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A Tale of Two Airborne LiDAR Scanners—Lower Colorado River Basin Survey

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In January 2016, a team of Bureau of Economic Geology (BEG) researchers and Surveying And Mapping, LLC (SAM) staff mobilized to Parker, Arizona, from Austin, Texas, to conduct airborne LiDAR surveys in the lower Colorado River basin, between the states of California and Arizona. The purpose of these surveys was to acquire aerial imagery and airborne LiDAR data to build digital orthophotography and a topographical map that meets the U.S. national mapping accuracy standard of 30 cm. Because two separate airborne LiDAR systems were involved in this project, bathymetric and topographic LiDAR data sets had to be merged in order to develop a seamless elevation map that included the bottom of the river.

The end products were intended to facilitate understanding of the basin geomorphology. The Colorado River, classified as the most endangered river in the United States in 2015, runs through seven states and Mexico, providing water for nearly 40 million people and irrigating close to 2 million hectares of land before it drains into the Sea of Cortez. However, water flow is expected to be reduced by 10 to 30 percent by 2050. Warmer weather, less snowfall, and more than 100 dams built into the river's path have placed significant stress on its ecosystem, impacting fish and wildlife habitat as well as the river's $26 billion recreational economy.

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The airborne surveys were planned to cover approximately 180 km of the river area, with varying terrain altitude, water clarity, depth, and flow conditions. The project was administered by Allied GIS of Anchorage, Alaska, and data acquisition was carried out using two aircraft: one equipped with a sensor specifically designed to collect bathymetric data and the other to collect topographic data. The bathymetric component of the survey was conducted using the Leica AHAB Chiroptera I airborne LiDAR system. BEG researchers installed the system in a Partenavia P.68 aircraft, owned and operated by Aspen Helicopters of Oxnard, California, and completed initial calibration flights locally before mobilizing to Parker, Arizona.

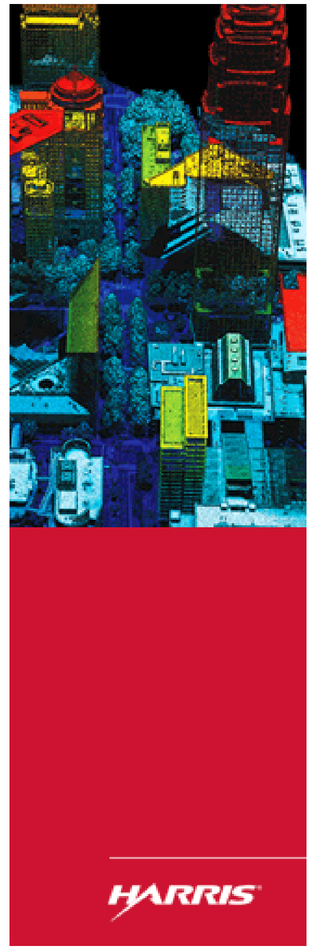
AHAB Chiroptera has two independent scanners: a red channel (nearinfrared) for topographic ("topo") and a green channel for bathymetric ("hydro") data collection. The effective range is 400 m for the hydro scanner, which records information with a repetition rate of 35 kHz sampled from waveform information. Because the system is designed to acquire data concurrently with both scanners, it is possible to conduct surveys in complex landscapes with shallow water bodies (e.g., lakes, rivers, shorelines), where land/water boundaries can only be detected using a red-wavelength scanner. During the data acquisition stage, both of these scanners were used simultaneously to map the water surface, water bottom, and immediate shoreline. In the Havasu section, because of the higher mountain peaks near the Parker Dam area, four separate missions were completed, with short flight lines for safe aircraft maneuvering. Weather conditions in the survey location were mostly ideal, and the entire hydro survey of 133 flight lines covering an area of 213 km2 was completed in 21 hours of airborne time.

SAM operated a Trimble Harrier 68i airborne LiDAR system with a red-wavelength scanner. The system was installed in a Cessna 206 aircraft in Topeka, Kansas, where it was staged. Topo LiDAR data surrounding the river was collected at 400 kHz at a flight altitude of 550 m, with 106 linear flight lines. A total of 6,200 images were acquired with a 7-cm ground-sampling density, with 60% overlapping in the forward direction of the aircraft. We collected and processed nearly 3 TB of raw hydro data, 2 TB of raw topo data, and 0.5 TB of aerial imagery throughout the entire survey.

Special considerations were made to ensure the compatibility of data sets acquired by separate scanners. The Parker airport (Avi Suquilla) runway was precisely surveyed by SAM to align LiDAR returns from both systems with absolute ground level, as well as with each other. We calculated the goodness of fit between all scanners--Chiroptera hydro, Chiroptera topo, and Trimble topo. The results were impressive: for all returns computed, the standard deviation was less than 2 cm in the vertical space, and the R-square was 0.9991 (a perfect result would be 1), enabling a seamless integration of all data sets with each other.

We held various discussions with the Parker Dam authority on scheduling the hydro survey to coincide with the low discharge rates from the dam, which is the deepest of its kind in the world. The mean daily discharge rate was 85 to 125 m3/sec during the field mission, which was much lower compared to rates in other months. Reduced discharge rates enabled a shallower water column--especially in the Havasu section, where the river runs deep--and possibly contributed to lower turbidity levels. Of all challenges for airborne hydro surveys, turbidity is significant because it will absorb light beams and prevent them from penetrating into the water column. Therefore, when we measured water clarity across the river, we were pleased to find very low levels of particles in the deeper northern section. In the south, however, the river was much shallower and had high turbidity levels, possibly caused by a combination of lower water levels, heavy agricultural intake, and dustier environments. In our experience, ideal turbidity levels for airborne LiDAR hydro surveys should be less than 1 NTU. Light beams easily penetrated into the clear waters of northern sections of the river, and we created a seamless water-bottom representation where depths exceeded 10 m. In the south, where turbidity levels were higher, we used available returns and interpolation methods to estimate and create a seamless 1-m DEM water-bottom representation.

AHAB recently introduced its LSS 2.3 processing application, with an



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updated turbid-water algorithm that filters some of the weaker backscatter noise created by low or moderate levels of turbidity and selects the most distinctive peak as the water-bottom reflectance. This algorithm enabled the discovery of more returns from deeper waters of the river, and we measured an overall improvement of 0.66 m compared to normal returns--a significant achievement.

Our team operated a low-cost, dualbeam sonar and collected information concurrently with the airborne hydro survey. We installed the sonar on a Jet-Ski because of the latter's mobilization speed and its ability to maneuver in tight and shallow areas of the river. We recorded approximately 4,200 waypoints over a total of 14 transects across the deeper pockets of the river and used these recordings as a reference for understanding the depth of the water column.

We also fused LiDAR data with multiband satellite imagery. Georectified and radiometrically corrected RapidEye imagery with 6.5-m resolution enabled us to visualize the extended landscape and the natural beauty of the Colorado River. Overall, combining two different airborne LiDAR systems and the data sets was a success. We were able to identify the water-column depth and map the bottom of the river, the shoreline, and the overall topography of the river as requested by the project sponsor. Both parties gained valuable knowledge for undertaking similar projects in the future and were pleased to provide critical information to facilitate the study of Colorado River geomorphology.

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