Report for LiDAR Data

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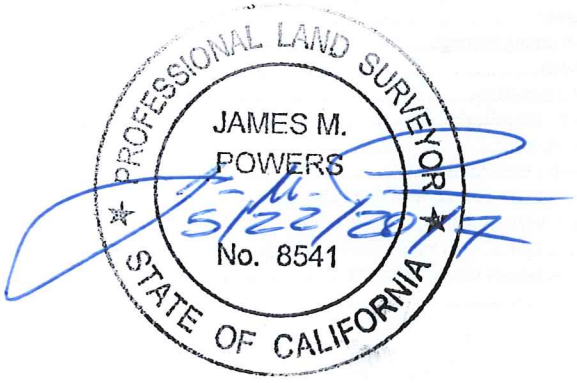
Prepared for:

Los Angeles Region Imagery Acquisition Consortium (LAR-IAC)

PICTOMETRY®
INTELLIGENT IMAGES

Prepared by:
Pictometry International Corp.
25 Methodist Hill Dr.
Rochester, NY 14623
Phone# 585-486-0093 Fax# 585-486-0098



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Collection Procedures

Pictometry offers LiDAR datasets collected at several different point density and accuracy levels to suit a variety of mapping requirements. The following report details Pictometry's data collection and processing methodology and techniques, in compliance with LARIAC specifications and USGS standards.

Data Capture

LiDAR data is collected while atmospheric conditions are such that the air between the aircraft and the ground is cloud and fog free and the ground is generally snow free. Pictometry captures LiDAR using an Optech Galaxy sensor. Pictometry's LiDAR system is capable of recording surface elevation measurements at up to 550 kHz, and at vertical accuracies up to 5cm. Pictometry operates the system in the manner prescribed and based upon the point density chosen. These capture parameters, in conjunction with the utilization of Pictometry's Trimble R8 receivers, enable production of accurate data to create any selected derivative products. Pictometry's data collection techniques and operational parameters have been chosen to be compliant with USGS standards.

Optech Galaxy Specification Page

Parameter	Specification
Laser Configuration	
Topographic laser	1064-nm near-infrared
Laser classification	Class IV (US FDA 21 CFR 1040.10 and 1040.11; IEC/EN 60825-1)
Beam divergence	0.25 mrad (1/e)
Operating altitudes (1,2,3,4)	150-4700 m AGL, nominal
Effective pulse repetition frequency	Programmable, 35-550 kHz
Laser range precision (5)	< 0.008 m, 1 σ
Scan angle (FOV)	Programmable, 0-60°
Swath width	Programmable, 0-115% of AGL
Scan frequency	Programmable, 0-100 Hz advertised (0-200 scan lines/sec)
Sensor scan product	1400 maximum
Absolute horizontal accuracy (2,3)	1/ 7,500 × altitude; 1 σ
Absolute elevation accuracy (2,3)	< 0.03-0.20 m RMSE from 150-5000 m AGL
Sensor Configuration	
Position and orientation system	POS AV™ AP50 (OEM); 220-channel dual frequency GNSS receiver; GNSS airborne antenna with Iridium filters; high-accuracy IMU (IMU-8)
Flight management system	Optech FMS
PulseTRAK™	Continuous operating envelope; Swath Tracker mode; real-time XYZi
Range capture	Up to 8 range measurements, including last
Intensity capture	Up to 8 intensity returns for each pulse, including last (12-bit)
Roll compensation	Programmable; ±5° at 50° FOV, increasing as FOV is reduced from 50°
Minimum target separation distance	< 0.7 m (discrete)
Data storage	Internal solid state drive SSD (SATA II)
Power requirements	28 V, 300 W; 12 A
Dimensions and weight	Sensor: 0.34 × 0.34 × 0.25 m, 27 kg — PDU: 0.42 × 0.33 × 0.10 m, 6.5 kg
Operating temperature	0 to +35°C
Optional Peripherals	
ITAR-free IMU	FMU-301 (IMU-46)
External data storage	Ruggedized, removable 2.5" SSD (SATA II)
Image capture	Compatible with all Optech CS-Series and most 3rd party digital metric cameras
Full waveform capture	12-bit Optech IWR-2 Intelligent Waveform Recorder with removable SSD
Gyro-stabilization	SOMAG GSM 3000/4000 integration kit
Multi-sensor mounts and pods	2 and 4-station machined aluminum sensor mounts (aircraft and/or helicopter) Carbon-fiber heli-pod sensor mount supporting nadir and fore/aft oblique cameras Heli-sensor pod and mount options for Bell 206 (includes STC)

1. Target reflectivity ≥20%.
2. Dependent on selected operational parameters; assumes nominal FOV of up to 40° in standard atmospheric conditions (i.e. 23-km visibility) and use of Optech LMS Professional software suite.
3. Angle of incidence ≤20°
4. Target size ≥ laser footprint
5. Under Optech test conditions, 1 sigma

Responsible Surveyor

James M. Powers, PLS
California Professional Land Surveyor No. 8541

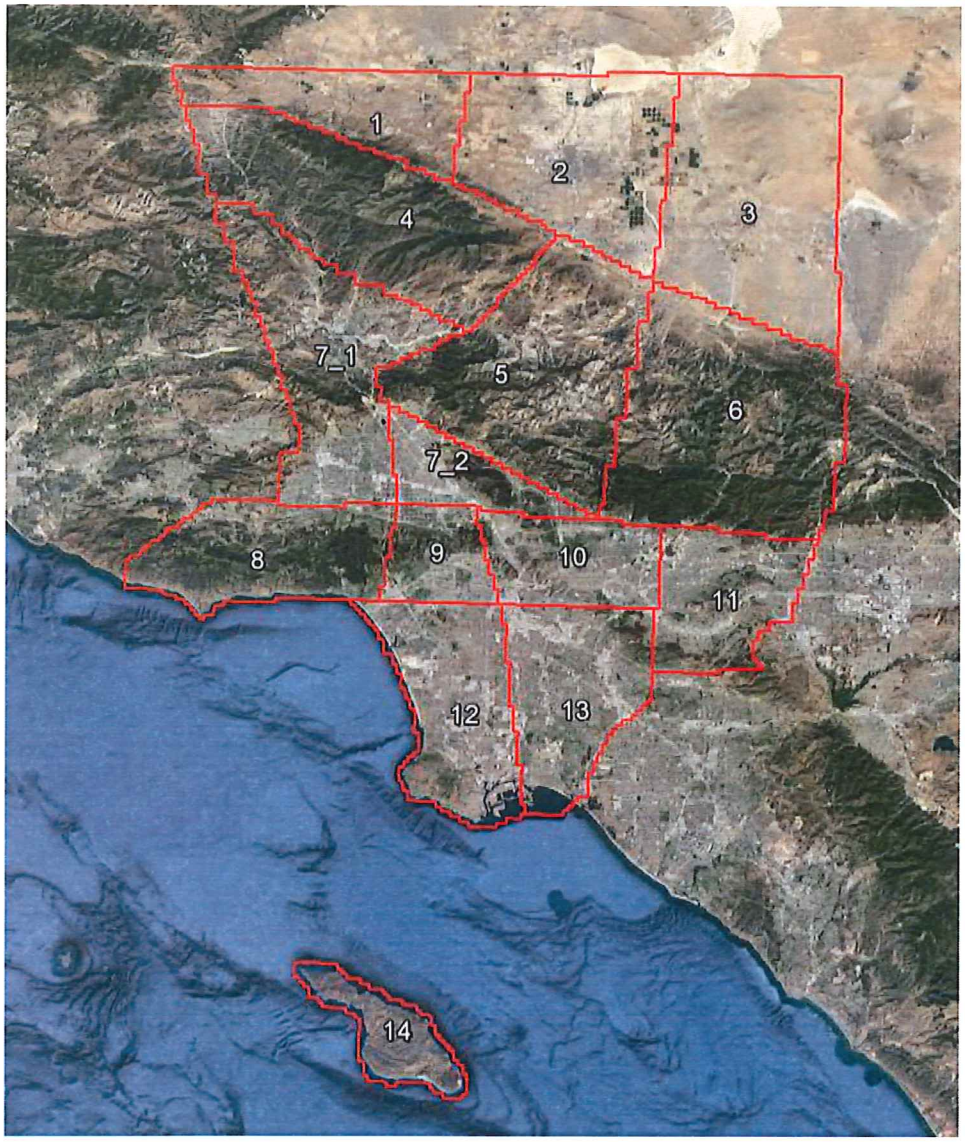
Project Area

The project area for this report encompasses approximately 4213.2 square miles within Los Angeles County, California.

Project Datum

Horizontal Datum: State Plane California Zone V NAD83
Vertical Datum: NAVD88 US Survey Feet (Geoid 12B)

Map Reference



Equipment and Software

Data was captured using Pictometry's Optech ALTM Galaxy LiDAR system mounted in the belly of a Piper Aztec twin engine aircraft. Capture missions were performed by a two-person crew, a pilot to fly the aircraft and a systems operator to operate the LiDAR unit. The project was undertaken to achieve at a minimum the specifications listed below.

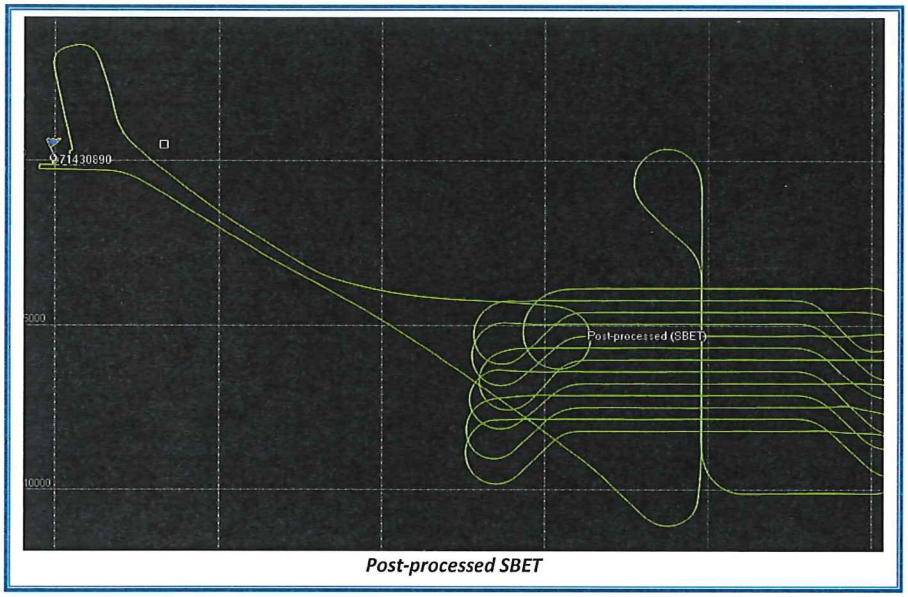
Calibration of the Optech ALTM Galaxy LiDAR sensor involves measurement of many different parameters. These parameters fall into two classes. The first is the group of internal parameters that were measured at Optech Inc., prior to Pictometry's taking delivery of the system. The second class consists of external parameters including the orientation of the laser with respect to the GPS/INS system. Following system installation and prior to undertaking the mission, the GPS antenna is surveyed with respect to the LiDAR sensor. These values (known as lever arms) are recorded for use in post-processing of GPS/INS data. After the lever arm measurement, the system is flown over an array of surveyed points in order to determine the orientation of the sensor. This flight is performed periodically as well as every time the system's components are manipulated or uninstalled.
Specific information pertaining to the system calibration can be found in Appendix A.

GPS/INS Processing

During the collection flights, GPS data is logged both on board the aircraft and ground reference station. The Optech Galaxy contains an Applanix POS module equipped with a NovAtelMilleniumL1/L2 card, which logs GPS data rate of 10Hz. The ground reference station used was two Trimble R8 dual frequency GPS receiver, which logs data at a rate of 2Hz. Flight windows are monitored for ideal satellite formation, i.e. times of minimal Position Dilution of Precision (PDOP). For successful data collection to occur, both the POS module in the aircraft and the ground-based receiver are required to log data from at least 6 satellites, and adhere to a PDOP value of generally less than 3.0.

In addition to the GPS data logging, the Applanix POS module also contains an Inertial Measurement Unit (IMU). The IMU logs data at a rate of 200Hz throughout the flight. The IMU acts in conjunction with the GPS to allow precise determination of both the position and orientation of the sensor head throughout the flight.

Upon receipt by the production team, the data is immediately backed up and post-processing begins. Applanix POSPac software is utilized to post process the GPS/IMU data utilizing the SmartBase (IN-fusion). The SmartBase technology uses a centralized filter approach to combine the GPS receiver's raw observables (psuedorange and phase observables) with the IMU data (tightly coupled solution). The Applanix SmartBase engine processes the raw observables (phase and psuedorange to each tracked satellite) from a minimum of four to a maximum of 50 continuously-working GPS reference stations surrounding the trajectory. The computed ionospheric, tropospheric, satellite clock, and orbital errors at all the reference stations are used to correct for the errors at the location of the remote receiver. The SmartBase Quality Check tool is utilized to perform a network adjustment on all the base-lines and reference stations in the network. Quality checks are also performed on the individual reference station observation files before the Applanix SmartBase is computed. The result of this process is that the integrity of the reference station's data and coordinates are known before the data is processed. The single base technology, if utilized, is different as only one dedicated base station is used as a reference station and atmospheric delay and other correction data are only retrieved at the dedicated master station.



Post-processed SBET

The final smoothed best estimated trajectory (SBET) is computed from the GPS track (including Kalman Filtering).

Point Cloud Processing

The completed SBET is applied to the raw laser data using Optech's Lidar Mapping Suite (LMS) software package to generate the initial point cloud. During this phase, the system calibration data is also applied to provide corrections to the point cloud based on the specific characteristics of the laser scanner. In addition to this semi-annual calibration, Pictometry calculates fine corrections on a mission by mission basis using TerraMatch software, as described in the next steps.

GeoCue – Project Setup and Initial Ground Macro

Upon completion of post-processing, raw swath LAS files are generated. When an entire block's worth of data is generated, these swaths are then imported into a project in GeoCue and divided into processing tiles for the purpose of creating more manageable data. Blocks of data are then subjected to an automatic ground routine utilizing GeoCue's distributive network and Terra Solid's TScan software. Upon execution of the grounding routine dZ ortho images are generated through GeoCue in order to visually inspect the data for any substantial differences in elevation data between swaths.

TerraSolid – Secondary Matching and Classification

After generation of the raw point cloud data in LAS format in LMS, the data is imported into the TerraSolid software suite (running under Bentley's Map PowerView) for secondary matching and classification. The data in the blocks are analyzed by TerraMatch and adjustments to the roll, pitch, heading, scale, and elevation are determined and applied to correct inter-sortie offsets or misalignments. Data is then analyzed for fluctuations of elevation between flight lines and then elevation corrections are applied. Across the mission data is then manually reviewed to ensure proper alignment between flightlines has been achieved. This process is then repeated for each block; once complete, inter-block alignment is verified. Ultimately, the data is checked against a set of ground control points to determine overall accuracy and may be shifted uniformly to best fit the control data.

Classification

During this phase, points are assigned to various classes per the USGS Standard LiDAR point class as set forth in Lidar Base Specification v1.2 published in November, 2014. Noise points – generally low points and atmospheric noise – will be identified and moved to class 7 and 18 as specified. Points representing the ground surface will be assigned to Class 2; classification of ground points is accomplished by application of a series of automatic filters followed by manual reviews to determine filter performance. A variety of filters may be utilized depending on the terrain types present in the project area, augmented by manual review and cleanup to remove outlying points.

Quality Assurance and Quality Checks

After clean-up of the automatic filters, Pictometry reviewed the point clouds for any remaining defects and/or issues. This was accomplished by the generation of a series of rasters, flagging offending tiles and re-editing the tiles for compliance. LAS data went through additional quality assurance and quality control checks through Dewberry.

Metadata

Pictometry develops and delivers FGDC compliant metadata at the project level in conjunction with its LiDAR data offering.

Standard LiDAR Data Deliverables:

- LiDAR Point Cloud Data
    - Tiled* LAS v1.4 files including Return Number and Intensity attribute for each return
        - Duplicate points and 95% of outliers removed

    - Ground points classified via automated methods with manual review and clean up
        - 95% of vegetation features removed
        - 98% of buildings removed
    - Buildings and vegetation not classified separately
- Raw GPS/INS data and laser range files with supporting information
- FGDC compliant metadata

Ground Control Surveying

Based upon Pictometry's surveying experience utilizing the National Geodetic Survey (NGS) published control network and CORS stations, the existing NGS published control network is considered adequate to support the identified accuracy specifications for this project. No additional high order geodetic surveying networks were established for purposes of this project unless otherwise noted herein.

Although Pictometry preferred solution utilizes the Applanix SmartBase technology, Pictometry maintains GPS base stations during all capture windows should there be a need to post-process the GPS data utilizing more traditional single-base techniques. The capture of this data is additionally utilized in Pictometry's QA/QC process when the SmartBase technology is utilized.

Source of Ground Control

Pictometry collects individual ground control points to support each project. The coordinate values collected are utilized to determine the overall project bias and to validate final surfaces computed.
Specific information pertaining to the GCP validation of the final project surface can be found in Appendix B.

Ground control points for this project were collected by Red Plains Surveying Company under the supervision of James M. Powers, PLS.

Information pertaining to GCP control point values and points collected by specific vendors/entities can be found in Appendix E.

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Appendix A: System Calibration Information

Vertical accuracy over calibration control field

Data was collected over Daytona Beach, Florida and compared against 183 of survey control points to analyze the scanner swath against a trusted control field. The following table shows the results of the vertical accuracy of the strips compared to the calibration control field.

Results indicate that the system with sensor S/N 5060352 demonstrates swath vertical accuracy equal to or better than the system specification, using a 40° full field of view.

Table 1: Absolute accuracy over calibration control field

Flight day	Flight altitude (m AGL)	Expected accuracy (m)	Control points used	Laser PRF (kHz)	FOV (±°)	Scan freq. (Hz)	Mean diff. from GCPs (m)	Std dev. (m)	RMS (m)
23215	907	0.05	183	100	20	51	-0.182	**0.012**	0.182
23215	939	0.05	183	100	20	51	-0.164	**0.008**	0.164
23315	1006	0.05	183	100	20	51	-0.181	**0.008**	0.181
23315	1000	0.05	183	300	20	60	-0.170	**0.011**	0.171
23315	640	0.05	183	550	10	100	-0.170	**0.011**	0.170

Optech LMS accuracy verification

Relative horizontal accuracy: Roof line analysis

The roof line analysis compares roof lines in the overlapping areas of flight lines. For a pair of roof lines, it computes the shortest vector between the lines at the center point of one of the lines. The roof line table compares the position and orientation of line features between flight lines. Based on the specification and the flying height of 1000 meters, the ALTM must meet a horizontal accuracy of 1000m / 7500 = 0.133 m.

The sensor with S/N 5060352 exceeds this horizontal specification with an RMS value of the horizontal distance between roof lines of 0.071m.

Table 2: Relative horizontal roof line analysis from Optech LMS for area

23315 Flight	Mean	RMS	Minimum	Maximum
Delta East X	0.002	0.049	-0.656	0.809
Delta North Y	-0.011	0.052	-0.425	0.741
Delta Height Z	-0.003	0.031	-0.962	0.343
Horizontal Separation	-0.000	**0.071**	-0.860	0.755
Diff. Azimuth	-0.00221	0.14115	-0.85340	0.98100
Diff. Slope	-0.00198	0.05542	-0.50925	0.62235

Relative vertical accuracy: Selected tie planes

The results of this section are used to assess the laser point accuracy after applying calibration corrections. Part of the calibration process is to find common artificial and natural planes between flightlines. This relative accuracy demonstrates how well the points of different flight lines agree in their comparison to the common tie planes.

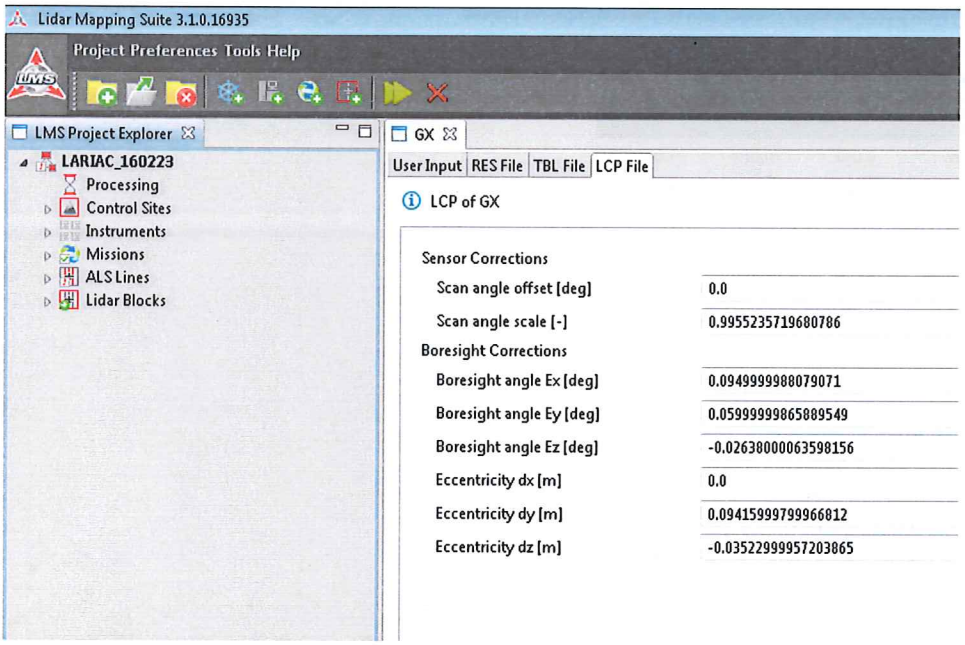
Table 3: Selected tie planes from the runway strips

Flight	Line	No. points	Mean-d	RMS-d	Pass/Fail
23315	9	56627	0.000	0.029	Pass
	10	136887	0.000	0.028	Pass
	11	136795	0.001	0.030	Pass
	12	56120	-0.001	0.026	Pass
	13	64810	0.000	0.24	Pass
	14	42512	0.000	0.026	Pass
	15	70170	-0.001	0.025	Pass
	16	360170	-0.002	0.026	Pass
	17	587859	-0.001	0.025	Pass

Legend

Column 2 – Flight	Julian date of the flight.
Column 3 – Line	Flight line number designated by Optech LMS.
Column 4 – No. points	Total number of points on the common tie planes for the given flight line.
Column 5 – Mean-d	Average point-to-plane distance for the points on the tie-planes for the given flight line.
Column 6 – RMS-d	Root-mean-square value for the point-to-plane distances for the points on the tie-planes for the given flight line.

Pre-Project Boresight Calibration



Appendix B: Ground Control Point Comparisons

Block 01

Number	Easting	Northing	Known Z	Laser Z	Dz
3	6340263.520	2102511.562	3351.227	3351.870	+0.643
5	6458446.118	2120875.118	2512.748	2513.160	+0.412
6	6418913.621	2120260.730	2685.671	2685.850	+0.179
1	6354297.012	2120111.157	3050.814	3050.890	+0.076

Average dz +0.328
Minimum dz +0.076
Maximum dz +0.643
Average magnitude 0.328
Root mean square 0.394
Std deviation 0.253

Block 02

Number	Easting	Northing	Known Z	Laser Z	Dz
8	6510190.919	2035204.797	2775.533	2775.790	+0.257
7	6511655.916	2121154.386	2315.868	2315.940	+0.072

Average dz +0.165
Minimum dz +0.072
Maximum dz +0.257
Average magnitude 0.165
Root mean square 0.189
Std deviation 0.131

Block 03

Number	Easting	Northing	Known Z	Laser Z	Dz
12	6624068.520	2083566.965	3024.797	3025.030	+0.233
11	6629369.690	2121973.699	2540.822	2540.870	+0.048
9	6574789.871	2121985.451	2293.864	2293.840	-0.024
13	6661644.429	2121840.431	2913.354	2913.220	-0.134
10	6570792.524	2078931.698	2413.640	2413.460	-0.180
14	6664287.957	2053666.880	2912.137	2911.790	-0.347

Average dz -0.067
Minimum dz -0.347
Maximum dz +0.233
Average magnitude 0.161
Root mean square 0.195
Std deviation 0.200

Block 04

Number	Easting	Northing	Known Z	Laser Z	Dz
61	6412011.952	2075689.300	3647.381	3647.800	+0.419
4	6448174.383	2062649.510	3333.770	3334.110	+0.340
2	6322267.693	2099678.645	3265.496	3265.760	+0.264
19	6393019.192	2043708.655	2009.163	2009.400	+0.237
27	6460370.031	2003630.267	2601.524	2601.760	+0.236
32	6344045.241	2044218.959	2485.146	2485.350	+0.204

Average dz +0.284
Minimum dz +0.204
Maximum dz +0.419
Average magnitude 0.284
Root mean square 0.293
Std deviation 0.081

Block 05

Number	Easting	Northing	Known Z	Laser Z	Dz
25	6506488.912	1975576.075	3058.321	3058.910	+0.589
28	6461166.654	1981399.994	1959.484	1960.000	+0.516
21	6526123.584	1936930.716	3362.293	3362.650	+0.357
16	6563964.929	2012068.390	2911.133	2910.950	-0.183

Average dz +0.320
Minimum dz -0.183
Maximum dz +0.589
Average magnitude 0.411
Root mean square 0.440
Std deviation 0.349

Block 06

Number	Easting	Northing	Known Z	Laser Z	Dz
23	6606606.363	1952193.464	6662.080	6662.060	-0.020
15	6610846.453	1994563.625	3531.200	3531.080	-0.120
18	6584822.834	1979447.465	4663.331	4663.160	-0.171
45	6600864.373	1910501.284	1578.685	1578.270	-0.415
24	6632519.605	1908691.996	2033.132	2032.520	-0.612

Average dz -0.268
Minimum dz -0.612
Maximum dz -0.020
Average magnitude 0.268
Root mean square 0.344
Std deviation 0.241

Block 07-1

Number	Easting	Northing	Known Z	Laser Z	Dz
29	6408783.566	1957930.808	1406.700	1406.930	+0.230
31	6384250.912	2011412.076	1937.030	1937.260	+0.230
30	6416920.735	1940707.939	1414.344	1414.360	+0.016
33	6352303.528	1996782.492	1584.147	1584.050	-0.097
34	6369240.657	1919437.234	1528.681	1528.290	-0.391
35	6370168.775	1885592.114	883.174	882.620	-0.554

Average dz -0.095
Minimum dz -0.554
Maximum dz +0.230
Average magnitude 0.253
Root mean square 0.310
Std deviation 0.323

Block 07-2

Number	Easting	Northing	Known Z	Laser Z	Dz
36	6425289.852	1887578.026	693.378	693.660	+0.282
22	6454498.071	1922953.762	1178.341	1178.270	-0.071

Average dz +0.106
Minimum dz -0.071
Maximum dz +0.282
Average magnitude 0.176
Root mean square 0.206
Std deviation 0.250

Block 08

Number	Easting	Northing	Known Z	Laser Z	Dz
38	6302939.050	1839160.314	654.523	654.930	+0.407
39	6352341.022	1835444.500	15.066	15.030	-0.036
37	6321956.273	1882090.963	1032.662	1032.620	-0.042

Average dz +0.110
Minimum dz -0.042
Maximum dz +0.407
Average magnitude 0.162
Root mean square 0.237
Std deviation 0.257

Block 09

Number	Easting	Northing	Known Z	Laser Z	Dz
64	6453603.710	1884655.729	609.359	609.630	+0.271
65	6453605.439	1884650.171	609.352	609.580	+0.228
41	6464976.977	1885899.338	555.051	555.140	+0.089

Average dz +0.196
Minimum dz +0.089
Maximum dz +0.271
Average magnitude 0.196
Root mean square 0.211
Std deviation 0.095

Block 10

Number	Easting	Northing	Known Z	Laser Z	Dz
43	6537866.080	1880732.810	884.162	884.230	+0.068

Average dz +0.068
Minimum dz +0.068
Maximum dz +0.068
Average magnitude 0.068
Root mean square 0.068
Std deviation 0.000

Block 11

Number	Easting	Northing	Known Z	Laser Z	Dz
66	6600070.703	1876059.302	822.416	822.900	+0.484
20	6574610.410	1878448.051	985.037	985.260	+0.223
49	6572854.570	1801075.945	374.829	375.030	+0.201
67	6586413.306	1801825.110	495.376	495.550	+0.174
46	6573435.711	1835262.773	314.976	315.140	+0.164
26	6658357.378	1872648.108	1800.928	1800.990	+0.062
47	6648188.363	1848546.378	976.632	976.640	+0.008

Average dz +0.188
Minimum dz +0.008
Maximum dz +0.484
Average magnitude 0.188
Root mean square 0.234
Std deviation 0.152

Block 12

Number	Easting	Northing	Known Z	Laser Z	Dz
62	6484651.804	1831516.701	225.446	226.090	+0.644
42	6478466.219	1831626.054	202.460	203.010	+0.550
53	6434556.632	1792191.780	130.305	130.560	+0.255
40	6416732.245	1832584.209	142.992	143.190	+0.198
55	6462832.572	1731090.229	709.549	709.720	+0.171
63	6457111.823	1832625.224	101.286	101.320	+0.034

Average dz +0.309
Minimum dz +0.034
Maximum dz +0.644
Average magnitude 0.309
Root mean square 0.377
Std deviation 0.237

Block 13

Number	Easting	Northing	Known Z	Laser Z	Dz
54	6531516.064	1741385.087	12.021	12.250	+0.229
44	6535843.548	1831838.124	248.940	249.060	+0.120
52	6498275.996	1737083.757	21.863	21.940	+0.077
50	6533604.819	1799482.457	122.418	122.490	+0.072
51	6491969.742	1785804.578	71.565	71.610	+0.045

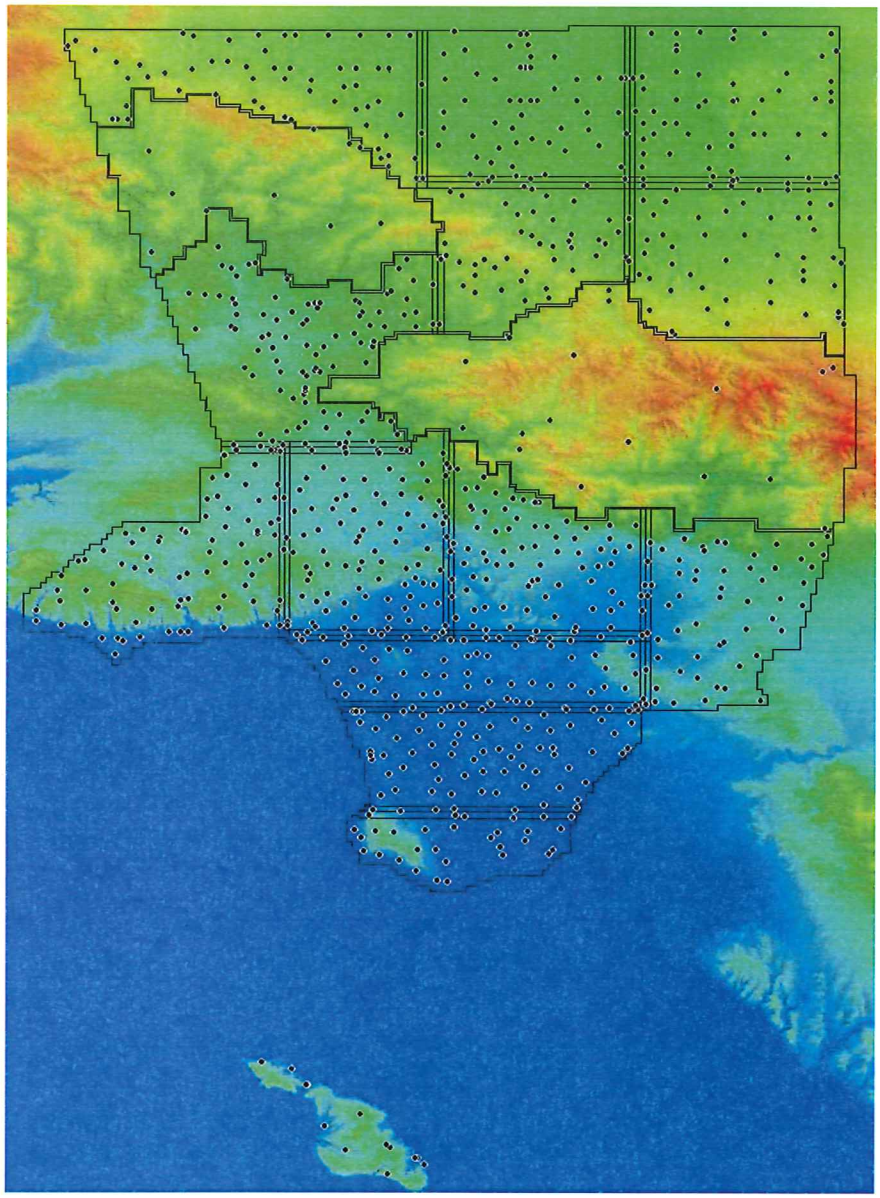
Average dz +0.109
Minimum dz +0.045
Maximum dz +0.229
Average magnitude 0.109
Root mean square 0.127
Std deviation 0.072

Block 14

Number	Easting	Northing	Known Z	Laser Z	Dz
57	6434976.394	1605247.406	1586.283	1586.400	+0.117
56	6387481.132	1630083.652	622.384	622.470	+0.086
58	6428179.922	1588099.963	687.282	687.360	+0.078
60	6462339.771	1585574.955	13.251	13.180	-0.071
59	6449373.394	1589686.618	1452.267	1452.050	-0.217

Average dz -0.002
Minimum dz -0.217
Maximum dz +0.117
Average magnitude 0.114
Root mean square 0.126
Std deviation 0.141

Ground Control Map



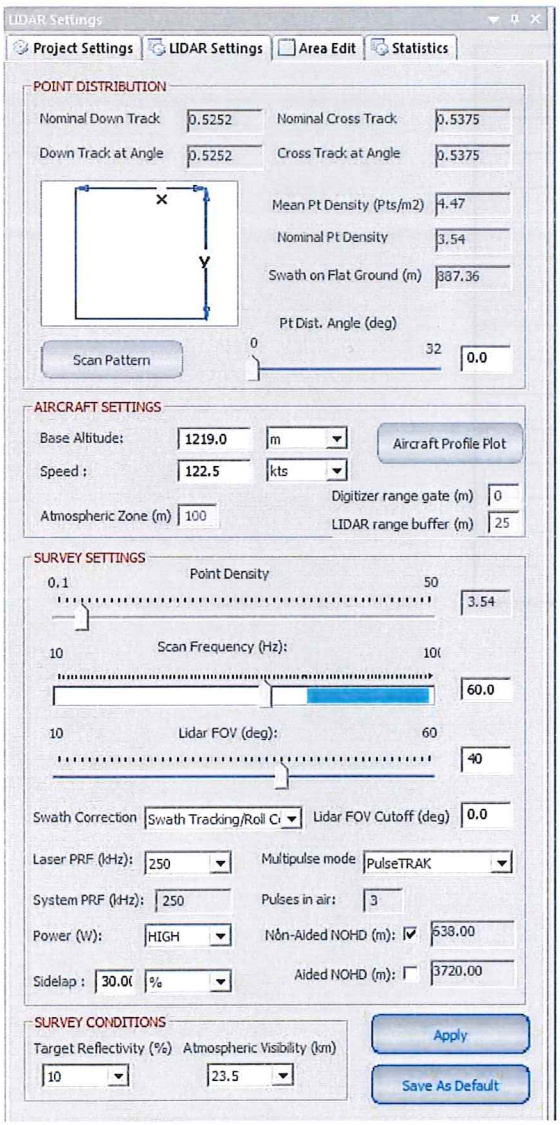
Appendix C: Flight Planning Data

Nominal Capture Settings

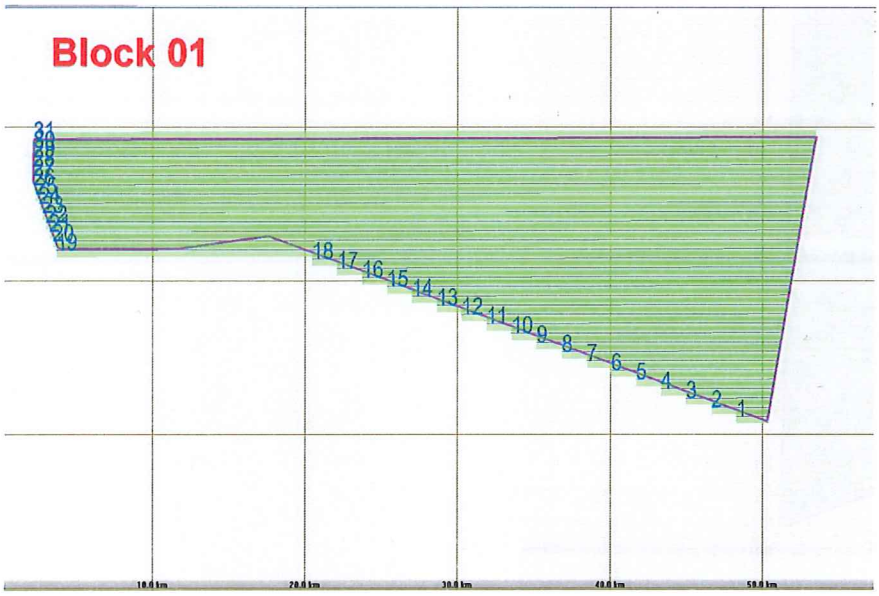
	Nominal Point Spacing
Parameter	**0.7m**
Flight Altitude	760m/2500ft
Point Density	2 points/m^2
Pulse Repetition Frequency	70kHz
Scan Angle (+/-)	15.8°
Scan Frequency	56Hz
Swath Width (raw)	430m/1400ft
Overlap	30%
Vertical Accuracy (bare earth)	9.25cm$RMSE_z$
	18.2cmNSSDA 95%
Horizontal Accuracy*	20cm, RMSE
Contour Interval Supported	1ft
Returns	*Up to four per pulse*
Intensity Records	*Recorded for each return*

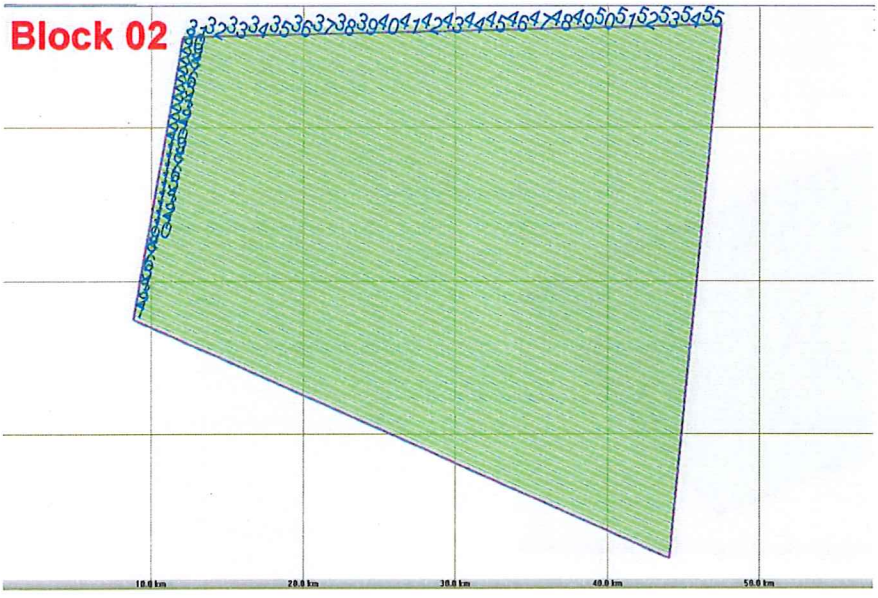
**theoretical value per manufacturer's specification*

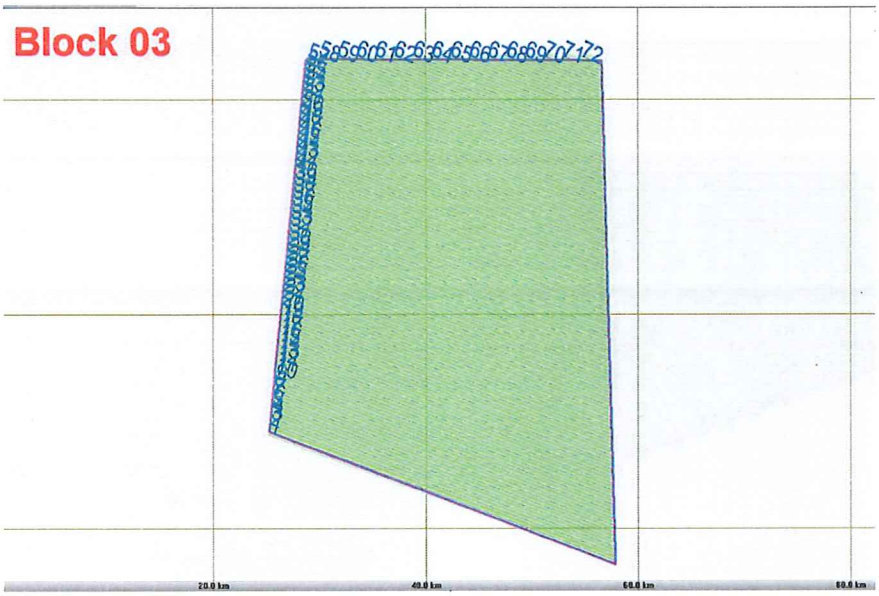
Flight Planning Settings

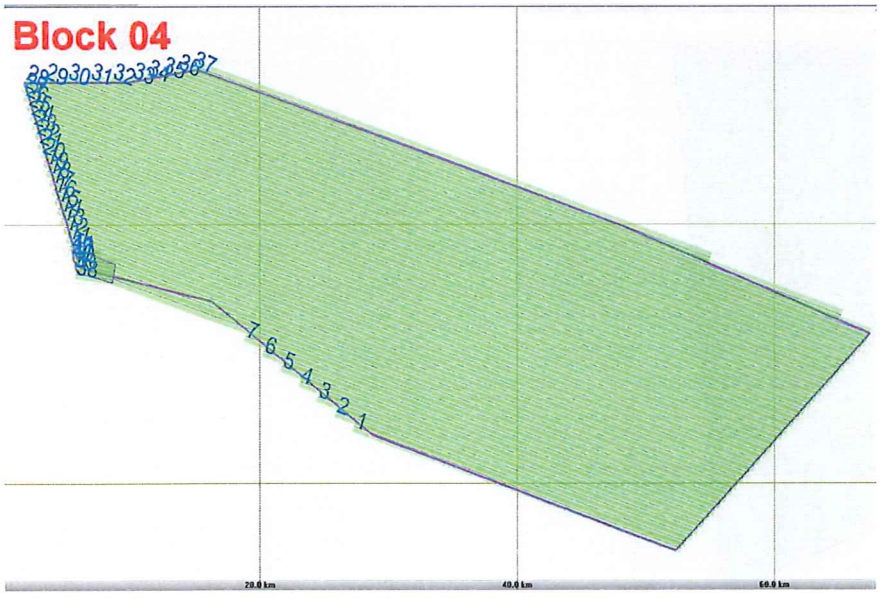


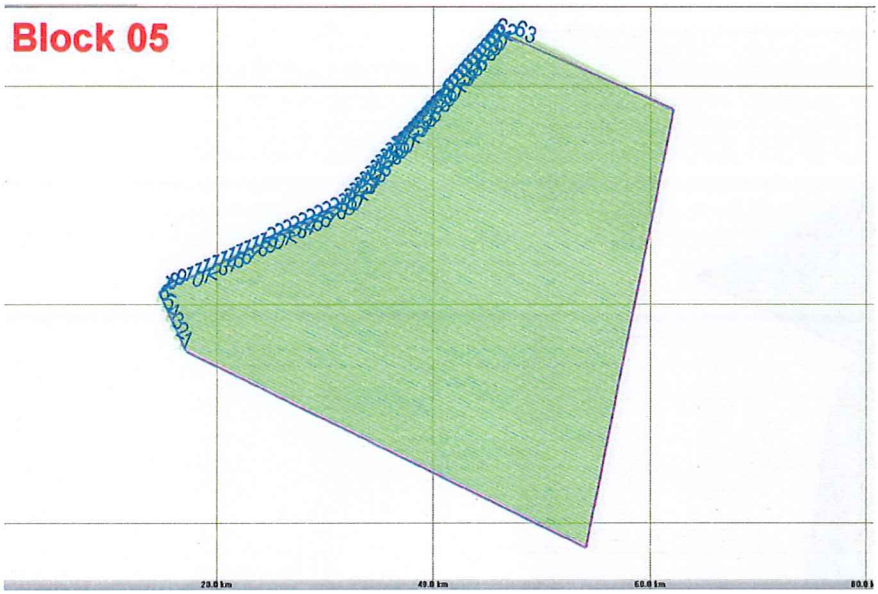
Flight Plans



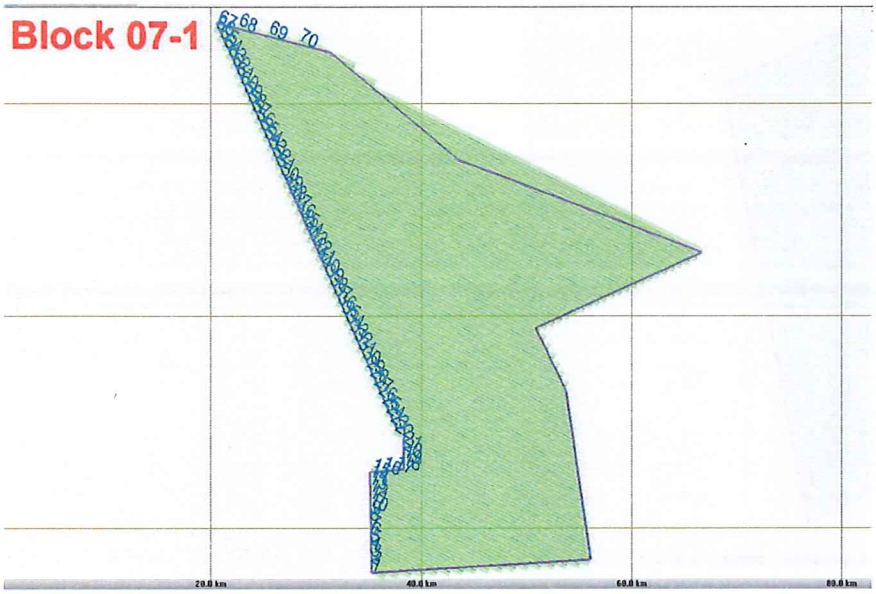


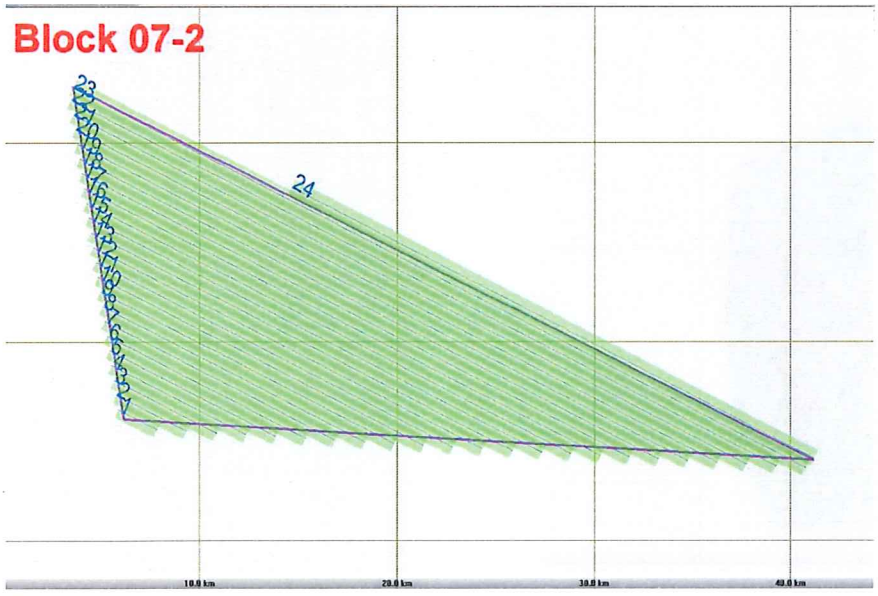

Block 03

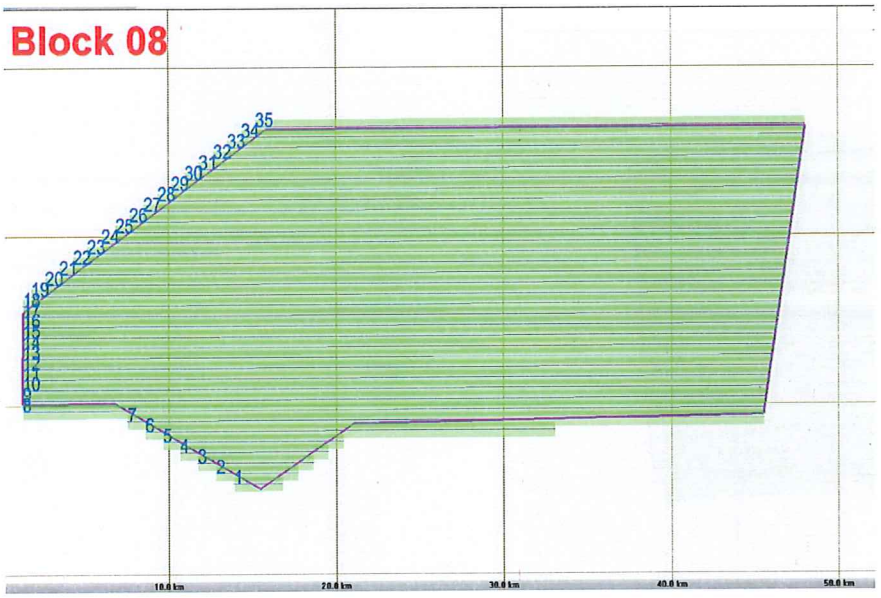

Block 04

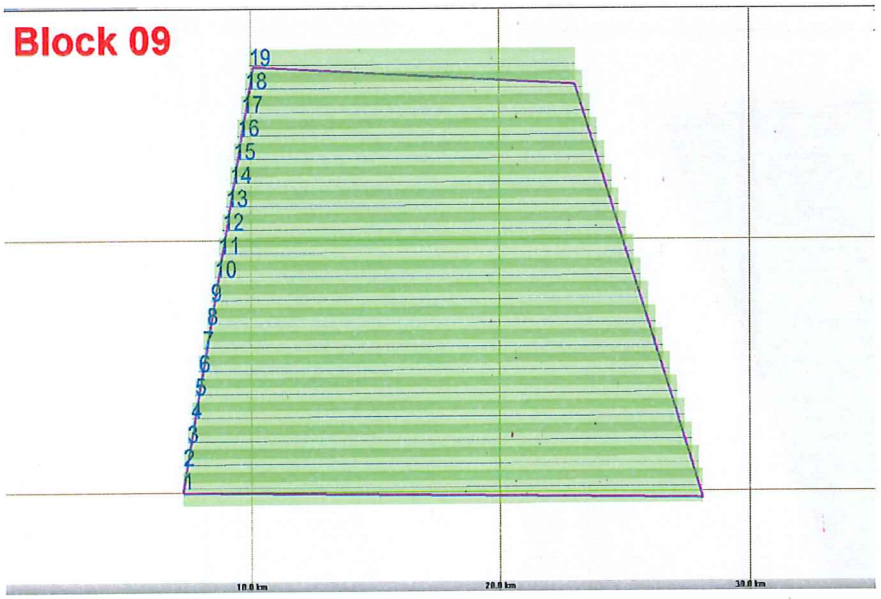

Block 05

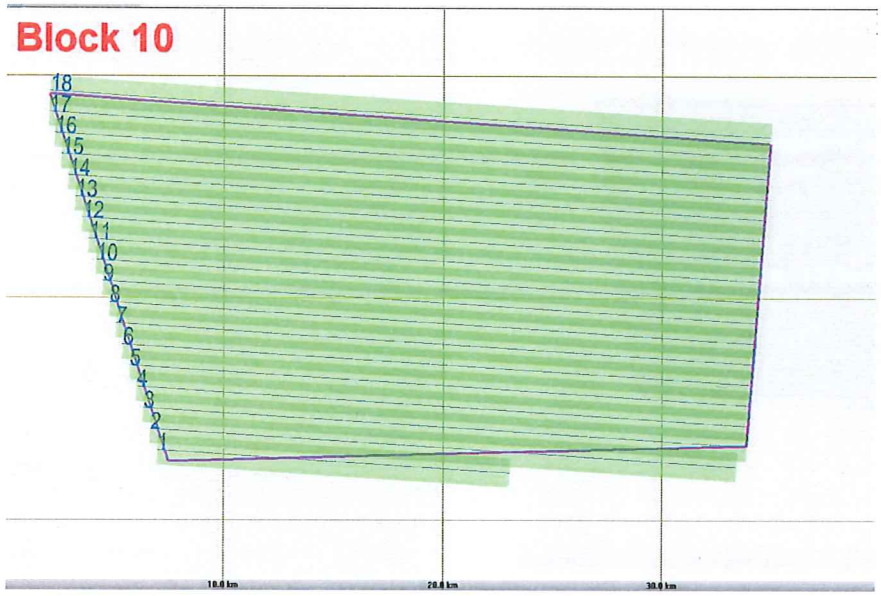

Block 06
36
35
34
33

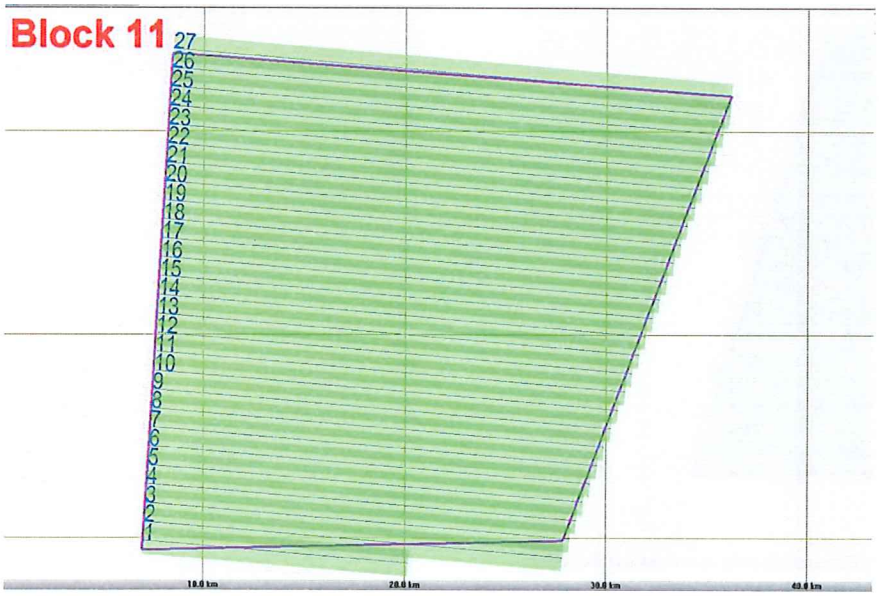

Block 07-1
67
68
69
70
20.0 km
40.0 km
60.0 km
80.0 km

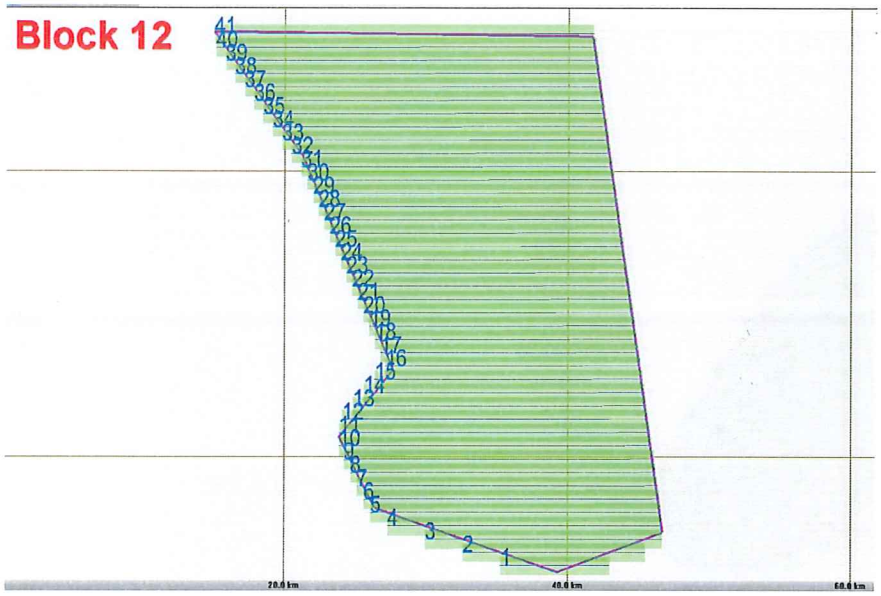

Block 07-2
23
24
10.0 km
20.0 km
30.0 km
40.0 km

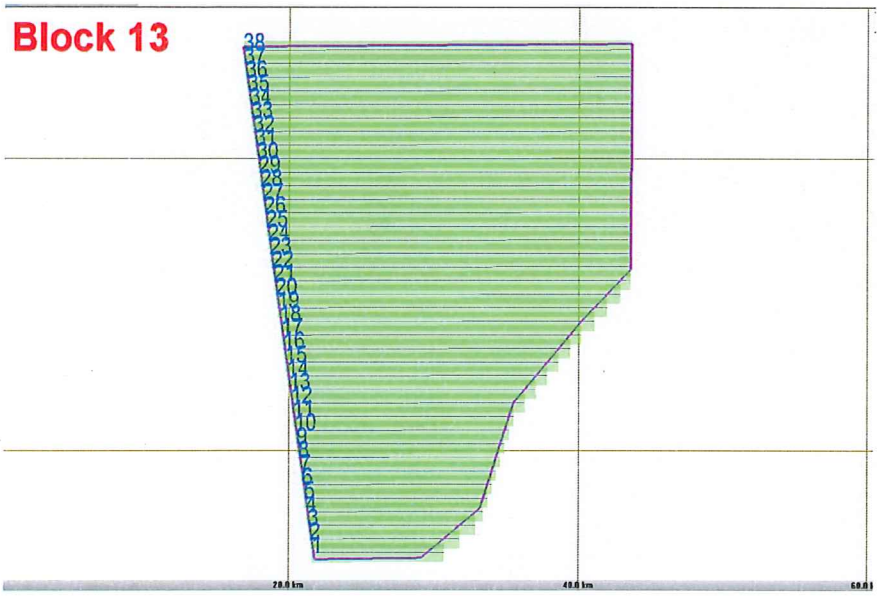

Block 08
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35
10.0 km
20.0 km
30.0 km
40.0 km
50.0 km

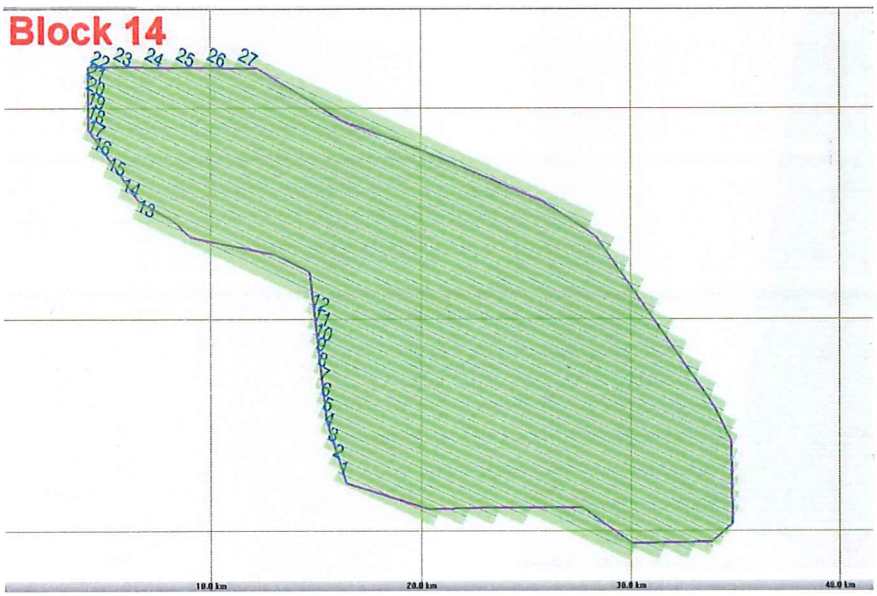

Block 09
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
10.0 km
20.0 km
30.0 km


Block 10
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10.0 km
20.0 km
30.0 km


Block 11
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
10.0 km
20.0 km
30.0 km
40.0 km


Block 12


Block 13


Block 14
22 23 24 25 26 27
16 15 14 13
10.0 km
20.0 km
30.0 km
40.0 km

Flight Information

Sortie	Julian Date	Start Date	Start Time	End Date	End Time
9DS_A_150927	15270	9/27/2015	6:09:21 PM	9/27/2015	8:51:42 PM
9DS_B_150927	15270	9/27/2015	10:36:57 PM	9/28/2015	12:35:24 AM
9DS_A_150929	15272	9/29/2015	1:21:02 AM	9/29/2015	4:21:07 AM
9DS_A_150930	15273	9/30/2015	12:57:24 AM	9/30/2015	5:51:56 AM
9DS_B_150930	15273	9/30/2015	8:26:11 PM	10/1/2015	12:26:22 AM
9DS_A_151001	15274	10/1/2015	7:58:52 PM	10/1/2015	10:52:14 PM
9DS_A_151002	15275	10/2/2015	6:32:56 PM	10/2/2015	10:06:34 PM
9DS_A_151008	15281	10/8/2015	8:25:59 PM	10/8/2015	10:55:17 PM
9DS_A_151009	15282	10/9/2015	7:01:35 PM	10/9/2015	10:49:39 PM
9DS_A_151021	15294	10/21/2015	5:24:10 AM	10/21/2015	7:27:57 AM
9DS_A_151022	15295	10/22/2015	2:04:18 AM	10/22/2015	3:49:48 AM
9DS_A_151024	15297	10/24/2015	5:17:28 AM	10/24/2015	7:16:53 AM
9DS_A_151031	15304	10/31/2015	12:09:55 AM	10/31/2015	4:33:39 AM
9DS_B_151031	15304	10/31/2015	7:03:51 AM	10/31/2015	9:07:19 AM
9DS_A_151104	15308	11/4/2015	7:50:54 AM	11/4/2015	10:33:17 AM
9DS_A_151105	15309	11/5/2015	7:19:28 AM	11/5/2015	11:14:52 AM
9DS_A_151108	15312	11/8/2015	3:40:14 AM	11/8/2015	5:32:40 AM
9DS_B_151108	15312	11/8/2015	6:11:54 AM	11/8/2015	8:38:07 AM
9DS_A_151109	15313	11/9/2015	1:43:51 AM	11/9/2015	3:34:02 AM
9DS_B_151109	15313	11/9/2015	5:49:58 AM	11/9/2015	7:54:28 AM
9DS_A_151111	15315	11/11/2015	6:05:34 PM	11/11/2015	10:51:38 PM
9DS_B_151111	15315	11/11/2015	11:49:02PM	11/12/2015	1:27:08 AM
9DS_A_151118	15322	11/18/2015	5:58:14 PM	11/18/2015	10:59:47 PM
9DS_A_151119	15323	11/19/2015	1:42:25 AM	1/19/2015	5:52:26 AM
9DS_B_151119	15323	11/19/2015	10:08:20 PM	11/20/2015	2:21:40 AM
9DS_A_151120	15324	11/20/2015	7:08:16 PM	11/20/2015	10:52:33 PM
9DS_A_151121	15325	11/21/2015	12:34:05 AM	11/21/2015	2:59:36 AM
9DS_B_151121	15325	11/21/2015	5:23:44 PM	11/21/2015	11:16:40 PM
9DS_A_151122	15326	11/22/2015	12:00:01 AM	11/22/2015	3:28:33 AM
9DS_B_151122	15326	11/22/2015	7:10:49 PM	11/22/2015	9:57:28 PM
9DS_A_151123	15327	11/23/2015	12:29:21 AM	11/23/2015	4:56:11 AM
9DS_A_151201	15335	12/1/2015	7:23:19 AM	12/1/2015	11:08:29 AM
9DS_B_151201	15335	12/1/2015	8:43:20 PM	12/2/2015	1:49:52 AM
9DS_A_151203	15337	12/3/2015	5:35:20 PM	12/3/2015	10:27:45 PM
9DS_A_151204	15338	12/4/2015	1:46:56 AM	12/4/2015	3:57:18 AM
9DS_A_151206	15340	12/6/2015	12:11:22 AM	12/6/2015	4:13:26 AM
9DS_B_151206	15340	12/6/2015	5:25:41 AM	12/6/2015	8:07:12 AM
9DS_C_151206	15340	12/6/2015	8:17:18 PM	12/7/2015	12:08:11 AM
9DS_A_151208	15342	12/8/2015	3:17:02 AM	12/8/2015	6:45:43 AM
9DS_A_151209	15343	12/9/2015	3:55:37 AM	12/9/2015	10:28:35 AM
9DS_B_151209	15343	12/9/2015	9:17:54 AM	12/9/2015	11:05:09 AM
9DS_C_151209	15343	12/9/2015	11:12:47 AM	12/9/2015	1:58:32 PM
9DS_A_151212	15346	12/12/2015	10:03:18 PM	12/12/2015	11:14:32 PM
9DS_A_151213	15346	12/12/2015	11:27:28 PM	12/13/2015	1:29:49 AM
9DS_B_151213	15347	12/13/2015	2:52:13 AM	12/13/2015	5:05:36 AM
9DS_C_151213	15347	12/13/2015	7:19:10 AM	12/13/2015	12:06:18 PM
9DS_D_151213	15347	12/13/2015	8:02:16 PM	12/13/2015	9:42:22 PM
9DS_A_151215	15349	12/15/2015	9:15:23 PM	12/15/2015	11:25:33 PM
9DS_A_151216	15350	12/16/2015	12:11:47 AM	12/16/2015	1:29:56 AM
9DS_A_151217	15351	12/17/2015	6:41:08 PM	12/17/2015	9:08:52 PM
9DS_B_151217	15351	12/17/2015	10:34:57 PM	12/18/2015	12:02:00 AM
9DS_A_151218	15352	12/18/2015	12:07:22 AM	12/18/2015	2:34:48 AM
9DS_A_151220	15354	12/20/2015	6:56:12 PM	12/20/2015	9:26:15 PM
9DS_A_151227	15361	12/27/2015	8:34:04 PM	12/27/2015	11:22:49 PM
9DS_A_151228	15362	12/28/2015	12:47:30 AM	12/28/2015	2:48:01 AM

9DS_A_151229	15363	12/29/2015	9:27:15 PM	12/30/2015	2:17:43 AM
9DS_A_151230	15364	12/30/2015	7:25:16 AM	12/30/2015	9:25:09 AM
9DS_B_151230	15364	12/30/2015	8:38:39 PM	12/30/2015	11:19:25 PM
9DS_A_151231	15365	12/31/2015	1:58:25 AM	12/31/2015	4:21:53 AM
9DS_A_160101	16001	1/1/2016	7:53:46 PM	1/1/2016	10:19:14 PM
9DS_B_160101	16001	1/1/2016	11:22:09 AM	1/2/2009	1:12:07 AM
9DS_A_160109	16009	1/9/2016	7:40:04 AM	1/9/2016	11:58:53 AM
9DS_A_160112	16012	1/12/2016	9:34:31 AM	1/12/2016	1:25:08 PM
9DS_A_160115	16015	1/15/2016	7:41:01 AM	1/15/2016	9:07:51 AM
9DS_A_160120	16020	1/20/2016	11:59:39 PM	1/21/2016	3:06:18 AM
9DS_A_160123	16023	1/23/2016	9:10:48 AM	1/23/2016	11:25:05 AM
9DS_A_160124	16024	1/24/2016	8:52:20 AM	1/24/2016	11:24:11 AM
9DS_A_160125	16025	1/25/2016	9:20:43 AM	1/25/2016	2:03:39 PM
9DS_A_160126	16026	1/26/2016	9:42:49 AM	1/26/2016	12:06:09 PM
9DS_A_160127	16027	1/27/2016	9:39:22 AM	1/27/2016	1:00:18 PM
9DS_A_160130	16030	1/30/2016	12:40:46 AM	1/30/2016	5:58:09 AM
9DS_A_160203	16034	2/3/2016	12:24:49 AM	2/3/2016	2:35:35 AM
9DS_A_160213	16044	2/13/2016	12:12:40 AM	2/13/2016	1:02:15 AM
9DS_A_160219	16050	2/19/2016	7:04:56 AM	2/19/2016	9:18:41 AM
9DS_A_160220	16051	2/20/2016	3:50:42 AM	2/20/2016	5:21:55 AM
9DS_B_160220	16051	2/20/2016	6:02:49 AM	2/20/2016	7:57:37 AM
9DS_C_160220	16051	2/20/2016	9:46:22 PM	2/21/2016	3:00:04 AM
9DS_A_160223	16054	2/23/2016	11:07:46 PM	2/23/2016	2:10:12 AM
9DS_A_160302	16062	3/2/2016	10:21:38 PM	3/2/2016	11:16:10 PM
9DS_A_160303	16063	3/3/2016	9:57:47 PM	3/4/2016	2:38:44 AM
9DS_A_160304	16064	3/4/2016	8:33:08 PM	3/5/2016	12:46:51 AM
9DS_A_160308	16068	3/8/2016	7:15:34 PM	3/8/2016	8:41:33 PM
9DS_A_160310	16070	3/10/2016	2:56:25 AM	3/10/2016	4:40:21 AM
9DS_A_160318	16078	3/18/2016	11:05:19 PM	3/19/2016	12:46:58 AM
9DS_A_160323	16083	3/23/2016	1:36:17 AM	3/23/2016	2:44:45 AM
9DS_B_160323	16083	3/23/2016	9:09:47 PM	3/23/2016	10:45:22 PM

Appendix D: Base Station List

CORS Network

JPLM	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2493303.871 m latitude = 34 12 17.34133 N Y = -4655216.557 m longitude = 118 10 23.57006 W Z = 3565497.688 m ellipsoid height = 424.836 m
LORS	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2012. X = -2461265.277 m latitude = 34 07 59.96495 N Y = -4677292.099 m longitude = 117 45 14.60443 W Z = 3558949.677 m ellipsoid height = 449.692 m
P470	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2422554.662 m latitude = 34 27 44.64332 N Y = -4674804.680 m longitude = 117 23 37.95204 W Z = 3589415.257 m ellipsoid height = 992.188 m
P554	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Apr 2012. X = -2530441.786 m latitude = 34 47 32.25609 N Y = -4593733.615 m longitude = 118 50 52.85162 W Z = 3619635.640 m ellipsoid height = 1170.902 m
CHIL	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2478002.904 m latitude = 34 20 00.30966 N Y = -4655350.824 m longitude = 118 01 33.54939 W Z = 3577932.788 m ellipsoid height = 1568.928 m
VDCY	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Jan 2012. X = -2497835.805 m latitude = 34 10 42.82348 N Y = -4654544.653 m longitude = 118 13 11.95192 W Z = 3563029.064 m ellipsoid height = 318.969 m
P560	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Apr 2012. X = -2504755.336 m latitude = 34 49 18.50629 N Y = -4605351.716 m longitude = 118 32 27.07015 W Z = 3622134.998 m ellipsoid height = 839.033 m

P562	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2471753.188 m latitude = 34 58 55.66573 N Y = -4611978.148 m longitude = 118 11 19.43025 W Z = 3636954.675 m ellipsoid height = 1241.841 m
P582	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Apr 2012. X = -2430134.323 m latitude = 34 38 03.31728 N Y = -4658543.632 m longitude = 117 32 55.84568 W Z = 3605038.372 m ellipsoid height = 848.817 m
SFDM	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2532675.825 m latitude = 34 27 35.28710 N Y = -4615600.111 m longitude = 118 45 16.17441 W Z = 3588781.484 m ellipsoid height = 292.283 m
SKYB	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Jan 2012. X = -2511146.361 m latitude = 34 26 19.03344 N Y = -4629075.503 m longitude = 118 28 43.01647 W Z = 3586973.136 m ellipsoid height = 521.018 m
ZLA1	NAD_83 (2011) POSITION (EPOCH 2010.0) Transformed from IGS08 (epoch 2005.0) position in Aug 2011. X = -2474409.096 m latitude = 34 36 12.65216 N Y = -4637296.012 m longitude = 118 05 01.96910 W Z = 3602183.576 m ellipsoid height = 764.200 m

Pictometry Base Station List

				OPUS comparison					
ID	Easting (Meter)	Northing (Meter)	Elevation (Meter)	Northing (Meter)	Easting (Meter)	Elevation (Meter)	Delta Northing (Meter)	Delta Easting (Meter)	Delta Elevation (Meter)
98810510	423531.124	3829829.920	794.154	3829829.937	423531.115	794.169	-0.017	0.009	-0.015
40890513	389974.375	3815324.079	801.351	3815324.093	389974.361	801.360	-0.014	0.014	-0.009
98810511	389871.680	3815317.907	801.291	3815317.919	389871.665	801.306	-0.012	0.015	-0.015
71252810	357070.814	3826234.587	584.315	3826234.589	357070.804	584.073	-0.002	0.010	0.242
71252820	355780.727	3807650.262	374.048	3807650.252	355780.721	373.816	0.010	0.006	0.232
71252850	341945.710	3774497.159	142.458	3774497.108	341945.733	142.191	0.051	-0.023	0.267
71252940	421883.962	3765342.025	152.835	3765342.013	421883.959	152.565	0.012	0.003	0.270
71252950	421883.953	3765342.029	152.828	3765342.018	421883.957	152.539	0.011	-0.004	0.289
71252960	421883.957	3765342.028	152.843	3765342.017	421883.954	152.565	0.011	0.003	0.278
71252970	421883.964	3765342.028	152.829	3765342.014	421883.961	152.553	0.014	0.003	0.276
71272810	357026.765	3826201.958	586.144	3826201.964	357026.756	585.934	-0.006	0.009	0.210
71272850	341922.729	3774385.582	140.046	3774385.544	341922.739	139.838	0.038	-0.010	0.208
71272940	421739.948	3765342.459	153.213	3765342.448	421739.946	152.984	0.011	0.002	0.229
71272950	421739.924	3765342.472	153.204	3765342.459	421739.929	152.959	0.013	-0.005	0.245
71272960	421739.932	3765342.470	153.220	3765342.459	421739.930	152.987	0.011	0.002	0.233
71272970	421739.937	3765342.475	153.209	3765342.461	421739.934	152.977	0.014	0.003	0.232
71253030	421883.965	3765342.029	152.772	3765341.996	421883.969	152.555	0.033	-0.004	0.217
71253040	421883.968	3765342.033	152.778	3765342.012	421883.970	152.555	0.021	-0.002	0.223
71253060	421883.963	3765342.035	152.776	3765342.016	421883.971	152.552	0.019	-0.008	0.224
71253080	421883.970	3765342.030	152.770	3765342.016	421883.974	152.553	0.014	-0.004	0.217
71253090	421883.971	3765342.026	152.777	3765342.011	421883.968	152.552	0.015	0.003	0.225
71273030	421739.948	3765342.482	153.190	3765342.443	421739.958	152.970	0.039	-0.010	0.220
71273040	421739.941	3765342.476	153.199	3765342.455	421739.942	152.988	0.021	-0.001	0.211
71273050	421739.956	3765342.475	153.195	3765342.466	421739.959	152.974	0.009	-0.003	0.221
71273060	421739.946	3765342.471	153.197	3765342.453	421739.943	152.981	0.018	0.003	0.216

71273080	421739.934	3765342.457	153.189	3765342.443	421739.932	152.963	0.014	0.002	0.226
71273090	421739.946	3765342.484	153.188	3765342.469	421739.945	152.963	0.015	0.001	0.225
71253130	355699.111	3852423.046	846.564	3852423.045	355699.104	846.397	0.001	0.007	0.167
71253150	355699.101	3852423.063	846.563	3852423.063	355699.102	846.404	0.000	-0.001	0.159
71273130	355778.585	3852414.959	846.386	3852414.960	355778.595	846.222	-0.001	-0.010	0.164
71273150	355779.159	3852415.163	846.373	3852415.160	355779.158	846.209	0.003	0.001	0.164
71253220	357084.570	3826246.025	583.458	3826246.009	357084.617	583.371	-0.016	0.047	-0.087
71253221	357084.570	3826246.027	583.446	3826246.005	357084.610	583.385	-0.022	0.040	-0.061
71253230	357084.567	3826246.029	583.472	3826246.014	357084.616	583.391	-0.015	0.049	-0.081
71253231	357084.642	3826245.980	583.512	3826245.956	357084.687	583.430	-0.024	0.045	-0.082
71253240	389974.264	3815324.105	801.465	3815324.098	389974.292	801.392	-0.007	0.028	-0.073
71253241	389974.261	3815324.123	801.463	3815324.112	389974.289	801.398	-0.011	0.028	-0.065
71253250	423598.454	3829763.725	792.818	3829763.737	423598.445	792.745	0.012	-0.009	-0.073
71253252	423598.455	3829763.726	792.819	3829763.739	423598.448	792.739	0.013	-0.007	-0.080
71253260	423598.456	3829763.523	792.245	3829763.537	423598.447	792.172	0.014	-0.009	-0.073
71253270	423598.458	3829763.522	792.251	3829763.534	423598.448	792.183	0.012	-0.010	-0.068
71273220	357020.061	3826201.243	588.148	3826201.223	357020.098	588.018	-0.020	0.037	-0.130
71273221	357020.052	3826201.244	588.148	3826201.226	357020.101	588.012	-0.018	0.049	-0.136
71273230	357020.044	3826201.240	588.146	3826201.220	357020.090	588.137	-0.020	0.046	-0.009
71273231	357020.074	3826201.270	588.108	3826201.249	357020.117	587.963	-0.021	0.043	-0.145
71273240	389871.641	3815317.925	801.310	3815317.911	389871.911	801.168	-0.014	0.270	-0.142
71273241	389871.641	3815317.925	801.311	3815317.915	389871.669	801.174	-0.010	0.028	-0.137
71273250	423531.137	3829829.934	794.164	3829829.942	423531.128	794.041	0.008	-0.009	-0.123
71273260	423531.144	3829829.948	793.585	3829829.966	423531.129	793.459	0.018	-0.015	-0.126
71273270	423531.139	3829829.932	793.579	3829829.948	423531.122	793.584	0.016	-0.017	0.005
71253511	423598.477	3829763.568	792.714	3829763.585	423598.458	792.736	-0.017	0.019	-0.022
71273511	423531.150	3829829.949	794.157	3829829.950	423531.136	794.028	-0.001	0.014	0.129
40890160	423531.121	3829829.950	794.169	3829829.951	423531.128	794.109	-0.001	-0.007	0.060
40890200	423531.140	3829829.947	794.163	3829829.939	423531.142	794.088	0.008	-0.002	0.075
40890440	423598.436	3829763.595	792.728	3829763.585	423598.439	792.648	0.010	-0.003	0.080

40890510	423598.450	3829763.581	792.715	3829763.573	423598.460	792.651	0.008	-0.010	0.064
98810160	423598.447	3829763.591	792.750	3829763.592	423598.453	792.683	-0.001	-0.006	0.067
98810210	423598.442	3829763.592	792.734	3829763.586	423598.442	792.639	0.006	0.000	0.095
98810440	423531.124	3829829.949	794.159	3829829.940	423531.128	794.083	0.009	-0.004	0.076
98810510	423531.105	3829829.944	794.164	3829829.937	423531.114	794.103	0.007	-0.009	0.061
40890470	384288.593	3747500.850	4.346	3747500.836	384288.585	4.304	0.014	0.008	0.042
71250240	384147.986	3747555.644	-0.158	3747555.642	384147.986	-0.163	0.002	0.000	0.005
71250241	384147.983	3747555.642	-0.161	3747555.642	384147.981	-0.172	0.000	0.002	0.011
71250251	384147.941	3747555.648	-0.143	3747555.656	384147.947	-0.141	-0.008	-0.006	-0.002
71250270	384147.971	3747555.645	-0.145	3747555.644	384147.972	-0.139	0.001	-0.001	-0.006
71250271	384147.975	3747555.646	-0.136	3747555.655	384147.979	-0.159	-0.009	-0.004	0.023
71270240	384288.641	3747500.817	4.320	3747500.817	384288.647	4.282	0.000	-0.006	0.038
71270241	384288.654	3747500.814	4.317	3747500.809	384288.652	4.286	0.005	0.002	0.031
71270242	384288.654	3747500.812	4.318	3747500.803	384288.649	4.278	0.009	0.005	0.040
71270250	384288.593	3747500.845	4.343	3747500.841	384288.595	4.326	0.004	-0.002	0.017
71270251	384288.596	3747500.845	4.341	3747500.848	384288.601	4.283	-0.003	-0.005	0.058
71270260	384288.592	3747500.853	4.350	3747500.847	384288.588	4.332	0.006	0.004	0.018
71270261	384288.595	3747500.854	4.355	3747500.860	384288.599	4.309	-0.006	-0.004	0.046
71270270	384288.594	3747500.853	4.354	3747500.841	384288.587	4.318	0.012	0.007	0.036
98810470	384148.060	3747560.893	0.019	3747560.882	384148.054	0.004	0.011	0.006	0.015
40890520	355846.068	3807723.027	366.607	3807723.045	355846.098	366.559	-0.018	-0.030	0.048
40890540	355845.224	3807722.025	366.721	3807722.014	355845.227	366.714	0.011	-0.003	0.007
98810520	355780.327	3807650.586	373.909	3807650.607	355780.359	373.968	-0.021	-0.032	-0.059
98810540	355772.170	3807652.970	373.700	3807652.961	355772.175	373.687	0.009	-0.005	0.013
40890630	420768.329	3788842.947	428.223	3788842.942	420768.320	428.143	0.005	0.009	0.080
40890640	420795.964	3788842.891	426.529	3788842.888	420795.964	426.454	0.003	0.000	0.075
40890650	420795.972	3788842.897	426.529	3788842.925	420795.967	426.442	-0.028	0.005	0.087
98810630	420795.232	3788843.253	426.581	3788843.247	420795.223	426.497	0.006	0.009	0.084
98810640	420765.459	3788843.218	428.274	3788843.209	420765.456	428.172	0.009	0.003	0.102
98810650	420765.465	3788843.224	428.272	3788843.215	420765.454	428.186	0.009	0.011	0.086

Appendix E: Ground Control Point List

Ground Control Points			
Point	**Northing**	**Easting**	**Elev**
LA01	1568885.40	6464911.95	363.62
LA02	1576613.15	6448977.93	1611.97
LA03	1589684.26	6449708.23	1476.47
LA04	1599553.18	6418088.82	83.12
LA05	1619213.08	6409721.04	23.99
LA06	1624097.87	6392975.45	1532.26
LA07	1922670.29	6511496.19	3421.50
LA08	1926369.45	6563806.14	5121.86
LA09	1933186.52	6483640.91	1807.67
LA10	1948790.63	6407686.55	1731.47
LA11	1959365.09	6414887.26	1470.40
LA12	1961595.60	6379195.60	1552.42
LA13	1981399.79	6461113.04	1958.61
LA14	1982543.77	6469457.03	2085.29
LA15	1982631.03	6472707.75	2129.44
LA16	1996782.51	6352303.53	1584.30
LA17	1997183.58	6447725.64	2218.91
LA18	2000424.78	6599683.21	3264.79
LA19	2000424.78	6599683.21	3264.79
LA20	2012315.81	6666429.85	3250.10
LA21	2013297.67	6456606.94	2620.08
LA22	2013675.02	6611162.35	3016.52
LA23	2014533.14	6648008.01	3165.71
LA24	2014695.79	6662614.82	3202.59
LA25	2021039.99	6475358.41	3289.43
LA26	2025195.61	6491863.36	3720.38
LA27	2025429.84	6620086.11	2868.92
LA28	2025504.74	6600613.25	2826.31
LA29	2033285.04	6564249.15	2644.91
LA30	2040371.74	6661774.26	2928.96
LA31	2044218.94	6344045.25	2485.17
LA32	2046886.24	6586783.92	2669.96
LA33	2049044.49	6570867.47	2567.06
LA34	2050316.31	6659154.48	2879.02
LA35	2050453.70	6640367.48	2756.81
LA36	2052034.30	6464311.03	3285.90
LA37	2052106.70	6562021.50	2531.48
LA38	2053666.83	6664287.91	2911.98

LA39	2057834.06	6448197.42	3453.04
LA40	2068122.78	6471814.19	2533.36
LA41	2073540.56	6613567.19	2682.87
LA42	2073469.47	6562804.96	2429.48
LA43	2080259.36	6317312.30	2921.94
LA44	2081038.29	6398016.15	3861.47
LA45	2085422.40	6387161.10	3780.52
LA46	2086765.81	6347360.50	4117.51
LA47	2091864.58	6364786.63	3988.74
LA48	2093897.87	6661607.41	2956.42
LA49	2097810.54	6614266.67	3049.40
LA50	2103107.55	6640186.70	2987.00
LA51	2104042.58	6353707.91	3168.21
LA52	2105119.10	6513764.71	2306.85
LA53	2113670.71	6663813.12	2882.42
LA54	2120259.16	6418891.80	2687.22
LA55	2120515.58	6385336.07	2929.83
LA56	2120638.34	6398018.43	2843.77
LA57	2120676.86	6402993.50	2794.71
LA58	2121405.13	6349210.86	3090.07
LA59	2120682.89	6447808.06	2566.13
LA60	2121840.77	6661644.54	2913.43
LA61	2121972.38	6629369.84	2541.08

Appendix F: Vertical Accuracy Assessment

Background

Dewberry quantitatively tested the dataset by testing the vertical accuracy of the lidar. The vertical accuracy is tested by comparing the discreet measurement of the survey checkpoints to that of the interpolated value within the three closest lidar points that constitute the vertices of a three-dimensional triangular face of the TIN. Therefore, the end result is that only a small sample of the lidar data is actually tested. However there is an increased level of confidence with lidar data due to the relative accuracy. This relative accuracy in turn is based on how well one lidar point "fits" in comparison to the next contiguous lidar measurement, and is verified as part of the initial processing. If the relative accuracy of a dataset is within specifications and the dataset passes vertical accuracy requirements at the location of survey checkpoints, the vertical accuracy results can be applied to the whole dataset with high confidence due to the passing relative accuracy. Dewberry typically uses LP360 software to test the swath lidar vertical accuracy, Terrascan software to test the classified lidar vertical accuracy, and Esri ArcMap to test the DEM vertical accuracy so that three different software programs are used to validate the vertical accuracy for each project.

NVA (Non-vegetated Vertical Accuracy) is determined with check points located only in non-vegetated terrain, including open terrain (grass, dirt, sand, and/or rocks) and urban areas, where there is a very high probability that the lidar sensor will have detected the bare-earth ground surface and where random errors are expected to follow a normal error distribution. The NVA determines how well the calibrated lidar sensor performed. With a normal error distribution, the vertical accuracy at the 95% confidence level is computed as the vertical root mean square error (RMSEz) of the checkpoints x 1.9600. For the Lariac4 lidar project, vertical accuracy must be 0.64 ft or less based on an RMSEz of 10 cm x 1.9600.

VVA (Vegetated Vertical Accuracy) is determined with all checkpoints in vegetated land cover categories, including tall grass, weeds, crops, brush and low trees, and fully forested areas, where there is a possibility that the lidar sensor and post-processing may yield elevation errors that do not follow a normal error distribution. VVA at the 95% confidence level equals the 95th percentile error for all checkpoints in all vegetated land cover categories combined. The Lariac4 Lidar Project VVA standard is 0.96 ft based on the 95th percentile. The VVA is accompanied by a listing of the 5% outliers that are larger than the 95th percentile used to compute the VVA; these are always the largest outliers that may depart from a normal error distribution. Here, Accuracy$_z$ differs from VVA because Accuracy$_z$ assumes elevation errors follow a normal error distribution where RMSE procedures are valid, whereas VVA assumes lidar errors may not follow a normal error distribution in vegetated categories, making the RMSE process invalid.

The relevant testing criteria are summarized in Table 1.

Quantitative Criteria	Measure of Acceptability
Non-Vegetated Vertical Accuracy (NVA) in open terrain and urban land cover categories using RMSE$_z$ *1.9600	0.64 ft (based on RMSE$_z$ (10 cm) * 1.9600)
Vegetated Vertical Accuracy (VVA) in all vegetated land cover categories combined at the 95% confidence level	0.96 ft (based on combined 95th percentile)

Table 1 — Acceptance Criteria

The primary QA/QC vertical accuracy testing steps used by Dewberry are summarized as follows:

1. Dewberry's team surveyed QA/QC vertical checkpoints in accordance with the project's specifications.
2. Next, Dewberry interpolated the bare-earth lidar DTM to provide the z-value for every checkpoint.
3. Dewberry then computed the associated z-value differences between the interpolated z-value from the lidar data and the ground truth survey checkpoints and computed NVA, VVA, and other statistics.
4. The data were analyzed by Dewberry to assess the accuracy of the data. The review process examined the various accuracy parameters as defined by the scope of work. The overall descriptive statistics of each dataset were computed to assess any trends or anomalies. This report provides tables, graphs and figures to summarize and illustrate data quality.

Vertical Accuracy Results

The table below summarizes the tested vertical accuracy resulting from a comparison of the surveyed checkpoints to the elevation values present within the fully classified lidar LAS files.

Land Cover Category	# of Points	NVA — Non-vegetated Vertical Accuracy (RMSEz x 1.9600) Spec=0.64 ft	VVA — Vegetated Vertical Accuracy (95th Percentile) Spec=0.96 ft
NVA	144	0.64	
VVA	23		0.53

Table 2 — Tested NVA and VVA

This lidar dataset was tested to meet ASPRS Positional Accuracy Standards for Digital Geospatial Data (2014) for a 0.33 ft RMSEz Vertical Accuracy Class. Actual NVA accuracy was found to be $RMSE_z$ =0.32 ft, equating to +/- 0.33 ft at 95% confidence level. Actual VVA accuracy was found to be +/- 0.53 ft at the 95th percentile.

Table 3 lists the 5% outliers that are larger than the VVA 95th percentile.

Point ID	NAD83 State Plane CA Zone 5 (FIPS 0405)		NAVD88 (Geoid 12B)		DeltaZ	AbsDeltaZ
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)		
825GR	6421519.31	2116759.62	2671.66	2672.53	0.87	0.87

Table 3 — 5% Outliers

Table 4 provides overall descriptive statistics.

100 % of Totals	# of Points	RMSEz (ft) NVA Spec=0.33 ft	Mean (ft)	Median (ft)	Skew	Std Dev (ft)	Kurtosis	Min (ft)	Max (ft)
NVA	144.00	0.32	0.20	0.24	-0.64	0.25	0.27	-0.65	0.71
VVA	23.00	N/A	0.19	0.18	0.40	0.25	1.38	-0.26	0.87

Table 4 — Overall Descriptive Statistics

Appendix G: QA/QC Checkpoint Location Map

The figure below shows the location of the QA/QC checkpoints used to test the positional accuracy of the dataset.

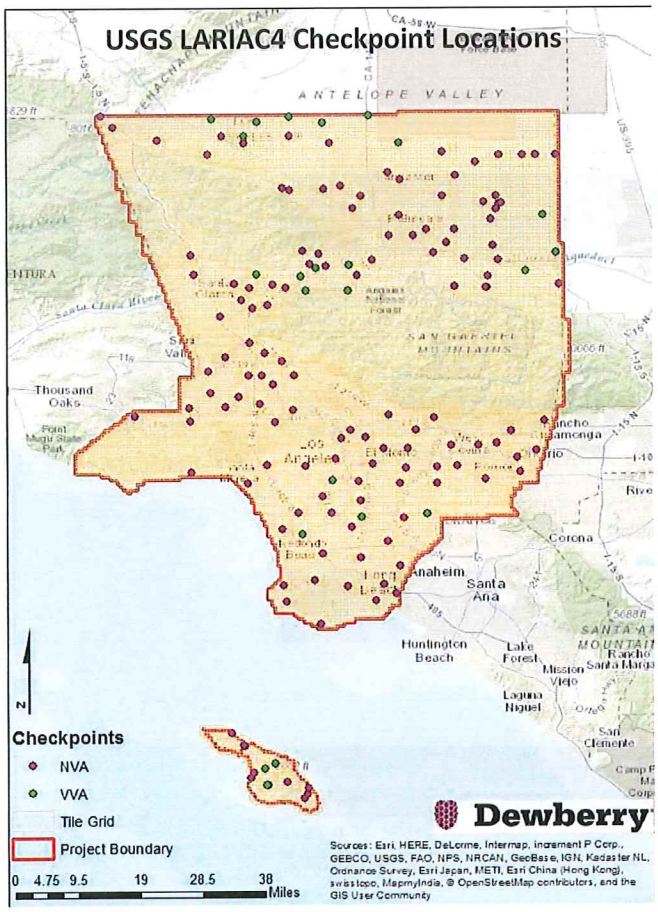


Figure 1 – Location of QA/QC Checkpoints

Appendix H: Survey Check Point List

For the vertical accuracy assessment, one hundred sixty seven (167) check points were surveyed for the project and are located within vegetated and non-vegetated land cover categories.

Commented [RS1]: Changed to say "one hundred sixty seven" instead of "one hundred seventy seven"

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Checkpoints were evenly distributed throughout the project area so as to cover as many flight lines as possible using the "dispersed method" of placement. Checkpoints were acquired over multiple years of the project.

All checkpoints surveyed for vertical accuracy testing purposes are listed in the following table:

Point ID	NAD83 SP CA 5 (FIPS 0405)		NAVD88 (Geoid 12B)		Land Cover Type
	Easting X (ft)	Northing Y (ft)	Z-Survey (ft)	Z-LiDAR (ft)	
801	6441654.01	1746932.13	866.01	866.18	NVA
802	6444508.82	1734503.04	1077.01	1077.14	NVA
803	6471859.02	1716849.07	148.78	149.24	NVA
805	6493798.35	1746595.00	9.63	9.87	NVA
806	6516626.62	1735289.04	36.06	36.37	NVA
807	6523074.45	1748515.16	18.92	19.15	NVA
808	6532433.21	1740739.16	9.34	9.63	NVA
809	6473418.22	1772712.20	36.85	37.18	NVA
810	6466929.03	1751187.48	73.66	73.88	NVA
811	6504295.49	1769205.55	47.10	47.10	NVA
812	6536247.84	1763131.78	35.17	35.53	NVA
814	6497438.69	1793490.65	82.69	82.93	NVA
815	6526472.24	1782180.71	76.00	76.17	NVA
817	6305674.13	2112324.55	3822.49	3822.46	NVA
818	6295657.35	2121243.33	3829.34	3829.52	NVA
819	6381772.48	2090734.07	3431.16	3431.38	NVA
820	6341551.49	2101466.93	3387.00	3387.23	NVA
821	6393251.59	2104763.33	2971.56	2971.95	NVA
826	6442140.18	2063822.10	3286.65	3287.22	NVA
827	6447955.22	2061682.54	3334.26	3334.56	NVA
828	6410889.40	2099322.01	2908.51	2908.91	NVA
829	6447927.64	2104840.79	2579.35	2579.87	NVA
830	6475249.31	2062765.18	2626.47	2626.92	NVA
831	6489263.24	2065337.91	2400.19	2400.69	NVA
832	6505238.96	2057424.85	2521.79	2522.40	NVA
833	6511574.31	2121072.15	2316.92	2317.15	NVA
834	6474501.90	2115676.33	2441.83	2442.01	NVA
835	6479858.86	2099765.65	2407.18	2407.51	NVA
837	6536723.15	2069859.80	2412.52	2413.18	NVA

839	6570748.70	2092261.09	2365.92	2365.95	NVA
840	6570776.94	2057503.33	2528.48	2528.28	NVA
841	6527490.77	2075486.05	2383.81	2384.00	NVA
842	6613575.14	2057401.08	2586.77	2586.62	NVA
843	6604296.12	2052094.33	2602.15	2601.95	NVA
844	6597482.27	2084240.80	2444.52	2444.46	NVA
845	6581414.97	2073545.47	2454.53	2454.59	NVA
846	6661524.26	2089770.48	2922.93	2922.97	NVA
847	6634918.69	2089930.06	3019.58	3019.92	NVA
848	6616322.77	2050812.51	2634.27	2634.17	NVA
849	6616129.98	2089861.99	2977.72	2977.83	NVA
850	6645553.18	2089897.56	3024.04	3024.27	NVA
851	6574232.56	2019840.62	2804.00	2803.64	NVA
852	6580378.86	2030812.47	2702.51	2702.40	NVA
853	6611409.45	2017394.71	2955.26	2955.21	NVA
854	6613654.25	2046942.39	2652.37	2652.14	NVA
855	6609914.70	2038752.98	2814.72	2814.34	NVA
859	6498374.24	2047645.66	2699.84	2700.04	NVA
860	6527818.75	2025431.57	2747.34	2747.63	NVA
862	6547778.10	2025571.00	2678.37	2678.47	NVA
863	6558127.86	2030479.25	2666.41	2666.86	NVA
864	6535871.23	2041853.29	2561.51	2562.16	NVA
865	6664474.56	1986716.51	3882.85	3882.69	NVA
867	6615800.81	2006379.76	3204.34	3204.10	NVA
868	6607227.68	1993224.82	3591.85	3591.70	NVA
869	6606255.41	1984281.87	3717.52	3717.10	NVA
870	6588904.90	2006555.89	3052.51	3052.28	NVA
871	6580986.41	1984793.14	4288.58	4288.26	NVA
872	6513992.95	2005807.49	3316.58	3316.41	NVA
873	6501664.61	1994273.61	2718.51	2718.59	NVA
874	6476677.95	2001561.79	2932.37	2932.64	NVA
875	6563959.58	2011946.57	2914.11	2914.43	NVA
876	6495778.08	2001974.45	2935.04	2934.90	NVA
877	6494610.06	1982128.76	2508.99	2509.27	NVA
879	6458068.57	2013208.62	2589.00	2588.99	NVA
880	6471308.25	2011318.67	2788.06	2788.27	NVA
881	6463512.87	2002513.48	2519.97	2520.23	NVA
884	6444105.76	1984555.69	1770.52	1770.93	NVA
885	6460314.27	1981921.45	1961.08	1961.53	NVA
886	6417976.66	1967665.53	1583.29	1583.76	NVA
887	6429435.22	1970109.97	1577.67	1578.05	NVA

888	6415431.71	1984334.97	1511.75	1512.00	NVA
889	6434026.07	1986319.15	1698.99	1699.17	NVA
890	6408739.29	1974189.05	1338.85	1339.18	NVA
891	6391841.99	1961478.99	1359.81	1360.20	NVA
892	6402898.29	1987160.03	1449.22	1449.47	NVA
893	6370556.80	1994484.70	1387.70	1387.99	NVA
894	6368069.29	2010507.21	1559.80	1559.90	NVA
895	6441463.61	1791997.47	110.23	110.60	NVA
896	6413620.62	1828421.77	89.04	89.41	NVA
897	6454047.30	1804714.56	105.07	105.11	NVA
898	6480661.05	1804720.61	124.76	125.01	NVA
899	6473959.68	1817703.82	146.13	146.66	NVA
901	6503042.18	1829704.76	195.92	196.06	NVA
902	6504017.39	1814915.02	146.16	146.21	NVA
904	6536161.54	1828168.57	182.19	182.82	NVA
905	6565981.87	1841509.58	305.70	306.13	NVA
906	6539140.02	1801124.93	141.43	141.63	NVA
907	6566170.23	1828843.23	357.91	358.30	NVA
909	6540834.32	1840243.12	223.80	224.51	NVA
910	6523055.43	1856010.84	478.34	478.30	NVA
911	6542378.71	1856279.10	338.42	339.13	NVA
912	6563579.92	1880147.94	773.30	773.75	NVA
913	6548831.56	1870614.38	443.00	443.36	NVA
914	6527510.44	1882480.77	960.31	960.55	NVA
915	6514295.18	1843704.07	471.28	471.40	NVA
916	6508473.18	1864946.07	567.81	568.20	NVA
917	6484398.52	1847836.21	486.15	486.42	NVA
920	6496028.07	1870773.92	530.37	530.86	NVA
921	6441215.44	1925811.84	1207.30	1207.42	NVA
922	6427267.41	1932422.98	1194.42	1194.95	NVA
923	6395855.06	1929124.13	1597.16	1597.30	NVA
924	6415309.68	1940374.55	1414.53	1414.89	NVA
925	6382085.98	1917875.09	1000.13	1000.64	NVA
926	6366254.69	1888095.97	866.39	866.68	NVA
927	6406254.53	1897532.78	757.05	757.34	NVA
928	6425122.68	1914289.84	905.22	905.62	NVA
929	6433525.85	1907016.49	848.85	849.22	NVA
930	6422954.37	1891978.30	724.28	724.61	NVA
931	6450310.90	1886546.01	636.35	636.64	NVA
932	6368454.65	1837533.77	60.60	60.76	NVA
933	6322339.10	1882136.38	1025.30	1025.31	NVA
934	6383263.69	1900958.72	816.87	816.98	NVA

935	6428716.21	1842776.28	270.06	270.38	NVA
936	6459994.40	1842571.31	186.81	187.32	NVA
937	6435131.90	1877003.79	630.23	630.66	NVA
939	6604601.55	1831931.58	646.07	646.50	NVA
940	6582114.41	1842179.30	383.34	383.69	NVA
941	6577302.74	1858703.48	429.06	429.44	NVA
942	6599065.92	1858329.20	620.26	620.40	NVA
944	6632172.47	1837533.84	801.57	801.92	NVA
945	6630418.80	1849081.90	846.73	847.05	NVA
946	6645573.14	1854132.71	1070.36	1070.92	NVA
947	6652130.96	1877613.45	1922.76	1923.15	NVA
948	6625605.83	1870039.63	1116.94	1117.34	NVA
949	6613966.38	1860459.98	858.28	858.38	NVA
950	6488816.91	1864162.53	391.62	392.02	NVA
951	6450877.75	1914691.57	978.81	979.16	NVA
952	6414471.09	1914425.96	898.57	899.00	NVA
953	6366953.90	1877628.04	979.99	980.22	NVA
954	6395769.09	1889262.65	749.36	749.57	NVA
960	6457831.33	1577835.99	310.30	310.20	NVA
961	6460569.75	1581406.85	77.62	77.75	NVA
962	6461150.59	1586268.04	24.36	24.14	NVA
971	6428561.37	1588374.44	721.48	721.14	NVA
972	6414911.55	1593942.63	404.42	404.70	NVA
973	6417401.62	1598292.34	44.18	44.45	NVA
974	6409979.32	1619230.22	29.21	29.25	NVA
975	6399631.29	1629445.99	9.94	9.95	NVA
976	6409361.82	1619667.12	12.44	12.58	NVA
979	6444719.91	1590509.11	1012.52	1012.60	NVA
848R	6617794.26	2051851.24	2632.26	2632.02	NVA
853A	6611363.26	2017288.30	2957.87	2957.23	NVA
867A	6615747.83	2006474.66	3201.69	3201.48	NVA
869A	6606200.36	1984288.87	3715.95	3715.71	NVA
813T	6457630.26	1787638.22	58.82	59.08	VVA
822T	6385464.25	2118710.44	2889.06	2888.87	VVA
823Base	6447808.10	2120682.89	2565.96	2566.14	VVA
824Base	6410855.56	2104729.92	2820.03	2820.56	VVA
825GR	6421519.31	2116759.62	2671.66	2672.53	VVA
833Base	6511627.27	2121140.13	2316.09	2316.37	VVA
834Base	6474346.48	2115708.01	2443.07	2443.22	VVA
838GR	6535800.54	2099635.77	2315.53	2315.68	VVA
856GR	6661413.75	2011921.77	3244.71	3244.56	VVA
857Brush	6651132.41	2041700.42	2869.82	2869.61	VVA
866T	6637700.67	1997257.83	3637.85	3637.59	VVA
876Base	6495753.64	2001921.29	2930.46	2930.50	VVA
877Base	6494692.45	1982050.69	2515.62	2515.88	VVA

877Brush	6421157.80	1995037.42	1522.17	1522.47	VVA
882T	6468630.42	1999817.17	2575.91	2576.24	VVA
883BareEarth	6456374.45	1992787.90	2562.20	2562.38	VVA
885Base	6460410.72	1981905.01	1965.33	1965.82	VVA
900T	6481891.03	1831195.26	220.52	220.64	VVA
903T	6504838.32	1801598.45	106.89	107.17	VVA
908T	6557544.55	1804496.32	245.35	245.49	VVA
977GR	6426782.05	1601346.22	773.66	773.95	VVA
978GR	6435005.65	1605309.07	1585.69	1585.98	VVA
RanchBase	6428369.62	1588404.89	711.92	711.97	VVA