San Diego Co., CA FEMA Region IX 2016 QL2 LiDAR Project Report

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1. Summary / Scope

1.1. Summary

This report contains a summary of the San Diego County, CA FEMA Region IX 2015 LiDAR acquisition task order, issued by the Strategic Alliance for Risk Reduction (STARR II) under their task order issued on October 23, 2015. The task order yielded a project area covering 1,617 square miles over San Diego County, California. The intent of this document is only to provide specific validation information for the data acquisition/collection, processing, and production of deliverables completed as specified in the task order.

1.2. Scope

Aerial topographic LiDAR was acquired using state of the art technology along with the necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems. The aerial data collection was designed with the following specifications listed in Table 1 below.

Table 1. Originally Planned LiDAR Specifications

Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
≥ 2 pts / m^2	5,577 ft	40.0°	40%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers 1,617 square miles and encompasses the entirety of San Diego County in southern California. A buffer of 100 meters was created in order to meet task order specifications. LiDAR extents are shown in Figure 1 on the following page.

1.4. Duration

LiDAR data was acquired from October 30, 2015 to November 23, 2016 in 23 total lifts. See "Section: 2.5. Time Period" for more details.

1.5. Issues

There were no issues with this project.

1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR point cloud data swaths, in LAS 1.4 format
- Hydro-flattened continuous breaklines, in Esri file geodatabase format
- 2.5-foot hydro-flattened bare-earth raster DEMs, tiled, in ERDAS .IMG format
- Tile index, in Esri shapefile format

All geospatial deliverables were produced with a horizontal datum of NAD83 (2011) State Plane California Zone VI, US survey feet and a vertical datum of NAVD88 (Geoid 12B), US survey feet. All tiled deliverables have a tile size of 2,500-feet x 2,500-feet and matches the adjoining USGS/ SANDAG project.

Figure 1. Project Boundary

2. Planning / Equipment

2.1. Flight Planning

Flight planning was based on the unique project requirements and characteristics of the project site. The basis of planning included: required accuracies, type of development, amount / type of vegetation within project area, required data posting, and potential altitude restrictions for flights in project vicinity. Please note that certain values in the table below are listed as "Variable" due to the various flight plans used, as described in "Section: 1.5. Issues" of this document.

Detailed project flight planning calculations were performed for the project using Leica MissionPro planning software. The entire target area was broken into seven areas to account for airports and potential GPS Base Stations: Brown, Campo, Descano, Fallbrook, Palomar, Pauma, and Warner. Brown has 47 flight lines and approximately 888 flight line miles; Campo had 38 flight lines and approximately 686 flight line miles; Descanso has 133 flight lines and approximately 2,896 flight line miles; Fallbrook has 18 flight lines and approximately 171 flight line miles; Palomar has 32 flight lines and approximately 538 flight line miles; Pauma has 25 flight lines and approximately 267 flight line miles; and Warner has 106 flight lines and approximately 1674 flight line miles. As a whole, the project area is comprised of 399 planned flight lines and approximately 7120 flight line miles. See Figure 2 through Figure 9.

2.2. LiDAR Sensor

Quantum Spatial utilized a Leica ALS 80 LiDAR sensor (Figure 3), serial number 8146, during the project. This system is capable of collecting data at a maximum frequency of 1 MHz, which affords elevation data collection of up to 1,000,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). This sensor is also equipped with the ability to measure an unlimited number of returns per outgoing pulse from the laser. The intensity of the first four returns is also captured during aerial acquisition.

A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specifications in Table 2.

Figure 2. Planned Flight Lines - Overview

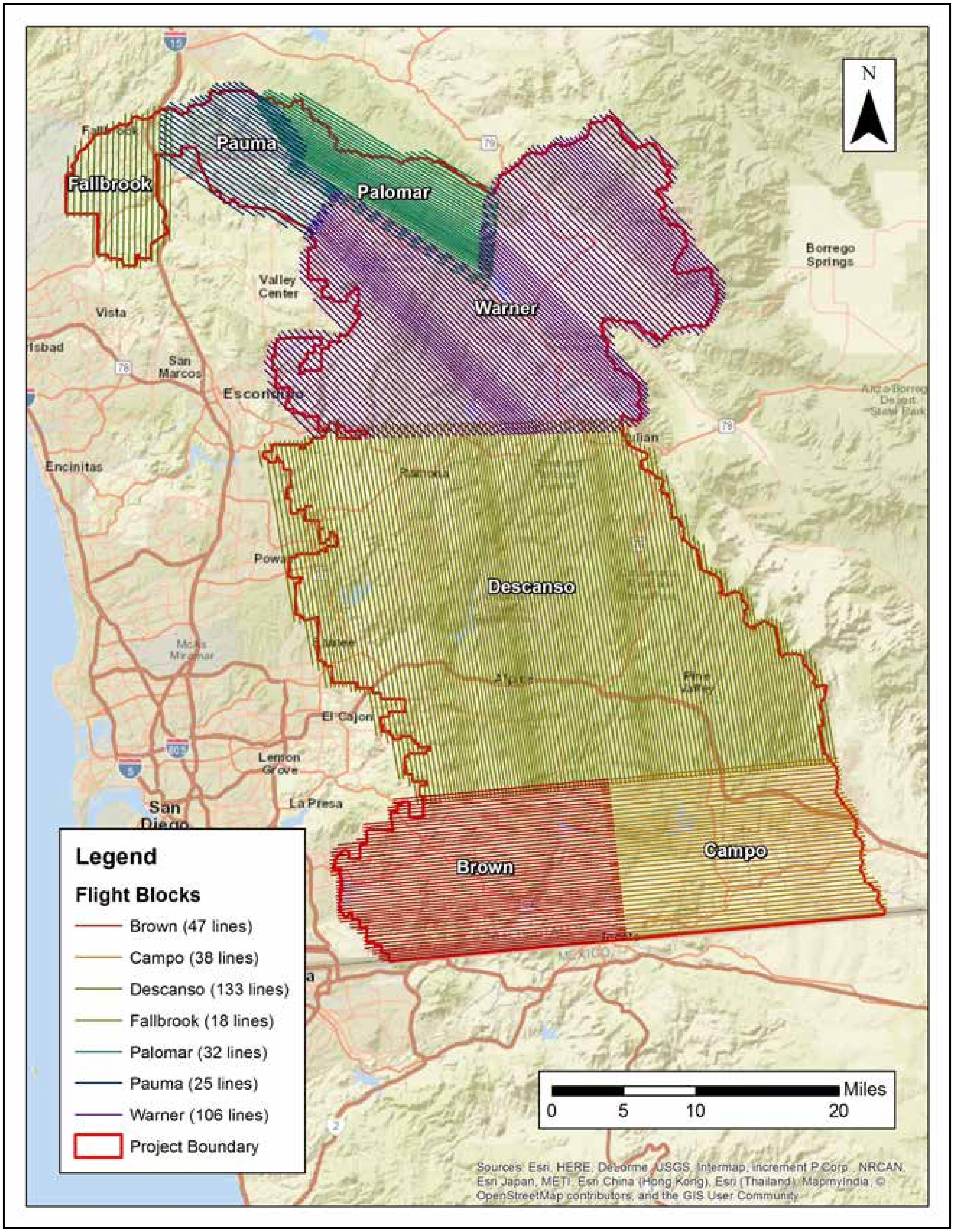


Figure 3. Planned Flight Lines - Brown

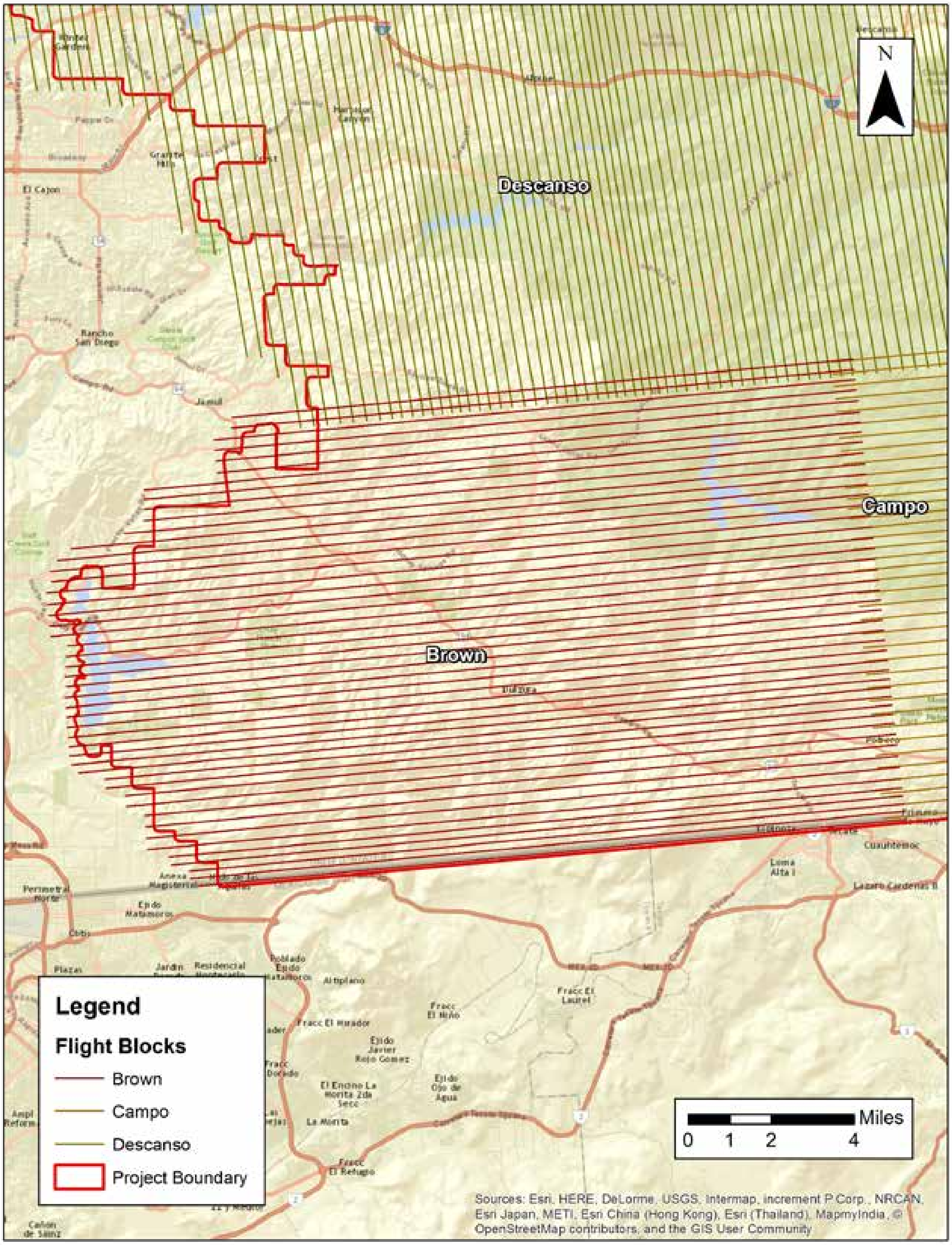


Figure 4. Planned Flight Lines - Campo

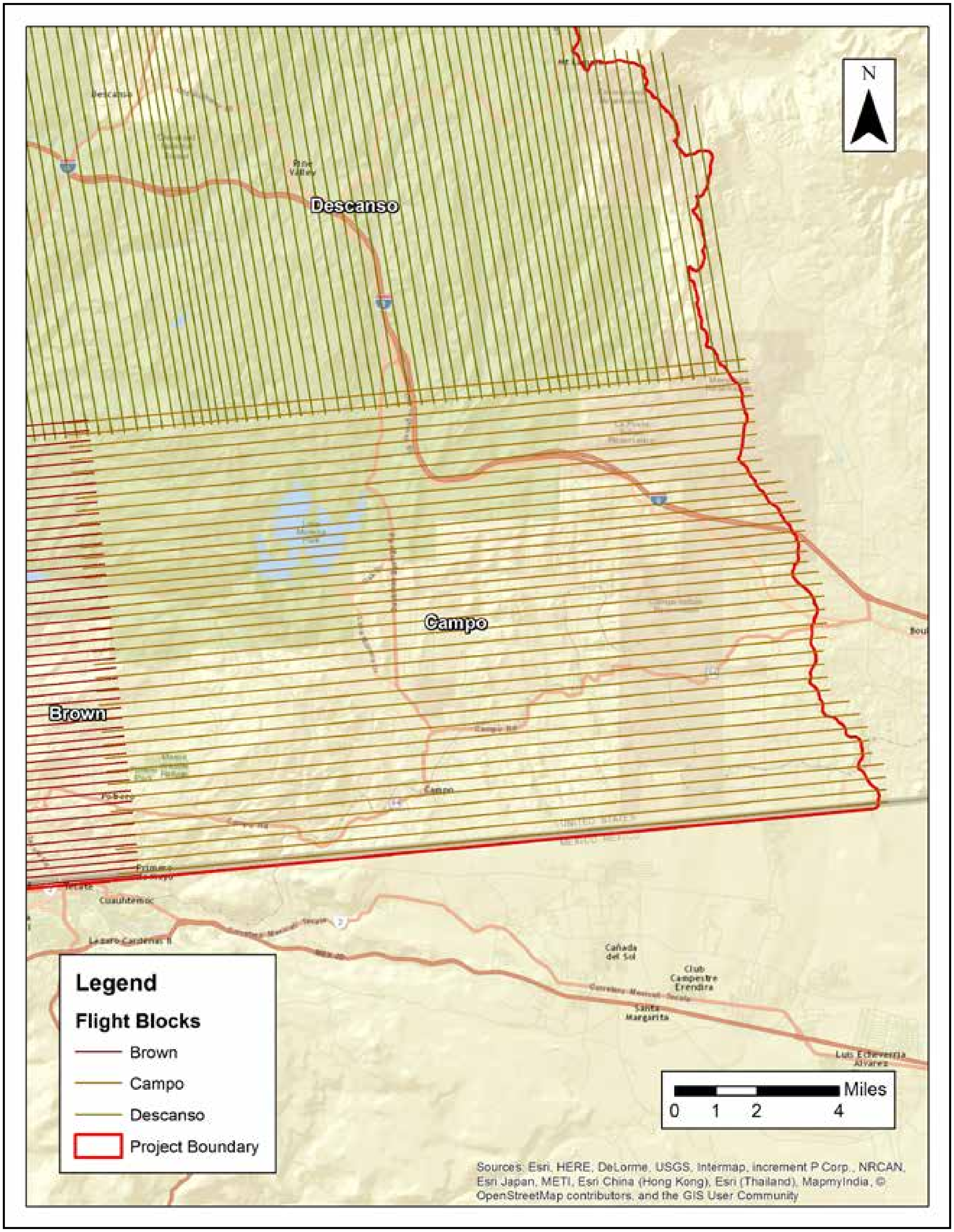


Figure 5. Planned Flight Lines - Descanso

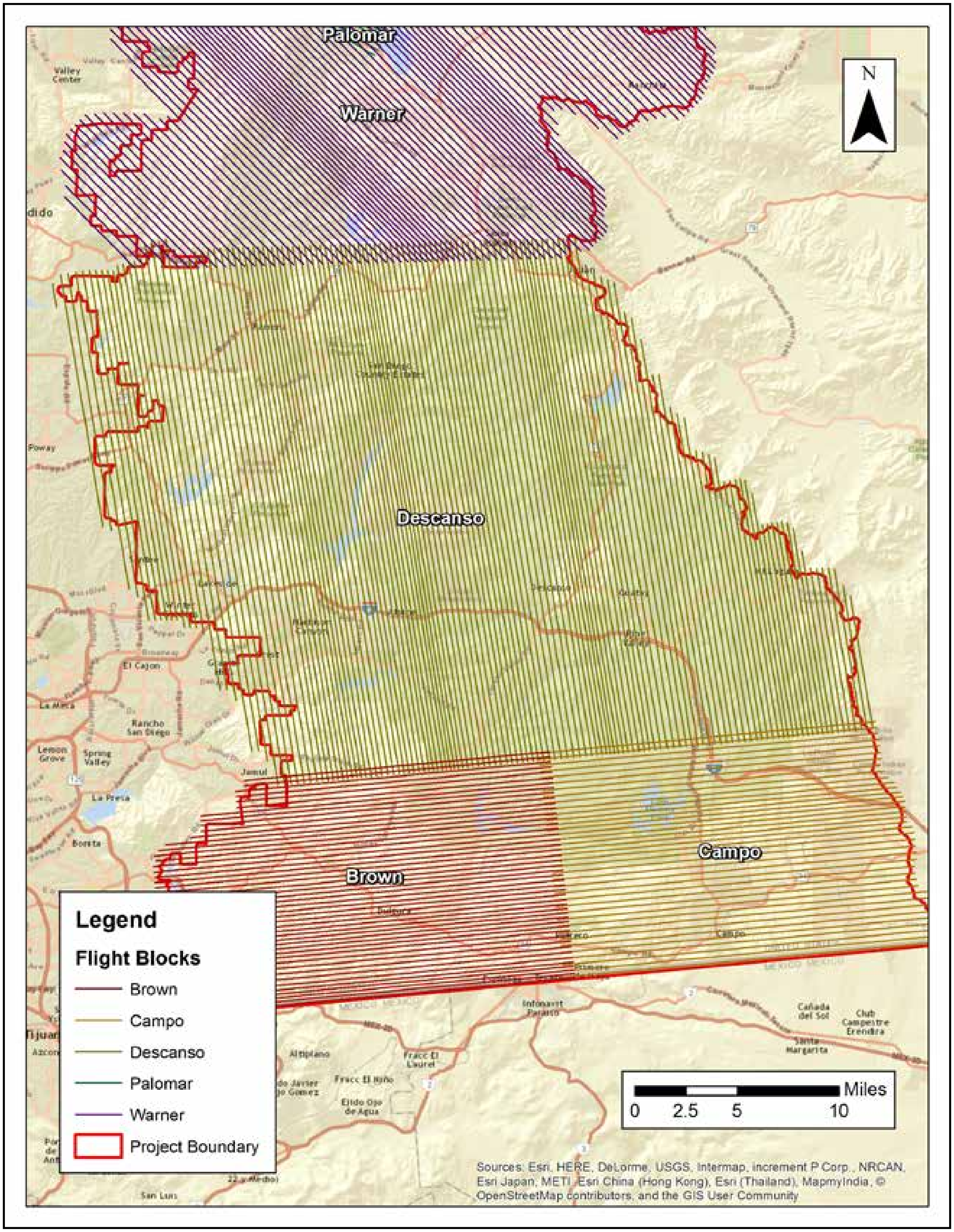


Figure 6. Planned Flight Lines - Fallbrook

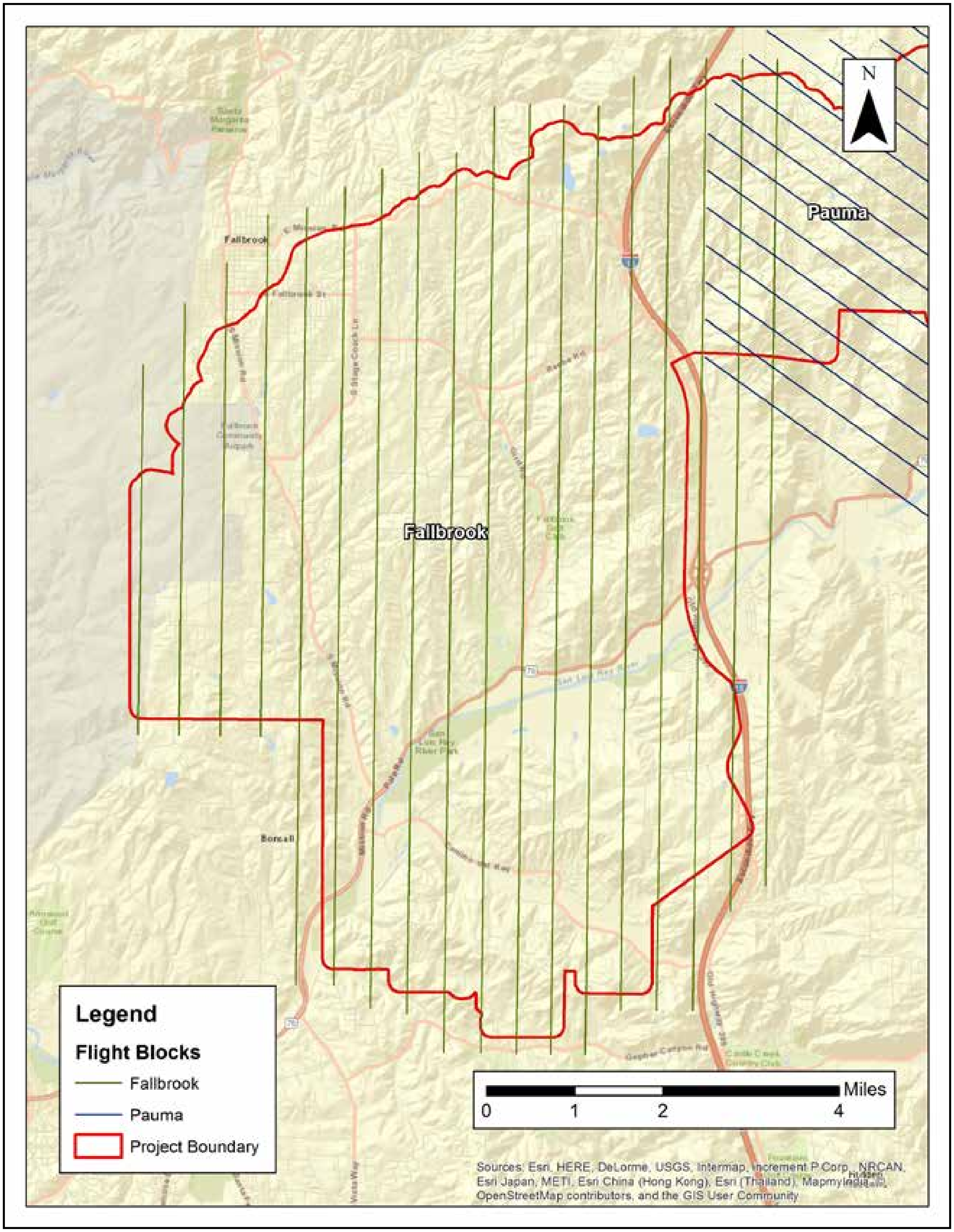


Figure 7. Planned Flight Lines - Palomar

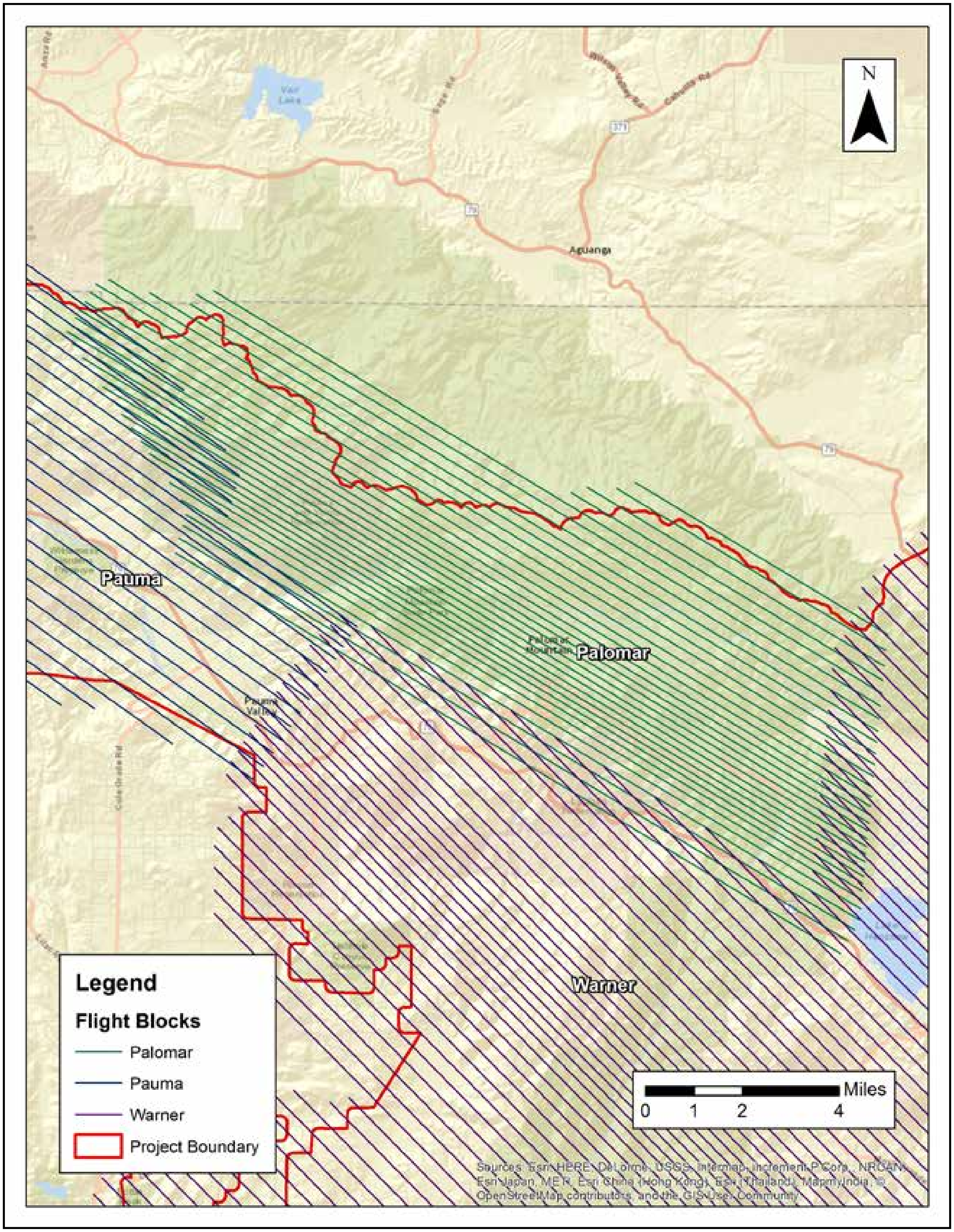


Figure 8. Planned Flight Lines - Pauma

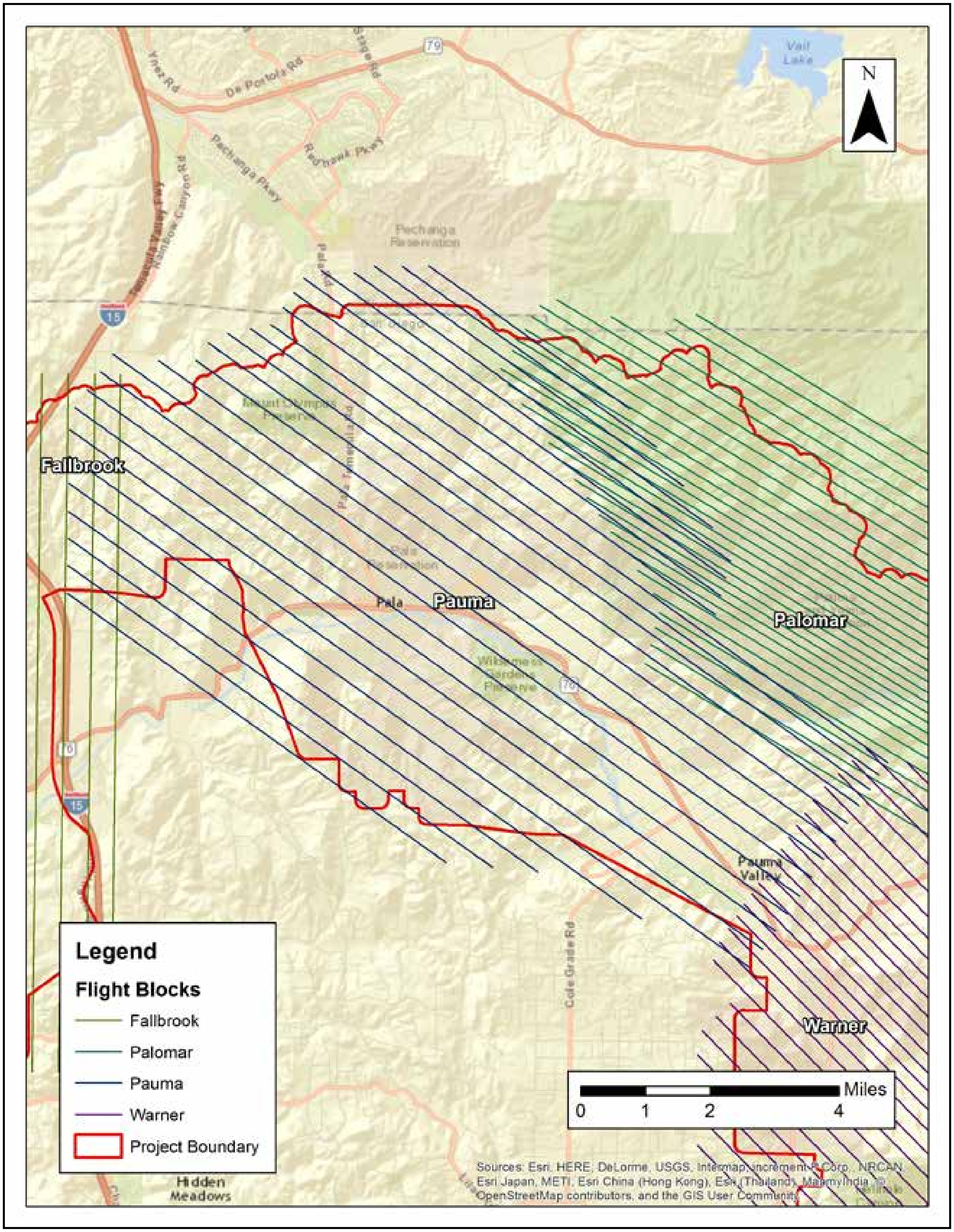


Figure 9. Planned Flight Lines - Warner

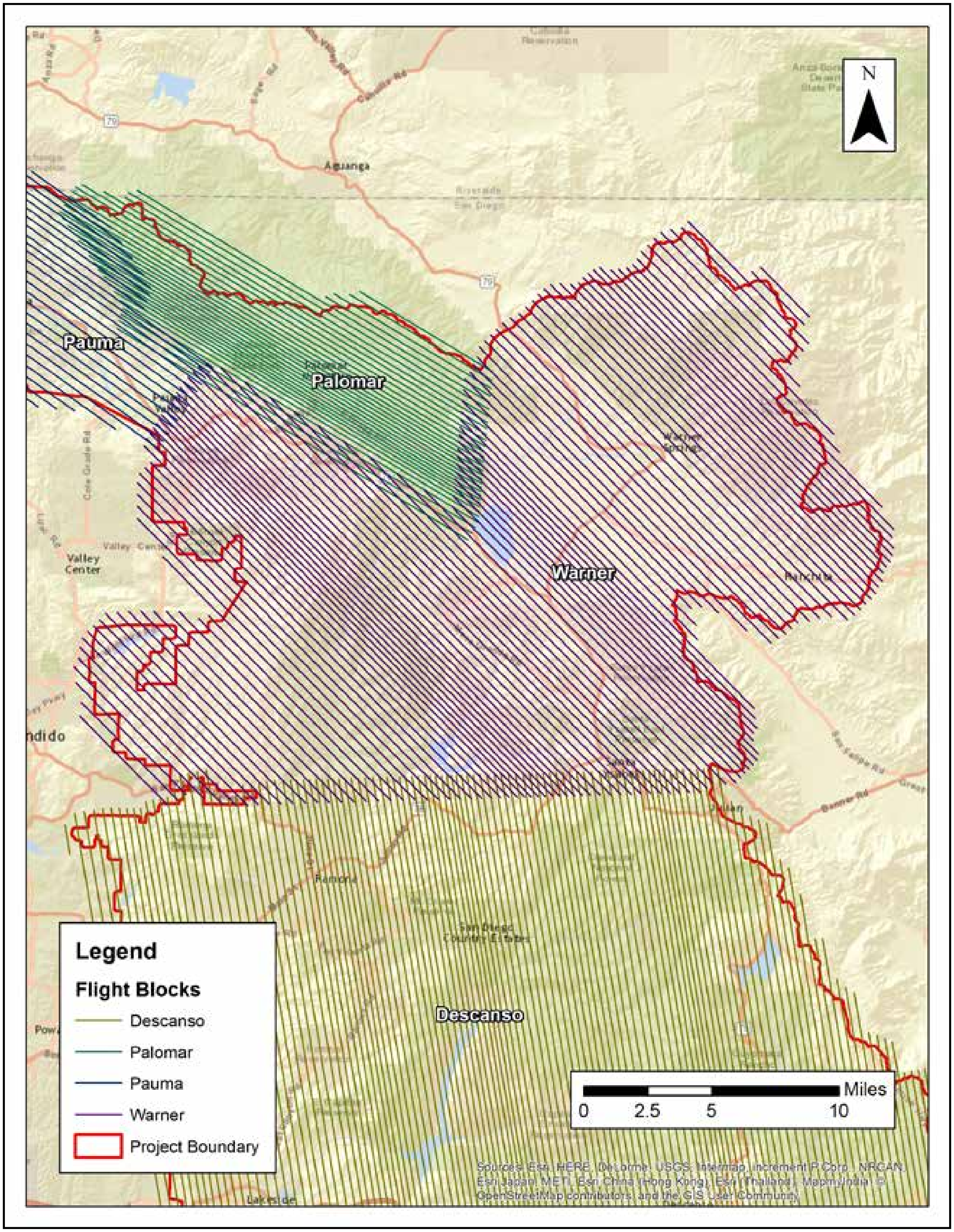


Table 2. Lidar System Specifications

		Brown Block	Campo Block	Descanso Block	Fallbrook Block
Terrain and Aircraft Scanner	Flying Height	1,700 m	1,700 m	1,700 m	1,800 m
	Recommended Ground Speed	115 kts	115 kts	115 kts	140 kts
Scanner	Field of View	40.0°	40.0°	40.0°	40.0°
	Scan Rate Setting Used	41.8 Hz	41.8 Hz	41.8 Hz	52.0 Hz
Laser	Laser Pulse Rate Used	158.0 kHz	158.0 kHz	158.0 kHz	299.0 kHz
	Multi Pulse in Air Mode	Enabled	Enabled	Enabled	Enabled
Coverage	Full Swath Width	1,237.50 m	1,237.50 m	1,237.50 m	1,310.29 m
	Line Spacing	303.38 m	368.39 m	166.19 m	756.08 m
Point Spacing and Density	Maximum Point Spacing Along Track	1.42 m	1.42 m	1.42 m	0.99 m
	Maximum Point Spacing Along Track	1.42 m	1.42 m	1.42 m	1.39 m
	Average Point Density	2.16 pts / m^2	2.16 pts / m^2	2.16 pts / m^2	3.17 pts / m^2

Table 3. Lidar System Specifications

		Palomar Block	Pauma Block	Warner Block
Terrain and Aircraft Scanner	Flying Height	1,700 m	1,700 m	1,700 m
	Recommended Ground Speed	115 kts	115 kts	115 kts
Scanner	Field of View	40.0°	40.0°	40.0°
	Scan Rate Setting Used	41.8 Hz	41.8 Hz	41.8 Hz
Laser	Laser Pulse Rate Used	158.0 kHz	158.0 kHz	158.0 kHz
	Multi Pulse in Air Mode	Enabled	Enabled	Enabled
Coverage	Full Swath Width	1,237.50 m	1,237.50 m	1,237.50 m
	Line Spacing	81.84 m	369.60 m	159.56 m
Point Spacing and Density	Maximum Point Spacing Along Track	1.42 m	1.42 m	1.42 m
	Maximum Point Spacing Along Track	1.42 m	1.42 m	1.42 m
	Average Point Density	2.16 pts / m^2	2.16 pts / m^2	2.16 pts / m^2

Figure 10. Leica ALS 80 LiDAR Sensor

2.3. Aircraft

All flights for the project were accomplished through the use of a customized Cessna Caravan (single turbo-prop), Tail Number N840JA. This aircraft provided an ideal, stable aerial base for LiDAR acquisition. This aerial platform has relatively fast cruise speeds which are beneficial for project mobilization / demobilization while maintaining relatively slow stall speeds which proved ideal for collection of high-density, consistent data posting using a state-of-the-art Leica LiDAR systems.

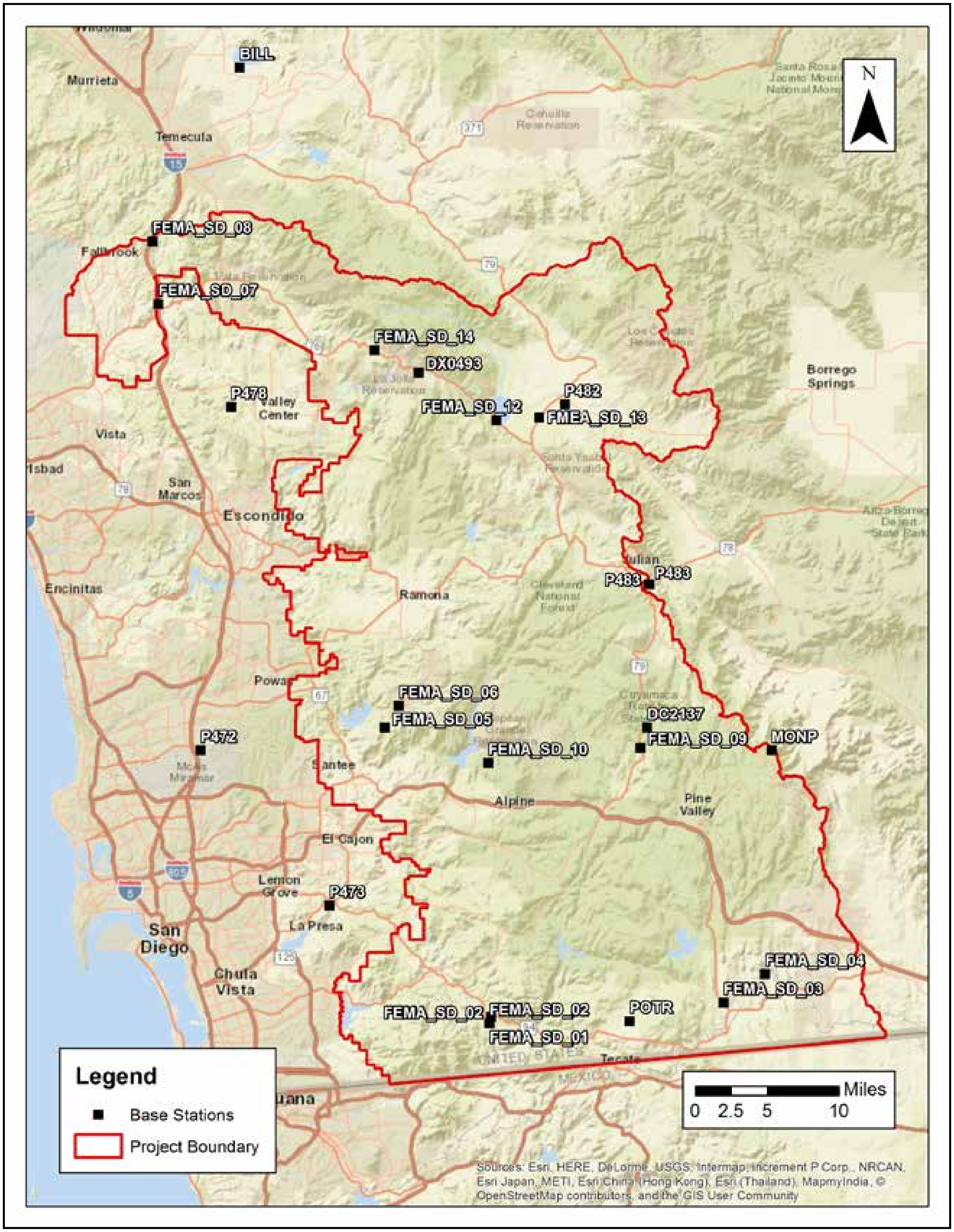
2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 4). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 11. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 4. Base Station Locations

Base Station	Latitude	Longitude	Ellipsoid Height (m)
P482	33° 14′ 24.63146″	116° 40′ 17.03637″	879.467
P483	33° 3′ 32.97633″	116° 34′ 9.52281″	1376.313
P472	32° 53′ 21.13975″	117° 6′ 16.85407″	138.603
P473	32° 44′ 1.58057″	116° 56′ 58.20691″	189.328
POTR	32° 37′ 6.26918″	116° 35′ 27.05963″	731.041
P478	33° 14′ 8.56044″	117° 4′ 17.67752″	372.326
FEMA_SD_02	32° 36′ 56.04822″	116° 45′ 29.1272″	407.935
FEMA_SD_05	32° 54′ 47.2768″	116° 53′ 4.81516″	441.162
FEMA_SD_10	32° 52′ 41.68683″	116° 45′ 38.89579″	678.325
FEMA_SD_04	32° 39′ 58.37218″	116° 25′ 46.87472″	912.172
FEMA_SD_03	32° 38′ 14.48612″	116° 28′ 45.13172″	799.376
FEMA_SD_02	32° 37′ 19.62403″	116° 45′ 22.34385″	439.361
FEMA_SD_01	32° 36′ 56.04822″	116° 45′ 29.1272″	407.935
FEMA_SD_07	33° 20′ 20.59807″	117° 9′ 36.50077″	67.701

Figure 11. Base Station Locations



2.5. Time Period

Project specific flights were conducted over two months. Twenty-three sorties, or aircraft lifts were completed. Accomplished LiDAR and ortho sorties are listed below.

- Oct 30, 2015-A (N840JA, SN8146)
- Oct 31, 2015-A (N840JA, SN8146)
- Oct 31, 2015-B (N840JA, SN8146)
- Oct 31, 2015-C (N840JA, SN8146)
- Nov 01, 2015-A (N840JA, SN8146)
- Nov 02, 2015-A (N840JA, SN8146)
- Nov 05, 2015-A (N840JA, SN8146)
- Nov 06, 2015-A (N840JA, SN8146)
- Nov 07, 2015-A (N840JA, SN8146)
- Nov 08, 2015-A (N840JA, SN8146)
- Nov 11, 2015-A (N840JA, SN8146)
- Nov 12, 2015-A (N840JA, SN8146)
- Nov 13, 2015-A (N840JA, SN8146)
- Nov 13, 2015-B (N840JA, SN8146)
- Nov 14, 2015-A (N840JA, SN8146)
- Nov 16, 2015-A (N840JA, SN8146)
- Nov 17, 2015-A (N840JA, SN8146)
- Nov 18, 2015-A (N840JA, SN8146)
- Nov 19, 2015-A (N840JA, SN8146)
- Nov 20, 2015-A (N840JA, SN8146)
- Nov 21, 2015-A (N840JA, SN8146)
- Nov 22, 2015-A (N840JA, SN8146)
- Nov 23, 2015-A (N840JA, SN8146)

3. Processing Summary

3.1. Flight Logs

Flight logs were completed by LIDAR sensor technicians for each mission during acquisition. These logs depict a variety of information, including:

- Job / Project #
- Flight Date / Lift Number
- FOV (Field of View)
- Scan Rate (HZ)
- Pulse Rate Frequency (Hz)
- Ground Speed
- Altitude
- Base Station
- PDOP avoidance times
- Flight Line #
- Flight Line Start and Stop Times
- Flight Line Altitude (AMSL)
- Heading
- Speed
- Returns
- Crab

Notes: (Visibility, winds, ride, weather, temperature, dew point, pressure, etc). Project specific flight logs for each sortie are available in Appendix A.

3.2. LiDAR Processing

Inertial Explorer software was used for post-processing of airborne GPS and inertial data (IMU), which is critical to the positioning and orientation of the LiDAR sensor during all flights. Inertial Explorer combines aircraft raw trajectory data with stationary GPS base station data yielding a "Smoothed Best Estimate Trajectory (SBET) necessary for additional post processing software to develop the resulting geo-referenced point cloud from the LiDAR missions.

During the sensor trajectory processing (combining GPS & IMU datasets) certain statistical graphs and tables are generated within the Inertial Explorer processing environment which are commonly used as indicators of processing stability and accuracy. This data for analysis include: Max horizontal / vertical GPS variance, separation plot, altitude plot, PDOP plot, base station baseline length, processing mode, number of satellite vehicles, and mission trajectory. All relevant graphs produced in the Inertial Explorer processing environment for each sortie during the project mobilization are available in Appendix A.

The generated point cloud is the mathematical three dimensional composite of all returns from all laser pulses as determined from the aerial mission. Laser point data are imported into TerraScan and a manual calibration is performed to assess the system offsets for pitch, roll, heading and scale. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above-ground features are removed from the data set. Point clouds were created using the Leica CloudPro software. GeoCue distributive processing software was used in the creation of some files needed in downstream processing, as well as in the tiling of the dataset into more manageable file sizes. TerraScan and TerraModeler software packages were then used for the automated data classification, manual cleanup, and bare earth generation. Project specific macros were developed to classify the ground and remove side overlap between parallel flight lines.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. In-house software was then used to perform final statistical analysis of the classes in the LAS files.

3.3. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.2 specifications and are an industry standard for the classification of LIDAR point clouds. All data starts the process as Class 1 (Unclassified), and then through automated classification routines, the classifications are determined using TerraScan macro processing.

The classes used in the dataset are as follows and have the following descriptions:

- Class 1 – Processed, but Unclassified – These points would be the catch all for points that do not fit any of the other deliverable classes. This would cover features such as vegetation, cars, etc.
- Class 2 – Bare-Earth Ground – This is the bare earth surface
- Class 7 – Low Noise – Low points, manually identified below the surface that could be noise points in point cloud.
- Class 9 – In-land Water – Points found inside of inland lake/ponds
- Class 10 – Ignored Ground – Points found to be close to breakline features. Points are moved to this class from the Class 2 dataset. This class is ignored during the DEM creation process in order to provide smooth transition between the ground surface and hydro flattened surface.
- Class 13 – Hydro-Enforced Ground Points – Points removed during the hydro-enforcement process.
- Class 17 – Bridge Decks – Points falling on bridge decks.
- Class 18 – High Noise – High points, manually identified above the surface that could be noise points in point cloud.

3.4. Classified LAS Processing

The bare earth surface is then manually reviewed to ensure correct classification on the Class 2 (Ground) points. After the bare-earth surface is finalized, it is then used to generate all hydro-breaklines through heads-up digitization.

All ground (ASPRS Class 2) LiDAR data inside of the Lake Pond and Double Line Drain hydro flattening breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro-flattened feature to classify these ground (ASPRS Class 2) points to Ignored ground (ASPRS Class 10). All Lake Pond Island and Double Line Drain Island features were checked to ensure that the ground (ASPRS Class 2) points were reclassified to the correct classification after the automated classification was completed.

All overlap data was processed through automated functionality provided by TerraScan to classify the overlapping flight line data to approved classes by USGS. Overlap points were flagged using the overlap bit, per LAS 1.4 specifications.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper was used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for both the All Point Cloud Data and the Bare Earth. Quantum Spatial proprietary software was used to perform final statistical analysis of the classes in the LAS files, on a per tile level to verify final classification metrics and full LAS header information.

3.5. Hydro-Flattened Breakline Creation

Class 2 LiDAR was used to create a bare earth surface model. The surface model was then used to heads-up digitize 2D breaklines of Inland Streams and Rivers with a 100 foot nominal width and Inland Ponds and Lakes of 2 acres or greater surface area.

Elevation values were assigned to all Inland Ponds and Lakes, Inland Pond and Lake Islands, Inland Streams and Rivers and Inland Stream and River Islands using TerraModeler functionality.

Elevation values were assigned to all Inland streams and rivers using Quantum Spatial proprietary software.

All ground (ASPRS Class 2) LiDAR data inside of the collected inland breaklines were then classified to water (ASPRS Class 9) using TerraScan macro functionality. A buffer of 3 feet was also used around each hydro flattened feature. These points were moved from ground (ASPRS Class 2) to Ignored Ground (ASPRS Class 10).

The breakline files were then translated to Esri file-geodatabase format using Esri conversion tools.

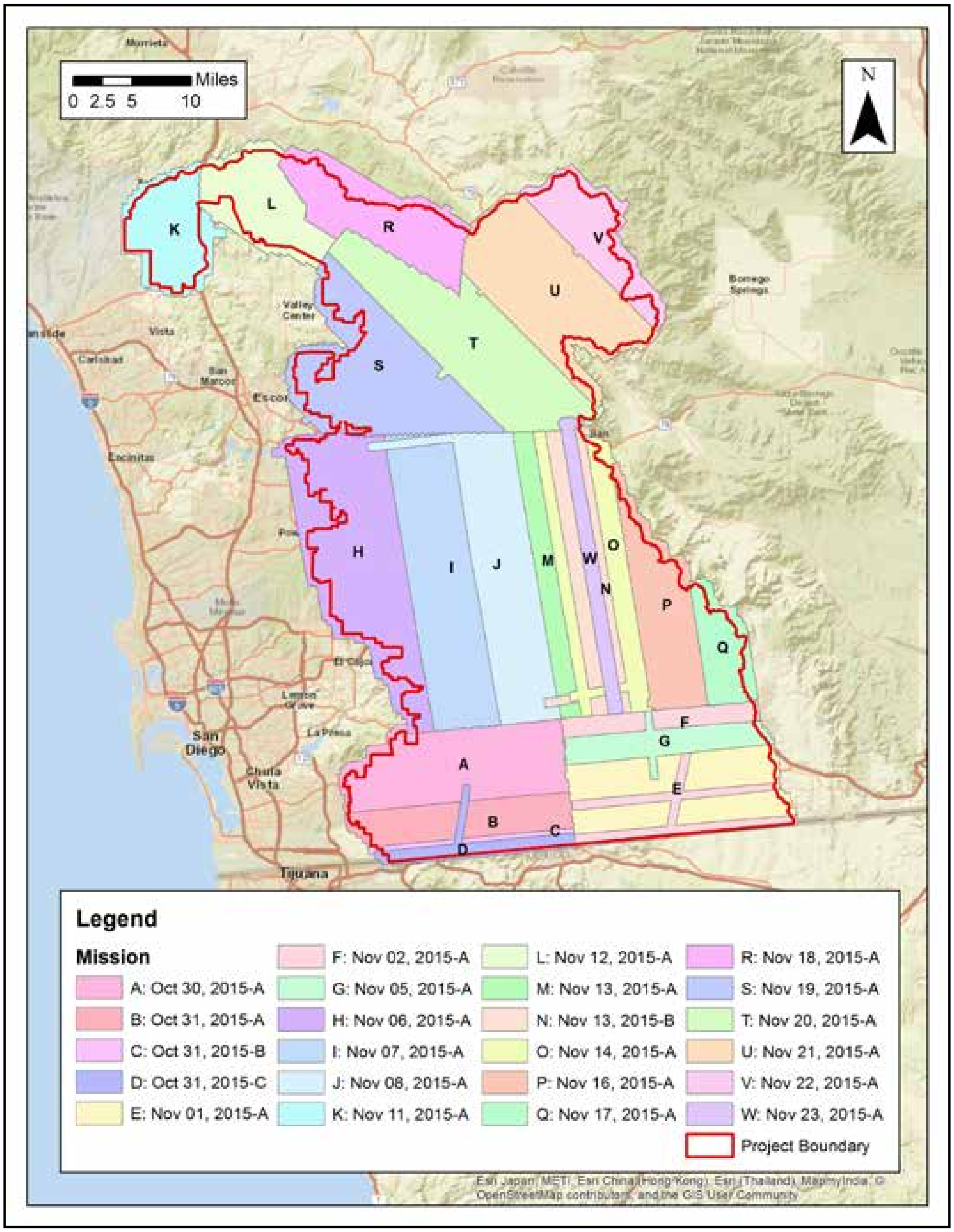
3.6. Hydro-Flattened Bare-Earth Raster DEM Creation

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 2.5-foot bare-earth raster DEM. Using automated scripting routines within ArcMap, an ERDAS Imagine .IMG file was created for each tile. Each surface is reviewed using Global Mapper to check for any surface anomalies or incorrect elevations found within the surface.

4. Project Coverage Verification

Coverage verification was performed by comparing coverage of processed .LAS files captured during project collection to generate project shape files depicting boundaries of specified project areas. Please refer to Figure 12.

Figure 12. Flightline Swath LAS File Coverage



5. Ground Control and Check Point Collection

Quantum Spatial partnered with Compass Data to complete a field survey of 39 ground control (calibration) points along with 119 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 158 points) as an independent test of the accuracy of this project.

The required accuracy testing was performed on the LiDAR dataset (both the LiDAR point cloud and derived DEM's) according to the USGS LiDAR Base Specification Version 1.2 (2014). In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in NAD83 (2011) State Plane California Zone VI, US survey feet; NAVD88 (Geoid 12B), US survey feet.

5.1. Calibration Control Point Testing

Figure 11 shows the location of each bare earth calibration point for the project area. Table 6 depicts the Control Report for the LiDAR bare earth calibration points, as computed in TerraScan as a quality assurance check. Note that these results of the surface calibration are not an independent assessment of the accuracy of these project deliverables, but the statistical results do provide additional feedback as to the overall quality of the elevation surface.

5.2. Point Cloud Testing

Raw Nonvegetated Vertical Accuracy (Raw NVA): The tested Raw NVA for the dataset was found to be 0.045 meters (0.147 feet) in terms of the RMSEz. The resulting NVA stated as the 95% confidence level (RMSEz x 1.96) is 0.087 meters (0.287 feet). This dataset meets the required NVA of 0.196 meters (0.060 feet) at the 95% confidence level (according to the National Standard for Spatial Database Accuracy (NSSDA)), based on TINs derived from the final calibrated and controlled LiDAR swath data. See Figure 14 and Table 6.

5.3. Digital Elevation Model (DEM) Testing

The tested Non-Vegetated Vertical Accuracy (NVA) for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be # meters (# feet) in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is # meters (# feet). This dataset meets the required NVA of 0.196 meters (0.643 feet) at the 95% confidence level (based on NSSDA). See Figure 15 and Table 7.

The tested Vegetated Vertical Accuracy (VVA) for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.184 meters (0.604 feet), which is stated in terms of the 95th percentile error. Therefore the data meets the required VVA of 0.184 meters (0.604 feet). This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories. See Figure 16 and Table 8.

Figure 13. Calibration Control Point Locations

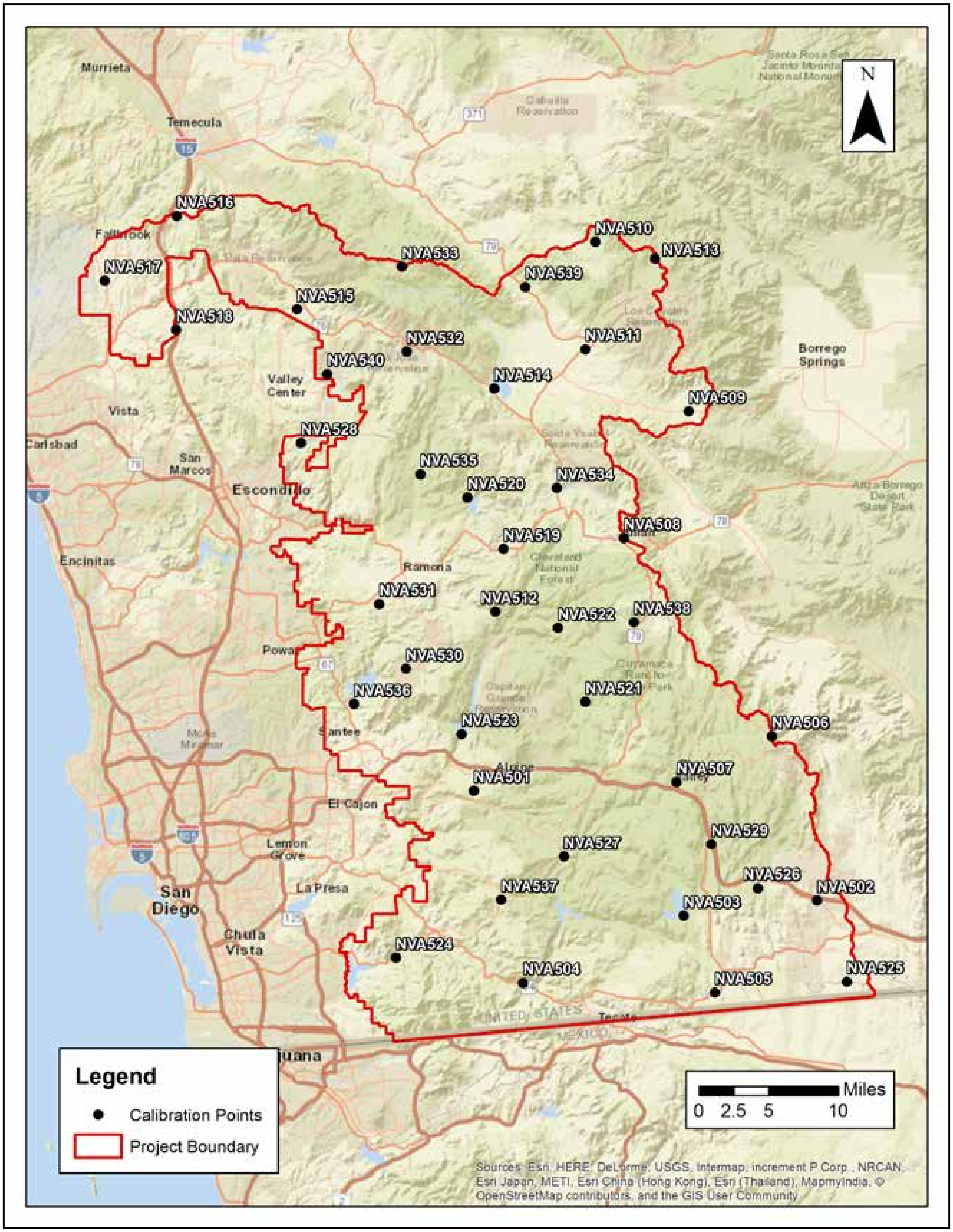


Table 5. Calibration Control Point Report

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
NVA501	6398884.191	1876733.532	1810.15	1810.1	-0.05
NVA502	6528821.481	1835195.149	4139.87	4139.89	0.02
NVA503	6478251.828	1829346.948	3044.42	3044.26	-0.16
NVA504	6417540.022	1804041.914	1023.29	removed	*
NVA505	6490078.832	1800371.819	2482.96	2483.08	0.12
NVA506	6511737.687	1897307.494	6044.43	6044.23	-0.2
NVA507	6475601.38	1879969.496	3717.35	3717.15	-0.2
NVA508	6455742.463	1972182.261	4235.69	4235.72	0.03
NVA509	6480331.333	2020256.338	4072.8	4072.72	-0.08
NVA510	6444895.934	2084314.116	4665.38	4665.2	-0.18
NVA511	6441120.21	2043720.777	3045.05	3045.05	0
NVA512	6406952.046	1944408.011	1725.8	1725.9	0.1
NVA513	6467478.206	2077974.103	4872.32	4872.01	-0.31
NVA514	6406640.057	2028819.844	2713.6	2713.66	0.06
NVA515	6331946.739	2058808.511	746.54	746.53	-0.01
NVA516	6286464.407	2094112.851	1062.53	1062.54	0.01
NVA517	6259193.211	2069693.585	472.5	472.48	-0.02
NVA518	6286156.992	2051135.038	794.61	794.61	0
NVA519	6410102.61	1968164.843	2494.25	2494.44	0.19
NVA520	6396493.704	1987585.2	2064.57	2064.82	0.25
NVA521	6441091.204	1910382.74	3132.56	3132.41	-0.15
NVA522	6430699.536	1938284.149	2939	2939.06	0.06
NVA523	6394220.581	1898168.374	720.51	720.56	0.05
NVA524	6369433.208	1813505.754	558.56	558.6	0.04
NVA525	6539986.454	1804460.766	3630.01	3630.04	0.03
NVA526	6506319.544	1839817.937	3415.78	3415.75	-0.03
NVA527	6432916.568	1851813.186	2479.88	2479.76	-0.12
NVA528	6333515.051	2008240.034	1525.77	1525.91	0.14
NVA529	6488871.496	1856496.862	3252.84	3252.73	-0.11

Number	Easting	Northing	Known Z	Laser Z	Dz
NVA530	6373167.141	1922849.088	1337.05	1337.19	0.14
NVA531	6363112.121	1947301.185	1429.84	1429.92	0.08
NVA532	6373411.159	2042837.173	2218.26	2218.05	-0.21
NVA533	6371658.08	2074935.443	5443.99	5443.99	0
NVA534	6430292.875	1991177.712	2944.51	2944.3	-0.21
NVA535	6378679.201	1996445.875	1027.13	1027.4	0.27
NVA536	6353504.977	1909540.145	451.46	451.72	0.26
NVA537	6409285.474	1835486.816	2623.78	2623.73	-0.05
NVA538	6459550.919	1940424.758	4653.49	4653.5	0.01
NVA539	6418327.673	2067295.323	3094.79	3094.79	0
NVA540	6343487.848	2034302.297	991.26	991.5	0.24
	Average Dz	0.00 ft			
	Minimum Dz	-0.312 ft			
	Maximum Dz	0.27 ft			
	Root Mean Square	0.139 ft			
	Std. Deviation	0.141 ft			

Figure 14. QC Checkpoint Locations - Raw NVA

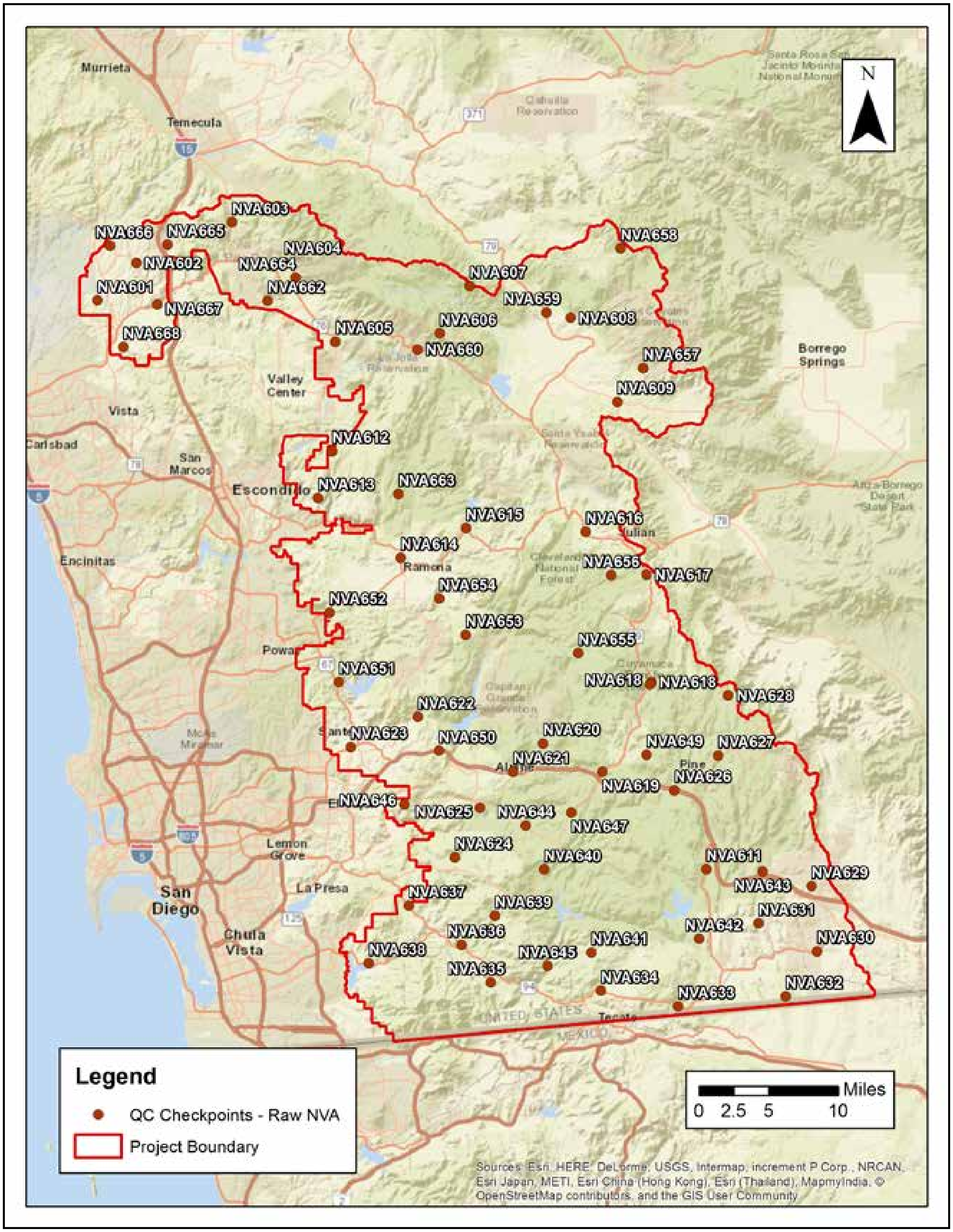


Table 6. QC Checkpoint Report - Raw NVA

Units = US survey feet

Number	Easting	Northing	Known Z	Laser Z	Dz
NVA601	6256462.32	2062162.163	524.83	524.87	0.037
NVA602	6271173.346	2076426.527	544.29	544.21	-0.077
NVA603	6307328.911	2091828.175	864.06	864.15	0.095
NVA604	6327144.91	2076714.468	1109.34	1109.45	0.11
NVA605	6346475.926	2046513.192	944.64	944.97	0.334
NVA606	6386022.887	2049642.925	4637.87	4637.89	0.018
NVA607	6397388.141	2067629.101	5154.4	5154.43	0.029
NVA608	6435459.878	2055607.392	2980.22	2980.14	-0.077
NVA609	6453189.724	2023791.462	3351.92	3351.9	-0.017
NVA611	6486801.872	1846988.974	3145.61	3145.52	-0.089
NVA612	6345266.674	2005150.67	1911.47	1911.62	0.151
NVA613	6339966.61	1987411.414	1548.06	1548.03	-0.033
NVA614	6371176.962	1964780.074	1537.49	1537.74	0.255
NVA615	6395861.32	1976006.041	2303.17	2303.41	0.242
NVA616	6441194.97	1974587.714	3632.27	3632.42	0.15
NVA617	6464216.811	1958323.931	4681.61	4681.8	0.195
NVA618	6466038.908	1917741.072	4112.41	4112.21	-0.198
NVA619	6447538.983	1883797.035	3316.2	3316.18	-0.02
NVA620	6425112.544	1894532.844	2508.29	2508.22	-0.071
NVA621	6413819.266	1883906.857	2191.82	2191.85	0.031
NVA622	6377638.858	1904594.822	505.78	505.93	0.154
NVA623	6352309.861	1893313.847	385.57	385.71	0.145
NVA624	6391722.754	1851465.008	1933.15	1933.06	-0.086
NVA625	6401276.976	1870299.818	1681.54	1681.6	0.059
NVA626	6474789.679	1876860.298	3882.44	3882.47	0.031
NVA627	6491398.697	1889967.903	5081.93	5082.06	0.127
NVA628	6495196.63	1912771.992	5340.35	5340.22	-0.127
NVA629	6526772.29	1840629.207	4336.49	4336.29	-0.198
NVA630	6528764.591	1815973.796	3392.44	3392.45	0.013
NVA631	6506669.596	1826537.492	3225.08	3224.97	-0.107
NVA632	6516935.808	1798955.702	3519.05	3518.94	-0.11
NVA633	6476237.915	1795154.265	2206.1	2206.16	0.059

Number	Easting	Northing	Known Z	Laser Z	Dz
NVA634	6447046.63	1801040.399	2288.28	2288.13	-0.154
NVA635	6405276.219	1804132.368	1431.7	1431.79	0.091
NVA636	6394268.24	1818338.567	863.47	863.49	0.017
NVA637	6374371.195	1833237.842	818.52	818.55	0.034
NVA638	6359159.557	1811410.813	512.37	512.28	-0.087
NVA639	6406856.546	1829377.113	2116.43	2116.18	-0.253
NVA640	6425562.643	1846901.278	2222.56	2222.57	0.009
NVA641	6443399.374	1815461.655	2588.32	2588.38	0.065
NVA642	6484206.602	1820652.378	3073.11	3073.13	0.023
NVA643	6508154.303	1846103.967	3378.61	3378.53	-0.082
NVA644	6418496.661	1863539.739	2049.41	2049.63	0.221
NVA645	6426763.451	1810398.446	912.49	912.51	0.022
NVA646	6372674.467	1871530.302	1513.01	1513.22	0.208
NVA647	6435772.949	1868362.333	2826.76	2826.74	-0.023
NVA649	6464224.951	1890249.661	3870.64	3869.57	-1.066
NVA650	6385617.879	1891825.806	1279.42	1279.55	0.134
NVA651	6347757.279	1917828.016	1082.22	1082.31	0.093
NVA652	6344350.196	1944087.34	1842.21	1842.37	0.161
NVA653	6395850.973	1935590.098	1947.3	1947.18	-0.118
NVA654	6385842.921	1949330.164	1446.75	1446.7	-0.054
NVA655	6438428.83	1928767.035	3151.58	3151.47	-0.106
NVA656	6450949.222	1958193.127	4386.68	4386.6	-0.078
NVA657	6462963.24	2036485.349	3881.09	3881.04	-0.052
NVA658	6454404.094	2081851.185	4922.95	4922.78	-0.169
NVA659	6426348.075	2057637.559	2927.53	2927.61	0.077
NVA660	6377533.231	2043604.592	2193.97	2193.69	-0.278
NVA662	6320846.734	2062077.031	999.08	999.03	-0.047
NVA663	6370374.024	1988927	1668.8	1669.02	0.216
NVA664	6331389.656	2070822.861	1182.57	1182.73	0.162
NVA665	6282895.743	2083319.881	531.62	531.89	0.269
NVA666	6261153.143	2082847.808	738.22	738.56	0.341
NVA667	6279157.478	2060649.955	245.64	245.54	-0.096
NVA668	6266314.626	2044479.011	596.37	596.03	-0.338
NVA618	6465561.863	1916996.536	4144.48	4144.29	-0.187

Number	Easting	Northing	Known Z	Laser Z	Dz
Average Dz		0.02 ft			
Minimum Dz		-0.338 ft			
Maximum Dz		0.341 ft			
Root Mean Square		0.147 ft			
95% Confidence Level		0.287 ft			

Figure 15. QC Checkpoint Locations - VVA