LiDAR MAPPING REPORT

AZ MOHAVE 3DEP – QL1 AERIAL SURVEY

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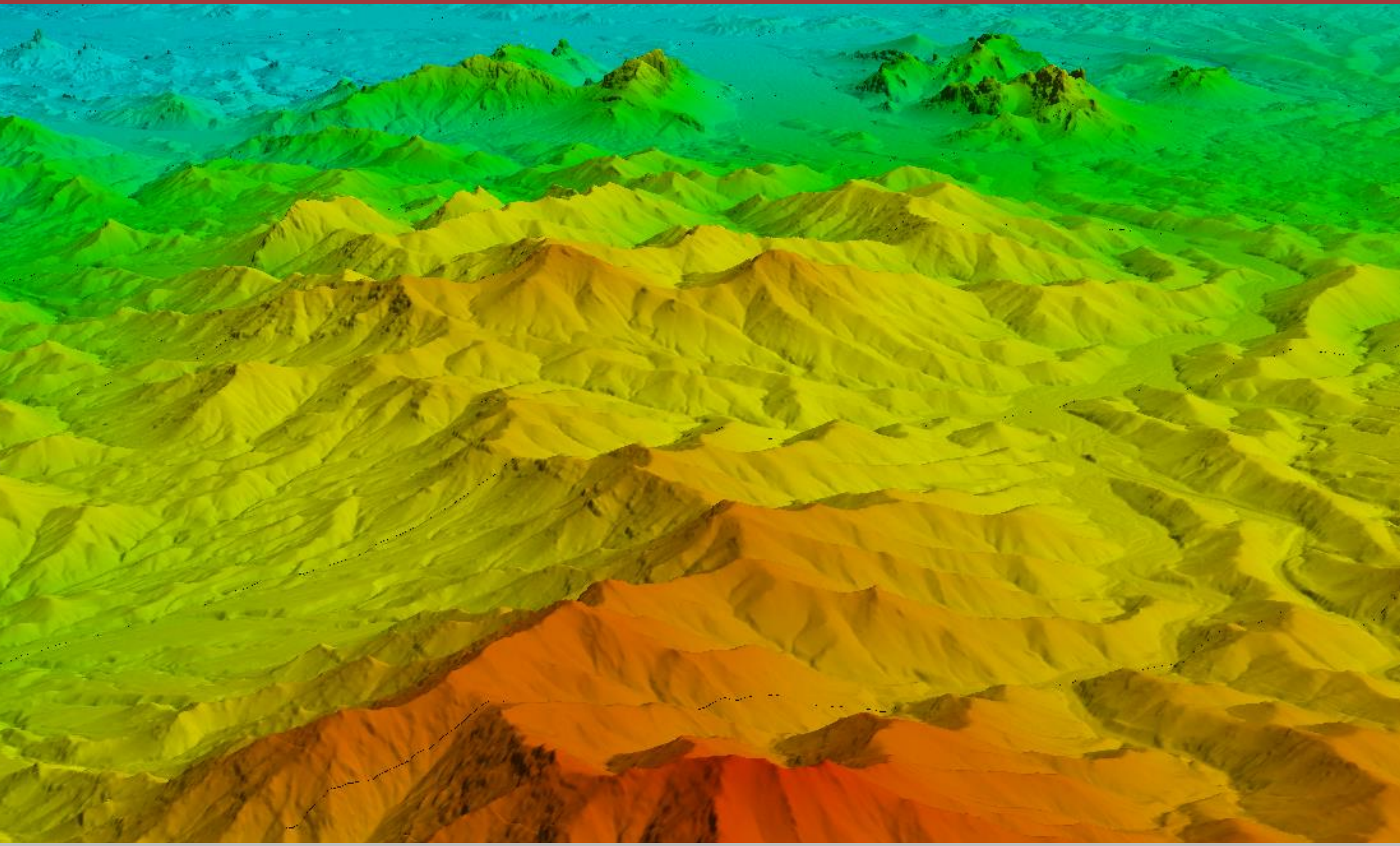

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LiDAR Mapping Report
AZ Mohave 3DEP - QL1 Aerial Survey

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1. OVERVIEW

1.1 PROJECT AREA

Aero-Graphics, Inc., a full-service geospatial firm located in Salt Lake City, Utah, was contracted by the U.S. Geological Survey (USGS) and partners to acquire, process, and deliver aerial lidar data and derivative products that adhere to U.S. Geological Survey (USGS) National Geospatial Program (NGP) Lidar Base Specification 2023, Revision A, QL1 standards. The project area covered both UTM 11 and UTM 12. The assigned project area covers approximately 674 square miles in Mohave County, Arizona. The area of the UTM 11 boundary is approximately 486 square miles. The area of the UTM 12 boundary is approximately 188 square miles. Lidar data was delivered as processed Classified LAS 1.4 files, formatted to 1,953 (1,372 tile for UTM 11 and 581 tiles for UTM 12) individual 1000 m x 1000 m tiles, as tiled Intensity Imagery and DSMs, and as tiled Bare-Earth Hydro Flattened DEMs.

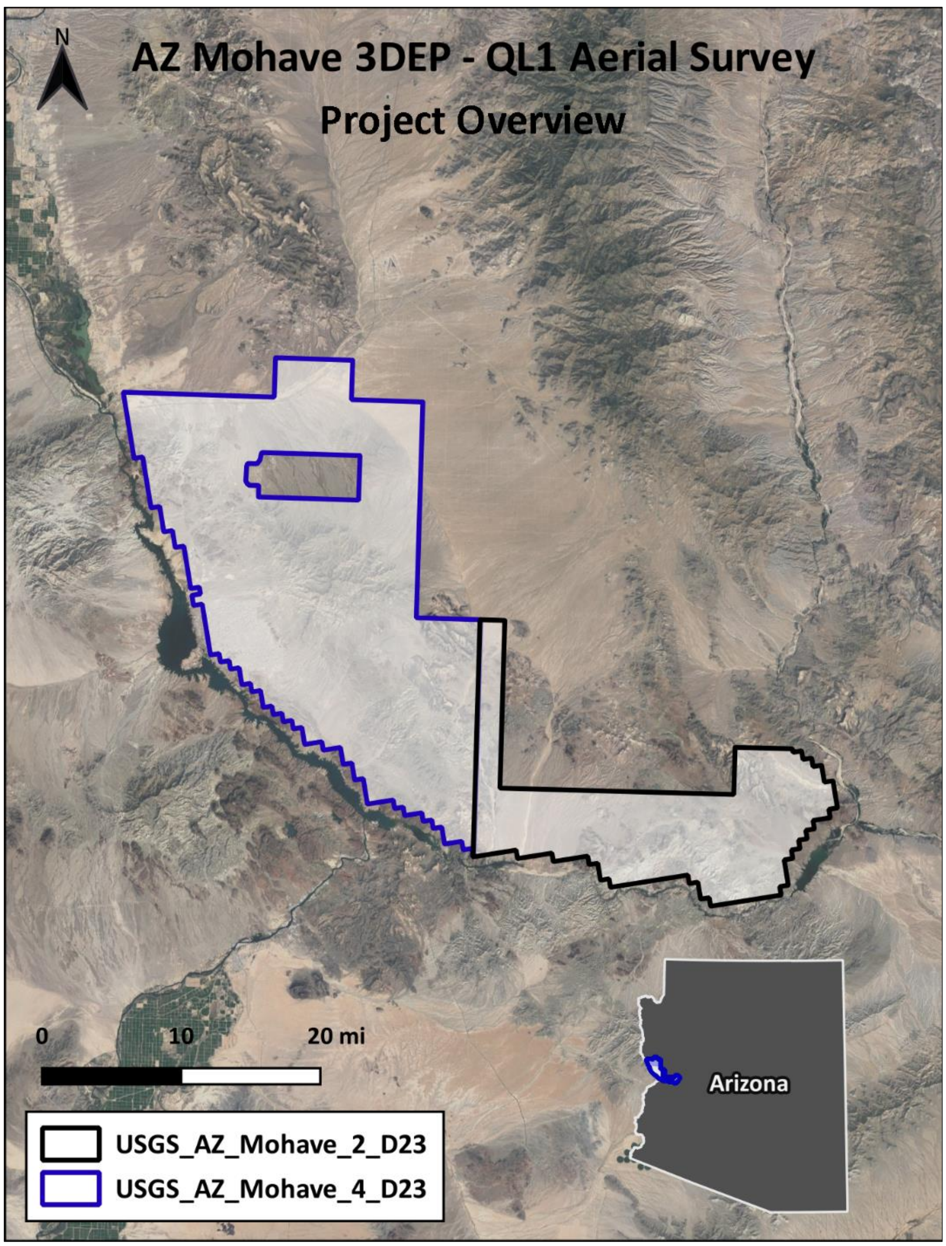
1.2 PROJECT DELIVERABLES

LiDAR Data	▪ Classified point cloud data in LAS v1.4 format
Raster Data	▪ Bare-earth DEM, Digital Surface Model (DSM), Maximum surface height rasters (MSHR), and intensity imagery in GeoTIFF format ▪ Swath separation images in GeoTIFF format
Vector Data	▪ Breaklines in SHP format ▪ Flight index, tile index, low confidence polygons and AOI in SHP format ▪ Surveyed GCPs and checkpoints in .gpkg format
Report of Survey	▪ Reports and metadata as described in TO

1.3 Projection, Datum, Units

Projection		UTM Zone 11/12
EPSG		6340/6341
Datum	Vertical	NAVD88 (GEOID18)
	Horizontal	NAD83 (2011)
Units		Meters

Exhibit 1: AZ Mohave 3DEP - QL1 project boundary



2. Acquisition

2.1 Flight Planning

Aero-Graphics Aerial Department created a unique flight plan for this project using Optech's Airborne Mission Manager (AMM) flight planning software. AMM simulates flight plans based on the project area's terrain, as well as the sensor's model, mount, and settings. These features helped ensure that all contract specifications are met in the most efficient way possible. Prior to mobilizing to the acquisition sites, Aero-Graphics' staff monitored all site conditions and potential weather hazards including wind, rain, snow, and blowing dust. Additionally, Aero-Graphics ensured all airspace clearances were secured by the proper officials before acquisition occurred. A summary of the flight parameters and sensor settings for the AZ Mohave 3DEP - QL1 Aerial Survey are outlined in **Exhibit 2**.

Exhibit 2: Summary of planned flight parameters and sensor settings

Planned Specifications		
Aircraft		Cessna 310
Altitude (ft above ground level)		7,600
Speed (kts)		145
LiDAR Sensor		Optech Galaxy T2000
PRF (kHz)		900
Scan frequency (Hz)		90
Laser power		High (Boost)
Scan Angle	Full	42°
	From nadir	± 21°
Planned Average Point Density (p/m²)		10.88
Post Spacing at Nadir	Cross Track (m)	0.30
	Down Track (m)	0.30
Swath Width (m)		1,761
Sidelap (%)		55
No. of Flightlines		72

2.2 Data Acquisition

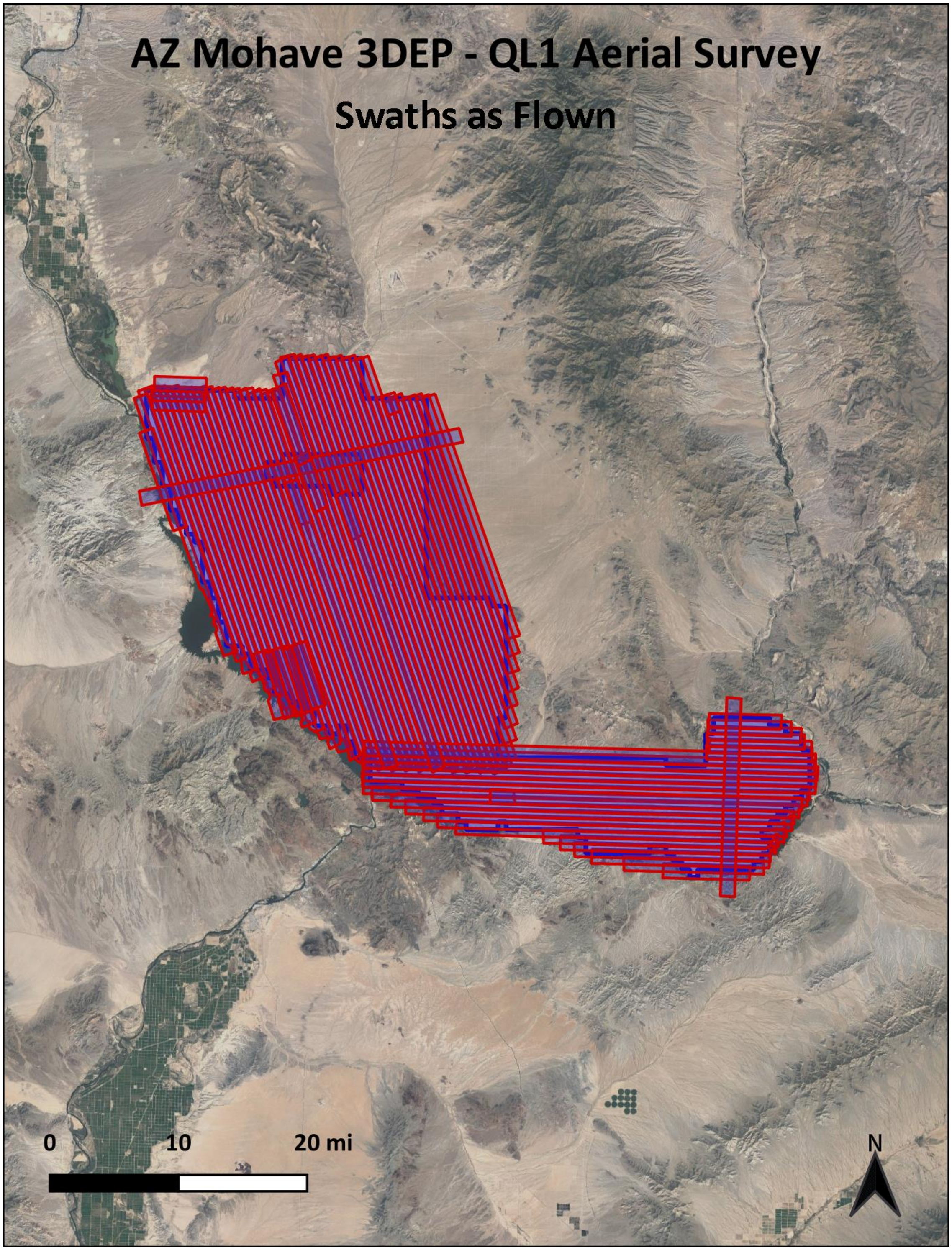
Aero-Graphics acquired LiDAR data from March to April of 2023 with a turbocharged Cessna 310 (**Exhibit 3**). The stability of this platform is ideal for efficient data collection at high and low altitudes and at a variety of airspeeds. Additionally, our Cessna 310 has been customized to house a variety of airborne sensors, and the power system and avionics have been upgraded specifically to meet aerial survey needs.

<u>Exhibit 3</u>: A Cessna 310 was the acquisition platform for this project

The Optech Galaxy T2000 was selected for this project on account of its high accuracy and efficiency (**Exhibit 4**). This sensor uses SwathTrak technology, which dynamically adjusts the scan field of view in real time to maintain a more consistent swath width over a variety of terrains. It also features up to 8 returns per pulse, which increases the vertical resolution of complex terrains. The sensor is complemented with the use of FMS Nav, which allowed the system operator to monitor the point density and swath attributes of this project in real time, ensuring quality data and full coverage, as shown in **Exhibit 5**. More information about point density can be found in Section 4.4.

<u>Exhibit 4:</u> The Optech Galaxy T2000 was used for data acquisition

Exhibit 5: **Swath data for the AZ Mohave 3DEP - QL1 project was recorded and viewed in real-time by the sensor operator.**



2.3 ACQUISITION SUMMARY

Aero-Graphics acquired LiDAR data beginning March 13, 2023 and concluded acquisition on April 21, 2023. During acquisition on March 16, 2023, the flight crew flew over low clouds which created cloud shadows in the Lidar data. This area was delineated in acquisition QC and a patch reflight was planned to fill in the areas affected. The patch reflight was executed however the re-flight was planned with only 35% overlap causing there to be some pockets of low density areas between flight lines. This is visible in the SSI and the 2 areas are delineated in the low confidence polygons submitted with the delivery. The resulting density in these two areas is between 5-8 points per meter and does not appear to have affected the quality or usability of the data in any way.

During acquisition on March 14, 2023, there were 5 unexpected mid line sensor restarts due to heavy turbulence which caused the aerial crew to circle back and pick up flight lines where the sensor had shutdown. Several double coverage side lap gaps were identified in this lift during acquisition QC due to this turbulence and were patched on following flights but one such re-start resulted in a slight delay in starting the laser causing a roughly 40 m space between lines. This area is covered by the overlap of adjacent swaths but resulted in two areas where point density is below the 8 point per meter specification. Aero-Graphics inspected the final data products and determined that the low density areas did not negatively impact the project deliverables or ground surface modeling. These two areas are identified in the low confidence polygons delivered with the project deliverables.

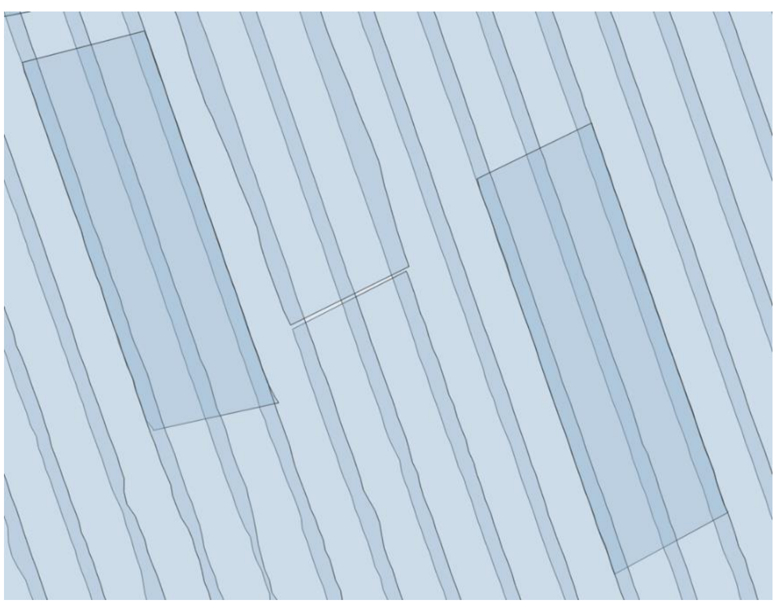
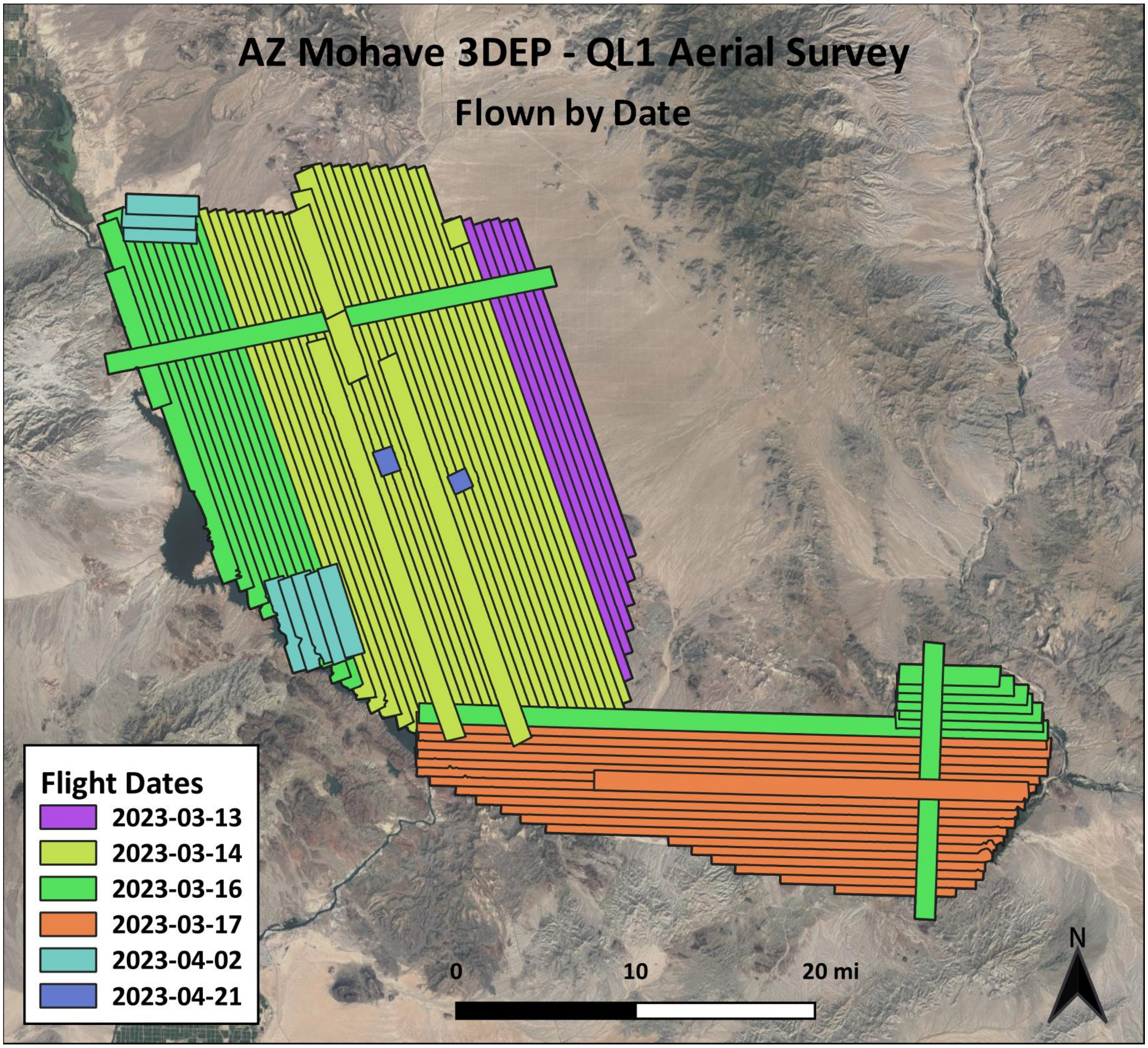


Exhibit 6: Small gap in double overlap coverage caused by a sensor restart



<u>Exhibit 7:</u> The lines flown by date for the AZ Mohave 3DEP - QL1 project

2.4 Ground Control and Check Point Survey

Aero-Graphics' professional land surveyor identified, targeted, and surveyed 38 ground control points (**Exhibit 8**) for use in data calibration as well as 63 QC check points (**Exhibit 9**) in vegetated and non-vegetated land cover classification as an independent test of accuracy for this project. A combination of precise GPS surveying methods, including static and RTK observations were used to establish the 3D position of ground control points and QC check points. Ground control coordinates can be found in Appendix A. A summary of LiDAR calibration control vertical accuracy can be found in Section 4.2 with a more detailed report in Appendix B.

Exhibit 8: Static ground control for the AZ Mohave 3DEP - QL1 project

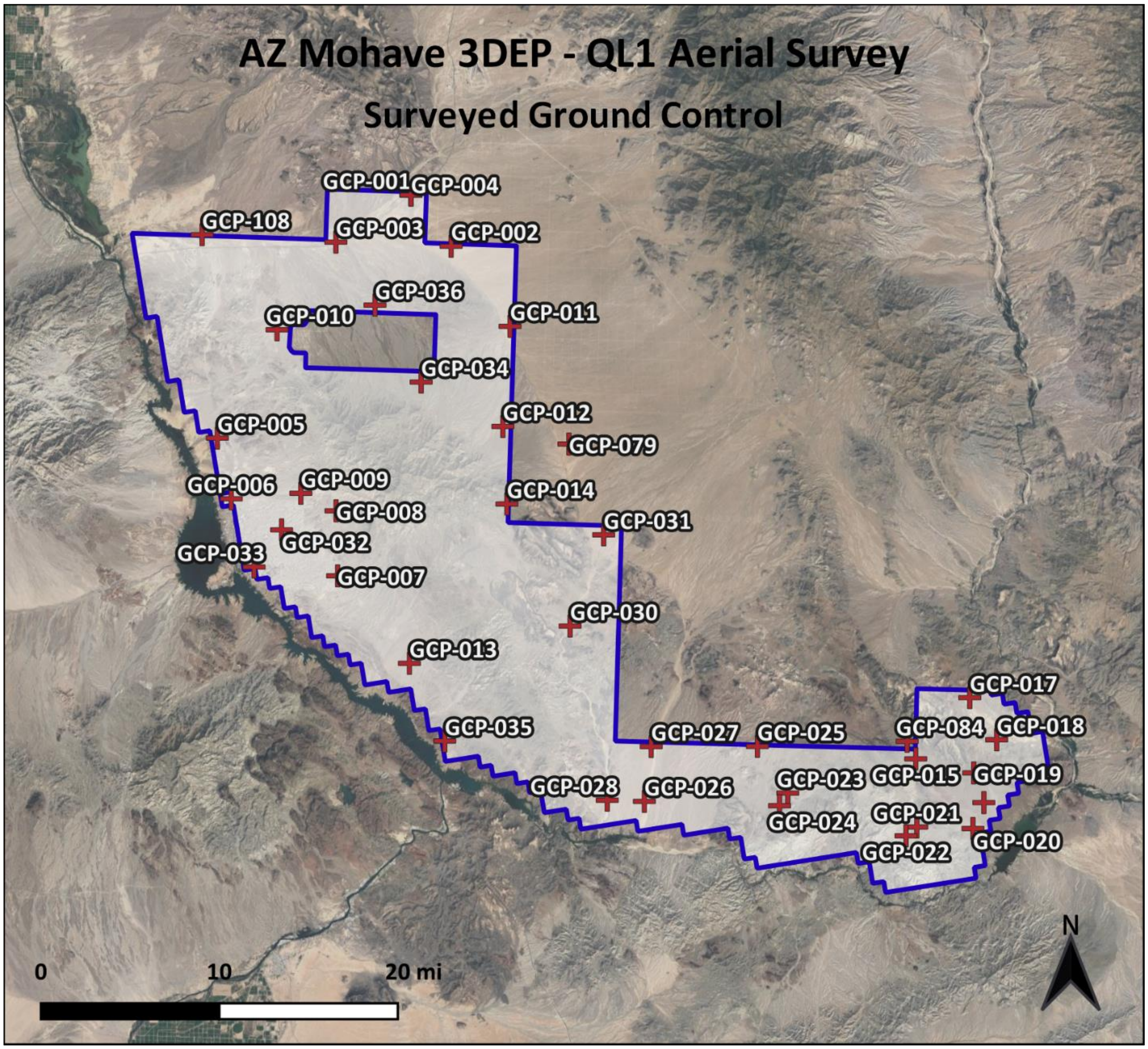
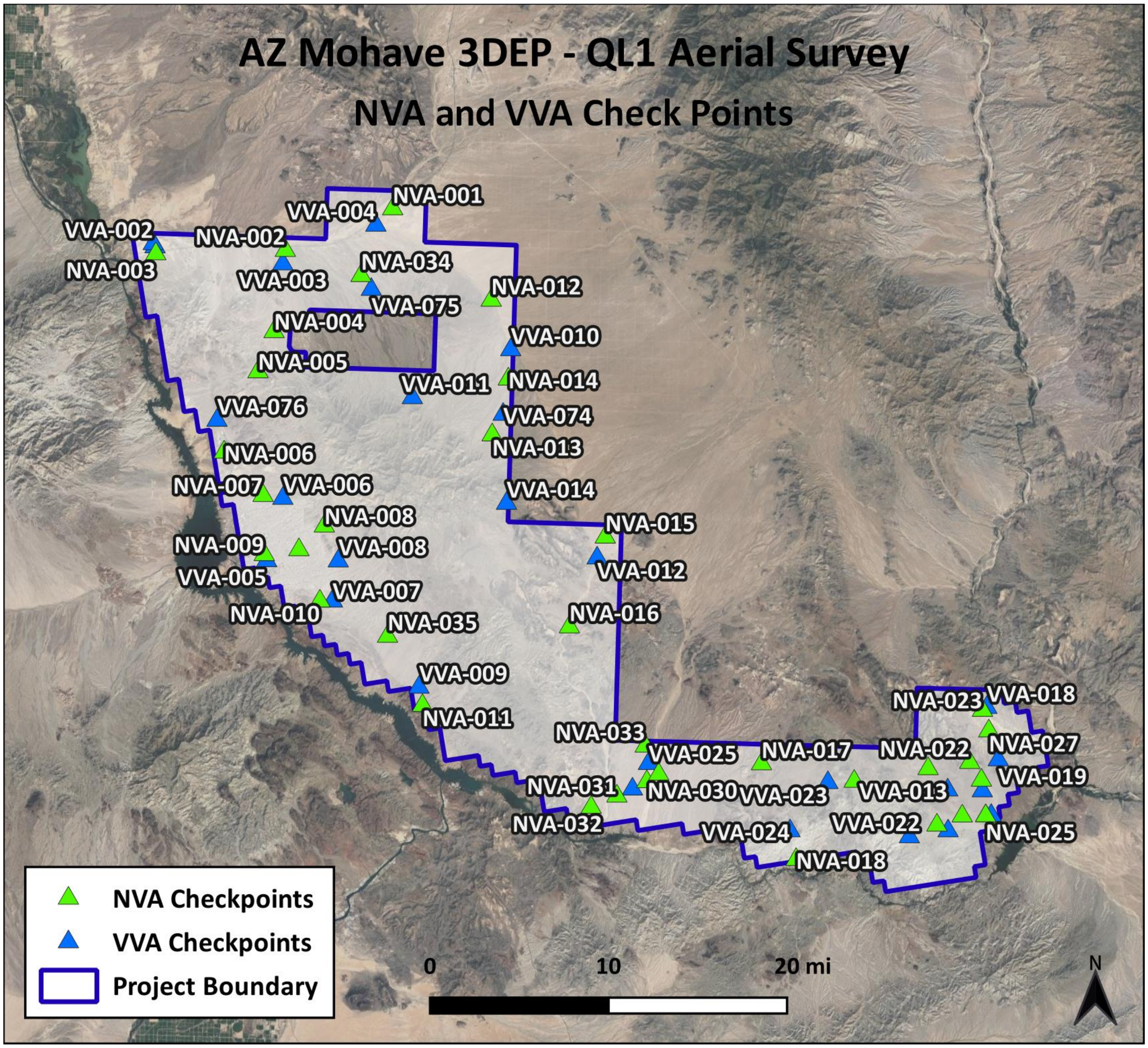


Exhibit 9: Check Points for the AZ Mohave 3DEP - QL1 project



3. LIDAR PROCESSING WORKFLOW

1. **Absolute Sensor Calibration**. Following sensor installation, lever arm values were surveyed. A boresight mission was flown over our fully controlled local range, and when adjusted to the surveyed ground control for roll, pitch, heading, and scale errors, boresight angles were developed for application to the POS processing in subsequent steps.
2. **Kinematic Air Point Processing.** The airborne GPS positions (collected at 1-second intervals) were post-processed using Applanix's POSPac MMS GNSS Inertial software (PP-RTX). A smoothed best estimate of trajectory (SBET) was developed by combining the corrected GPS positions with 1/200-second inertial measurement unit (IMU) data, which tracked the plane's roll, pitch, and yaw throughout the flight. The reference frame used for this processing does not always match the project spatial reference system and is shown in **Exhibit 10**.

Parameter	Value
Horizontal Datum	North American Datum of 1983 (NAD83 (2011))
Vertical Datum	North American Vertical Datum of 1988 (NAVD88)
Geoid Model	Geoid18
Coordinate Reference System	UTM Zone 12
Horizontal Units	Meters
Vertical Units	Meters

Exhibit 10: The reference frame used in POS processing for the AZ Mohave 3DEP – QL1 project

3. **Raw LiDAR Point Processing (Calibration).** The SBET and LiDAR range data were combined in LMS version 4.6.2 to solve for the real-world positions of each laser point. Point cloud data was produced by flight strip in ASPRS v1.4 LAS format. Flight strips were output in the project's coordinate system. LMS also does some noise filtering which flags likely noise points as Withheld. Points flagged as Withheld by LMS are "rasterized" and inspected during acquisition qc and the noise filtering parameters are adjusted as needed on a lift-by-lift basis. These points are also reviewed during classification and can often be un-flagged if found to be valid data.

4. **Relative Calibration.** The raw laser point cloud was calibrated automatically using Bayes Strip Align. This software uses last returns of overlapping swaths, filters out outliers, and adjusts for IMU drifts to correct for geometric errors. Relative accuracy is checked by generating a Dz Stat Log text report before and after calibration as well as a qualitative assessment of color JPEG Z-difference maps. The relative calibration accuracy results are presented in Section 4.1.

a. A **Dz Ortho Raster** was generated as part of this process (**Exhibit 11**). The Aero-Graphics Team generated swath separation images using LP360 software. These images were created from the last return of all points except points classified as noise and/or flagged as withheld. Point Insertion was used as the Surface Method and the cell size was set to 2x the deliverable DEM cell size. The GeoTIFF rasters were tiled to the project tile grid, clipped to the master DPA, and formatted (including defining the CRS which matches the project CRS) using GDAL software, version 2.4.0. This raster identifies clusters of large residuals and differences in measured elevations between overlapping flightlines. These errors are usually caused by topographic relief or environmental factors and require manual adjustments to correct. In some cases, multiple iterations of the Dz ortho raster are created to aid in fine tuning relative calibration parameters.

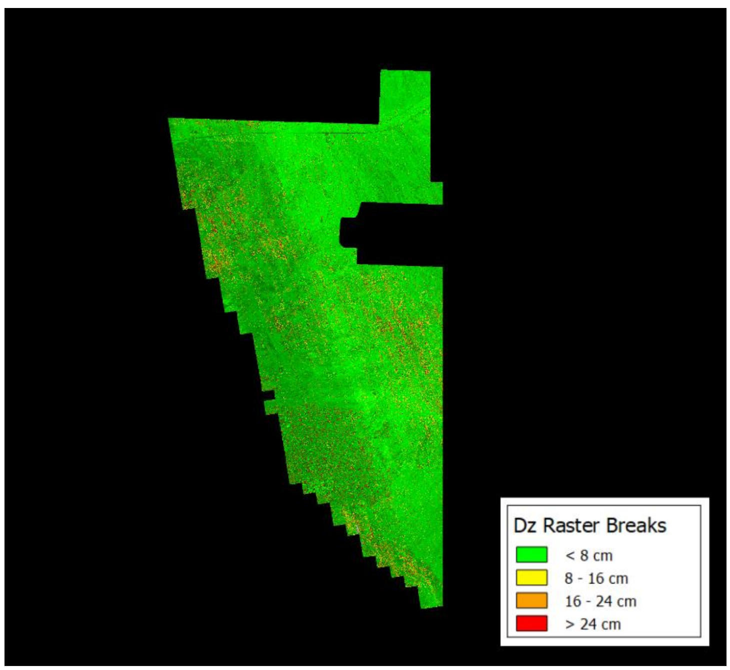


Exhibit 11: A Dz ortho raster sample generated for the AZ Mohave 3DEP - QL1 project

5. **Calibration QC.** Calibrated data is reviewed to ensure the project meets specifications. File formatting is checked for consistency. The calibrated data is reviewed against control to confirm it meets the required Vertical Accuracy Class (Results are presented in Section 4.2). Point density is analyzed and questionable areas of overlap are investigated and measured in LP360.

6. **Long/Short Filtering & Tiling.** After calibrated swaths are reviewed, additional noise filtering is applied if needed and the las swaths are tiled to the project tiling scheme using TerraScan functionality. Extremely long and short returns were also filtered

out as outliers and classified to a temporary class to be reclassified to low or high noise after completion of ground point classification.

7. **Classified LAS Processing.** The point classification was performed with the ASPRS classes described in **Exhibit 12**. The bare-earth surface is classified using a combination of TerraScan macro functionality as well as proprietary software. The bare-earth surface is then manually reviewed and corrected to ensure correct classification on the Class 2 (Ground) points. Quality Control (QC) DEMs are then created using Whitebox Tools Tin Gridding software and automated means and manual means are used to generate QC calls. The QC Dems are also symbolized as hillshades in QGIS and a manual qualitative review is conducted by an Aero-Graphics technician to identify any remaining artifacts. Each resulting QC call is then addressed using functionality provided by TerraScan.

Exhibit 12: The ASPRS classes used in lidar point classification

ASPRS Version 1.4 minimum point cloud classification scheme		
CLASS #	**CLASS NAME**	**DESCRIPTION**
1	Processed, but unclassified	Points that do not fit any other classes
2	Bare earth	Bare earth surface
7	Low noise	Low points identified below surface
9	Water	Points inside of lakes/ponds
17	Bridge decks	Points on bridge decks
18	High noise	High points identified above surface
20	Ignored ground	Points near breakline features; ignored in DEM creation process

8. **Breakline Collection.** Ground LiDAR points were used to create a bare earth surface model, which was 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, and inland stream and river islands, using LP360 functionality. Elevation values were assigned to all inland streams and rivers using Aero-Graphics, Inc. proprietary software. All ground LiDAR data inside of the collected inland breaklines were then classified to water using TerraScan macro functionality.

   Breaklines were collected at bridges but not culverts. The distinction between bridges and culverts was based on the following guidelines: Bridges are structures carrying a road, path, railroad, canal, aircraft taxiway, or any other transit between two locations of higher elevation over an area of lower elevation. A bridge may traverse a river, ravine, road, railroad, or other obstacle. "Bridge" also includes but is not limited to aqueduct, drawbridge, flyover, footbridge, overpass, span, trestle, and viaduct. In mapping, the term "bridge" is distinguished from a roadway over a culvert in that a bridge is an elevated deck that is not underlain with earth or soil. Culverts are a tunnel carrying a stream or open drainage under a road or railroad or through another type of obstruction to natural drainage.

The breakline files were translated to ESRI shapefile format using were reviewed against LiDAR intensity imagery to verify completeness of capture. All breaklines were compared to triangular irregular networks (TINs) created from ground-only points prior to water classification. To ensure the breaklines matched the LiDAR within accepted tolerances, the horizontal placement of breaklines was compared to terrain features, and the breakline elevations were compared to LiDAR elevations. Some deviation is expected between breakline and LiDAR elevations due to monotonicity enforcement, connectivity, and flattening rules that are enforced on the breaklines. Once horizontal placement and vertical variance was reviewed, all breaklines were checked for topological consistency and data integrity using a combination of ESRI ArcMap tools and proprietary tools.

9. **Hydro-Flattened Raster DEM Creation.** A hydro-flattened raster digital elevation model (DEM) was created from a TIN surface generated using the ground classified LiDAR points. The hydro-flattened DEMs, clipped to the project tile grid, were generated using commercial off the shelf software (COTS). The tiled DEMs were reviewed at a scale of 1:5,000 to look for artifacts caused by the DEM generation process and to verify correct and complete hydro-flattening was applied. Upon correction of any outstanding issues, the DEM data was loaded into QGIS for its second review and to verify corrections. Final DEMs are formatted using GDAL software version 3.8.2.

10. **DSM/First Return Raster Creation.** A first-return raster digital surface model (DSM) was created using the first-return LiDAR points, which was then tiled in the GeoTIFF format using LP360 and automated scripting routines. Each surface was reviewed in QGIS to check for any surface anomalies or incorrect elevations found within the surface.

11. **Intensity Raster Creation**. The intensity imagery was created with PDAL software. All noise classes as well as withheld flagged points were ignored during this process. Full project coverage and data review was performed in QGIS.

12. **Maximum Surface Height Rasters Creation**. MSHRs are delivered as tiled GeoTIFFs (32-bit, floating point), with the tile size and naming convention matching the

project tile grid. All points, excluding points flagged as withheld, are used to produce MSHRs using PDAL software. The rasters are produced with a binning method in which the highest elevation of all lidar points intersecting each pixel is applied as the pixel elevation in the resulting raster. Final MSHRs are formatted using GDAL software version 2.4.0, spatially defined to match the project CRS, and the cell size equals 2x the deliverable DEM cell size.

13. **LAS and GeoTIFF Formatting.** Las files are formatted using PDAL software. Any extra dimensions generated during classification are removed and the projection wkt string is written to the header. Tif files are compressed and headers are formatted using a combination of GDAL and proprietary software. The DEMs and DSMs are then processed through the open source software "cogger" to produce the COG formatted deliverable elevation data.

4. Accuracy Testing and Results

4.1 Relative Calibration Accuracy Results

Inter-swath relative accuracy is defined as the elevation difference in the overlapping area of parallel swaths. The elevation difference between these overlapping areas is used to measure the between-swath relative accuracy of the dataset. During calibration, this process is carried out to verify consistency from swath to swath, but as a quality assurance measure it can also point toward the internal consistency of the overall dataset. This testing was performed using COTS which produces an overall DZ ortho, summary statistics for each swath pair, and global statistics. Each of the QC products is inspected by an Aero-Graphics calibration technician who determines if further corrections need to be applied.

The inspection consists of the following steps:

1. The calibration DZ produced by the COTS Lidar calibration software is brough into a GIS and overlayed on satellite imagery. The technician looks for any anomalies and pays close attention to roads as well as roofs and other sloped areas which can indicate issues with the vertical and horizontal alignment. The technician also monitors swath edges closely which may indicate that the Lidar sensor's calibration profile may need a slight adjustment.

a. The DZ produced during calibration uses a continuous color ramp based on the range of the resulting DZ values.

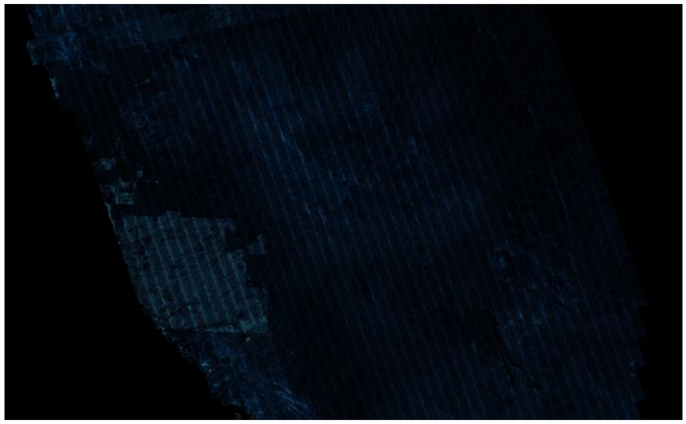
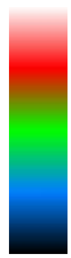


Exhibit 13: Example of calibration DZ

b. Color ramp of calibration DZs: 

2. The calibration technician then inspects the pair wise statistics to see if any swath pairs are misaligned. Testing for this project was based on a total of 402 pairs covering a total of 487 square kilometers. For this project all pairs displayed similar RMS DZ results and were found to be well below acceptable levels.
3. Lastly the calibration technician inspects the global statistics to determine if the overall inter-swath accuracy of the project is within project specifications. A qualitative review of the deliverable swath separation rasters is also done as soon as calibration is complete and the Lidar data has been tiled for further processing. This is done in order to validate the swath separation rasters as well as identify any potential issues the calibration technician may have missed. This process is described in section 3.4 of this report.
   a. **AZ Mohave 3DEP - QL1 project area: (402 pairs, 487 square kilometers)**
      - Inter-swath relative accuracy **average** of 0.022 m

Intra-swath Precision is a measure of the expected precision of the laser ranging measurement. The metric is derived by calculating the variation in elevation values across a smooth flat surface and was calculated using a kernal size of 2 meters around each control point. The intra-swath precision average was found to be 0.019 m. This was performed using Lidar calibration COTS which produces detailed reports of many calibration quality assurance metrics.

4.2 Calibration Control Vertical Accuracy

Vertical absolute accuracy reports were generated as a quality assurance check. The location of each control point is displayed in the Surveyed Ground Control map in **Exhibit 8**. Detailed results for each point are included in **Appendix B**.

Exhibit 14: Calibration control vertical accuracy results summary

Calibration Control Accuracy$_z$: AZ Mohave 3DEP - QL1 Project Area	
Average Error = +0.000 m	Average Magnitude = 0.019 m
Minimum Error = -0.042 m	RMSE = 0.027 m
Maximum Error = +0.088 m	σ = 0.027 m
Survey Sample Size: n = 38	

4.3 Point Cloud Testing

The project specifications require that Non-Vegetated Vertical Accuracy (NVA) and Vegetated Vertical Accuracy (VVA) be computed for raw LiDAR point cloud swath files. NVA is defined as the elevation difference between the LiDAR ground surface and statically surveyed ground control points collected in open terrain (bare soil, sand, rocks, and short grass) as well as urban terrain (asphalt and concrete surfaces). The NVA for this project was tested with 36 check points. The VVA for this project was tested with 28 check points. These check points were not used in the calibration or post-processing of the LiDAR point cloud data. Elevations from the unclassified LiDAR surface were measured for the xy location of each check point. Elevations interpolated from the LiDAR surface were then compared to the elevation values of the surveyed control points.

The bare-earth LiDAR dataset was designed to meet or exceed ASPRS Positional Accuracy Standards at the 10 cm vertical accuracy class. Absolute accuracy for non-vegetated areas (NVA) must be accurate within 10.0 cm (0.32 ft) RMSEz and 19.6 cm (0.64 ft) at the 95% confidence level. The tested NVA for this dataset was found to be accurate within 4.8 cm (0.16 ft) in terms of the RMSEz. The resulting NVA stated at the 95% confidence level (RMSEz x 1.96) is 9.5 cm (0.31 ft). Therefore, this dataset meets the required NVA of 10 cm (0.32 ft) at the 95% confidence level as defined by the National Standards for Spatial Data Accuracy (NSSDA).

The tested Vegetated Vertical Accuracy (VVA) for this dataset captured from the DEM using bi-linear interpolation for all classes was found to be 4.8 cm (0.16 ft). Therefore, this dataset meets the required VVA of 10.3 cm based on the 95th percentile error.

4.4 Digital Elevation Model Testing

The project specifications require the accuracy of the derived DEM be calculated and reported in two ways: (1) Non-Vegetated Vertical Accuracy (NVA) calculated at a 95% confidence level in "bare earth" and "urban" land cover classes and (2) Vegetated Vertical Accuracy (VVA) in all vegetated land cover classes combined calculated based on the 95th percentile error. The NVA for this project was tested with 36 check points. The VVA was tested with 28 check points.

The Non-Vegetated Vertical Accuracy (NVA) for this dataset was tested by sampling the DEM elevation value at each NVA checkpoint and differencing the sampled DEM Value and the statically surveyed NVA checkpoint elevation value. The resulting RMSEz of the DEM values were found to be 4.7 cm (0.15 ft). The resulting accuracy stated as the 95% confidence level (RMSEz x 1.96) is 9.2 cm (0.3 ft). Therefore, this dataset meets the required NVA of 19.6 cm at the 95% confidence level.

The tested Vegetated Vertical Accuracy (VVA) for this dataset captured from the DEM using bi-linear interpolation for all classes was found to be 4.6 cm (0.15 ft). Therefore, this dataset meets the required VVA of 10.3 cm based on the 95th percentile error.

4.5 Testing Against Existing 3DEP Data

Upon completion of calibration, Aero-Graphis downloaded several DEM tiles from Woolpert's AZ Lower Colorado River 2018 QL1 project and Optimal Geo Inc's Mohave County 2021 QL2 project. The DEMs were converted to points and loaded into LP360 along with overlapping data from the current project. Good test locations were difficult to find, however some rock plateaus and flat dry river beds were present that allowed for a comparison to be made. In LP360, many cross sections were taken for comparisons between datasets to check that there was no shelving and data was aligned well.

Exhibit 15: Aero-Graphics Data

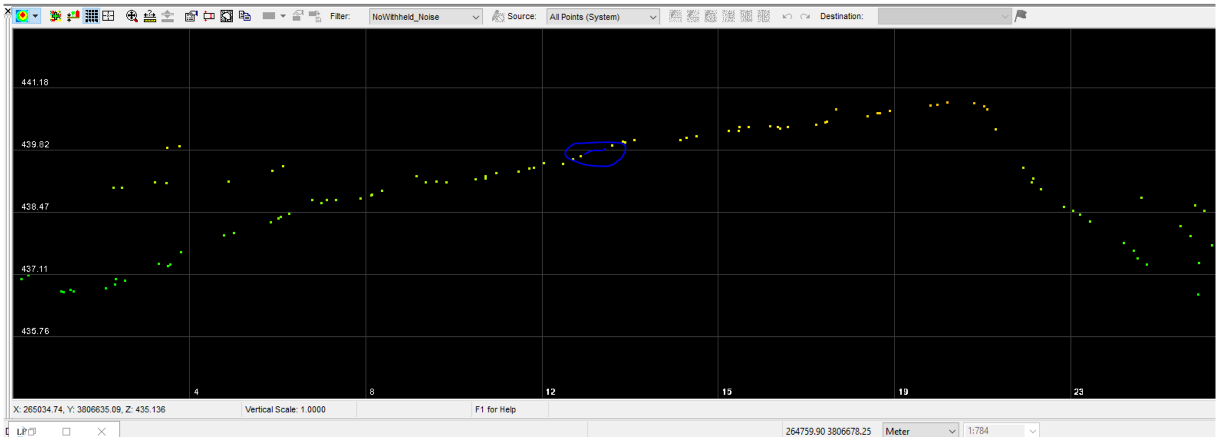
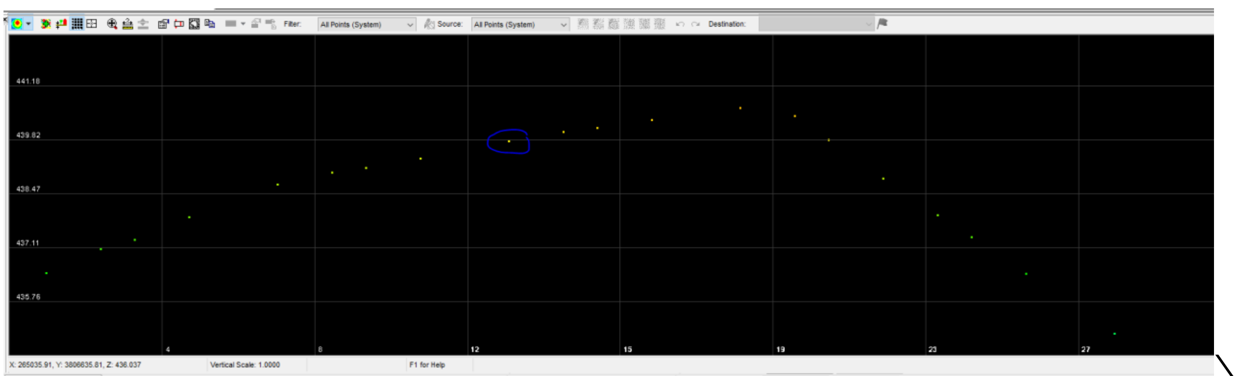


Exhibit 16: Existing 3DEP data after DEM to las conversion



With this initial qualitative analysis, Aero-Graphics concluded that the data from the current project matches in better with the Optimal Geo Inc's Mohave County 2021 QL2 project but also ties in well with the 2018 data as well.

After classification was complete and DEMs were produced, Aero Graphics conducted a second comparison between several existing DEMs and the DEMs produced for the project. 23 spot areas were sampled in the overlapping areas of the current project and the 2021 Mohave County and 2018 Lower Colorado projects. The resulting average magnitude of difference between the sample locations was 6.6 cm.

A shapefile with test locations, tiles tested, elevation values, and results is included with the delivery in a shapefile called "test_locations.shp".

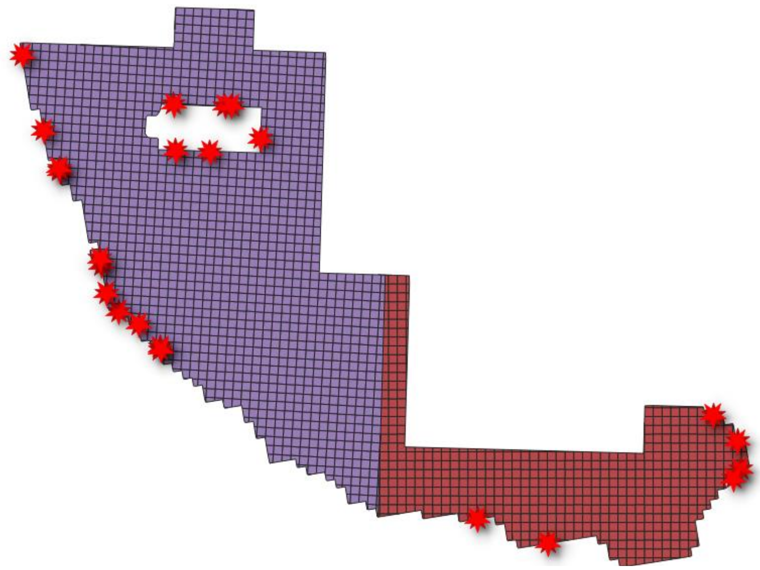


Exhibit 17: Test Locations used in testing against existing 3DEP data

4.6 DATA DENSITY

The goal for this project was to achieve a minimum LiDAR point density of **8.0** points per square meter. First return density is the best representation of the quality of the acquisition because the density of first returns is independent of vegetation and other random factors that could increase the overall point density. The acquisition mission achieved an actual average of **13.39** points per square meter for first returns. Please note that ground water and other random factors could decrease the overall point density.

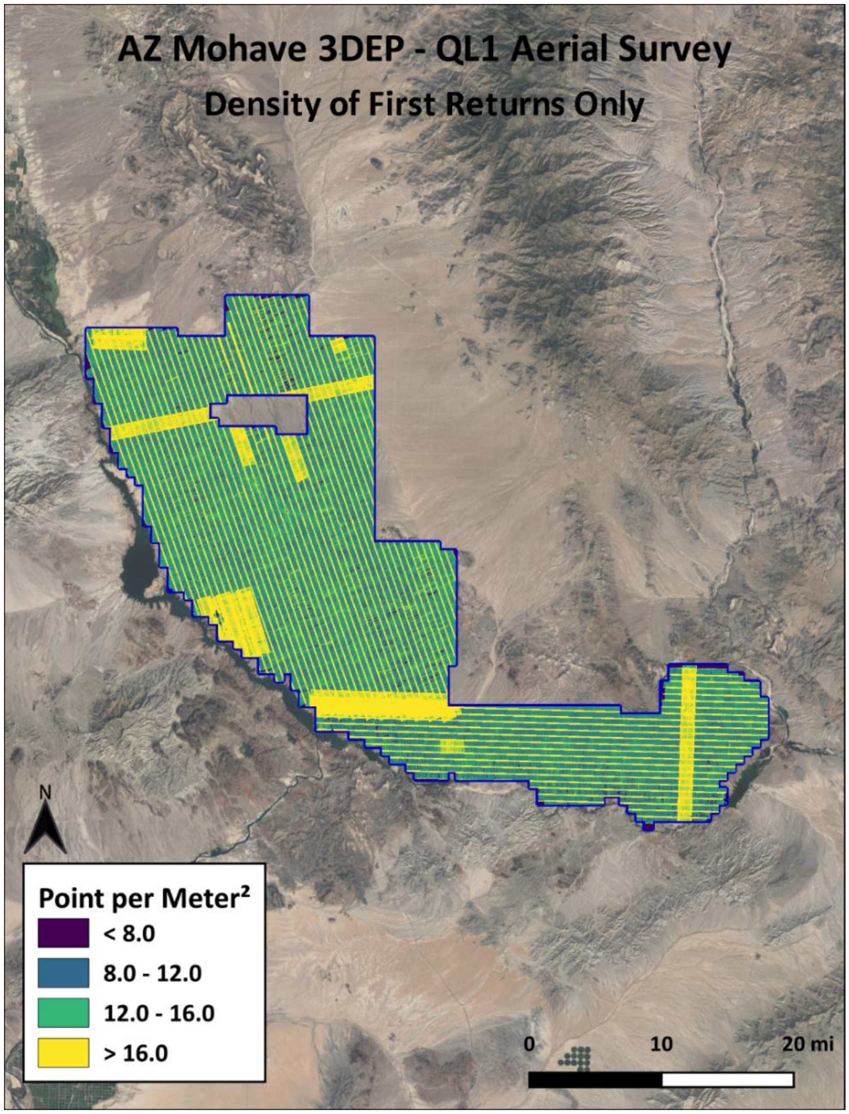


Exhibit 18: Density of first returns only in points per meter² for the AZ Mohave 3DEP - QL1 project.

APPENDIX A – CHECK POINTS

Survey Point	AZ Mohave 3DEP - QL1 Aerial Survey – UTM Zone 12		
	Easting	Northing	Elevation (m)
NVA-001	206757.677	3851466.791	409.248
NVA-002	197073.339	3847715.827	304.081
NVA-003	185391.702	3847410.074	242.714
NVA-004	196056.465	3840389.324	428.650
NVA-005	194607.137	3836773.181	403.215
NVA-006	191546.048	3829526.071	204.762
NVA-007	195062.023	3825613.778	297.410
NVA-008	200594.274	3822860.374	455.847
NVA-009	195173.600	3820281.926	227.512
NVA-010	200188.880	3816096.769	264.121
NVA-011	209441.616	3806683.717	201.139
NVA-012	215644.673	3843223.433	518.963
NVA-013	215731.388	3831082.627	665.812
NVA-014	217189.066	3836117.700	580.003
NVA-015	225930.691	3821865.298	566.169
NVA-016	222694.433	3813768.649	465.824
NVA-017	240024.718	3801420.430	441.146
NVA-018	243145.165	3792793.192	293.035
NVA-019	248384.353	3799838.903	602.167
NVA-020	198298.366	3820728.969	322.692
NVA-021	255049.596	3800984.474	561.391
NVA-022	258810.501	3801542.998	562.139
NVA-023	259954.612	3806243.484	624.073
NVA-024	258131.783	3796714.873	448.126
NVA-025	260244.090	3796736.258	407.047
NVA-026	259860.206	3799945.367	536.998
NVA-027	260527.838	3804391.885	551.856
NVA-028	255847.340	3795893.398	501.153
NVA-029	229678.376	3799809.441	301.365
NVA-030	230750.664	3800488.773	317.519
NVA-031	226979.086	3798510.237	260.529
NVA-032	224655.495	3797496.477	254.528
NVA-033	229536.877	3803018.495	354.763
NVA-034	203904.298	3845450.289	421.880
NVA-035	206293.440	3812921.690	322.177
VVA-001	185319.591	3848040.978	228.806
VVA-002	185157.663	3848320.789	221.621
VVA-003	196847.311	3846502.520	327.971

VVA-004	205240.829	3849990.261	387.279
VVA-005	195390.891	3819741.066	221.234
VVA-006	196847.743	3825356.796	372.673
VVA-007	201322.509	3816094.390	295.237
VVA-008	201845.053	3819711.878	404.900
VVA-009	209128.025	3808326.914	250.894
VVA-010	217402.456	3838758.985	551.004
VVA-011	208533.784	3834437.155	725.815
VVA-012	225193.843	3819984.210	535.678
VVA-013	228383.091	3799147.856	281.137
VVA-014	217023.849	3824909.832	718.609
VVA-013	256818.584	3799061.946	489.332
VVA-016	260244.087	3796736.270	407.057
VVA-017	259943.327	3798986.737	485.110
VVA-018	260349.458	3806501.237	625.213
VVA-019	261378.145	3801776.887	532.351
VVA-020	260742.335	3796775.340	401.819
VVA-021	256854.373	3795376.768	475.748
VVA-022	253361.108	3794833.924	523.080
VVA-023	246013.025	3799728.396	541.507
VVA-024	242598.453	3795375.435	397.102
VVA-025	229827.162	3801448.382	332.582
VVA-074	216722.633	3832935.534	622.465
VVA-075	204829.408	3844199.883	445.591
VVA-076	190908.546	3832395.241	234.899

Appendix B – Calibration Control Accuracy Report

AZ Mohave 3DEP - QL1 Aerial Survey – UTM Zone 12			
Survey Point	**Known Z (m)**	**Laser Z (m)**	**Dz (m)**
GCP-001	433.230	433.280	0.050
GCP-001	433.230	433.270	0.040
GCP-002	484.580	484.560	-0.010
GCP-002	484.580	484.550	-0.020
GCP-002	484.580	484.560	-0.020
GCP-003	351.350	351.370	0.020
GCP-003	351.350	351.370	0.020
GCP-004	433.110	433.160	0.040
GCP-004	433.110	433.150	0.040
GCP-005	210.520	210.500	-0.010
GCP-005	210.520	210.500	-0.010
GCP-006	193.430	193.410	-0.020

GCP-006	193.430	193.420	-0.010
GCP-006	193.430	193.430	0.000
GCP-007	369.990	369.970	-0.020
GCP-007	369.990	369.970	-0.020
GCP-008	545.970	545.940	-0.030
GCP-008	545.970	545.960	-0.010
GCP-009	451.080	451.070	-0.010
GCP-009	451.080	451.060	-0.020
GCP-010	424.300	424.280	-0.020
GCP-010	424.300	424.280	-0.010
GCP-011	544.140	544.220	0.080
GCP-011	544.140	544.230	0.090
GCP-012	638.180	638.170	-0.010
GCP-012	638.180	638.170	-0.010
GCP-013	300.870	300.880	0.010
GCP-013	300.870	300.880	0.010
GCP-014	717.750	717.740	-0.010
GCP-014	717.750	717.740	-0.010
GCP-015	588.920	588.910	-0.010
GCP-015	588.920	588.900	-0.020
GCP-016	448.910	448.940	0.030
GCP-016	448.910	448.940	0.030
GCP-017	692.120	692.110	-0.010
GCP-017	692.120	692.120	0.000
GCP-018	524.300	524.340	0.040
GCP-018	524.300	524.340	0.040
GCP-018	524.300	524.340	0.030
GCP-019	569.800	569.770	-0.030
GCP-019	569.800	569.760	-0.040
GCP-019	569.800	569.760	-0.030
GCP-020	420.490	420.470	-0.010
GCP-020	420.490	420.480	0.000
GCP-021	557.490	557.460	-0.030
GCP-021	557.490	557.450	-0.040
GCP-022	532.050	532.030	-0.020
GCP-022	532.050	532.030	-0.020
GCP-023	432.500	432.520	0.020
GCP-023	432.500	432.520	0.020
GCP-024	401.330	401.390	0.060
GCP-024	401.330	401.390	0.060
GCP-025	491.440	491.450	0.000
GCP-025	491.440	491.450	0.010
GCP-026	270.720	270.760	0.040
GCP-026	270.720	270.760	0.050
GCP-027	362.280	362.290	0.010
GCP-027	362.280	362.300	0.020

GCP-027	362.280	362.310	0.030
GCP-028	251.520	251.550	0.030
GCP-028	251.520	251.550	0.030
GCP-030	467.200	467.190	-0.010
GCP-030	467.200	467.200	0.000
GCP-031	566.800	566.780	-0.010
GCP-031	566.800	566.790	-0.010
GCP-032	318.900	318.860	-0.040
GCP-032	318.900	318.860	-0.040
GCP-033	183.300	183.260	-0.040
GCP-033	183.300	183.270	-0.030
GCP-034	663.300	663.290	-0.010
GCP-034	663.300	663.290	-0.010
GCP-035	199.480	199.470	-0.010
GCP-035	199.480	199.460	-0.010
GCP-035	199.480	199.470	-0.010
GCP-035	199.480	199.470	-0.010
GCP-035	199.480	199.460	-0.020
GCP-036	459.390	459.380	-0.010
GCP-036	459.390	459.380	-0.010
GCP-079	606.890	606.910	0.030
GCP-079	606.890	606.910	0.030
GCP-084	590.150	590.130	-0.020
GCP-084	590.150	590.130	-0.020
GCP-108	221.760	221.740	-0.020
GCP-108	221.760	221.740	-0.020
GCP-108	221.760	221.740	-0.020

Average Dz (m)	+0.000
Minimum Dz (m)	-0.042
Maximum Dz (m)	+0.088
Average Magnitude (m)	0.019
RMSE (m)	0.027
Std. Deviation (m)	0.027