AIRBORNE TOPOGRAPHIC LIDAR REPORT

FEMA REGION 6 TX – RIO GRANDE AND FORT WHITMAN WATERSHED QL 2 LIDAR

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1. Summary / Scope

1.1. Summary

This report contains a summary of the FEMA Region 6 – TX LiDAR acquisition task order, issued by the USGS National Geospatial Technical Operations Center (NGTOC), under their Geospatial Product and Services Contract (GPSC) on November 17, 2014. The combined task orders yielded one study area covering the Rio Grande and Fort Whitman Watersheds. The intent of this document is to only provide specific validation information for the LiDAR data acquisition/collection work completed for the USGS NGTOC project.

1.2. Scope

The scope of the FEMA Region 6 – TX LiDAR task order included the acquisition of aerial topographic LiDAR using state of the art technology, along with necessary surveyed ground control points (GCPs) and airborne GPS and inertial navigation systems, for the Rio Grande and Fort Whitman Watersheds. The aerial data collection was designed with the following specifications listed in Table 1 below.

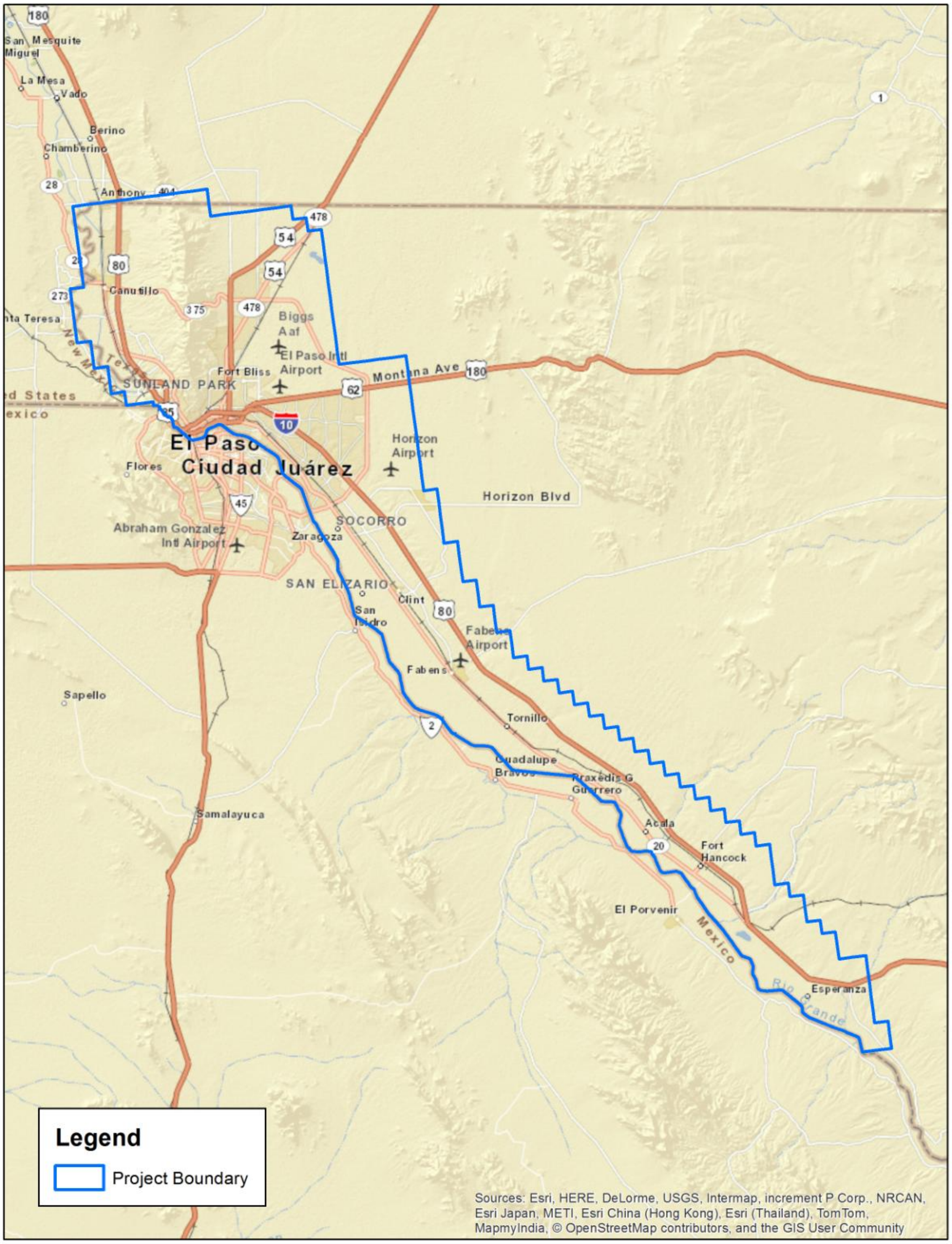
Table 1. Originally Planned LiDAR Specifications

Area	Average Point Density	Flight Altitude (AGL)	Field of View	Minimum Side Overlap	RMSEz
Rio Grande	2.30 pts / m^2	1,784 m	40.0 degrees	12.54%	9.25 cm or better
El Paso High	3.05 pts / m^2	1,292 – 1,784 m	40.0 degrees	10.57%	9.25 cm or better

1.3. Location / Coverage

The FEMA Region 6 – TX LiDAR project boundary consists of an area in Texas. The project area totals approximately 725 square miles as shown in Figure 1 on the following page.

Figure 1. FEMA Region 6 – TX LiDAR Project Boundary



1.4. Duration

The first mission was flown on November 30, 2014 and it took 9 total lifts to complete coverage of the area. See section 2.4 for more details.

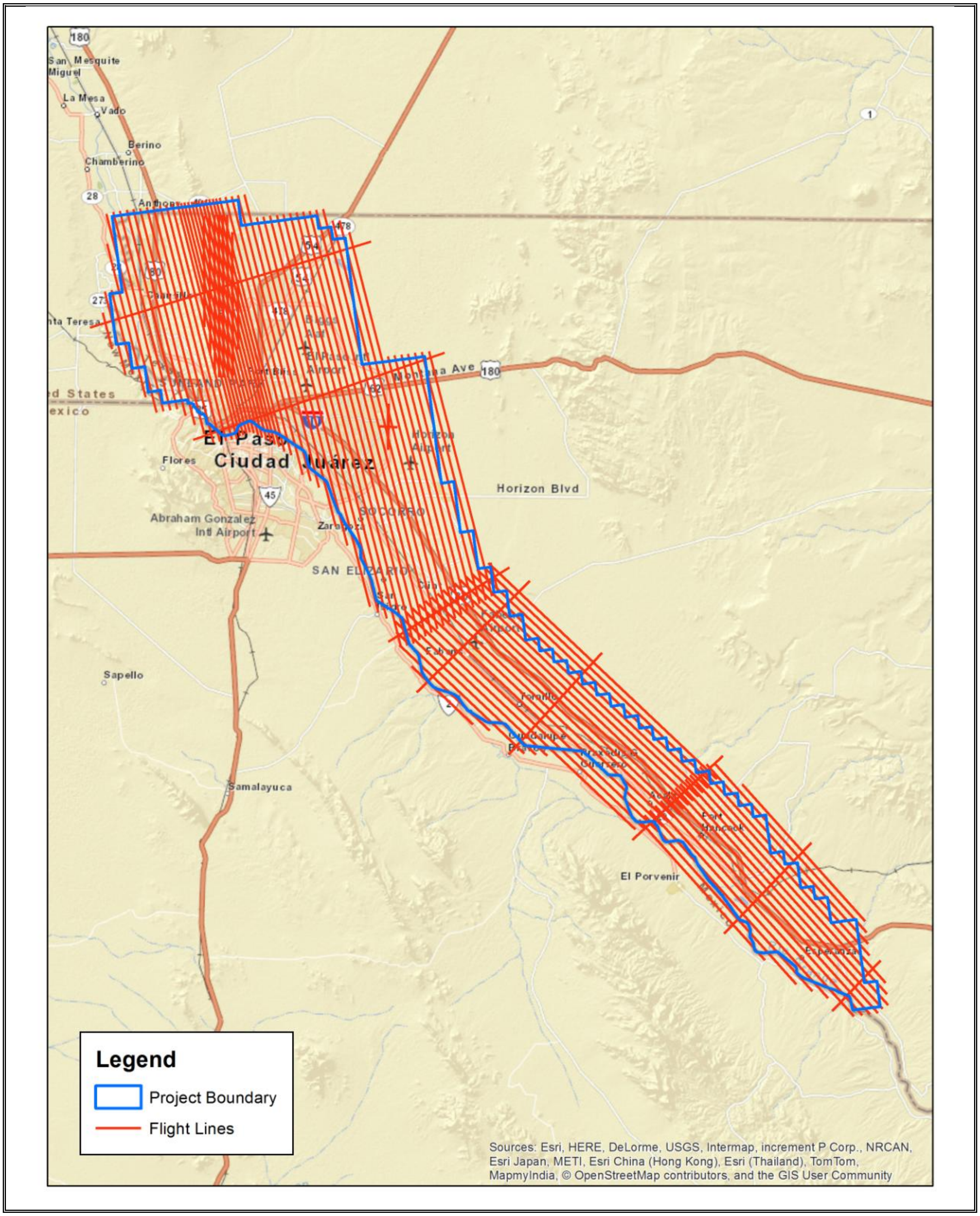
1.5. Issues

Re-flights were required for portions of the mountainous area north of El Paso in order to fill in data gaps from the original lifts. Mexican and military airspace were also complicating factors but were handled successfully.

2. Planning / Equipment

The entire target area was comprised of 109 planned flight lines and approximately 3438.13 flight line kilometers. Please refer to Figure 2 on the following pages.

Figure 2. Originally Planned Flight Lines



Detailed project flight planning calculations were performed for the FEMA Region 6 – TX project using the Leica Mission Pro planning software. 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. A brief summary of the aerial acquisition parameters for the project are shown in the LiDAR System Specification Table 2 below:

Table 2. LiDAR System Specifications for Leica 7170 Rio Grande and Rio Grande – El Paso High

		Rio Grande	El Paso High
Terrain and Aircraft	**Flying Height AGL**	**1784 meters**	**1292 – 1784 meters**
	Recommended Ground Speed (GS)	**150kts**	**150kts**
Scanner	**Field of View (FOV)**	**40°**	**40°**
	Scan Rate Setting used (SR)	**38.6 Hz**	**38.6 Hz**
Laser	**Laser Pulse Rate used**	**306,000 Hz**	**306,000 Hz**
	Multi Pulse in Air Mode	**Enabled**	**Enabled**
Coverage	**Full Swath Width**	**1298.57 meters**	**1298.57 meters**
	Line Spacing	**1161.27 meters**	**882.45**
Point Spacing and Density	**Maximum Point Spacing Across Track**	**1.00 m**	**1.00 m**
	Maximum Point Spacing Along Track	**1.00 m**	**1.00 m**
	Average Point Density	**3.05 pts / m^2**	**3.05 pts / m^2**

2.1. Equipment: Aircraft

All flights for the FEMA Region 6 – TX project were accomplished through the use of a customized twin piston Piper Navajo (Tail Number: N22GE).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 system.

2.2. LiDAR Sensor

Quantum Spatial utilized a Leica LiDAR sensor (see Figure 3), serial number 7170, during the project. The system is capable of collecting data at a maximum frequency of 500 kHz, which affords elevation data collection of up to 500,000 points per second. The system utilizes a Multi-Pulse in the Air option (MPIA). The sensor is also equipped with the ability to measure up to 4 returns per outgoing pulse from the laser and these come in the form of 1st, 2nd, 3rd and last returns. The intensity of the returns is also captured during aerial acquisition.

Figure 3. Leica ALS70 LiDAR System

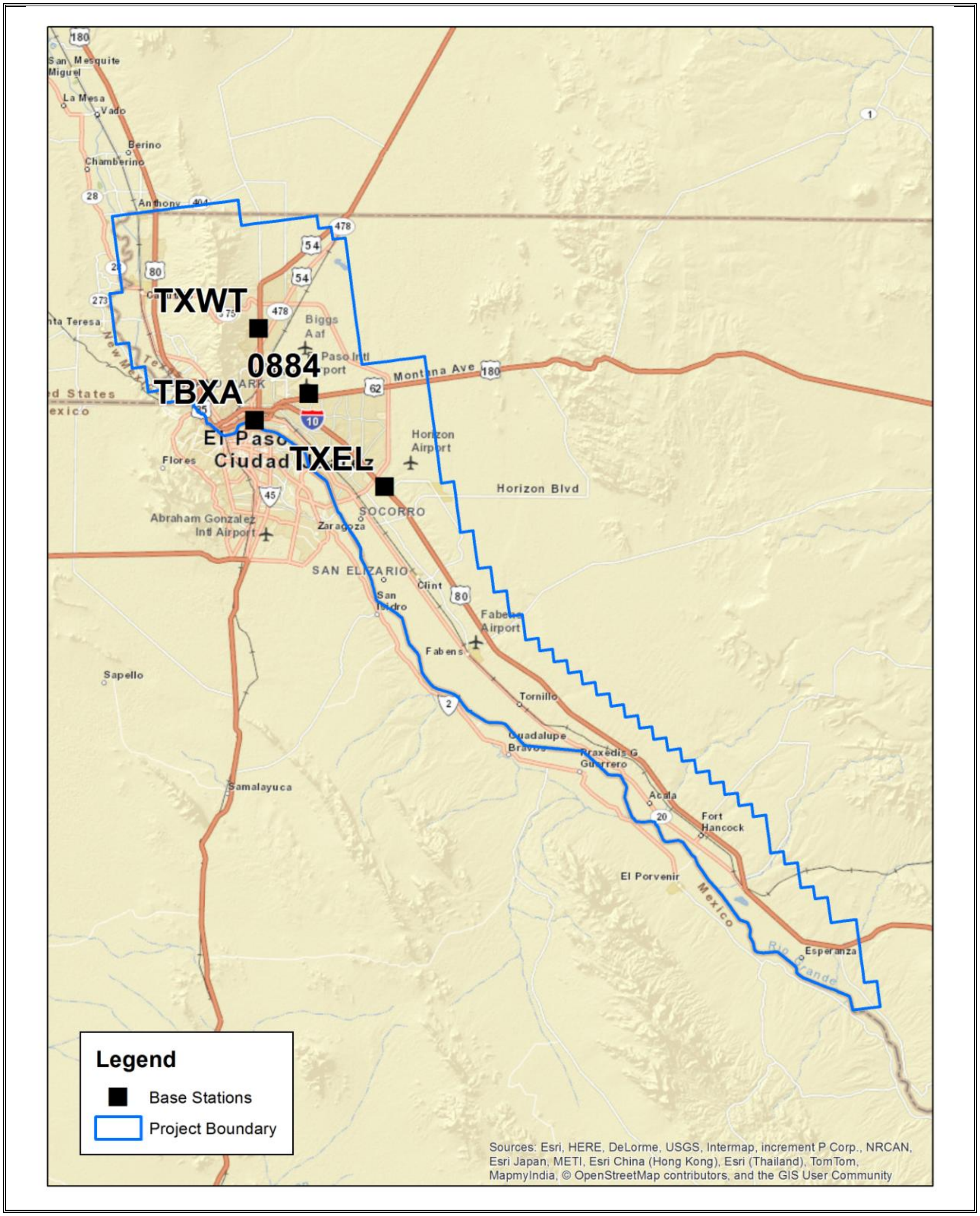
2.3. Base Station Information

GPS base stations were utilized during all phases of flight (see Table 3 below). The base station locations were verified using NGS OPUS service and subsequent surveys. Station locations are depicted in Figure 4. See Appendix A for more detailed information (data sheets, graphical depiction of base station locations, log sheets used during station occupation).

Table 3. Base Station Locations

Base Station	Latitude	Longitude	Ellipsoid Height (m)
0884	31° 47' 48.04158"	-106° 22' 27.13206"	1179.825
TXEL	31° 41' 29.43881"	-106° 16' 17.60354"	1123.060
TXWT	31° 52' 12.39971"	-106° 26' 33.61556"	1194.381
TXBA	31° 45' 56.12527"	-106° 26' 47.13561"	1114.154

Figure 4. FEMA Region 6 – TX Base Station Locations



2.4. Time Period

Project specific flights were conducted over several months. Nine sorties, or aircraft lifts were completed. Accomplished sorties are listed below:

- 113014A_7170
- 120114A_7170
- 120114B_7170
- 120214A_7170
- 120314A_7170
- 120614A_7170
- 120714A_7170
- 120814A_7170
- 121114A_7170

3. Processing Summary

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. 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 Quantum Spatial 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 ALS Post Processor. 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 will manually be reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. Global Mapper will be 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 will then be used to perform final statistical analysis of the classes in the LAS files.

Metadata was generated for the project on a deliverable level.

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. LAS Classification Scheme

The classification classes are determined by the USGS Version 1.0 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 – Noise – Low or high points, manually identified above or 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 – Overlap Default (Unclassified) – Points found in the overlap between flight lines. These points are created through automated processing methods and not cleaned up during processing.
- Class 18 – Overlap Bare-earth ground – Points found in the overlap between flight lines. These points are created through automated processing, matching the specifications determined during the automated process, that are close to the Class 2 dataset (when analyzed using height from ground analysis)
- Class 25 – Overlap Water – Points found in the overlap between flight lines that are located inside hydro features. These points are created through automated processing methods and not cleaned up during processing.

3.3. 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 1 meter 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 classified to Class 17 (Overlap Default), Class 18 (Overlap Ground) and Class 25 (Overlap Water). These classes were created through automated processes only and were not verified for classification accuracy. Due to software limitations within TerraScan, these classes were used to trip the withheld bit within various software packages. These processes were reviewed and accepted by USGS through numerous conference calls and pilot study areas.

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.

3.4. Hydro Flattening Breakline Process

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 30 meter 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 1 meter 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 Shapefile format using ESRI conversion tools.

3.5. Hydro Flattening Raster DEM Process

Class 2 LiDAR in conjunction with the hydro breaklines were used to create a 1 meter 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.

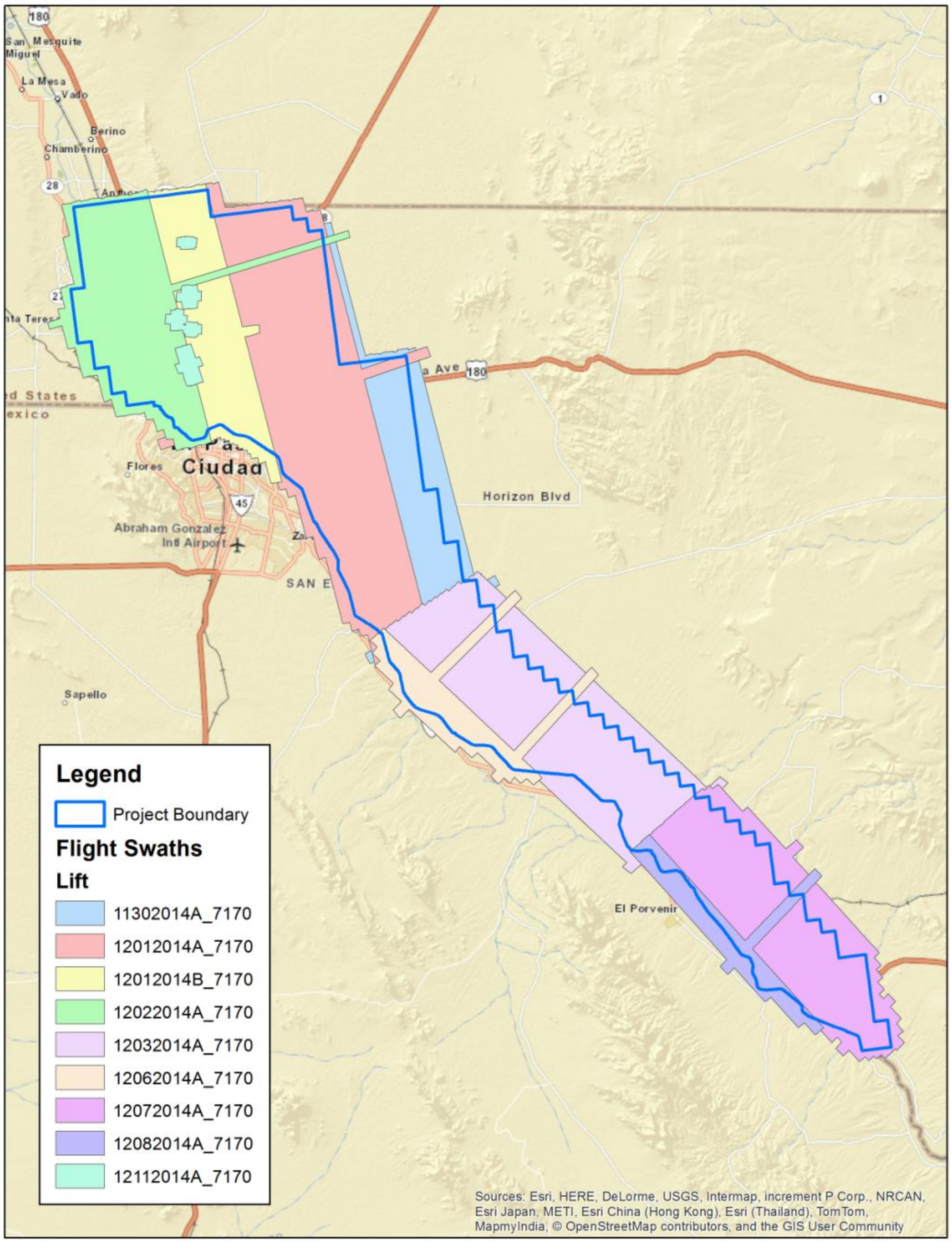
4. Deliverables

- Calibrated, unclassified point cloud swath LAS in version 1.2 format
- Classified point cloud tiled LAS in version 1.2 format
- Hydro flattened raster DEM in ERDAS .IMG format
- Hydro flattened breaklines in shape file format
- Ground control points in shape file format
- Tile index in shape file format
- Project and deliverable level metadata in XML format
- Accuracy Assessment in XLS format
- FOCUS Report
- Delivery Lot Report
- Project Report

5. Project Coverage Verification

The FEMA Region 6 – TX project area 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.

Figure 5. Flightline Swath LAS File Coverage



6. Ground Control and Check Point Collection

Quantum Spatial completed a field survey of 30 ground control (calibration) points along with 80 blind QA points in 5 different land cover classifications (total of 110 points) as an independent test of the accuracy of this project. The land cover classifications were selected from the dominant classifications for this project area. These included:

- Bare Earth
- Brushland, Low trees
- Tall Weeds
- Urban Areas

A combination of precise GPS surveying methods, including static and RTK observations were used to establish the 3D position of ground calibration points and QA points for the point classes above. GPS was not an appropriate methodology for surveying in the forested areas during the leaf-on conditions for the actual field survey (which was accomplished after the LiDAR acquisition). Therefore the 3D positions for the forested points were acquired using a GPS-derived offset point located out in the open near the forested area, and using precise offset surveying techniques to derive the 3D position of the forested point from the open control point. The explicit goal for these surveys was to develop 3D positions that were three times greater than the accuracy requirement for the elevation surface. In this case of the blind QA points the goal was a positional accuracy of 5 cm in terms of the RMSE.

Figure 6 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 shown in Figure 6, 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.

The project was delivered using the following horizontal projection(s): NAD83 (2011), UTM Zone 13, meters; NAVD88 (Geoid 12A), meters. In this document, horizontal coordinates for ground control and QA points for all LiDAR classes are reported in UTM Zone 13, meters.

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 1.0 (2012). The locations for all tested blind QA points are shown in Figure 7. The summary below provides the results of this testing:

Point Cloud Testing

- Raw Fundamental Vertical Accuracy (Raw FVA): The tested Raw FVA for the dataset was found to be 0.029 meters in terms of the RMSEz. The resulting FVA stated as the 95% confidence level (RMSEz x 1.96) is 0.058 meters. This dataset ***meets*** the required FVA of 18.13 cm 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. This is summarized in Table 5.

Digital Elevation Model (DEM) Testing

- Fundamental Vertical Accuracy (FVA): The tested FVA for the dataset captured from the DEM using bi-linear interpolation to derive the DEM elevations was found to be 0.027 meters in terms of the RMSEz. The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 0.053 meters. This dataset ***meets*** the required FVA of 18.13 cm at the 95% confidence level (based on NSSDA). This is summarized in Table 6.

- Supplemental Vertical Accuracy (SVA): The tested SVA accuracies for the dataset for each of the land cover classes other than open ground are summarized below. These results are stated in terms of the 95th percentile error (based on ASPRS guidelines) for each of the land cover classes other than open ground.

  The following land cover classes were tested and the resulting 95th percentile error values are listed below:

  - Brushland, Low Trees: 0.302 meters (Table 7)
  - Tall Weeds: 0.192 meters (Table 8)
  - Urban Areas: 0.066 meters (Table 9)

- Consolidated Vertical Accuracy (CVA): The tested CVA for the dataset captured from the DEM using bi-linear interpolation for all classes (including the bare earth class) was found to be 0.192 meters, which is stated in terms of the 95th percentile error. Therefore the data ***meets*** the required CVA of 36.3 cm. This test was based on the 95th percentile error (based on ASPRS guidelines) across all land cover categories

  This is also summarized in Table 10.

Figure 6. LiDAR Ground Control Points Used in Calibration

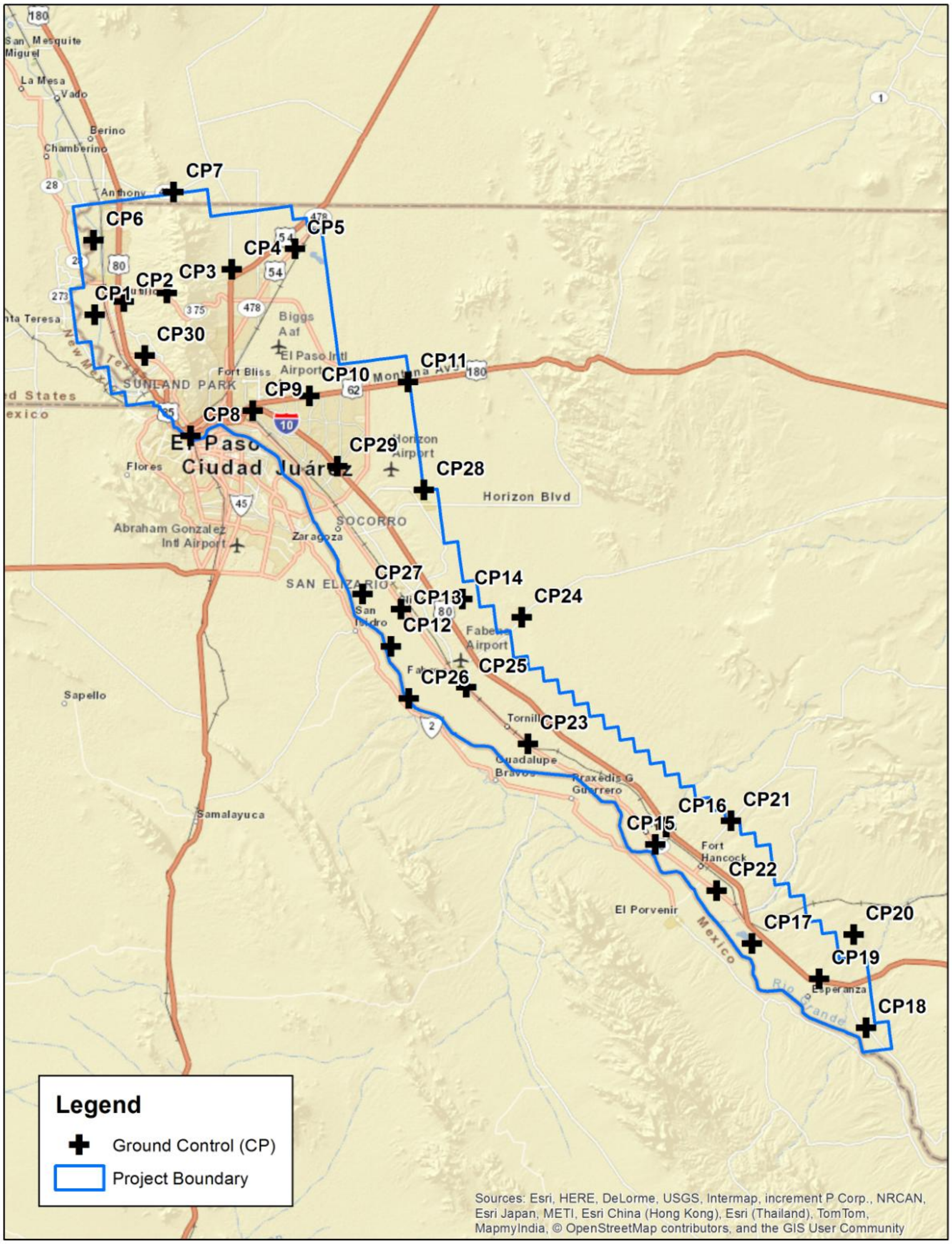


Figure 7. All Final LiDAR QA Point Locations

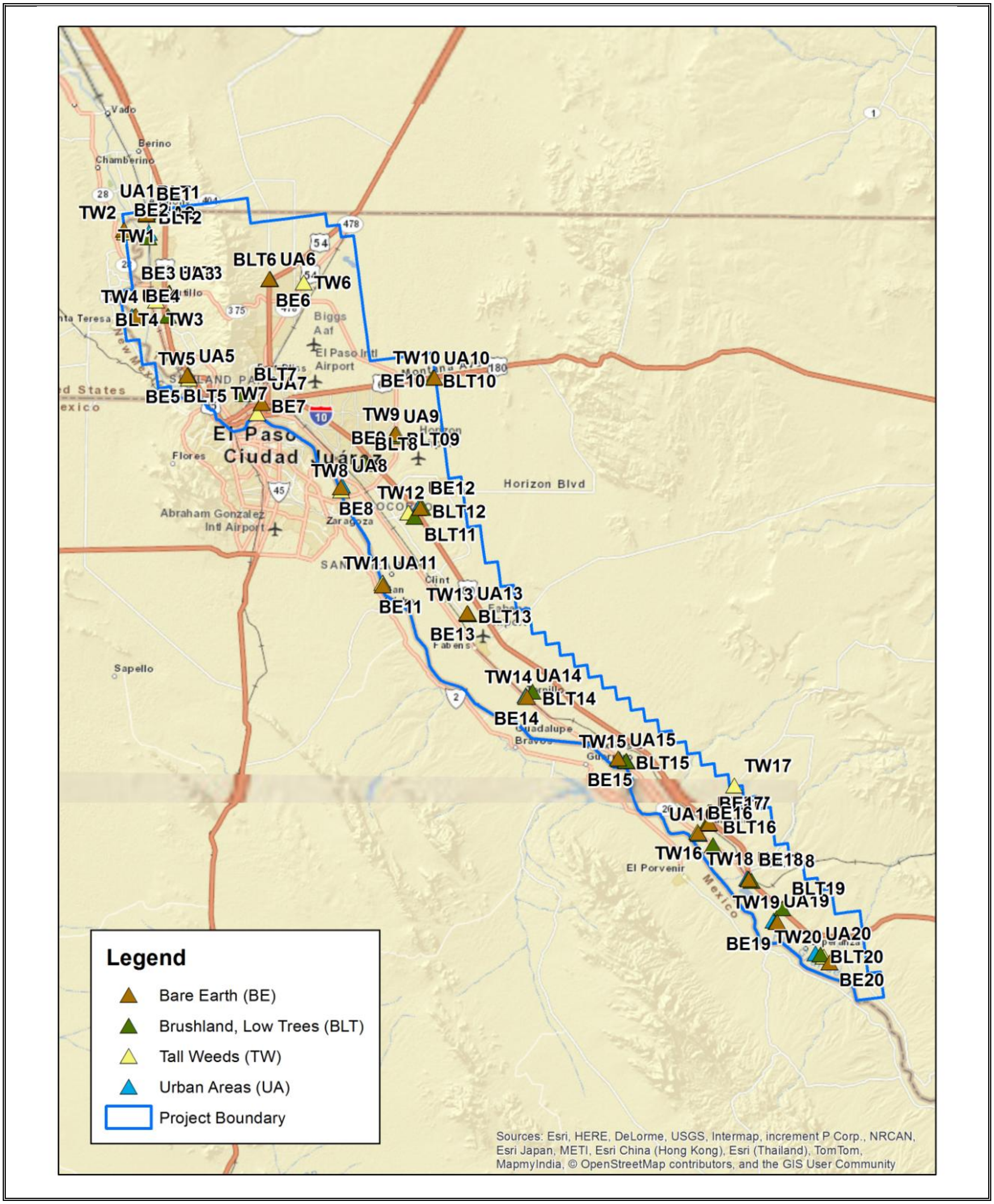


Figure 8. Bare Earth QA Point Locations

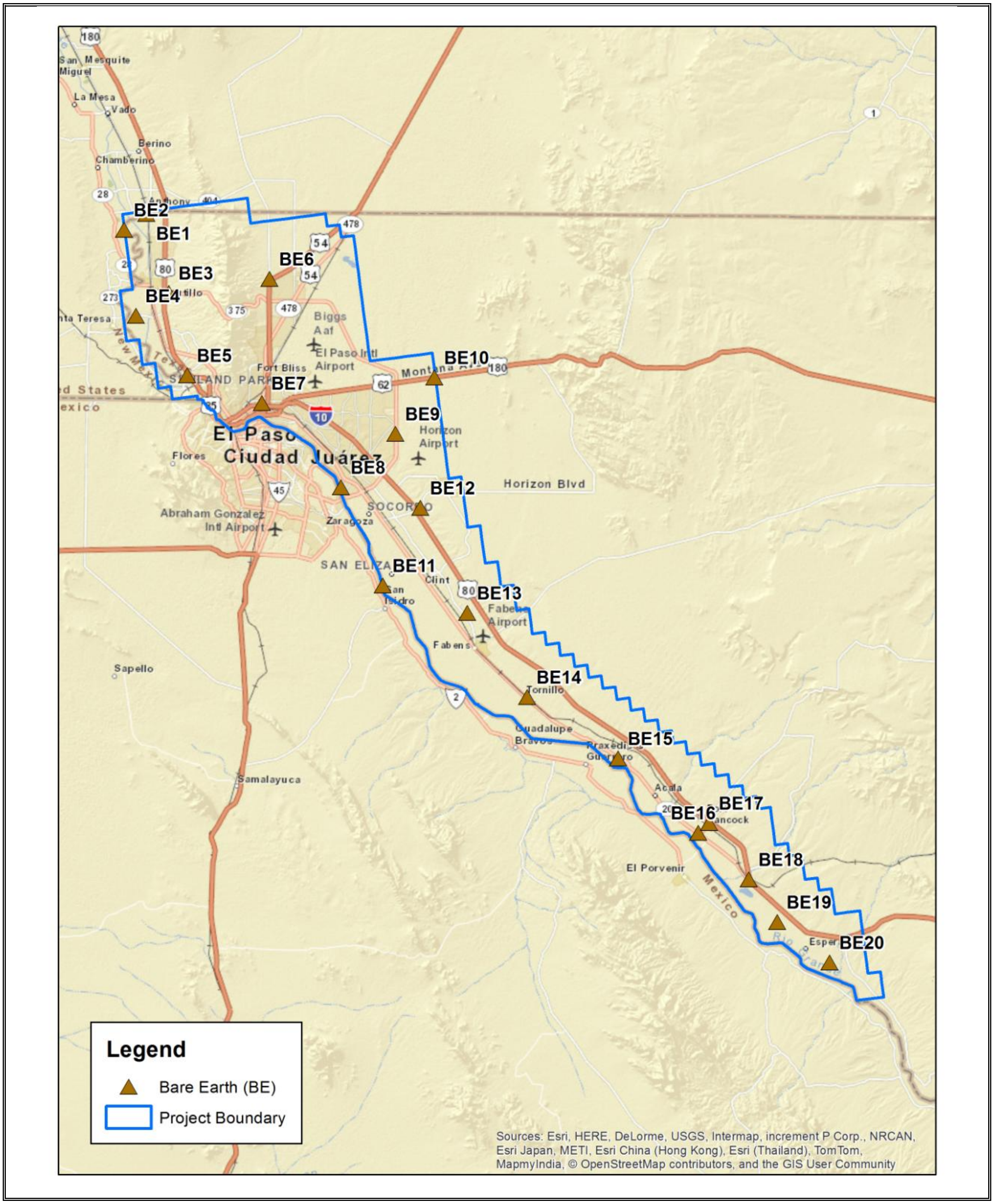


Figure 9. Brushland, Low Trees QA Point Locations

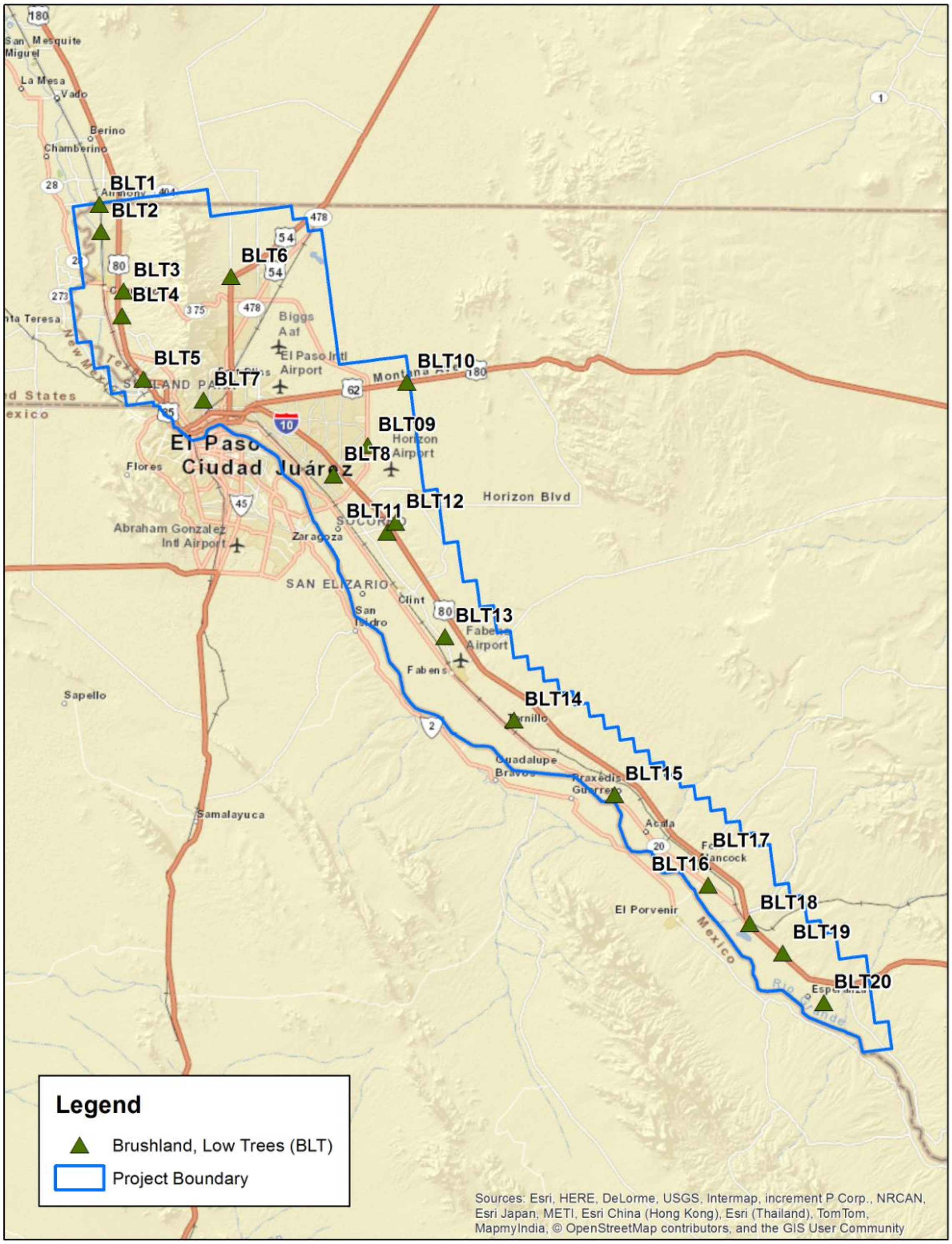


Figure 10. Tall Weeds QA Point Locations

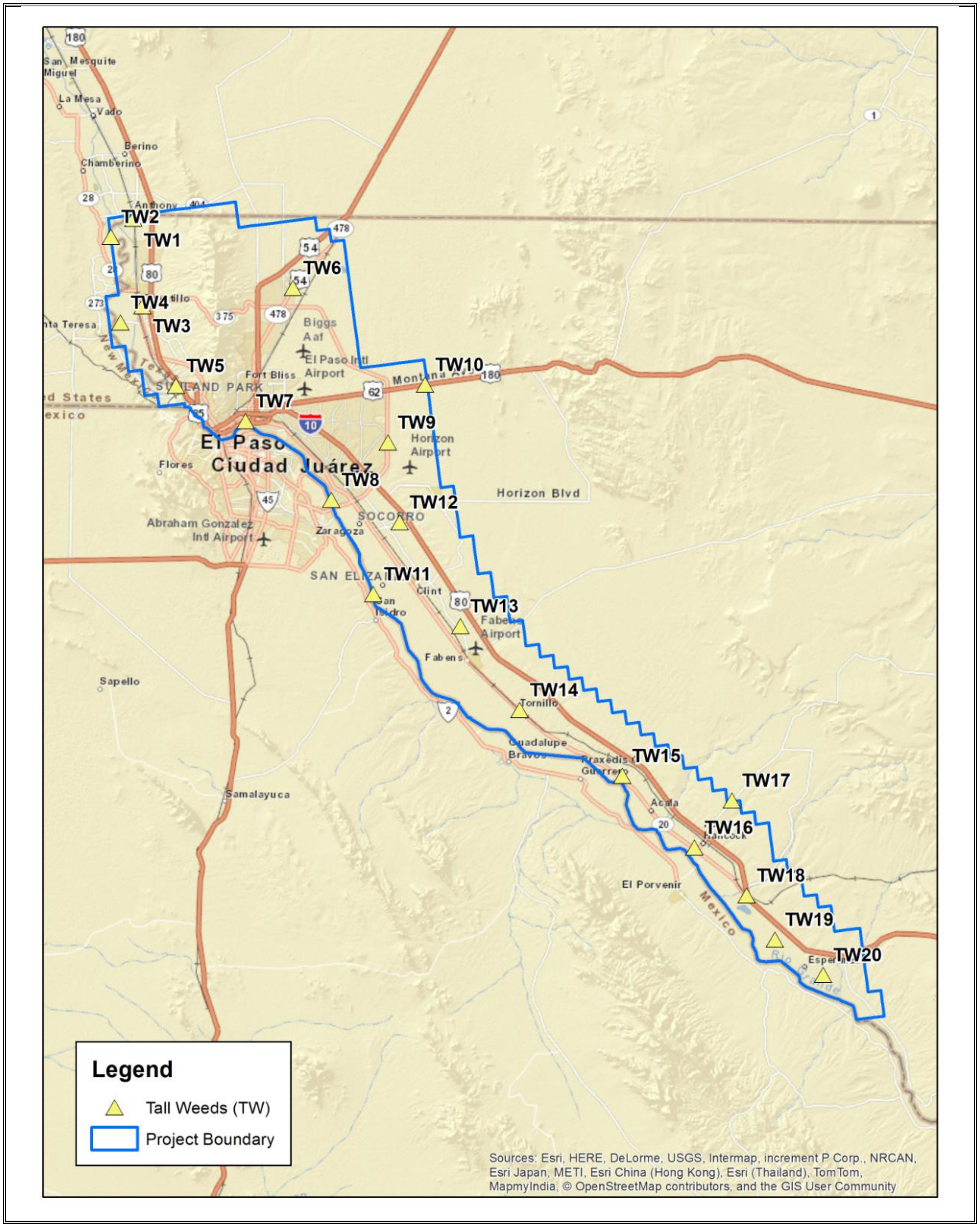


Figure 11. Urban Area QA Point Locations

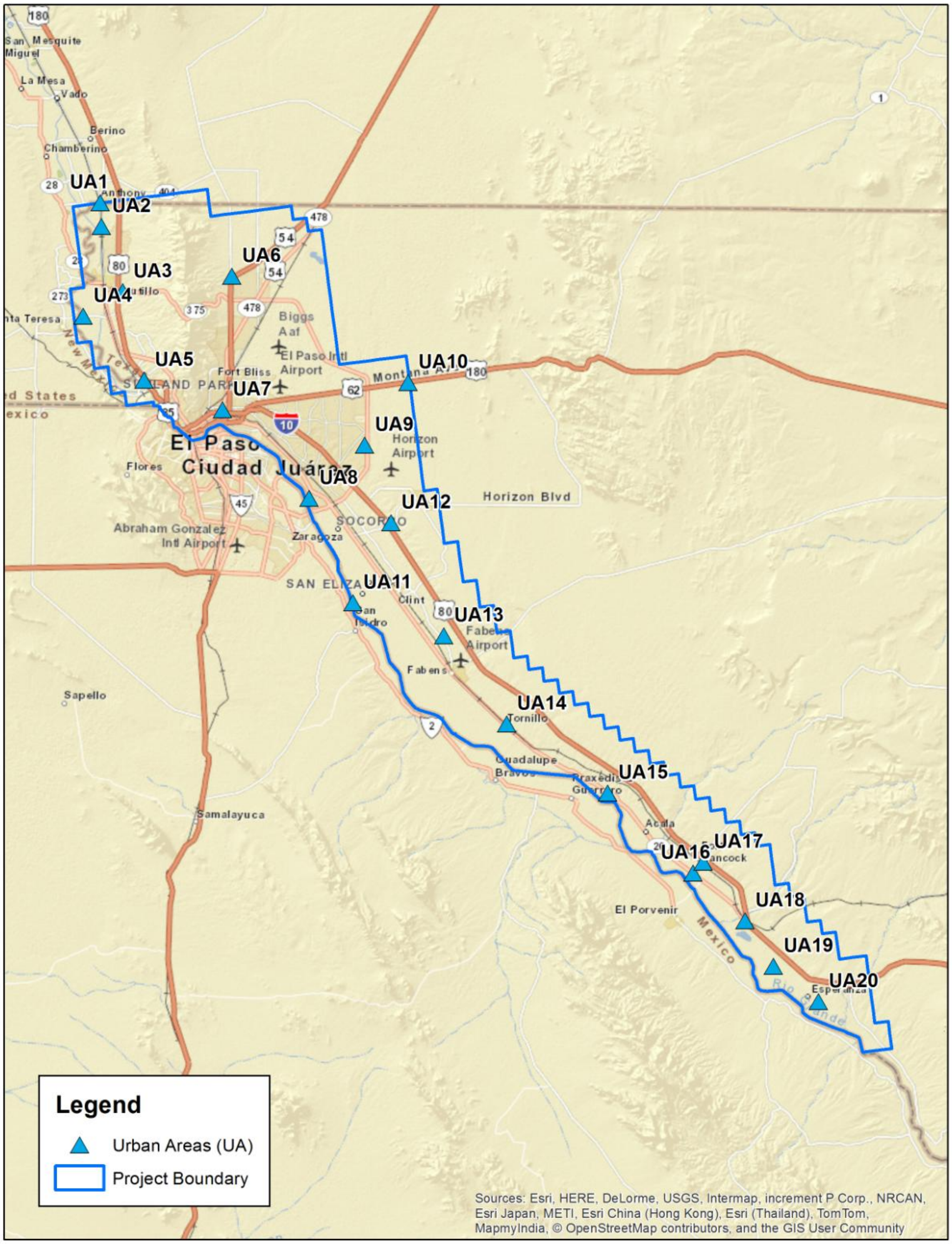


Table 4. LiDAR Ground Control Point Report (Units = Meters)

Number	Easting	Northing	Known Z	Laser Z	Dz
CP1	347623.801	3528278.157	1145.269	1145.28	0.011
CP2	351050.095	3529862.01	1192.049	1192.06	0.011
CP3	356158.252	3530886.192	1442.413	1442.41	-0.003
CP4	363876.759	3533693.576	1249.005	1249	-0.005
CP5	371366.189	3536144.463	1216.903	1216.91	0.007
CP6	347487.625	3537152.354	1151.586	1151.63	0.044
CP7	356981.977	3542869.465	1345.648	1345.63	-0.018
CP8	359008.253	3513939.599	1130.763	1130.77	0.007
CP9	366352.926	3516929.407	1173.991	1174.05	0.059
CP10	373086.157	3518685.628	1207.779	1207.74	-0.039
CP11	384798.608	3520335.874	1224.834	1224.77	-0.064
CP12	382755.378	3488922.632	1104.816	1104.79	-0.026
CP13	383988.095	3493379.17	1106.51	1106.53	0.02
CP14	391257.097	3494554.431	1205.415	1205.42	0.005
CP15	414148.841	3465460.287	1082.851	1082.85	-0.001
CP16	415445.844	3467535.368	1117.941	1117.95	0.009
CP17	425631.314	3453700.514	1069.862	1069.91	0.048
CP18	439159.064	3443698.042	1068.005	1067.99	-0.015
CP19	433611.695	3449500.662	1105.467	1105.45	-0.017
CP20	437702.374	3454740.826	1160.91	1160.92	0.01
CP21	423145.926	3468259.444	1181.093	1181.06	-0.033
CP22	421432.548	3459946.656	1073.302	1073.28	-0.022
CP23	399034.371	3477380.511	1089.911	1089.94	0.029
CP24	398314.128	3492386.26	1188.793	1188.82	0.027
CP25	391728.901	3484089.218	1097.359	1097.36	0.001
CP26	384867.296	3482762.337	1100.243	1100.21	-0.033
CP27	379417.044	3495172.986	1110.257	1110.28	0.023
CP28	386703.952	3507504.26	1227.606	1227.59	-0.016
CP29	376417.127	3510321.072	1150.689	1150.65	-0.039
CP30	353550.314	3523453.122	1221.989	1222	0.011

Average dz	**-0.000 m**
Minimum dz	**-0.064 m**
Maximum dz	**0.059 m**
Root Mean Square	**0.027 m**
Std Deviation	**0.028 m**

Table 5. Raw FVA - Bare Earth QA – Unclassified Points (Units = Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE1	348086.794	3541185.908	1154.474	1154.510	0.036
BE2	345202.229	3539154.364	1154.176	1154.240	0.064
BE3	350943.098	3531128.071	1197.942	1197.970	0.028
BE4	346715.928	3528225.059	1145.059	1145.060	0.001
BE5	353284.902	3520620.556	1149.512	1149.540	0.028
BE6	363791.236	3532911.708	1251.822	1251.830	0.008
BE7	362800.984	3517065.994	1135.974	1136.010	0.036
BE8	372918.926	3506327.322	1118.040	1118.040	0.000
BE9	379865.025	3513134.915	1223.821	1223.850	0.029
BE10	384855.765	3520338.263	1225.272	1225.270	-0.002
BE11	378247.416	3493794.221	1107.941	1107.910	-0.031
BE12	383067.835	3503702.124	1161.350	1161.340	-0.010
BE13	389051.049	3490293.838	1112.433	1112.450	0.017
BE14	396670.844	3479536.673	1094.101	1094.090	-0.011
BE15	408302.608	3471731.405	1083.246	1083.250	0.004
BE16	418505.671	3462196.972	1074.665	1074.720	0.055
BE17	419925.519	3463464.184	1102.944	1102.920	-0.024
BE18	424972.143	3456262.662	1084.231	1084.200	-0.031
BE19	428604.963	3450813.472	1065.023	1065.000	-0.023
BE20	435296.953	3445685.643	1067.890	1067.850	-0.040

Average dz	**0.01 m**
Minimum dz	**-0.040 m**
Maximum dz	**0.064 m**
Root Mean Square	**0.029 m**
95% Confidence	**0.058 m**

Table 6. FVA - Bare Earth QA – Derived DEMs Classified (Units = Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE1	348086.794	3541185.908	1154.474	1154.491	0.017
BE2	345202.229	3539154.364	1154.176	1154.234	0.058
BE3	350943.098	3531128.071	1197.942	1197.985	0.043
BE4	346715.928	3528225.059	1145.059	1145.062	0.003
BE5	353284.902	3520620.556	1149.512	1149.540	0.028
BE6	363791.236	3532911.708	1251.822	1251.835	0.013
BE7	362800.984	3517065.994	1135.974	1136.006	0.032
BE8	372918.926	3506327.322	1118.040	1118.053	0.013
BE9	379865.025	3513134.915	1223.821	1223.847	0.026
BE10	384855.765	3520338.263	1225.272	1225.262	-0.010
BE11	378247.416	3493794.221	1107.941	1107.952	0.011
BE12	383067.835	3503702.124	1161.350	1161.370	0.020
BE13	389051.049	3490293.838	1112.433	1112.464	0.031
BE14	396670.844	3479536.673	1094.101	1094.097	-0.004
BE15	408302.608	3471731.405	1083.246	1083.246	0.000
BE16	418505.671	3462196.972	1074.665	1074.693	0.028
BE17	419925.519	3463464.184	1102.944	1102.918	-0.026
BE18	424972.143	3456262.662	1084.231	1084.202	-0.029
BE19	428604.963	3450813.472	1065.023	1065.003	-0.020
BE20	435296.953	3445685.643	1067.890	1067.845	-0.045

Average dz	**0.01 m**
Minimum dz	**-0.045 m**
Maximum dz	**0.058 m**
Root Mean Square	**0.027 m**
95% Confidence	**0.053 m**

Table 7. SVA Brushland, Low Trees QA – Derived DEMs (Units = Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BLT1	348179.542	3541427.918	1155.536	1155.709	0.173
BLT2	348355.156	3538194.829	1151.925	1152.348	0.422
BLT3	351005.762	3531161.539	1199.636	1199.688	0.052
BLT4	350849.329	3528186.781	1196.189	1196.327	0.138
BLT5	353392.228	3520697.400	1152.953	1153.165	0.212
BLT6	363767.720	3532839.943	1250.889	1250.990	0.101
BLT7	360524.302	3518182.871	1234.654	1234.764	0.110
BLT8	375966.435	3509329.674	1132.259	1132.555	0.296
BLT09	380022.786	3512828.721	1222.720	1222.715	-0.005
BLT10	384669.370	3520310.348	1224.162	1224.328	0.166
BLT11	382287.393	3502534.672	1132.267	1132.340	0.073
BLT12	383317.957	3503677.080	1166.690	1166.753	0.063
BLT13	389192.294	3490143.251	1110.973	1111.085	0.112
BLT14	397368.077	3480211.750	1110.243	1110.290	0.047
BLT15	409303.638	3471381.268	1083.870	1083.890	0.020
BLT16	420415.381	3460649.243	1076.783	1076.867	0.084
BLT17	419694.901	3463441.736	1099.676	1099.698	0.022
BLT18	425349.917	3456068.092	1081.789	1081.803	0.014
BLT19	429245.074	3452592.921	1075.064	1075.147	0.083
BLT20	434134.633	3446687.886	1066.872	1066.981	0.109

Average dz	**0.11 m**
Minimum dz	**-0.005 m**
Maximum dz	**0.422 m**
Root Mean Square	**0.152 m**
95th Percentile	**0.302 m**

Table 8. SVA Tall Weeds QA – Derived DEMs (Units = Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
TW1	348166.284	3541124.549	1154.322	1154.528	0.206
TW2	345358.346	3538859.706	1153.615	1153.753	0.138
TW3	349303.446	3530160.638	1150.143	1150.208	0.065
TW4	346559.001	3528106.352	1144.518	1144.591	0.073
TW5	353522.045	3520175.195	1138.626	1138.708	0.082
TW6	368179.204	3532438.276	1194.787	1194.850	0.063
TW7	362239.164	3515777.325	1127.130	1127.197	0.067
TW8	372971.067	3505911.295	1117.715	1117.906	0.191
TW9	380029.322	3513070.838	1223.819	1223.858	0.039
TW10	384715.428	3520315.079	1224.445	1224.479	0.034
TW11	378215.828	3494124.240	1108.851	1109.032	0.181
TW12	381505.055	3503069.929	1123.655	1123.710	0.055
TW13	389107.746	3490095.096	1108.717	1108.770	0.053
TW14	396565.730	3479592.221	1093.192	1093.330	0.138
TW15	409386.751	3471339.545	1083.270	1083.391	0.121
TW16	418440.016	3462350.437	1074.926	1075.049	0.123
TW17	423120.416	3468262.167	1180.942	1180.951	0.009
TW18	424978.570	3456372.659	1085.395	1085.396	0.001
TW19	428539.531	3450842.017	1064.993	1065.009	0.016
TW20	434569.085	3446393.194	1067.320	1067.278	-0.042

Average dz	**0.08 m**
Minimum dz	**-0.042 m**
Maximum dz	**0.206 m**
Root Mean Square	**0.152 m**
95th Percentile	**0.192 m**

Table 9. SVA Urban Areas QA Points – Derived DEMs (Units – Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
UA1	348276.156	3541595.878	1158.669	1158.674	0.005
UA2	348411.543	3538781.420	1154.232	1154.285	0.052
UA3	350944.814	3531076.526	1197.561	1197.696	0.135
UA4	346231.583	3528150.495	1146.786	1146.787	0.001
UA5	353483.740	3520552.407	1155.154	1155.180	0.026
UA6	363873.488	3532882.464	1249.012	1249.005	-0.006
UA7	362767.421	3517045.269	1135.898	1135.883	-0.015
UA8	373050.142	3506525.886	1118.284	1118.259	-0.025
UA9	379623.587	3512853.073	1220.598	1220.622	0.024
UA10	384798.740	3520278.257	1224.939	1224.894	-0.045
UA11	378268.311	3494161.148	1109.126	1109.096	-0.030
UA12	382770.365	3503644.460	1155.596	1155.659	0.063
UA13	389042.530	3490225.941	1111.561	1111.544	-0.017
UA14	396481.539	3479785.446	1095.089	1095.104	0.015
UA15	408503.287	3471562.793	1084.062	1084.120	0.058
UA16	418638.464	3462068.908	1075.594	1075.600	0.006
UA17	419838.159	3463360.240	1101.007	1100.985	-0.022
UA18	424787.984	3456410.530	1086.349	1086.355	0.006
UA19	428171.570	3451038.422	1065.787	1065.783	-0.004
UA20	433502.071	3446846.076	1062.660	1062.625	-0.035

Average dz	**0.01 m**
Minimum dz	**-0.045 m**
Maximum dz	**0.135 m**
Root Mean Square	**0.042 m**
95th Percentile	**0.066 m**

Table 10. CVA for the 4 Classified Land Cover Classes (Units = Meters)

Number	Easting	Northing	Known Z	LiDAR Z	Dz
BE1	348086.794	3541185.908	1154.474	1154.491	0.017
BE2	345202.229	3539154.364	1154.176	1154.234	0.058
BE3	350943.098	3531128.071	1197.942	1197.985	0.043
BE4	346715.928	3528225.059	1145.059	1145.062	0.003
BE5	353284.902	3520620.556	1149.512	1149.540	0.028
BE6	363791.236	3532911.708	1251.822	1251.835	0.013
BE7	362800.984	3517065.994	1135.974	1136.006	0.032
BE8	372918.926	3506327.322	1118.040	1118.053	0.013
BE9	379865.025	3513134.915	1223.821	1223.847	0.026
BE10	384855.765	3520338.263	1225.272	1225.262	-0.010
BE11	378247.416	3493794.221	1107.941	1107.952	0.011
BE12	383067.835	3503702.124	1161.350	1161.370	0.020
BE13	389051.049	3490293.838	1112.433	1112.464	0.031
BE14	396670.844	3479536.673	1094.101	1094.097	-0.004
BE15	408302.608	3471731.405	1083.246	1083.246	0.000
BE16	418505.671	3462196.972	1074.665	1074.693	0.028
BE17	419925.519	3463464.184	1102.944	1102.918	-0.026
BE18	424972.143	3456262.662	1084.231	1084.202	-0.029
BE19	428604.963	3450813.472	1065.023	1065.003	-0.020
BE20	435296.953	3445685.643	1067.890	1067.845	-0.045
BLT1	348179.542	3541427.918	1155.536	1155.709	0.173
BLT2	348355.156	3538194.829	1151.925	1152.348	0.422
BLT3	351005.762	3531161.539	1199.636	1199.688	0.052
BLT4	350849.329	3528186.781	1196.189	1196.327	0.138
BLT5	353392.228	3520697.400	1152.953	1153.165	0.212
BLT6	363767.720	3532839.943	1250.889	1250.990	0.101
BLT7	360524.302	3518182.871	1234.654	1234.764	0.110
BLT8	375966.435	3509329.674	1132.259	1132.555	0.296
BLT09	380022.786	3512828.721	1222.720	1222.715	-0.005
BLT10	384669.370	3520310.348	1224.162	1224.328	0.166
BLT11	382287.393	3502534.672	1132.267	1132.340	0.073
BLT12	383317.957	3503677.080	1166.690	1166.753	0.063
BLT13	389192.294	3490143.251	1110.973	1111.085	0.112
BLT14	397368.077	3480211.750	1110.243	1110.290	0.047
BLT15	409303.638	3471381.268	1083.870	1083.890	0.020
BLT16	420415.381	3460649.243	1076.783	1076.867	0.084
BLT17	419694.901	3463441.736	1099.676	1099.698	0.022
BLT18	425349.917	3456068.092	1081.789	1081.803	0.014
BLT19	429245.074	3452592.921	1075.064	1075.147	0.083
BLT20	434134.633	3446687.886	1066.872	1066.981	0.109
TW1	348166.284	3541124.549	1154.322	1154.528	0.206
TW2	345358.346	3538859.706	1153.615	1153.753	0.138
TW3	349303.446	3530160.638	1150.143	1150.208	0.065
TW4	346559.001	3528106.352	1144.518	1144.591	0.073
TW5	353522.045	3520175.195	1138.626	1138.708	0.082
TW6	368179.204	3532438.276	1194.787	1194.850	0.063
TW7	362239.164	3515777.325	1127.130	1127.197	0.067
TW8	372971.067	3505911.295	1117.715	1117.906	0.191

Number	Easting	Northing	Known Z	LiDAR Z	Dz
TW9	380029.322	3513070.838	1223.819	1223.858	0.039
TW10	384715.428	3520315.079	1224.445	1224.479	0.034
TW11	378215.828	3494124.240	1108.851	1109.032	0.181
TW12	381505.055	3503069.929	1123.655	1123.710	0.055
TW13	389107.746	3490095.096	1108.717	1108.770	0.053
TW14	396565.730	3479592.221	1093.192	1093.330	0.138
TW15	409386.751	3471339.545	1083.270	1083.391	0.121
TW16	418440.016	3462350.437	1074.926	1075.049	0.123
TW17	423120.416	3468262.167	1180.942	1180.951	0.009
TW18	424978.570	3456372.659	1085.395	1085.396	0.001
TW19	428539.531	3450842.017	1064.993	1065.009	0.016
TW20	434569.085	3446393.194	1067.320	1067.278	-0.042
UA1	348276.156	3541595.878	1158.669	1158.674	0.005
UA2	348411.543	3538781.420	1154.232	1154.285	0.052
UA3	350944.814	3531076.526	1197.561	1197.696	0.135
UA4	346231.583	3528150.495	1146.786	1146.787	0.001
UA5	353483.740	3520552.407	1155.154	1155.180	0.026
UA6	363873.488	3532882.464	1249.012	1249.005	-0.006
UA7	362767.421	3517045.269	1135.898	1135.883	-0.015
UA8	373050.142	3506525.886	1118.284	1118.259	-0.025
UA9	379623.587	3512853.073	1220.598	1220.622	0.024
UA10	384798.740	3520278.257	1224.939	1224.894	-0.045
UA11	378268.311	3494161.148	1109.126	1109.096	-0.030
UA12	382770.365	3503644.460	1155.596	1155.659	0.063
UA13	389042.530	3490225.941	1111.561	1111.544	-0.017
UA14	396481.539	3479785.446	1095.089	1095.104	0.015
UA15	408503.287	3471562.793	1084.062	1084.120	0.058
UA16	418638.464	3462068.908	1075.594	1075.600	0.006
UA17	419838.159	3463360.240	1101.007	1100.985	-0.022
UA18	424787.984	3456410.530	1086.349	1086.355	0.006
UA19	428171.570	3451038.422	1065.787	1065.783	-0.004
UA20	433502.071	3446846.076	1062.660	1062.625	-0.035

Average dz	**0.05 m**
Minimum dz	**-0.045 m**
Maximum dz	**0.422 m**
Root Mean Square	**0.095 m**
95th Percentile	**0.192 m**