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Lane County LIDAR Project, 2013-2014 – Delivery 1-3 QC Analysis

LIDAR QC Report – October 8, 2014

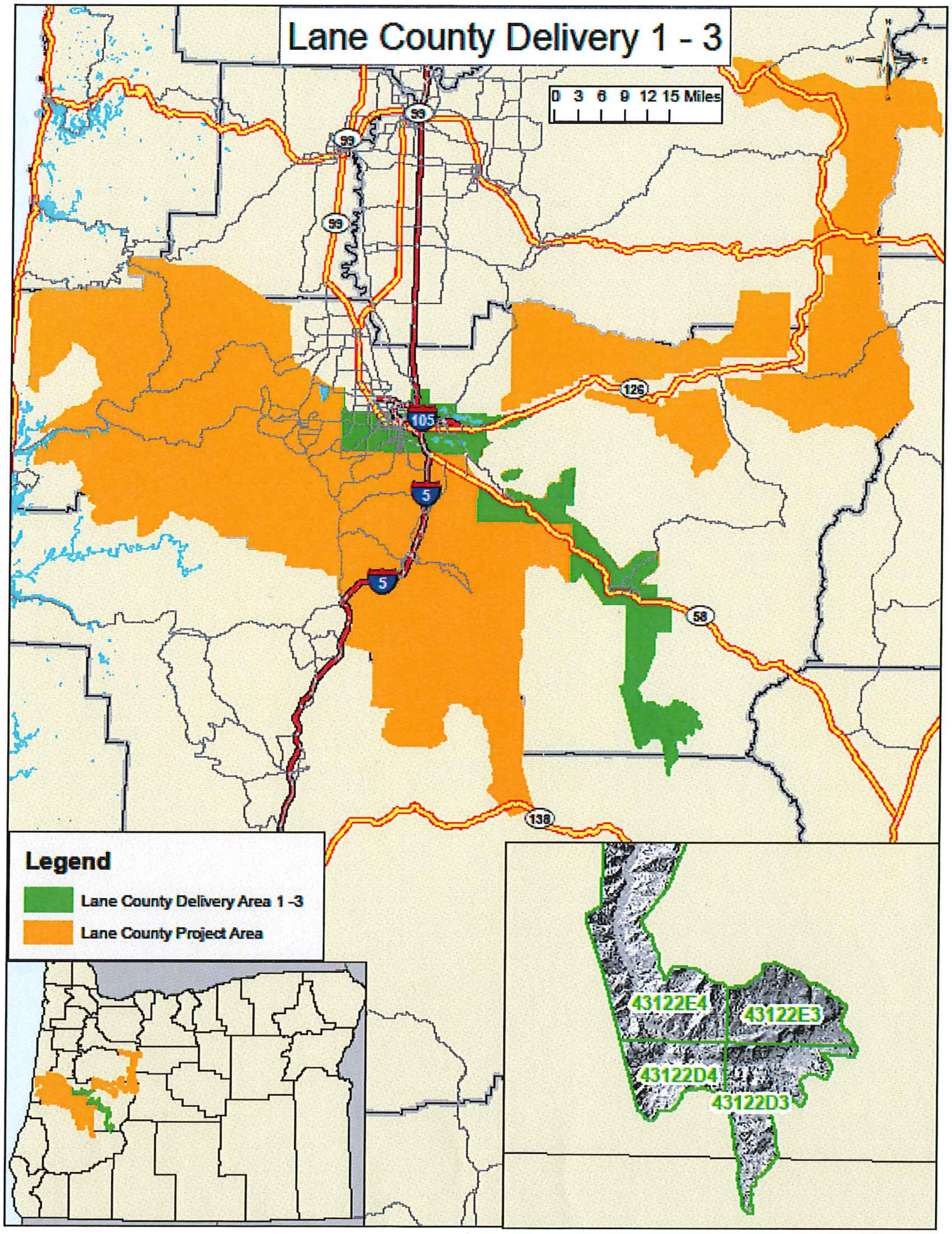

Figure 1. Map featuring Lane County Delivery 1- 3 data extent.

The Oregon Department of Geology & Mineral Industries (DOGAMI) has contracted with Watershed Sciences Inc. (WSI) 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 sections A through C (OPA #8865) of the 2007-2014 Lidar Data Acquisition Price Agreement (pages 14-23). Data submitted 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 Lane County Lidar Project – Delivery 1 - 3 (Figure 1) products furnished by the lidar vendor as documentation that all data meets project specific standards.

Upon receipt from vendor WSI, all lidar data for Delivery 1 - 3 were independently reviewed by DOGAMI staff to ensure project specifications were met. All data was inventoried for completeness and checked for quality, which included examining lidar data for errors associated with internal data consistency, model quality, and accuracy.

- <u>Data Completeness</u> examines all data associated with this delivery to ensure that all required data products are present and function correctly. Quality assurance and quality control is conducted on every data file delivered to DOGAMI. Lidar ASCII Standard (LAS) point files have been loaded into TerraSolid and ArcGIS to ensure complete and correct lidar data coverage and file integrity. Raster and vector files have been viewed in ArcMap and cross referenced with the delivery area to ensure proper coverage, extent and integrity.
- <u>Swath Overlap</u> was independently verified by analyzing flight line extents in TerraSolid and making direct measurements of flight line overlap in multiple lidar tiles.
- <u>Consistency Analysis</u> involves examining flight line offsets to quantify the accuracy of data calibration. Calibration influences elevation data quality. Poor calibration leads to small but systematic errors within lidar elevation points, which then create inaccuracies within derived lidar elevation models.
- <u>Visual Check</u> is 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 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 valid errors are found, data must be corrected and resubmitted.
- <u>Absolute Accuracy</u> compares the delivered bare-earth DEMs with independent GCPs to quantify vertical and horizontal accuracy. For each lidar collection project DOGAMI staff collects independent GPS ground control points, which are then compared against delivered lidar elevation models.
- <u>Ortho Imagery Analysis</u> involves a visual check of data quality and positional accuracy. A visual check is carried out in order to identify potential artifacts within or between orthoimagery tiles. Horizontal accuracy is determined by comparing the location of static features visible in both the orthoimagery and the lidar intensity image. If errors are found then the data must be resubmitted.

- Spot Diameter Analysis determines the area of ground that is intersected by a laser pulse from the lidar sensor. The spot diameter is a product of the flying height of the aircraft and the beam divergence of the sensor used during acquisition of the data
- Metadata Analysis compares the structure of the metadata file against FGDC standards. Metadata content was reviewed by using a visual check as well as analysis by the USGS Geospatial Metadata validation service.

Data Completeness

Data for Lane County Delivery 1 - 3 areas were collected between September 7th 2014 through January 25th 2014 (see WSI report for dates). Total area of delivered data equals 405.94 square miles. This delivery contains data for the following USGS 7.5 minute quads (listed by Ohio Code #) within the boundary of the Lane County survey collection area (Figure 2):

Delivery 1: 44122a6, 44122a7, 44122a8, 44123a1, 441223a2

Delivery 2: 43122d3, 43122d4, 43122e3, 43122e4

Delivery 3: 43122f3, 43122f4, 43122f5, 43122g4, 43122g5, 43122h5, 43122h6, 43122h7, 43122h8

We conduct quality control of data deliverables to ensure that project specifications (Table 1) have been met. Lane County Delivery 1 - 3 includes data in the format of grids, trajectory files, intensity images, LAS point files, ground point density rasters, RTK survey data, a shapefile of the delivery area, and the lidar delivery report. Bare earth and highest hit grids were delivered in Esri Grid format with 3ft cell size. Lidar point data is delivered in LAS binary format for ground classified returns as well as the entire lidar point cloud. The lidar point cloud is infused with RGB (red-green-blue) attributes per project specifications. Georeferenced intensity images are supplied in TIF format. Supplementary data includes ground density rasters displaying locations where ground returns are low, and time-stamped flightline shapefiles. Real time kinematic ground survey data (used for absolute vertical adjustment) is supplied in shapefile format.

We conduct quality assurance on data deliverables in order to determine if the data achieved project specifications outlined in sections A through C (OPA #8865) of the 2007-2014 Lidar Data Acquisition Price Agreement (pages 14-23). Specifically we test:

- Data completeness and consistency
- Spot Diameter
- Swath Overlap
- Swath to Swath Consistency
- DEM Quality
- Orthoimagery

First, each project deliverable's format, resolution and tiling scheme are reviewed in order to verify content completeness (Table 2.) DOGAMI staff verifies acquisition specifications by creating an LAS dataset from the all-return LAS points. The "Create LAS Dataset" tool in the ArcGIS Data Management toolbox is used to complete this task. Statistical information is then calculated for the LAS dataset using the "LAS Dataset Statistics" tool in ArcGIS. Statistical information was created for both the LAS dataset as well as the individual LAS files provided by the vendor. The tool exports a report that contains information pertaining to point classifications, number of pulse returns and the scan angle of the lidar sensor.

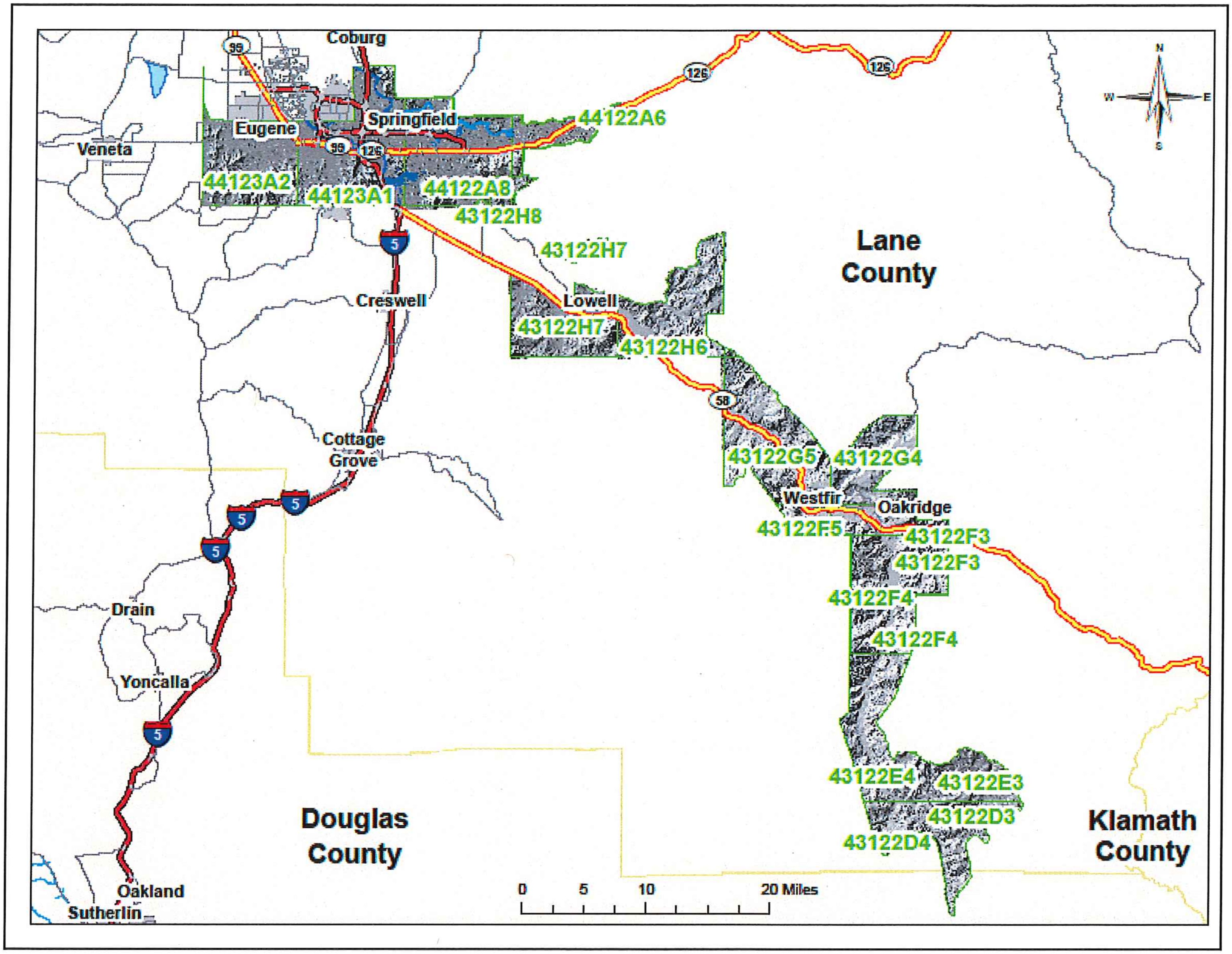

Figure 2: Lane County Delivery 1-3 area. Data is referenced to USGS 7.5 minute quadrangles within the extents of the Lane County Project Collection area.

Quality Control of Deliverables Achieving Delivery Specifications					
FINAL Delivery		**Format**	**Tiling**	**Description**	**Verified**
Bare Earth DEMs	3ft	32 bit pixel depth floating point GRID	Full USGS 7.5 minute quadrangle	Raster of ground surface, interpolated via triangulated irregular network from identified ground points.	***X***
Highest Hit DEMs	3ft	32 bit pixel depth floating point GRID	Full USGS 7.5 minute quadrangle	Rasters of first-return surface, cell heights are highest first return within that cell.	***X***
Ground Density Raster	3 ft	32 bit pixel depth floating point GRID	Full USGS 7.5 minute quadrangle	Raster showing the number of ground-classified returns per square meter over the project area.	***X***
Intensity Images	1.5ft	TIFF	Full USGS 7.5 minute quadrangle	Normalized geo-referenced 8-bit pixel depth grayscale	***X***
All-Return LAS	8pts/m^2	LAS version 1.2	1/100th USGS 7.5 minute quadrangle	LAS point could delivered in tiled LAS files. **RGB attributes infused into point cloud.**	***X***
Ground LAS	**Not specified**	LAS version 1.2	1/100th USGS 7.5 minute quadrangle	LAS point could delivered in tiled LAS files. **RGB attributes infused into point cloud.**	***X***
4 Band Ortho Imagery	3 inch pixel	4 Band (RGBI) 8-bit TIFF	1/100th USGS 7.5 minute quadrangle	Four-band (color infrared, i.e. red-green-blue-near infrared) orthophotographic imagery	***X***
Trajectory files	1 sec	ascii point file - (TXYZRPH) and ESRI shapefile	Date and time of acquisition	Recorded aircraft trajectory data compiled into (Smoothed Best Estimate of Trajectory (SBET)	***X***
GCP Shapefile		ESRI Shapefile		Ground Control Points used for survey calibration and assessment of absolute vertical accuracy	***X***
7.5 minute Quadrangle		ESRI Shapefile	Full USGS 7.5 minute quadrangle	Geometry file depicting the geospatial area associated with deliverables.	***X***
0.75 minute 1/100th quadrangle		ESRI Shapefile	1/100th USGS 7.5 minute quadrangle	Geometry file depicting the geospatial area associated with deliverables.	***X***
Ortho Imagery Shapefile		ESRI Shapefile	1/100th USGS 7.5 minute quadrangle	Geometry file depicting the geospatial area associated with imagery collection.	***X***
TerraSolid Processing Bins		DXF or DGN file	1/100th USGS 7.5 minute quadrangle	DGN file that contains processing bins for all LAS files	***X***

Project AOI Shapefile		ESRI Shapefile	OGIC, NAD83 (2011), Intl feet projection	Geometry file depicting the project area of interest.	***X***
Report		PDF		Digital text report that describes lidar **and photo** acquisition methods and results.	***X***

Table 1. Deliverable Checklist

Quality Assurance of Deliverables Achieving Acquisition Specifications			
Specification	**Description**	**Checked on this delivery**	**Independent Verification**
Data Collection Season	Target collection window is July 10, 2013 until July 10th 2014.	yes	September 7th 2013 through January 25th 2014
Survey Conditions	Lidar data collection shall be conducted in snow-free conditions with the contractor make best effort to acquire data in leaf-off and low stream conditions	yes	Within spec
Coverage	No voids between swaths. No voids due to cloud coverage or instrument failure.	yes	Within spec
Pulse Returns	Lidar sensor used must be capable of recording a minimum of 4 returns per laser pulse, including first and last returns.	yes	5 return classes
Projection	Oregon Lambert	yes	Within spec
Vertical Datum (units)	NAVD88 Geoid 12A (International feet)	yes	Within spec
Horizontal Datum (units)	NAD83 2011 (International feet)	yes	Within spec
Swath Overlap	Contractor shall plan surveys with 50% sidelap of adjacent swaths. Survey must be designed for 100% double coverage at planned aircraft height above ground.	yes	Within spec
Pulse Density	Aggregate design multi-swath pulse density must be 8.0 pulses per square meter or higher.	yes	8.7 per m^2
Scan Angle	Laser scan angle will not exceed 30 degrees overall (+15 to -15 degrees).	yes	Within spec

Table 2. Acquisition Specifications Checklist

Deliverable Descriptions:

- 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 (2011) 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.
- All data projected in Oregon Lambert, NAD83 (2011), Intl Feet with exception of trajectory files.

Spot Diameter Analysis

Horizontal accuracy is not specified in the price agreement since true horizontal accuracy is regarded as a product of the lidar spot diameter(SD). The lidar spot diameter is the area of ground that is intersected by a single pulse from the lidar sensor. SD is a function of range and beam divergence. The range is calculated as the distance between the laser aperture and the detected surface. The reported range value is given as above ground level flying height (AGL) of the sensor during collection. Beam divergence ($_{\gamma}$) is the degree by which the light pulse emitted from the sensor fans out from a straight line. Beam divergence is measured in radians, with 1 radian = 57.3 degrees. The lidar SD is calculated by multiplying AGL and beam divergence, SD = AGL * $_{\gamma}$

Lane County delivery 1 data was collected using Leica ALS70 and ALS50 lidar sensors flown at 1400 meters AGL. The Leica ALS70 specification sheet reports a beam divergence value of 0.22 milliradians @ $1/e^2$, meaning that ~85% of the laser energy falls within this divergence. The Leica ALS50 specification sheet reports a beam divergence value of 0.33 milliradians @ $1/e^2$, meaning that ~85% of the laser energy falls within this divergence.

Lane county delivery 2 and delivery 3 data were collected using a Leica ALS70 and ALS50 lidar sensor flown at 900 meters AGL. Leica ALS70 specification sheet reports a beam divergence value of 0.22 milliradians @ $1/e^2$, meaning that ~85% of the laser energy falls within this divergence. Leica ALS50 specification sheet reports a beam divergence value of 0.33 milliradians @ $1/e^2$, meaning that ~85% of the laser energy falls within this divergence.

The range of spot diameters for the Lane county deliveries 1-3 is between 0.308 meters and 0.462 meters. This equals an average spot diameter of 0.385 meters for these deliveries, which is within the project specification tolerance of 0.15 meter to 0.40 meter for SD.

Swath Overlap

Swath overlap is independently verified by measuring the amount of flight line overlap in multiple lidar tiles. This is accomplished by importing the all-return LAS files into a CAD software called TerraSolid™. Each LAS file contains header information that includes the trajectory number or flight line that was flown during its acquisition. The LAS files are assigned a color value based on the flight line number so that multiple swaths can be displayed and percent overlap can be measured (Figure 3). 100 all-return LAS files (10%) were loaded into TerraSolid and direct measurements were made in multiple locations. All 100 all-return LAS files contained ≥ 50% sidelap of adjacent swaths. These results show that all data are within specification.

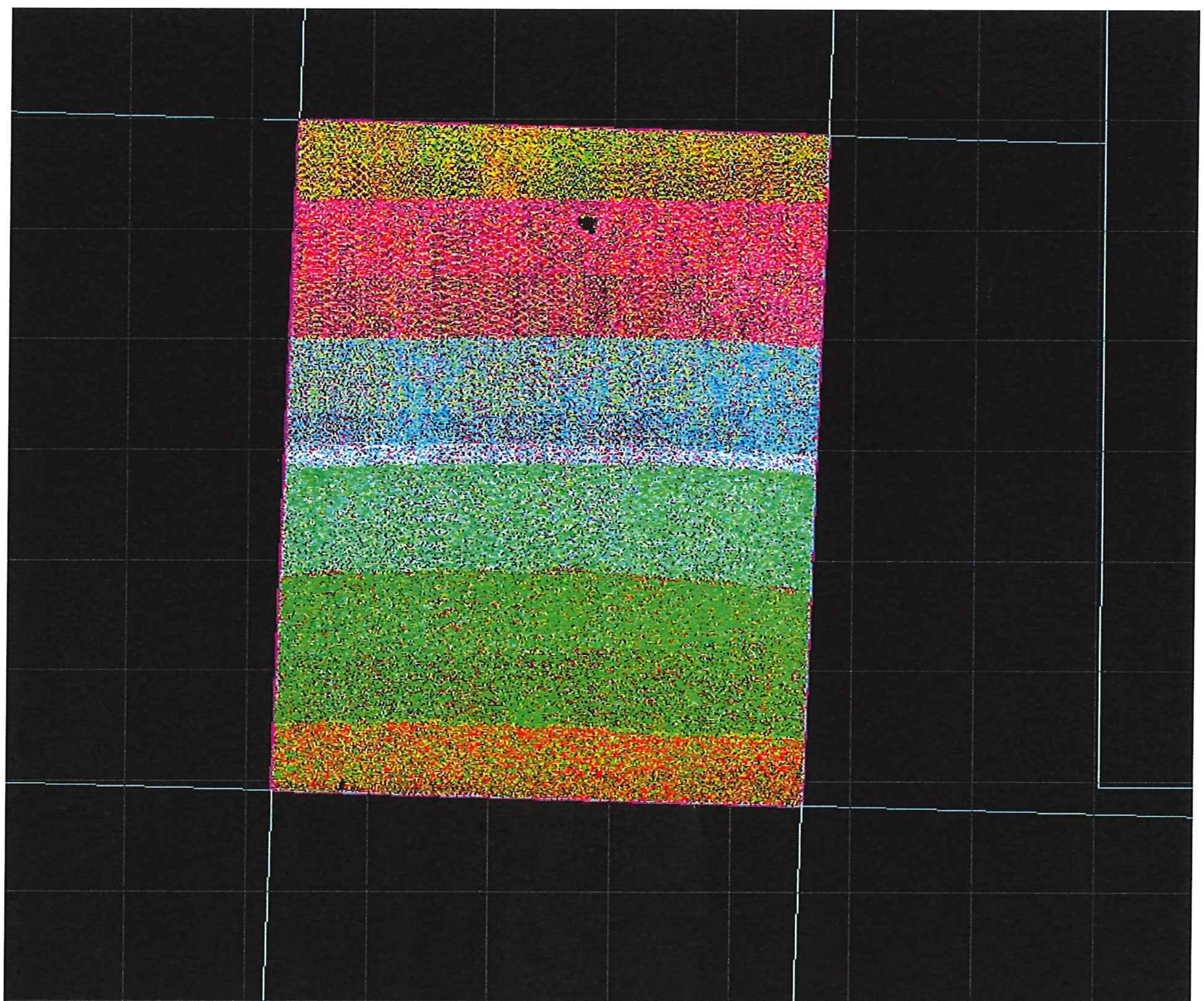

Figure 3. Lidar points colored by flight line in the 0.75 minute 1/100th quadrangle 44122A8119.

Swath-to-Swath Consistency Analysis:

DOGAMI has specified that lidar consistency must average less than 0.15m (0.49 feet) in vertical offsets between flight lines. 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 "Find 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 19,867 of 19,937 delivered data tiles (99.6%) were examined for vertical offset between flight lines. Data tiles with less than 1000 points were not used in analysis. Each tile measured 750 x 750 meters in size (Figure 4). The average number of points used for flight line comparison was 1,439,310 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. 905 flight lines out of 1,014 total flightlines (89%) were sampled and compared for consistency.

Results of the consistency analysis found the average flight line offset to be 0.029 meters with a maximum error of 0.047m (Table 2b). Distribution of error showed 96% of all error was less than 0.11m and 100% less than 0.15m (Figure 5). These results show that all data are within specification.

Summary Statistics

# of Tiles	19867
# of Flight Line Sections	905
Avg # of Points	1,439,310
Avg. Magnitude Z error (m)	0.072

Table 2a. Summary Results of Consistency Analysis

	meters	***feet***
Mean	0.072	0.237
Standard Error	0.001	0.002
Standard Deviation	0.022	0.073
Sample Variance	0.000	0.002
Range	0.141	0.464
Minimum	0.015	0.049
Maximum	0.156	0.513

Table 2b. Descriptive Statistics for Magnitude Z Error.

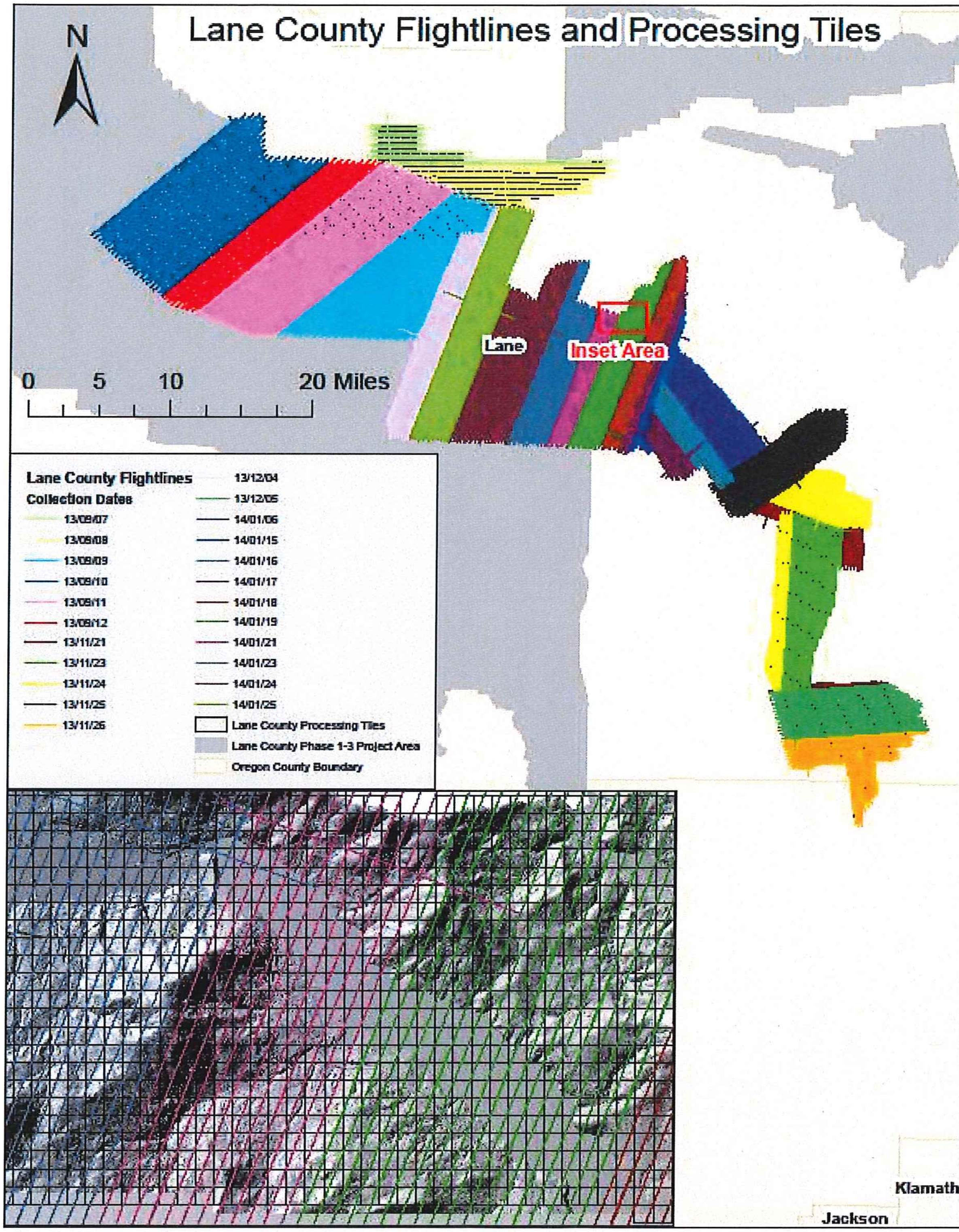

Figure 4. Spatial distribution of flight lines and an example of the processing tiles used in the consistency analysis

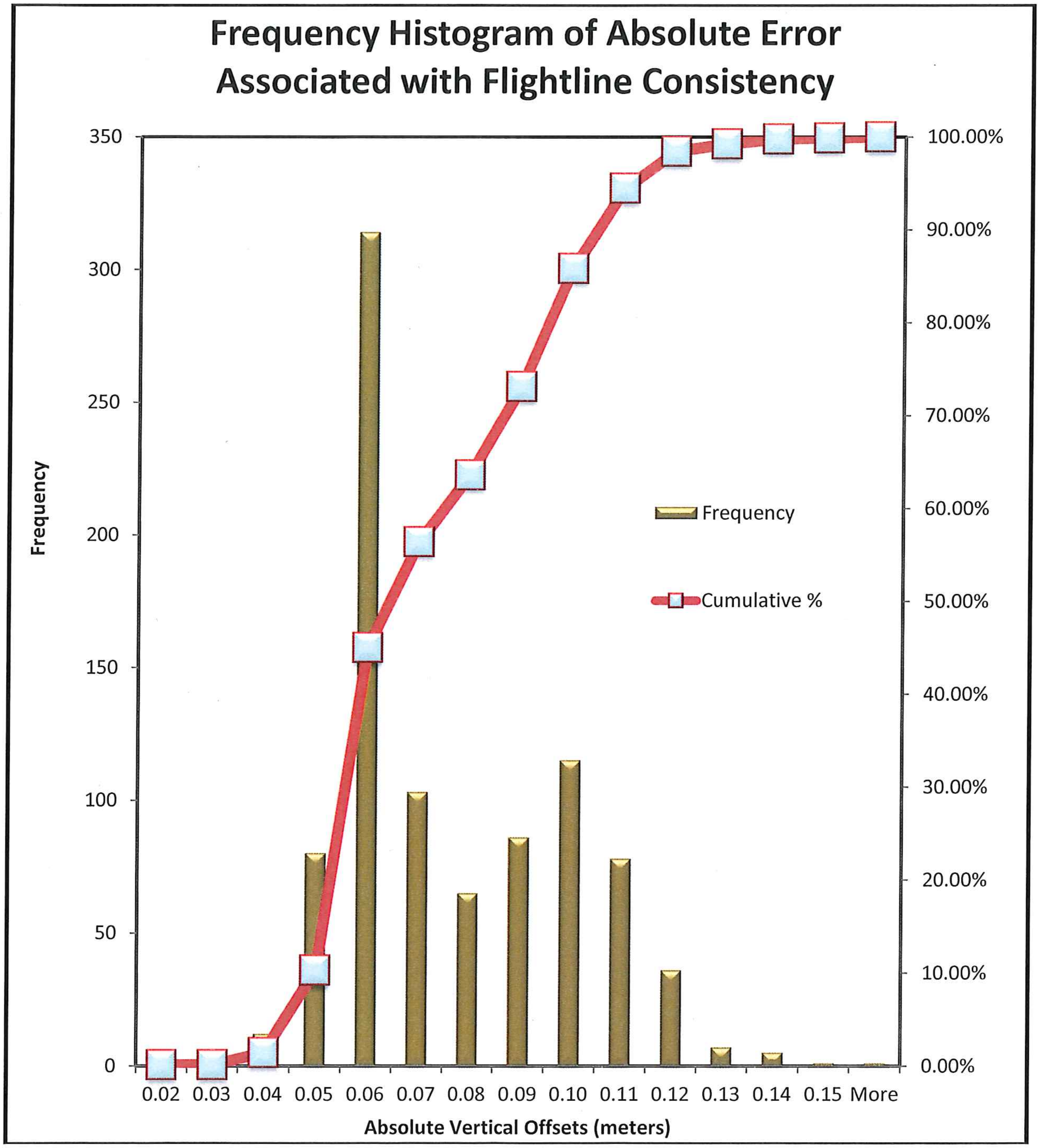

Figure 5. Flight line Consistency Histogram

DEM Quality Visual Inspection

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 6). Both bare-earth and highest hit models were examined for calibration offsets, tiling artifacts (Figure 7), seam line offsets, pits (Figure 8), and birds.

Calibration offsets typically are visualized as a corduroy-like pattern 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 7). 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 8). Birds (high points) typically occur where the laser comes into contact with atmospherics (atmospherics include clouds, rain, fog or virga).

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.

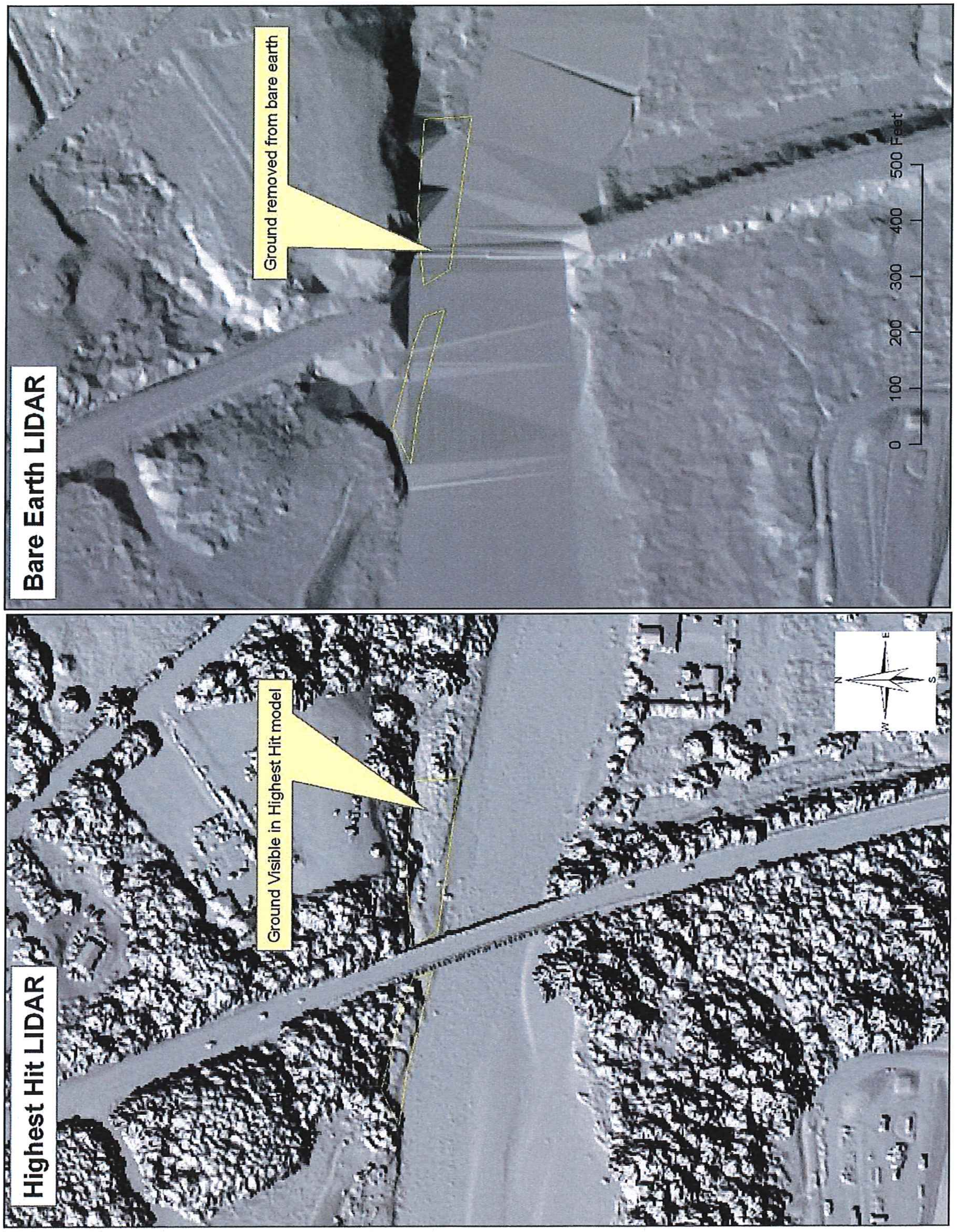

Figure 6. Example of missing ground in lidar bare earth data. Ground is clearly visible in highest hit model, but has been removed from the bare earth model. This type of classification error is common near water body features.

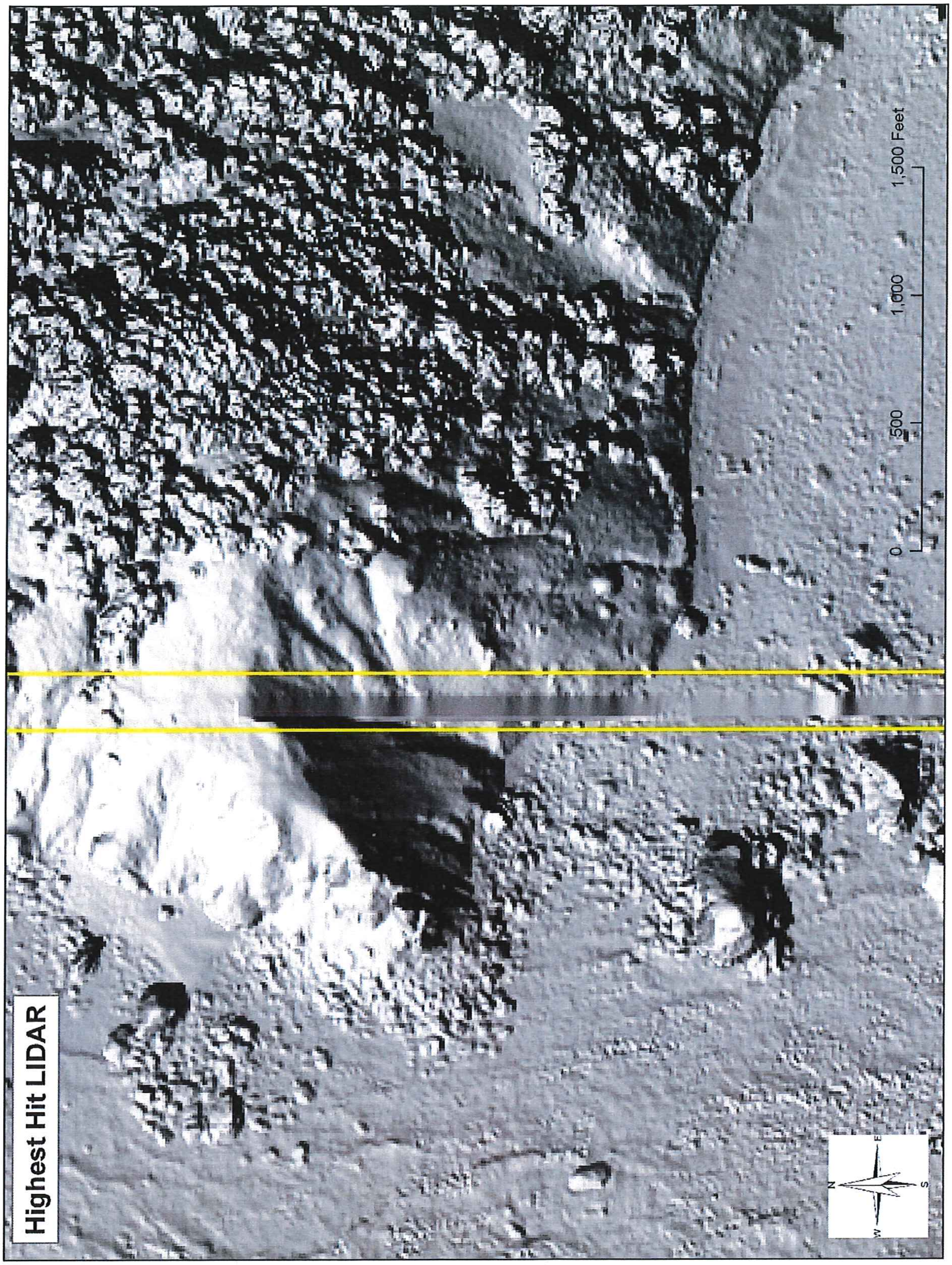

Figure 7. Example of tile artifact found in highest hit lidar data. Artifact is a seam line error created due to misclassification of ground at edge of lidar processing tiles.

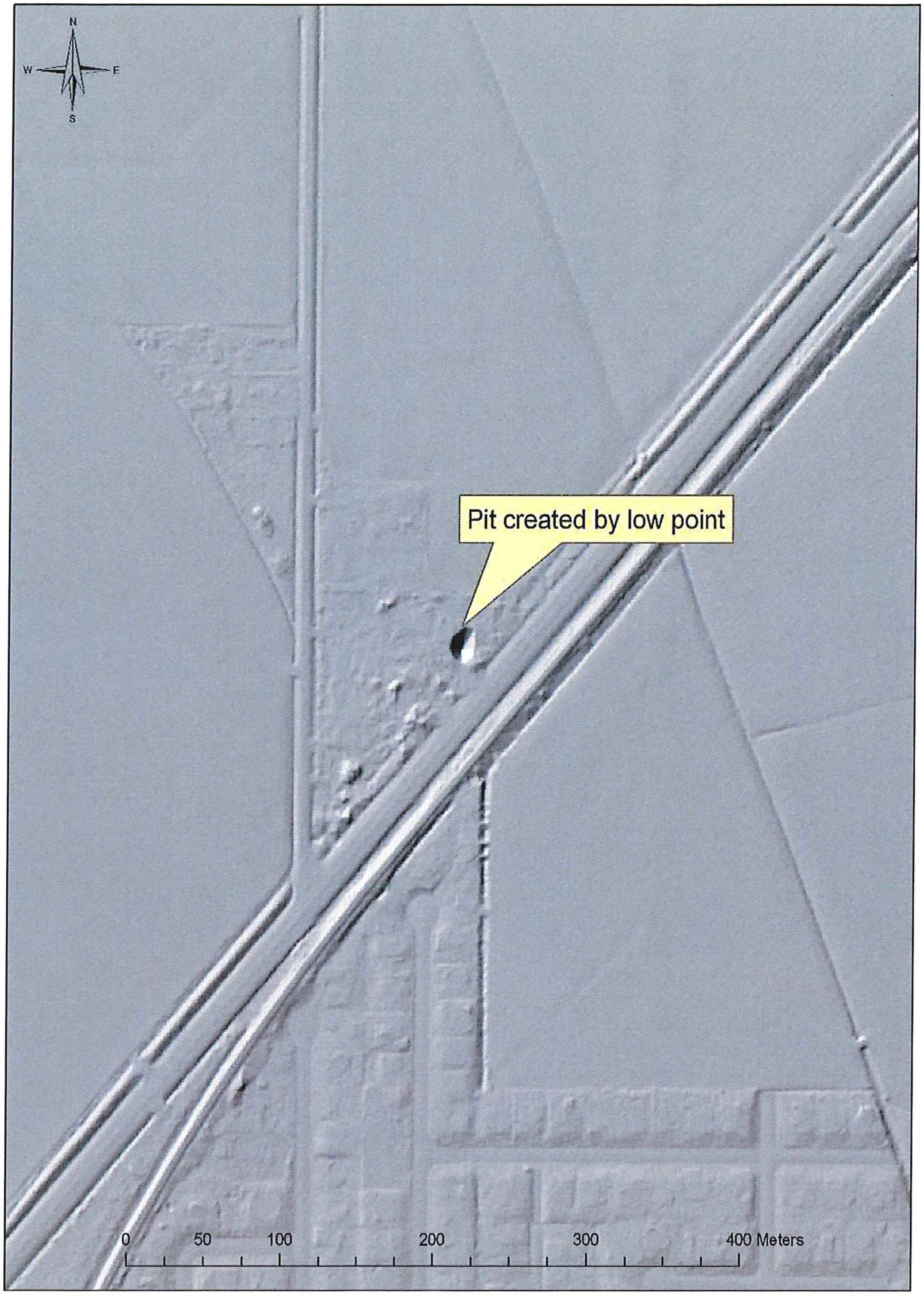

Figure 8. Example of "Pit" caused by low point in ground model. Pits are caused when standing water absorbs the lidar pulse. Pits are evident in ground model as the lowest point elevation is assigned to the grid cell value. Inversely the pit is not observable in the highest hit model as the highest point elevation is assigned to the grid value

Absolute Accuracy Analysis:

Absolute accuracy refers to the mean vertical offset of lidar data relative to measured ground-control points (GCP) obtained throughout the lidar sampling area. DOGAMI used a Trimble™ 5700/5800 Total Station GPS surveying system (Figure 9) to measure GCP's. This system consisted of a GPS base station (5700 unit), Zephyr Geodetic antenna, Trimmark 3 radio, and 5800 "rover". The 5700 base station was mounted on a fixed height (typically 2.0 m) tripod and located over a known geodetic survey monument followed by a site calibration on several adjacent benchmarks to precisely establish a local coordinate system. This step is critical in order to eliminate various survey errors. For example, Trimble reports that the 5700/5800 GPS system have horizontal errors of approximately ±1-cm + 1ppm (parts per million * the baseline length) and ±2-cm in the vertical (TrimbleNavigationSystem, 2005). These errors may be compounded by other factors such as poor satellite geometry, multipath, and poor atmospheric conditions, combining to increase the total error to several centimeters. Thus, the site calibration process is critical in order to minimize these uncertainties.

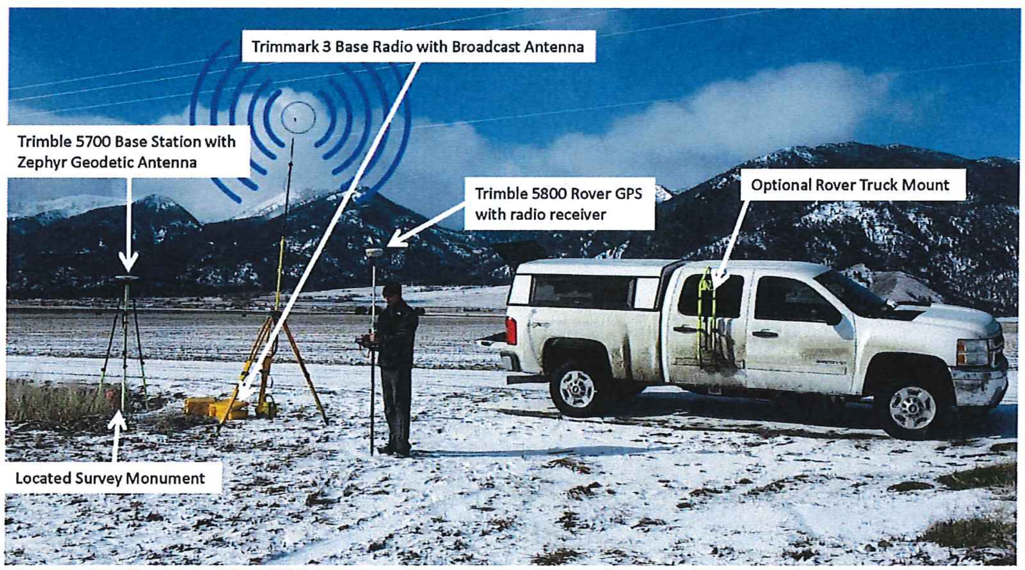

Figure 9. The Trimble 5700 base station antenna located over a known reference point outside Baker City. Corrected GPS position and elevation information is then transmitted by a Trimmark III base radio to the 5800 GPS rover unit.

The approach adopted for DOGAMI lidar surveys was comprised of two components:

1) Verify the horizontal and vertical coordinates established by WSI for a select number of survey monuments used to calibrate the lidar survey. These surveys typically involved a minimum of two hours of GPS occupation over a known point. The collected data were 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.
2) Collect GCP's along relatively flat surfaces (roads, paths, parking lots etc.). This step involved the collection of both continuous measurements (from a vehicle as well as from a backpack) as well as static measurements (typically 5 epochs).

Having collected the GCP data, the GPS data was post-processed using Trimble's Geomatic Office software. Data post-processing typically involved calibrations against at least three CORS stations as well as from local site calibrations performed in the field using those benchmarks that had been independently verified. Data is post processed to refine measurements so that horizontal and vertical errors are less than 0.02 meters (0.065 feet). Horizontal accuracy of data is tested by reoccupying a sample subset of survey monuments used for processing of lidar data. Each occupation's x and y coordinates are compared with the vendor coordinates for offsets.

DOGAMI collected GCP points on March 4th through March 7th 2014 and June 19th and 20th 2014. Ground conditions were good every day of collection with no snow and only minimal inclement weather on March 6th. The base stations used in the GCP data collection for Lane County Delivery 1 – 3 were located on monuments 13, 19, 24 and 34 which were established by WSI (See Report of Survey). Accuracy assessments of survey monuments are provided in the form of an OPUS solution from NGS, below is the OPUS solution for monument 13.

NAV FILE: brdc0620.14n	OBS USED: 5951 / 6211 : 96%
ANT NAME: TRM41249.00 SCIT # FIXED	AMB: 36 / 44 : 82%
ARP HEIGHT: 1.800	OVERALL RMS: 0.017(m)

REF FRAME:	NAD_83(2011) (EPOCH:2010.0000)		IGS08 (EPOCH:2014.1697)	
X:	-2501835.167(m)	0.017(m)	-2501836.022(m)	0.017(m)
Y:	-3853818.142(m)	0.016(m)	-3853816.920(m)	0.016(m)
Z:	4409086.400(m)	0.013(m)	4409086.422(m)	0.013(m)
LAT:	44 0 41.08496	0.010(m)	44 0 41.09806	0.010(m)
E LON:	237 0 32.51415	0.006(m)	237 0 32.45209	0.006(m)
W LON:	122 59 27.48585	0.006(m)	122 59 27.54791	0.006(m)
EL HGT:	119.032(m)	0.023(m)	118.644(m)	0.023(m)
ORTHO HGT:	142.473(m)	0.042(m)	[NAVD88 (Computed using GEOID12A)]	

	UTM COORDINATES UTM (Zone 10)	STATE PLANE COORDINATES SPC (3602 OR S)
Northing (Y) [meters]	4873140.441	263442.239
Easting (X) [meters]	500723.970	1300276.085
Convergence [degrees]	0.00627525	-1.70418938
Point Scale	0.99960001	1.00000292
Combined Factor	0.99958135	0.99998426

DOGAMI was able to test the horizontal accuracy of survey monuments used to reference the lidar data while conducting vertical control measurements. For internal purposes only, the XY coordinates of survey monuments surveyed by DOGAMI were compared to the survey monuments provided by the vendor. The average horizontal accuracy for all monument locations occupied by DOGAMI during GCP data collection is 0.008 meters Northing and 0.006

meters Easting (Table 3). The RMSE for positional accuracy for all monument locations occupied by DOGAMI during GCP data collection is 0.015 meters.

	meters	***feet***
Avg. Northing accuracy	0.008	0.026
Avg. Easting accuracy	0.006	0.019
Avg. RMSE for positional accuracy	0.015	0.059

Table 3. Average accuracy values for occupied monuments.

Vertical accuracy analysis of delivered lidar data consisted of differencing collected GCP data and the 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 610 measured GCP's were obtained in the Lane County delivery areas 1 – 3 (Figure 10) were compared with the lidar elevation grids. The data delivered to DOGAMI was found to have a mean vertical offset of -0.019 meters (-0.063 feet) and an RMSE value of 0.058 meters (0.189 ft). Offset values ranged from -0.061 to 0.052 meters (Table 4 and Figure 11).

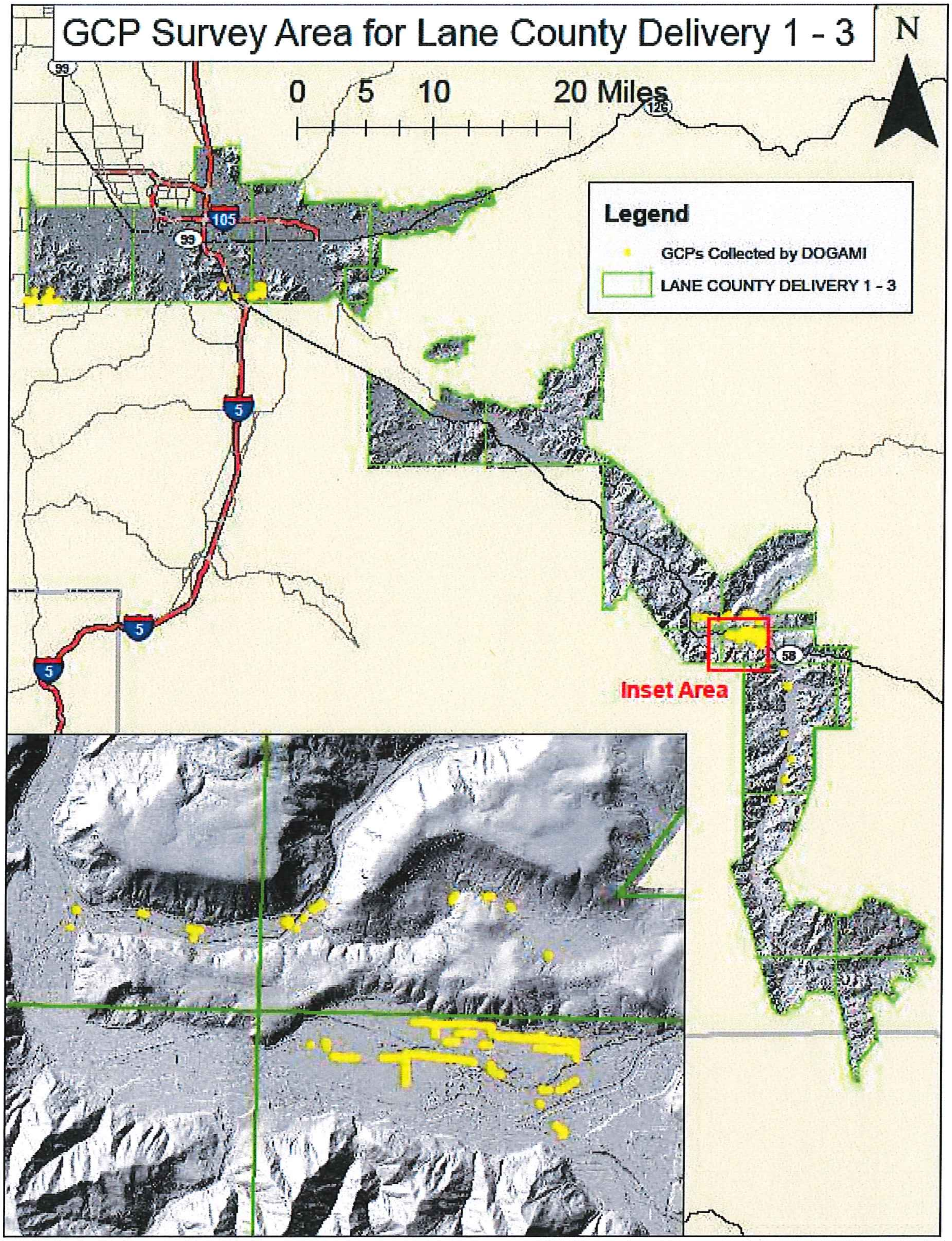

Figure 10. Locations of GCPs surveyed by DOGAMI staff. Data was used to test absolute accuracy for the Lane County lidar survey within the Delivery 1 - 3 project areas.

	Meters	*Feet*
Mean	-0.019	-0.063
Standard Error	0.001	0.003
Standard Deviation	0.025	0.083
Range	0.113	0.371
Minimum	-0.061	-0.199
Maximum	0.052	0.172
RMSE	0.058	0.189

Table 4. Descriptive Statistics for absolute value vertical offsets.

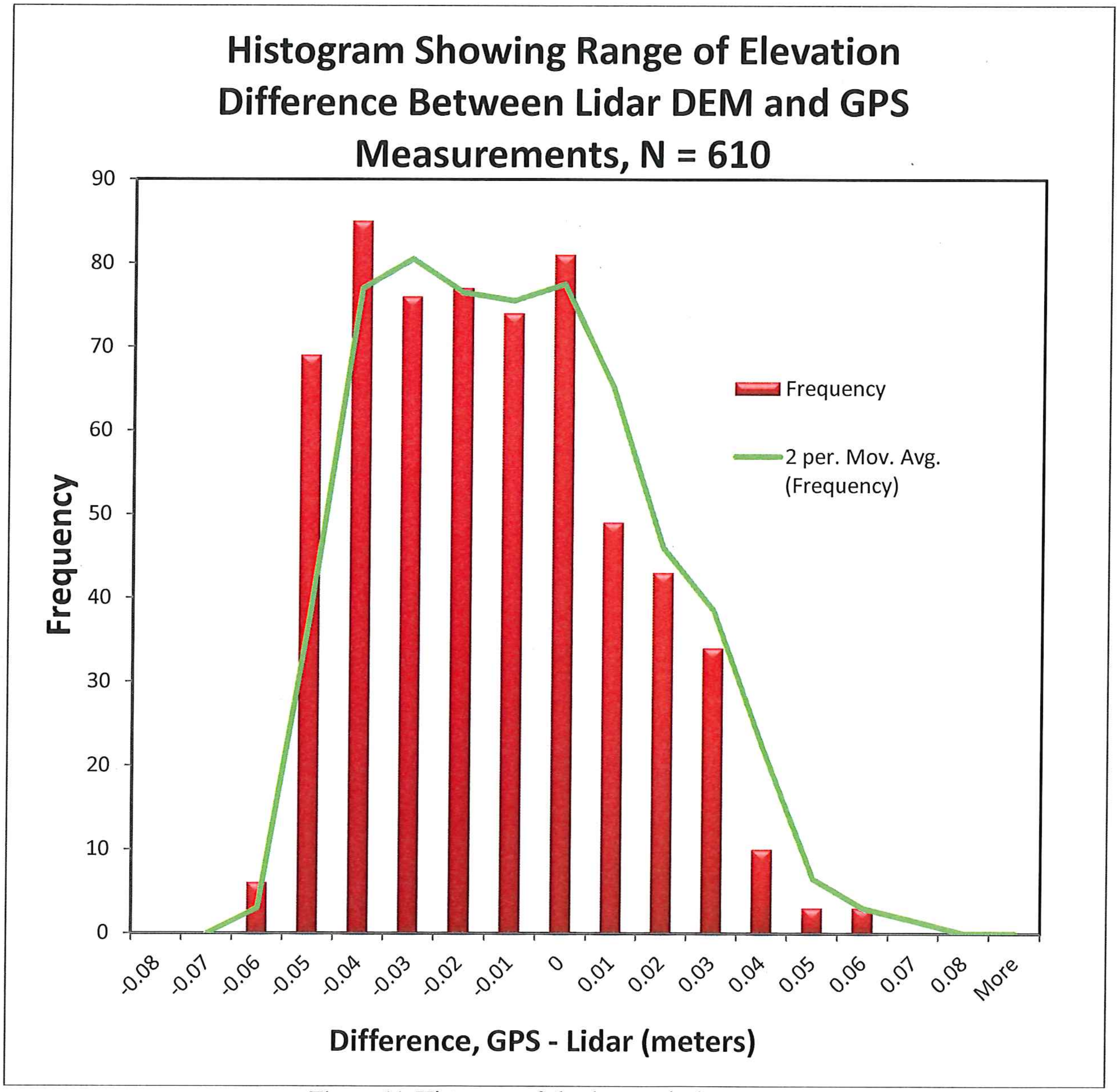

Figure 11. Histogram of absolute vertical accuracy

Ortho Imagery Quality by Visual Inspection

Aerial imagery was collected and processed by WSI to produce georeferenced and ortho-corrected 4 band, 8-bit imagery at 3 inch pixel size. The delivered raster data were checked for their completeness and positional accuracy. Positional accuracy was measured by comparing static features visible in both the orthoimagery and corresponding lidar intensity image (Figure 12). All orthoimagery files were reviewed by DOGAMI staff and imagery was found to have accuracy within 18 inches (one pixel), but since the intensity image has a 1.5ft pixel, that is the smallest error we can report. All ortho-imagery has been loaded and reviewed for completeness and reliability. Visual checks for gross seamline errors and warped pixels were performed by DOGAMI staff. All errors reported to WSI were corrected and resubmitted.

Figure 12. Comparison of orthoimagery to corresponding lidar intensity image

Metadata Analysis

Metadata analysis compared the structure of the metadata file against FGDC standards. Metadata content was reviewed by using a visual check as well as analysis by the USGS Geospatial Metadata validation service: http://geo-nsdi.er.usgs.gov/validation/ 76 metadata files, representing 10% of all metadata associated with this delivery were viewed by DOGAMI staff. No structure issues were found when validating the compliance of metadata to FGDC standards.

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 July 16th, 2013. Quality control has confirmed that all delivered data is within specification and function correctly. Quality Assurance has evaluated acquisition parameters to confirm that data was collected within project design scope. 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 the 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. Pulse density analysis has concluded that the multi-swath pulse density of the collection is higher than the 8.0 pulses per m^2 required by project specifications.

Approval Signatures

______________________ Date: 10/14/2014

Ian Madin
Chief Scientist – Department of Geology & Mineral Industries

______________________ Date: 10/14/2014

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