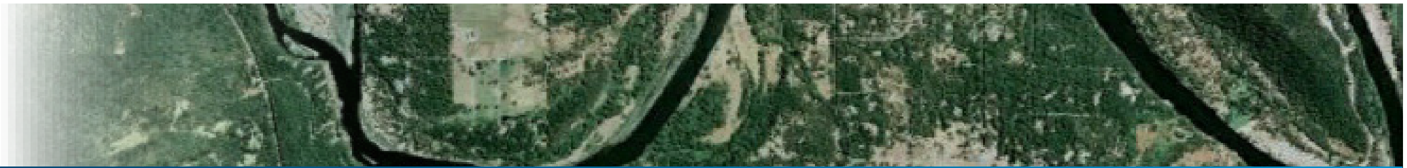


OLC Rogue River

LiDAR Remote Sensing Data

WSI Applied Remote Sensing and Analysis

August 31, 2012

Rogue River Valley, Oregon.

Data collected for:
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

Project Overview

WSI has collected Light Detection and Ranging (LiDAR) data of the Rogue River Study Area for the Oregon Department of Geology and Mineral Industries (DOGAMI). The Oregon LiDAR Consortium's Rogue River project area encompasses approximately 1.4 million acres in the southwestern region of the state. The area includes portions of the Siskiyou National Forest, the City of Grants Pass and the Rogue River.

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

Several agencies including DOGAMI, BLM, and FEMA contributed to the funding of the project. Between March 6th and August 16th, 2012, WSI employed remote-sensing lasers in order to obtain a total of 530,259 acres of data with a resolution of at least eight points per square meter. Final products created include LiDAR point cloud data, 1 meter digital elevation models of bare earth ground model and highest-hit returns, hydro-flattened raster data sets, intensity rasters, hydrologic shapefiles, and area vector shapes, and corresponding statistical data.

This delivery includes the southern portion of the study area.

Figure 1.1. OLC Rogue River Study Area By Funding Agency

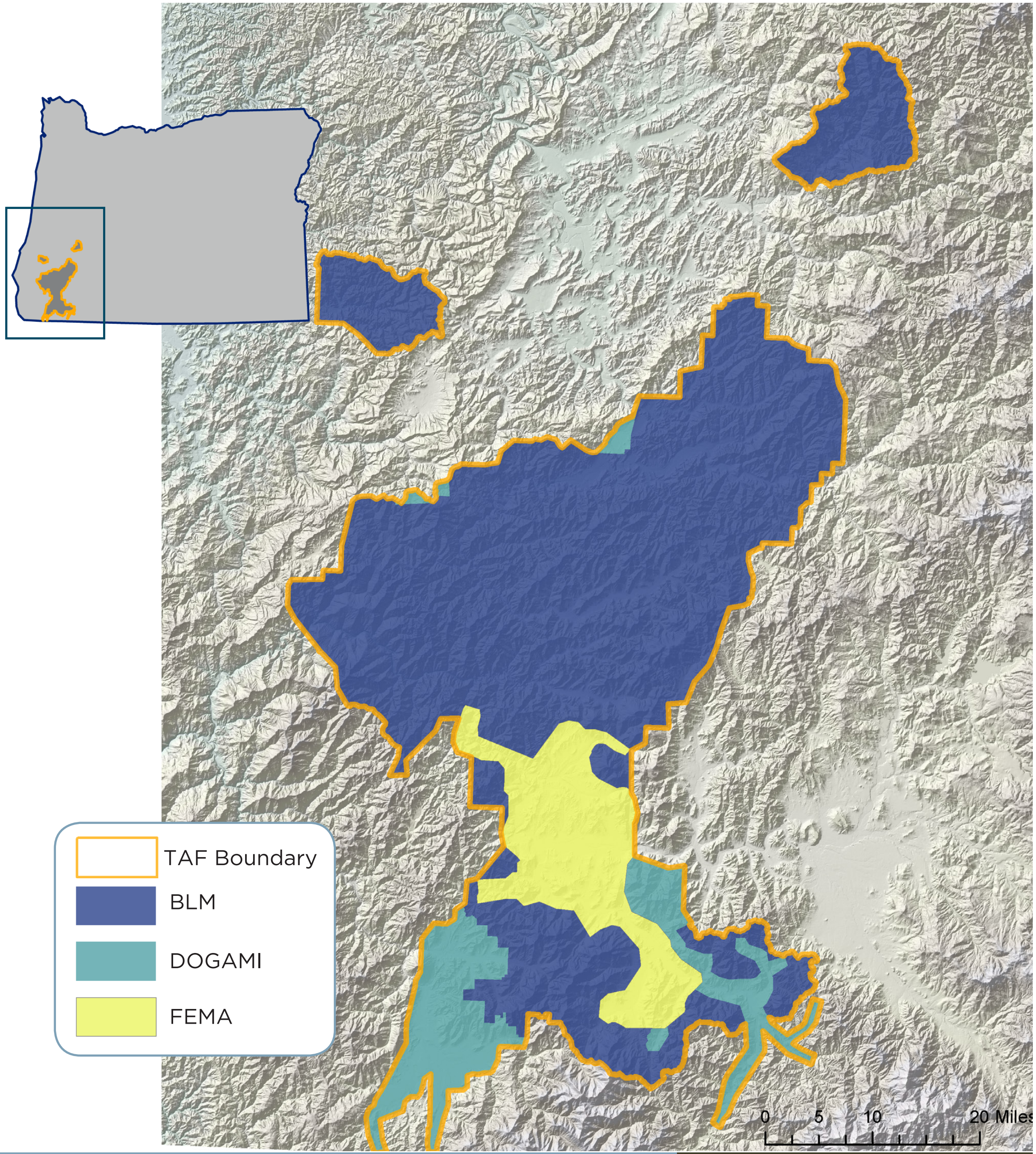


Figure 1.2 Delivery Area

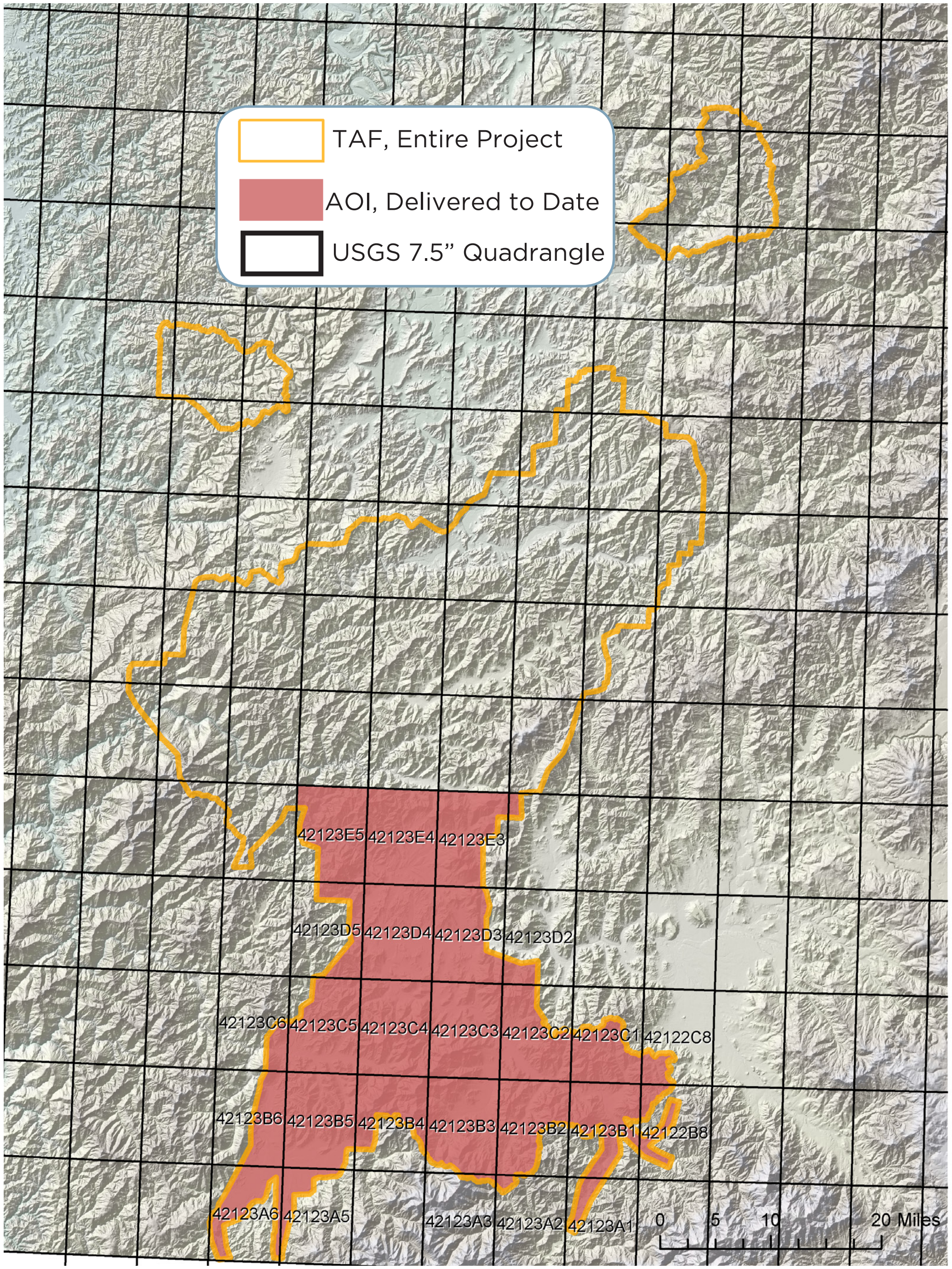
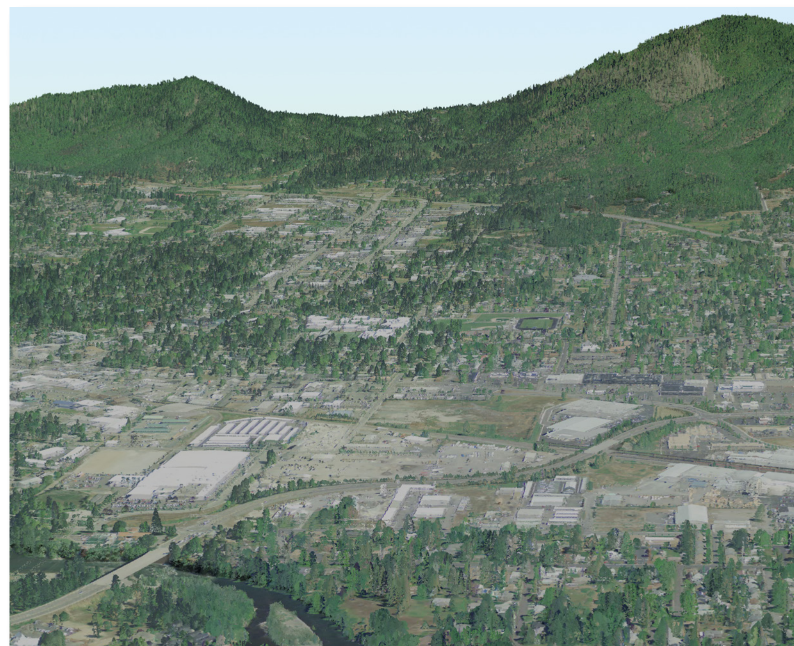


Table 1.1. Total delivered acreage to date is detailed below

Data Delivered August 31st, 2012	
Acquisition Date	March 8th - June 19th, 2012
Area of Interest	521,259 acres
Total Area Flown	530,259 acres
Data	OGIC HARN
Projection	Oregon Statewide Lambert Conformal Conic
Datum: Horizontal & vertical	NAD83 (HARN) NAVD88 (Geoid03)



LiDAR point cloud of Grants Pass, Oregon

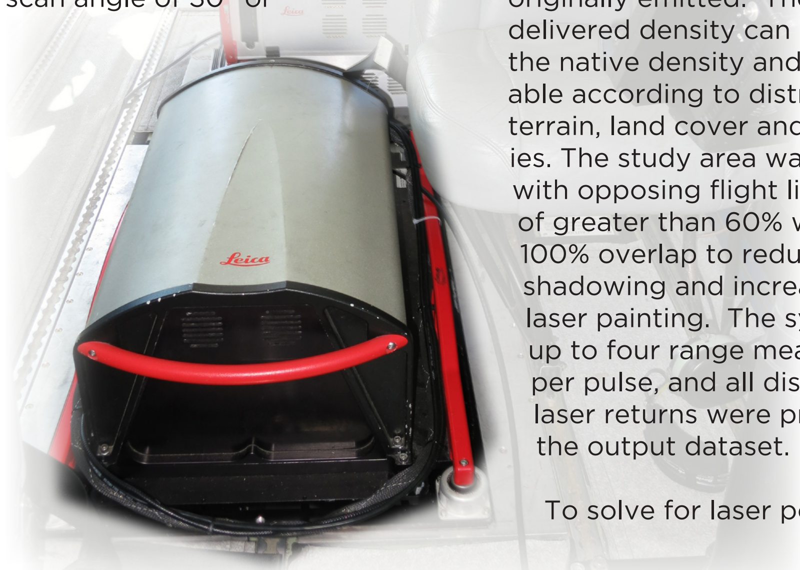
Cessna Caravan

Aerial Acquisition

Airborne Survey

The LiDAR survey utilized Leica ALS50, ALS60 and ALS70 sensors mounted in either Cessna Caravan 208B or Partenavia P.38 aircrafts. Depending on the pairing of sensor and aircraft, the systems were programmed to emit laser pulses at a rate of 52 or 47 kHz, and flown at 900 or 1300 meters above ground level (AGL), capturing a scan angle of 30° or 28° 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 discernible laser returns were processed for the output dataset.

To solve for laser point position,



Sensor ALS 6160

Table 2.1. Aerial Acquisition Specs are detailed below

Acquisition Specs	
Sensors Deployed	Leica ALS 50, Leica ALS 60
Aircraft	Partenavia P.38, Cessna Caravan 208B
Survey Altitude (AGL)	900m / 1300m
Pulse Rate	52.2 hz (at 900m) / 46.7 hz (at 1300m)
Pulse Mode	Single (SPiA)
Field of View (FOV)	30° (at 900m) / 28° (at 1300m)
Roll Compensated	Yes
Overlap	100% overlap with 60% sidelap
Pulse Emission Density	≥ 8 points / square meter

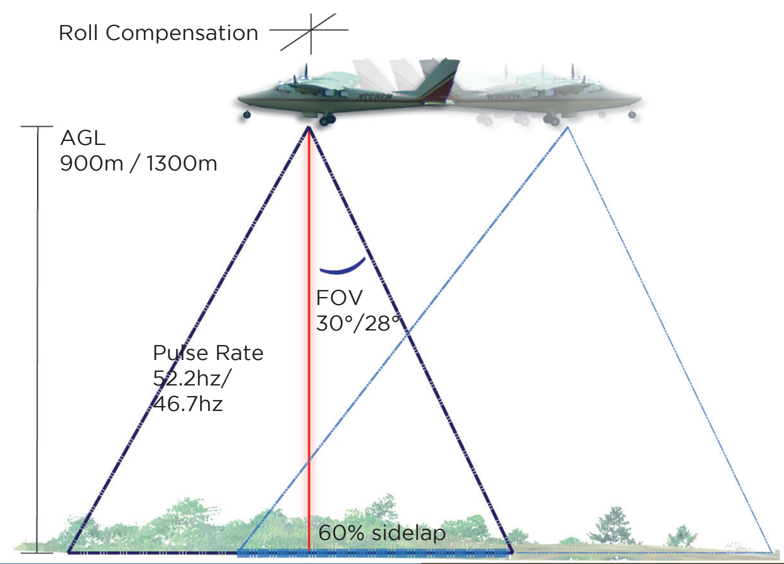
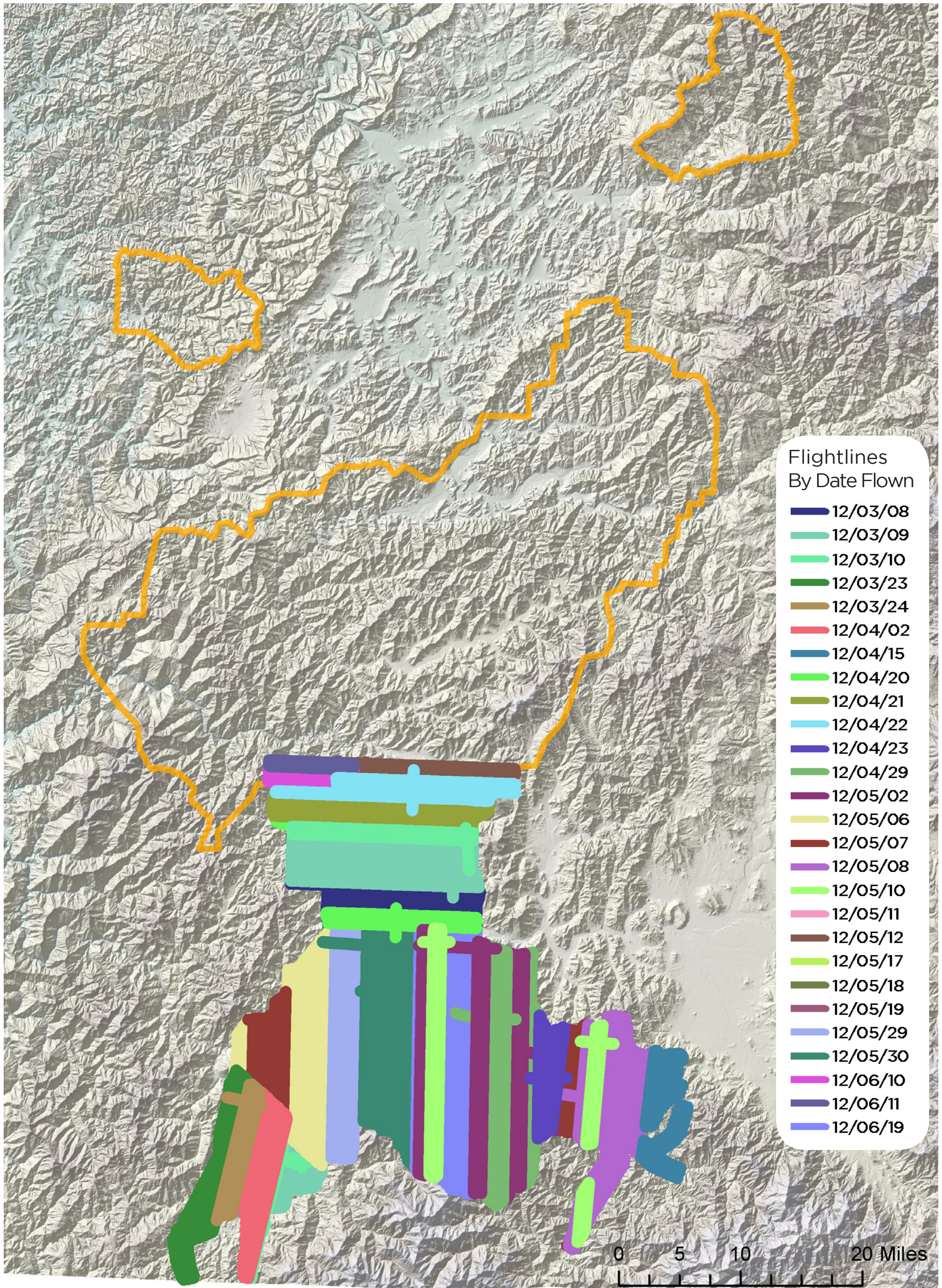


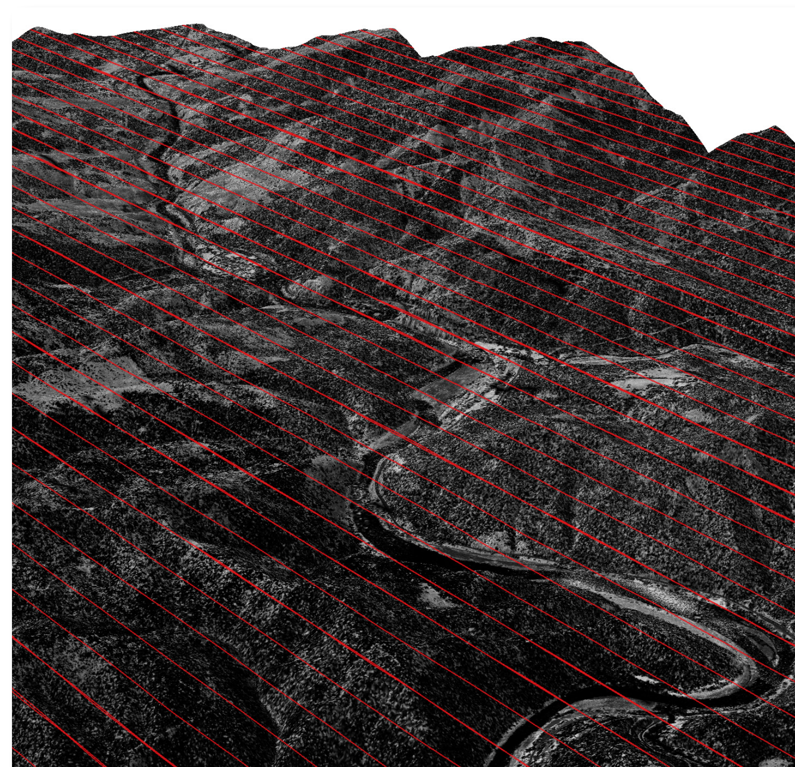
Figure 2.1. Project Flightlines



Partenavia

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 **Figure 2.1**, 1,001 flightlines provide coverage for the area delivered to date.

Flightlines over survey area



Ground Survey

During the LiDAR survey, static (1 Hz recording frequency) ground surveys were conducted over 56 monuments with known coordinates. A table with coordinate information is provided in the Appendix. 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 GPS receiver model R7 with a Zephyr Geodetic antenna with ground plane 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

Whenever possible, existing and established survey benchmarks shall serve as control points during LiDAR acquisition including those previously set by WSI. In addition to NGS, the county surveyor's offices and the Oregon Department of Transportation (ODOT) often establish their own benchmarks. NGS benchmarks are preferred for control points. In the absence of NGS benchmarks, county surveys, or ODOT monumentation, WSI produces our own monuments. These monuments are spaced at a minimum of one mile and every effort is made to keep these monuments 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.".

Figure 3.1. Project Monuments

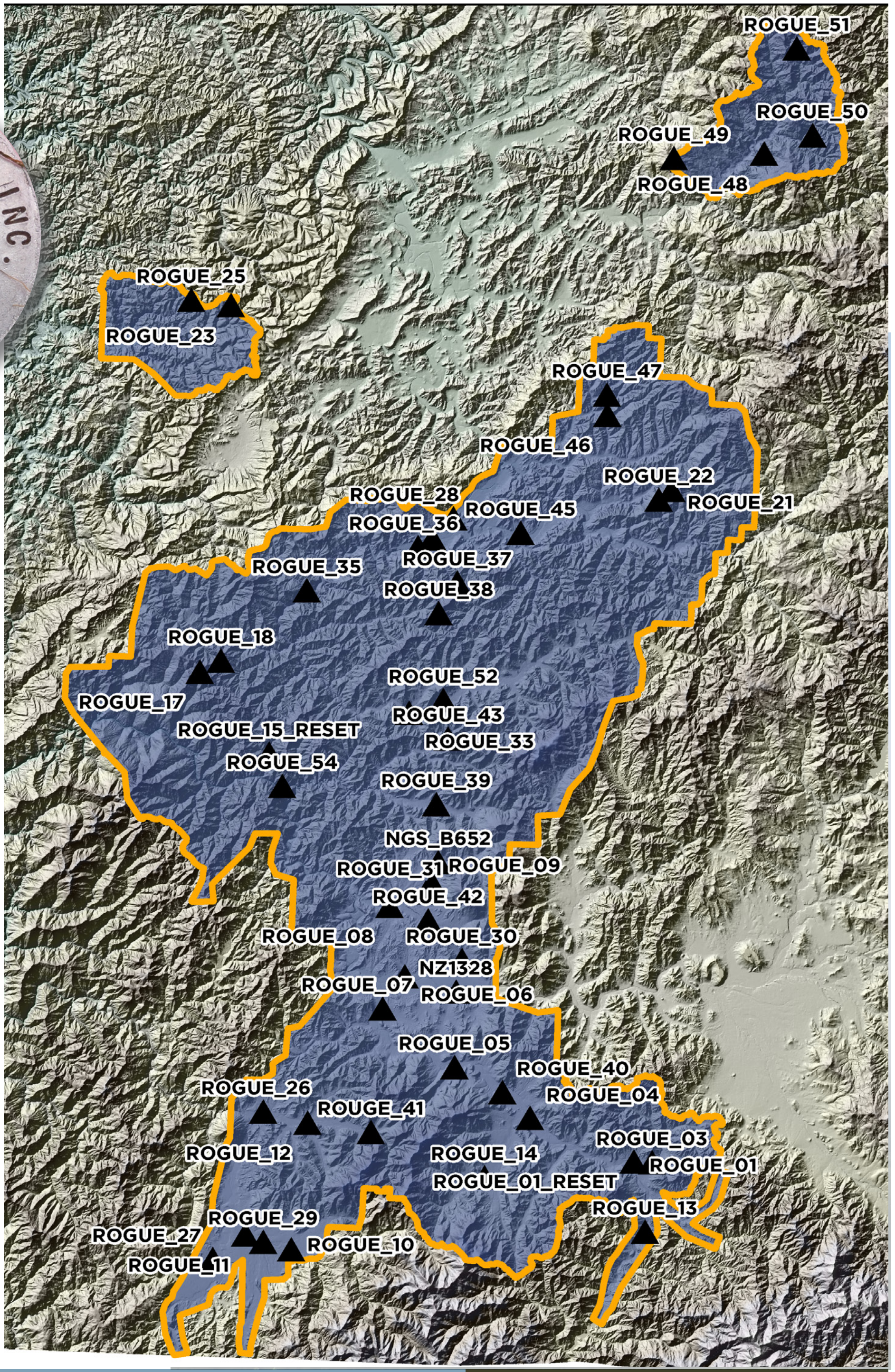
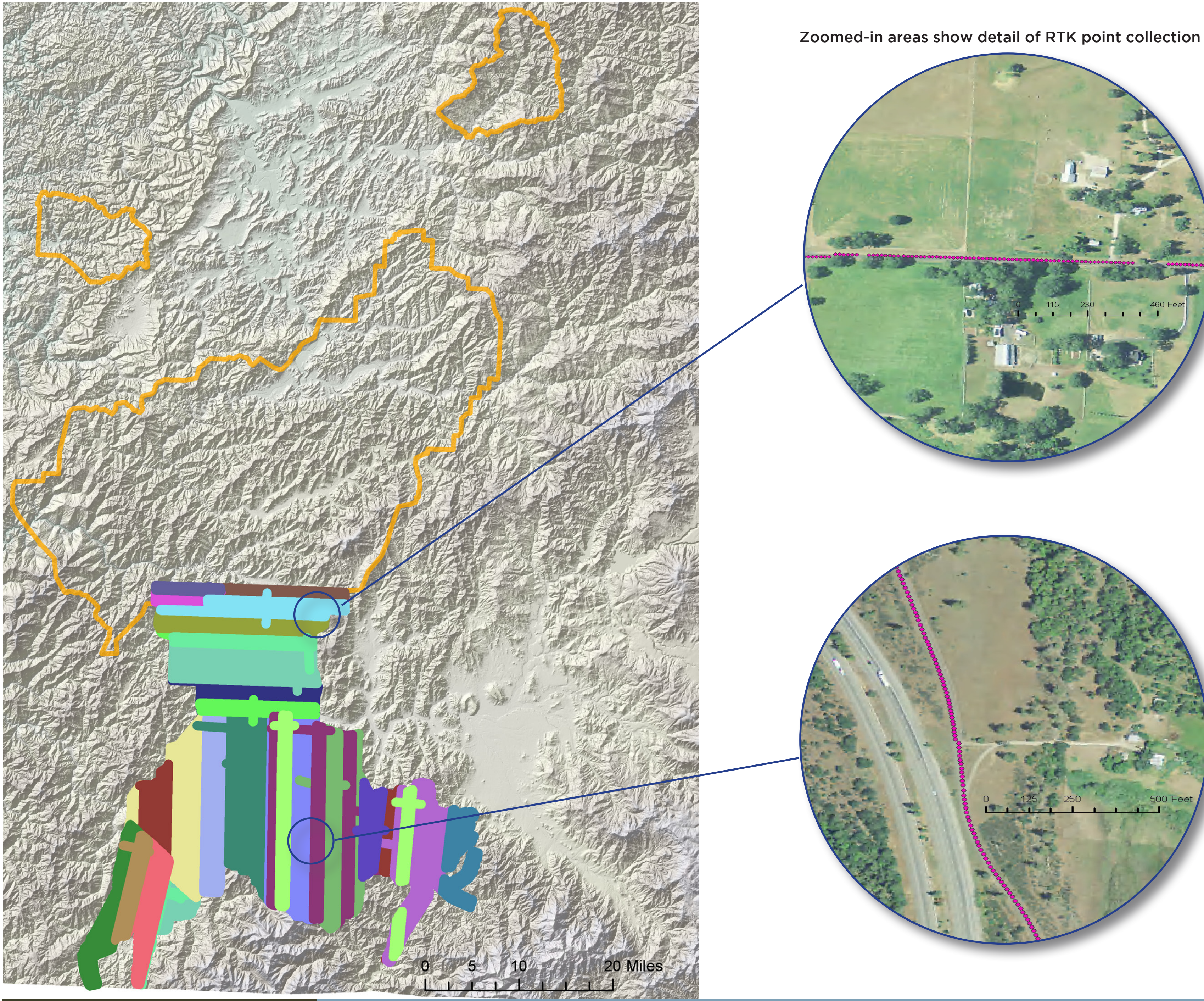


Figure 3.2. Selected RTK point locations in study area for delivery area



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. CORPSCON 6.0.1 software 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 (**Table 4.1**).

ALS Operation

WSI collected 4,971 RTK points and utilized 56 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. In addition, it is desirable to include locations that can be readily identified and occupied during subsequent field visits in support of other quality control procedures described later. Examples of identifiable locations would include manhole and other flat utility structures that have clearly indicated center points or other measurement locations. In the absence of utility structures, a PK nail can be driven into asphalt or concrete and marked with paint. 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). **Figure 3.2** shows a subset of these RTK locations.

R7 Receiver

Table 3.1. FGDC-STD-007.2-19986 AT 95% Confidence level for the Quinault USGS survey area

Monument Accuracy	
FGDC-STD-007.2-1998 Rating	
St Dev NE	0.050 m
St Dev z	0.100 m

Hydro-Flattening

All bare-earth hydro-flattened digital elevation models (DEMs) have been hydro-flattened according to the U.S. Geological Survey's National Geospatial Program's "LiDAR Guidelines and Base Specification" Version 13 (USGS NGP). For all water bodies perceived to be "flat," LiDAR points were sampled to arrive at an elevation threshold defining the water surface at a uniform elevation where the water edge meets the surrounding terrain. 3-D breaklines were then created to encompass all areas considered to be water and were assigned the water surface elevation value determined previously. All "flat" water bodies greater than 2 acres were considered for hydro-flattening. All "islands" greater than 100 square meters were retained in the DEMs.

Centerlines were digitized for all water surfaces not perceived as "flat." Thousands of points were sampled along the stream and channel centerlines to generate three-dimensional z values. A smoothing algorithm was then applied to ensure the centerlines consistently run downstream. LiDAR points were classified as water using the z threshold values of the appropriate centerlines. A breakline polygon was created around the water points with all discontinuities such as bridges and overhanging vegetation removed. Z values were applied to the breakline polygon based on the elevation values of the closest, associated centerline vertex. Again, "islands" were retained in the bare-earth DEMs if greater than 100 square meters.

The bare-earth DEMs were created by triangulating all ground classified points and inserting 3-D breaklines utilizing TerraSolid's TerraScan and TerraModeler software. Any ground points within 1 meter of the breaklines were reclassified to "ignored-ground" (ASPRS code: 10) before triangulation. The highest-hit DEMs were generated from "ground" and "default" classified points. In instances where "water" classified points had the highest elevation value, the water surface elevation from the bare-earth raster was used.

Hydro-Flattening in high gradient streams such as those found in the Rogue River dataset can produce artifacts that differ from true channel morphology. High gradient streams are often characterized by sediment bars and other impediments that result in cross-channel flows (i.e. flow not parallel to channel centerline and banks). Page 8, guideline 3, section 2, bullet point 2 of the USGS Specification states that river breaklines should be "level bank-to-bank (perpendicular to the apparent flow centerline)" and that "the water surface edge (is) at or below the immediately surrounding terrain". WSI has adhered to the letter of these guidelines, recognizing that artificial stream surface elevation artifacts may be introduced (see **Figure 4.2**).

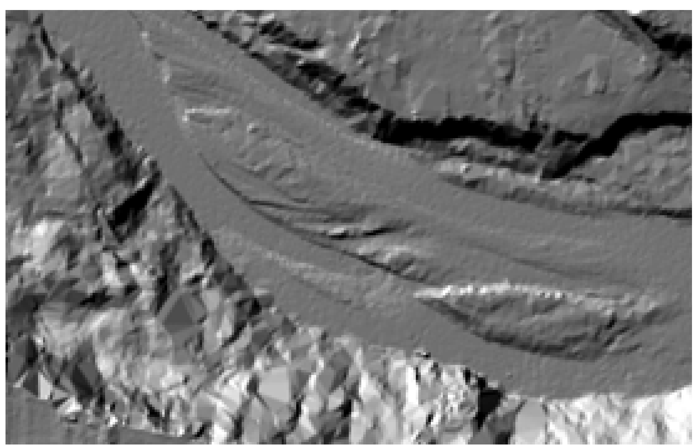


Figure 4.1. Regular Hill-shaded DEM

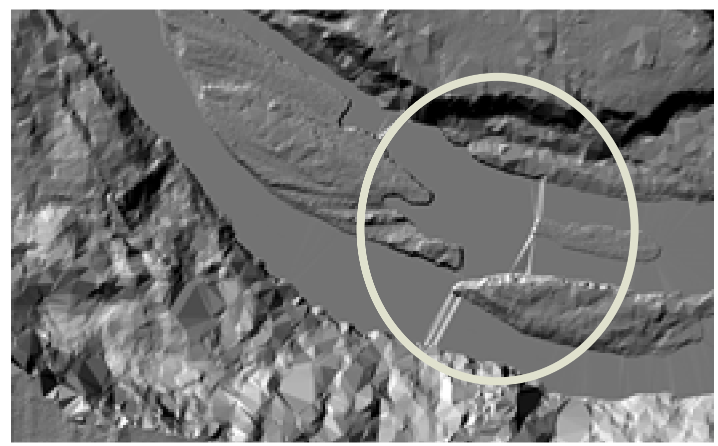
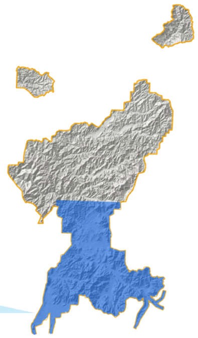


Figure 4.2. Hydro-Flattened Hill-shaded DEM, showing artifact from extreme change in channel elevation

Accuracy



Accuracy Coverage Area

Relative Accuracy

Relative accuracy refers to the internal consistency of the data set and is measured as the divergence between points from different flight-lines within an overlapping area. Divergence is most apparent when flight-lines 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 shown in Figures 5.1 and 5.2 are based on the comparison of 1,001 flightlines and over 22 billion points. Relative accuracy is reported for the entire delivered portion of the study area, shown in Table 5.1 below.

Table 5.1. Relative Accuracy Calibration is detailed below

Relative Accuracy Calibration Results	
Project Average	0.20 ft (0.06 m)
Median Relative Accuracy	0.19 ft (0.06 m)
1σ Relative Accuracy	0.21 ft (0.06 m)
2σ Relative Accuracy	0.29 ft (0.09 m)

Figure 5.1. Statistical relative accuracies, non slope-adjusted

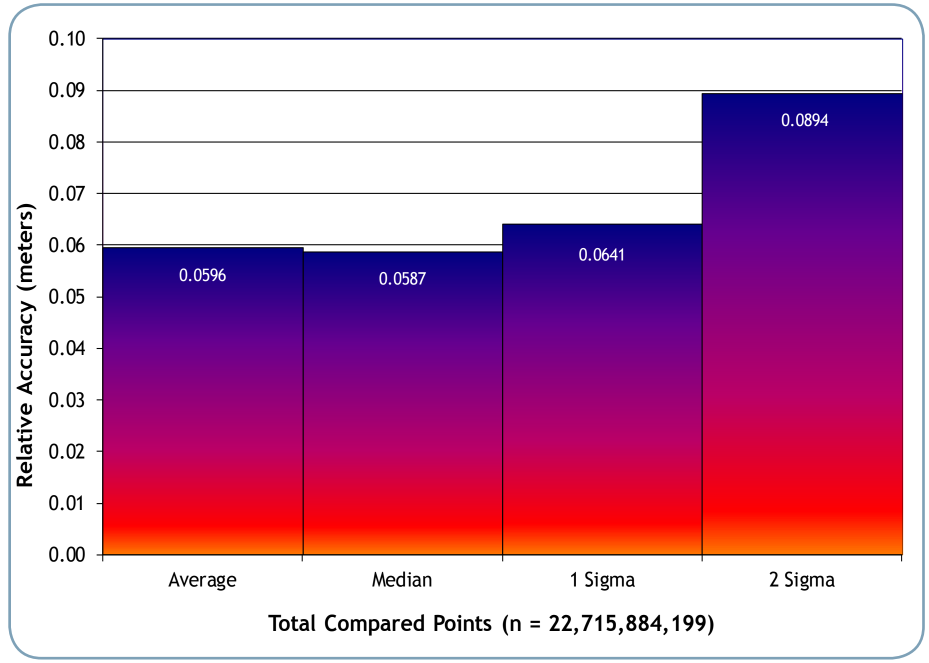
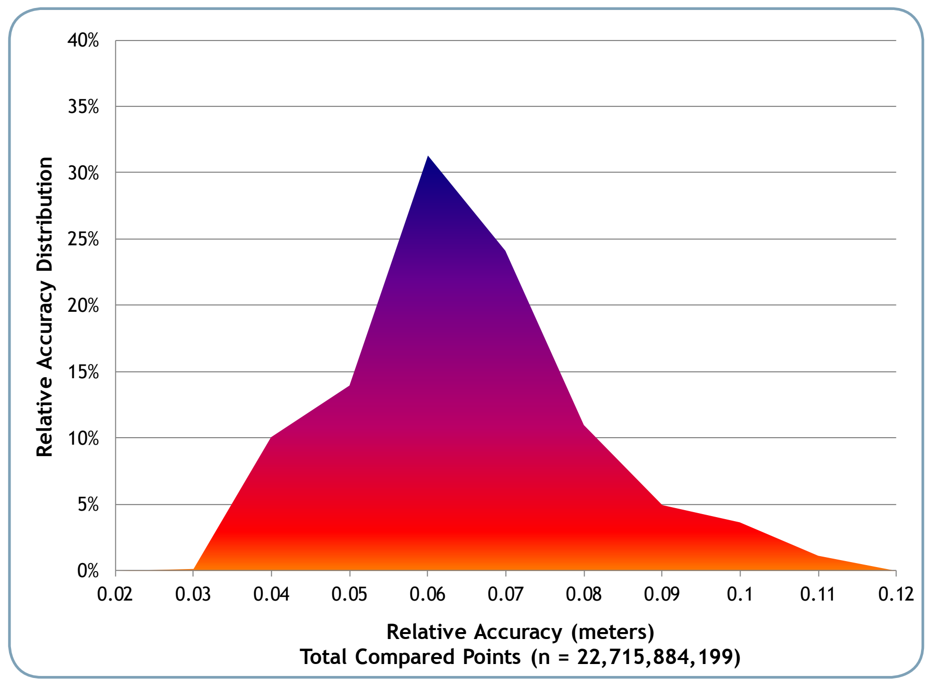


Figure 5.2. Percentage distribution of relative accuracies, non slope-adjusted



Fundamental Vertical Accuracy

FVA accuracy reporting is designed to meet guidelines presented in the National Standard for Spatial Data Accuracy (NSSDA) (FGDC, 1998). FVA compares known RTK ground survey points to the closest laser point. FVA uses ground control points in open areas where the LiDAR system has a "very high probability" that the sensor will measure the ground surface and is evaluated at the 95% percentile of RMSEZ. For the Rogue River Study Area, 64,971 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," in accordance with the ASPRS Guidelines for Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004). Fundamental Vertical Accuracy is reported for the entire study area shown in Table 5.2 below. Histogram and absolute deviation statistics are reported in Figures 5.3 and 5.4.

Table 5.2. Vertical Accuracy -- Deviation between laser points and RTK survey points.

Fundamental Vertical Results

Compiled to meet 0.34 ft. (0.10m) accuracy at 95% confidence level in open terrain

Sample Size (n)	4,971
Root Mean Square Error	0.17 ft (0.05 m)
1 Standard Deviation	0.16 ft (0.05 m)
2 Standard Deviation	0.34 ft (0.10 m)
Average Deviation	-0.02 ft (-0.01 m)
Minimum Deviation	-0.92 ft (-0.28 m)
Maximum Deviations	0.58 ft (0.18 m)

Figure 5.3. Rogue River Study Area vertical accuracy histogram statistics

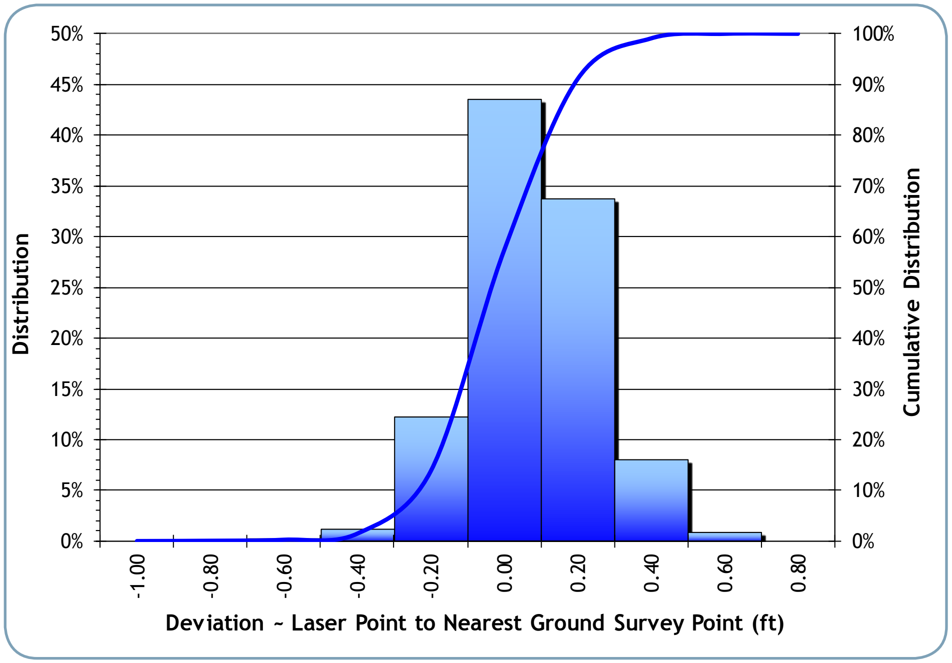
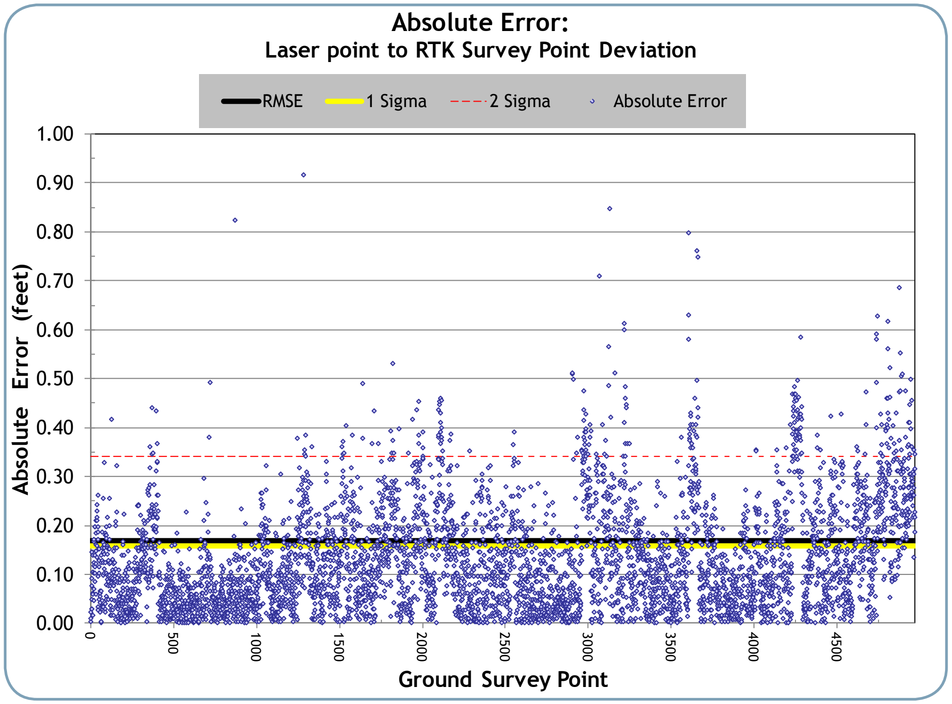


Figure 5.4. Rogue River Study Area point absolute deviation statistics



Land Cover Accuracy

In addition to the hard surface RTK data collection, check points were also collected across the project area on four different land cover types to provide Supplemental Vertical Accuracy (SVA) statistics in accordance with NSSDA guidelines. All data collection was completed by WSI. As such, SVA statistics are reported as "Compiled to meet" in accordance with the ASPRS Guidelines Vertical Accuracy Reporting for LiDAR Data V1.0 (ASPRS, 2004).

The dominant land cover classes within the present project area are listed below. The descriptions provide further detail regarding the actual vegetation. This analysis demonstrates that the vertical accuracy of the interpolated ground surface, across all land cover classes, meets or exceeds vertical accuracy specifications.

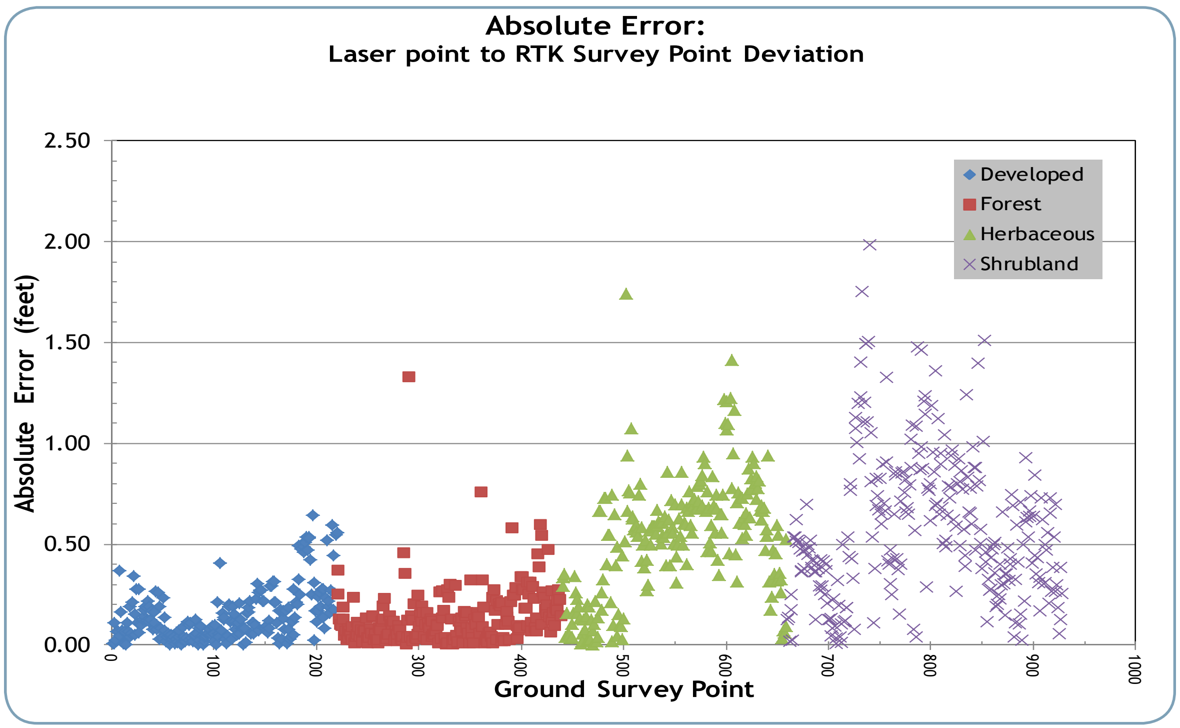
Table 5.3. Dominant Land Cover Classes Detailed Below

Dominant Land Cover Classes	
Herbaceous	Less than 2 ft in height
Shrubland	Woody vegetation more than 6 ft in height
Forest	Full coverage of mature forest
Developed	Permanent dwellings and other structures

Table 5.4. Summary statistics for Supplemental Vertical Accuracy by land cover class.

Dominant Land Cover Classes					
LAND COVER	SAMPLE SIZE	RMSE	AVE DZ	1 SIGMA	2 SIGMA
Herbaceous	220	0.56 ft. (0.17 m)	0.51 ft. (0.16 m)	0.66 ft. (0.20 m)	0.94 ft. (0.29 m)
Shrubland	269	0.64 ft. (0.20 m)	0.57 ft. (0.18 m)	0.70 ft. (0.21 m)	1.23 ft. (0.38 m)
Forest	219	0.21 ft. (0.06 m)	-0.03 ft. (-0.01 m)	0.14 ft. (0.04 m)	0.35 ft. (0.11 m)
Developed	220	0..20 ft. (0..06 m)	0.04 ft. (0.01 m)	0.17 ft. (0.05 m)	0.49 ft. (0.15 m)

Figure 5.5. Absolute deviation values by land cover class survey points used in Supplemental Vertical Accuracy assessment.



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 (Figures 6.1 – 6.4) have been calculated based on first return laser point density and ground-classified laser point density.

Table 6.1. Average Point Densities Detailed Below

Average Point Densities			
Pulse Density (sq ft)	Pulse Density (sq m)	Ground Density (sq ft)	Ground Density (sq m)
.99	10.70	.10	1.12

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.

Figure 6.1. Histogram of first return laser point density for data delivered to date.

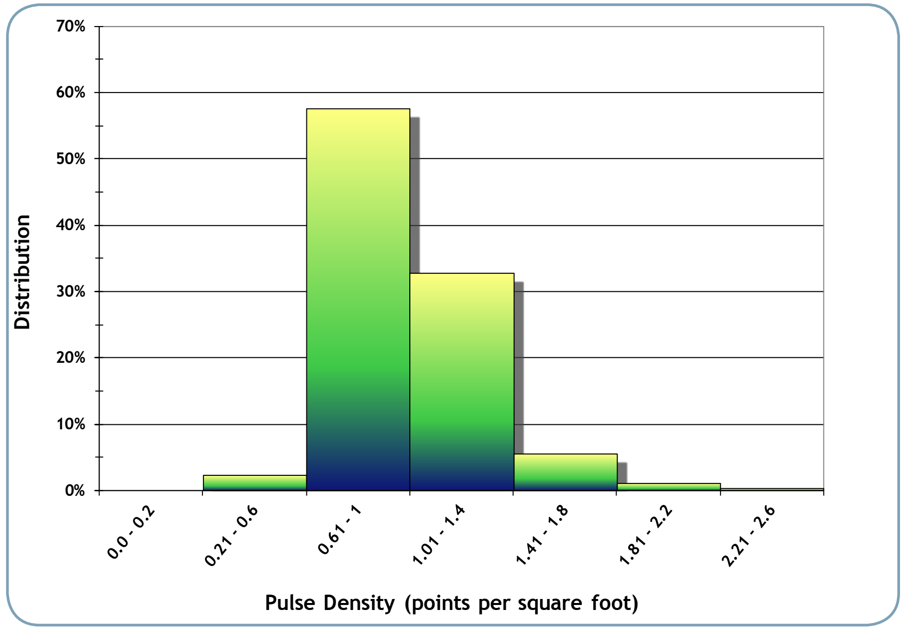


Figure 6.2. Histogram of ground-classified laser point density for entire study area.

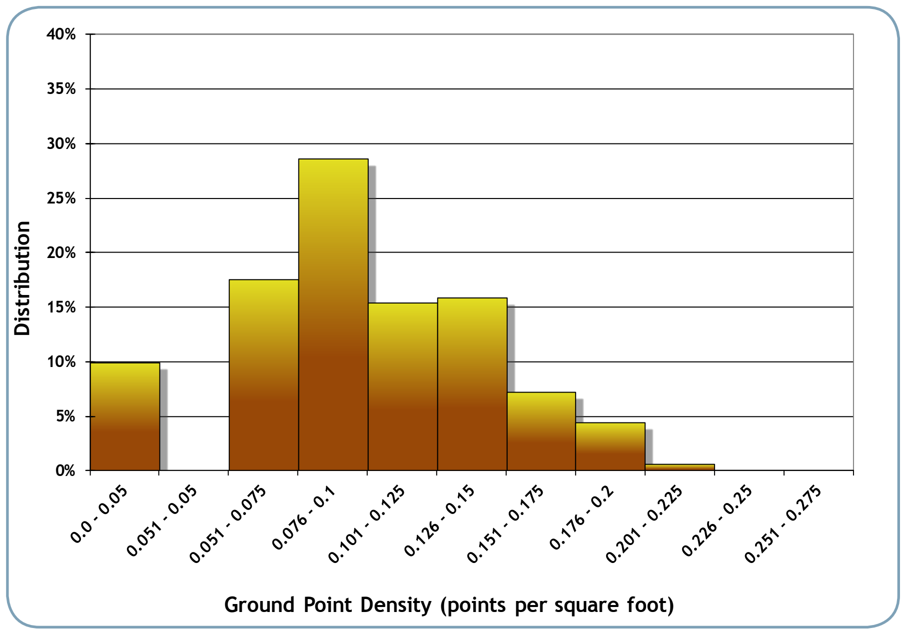


Figure 6.3. First return laser point densities per 0.75' USGS Quad.

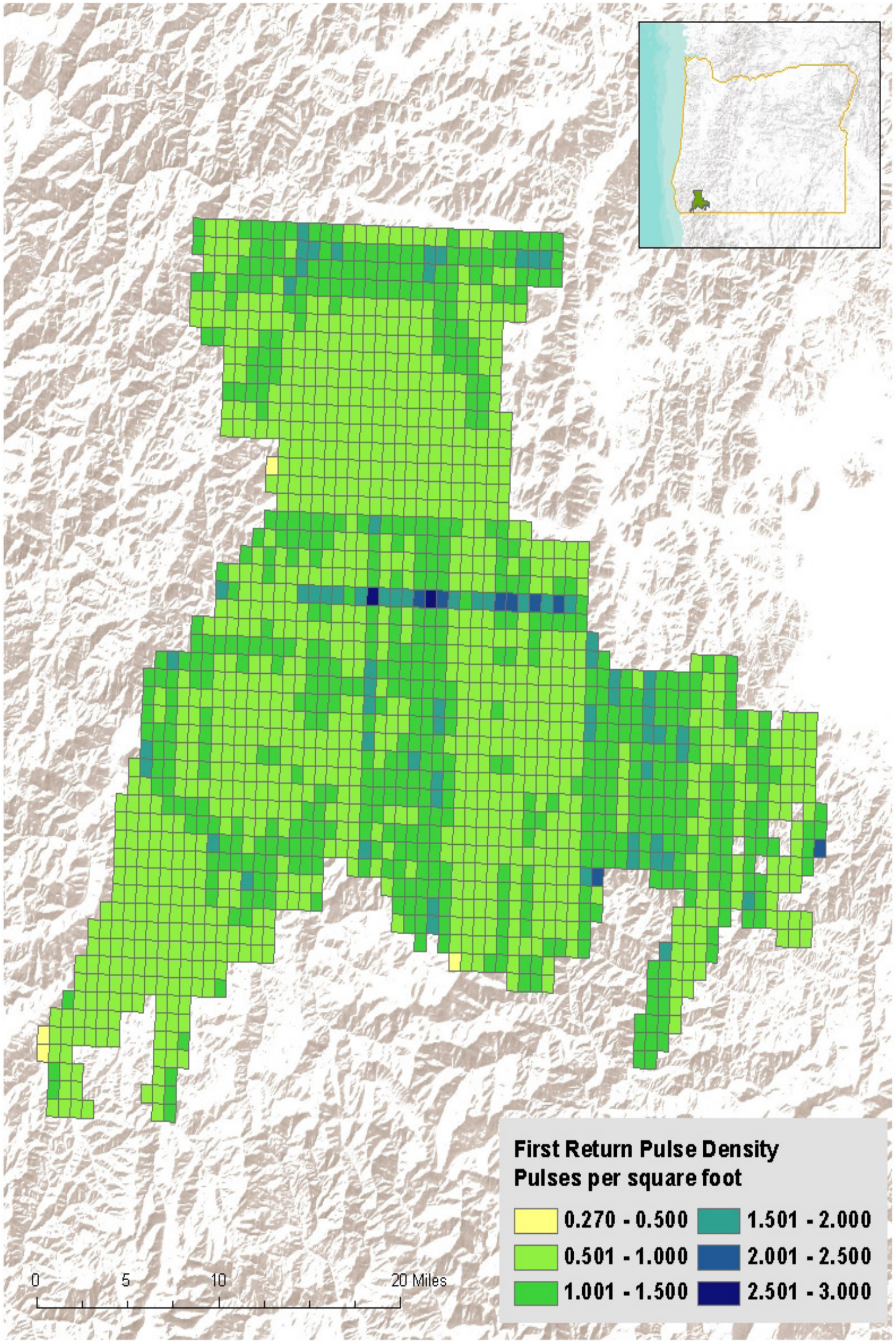
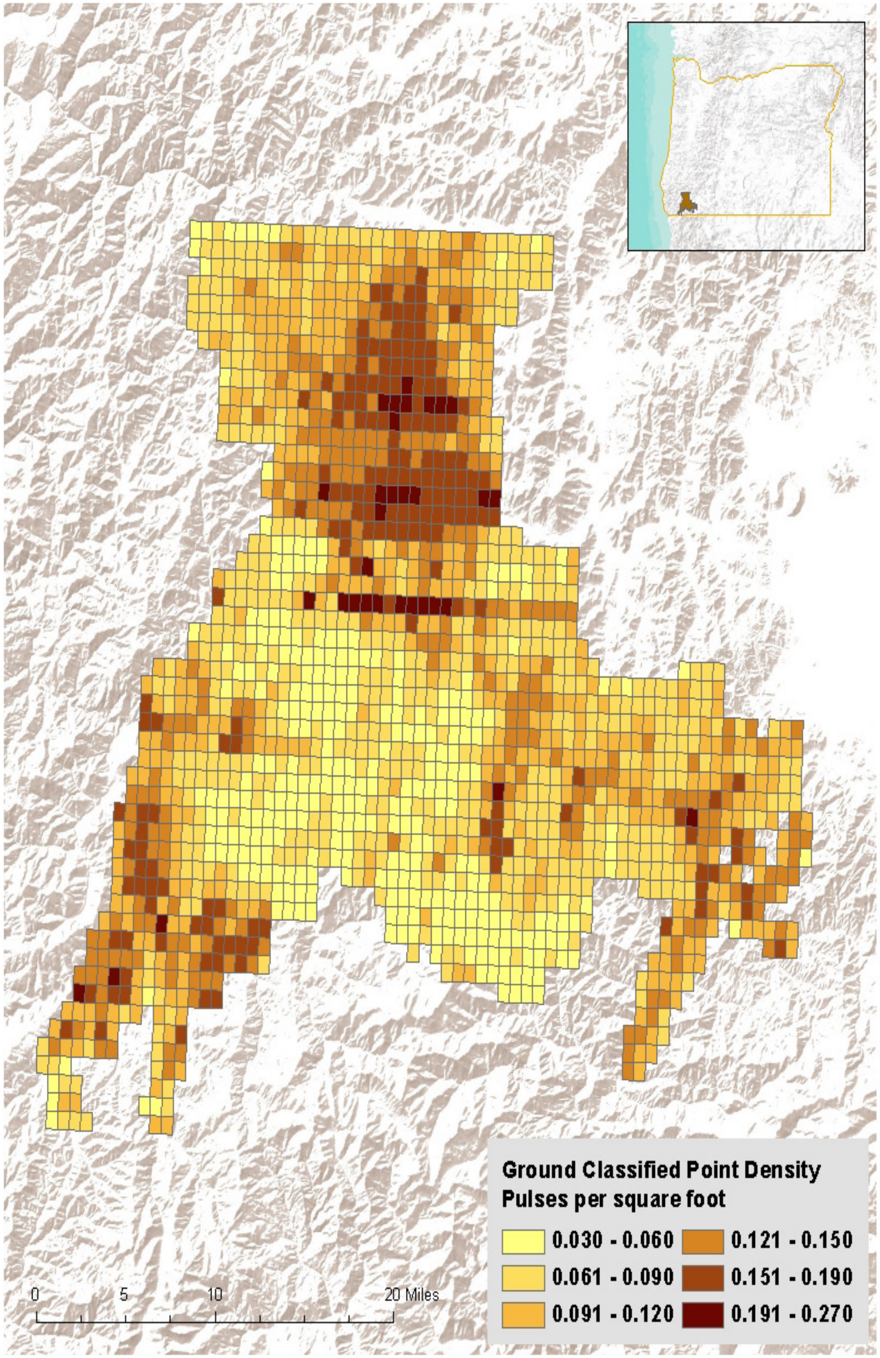


Figure 6.4. Ground-classified laser point density per 0.75' USGS Quad.



Appendix

Certifications

WSI provided LiDAR services for the Central Coast 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

8/30/2012

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

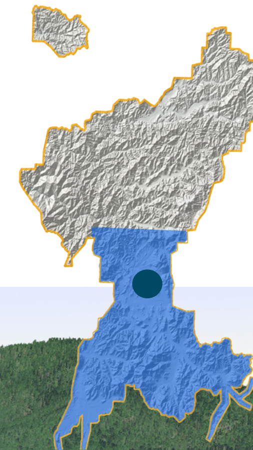
RENEWAL DATE: 6/30/2014

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

Table of Monuments

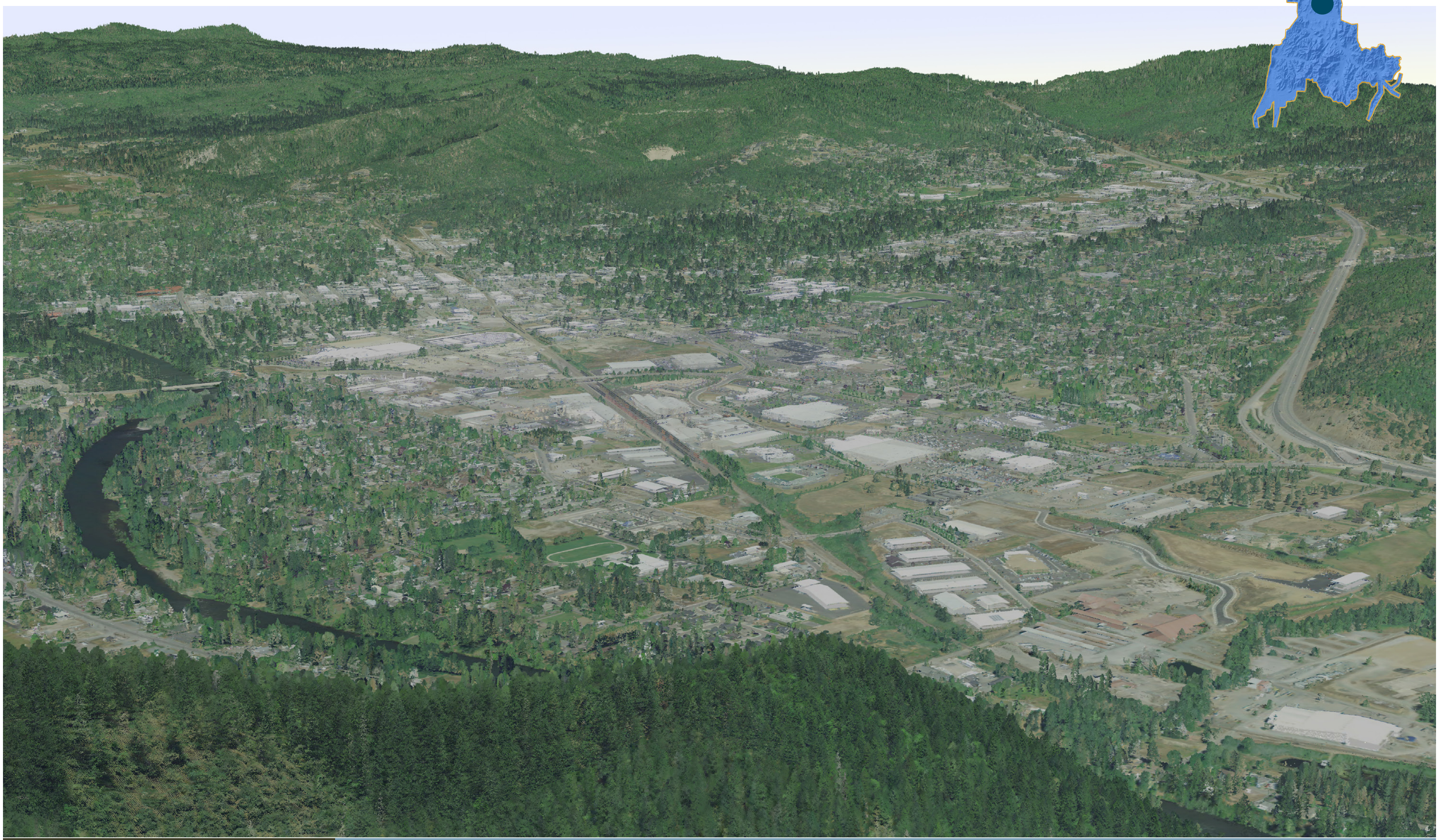
Base Station ID	Latitude (North)	Longitude(West)	Ellipsoide Height(M)
ROGUE_01	42 14 15.22394	-123 04 13.02678	403.572
ROGUE_03	42 14 14.67214	-123 02 36.86115	437.288
ROGUE_06	42 26 19.67958	-123 24 53.54383	243.353
ROGUE_08	42 31 05.84655	-123 26 28.75168	241.171
ROGUE_10	42 07 31.42212	-123 33 57.90103	418.454
ROGUE_11	42 08 24.76769	-123 38 01.69485	378.810
ROGUE_27	42 06 39.49461	-123 40 49.42526	388.301
ROGUE_28	42 57 34.13966	-123 22 06.18232	210.266
ROGUE_29	42 07 57.76899	-123 36 27.66080	392.790
ROGUE_30	42 27 34.08136	-123 19 56.31117	304.330
ROGUE_31	42 32 05.46430	-123 23 19.39622	306.847
ROGUE_33	42 44 14.60836	-123 25 23.09815	408.058
ROGUE_34	42 56 09.44642	-123 23 54.09873	190.615
ROGUE_35	42 52 19.10589	-123 34 51.83742	300.489
ROGUE_12	42 16 09.58154	-123 32 57.93591	404.055
ROGUE_13	42 09 29.74087	-123 03 01.75602	455.061
ROGUE_36	42 55 31.68057	-123 25 09.09539	190.546
ROGUE_01_R	42 14 15.22394	-123 04 13.02600	403.502
ROGUE_37	42 53 12.75018	-123 21 32.52545	753.014
ROGUE_38	42 51 05.27825	-123 23 06.69575	1011.365
ROGUE_09	42 32 41.35376	-123 22 45.99439	319.683
NGS_B652	42 34 10.04885	-123 22 19.20944	341.015
ROGUE_39	42 38 06.44408	-123 22 41.17969	341.225
NZ1328	42 25 24.56080	-123 20 19.88330	264.622
ROGUE_04	42 16 59.75279	-123 13 26.00084	339.504
ROGUE_40	42 18 41.92800	-123 15 57.44664	319.379

Base Station ID	Latitude (North)	Longitude(West)	Ellipsoide Height(M)
ROGUE_07	42 24 06.12968	-123 26 44.64024	276.271
ROGUE_26	42 16 49.17673	-123 36 54.53498	380.954
ROUGE_41	42 15 41.02929	-123 27 22.04084	484.687
ROGUE_42	42 30 11.88273	-123 23 02.27095	316.696
ROGUE_14	42 12 52.12129	-123 17 14.80658	425.906
ROGUE_21	42 59 57.39928	-123 02 47.55534	836.996
ROGUE_22	42 59 17.45662	-123 03 54.63570	790.497
ROGUE_43	42 42 35.49870	-123 21 52.11544	417.545
ROGUE_46	43 04 56.89779	-123 08 43.34384	547.648
ROGUE_52	42 45 11.79741	-123 22 24.73131	417.025
ROGUE_23	43 11 30.66425	-123 42 36.42250	704.132
ROGUE_25	43 11 45.85919	-123 46 10.04451	665.235
ROGUE_47	43 06 18.53433	-123 08 49.03493	513.020
ROGUE_48	43 23 00.55829	-122 55 29.04699	561.507
ROGUE_49	43 22 32.61104	-123 03 32.63365	1157.002
ROGUE_50	43 24 20.88696	-122 51 10.76425	859.545
ROGUE_05	42 20 17.55719	-123 20 13.90831	311.115
ROGUE_45	42 56 43.94502	-123 16 04.38116	200.676
ROGUE_51	43 30 14.07954	-122 52 50.92855	1220.237
ROGUE_15_R	42 41 08.88758	-123 37 37.94685	428.217
ROGUE_54	42 38 58.39168	-123 36 21.92799	409.067
ROGUE_17	42 46 32.01662	-123 44 02.80973	1018.353
ROGUE_18	42 47 20.41085	-123 42 14.19172	1089.192

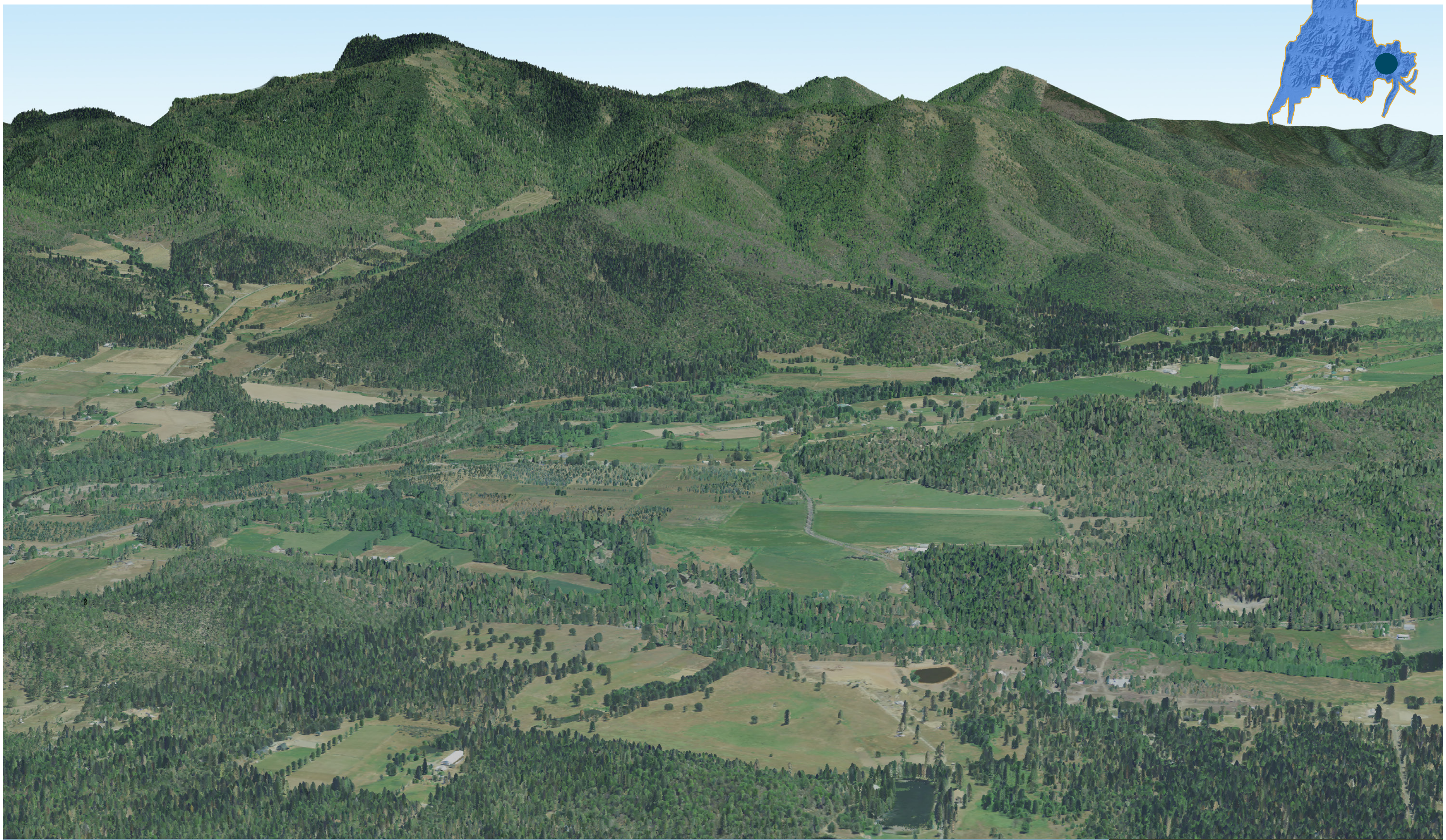


LiDAR-derived Imagery

LiDAR point cloud with RGB extraction from 2009 NAIP imagery. City of Grants Pass, Oregon. View to the North.



LiDAR point cloud with RGB extraction from 2009 NAIP imagery. Forested hills north of Applegate, Oregon. View to the East.



LiDAR point cloud with RGB extraction from 2009 NAIP imagery. Bridge over Hell's Gate Canyon, Oregon. View to the West.

Hillshade of LiDAR-derived 1m DEM. Carpenters Island on the Rogue River, Oregon. View to the East.