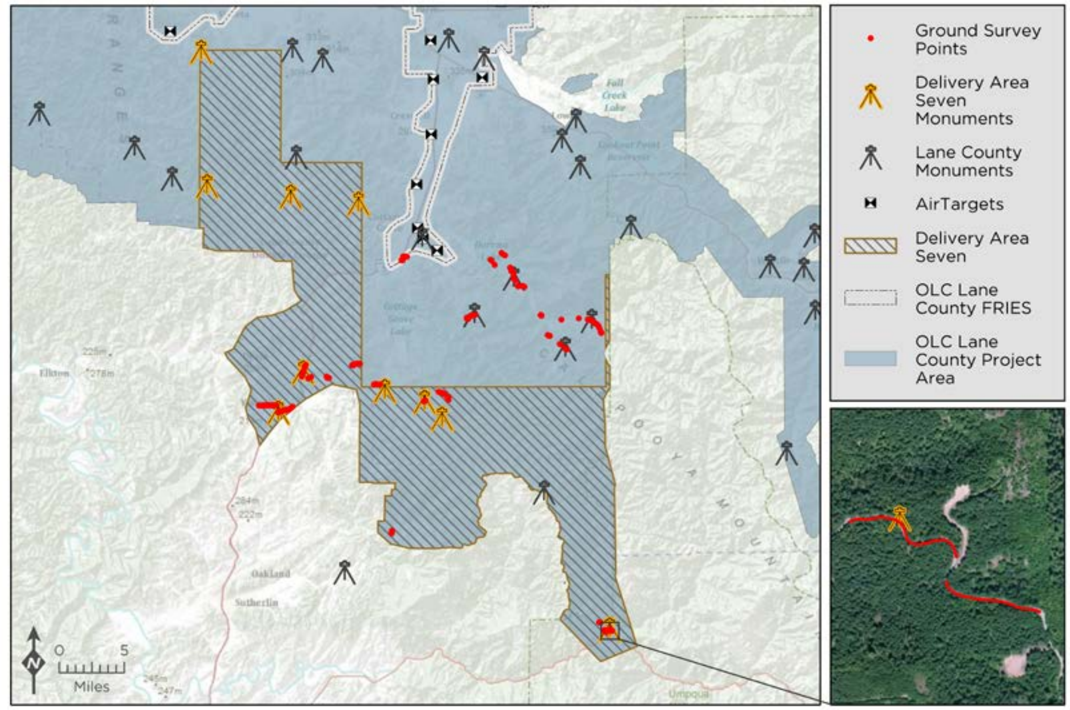
All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R8 and Trimble R10 GNSS receivers. See the table on the following page 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, WSI produces our own 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, Inc. Control." The table at right provides the list of monuments used in Delivery Area Seven. See Appendix B for a complete list of monuments placed within the OLC Lane County 2014 Study Area.

OLC Lane County

Delivery Area Seven Ground Control



Delivery Area Seven Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
LANE_07	43° 59' 52.25896"	-123° 22' 23.48186"	143.322	166.275
LANE_14	43° 50' 13.64839"	-123° 14' 03.11154"	175.699	198.720
LANE_16	43° 49' 45.78726"	-123° 07' 47.74145"	212.747	235.886
LANE_30	43° 37' 14.50986"	-123° 05' 19.83916"	253.542	276.603
LANE_33	43° 36' 30.58173"	-123° 01' 40.84386"	471.540	494.595
LANE_36	43° 50' 54.28025"	-123° 21' 47.73924"	229.292	252.262
LANE_40	43° 35' 23.35579"	-123° 00' 04.90380"	479.127	502.200
LANE_43	43° 21' 17.49608"	-122° 44' 41.88280"	524.594	547.828
LANE_46	43° 38' 28.84405"	-123° 12' 52.40829"	104.565	127.599
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980	129.003

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Methodology

To correct the continuously recorded aircraft position, WSI 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.

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

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK), Post-Processed Kinematic (PPK), and Fast-Static (FS) 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 and FS 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.

Ground professional collecting RTK

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
Trimble R10	Integrated Antenna R10	TRMR10	Rover

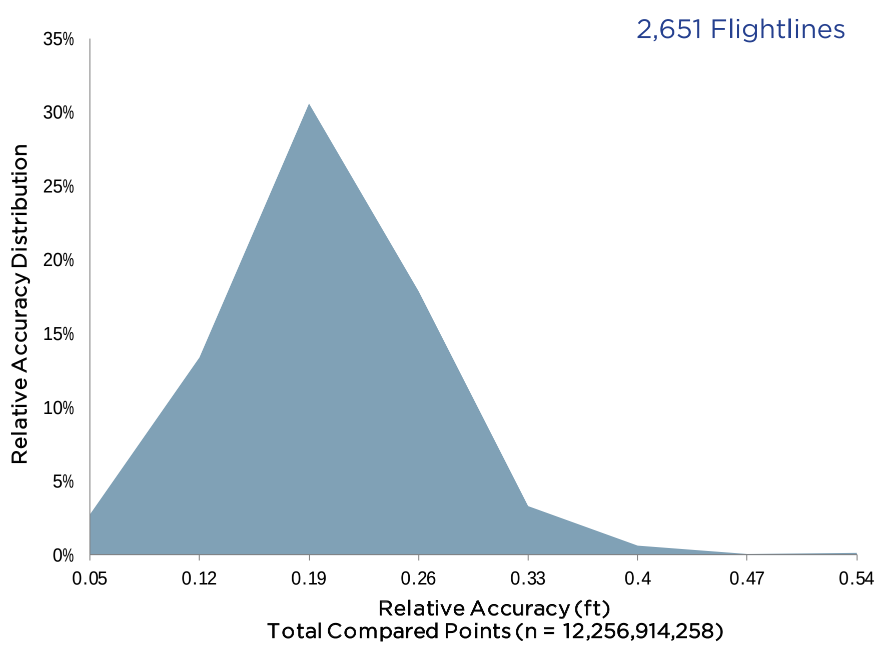
LiDAR Accuracy

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 2,651 full and partial flightlines (795 full and partial flightlines from Delivery Area Seven) and over 12 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Distribution



Relative Accuracy Calibration Results N = 2,651 flightlines	
Project Average	0.17 ft. (0.05 m)
Median Relative Accuracy	0.17 ft. (0.05 m)
1σ Relative Accuracy	0.19 ft. (0.06 m)
2σ Relative Accuracy	0.27 ft. (0.08 m)

R7 Receiver

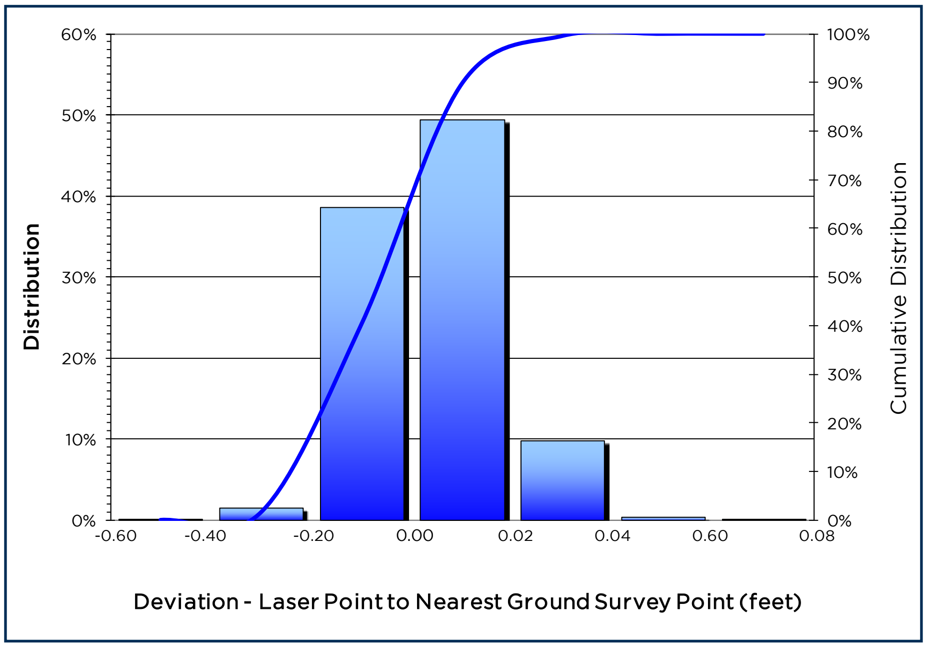
Vertical Accuracy

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 survey points to the triangulated LiDAR surface. 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 seven study area, 2,607 GSPs were collected. Statistics are shown for Delivery Area Seven.

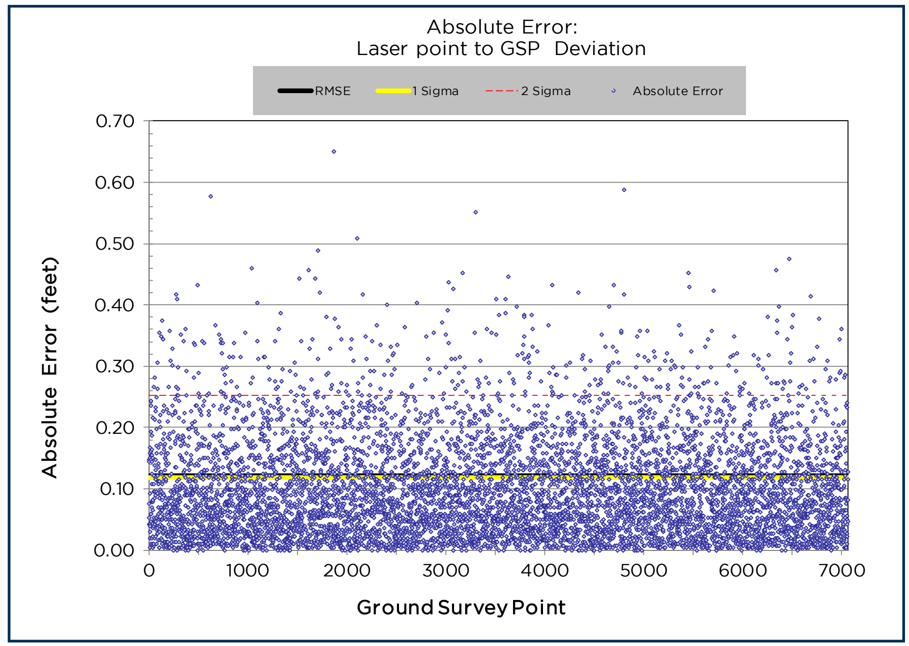
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results		
	Delivery Area Seven	Cumulative
Sample Size (n)	2,607 Ground survey points	7,062 Ground survey points
Root Mean Square Error	0.11 ft. (0.03 m)	0.09 ft. (0.03 m)
1 Standard Deviation	0.18 ft. (0.05 m)	0.09 ft. (0.03 m)
2 Standard Deviation	0.31 ft. (0.10 m)	0.18 ft. (0.06 m)
Average Deviation	-0.13 ft. (0.04 m)	-0.02 ft. (0.00 m)
Minimum Deviation	-0.37 ft. (-0.11 m)	-0.55 ft. (-0.17 m)
Maximum Deviation	0.65 ft. (0.20 m)	0.42 ft. (0.13 m)

Vertical Accuracy Distribution



GSP Absolute Error



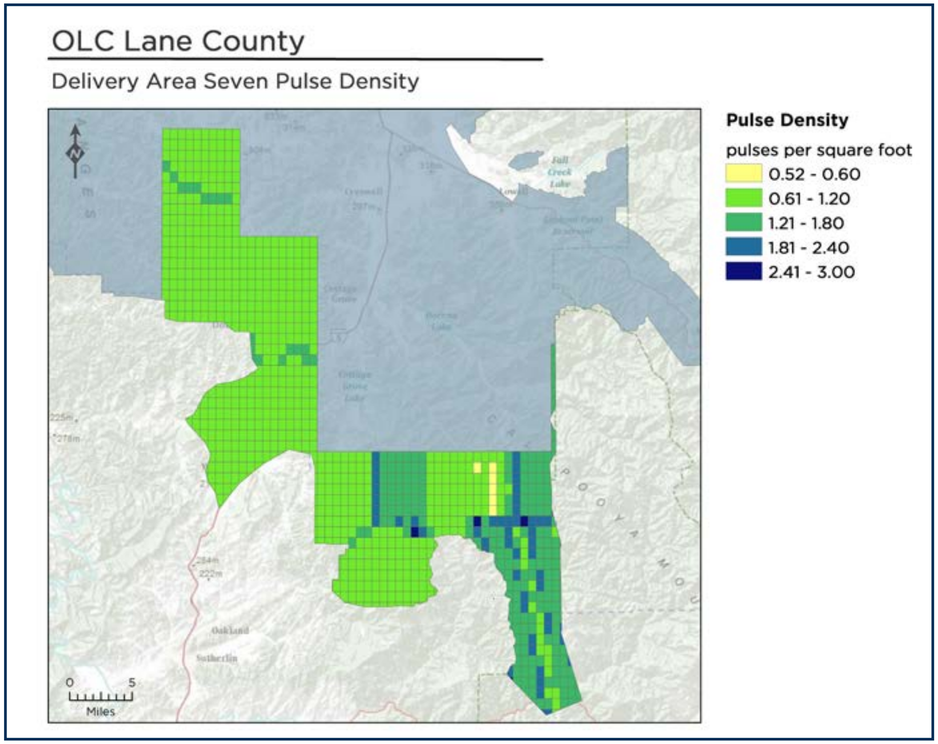
Density

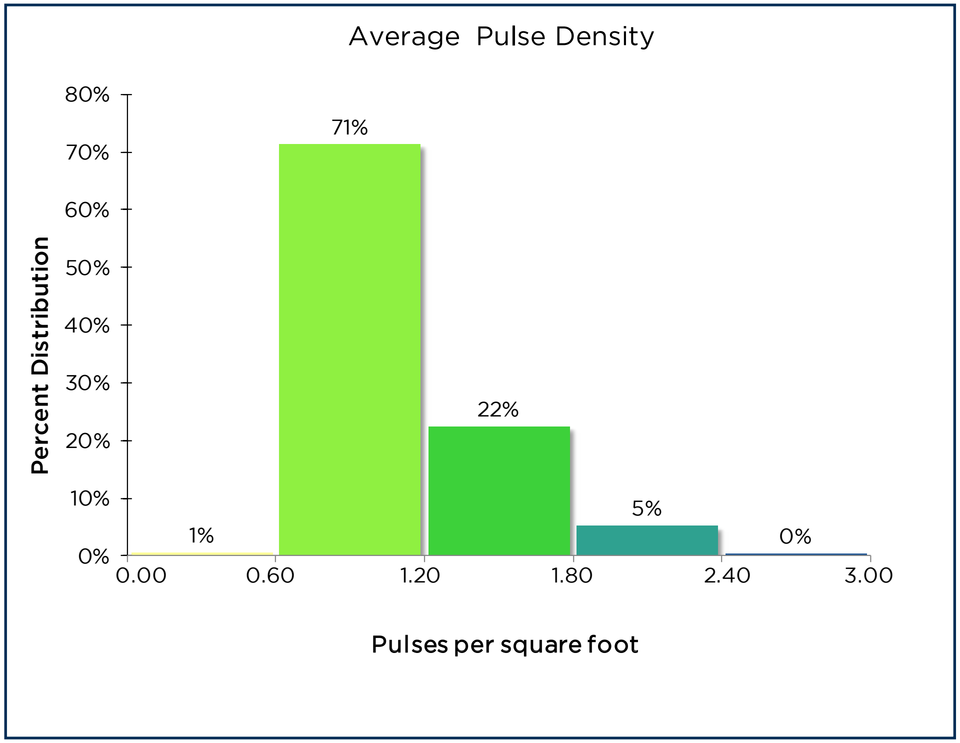
Pulse Density

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.

Average Pulse Density	pulses per square meter	pulses per square foot
	11.27	1.05

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



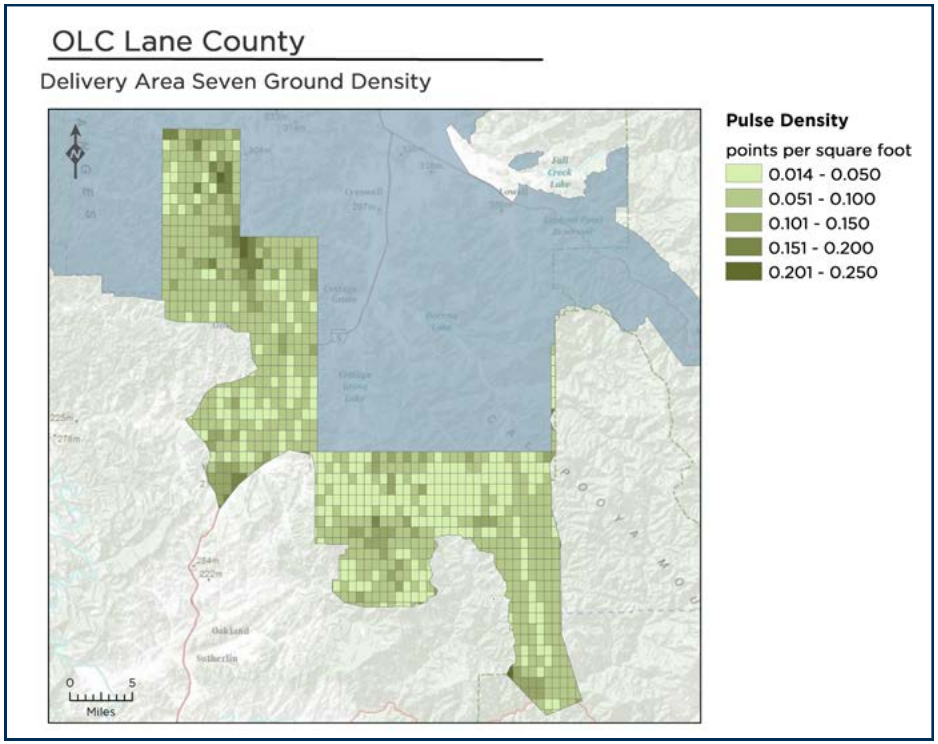


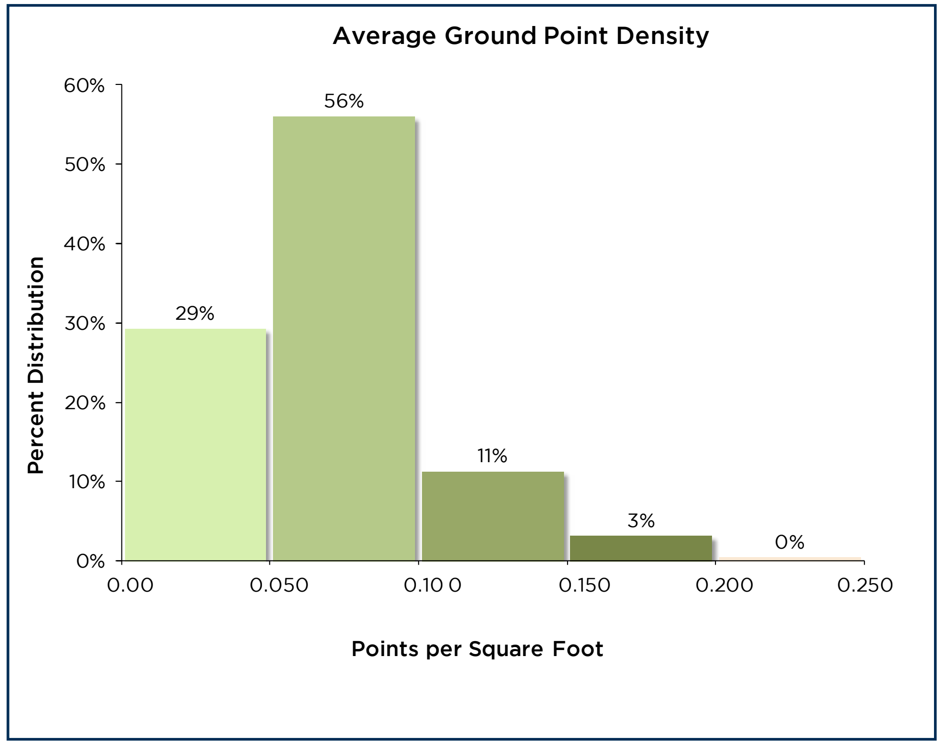
Ground Density

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 is a measure of ground-classified point data for the the delivery area.

Ground Density	points per square meter	points per square foot
	0.74	0.07

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





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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. Accuracy statistics are reported for the entire Lane County Orthophoto AOI.

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

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI provided LiDAR Services for OLC Lane County LiDAR project Delivery 7 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.

1/15/2015

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 GCP's were performed using commonly accepted Standard Practices. Field work conducted for this report was conducted between September 10, 2014 and July 6, 2014. 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".

1/15/2015

Christopher Glantz, PLS
Land Surveyor
WSI, a Quantum Spatial Company
Portland, OR 97204

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648

RENEWS 6/30/2015

Appendix B : GPS Monument Table

List of GPS monuments used in OLC Lane County Survey Area. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Lane County GPS Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
AI1987	44° 12’ 27.42931”	-122° 49’ 49.03656”	157.321	180.546
AI1995	44° 01’ 06.96543”	-123° 51’ 37.53642”	-15.700	7.830
AI2001	43° 55’ 19.20493”	-122° 47’ 41.08223”	195.963	219.207
AJ8191	44° 39’ 23.18028”	-121° 41’ 33.57573”	1983.063	2004.142
BLUE_RIV_04	44° 19’ 45.50913”	-122° 06’ 01.51323”	1412.718	1434.493
LANE_01	44° 13’ 34.22103”	-123° 55’ 25.99216”	487.832	510.916
LANE_02	44° 11’ 04.59366”	-123° 51’ 03.90195”	104.844	127.922
LANE_03	44° 17’ 35.16542”	-123° 41’ 42.13047”	69.602	92.380
LANE_04	44° 19’ 30.86443”	-123° 39’ 58.03953”	230.843	253.545
LANE_05	44° 16’ 43.86859”	-124° 02’ 41.13217”	458.248	481.770
LANE_06	44° 12’ 10.80761”	-123° 30’ 31.42667”	196.503	219.150
LANE_06	44° 12’ 10.80764”	-123° 30’ 31.42667”	196.522	219.169
LANE_06A	44° 14’ 32.55999”	-123° 24’ 47.48386”	336.456	359.076
LANE_07	43° 59’ 52.25896”	-123° 22’ 23.48186”	143.322	166.275
LANE_08	44° 08’ 23.10388”	-123° 35’ 55.56664”	168.733	191.568
LANE_09	44° 04’ 26.42150”	-123° 30’ 21.24330”	133.059	155.944
LANE_10	44° 00’ 11.70302”	-123° 59’ 45.31927”	-21.486	2.572
LANE_11	44° 04’ 08.74341”	-122° 48’ 06.59661”	161.587	184.843
LANE_12	44° 05’ 44.71178”	-123° 43’ 49.91180”	63.439	86.487
LANE_13	44° 00’ 41.08475”	-122° 59’ 27.48519”	119.047	142.488
LANE_14	43° 50’ 13.64839”	-123° 14’ 03.11154”	175.699	198.720
LANE_15	43° 59’ 28.97732”	-122° 56’ 10.19436”	139.378	162.854
LANE_16	43° 49’ 45.78726”	-123° 07’ 47.74145”	212.747	235.886
LANE_17	43° 59’ 22.07068”	-123° 11’ 07.80197”	111.693	134.821
LANE_18	43° 55’ 40.86962”	-123° 37’ 20.35729”	178.186	201.375
LANE_19	44° 00’ 01.44296”	-123° 13’ 56.62771”	104.781	127.866

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_20	43° 53’ 27.38516”	-123° 28’ 30.83622”	153.934	176.937
LANE_22	43° 52’ 51.72856”	-123° 13’ 33.92296”	147.785	170.814
LANE_23	43° 47’ 25.93196”	-123° 01’ 54.25135”	176.209	199.467
LANE_24	43° 42’ 26.18996”	-122° 25’ 40.56001”	450.794	473.495
LANE_25	43° 42’ 51.38283”	-122° 23’ 45.43363”	792.318	814.931
LANE_26	43° 33’ 00.45694”	-122° 28’ 22.66794”	815.341	838.000
LANE_27	43° 31’ 20.08417”	-122° 20’ 15.46234”	1080.075	1102.415
LANE_28	43° 53’ 58.92454”	-122° 48’ 59.17889”	194.478	217.704
LANE_29	43° 52’ 12.08177”	-122° 47’ 18.45224”	420.380	443.438
LANE_29A	43° 52’ 12.08161”	-122° 47’ 18.45256”	420.361	443.419
LANE_30	43° 37’ 14.50986”	-123° 05’ 19.83916”	253.542	276.603
LANE_31	43° 45’ 16.82389”	-122° 26’ 41.15314”	492.053	514.761
LANE_32	43° 47’ 33.82161”	-122° 25’ 40.76291”	677.205	699.811
LANE_33	43° 36’ 30.58173”	-123° 01’ 40.84386”	471.540	494.595
LANE_34	43° 45’ 30.54400”	-122° 29’ 48.47559”	308.081	330.844
LANE_35	43° 48’ 11.57911”	-122° 42’ 37.56859”	1041.596	1064.353
LANE_36	43° 50’ 54.28025”	-123° 21’ 47.73924”	229.292	252.262
LANE_37	43° 51’ 23.46541”	-123° 25’ 02.19196”	197.776	220.754
LANE_38	43° 58’ 54.14928”	-123° 41’ 53.55130”	424.298	447.505
LANE_39	43° 42’ 19.93987”	-122° 57’ 05.04012”	456.450	479.572
LANE_40	43° 35’ 23.35579”	-123° 00’ 04.90380”	479.127	502.200
LANE_41	43° 44’ 45.10607”	-122° 53’ 27.75969”	236.302	259.436
LANE_42	43° 40’ 03.45665”	-122° 48’ 42.76721”	311.004	334.075
LANE_43	43° 21’ 17.49608”	-122° 44’ 41.88280”	524.594	547.828
LANE_45	43° 30’ 26.64379”	-122° 50’ 42.75367”	1160.885	1183.729

Lane County GPS Monuments

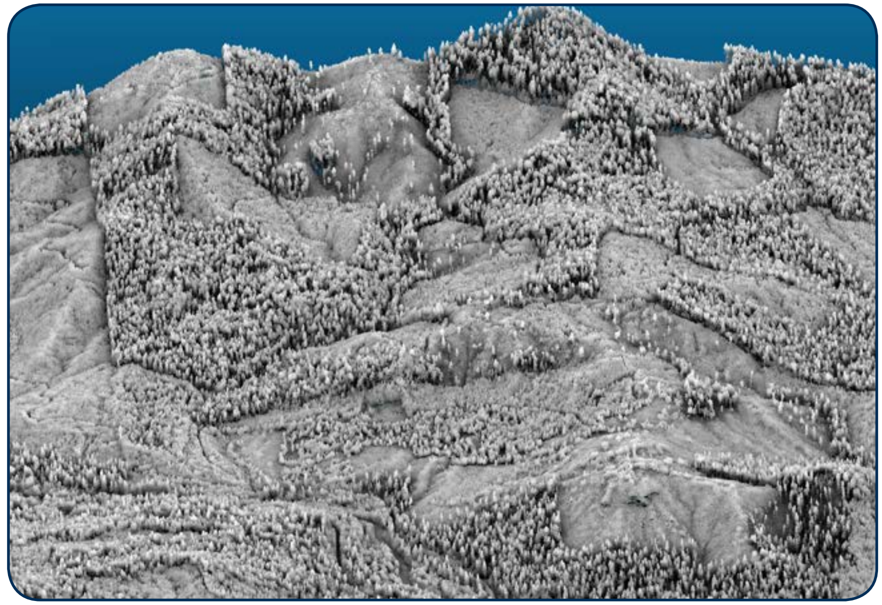
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_46	43° 38' 28.84405"	-123° 12' 52.40829"	104.565	127.599
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980	129.003
LANE_49	43° 41' 54.47511"	-122° 46' 16.97790"	331.018	354.016
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973	569.170
LANE_53	44° 11' 00.46734"	-121° 55' 12.33453"	1466.849	1487.977
LANE_54	44° 10' 41.98041"	-121° 57' 40.08010"	1208.453	1229.835
LANE_55	44° 14' 58.44023"	-121° 49' 52.63978"	1558.758	1579.651
LANE_56	44° 15' 38.38604"	-121° 48' 09.68817"	1601.779	1622.656
LANE_57	44° 25' 19.90234"	-121° 51' 23.67546"	1434.237	1455.410
LANE_58	44° 26' 11.01683"	-121° 56' 36.51882"	1117.648	1139.019
LANE_59	44° 42' 09.70199"	-122° 04' 57.99867"	497.773	519.607
LANE_60	44° 40' 38.57139"	-121° 54' 04.98722"	1281.918	1303.188
LANE_63	44° 15' 13.30087"	-122° 07' 55.02809"	1377.917	1399.838
LANE_64	44° 13' 05.95603"	-122° 06' 13.58282"	1482.944	1504.845
LANE_67	44° 09' 58.41010"	-122° 40' 34.96786"	736.802	759.768
LANE_68	44° 12' 06.66895"	-122° 39' 43.82798"	699.408	722.355
LANE_69	44° 42' 36.07455"	-122° 06' 34.98373"	463.920	485.801
LANE_70	44° 07' 45.63642"	-122° 26' 24.72517"	543.955	566.617
LANE_71	44° 10' 24.58901"	-122° 32' 25.77843"	536.990	559.796
LANE_74	44° 04' 58.19343"	-122° 21' 53.66019"	715.086	737.580
RP_265+4988	43° 25' 06.36155"	-123° 09' 01.37675"	201.245	224.5265
WRM_SP_01	44° 39' 22.75371"	-121° 41' 33.13407"	1981.876	2002.956

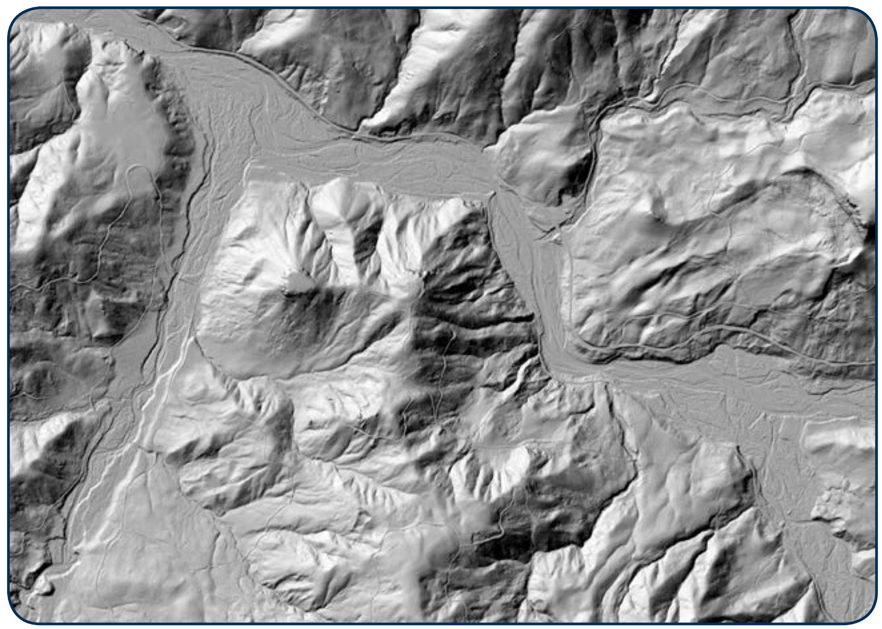
Appendix C : Selected Imagery

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, Spring-field, Oregon.

Highest Hit DEM of section of Delivery Area Two.

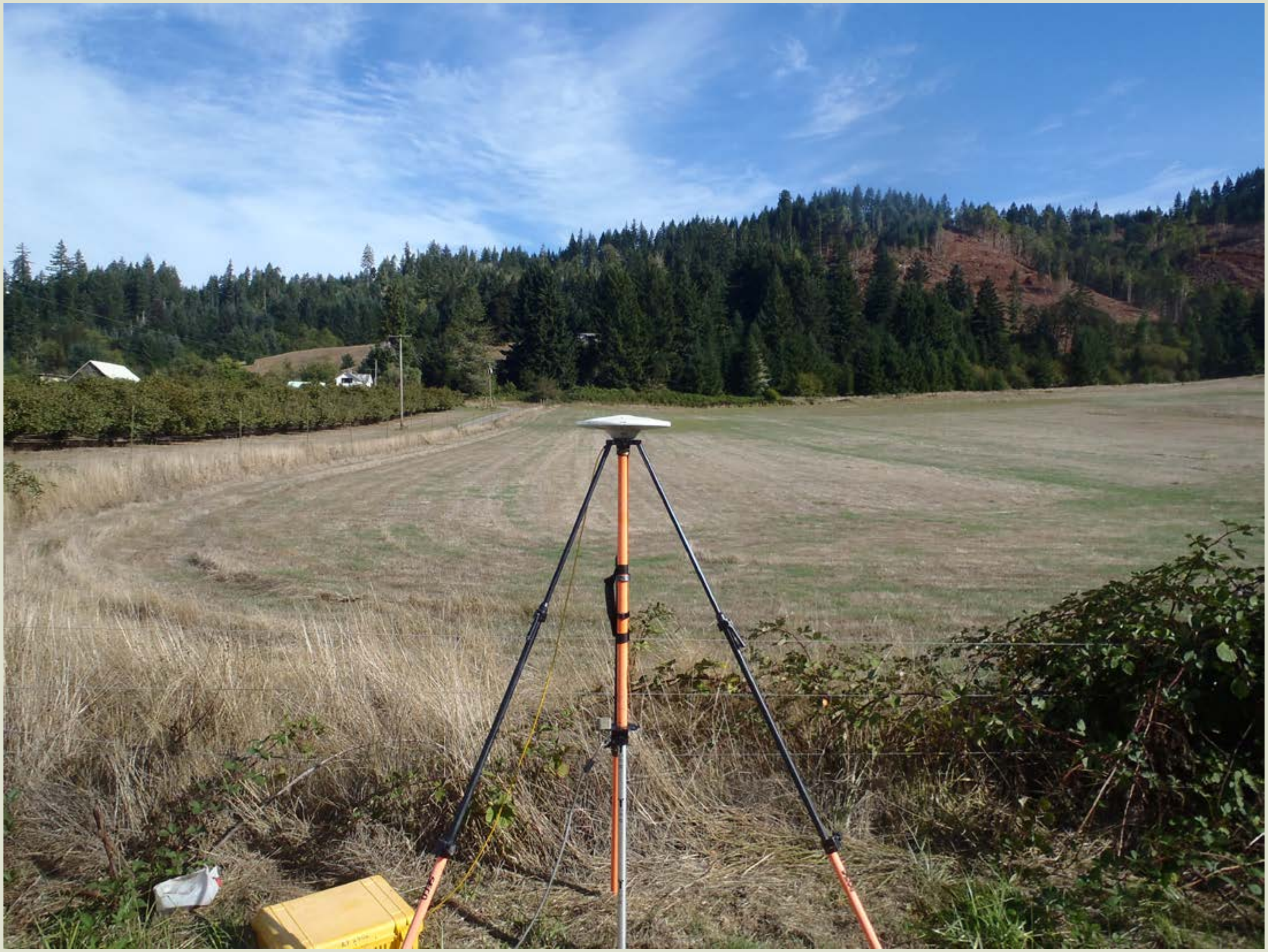
LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





Applied Remote Sensing and Analysis

OLC Lane County: Delivery 8



February 20 , 2015

Data collected for:
Oregon Department of Geology and Mineral Industries

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Contents

GPS Monument “AI1995”

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radiometric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Eight, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 2,030,101. Delivery Area Eight encompasses 352,256 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.

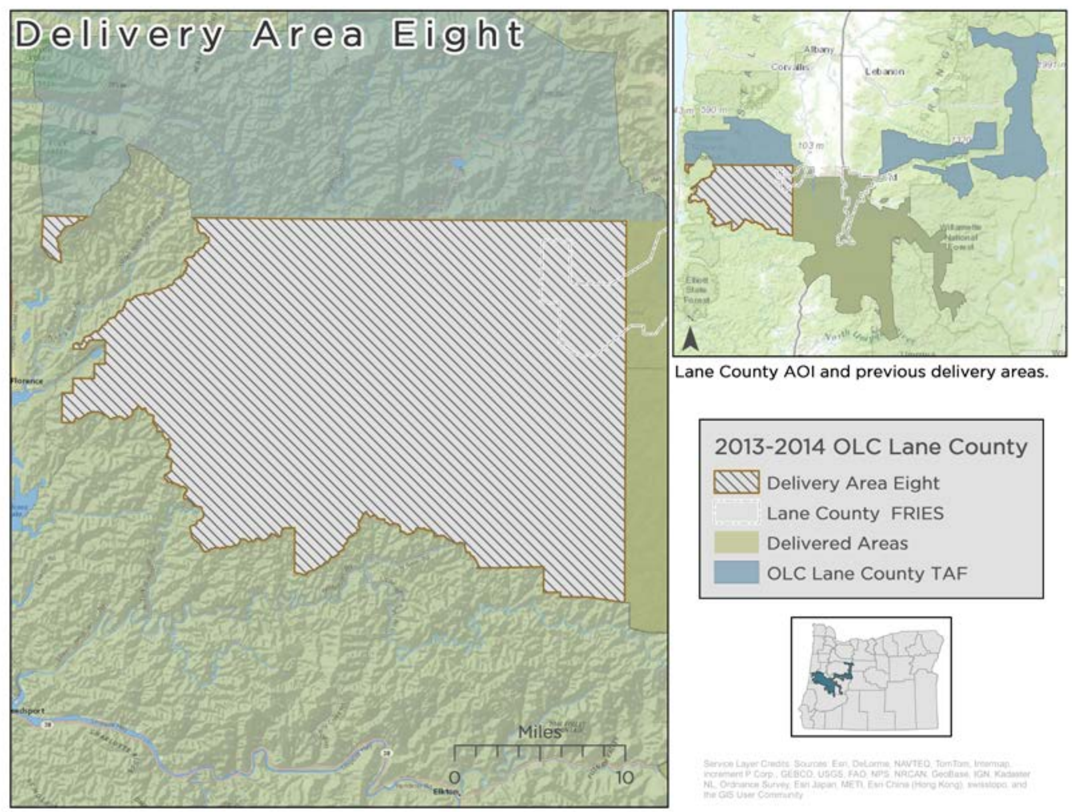
WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

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.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

OLC Lane County AOI Data Delivered February 20, 2015	
Acquisition Dates	September 7 - 14, 2013 April 10 - 30, 2014 May 1 - 15, 2014 June 10 - 30, 2014 July 1 - 6, 2014
Delivery Area Eight Area of Interest	352,256 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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

Aerial Acquisition

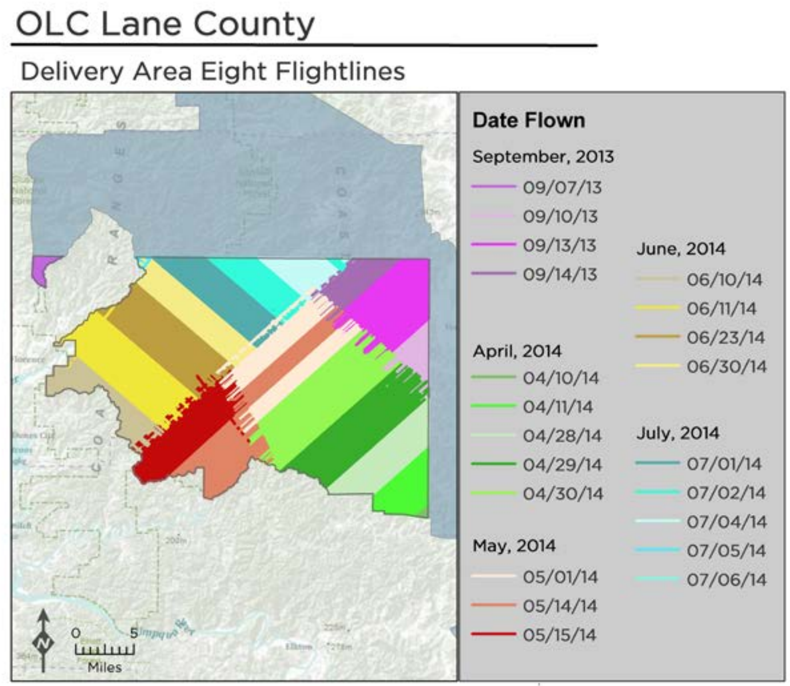
Cessna Caravan

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 or 900 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.

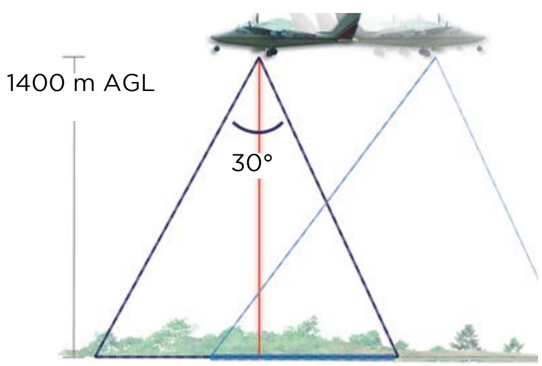
The native pulse density is the number of pulses emitted by the LiDAR system. Some types of surfaces such as dense vegetation or water may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and lightly vary according to distributions 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, 723 full and partial flightlines provide coverage of the study area.



Project Flightlines

Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper PA-31
Survey Altitude (AGL)	1400 m / 900 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



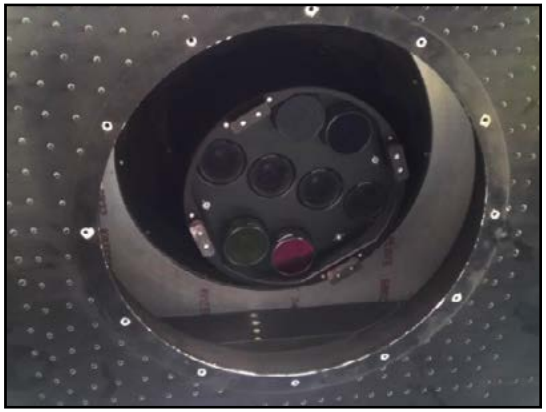
Aerial Acquisition

Photography

The photography or Four-Band Radiometric 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 POSPac MMS, 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 usable 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	≤ 13 nm
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 monument "AI1995".

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

Ground control surveys, including monumentation, aerial targets, 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 and orthoimagery products.

Instrumentation

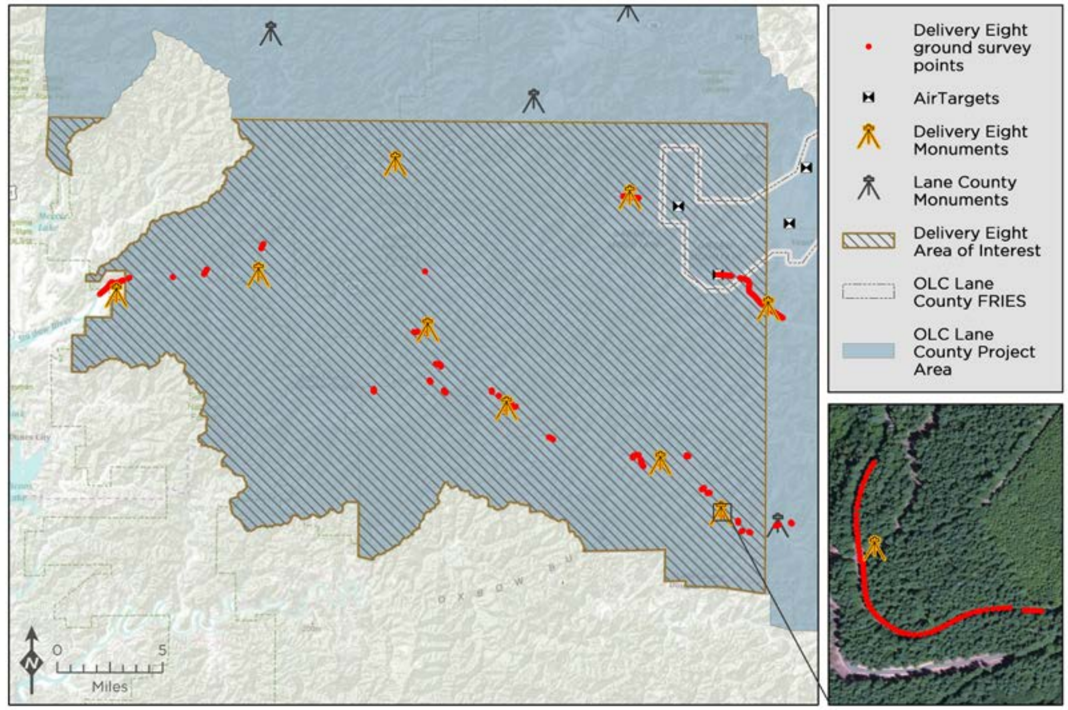
All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R8 and Trimble R10 GNSS receivers. See the table on the following page 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, WSI produces our own 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, Inc. Control." The table at right provides the list of monuments used in Delivery Area Eight. See Appendix B for a complete list of monuments placed within the OLC Lane County 2014 Study Area.

OLC Lane County

Delivery Area Eight Ground Control



Delivery Area Eight Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
AI1995	44° 01' 06.96543"	-123° 51' 37.53642"	-15.7	7.83
LANE_07	43° 59' 52.25896"	-123° 22' 23.48186"	143.322	166.275
LANE_09	44 04 26.42150	-123 30 21.24330	133.059	155.944
LANE_10	44 00 11.70302	-123 59 45.31927	-21.486	2.572
LANE_12	44 05 44.71178	-123 43 49.91180	63.439	86.487
LANE_18	43 55 40.86962	-123 37 20.35729	178.186	201.375
LANE_20	43 53 27.38516	-123 28 30.83622	153.934	176.937
LANE_37	43 51 23.46541	-123 25 02.19196	197.776	220.754
LANE_38	43 58 54.14928	-123 41 53.55130	424.298	447.5055

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Methodology

To correct the continuously recorded aircraft position, WSI 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.

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

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK), Post-Processed Kinematic (PPK), and Fast-Static (FS) 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 and FS 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.


Ground professional collecting RTK

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R6	Integrated GNSS Antenna R6	TRM_R6	Rover
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover
Trimble R10	Integrated Antenna R10	TRMR10	Rover

LiDAR Accuracy

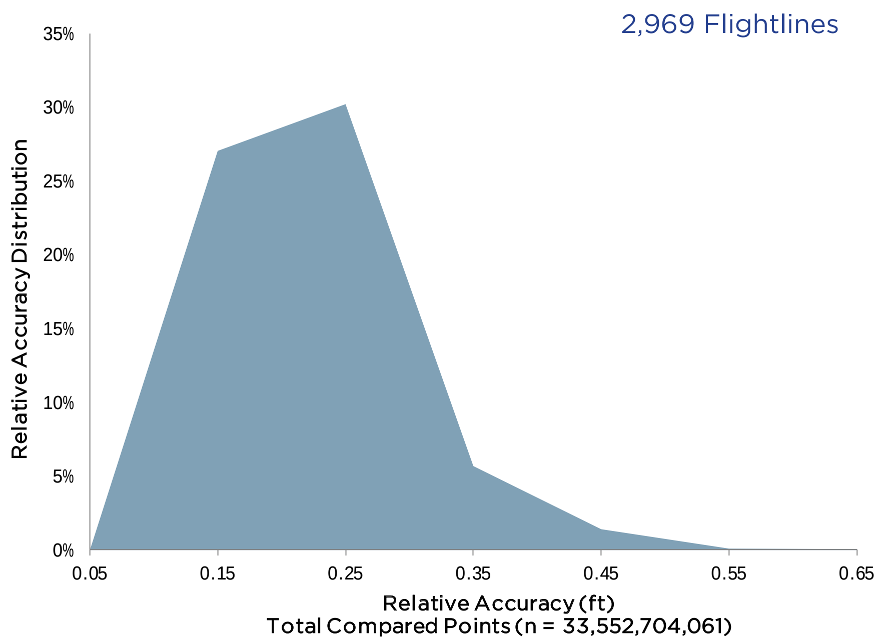
Relative Accuracy

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 2,969 full and partial flightlines (795 full and partial flightlines from Delivery Area Eight) and over 33 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Calibration Results N = 2,969 flightlines	
Project Average	0.17 ft. (0.05 m)
Median Relative Accuracy	0.16 ft. (0.05 m)
1σ Relative Accuracy	0.19 ft. (0.06 m)
2σ Relative Accuracy	0.30 ft. (0.09 m)

Relative Accuracy Distribution




R7 Receiver

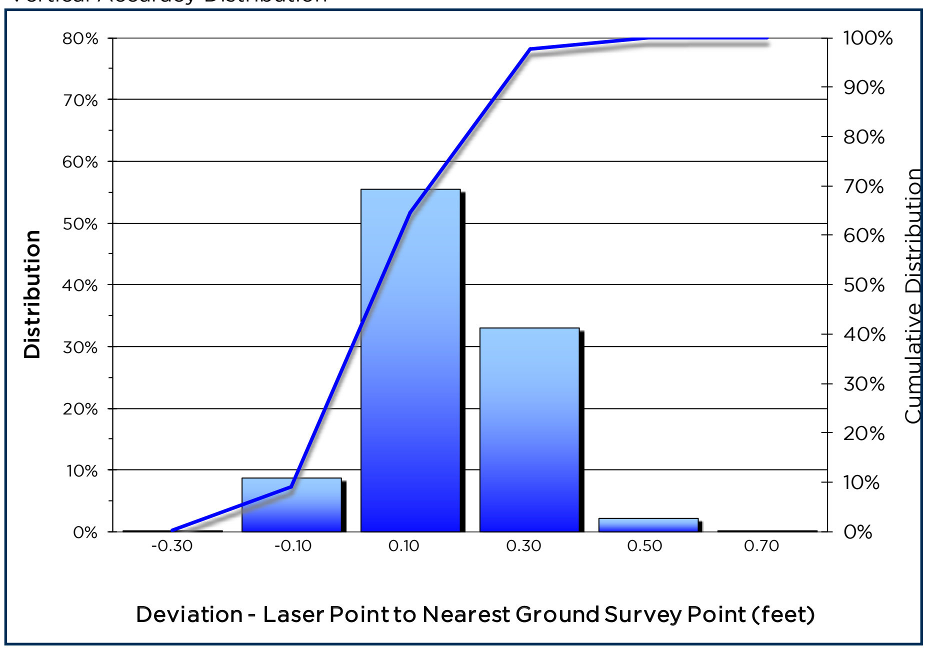
Vertical Accuracy

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 survey points to the triangulated LiDAR surface. 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 eight study area, 3,190 GSPs were collected. Statistics are shown for Delivery Area Eight and cumulative (right).

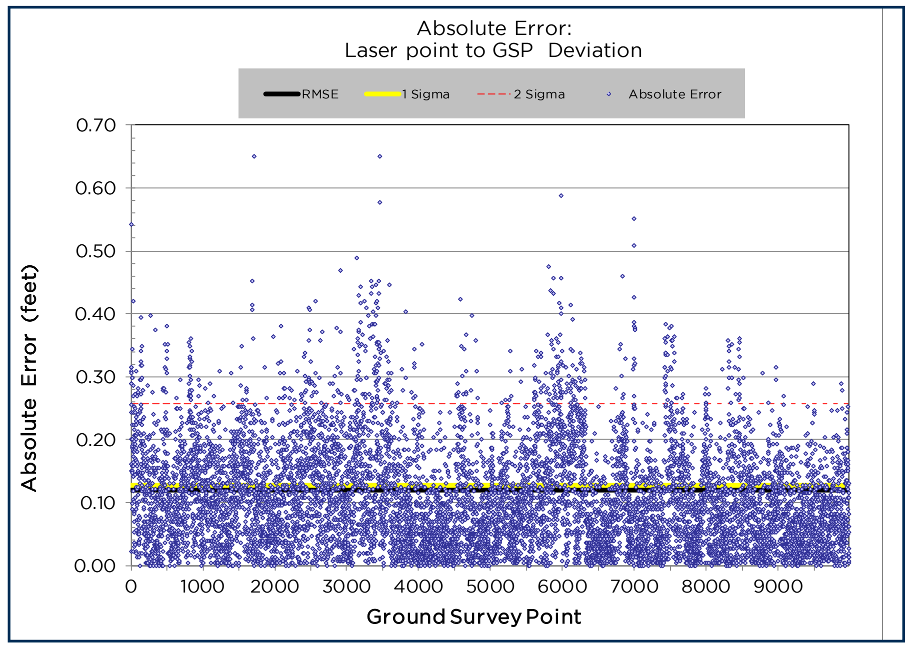
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed below.

Vertical Accuracy Results		
	Delivery Area Eight	Cumulative
Sample Size (n)	3,190 Ground survey points	9,990 Ground survey points
FVA (RMSE*1.96)	0.22 ft. (0.07 m)	0.24 ft. (0.07 m)
Root Mean Square Error	0.11 ft. (0.03 m)	0.12 ft. (0.04 m)
1 Standard Deviation	0.15 ft. (0.05 m)	0.13 ft. (0.04 m)
2 Standard Deviation	0.27 ft. (0.08 m)	0.26 ft. (0.08 m)
Average Deviation	0.09 ft. (0.03 m)	0.06 ft. (0.02 m)
Minimum Deviation	-0.65 ft. (-0.20 m)	-0.65 ft. (-0.20 m)
Maximum Deviation	0.54 ft. (0.17 m)	0.65 ft. (0.20 m)

Vertical Accuracy Distribution



GSP Absolute Error



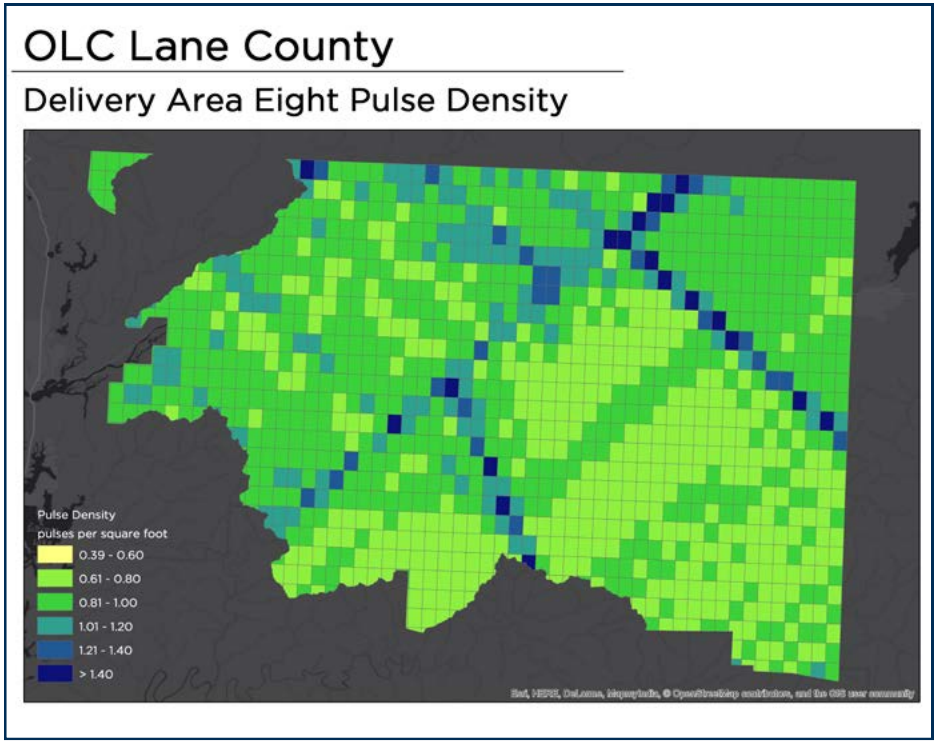
Density

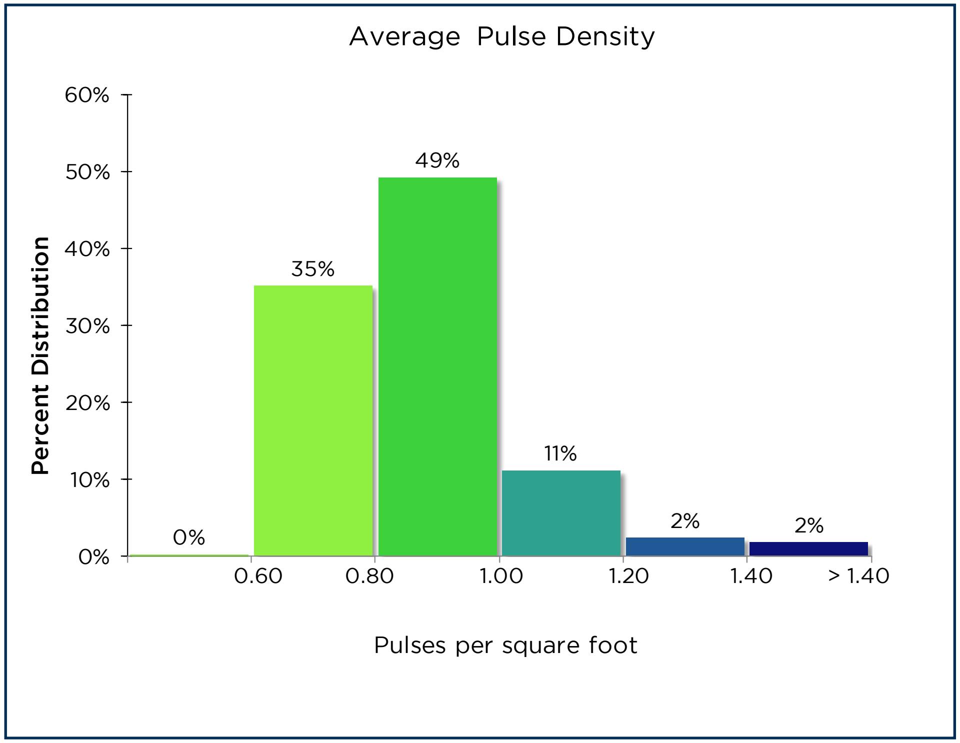
Pulse Density

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.

Average Pulse Density	pulses per square meter	pulses per square foot
	10.41	0.88

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



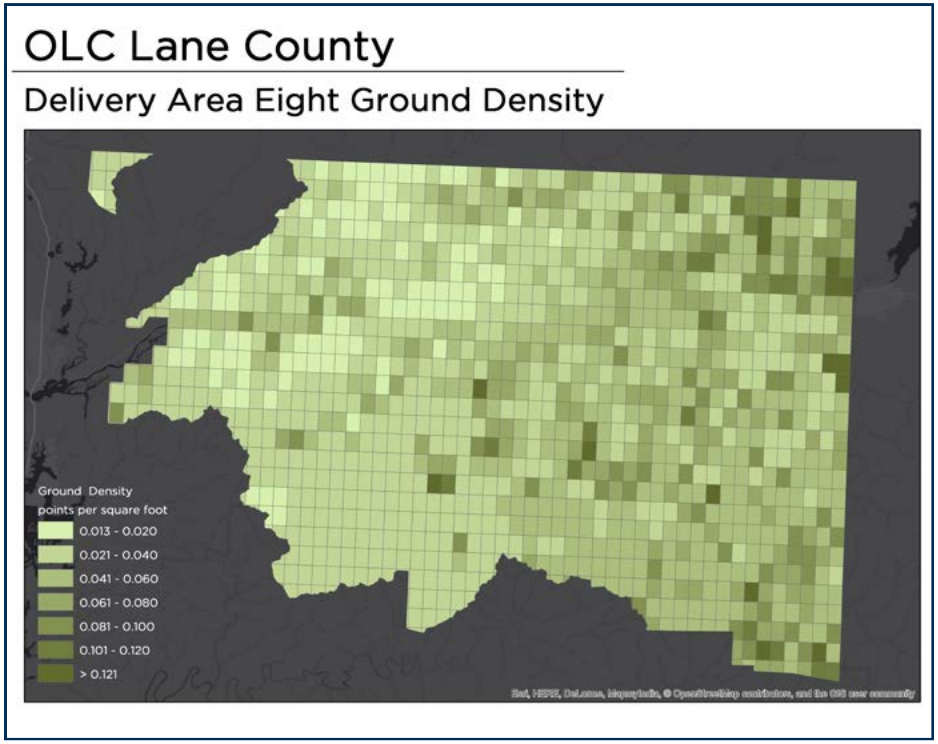


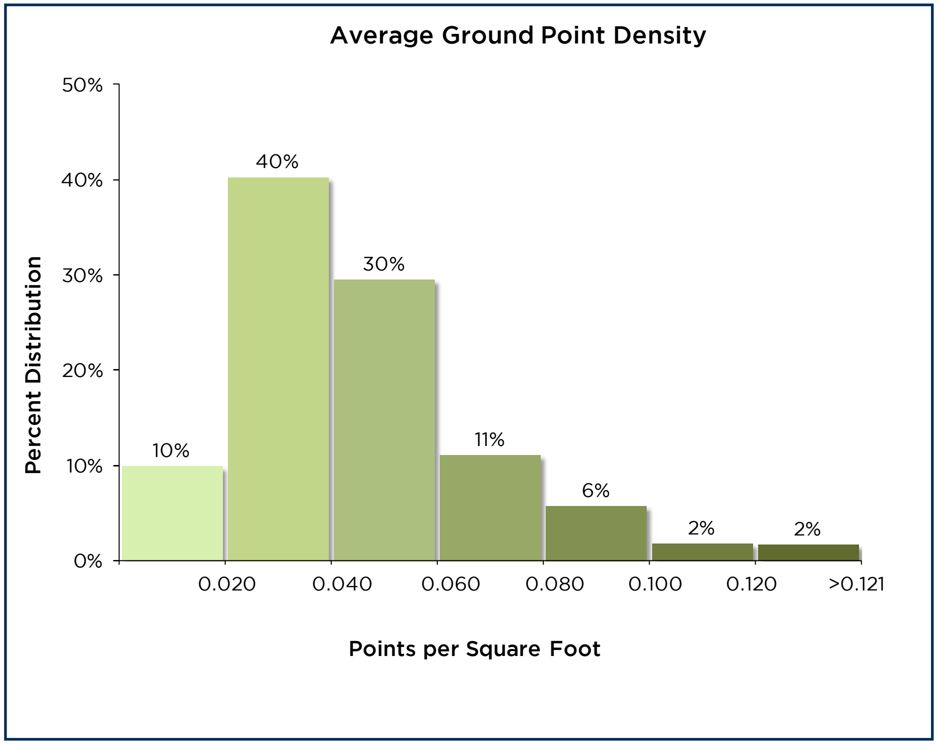
Ground Density

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 is a measure of ground-classified point data for the delivery area.

Ground Density	points per square meter	points per square foot
	0.54	0.05

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





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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. Accuracy statistics are reported for the entire Lane County Orthophoto AOI.

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

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for OLC Lane County LiDAR project Delivery 8 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.

2/20/2015

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 September 7, 2013 and July 6, 2014. 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".

2/20/2015

Christopher Glantz, PLS
Land Surveyor
WSI, a Quantum Spatial Company
Portland, OR 97204

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648

RENEWS 6/30/2015

Appendix B : GPS Monument Table

List of GPS monuments used in OLC Lane County Survey Area. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Lane County GPS Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
AI1987	44° 12' 27.42931"	-122° 49' 49.03656"	157.321	180.546
AI1995	44° 01' 06.96543"	-123° 51' 37.53642"	-15.700	7.830
AI2001	43° 55' 19.20493"	-122° 47' 41.08223"	195.963	219.207
AJ8191	44° 39' 23.18028"	-121° 41' 33.57573"	1983.063	2004.142
BLUE_RIV_04	44° 19' 45.50913"	-122° 06' 01.51323"	1412.718	1434.493
LANE_01	44° 13' 34.22103"	-123° 55' 25.99216"	487.832	510.916
LANE_02	44° 11' 04.59366"	-123° 51' 03.90195"	104.844	127.922
LANE_03	44° 17' 35.16542"	-123° 41' 42.13047"	69.602	92.380
LANE_04	44° 19' 30.86443"	-123° 39' 58.03953"	230.843	253.545
LANE_05	44° 16' 43.86859"	-124° 02' 41.13217"	458.248	481.770
LANE_06	44° 12' 10.80761"	-123° 30' 31.42667"	196.503	219.150
LANE_06	44° 12' 10.80764"	-123° 30' 31.42667"	196.522	219.169
LANE_06A	44° 14' 32.55999"	-123° 24' 47.48386"	336.456	359.076
LANE_07	43° 59' 52.25896"	-123° 22' 23.48186"	143.322	166.275
LANE_08	44° 08' 23.10388"	-123° 35' 55.56664"	168.733	191.568
LANE_09	44° 04' 26.42150"	-123° 30' 21.24330"	133.059	155.944
LANE_10	44° 00' 11.70302"	-123° 59' 45.31927"	-21.486	2.572
LANE_11	44° 04' 08.74341"	-122° 48' 06.59661"	161.587	184.843
LANE_12	44° 05' 44.71178"	-123° 43' 49.91180"	63.439	86.487
LANE_13	44° 00' 41.08475"	-122° 59' 27.48519"	119.047	142.488
LANE_14	43° 50' 13.64839"	-123° 14' 03.11154"	175.699	198.720
LANE_15	43° 59' 28.97732"	-122° 56' 10.19436"	139.378	162.854
LANE_16	43° 49' 45.78726"	-123° 07' 47.74145"	212.747	235.886
LANE_17	43° 59' 22.07068"	-123° 11' 07.80197"	111.693	134.821
LANE_18	43° 55' 40.86962"	-123° 37' 20.35729"	178.186	201.375
LANE_19	44° 00' 01.44296"	-123° 13' 56.62771"	104.781	127.866

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_20	43° 53’ 27.38516”	-123° 28’ 30.83622”	153.934	176.937
LANE_22	43° 52’ 51.72856”	-123° 13’ 33.92296”	147.785	170.814
LANE_23	43° 47’ 25.93196”	-123° 01’ 54.25135”	176.209	199.467
LANE_24	43° 42’ 26.18996”	-122° 25’ 40.56001”	450.794	473.495
LANE_25	43° 42’ 51.38283”	-122° 23’ 45.43363”	792.318	814.931
LANE_26	43° 33’ 00.45694”	-122° 28’ 22.66794”	815.341	838.000
LANE_27	43° 31’ 20.08417”	-122° 20’ 15.46234”	1080.075	1102.415
LANE_28	43° 53’ 58.92454”	-122° 48’ 59.17889”	194.478	217.704
LANE_29	43° 52’ 12.08177”	-122° 47’ 18.45224”	420.380	443.438
LANE_29A	43° 52’ 12.08161”	-122° 47’ 18.45256”	420.361	443.419
LANE_30	43° 37’ 14.50986”	-123° 05’ 19.83916”	253.542	276.603
LANE_31	43° 45’ 16.82389”	-122° 26’ 41.15314”	492.053	514.761
LANE_32	43° 47’ 33.82161”	-122° 25’ 40.76291”	677.205	699.811
LANE_33	43° 36’ 30.58173”	-123° 01’ 40.84386”	471.540	494.595
LANE_34	43° 45’ 30.54400”	-122° 29’ 48.47559”	308.081	330.844
LANE_35	43° 48’ 11.57911”	-122° 42’ 37.56859”	1041.596	1064.353
LANE_36	43° 50’ 54.28025”	-123° 21’ 47.73924”	229.292	252.262
LANE_37	43° 51’ 23.46541”	-123° 25’ 02.19196”	197.776	220.754
LANE_38	43° 58’ 54.14928”	-123° 41’ 53.55130”	424.298	447.505
LANE_39	43° 42’ 19.93987”	-122° 57’ 05.04012”	456.450	479.572
LANE_40	43° 35’ 23.35579”	-123° 00’ 04.90380”	479.127	502.200
LANE_41	43° 44’ 45.10607”	-122° 53’ 27.75969”	236.302	259.436
LANE_42	43° 40’ 03.45665”	-122° 48’ 42.76721”	311.004	334.075
LANE_43	43° 21’ 17.49608”	-122° 44’ 41.88280”	524.594	547.828
LANE_45	43° 30’ 26.64379”	-122° 50’ 42.75367”	1160.885	1183.729

Lane County GPS Monuments

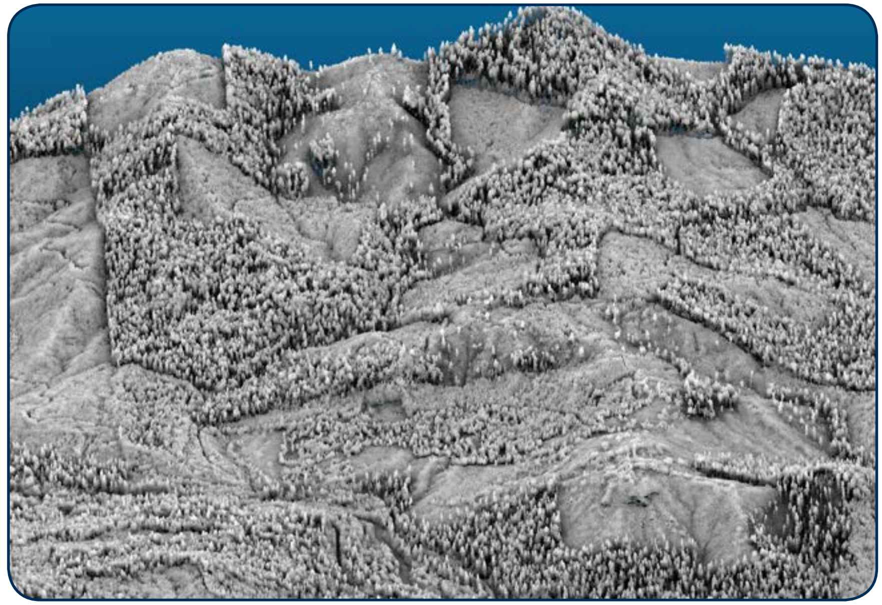
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_46	43° 38' 28.84405"	-123° 12' 52.40829"	104.565	127.599
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980	129.003
LANE_49	43° 41' 54.47511"	-122° 46' 16.97790"	331.018	354.016
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973	569.170
LANE_53	44° 11' 00.46734"	-121° 55' 12.33453"	1466.849	1487.977
LANE_54	44° 10' 41.98041"	-121° 57' 40.08010"	1208.453	1229.835
LANE_55	44° 14' 58.44023"	-121° 49' 52.63978"	1558.758	1579.651
LANE_56	44° 15' 38.38604"	-121° 48' 09.68817"	1601.779	1622.656
LANE_57	44° 25' 19.90234"	-121° 51' 23.67546"	1434.237	1455.410
LANE_58	44° 26' 11.01683"	-121° 56' 36.51882"	1117.648	1139.019
LANE_59	44° 42' 09.70199"	-122° 04' 57.99867"	497.773	519.607
LANE_60	44° 40' 38.57139"	-121° 54' 04.98722"	1281.918	1303.188
LANE_63	44° 15' 13.30087"	-122° 07' 55.02809"	1377.917	1399.838
LANE_64	44° 13' 05.95603"	-122° 06' 13.58282"	1482.944	1504.845
LANE_67	44° 09' 58.41010"	-122° 40' 34.96786"	736.802	759.768
LANE_68	44° 12' 06.66895"	-122° 39' 43.82798"	699.408	722.355
LANE_69	44° 42' 36.07455"	-122° 06' 34.98373"	463.920	485.801
LANE_70	44° 07' 45.63642"	-122° 26' 24.72517"	543.955	566.617
LANE_71	44° 10' 24.58901"	-122° 32' 25.77843"	536.990	559.796
LANE_74	44° 04' 58.19343"	-122° 21' 53.66019"	715.086	737.580
RP_265+4988	43° 25' 06.36155"	-123° 09' 01.37675"	201.245	224.5265
WRM_SP_01	44° 39' 22.75371"	-121° 41' 33.13407"	1981.876	2002.956

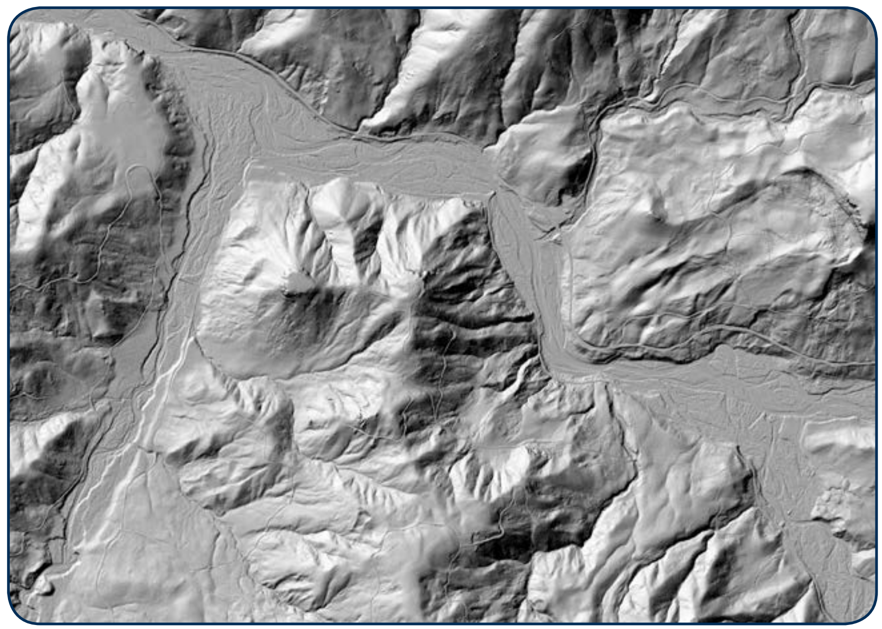
Appendix C : Selected Imagery

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, Spring-field, Oregon.

Highest Hit DEM of section of Delivery Area Two.

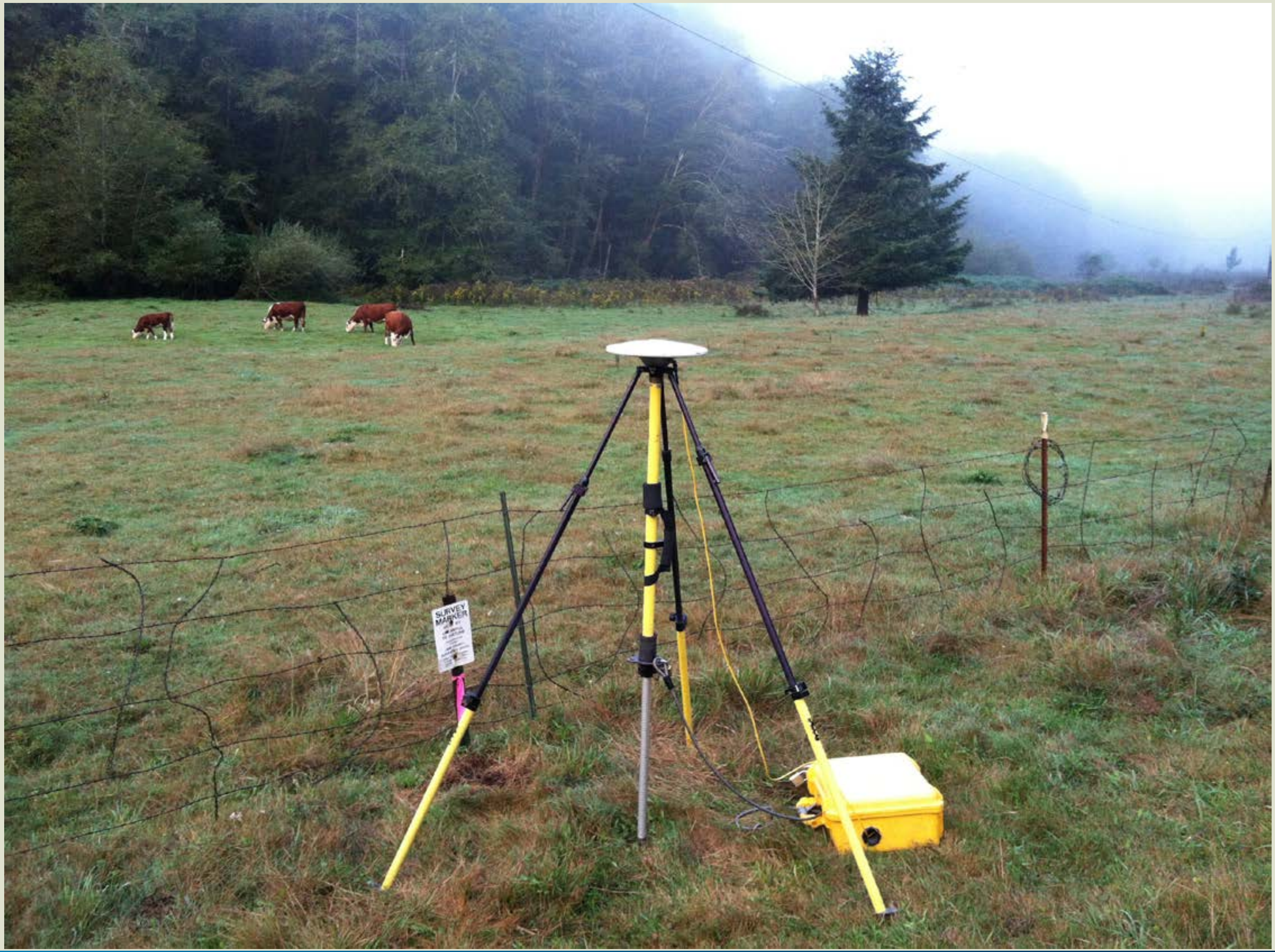
LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





WSI Applied Remote Sensing and Analysis

OLC Lane County: Delivery 9



GPS Monument Lane_06 with Trimble R7 and R8.

Data collected for:
Oregon Department of Geology and Mineral Industries

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Contents

GPS Monument “Lane_05”

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radiometric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Nine, for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 2,030,101. Delivery Area Nine encompasses 259,785 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.

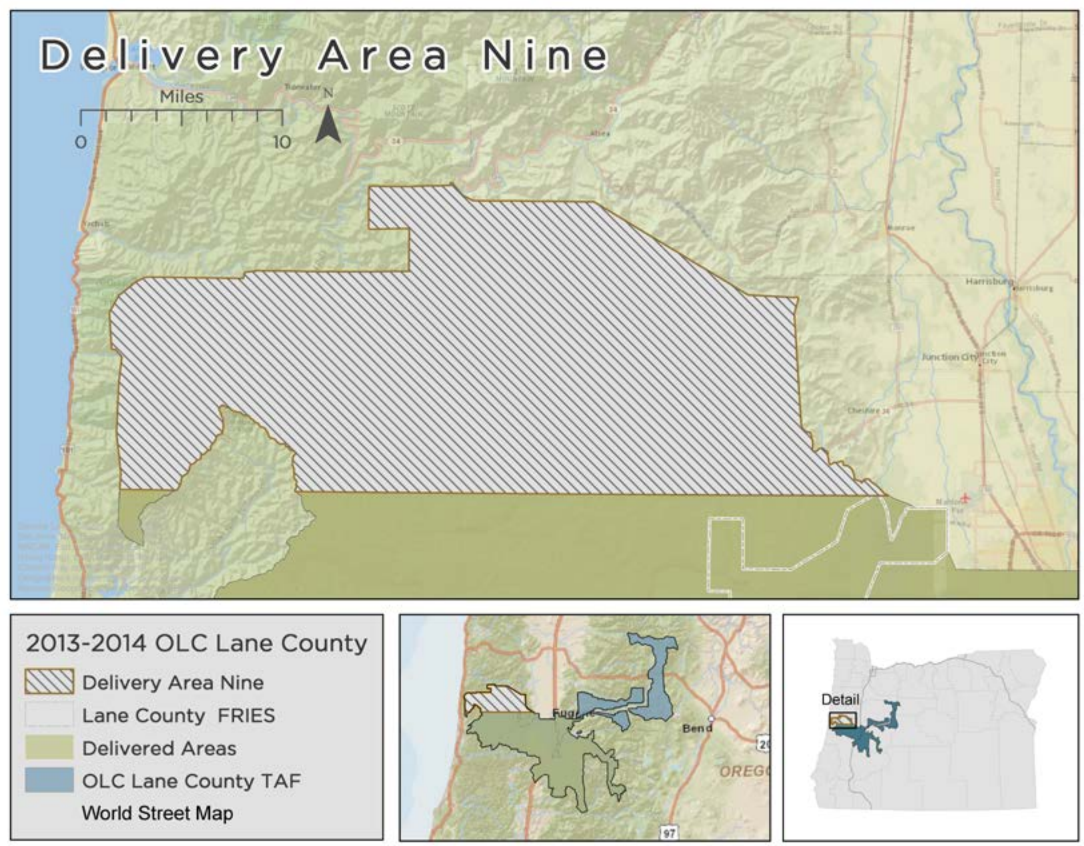
WSI began data collection on September 5, 2013 for the Lane County project and collection is currently ongoing contingent upon weather. Delivery Area Nine was acquired between September 9, 2013 and October 10, 2014. Settings for LiDAR data capture produced an average resolution of at least eight pulses 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.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

OLC Lane County AOI Data Delivered April 3, 2015	
Acquisition Dates	September 7 - 14, 2013 June 10 - 30, 2014 July 1 - 7, 2014 October 8 - 10,2014
Delivery Area Nine Area of Interest	259,785 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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

Aerial Acquisition

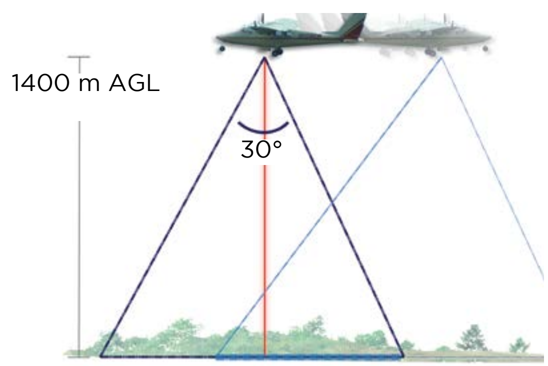
Cessna Caravan

LiDAR Survey

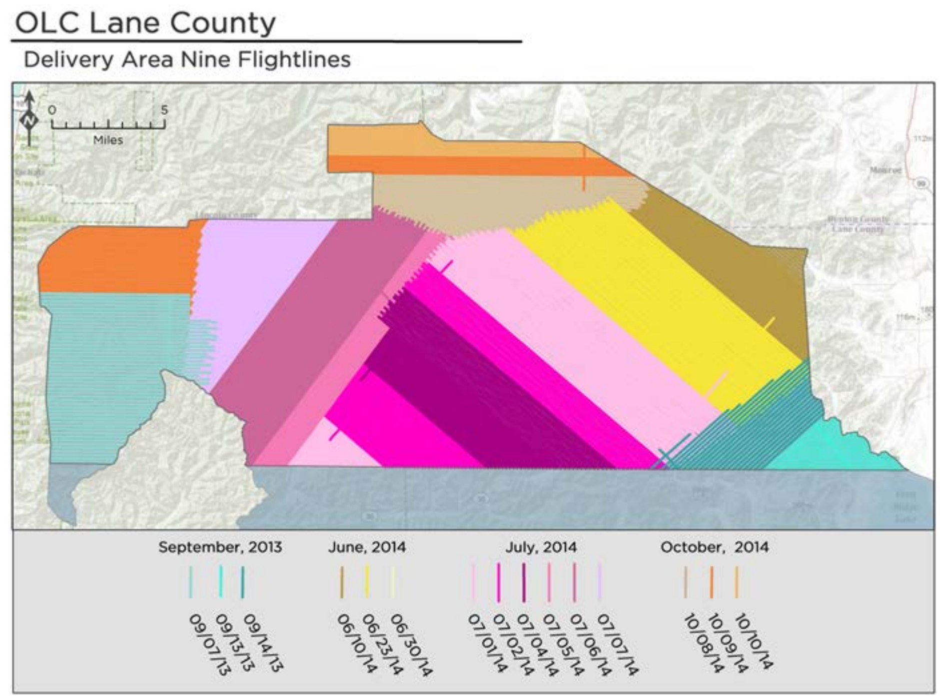
The LiDAR survey utilized both Leica ALS70 and ALS50 sensors mounted in a Cessna Caravan 208B and Piper PA-31 respectively. The systems were programmed to emit single pulses at a rate of 190 to 198 kilohertz and flown at 1,400 meters or 900 meters above ground level (AGL), capturing a scan angle of +/-15 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, 723 full and partial flightlines provide coverage of the study area.



Project Flightlines



Lane County Acquisition Specifications	
Sensors Deployed	Leica ALS 50 and Leica ALS 70
Aircraft	Cessna Caravan 208B, Piper PA-31
Survey Altitude (AGL)	1400 m / 900 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

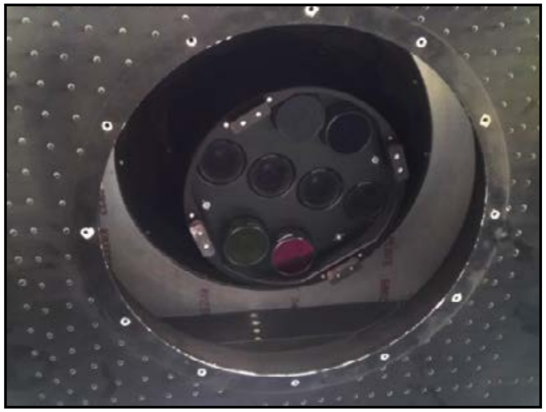
Aerial Acquisition

Photography

The photography or Four-Band Radiometric 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 POSPac MMS, 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 usable 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	≤ 13 nm
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 monument "AI1995".

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

Ground control surveys, including monumentation, aerial targets, 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 and orthoimagery products.

Instrumentation

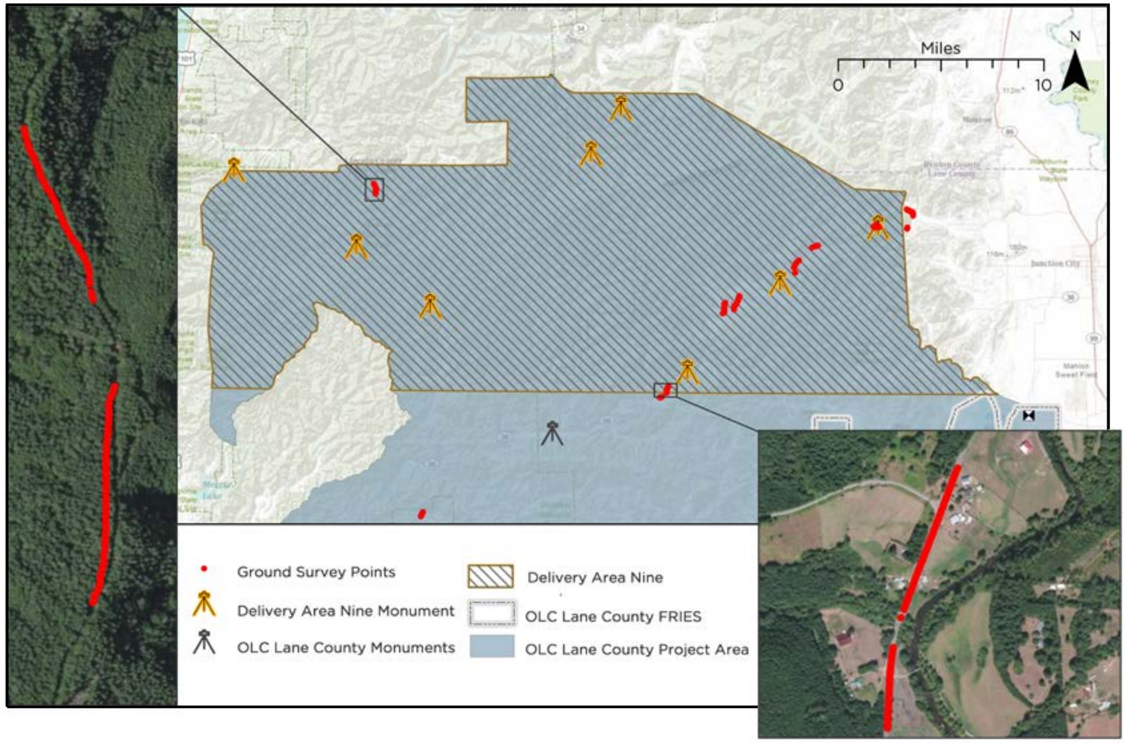
All Global Navigation Satellite System (GNSS) static surveys utilized Trimble R7 GNSS receivers with Zephyr Geodetic Model 2 RoHS antennas and Trimble R8 GNSS receivers with internal antennas. Rover surveys for GSP collection were conducted with Trimble R8 and Trimble R10 GNSS receivers. See the table on the following page 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, WSI produces our own 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, Inc. Control." The table at right provides the list of monuments used in Delivery Area Nine. See Appendix B for a complete list of monuments placed within the OLC Lane County 2014 Study Area.

OLC Lane County

Delivery Area Nine Ground Control



Delivery Area Nine Monuments				
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
LANE_01	44° 13' 34.22103"	-123° 55' 25.99216"	487.832	510.916
LANE_02	43° 11' 04.59366"	-123° 51' 03.90195"	104.844	127.923
LANE_03	44° 17' 35.16542"	-123° 41' 42.13047"	69.602	92.380
LANE_04	44° 19' 30.86443"	-123° 39' 58.03953"	230.843	253.546
LANE_05	44° 16' 43.86859"	-124° 02' 41.13217"	458.248	481.771
LANE_06A	44° 14' 32.55999"	-123° 24' 47.48386"	336.456	359.076
LANE_08	44° 08' 23.10388"	-123° 35' 55.56664"	168.733	191.568

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Methodology

To correct the continuously recorded aircraft position, WSI 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.

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

Ground Survey Points (GSPs) are collected using Real Time Kinematic (RTK), Post-Processed Kinematic (PPK), and Fast-Static (FS) 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 and FS 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.


Ground professional collecting RTK

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R6	Integrated GNSS Antenna R6	TRM_R6	Rover
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2 RoHS	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover
Trimble R10	Integrated Antenna R10	TRMR10	Rover

LiDAR Accuracy

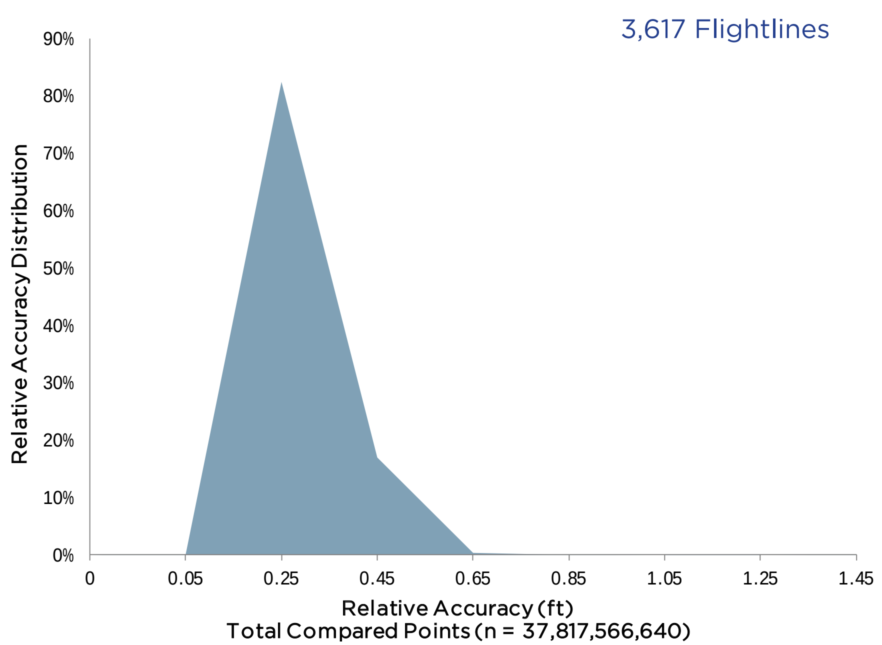
Relative Accuracy

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 3,617 full and partial flightlines (1,239 full and partial flightlines from Delivery Area Nine) and over 37 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Relative Accuracy Calibration Results N = 3,617 flightlines	
Project Average	0.19 ft. (0.06 m)
Median Relative Accuracy	0.18 ft. (0.06 m)
1σ Relative Accuracy	0.21 ft. (0.06 m)
2σ Relative Accuracy	0.32 ft. (0.10 m)

Relative Accuracy Distribution



R7 Receiver

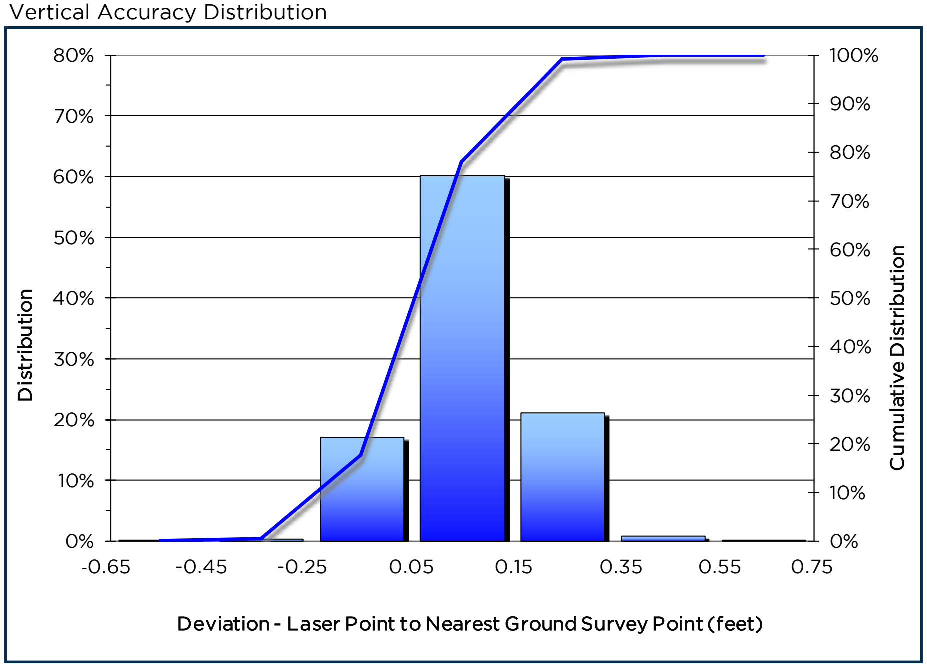
Vertical Accuracy

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 survey points to the triangulated LiDAR surface. 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 Nine study area, 826 GSPs were collected. Statistics are shown for Delivery Area Nine and cumulative (right).

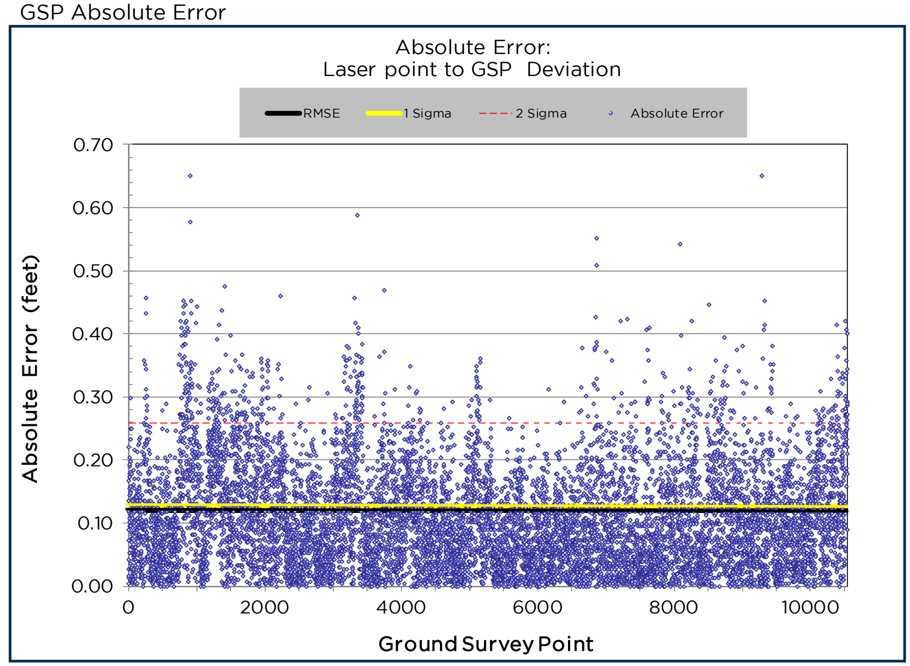
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed for the cumulative data delivered below.

Vertical Accuracy Results		
	Delivery Area Nine	Cumulative
Sample Size (n)	826 Ground survey points	10,550 Ground survey points
FVA (RMSE*1.96)	0.21 ft. (0.06 m)	0.23 ft. (0.07 m)
Root Mean Square Error	0.10 ft. (0.03 m)	0.12 ft. (0.04 m)
1 Standard Deviation	0.14 ft. (0.04 m)	0.13 ft. (0.04 m)
2 Standard Deviation	0.27 ft. (0.08 m)	0.26 ft. (0.08 m)
Average Deviation	0.10 ft. (0.03 m)	0.06 ft. (0.02 m)
Minimum Deviation	-0.27 ft. (-0.08 m)	-0.65 ft. (-0.20 m)
Maximum Deviation	0.42 ft. (0.13 m)	0.65 ft. (0.20 m)

Vertical Accuracy Distribution



GSP Absolute Error



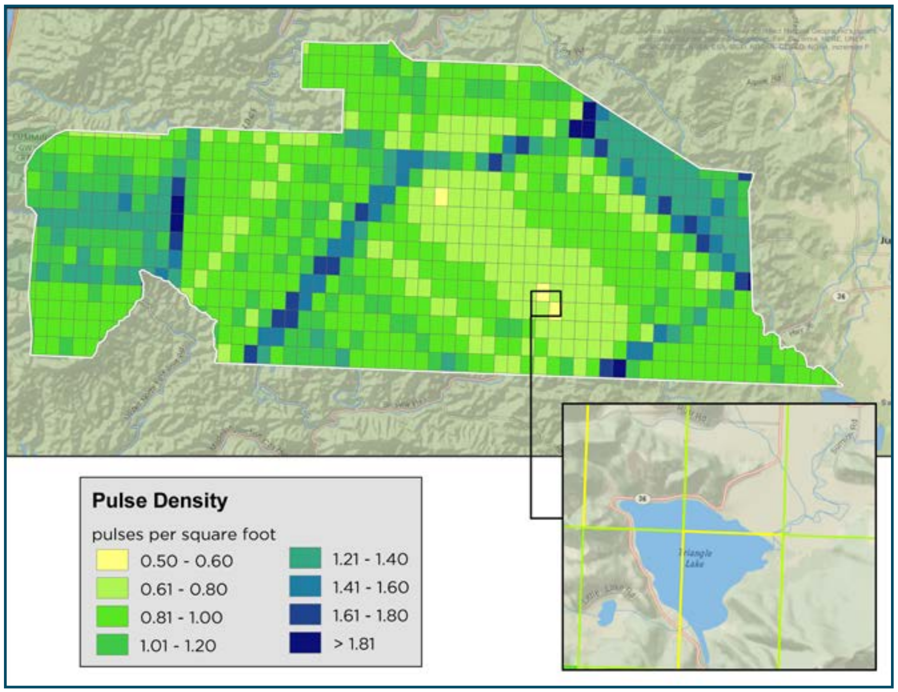
Density

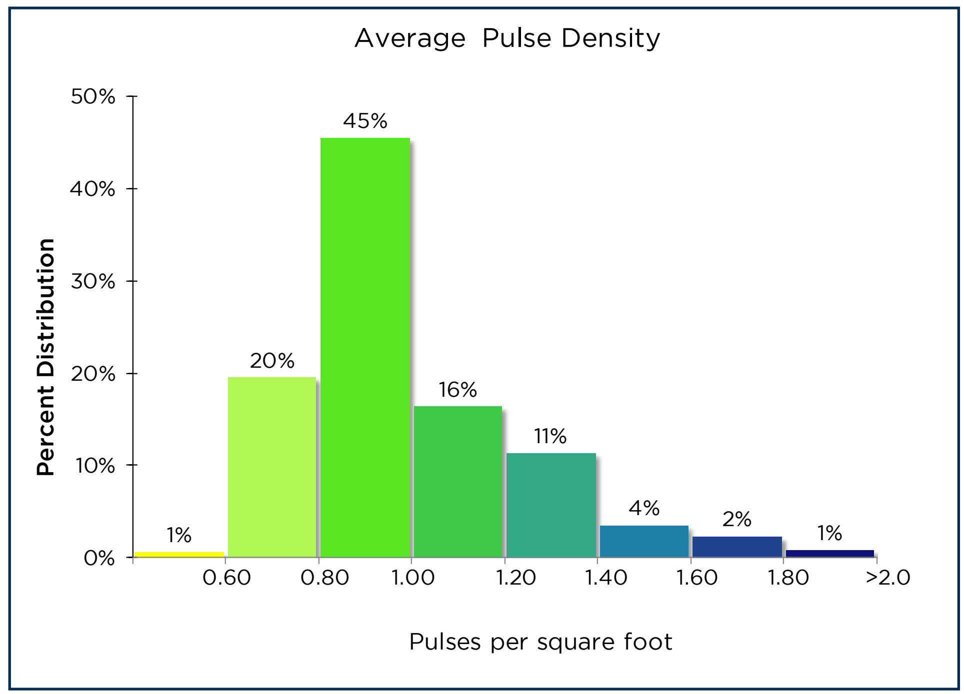
Pulse Density

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.

Average Pulse Density	pulses per square meter	pulses per square foot
	10.57	0.98

Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart). Below left, note area of minimal pulse density over water body.



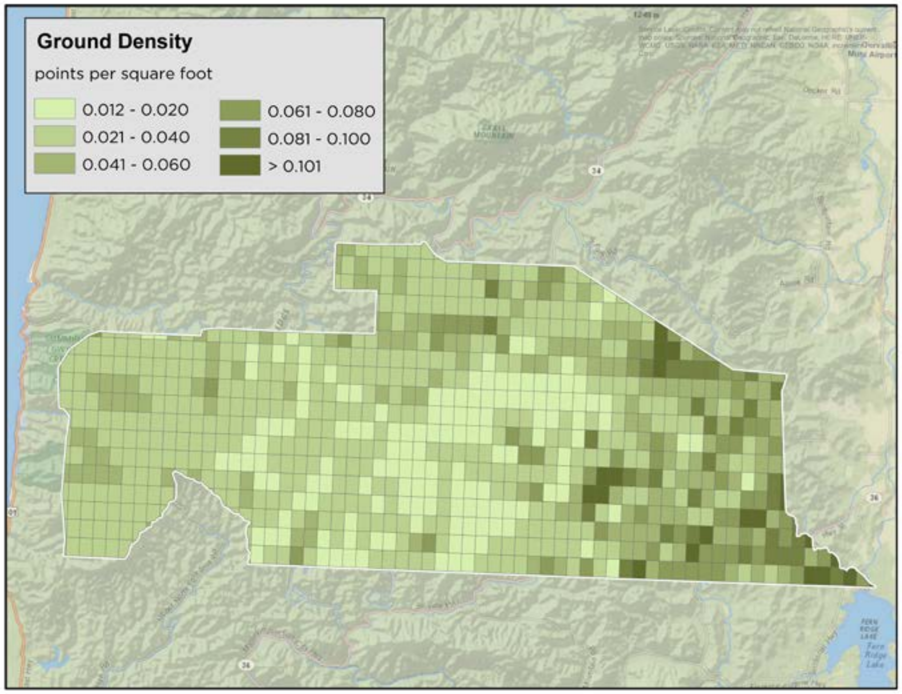


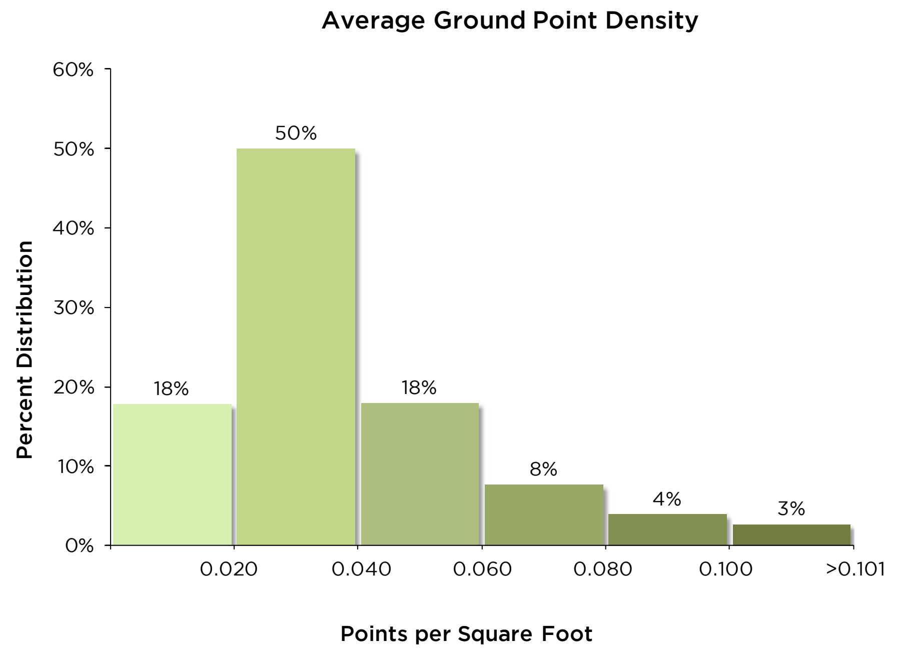
Ground Density

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 is a measure of ground-classified point data for the delivery area.

Ground Density	points per square meter	points per square foot
	0.40	0.04

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





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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. Accuracy statistics are reported for the entire Lane County Orthophoto AOI.

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

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for OLC Lane County LiDAR project Delivery 9 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.

4/3/2015

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 September 7, 2013 and July 6, 2014. 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".

4/3/2015

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

REGISTERED
PROFESSIONAL
LAND SURVEYOR

OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648

RENEWS 6/30/2015

Appendix B : GPS Monument Table

List of GPS monuments used in OLC Lane County Survey Area. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
AI1987	44° 12’ 27.42931”	-122° 49’ 49.03656”	157.321	180.546
AI1995	44° 01’ 06.96543”	-123° 51’ 37.53642”	-15.700	7.830
AI2001	43° 55’ 19.20493”	-122° 47’ 41.08223”	195.963	219.207
AJ8191	44° 39’ 23.18028”	-121° 41’ 33.57573”	1983.063	2004.142
BLUE_RIV_04	44° 19’ 45.50913”	-122° 06’ 01.51323”	1412.718	1434.493
LANE_01	44° 13’ 34.22103”	-123° 55’ 25.99216”	487.832	510.916
LANE_02	44° 11’ 04.59366”	-123° 51’ 03.90195”	104.844	127.922
LANE_03	44° 17’ 35.16542”	-123° 41’ 42.13047”	69.602	92.380
LANE_04	44° 19’ 30.86443”	-123° 39’ 58.03953”	230.843	253.545
LANE_05	44° 16’ 43.86859”	-124° 02’ 41.13217”	458.248	481.770
LANE_06	44° 12’ 10.80764”	-123° 30’ 31.42667”	196.522	219.169
LANE_06A	44° 14’ 32.55999”	-123° 24’ 47.48386”	336.456	359.076
LANE_07	43° 59’ 52.25896”	-123° 22’ 23.48186”	143.322	166.275
LANE_08	44° 08’ 23.10388”	-123° 35’ 55.56664”	168.733	191.568
LANE_09	44° 04’ 26.42150”	-123° 30’ 21.24330”	133.059	155.944
LANE_10	44° 00’ 11.70302”	-123° 59’ 45.31927”	-21.486	2.572
LANE_11	44° 04’ 08.74341”	-122° 48’ 06.59661”	161.587	184.843
LANE_12	44° 05’ 44.71178”	-123° 43’ 49.91180”	63.439	86.487
LANE_13	44° 00’ 41.08475”	-122° 59’ 27.48519”	119.047	142.488
LANE_14	43° 50’ 13.64839”	-123° 14’ 03.11154”	175.699	198.720
LANE_15	43° 59’ 28.97732”	-122° 56’ 10.19436”	139.378	162.854
LANE_16	43° 49’ 45.78726”	-123° 07’ 47.74145”	212.747	235.886
LANE_17	43° 59’ 22.07068”	-123° 11’ 07.80197”	111.693	134.821
LANE_18	43° 55’ 40.86962”	-123° 37’ 20.35729”	178.186	201.375
LANE_19	44° 00’ 01.44296”	-123° 13’ 56.62771”	104.781	127.866

Lane County GPS Monuments

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_20	43° 53’ 27.38516”	-123° 28’ 30.83622”	153.934	176.937
LANE_22	43° 52’ 51.72856”	-123° 13’ 33.92296”	147.785	170.814
LANE_23	43° 47’ 25.93196”	-123° 01’ 54.25135”	176.209	199.467
LANE_24	43° 42’ 26.18996”	-122° 25’ 40.56001”	450.794	473.495
LANE_25	43° 42’ 51.38283”	-122° 23’ 45.43363”	792.318	814.931
LANE_26	43° 33’ 00.45694”	-122° 28’ 22.66794”	815.341	838.000
LANE_27	43° 31’ 20.08417”	-122° 20’ 15.46234”	1080.075	1102.415
LANE_28	43° 53’ 58.92454”	-122° 48’ 59.17889”	194.478	217.704
LANE_29A	43° 52’ 12.08161”	-122° 47’ 18.45256”	420.361	443.419
LANE_30	43° 37’ 14.50986”	-123° 05’ 19.83916”	253.542	276.603
LANE_31	43° 45’ 16.82389”	-122° 26’ 41.15314”	492.053	514.761
LANE_32	43° 47’ 33.82161”	-122° 25’ 40.76291”	677.205	699.811
LANE_33	43° 36’ 30.58173”	-123° 01’ 40.84386”	471.540	494.595
LANE_34	43° 45’ 30.54400”	-122° 29’ 48.47559”	308.081	330.844
LANE_35	43° 48’ 11.57911”	-122° 42’ 37.56859”	1041.596	1064.353
LANE_36	43° 50’ 54.28025”	-123° 21’ 47.73924”	229.292	252.262
LANE_37	43° 51’ 23.46541”	-123° 25’ 02.19196”	197.776	220.754
LANE_38	43° 58’ 54.14928”	-123° 41’ 53.55130”	424.298	447.505
LANE_39	43° 42’ 19.93987”	-122° 57’ 05.04012”	456.450	479.572
LANE_40	43° 35’ 23.35579”	-123° 00’ 04.90380”	479.127	502.200
LANE_41	43° 44’ 45.10607”	-122° 53’ 27.75969”	236.302	259.436
LANE_42	43° 40’ 03.45665”	-122° 48’ 42.76721”	311.004	334.075
LANE_43	43° 21’ 17.49608”	-122° 44’ 41.88280”	524.594	547.828
LANE_45	43° 30’ 26.64379”	-122° 50’ 42.75367”	1160.885	1183.729
LANE_46	43° 38’ 28.84405”	-123° 12’ 52.40829”	104.565	127.599

Lane County GPS Monuments

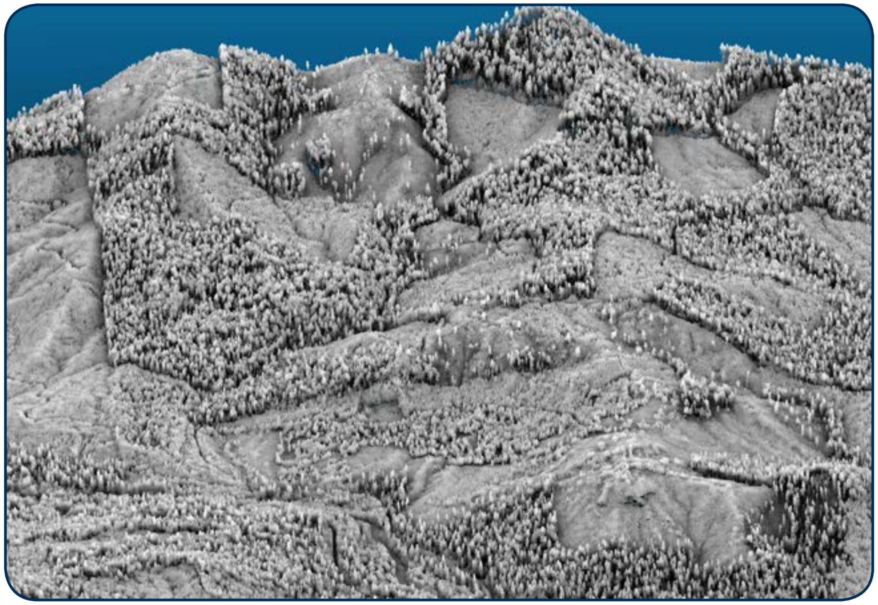
PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD88 Height (m)
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980	129.003
LANE_49	43° 41' 54.47511"	-122° 46' 16.97790"	331.018	354.016
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973	569.170
LANE_53	44° 11' 00.46734"	-121° 55' 12.33453"	1466.849	1487.977
LANE_54	44° 10' 41.98041"	-121° 57' 40.08010"	1208.453	1229.835
LANE_55	44° 14' 58.44023"	-121° 49' 52.63978"	1558.758	1579.651
LANE_56	44° 15' 38.38604"	-121° 48' 09.68817"	1601.779	1622.656
LANE_57	44° 25' 19.90234"	-121° 51' 23.67546"	1434.237	1455.410
LANE_58	44° 26' 11.01683"	-121° 56' 36.51882"	1117.648	1139.019
LANE_59	44° 42' 09.70199"	-122° 04' 57.99867"	497.773	519.607
LANE_60	44° 40' 38.57139"	-121° 54' 04.98722"	1281.918	1303.188
LANE_63	44° 15' 13.30087"	-122° 07' 55.02809"	1377.917	1399.838
LANE_64	44° 13' 05.95603"	-122° 06' 13.58282"	1482.944	1504.845
LANE_67	44° 09' 58.41010"	-122° 40' 34.96786"	736.802	759.768
LANE_68	44° 12' 06.66895"	-122° 39' 43.82798"	699.408	722.355
LANE_69	44° 42' 36.07455"	-122° 06' 34.98373"	463.920	485.801
LANE_70	44° 07' 45.63642"	-122° 26' 24.72517"	543.955	566.617
LANE_71	44° 10' 24.58901"	-122° 32' 25.77843"	536.990	559.796
LANE_74	44° 04' 58.19343"	-122° 21' 53.66019"	715.086	737.580
RP_265+4988	43° 25' 06.36155"	-123° 09' 01.37675"	201.245	224.5265
WRM_SP_01	44° 39' 22.75371"	-121° 41' 33.13407"	1981.876	2002.956

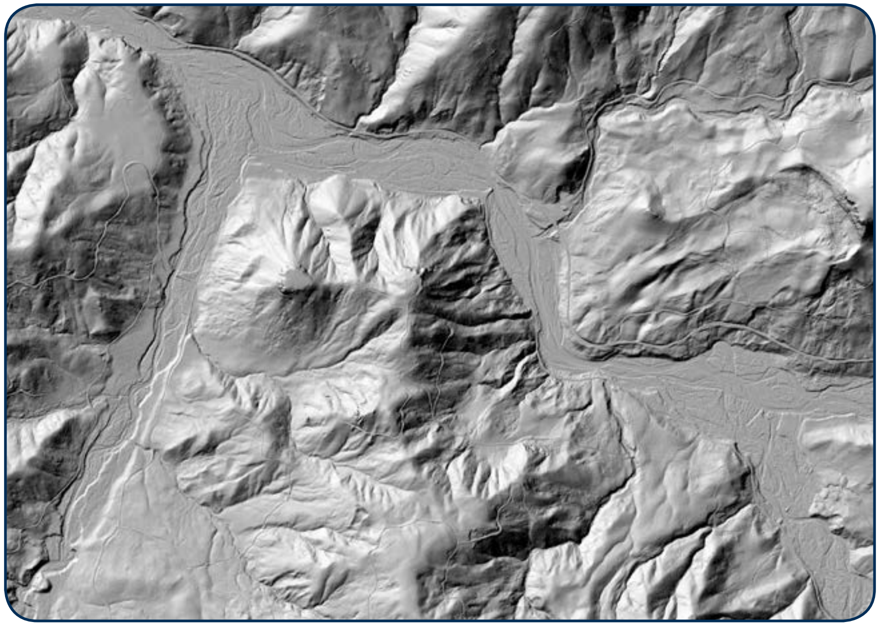
Appendix C : Selected Imagery

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.

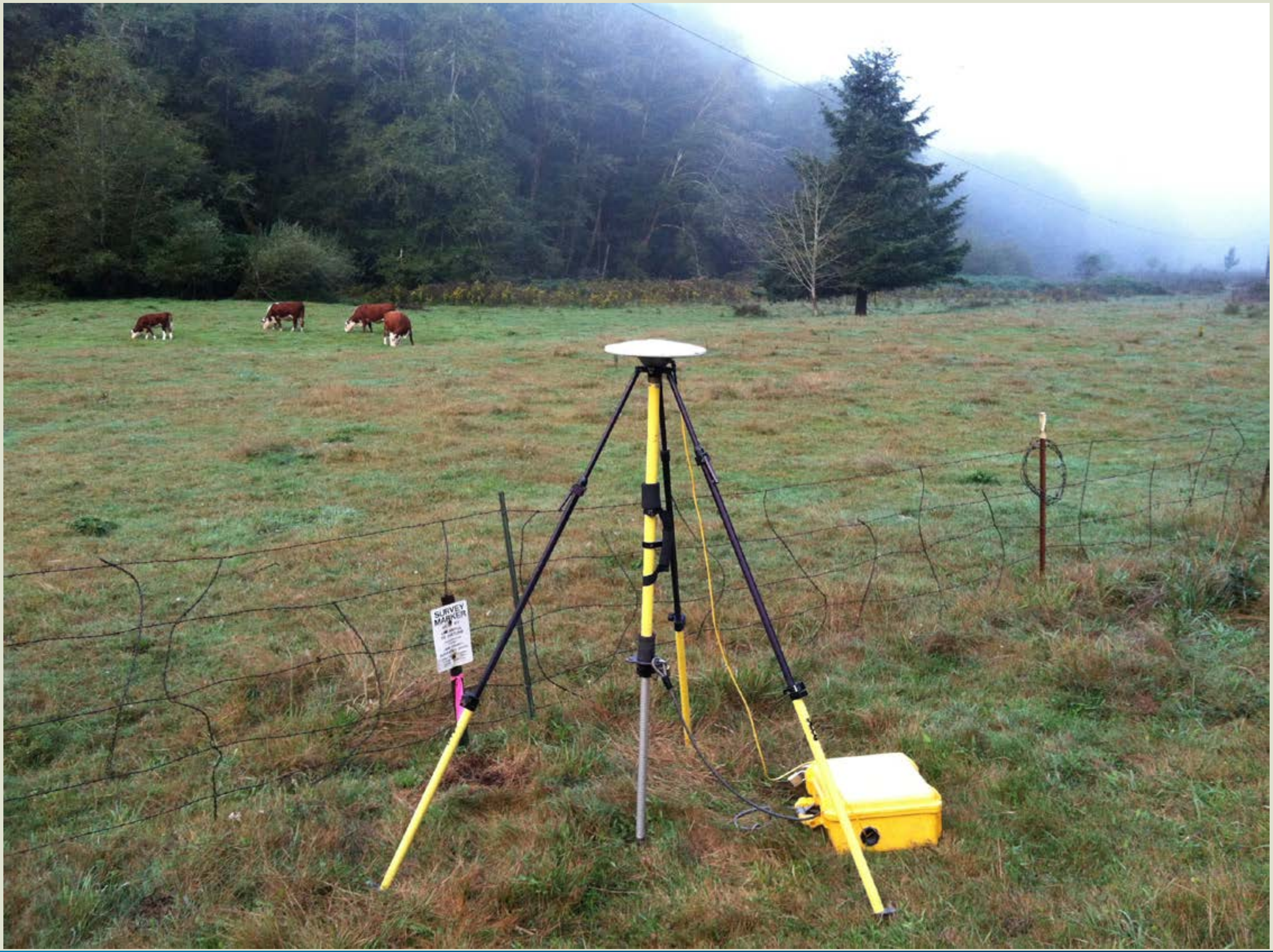
Highest Hit DEM of section of Delivery Area Two.

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.





OLC Lane County: Delivery 10



December 28 , 2015

GPS Monument Lane_06 with Trimble R7 and R8.

Data collected for:
Oregon Department of Geology and Mineral Industries

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Contents

GPS Monument “Lane_05”

Project Overview

WSI has completed the acquisition and processing of Light Detection and Ranging (LiDAR) data and Four-Band Radiometric Image Enhanced Survey (FRIES) of the OLC Lane County Delivery Area Ten (final delivery), for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Lane County project area of interest (AOI) encompasses 2,030,099 acres. Delivery Area Ten encompasses 548,022 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.

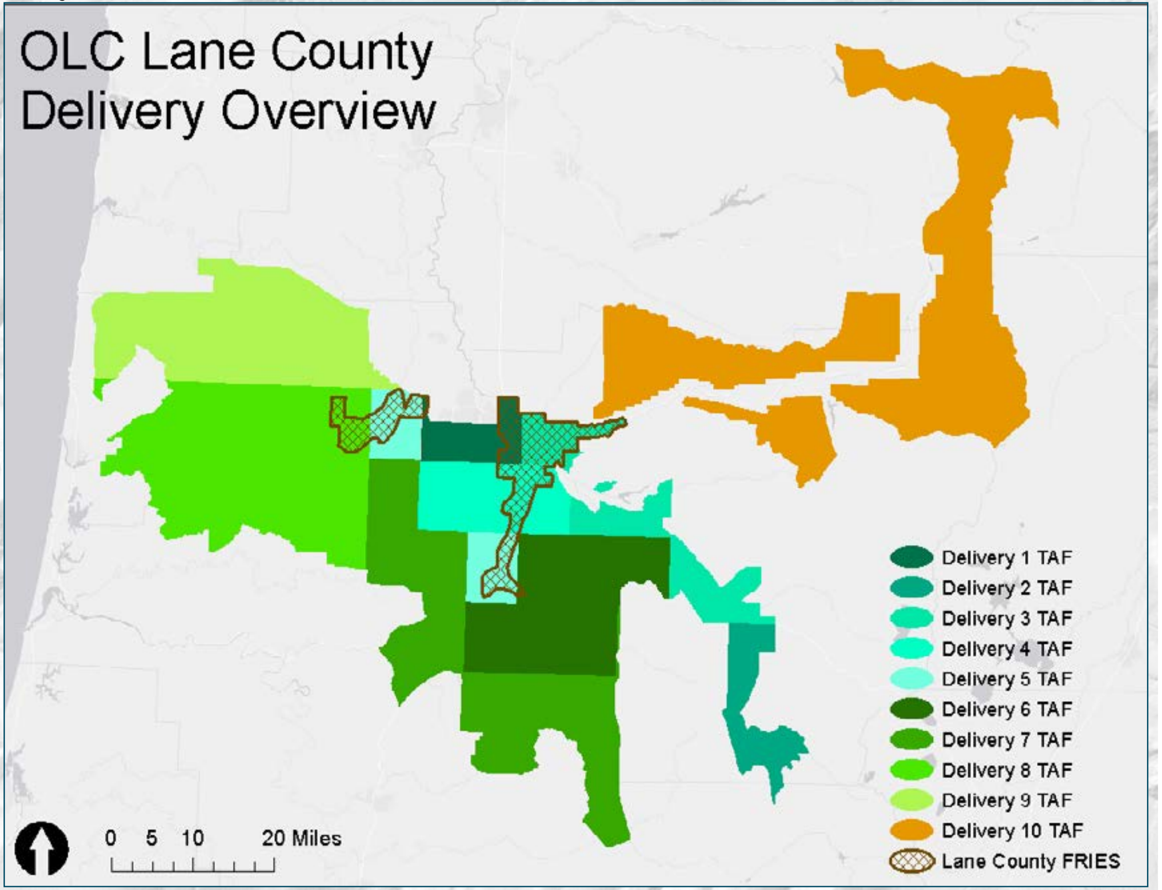
WSI began data collection on September 5, 2013 and was completed on June 8, 2015. Delivery Area Ten was acquired between July 7, 2014 and June 8, 2015. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

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, acquisition shapes, and corresponding statistical data.

WSI acquires and processes data in the most current, NGS-approved datums and geoid. For OLC Lane county, 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.

OLC Lane County Delivery 10 Data Delivered December 28, 2015	
Acquisition Dates	7/7/2014 - 6/8/2015
Delivery Area Ten Area of Interest	548,022 acres
Projection	Oregon Lambert
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

Study Area



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

Aerial Acquisition

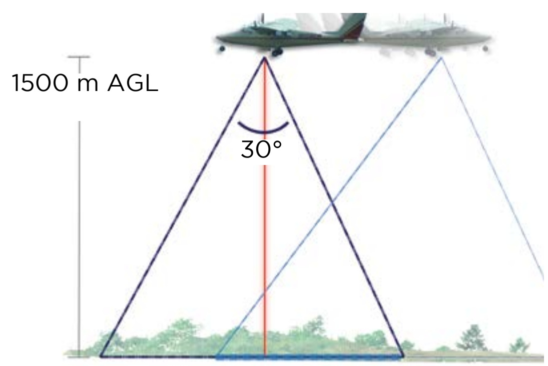
Cessna Caravan

LiDAR Survey

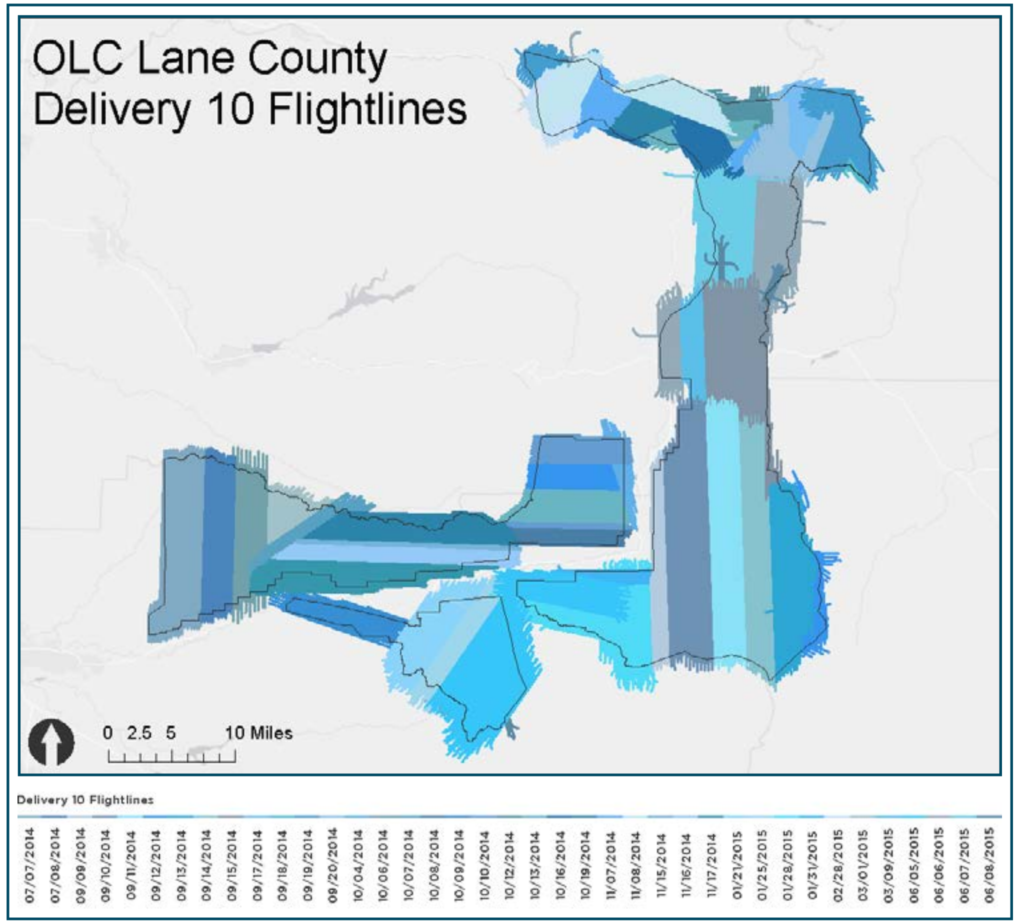
The OLC Lane County Delivery 10 LiDAR survey utilized the Leica ALS80 sensor mounted in a Cessna Caravan 208. The system was programmed to emit single pulses at a rate of 350 kilohertz and flown at 1,500 meters above ground level (AGL), capturing a scan angle of +/-15 degrees from nadir (field of view 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, 1,460 full and partial flightlines provide coverage of the study area.



Project Flightlines



Lane County Delivery 10 Acquisition Specifications	
Sensors Deployed	Leica ALS 80
Aircraft	Cessna Caravan 208B
Survey Altitude (AGL)	1,500 m
Pulse Rate	350 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

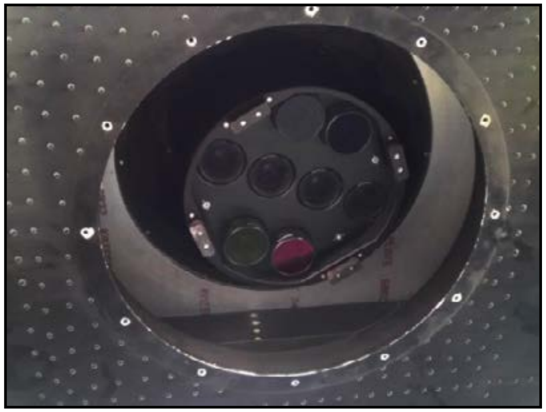
Aerial Acquisition

Photography

The photography or Four-Band Radiometric 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 POSPac MMS, 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 usable 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	≤ 13 nm
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 monument "AI1995".

Aerial Targets

Prior to photo acquisition, permanent and temporary aerial photo targets were located and installed throughout the study area. The air targets were set within two miles of a GPS base location and target control points (TCPs) were collected at each corner of the target, as well as the center point, for utilization in the processing and quality control of the orthophoto deliverables.

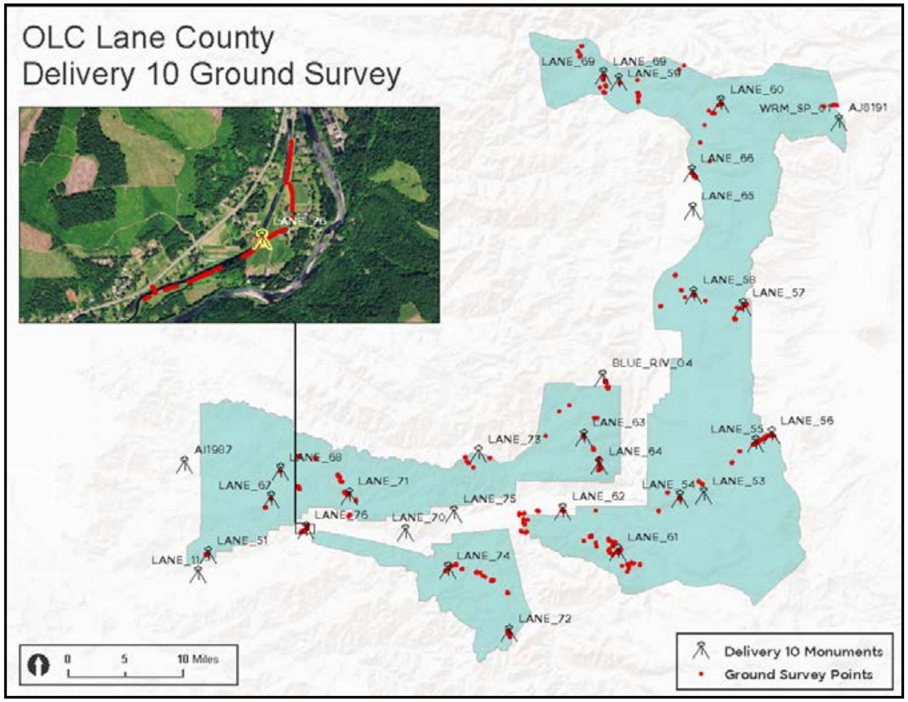
Because temporary air targets are subject to possible outside influences (e.g., weather, curious public, wildlife), WSI identifies locations adequate for collection of TCPs that are on permanent features. Selected locations include existing aerial targets, turn-arrows, STOP bars, etc. that are visible from the aircraft. WSI also paints permanent targets in appropriate locations when necessary. Additional permanent air targets were identified in the field and used for processing orthophotos.

All TCPs were acquired using one of two methods. The air targets that were set within two miles of a GPS base location had TCPs collected at each corner of the target as well as the center point. In order to increase TCP sample size for data quality, WSI also used a Fast-Static (FS) survey technique by baseline post-processing. For the air targets that were set this way, WSI collected a single static session with the R8 rover set over the center point of the target. The FS sessions lasted 15-30 minutes, depending on the distance from the air target to the base station. The static sessions and the concurrent R7 base session data were later processed in Trimble Business Center software. The use of post processing eliminates the need to deal with radio link issues, and fast static methodology generally results in precision equal to or better than full RTK collection on each target.

Examples of permanent air targets.

Ground Survey

Ground control surveys, including monumentation, aerial targets, 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 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 R6, Trimble R8, and Trimble R10 GNSS receivers.

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).

Monument locations were selected with consideration for satellite visibility, field crew safety, and optimal location for GSP coverage. QSI utilized 26 new monuments and four existing monuments for the OLC Lane County project. New monumentation was set using 5/8” x 30” rebar topped with stamped 2” aluminum caps. QSI’s professional land surveyor, Christopher Glantz (OR PLS #83648) 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 page nine provides the list of monuments used in Delivery Area Ten. See Appendix B for a complete list of monuments placed within the OLC Lane County 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 Trimble R7 base unit was set up over an appropriate monument to broadcast a real-time correction to a roving R6, R8, or R10 unit. This RTK rover survey allows for precise location measurement (2.0 centimeter). All RTK measurements were 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. For RTK data, the collector recorded at least a five-second stationary observation, and then calculated the pseudorange position from three one-second epochs with relative error less than 1.5 centimeter horizontal and 2.0 centimeter vertical.

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

GSP positions were collected on bare earth locations such as paved, gravel or stable dirt roads, and other locations where the ground was clearly visible (and was likely to remain visible) from the sky during the data acquisition and GSP measurement periods. In order to facilitate comparisons with LiDAR data, GSP measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads. The planned locations for control points were determined prior to field deployment, and the suitability of these locations was verified on site. The distribution of ground survey points depended on ground access constraints, and may not be equitably distributed throughout the study area.


Ground professional collecting RTK

Instrumentation			
Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R6	Integrated GNSS Antenna R6	TRM_R6	Rover
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Static, Rover
Trimble R10	Integrated Antenna R10	TRMR10	Rover

PID	Latitude	Longitude	Ellipsoid Height (m)	Othometric Height (m)
AI1987	44° 12' 27.42931"	-122° 49' 49.03656"	157.321	180.547
AJ8191	44° 39' 23.18028"	-121° 41' 33.57573"	1983.063	2004.142
BLUE_RIV_04	44° 19' 45.50913"	-122° 06' 01.51323"	1412.718	1434.494
LANE_11	44° 04' 08.74341"	-122° 48' 06.59661"	161.587	184.843
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973	569.170
LANE_53	44° 11' 00.46734"	-121° 55' 12.33453"	1466.849	1487.977
LANE_54	44° 10' 41.98041"	-121° 57' 40.08010"	1208.453	1229.835
LANE_55	44° 14' 58.44023"	-121° 49' 52.63978"	1558.758	1579.651
LANE_56	44° 15' 38.38604"	-121° 48' 09.68817"	1601.779	1622.656
LANE_57	44° 25' 19.90234"	-121° 51' 23.67546"	1434.237	1455.411
LANE_58	44° 26' 11.01683"	-121° 56' 36.51882"	1117.648	1139.020
LANE_59	44° 42' 09.70199"	-122° 04' 57.99867"	497.773	519.608
LANE_60	44° 40' 38.57139"	-121° 54' 04.98722"	1281.918	1303.188
LANE_61	44° 06' 36.49027"	-122° 04' 04.83173"	1438.496	1460.115
LANE_62	44° 09' 36.54184"	-122° 09' 57.92458"	418.342	440.548
LANE_63	44° 15' 13.30087"	-122° 07' 55.02809"	1377.917	1399.839
LANE_64	44° 13' 05.95603"	-122° 06' 13.58282"	1482.944	1504.845
LANE_65	44° 32' 32.44739"	-121° 56' 55.23407"	1309.719	1331.132
LANE_66	44° 35' 22.26603"	-121° 57' 03.82977"	1007.465	1028.968
LANE_67	44° 09' 58.41010"	-122° 40' 34.96786"	736.802	759.768
LANE_68	44° 12' 06.66895"	-122° 39' 43.82798"	699.408	722.356
LANE_69	44° 42' 36.07454"	-122° 06' 34.98350"	463.910	485.791
LANE_70	44° 07' 45.63642"	-122° 26' 24.72517"	543.955	566.617
LANE_71	44° 10' 24.58901"	-122° 32' 25.77843"	536.990	559.796
LANE_72	44° 00' 18.08908"	-122° 15' 17.28580"	1623.222	1645.274
LANE_73	44° 13' 48.46606"	-122° 18' 56.85686"	1319.790	1341.995
LANE_74	44° 04' 58.19343"	-122° 21' 53.66019"	715.086	737.581
LANE_75	44° 09' 14.03758"	-122° 21' 22.49449"	302.432	324.989
LANE_76	44° 07' 45.92618"	-122° 36' 53.81440"	205.074	227.969
WRM_SP_01	44° 39' 22.75371"	-121° 41' 33.13407"	1981.876	2002.956

Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

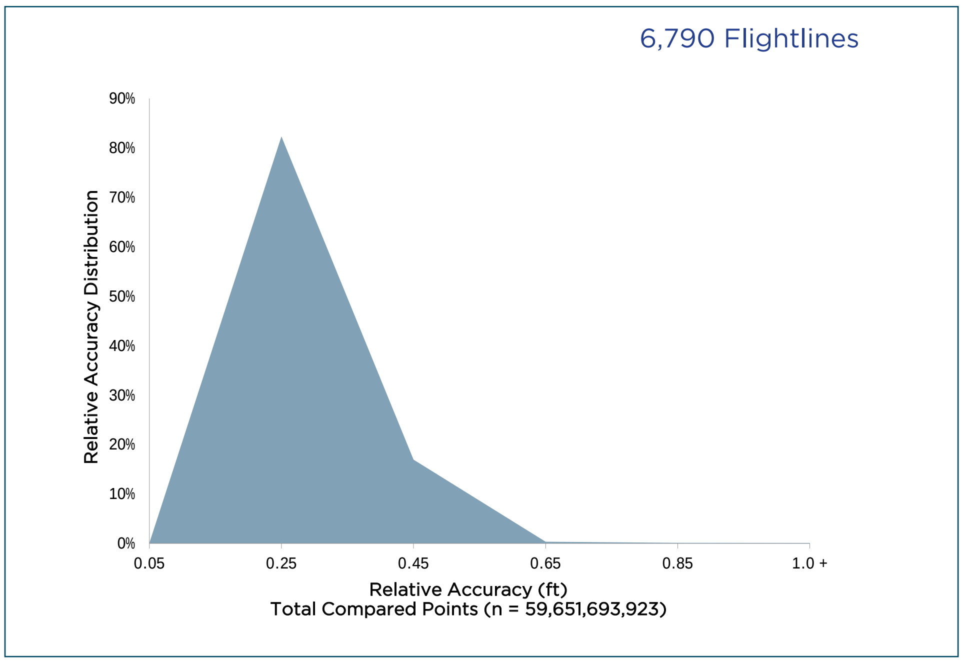
LiDAR Accuracy

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 6,790 full and partial flightlines (1,460 full and partial flightlines from Delivery Area Ten) and over 59 billion points. Relative accuracy is reported for the cumulative delivered portions of the study area.

Cumulative Relative Accuracy Distribution



Relative Accuracy Results	Delivery 10	Cumulative
Sample Size (N)	1,460 flightlines	6,790 flightlines
Project Average	0.201 ft. (0.061 m)	0.196 ft. (0.057 m)
Median Relative Accuracy	0.197 ft. (0.060 m)	0.190 ft. (0.058 m)
1σ Relative Accuracy	0.223 ft. (0.068 m)	0.217 ft. (0.066 m)
2σ Relative Accuracy	0.274 ft. (0.083 m)	0.313 ft. (0.096 m)

R7 Receiver

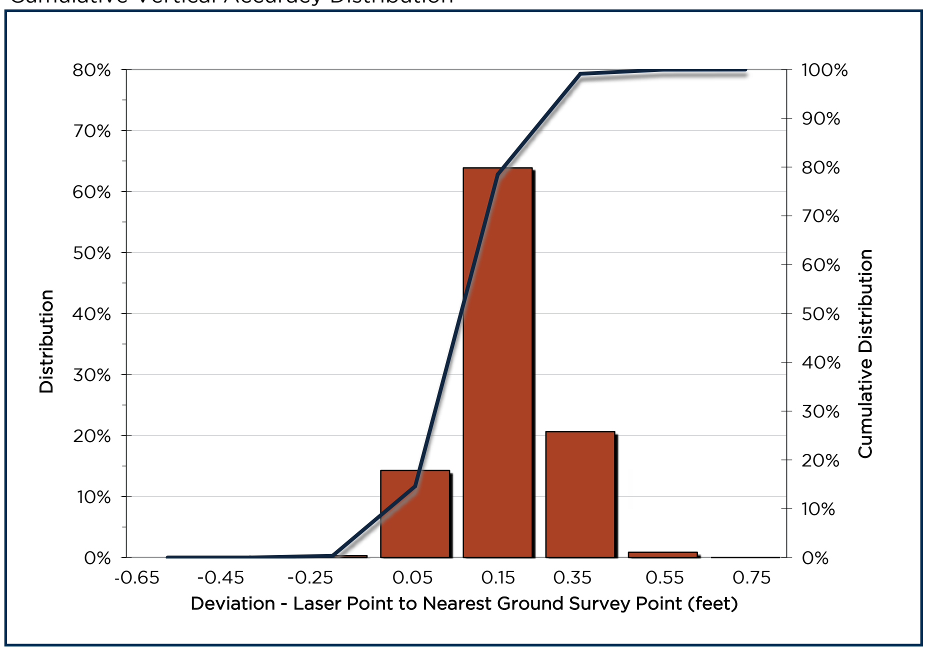
Vertical Accuracy

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 survey points to the triangulated LiDAR surface. 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 Ten study area, 5,535 GSPs were collected. Statistics are shown for Delivery Area Ten and cumulative (right).

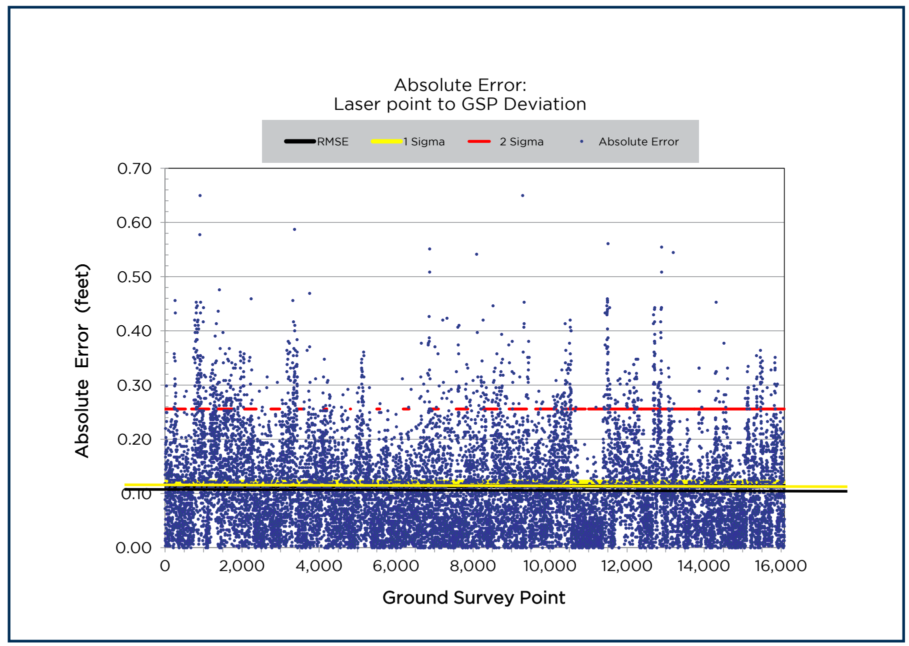
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as “Compiled to Meet.” Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation statistics displayed for the cumulative data delivered below.

Vertical Accuracy Results		
	Delivery Area Ten	Cumulative
Sample Size (n)	5,535 Ground survey points	16,085 Ground survey points
Root Mean Square Error	0.10 ft. (0.03 m)	0.11 ft. (0.03 m)
1 Standard Deviation	0.11 ft. (0.04 m)	0.12 ft. (0.04 m)
2 Standard Deviation	0.25 ft. (0.08 m)	0.26 ft. (0.08 m)
Average Deviation	0.10 ft. (0.03 m)	0.10 ft. (0.03 m)
Minimum Deviation	-0.54 ft. (-0.17 m)	-0.65 ft. (-0.20 m)
Maximum Deviation	0.56 ft. (0.17 m)	0.65 ft. (0.20 m)

Cumulative Vertical Accuracy Distribution



Cumulative GSP Absolute Error



Density

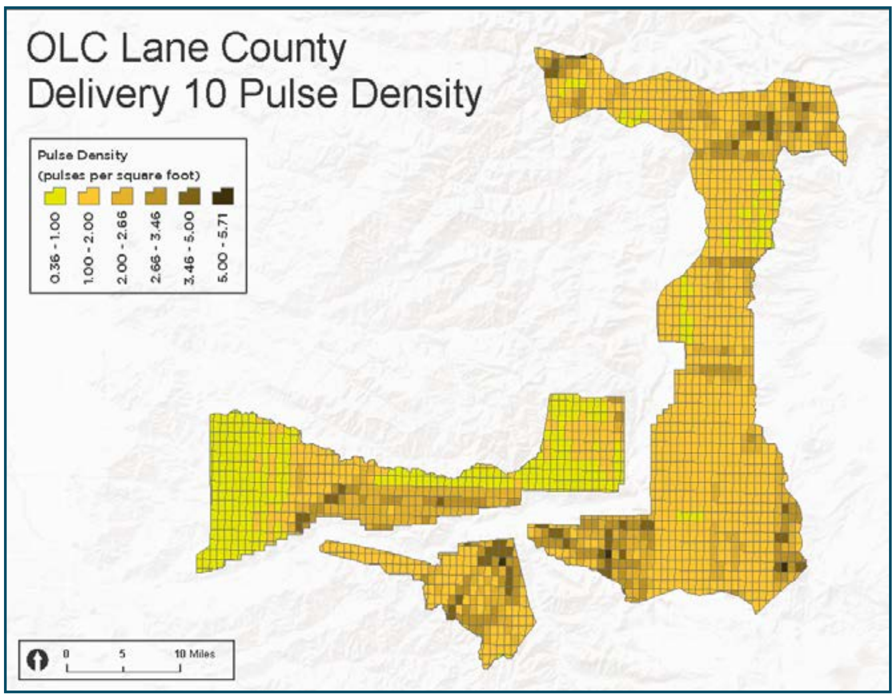
Pulse Density

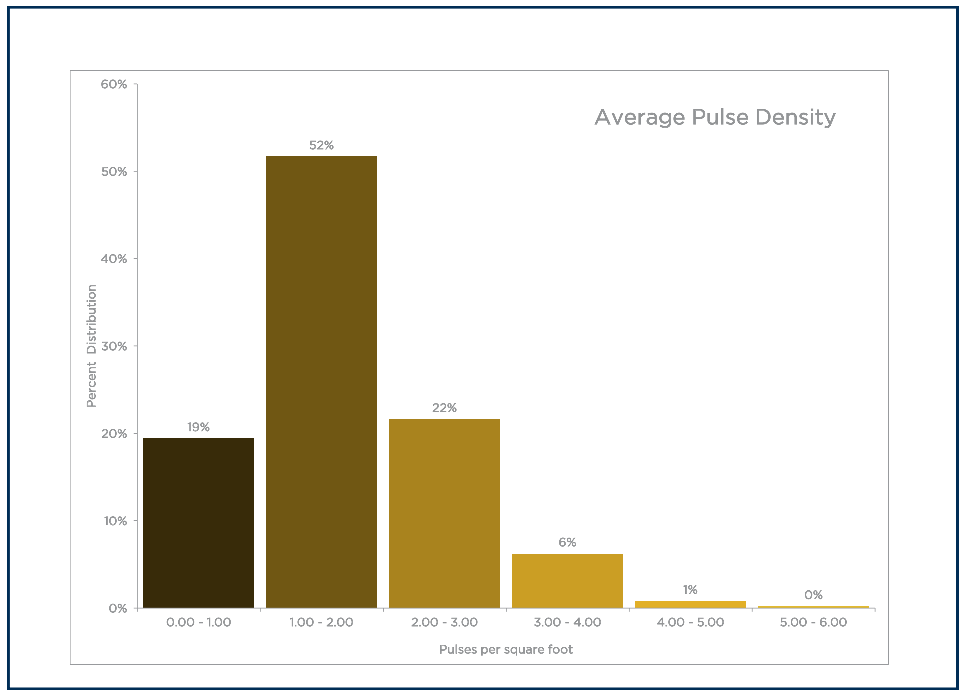
Final pulse density is calculated after processing and is a measure of first returns per sampled area. Some types of surfaces (e.g., dense vegetation, water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according 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.

Delivery 10 Average Pulse Density	pulses per square meter	pulses per square foot
	18.08	1.68

Cumulative Average Pulse Density	pulses per square meter	pulses per square foot
	12.44	1.16

Average Pulse Density per 0.75' USGS Quad (color scheme aligns with density chart). Below left, note area of minimal pulse density over water body.





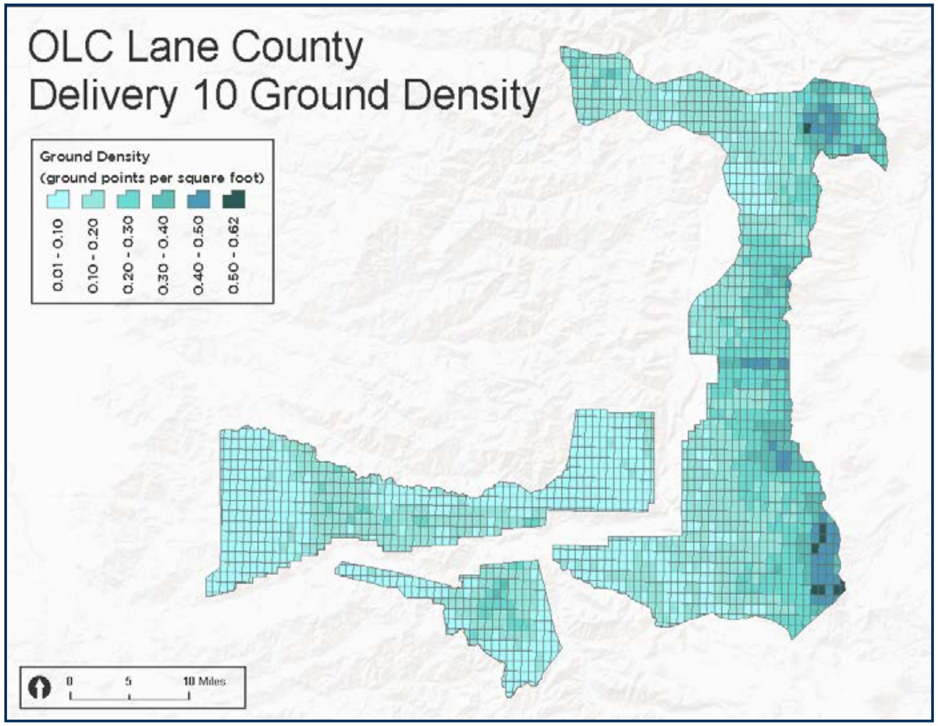
Ground Density

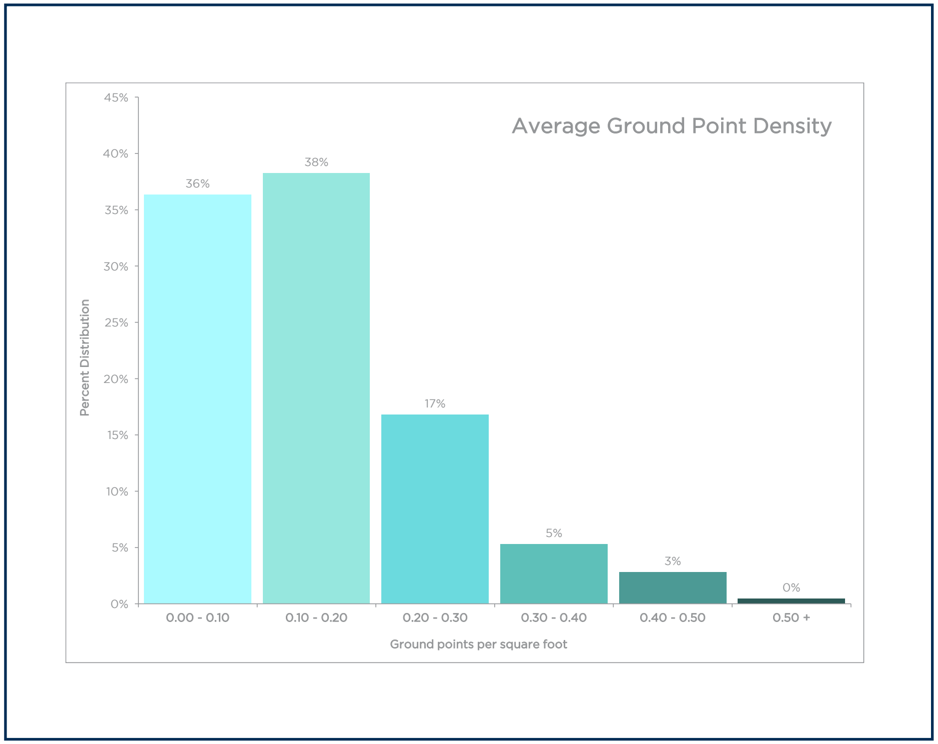
Ground classifications were derived from ground surface modeling. Further classifications were performed by reseeding of the ground model where it was determined that the ground model failed, usually under dense vegetation and/or at breaks in terrain, steep slopes, and at tile boundaries. The classifications are influenced by terrain and grounding parameters that are adjusted for the dataset. The reported ground density is a measure of ground-classified point data for the delivery area.

Delivery 10 Average Ground Density	ground points per square meter	ground points per square foot
	1.67	0.16

Cumulative Average Ground Density	ground points per square meter	ground points per square foot
	0.99	0.09

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





Orthophoto Accuracy

Orthophoto Accuracy Assessment

To assess the spatial accuracy of the orthophotographs, artificial check points were established. Thirteen target control points, distributed evenly across the total acquired area, were generated on permanent air target surface features, such as painted road lines and fixed high-contrast objects or on temporary air targets. 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. Accuracy statistics are reported for the entire Lane County Orthophoto AOI.

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

Orthophoto horizontal accuracy results.

Orthophoto Horizontal Accuracy (n=13)	WSI Achieved (m)	WSI Achieved (ft.)
RMSE	0.110	0.360
1 Sigma	0.118	0.388
2 Sigma	0.187	0.612

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Appendix A : PLS Certification

WSI, a Quantum Spatial company, provided LiDAR Services for OLC Lane County LiDAR project Delivery 10 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.

John T English 12/23/2015

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 July 7, 2014 and March 1, 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".

12/23/2015

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

REGISTERED
PROFESSIONAL
LAND SURVEYOR
OREGON
JUNE 2, 2010
CHRISTOPHER A. GLANTZ
83648
RENEWS 6/30/2017

Appendix B : GPS Monument Table

List of GPS monuments used in OLC Lane County Survey Area. Coordinates are on the NAD83 (2011) datum, epoch 2010.00. NAVD88 height referenced to Geoid12A.

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
AI1987	44° 12’ 27.42931”	-122° 49’ 49.03656”	157.321	180.547
AI1995	44° 01’ 06.96543”	-123° 51’ 37.53642”	-15.700	7.830
AI2001	43° 55’ 19.20493”	-122° 47’ 41.08223”	195.963	219.207
AJ8191	44° 39’ 23.18028”	-121° 41’ 33.57573”	1983.063	2004.142
BLUE_RIV_04	44° 19’ 45.50913”	-122° 06’ 01.51323”	1412.718	1434.494
LANE_01	44° 13’ 34.22103”	-123° 55’ 25.99216”	487.832	510.916
LANE_02	44° 11’ 04.59366”	-123° 51’ 03.90195”	104.844	127.923
LANE_03	44° 17’ 35.16542”	-123° 41’ 42.13047”	69.602	92.380
LANE_04	44° 19’ 30.86443”	-123° 39’ 58.03953”	230.843	253.546
LANE_05	44° 16’ 43.86859”	-124° 02’ 41.13217”	458.248	481.771
LANE_06	44° 12’ 10.80761”	-123° 30’ 31.42667”	196.503	219.151
LANE_06	44° 12’ 10.80764”	-123° 30’ 31.42667”	196.522	219.169
LANE_06A	44° 14’ 32.55999”	-123° 24’ 47.48386”	336.456	359.076
LANE_07	43° 59’ 52.25896”	-123° 22’ 23.48186”	143.322	166.275
LANE_08	44° 08’ 23.10388”	-123° 35’ 55.56664”	168.733	191.568
LANE_09	44° 04’ 26.42150”	-123° 30’ 21.24330”	133.059	155.944
LANE_10	44° 00’ 11.70302”	-123° 59’ 45.31927”	-21.486	2.572
LANE_11	44° 04’ 08.74341”	-122° 48’ 06.59661”	161.587	184.843
LANE_12	44° 05’ 44.71178”	-123° 43’ 49.91180”	63.439	86.487
LANE_13	44° 00’ 41.08475”	-122° 59’ 27.48519”	119.047	142.488
LANE_14	43° 50’ 13.64839”	-123° 14’ 03.11154”	175.699	198.720
LANE_15	43° 59’ 28.97732”	-122° 56’ 10.19436”	139.378	162.854
LANE_16	43° 49’ 45.78726”	-123° 07’ 47.74145”	212.747	235.886
LANE_17	43° 59’ 22.07068”	-123° 11’ 07.80197”	111.693	134.821
LANE_18	43° 55’ 40.86962”	-123° 37’ 20.35729”	178.186	201.375
LANE_19	44° 00’ 01.44296”	-123° 13’ 56.62771”	104.781	127.866
LANE_20	43° 53’ 27.38516”	-123° 28’ 30.83622”	153.934	176.937
LANE_22	43° 52’ 51.72856”	-123° 13’ 33.92296”	147.785	170.814

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
LANE_23	43° 47' 25.93196"	-123° 01' 54.25135"	176.209	199.467
LANE_24	43° 42' 26.18996"	-122° 25' 40.56001"	450.794	473.495
LANE_25	43° 42' 51.38283"	-122° 23' 45.43363"	792.318	814.931
LANE_26	43° 33' 00.45694"	-122° 28' 22.66794"	815.341	838.000
LANE_27	43° 31' 20.08417"	-122° 20' 15.46234"	1080.075	1102.416
LANE_28	43° 53' 58.92454"	-122° 48' 59.17889"	194.478	217.704
LANE_29	43° 52' 12.08177"	-122° 47' 18.45224"	420.380	443.439
LANE_29A	43° 52' 12.08161"	-122° 47' 18.45256"	420.361	443.420
LANE_30	43° 37' 14.50986"	-123° 05' 19.83916"	253.542	276.603
LANE_31	43° 45' 16.82389"	-122° 26' 41.15314"	492.053	514.761
LANE_32	43° 47' 33.82161"	-122° 25' 40.76291"	677.205	699.811
LANE_33	43° 36' 30.58173"	-123° 01' 40.84386"	471.540	494.595
LANE_34	43° 45' 30.54400"	-122° 29' 48.47559"	308.081	330.845
LANE_35	43° 48' 11.57911"	-122° 42' 37.56859"	1041.596	1064.354
LANE_36	43° 50' 54.28025"	-123° 21' 47.73924"	229.292	252.262
LANE_37	43° 51' 23.46541"	-123° 25' 02.19196"	197.776	220.754
LANE_38	43° 58' 54.14928"	-123° 41' 53.55130"	424.298	447.506
LANE_39	43° 42' 19.93987"	-122° 57' 05.04012"	456.450	479.573
LANE_40	43° 35' 23.35579"	-123° 00' 04.90380"	479.127	502.200
LANE_41	43° 44' 45.10607"	-122° 53' 27.75969"	236.302	259.436
LANE_42	43° 40' 03.45665"	-122° 48' 42.76721"	311.004	334.076
LANE_43	43° 21' 17.49608"	-122° 44' 41.88280"	524.594	547.828
LANE_45	43° 30' 26.64379"	-122° 50' 42.75367"	1160.885	1183.730
LANE_46	43° 38' 28.84405"	-123° 12' 52.40829"	104.565	127.600
LANE_47	43° 35' 46.97747"	-123° 15' 08.04840"	105.980	129.003
LANE_49	43° 41' 54.47511"	-122° 46' 16.97790"	331.018	354.016
LANE_51	44° 05' 39.63958"	-122° 47' 04.98635"	545.973	569.170
LANE_53	44° 11' 00.46734"	-121° 55' 12.33453"	1466.849	1487.977
LANE_54	44° 10' 41.98041"	-121° 57' 40.08010"	1208.453	1229.835
LANE_55	44° 14' 58.44023"	-121° 49' 52.63978"	1558.758	1579.651

PID	Latitude	Longitude	Ellipsoid Height (m)	NAVD 88 Height (m)
LANE_56	44° 15’ 38.38604”	-121° 48’ 09.68817”	1601.779	1622.656
LANE_57	44° 25’ 19.90234”	-121° 51’ 23.67546”	1434.237	1455.411
LANE_58	44° 26’ 11.01683”	-121° 56’ 36.51882”	1117.648	1139.020
LANE_59	44° 42’ 09.70199”	-122° 04’ 57.99867”	497.773	519.608
LANE_60	44° 40’ 38.57139”	-121° 54’ 04.98722”	1281.918	1303.188
LANE_61	44° 06’ 36.49027”	-122° 04’ 04.83173”	1438.496	1460.115
LANE_62	44° 09’ 36.54184”	-122° 09’ 57.92458”	418.342	440.548
LANE_63	44° 15’ 13.30087”	-122° 07’ 55.02809”	1377.917	1399.839
LANE_64	44° 13’ 05.95603”	-122° 06’ 13.58282”	1482.944	1504.845
LANE_65	44° 32’ 32.44739”	-121° 56’ 55.23407”	1309.719	1331.132
LANE_66	44° 35’ 22.26603”	-121° 57’ 03.82977”	1007.465	1028.968
LANE_67	44° 09’ 58.41010”	-122° 40’ 34.96786”	736.802	759.768
LANE_68	44° 12’ 06.66895”	-122° 39’ 43.82798”	699.408	722.356
LANE_69	44° 42’ 36.07454”	-122° 06’ 34.98350”	463.910	485.791
LANE_70	44° 07’ 45.63642”	-122° 26’ 24.72517”	543.955	566.617
LANE_71	44° 10’ 24.58901”	-122° 32’ 25.77843”	536.990	559.796
LANE_72	44° 00’ 18.08908”	-122° 15’ 17.28580”	1623.222	1645.274
LANE_73	44° 13’ 48.46606”	-122° 18’ 56.85686”	1319.790	1341.995
LANE_74	44° 04’ 58.19343”	-122° 21’ 53.66019”	715.086	737.581
LANE_75	44° 09’ 14.03758”	-122° 21’ 22.49449”	302.432	324.989
LANE_76	44° 07’ 45.92618”	-122° 36’ 53.81440”	205.074	227.969
RP_265+4988	43° 25’ 06.36155”	-123° 09’ 01.37675”	201.245	224.527
WRM_SP_01	44° 39’ 22.75371”	-121° 41’ 33.13407”	1981.876	2002.956

Appendix C : 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, Spring-field, Oregon.

Highest Hit DEM of section of Delivery Area Two.

LiDAR derived DEM's: **Above** highest hit DEM and **Below:** bare earth DEM. Both areas depicted are within delivery area three.