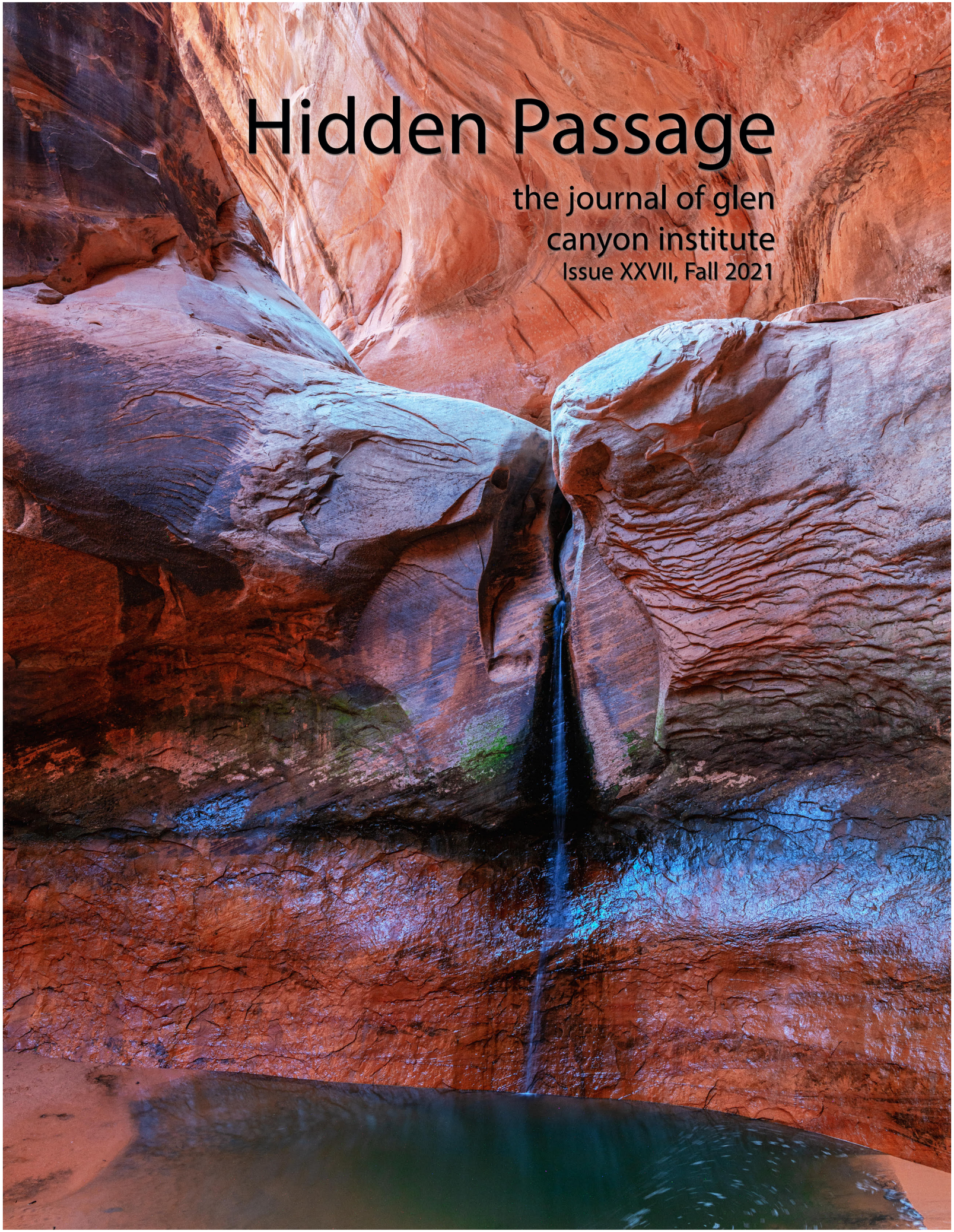


Hidden Passage

the journal of glen canyon institute

Issue XXVII, Fall 2021

3090 East 3300 South
Suite 400
Salt Lake City, Utah 84109
tel (801) 363-4450
fax (801) 363-4451
info@glencanyon.org

www.glencanyon.org

Hidden Passage
Issue XXVII Fall 2021

Editor
Wade Graham
wade@wadegraham.com

Cover: The waterfall in Cathedral in the Desert now closely resembles what it looked like before the dam. Photo by John Buckley. October, 2021.

Director's Introduction

by Eric Balken

It would be an understatement to say 2021 was a momentous year for Glen Canyon and the Colorado River. A paltry spring runoff failed to bring up the levels of Lake Powell reservoir beyond a couple of feet, followed by a summer decline to its lowest level since it began filling in the 1960's. As of this writing, it continues to drop. The Bureau of Reclamation projects that Glen Canyon Dam may lose its ability to generate hydropower within a year or two, and may even reach dead pool in the years after that. Downstream at Lake Mead, an official shortage was declared for the first time ever, triggering cuts to water deliveries in Arizona and Nevada.

Shocking as it may be to see these events come to pass, Glen Canyon Institute and others have been anticipating this moment for years. After all, the realities of climate change and the over-allocation of the river have been known for some time. The past work we've done to flesh out what a managed drawdown of Lake Powell could look like is now more important than ever.

Meanwhile, the world is starting to acknowledge the miracle of Glen Canyon's reemergence. Cathedral in the Desert, one of the Glen's most revered landmarks, emerged early in the spring and was flushed of much of its sediment over the summer, revealing almost the entirety of its original waterfall. Gregory Natural Bridge, one of the largest in the country, has emerged for the first time since 1969. And upstream on the main stem Colorado River, the rapids of Cataract Canyon are roaring back to life. Even Lake Powell Resort and Marinas is advertising "spectacular new sites" as a main attraction for visitors.

It's becoming more apparent that the returning canyons, waterways, cultural sites, flora, and fauna in Glen Canyon have tremendous value. GCI's focus in this new era is to document, quantify, and demonstrate this value to decision makers and stakeholders in the Colorado River Basin. As the management of Lakes Powell and Mead are set to be renegotiated to adapt to a river with less water by 2026, the unique resources emerging in Glen Canyon must be taken into consideration.

We're proud to continue our partnership with the Returning Rapids Project, which is meticulously analyzing the return of the Colorado River in Cataract and Narrow Canyons. We're continuing our work with scientists to study the return of Glen Canyon ecosystems, with a busy season of field research planned next year. We're looking forward to collaborating with other conservation groups, tribal leaders, academics, writers, photographers, and members of the media to expand the understanding of Glen Canyon's return and ultimately make the case for its protection.

Once considered a pipe-dream of environmentalists, the return of Glen Canyon is now reality. The restoration of "America's Lost National Park" will be complex and in many ways messy—the amount of sediment that's been dropped into the canyon over the past 58 years is almost beyond comprehension. But the speed at which the bridges, arches, alcoves, amphitheaters, streams, creeks, rivers, and ecosystems have bounced back has been truly stunning. One can only imagine the treasures to be revealed in the years to come.

The controversy of Glen Canyon Dam has been a historically polarizing part of natural resource management in the West, with many identifying either as "pro" or "anti" Lake Powell. But in the 21st century, the hydrologic realities of the Colorado River have superseded this debate. Glen Canyon is coming back to life, and it's imperative that policy adapts to manage it as such.

As Billy Shott, superintendent of Glen Canyon National Recreation Area said this summer, "…you know what? We'll have more people coming here to raft than they have in the Grand Canyon. It'll be a different place, but people will still enjoy it. It's just change. We just have to adapt to it."

Re-Creating "LaRue's Riffle" Photo 100 Years Later

—EB

Left: Emery Kolb running the riffle in 1921. Photo by E.C. LaRue. Right: Mike Freeman running the riffle in 2021. Photo by Meg Flynn.

On a balmy September day on the banks of the Colorado River, I followed Mike DeHoff as he plodded upstream in ankle-deep water. "Are we in the right place?" he asked his wife Meg Flynn. "That's the rock pile," she replied. Earlier in the summer they'd marked the location where a photo was taken by United States Geological Survey surveyor E.C. LaRue a century before.

"Right here is where the picture was taken for the survey where they first came down to try and determine the profile of the river's elevation as it dropped through this part of Cataract Canyon." The photo (above) was of famed Grand Canyon explorer and photographer Emery Kolb rowing a wooden boat through a riffle above Gypsum Canyon Rapid—now known as rapid #31.

The photo of Kolb is significant because it's one of the newest sections of rapids emerging amidst the continued drawdown of Lake Powell reservoir. About six years ago, the large rocks in the rapid began to emerge, and in 2018 the Returning Rapids crew was able to match a photo of the rapid and get a real sense of how close it was to full restoration. It was the "eureka" moment that inspired the formation of the Returning Rapids Project and the extensive documentation, scientific research, and photo-matching that's happened since.

DeHoff explained, "this was one of the first photo matches we did for the Returning Rapids Project because these rocks started coming out of the mud in 2015, and now it's almost the whole way back. Why not celebrate it being a hundred years later and get a good picture?"

After setting up at the photo rematch location, our group huddled around the site and held up the historic photo. We made sure to frame our shot exactly while relishing the unique milestone of seeing this rapid come back to life after being drowned by reservoir backwater and mud for decades. Fittingly, the person rowing the boat for the re-creation would be Mike Freeman of the USGS Utah Water Research Center.

Meg stressed the rarity of this moment. "What's extra special about this one is not only that the rocks are matching up, so is the light on them, which is not something we've specifically done before," she said. The light would match perfectly because the original photo was taken on September 21st, 1921, with a time stamp of 12:25 PM. We were in position on September 21st, 2021, with the goal of taking the photo at the exact same time—down to the minute.

To time it perfectly, the "re-creation boat" was perched just upstream of the rapid, ready to push off. Rob DeHoff, Mike's brother, was stationed at a rock outcropping between the boat and our group to communicate between us. At 12:24, he signaled that the boat had pushed off toward the rapid. As Freeman squared his boat up toward the gap between the signature boulders, Meg yelled, "Can you tell him to slow down? We need twenty more seconds!"

As the entire group broke out in laughter, Freeman furiously back stroked to hit the minute mark. When the clock struck 12:25, we yelled for him to go for it and he made his way down. He rowed through the rocks as the group cheered, clapped, and snapped photos. As you can see from the pictures above, the centennial photo match was successful.

Another goal of this trip was to install several new USGS brasscap benchmarks to help create a new river profile—a modern version of what LaRue and Kolb helped create a century earlier. With help from many members of the trip, Chris Wilkowske from the USGS Utah Water Research Center teamed up with Mike Freeman to install a benchmark near the old "high stand" elevation of the reservoir, one at Clearwater Canyon, and one at Rockfall Canyon. These benchmarks, with precision satellite elevation readings, will create reference points for measurements taken at the river level, and later on, scans of the river bottom. By building a new and accurate river profile, the Returning Rapids Project and coordinating scientists will establish a deeper understanding of how the Colorado River is restoring in Cataract Canyon—making their own place in the long history of this place, a hundred years

Fall Science Trip with the Returning Rapids Project

by Jack Stauss

Jack Schmidt, Center For Colorado River Studies, rows the Colorado River on the trip's last day. A river flows where there once was reservoir. Photo by Jack Stauss.

In mid-October, Glen Canyon Institute embarked on a trip with the Returning Rapids Project and a cross-disciplinary group of researchers, river runners, and environmental advocates. Our goal was to help quantify and tell the story of the Colorado River reemerging from Lake Powell reservoir. The six-day journey took us through Cataract, Narrow, and upper Glen Canyons, where we spent our days hiking and conducting surveys in the side canyons below the reservoir's high water mark.

While this trip had many specific focuses of study, one thing stood out above all else—the rapids below Big Drop 3, the former upper reach of Lake Powell, and the river all the way down past the North Wash boat ramp are no longer a reservoir. This is once again a golden, flowing Colorado River.

This trip was the most logistically complicated Returning Rapids expedition to date. Mike DeHoff, Pete Lefebvre, Jamie Moulton, and Meg Flynn from RRP have been working on this for years, and now they are facilitating and leading two dozen people with a huge array of interests and expertise into a place they love deeply.

Scientists from the University of Utah, U.S. Geological Survey, Utah State University, Grand Canyon Monitoring and Research Center, Western Water Assessment, and U.S. Fish and Wildlife, all joined to study a variety of topics. Each day we broke into three or four groups to make sure each crew was able to focus on their areas of interest.

GCI spent the first two days on the mothership—a flotilla of boats working its way down Meander Canyon to the Confluence of the Green and Colorado Rivers. Another boat team, "The Sand People," were a crew from the USGS led by Scott Hynek. Every 3–5 kilometers they would stop and collect sand samples from beaches. Yet another survey team, led by Paul Grams from GCMRC, worked to map the bottom of the river using sonar scanning technology.

And finally, a team worked to map the entire river profile from Potash all the way down to White Canyon. This was done using Real-Time Kinematic GPS units we installed in different locations each day to measure locations and elevations. This was the first time in 100 years mapping of this scale has been done. On day one, Meg took the lead and each day she would help facilitate moving the units downstream, measuring as they went. At one point she and her team left camp early and spent

a very full windy day at the Confluence letting the GPS unit run its course.

We would all regroup in the evenings for dinner and discussion. Of particular interest was the goal of getting back into Waterhole Canyon and building upon the research conducted by USGS and U of U researchers there last year. Their work was to continue analyzing the changing layers of sediment from Lake Powell as its levels shifted.

After a rainy night at the Confluence, we spent the day rowing the famous whitewater of Cataract Canyon. As soon as we completed the notorious Big Drops, we were in the restoration zone and the real work began.

When asked how many times he has run Cat, Mike DeHoff says, "Well, I stopped counting at 100, and that was a long time ago." There really is no one better to help scout the rapids. Between him and the RRP team there is an invaluable and immense amount of knowledge and passion surrounding the canyon and this section of the Colorado River.

The geologists broke out into Waterhole Canyon. The visible changes were like watching millions of years of geological processes taking place in only a few decades. For the geologists, it's like having a giant outdoor laboratory.

The "Fish People," biologists from the U.S. Fish and Wildlife, caught native fish, the GCMRC team continued mapping the bottom of the river, and Seth Arens of Western Water Assessment returned to "plant transects" he established on research trips from the previous two years.

The transects are essentially focus areas that span a side canyon, allowing him to survey changes of plants and ground cover in that specific area over time. These cross sections can be as long as 90 meters and will help us understand how ecosystems are changing, restoring, and ideally, thriving in both the previous reservoir area as well as above high water.

Over the late summer and early fall, a series of flash floods drastically impacted the areas surrounding Lower Cataract and Glen Canyons. In some places, 30 feet or more of sediment was cleaned away in a single flood—blasted out by extreme torrents of water. So, some of the transects that we expected to be heavily vegetated were instead cleared-out washes and canyon bottoms.

After the days spent in Gypsum and Clearwater Canyons, the group camped one more night out on the river, sharing stories from our previous days of work and running the rapids. For the Returning Rapids Project and GCI, it was an amazingly collaborative effort, and an inspiration to see so many people curious about what was happening in a landscape that has been historically overlooked by scientists and managers. To many in the group, the fact that Big Drop 3 used to be the high water mark was a shock—today there's barely any sign the reservoir was ever there.

It's hard to emphasize how much work really goes into a trip like this. From Pete fixing motors on the fly, to pushing the Mothership and the river mappers downstream, to Jamie organizing six days of amazing meals—it's a labor of love and

Mike and Rob DeHoff looking downstream toward "LaRue's Riffle" and Gypsum Canyon. Photo: Eric Balken.

one that has paid off over the last three years of these increasingly complicated trips.

In some ways, the work of the geologists and ecologists overlapped with one another. The USGS team was looking at changing levels of salinity in the mud, and as we conducted plant transects, we took soil samples too. Soil samples were collected under native plants like willows and non-natives like tamarisk to see if there are differences in soil chemistry, like salinity.

But, surprisingly, in the Dominy Formation—the sediment layer created by the reservoir—we were finding an abundance of native plants: grasses, willows, reeds, shrubs, flowers, and even a lot of cryptobiotic soil, green and mossy from the season's big rains.

One of the most beautiful and mysterious places was still to come for our last day of work. Dark Canyon had apparently experienced massive flooding, mobilizing huge amounts of mud and sand—surely to be of interest for the geologists. It was also home to three transects.

Dark Canyon, like Clearwater and Gypsum, had flashed in an astonishing way. Where there were once gnarled tamarisk and tight willow groves, there was now an open wash. Where there were beaver ponds, there was a creek. Where there was once mucky sediment, there was gravel. Up into the canyon we went to do our surveys and take in what might be the most beautiful canyon I have ever seen.

After we completed our last transect, I romped up Dark Canyon for a few more minutes. I visited the fluted waterfall we could see from the transect, and scrambling beyond, I could hear more babbling creek out of sight. Just another bend and I was greeted with shining sandstone bedrock that the stream had forged its way through, twisting and turning over the course of thousands of years. I sat there for a while, listening to more flowing water further up—drawn in by a glowing cottonwood around the next bend. The canyon continued on but I had to get back. Back to the river that was once a reservoir, and all of the incredible changes happening there before our eyes.

The teams prepare for a day of field work. The Returning Rapids fall science trip involved 28 people from a number of different government agencies, conservation groups, and universities. Photo by Jack Stauss.

Completing a New River Profile in Cataract Canyon

by Mike DeHoff

The RTK team catches a ride on a jet boat. Photo: Mike Dehoff

"I think we got it. Wow. I can't believe it but I think we got the river profile." These thoughts were going through my mind as I eased the throttle down on the motor and our boat settled into the turgid fast-moving water.

Paul Grams was sitting in the front of the bare bones 16' aluminum skiff we were in. He looked back and said "I think that was the best way to get that last leg of measurements. There is no way our boat could have made it through that stuff." Paul had a stubbly beard of a week's long river trip and a smile on his face. He had on a slightly faded red Gore-Tex jacket, a green pointed wool cap, and had a few bits of electronic survey gear sitting on the boat bench next to him. As he had been asking me to do, I looked at the sending/receiving unit that was strapped in the boat right next to me at eye level to make sure the orange lights were still on and the unit was operating.

We had just run downriver from the "normal" take out for Cataract Canyon another 3-4 miles to map more of the water surface elevation. The area below the take out was a weird No Person's land of steep sand banks and mud bergs sticking out of the water that contains a giant reservoir-caused sediment delta. We were glad to have made it back upstream to the take out to help the rest of the crew with the last tasks of the trip.

On the shore to our left were the other ten boats from the trip. Like all the people, our rafts and catarafts were a mixed speckling of various dirty earth tones and grays, yellows, reds, and blues. These were all tied to the shore, waiting to be hauled up a steep slope to awaiting trailers. Over 20 people were moving around in an organized ant-like fashion—one person hauling a large dry bag, another cluster of three people rigging a long line to the next raft to be pulled out of the river and up the slope.

This was the "we" I referred to getting the river profile. The group was one of the most talented and educated crew of people I have ever been on the river with. There was a wide swath of USGS scientists from both the Utah Water Science Center and the Grand Canyon Research and Monitoring Center. Also represented were two major universities in Utah—Utah State University and the University of Utah. The rest of the group was made up of a few other scientists, people from American Rivers, a couple of journalists, and a few lucky and skilled rag tag river runners.

The group had just traveled downstream about 100 miles on the Colorado River through Cataract Canyon, all the while trying to stay organized and accomplish a tremendous amount of data gathering. It included everything from sediment sampling, water sampling, vegetation cross sections… and the river profile.

In 1921, a group of people ran through this same stretch as a USGS survey group. On that trip they generated a river profile, which is a representation of the gradient of a river as it travels down river. Said another way, it shows the rate of drop per mile. (To see the 1921 maps and profile in detail, visit https://pubs.er.usgs.gov/publication/70191006.)

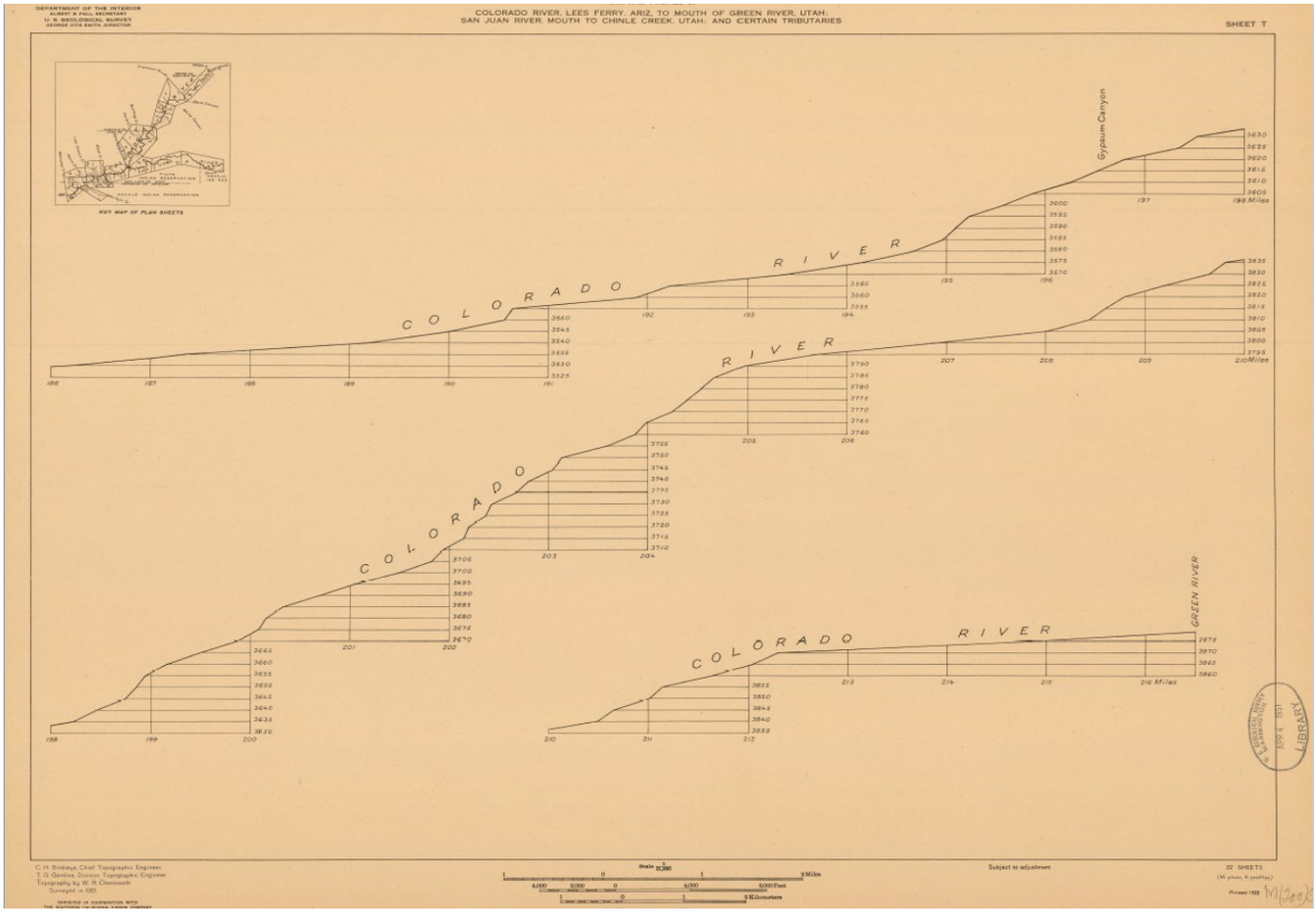
Other parties have recently attempted to re-create this river profile, but it had not been completed for the entire stretch. Since that 1921 profile there has been a tremendous amount of change. One of the biggest changes in the area was the construction of a large dam 150 miles downstream from the take out and a huge sediment delta that dropped out into the lower part of Cataract Canyon. In places, the delta is 150 feet thick and has caused the river to be displaced from its channel.

Now, in 2021, as we watch the reservoir behind Glen Canyon Dam recede to its lowest level ever and the delta is exposed, it was collectively decided that we needed to complete another river profile.

Working with the many USGS staff, we laid out a plan. Scott Hynek from the Utah Water Science Center first pushed for the idea. We then organized a trip in September 2021 to complete the preliminary work of putting in control points, or brass caps/reference points through the area to be mapped. Chris Wilkowske and Mike Freeman from the Utah Water Science Center agreed to come on the September trip to help do the initial work. Fortunately, the trip also coincided with the same dates of the 1921 survey trip, so we were able to have some fun matching historic photos to the exact day 100 years later.

Then, for the big October trip, the Grand Canyon Research and Monitoring Center folks agreed to bring equipment that can capture the river profile on 2 levels—the water surface and the river bed elevations. Paul Grams and Bob Tusso showed up with a 16 foot cataraft that looked like a combination of some canopied castaway's survival boat that mated with a space ship. On the decks and overhead structure of their boat, receiving and mapping units were mounted along with a multi-beam sonar unit that could swing down into the water to image the bottom of the river. Bob would putter the raft and look for the main channel down the river while Paul sat over a laptop making sure all the information was coming in to be saved.

The control points came into play with other members of the group. Each day, a contingent of 2-5 people hurried out of camp to get to the next night's camp. They had to go fast and set up a GPS sending/ receiving unit (an RTK) over one of the previously surveyed control points. As the mapping boat traveled, it collected data that could later be compared with the other RTK's data set. At times on the trip getting the RTKs set up meant leaving camp quickly, running rapids in the cold October morning breeze, and passing up opportunities to see other members of the group complete other data collection. Meg Flynn of the Returning Rapids Project really showed her diversity of skills in the face of all the leapfrogging of surveying equipment; rowing a boat, setting up the unit, and making sure the RTK was operational.



A profile of the Colorado River circa 1921, which hasn't been repeated in 100 years. USGS Public Domain - https://pubs.er.usgs.gov/publication/70191006.

Clockwise from left: Mike Freeman sets up an RTK above Clearwater Canyon. MIke DeHoff and crew examine the Les Jones scroll map. Meg Flynn operates an RTK to help finish the new river profile.

That was the way the October trip was able to complete a river profile—organize people to run ahead, organize people to escort the mapping boat for the day (specific thanks to Peter Lefebvre and Jamie Moulton for keeping them safe in the rapids), and coordinate if the current camp RTK needed to be kept running.

Many of the scientists shared that no one gets really excited about collecting base line data and that there is little value to the data until changes start to happen—which, holy cow, they are. If the USGS tag line is "Science for a changing world" then this was an excellent expression of that mission.

Hopefully, as the data collected on the trip gets processed it will generate a cross section map that can help us monitor how the river is continuing to recover from the effects of a major dam and inundation.

People who specifically deserve credit for pulling off the river profile include: Meg Flynn, Jamie Moulton, Peter Lefebvre, Scott Hynek, Mike Freeman, Ashley Nielsen, Chris Wilkowske, Kevin Walker, Jian Wang, Bob Tusso, Sasha Reed, Christine Rumsey, Jack Schmidt, Steve Dundorf, Paul Grams, Noah Derrick, Eric Balken, and many more…

On our last few trips it has occurred to me that we are helping to write another chapter in the history of the Colorado River. The group of people who have been along on our endeavors have been a delight to work with. The 1921 survey was part of a data set that informed the Colorado River Compact of 1922. It is my hope that 100 years later, the 2021 river profile will provide information that can inform a revised and better future for the river.

Insights on the Basin: an Interview with John Berggren

—Interview by EB

John Berggren is a Water Policy Analyst for Western Resource Advocates with an extensive background in Colorado River policy. He completed his Ph.D. at the University of Colorado–Boulder where he focused on sustainable and equitable water management in the Colorado River Basin. With changes happening so rapidly today, we asked John a few questions to get his insights on where we may be headed.

EB: The decline of reservoir levels at Lakes Powell and Mead have accelerated more quickly than many anticipated with the exceptionally low runoff last year. How do you think this influences the negotiations of the Interim Guidelines?

JB: The recent hydrology has intensified the energy around the Interim Guidelines renegotiations. The silver lining around the bad hydrology is that it has also reinforced just how important these renegotiations really are. The states are coming together to craft new policy that will guide management for the next 20-30 years. Given the current state of reservoir storage, bad hydrology, and the worsening impacts of climate change, those new guidelines must be robust enough to not only get us through these current challenging times, but handle even worse conditions going forward. The Basin States and federal government understand this, but the challenge will be ensuring they can collaborate effectively without letting politics create insurmountable barriers.

The other silver lining to the bad hydrology is it may open the door for new thinking, ideas, policies, and engagement. We have seen how quickly the system can crash, so it may require innovative strategies that have previously been considered politically or physically impossible. Just look at the Lower Basin Drought Contingency Plans (DCP) and how tribes were essential to getting the plan passed and adopted. The Basin States are seeing how a more inclusive process may actually benefit them in securing the policies needed. I don't hope for bad hydrology, but in this case, there seems to be some real benefits, at least process-wise.

EB: The most recent runoff and reservoir elevation projections from BOR reflect a much drier hydrology than what was used in the past, with Lake Powell potentially dipping past minimum power pool and even dead pool in the next five years. How do you think the Basin States and other stakeholders interpret that? Will they be more open to out-of-the-box ideas, or will they dig in their heels? Will we see more cohesion or more division?

JB: I think the recent Reclamation projections were quite alarming, both to the Basin States and other stakeholders. The projections really demonstrated the severity of the situation, and how dire reservoir conditions that, even a few years ago, seemed like a long shot, are now within the realm of possibility. We no longer have the luxury of time before the system could potentially crash. The fact that Reclamation is using a different period of record for modeling projections is a really important point. Not only does it more accurately reflect recent, drier hydrology and better account for the impacts of climate change, but it also represents a shift in how Reclamation is viewing the problem. Climate change is no longer a potential scenario we should consider—climate change is the scenario we should use for our planning. It is a positive step forward and I am thankful Reclamation has moved in that direction.

Regarding the Basin States' response, I am cautiously optimistic. Like I said before, the dire situation may require strategies once considered politically or physically impossible, but that does not mean the Basin States will rip up the Law of the River and start from scratch. I think we'll see them build upon previous efforts and continue to find ways to improve reservoir operations, tweak shortage determinations, and consider new and more robust programs. I think we'll see them really explore DCP implementation and what that could look like in the Upper Basin, and I think we'll see a framework in the Lower Basin that includes additional shortages.

Make no mistake, the renegotiations will be incredibly challenging and under a tight timeline, so nothing about them will be easy. Achieving the things I mentioned will be a tall order. I do hope the Basin States will begin to at least consider more out-of-the-box ideas. To begin with, one thing I am optimistic will come out of them is a recognition of the actual, long-term hydrology of the Colorado River. I sincerely hope that even if nothing else, the Basin States publicly acknowledge this river is over-allocated and climate change makes things worse. I hope they acknowledge we can no longer plan on a 14-15 million acre-foot river, but need to be planning for a 11-12 million acre-foot river. I realize acknowledging reality seems like a low bar, but to me, that would be a huge win for the Basin.

EB: Do you think the existing framework of the 2019 Drought Contingency Plans will be enough to "hold the system over" until the new guidelines are completed in 2026?

JB: I think about this question quite a bit. Given the recent projections we already talked about, the ability of the DCPs to keep the system from crashing before 2026 is concerning. Lakes Powell and Mead are projected to continue to lose storage and start flirting with pretty scary elevation levels. I think it will take one or two above average snowpack years to help us avoid those worst-case scenarios. But I also know how this Basin works, and I suspect that both Reclamation and the Basin States will do everything they can to avoid those worst-case scenarios. This may include significant Lower Basin curtailments, emergency reservoir re-operations, and other somewhat drastic measures that will be painful for many

groups, so I do not view them as harmless. My only hope is that the Basin States and Reclamation do their best to mitigate or limit those harms. One positive thing to note is the recently passed Infrastructure Investment and Jobs Act includes significant amounts of funding for the Colorado River Basin. The timeline may be challenging, but I suspect that money will help us get through 2026.

EB: Colorado River Tribes are playing a bigger role in negotiations today, adding a new dimension to the dialogue. What opportunities and challenges do you see from this?

JB: I think this is one of the most important parts of this whole discussion and I am really heartened to see the tribes playing a bigger role. The challenge will be ensuring that role is meaningful and sustained, and actually addresses each of the tribes' individual needs. Each of the 30 federally recognized tribes in the Basin are sovereigns and have their own specific needs, challenges, and opportunities. Key to each of their success will be proactive and adequate participation in Colorado River negotiations, with strong leadership from the federal government. In terms of opportunities, tribes in the Basin have recognized water rights to approximately 25% of the Colorado River's annual flow. That's a huge quantity, meaning the tribes could be well positioned to contribute to system-wide conservation, in addition to meeting their own needs. Again, look at the Lower Basin DCP agreement, specifically in Arizona, and you can see how essential certain tribes were in allowing that deal to be completed. I think that could be replicated across the Basin. But it is important to emphasize that some tribes do not have access to their water rights or have unresolved water rights. People living in this country do not have basic access to drinking water and that is unacceptable. Addressing that historic and monumental wrong is top priority for the Basin. Many people hope to see a sustainable Colorado River, but I argue that we cannot have a sustainable river until everyone within its basin has access to clean drinking water.

Runoff Efficiency Driving Our Water Future

by Ashley Nielson

Like many others who are invested in the Upper Colorado River, you may have found yourself asking the following question the past couple years: the snow conditions were near normal, so why was the runoff so terrible? A common misconception is that snow water equivalent (SWE) has a 1:1 relationship with runoff, which essentially means that every drop of snow ends up as streamflow. Average snowpack = average runoff right? Unfortunately it is not that simple, which leads to the topic of runoff efficiency. Figure 1 helps to illustrate this point by showing a hypothetical perfect 1:1 SWE: Runoff relationship (1a) and the actual SWE: Runoff relationship for the Lake Powell Inflow (1b).

Runoff efficiency is defined as the ratio of the volume of runoff to the volume of precipitation over a given area over a defined time period. In the Upper Colorado River Basin, we are typically referring to "cool" season or winter precipitation (Oct-Mar) and snowmelt/spring runoff (Apr-Jul). In general, when winter precipitation is high, runoff is high and when it is low, runoff is low. However, in certain years, extended dry or wet periods, or in specific basins, precipitation and runoff do not always track each other well suggesting other variables are impacting runoff.

In addition to precipitation, runoff can be impacted by a number of factors including but not limited to soil moisture conditions, spring weather (temperature and precipitation), land use changes (e.g fire, agriculture, etc) and changes in basin water use/demand. Two of the more discussed factors are antecedent soil moisture conditions and spring weather.

Soil moisture conditions are determined by the previous year(s) runoff and summer and fall precipitation. Before runoff can occur, the soil moisture deficit must be fulfilled. Both wet and dry soil moisture conditions can impact the runoff efficiency. Wet soil moisture conditions have less of a deficit to overcome which typically results in increased runoff efficiency while dry conditions require more water to overcome the deficit resulting in decreased runoff efficiency.

Spring (Apr-May) weather can often make or break water supply conditions. In years where the difference between precipitation and runoff is large, it is most often a result of extreme spring weather. In general, warm and dry conditions can accelerate snowmelt which results in early runoff, increased losses to evapotranspiration and evaporation, extended periods of low streamflow, and poor runoff efficiency. Cool and wet weather conditions typically result in high runoff efficiency as result of delayed snowmelt, late season snow accumulation, wet soil moisture conditions, and less overall system losses. Each year there are many possible spring weather and runoff scenarios that will ultimately impact the runoff efficiency and resulting streamflow volume.

So how did the 2021 Lake Powell observed inflow end up being the third lowest on record? Rewind back to early 2020. A record warm and dry spring in 2020 produced a below average

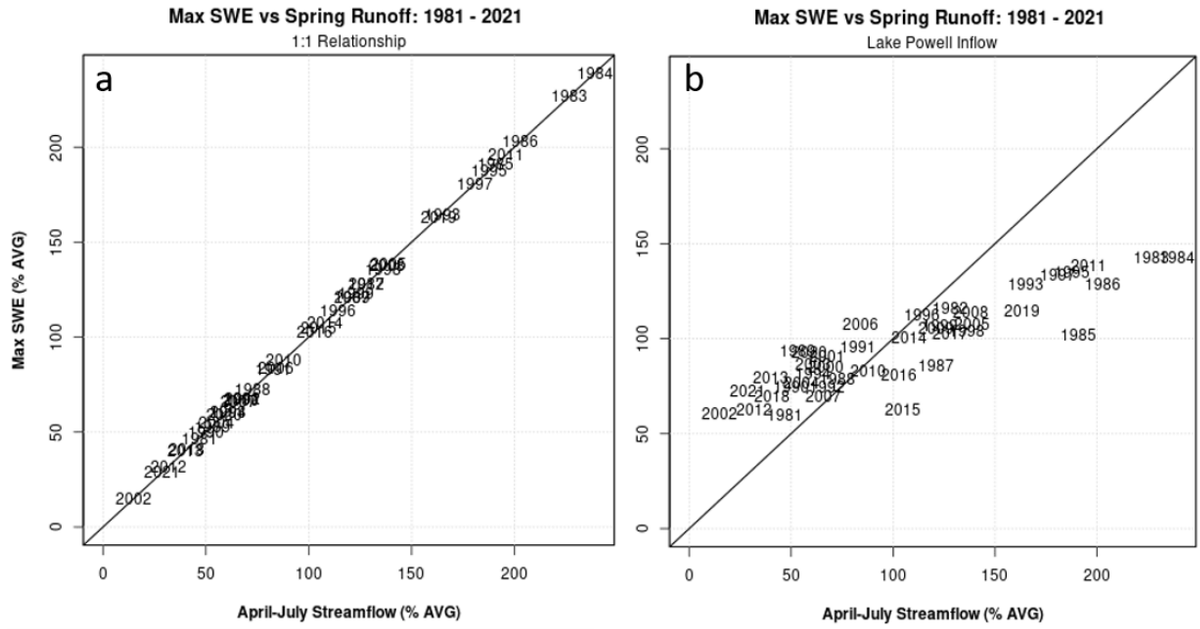


Figure1. Snow water equivalent (SWE) relationship to spring runoff for Lake Powell. a) hypothetical perfect 1:1 SWE: runoff relationship. b) and the actual SWE: Runoff relationship for the Lake Powell Inflow 1981-2021.

runoff which was followed by the second year of no monsoon and a dry fall. The period from Aug-Dec of 2020 was the driest in the last 40 years for many high elevation locations in the Upper Colorado River Basin. In addition to the dry conditions, temperatures were also well above average across the basin, exacerbating the poor streamflow conditions. The combination of two years with minimal summer or fall precipitation, a poor runoff in 2020, and above average temperatures resulted in record dry soil moisture conditions across the entirety of the Upper Colorado River Basin entering the winter of 2021. What looked like not a great but not a terrible winter quickly took a turn for the worse with yet another record warm and dry spring. The majority of the snowmelt went to the parched soils acquired from the previous two years and little materialized as streamflow. Table 1 highlights the complexity of the relationship between streamflow, precipitation, spring weather, and soil moisture in the Upper Colorado River Basin over the last five years. It should be noted dry soil moisture conditions can be overcome in years that have cool/wet springs and above normal snowpack (2019). The problem arises when the soil moisture deficits are carried into the next runoff season as seen in 2020/2021.

The last two years provide an example of what runoff efficiency looks like in an extended warm and dry period. Back-to-back years of warm and dry conditions have had compounding effects on the runoff efficiency in the Upper Colorado River Basin. We should not be surprised to see similar or worse runoff efficiency as we continue into a warmer and drier future where consecutive years of warm and dry conditions may be more frequent. Decreased runoff efficiency could have serious implications for water management within the basin.

—Ashley is a senior hydrologist for the Colorado River Basin Forecast Center

Upper Colorado River Runoff					
Water Year	**Runoff % AVG**	**Runoff Efficiency**	**Max SWE**	**Fall Soil Moisture**	**Spring Weather**
2021	29%	Flow < Precipitation	Below normal	Dry	Warm/Dry
2020	59%	Flow < Precipitation	Near normal	Mixed*	Warm/Dry
2019	162%	Flow > Precipitation	Above normal	Dry	Cool/Wet
2018	41%	Flow < Precipitation	Below normal	Normal-Wet	Warm/Dry
2017	128%	Flow > Precipitation	Above normal	Mixed*	Cool/Normal
*Mixed indicates the soil moisture conditions were both wet/dry across the basin.					
Runoff % of AVG is the April-July observed inflow to Lake Powell compared to the 1991-2020 average period.					

Table 1. Runoff Conditions for the Upper Colorado River Basin 2017-2021. All conditions are representative of the area above Lake Powell.

Notes from the Field

—EB & JS

As the subpar winter of 2021 translated to a parched runoff, it became clear that Lake Powell reservoir would be dropping to historic lows. As Glen Canyon began to reveal treasures not seen for decades, GCI jumped at the opportunity to get into the canyons, document what is emerging, bring members of the media to cover its restoration, and lay the groundwork for further ecological research.

Spring Research Trip in the Escalante

In early 2021, GCI embarked on a research mission around the Escalante drainage of Glen Canyon with Scott Hynek and Casie Root from USGS, as well as Seth Arens, a researcher from Western Water Assessment. The goal of the trip was to revisit 50-mile Canyon, where GCI led a bioblitz two years prior, to do plant surveys and gauge changes in flora from the previous study. We also took preliminary observations of plant life in Willow Gulch. The USGS researchers were interested in the distribution and quantities of sediment being deposited in the canyon, as well as salinity levels.

Above: Seth Arens documents a riparian plant community. Photo By Dawn Kish.

Right: Scott Hynek and Casie Root take soil samples from the new delta of the Escalante River. Photo by Eric Balken.

Media Expeditions

The stunning emergence of geological features as well as ecological restoration precipitated a groundswell of interest from the media and the public. GCI led multiple media trips throughout spring, summer, and fall, generating a wave of extensive coverage on Glen Canyon's restoration from outlets like KUER Public Radio, NPR, *The Guardian*, KSL News, *The Salt Lake Tribune,* Gizmodo, and garnered interest from legendary environmental writers like Rebecca Solnit and Elizabeth Kolbert of *The New Yorker.*

Above: GCI founder Rich Ingebretsen talks to the KSL News crew in Cathedral in the Desert. Below: *The New Yorker* writer Elizabeth Kolbert takes in LaGorce Arch in Davis Gulch.

GCI Member Trip on the Yampa

While it's not yet practical to do full river trips in Glen Canyon, we can still learn about the landscape through other rivers on the Colorado Plateau. One amazing place for this is the Yampa River, the last free flowing river in the basin. Author and naturalist Steve Trimble joined GCI members for an amazing four-day river journey there with Holiday River Expeditions this summer.

Above: The GCI crew on the banks of Yampa River. Below: Tom Leubben paddles the Yampa in an inflatable kayak. Photos by Steve Trimble.

Revealed Treasures

The last time the span of Gregory Natural Bridge was exposed was spring of 1969. This summer, the span was revealed once again. Photo: Bill Bullers.

Left: Cathedral in the Desert, May 2021. Right: Cathedral in the Desert, October 2021. Flash floods cleared out half of the sediment in the Cathedral's chamber in a few months. Photos: Eric Balken.

3090 East 3300 South
Suite 400
Salt Lake City, UT 84109

ADDRESS SERVICE REQUESTED

"I sincerely hope that even if nothing else, the Basin States publicly acknowledge this river is over-allocated and climate change makes things worse. I hope they acknowledge we can no longer plan on a 14-15 million acre-foot river, but need to be planning for a 11-12 million acre-foot river. I realize acknowledging reality seems like a low bar, but to me, that would be a huge win for the Basin"
—John Berggren, Western Resource Advocates