Hoover Dam, symbol of the modern West, faces a new test with an epic water shortage

Hoover Dam has helped store Colorado River water since 1935, but reservoir levels are nearing the lowest point since Lake Mead was filled.

10:33 AM MDT May. 27, 2021

BOULDER CITY, Nevada — Hoover Dam towers more than 700 feet above Black Canyon on the Arizona-Nevada state line, holding back the waters of the Colorado River. On top of the dam, where visitors peer down the graceful white arc of its face, one of its art deco-style towers is adorned with a work of art that memorializes the purposes of the dam.

In five relief sculptures by Oskar Hansen, muscular men are shown gripping a

boat's wheel, harvesting an armful of wheat, standing beside cascading water and lifting a heavy weight overhead. With the concrete figures are words that encapsulate why the dam was built, as laid out in a 1928 law: FLOOD CONTROL, NAVIGATION, IRRIGATION, WATER STORAGE and POWER.

Eighty-six years after its completion in 1935, the infrastructure at Hoover Dam continues doing what it was designed to do: holding water and sending it coursing through intake tunnels, spinning turbines and generating electricity. But the rules for managing the river and dividing up its water — which were laid down nearly a century ago starting with the 1922 Colorado River Compact and which have repeatedly been tweaked — are now facing the greatest strains since the dam was built.

The effects of years of severe drought and temperatures pushed higher by climate change are strikingly visible along Lake Mead's retreating shorelines near Las Vegas, where the growing "bathtub ring" of whitish minerals coats the rocky desert slopes.

Since 2000, the water level in the reservoir, which is the largest in the country, has dropped about 140 feet. Lake Mead is now just 37% full, headed for a first-ever official shortage and sinking toward its lowest levels since it was filled.

One of the driest 22-year periods in centuries is colliding with the river's chronic overuse. As the reservoir falls toward record lows, its decline threatens the water supplies of cities and farmlands, and reveals how the system of managing water in the desert Southwest faces growing risks.

A high-water mark or "bathtub ring" is visible on the shoreline of Lake Mead at Hoover Dam. Mark Henle/The Repbulic

On top of the dam, where sidewalks run along the curving parapet, the views are dominated by four intake towers that protrude from the water. Each of the

dam's two giant spillways, where water last ran in 1983, sits dry and empty, leading to a gaping 50-foot-wide tunnel.

In a room with large windows overlooking the intake towers, Mike Bernardo of the federal Bureau of Reclamation begins a tour of the dam. He and Patti Aaron, a bureau spokesperson, have agreed to take me and Arizona Republic photojournalist Mark Henle inside to show us how the dam works and explain what the lower water levels will mean over the coming year.

Bernardo leads a team of engineers and hydrologists who plan water releases from Hoover Dam, as well as Davis and Parker dams downstream, sending flows that travel through pipelines and canals to Phoenix, Los Angeles and farmlands in the U.S. and Mexico that produce crops such as hay, cotton, grapes and lettuce.

Bernardo's team also sets power generation goals and produces a monthly report with the latest projections of how reservoir levels will likely change over the next 24 months. Lately, each month's report has brought worsening numbers. Predicted water-level declines have grown as estimates of inflows into Lake Powell, the upstream reservoir, have shrunk due to extremely parched conditions across the upper watershed in the Rocky Mountains, where much of the river's flow originates as melting snow.

"Unfortunately, due to how dry things have been," Bernardo says, "what we're seeing is Lake Powell's elevations are dropping."

And that will mean less water flowing into Lake Mead for the rest of the year. The past 12 months have been among the driest on record across the Colorado River Basin. Inflows into Lake Powell from April through July are estimated to be just 26% of the long-term average, and that's leading to rapid declines in both Powell and Mead, the two largest pieces of the river's water-storage system.

The warm, dry conditions over the past two years have baked the watershed's soils to such an extent, Bernardo says, that "when the snowmelt starts to run off, it just gets sucked up into the ground like a sponge."

But the demands for water downstream from Hoover Dam continue. And with the Southwest's farmlands in peak irrigation season through June, Bernardo says, Lake Mead's surface is dropping about 1 foot each week.

"Due to how dry things have been, what we're seeing is Lake Powell's elevations are dropping," says Mike Bernardo of the federal Bureau of Reclamation at Hoover Dam.
Mark Henle/USA TODAY NETWORK

The reservoir has declined more than 16 feet over the past year and is forecast to fall about 9 feet more by the end of this year.

The latest projections show that by the end of 2021, Lake Mead will decline below an elevation of 1,066 feet, far below the threshold — 1,075 feet — for the federal government to declare a shortage. That's expected to happen in August, triggering the largest water cuts to date next year for Arizona, Nevada and Mexico.

Even larger cutbacks could come in 2023 if the reservoir continues to decline as projected over the next year into a more severe "Tier 2" shortage.

Lake Mead's downward spiral is being driven largely by the dire situation upstream at Lake Powell, which has declined to 34% of full capacity.

"We need three to four consecutive years of above-average inflow, snowpack runoff and inflow into Lake Powell, to refill these reservoirs," Bernardo says. "So that's what we're hoping for."

The Colorado River naturally cycles through wet and dry periods. But over the past 22 years, the watershed has had 17 dry years, Bernardo says, and only 5

years with above-average or wet conditions.

With climate change, hotter temperatures have been evaporating more moisture off the landscape and leaving less flowing in the river and its tributaries. Scientists describe it as a "megadrought" and one that, unlike the long droughts of the past, is being amplified by carbon pollution and the heating of the planet.

One of the unknowns facing the officials who manage Colorado River water is just how severely the reservoirs could be affected by climate-driven "aridification" in the years to come. But some scientists have estimated the river could lose roughly one-fourth of its flow by 2050 as temperatures continue to rise, and that for each additional 1 degree C (1.8 degrees F) of warming, the average flow is likely to drop by about 9%.

"With the warmer temperatures," Bernardo says, "not only do we see things melt off quicker but you have that rising snow line, which creates less inflow."

The Overton Arm of Lake Mead at Lake Mead National Recreation Area, Nevada. The reservoir has declined dramatically since 2000.
Mark Henle/USA TODAY NETWORK

The declines in the reservoirs have accelerated over the past two years.

In 2019, representatives of Arizona, Nevada and California agreed under a deal called the Drought Contingency Plan to share in water reductions through 2026 to reduce the risks of Lake Mead falling to critically low levels. The agreement calls for progressively larger cutbacks if Lake Mead continues to drop below lower trigger points in the coming years.

If the reservoir drops below 1,045 feet, California would start to take cuts. And Mexico is already contributing by leaving some water in Lake Mead.

“These mechanisms have been put into place to protect these reservoir elevations,” Bernardo says.

While the latest agreement is intended as a temporary stopgap measure, officials from the seven states that depend on the river are preparing to negotiate new rules for managing shortages after 2026. And those talks promise to be tougher.

“The biggest challenge is how the future water officials will look at that imbalance of the actual water that's coming into the reservoirs now, and use that information and plan for the future,” Bernardo says.

In the meantime, he says, the bureau's responsibilities in managing the dams and water deliveries remain the same. And that includes incorporating the latest science and models, and providing up-to-date information to representatives of the states, water districts, tribes and other entities along the river, Bernardo says, “to communicate what's going on and what we're seeing, so everyone can act proactively.”

“When you have a river system like this, a complex reservoir and river system especially, that is experiencing the hydrology that we've been seeing, and such a quick decline in the Upper Basin over these last two years, transparency and communication is key,” Bernardo says.

Leaving the room overlooking the lake, Bernardo leads us along the sidewalk and into a tower, where golden elevator doors roll open.

We step in and descend into the belly of Hoover Dam.

Patti Aaron with the Bureau of Reclamation explains how Hoover Dam works.
Mark Henle/USA TODAY NETWORK

Iconic dam holds less and less

Bernardo is 35 and has worked for the Bureau of Reclamation for nearly a decade, including the last two years as river operations manager. A mechanical engineer who grew up in New Jersey, he usually works with his staff at the agency's office in Boulder City, Nevada, but he also regularly drives out to visit the dam, sometimes to lead special tours.

Whenever he rounds the curve in the canyon and sees the dam, Bernardo says, he feels awestruck and "the hair still sticks up on my arms."

"It never gets old," he says. "I'm wowed by the engineering marvel."

Part of that comes from knowing the history of all that went into the dam's design and construction during the Great Depression, from the hand-drawn blueprints to the blasting with dynamite, the railroad that carried supplies, and the massive amounts of concrete that were poured in, creating a dam that is 660 feet thick at its base — nearly as thick between the reservoir and the downstream side as it is tall. (According to the Bureau of Reclamation, Hoover Dam contains enough concrete to build a sidewalk 4-feet wide around the entire Earth at the equator.)

Whenever he visits the dam, Bernardo says, its historical significance is also inescapable: how it controlled the Colorado's floods, opened up arid lands for farming and fed the rise of cities across the Southwest. As he describes it, the dam "helped nourish our nation" and helped the West thrive.

"We like to show it off," he says.

Bernardo is steeped in numbers and rattles off details about river flows, the dam, the volumes of water released and the amounts of hydroelectricity generated.

With higher lake levels, Hoover Dam's normal capacity is 2,074 megawatts, he explains, generating enough power per year to supply approximately 450,000 average households. But at today's lake level, the dam's capacity has decreased about 25% to 1,567 megawatts, and it's generating enough power for roughly 350,000 homes.

With every foot the lake declines, about 6 megawatts of power-generating capacity is lost. The lowest level at which Hoover could produce power is about 950 feet, with an expected capacity of 650 megawatts. If the lake were to fall below that point — a scenario the existing rules are geared toward avoiding — the dam would no longer be able to generate power.

Wearing hardhats, we stand facing a row of colossal generators in the power house on the Arizona side of the dam. Each one weighs more than four Boeing 747-400 jets. On their sides are plaques listing the manufacturers: Westinghouse, GE, I.P. Morris and Allis-Chalmers. The oldest generators have been operating since 1936.

Inside each generator, Bernardo says, a rotor weighing 1.2 million pounds spins at 180 revolutions per minute.

The water flows in through intake towers, comes jetting through under high pressure and spins the turbines, generating electricity. Only two of the nine turbines on the Arizona side are spinning at the moment to meet power demands, but the chamber still hums with the rumble of whirring metal.

Bernardo steps close to a generator and puts a hand on one of several round windows containing oil. It's warm from circulating through the machinery.

Bernardo is fascinated by the mechanics of the dam, including its custom-made parts and tools, such as special wrenches nearly 4 feet in length. When a bolt needs to be replaced, he says, it must be fabricated from scratch.

He's also studied the data on water levels, inflows and releases to a point that he can describe off the top of his head how releasing a certain amount of water will affect Lake Mead.

"Every 85,000 acre-feet is equivalent to one foot in elevation in Lake Mead right now at the current elevations," Bernardo says.

As water levels drop, Hoover Dam is less able to generate power.
Mark Henle/USA TODAY NETWORK

But as the reservoir continues to decline, releasing that same amount of water yields a bigger drop in lake level.

"That's one of the concerning pieces," Bernardo says. "The reservoir is shaped, we call it a teacup, but more like a martini glass. And the lower the elevation goes, the faster the rate of decline."

That dynamic also affects how much the planned water cuts can help Mead's level. Under a first-tier shortage next year, for example, Arizona, Nevada and Mexico are preparing for cuts totaling 613,000 acre-feet, which Bernardo says is equivalent to 7-8 feet in Lake Mead.

If the reservoir were to drop through lower shortage levels to below 1,025 feet, the total cuts among the three states and Mexico would add up to more than 1.3 million acre-feet. That amount, Bernardo says, would equal nearly 20 feet conserved in Lake Mead at those low levels.

When representatives of California, Arizona and Nevada were negotiating the deal, they decided on 1,025 feet as a threshold to avoid, and one they thought the lake would be unlikely to reach. The agreement also includes a backup provision. If the two-year projections show Mead is likely to decline below 1,030 feet, the agreement says the states and the Interior secretary "shall

consult and determine what additional measures will be taken."

The government's latest five-year projections, using an approach that considers the river's lower flows over the past three decades, estimate a 25% chance of Lake Mead declining below 1,025 feet in 2025.

Much could change, though, with a snowy winter in the mountains.

"We hope and we feel very strongly that the measures that have been put into place should slow down the decline," Bernardo says. "Now, if it's enough to make it recover, your guess is as good as mine, because the hydrology has been so bad."

But if the river basin gets a wet year with average flows, Bernardo says, the cutbacks in the existing plan "will buy us time to get to the next year, in hopes to get a better water year."

"And I think that's what the system is designed to do," he says.

An 'Era of Limits'

The outlook for the Colorado River has grown increasingly dire over the past several years. In one study, scientists found that about half the trend of decreasing runoff in the Upper Colorado River Basin since 2000 was due to unprecedented warming.

Other researchers warned in a report this year that an "incremental approach to adaptation" is unlikely to be enough in the future. They pointed out that flows from 2000 through 2018 were about 18% less than the 20th century average and said the downward trend will likely continue as temperatures rise with climate change.

Worries about overusing the river predate the current dry spell. In fact, some

early warnings came before the legal framework that divided the Colorado among the seven states and Mexico.

John Wesley Powell famously voiced concerns in 1893, some 24 years after his expedition down the river in the Grand Canyon, when he told the attendees at the International Irrigation Congress in Los Angeles: "I tell you, gentlemen, you are piling up a heritage of conflict and litigation over water rights, for there is not sufficient water to supply these lands."

Under the 1922 Colorado River Compact and subsequent agreements, the river has long been severely overallocated. As University of Arizona law professor Robert Glennon has succinctly put it, "there are more water rights than there is water."

So much has been diverted that most of the river's delta in Mexico was transformed decades ago into stretches of dry riverbed that wind through farmlands and desert in the Mexicali Valley. Only a smattering of natural wetlands remain.

A journey into the heart of a river forever changed by human hands

Read more

In his 1986 book "Cadillac Desert," Marc Reisner wrote that Hoover Dam "rose up at the depths of the Depression and carried America's spirits with it. Its electricity helped produce the ships and planes that won the Second World War, and its water helped grow the food."

But Reisner wrote that from these hopeful beginnings, "the tale of human intervention in the Colorado River degenerates into a chronicle of hubris and

obtuseness" and that people in the river basin — at that time only 20 million — "will probably find themselves facing chronic shortages, if not some kind of catastrophe."

"One could say that the age of great expectations was inaugurated at Hoover Dam," Reisner wrote. "And one could say that, amid the salt-encrusted sands of the river's dried-up delta, we began to founder on the Era of Limits."

More recently, authors Eric Kuhn and John Fleck wrote in their 2019 book "Science Be Dammed: How Ignoring Inconvenient Science Drained the Colorado River" that "even absent climate change, we would be in trouble" and that the current problems surrounding the river "are the inevitable result of critical decisions made by water managers and politicians who ignored the science" as early as the 1920s.

They found that in 1925, U.S. Geological Survey scientist Eugene Clyde LaRue had "tallied what was known at the time about the river's flow, potentially irrigable farmland, and growing cities, and concluded that if we built the dams and canals to use all the water being allocated on paper in the 1920s to meet all the anticipated demand, the Colorado River would be in deficit."

Two other scientific analyses in the 1920s reached the same conclusion, Kuhn and Fleck wrote, but the scientists' warnings were ignored, and that "set in motion decades of decisions that would end in the overuse seen today."

They suggested that addressing the river's deficit will require recognizing that the "over-allocation became embedded in basin rules in very specific ways that remain unresolved" and should be fixed.

Negotiating the post-2026 rules will be challenging for everyone involved, Kuhn and Fleck wrote, and some of the fundamental issues facing negotiators now are similar to those a century ago, including questions of how much water

the river will provide in the years ahead, and how the system should be governed amid uncertainty.

The Colorado River Basin needs "a stable and effective governance of the use of the river's waters under conditions where current demands already exceed the exiting supplies," Kuhn and Fleck wrote. "Like one hundred years ago, the river's future is not all dark. Innovation, cooperation, and an expanded reliance on science are now the foundation for basin-wide solutions."

One effort to restore some of the wetlands and ecosystems in Mexico began this month, as water began flowing into the delta under an agreement between the U.S. and Mexican governments. The water releases in the delta, which will total 35,000 acre-feet between May and October, are intended to nourish vegetation and wildlife at habitat restoration sites where conservation groups have planted cottonwoods and willows.

The influx of water is supposed to mimic a small portion of the floods that once swept across the delta toward the Sea of Cortez. This year's releases amount to a smaller version of a planned flood that coursed through the delta in 2014. In that "pulse flow," 105,000 acre-feet of water brought back a flowing river in areas that had been dry since floods in the late 1990s.

The releases in the delta this year, using water previously stored in Lake Mead, amount to just 5 inches of water in the reservoir. Much more of the water that passes through Hoover Dam is pumped to Phoenix, Tucson and Los Angeles, and flows through canals to irrigate farmlands along the river from Parker to Yuma, and across the Coachella, Imperial and Mexicali valleys.

Hoover Dam, on the Arizona/Nevada border, is one of the great feats of engineering.
Mark Henle/USA TODAY NETWORK

Low water levels bring risks

As we continue through the innards of Hoover Dam, the polished terrazzo floors and hallways give way to a dim tunnel, which cuts into the canyon wall. Its ceiling and sides are rough-hewn jagged rock resembling a mineshaft.

Stopping, Bernardo holds his phone and points its light at a round hole in the tunnel wall.

“They would load it up with dynamite and they'd blast,” he says. “Drill it in, put the dynamite, blast it, remove the debris, over and over again.”

In places, the tunnel walls are wet. Dripping water dribbles down the rocks.

“All dams have seepage, no matter where they are. We never call it a leak because it's not a leak. It's just seepage, the natural process,” Bernardo explains. The water seeps from the lake through cracks in the rock and is routed to drains and a sump, then pumped to the river below the dam.

When the reservoir is higher, Bernardo says, the amount of water seeping through increases because the lake exerts more pressure.

A view of the 30-foot diameter penstock (bottom) from the penstock access room on the Arizona side, May 11, 2021, at Hoover Dam, on the Arizona/Nevada border.
Mark Henle/The Republic

At the end of the passage, we step into a room with windows that look out over the diversion tunnel and the penstock, a steel pipe 30 feet in diameter. Referring to a diagram on the wall, Bernardo explains how water enters the dam, spins the turbines and discharges into the river.

If the water were to decline about 125 feet from where it stands, below the elevation of 950 feet, he says, Hoover Dam would lose the ability to generate power.

"That's what we call minimum power pool," Bernardo says.

If Mead continues to fall further, the dam could still release water down to a level of 895 feet.

"At 895 and below, Hoover Dam is unable to pass water by any conventional means. So you would essentially have to pump it out of Lake Mead. That's what we call dead pool," Bernardo says. "And at dead pool, Lake Mead still has 2.5 million acre-feet in storage, but there's just no way to get it out."

If the lake declines that much, only the Southern Nevada Water Authority, which supplies Las Vegas, has an intake deep enough to continue pumping water.

The risks of Mead falling to such lows gave impetus to the last round of negotiations, which led to the 2019 signing of the Drought Contingency Plan at Hoover Dam.

The river would have been in a shortage already years ago if the states and Mexico hadn't made concerted efforts to prop up Lake Mead's levels, Bernardo says, and those steps included various conservation programs that have yielded 4 million acre-feet over the past 15 years, representing about 50 feet of water in the lake.

But with the unrelenting dry years, he says, "we knew that we couldn't postpone a shortage forever."

Mike Bernardo of the federal Bureau of Reclamation says that if the water level fell below the elevation of 950 feet, Hoover Dam would lose the ability to generate power.
Mark Henle/USA TODAY NETWORK

He reiterates that the shortage measures, including the mandatory cutbacks, were adopted to reduce risks.

“And although it's scary that this will be the first time we're using them, they were designed by very smart people throughout the Colorado River Basin,” Bernardo says. “And let's hope that they work the way that they were designed to work.”

If the situation continues to worsen, he says, everyone involved in managing the river’s water will get together again, as stipulated in the 2019 agreements, to take steps to protect the reservoirs. With about 40 million people relying on water from the Colorado and its tributaries, he says, “all of us as water managers have a responsibility to all of those that are in the basin.”

Stepping out of the power house, we turn a corner and look up. Bernardo says it’s his favorite part of the tour.

The sloping face of the dam towers overhead. Below is the blue-green river. Swallows glide and swoop over the churning water.

After taking photos, we walk to the base of the dam, where a white stripe is painted on the platform marking the Arizona-Nevada line.

Putting a hand on the concrete, I feel the vibrations of the dam’s turbines whirring.

By mid-June, Lake Mead is set to decline to its lowest levels on record. Hoover Dam will soon hold the smallest amount of water since it was filled in the 1930s. The next few years may show how much water use needs to decrease to rebalance the river and reduce the risk that Hoover Dam might one day fall silent.

Ian James covers water, climate change and the environment for The Arizona Republic. Send him story tips, comments and questions at ian.james@arizonarepublic.com and follow him on Twitter at

@BylanJames.

Environmental coverage on azcentral.com and in The Arizona Republic is supported by a grant from the Nina Mason Pulliam Charitable Trust. Follow The Republic environmental reporting team at environment.azcentral.com and @azcenvironment on Facebook, Twitter and Instagram.