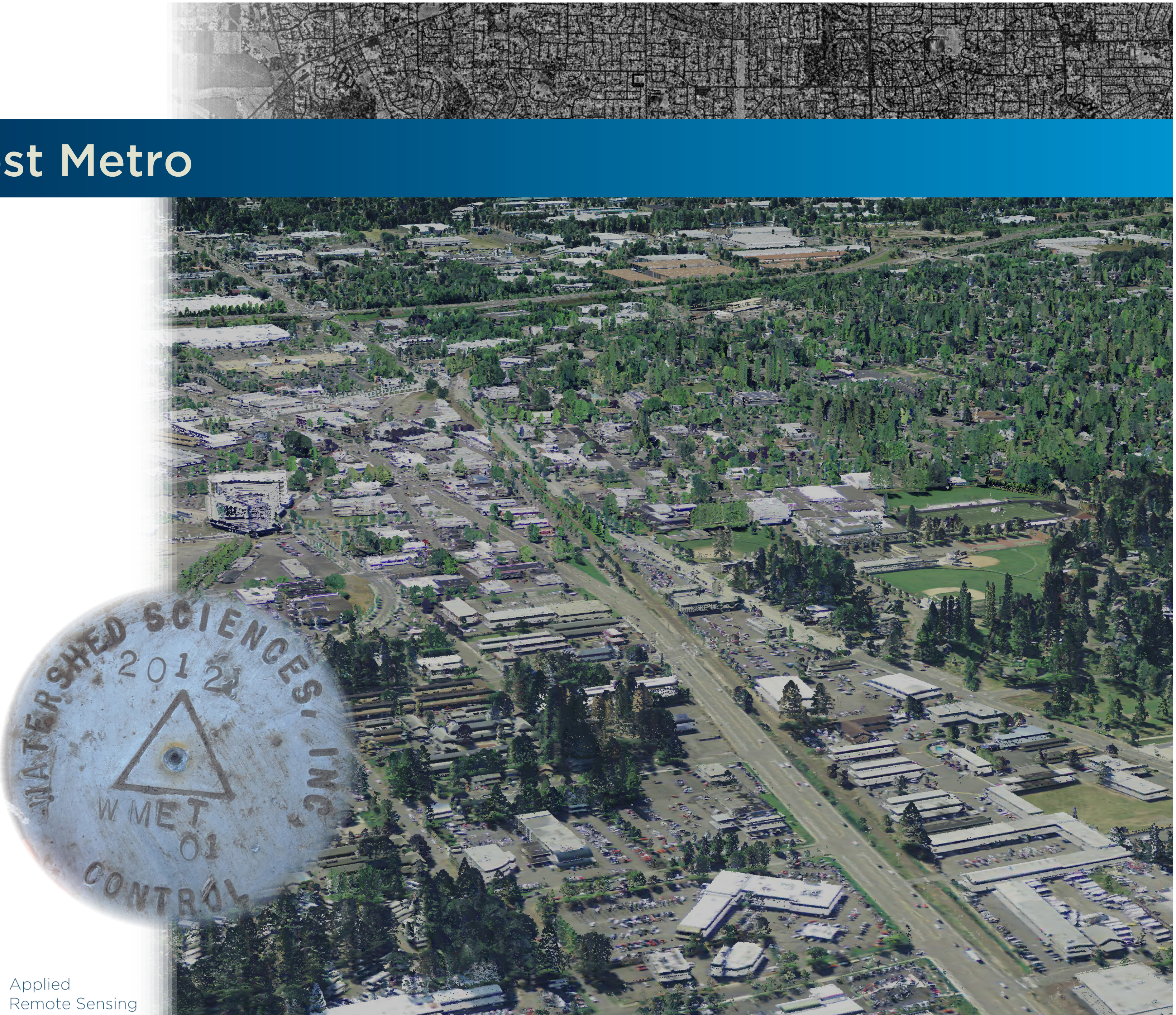
OLC West Metro



Applied
Remote Sensing
and Analysis

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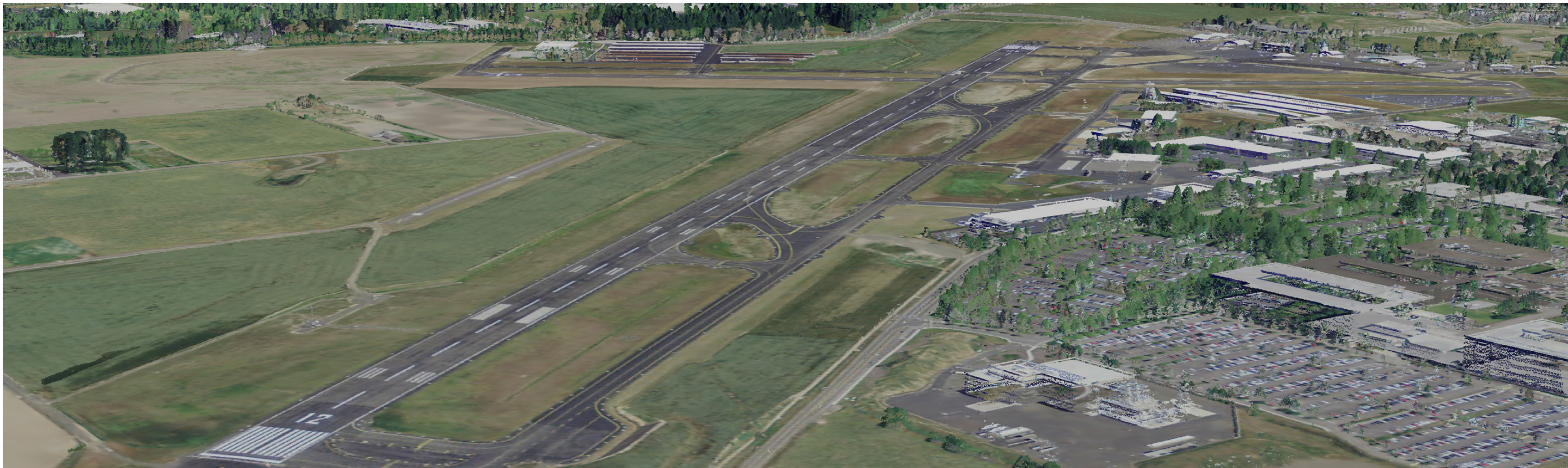
February 19, 2013



Hillsboro Airport, LiDAR point cloud

Data collected for:
Department of Geology and Mineral Industries

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Prepared by:
WSI

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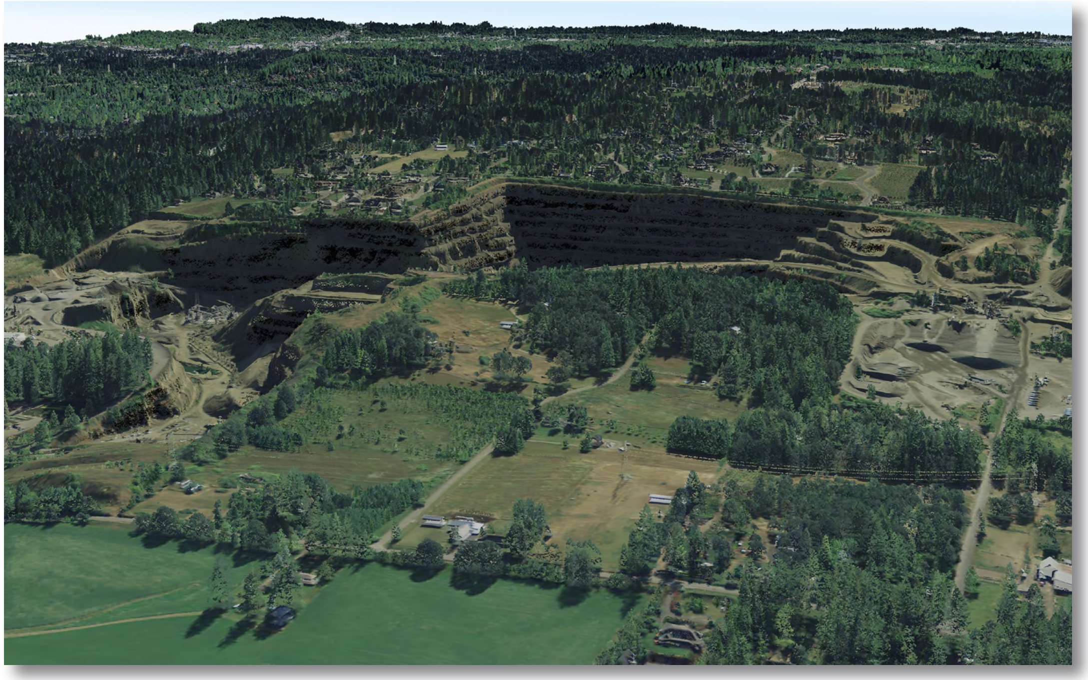
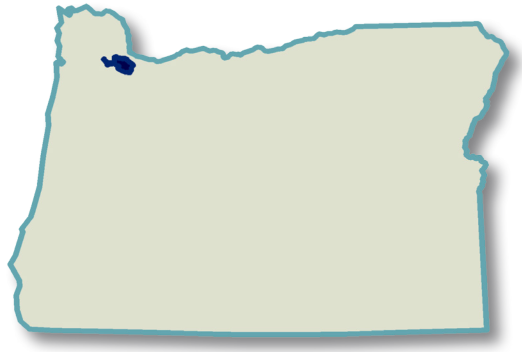




Project Overview

WSI has collected Light Detection and Ranging (LiDAR) data of the Oregon West Metro Study Area for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's West Metro project area encompasses approximately 100,000 acres in Washington, Multnomah, and Clackamas County, Oregon. The study area includes the Beaverton, Hillsboro, and Forest Grove metro areas.

Data Delivered February 19th, 2012	
Acquisition Date	Dec 28th 2012 - Jan 4th, 2013
Area of Interest	96,543 acres
Total Area Flown	99,684 acres
Data	Oregon State Plane North
Projection	Oregon Statewide Lambert Conformal Conic
Datum: horizontal & vertical	NAD83 (2011) NAVD88 (Geoid 12A)
Units	International Feet

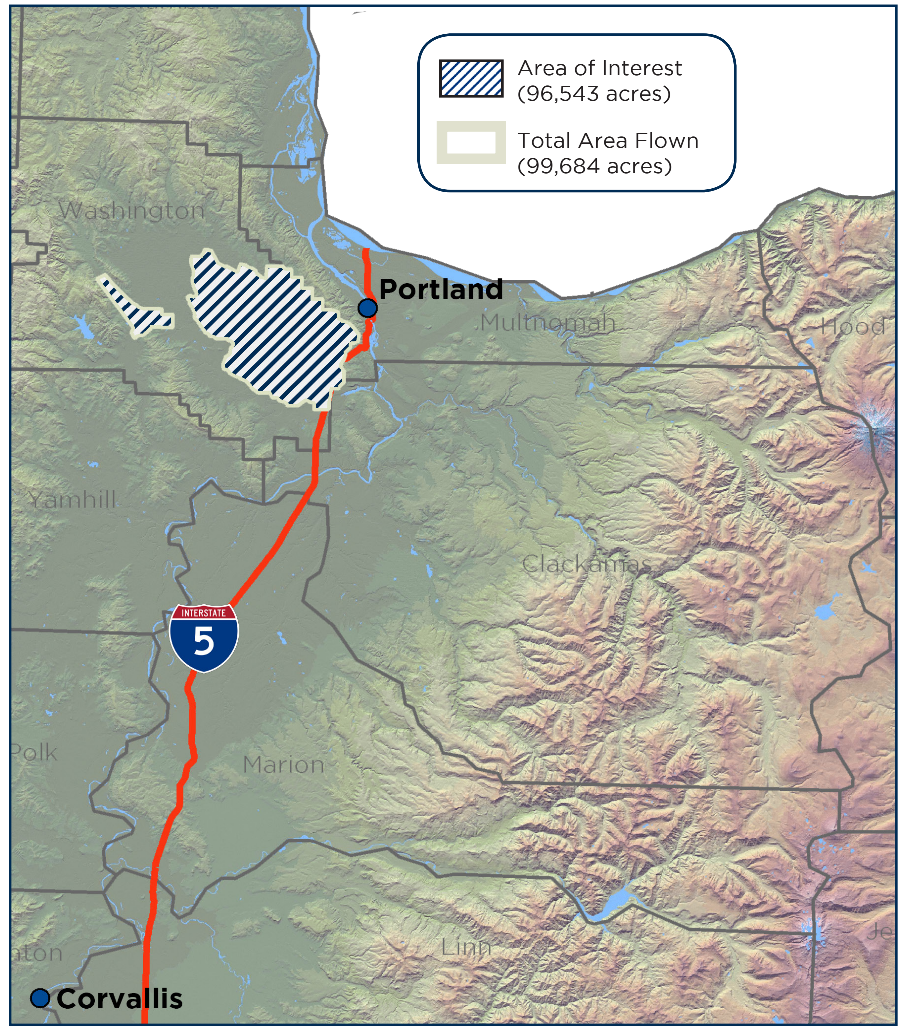
The collection of high resolution geographic data is part of an ongoing pursuit to amass a library of information accessible to government agencies as well as the general public.

Between December 28th, 2012 and January 4th, 2013, WSI employed remote-sensing lasers in order to obtain a total area flown of 99,684 acres of which 96,543 acres comprise the area of interest. Settings for LiDAR data capture produced an average resolution of at least eight pulses per square meter.

In addition to LiDAR survey, OLC West Metro included high-resolution aerial photography was acquired for the entire study area.

Final products created include LiDAR point cloud data, 1 meter digital elevation models of bare earth ground model and highest-hit returns, intensity rasters, ortho-imagery, study area vector shapes, and corresponding statistical data.

Study Area



Cessna Caravan

Aerial Acquisition

LiDAR Survey

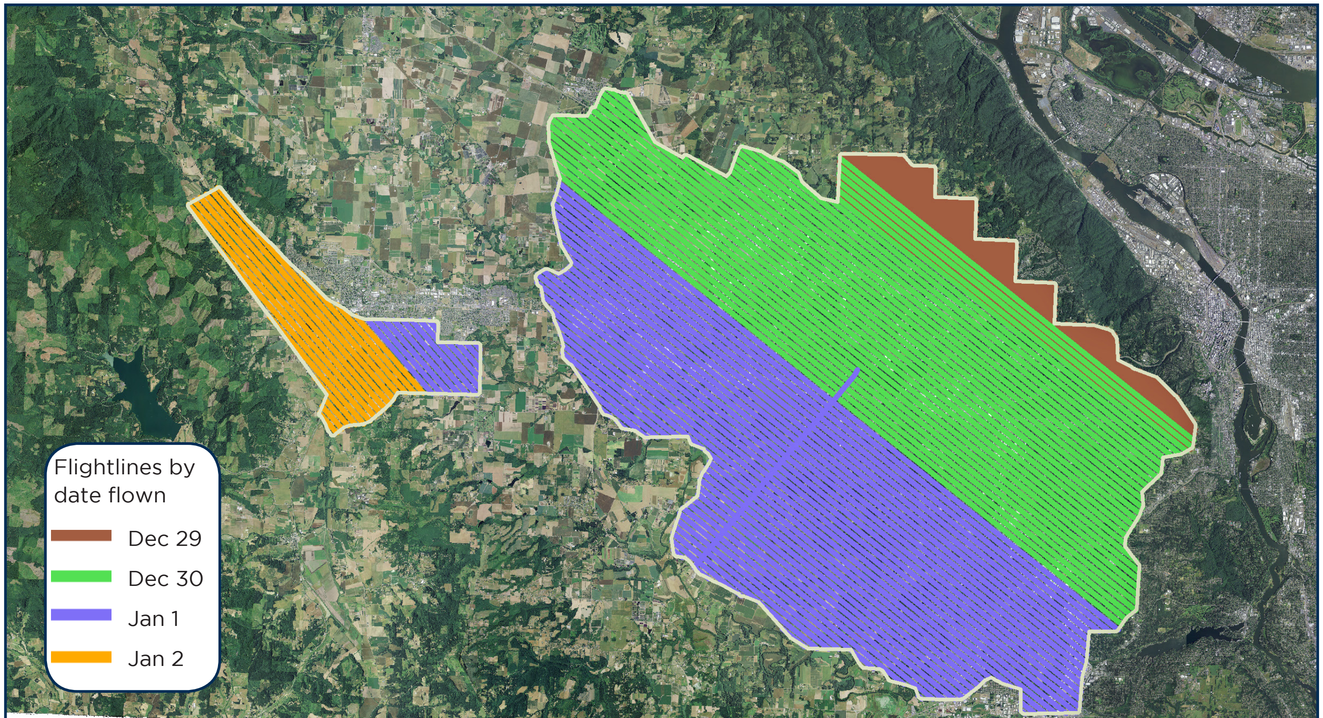
The LiDAR survey utilized Leica ALS60 sensor mounted in a Cessna Caravan 208B. The systems were programmed to emit either single or multi-laser pulses at a rate of 61.1 or 63.3 Hz, and flown at 900 or 1500 meters above ground level (AGL), capturing a scan angle of 30° from nadir. These settings are developed to yield points with an average native density of greater than eight points 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 variable according to distributions of terrain, land cover and water bodies. The study area was surveyed with opposing flight line side-lap of greater than 60% with at least 100% overlap to reduce laser shadowing and increase surface laser painting. The system allows up to four range measurements per pulse, and all discernable 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 (2 Hz) by an onboard differential GPS unit. Aircraft attitude is measured 200 times per second (200 Hz) as pitch, roll and yaw (heading) from an onboard inertial measurement unit (IMU). As illustrated in the accompanying map, 114 flightlines provide coverage for the study area.

Sensor ALS 60

Acquisition Specs	
Sensors Deployed	Leica ALS 60
Aircraft	Cessna Caravan 208B
Survey Altitude (AGL)	900/1500 m
Pulse Rate	61.1/63.3 hz
Pulse Mode	Single (SPiA) / Multi (MPiA)
Field of View (FOV)	30°
Roll Compensated	Yes
Overlap	100% overlap with 60% sidelap
Pulse Emission Density	≥ 8 pulse / m^2

Project Flightlines



Ground Survey

During the LiDAR survey, static (1 Hz recording frequency) ground surveys were conducted over 4 monuments with known coordinates. After the airborne survey, the static GPS data were processed using triangulation with CORS stations and checked against 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 5 seconds then calculating the pseudo range position from at least three epochs with the relative error under 1.5 cm horizontal and 2 cm vertical. All GPS measurements are made with dual frequency L1-L2 receivers with carrier-phase correction.

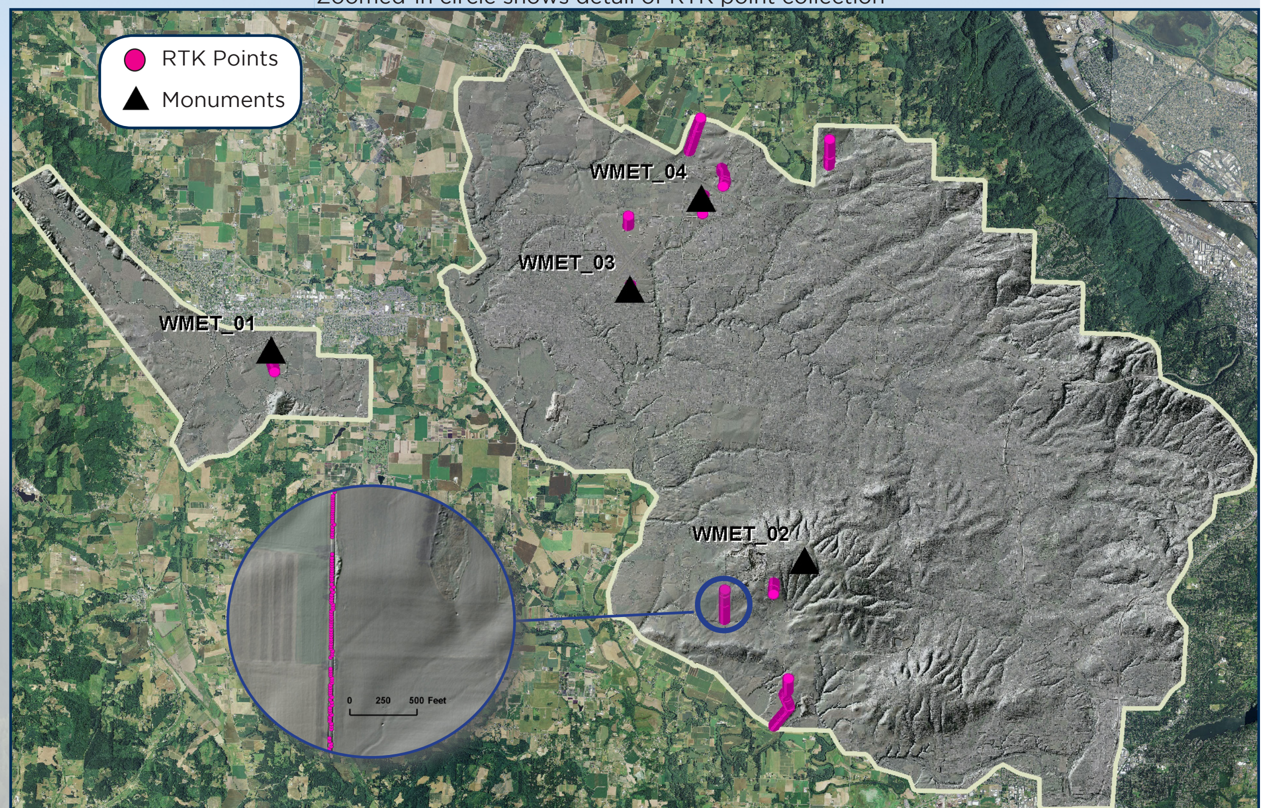
Monumentation

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 its 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 required on private property, consent from the owner is required.

All monumentation is done with 5/8" x 30" rebar topped with a 2" diameter aluminum cap stamped "Watershed Sciences, Inc. Control."

Monuments			
	Datum NAD 83 (2011)		GRS 80
Name	Latitude	Longitute	Ellipsoid Height (m)
WMET_01	45 30 30.77328	-123 05 28.21684	26.432
WMET_02	45 27 09.40247	-122 52 21.17650	206.046
WMET_03	45 31 45.54323	-122 56 47.59188	38.553
WMET_04	45 33 21.75895	-122 55 07.19967	41.859

Project Monuments & RTK points
Zoomed-in circle shows detail of RTK point collection



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 2 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 1Hz 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 3 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% confidence level (see monument accuracy table).

Field employee collecting RTK

WSI collected 1,347 RTK points and utilized 4 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% 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 measurements, 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 (RTK) 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 cm).

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

R7 Receiver

Orthophotography

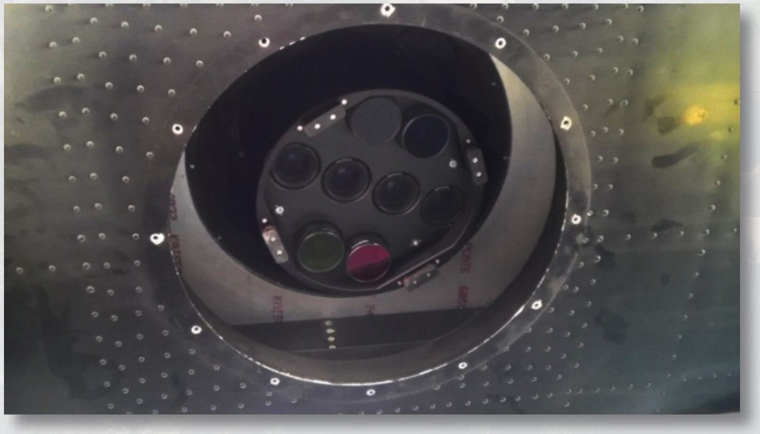
The photography survey utilized UltraCam Eagle 260 megapixel camera, and the images were acquired in 4 spectral bands (red, green, blue, near infrared). Flight parameters were adjusted to collect imagery with a native pixel size (ground sample distance) of 3 inches. The resulting spatial accuracies (RMSE) were routinely ≤ 1.5 feet at 95% confidence level.

The Eagle is a large format digital aerial camera manufactured by the Microsoft Corporation. The system is gyro-stabilized and simultaneously collects panchromatic and multispectral (RGB, NIR) imagery. Panchromatic lenses collect high resolution imagery by illuminating 9 CCD (charged coupled device) arrays, writing 9 raw image files. RGB and NIR lenses collect lower resolution imagery, written as 4 individual raw image files. Level 2 images are created by stitching together raw image data from the 9 panchromatic CCDs, and ultimately combined with the multispectral image data to yield Level 3 pan-sharpened tiffs.

Manufacturer Specifications	UltraCam Eagle
Focal Length	80 mm
Data format	RGBI
Pixel size	5.2 Qm
Image size	20,010 x 13,080 pixels
Frame rate	1.8 seconds
FOV	66 x 46 deg
GSD at 1000m	6.5 cm
Coverage at 1000m	1300 m x 850 m

Calibrated Digital Orthophotography Specifications	
Resolution	15 cm pixel size
Spectral Bands	Red, Green, Blue, Near Infrared
Along Track Overlap	≥ 70%
Side Track Overlap	≥ 50%
Image	8-bit GeoTiff
GPS Baselines	≤ 25 nm
GPS PDOP	≤ 3.0
GPS Satellite Constellation	≥ 6
Planned Height	924 m (above ground level)
Deliverable Type	GeoTIF

UltraCam Eagle Lenses



Air Targets

Prior to photo acquisition, aerial photo targets were installed throughout the study area, with at least two targets placed in proximity to the each survey monument (within 0.5 mi) and at least two additional targets placed within 3.0 miles of the monument, depending on radio range. Both temporary and permanent TCPs are utilized in the processing and QC of the orthophoto deliverable.
To improve the total number of air targets set on this project, WSI used a fast-static survey technique by baseline post-processing. On the air targets that were set this way, a single static session with the R8 set over the center point was collected. The static sessions were 20 to 30 minutes in length, then in the office those static sessions and the concurrent R7 base session data was processed in Trimble Business Center.

Temporary Targets
WSI uses vinyl and canvas aerial targets measuring 48” x 48”. We identified potential aerial target locations based on the allocation of 2 per base station, and at least 1/2 mile apart. RTK target check points (TCPs) were collected on each target, at a collection rate of five points per target, yielding 10 TCPs per base station. After the survey, WSI temporary targets were collected.

Permanent Targets
WSI is aware that the temporary air targets are subject to possible outside influences (weather, curious public, wildlife, etc) and take measures to identify potential locations adequate for collection of TCPs that are on permanent features. These are located within 2 miles of our proposed GPS base locations, and within the photo collection swath. Selected locations include painted lines on the pavement, existing aerial targets, arrows, STOP bars, parking spaces, etc. that are visible from the aircraft.

Temporary Target

Permanent Target

Accuracy

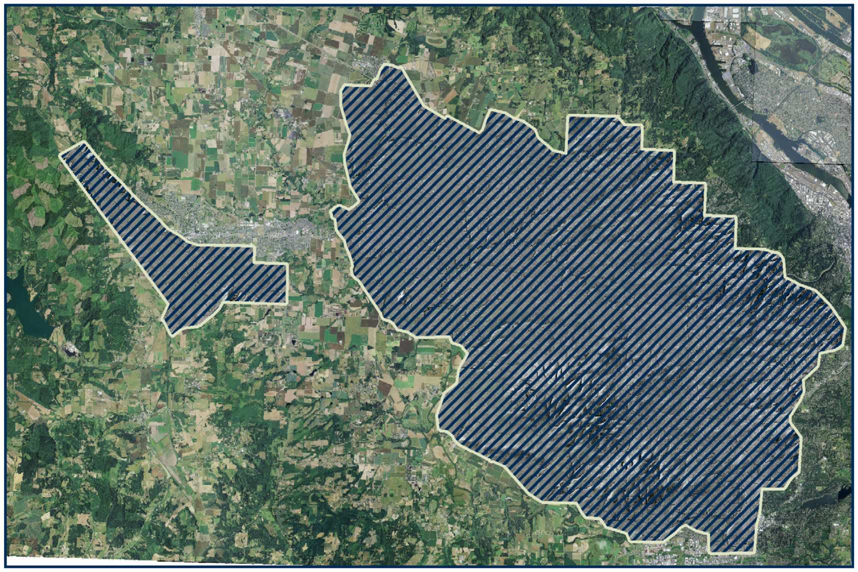
Relative Accuracy

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 cm). Internal consistency is affected by system attitude offsets (pitch, roll and heading), mirror flex (scale), and GPS/IMU drift.

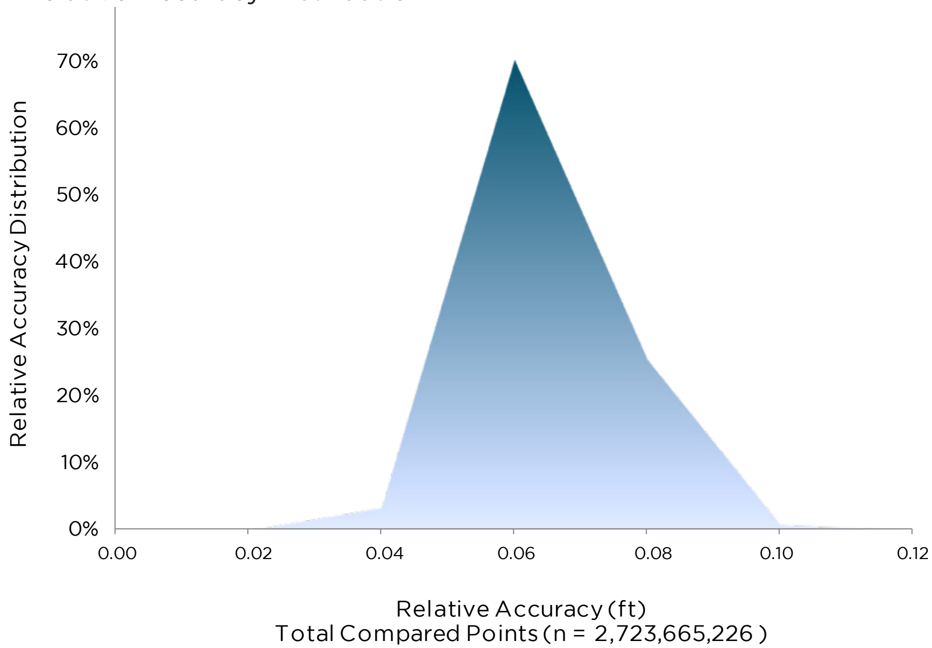
Relative accuracy statistics are based on the comparison of 114 flightlines and over 2.7 billion points. Relative accuracy is reported for the entire study area.

Relative Accuracy Calibration Results	
Project Average	0.07 ft (0.02 m)
Median Relative Accuracy	0.07 ft (0.02 m)
1σ Relative Accuracy	0.07 ft (0.02 m)
2σ Relative Accuracy	0.09 ft (0.03 m)

Accuracy Coverage Area (100% Coverage)



Relative Accuracy Distribution



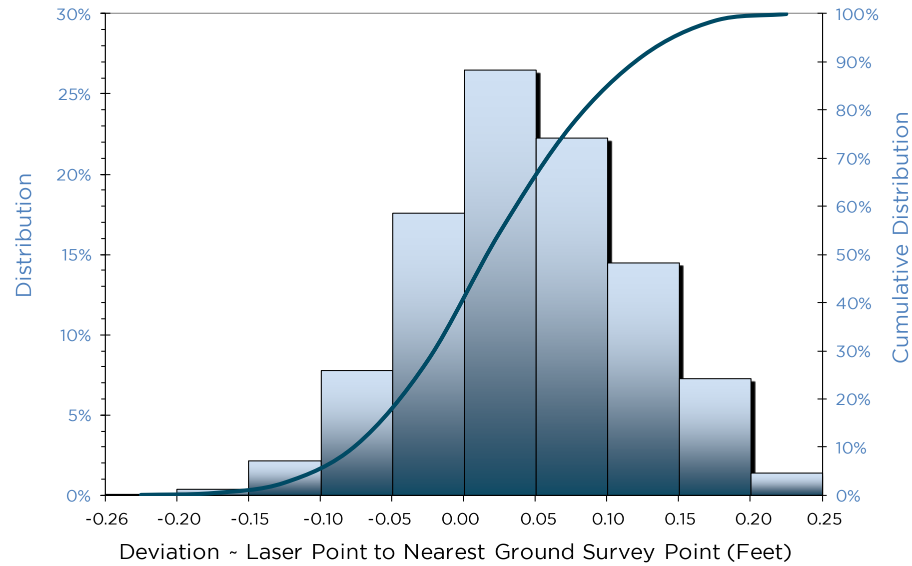
Vertical Accuracy

Vertical Accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998) and the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). The statistical model compares known RTK ground survey 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 West Metro study area, 1,347 RTK points were collected.

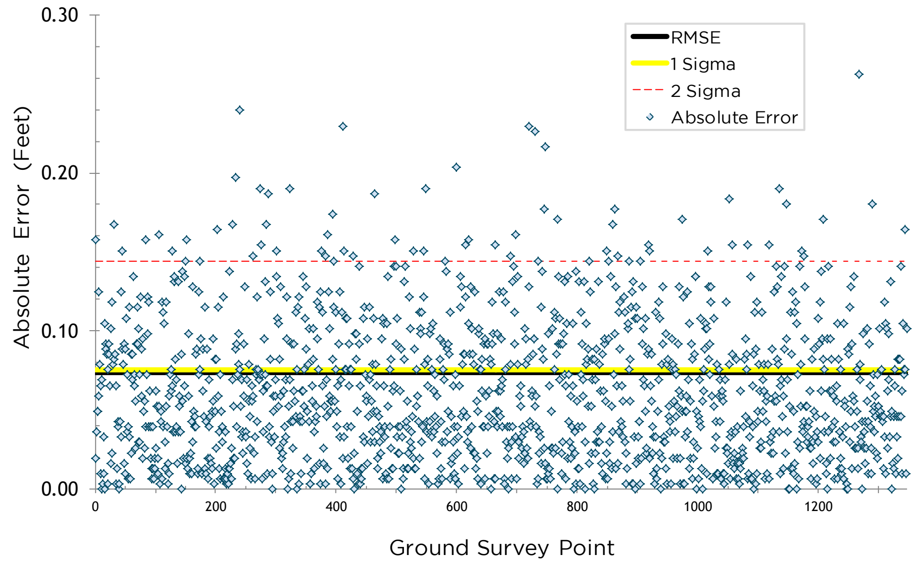
For this project, no independent survey data were collected, nor were reserved points collected for testing. As such, vertical accuracy statistics are reported as "Compiled to Meet." Vertical Accuracy is reported for the entire study area and reported in the table below. Histogram and absolute deviation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

Vertical Accuracy Results	
Sample Size (n)	1,347
Root Mean Square Error	0.08 ft (0.02 m)
1 Standard Deviation	0.08 ft (0.02 m)
2 Standard Deviation	0.14 ft (0.04 m)
Average Deviation	0.00 ft (-0.01 m)
Minimum Deviation	-0.26 ft (-0.08 m)
Maximum Deviation	0.23 ft (0.07 m)

Vertical Accuracy Distribution



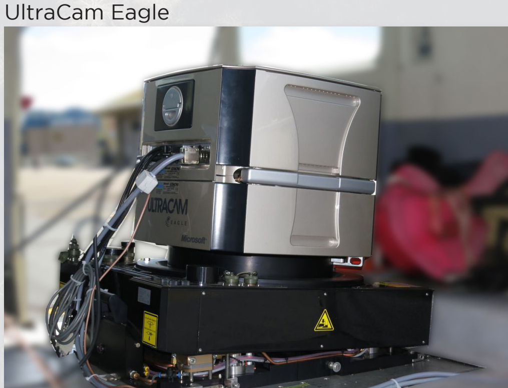
RTK Absolute Error



Orthophotography Accuracy

Images were calibrated to specific geometric, gain and exposure settings associated with each capture using Microsoft's UltraMap software suite. The corrected images were output in 8 bit tiff format for input into subsequent processes. Photo position and orientation were 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. Within the Inpho software suite, automated aerial triangulation was performed to tie images together and adjust block to align with ground control. Adjusted images were then draped upon a ground model and orthorectified. Individual orthorectified tiffs were blended together to remove seams and corrected for any remaining radiometric differences between images using Inpho's OrthoVista.

UltraCam Eagle



Accuracy

The orthophotos used were collected by WSI for OLC West Metro using the UltraCam Eagle ultra large format digital aerial camera. To assess the spatial accuracy of the orthophtographs, they were compared against control points identified from the LiDAR intensity images. 53 control points, distributed evenly across the total acquired area, were collected/measured on surface features such as painted road lines and fixed high-contrast objects on the ground surface. The accuracy of the final mosaic was calculated in relation to the LiDAR-derived control points.The orthophoto horizontal accuracy achieved by WSI was 0.76 ft RMSE, and 1.46 ft at a 95% confidence interval, which meets the contracted accuracy of 61 cm RMSE.

Orthophoto Accuracy	
RMSE	0.76 ft (23 cm)
1 standard deviation	0.74 ft (23 cm)
2 standard deviation	1.46 ft (45cm)

Density

Pulse Density

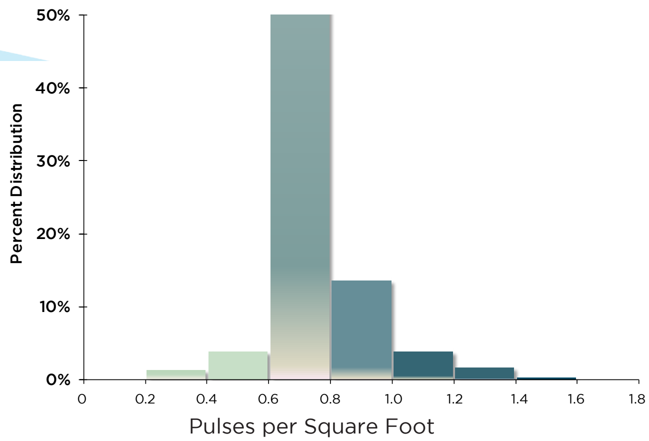
Some types of surfaces (i.e. dense vegetation or water) may return fewer pulses than the laser originally emitted. Therefore, the delivered density can be less than the native density and vary according to terrain, land cover and water bodies. Density histograms and maps have been calculated based on first return laser pulse density and ground-classified laser point density.

Average Point Densities			
Pulse Density (sq ft)	Pulse Density (sq m)	Ground Density (sq ft)	Ground Density (sq m)
0.76	8.13	0.20	2.20

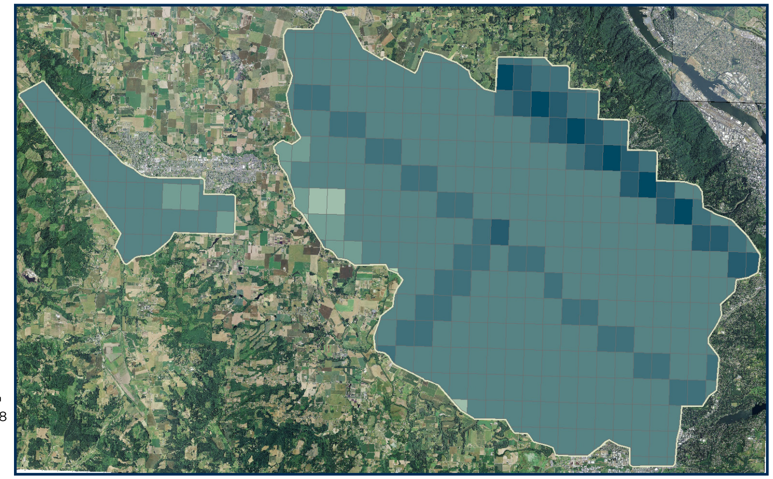
Ground Density

Ground classifications were derived from ground surface modeling. 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 bin boundaries.

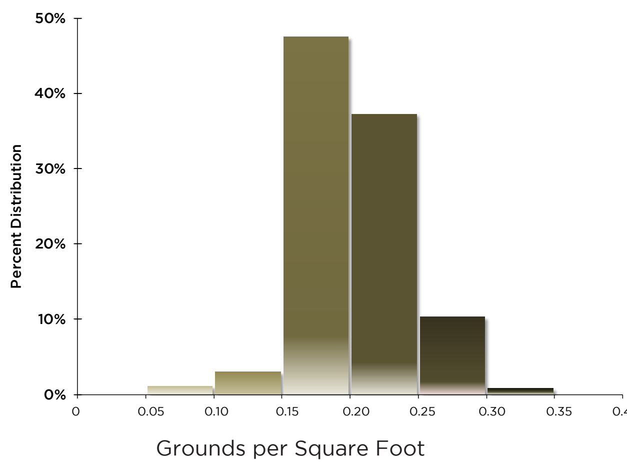
Pulse Density Distribution



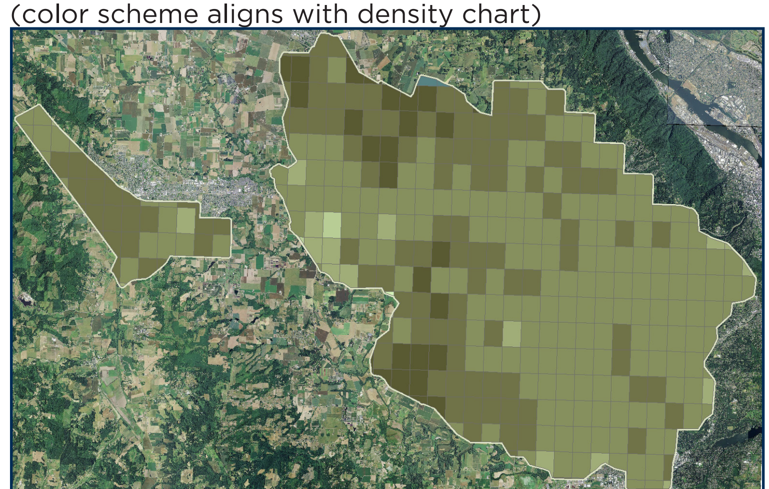
Average Pulse Density per 0.75'USGS Quad (color scheme aligns with density chart)



Ground Density Distribution



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



Appendix

LiDAR-derived Imagery

LiDAR point cloud with RGB extraction from 2009 NAIP imagery. Neighborhood in Beaverton, OR. View to the North.

LiDAR point cloud with RGB extraction from 2009 NAIP imagery. Nike Headquarters. View to the South.

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Certifications

WSI provided LiDAR services for the OLC West Metro study area as described in this report.
I, Mathew Boyd, have reviewed the attached report for completeness and hereby state that it is a complete and accurate report of this project.

Mathew Boyd
Principal
WSI

I, Christopher W. Yotter-Brown, being first dully sworn, say that as described in the Ground Survey subsection of the Acquisition section of this report was completed by me or under my direct supervision and was completed using commonly accepted standard practices. Accuracy statistics shown in the Accuracy Section have been reviewed by me to meet National Standard for Spatial Data Accuracy.

REGISTERED
PROFESSIONAL
LAND SURVEYOR

2/13/2013

OREGON
JULY 13, 2004
Christopher W. Yotter - Brown
60438 LS

RENEWAL DATE: 6/30/2014

Christopher W. Yotter-Brown, PLS Oregon & Washington
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