Project Report

LIDAR Data Collection and Processing for the Central Coast of California, 2010

Prepared by:

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SUMMARY

Digital Mapping, Inc. (DMI) was contracted by the Association of Monterey Bay Area Governments (AMBAG) to perform high resolution LIDAR (Light Detection and Ranging) survey work for the Central Coast of California including areas of Monterey, San Benito, and Santa Cruz Counties. LIDAR data were collected for an area of 1,713 square miles. The data was used in the development of the bare earth elevation datasets.

The Optech ALTM GEMINI LIDAR system was used for data collection. The LIDAR system was calibrated by conducting flight passes over an airport runway. The calibration parameters were inserted into the post-processing software to eliminate IMU errors.

The acquired LIDAR data was processed to obtain four-return point data. The LIDAR data was further filtered to yield a LIDAR surface representing the bare earth. This bare earth dataset was then used to generate TINs and 10 feet DEMs along with breaklines.

This report summarizes the methods used to establish ground control points, perform the LIDAR data collection, post-processing, as well as the results of these methods.

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INTRODUCTION

This document is the technical write-up of the Central Coast of California LIDAR mission. It includes LIDAR system calibration techniques, the establishment of the control points, and the collection and post-processing of the LIDAR data.

Contact Information

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Purpose of the LIDAR Acquisition

The LIDAR operation was designed to provide a highly detailed ground surface dataset to be used for the development of topographic, contour mapping, and hydraulic modeling. Oceanographic, agricultural, and atmospheric research facilities, etc. will directly benefit from the LIDAR and elevation data sets produced from this project.

Project Location

Central Coast of California including areas of Monterey, San Benito and Santa Cruz Counties. Figure 1 shows the project area's extent.

Project Scope and Specifications

The LIDAR mission required the collection of 1,713 square miles of data. The project was flown in multiple dates. The final LIDAR product is within vertical accuracy of +/- 1.2 foot at the 95% confidence level which meets base LIDAR specification for projects funded under the American Recovery and Reinvestment Act of 2009 U.S. Geological Survey Program Announcement 10HQPA0014.

Survey Report

A survey crew was sent to the project area and physically set eighty six (86) control points using a 60D spike in the natural ground areas and a PK Nail and flasher in pavement areas. The approximate latitude and longitude for these points were provided by Digital Mapping, Inc.

All aerial targets are semi-permanent in nature and properly documented in the description chart in Tables 1 through 3. The targets are “X’s” in style with legs measuring 6” wide x 4’ long. The center of each target marks the location of the control point Figure 1 shows the location of the ground control points.

The ground control points have the following parameters.

Coordinate System	State Plane California Zone 3 and Zone 4
Units	Survey Feet
Horizontal Datum	NAD83
Vertical Datum	NAVD88
Ellipsoid Model	GRS1980
Geoid Model	GEOID03

Table 1: Projection Specifications

The survey crew went into the field and set targets at designated positions as shown in Figure 1 and Tables 2 and 3. After the target was set, the crew occupied the points for 15 minutes using Leica 1200 GPS Receivers and the Leica Smart Rover. Information gathered was stored and uploaded later at the main office. These locations were then used for geo-referencing the LIDAR vertical projection.

Control Points were set for Monterey, Carmel, and the Salinas Valley Region at State Plane Zone 4. The only region that was set apart from this was the Santa Cruz block of control points, which were set at Zone 3.

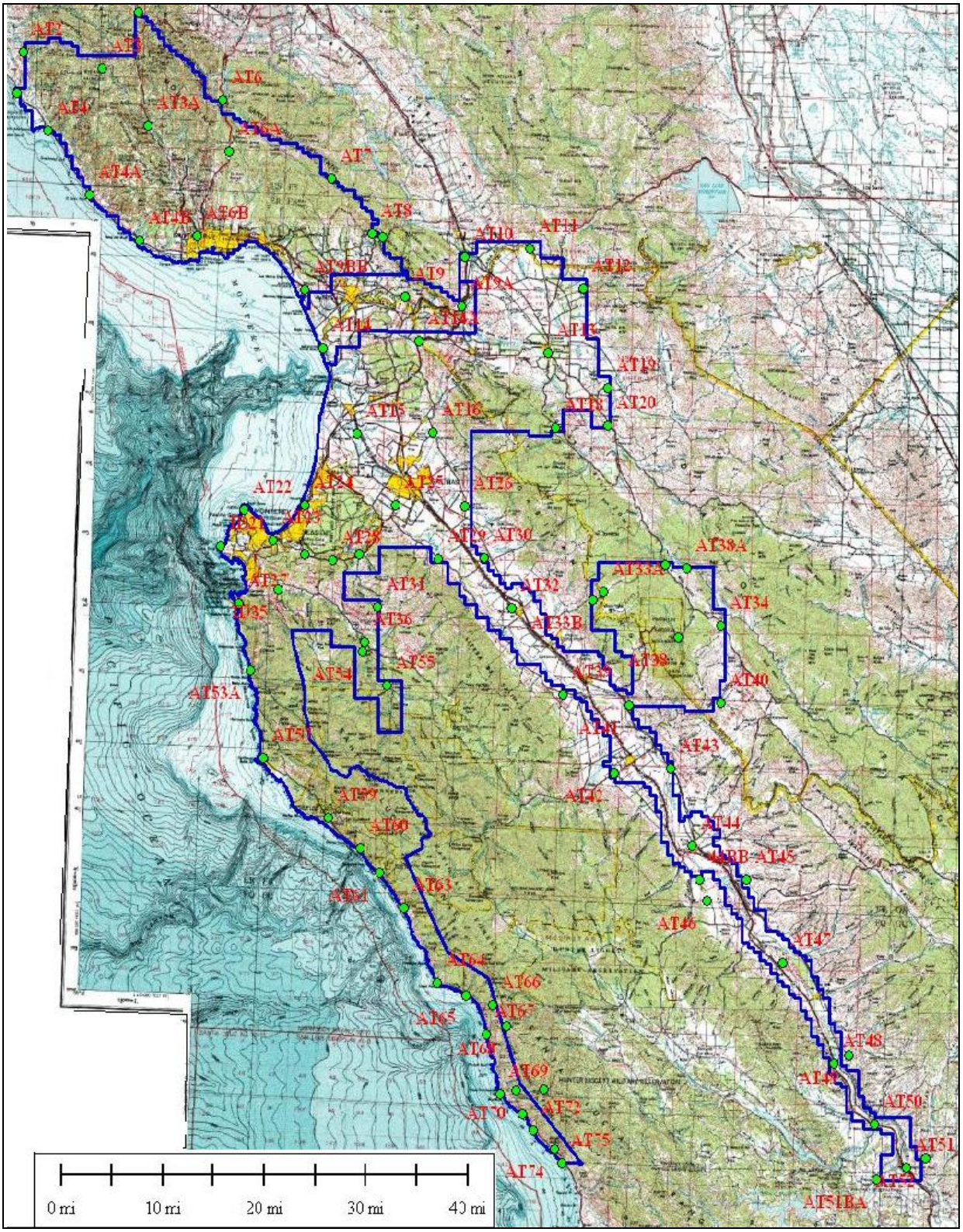


Figure 1: Project Limit and Control Layout

POINTS	NORTHING	EASTING	ELEVATION	DESCRIPTION
AT 13	2199992.8074	5858861.6603	291.5733	FD. "X" IN SIDEWALK
AT 15	2161689.1559	5760108.4500	20.0089	SET 60D SPIKE
AT 16	2162250.7678	5799076.3217	177.7031	SET 60D SPIKE
AT 18	2164840.3125	5862955.2549	1075.4418	SET PK NAIL
AT 19	2183385.5648	5889863.0216	848.1776	SET PK NAIL
AT 20	2165881.4131	5890144.0604	570.1304	SET 60D SPIKE
ID 21	2108930.4791	5689242.7153	21.7069	18" X 18" DRAIN GRATE
AT 22	2126122.0142	5701315.7027	77.1367	SET PK NAIL
AT 23	2111732.1490	5716218.4681	42.8934	SET 60D SPIKE
AT 24	2128139.3162	5732765.4877	118.1036	SET 60D SPIKE
AT 25	2127848.5687	5779976.3873	50.8782	SET 60D SPIKE
AT 26	2127317.9881	5815883.0777	135.7505	SET 60D SPIKE
AT 27	2081403.5137	5698701.3162	129.6852	SET 60D SPIKE
AT 28	2101967.6230	5747063.0339	369.8018	SET 60D SPIKE
AT 29	2102666.4415	5802349.1100	97.9742	SET 60D SPIKE
AT 30	2103241.5674	5825947.8404	183.9864	SET 60D SPIKE
AT 31	2080178.7095	5770598.9611	1090.9846	SET 60D SPIKE
AT 32	2079401.6811	5840498.3561	122.8953	SET 60D SPIKE
AT 34 A	2071186.8841	5948987.4181	1456.9905	SET 60D SPIKE
AT 34 B	2099853.5262	5919842.2369	1446.5677	SET 60D SPIKE
ID 35	2088289.3185	5719280.9775	92.5054	
AT 36	2063366.5834	5763937.6830	409.4034	SET 60D SPIKE
AT 38	2065639.0472	5926773.0851	984.3355	SET 60D SPIKE
AT 39	2038589.3250	5867050.3316	171.1383	SET 60D SPIKE
AT 40	2034757.4772	5948623.7126	967.9926	SET 60D SPIKE
AT 41	2033321.2941	5900951.5104	316.8689	SET 60D SPIKE
AT 42	2001111.7607	5893349.1330	334.7734	SET 60D SPIKE
AT 43	2003566.3144	5922755.5470	256.3294	SET 60D SPIKE
AT 44	1966866.9242	5933575.9488	328.9584	SET PK NAIL
AT 45	1951130.7199	5962015.9653	446.1401	SET PK NAIL
AT 46	1940762.2942	5941618.8940	448.7431	SET 60D SPIKE
AT 47	1911832.4685	5980606.9128	541.3521	SET 60D SPIKE
AT 48	1864116.8465	6007600.7475	535.4057	SET 60D SPIKE
AT 49	1868189.0831	6015378.4741	635.2791	SET 60D SPIKE
AT 50	1835245.3951	6028451.9719	534.5067	
AT 51	1814854.2743	6045032.7043	611.4281	SET 60D SPIKE
AT 52	1819213.4828	6054805.5560	681.5982	SET PK NAIL
AT 54	2059075.3414	5762937.4956	466.3557	SET PK NAIL
AT 55	2043034.6442	5775817.5240	821.0355	SET 60D SPIKE
AT 57	2008607.0495	5711412.5406	145.4202	SET PK NAIL
AT 59	1980581.7162	5745325.8582	763.7292	SET 60D SPIKE
AT 60	1966004.1348	5761665.1322	544.0905	24" X 24" DRAIN GRATE
AT 61	1954174.3390	5771849.2589	372.6931	SET 60D SPIKE
AT 63	1937868.8163	5784479.6488	359.1325	SET 60D SPIKE
AT 64	1902081.3688	5801446.0566	234.5986	SET 60D SPIKE
AT 65	1896375.9852	5816342.6641	107.4073	FD. PK NAIL AND TARGET
AT 66	1891855.0714	5830390.7102	1810.3084	SET 60D SPIKE
AT 67	1877902.9944	5826985.9280	204.3916	SET 60D SPIKE

AT 68	1881557.7372	5837393.0779	3324.4866	SET 60D SPIKE
AT 69	1849644.1563	5834399.1604	294.8938	SET 60D SPIKE
POINTS	**NORTHING**	**EASTING**	**ELEVATION**	**DESCRIPTION**
AT 70	1851360.2954	5842321.4935	2016.3277	SET 60D SPIKE
AT 71	1840475.7393	5845706.1485	57.6277	SET 60D SPIKE
AT 72	1832513.5908	5851399.0748	487.8411	SET 60D SPIKE
AT 74	1823487.7956	5862275.7428	349.4572	SET 60D SPIKE
AT 75	1817311.3863	5866086.9012	501.3924	SET 60D SPIKE
AT 28AA	2105060.1500	5761223.6610	290.7212	SET 60D SPIKE
AT 28BB	2104883.8580	5732934.0460	138.4938	FOUND GEAR SPIKE AND TARGET
AT 53A	2049986.3360	5704955.1580	109.5536	SET PK NAIL
AT 73A	1852107.2540	5856770.5470	3233.878	SET 60D SPIKE
44BB	1950867.7880	5937639.4900	383.4146	SET 60D SPIKE
AT 14A	2205548.2100	5792269.4330	160.5837	SET PK NAIL
AT 33A	2087385.0080	5887974.0020	2305.8484	SET 60D SPIKE
AT 33B	2083032.4910	5882640.6330	1694.6817	SET 60D SPIKE
AT 38A	2097972.2710	5930895.5430	1132.4288	SET 60D SPIKE
AT 51 B	1809269.6280	6029735.6480	565.4321	SET 60D SPIKE
AT 9A	2222424.4220	5814132.6030	179.7746	FOUND VERTICAL CONTROL G1236

Table 2: Control Points in California Zone 4

POINT	**NORTHING**	**EASTING**	**ELEVATION**	**DESCRIPTION**
AT 1	1886680.5789	6020218.1353	50.4591	SET 60D SPIKE
AT 2	1905847.3735	6023735.8991	132.2452	SET PK NAIL
AT 3	1898850.7148	6064455.3640	1617.0356	SET 60D SPIKE
AT 4	1869089.0604	6036510.9433	98.6204	SET PK NAIL
AT 5	1925589.3086	6082801.3511	2558.2396	SET 60D SPIKE
AT 6	1885002.6208	6127159.7993	1186.1125	SET PK NAIL
AT 7	1848351.7207	6184421.0196	2704.8345	SET 60D SPIKE
AT 8	1822774.6114	6205805.0475	1316.8949	SET PK NAIL
AT 9	1793425.8549	6223433.2290	72.8551	SET PK NAIL
AT 10	1812810.5489	6254059.1454	179.4433	SET 60D SPIKE
AT 11	1817044.6179	6287500.1384	163.6716	SET 60D SPIKE
AT 12	1798299.7109	6315723.8196	442.5504	SET 60D SPIKE
AT 14	1768017.8435	6181052.8169	9.4954	SET 60D SPIKE
AT 3A	1872287.1610	6088696.6580	493.0011	SET PK NAIL
AT 4A	1839032.3100	6058735.2780	102.2669	SET PK NAIL
AT 4B	1817551.1220	6085168.3250	107.7852	SET PK NAIL
AT 6A	1860491.9190	6131034.2310	1276.3787	CENTER BRICK PAVINGS
AT 6B	1820598.4750	6115228.8680	34.8553	SET PK NAIL
AT 9BB	1795598.6780	6171478.5660	176.0628	SET PK NAIL
AT 6C	1821294.3920	6211043.5590	929.5027	SET PK NAIL

Table 3: Control Points in California Zone 3

LIDAR REPORT

Flight Mission

Due to irregular shape of the project area and the changing terrain heights, the project is divided into 9 blocks. All the blocks except Block1 are in State Plane Coordinate System California Zone 4. Block 1 is in State Plane Coordinate System California Zone 3 (Figure 2). The data capture campaign required an unobstructed view of the ground from the flying height (i.e. no fog or clouds) and relatively smooth air in which to fly.

Pre-flight checks such as cleaning the sensor head glass were performed. A five minute INS initialization was conducted on the ground, with the engines running, prior to flight, to establish fine-alignment of the INS.

The Optech “ALTM NAV” software was used to plan and navigate the aircraft in real time. The LIDAR system operator uses this comprehensive flight management system to see, among other things, real-time swath coverage so that any gaps or GPS quality issues can be resolved before landing or leaving the site. A careful record of every flight line, or strip, is taken on the airborne log sheets in a digital form. Start and stop time, system parameters, and system observables represent some of the information recorded in these logs. During the data collection, the operator also recorded information on paper log sheets, which include weather conditions and flight line statistics. Following every flight, the LIDAR and GPS data were downloaded and initial post-processing began immediately.

The mission was flown in multiple days. Two base stations were set up for each mission. Both of them were within the project area.

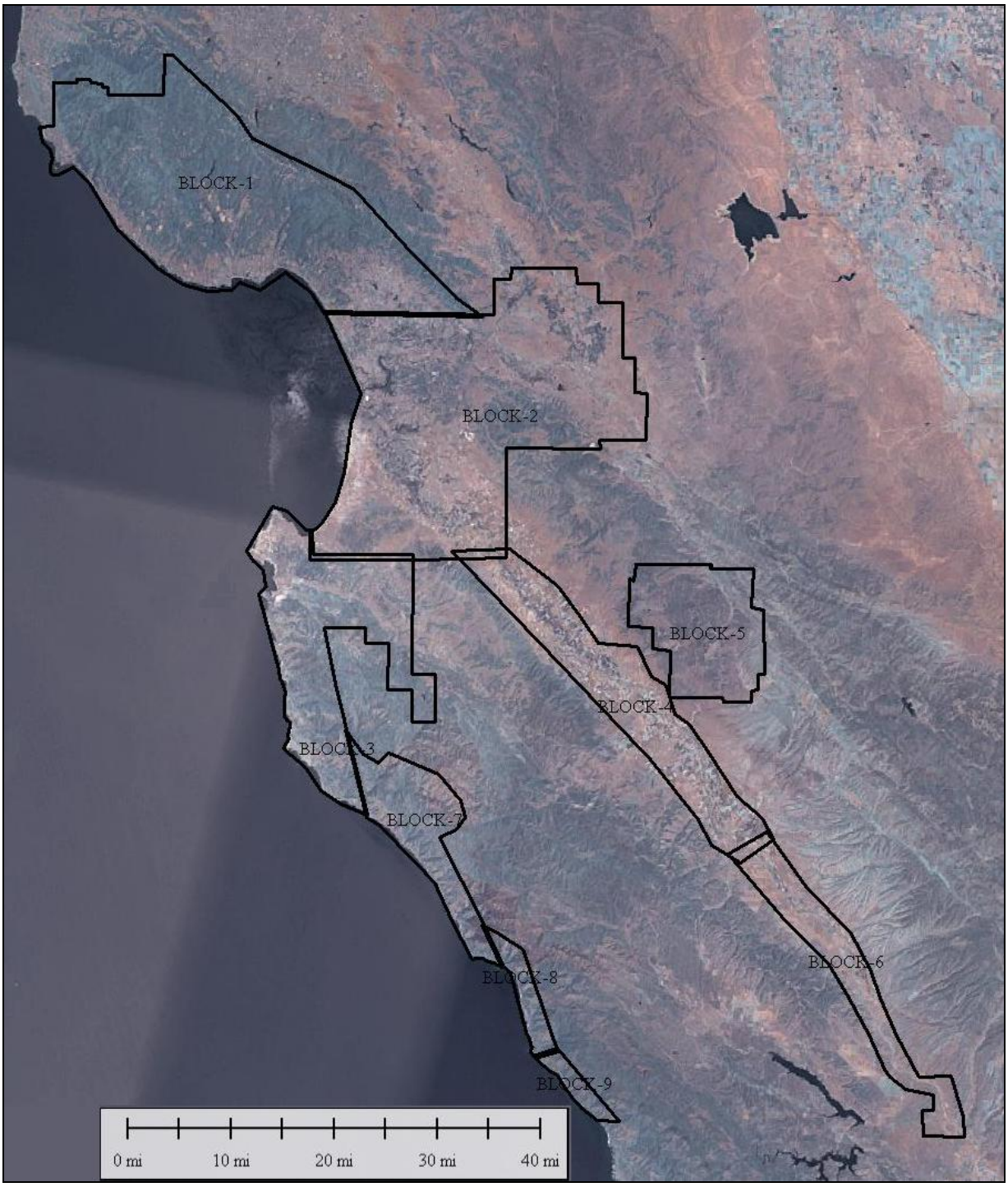


Figure 2: Block Layout

Figure 3: Block 1—Santa Cruz

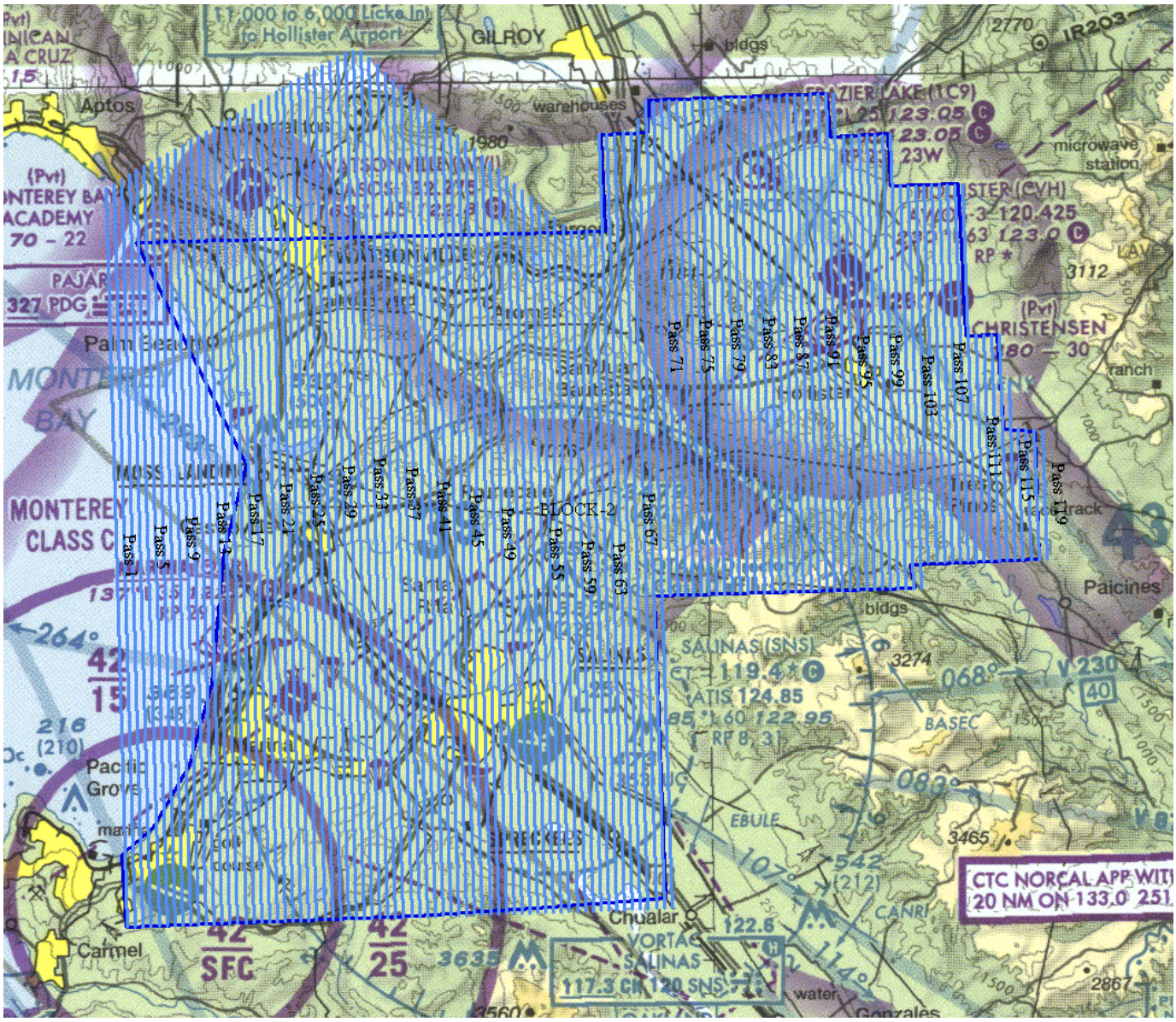


Figure 4: Block 2—Monterey - Salinas

Figure 5: Block 3–Carmel

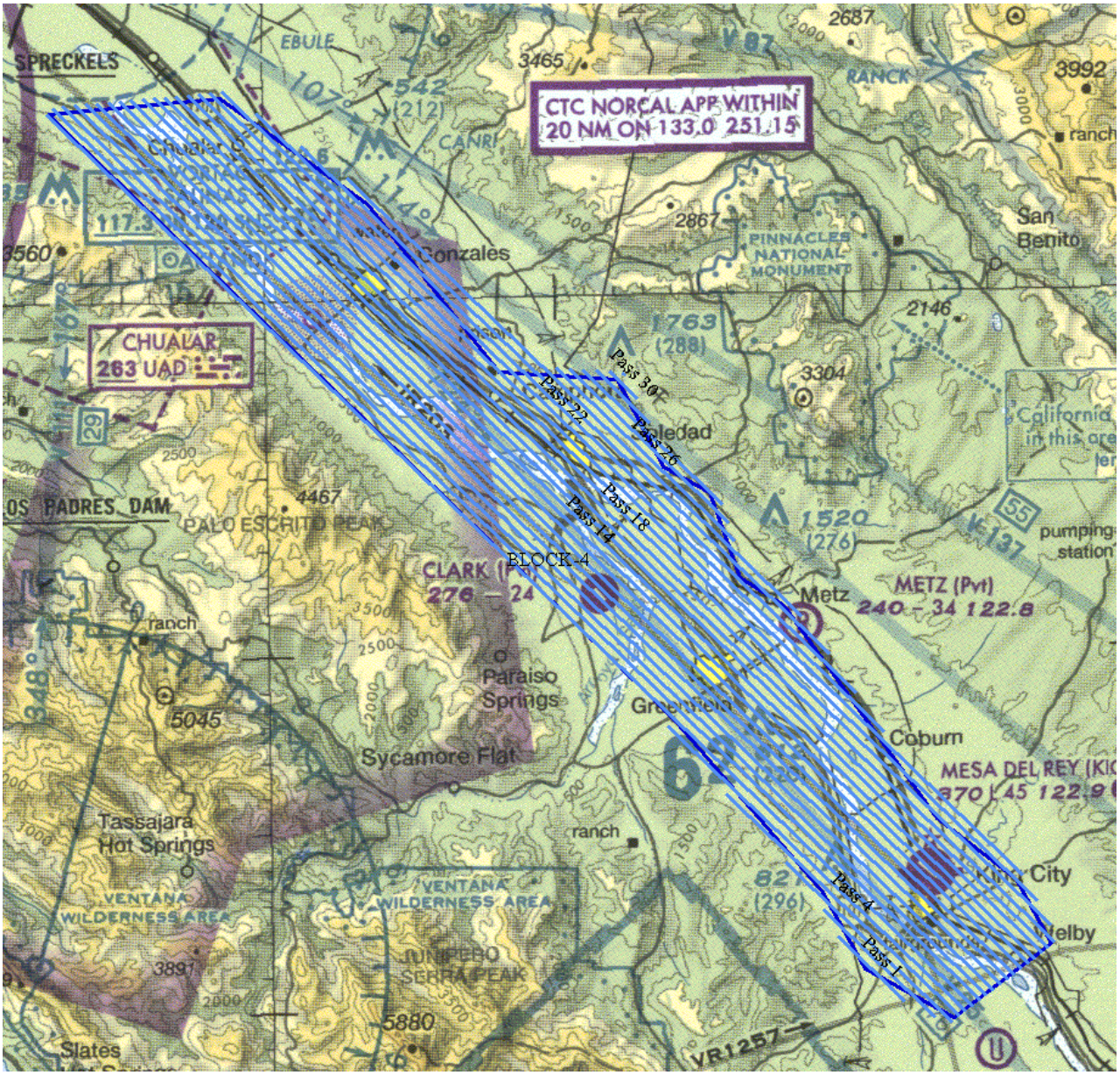
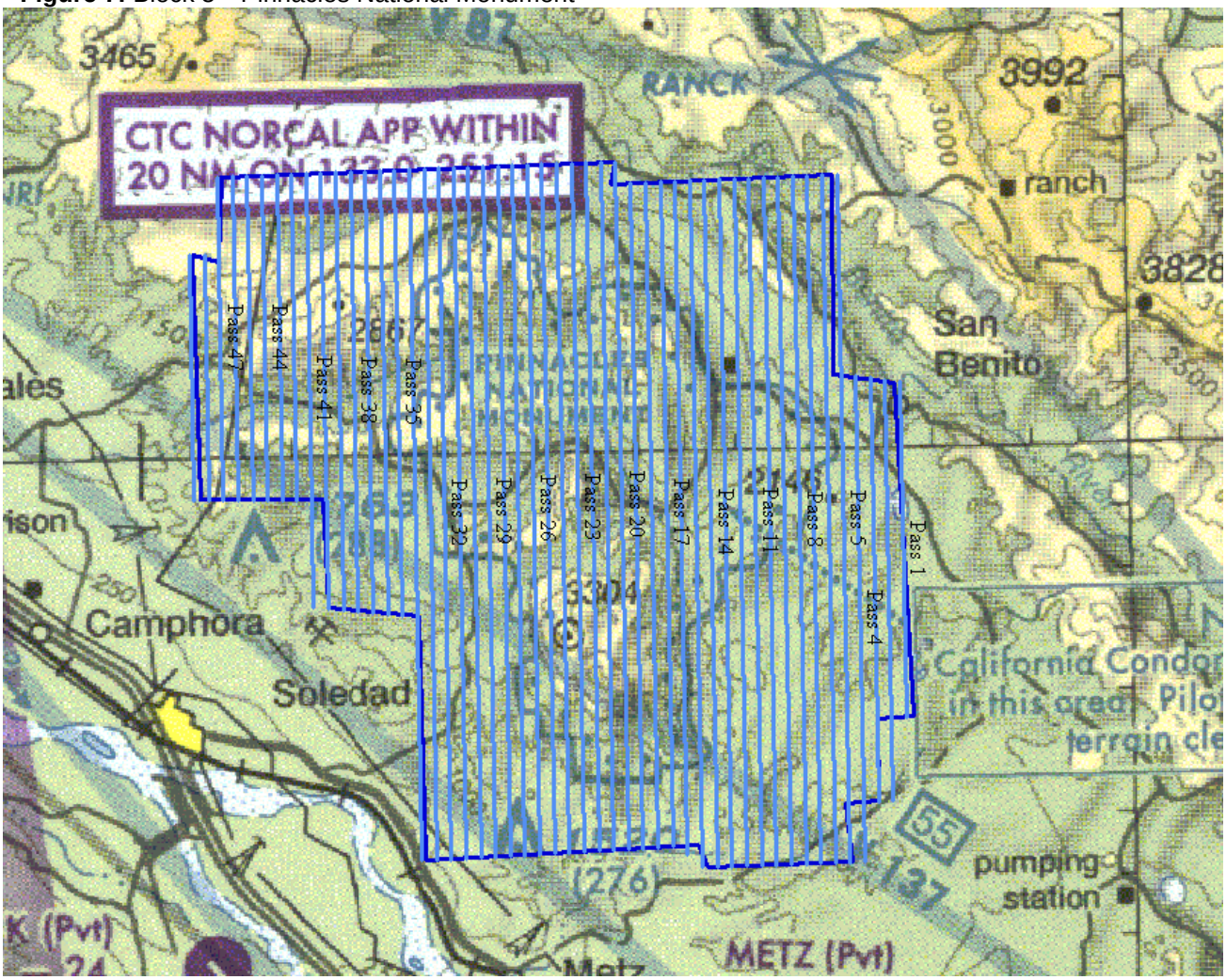


Figure 6: Block 4—Lower Salinas River – King City

Figure 7: Block 5—Pinnacles National Monument



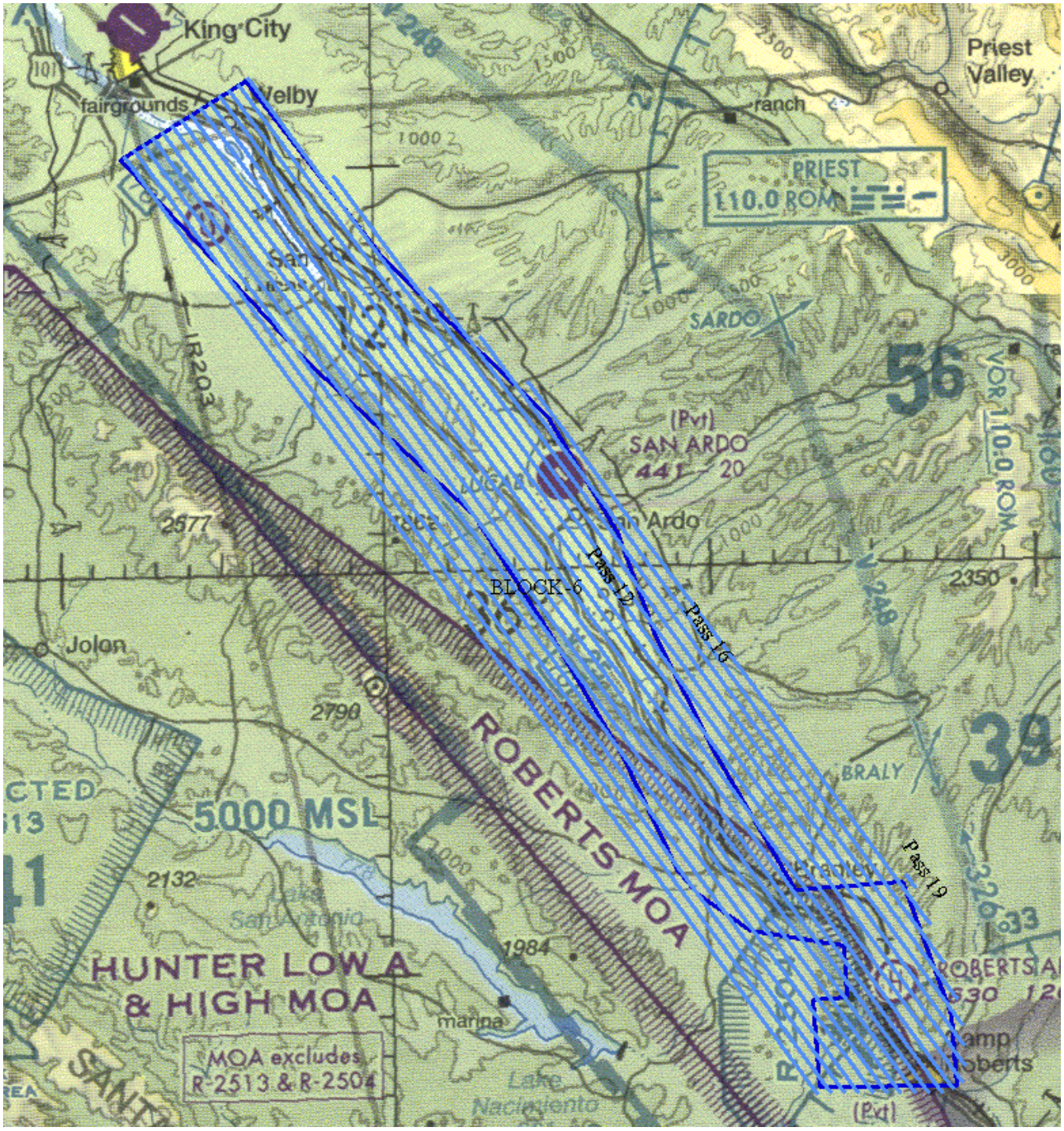


Figure 8: Block 6—Upper Salinas River – Camp Roberts

Figure 9: Block 7—Big Sur

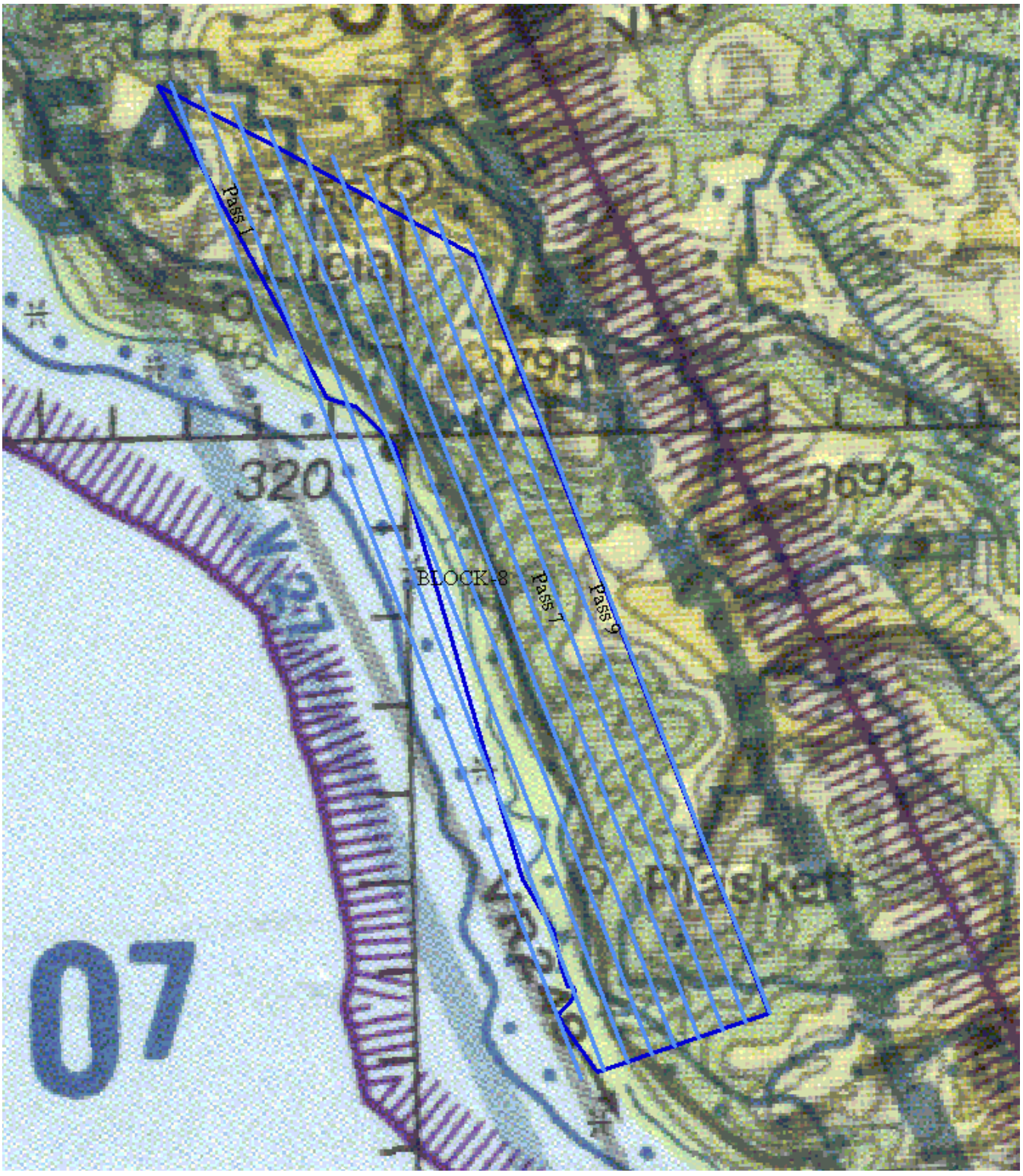


Figure 10: Block 8–St. Lucia - Plaskett

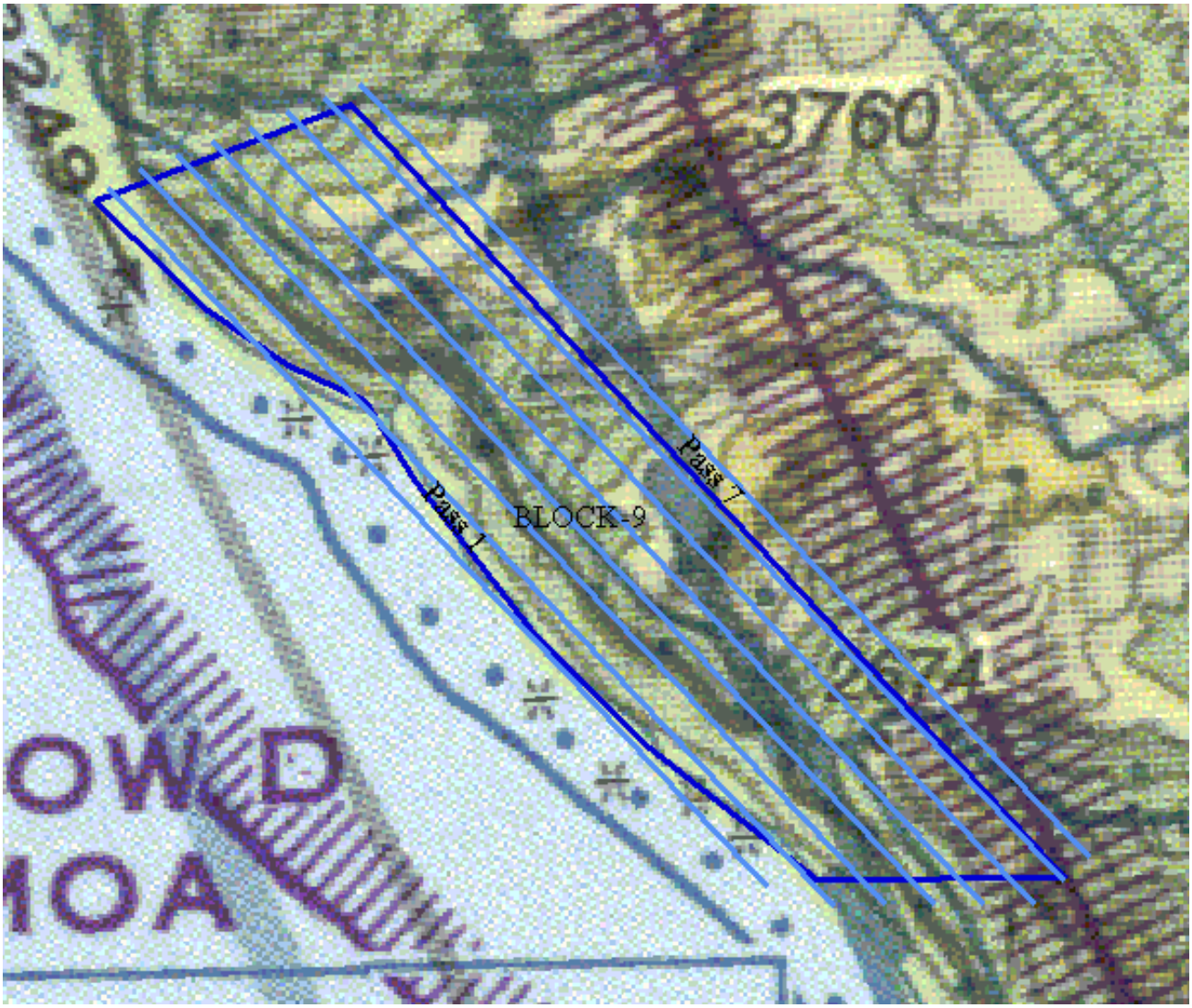


Figure 11: Block 9—Ventana – Silver Peak

mission	flight_date	Job #	block #	system _prf	Scan Freq	Scan Angle	Scan Cutoff	Flight Height (sf)	Aircraft Speed
0817	8/17/2010	dmi10075	6	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0818am	8/18/2010	dmi10075	6	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0818pm	8/18/2010	dmi10075	4	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0819am	8/19/2010	dmi10075	4	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0819pm	8/19/2010	dmi10075	4&5	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0820am	8/20/2010	dmi10075	5	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0820pm	8/20/2010	dmi10075	5	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0821	8/21/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0823	8/23/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0824am	8/24/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0824pm	8/24/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0825am	8/25/2010	dmi10075	3	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0825pm	8/25/2010	dmi10075	3	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0826	8/26/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0827am	8/27/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0827pm	8/27/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0831am	8/31/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0831pm	8/31/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0901am	9/1/2010	dmi10075	3	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0901pm	9/1/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0901pm2	9/1/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0902am	9/2/2010	dmi10075	3	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0902pm	9/2/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0903	9/3/2010	dmi10075	2	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0912	9/12/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0913	9/13/2010	dmi10075	7	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0914am	9/14/2010	dmi10075	7	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0914pm	9/14/2010	dmi10075	8&9	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0915am	9/15/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0915pm	9/15/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0916am	9/16/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
0916pm	9/16/2010	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	4000	120 kts
1117pm	11/17/2010	dmi10075	8	100 kHz	40 Hz	+\- 25°	5°	5000	120 kts
0117pm	01/17/2011	dmi10075	7	100 kHz	40 Hz	+\- 25°	5°	5000	120 kts
0119pm	01/19/2011	dmi10075	1	100 kHz	40 Hz	+\- 25°	5°	5000	120 kts
0120am	01/20/2011	dmi10075	2,3,7,8,9	100 kHz	40 Hz	+\- 25°	5°	5000	120 kts

Table 4: Flight Dates and Acquisition Parameters

LIDAR Calibration

LIDAR calibration is performed to determine and eliminate systematic biases that occur within the hardware of the OPTECH GEMINI system. Once the biases are determined, they can be modeled out. The corrected systematic biases include scale, roll, pitch, and heading error. Calibration procedures are intended to prevent operational errors in the field and office work and are designed to detect inconsistencies.

Calibration Procedures

Three passes were flown over the airport runway. Calibration parameters were computed with previous calibration runs. If there was any change, the new values were entered into the LIDAR post-processing software before the final data post-processing was completed.

Data Processing

The range files, flight logs, raw airborne and ground GPS files were taken to the office for data processing. Real time GPS data from the aircraft were used to check for coverage throughout the project area.

The airborne GPS data was processed from two base stations using POSGPS from Applanix, Inc. The inertial data was processed using POSProc from Applanix, Inc. This software produces an SBET (Smooth Best Estimate of Trajectory) using the GPS trajectory from POSGPS and the roll, pitch, and heading information recorded by the POS (Position Orientation System).

DASHMAP uses the SBET to generate a set of data points for each laser return in the LAS file format. Each data point is assigned an echo value so it can be segregated based on the first and last pulse information. This project's data was processed in strip form, meaning each flight line was processed independently. Processing the lines individually provides the data analyst with the ability to QC the overlap between flight lines.

After the LIDAR data was outputted to the LAS files per strip, the LIDAR processing steps were organized using GeoCue software. In GeoCue the coordinate and datum transformations were applied to the data set to reflect the required deliverable projection, coordinate, and datum systems as provided in the contract. LIDAR filtering was accomplished using TerraScan software. The filtering process reclassifies all the data into classes within the LAS formatted file based scheme using the LAS format 1.2 specifications. Table 5 lists the classification used for this project.

Code	Description
1	Processed, but unclassified
2	Bare-earth ground
7	Noise (low or high, manually identified, if needed)
9	Water
10	Ignored Ground (Breakline Proximity)

Table 5: LIDAR Point Classes

After the classification, the entire dataset was reviewed and manually edited for anomalies that were outside the required guidelines of the product specifications. Man-made structures were removed from bare earth data including bridges. The final bare earth product was verified to meet the accuracy requirements for the job.

LIDAR Checkpoint Vertical Accuracy Assessment

The vertical accuracy of the LIDAR data for this project was evaluated by a set of 124 surveyed check points. In Zone 4, there were 104 check points set in six various ground cover categories. In Zone 3, there were 20 check points set in four categories.

This vertical accuracy was tested using the GPS results from the checkpoints with the LIDAR results to find the distance of Z score. This is the average level of error present in the dataset in survey feet.

The results of a consolidated $RMSE_z$ came out to a 0.232 for Zone 3. Zone 4 had a consolidated $RMSE_z$ of 0.278. All other surface cover groupings for FVA and SVA were within the 0.492 margin of error in survey feet, or as NSSDA $RMSE_z$ = 15 cm. All check points showed a vertical accuracy level well within the 95^{th} percentile margin of error. The NSSDA $Accuracy_z$ mark of $RMSE_z$ x 1.96 for the Zone 4 Monterey area and southern hinterland showed a Consolidated Score of 0.545. This comes to about 16.6 cm, which goes above the project requirement of a minimum of 30 cm by a fair margin. The NSSDA $Accuracy_z$ mark for the Zone 3 Santa Cruz area showed a Consolidated Score of 0.455, which is about 14 cm; also well beyond the project requirement for 95% vertical accuracy.

Average dz	0.098
Root Mean Square Error	0.278
minimum dz	-0.683
maximum dz	0.648
Standard Deviation	0.261

Table 6: Consolidated Vertical Accuracy (CVA) Result for Zone 4

Average dz	0.233
Root Mean Square Error	0.305
Minimum dz	-0.258
Maximum dz	0.479
Std deviation	0.201

Table 7: Fundamental Vertical Accuracy (FVA) Result for Zone 4

Average dz	0.051
Root Mean Square Error	0.268
Minimum dz	-0.683
Maximum dz	0.648
Std deviation	0.265

Table 8: Supplemental Vertical Accuracy (SVA) Result for Zone 4

Number	Easting	Northing	KnownZ	LaserZ	Dz	Surface Type
z4-1	5747261	2103059	399.582	400.23	0.648	BRUSHLAND
z4-2	5804532	2132567	94.141	94.62	0.479	BARE GROUND
z4-3	5803364	2131893	91.061	91.54	0.479	BARE GROUND
z4-4	5747236	2102948	395.622	396.08	0.458	BRUSHLAND
z4-5	5803655	2131987	90.771	91.19	0.419	BARE GROUND
z4-6	5803183	2132158	92.121	92.51	0.389	BARE GROUND
z4-7	5804098	2132278	92.431	92.79	0.359	BARE GROUND
z4-8	5803243	2132067	91.831	92.19	0.359	BARE GROUND
z4-9	5803118	2132254	92.601	92.96	0.359	BARE GROUND
z4-10	5804449	2132511	93.791	94.14	0.349	BARE GROUND
z4-11	5803925	2132163	91.621	91.97	0.349	BARE GROUND
z4-12	5803304	2131978	91.531	91.87	0.339	BARE GROUND
z4-13	5803840	2132107	91.291	91.62	0.329	BARE GROUND
z4-14	5803005	2132423	93.151	93.48	0.329	BARE GROUND
z4-15	5803595	2131949	91.401	91.72	0.319	BARE GROUND
z4-16	5746703	2102497	384.072	384.38	0.308	BRUSHLAND

z4-17	5747299	2102587	386.722	387.02	0.298	TREE
z4-18	5804186	2132337	92.641	92.91	0.269	BARE GROUND
z4-19	5804274	2132395	93.391	93.65	0.259	BARE GROUND
z4-20	5746990	2102431	388.972	389.21	0.238	LOW GRASS
z4-21	5747090	2102783	391.152	391.39	0.238	LOW GRASS
z4-22	5804011	2132220	92.091	92.32	0.229	BARE GROUND
z4-23	5804704	2132680	95.521	95.75	0.229	BARE GROUND
z4-24	5803746	2132046	91.181	91.41	0.229	BARE GROUND
z4-25	5746957	2102347	391.242	391.45	0.208	LOW GRASS
z4-26	5746952	2102646	388.922	389.11	0.188	LOW GRASS
z4-27	5802945	2132507	93.571	93.74	0.169	BARE GROUND
z4-28	5747038	2102696	389.822	389.97	0.148	LOW GRASS
z4-29	5747200	2102840	394.692	394.82	0.128	LOW GRASS
z4-30	5802943	2132536	94.098	94.22	0.122	BARE GROUND
z4-31	5747023	2102381	391.282	391.39	0.108	LOW GRASS
z4-32	5747028	2102597	389.212	389.32	0.108	LOW GRASS
z4-33	5746874	2102296	391.902	392.01	0.108	LOW GRASS
z4-34	5804618	2132623	94.871	94.97	0.099	BARE GROUND
z4-35	5746958	2102501	388.642	388.71	0.068	LOW GRASS
z4-36	5747110	2102373	380.132	380.2	0.068	PAVEMENT
z4-37	5747150	2102741	392.122	392.18	0.058	LOW GRASS
z4-38	5746847	2102440	387.082	387.11	0.028	LOW GRASS
z4-39	5747172	2102445	382.842	382.87	0.028	PAVEMENT
z4-40	5746919	2102229	375.272	375.3	0.028	PAVEMENT
z4-41	5746787	2102241	388.292	388.31	0.018	LOW GRASS
z4-42	5747137	2102642	392.122	392.14	0.018	LOW GRASS
z4-43	5746761	2102400	381.112	381.13	0.018	LOW GRASS
z4-44	5746599	2102453	380.122	380.11	-0.012	BRUSHLAND
z4-45	5747023	2102295	377.072	377.06	-0.012	PAVEMENT
z4-46	5804364	2132453	93.481	93.43	-0.051	BARE GROUND
z4-47	5747072	2102559	392.242	392.19	-0.052	LOW GRASS
z4-48	5746629	2102379	374.442	374.39	-0.052	LOW GRASS
z4-49	5746806	2102535	398.612	398.55	-0.062	LOW GRASS
z4-50	5746853	2102602	396.982	396.9	-0.082	LOW GRASS
z4-51	5746651	2102319	374.412	374.22	-0.192	LOW GRASS
z4-52	5746810	2102162	372.355	372.12	-0.235	BARE GROUND
z4-53	5747047	2102879	398.272	398.02	-0.252	TREE
z4-54	5934209	1964484	319.704	319.99	0.286	BARE GROUND
z4-55	5933794	1964202	316.561	316.84	0.279	BARE GROUND
z4-56	5934568	1964706	321.044	321.49	0.446	PAVEMENT URBAN AREA
z4-57	5934485	1964655	320.164	320.43	0.266	PAVEMENT URBAN AREA
z4-58	5934406	1964606	320.204	320.69	0.486	PAVEMENT URBAN AREA
z4-59	5934328	1964556	320.084	320.49	0.406	PAVEMENT URBAN AREA
z4-60	5934254	1964510	319.914	320.28	0.366	PAVEMENT URBAN AREA
z4-61	5934114	1964638	320.054	320.2	0.146	TREE
z4-62	5934234	1964463	320.324	320.87	0.546	PAVEMENT URBAN AREA
Number	**Easting**	**Northing**	**KnownZ**	**LaserZ**	**Dz**	**Surface Type**
z4-63	5934287	1964379	319.954	319.95	-0.004	PAVEMENT URBAN AREA

z4-64	5934337	1964300	320.314	320.68	0.366	PAVEMENT URBAN AREA
z4-65	5934383	1964216	318.134	318.51	0.376	PAVEMENT URBAN AREA
z4-66	5934172	1964459	320.264	320.62	0.356	PAVEMENT URBAN AREA
z4-67	5934087	1964406	319.884	320.12	0.236	PAVEMENT URBAN AREA
z4-68	5934005	1964351	319.424	319.68	0.256	PAVEMENT URBAN AREA
z4-69	5933922	1964292	318.344	318.76	0.416	PAVEMENT URBAN AREA
z4-70	5933844	1964235	317.034	317.52	0.486	PAVEMENT URBAN AREA
z4-71	6002036	1877500	437.015	437.32	0.305	BRUSHLAND
z4-72	6001682	1877247	440.995	441.25	0.255	BRUSHLAND
z4-73	6001773	1877201	441.105	441.29	0.185	BRUSHLAND
z4-74	6002149	1877178	437.925	438.05	0.125	BRUSHLAND
z4-75	6001976	1877095	436.955	437.05	0.095	BRUSHLAND
z4-76	6001473	1877447	444.015	444.07	0.055	BRUSHLAND
z4-77	6001356	1877618	443.905	443.9	-0.005	BRUSHLAND
z4-78	6001602	1877313	442.335	442.3	-0.035	BRUSHLAND
z4-79	6001858	1877139	441.085	441.03	-0.055	BRUSHLAND
z4-80	6001416	1877535	444.475	444.41	-0.065	BRUSHLAND
z4-81	6001832	1877850	436.105	436.02	-0.085	BRUSHLAND
z4-82	6001919	1877673	436.515	436.43	-0.085	BRUSHLAND
z4-83	6002087	1877412	437.085	436.98	-0.105	BRUSHLAND
z4-84	6001294	1877705	444.545	444.43	-0.115	BRUSHLAND
z4-85	6001979	1877588	437.805	437.65	-0.155	BRUSHLAND
z4-86	6001769	1877940	436.415	436.25	-0.165	BRUSHLAND
z4-87	6001893	1877767	436.605	436.42	-0.185	BRUSHLAND
z4-88	6001493	1877115	466.685	466.5	-0.185	BARE GROUND
z4-89	6002092	1876990	437.128	436.87	-0.258	BARE GROUND
z4-90	6002072	1877055	436.665	436.35	-0.315	BRUSHLAND
z4-91	6002107	1877290	438.985	438.67	-0.315	BRUSHLAND
z4-92	6002134	1877077	437.185	436.82	-0.365	BRUSHLAND
z4-93	5833002	1855353	188.553	189.05	0.497	PAVEMENT
z4-94	5833176	1854914	163.193	163.08	-0.113	PAVEMENT
z4-95	5833128	1855111	171.773	171.51	-0.263	PAVEMENT
z4-96	5833182	1854813	159.413	159.15	-0.263	PAVEMENT
z4-97	5833154	1854603	148.303	148.03	-0.273	PAVEMENT
z4-98	5833153	1855012	166.423	166.14	-0.283	PAVEMENT
z4-99	5833109	1855212	177.653	177.37	-0.283	PAVEMENT
z4-100	5833086	1855325	184.223	183.91	-0.313	PAVEMENT
z4-101	5833125	1854500	141.343	141.02	-0.323	PAVEMENT
z4-102	5833171	1854711	154.263	153.93	-0.333	PAVEMENT
z4-103	5833013	1854337	125.863	125.47	-0.393	PAVEMENT
z4-104	5833068	1854424	132.983	132.3	-0.683	PAVEMENT

Table 9: Surveyed Checkpoint List for Zone 4

Average dz	-0.032
Root mean square	0.232
Minimum dz	-0.595
Maximum dz	0.315
Std deviation	0.236

Table 10: Consolidated Vertical Accuracy (CVA) Result for Zone 3

Average dz	0.205
Root mean square	0.205
Minimum dz	0.205
Maximum dz	0.205
Std deviation	0.000

Table 11: Fundamental Vertical Accuracy (FVA) Result for Zone 3

Average dz	-0.044
Root mean square	0.233
Minimum dz	-0.595
Maximum dz	0.315
Std deviation	0.235

Table 12: Supplemental Vertical Accuracy (SVA) Result for Zone 3

Number	Easting	Northing	Known Z	Laser Z	Dz	Surface Type
z3-1	6149355.81	1815822.05	107.395	107.6	0.205	BARE GROUND
z3-2	6149232.37	1815502.2	99.065	99.07	0.005	LOW GRASS
z3-3	6149755.74	1815271.68	100.085	100.15	0.065	SAWGRASS
z3-4	6149832.94	1815388.2	101.965	102.18	0.215	SAWGRASS
z3-5	6149675.03	1815371.81	101.325	101.64	0.315	SAWGRASS
z3-6	6149634.93	1815301.77	99.925	99.98	0.055	SAWGRASS
z3-7	6149528.1	1815353.75	99.545	99.42	-0.125	SAWGRASS
z3-8	6149550.58	1815477.09	101.605	101.72	0.115	SAWGRASS
z3-9	6149577.1	1815589.98	103.595	103.42	-0.175	SAWGRASS
z3-10	6149485.54	1815628.04	104.115	103.99	-0.125	SAWGRASS
z3-11	6149432.42	1815520.78	100.455	100.45	-0.005	SAWGRASS
z3-12	6149383.66	1815415.92	96.955	96.92	-0.035	SAWGRASS
z3-13	6149304.06	1815458.65	98.365	98.66	0.295	SAWGRASS
z3-14	6149433.65	1815711.63	106.355	105.98	-0.375	SAWGRASS
z3-15	6149323.64	1815643.2	103.735	103.55	-0.185	SAWGRASS
z3-16	6149248.92	1815654.02	103.615	103.57	-0.045	SAWGRASS
z3-17	6149317.81	1815782.37	107.025	106.61	-0.415	TREES
z3-18	6149035.85	1815697.8	102.825	102.94	0.115	TREES
z3-19	6149101.19	1815814.21	105.015	105.07	0.055	TREES
z3-20	6149172.33	1815947.03	107.725	107.13	-0.595	TREES

Table 13: Surveyed Checkpoint List for Zone 3

Following the accuracy verification, Triangular Irregular Network (TIN) files were generated from bare earth LIDAR points, breaklines and hydro-flattened water features. From this TIN dataset 10 sf grid size DEM were generated in ERDAS .IMG format. A final QC process was undertaken to validate all the deliverables for the project prior to release of data for delivery.

Deliverables

DMI is submitting following deliverables to AMBAG.

1-Raw LIDAR

Raw data in LAS 1.2, point format 1 with 4 returns. All the LAS files have geo-reference information. GPS times are recorded as Adjusted GPS Time. The LAS files have 8-bit intensity values for each point. Each file consists of one flight line. The flight lines which exceed 2 GB in size are split. All the collected points are included.

2-Classified Point Data

Classified point data in LAS 1.2, point format 1. All the LAS files have geo-reference information. GPS times are recorded as Adjusted GPS Time. The LAS files have 8-bit intensity values for each point. Classified point data are delivered as tiles without overlap. The tiling scheme is provided by AMBAG. Each tile is 12000sf by 8000sf.

3-Bare Earth Surface (Raster DEM)

DEM cell size is 10 survey feet. The DEM files are delivered as 32-bit floating point raster format as Erdas .IMG. Geo-reference information is included. The DEM data are tiled without overlap. Areas outside the project boundary but within the tiling scheme are coded as NODATA.

4-Breaklines

Breaklines are provided as a continuous shapefile.

5-Hydro flattening water bodies

All breaklines developed for use in hydro-flattening are delivered as a feature class in shapefile format in PolylineZ format. Water bodies (ponds and lakes), wide streams and rivers ("double-line"), and other non-tidal water bodies are hydro-flattened within the DEM.

6-DTM

The DTM is delivered in ESRI TIN format. TIN data are tiled.

7-Metadata

Project information, flight maps, ground control information and LIDAR data QA/QC report are provided. Product metadata (FGDC compliant, XML format metadata) will be provided separately for Zone 3 and Zone 4.

8-Raster DEM in MrSID

DEM files will be a mosaic, using MrSID compression format. This will be the final delivery after all the DEMs are generated.