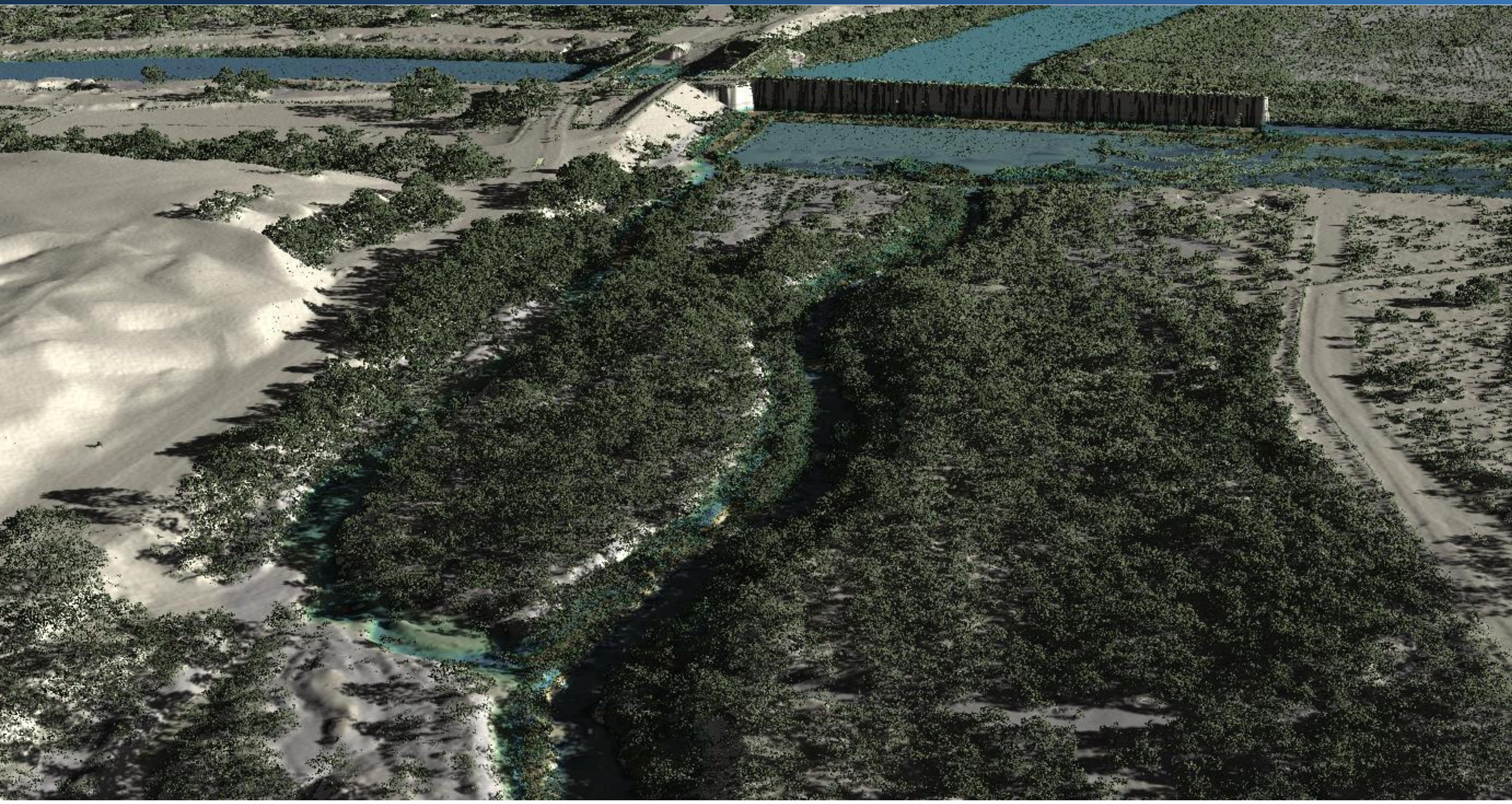
October 31, 2014



Colorado River Basin Post-Pulse LiDAR

USGS Contract G10PC00026, Task Order G14PD00258

Project Report

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Cover Photo: A view looking north at Morelos Dam on the Colorado River. The image was created from the LiDAR bare earth model colored by elevation and overlaid with the above-ground LiDAR point cloud.

Introduction

This photo taken by QSI acquisition staff shows a view of the canal system that connects to the Colorado River in the project area.

In February 2014, GMR Aerial Surveys Inc. d/b/a Photo Science, a Quantum Spatial Company (QSI), was contracted by the United States Geological Survey (USGS) (contract no. G10PC00026, task order no. G14PD00258) to collect Light Detection and Ranging (LiDAR) data of the Colorado River Basin from the US/Mexico Border near Morelos Dam to just north of the Sea of Cortez. Data collection was contracted to aid USGS in assessing the impact of water released to Mexico and the Colorado River Delta per the Minute 319 Agreement. Data collection was therefore scheduled for both pre and post water release. The first acquisition (post-pulse) occurred on March 7th – 20th, 2014. Water was subsequently released on March 23rd, 2014. The second acquisition (post-pulse) then occurred from July 31st to August 6th, 2014[1].

This report accompanies the delivered LiDAR data of the post-pulse acquisition and documents contract specifications, data acquisition procedures, processing methods, and analysis of the final dataset including LiDAR accuracy and density. Acquisition dates and acreage are shown in Table 1, a complete list of contracted deliverables provided to USGS is shown in Table 2, and the project extent is shown in Figure 1. The post pulse delivery is based on a modified boundary from the pre-pulse delivery per USGS communication, as shown in Figure 1.

[1] Project limits were modified under USGS Mod-1, to better meet USGS needs for post-pulse data acquisition.

Table 1: Acquisition dates, acreage, and data types collected on the Colorado River Basin Post-Pulse site

Project Site	Contracted Acres	Buffered Acres	Acquisition Dates	Data Type
Colorado River Basin Post-Pulse	168,325	176,658	07/31/2014 – 08/01/2014, & 08/03/2014 – 08/06/2014	LiDAR

Deliverable Products

Table 2: Products delivered to USGS for the Colorado River Basin Post-Pulse site

Colorado River Basin Post-Pulse Products Projection: UTM Zone 11 Horizontal Datum: WGS 84 Vertical Datum: NAVD88 (GEOID12a) Units: Meters	
Points	LAS v 1.3 • Classified Point Cloud • Flightline Swaths (unclassified)
Rasters	1.0 Meter ERDAS .img • Hydroflattened Bare Earth Model 0.5 Meter GeoTiffs • Intensity Images
Vectors	Shapefiles (*.shp) • Site Boundary • LiDAR Tile Index • Base Station Control • Supplemental Ground Control Points • Ground Control Quality Check Points (QCP) • Contours (0.3 m interval)

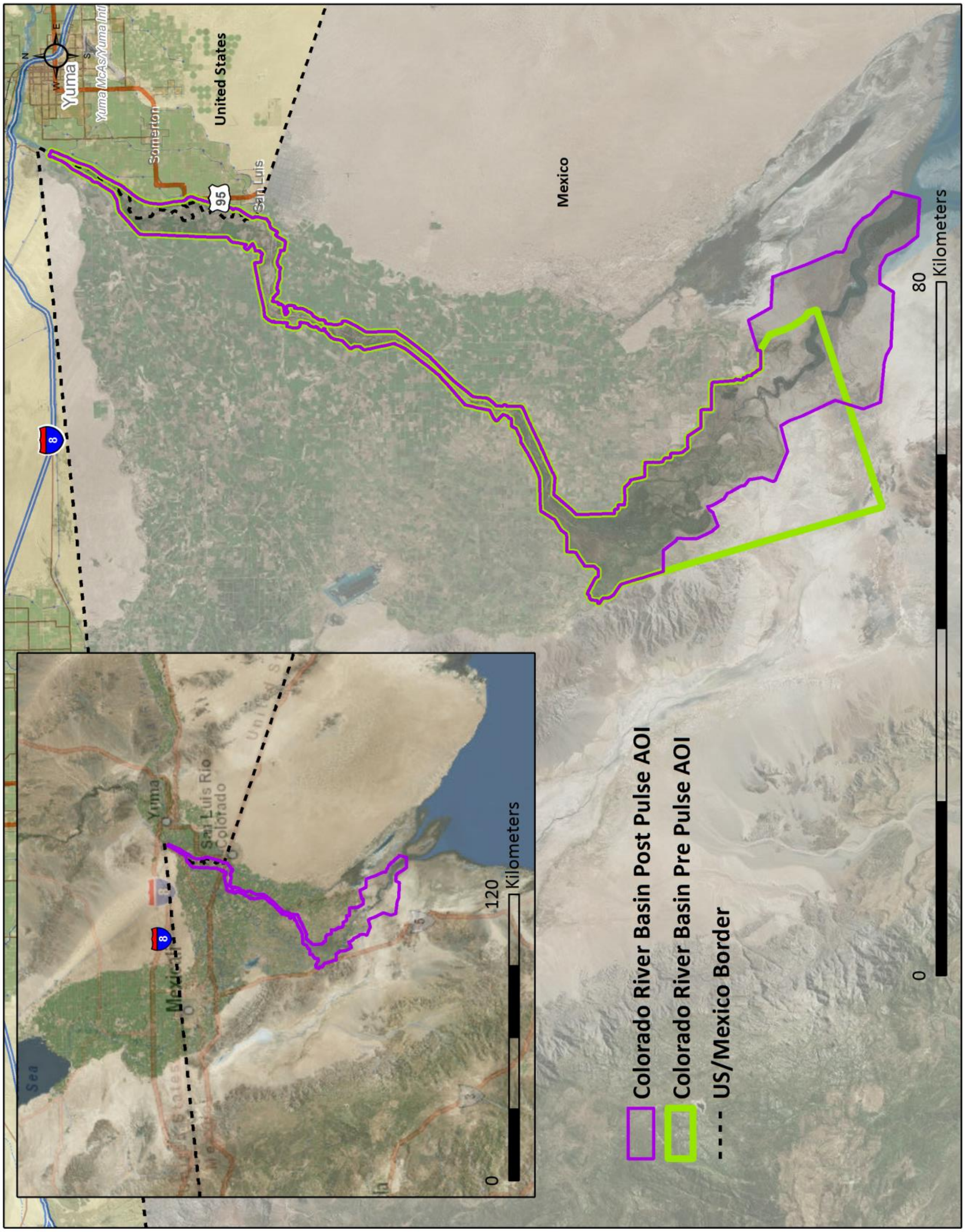


Figure 1: Location map of the Colorado River Basin Post-Pulse site spanning the US/Mexico Border

Acquisition

QSI's ground acquisition equipment set up in the Colorado River Basin Post-Pulse LiDAR study area.

Planning

In preparation for data collection, QSI reviewed the project area and developed a specialized flight plan to ensure complete coverage of the Colorado River Basin Post-Pulse LiDAR study area at the target point density of ≥8.0 points/m^2. Acquisition parameters including orientation relative to terrain, flight altitude, pulse rate, scan angle, and ground speed were adapted to optimize flight paths and flight times while meeting all contract specifications.

Factors such as satellite constellation availability and weather windows must be considered during the planning stage. Any weather hazards or conditions affecting the flight were continuously monitored due to their potential impact on the daily success of airborne and ground operations. In addition, logistical considerations including private property and road access were reviewed.

Due to the project area spanning an international border, additional considerations for air space restrictions and ground access were made. Due to security and other constraints, Quantum Spatial's task order scoping did not provide for the deployment of its own personnel to support ground based activities on the Mexican side of the border (where the majority of the Task Order AOI resides). Although QSI aircraft did fly and acquire LiDAR data of that entire AOI (US & MX), the aircraft and crew never based nor landed in Mexico. In order to establish control within Mexico, project partner , the Sonoran Desert Institute (SDI) working with USGS and BOR separately contracted and coordinated all ground survey work for the project area (including Base Station Control and Supplemental Ground Control) falling within Mexican territory. This work was completed by independent Mexican survey contractor Geo Castellini (See Appendix B). QSI flight and survey operation staff coordinated and utilized base station data and supplemental control survey data provided by Geo Castellini to support the post processing of the LiDAR data. All ground survey work for the project area falling within the United States was completed by survey crews associated with GMR Aerial Surveys Inc., d/b/a Photo Science, a Quantum Spatial Company.

Ground Survey Work

Ground surveys, including base station control, and supplemental ground control (SGC) were conducted to support the airborne acquisition process. Supplemental ground control data were used to geospatially correct the aircraft positional coordinate data and ground control quality check points were used to perform quality assurance checks on final LiDAR data.

Base Station Control

The spatial configuration of base station control provided redundant control within 13 nautical miles of the mission areas for LiDAR flights. Base stations were also used for collection of supplemental ground control points using real time kinematic (RTK) survey techniques.

Base station locations were selected with consideration for satellite visibility, field crew safety, and optimal location for SGC coverage. QSI established four new base stations in the United States for the Colorado River Basin Post-Pulse LiDAR project (Table 3, Figure 3). In addition, Mexican surveying firm Geo Castellini established three new base stations in Mexican territory.

Table 3: Base Stations established for the Colorado River Basin Post-Pulse acquisition. Coordinates are on the WGS84 datum, epoch 2014.20.

Base Station ID	Agency	Latitude	Longitude	Ellipsoid (meters)
CRB_02	Geo Castellini	32° 12' 01.53005"	-115° 09' 31.88033"	-23.519
CRB_03	Geo Castellini	32° 23' 00.16894"	-114° 58' 31.83067"	-12.765
CRB_04	Geo Castellini	31° 56' 37.26232"	-114° 57' 40.18617"	-30.926
CRD_01	QSI	32° 30' 03.20128"	-114° 47' 39.60133"	-4.548
CRD_02	QSI	32° 30' 10.27714"	-114° 47' 43.68409"	-5.044
CRD_03	QSI	32° 36' 41.51145"	-114° 47' 17.77803"	-0.115
CRD_04	QSI	32° 42' 25.56057"	-114° 43' 27.86648"	2.584

To correct the continuously recorded onboard measurements of the aircraft position, QSI concurrently conducted multiple static Global Navigation Satellite System (GNSS) ground surveys (1 Hz recording frequency) over each base station established within the United States. During post-processing, the static GPS data were triangulated with nearby Continuously Operating Reference Stations (CORS) using the Online Positioning User Service (OPUS[2]) for precise positioning. Multiple independent sessions over the same base station were processed to confirm antenna height measurements and to refine position accuracy.

[2] OPUS is a free service provided by the National Geodetic Survey to process corrected monument positions. http://www.ngs.noaa.gov/OPUS.

QSI Control Points

Control points (both supplemental ground control and quality check points) within the United States were collected by QSI using real time kinematic survey techniques. A Trimble R7 base unit was positioned at a nearby base station to broadcast a kinematic correction to a roving Trimble R8 GNSS receiver. All measurements were made during periods with a Position Dilution of Precision (PDOP) of ≤ 3.0 with at least six satellites in view of the stationary and roving receivers. When collecting RTK data, the rover records data while stationary for five seconds, then calculates the pseudorange position using at least three one-second epochs. Relative errors for the position must be less than 1.5 cm horizontal and 2.0 cm vertical in order to be accepted. See Table 4 for Trimble unit specifications.

Table 4: Trimble equipment identification

Receiver Model	Antenna	OPUS Antenna ID	Use
Trimble R7 GNSS	Zephyr GNSS Geodetic Model 2	TRM57971.00	Static
Trimble R8	Integrated Antenna R8 Model 2	TRM_R8_GNSS	Rover

Supplemental Ground Control

Supplemental Ground Control points were collected within the United States (by QSI) and within Mexico (by Geo Castellini) in order to refine Airborne GPS positional accuracy during the calibration process. Supplemental ground control were collected in areas where good satellite visibility was achieved on paved roads and other hard surfaces such as gravel or packed dirt roads. Ground control measurements were not taken on highly reflective surfaces such as center line stripes or lane markings on roads due to the increased noise seen in the laser returns over these surfaces. Ground control points were collected within as many flightlines as possible, however the distribution of ground control points depended on ground access constraints and base station locations and may not be equitably distributed throughout the study area (Figure 2).

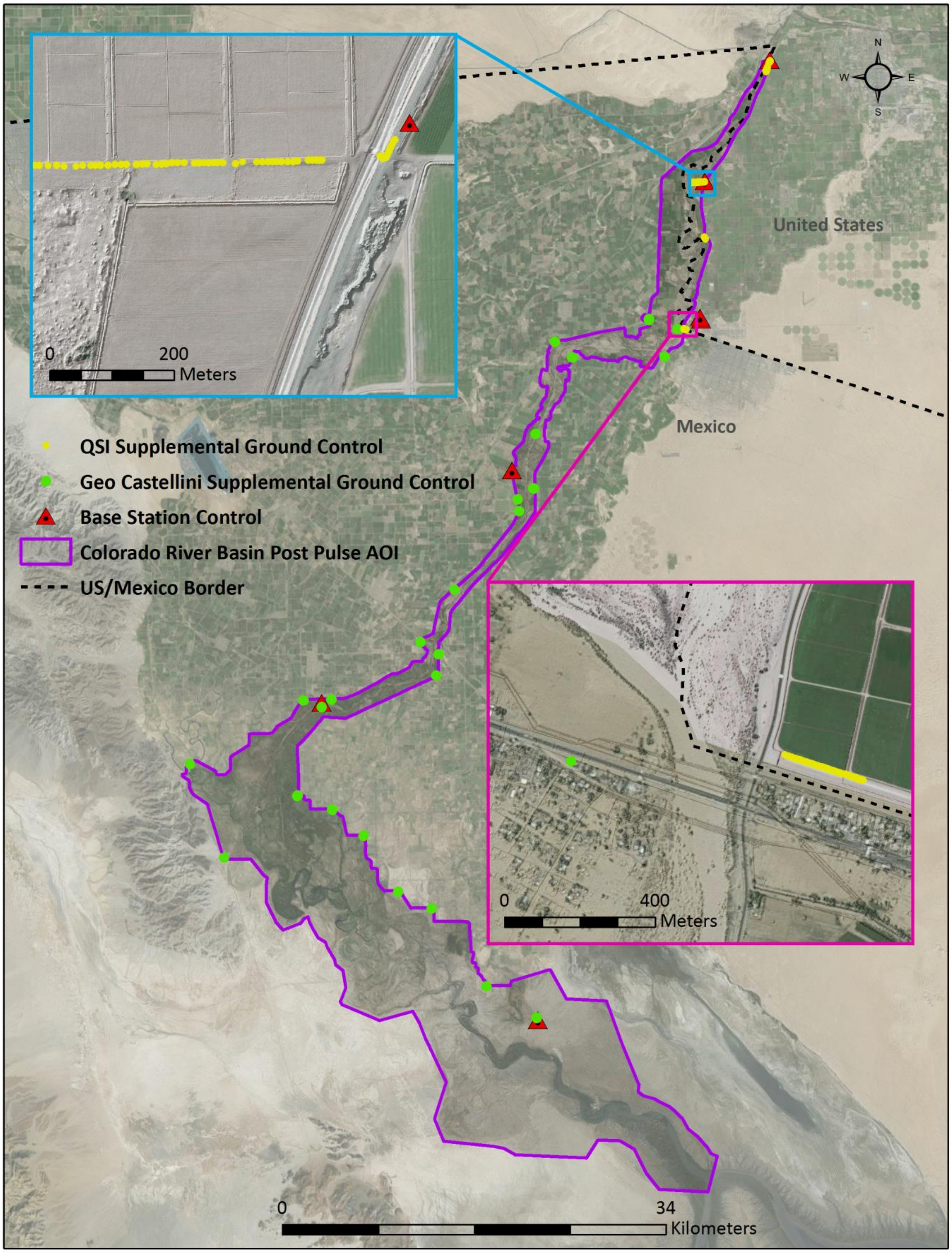


Figure 2: Supplemental Ground Control point location map

Ground Control Quality Check Points (QCP)

Ground Control Quality Check Points (QCPs) were collected by QSI personnel within *only* the United States portion of the Project AOI to support accuracy assessment and reporting within the Colorado River Basin study area (Figure 3). Budget constraints prohibited the collection of any QCPs within the Mexican portion of the AOI by SDI's survey contractor. Ground control QCPs were collected exclusively for accuracy assessment, and were not used in data calibration. Individual accuracies were calculated for each QCP land cover type to assess confidence in the LiDAR derived ground models across land cover classes, and reported statistics were updated. Land cover types and descriptions are shown in Table 5.

Table 5: Land cover descriptions of check points taken for the Colorado River Basin Post-Pulse site

Land cover type	Number of Points	Land cover code	Example	Description
Bare Earth/Gravel	144	BARE GVL		Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material
Tall Grass	59	TALL_GRASS TALL_WEEDS		Areas characterized by grasses, legumes, or natural and semi-natural grasslands
Brush/Shrubland	76	SHRUB BRUSH		Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material
Urban	34	URBAN URBAN(PAVED) PARK/URBAN/REC		Urban and developed areas

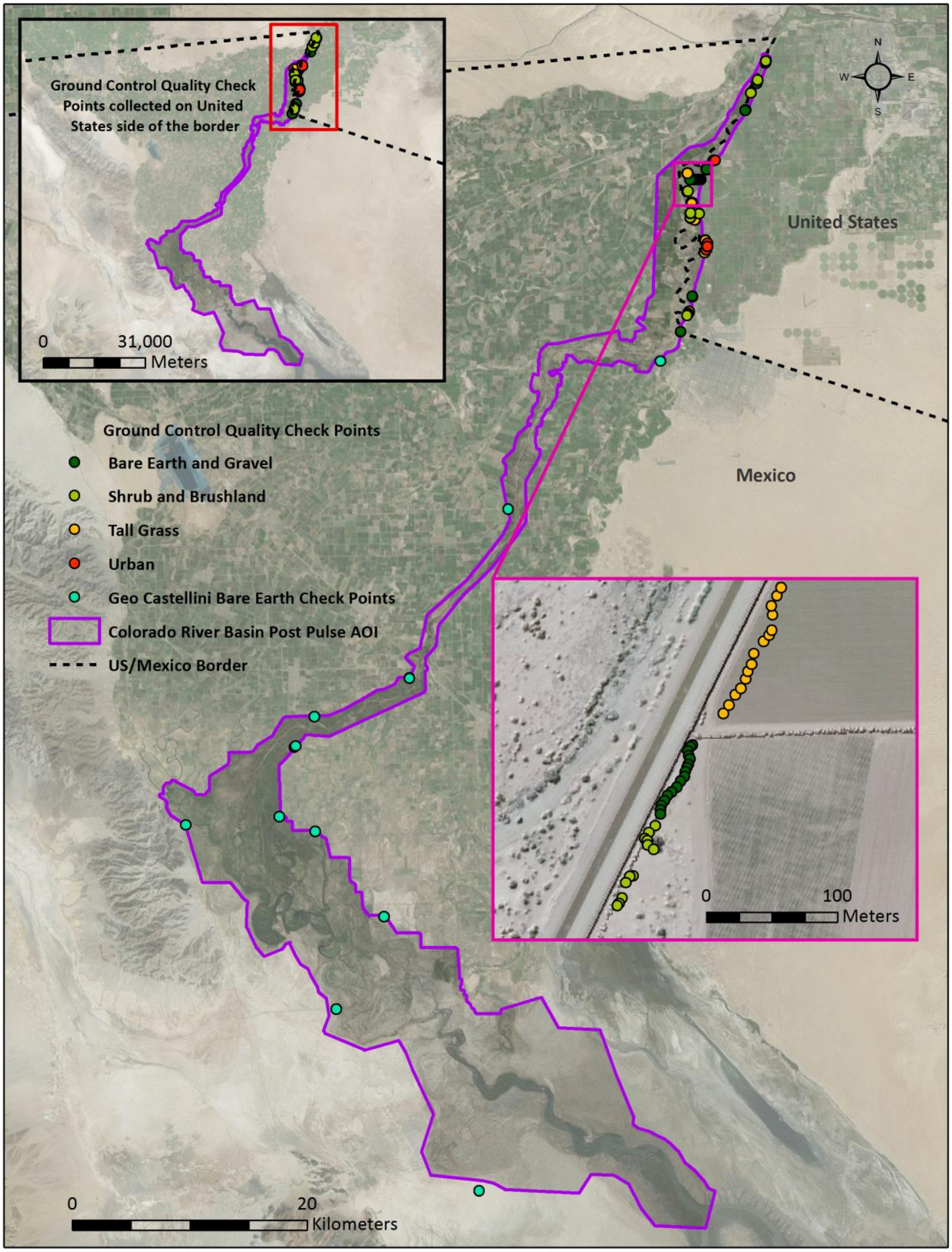


Figure 3: Location Map of Ground Control Quality Assurance Points (QAPs)

Airborne Survey

LiDAR

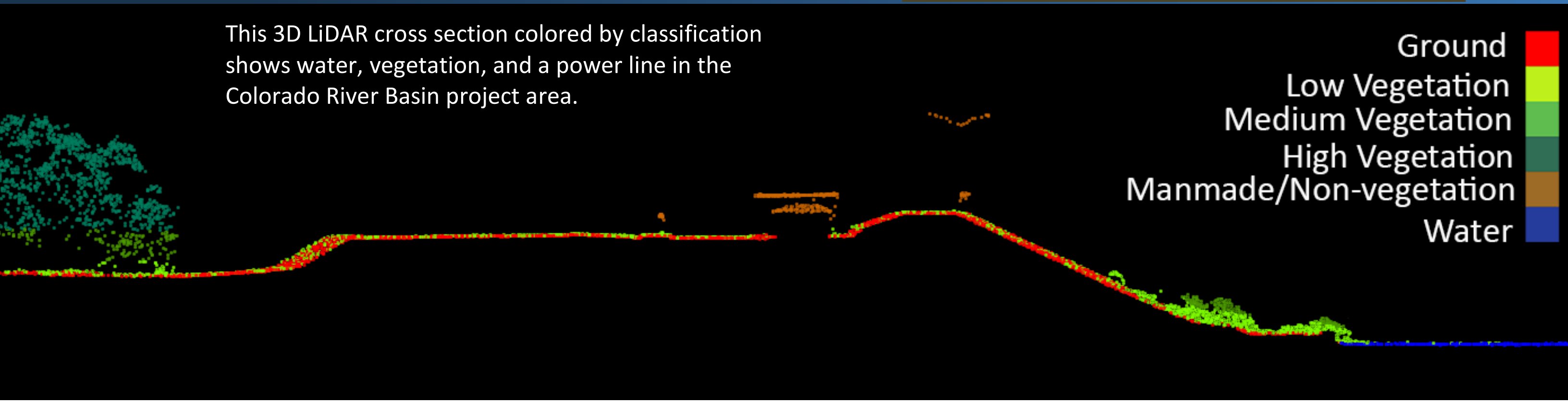
The LiDAR survey was accomplished using a Leica ALS70 system mounted in a Cessna Caravan. Table 6 summarizes the settings used to yield an average pulse density of ≥8 pulses/m^2 over the Colorado River Basin Post-Pulse project area. The Leica ALS70 laser system can record unlimited range measurements (returns) per pulse, but typically does not record more than 5 returns per pulse. It is not uncommon for some types of surfaces (e.g., dense vegetation or water) to return fewer pulses to the LiDAR sensor than the laser originally emitted. The discrepancy between first return and overall delivered density will vary depending on terrain, land cover, and the prevalence of water bodies. All discernible laser returns were processed for the output dataset.

Table 6: LiDAR specifications and survey settings

LiDAR Survey Settings & Specifications	
Acquisition Dates	July 31st – August 1st, 2014, August 3rd – August 6th, 2014
Aircraft Used	Cessna Caravan
Sensor	Leica ALS70
Survey Altitude (AGL)	1400 m
Target Pulse Rate	195 – 199 kHz
Sensor Configuration	Single Pulse in Air (SPiA)
Laser Pulse Diameter	32 cm
Field of View	30^o
GPS Baselines	≤13 nm
GPS PDOP	≤3.0
GPS Satellite Constellation	≥6
Maximum Returns	5
Intensity	8-bit
Resolution/Density	Average 8 pulses/m^2
Accuracy	$RMSE_Z$ ≤ 15 cm

Leica ALS70 LiDAR sensor

All areas were surveyed with an opposing flight line side-lap of ≥50% (≥100% overlap) in order to reduce laser shadowing and increase surface laser painting. To accurately solve for laser point position (geographic coordinates x, y and z), the positional coordinates of the airborne sensor and the attitude of the aircraft were recorded continuously throughout the LiDAR data collection mission. Position of the aircraft was measured twice per second (2 Hz) by an onboard differential GPS unit, and aircraft attitude was measured 200 times per second (200 Hz) as pitch, roll and yaw (heading) from an onboard inertial measurement unit (IMU). To allow for post-processing correction and calibration, aircraft and sensor position and attitude data are indexed by GPS time.



This 3D LiDAR cross section colored by classification shows water, vegetation, and a power line in the Colorado River Basin project area.

LiDAR Data

Upon completion of data acquisition, QSI processing staff initiated a suite of automated and manual techniques to process the data into the requested deliverables. Processing tasks included GPS control computations, smoothed best estimate trajectory (SBET) calculations, kinematic corrections, calculation of laser point position, sensor and data calibration for optimal relative and absolute accuracy, and LiDAR point classification (Table 7). Processing methodologies were tailored for the landscape. Brief descriptions of these tasks are shown in Table 8.

Table 7: ASPRS LAS classification standards applied to the Colorado River Basin Post-Pulse dataset

Classification Number	Classification Name	Classification Description
2	Ground	Bare earth ground, determined by a number of automated and manual cleaning algorithms
3	Low Vegetation	Any vegetation within 1.5 m of the ground surface
4	Medium Vegetation	Any vegetation between 1.5 and 4.6 m above ground
5	High Vegetation	Any vegetation greater than 4.6 m above ground
6	Building	All man-made structures such as buildings, bridges, fences and utilities.
7	Noise	Laser returns that are often associated with birds, scattering from reflective surfaces, or artificial points below the ground surface
9	Water	Laser returns that are determined to be water using automated and manual cleaning algorithms
10	Ignored Ground	Ground points proximate to water's edge breaklines; ignored for correct model creation
11	Withheld	Laser returns that have intensity values of 0 or 255

Table 8: LiDAR processing workflow

LiDAR Processing Step	Software Used
Resolve kinematic corrections for aircraft position data using kinematic aircraft GPS and static ground GPS data. Develop a smoothed best estimate of trajectory (SBET) file that blends post-processed aircraft position with sensor head position and attitude recorded throughout the survey.	IPAS TC v.3.1
Calculate laser point position by associating SBET position to each laser point return time, scan angle, intensity, etc. Create raw laser point cloud data for the entire survey in *.las (ASPRS v. 1.3) format. Convert data to orthometric elevations by applying a geoid12a correction.	ALS Post Processing Software v.2.75
Import raw laser points into manageable blocks (less than 500 MB) to perform manual relative accuracy calibration and filter erroneous points. Classify ground points for individual flight lines.	TerraScan v.14
Using ground classified points per each flight line, test the relative accuracy. Perform automated line-to-line calibrations for system attitude parameters (pitch, roll, heading), mirror flex (scale) and GPS/IMU drift. Calculate calibrations on ground classified points from paired flight lines and apply results to all points in a flight line. Use every flight line for relative accuracy calibration.	TerraMatch v.14
Classify resulting data to ground and other client designated ASPRS classifications (Table 7). Assess statistical absolute accuracy via direct comparisons of ground classified points to supplemental ground control points.	TerraScan v.14 TerraModeler v.14
Generate bare earth models as triangulated surfaces with hydro-flattening breaklines enforced. Export surface models in EDRAS Imagine (.img) format at a 1 meter pixel resolution.	TerraScan v.14 TerraModeler v.14 ArcMap v. 10.1
Export intensity images as GeoTIFFs at a 0.5 meter pixel resolution.	TerraScan v.14 TerraModeler v.14 ArcMap v. 10.1

Feature Extraction

Water's edge breaklines

The Colorado River and other water bodies within the project area were flattened to a consistent water level. Bodies of water that were flattened include lakes and other closed water bodies with a surface area greater than 2 acres, all streams and rivers that are nominally wider than 30 meters, all non-tidal waters bordering the project, and select smaller bodies of water as feasible. The hydro-flattening process eliminates artifacts in the digital terrain model caused by both increased variability in ranges or dropouts in laser returns due to the low reflectivity of water.

Hydro-flattening of closed water bodies was performed through a combination of automated and manual detection and adjustment techniques designed to identify lake boundaries and water levels. Water boundary polygons were developed using an algorithm which weights LiDAR-derived slopes, intensities, and return densities to detect the water's edge. The water edges were then manually reviewed and edited as necessary. Specific care was taken to not hydro-flatten wetland and marsh habitat found throughout the study site.

Once polygons were developed, water elevations were obtained from the filtered LiDAR returns. Lakes were assigned a consistent elevation for an entire polygon while the river was assigned consistent elevations on opposing banks and smoothed to ensure downstream flow through the entire river channel. The initial ground classified points falling within water polygons were reclassified as water points to omit them from the final ground model and replaced with the flat water surface of the water's edge breaklines.

Water boundary breaklines were then incorporated into the hydro-flattened DEM by enforcing triangle edges (adjacent to the breakline) to the elevation values of the breakline. This implementation corrected interpolation along the hard edge. Water surfaces were obtained from a TIN of the 3D water edge breaklines resulting in the final hydroflattened model (Figure 4).

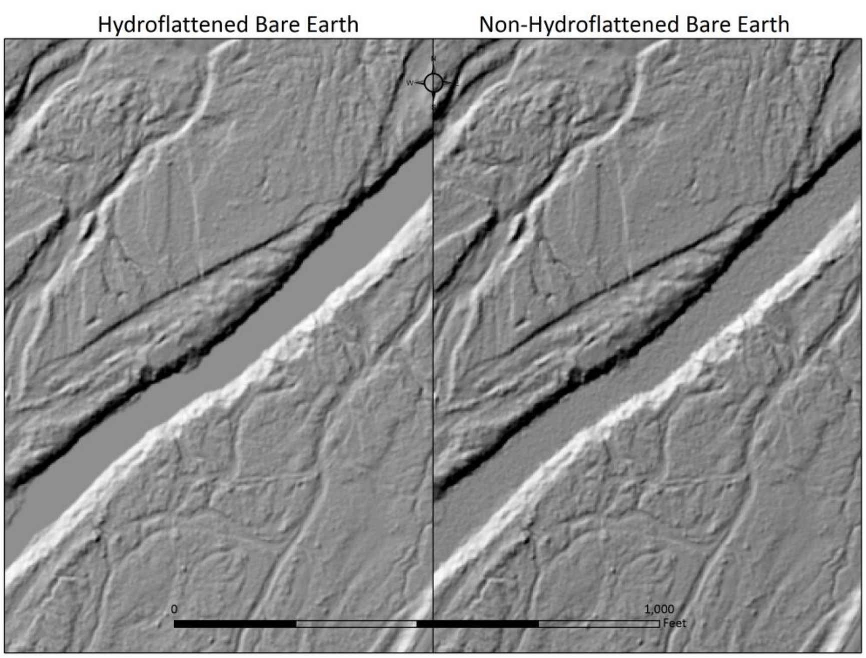


Figure 4: Example of hydro-flattening in the Colorado River Basin LiDAR dataset

Contours

Contour generation from LiDAR point data required a thinning operation in order to reduce contour sinuosity. The thinning operation reduced point density where topographic change is minimal (i.e., flat surfaces) while preserving resolution where topographic change was present. These model key points were selected from the ground model every 6.09 m with the spacing decreased in regions with high surface curvature (Z tolerance of 0.07 m). Generation of model key points eliminated redundant detail in terrain representation, particularly in areas of low relief, and provided for a more manageable dataset. Contours were produced through TerraModeler by interpolating between the model key points at even elevation increments.

Elevation contour lines were then intersected with ground point density rasters and a confidence field was added to each contour line. Contours which crossed areas of high point density have high confidence levels, while contours which crossed areas of low point density have low confidence levels. These areas with low ground point density were commonly beneath buildings and bridges, in locations with dense vegetation, over water, and in other areas where laser penetration to the ground surface was impeded (Figure 5).

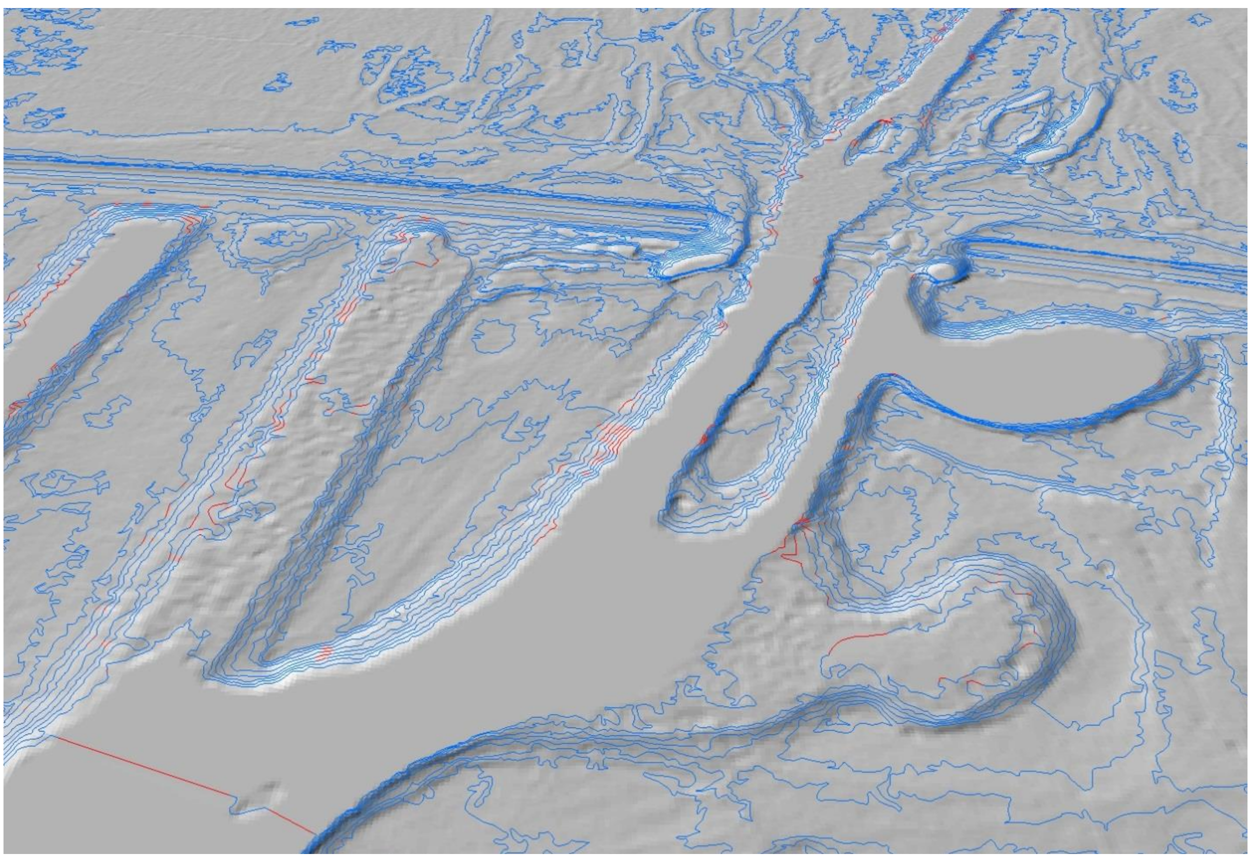
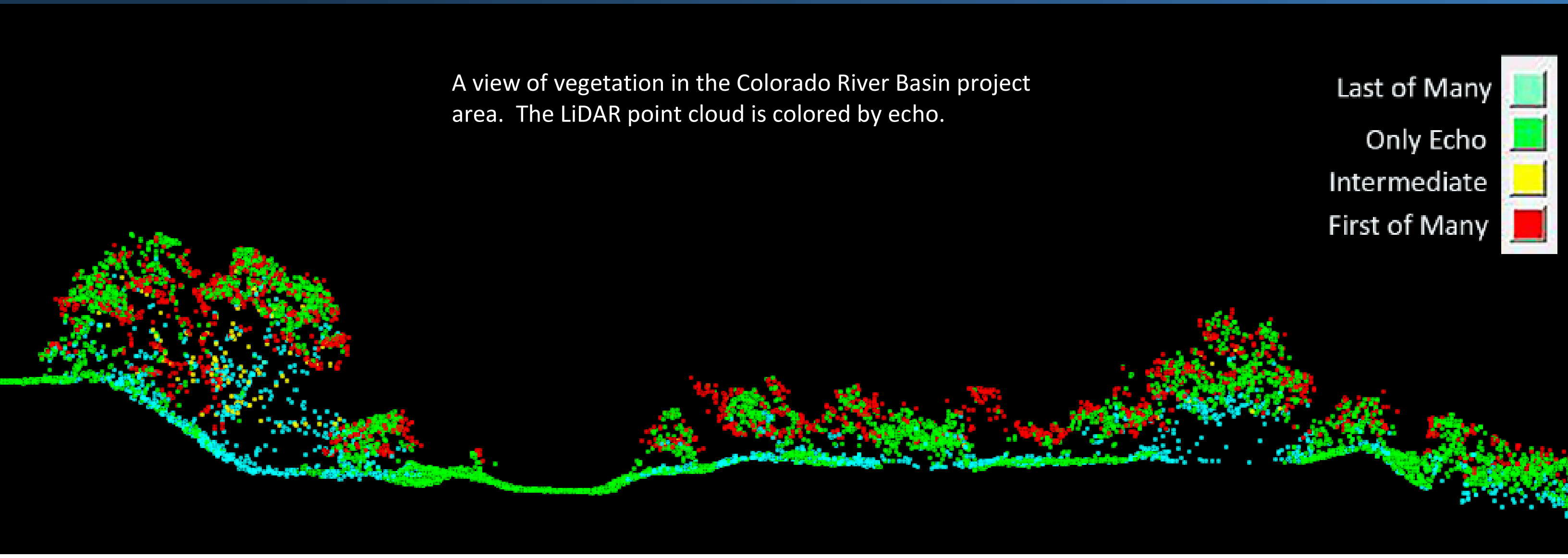


Figure 5: Contours draped over the Colorado River Basin bare earth elevation model. Blue contours represent high confidence while the red contours represent low confidence.



A view of vegetation in the Colorado River Basin project area. The LiDAR point cloud is colored by echo.

LiDAR Density

The acquisition parameters were designed to acquire an average first-return density of 8 points/m^2. First return density describes the density of pulses emitted from the laser that return at least one echo to the system. Multiple returns from a single pulse were not considered in first return density analysis. Pulse density distribution varied within the study area due to laser scan pattern and flight conditions. Additionally, some types of surfaces (e.g., breaks in terrain, water and steep slopes) may have returned fewer pulses than originally emitted by the laser. First returns typically reflect off the highest feature on the landscape within the footprint of the pulse. In forested or urban areas the highest feature could be a tree, building or power line, while in areas of unobstructed ground, the first return will be the only echo, and represents the bare earth surface.

The density of ground-classified LiDAR returns was also analyzed for this project. Terrain character, land cover, and ground surface reflectivity all influenced the density of ground surface returns. In vegetated areas, fewer pulses may penetrate the canopy, resulting in lower ground density.

The average first-return density of LiDAR data for the Colorado River Basin Post-Pulse project was 10.65 points/m^2 while the average ground classified density was 5.31 points/m^2 (Table 9). The statistical and spatial distributions of first return densities and classified ground return densities per 100 m x 100 m cell are portrayed in Figure 6 through Figure 9.

Table 9: Average LiDAR point densities

Classification	Point Density
First-Return	10.65 points/m^2
Ground Classified	5.31 points/m^2

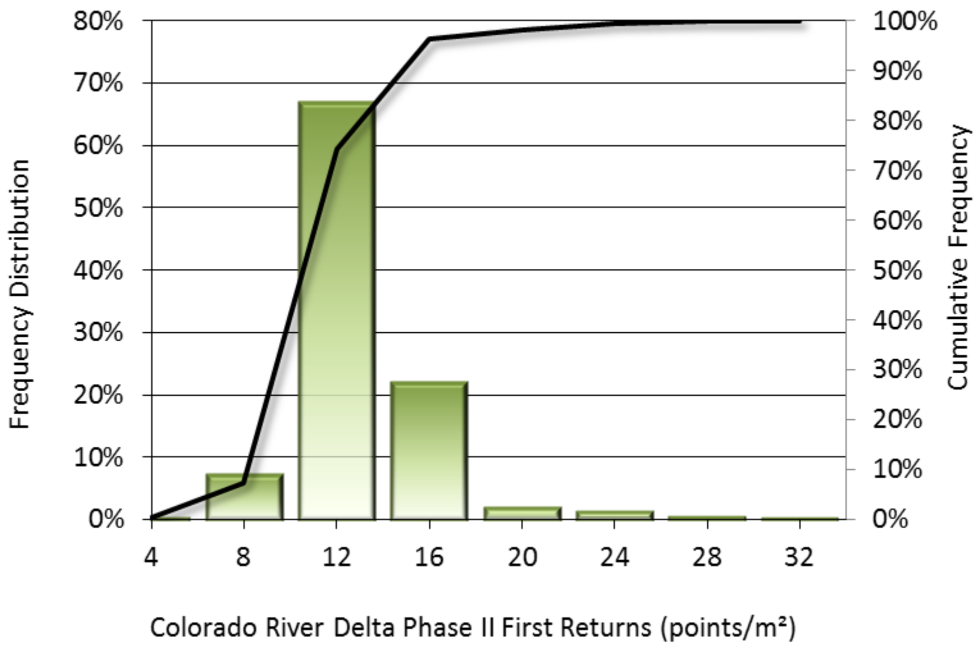


Figure 6: Frequency distribution of first return densities per 100 x 100 m cell

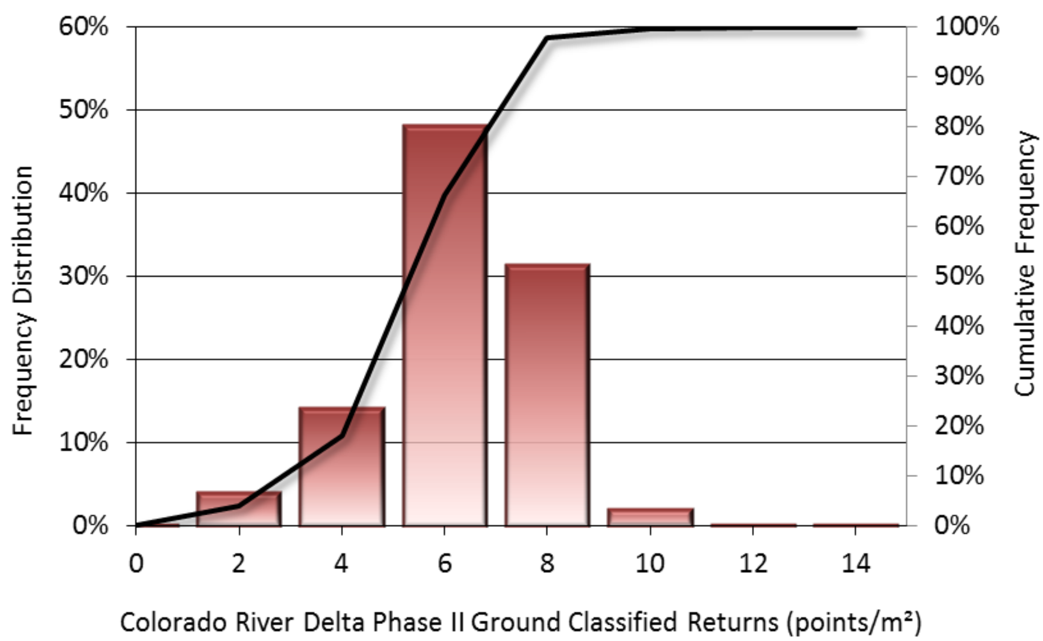


Figure 7: Frequency distribution of ground return densities per 100 x 100 m cell

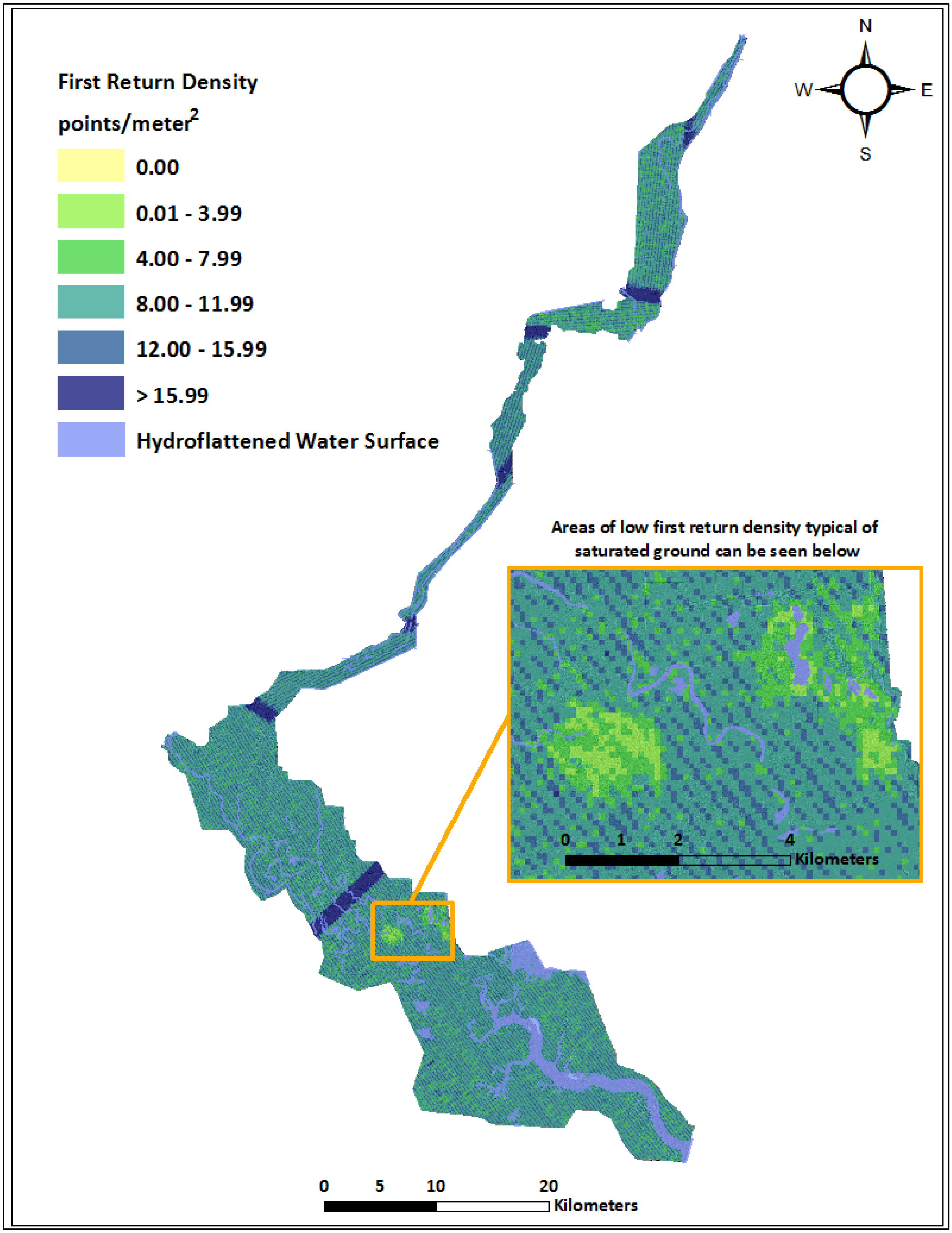


Figure 8: First return density map for the Colorado River Basin Post-Pulse site (100 m x 100 m cells)

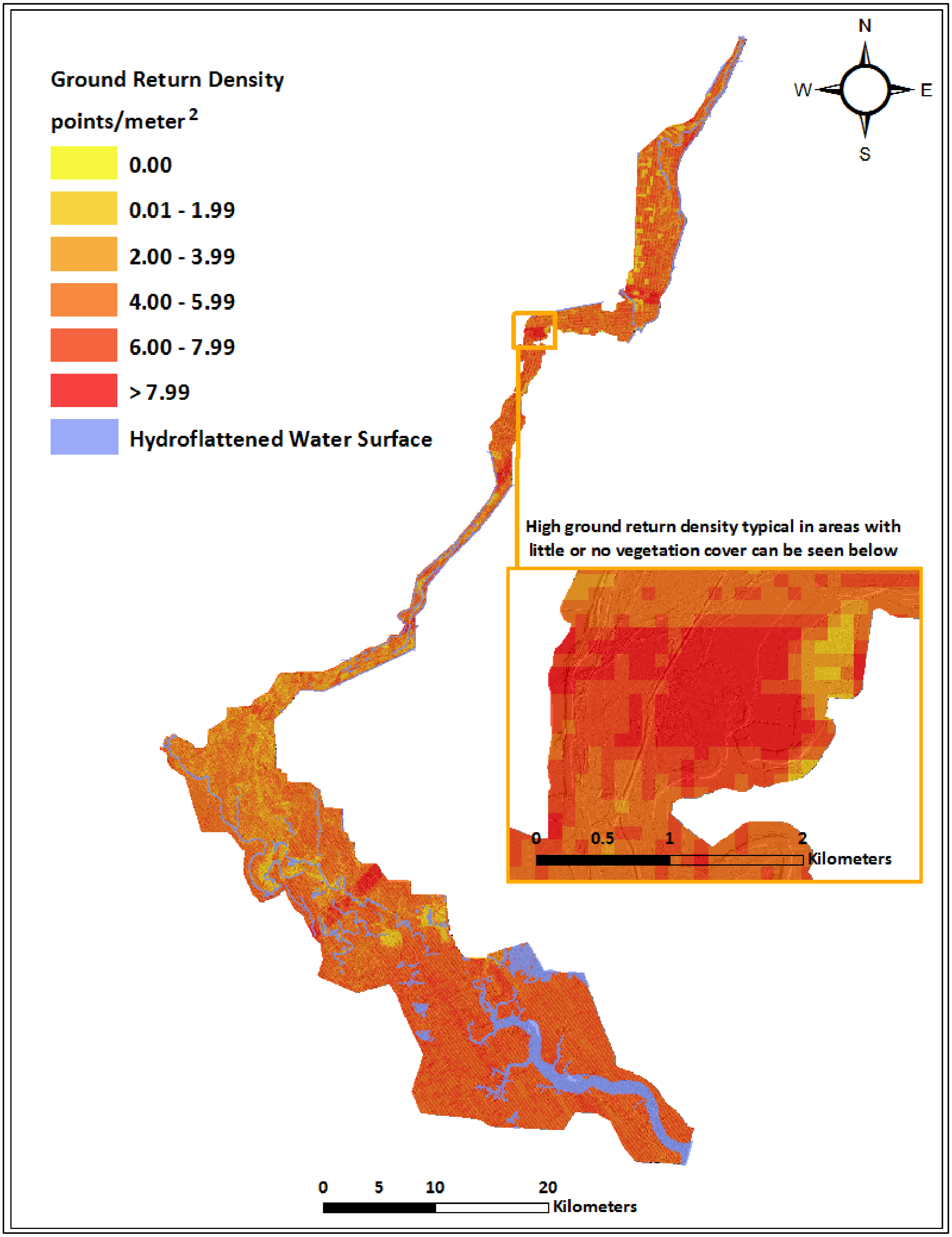


Figure 9: Ground density map for the Colorado River Basin Post-Pulse site (100 m x 100 m cells)

LiDAR Accuracy Assessment

The accuracy of the LiDAR data collection can be described in terms of absolute accuracy (the consistency of the data with external data sources) and relative accuracy (the consistency of the dataset with itself). *Accuracy assessment could only be conducted for data within the United States as ground control quality check points were not collected in Mexico by Geo Castellini*. See Appendix A for further information on sources of error and operational measures used to improve relative accuracy.

LiDAR Fundamental Vertical Accuracy

Fundamental Vertical Accuracy (FVA) compares known real-time kinematic ground control quality check points collected on open, bare earth surfaces with level slope (<20°) to the triangulated ground surface generated by the LiDAR points. FVA is a measure of the accuracy of LiDAR point data in open areas where the LiDAR system has a high probability of measuring the ground surface and is evaluated at the 95% confidence interval (1.96 * RMSE), as shown in Table 10. The required FVA of 18.13 cm was exceeded for this project with a final FVA of 2.5 cm at the 95% confidence interval (Table 10, Figure 10).

Table 10: Absolute accuracy – FVA

Absolute FVA Accuracy	
Sample	141 Points
FVA (1.96*RMSE)	0.084 m
Average	0.025 m
Median	0.026 m
RMSE	0.043 m
Standard Deviation (1σ)	0.068 m

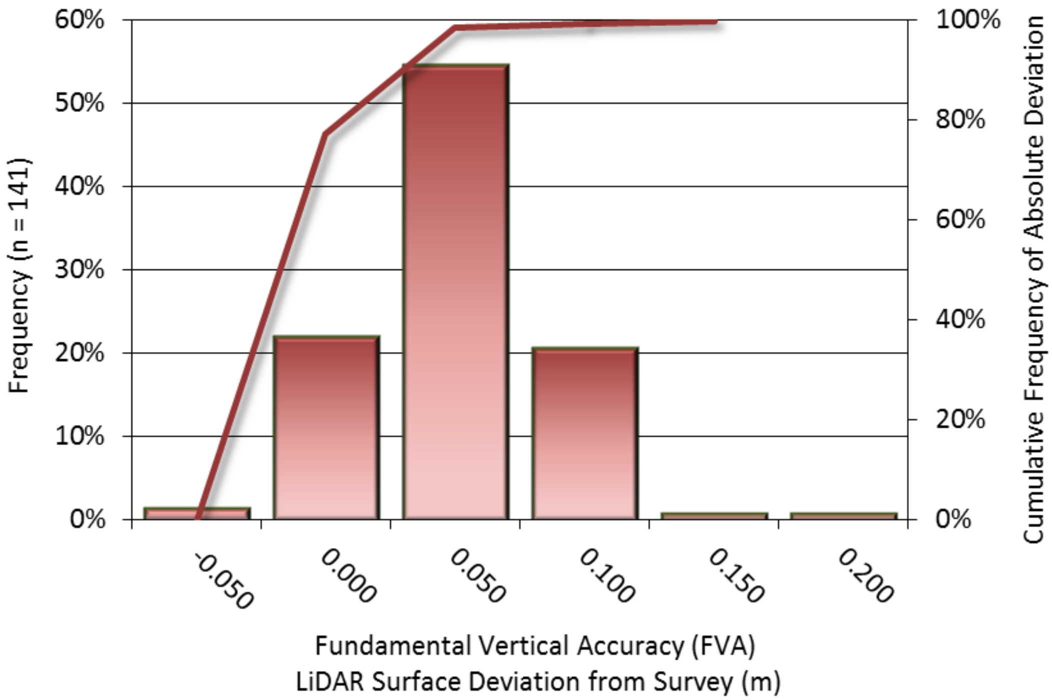


Figure 10: Frequency histogram for LiDAR surface deviation from ground check point values – FVA

LiDAR Supplemental and Consolidated Vertical Accuracies

QSI also assessed absolute vertical accuracy using Supplemental Vertical Accuracy (SVA) and Consolidated Vertical Accuracy (CVA) reporting. SVA compares known ground control quality check point data within individual land cover class categories to the triangulated ground surface generated by the LiDAR points. CVA represents the comparison of all QCPs across all land cover classes to the triangulated ground surface generated by LiDAR points. SVA and CVA are evaluated at the 95th percentile, as shown in Table 11. Frequency histograms for all SVA and CVA accuracies can be seen in Figure 11 through Figure 15.

Table 11: Supplemental and Consolidated Vertical Accuracies

	SVA				CVA
	Bare Earth and Gravel	Shrub and Brushland	Urban	Tall Grass	N/A
Sample	144	76	34	59	329
Average	0.002 m	0.020 m	-0.006 m	0.015 m	0.007 m
Median	-0.003 m	0.016 m	-0.002 m	-0.003 m	0.002 m
RMSE	0.034 m	0.045 m	0.034 m	0.095 m	0.052 m
Standard Deviation (1σ)	0.034 m	0.041 m	0.034 m	0.095 m	0.052 m
95th Percentile	0.063 m	0.093 m	0.059 m	0.232 m	0.075 m

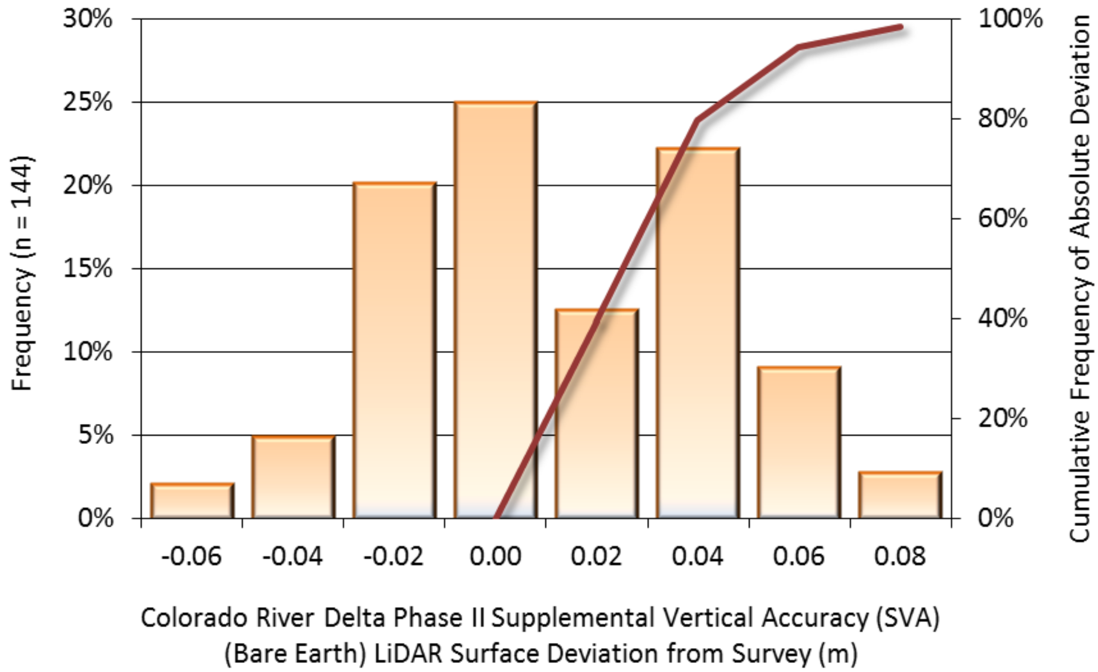


Figure 11: Frequency histogram of LiDAR surface deviation from Bare Earth/Gravel QCP values - SVA

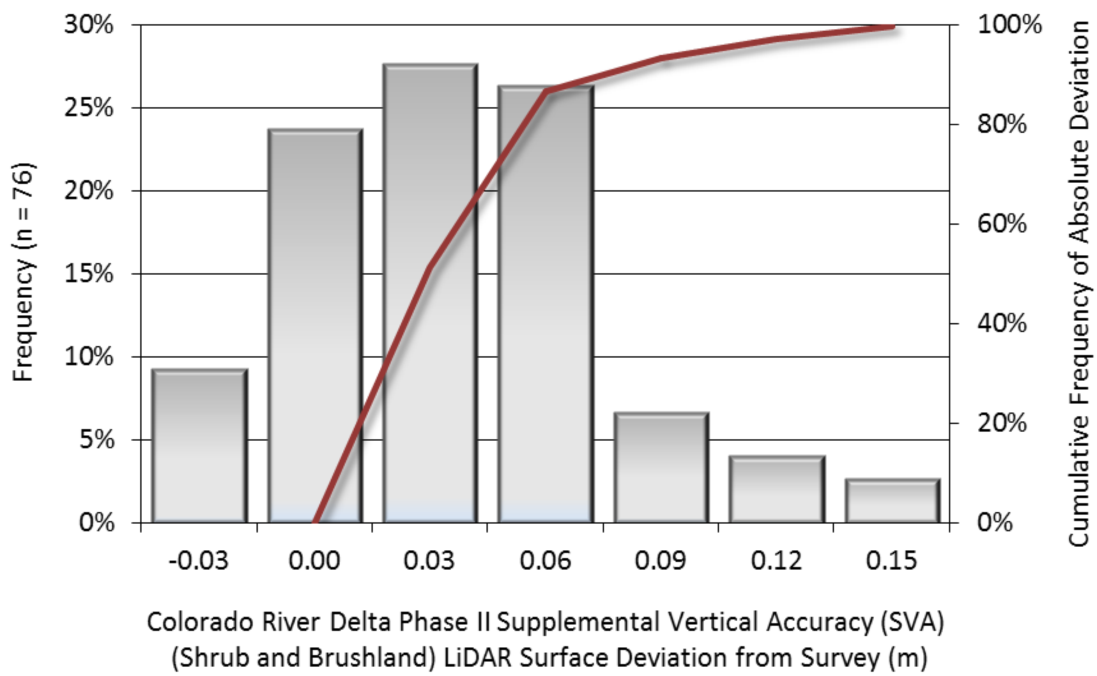


Figure 12: Frequency histogram of LiDAR surface deviation from Shrub and Brushland QCP values - SVA

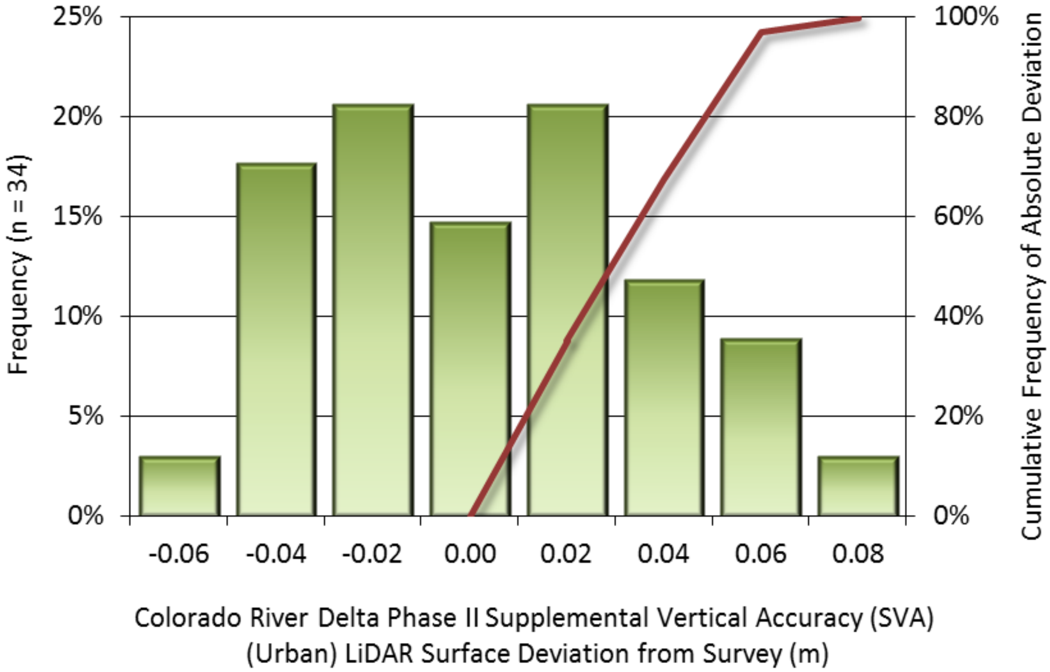


Figure 13: Frequency histogram of LiDAR surface deviation from Urban QCP values - SVA

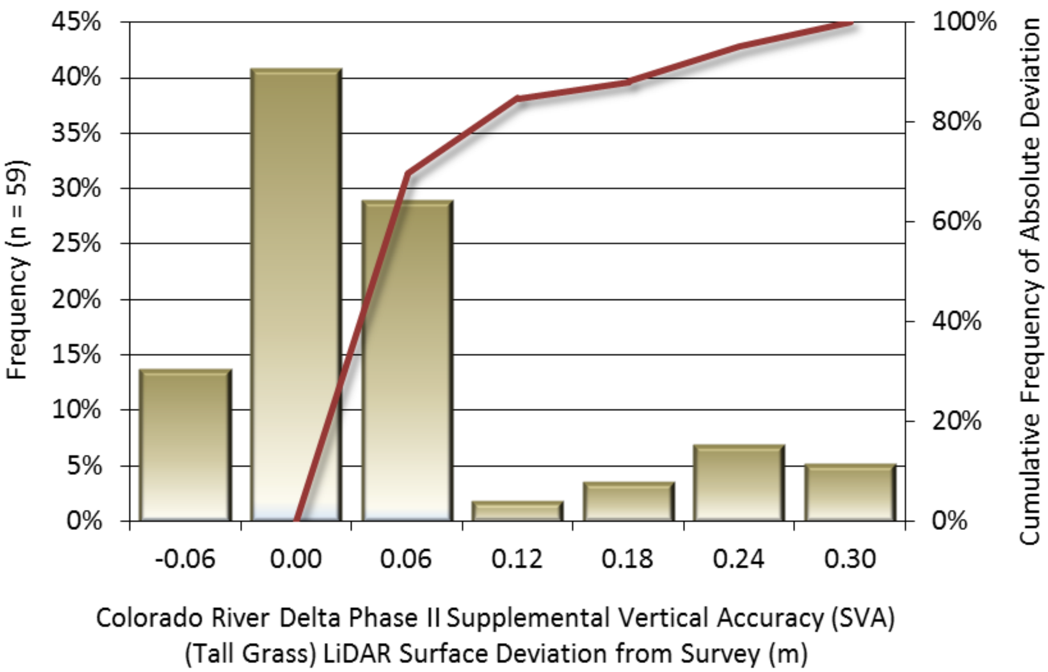


Figure 14: Frequency histograms for LiDAR surface deviation from Tall Grass QCP values – SVA

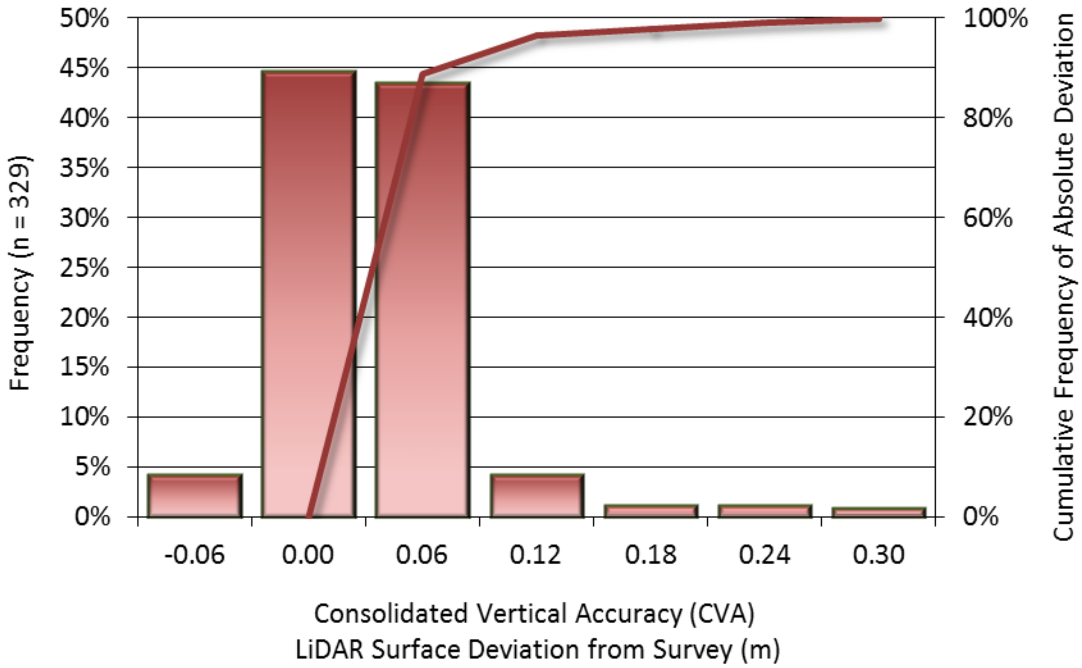


Figure 15: Frequency histogram of LiDAR surface deviation from Land Cover Class QCP values - CVA

LiDAR Vertical Relative Accuracy

Relative vertical accuracy refers to the internal consistency of the data set as a whole: the ability to place an object in the same location given multiple flight lines, GPS conditions, and aircraft attitudes. Relative accuracy was set to comply with ≤5 cm $RMSE_z$ within individual swaths and ≤8 cm $RMSE_z$ between adjacent swaths. When the LiDAR system is well calibrated, the swath-to-swath vertical divergence is low (<0.10 meters). The relative vertical accuracy was computed by comparing the ground surface model of each individual flight line with its neighbors in overlapping regions. The average (mean) line to line relative vertical accuracy for the Colorado River Basin Post-Pulse LiDAR project was 0.031 meters (Table 12, Figure 16).

Table 12: Relative accuracy

Relative Accuracy	
Sample	180 surfaces
Average	0.031 m
Median	0.032 m
RMSE	0.032 m
Standard Deviation (1σ)	0.002 m
1.96σ	0.004 m

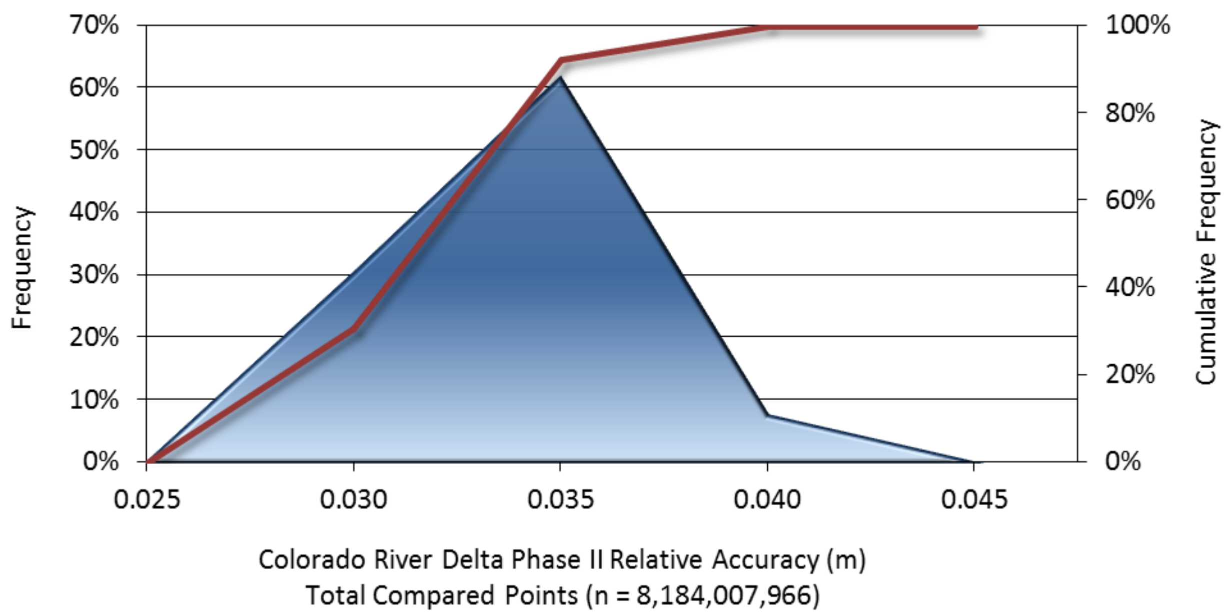


Figure 16: Frequency plot for relative vertical accuracy between flight lines

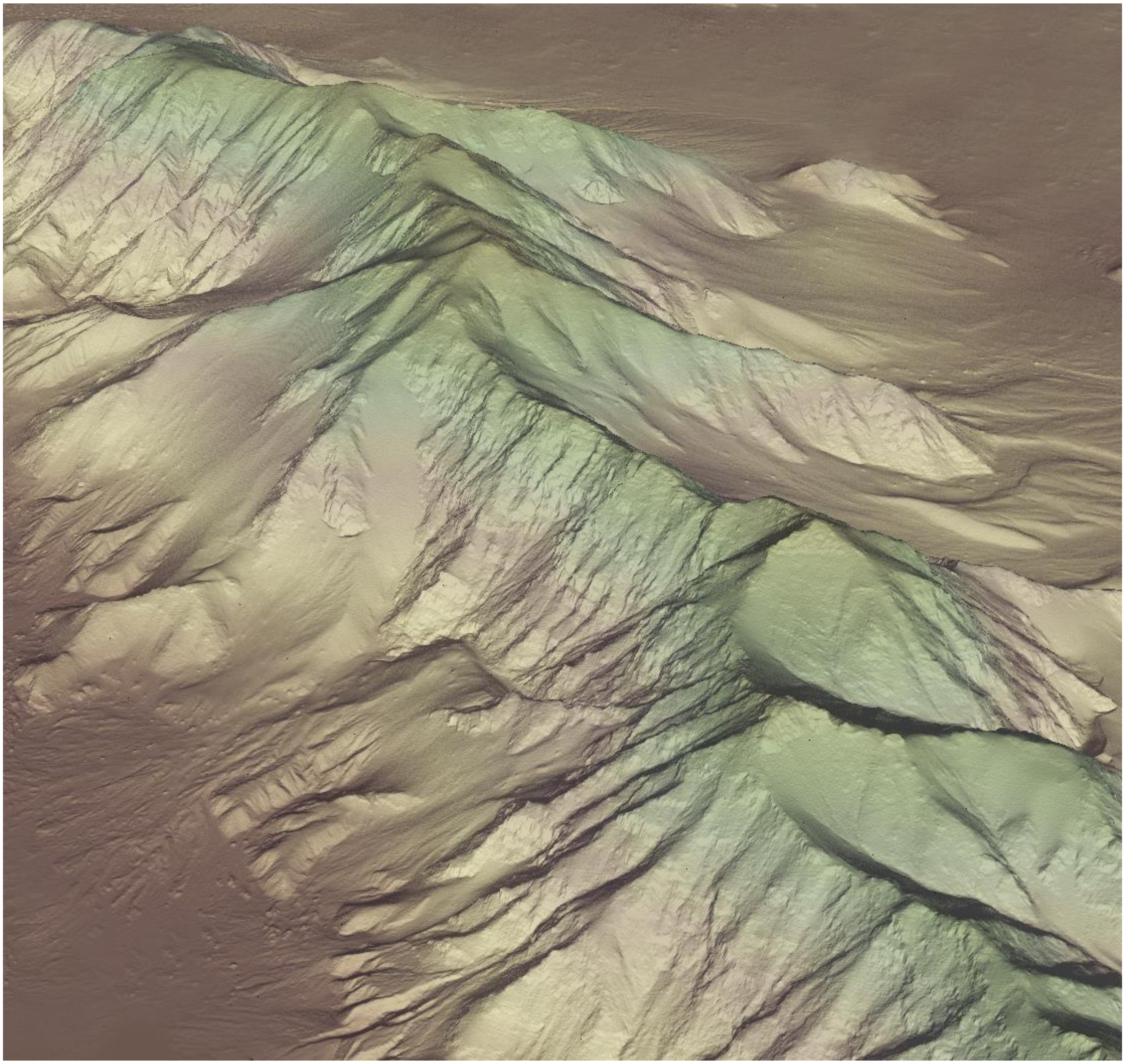


Figure 17: Image looking north-northeast of a mountain range in the Colorado River Basin study area. The image was created from the LiDAR bare earth model colored by elevation.

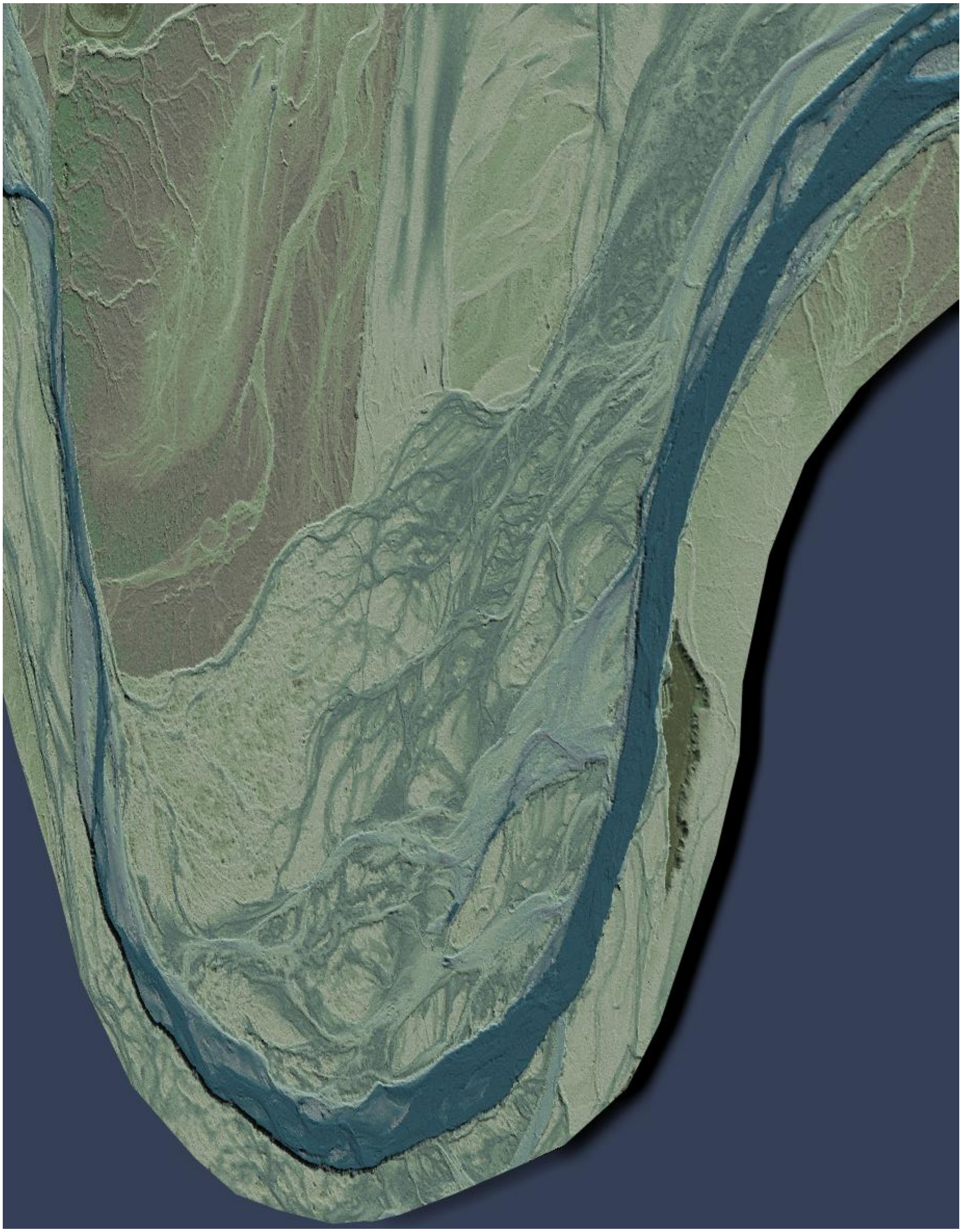


Figure 18: View looking west at the Colorado River, from west of Gadsden. The image was created from the LiDAR bare earth model colored by elevation.

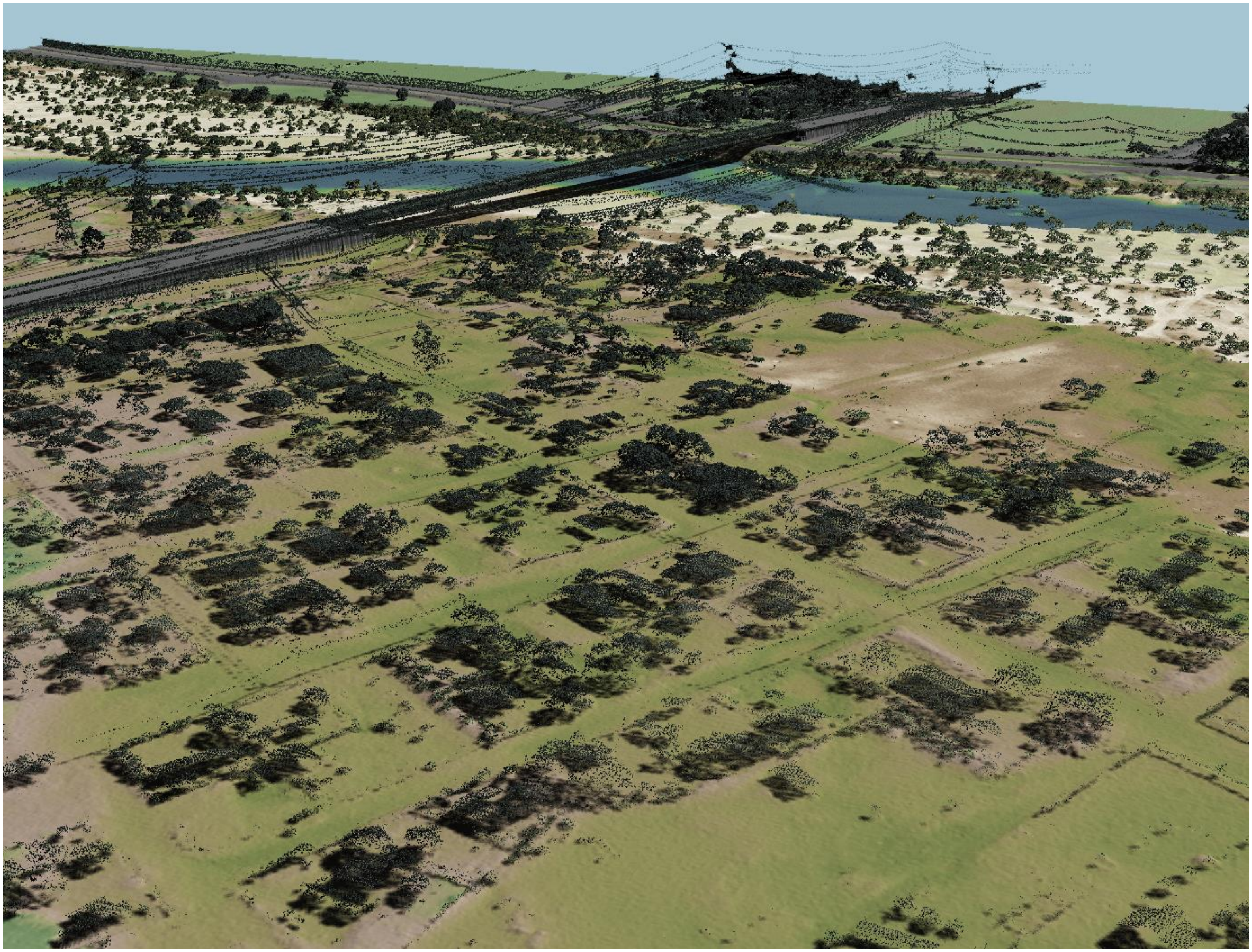


Figure 19: Image shows a view looking northeast over Colonel Migel Aleman. The image was created from the bare earth model colored by elevation, and is overlain with the above-ground LiDAR point cloud.

GLOSSARY

1-sigma (σ) Absolute Deviation: Value for which the data are within one standard deviation (approximately 68th percentile) of a normally distributed data set.

1.96 * RMSE Absolute Deviation: Value for which the data are within two standard deviations (approximately 95th percentile) of a normally distributed data set, based on the FGDC standards for Fundamental Vertical Accuracy (FVA) reporting.

Accuracy: The statistical comparison between known (surveyed) points and laser points. Typically measured as the standard deviation (sigma σ) and root mean square error (RMSE).

> **Absolute Accuracy:** The vertical accuracy of LiDAR data is described as the mean and standard deviation (sigma σ) of divergence of LiDAR point coordinates from ground survey point coordinates. To provide a sense of the model predictive power of the dataset, the root mean square error (RMSE) for vertical accuracy is also provided. These statistics assume the error distributions for x, y and z are normally distributed, and thus we also consider the skew and kurtosis of distributions when evaluating error statistics.
>
> **Relative Accuracy:** Relative accuracy refers to the internal consistency of the data set; i.e., the ability to place a laser point in the same location over multiple flight lines, GPS conditions and aircraft attitudes. Affected by system attitude offsets, scale and GPS/IMU drift, internal consistency is measured as the divergence between points from different flight lines within an overlapping area. Divergence is most apparent when flight lines are opposing. When the LiDAR system is well calibrated, the line-to-line divergence is low (<10 cm).
>
> **Root Mean Square Error (RMSE):** A statistic used to approximate the difference between real-world points and the LiDAR points. It is calculated by squaring all the values, then taking the average of the squares and taking the square root of the average.

Data Density: A common measure of LiDAR resolution, measured as points per square meter.

Digital Elevation Model (DEM): File or database made from laser points, containing elevation points over a contiguous area. Digital terrain models (DTM) and digital surface models (DSM) are types of DEMs. DTMs consist solely of the bare earth surface (ground points), while DSMs include information about all surfaces, including vegetation and man-made structures.

Intensity Values: The peak power ratio of the laser return to the emitted laser, calculated as a function of surface reflectivity.

Nadir: A single point or locus of points on the surface of the earth directly below a sensor as it progresses along its flight line.

Overlap: The area shared between flight lines, typically measured in percent. 100% overlap is essential to ensure complete coverage and reduce laser shadows.

Pulse Rate (PR): The rate at which laser pulses are emitted from the sensor; typically measured in thousands of pulses per second (kHz).

Pulse Returns: For every laser pulse emitted, the number of wave forms (i.e., echos) reflected back to the sensor. Portions of the wave form that return first are the highest element in multi-tiered surfaces such as vegetation. Portions of the wave form that return last are the lowest element in multi-tiered surfaces.

Real-Time Kinematic (RTK) Survey: A type of surveying conducted with a GPS base station deployed over a known monument with a radio connection to a GPS rover. Both the base station and rover receive differential GPS data and the baseline correction is solved between the two. This type of ground survey is accurate to 1.5 cm or less.

Post-Processed Kinematic (PPK) Survey: GPS surveying is conducted with a GPS rover collecting concurrently with a GPS base station set up over a known monument. Differential corrections and precisions for the GNSS baselines are computed and applied after the fact during processing. This type of ground survey is accurate to 1.5 cm or less.

Scan Angle: The angle from nadir to the edge of the scan, measured in degrees. Laser point accuracy typically decreases as scan angles increase.

Native LiDAR Density: The number of pulses emitted by the LiDAR system, commonly expressed as pulses per square meter.

Relative Accuracy Calibration Methodology:

Manual System Calibration: Calibration procedures for each mission require solving geometric relationships that relate measured swath-to-swath deviations to misalignments of system attitude parameters. Corrected scale, pitch, roll and heading offsets were calculated and applied to resolve misalignments. The raw divergence between lines was computed after the manual calibration was completed and reported for each survey area.

Automated Attitude Calibration: All data were tested and calibrated using TerraMatch automated sampling routines. Ground points were classified for each individual flight line and used for line-to-line testing. System misalignment offsets (pitch, roll and heading) and scale were solved for each individual mission and applied to respective mission datasets. The data from each mission were then blended when imported together to form the entire area of interest.

Automated Z Calibration: Ground points per line were used to calculate the vertical divergence between lines caused by vertical GPS drift. Automated Z calibration was the final step employed for relative accuracy calibration.

LiDAR accuracy error sources and solutions:

Type of Error	Source	Post Processing Solution
GPS (Static/Kinematic)	Long Base Lines	None
	Poor Satellite Constellation	None
	Poor Antenna Visibility	Reduce Visibility Mask
Relative Accuracy	Poor System Calibration	Recalibrate IMU and sensor offsets/settings
	Inaccurate System	None
Laser Noise	Poor Laser Timing	None
	Poor Laser Reception	None
	Poor Laser Power	None
	Irregular Laser Shape	None

Operational measures taken to improve relative accuracy:

Low Flight Altitude: Terrain following was employed to maintain a constant above ground level (AGL). Laser horizontal errors are a function of flight altitude above ground (about 1/3000th AGL flight altitude).

Focus Laser Power at narrow beam footprint: A laser return must be received by the system above a power threshold to accurately record a measurement. The strength of the laser return (i.e., intensity) is a function of laser emission power, laser footprint, flight altitude and the reflectivity of the target. While surface reflectivity cannot be controlled, laser power can be increased and low flight altitudes can be maintained.

Reduced Scan Angle: Edge-of-scan data can become inaccurate. The scan angle was reduced to a maximum of ±15^{o} from nadir, creating a narrow swath width and greatly reducing laser shadows from trees and buildings.

Quality GPS: Flights took place during optimal GPS conditions (e.g., 6 or more satellites and PDOP [Position Dilution of Precision] less than 3.0). Before each flight, the PDOP was determined for the survey day. During all flight times, a dual frequency DGPS base station recording at 1 second epochs was utilized and a maximum baseline length between the aircraft and the control points was less than 13 nautical miles at all times.

Ground Survey: Ground survey point accuracy (<1.5 cm RMSE) occurs during optimal PDOP ranges and targets a minimal baseline distance of 4 miles between GPS rover and base. Robust statistics are, in part, a function of sample size (n) and distribution. Ground survey points are distributed to the extent possible throughout multiple flight lines and across the survey area.

50% Side-Lap (100% Overlap): Overlapping areas are optimized for relative accuracy testing. Laser shadowing is minimized to help increase target acquisition from multiple scan angles. Ideally, with a 50% side-lap, the nadir portion of one flight line coincides with the swath edge portion of overlapping flight lines. A minimum of 50% side-lap with terrain-followed acquisition prevents data gaps.

Opposing Flight Lines: All overlapping flight lines have opposing directions. Pitch, roll and heading errors are amplified by a factor of two relative to the adjacent flight line(s), making misalignments easier to detect and resolve.

APPENDIX B - GEO CASTELLINI GROUND SURVEY REPORT

GEO CASTELLINI

ING. YALEXY GUERRA CASTELLINI
ING. FOTO-TOPÓGRAFO

INFORME TECNICO

MEXICALI, BC. MEXICO
AUGOST DE 2014

PROYECTO

COLORADO RIVER BASIN
CONTROL TERRESTRE
GPS
II ETAPA

Calle Baralla #169 Fracc Villa Lomas Altas 3ra secc cp 21355, Mexicali, B. C., Tel cel. (686) 1575830
RFC: GUCY 691012H30 Correo electrónico: yale1213@yahoo.com.mx

RESUMEN

Se efectuó principalmente la medicion de Puntos de Control Geodésico en el Municipio de Mexicali, B.C. especificamente en la zona Agricola del Valle de Mexicali en los margenes del Delta del Rio Colorado, con equipo Gps Marca Topcon Modelo GR3 de doble frecuencia, midiendose 5 vértices **"CRB"** de Control, inominados **CRB01, CRB02, CRB03 Y EL CRB04** de nueva creacion **.**

Se realizaron mediciones estaticas a intervalos de gravacion a 1", realizando varias sesiones en cada uno de ellos en diverso dias por varias horas de medicion. Se efectuo tambien la medicion de diversos puntos de control en tiepo real (RTK) inominados **"GCP"** a partir de de los 4 puntos antes mencionados, tomando como referencia inicial las coordenadas absolutas de estos puntos para posteriormente re-calcular sus coordenadas finales .

Los trabajos consistieron en la localizacion, Monumentacion y medicion en campo del punto de control CRB 04, en base a las coordenadas aproximadas que nos fueron proporcionadas por Quantum Spacial .

El procedimiento general fue el siguiente:

a).- Obtencion de la informacion (Coordenadas Aproximadas) de los puntos de interes.

b).- Localizacion de los puntos de interes a Monumentar.

c).- Monumentacion de cada uno de los puntos conforme a lo solicitado (Monumento de concreto con Placa de aluminio)

d).- Medicion en campo de cada uno de los puntos de interes.

e).- Envio diario de los datos crudos via internet para su analisis y/o revicion.

e).- Recepcion de las Coordenadas definitivas de los 4 puntos de control base **"CRB"**.

f).- A partir de las coordenadas Definitivas de los 4 puntos de control Base **"CRB"**, se Re-calculo las coordenadas de los puntos **"GCP"**

g).- Elaboracion del Informe.

OBJETIVO GENERAL:

Proporcionar apoyo terrestre en base a mediciones Satelitales utilizando Equipos GPS de doble frecuencia con doble constelación (Glonass /Navstar) a intervalos de grabación de 1 Hertz (1 Segundo), Sobre 4 monumentos de concreto elaborados, lo anterior para la obtención de mediciones y/o imágenes LIDAR realizadas en la zona conocida como valle de Mexicali y/o delta del rio colorado.

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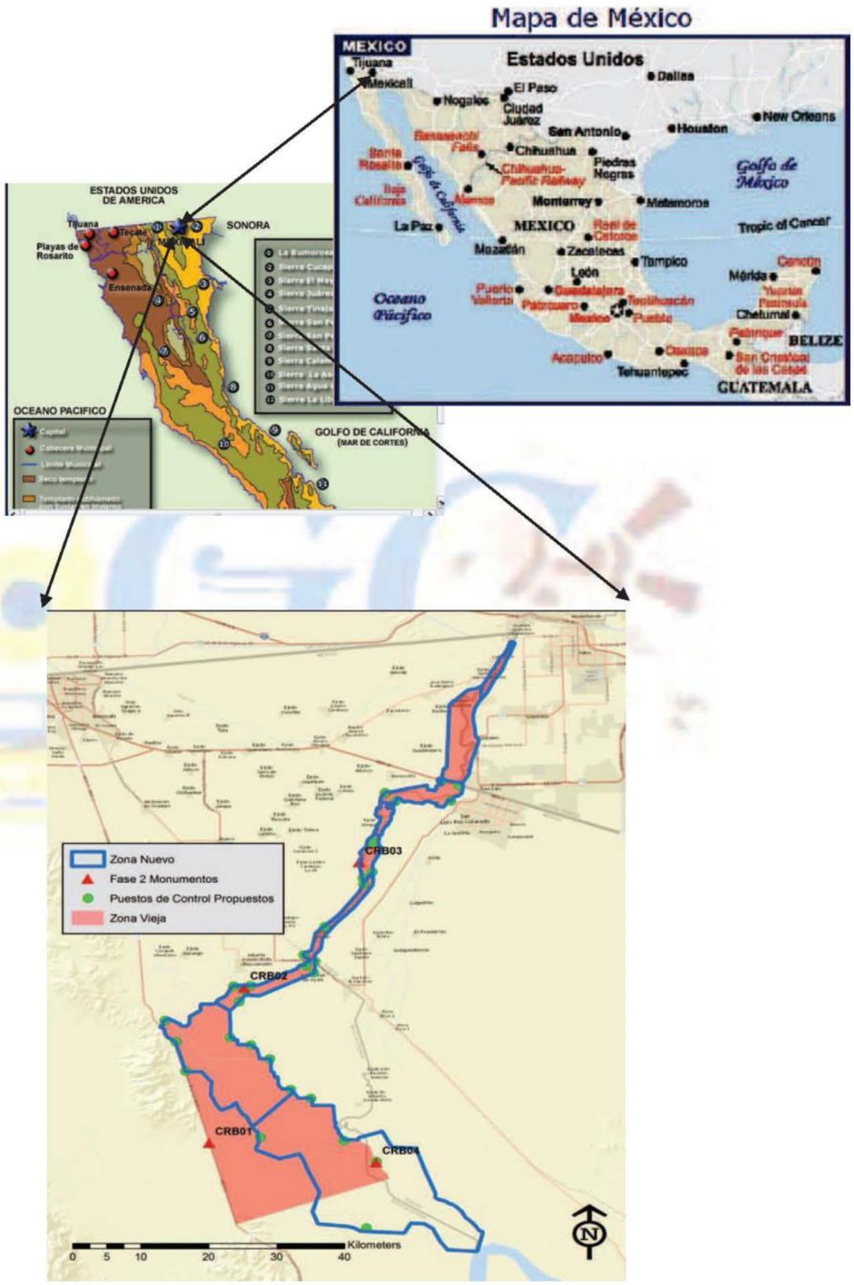
LOCALIZACION DE LA ZONA DE ESTUDIO:



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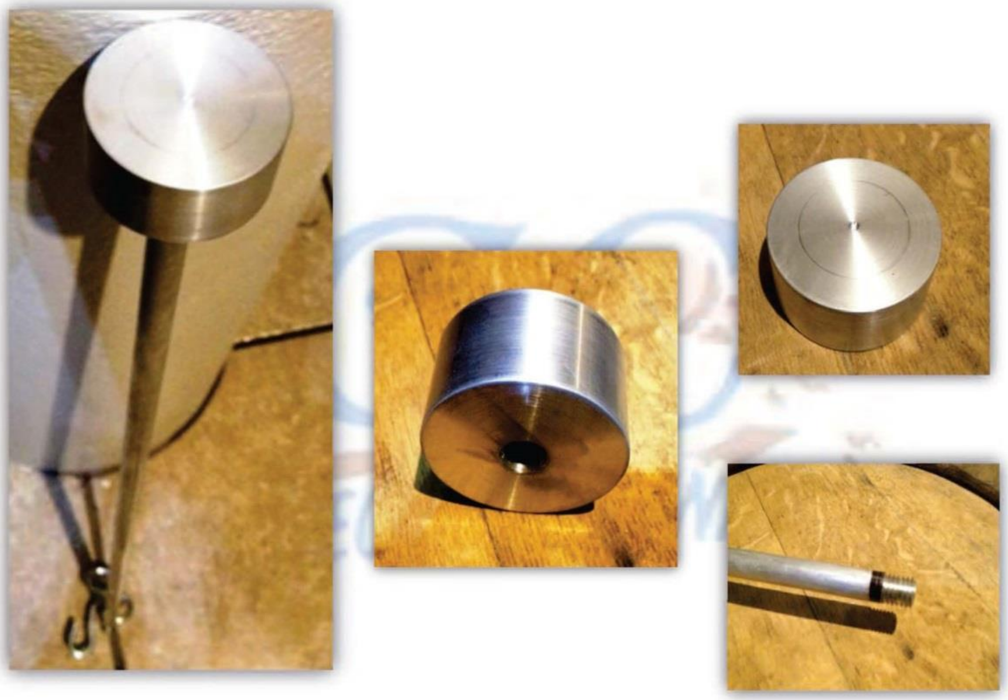
ING. FOTO-TOPÓGRAFO

TRABAJOS REALIZADOS

MONUMENTACION:

Antes de realizar las mediciones se elaboraron 4 mojoneras de control , con vástago de 40 cm de largo y placa de aluminio con diámetro de 2" y con 2" de espesor de forma piramidal dejando en la mayoría de ellas 5 cm sobre el terreno natural., la ubicación de estas fue lo mas próximo a las coordenadas que nos fueron proporcionadas, los criterios para la ubicación de cada una de ellas fue la de garantizar su permanencia, sitio más alto y menor obstrucción en un Angulo de 15 grados sobre el horizonte , alrededor del punto.

Fotos de la PLACA:



Fotos 1,2 3 y 4 fotos de composiciond ela palca de la mojonera

Fotos de los sitios al momento de la monumentacion:

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CRB04

Fotos 5,6 y7. Construcción del monumento CRB04

MEDICION:

Puntos de Control (CRB)
Para la realización de los trabajos de medición se utilizo un equipos GPS Marca Topcon, Modelo GR3 de Doble Frecuencia y Doble Constelación, con tripie de Madera, Para el centrado y Nivelación del mismo se aplico el criterio de medir 3 veces la altura del receptor del centro del punto a tres esquinas diferentes del receptor en forma inclinada, anotándolo en una hoja y/o cedula de campo , su diferencia no debería ser mayor a un milímetro, la altura final se considero la promediada.
Para garantizar su estabilidad durante el periodo largo de medición se reforzó cada uno de las patas del tripie ya sea con bolsas rellenas con arena o bien con rocas pesadas, colocadas de tal forma que minimizaran al máximo el empuje que ejercen los vientos en la zona.
Para e l suministro de la energía del equipo se utilizo una batería externa de tal forma que garantizara la energía durante todo el periodo de la medición.

Puntos de control del Terreno (GCP)
Para la realización de los trabajos de medición se utilizo un equipos GPS Marca Topcon, Modelo GR3 de Doble Frecuencia y Doble Constelación se utilizo un bipode con una baliza con una altura de 2.00 mas un adaptador (Quik adapter) con una altura de 0.04 mts lo que nos resulta una altura total (Vertical) de 2.04 mts.
Para la medición de estos puntos se utilizaron la técnicas de medición de RTK (Real Time Kinematic) , se tomo como punto de referencia base "CRB" la mas cercana que se localizara a cada uno de los puntos "GCP" a medir, en algunos sitios solicitados (GCP) se midio más de un punto que se considero como de interes como mojoneras existentes.

Se anexan Cedulas de levantamiento de cada uno de los puntos medidos en modo estatico.

Fotos de los sitios al momento de la medicion:

CRB4

Fotos 8 y 9. M$edicion modo Estatico CRB04

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Foto 10.M edicicon modo estatico CRB04

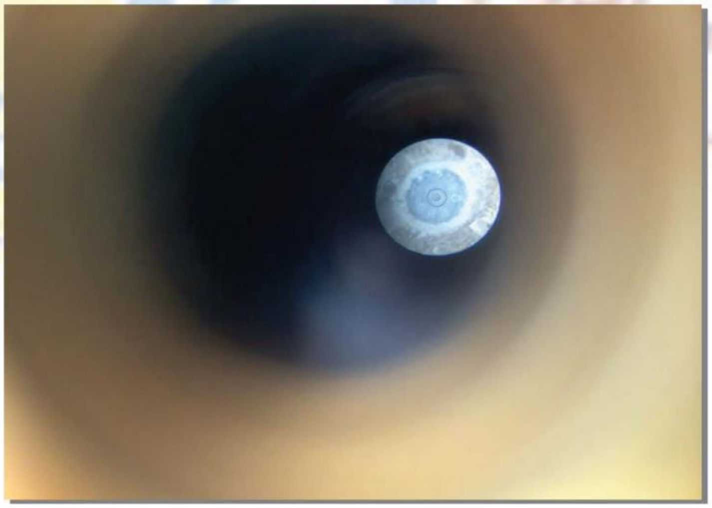

Foto 11. Centrado del equipo de medicion

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CRB2

Fotos 12 y 13medicion modo Estatico GRB02

CRB01

Foto 14y 15 . Medicion modo Estatico CRB01

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CRB3

Fotos 16 y 17. *Medicion modo Estatico CRB03*

CALCULOS:

Para Re- Calcular las coordenadas de los puntos "GCP" de la información se empleo el programa Propio del Equipo (Libreta Tesla) llamado Magnet Field.
Se considero para cada uno de los puntos bases las coordenadas Finales Recibidas por Sonora Institute, mismas que fueron ingresadas a la libreta modificando las coordenadas iniciales (Absolutas) por estas ultimas, de lo anterior el programa y/o libreta recalculo las posiciones de cada uno de los puntos medidos.

RESULTADOS

RESUMEN DE LEVANTAMIENTO

DIA JULIANO	FECHA	HORA INICIO	HORA FINAL	HORAS MEDIDAS
213	01-AGOSTO-2014*	8:07	5:51	9:44
214	02-AGOSTO-2014	7:45	3:45	8:00
215	03-AGOSTO-2014*	7:46	13:02	5:16
216	04-AGOSTO-2014*	7:55	4:13	8:18
217	05-AGOSTO-2014*	7:59	3:57	7:58
218	06-AGOSTO-2014*	7:52	14:28	6:35
218	06- AGOSTO-2014*	3:50	5:54	2:04
219	07-AGOSTO-2020*	8:40	3:39	6:59
220	08-AGOSTO-2021*	13:27	20:01	6:34
TOTAL HORAS				62:28:00

*.- Senala el dia en que se efectuo la medicion con RTK de los puntos "GCP"

GEO CASTELLINI

ING. YALEXY GUERRA CASTELLINI
ING. FOTO-TOPÓGRAFO

COORDENADAS DE PUNTOS **GCP**
REFERNCIADOS A LAS COORDENADAS DEFINITIVAS DE LOS PUNTOS CRB

ID	X	Y	ELIP
GCP01	705095.929	3597290.684	-8.127
GCP02	702553.808	3598154.477	-4.099
GCP02A	702538.232	3598103.383	-5.293
GCP03	694214.462	3596155.806	-7.992
GCP04	703923.668	3594811.226	-5.305
GCP04A	703924.957	3594853.512	-6.982
GCP05	695761.195	3594774.613	-9.699
GCP05A	695780.619	3594753.666	-9.816
GCP06	692495.003	3587997.495	-18.263
GCP07	692306.795	3583159.938	-14.942
GCP07A	692321.881	3583158.788	-13.595
GCP08	690922.235	3582190.006	-15.779
GCP08A	690950.279	3582190.006	-15.295
GCP09	691033.599	3581116.804	-16.083
GCP09A	691072.097	3581116.890	-15.165
GCP 10	685312.280	3574182.724	-16.687
GCP11	682291.490	3569537.844	-19.514
GCP12	683909.289	3568428.994	-18.808
GCP12A	683887.082	3568430.358	-19.149
GCP13	682515.000	3567734.640	-18.385
GCP13A	682513.730	3567751.131	-19.156
GCP14	683670.330	3566584.117	-19.424
GCP15	674379.031	3564452.210	-23.758
GCP15A	674368.064	3564461.822	-25.884
GCP15B	674363.763	3564443.011	-21.663
GCP16	673526.103	3563786.352	-23.888
GCP17	672675.466	3561851.623	-24.222
GCP17A	672766.479	3561953.783	-24.638
GCP18	671909.873	3564341.446	-22.676
GCP18A	671871.239	3564359.454	-25.75
GCP19	671394.888	3555919.924	-28.462
GCP19A	671372.221	3555919.835	-26.078
GCP19B	671349.792	3555907.562	-28.166
GCP20	661832.493	3558725.550	-26.093
GCP21	663408.207	3555213.263	-26.153
GCP22	664866.302	3550421.827	-26.306
GCP23	674439.263	3554667.392	-27.434
GCP23A	674437.076	3554700.926	-29.904
GCP23B	674439.948	3554653.341	-29.957
GCP24	677224.443	3552385.363	-28.579
GCP24A	677224.919	3552405.189	-30.914
GCP24B	677224.937	3552368.652	-30.829
GCP25	680327.356	3547408.289	-29.171
GCP25A	680329.549	3547419.787	-31.126
GCP25B	680322.498	3547396.454	-30.404

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GCP26	683286.397	3545904.727	-29.373
GCP26A	683287.016	3545915.273	-31.624
GCP26B	683286.361	3545889.340	-31.268
GCP27	688127.895	3538985.915	-29.494
GCP28	692620.714	3536206.503	-31.053
GCP28A	692591.050	3536248.197	-31.484
GCP29	676254.057	3539500.947	-30.9
GCP30	688456.845	3523972.884	-31.255

ANEXOS..

CEDULAS DE LOS PUNTOS MEDIDOS.

Agradeciendo de antemano la atención a la presente, quedo de usted.

Ing. Yalexy Guerra Castellini

GEO CASTELLINI
ING. YALEXY GUERRA CASTELLINI
ING. FOTO-TOPÓGRAFO

CEDULA DE LEVANTAMIENTO / RECORD FIELD SURVEY

PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 04**

Fecha/ Date: 01/ Agosto - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 8:07 Tiempo Local /Time Local **Hora Final / Final Hour:** 17: 51 Tiempo Local /Time Local
Hora de inicio / Time Began: 4: 07 UTC (+ 8 Hrs) **Hora Final / Final Hour:** 01:51 UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 31° 56' 37.26" Aprox.
(WGS84) LON . W 114° 57 ' 40.181" Aprox

ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.591 mts.**

Segunda Lectura/ Second Reading: **1.592 mts.**

Tercera Lectura / Third Reading: **1.592mts.**

Promedio / Average: **1.5233 mts.**

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen

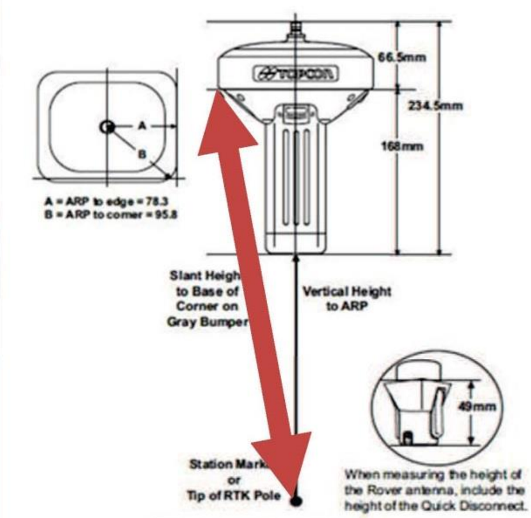


Figure 4-3. Antenna Offset Measurements

- SHMM to ARP vertical offset = 168mm
- SHMM to ARP radius = 78.3mm to side; 95.8mm to corner

Table 4-1 gives the offset values for the receivers.

Table 4-1. Offset Values for GR-3 Receiver

	ARP To L1 Phase Center	ARP To L2 Phase Center
Up	228.8 MM.	216.3 MM.

Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

Blv. Lázaro Cárdenas Esq. con Gómez Morín Mexicali, B. C., Tel cel. (686) 1575830
RFC: GUCY 691012H30 Correo electrónico: yale1213@yahoo.com.mx

GEO CASTELLINI
ING. YALEXY GUERRA CASTELLINI
ING. FOTO-TOPÓGRAFO

CEDULA DE LEVANTAMIENTO / RECORD FIELD SURVEY

PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 04**

Fecha/ Date: 03/ Agosto - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 7:46 Tiempo Local /Time Local **Hora Final / Final Hour:** 14: 25 Tiempo Local /Time Local
Hora de inicio / Time Began: 3: 46UTC (+ 8 Hrs) **Hora Final / Final Hour:** 22:25 UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 31° 56' 37.26" Aprox.
(WGS84) LON . W 114° 57 ' 40.181" Aprox

ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.547mts.**

Segunda Lectura/ Second Reading: **1.547 mts.**

Tercera Lectura / Third Reading: **1.548mts.**

Promedio / Average: **1.5473 mts.**

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen

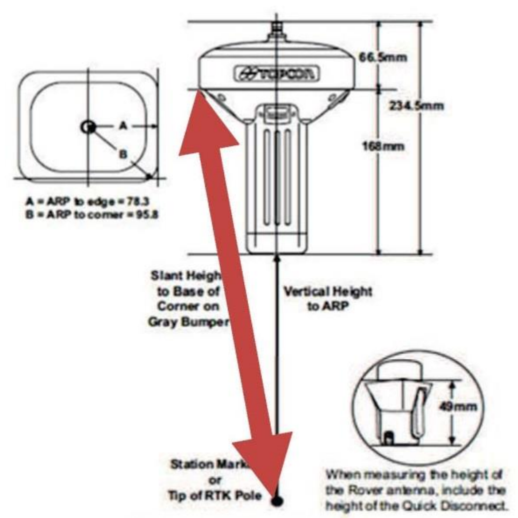


Figure 4-3. Antenna Offset Measurements

- SHMM to ARP vertical offset = 168mm
- SHMM to ARP radius = 78.3mm to side; 95.8mm to corner

Table 4-1 gives the offset values for the receivers.

Table 4-1. Offset Values for GR-3 Receiver

	ARP To L1 Phase Center	ARP To L2 Phase Center
Up	228.8 MM.	216.3 MM.

Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

Blv. Lázaro Cárdenas Esq. con Gómez Morín Mexicali, B. C., Tel cel. (686) 1575830
RFC: GUCY 691012H30 Correo electrónico: yale1213@yahoo.com.mx

GEO CASTELLINI

ING. YALEXY GUERRA CASTELLINI
ING. FOTO-TOPÓGRAFO

CEDULA DE LEVANTAMIENTO / RECORD FIELD SURVEY

PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 04**

Fecha/ Date: 04/ Agosto - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 7:55 Tiempo Local /Time Local **Hora Final / Final Hour:** 16: 14Tiempo Local /Time Local
Hora de inicio / Time Began: 15: 55 UTC (+ 8 Hrs) **Hora Final / Final Hour:** 24:14 UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 31° 56' 37.26" Aprox.
(WGS84)
LON . W 114° 57 ' 40.181" Aprox

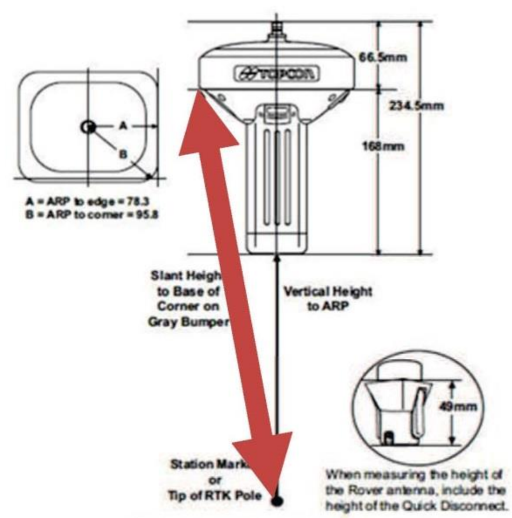
ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.650mts.**

Segunda Lectura/ Second Reading: **1. 650 mts.**

Tercera Lectura / Third Reading: **1. 650mts.**

Promedio / Average: **1.650 mts.**



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Up	228.8 MM.	216.3 MM.

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen

Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

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CEDULA DE LEVANTAMIENTO / RECORD FIELD SURVEY

PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 02**

Fecha/ Date: 05/ Agosto - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 7:59Tiempo Local /Time Local **Hora Final / Final Hour:** 15: 57Tiempo Local /Time Local
Hora de inicio / Time Began: 16: 59 UTC (+ 8 Hrs) **Hora Final / Final Hour:** 24:57UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 32° 12' 01.53005"
(WGS84)
LON . W 115° 09 ' 31.88033"

ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.351mts.**

Segunda Lectura/ Second Reading: **1. 351 mts.**

Tercera Lectura / Third Reading: **1. 349mts.**

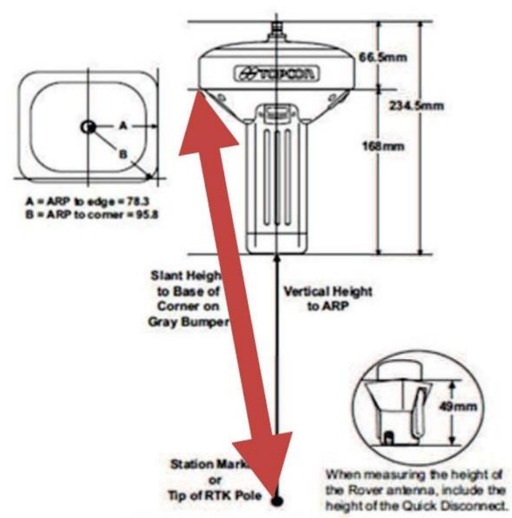
Promedio / Average: **1.3503 mts.**

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen



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Up	228.8 MM.	216.3 MM.

Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

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PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 02**

Fecha/ Date: 6 - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 7:52 Tiempo Local /Time Local **Hora Final / Final Hour:** 14: 28 Tiempo Local /Time Local
Hora de inicio / Time Began: 15: 52 UTC (+ 8 Hrs) **Hora Final / Final Hour:** 22:28 UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 32° 12' 01.53005"
(WGS84) LON . W 115° 09 ' 31.88033"

ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.452mts.**

Segunda Lectura/ Second Reading: **1. 450mts.**

Tercera Lectura / Third Reading: **1. 451mts.**

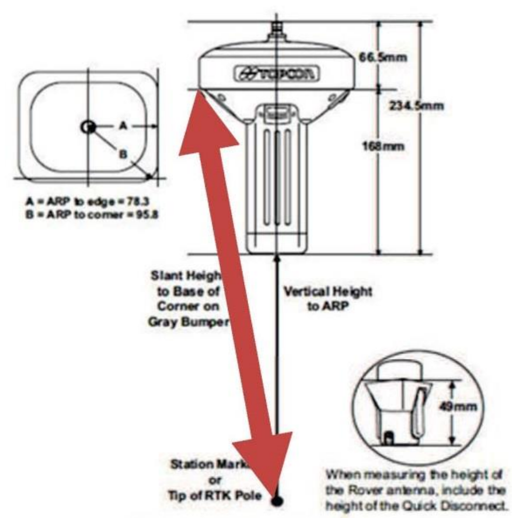
Promedio / Average: **1.451 mts.**

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen



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Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

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PROYECTO/ PROYECT
CUENCA DEL RIO COLORADO / COLORADO RIVER BASIN

NOMBRE DEL PUNTO / POINT NAME: **CRB 03**

Fecha/ Date: 6 - August / 2014
Lugar / Place: Valle de Mexicali
Municipio/ Municipality: Mexicali
Estado / Estate: Baja California
País / County: México

Hora de inicio / Time Began: 3:50 Tiempo Local /Time Local **Hora Final / Final Hour:** 17: 54 Tiempo Local /Time Local
Hora de inicio / Time Began: 11: 50 UTC (+ 8 Hrs) **Hora Final / Final Hour:** 25:54 UTC (+ 8 Hrs)

Coordenadas del Punto/ Point Coordinates : LAT . N 32° 23' 00.16894"
(WGS84) LON . W 114° 58 ' 31.83067"

ALTURA DE LA ANTENA (Distancia Inclinada) / ANTENNS HEIGH (Slope distance):

Primer Lectra / First Reading: **1.528mts.**

Segunda Lectura/ Second Reading: **1. 529mts.**

Tercera Lectura / Third Reading: **1. 529 mts.**

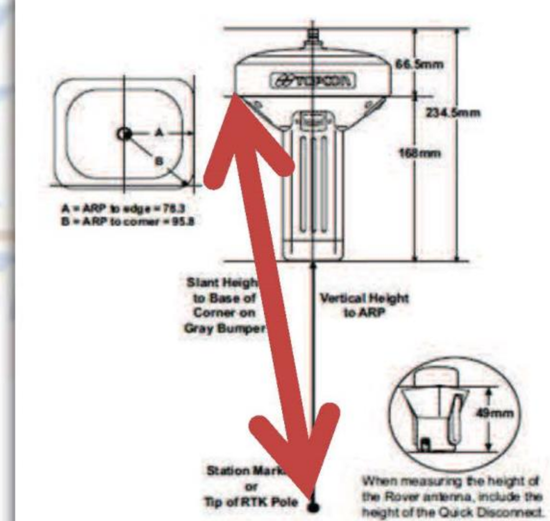
Promedio / Average: **1.5286 mts.**

OBSERVACIONES OBSERVATIONS:

Las alturas del aparto se tomaron a tres puntos alrededor del equipo.

OBSERVATIONS OBSERVATIONS:

Receiver heights were taken at three points around the equipmen



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Levanto / Measured: Ing. Yalexi Guerra / Ing. Raúl Ochoa
Receptor GPS Utilizado / GPS Receiver Used: TOPCON - GR3 (RTK, L1, L2, Glonass , Navstar) **S/N: 444-0810**

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