Lower Colorado River Bathymetric Survey

A 342 Mile Juggling Act

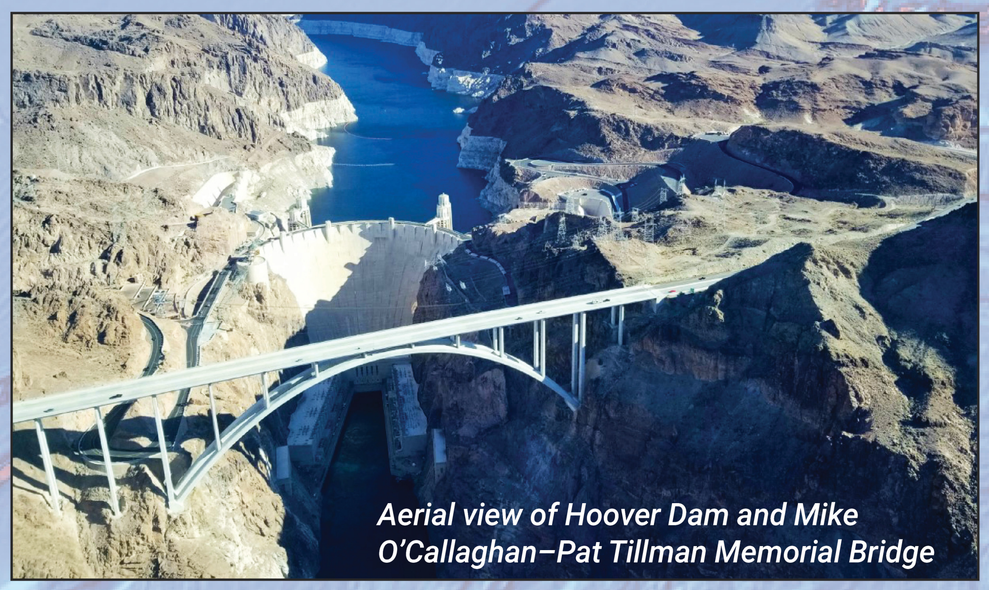
NV5 GEOSPATIAL
St. Petersburg, FL

RIVER RESTORATION.ORG
Carbondale, CO

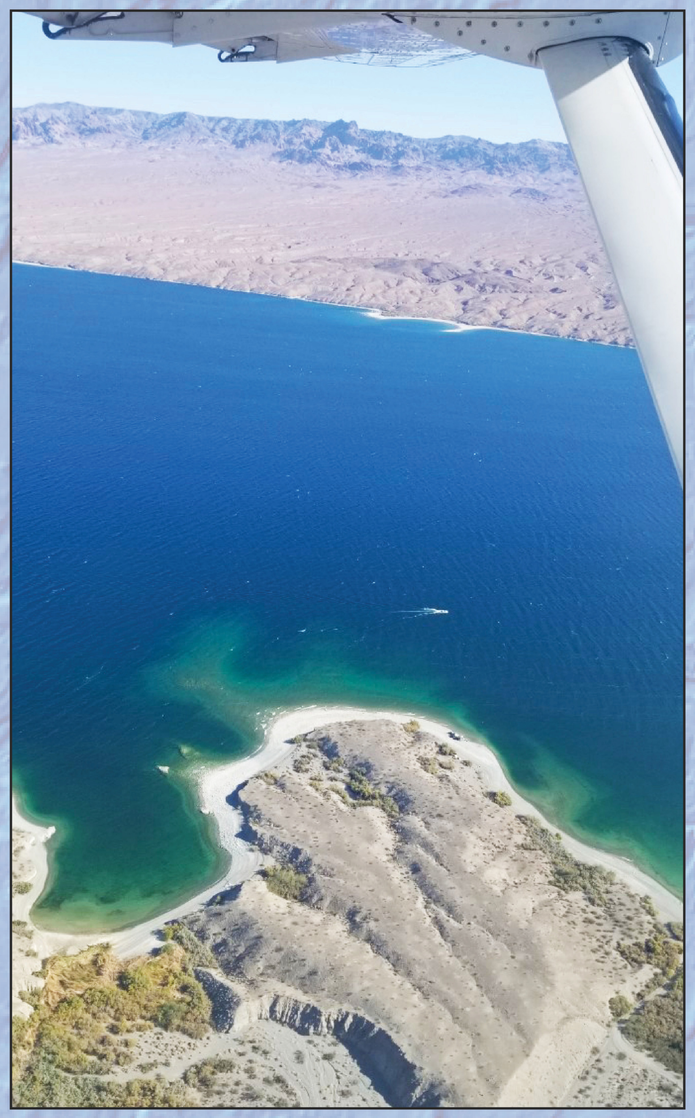
MAPPS

Banner photo courtesy Waterman

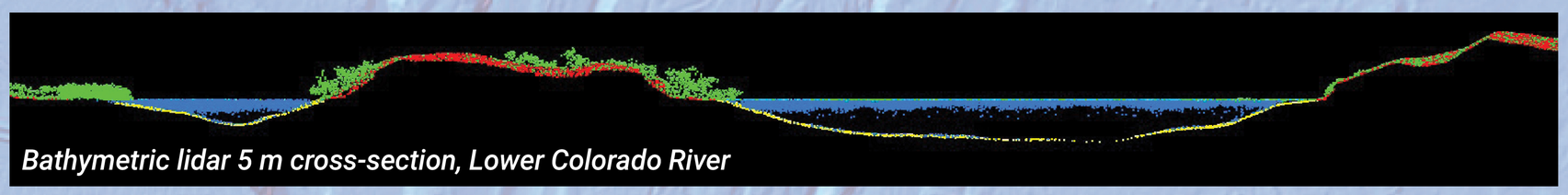
Integrated bathymetric lidar and sonar, Lake Mohave reservoir



Aerial view of Hoover Dam and Mike O'Callaghan–Pat Tillman Memorial Bridge



Lower Colorado from NV5G's Cessna Caravan



Bathymetric lidar 5 m cross-section, Lower Colorado River

To understand the Lower Colorado River's capacity for water storage, the Bureau of Reclamation contracted River Restoration Organization (RRO) to survey the river's bathymetry along its entire 342 mile US length. Being non-navigable and wildly varying in depth, acquiring bathymetry solely with vessel deployed methods was not feasible. To maximize collection efficiency, RRO contracted NV5 Geospatial to collect airborne bathymetric lidar for the bulk of the project area.

Complexity & Innovation

- Among longest airborne bathymetric lidar surveys ever conducted
- Complicated flight schedule so that different sectors of the river were surveyed at right time regarding low flow and turbidity
- Daily coordination calls among participants to work with variable flow schedules at Hoover, Davis, and Parker Dams
- Voids in the dataset were accurately identified for sonar teams to collect at higher flows

Future Value and Client Satisfaction

- Stakeholders can now study, model, and monitor the river to better mitigate the impacts of climate change and water use on the river's capacity to provide water and energy
- Data soon will be publicly available (upon USGS approval) allowing effective planning and implementation of future riverine projects
- Prototype for comprehensive bathymetric mapping of inland non-navigable rivers, demonstrating airborne bathymetric lidar as a cost-effective method for surveying long complex river systems

Lower Colorado River Bathymetric Survey

A 342 Mile Juggling Act

Overview

The **Colorado River is the lifeblood** of the Southwest, an essential source of drinking water and electrical power to over 40 million Americans across seven states. Severe drought across the entire river basin for the last two decades and overuse of water resources has left federal agencies, state governments, environmental groups, and citizens and stakeholders significantly concerned about the future health and viability of the river given our intense reliance on it. To enable cost-effective mitigation strategies, the US Bureau of Reclamation (BOR) recognized that to **better understand the Lower Colorado's capacity for water storage**, it would be essential to characterize, quantify and monitor the river's morphology along its entire US length. In August 2021, the Bureau contracted our client, River Restoration.Org (RRO), to obtain full **bank-to-bank bathymetry** of the river bottom and all reservoirs for **342 miles** of the Colorado River from Hoover Dam to the southern border with Mexico.

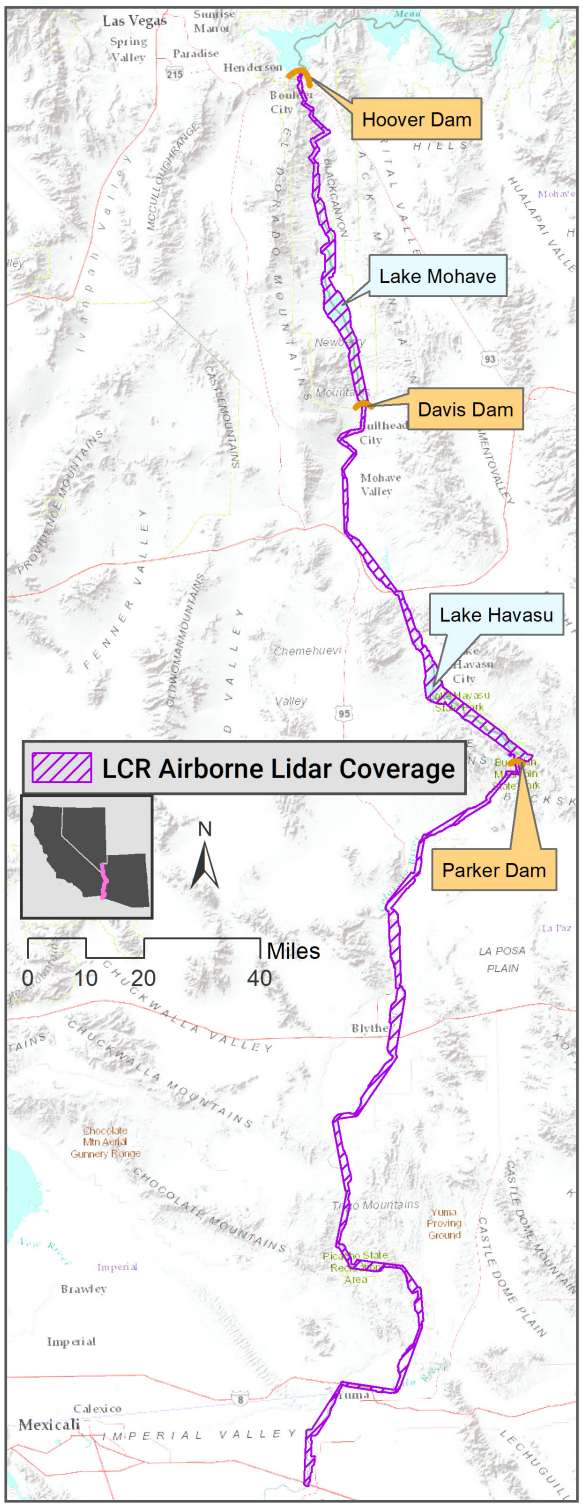
Deep canyons of the Lower Colorado River

The Colorado River is unique in its remote, sinuous nature, cutting through deep canyons for many miles. It is also dammed and diverted from reaching the Sea of Cortez, making it **non-navigable**. The river varies in depth from over 100 feet deep in reservoirs to the many shallow shorelines and exposed floodplains along its winding path. These features precluded acquiring bathymetry solely with vessel deployed methods, and RRO recognized that utilizing airborne methods for a good part of the survey would be essential to the success of the project. Consequently, RRO contracted **NV5 Geospatial** to join their team for the collection of 342 miles of shallow water bathymetry via airborne remote sensing. The lidar data would be pivotal to designing an efficient and safe plan for sonar collection by identifying precisely where sonar collection of deeper waters would be required. NV5G joined a **diverse team of river survey specialists** who each contributed to the larger project, including Precision Surveys (ground survey), River Restoration and Survey Systems, Inc (collecting vessel-borne sonar), and Tetra Tech (collecting sonar and integrating the data with lidar).

Complexity and Innovation

The bathymetric lidar survey was a **complicated collection** that required **significant coordination** with the BOR and the RRO/Precision ground survey team to maneuver around dam release schedules, flow controls, and ground control field work. Simply the mere length of the river surveyed, at 342 total miles, was unprecedented for a continuous riverine bathymetric survey with high accuracy. To ensure success, shallow-water bathymetric lidar must be collected at low flow and high clarity. With aerial data to be collected between Nov 21 – Dec 1 (~10 days), by far the greatest challenge was **designing a complicated low flow flight schedule** so that different sectors of the river would be surveyed at just the right time with respect to river conditions. Given the daily dynamics of flow and its impact on depth and water clarity, it took significant additional formulation, preparation, and planning to determine and follow a flight plan that would enable feasibly and safely collecting each reach within a single day at low flow.

For example, to meet increased power demands, Hoover Dam operates at higher flows during the weekend, impacting river miles (RM) 342 to 316, so we planned for collection in this stretch during non-weekends. A low flow release was planned for Sunday Nov 21 which we then targeted for our first mission for this section. For the Mohave Reservoir (RM 316 – 276), we had to target collection before a planned increase in water levels in early December. Downstream of Davis Dam (RM 276 - 220), higher flows planned for Thanksgiving to accommodate boating recreation required lidar collection well before November 25. There was a planned low flow release Nov 23 which we successfully targeted. We acquired the stretch below Parker Dam (RM 192) to Imperial Dam (RM 49) during a 3-day drawdown event following a planned low flow release on Nov 25, where travel time of the drawdown downstream had to be carefully factored in and considered. Finally, Because Havasu Reservoir (RM 220 – 192) was planned for drawdown in late November, we acquired this stretch last. In the end, it took at least 10 collection missions to successfully acquire all data at low flow and turbidity.



As one can imagine, juggling the timing of collection for each of these reaches relied on **intensive coordination** among several partners – BOR Boulder Canyon Operations Office, River Restoration, Precision Surveys, and NV5G's team of project managers, acquisition managers, pilots and sensor operators, and remote sensing technical experts. Choreographing the targeted flight windows in advance with respect to reservoir water levels and downstream releases, stability of flow levels, and predicted impacts on optimal water clarity, was challenging enough. In addition, NV5G had to carefully time airborne surveys with all ground operations performed by Precision Surveys (measurements for turbidity; setting lidar terrestrial and submerged QA points; and collecting verification depth data). Further, the NV5G crew had to coordinate the proposed low flow acquisition schedule with restricted airspace constraints; acquiring the project during the Thanksgiving week/weekend was advantageous to gaining access to airspace. Weekly multi-party coordination calls prior to project initiation led to daily calls during the execution to ensure flow schedules were unchanged, flight schedules were still on target, and survey crews were in position. Once conditions aligned for each reach, over the next 10 days the NV5G Team collected a body of data that would become central to supporting the largest comprehensive mapping project for a non-navigable river in US history.

Once collected, the bathymetric data went through **rigorous post-processing and QC workflows**. With many production steps involved - **calibrating the increased number of missions**, correcting the data for light refraction through water, evaluating the impact of water clarity and surface reflectivity on results – deriving an accurate, seamless, and thoroughly vetted bathymetric surface model for 342 river miles was no small undertaking. Water clarity at the time of collection resulted in laser depth penetration of up to 4.5 meters (~15 ft). All told the dataset resulted in an average first return point density of 57 points/m^2, a bathymetric ground point density of 8 points/m^2 (for bathymetric surfaces mapped) and a topographic ground point density of 19 points/m^2 (combined topographic surfaces), exceeding expected results. The combined topobathymetric lidar DEM was accurate to within 6.4 cm of true ground (95% confidence interval), exceeding USGS vertical accuracy requirement (for non-vegetated vertical accuracy) of 18 cm or less. But most importantly, and contributing to the larger project, voids in the dataset where the bathymetric sensor could not reach were accurately identified and outlined for the sonar teams to upload into their vessel navigation systems for collection at higher flows in the spring of 2022.

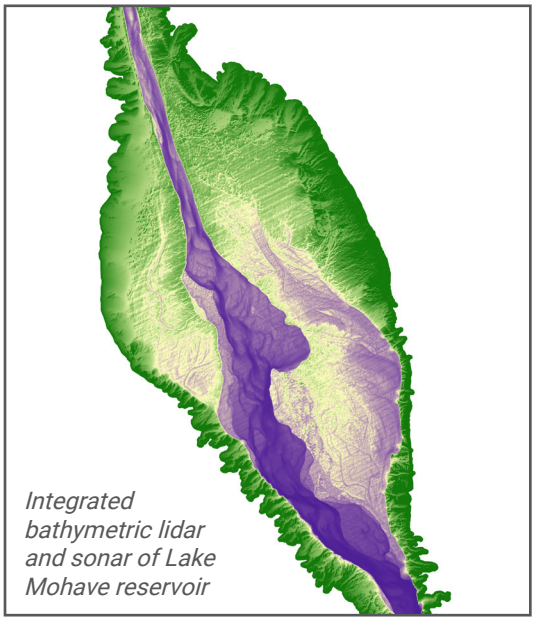
Airborne bathymetric lidar derived DEM colored by imagery along the Lower Colorado River at Bullhead City, AZ.

Future Value & Client Satisfaction

Results of the Lower Colorado River bathymetric lidar survey provide several **societal and economic benefits** on both a local and global scale. Since the 1900s, the BOR has periodically collected bathymetric data or studied the sediment to try to record and document changes in the Colorado River. But now, with a thorough understanding of the bathymetry of the river, water managers can **accurately calculate stage capacity curves** for the Mohave and Havasu reservoirs. Stakeholders can now study, model, and monitor the river to better mitigate the impacts of a changing climate and water use on the river's capacity to provide water and energy. Effective planning and implementation of future projects along the Colorado River is now possible, and with data soon to be integrated into USGS's 3D Elevation Program (pending USGS approval), these data will be available to the public for unlimited applications, including ecosystem restoration. The project also serves as a **prototype for comprehensive bathymetric mapping of inland non-navigable rivers**, demonstrating that **airborne bathymetric lidar is a more cost-effective method** for surveying shallow water zones of lengthy river systems. When used to pinpoint where more expensive vessel-based methods are necessary, airborne bathymetry facilitates achieving wall-to-wall bathymetric coverage without breaking the bank.

For accurate (sub 10 cm) vertical data in continuous bathymetric surfaces, no single technology would have been adequate for… the vast, tortuous, and complex shorelines. NV5G's data greatly improved the safety and efficiency of the RRO team's bathymetric sonar data collection.

~ Jason Carey, River Restoration



Integrated bathymetric lidar and sonar of Lake Mohave reservoir