

Eastern San Diego County, CA 2016 QL2 LiDAR Project Report



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1. Summary / Scope

1.1. Summary

This report contains a summary of the Eastern San Diego County, CA 2016 QL2 LiDAR acquisition task order, issued by USGS National Geospatial Technical Operations Center (NGTOC) under their Geospatial Product and Services Contract (GPSC) on September 16, 2016. The task order yielded a project area covering approximately 1,353 square miles over San Diego County, California. The intent of this document is only to provide specific validation information for the data acquisition/collection work 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	2,100 m	40°	30%	≤ 10 cm

1.3. Coverage

The LiDAR project boundary covers approximately 1,353 square miles and includes partial coverage of the northern and eastern portions of San Diego County in southern California. A buffer of 100 meters was created to meet task order specifications. LiDAR extents are shown in Figure 1.

1.4. Duration

LiDAR data was acquired from October 31, 2016 to January 31, 2017 in 32 total lifts. See “Section: 2.5. Time Period” for more details.

1.5. Issues

There were no issues to report with this project.

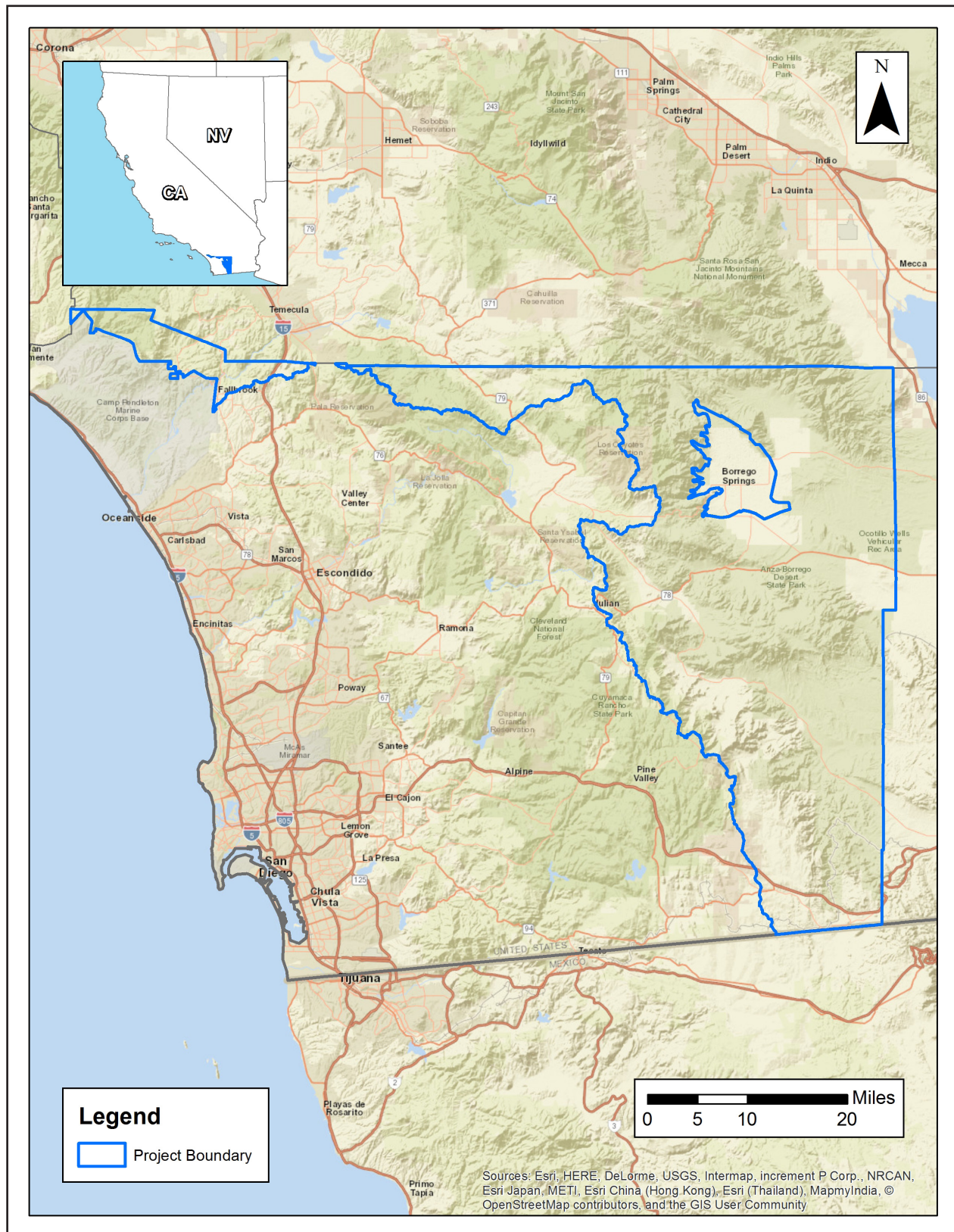
1.6. Deliverables

The following products were produced and delivered:

- Raw LiDAR Point Cloud data swaths in LAS 1.4 format
- Classified Point cloud data, tiled, in LAS 1.4 format
- Continuous hydro-flattened breaklines in Esri file geodatabase format
- 2.5-foot hydro-flattened bare earth raster DEM, tiled, in ERDAS .IMG format
- 2.5-foot intensity images, tiled, in ERDAS .IMG format
- 2-foot contours, tiled, in Esri file geodatabase format
- Building footprints in Esri file geodatabase format
- Processing boundary in Esri shapefile format
- Tile index in Esri shapefile format
- Calibration and QC Checkpoints in Esri shapefile format
- Accuracy assessment in Excel .XLS format
- FOCUS report in .PDF format
- GPS/IMU Statistics and Flight Logs in .PDF format
- Survey report in .PDF format
- Project-, deliverable-, and tile-level metadata in .XML format

All geospatial deliverables were produced in NAVD83 (2011) State Plane California Zone VI, US survey feet; NAVD88 (GEOID12B), US survey feet. All tiled deliverables have a tile size of 5,000 ft x 5,000 ft. Tile names are derived from the tile index provided by San Diego County.

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.

Detailed project flight planning calculations were performed for the project using Optech MissionNAV planning software. The entire target area was comprised of 555 planned flight lines measuring approximately 6,160 total flight line miles (Figure 2).

2.2. LiDAR Sensor

Quantum Spatial utilized an Optech Orion LiDAR sensor (Figure 3), serial number 315, during the project. These systems are capable of collecting data at a maximum frequency of 167 kHz, which affords elevation data collection of up to 167,000 points per second. These systems utilize a Multi-Pulse in the Air option (MPIA). These sensors are also equipped with the ability to measure up to 5 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd, 4th, and last returns. 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

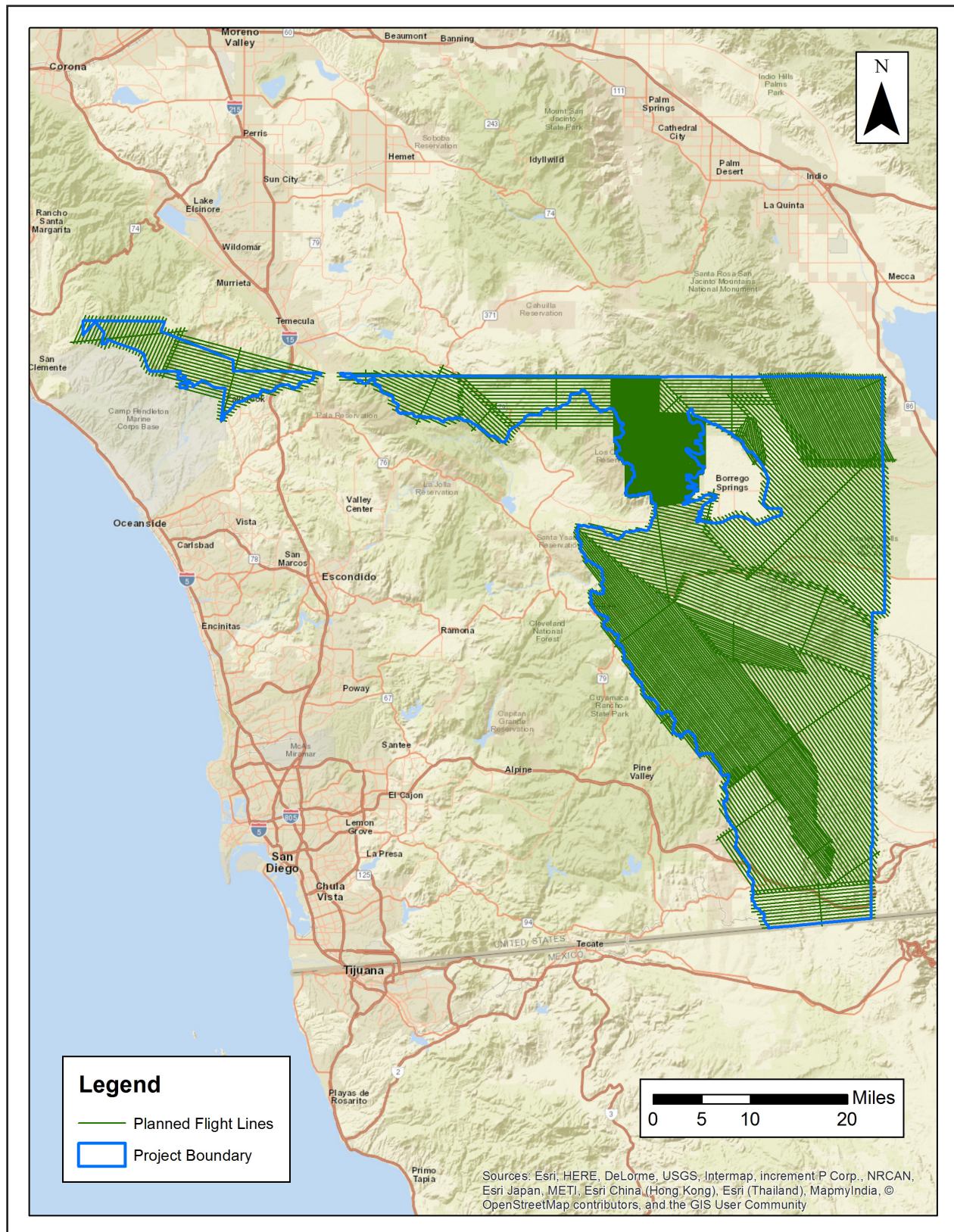


Table 2. Lidar System Specifications

Terrain and Aircraft Scanner	Flying Height	1,800 m
	Recommended Ground Speed	115 kts
Scanner	Field of View	38°
	Scan Rate Setting Used	41.8 Hz
Laser	Laser Pulse Rate Used	125 kHz
	Multi Pulse in Air Mode	Enabled
Coverage	Full Swath Width	900 m
	Line Spacing	560 m
Point Spacing and Density	Average Point Spacing	0.67 m
	Average Point Density	2.26 pts / m ²

Figure 3. Optech Orion LiDAR Sensor



2.3. Aircraft

All flights for the project were accomplished through the use of customized planes. Plane type and tail numbers are listed below.

- Cessna T206H Fixed wing single-engine, Tail Number: N27DV
- Cessna 206 Stationair (piston-single), Tail Number: N7269T

These aircraft provided an ideal, stable aerial base for LiDAR acquisition. These aerial platforms 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 Optech LiDAR systems.

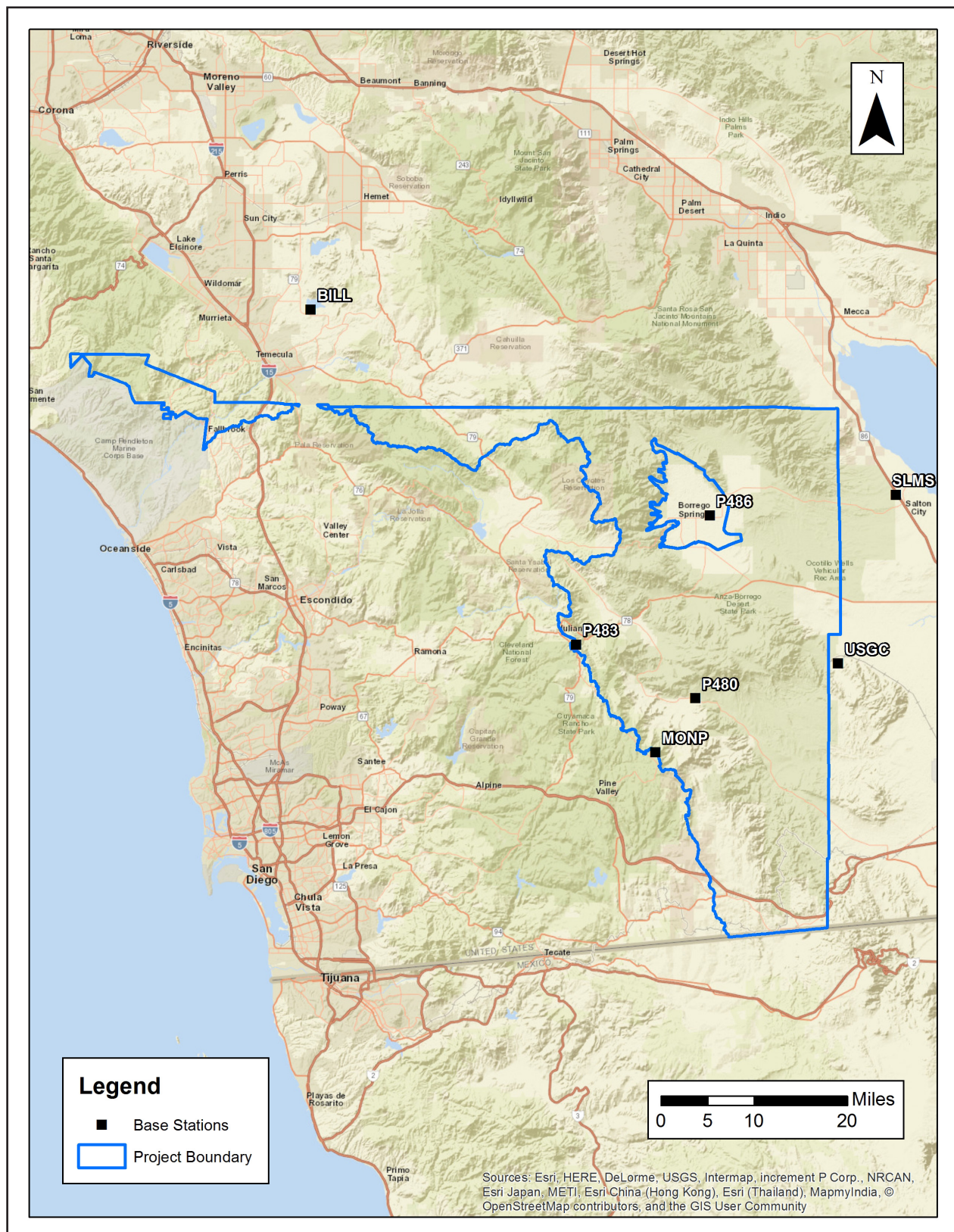
2.4. Base Station Information

GPS base stations were utilized during all phases of flight (Table 3). The base station locations were verified using NGS OPUS service and subsequent surveys. Base station locations are depicted in Figure 4. Data sheets, graphical depiction of base station locations or log sheets used during station occupation are available in Appendix A.

Table 3. Base Station Locations

Base Station	Longitude	Latitude	Ellipsoid Height (m)
BILL	117° 3' 52.51376"	33° 34' 41.66355"	470.789
MONP	116° 25' 20.41161"	32° 53' 30.97273"	1843.44
P480	116° 20' 54.67946"	32° 58' 33.57113"	436.797
P483	116° 34' 9.52281"	33° 3' 32.97633"	1376.313
P486	116° 19' 20.18099"	33° 15' 36.67494"	127.051
SLMS	115° 58' 40.18244"	33° 17' 32.00589"	-45.148
USGC	116° 5' 7.15702"	33° 1' 48.21584"	134.219

Figure 4. Base Station Locations



2.5. Time Period

Project specific flights were conducted over several months. Thirty-two sorties, or aircraft lifts were completed. Accomplished sorties are listed below.

- Oct 31, 2016-A (N27DV, SN315)
- Nov 1, 2016-A (N27DV, SN315)
- Nov 3, 2016-A (N27DV, SN315)
- Nov 4, 2016-A (N27DV, SN315)
- Nov 5, 2016-A (N27DV, SN315)
- Nov 13, 2016-A (N27DV, SN315)
- Nov 14, 2016-A (N27DV, SN315)
- Nov 14, 2016-B (N27DV, SN315)
- Nov 15, 2016-A (N27DV, SN315)
- Nov 15, 2016-B (N27DV, SN315)
- Nov 16, 2016-A (N7269T, SN315)
- Nov 17, 2016-A (N7269T, SN315)
- Nov 18, 2016-A (N7269T, SN315)
- Nov 18, 2016-B (N7269T, SN315)
- Nov 19, 2016-A (N7269T, SN315)
- Nov 19, 2016-B (N7269T, SN315)
- Nov 20, 2016-A (N7269T, SN315)
- Nov 22, 2016-A (N7269T, SN315)
- Nov 23, 2016-A (N7269T, SN325)
- Nov 24, 2016-A (N7269T, SN315)
- Nov 24, 2016-B (N7269T, SN315)
- Nov 25, 2016-A (N7269T, SN315)
- Nov 26, 2016-A (N7269T, SN315)
- Nov 29, 2016-A (N7269T, SN315)
- Nov 29, 2016-B (N7269T, SN315)
- Nov 30, 2016-A (N7269T, SN315)
- Nov 30, 2016-B (N7269T, SN315)
- Jan 14, 2017-A (N27DV, SN315)
- Jan 26, 2017-A (N27DV, SN315)
- Jan 28, 2017-A (N27DV, SN315)
- Jan 28, 2017-B (N27DV, SN315)
- Jan 31, 2017-A (N27DV, SN315)

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

Applanix + POSPac Mobile Mapping Suite 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/POSPac 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 Applanix POSPac 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 POSPac 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 Optech DashMap Post Processor 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 6 – Man-Made Structures – Points falling on buildings, structures inside of water bodies, docks, and piers.
- 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 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. The overlap data was identified using the Overlap Flag, per LAS 1.4 specifications.

All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper is used as a final check of the bare earth dataset. GeoCue was then used to create the deliverable industry-standard LAS files for

all point cloud data. 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 Raster DEM Creation

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 2.5-foot 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.

3.7. Intensity Image Creation

GeoCue software was used to create the deliverable Intensity Images. All overlap classes were ignored during this process. This helps to ensure a more aesthetically pleasing image. The GeoCue software was then used to verify full project coverage as well. Tiled ERDAS .IMG files with a cell size of 2.5-feet were then provided as the deliverable for this dataset requirement.

3.8. Building Polygon Processing

Polygons were generated with an automated routine that utilized the Class 6 (Buildings) building points as an input. The polygons were then simplified to remove any extraneous vertices.

3.9. Contour Processing

Using automated scripting routines within ArcMap, a terrain surface was created using the

ground (ASPRS Class 2) LiDAR data as well as the hydro-flattened breaklines. This surface was then used to generate the final 2-foot contour dataset in Esri file geodatabase format.

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 5 and Figure 6.

Figure 5. Flightline Swath LAS File Coverage - pt. 1

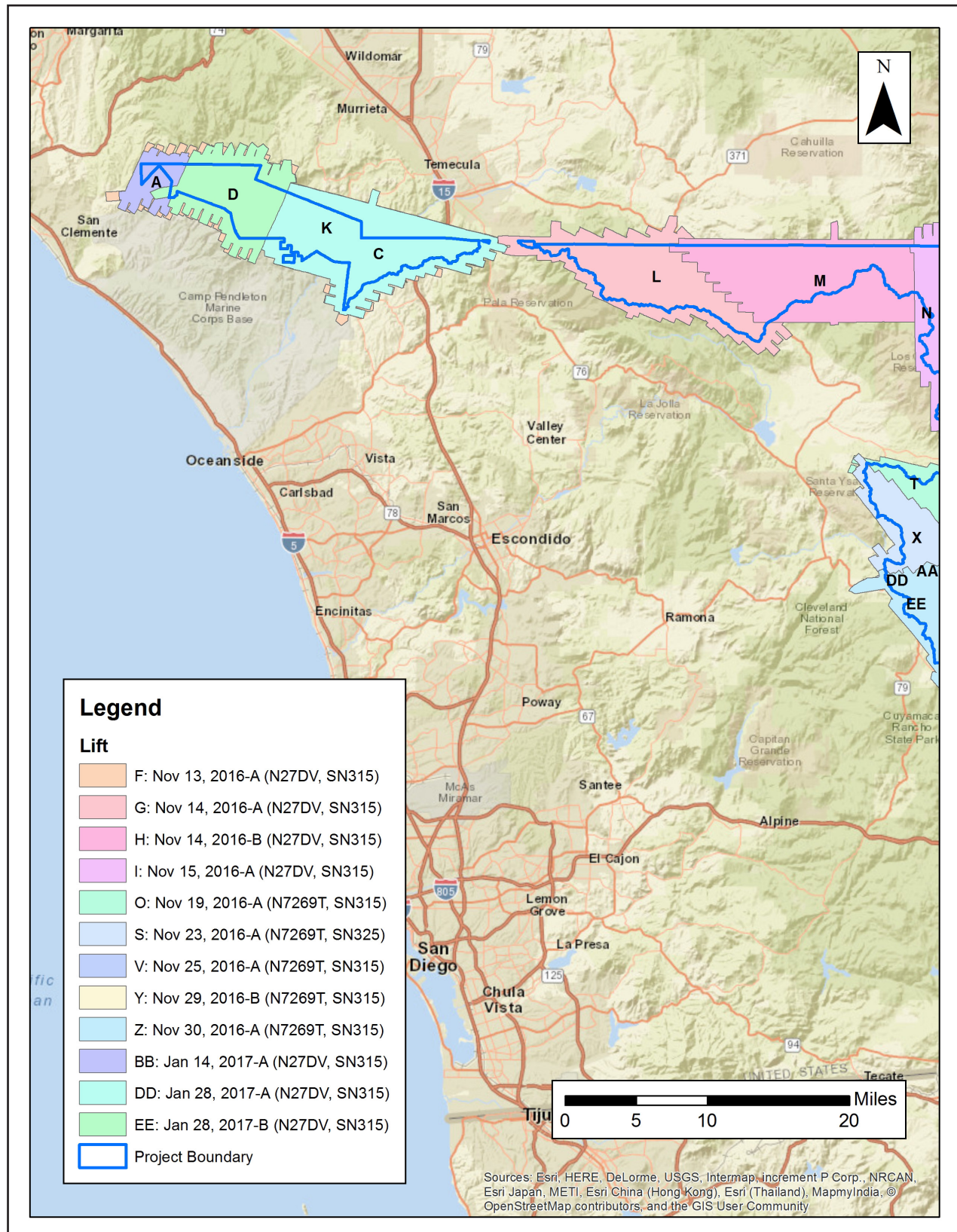
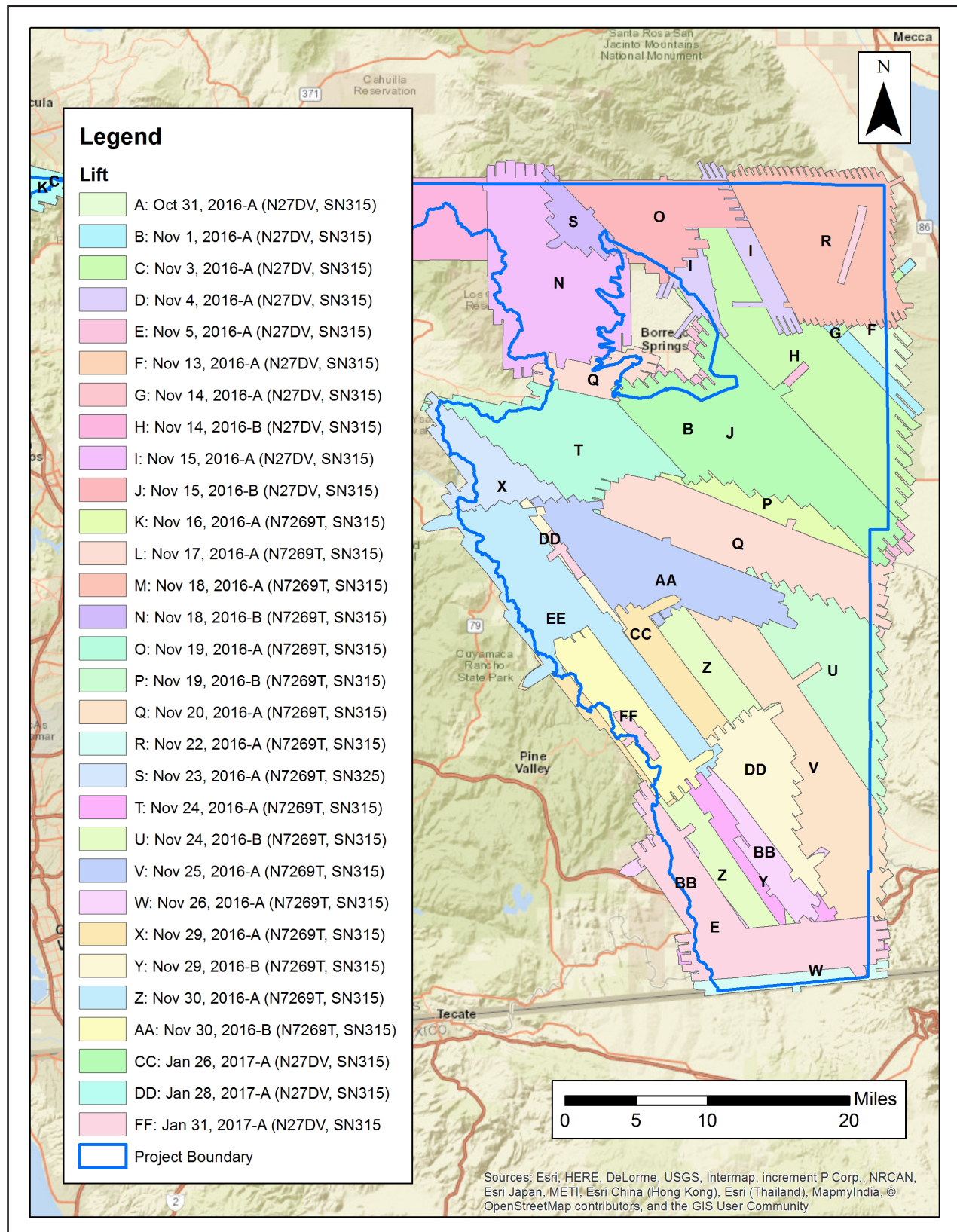


Figure 6. Flightline Swath LAS File Coverage - pt. 2



5. Ground Control and Check Point Collection

Quantum Spatial partnered with Compass Data, Inc. to complete a field survey of 28 ground control (calibration) points along with 116 blind QA points in Vegetated and Non-Vegetated land cover classifications (total of 144 points) as an independent test of the accuracy of this project.

For more information, see the Survey Report in Appendix B.

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 (GEOID12B) US survey feet.

5.1. Calibration Control Point Testing

Figure 7 shows the location of each bare earth calibration point for the project area. Table 4 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

The project specifications require that only Non-Vegetated Vertical Accuracy (NVA) be computed for raw lidar point cloud swath files. The required accuracy (ACCz) is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the "bare earth" and "urban" land cover classes. The NVA was tested with 64 checkpoints located in bare earth and urban (non-vegetated) areas. These check points were not used in the calibration or post processing of the lidar point cloud data. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See survey report for additional survey methodologies.

Elevations from the unclassified lidar surface were measured for the x,y location of each check point. Elevations interpolated from the lidar surface were then compared to the elevation values of the surveyed control points. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASRPS Guidelines. See Figure 8 and Table 5.

5.3. Digital Elevation Model (DEM) Testing

The project specifications require the accuracy (ACCz) of the derived DEM be calculated and reported in two ways:

1. The required NVA is: 19.6 cm at a 95% confidence level, derived according to NSSDA, i.e., based on RMSE of 10 cm in the “bare earth” and “urban” land cover classes. This is a required accuracy. The NVA was tested with 62 of 64 checkpoints located in bare earth and urban (non-vegetated) areas; points BE46 and BE58 were removed as they fell outside the AOI. See Figure 9 and Table 6.
2. Vegetated Vertical Accuracy (VVA): VVA shall be reported for “forested”, “brushlands/low trees”, and “tall weeds/crops” land cover classes. The target VVA is: 29.4 cm at the 95th percentile, derived according to ASPRS Guidelines, Vertical Accuracy Reporting for Lidar Data, i.e., based on the 95th percentile error in all vegetated land cover classes combined. This is a target accuracy. The VVA was tested with 51 of 52 checkpoints located in forested, tall weeds/crops, and brushlands/low trees (vegetated) areas; point SH29 was removed as it fell outside the AOI. The checkpoints were distributed throughout the project area and were surveyed using GPS techniques. See Figure 10 and Table 7.

See survey report for additional survey methodologies. AccuracyZ has been tested to meet 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA); assessed and reported using National Digital Elevation Program (NDEP)/ASPRS Guidelines.

Figure 7. Calibration Control Point Locations

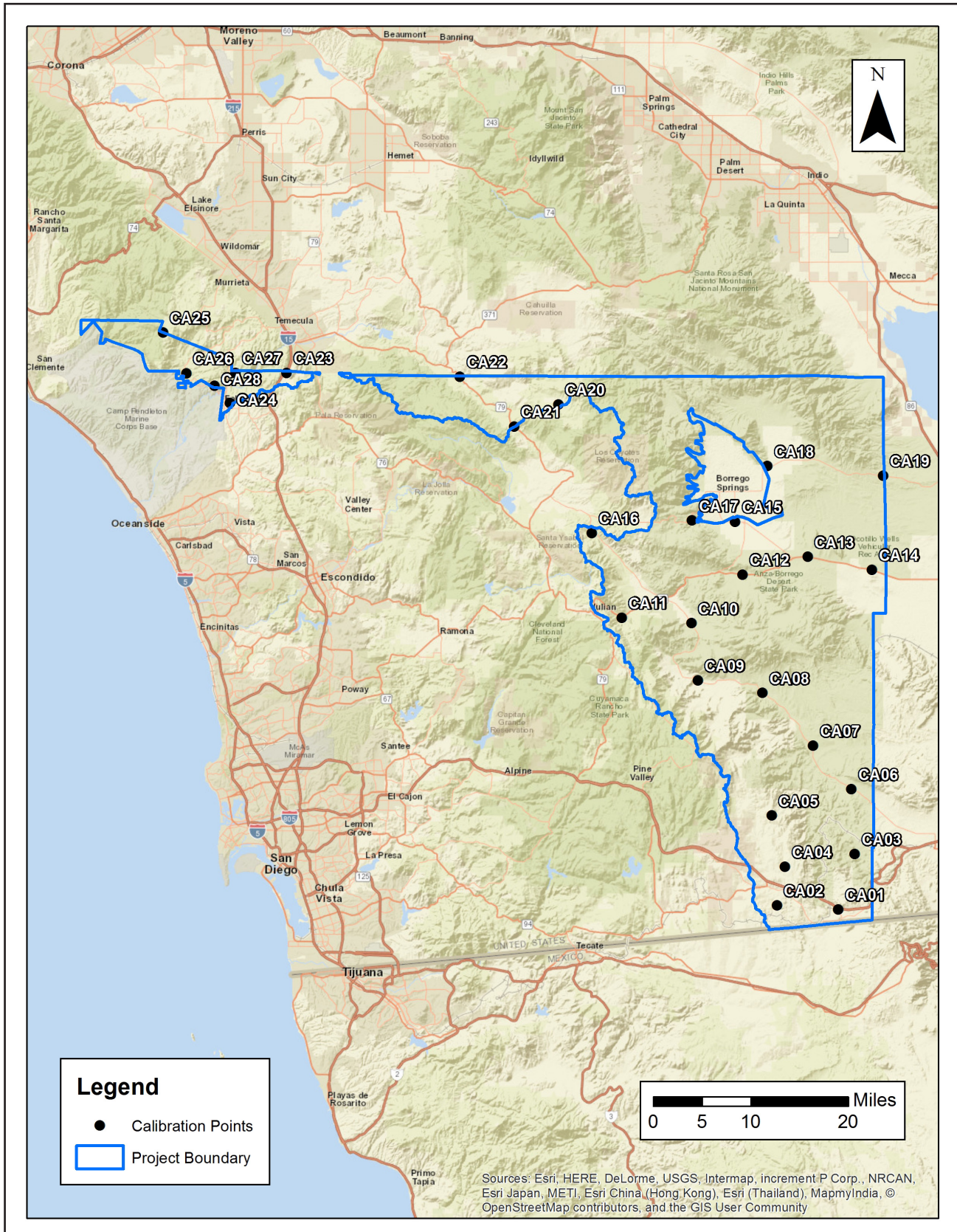


Table 4. Calibration Control Point Report

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
CA12	6536016.792	1991874.830	1247.78	1248.04	-0.26
CA04	6558978.264	1833646.225	3623.24	3623.49	-0.25
CA07	6574175.540	1899261.566	707.32	707.57	-0.25
CA15	6531925.357	2020507.445	601.51	601.67	-0.16
CA13	6571229.830	2001528.899	650.05	650.16	-0.11
CA06	6594911.669	1875741.248	1180.92	1181.00	-0.08
CA22	6382857.691	2099143.089	2450.46	2450.53	-0.07
CA18	6549382.480	2050690.317	627.65	627.70	-0.05
CA03	6596705.938	1840613.031	1861.74	1861.79	-0.05
CA02	6554631.637	1812794.980	3421.00	3421.03	-0.03
CA25	6222149.380	2123119.116	2062.29	2062.32	-0.03
CA23	6289021.912	2101119.058	1148.34	1148.37	-0.03
CA10	6508256.524	1965621.002	2347.84	2347.86	-0.03
CA24	6258247.338	2084891.938	727.09	727.11	-0.02
CA17	6508581.886	2021278.654	2325.09	2325.10	-0.01
CA08	6546728.106	1927803.590	1227.09	1227.07	0.02
CA05	6551713.730	1861379.615	4044.12	4044.10	0.02
CA14	6606087.589	1994562.912	162.26	162.22	0.04
CA27	6261316.160	2101176.017	753.62	753.58	0.04
CA21	6412220.056	2072121.220	3288.37	3288.31	0.06
CA19	6612005.688	2045511.685	524.94	524.88	0.06
CA11	6470528.832	1968555.895	2751.67	2751.60	0.07
CA09	6511680.204	1934637.009	1731.48	1731.39	0.09
CA28	6249934.308	2094143.453	895.97	895.82	0.15
CA20	6436168.544	2084059.437	4334.34	4334.18	0.16
CA16	6454400.921	2014460.702	3483.83	3483.67	0.16
CA26	6234758.453	2100978.118	357.62	357.42	0.20
CA01	6587759.094	1810503.428	2829.51	2829.21	0.30
Average Dz		0.000 ft			
Minimum Dz		-0.256 ft			
Maximum Dz		0.302 ft			
Root Mean Square		0.131 ft			
Std. Deviation		0.133 ft			

Figure 8. QC Checkpoint Locations - Raw NVA

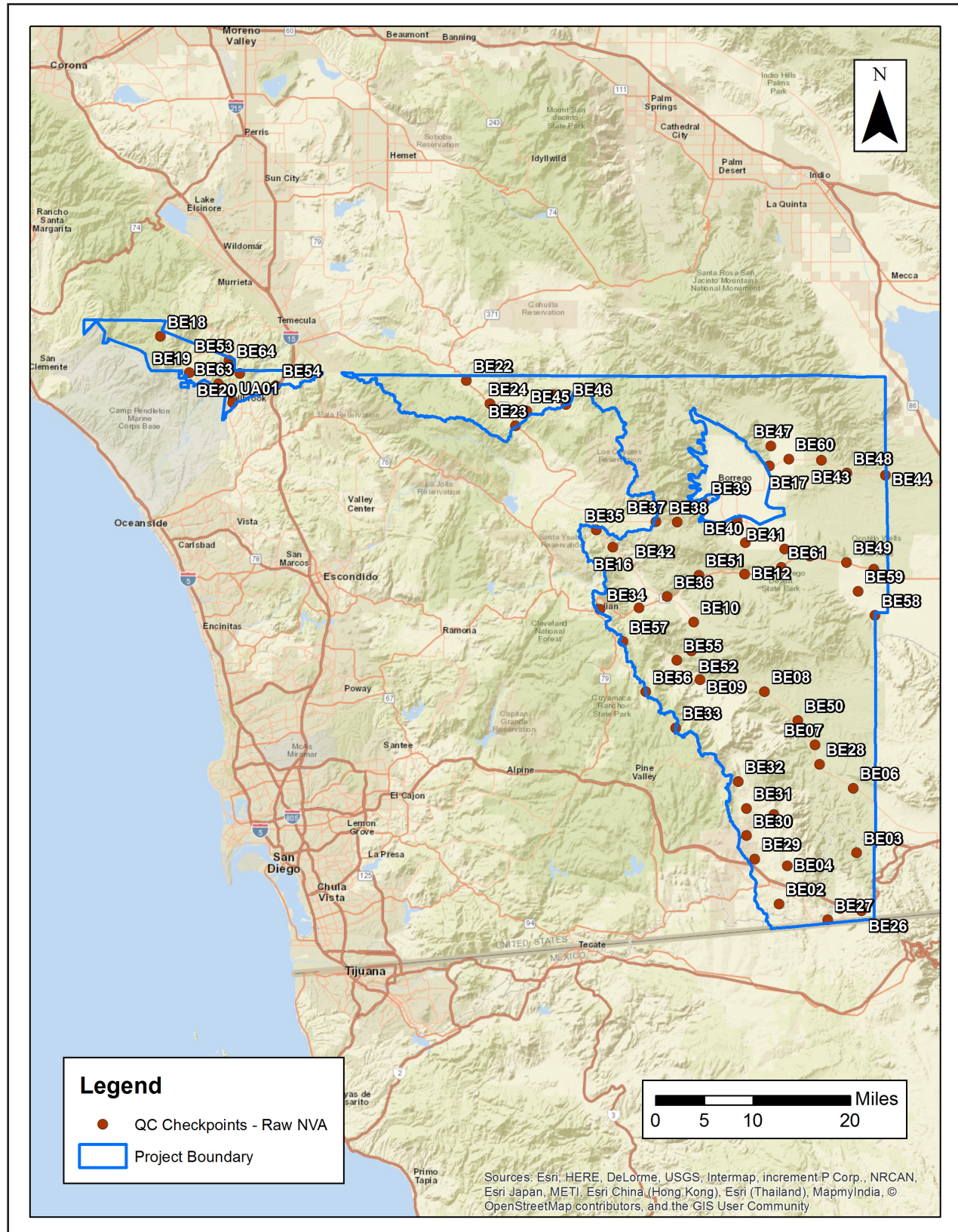


Table 5. QC Checkpoint Report - Raw NVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE01	6587741.172	1810523.185	2829.28	2828.99	0.29
BE02	6554641.615	1812937.566	3430.74	3430.74	0.00
BE03	6596702.932	1840653.262	1858.55	1858.60	-0.05
BE04	6558993.260	1833551.260	3619.88	3620.05	-0.17
BE05	6551686.126	1861395.964	4044.90	4044.82	0.08
BE06	6594867.687	1875762.415	1182.20	1182.27	-0.08
BE07	6574212.126	1899242.147	706.15	706.34	-0.19
BE08	6546763.128	1928082.062	1225.34	1225.56	-0.22
BE09	6511682.077	1934657.793	1731.97	1731.92	0.05
BE10	6508332.693	1965776.479	2345.06	2345.09	-0.03
BE11	6478685.600	1973505.766	2536.59	2536.59	-0.01
BE12	6536017.842	1991904.822	1246.93	1247.11	-0.18
BE13	6571304.769	2001661.695	649.88	650.02	-0.14
BE14	6606040.268	1994431.040	167.72	167.75	-0.03
BE15	6531948.855	2020684.021	597.24	597.33	-0.09
BE16	6464458.929	2006386.507	2919.72	2919.56	0.16
BE17	6549331.702	2050504.368	624.58	624.56	0.02
BE18	6219205.672	2120777.753	1989.70	1989.51	0.19
BE19	6234807.125	2101077.877	366.90	366.83	0.06
BE20	6262121.995	2100703.819	700.45	700.45	0.00
BE21	6288774.378	2101442.669	1154.30	1154.21	0.09
BE22	6385129.073	2096797.521	2480.24	2480.11	0.13
BE23	6411648.265	2072237.654	3274.26	3274.28	-0.02
BE24	6397905.981	2084209.260	2786.47	2786.41	0.06
BE25	6432403.692	2089094.227	4386.21	4386.20	0.01
BE26	6599366.794	1809182.139	3140.82	3140.49	0.33
BE27	6580922.849	1804382.733	2813.21	2813.09	0.12
BE28	6576452.218	1888688.124	728.96	728.91	0.05
BE29	6541520.773	1837370.700	3883.57	3883.81	-0.24
BE30	6536952.822	1850068.035	4059.14	4059.06	0.08
BE31	6537002.491	1864762.200	4464.34	4464.46	-0.12
BE32	6532450.976	1879385.803	4424.25	4424.31	-0.06

Number	Easting	Northing	Known Z	Laser Z	Dz
BE33	6498599.219	1908468.701	5463.59	5463.44	0.15
BE34	6457559.352	1972651.682	4143.98	4143.99	-0.01
BE35	6455452.693	2015751.046	3468.39	3468.21	0.18
BE36	6493901.953	1979567.708	2256.47	2256.49	-0.02
BE37	6487857.489	2020179.597	4098.47	4098.29	0.18
BE38	6499350.670	2019982.669	2964.27	2964.27	0.00
BE39	6514080.043	2030420.434	1223.49	1223.55	-0.06
BE40	6536291.836	2008830.794	1019.08	1019.26	-0.18
BE41	6557626.425	2005371.987	731.55	731.59	-0.04
BE42	6472971.500	1996127.420	2639.85	2639.90	-0.05
BE43	6577511.422	2053653.581	964.13	964.10	0.03
BE44	6612199.356	2045515.496	518.44	518.29	0.14
BE45	6417808.401	2080355.397	3587.21	3587.02	0.19
BE46	6439082.559	2083883.535	4434.12	4433.87	0.25
BE47	6550131.676	2061378.613	556.60	556.68	-0.08
BE48	6591284.679	2046627.668	887.63	887.61	0.02
BE49	6591189.282	1998150.607	298.41	298.47	-0.06
BE50	6564835.521	1912454.145	968.67	968.84	-0.17
BE51	6511157.291	1991282.885	1624.01	1623.77	0.24
BE52	6507179.908	1950119.275	2649.99	2649.84	0.15
BE53	6256368.858	2107699.699	835.06	835.08	-0.03
BE54	6281602.544	2094017.132	1037.90	1037.87	0.03
BE55	6499092.660	1945177.121	2229.16	2229.06	0.10
BE56	6482419.170	1928044.431	5179.17	5179.38	-0.22
BE57	6469863.380	1955232.939	4755.77	4755.73	0.04
BE58	6606621.756	1969494.843	107.33	107.54	-0.21
BE59	6597495.272	1982556.531	109.18	109.39	-0.21
BE60	6559932.925	2054234.989	686.29	686.21	0.07
BE61	6555867.887	1995582.306	971.31	971.21	0.10
BE63	6250617.471	2095088.015	975.93	976.05	-0.12
BE64	6256774.481	2104880.035	898.99	899.03	-0.04
UA01	6258248.283	2084842.136	725.78	725.83	-0.05

Number	Easting	Northing	Known Z	Laser Z	Dz
	Average Dz	0.010 ft			
	Minimum Dz	-0.241 ft			
	Maximum Dz	0.325 ft			
	Root Mean Square	0.132 ft			
	95% Confidence Level	0.259 ft			

Figure 9. QC Checkpoint Locations - NVA

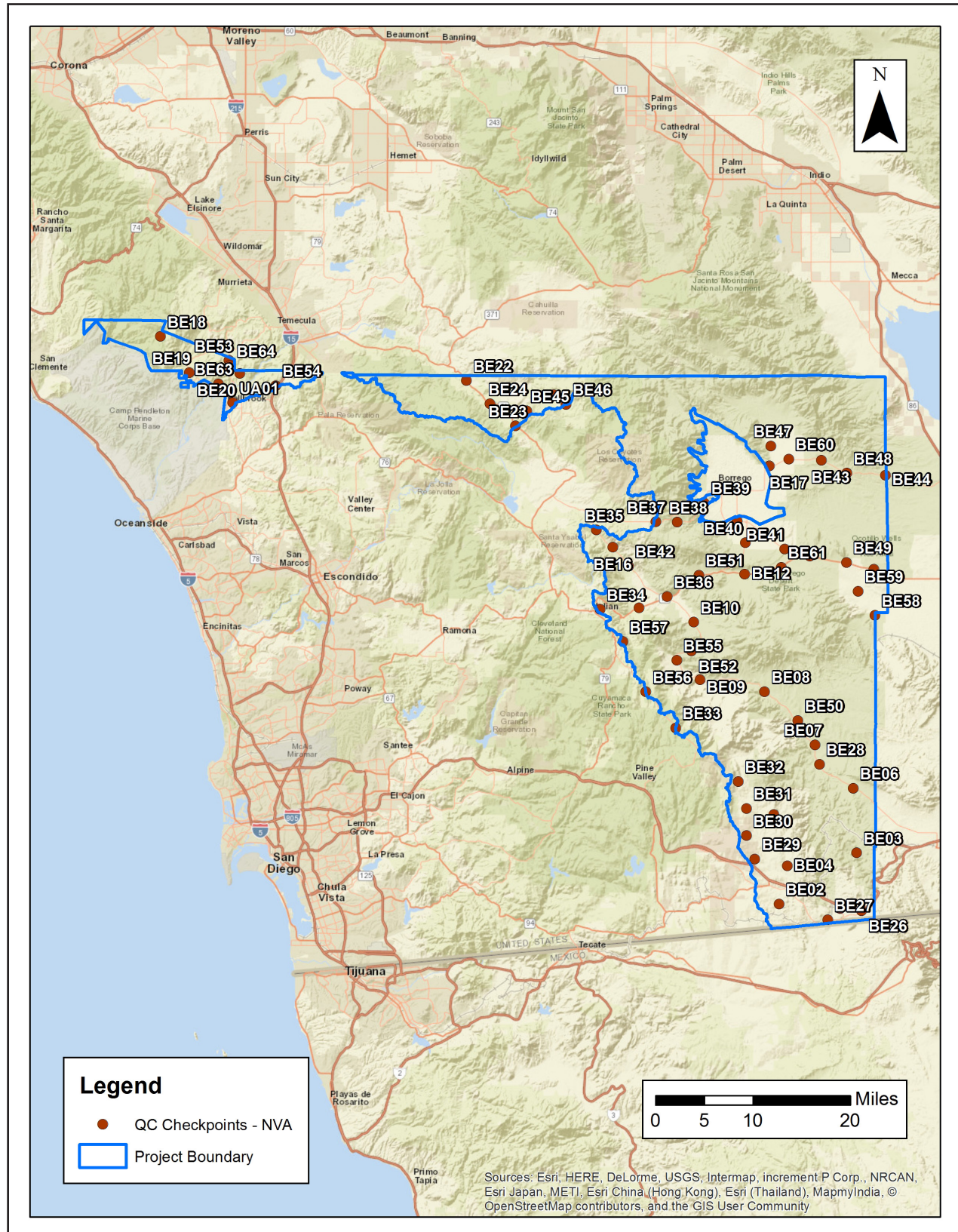


Table 6. QC Checkpoint Report - NVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
BE01	6587741.17	1810523.19	2829.28	2828.99	-0.29
BE02	6554641.62	1812937.57	3430.74	3430.73	0.00
BE03	6596702.93	1840653.26	1858.55	1858.62	0.07
BE04	6558993.26	1833551.26	3619.88	3620.08	0.20
BE05	6551686.13	1861395.96	4044.90	4044.80	-0.09
BE06	6594867.69	1875762.42	1182.20	1182.27	0.08
BE07	6574212.13	1899242.15	706.15	706.36	0.21
BE08	6546763.13	1928082.06	1225.34	1225.55	0.21
BE09	6511682.08	1934657.79	1731.97	1731.91	-0.06
BE10	6508332.69	1965776.48	2345.06	2345.07	0.01
BE11	6478685.60	1973505.77	2536.59	2536.60	0.02
BE12	6536017.84	1991904.82	1246.93	1247.10	0.16
BE13	6571304.77	2001661.70	649.88	650.04	0.15
BE14	6606040.27	1994431.04	167.72	167.75	0.03
BE15	6531948.86	2020684.02	597.24	597.33	0.10
BE16	6464458.93	2006386.51	2919.72	2919.50	-0.21
BE17	6549331.70	2050504.37	624.58	624.56	-0.02
BE18	6219205.67	2120777.75	1989.70	1989.51	-0.18
BE19	6234807.13	2101077.88	366.90	366.81	-0.09
BE20	6262122.00	2100703.82	700.45	700.44	-0.01
BE21	6288774.38	2101442.67	1154.30	1154.20	-0.10
BE22	6385129.07	2096797.52	2480.24	2480.11	-0.13
BE23	6411648.27	2072237.65	3274.26	3274.24	-0.02
BE24	6397905.98	2084209.26	2786.47	2786.42	-0.05
BE25	6432403.69	2089094.23	4386.21	4386.19	-0.02
BE26	6599366.79	1809182.14	3140.82	3140.49	-0.32
BE27	6580922.85	1804382.73	2813.21	2813.08	-0.13
BE28	6576452.22	1888688.12	728.96	728.91	-0.05
BE29	6541520.77	1837370.70	3883.57	3883.81	0.24
BE30	6536952.82	1850068.04	4059.14	4059.04	-0.10
BE31	6537002.49	1864762.20	4464.34	4464.46	0.13
BE32	6532450.98	1879385.80	4424.25	4424.37	0.12

Number	Easting	Northing	Known Z	Laser Z	Dz
BE33	6498599.22	1908468.70	5463.59	5463.45	-0.14
BE34	6457559.35	1972651.68	4143.98	4143.99	0.01
BE35	6455452.69	2015751.05	3468.39	3468.24	-0.15
BE36	6493901.95	1979567.71	2256.47	2256.50	0.03
BE37	6487857.49	2020179.60	4098.47	4098.27	-0.20
BE38	6499350.67	2019982.67	2964.27	2964.26	-0.01
BE39	6514080.04	2030420.43	1223.49	1223.56	0.07
BE40	6536291.84	2008830.79	1019.08	1019.28	0.20
BE41	6557626.43	2005371.99	731.55	731.58	0.03
BE42	6472971.50	1996127.42	2639.85	2639.93	0.08
BE43	6577511.42	2053653.58	964.13	964.09	-0.04
BE44	6612199.36	2045515.50	518.44	518.27	-0.16
BE45	6417808.40	2080355.40	3587.21	3587.03	-0.18
BE46	6439082.56	2083883.54	4434.12	*	*
BE47	6550131.68	2061378.61	556.60	556.68	0.08
BE48	6591284.68	2046627.67	887.63	887.64	0.00
BE49	6591189.28	1998150.61	298.41	298.48	0.08
BE50	6564835.52	1912454.15	968.67	968.83	0.16
BE51	6511157.29	1991282.89	1624.01	1623.82	-0.19
BE52	6507179.91	1950119.28	2649.99	2649.83	-0.16
BE53	6256368.86	2107699.70	835.06	835.16	0.11
BE54	6281602.54	2094017.13	1037.90	1037.87	-0.03
BE55	6499092.66	1945177.12	2229.16	2229.05	-0.11
BE56	6482419.17	1928044.43	5179.17	5179.36	0.20
BE57	6469863.38	1955232.94	4755.77	4755.73	-0.05
BE58	6606621.76	1969494.84	107.33	*	*
BE59	6597495.27	1982556.53	109.18	109.39	0.21
BE60	6559932.93	2054234.99	686.29	686.23	-0.05
BE61	6555867.89	1995582.31	971.31	971.29	-0.02
BE63	6250617.47	2095088.02	975.93	976.05	0.12
BE64	6256774.48	2104880.04	898.99	899.10	0.12
UA01	6258248.28	2084842.14	725.78	725.83	0.06

Number	Easting	Northing	Known Z	Laser Z	Dz
	Average Dz	0.000 ft			
	Minimum Dz	-0.322 ft			
	Maximum Dz	0.245 ft			
	Root Mean Square	0.132 ft			
	95% Confidence Level	0.258 ft			

***Points BE46 and BE58 were removed as they fell outside the AOI.**

Figure 10. QC Checkpoint Locations - VVA

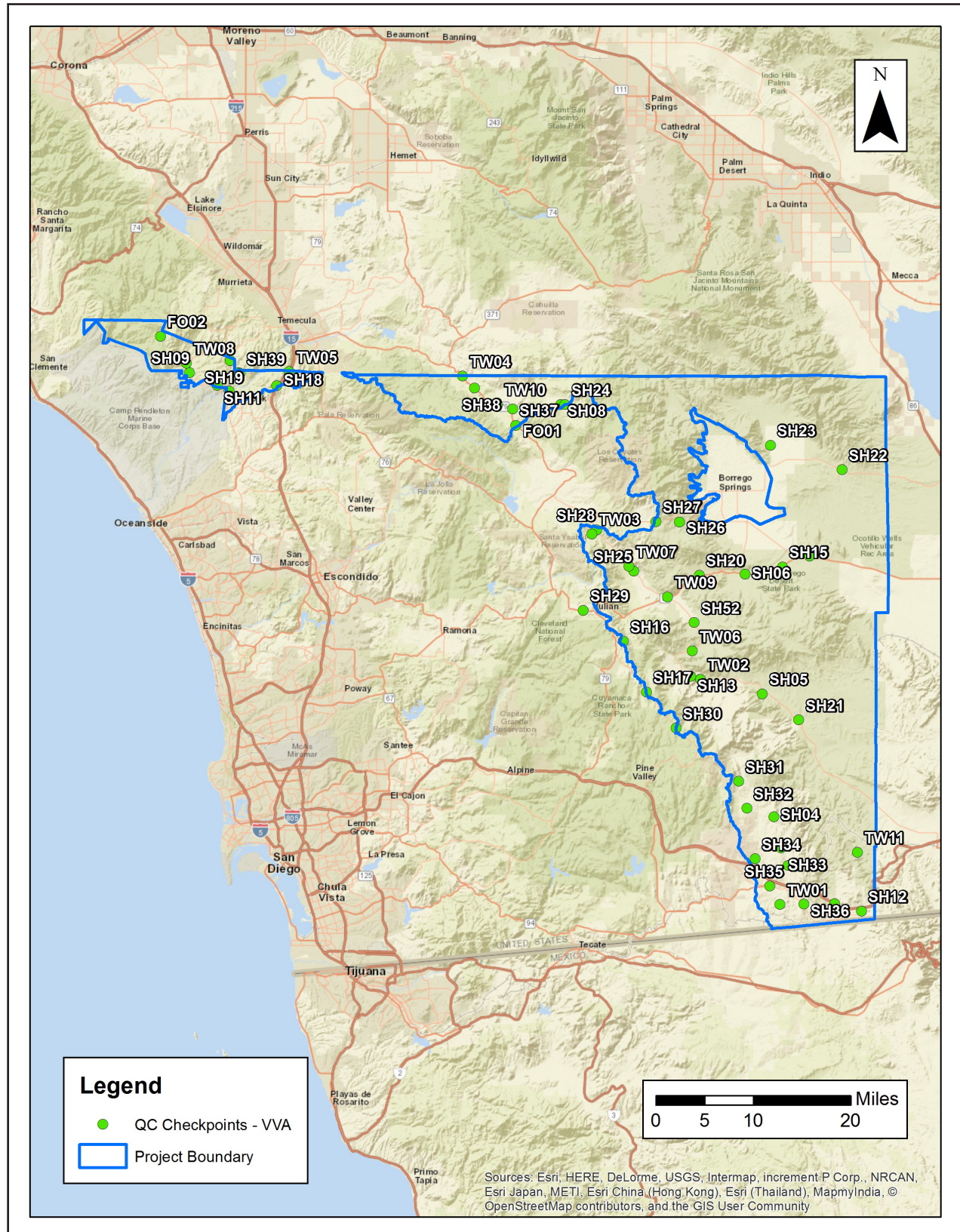


Table 7. QC Checkpoint Report - VVA

Units = US Survey Feet

Number	Easting	Northing	Known Z	Laser Z	Dz
FO01	6411738.23	2072357.78	3273.88	3273.93	0.05
FO02	6219162.82	2120849.21	1994.10	1994.02	-0.08
FO03	6256242.55	2091159.12	317.12	317.19	0.07
SH01	6584452.76	1813116.01	2743.53	2743.69	0.16
SH03	6559348.54	1833887.81	3650.22	3650.47	0.25
SH04	6551555.00	1860169.13	4041.35	4041.36	0.01
SH05	6545374.02	1926865.71	1287.89	1288.58	0.69
SH06	6535932.85	1991932.68	1250.90	1251.46	0.56
SH07	6570897.65	2001619.64	657.46	657.73	0.27
SH08	6436064.53	2083907.78	4328.39	4328.48	0.09
SH09	6234811.98	2101129.35	374.68	374.67	-0.01
SH10	6261340.89	2101115.33	752.04	752.18	0.13
SH11	6249835.03	2094162.88	881.75	882.19	0.45
SH12	6599035.74	1809140.94	3131.29	3131.17	-0.13
SH13	6506399.60	1936346.62	2018.81	2018.92	0.10

Number	Easting	Northing	Known Z	Laser Z	Dz
SH15	6556213.56	1995706.46	958.77	958.80	0.03
SH16	6469999.52	1955463.89	4748.57	4748.82	0.25
SH17	6482537.46	1927940.94	5162.75	5163.16	0.41
SH18	6282149.73	2093916.26	1020.30	1020.58	0.28
SH19	6256833.69	2107563.90	893.07	893.28	0.21
SH20	6511073.75	1991325.20	1625.44	1625.74	0.29
SH21	6565040.13	1912794.57	957.20	957.49	0.29
SH22	6588508.75	2048433.56	897.62	897.60	-0.02
SH23	6549697.48	2061748.27	554.37	554.62	0.25
SH24	6438275.43	2083756.22	4402.00	4401.86	-0.14
SH25	6475629.17	1993559.94	2603.26	2603.57	0.31
SH26	6500499.00	2020125.46	2895.34	2895.81	0.47
SH27	6487629.07	2020364.44	4122.30	4122.29	-0.01
SH28	6455596.00	2015831.36	3490.25	3490.16	-0.09
SH29	6448279.00	1972159.33	3985.34	*	*
SH30	6498597.46	1908278.20	5471.59	5471.89	0.30
SH31	6532453.59	1879437.42	4424.39	4424.61	0.21
SH32	6536963.48	1864818.12	4469.53	4469.75	0.23
SH33	6555532.61	1843345.40	3801.75	3802.07	0.32
SH34	6541393.48	1837490.67	3891.41	3891.57	0.16
SH35	6549382.41	1822740.06	3530.10	3530.14	0.04
SH36	6567744.90	1813024.31	3336.32	3336.41	0.09
SH37	6410025.45	2081428.83	3073.19	3073.51	0.32
SH38	6389402.29	2092743.51	2604.44	2604.46	0.02
SH39	6262192.51	2100614.55	696.79	697.35	0.56
SH52	6508365.98	1965598.30	2348.21	2348.27	0.06
TW01	6554888.17	1812627.34	3410.61	3410.61	0.00
TW02	6511730.77	1934793.88	1734.01	1734.21	0.20
TW03	6452879.48	2013618.49	3525.80	3525.68	-0.12
TW04	6382903.83	2099226.35	2454.31	2454.50	0.19
TW05	6288843.81	2101626.21	1157.85	1157.82	-0.03
TW06	6507330.48	1950102.99	2652.63	2652.59	-0.04
TW07	6473042.70	1996003.21	2634.77	2634.82	0.05
TW08	6233108.15	2106220.49	473.45	473.78	0.33
TW09	6493863.27	1979542.82	2256.38	2256.53	0.15

Number	Easting	Northing	Known Z	Laser Z	Dz
TW10	6401704.93	2083868.70	2813.00	2813.05	0.05
TW11	6596799.96	1840962.32	1832.58	1832.71	0.13
Average Dz		0.160 ft			
Minimum Dz		-0.139 ft			
Maximum Dz		0.689 ft			
Root Mean Square		0.248 ft			
95th Percentile		0.362 ft			

*Point SH29 was removed as it fell outside the AOI.