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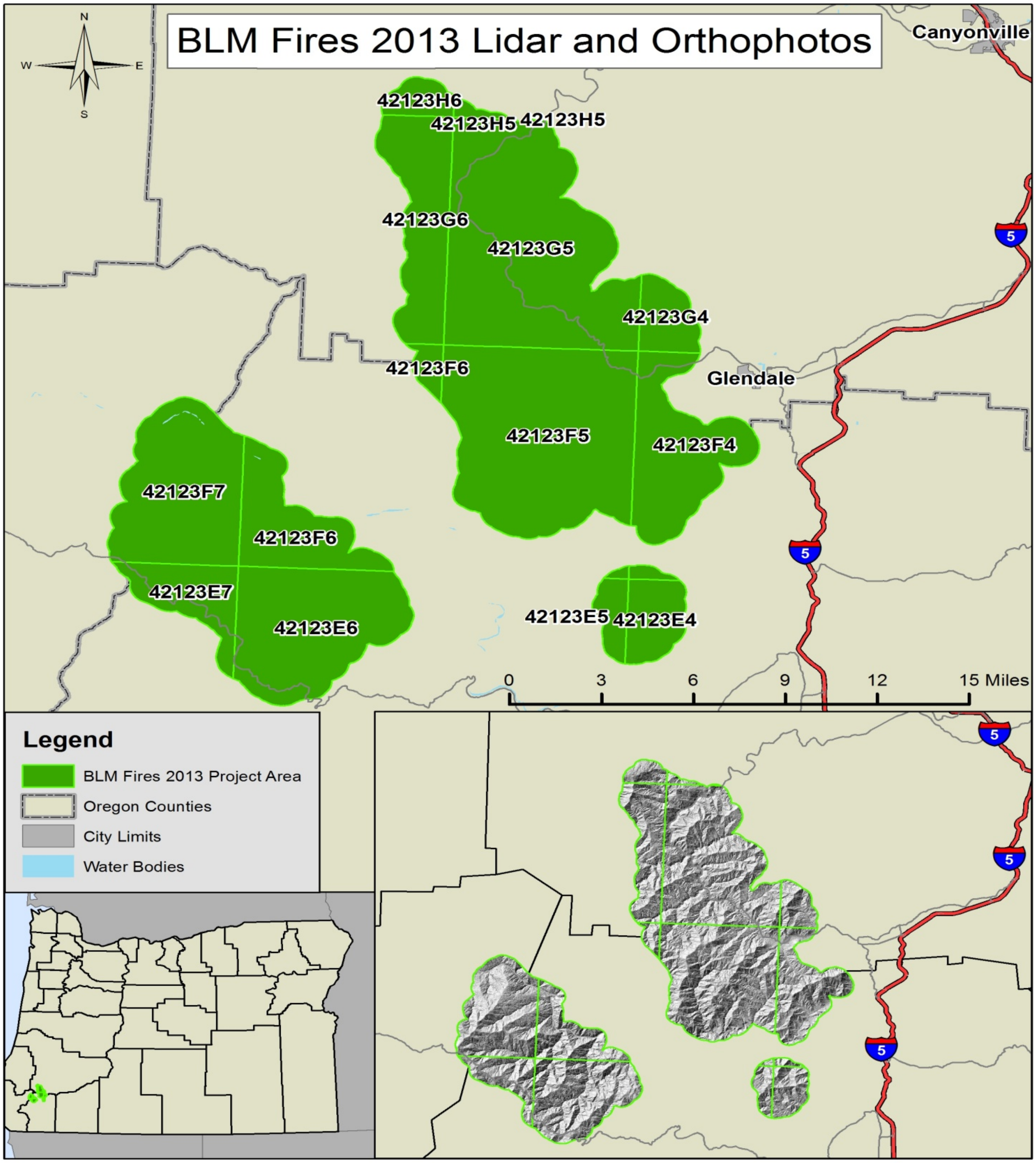
BLM Fire Project, 2013 –QC Analysis

Lidar and Orthophoto QC Report – November 25th, 2013



Map featuring BLM Fire 2013 data extent.

The Oregon Department of Geology and Mineral Industries (DOGAMI) has contracted with a vendor (Watershed Sciences, Incorporated) to collect high resolution lidar topographic data for multiple areas within the State of Oregon. Areas for lidar data collection have been designed as part of a collaborative effort of State, Federal, and Local agencies in order to meet a wide range of project goals. The vendor has agreed to certain conditions of data quality and standards for all lidar data deliverables listed in Exhibit A (OPA #8865) of the 2007-2009 Lidar Data Acquisition Price Agreement (pgs 14-23). Data purchased under this price agreement are to be collected at a resolution of at least 8 points per square meter and processed to meet or exceed the agreed upon data quality standards. This document itemizes and reports upon BLM Fire 2013 Lidar Project products furnished by the lidar vendor as documentation that all data meets project specific standards.

Upon receipt from vendor, all lidar data for BLM Fire 2013 were independently reviewed by DOGAMI staff to ensure project specifications were met. All data were inventoried for completeness and data were checked for quality, which included examining lidar data for errors associated with internal data consistency, model quality, and accuracy.

- Consistency Analysis involves examining flight line offsets to quantify the accuracy of data calibration. Calibration influences elevation data quality with poor calibration leading to small but systematic errors in lidar point elevations s, which then create inaccuracies within derived lidar elevation models.
- Visual checks are carried out in order to identify potential data artifacts and misclassifications of lidar point data. Lidar point data is classified as either ground, above ground, or error points. Sophisticated processing scripts are used to classify point data and remove error points. The data vendor performs quality control analysis to fix misclassifications of point data. The delivered bare earth DEM is then reviewed by DOGAMI to ensure that the data classification is correct and there are no topographic processing artifacts. If errors are found, data must be fixed and resubmitted, or the vendor must explain why there is no error.
- Accuracy of the data is examined by comparing lidar elevation data with independent survey control to quantify vertical and horizontal accuracy. For each lidar collection project DOGAMI independently collects accurate elevations for GPS ground control points, which are then compared against delivered lidar elevation models.

<u>Data Completeness</u>

Data for BLM Fire 2013 were collected between September 26th 2013 and October 23rd, 2013. The total area of delivered data equals 123,340 acres in Curry, Douglas, and Jefferson counties in Oregon. The BLM Fire 2013 (Figure 1) includes data in the form of bare earth and highest hit grids, trajectory files, intensity images, orthophotos, point clouds in ASPRS LASer (LAS) format, ground point density rasters, RTK survey data, a shapefile of the delivery area, and the lidar delivery report (Table 1). Bare earth and highest hit grids were delivered in ArcInfo Grid format with 3ft cell size. Lidar point data are delivered in separate files for all returns and for ground classified returns only. Georeferenced intensity images are supplied in TIF format. Supplementary data includes ground density rasters displaying locations where ground returns are low. Real time kinematic ground survey data (used for absolute vertical adjustment) is supplied in shapefile format. This delivery contains data for the following USGS 7.5 minute quads (listed by Ohio Code #) within the boundary of the Biscuit Fire dataset collected in 2007 and the Rogue River Lidar dataset collected in 2012 (Figure 1):

Delivery: 42123E4, 42123E5, 42123E6, 42123E7, 42123F4, 42123F5, 42123F6, 42123F7, 42123G4, 42123G5, 42123G6, 42123H5, 42123H6,

FINAL Delivery	Resolution	Format	Tiling	
Bare Earth DEMs	3ft	Grid	quad	x
Highest Hit DEMs	3ft	Grid	quad	x
Trajectory files	1 sec	ascii (TXYZRPH)	flight	x
Ortho Imagery	3 inches	GeoTIFF	200th quad	x
LAS	8pts/m^2	Las	100th quad	x
Ground Returns	N/A	Las	100th quad	x
Ground Density Raster	3ft	Grid	quad	x
RTK point data		Shape		x
Delivery Area shapefile		Shape	quad	x
Report		Pdf		x
Miscellaneous		**Format**	**Tiling**	
Processing bins		dxf or dgn	project	x

Table 1. Deliverable Checklist

All data associated with this delivery have been loaded and viewed to ensure completeness. Raster imagery such as elevation grids and intensity geotifs have been viewed in ArcMap, cross referenced with the delivery area. Las files have been loaded into Terrasolid software to ensure completeness and readability.

Deliverable Descriptions: (All data projected in Oregon Lambert, NAD83 (HARN), Intl Feet with exception of trajectory files).

- Bare Earth Grids: Tin interpolated grids created from lidar ground returns.
- Highest Hit Grids: Tin interpolated grids created from the highest lidar elevation for a given 3ft cell.
- Intensity TIF: TIF raster built using returned lidar pulse intensity values gathered from highest hit returns.
- Trajectory File: File contains point location measurement of the aircraft used to collect lidar data. Data is collected using an Inertial Measurement Unit (IMU), and collects measurements of: Easting(meters), Northing (meters), Ellipsoid Height (meters) of aircraft, aircraft roll (degrees), aircraft pitch (degrees), aircraft heading (degrees). Measurements are collected at one second intervals. Data is projected in UTM zone 10, NAD83 (HARN).

- LAS: Binary file of all lidar points collected in survey (Class, flight line #, GPS Time, Echo, Easting, Northing, Elevation, Intensity, Scan Angle, Echo Number, and Scanner).
- Ground LAS: Binary file of lidar points classified as ground (Class, flight line #, GPS Time, Echo, Easting, Northing, Elevation, Intensity, Scan Angle, Echo Number, and Scanner).
- RTK Point Data: Ground GPS Survey data used to correct raw lidar point cloud for vertical offsets.
- Delivery Area Shapefile: Geometry file depicting the geospatial area associated with deliverables.
- Report: Report provides detailed description of data collection methods and processing. The vendor also reports accuracies associated with calibration, consistency, absolute error, and point classifications.

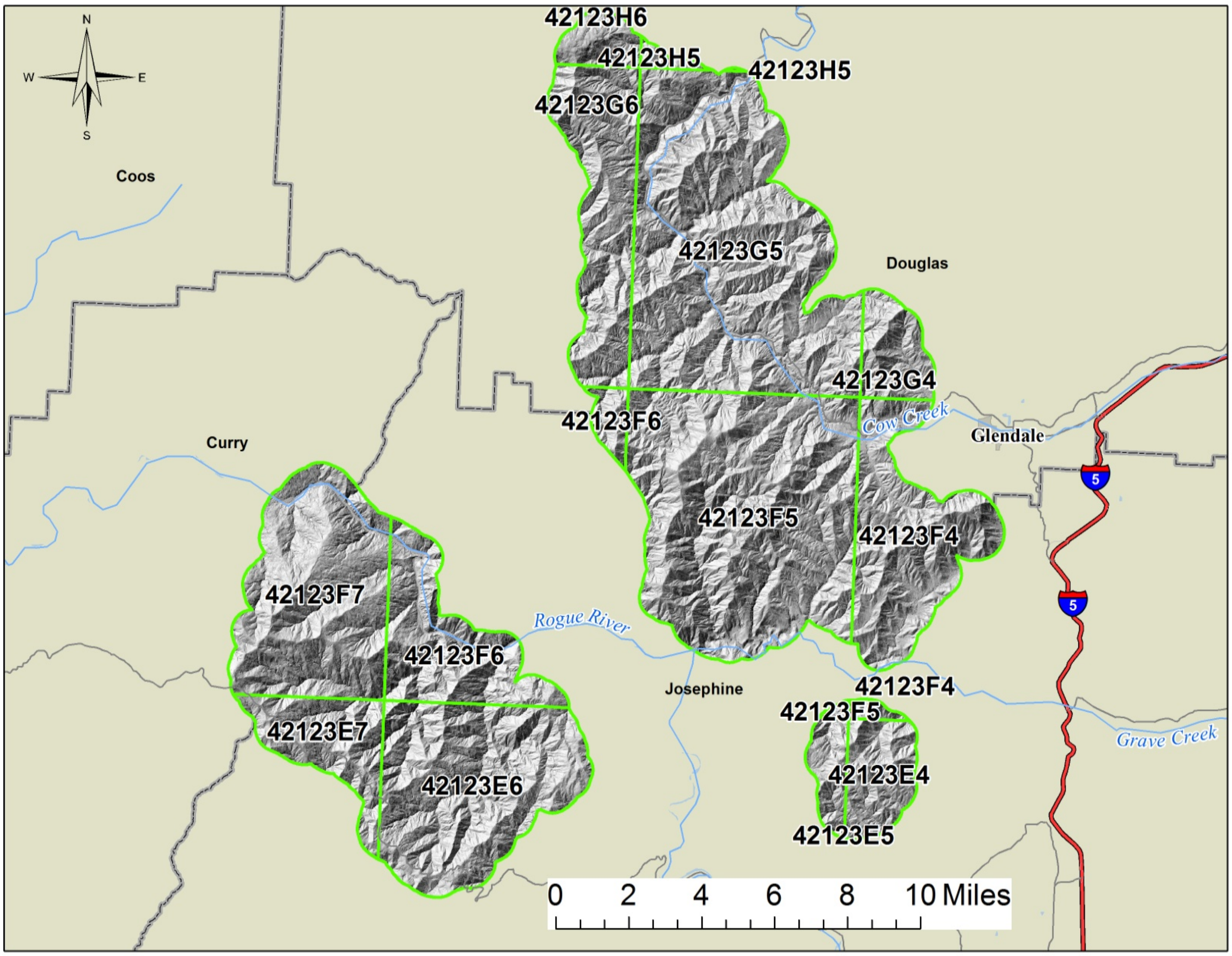


Figure 1. BLM Fire 2013 location area. Data is referenced to USGS 7.5 minute quadrangles within the extents of the Rogue River Lidar and the Biscuit Fire collection areas.

Consistency Analysis:

DOGAMI has specified that lidar consistency, as measured by vertical offsets between flight lines, must average less than 0.15m (0.49 feet). DOGAMI measures consistency offsets throughout delivered datasets to ensure that project specifications are met.

Consistency refers to lidar elevation differences between overlapping flight lines. Consistency errors are created by poor lidar system calibration settings associated with sensor platform mounting. Errors in consistency manifest as vertical offsets between individual flight lines. Consistency offsets were measured using the “Measure Match” tool within the TerraMatch© software toolset. This tool uses aircraft trajectory information linked to the lidar point cloud to quantify flight line-to-flight line offsets.

To quantify the magnitude of this error 1209 delivered data tiles were examined for vertical offset between flight lines. Data tiles with less than 1000 points were not used in analysis. Selection of tiles aimed to evenly sample the delivered spatial extent of data. Each tile measured 750 x 750 meters in size. Within each tile, we selected all ground classified points from each flight line, and compared the elevations of the points in each set of overlapping lines. The average number of points used for flight line comparison was 1,881,920 per tile (Table 2a). Error measurements were calculated by differencing the nearest point from an adjacent flight line within 1 meter in the horizontal plane and 0.2 meters in the vertical plane. Each flight line was compared to adjacent flight lines, and the average magnitude of vertical error was calculated. A total of 389 flight lines were sampled and compared for consistency.

Summary Statistics

# of Tiles	1209
# of Flight Line Sections	389
Avg # of Points	1,881,920
Avg. Magnitude Z error (m)	0.04768

Table 2a. Summary Results of Consistency Analysis

	meters	***feet***
Mean	0.0478	0.1571
Standard Error	0.0002	0.0006
Standard Deviation	0.0040	0.0134
Sample Variance	0.0000	0.0000
Range	0.0311	0.1020
Minimum	0.037	0.121
Maximum	0.068	0.223

Table 2b. Descriptive Statistics for Magnitude Z Error.

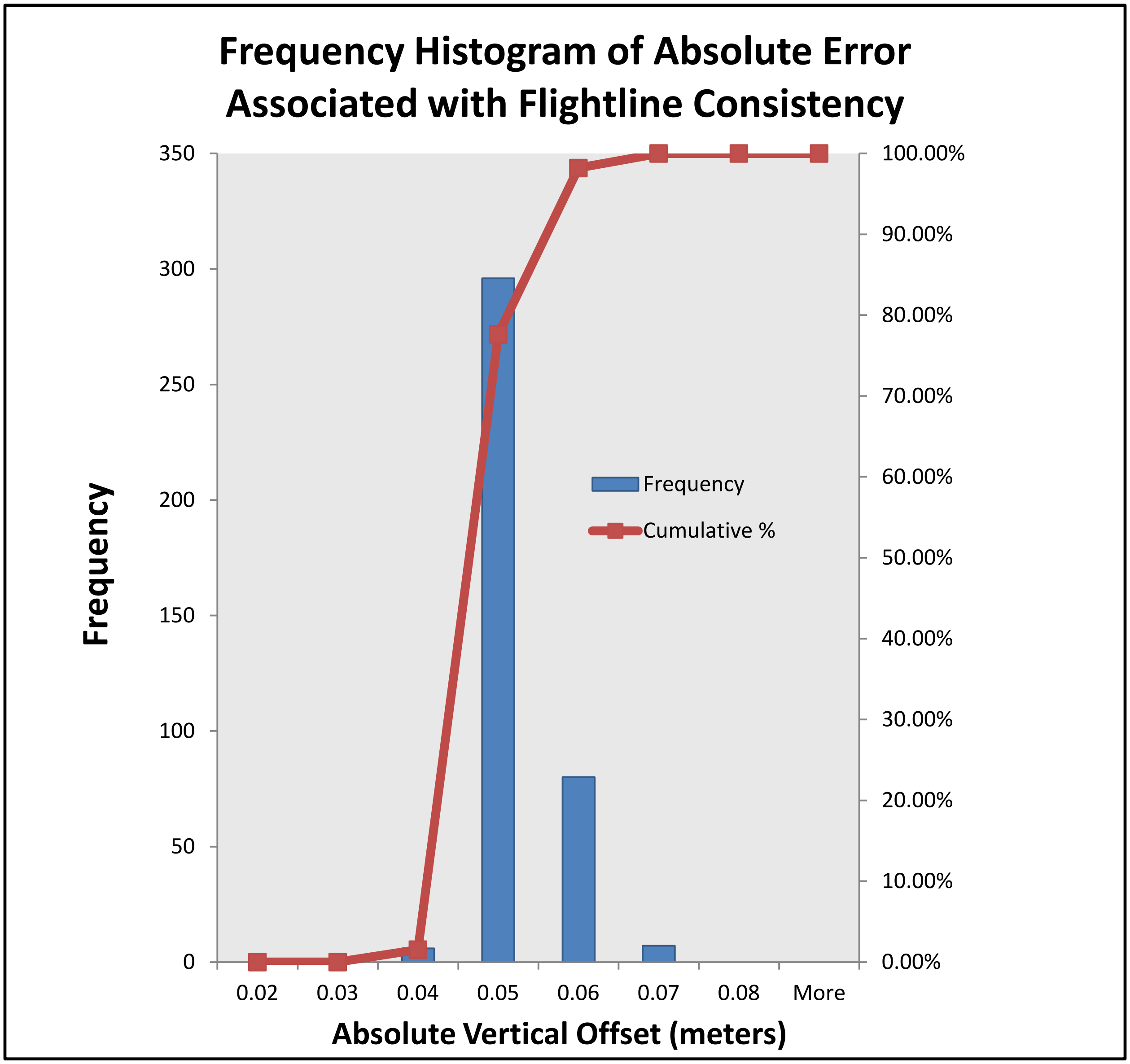


Figure 2. Calibration results for BLM Fire 2013

Results of the consistency analysis found the average flight line offset to be 0.0478 meters with a maximum error of 0.068 (Table 2b). Distribution of error showed 100% of all error was less than 0.08m (Figure 2). These results show that all data are within tolerances of data consistency according to contract agreement.

Visual Analysis

Lidar 3ft grids were loaded into ArcGIS software for visual analysis. Data were examined through slope and hillshade models of bare earth returns. Hillshades of the highest hit models were used to identify areas of missing ground (Figure 3). Both bare earth and highest hit models were examined for calibration offsets, tiling artifacts (Figure 4), seam line offsets, pits (Figure 5), and birds.

Calibration offsets typically are visualized as a corduroy-like patterning within a hillshaded lidar model. These offsets present themselves along steep slopes and typically stand out more in highest hit models than bare earth. Tiling artifacts are a result of missing or misclassified data along the edge of lidar processing tiles. These artifacts present themselves as linear features typically 1-2 grid cells in width, and are present in both the highest hit and bare earth models (e.g. Figure 3). Seam line offsets occur where two distinct days of lidar data overlap. Errors occur as a result of improper absolute vertical error adjustments. These errors are typically visualized as a linear stair step running along the edge of connecting flight lines. Pits and birds refer to uncommonly high or low points that are the result of atmospheric and sensor noise. Pits (low points) typically occur where the laser comes in contact with water on the ground (Figure 5). Birds (high points) typically occur where the laser comes into contact with atmospherics[1].

Errors located during visual analysis were digitized for spatial reference and stored in ESRI shapefile format. Each feature was assigned an ID value and commented to describe the nature of the observed error. The shapefile was delivered to the vendor for locating and fixing errors. Upon receiving the observed error locations, the vendor performed an analysis to conclude whether the error was valid. For all valid errors found, the vendor has reprocessed the data to accommodate fixes. For all observed errors that are found to be false, the vendor has produced an image documenting the nature of the feature in grid and point data format. A readme file was created explaining all edits performed. Corrected data was delivered to DOGAMI. This data were examined to ensure edits were made, and visually inspected for completeness, then combined into the original delivery.

[1] Atmospherics include clouds, rain, fog, or virga.

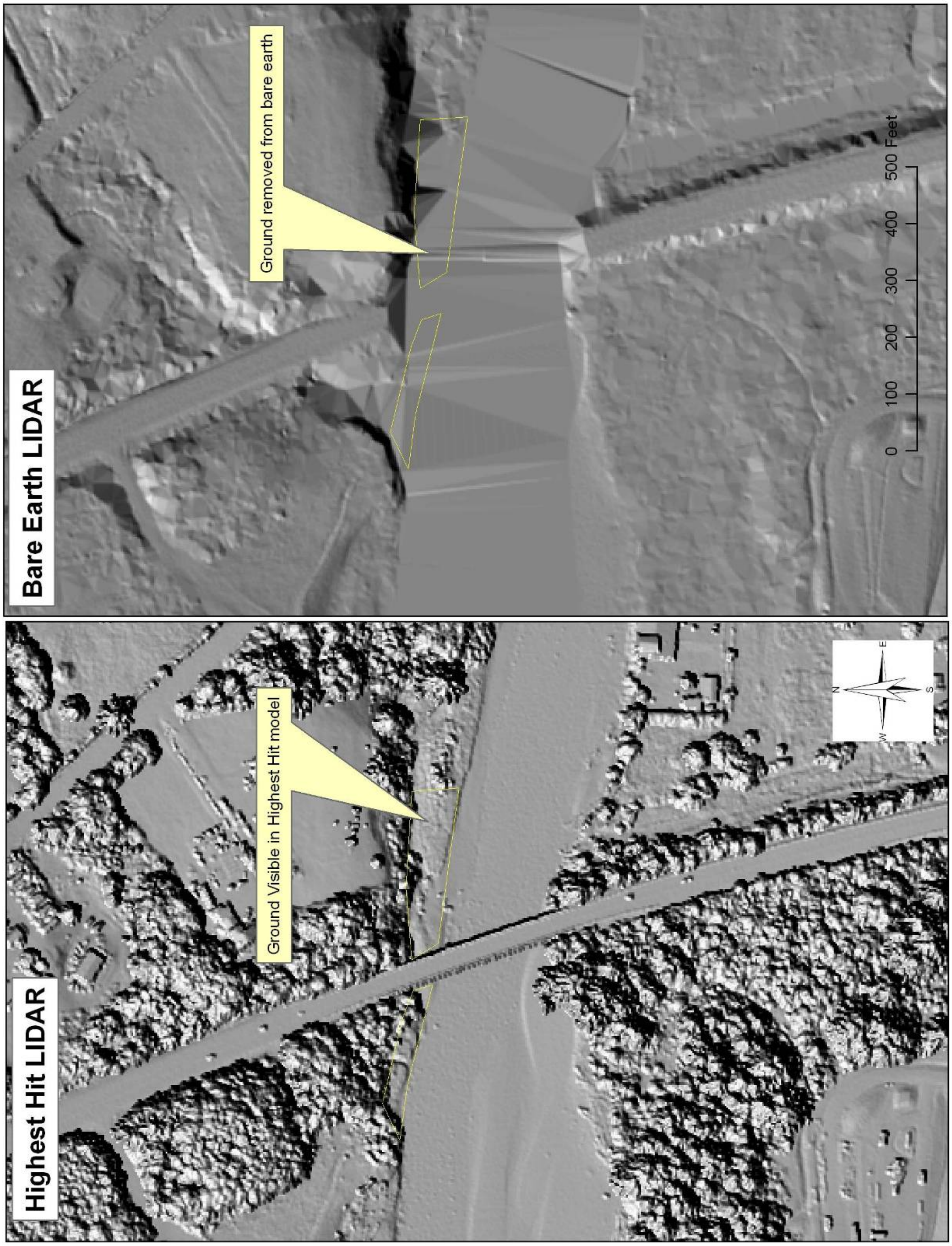


Figure 3. Example of missing ground in lidar bare earth data. Ground is clearly visible in highest hit model, but has been removed from the bare earth model. This type of classification error is common near water body features.

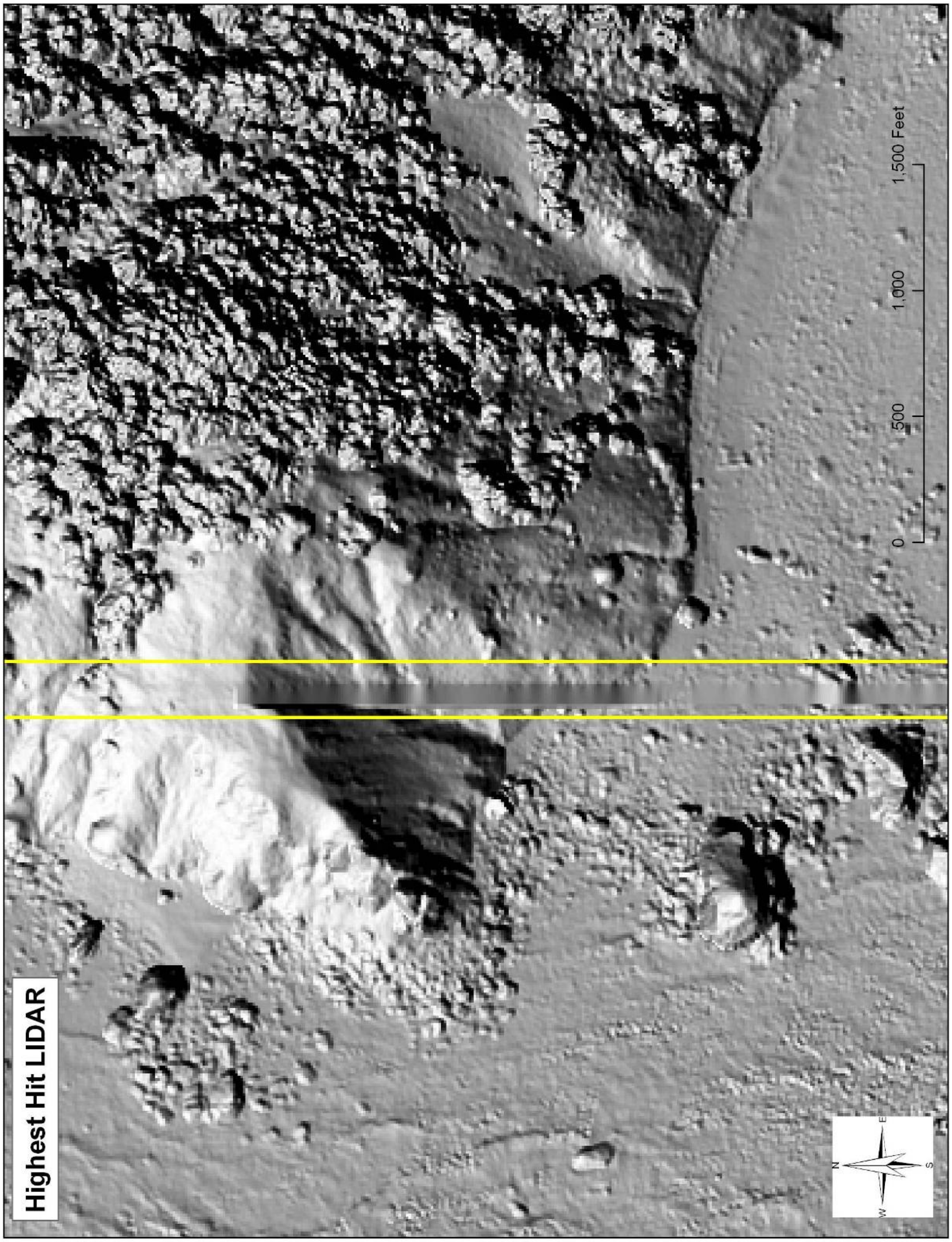


Figure 4. Example of tile artifact found in highest hit lidar data. Artifact is a seam line error created due to misclassification of ground at edge of lidar processing tiles.

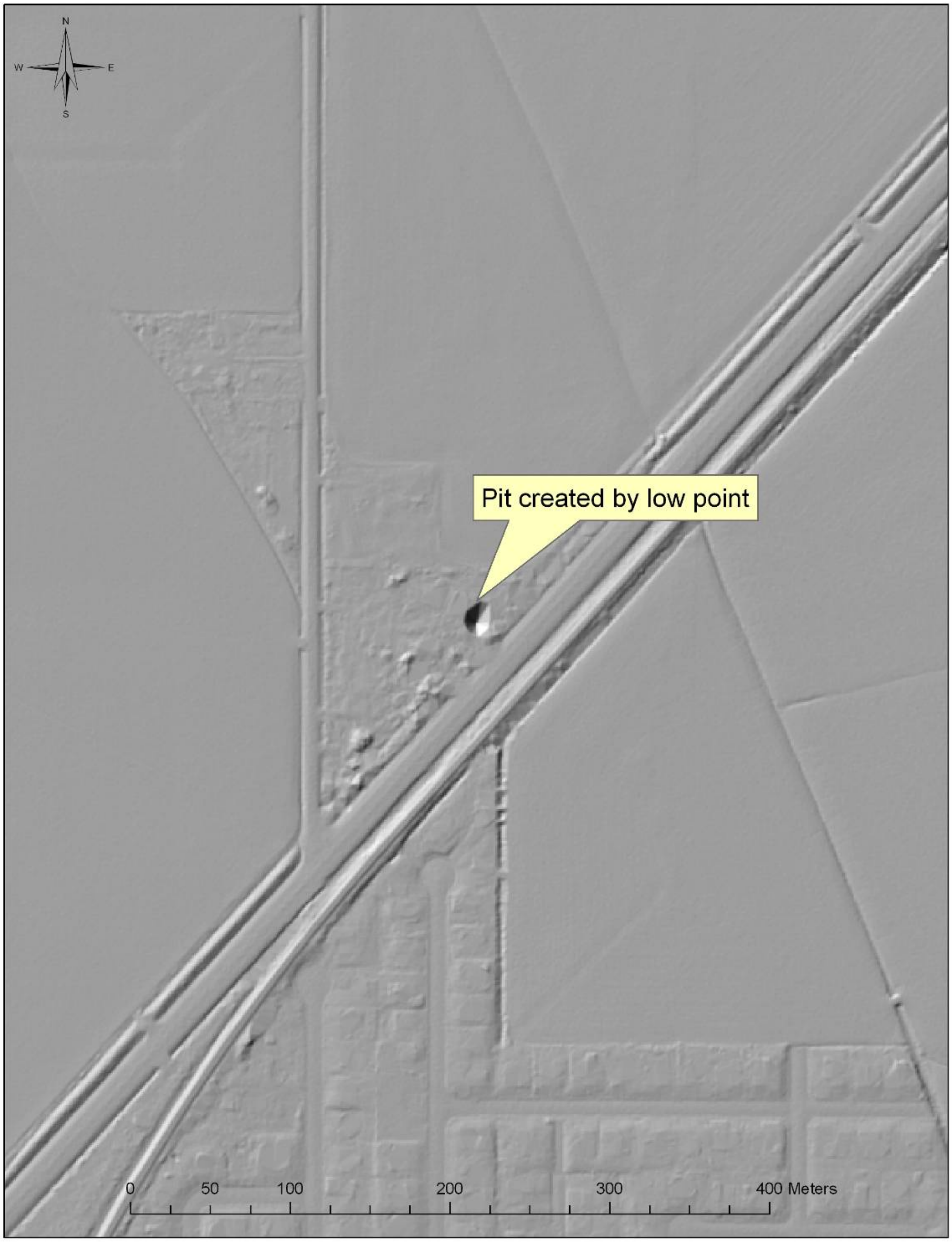


Figure 5. Example of "Pit" caused by low point in ground model. Pits are caused when standing water absorbs the lidar pulse. Pits are evident in ground model as the lowest point elevation is assigned to the grid cell value. Inversely the pit is not observable in the highest hit model as the highest point elevation is assigned to the grid value

Vertical Accuracy Analysis:

Vertical accuracy refers to the mean vertical offset of lidar data relative to measured ground-control points (GCP) obtained throughout the lidar sampling area. For this project, no independent survey data was collected by DOGAMI. Instead the vendor, Watershed Sciences Inc. (WSI) provided GCP points that were then independently analyzed by DOGAMI. The vertical accuracy analysis consisted of establishing the vertical offsets between the control data and the lidar Digital Elevation Model (DEM).

WSI collected ground surveyed points by setting up a GPS base unit over nine geodetic survey monuments located within the project area. The GPS base unit broadcasts a kinematic correction to a roving GPS unit operated by a field technician. WSI used a Trimble GNSS receiver model R7 with a Zephyr Geodetic Antenna Model 2 for static control points (figure 5). All real-time kinematic measurements were made with an R8 "rover" receiver (figure 5). The kinematic correction received by the R8 "rover" from the GPS base unit allowed for precise location measurements of ≤1.5 centimeters in the horizontal and ≤ 2.0 centimeters in the vertical. All GPS measurements were made with dual frequency L1-L2 receivers with carrier-phase correction.

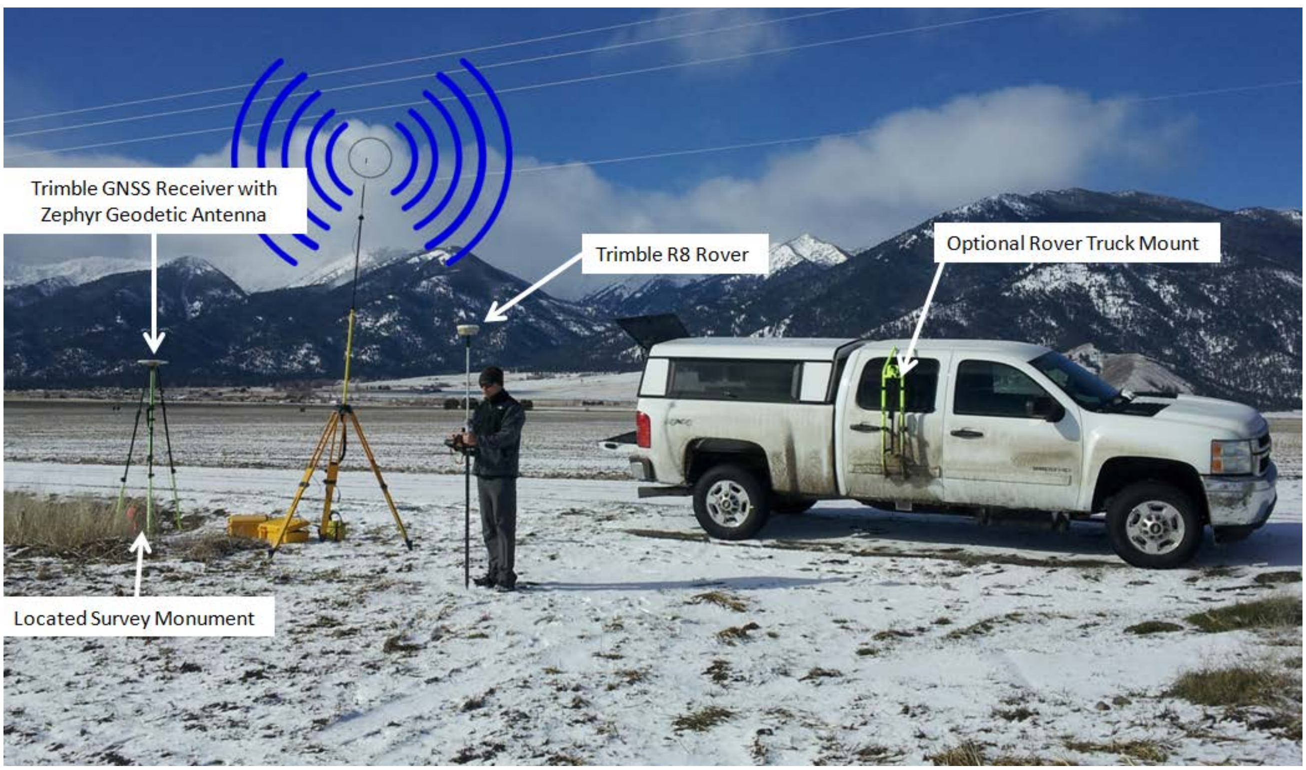


Figure 5. Example photo of a Trimble GNSS Receiver with Zephyr Geodetic Antenna located over a known reference point at Cape Lookout State Park. Corrected GPS position and elevation information is then transmitted to the 5800 GPS rover unit.

The approach utilized by WSI was comprised of two components:

1) Establish horizontal and vertical coordinates for survey monuments that are to be used to calibrate the lidar survey. All monuments are observed for a minimum of two survey session lasting no fewer than two hours. Watershed

Sciences collected data at a rate of one hertz, utilizing a 10 degree antenna mask. After multiple data collections at each monument, accuracy was collected in order to eliminate various survey errors. The collected data was then submitted to the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) for post-processing against several Continuously Operating Reference Stations (CORS) operated by the NGS. Due to the US government shutdown from October 1st to October 16th, 2013, WSI was not able to process GPS data through the Online Positioning User Service (OPUS). Instead, WSI determined that Trimble RTX provided consistent, accurate solutions when comparing to past sessions holding OPUS as the standard.

2) Collect RTK measurements along relatively flat surfaces (roads, paths, parking lots etc.). 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. RTK positions were collected on 20 percent of the flight lines. RTK measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads. RTK points were taken no closer than one meter to any nearby terrain breaks such as road edges or drop offs.

Vertical accuracy analysis consisted of differencing control data and the delivered lidar Digital Elevation Models (DEM) to expose offsets. These offsets were used to produce a mean vertical error and vertical RMSE value for the entire delivered data set. Project specifications list the maximum acceptable mean vertical offset to be 0.20 meters (0.65 feet). A total of 1661 measured GCP's obtained by Watershed Sciences were used by DOGAMI to compare against the lidar elevation DEM. The data delivered to DOGAMI was found to have a mean vertical offset of -0.0009 meters (-0.003 feet) and an RMSE value of 0.045 meters (0.148 ft). Offset values ranged from -0.179 to 0.163 meters (Table 3 and Figure 7).

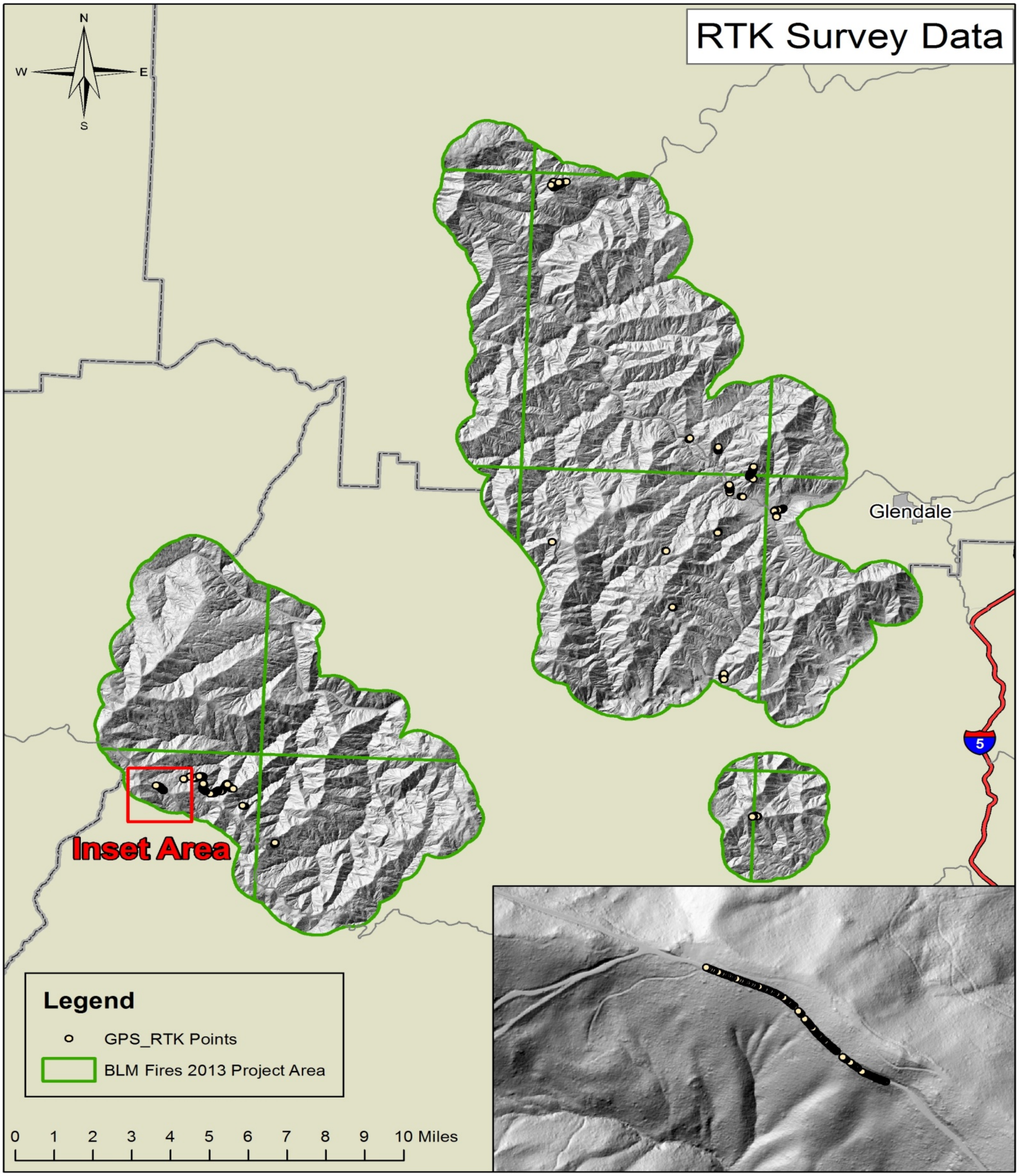


Figure 6. Locations of RTK control surveyed by WSI. Data was used to test absolute accuracy for the BLM Fire 2013 survey within the project extent.

	Meters	*Feet*
Mean	-0.0009	-0.0029
Standard Error	0.0011	0.0036
Standard Deviation	0.0451	0.1479
Range	0.3433	1.1263
Minimum	-0.1798	-0.5898
Maximum	0.163	0.535
RMSE	0.045	0.147

Table 3. Descriptive Statistics for absolute value vertical offsets.

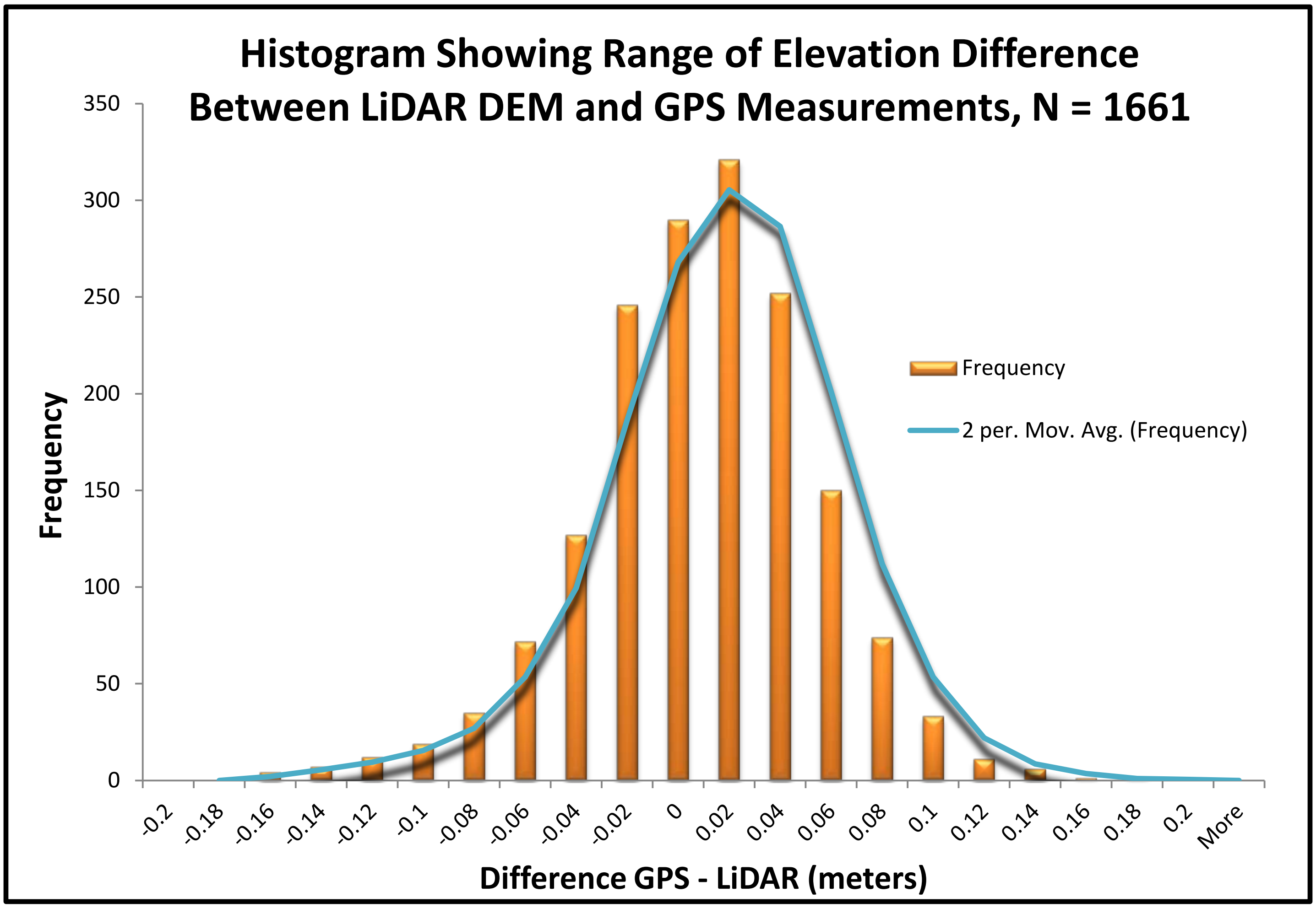


Figure 7. Histogram of absolute vertical accuracy

Horizontal Accuracy Analysis

Horizontal accuracies were not specified in the agreement since true horizontal accuracy is regarded as a product of the lidar ground foot print. Lidar is referenced to co-acquired GPS base station data that has accuracies far greater than the value of the lidar foot print. The ground footprint is equal to 1/3333rd of above ground flying height. Survey altitude for this acquisition was targeted at 900 meters AGL (above ground level) yielding a ground foot print of 0.27 meters. This value exceeds the typical accuracy value of ground control used to reference the lidar data (<0.01m). Project specifications require the lidar foot print to fall between 0.15 and 0.40 meters.

Orthophotography Image Inventory

Aerial imagery was collected and processed to produce georeferenced and ortho-corrected raster imagery. These orthophotos were then used to attribute the LiDAR LAS point cloud with RGB and Infrared values. The delivered raster data were checked for their completeness and locations of ortho calibration targets were checked for consistency. Imagery was also checked for gross seam lines and raster errors. DOGAMI requires a horizontal accuracy of ≤0.61 meters for delivered ortho photography. The horizontal accuracy of the delivered orthophotography has a reported RMSE of 0.31 meters (1.017 feet). Ground features were used as control for accuracy assessment (Figure 8). All imagery has been loaded and reviewed for completeness and readability.

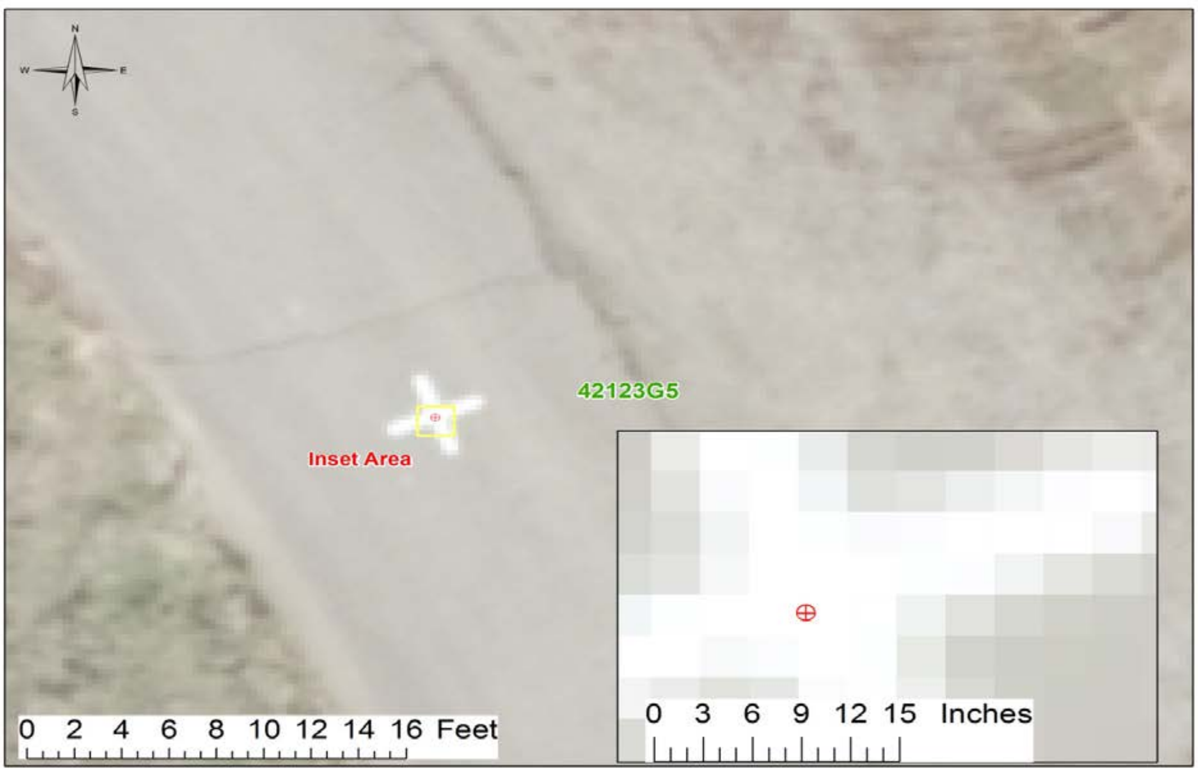


Figure 8. Aerial Target feature used to orthorectify imagery.

Acceptance

The data described in this report meets and exceeds project specifications laid out in the contracted data standards agreement. All components of data to be delivered have been received as of November 25th, 2013. Consistency analysis has concluded that all data contains flight line to flight line vertical offset less than the threshold of 0.15 meters as specified in agreement. The vendor has adequately responded to all fixable errors identified as part of the visual analysis. Perceived grid errors identified by DOGAMI that were found to be false have been documented by the vendor and explained to the satisfaction of DOGAMI reviewers. Absolute accuracy analysis of the data has concluded that absolute vertical error of lidar data is less than the specified tolerance of 0.20 meters as specified in the data standards agreement.

Approval Signatures

____ Date: _12/2/2013____

Ian Madin
Chief Scientist – Department of Geology & Mineral Industries

____ Date____12/2/2013___

Jacob Edwards
Lidar Database Coordinator – Department of Geology & Mineral Industries