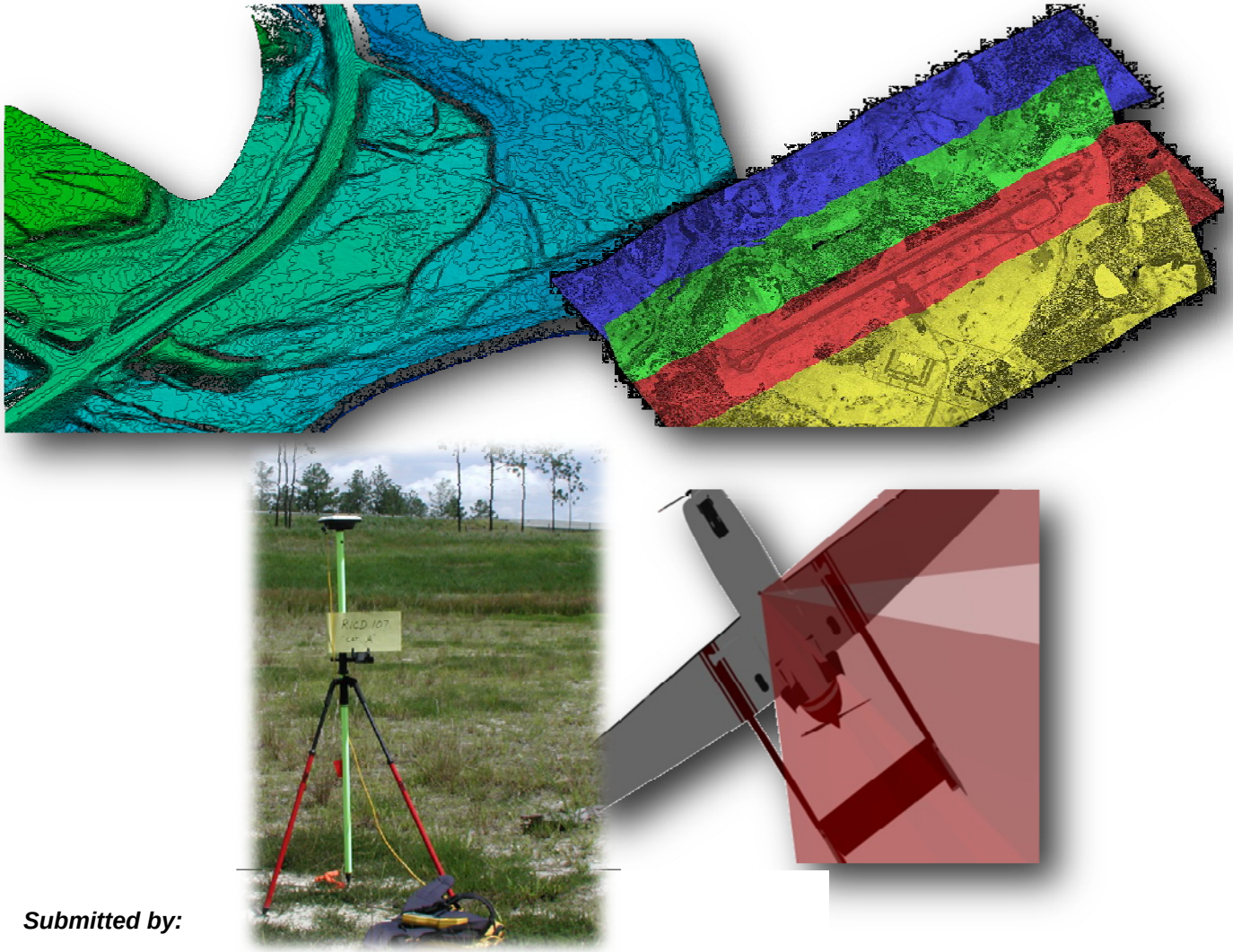
Region 9- Modoc

MODOC COUNTY, CALIFORNIA

Accuracy Assessment and QC Report

FEBRUARY 2012



Submitted by:

BakerAECOM
An Integrated Production Team

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1. INTRODUCTION

BakerAECOM performed an independent accuracy assessment and quality control review of the bare-earth randomly spaced LIDAR data collected and processed in 6 areas in Region 9 by DMI. The project was carried out using the specifications and the guidelines provided in the following documents.

1) FEMA's Flood Hazard Mapping Program; Guidelines and Specifications for Flood Hazard Mapping Partners - Appendix A, Guidance for Aerial Mapping and Surveying,

2) FEMA's Memorandum for Regional Risk Analysis Branch Chiefs, Procedure Memorandum No. 61: Standards for LiDAR and Other High Quality Digital Topography, Effective Date September 27, 2010;

3) U.S. Geological Survey (USGS), National Geospatial Program, LiDAR Guidelines and Base Specification, vers. 13, Effective Date February 22, 2010;

4) American Society for Photogrammetry and Remote Sensing (ASPRS), ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, vers. 1.0, May 24, 2004.

5) National Geodetic Survey (NGS), NOAA Technical Memorandum NOS NGS-58, Guidelines for establishing GPS-Derived Ellipsoid Heights, (Standards: 2cm and 5 cm), Vers. 4.3., November, 1997.

This document presents the results of the accuracy assessment and quality review.

1.1 PROJECT SITE AND PARAMETERS

The following table provides a summary of the project area and related parameters.

Table 1 Parameters for Region 9 Project Sites

PROJECT SITE PARAMETERS	MODOC, CA
Nominal Pulse Spacing (NPS)	< 1 m
FEMA Project Area (Sq. Miles)	42
Acquisition Area (Sq. Miles)*	43
Equivalent Contour Accuracy	2 ft
Bare Earth Processing Area (Sq. Miles)	21

*The Acquisition Area contains the original FEMA Project Area and the required 100 meter buffer as defined in PM No. 61.

The study area has been shown in Fig 1.

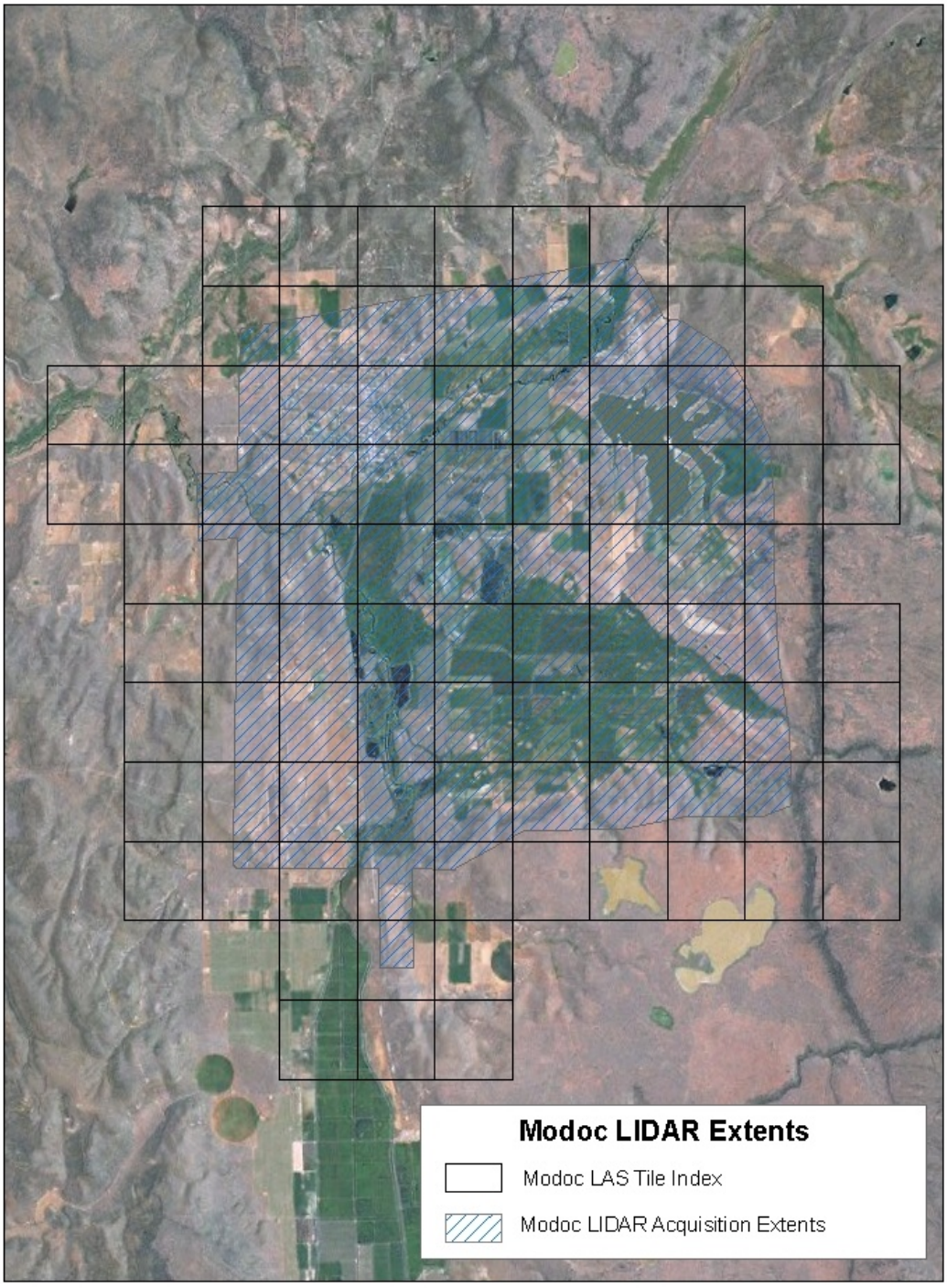

FIG 1: PROJECT SITE MAP

1.2 LiDAR Preliminary Processing (Acquisition Area)

LiDAR Preliminary Processing was performed by Digital Mapping, Inc. (DMI) for the entire acquisition area. Preliminary processing involves filtering the data for noise, differentially correcting, and assembling data into flight lines by "return layer." This processing computes the laser point coordinates from the independent data parameters: scanner position, orientation parameters, scanner angular deflection, and the laser pulse time of flight, or slant range. The deliverable of the preliminary processing task is a fully calibrated point cloud data set, unclassified, which has been tiled and prepared for delivery in LAS v. 1.3 format.

1.3 LiDAR Post- Processing (Bare Earth Area)

LiDAR Post-Processing consists of classifying the LiDAR data's first and last return data points to remove vegetation and buildings. This process is restricted to the floodplain areas as defined by the Bare Earth Processing Areas. Points were filtered, and those representing above ground features (such as trees and buildings) have been classified "out" to obtain points that represent the ground surface. Acceptable data with voids (e.g., water or low near infrared reflectivity, such as freshly laid asphalt) are excluded from the final data.

The deliverable of the post-processing task is a classified point cloud delivered in full compliance with LAS classes:

1	processed, but unclassified
2	bare-earth ground
7	noise
9	water
10	ignored
11	withheld (all points not identified as "withheld" are to be classified)
12	Overlap (Shall not be used)

1.4 Hydrologically-Enforced Water Bodies

Hydro break lines were compiled at a minimum, for inland ponds and lakes that are 2 acres or larger; for inland streams with a nominal width of 100 feet or greater; and for tidal waters, such as oceans, seas, gulfs, bays, inlets, salt marshes, and very large lakes. FEMA will use this break lines to generate hydrologically-enforced products.

1.5 Breaklines

As part of the terrain deliverable, topologically structured, 3-dimensional (3-D) hydrology coverage in ESRI personal geodatabase format created from newly generated 3-D breaklines is required. The primary function of the hydrology dataset is to supplement and constrain TINs created from the LIDAR data; however it is also provides additional benefits to the engineers for hydrologic and hydraulic (H&H)

modeling. Because LIDAR data contains only points, the ability of a LIDAR-only terrain model to capture detailed linear features in their precise 3-D location is limited in some locations.

1.6 Survey for Check Points

To perform accuracy assessments of the LiDAR data, BakerAECOM acquired survey field checkpoints.

The following table lists the project site and the number of check points acquired.

Table 2 Check Point Survey for QA/QC

	Modoc, CA
Acquisition Area (square miles)	43
FVA Check Points*	25
Bare Earth Processing Area (square miles)	21
SVA Check Points (weeds and crops)**	5
SVA Check Points (brush and trees)	5
SVA Check Points (forested)	0
SVA Check Points (urban)	3
Total Number of Check Points	**38**

***FVA – Fundamental Vertical Accuracy**
****SVA – Supplemental Vertical Accuracy**

1.7 QA/QC Process

As part of the LIDAR acquisition proposed through Task Order HSFEHQ-10-J-0010, BakerAECOM performed the following QA/QC efforts under two mile stones:

Milestone 1 – LiDAR data QA/QC for acquisition area

Milestone 2 – LiDAR data QA/QC for processing area

2. MILESTONE 1 – LIDAR DATA QA/QC FOR ACQUISITION AREA

2.1 PROJECT BACKGROUND INFORMATION

The project background info for Modoc is given in Table 3.

Table 3 Project Background Info (All Predefined Information)

PROJECT AREA	SQUARE MILES
Points Spacing	1M
Point Density	1.63 average
Multiple Returns	Yes
Altitude	1200m
Overlap	35%
Pulse Rate	70 KHz
Scan Freq	39 Hz
Desired Resolution	0.804 m
Cross Track Resolution	0.818 m
Down Track Resolution	0.791 m
Points / Square Meter	1.55 m2
ASPRS Classification Scheme	Class 1 = Unclassified; and Class 11 = Withheld

Upon receipt of milestone 1 deliverables from DMI, BAKERAECOM performed the inventory of the deliverables based on the check list given in Table 4.

Table 4 Milestone 1 Check List

	NOT DELIVERED	PARTIAL DELIVERY	COMPLETE DELIVERY	COMMENTS
Pre-flight Operations Plan (Table 4.1, PM 61 Page 21)			X	
Pre-flight Review Checklist (PM 61 Page 25)			X	
Field Survey Control Report in accordance with FEMA Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying; Sec. A.6.5, Page A-29.			X	
Post- flight Aerial Survey and Calibration Report (Table 4.2, PM 61 Page 22)			X	
Post-flight Review Checklist (PM 61, Page 25)			X	
Checklist for Aerial Acquisition Report (PM 61, Page 26)			X	

	Not Delivered	Partial Delivery	Complete Delivery	Comments
Macro Review of Fully Calibrated Raw Point Cloud (Table 4.3, PM 61, Page 23)			X	
SBET File (Smoothed Best Estimate of Trajectory)			X	
All Raw Range Files (.range)				
Fully calibrated, unclassified point cloud data in LAS v 1.3 format in compliance with USGS LiDAR Guidelines and Base Specification, v13.			X	
Raw Flight Data Path Screen Shots Showing Data Coverage			X	
Tiling Scheme used as a Shapefile with tile names			X	
Milestone 1 MetaData			X	

2.2 Survey Related

The QA/QC process for survey control was performed based on the check list given in Table 5.

Table 5 Control Points used in Data Acquisition

Control Points used in Data Acquisition	
1. Check survey report for completeness.	Yes
2. Check proper order, distribution, type and stability of NGS NSRS stations, both horizontal and vertical.	Yes
3. Check baseline lengths to determine if proper network stations have been set up, local, secondary, primary, etc.	Yes
4. Check each baseline vector has been observed twice and to agree to 5 cm vertically.	Yes
5. Check processing computation results for outlying vectors, large residuals, observations failing tests, etc.	Yes

2.3 COMPLETENESS OF DATA – VISUAL

Examination of Pre-flight Operations Plan as given in Table 6.

Table 6 Pre-flight Operations Plan

ITEM	CONTENT	FORMAT	PASS/FAIL/MINOR	COMMENTS (COMPLETED/NOT COMPLETED)
Flight Operations Plan	Planned flight lines – sufficient coverage, spacing and length		Pass	
	Planned GPS stations		Pass	
	Planned ground control- sufficient to control and boresight.		Pass	
	Planned Airport location		Pass	
	Calibration plan		Pass	
	Planned Sensor setting and altitude		Pass	
	Procedure for tracking, executing and checking reflights.		Pass	
	Type of Aircraft and use of ABGPS		Pass	
	Project design supports accuracy requirements.		Pass	
	Project design supports diff land cover and terrain.		Pass	

Examination of Post-flight Aerial Acquisition and Calibration Reports as given in **Table 7.**

Table 7 Post Flight Aerial Acquisition and Calibration Report

ITEM	CONTENT	FORMAT	REPORTS INCLUDED	COMMENTS
GPS base station info	Base station name	ESRI shape file along with attributes.	Yes	
	Latitude& Longitude			
	Base Height,			
	PDOP			
	Map of location			
GPS and IMU processing summary	Maximum horizontal and vertical GPS variance	MS Word/Excel report	Yes	
	GPS separation plot			
	Altitude plot			
	PDOP plot			
	Plot of GPS base station from base station.			
Coverage	Verification of Project coverage	ESRI shape file	Yes	
Flight lines	As flown trajectories	ESRI shape file	Yes	
	Calibration lines			
Flight logs	Pilot, Operator name	MS Word/Excel	Yes	
	AGC switch setting			
	LASER Pulse			
	Mirror rate			
	Field of view			
	Date			
Control	Ground control and Base station layouts	ESRI shape files	Yes	
Data Verification/QC	Description of Data verification QC process	MS Word/Excel/Pdf	Yes	
	Results of Verification and QC steps			

Examine completeness of data on the following and summarized in Table 8:

- Naming convention
- File format
- Vertical and Horizontal coordinate system
- Classification
- Georeferencing

Table 8 Completeness Table

LIDAR DTM AND COMPLETENESS/USABILITY ACCEPTANCE	CHARACTERISTICS	METHOD OF CHECKING
Format and post spacing of LiDAR Mass Points	.LAS with 1.55 m/ sq m	Automatic
Units - Horizontal	U.S. Survey Feet	Automatic
Units - Vertical	U.S. Survey Feet	Automatic
Datum - Horizontal	NAD 83	Automatic
Datum - Vertical	NAVD 88, processed with Geoid03	Automatic
Classification used	Class 1 = unclassified; Class 11 = Withheld	Automatic
Flight lines	Flight lines flown as planned with 35-% overlap between flight swaths, correct altitude (1200' above mean terrain), PDOP < 4; no holidays; periodic, local, calibration checks.	Visual
Filename and Organization	Tiling scheme and 5000 X 5000 ft	Visual
Georeferencing	Opens in the correct location based on the tile grid provided by the Client.	Visual
Conformance of sheet to index grid (Las files to tile scheme polygon)	No gaps between the tiles and matches at grid line at 1:1 view.	Visual

2.4 DATA DENSITY AND DATA VOID CHECK

The data density for this data is expected to be 1 point in 1mX1m grid as the data has been collected with 1m NPS. The data void in the data was checked based on the guidelines given in USGS V13. A regular grid, with cell size equal to the design NPS*2 will be laid over the data. At least 90% of the cells in the grid shall contain at least 1 LiDAR point.

The results on Data Density and Data Void are summarized in Appendix 1.
Both the results are within the specs and the data is accepted.

2.5 CHECK POINT ANALYSIS

The check points collected independently were validated and are provided in Table 9.

Table 9 Analysis of Checkpoint

Check number of FVA points and their distribution	Yes
Check number of SVA points within each class category	Yes
Check the photographs of the all points to the appropriateness	Several show close up of GPS Rod, not showing the surroundings. Not critical.
Check Type, order and stability of the base stations used.	Yes
Check baseline vectors for length (20KM)	1 Found (sec4-str-fva4). Not critical.
Check adjustment for reliability.	Fixed cords off by a few hundredths. EG center of POP N0.09, U25 Elves 0.07'-Not significant.
Check duplicated baseline vectors for 5 cm rule	OK. Sampled
Check survey report for completeness	Yes

2.6 FUNDAMENTAL VERTICAL ACCURACY

Fundamental Vertical Accuracy (FVA) is defined as "The value by which vertical accuracy can be equitably assessed and compared among datasets. The FVA is determined with vertical checkpoints located only in open terrain, where there is a very high probability that the sensor will have detected the ground surface." (FEMA Procedure Memorandum No. 61- Standards for LiDAR and Other High Quality Digital topography, September, 27, 2010, Page 6) The twenty-five (25) points are to be evenly distributed throughout the project area.

The FVA has been computed and the results are given in Table 10.

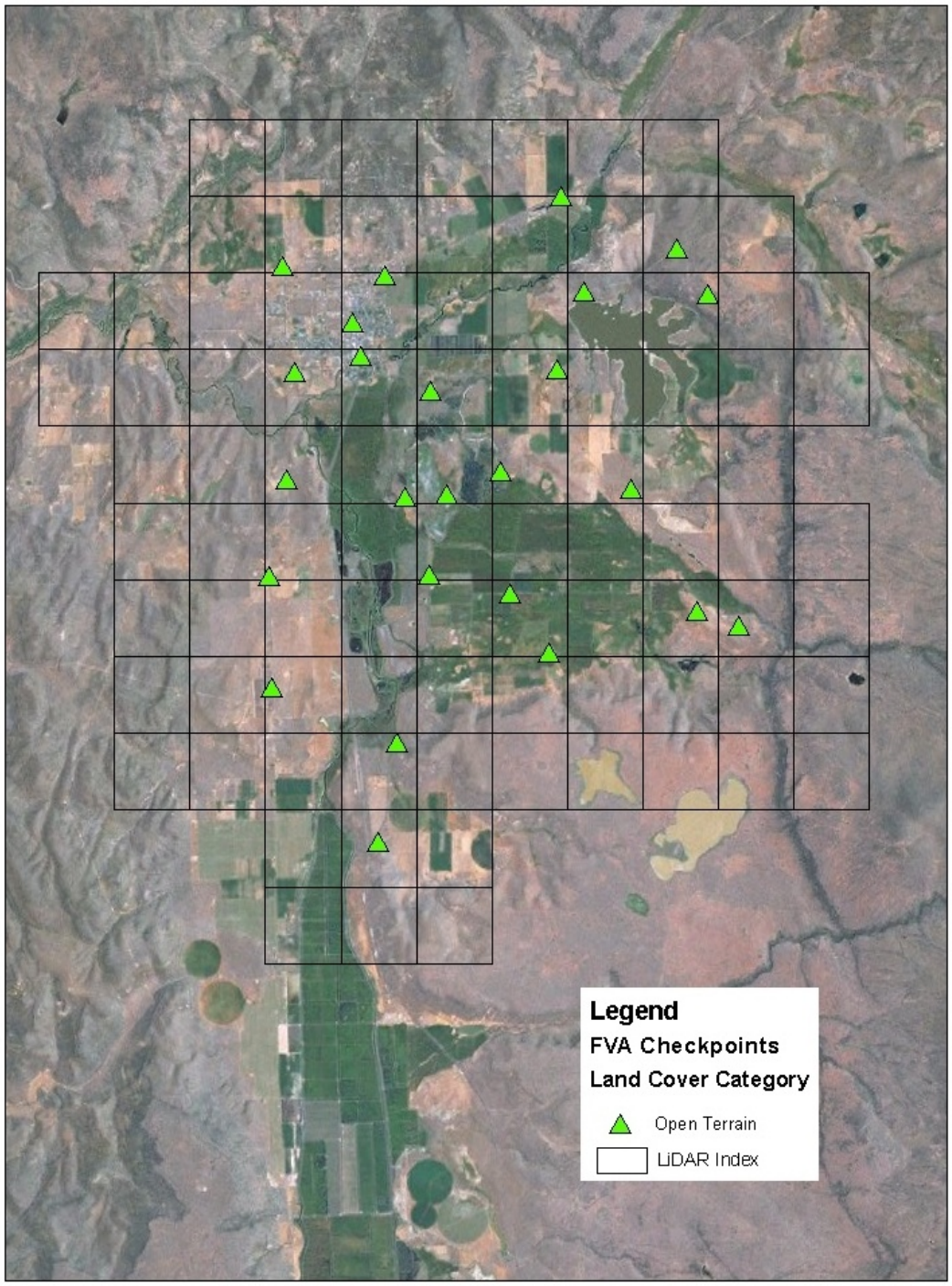

Fig 2: The FVA point's distribution is shown in the above diagram and results are summarized in the following table.

Table 10 Fundamental Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ΔZ²
1	*1*	6956185.491	6956185.491	2433131.808	2433131.808	4411.353	4411.0872	0.2658	0.0706496
2	*2*	6974662.413	6974662.413	2437742.37	2437742.37	4411.408	4411.2748	0.1332	0.0177422
3	*3*	6982352.482	6982352.482	2434308.038	2434308.038	4516.138	4515.8884	0.2496	0.0623002
4	*4*	6962951.544	6962951.544	2432559.873	2432559.873	4384.598	4384.5305	0.0675	0.0045563
5	*5*	6960867.586	6960867.586	2429431.695	2429431.695	4370.828	4370.728	0.1	0.01
6	*6*	6976172.165	6976172.165	2431414.887	2431414.887	4451.165	4451.01	0.155	0.024025
7	*7*	6984337.173	6984337.173	2431278.688	2431278.688	4496.751	4496.6506	0.1004	0.0100802
8	*8*	6957012.622	6957012.622	2426074.639	2426074.639	4394.915	4394.6894	0.2256	0.0508954
9	*9*	6961359.825	6961359.825	2427125.115	2427125.115	4365.663	4365.5684	0.0946	0.0089492
10	*10*	6966015.747	6966015.747	2424853.463	2424853.463	4372.055	4371.8265	0.2285	0.0522123
11	*11*	6974400.244	6974400.244	2426241.731	2426241.731	4409.805	4409.6631	0.1419	0.0201356
12	*12*	6956496.441	6956496.441	2418927.598	2418927.598	4383.775	4383.4763	0.2987	0.0892217
13	*13*	6964303.211	6964303.211	2417815.296	2417815.296	4363.103	4362.8433	0.2597	0.0674441
14	*14*	6967063.878	6967063.878	2417949.448	2417949.448	4367.339	4367.1046	0.2344	0.0549434
15	*15*	6970663.785	6970663.785	2419505.813	2419505.813	4383.062	4382.8952	0.1668	0.0278222
16	*16*	6979320.539	6979320.539	2418311.565	2418311.565	4448.272	4448.0719	0.2001	0.04004
17	*17*	6955301.844	6955301.844	2412567.914	2412567.914	4380.781	4380.4525	0.3285	0.1079122
18	*18*	6965881.161	6965881.161	2412665.02	2412665.02	4364.672	4364.5102	0.1618	0.0261792
19	*19*	6973843.418	6973843.418	2407476.457	2407476.457	4407.336	4407.021	0.315	0.099225
20	*20*	6971285.204	6971285.204	2411413.856	2411413.856	4380.491	4380.3157	0.1753	0.0307301
21	*21*	6983636.773	6983636.773	2410192.767	2410192.767	4533.74	4533.3113	0.4287	0.1837837
22	*22*	6986442.316	6986442.316	2409240.273	2409240.273	4539.888	4539.5161	0.3719	0.1383096
23	*23*	6955527.832	6955527.832	2405164.011	2405164.011	4438.292	4437.9934	0.2986	0.089162
24	*24*	6963799.493	6963799.493	2401541.641	2401541.641	4375.257	4375.1037	0.1533	0.0235009
25	*25*	6962504.035	6962504.035	2394869.194	2394869.194	4394.13	4394.1242	0.0058	3.364E-05
								Sum	1.3098536
								Average	0.0523941
								RMSEr	0.2288977
								FVA (ft)	**0.449**
								FVA (cm)	**13.69**

Modoc tested 0.449 ft (13.69 centimeters) Fundamental Vertical Accuracy at 95% confidence level in open terrain using RMSEz x 1.9600. The Modoc FVA value passes the minimum requirement of 24.5 centimeters. The table above describes the points and statistics associated with the FVA testing.

3. MILESTONE 2 – LIDAR DATA QA/QC FOR PROCESSED AREA

Milestone 2 review consists of a quantitative analysis of the supplemental and consolidated vertical accuracy as well as a qualitative review of classified bare earth LiDAR and breaklines. Supplemental and consolidated vertical accuracies are checked by comparing the elevation differences from surveyed points in a variety of land cover categories to the bare earth TIN surface created from the classified LiDAR. Qualitative review of the LiDAR is a visual inspection of the data for voids or gaps, noise, artifacts, aggressive filtering, continuity between swaths, breakline connectivity, monotonicity, topology, etc.

3.1 QUANTITATIVE ANALYSIS

Supplemental Vertical Accuracy (SVA) is the result of a test of accuracy of z-values over areas with ground cover categories or combination of categories other than open terrain. Each land cover type representing 10% or more of the total project area was tested and reported as an SVA.

The SVA has been computed and the results are given in Table 11.

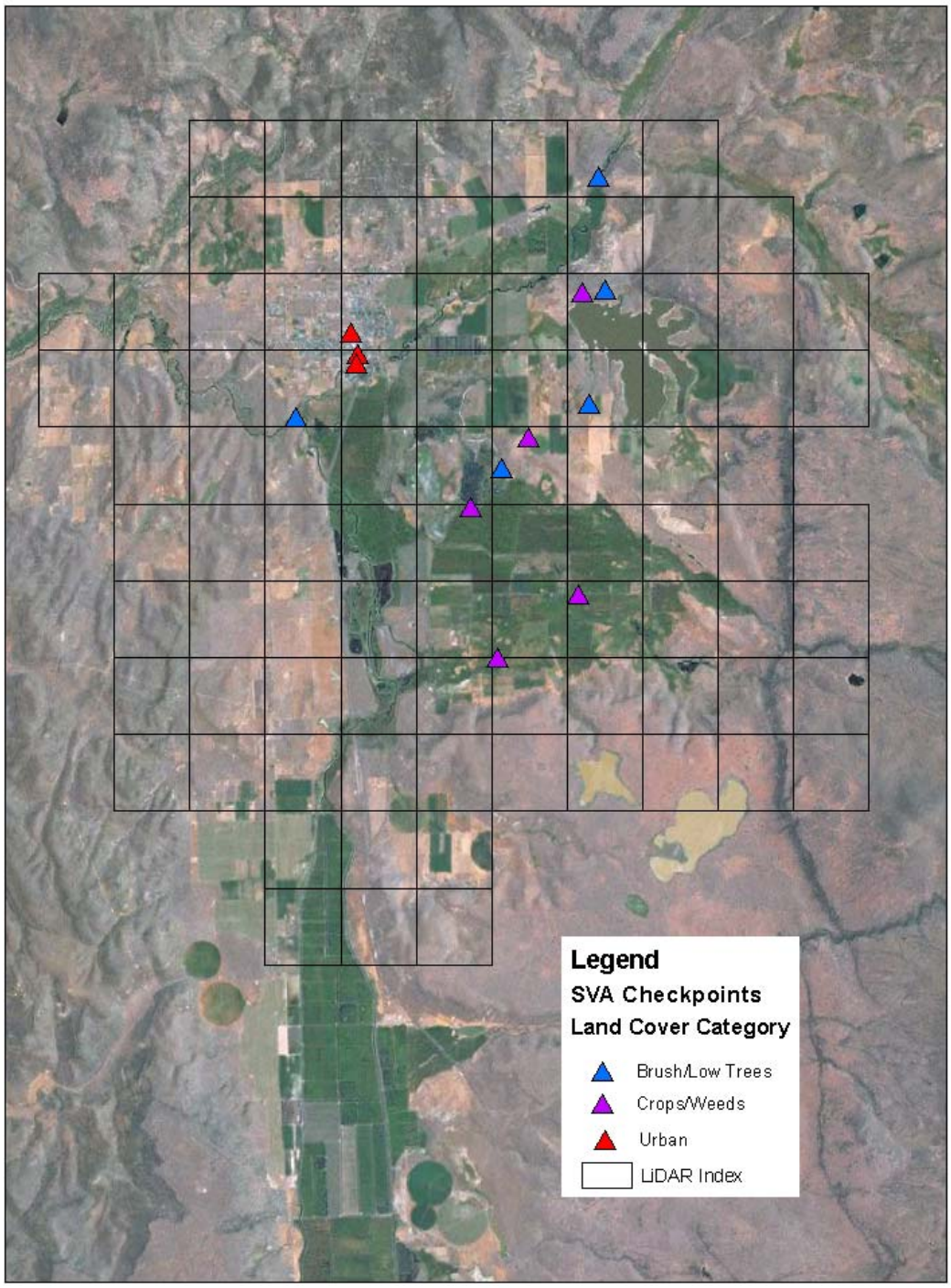

Fig 3: The SVA points' distribution is shown in the above diagram and results are summarized in the following table.

Table 11 Supplemental Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ABS ΔZ
31	SVA31CW	6968652.564	6968652.564	2417175.566	2417175.566	4366.364	4366.393	-0.029	0.029
32	SVA32CW	6975801.648	6975801.648	2411393.563	2411393.563	4395.086	4394.922	0.164	0.164
33	SVA33CW	6972539.789	6972539.789	2421778.933	2421778.933	4444.477	4444.400	0.077	0.077
34	SVA34CW	6970470.659	6970470.659	2407216.986	2407216.986	4378.976	4378.873	0.103	0.103
35	SVA35BT	6977142.164	6977142.164	2439151.980	2439151.980	4414.617	4414.685	-0.068	0.068
36	SVA36U	6960723.745	6960723.745	2428762.546	2428762.546	4371.102	4370.838	0.264	0.264
37	SVA37U	6961181.735	6961181.735	2427311.068	2427311.068	4366.181	4365.947	0.234	0.234
38	SVA38U	6961121.145	6961121.145	2426752.556	2426752.556	4366.540	4366.181	0.359	0.359
41	SVA41BT	6957112.007	6957112.007	2423183.538	2423183.538	4357.693	4357.493	0.200	0.200
42	SVA42BT	6976528.573	6976528.573	2424019.466	2424019.466	4411.120	4410.749	0.371	0.371
43	SVA43BT	6977619.595	6977619.595	2431656.255	2431656.255	4449.233	4449.193	0.040	0.040
44	SVA44BT	6970695.202	6970695.202	2419759.647	2419759.647	4382.631	4382.605	0.026	0.026
52	SVA52CW	6976090.867	6976090.867	2431409.397	2431409.397	4450.608	4450.506	0.102	0.102
								SVA (ft)	**0.364**
								SVA (cm)	**11.093**

Modoc tested 0.364 ft (11.09 centimeters) supplemental vertical accuracy at 95th percentile in urban areas and brush lands and low trees. The Modoc SVA value passes the minimum requirement of 36.3 centimeters. The table above describes the points and statistics associated with the SVA testing.

Consolidated Vertical Accuracy (CVA) is the result of a test of accuracy z-values consolidated for two or more of the major land cover categories, representing both open terrain and other land cover categories.

The CVA has been computed and the results are given in Table 12.

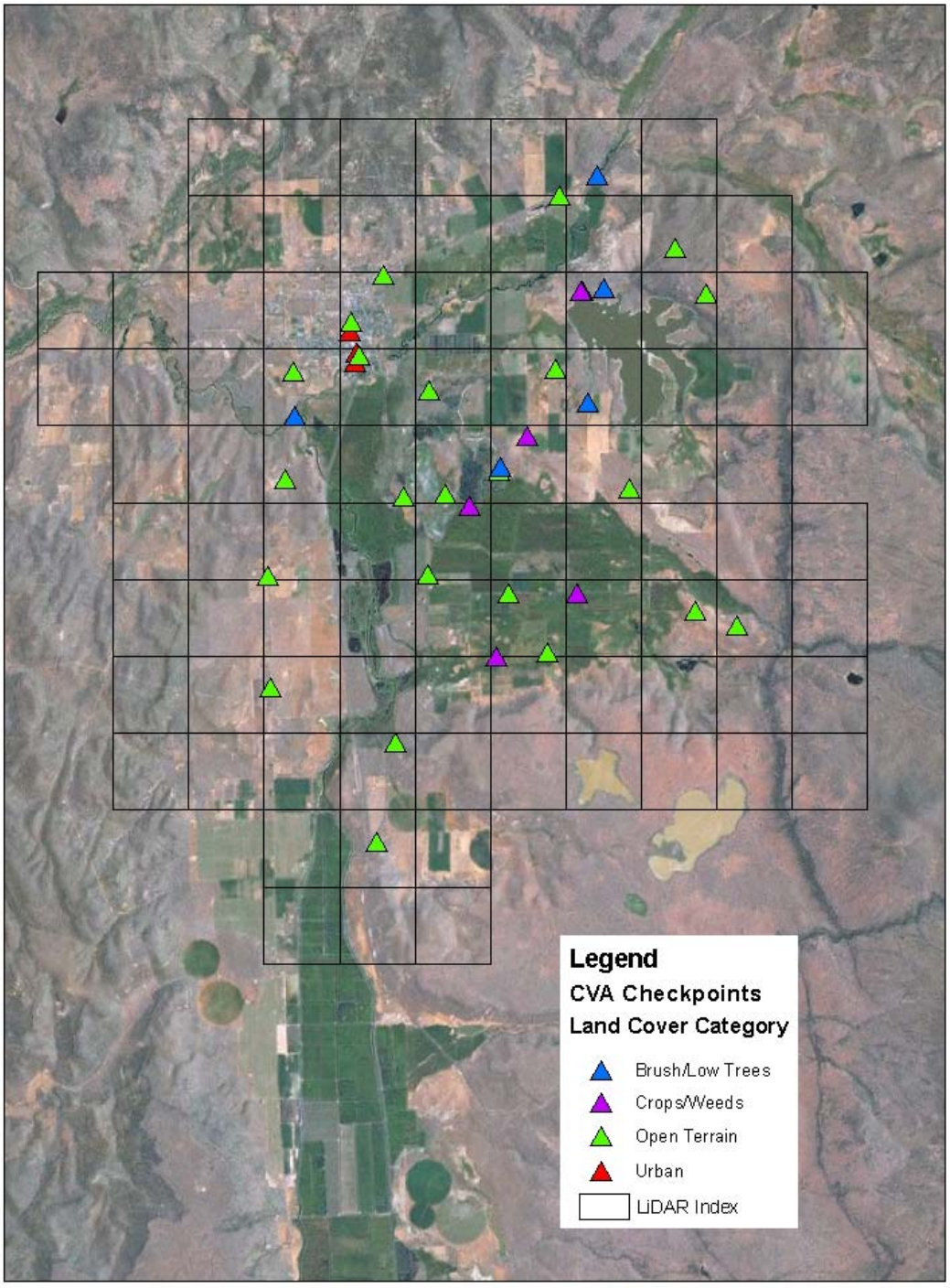

Fig 4: The CVA points' distribution is shown in the above diagram and results are summarized in the following table.

Table 12 Consolidated Vertical Accuracy

POINT	ALIAS	X (CONTROL)	X (LIDAR)	Y (CONTROL)	Y (LIDAR)	Z (CONTROL)	Z (LIDAR)	ΔZ	ABS ΔZ
1	FVA1	6962504.035	6962504.035	2394869.194	2394869.194	4394.130	4394.124	0.006	0.006
2	FVA2	6955527.832	6955527.832	2405164.011	2405164.011	4438.292	4437.993	0.299	0.299
3	FVA3	6963799.493	6963799.493	2401541.641	2401541.641	4375.257	4375.000	0.257	0.257
4	FVA4	6973843.418	6973843.418	2407476.457	2407476.457	4407.336	4407.044	0.292	0.292
5	FVA5	6986442.316	6986442.316	2409240.273	2409240.273	4539.888	4539.487	0.401	0.401
6	FVA6	6955301.844	6955301.844	2412567.914	2412567.914	4380.781	4380.448	0.333	0.333
7	FVA7	6965881.161	6965881.161	2412665.020	2412665.020	4364.672	4364.510	0.162	0.162
8	FVA8	6971285.204	6971285.204	2411413.856	2411413.856	4380.491	4380.299	0.192	0.192
9	FVA9	6983636.773	6983636.773	2410192.767	2410192.767	4533.740	4533.418	0.322	0.322
10	FVA10	6956496.441	6956496.441	2418927.598	2418927.598	4383.775	4383.435	0.340	0.340
11	FVA11	6964303.211	6964303.211	2417815.296	2417815.296	4363.103	4362.852	0.251	0.251
12	FVA12	6970663.785	6970663.785	2419505.813	2419505.813	4383.062	4382.939	0.123	0.123
13	FVA13	6979320.539	6979320.539	2418311.565	2418311.565	4448.272	4448.072	0.200	0.200
14	FVA14	6957012.622	6957012.622	2426074.639	2426074.639	4394.915	4394.690	0.225	0.225
15	FVA15	6966015.747	6966015.747	2424853.463	2424853.463	4372.055	4371.890	0.165	0.165
16	FVA16	6974400.244	6974400.244	2426241.731	2426241.731	4409.805	4409.663	0.142	0.142
17	FVA17	6984337.173	6984337.173	2431278.688	2431278.688	4496.751	4496.703	0.048	0.048
19	FVA19	6962951.544	6962951.544	2432559.873	2432559.873	4384.598	4384.530	0.068	0.068
20	FVA20	6976172.165	6976172.165	2431414.887	2431414.887	4451.165	4451.012	0.153	0.153
21	FVA21	6982352.482	6982352.482	2434308.038	2434308.038	4516.138	4515.874	0.264	0.264
22	FVA22	6974662.413	6974662.413	2437742.370	2437742.370	4411.408	4411.265	0.143	0.143
31	SVA31CW	6968652.564	6968652.564	2417175.566	2417175.566	4366.364	4366.393	-0.029	0.029
32	SVA32CW	6975801.648	6975801.648	2411393.563	2411393.563	4395.086	4394.922	0.164	0.164
33	SVA33CW	6972539.789	6972539.789	2421778.933	2421778.933	4444.477	4444.400	0.077	0.077
34	SVA34CW	6970470.659	6970470.659	2407216.986	2407216.986	4378.976	4378.873	0.103	0.103
35	SVA35BT	6977142.164	6977142.164	2439151.980	2439151.980	4414.617	4414.685	-0.068	0.068
36	SVA36U	6960723.745	6960723.745	2428762.546	2428762.546	4371.102	4370.838	0.264	0.264
37	SVA37U	6961181.735	6961181.735	2427311.068	2427311.068	4366.181	4365.947	0.234	0.234
38	SVA38U	6961121.145	6961121.145	2426752.556	2426752.556	4366.540	4366.181	0.359	0.359
41	SVA41BT	6957112.007	6957112.007	2423183.538	2423183.538	4357.693	4357.493	0.200	0.200
42	SVA42BT	6976528.573	6976528.573	2424019.466	2424019.466	4411.120	4410.749	0.371	0.371
43	SVA43BT	6977619.595	6977619.595	2431656.255	2431656.255	4449.233	4449.193	0.040	0.040
44	SVA44BT	6970695.202	6970695.202	2419759.647	2419759.647	4382.631	4382.605	0.026	0.026
51	FVA51	6967063.878	6967063.878	2417949.448	2417949.448	4367.339	4367.246	0.093	0.093
52	SVA52CW	6976090.867	6976090.867	2431409.397	2431409.397	4450.608	4450.506	0.102	0.102
54	FVA54	6961359.825	6961359.825	2427125.115	2427125.115	4365.663	4365.517	0.146	0.146
53	FVA53	6960867.586	6960867.586	2429431.695	2429431.695	4370.828	4370.637	0.191	0.191
								CVA (ft)	**0.361**
								CVA (cm)	**11.02**

Modoc tested 0.361 ft (11.02 centimeters) consolidated vertical accuracy at the 95th percentile in open terrain, urban areas, brush lands and low trees. The Modoc CVA value passes the minimum requirement of 36.3 centimeters. The table below describes the points and statistics associated with the CVA testing.

3.2 QUALITATIVE ANALYSIS

3.2.1 LiDAR Macro Review

During the macro review, the Pre Flight Operations Plan, the Post Flight Aerial Acquisition and Calibration Report, and the Checklist for Aerial Acquisition Report were reviewed from Milestone 1 and confirmed to be complete and passed.

Table 13 Checklist for Quality Assurance of Terrain Products

CHECKLIST	PASS/FAIL	COMMENTS
Vertical datum correct	**Pass**	
Horizontal datum correct	**Pass**	
Projection correct	**Pass**	
Vertical units correct	**Pass**	
Horizontal units correct	**Pass**	
Each return contains – GPS week, GPS second, easting, northing, elevation, intensity, return # and classification	**Pass**	
No duplicate entries	**Pass**	
GPS second reported to nearest microsecond	**Pass**	
Easting, northing, and elevation reported to nearest 0.01 m or 0.01 ft	**Pass**	
Classifications correct – 1. Unclassified; 2. Bare-earth ground; 7. Noise; 9. Water; 10. Ignored ground; 11. Withheld	**Pass**	
Deliverable tiles checked for significant gaps not covered by aerial acquisition checks and/or caused by data post-processing/filtering	**Pass**	

The following table highlights the main components of the qualitative analysis as it pertains to the visual inspection of the bare earth LiDAR. For the ground points (bare earth) review, the data were checked for correct classification and cleanliness. No more than 2% of the project area classified to bare ground should contain artifacts such as buildings, trees, overpasses, or other above-ground features in the ground point classification (Class 2). In addition, no more than 2% of the project area shall contain incorrect classification of points. The total classified project area was calculated and the total area of errors was calculated. The total area of errors was compared to the total processed area and the results were less than 2% of the total processed area contained errors.

Table 14 Qualitative Analysis of DTM

LIDAR ACCEPTANCE CATEGORY	DESCRIPTION	PASS/FAIL
Ground Points (Bare Earth)	Post-processed to remove structures and vegetation with <2 % residual artifacts	**Pass** – Error extent less than 2% of the processed tiles extent
Continuity	No gaps of sufficient size. No obvious vertical offsets between adjoining strips	**Pass**
Inconsistent Post Processing/Editing	No visible variations in DTM.	**Pass**
Over-smoothing	Smoothing techniques are not aggressive enough to remove topographic features necessary to define drainage features	**Pass**
Artifacts	No obvious artifacts, spikes, holes, or blunder.	**Pass**
Classification Used	Class 1 = unclassified; Class 2 = ground; Class 7 = Low point/noise Class 9 = Water Class 10 = Ignored Class 11 = Withheld	**Pass**
Low Confidence	2D Polygon shapefile meeting database specifications set forth in PM61_LIDAR Specs.	**Pass**

3.3 Low Confidence Areas

FEMA requires that low confidence areas be delineated by the data provider to indicate areas where the vertical data may not meet the data accuracy requirements due to heavy vegetation even though the specified nominal pulse spacing was met or exceeded in those areas. For the Modoc project area, there was an area of low confidence noted. A polygon shapefile delineating the low confidence area was delivered with the LIDAR dataset.

3.4 Breaklines

Submitted breaklines were reviewed through a combination of automated processes along with a visual review. Detailed QC was performed on all breaklines in 47 out of 92 project tiles. Some of the automated review processes were applied to all breaklines. The single drain lines were compared to bare earth profiles to ensure that they fall within water channels. 3D centerlines profiles were checked visually for all breaklines that intersect sample tiles, along with visual line work checks. Breaklines vertices were converted to points and compared to each other's within and across breaklines and surrounding ground values. The breaklines follow a downstream trend with the first upstream vertex being higher than the last downstream vertex. The elevations for each vertex decrease steadily as the stream flows downstream. Minimal vertical variance was noted but the elevation vendor acknowledged the variance and approved its inclusion. The following table highlights the main components of the qualitative analysis as it pertains to the visual inspection of the breakline submittal. This qualitative analysis includes verifying completeness, topology, consistency, and location of the breakline features.

Table 15 Breakline Acceptance

Breakline Acceptance Category		Pass/Fail
Check for monotonicity of hydro breaklines.	Visual	**Pass**
Verify that breakline vertices have z values equal to or less than the surrounding ground points.	Automated	**Pass**
Vertices should not have a 0 or null elevation	Automated	**Pass**
Vertices should not have excessive min or max z-values when compared to adjacent vertices	Visual	**Pass**
Double line stream breaklines elevations must match within 2 ft from each side of the stream	Visual	**Pass**
Check the metadata of the Milestone 2 delivery. Should include discussion on each delivered feature and a description of the creation process unique to that feature class. Should comply with FEMA Terrain Metadata Profile.		**Pass**
Verify ponding water breaklines have constant elevation and are equal to or less than the surrounding ground points.	Visual	**Pass**
Assure breaklines meet all specifications for completeness, size and feature type. Water body breaklines for polygons >2acres, stream centerline breaklines for streams <100' wide and shown on a USGS 7.5min Quads, and edge of water	Visual	**Pass**

BREAKLINE ACCEPTANCE CATEGORY		PASS/FAIL
breaklines for streams >100' wide		
Stream breaklines should break at culverts, and not break at bridges.	Visual	**Pass**
Run topology checks on all GIS lines and polygons.	Automated	**Pass**
Horizontal placement-stream should align horizontally with the LIDAR data	Visual	**Pass**
Culvert breaklines must snap to stream endpoints on both sides, and have the same elevation as the stream breakline at the snapping location.	Automated	**Pass**
Bridge breaklines should outline the bridge deck	Visual	**Pass**

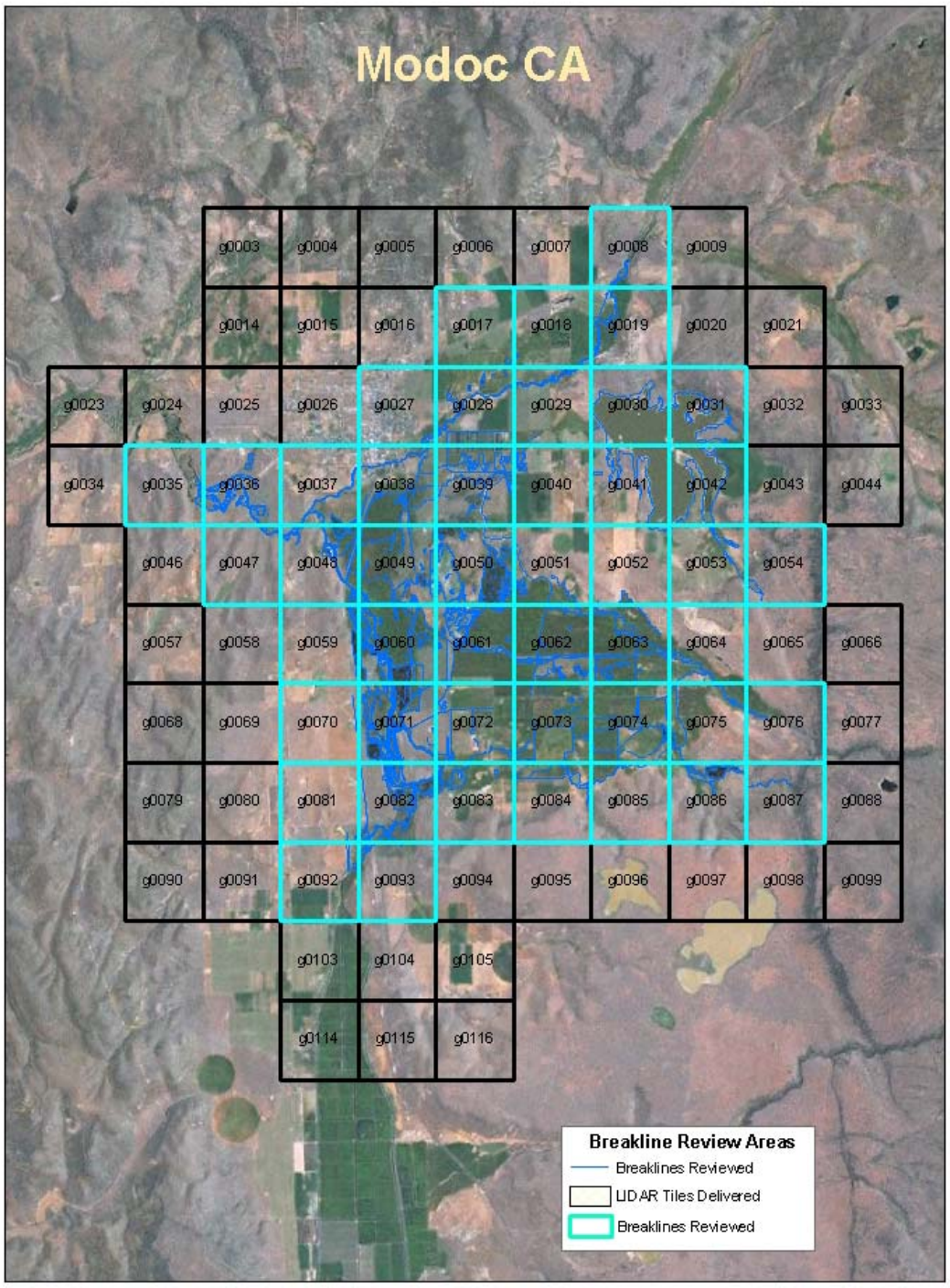

Fig 5. Breakline Review process diagram.

3.5 METADATA

Metadata were visually inspected and confirmed inclusion of documentation on classification methodology, breakline creation, low confidence area minimization, etc.

3.6 LIST OF DELIVERABLES

The major deliverables are provided in Table 16.

Table 16 Major Deliverables

FEDERAL GEOGRAPHIC DATA COMMITTEE COMPLIANT METADATA	METADATA FILE WAS PROVIDED
Reports (Collection, Survey, Processing, and QA/QC reports)	Yes
Raw point cloud in an LAS v 1.2 or 1.3 format	Yes
Classified point cloud in an LAS v 1.2 or 1.3 format	Yes
Break lines (Stream centerlines, drainage ditches, and tops and bottoms of stream banks in an ESRI shape file or geo database format	Yes
Checklist documenting QC processing steps completed	Yes
QC Non-conformance documentation	

4. SUMMARY

The LiDAR data for the Modoc, CA collection area meets all the FEMA specifications as given on PM 61 document. The data passes the accuracy assessment test for FVA, CVA and SVA. The final dataset passes all quality control specifications and the dataset has adequate documentation from the collection vendor.

5. REFERENCES

Bellamo, Doug A., Memorandum for Regional Risk Analysis Branch Chiefs, Procedure Memorandum No. 61 – Standards for LiDAR and Other High Quality Digital Topography, September, 2010.

Map Modernization Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A: Guidance for Aerial Mapping and Surveying, Federal Emergency Management Agency (FEMA), April 2003, from http://www.fema.gov/plan/prevent/fhm/dl_cgs.shtm

U.S. Geological Survey (USGS), National Geospatial Program, LiDAR Guidelines and Base Specification, vers. 13, Effective Date February 22, 2010;

American Society for Photogrammetry and Remote Sensing (ASPRS), ASPRS Guidelines, Vertical Accuracy Reporting for LiDAR Data, vers. 1.0, May 24, 2004.

Appendix 1 Data Density and Data Void check results

Data Density Check

No: of Tiles			92			
No: of LAS Files			92			
NPS			1 Meter			
Tile Name	**No of Points**	**Z Min (Feet)**	**Z Max (Feet)**	**Z Mean (Feet)**	**Point Density / Sq m**	**Comment**
g0003	1011940	1943.68	4910.9	4394.62	0.427154	Edge Tile
g0004	3536272	2195.06	8266.34	4563.43	1.49271	Edge Tile
g0005	4421149	2037.3	8249.06	4619.06	1.866229	Edge Tile
g0006	3693436	1911.09	7972.53	4576.75	1.559052	Edge Tile
g0007	3820096	1842.49	8089.9	4459.13	1.612517	Edge Tile
g0008	4632800	1970.98	8288.71	4447.17	1.95557	Edge Tile
g0009	1537852	2309.36	8120.18	4473.3	0.649149	Edge Tile
g0014	4144134	2025.71	8041.32	4403.5	1.749298	Edge Tile
g0015	5575551	1827.87	8236.46	4427.19	2.353519	
g0016	5867918	1788.77	8277.54	4440.96	2.476931	
g0017	5559861	1785.19	8182.29	4422.79	2.346896	
g0018	5353742	1911.25	8328.27	4399.32	2.25989	
g0019	5536093	2148.51	8322.98	4450.06	2.336863	
g0020	5344644	2843.11	8374.82	4515.75	2.25605	Edge Tile
g0021	1460648	1852.96	8291.89	4513.7	0.61656	Edge Tile
g0023	46919	4338.35	5910.36	4361.68	0.019805	Edge Tile
g0024	1075344	2170.46	8322.89	4362.74	0.453918	Edge Tile
g0025	5689303	2098	8353.52	4381.67	2.401535	Edge Tile
g0026	6698815	1938.65	8392.08	4377.78	2.827664	
g0027	6704203	1863.62	8398.39	4379.72	2.829939	
g0028	6033084	1853.85	8450.31	4378.72	2.54665	
g0029	6199841	1873.28	8437.86	4393.15	2.617041	
g0030	2721533	2210.88	8376.08	4427.58	1.148798	
g0031	4371929	1986.15	8390.08	4446.32	1.845453	
g0032	4005759	2603.41	8366.5	4502.46	1.690887	Edge Tile
g0033	1007574	1940.36	8363.13	4660.31	0.425311	Edge Tile
g0034	34910	4360.39	4416.03	4372.82	0.014736	Edge Tile
g0035	2040521	1890.23	8124.61	4381.89	0.861333	Edge Tile
g0036	5596957	2630.42	8036.31	4363.08	2.362555	
g0037	6046700	1933.26	8306.49	4376.57	2.552398	
g0038	6022697	2048.77	8267.01	4368.41	2.542266	

g0039	5386760	1912.2	8190.31	4376.68	2.273828	
g0040	5761087	1896.35	8207.71	4406.07	2.431836	
g0041	3855535	1967.1	8368.25	4411.24	1.627476	
g0042	3304462	2023.54	8310.76	4438.1	1.39486	
g0043	4941541	1845.49	8448.55	4526.11	2.085894	Edge Tile
g0044	239325	2579.56	4781.5	4685.58	0.101022	Edge Tile
g0046	1467749	1956.86	8185.13	4440.57	0.619558	Edge Tile
g0047	5313807	2070.07	5082.16	4402.55	2.243033	
g0048	5123907	1942.08	8317.06	4378.06	2.162874	
g0049	4957011	1882.19	8223.23	4359.03	2.092424	
g0050	3338592	1904.11	8296.89	4372.91	1.409267	
g0051	5142677	1939.17	8102.63	4410.14	2.170797	
g0052	5173578	1924.64	8274.02	4435.99	2.18384	
g0053	5377487	1833.31	8382.32	4451.15	2.269913	
g0054	4546227	2229.37	8425.27	4564.2	1.919027	Edge Tile
g0057	596491	4389.73	4561.38	4452.72	0.251787	Edge Tile
g0058	5405796	2095.33	4853.63	4416.31	2.281863	
g0059	5672184	2013.63	8177.08	4389.23	2.394309	
g0060	5051890	2587.73	8281.31	4355.13	2.132474	
g0061	5165246	2060.85	8203.4	4365.94	2.180323	
g0062	5706471	1923.08	8155.25	4381.2	2.408782	
g0063	5812651	1877.93	8279.18	4409.14	2.453602	
g0064	5894196	1872.52	8318.23	4471.84	2.488023	
g0065	5111109	1887.52	8456.62	4594.25	2.157471	Edge Tile
g0066	218577	4791.49	4954.09	4845.74	0.092264	Edge Tile
g0068	1177151	2406.19	8398.06	4477.3	0.496892	Edge Tile
g0069	6079707	1868.73	8414.89	4406.71	2.56633	
g0070	6411408	1868.27	8369.7	4383.08	2.706346	
g0071	5115212	2742.21	8358.56	4356.1	2.159203	
g0072	6011578	1800.49	8413.24	4367.39	2.537572	
g0073	6043976	1850.78	8417.03	4384.1	2.551248	
g0074	5964478	1905.05	8379.44	4403.99	2.51769	
g0075	6070850	1863.3	8375.77	4459.86	2.562592	
g0076	5625055	1896.97	8453.09	4574.22	2.374415	
g0077	326606	2274.08	8369.5	4846.39	0.137865	Edge Tile
g0079	65669	4416.33	4478.14	4429.75	0.02772	Edge Tile
g0080	4953436	2400.24	8050.05	4413.5	2.090915	
g0081	5476728	2026.62	8289.76	4393.93	2.311804	
g0082	4408459	2306.69	8318.08	4360.99	1.860873	
g0083	5012124	1699	8341.29	4423.39	2.115688	
g0084	4849136	1870	8294.84	4492.39	2.046889	
g0085	5303280	1862.97	8336.11	4525.32	2.238589	

g0086	5314023	1899.34	8346.69	4507.65	2.243124	
g0087	4875372	2116.84	8502.32	4647.36	2.057963	
g0088	2	3507	4951.63	4229.32	8.44E-07	Edge Tile
g0090	17203	4431.54	4477.86	4440.95	0.007262	Edge Tile
g0091	3983898	1928.41	8273.73	4409.77	1.68166	Edge Tile
g0092	4924316	1911.94	8286.46	4376.63	2.078623	Edge Tile
g0093	5225113	1857.65	8165.72	4395.54	2.205594	
g0094	4578114	1695.92	8326.58	4521.84	1.932487	Edge Tile
g0095	2263210	2498.35	5367.24	4640.81	0.955333	Edge Tile
g0096	2186198	4523.21	8297.84	4627.56	0.922825	Edge Tile
g0097	2135440	1956.69	8293	4626.21	0.901399	Edge Tile
g0098	1057333	2794.85	8358.82	4687.38	0.446315	Edge Tile
g0099	1147	4944.77	4951.82	4947.58	0.000484	Edge Tile
g0103	374195	4356.41	4440.08	4359.9	0.157953	Edge Tile
g0104	4652340	2111.37	8058.59	4401.85	1.963818	
g0105	421174	2108.44	8241.11	4384.53	0.177783	Edge Tile
g0114	38877	4358.44	4363.32	4359.29	0.016411	Edge Tile
g0115	231895	4357.91	4685.83	4452.58	0.097886	Edge Tile
g0116	2550	3291.58	4426.36	4422.3	0.001076	Edge Tile

Check for Data Void

Tile Size	5000x5000 Feet
Grid Size	2 Meters
Pass Percent	90

LASFILE	COMMENTS	NO OF POINTS	NO OF GRIDS/TILE	NO OF GRIDS MEETING THE SPEC	PERCENT OF GRIDS MEETING THE SPEC	STATUS
g0003	Edge	995932	592074	116040	19.59890149	
g0004	Edge	3135947	592074	374128	63.18939862	
g0005	Edge	3443540	592074	395359	66.77526796	
g0006	Edge	3326987	592074	381830	64.49024953	
g0007	Edge	3744584	592074	419539	70.85921692	
g0008	Edge	4337765	592074	534159	90.21828353	
g0009	Edge	1430958	592074	203781	34.41816395	
g0014	Edge	4016088	592074	476253	80.43808713	
g0015	Inside	5337952	592074	591539	99.90963967	Pass
g0016	Inside	5221110	592074	592017	99.99037283	Pass
g0017	Inside	5329772	592074	591314	99.87163767	Pass
g0018	Inside	5319501	592074	591705	99.93767671	Pass
g0019	Inside	5221596	592074	585511	98.89152369	Pass
g0020	Edge	4921100	592074	583288	98.51606387	
g0021	Edge	1423107	592074	201817	34.08644865	
g0023	Edge	45981	592074	10399	1.756368292	
g0024	Edge	1067584	592074	184642	31.18562882	
g0025	Edge	5646857	592074	556627	94.01307945	
g0026	Inside	6305020	592074	592012	99.98952834	Pass
g0027	Inside	6139763	592074	591553	99.91200424	Pass
g0028	Inside	5969364	592074	579925	97.94806055	Pass
g0029	Inside	6115534	592074	586947	99.13406095	Pass
g0030	Inside	2625370	592074	283076	47.81091553	Fail
g0031	Inside	4225680	592074	473319	79.94254097	Fail
g0032	Edge	3850589	592074	441899	74.63577188	
g0033	Edge	964297	592074	191562	32.35440165	
g0034	Edge	34751	592074	7507	1.267915835	
g0035	Edge	2007993	592074	302370	51.06962981	
g0036	Inside	5589244	592074	561800	94.8867878	Pass
g0037	Inside	5835602	592074	576791	97.41873482	Pass
g0038	Inside	5682760	592074	587635	99.25026264	Pass

LASFile	Comments	No of Points	No of Grids/Tile	No of Grids Meeting the Spec	Percent of Grids Meeting the Spec	Status
g0039	Inside	5333421	592074	560252	94.625334	Pass
g0040	Inside	5732299	592074	587080	99.15652435	Pass
g0041	Inside	3833561	592074	458520	77.44302232	Fail
g0042	Inside	3248092	592074	383683	64.80321717	Fail
g0043	Edge	4654607	592074	550341	92.95138783	
g0044	Edge	224651	592074	43052	7.271388374	
g0046	Edge	1451771	592074	223525	37.75288224	
g0047	Inside	5292836	592074	589064	99.4916176	Pass
g0048	Inside	5117644	592074	558911	94.39884204	Pass
g0049	Inside	4945110	592074	564825	95.39770367	Pass
g0050	Inside	3324457	592074	397557	67.14650534	Fail
g0051	Inside	5135914	592074	581721	98.25140101	Pass
g0052	Inside	5166366	592074	590613	99.7532403	Pass
g0053	Inside	5273597	592074	589382	99.5453271	Pass
g0054	Edge	4347674	592074	553986	93.56702034	
g0057	Edge	578388	592074	109134	18.43249324	
g0058	Inside	5353875	592074	592066	99.99864882	Pass
g0059	Inside	5653413	592074	569117	96.12261305	Pass
g0060	Inside	5029579	592074	541155	91.39989258	Pass
g0061	Inside	5156046	592074	544067	91.89172299	Pass
g0062	Inside	5682165	592074	581489	98.21221672	Pass
g0063	Inside	5807415	592074	588640	99.42000493	Pass
g0064	Inside	5845865	592074	585619	98.90976466	Pass
g0065	Edge	5006439	592074	569623	96.20807534	
g0066	Edge	218220	592074	40701	6.87430963	
g0068	Edge	1080830	592074	205014	34.62641494	
g0069	Inside	5871125	592074	592045	99.99510196	Pass
g0070	Inside	6401397	592074	591892	99.9692606	Pass
g0071	Inside	5114240	592074	532451	89.92980607	Fail
g0072	Inside	5987370	592074	587853	99.28708236	Pass
g0073	Inside	5893542	592074	590678	99.76421866	Pass
g0074	Inside	5940472	592074	586210	99.00958326	Pass
g0075	Inside	6041571	592074	588924	99.46797191	Pass
g0076	Inside	5427196	592074	581319	98.18350409	Pass
g0077	Edge	325334	592074	60537	10.22456652	
g0079	Edge	54513	592074	7112	1.201201201	
g0080	Inside	4886155	592074	591734	99.94257475	Pass

LASFile	Comments	No of Points	No of Grids/Tile	No of Grids Meeting the Spec	Percent of Grids Meeting the Spec	Status
g0081	Inside	5460491	592074	585703	98.92395207	Pass
g0082	Inside	4407112	592074	532311	89.90616038	Fail
g0083	Inside	5008246	592074	576622	97.39019109	Pass
g0084	Inside	4837566	592074	584975	98.80099447	Pass
g0085	Inside	5289234	592074	591763	99.94747278	Pass
g0086	Inside	5205133	592074	570789	96.40501018	Pass
g0087	Inside	4637254	592074	587323	99.19756652	Pass
g0088	Edge	1	592074	1	0.000168898	
g0090	Edge	16180	592074	1924	0.32495938	
g0091	Edge	3950229	592074	493104	83.28418407	
g0092	Edge	4912543	592074	540363	91.26612552	
g0093	Inside	5222340	592074	587569	99.23911538	Pass
g0094	Edge	4570648	592074	541079	91.38705635	
g0095	Edge	2263193	592074	304505	51.43022663	
g0096	Edge	2183716	592074	296168	50.02212561	
g0097	Edge	2128572	592074	269604	45.53552428	
g0098	Edge	1043753	592074	158414	26.75577715	
g0099	Edge	1147	592074	134	0.022632306	
g0103	Edge	374164	592074	66768	11.27696876	
g0104	Inside	4647062	592074	588689	99.42828092	Pass
g0105	Edge	421143	592074	65148	11.00335431	
g0114	Edge	38877	592074	7516	1.269435915	
g0115	Edge	231520	592074	37449	6.325053963	
g0116	Edge	2549	592074	395	0.066714634	

The tiles that were failed were visually checked and it was observed that the issue is due to water bodies present (as LiDAR is absorbed and not reflected) and it is acceptable. The data void check is pass 100%.