COLORADO RIVER PROJECT

River REPORT

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A project of the Water Education Foundation

A Warmer Future and Increased Risk

By Gary Pitzer

Water supply agencies in the Colorado River Basin are all too aware of the region's propensity for extreme variability.

For about 20 years, the Basin has been mired in a historic drought marked by the lowest 17-year period of inflow in more than 100 years of record keeping. The result has been a struggle to maintain adequate reservoir levels in a storage system that has declined from nearly full to about half of capacity.

In 2016, Lake Mead, the largest man-made reservoir in the nation, fell to 1,080 feet, a level not seen since 1937 when the lake was filling for the first time. By comparison, when full, Lake Mead sits at 1,221.4 feet above mean sea level. It ended the 2017 Water Year at 10.1 million acre-feet, about 39 percent of its capacity.

Forecasts about future conditions have improved, but the specter of drought continually looms over the Basin.

Added to that equation is a record of marked temperature increases that portend a different hydrologic future and the need for people to adapt to a new normal. Bureau of Reclamation's 2012 Colorado River Basin Water Supply and Demand Study assessed a wide range of future water supply

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Aerial view in 2015 of Lake Mead near Callville and Swallow bays, near an area known as the Narrows. Lake water elevation is at 1,075 feet.

Dear Readers

Persistent drought along the Colorado River has vexed water managers for years. The last 17 years have seen the lowest inflow in the Colorado River Basin in more than 100 years of record keeping. Water in Lake Mead fell in 2016 to levels not seen since 1937, when the reservoir behind Hoover Dam was first filling. Things may improve in the short term. But in the long term, they are likely to get worse.

Climate change already is showing its effects, with global mean temperatures rising 1.5 degrees Fahrenheit since the late 19th century. Snowpack in the Colorado River Basin is smaller and it's melting earlier, diminishing the river system's natural reservoir. A growing body of science is assessing what all this could mean for the Colorado River and the seven states and the nation of Mexico that depend on it for household needs, crop irrigation and the environment.

In this issue of River Report, writer Gary Pitzer examines what scientists are projecting, and how water managers are preparing for a future of increasing scarcity. Rising temperatures could accelerate evaporation along the river system and dry the soil. Hotter, drier weather is likely to increase demand for water. Farmers in the southern region of the Basin, a source of year-round food crops, may find some crops are no longer viable. Complicating solutions is the long-established framework for dividing the river's waters and deciding who is first in line when there's too little to go around. The uncertainty surrounding both the supply along the Colorado and increasing demand is pressing water managers to find ways to cooperate, collaborate and adapt.

– Doug Beeman

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The mission of the Water Education Foundation, an impartial, nonprofit organization, is to create a better understanding of water resources and foster public understanding and resolution of water resource issues through facilitation, education and outreach.

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and demand scenarios and found that the Basin is projected to experience a median deficit of 3.2 million acre-feet per year between supply and demand by 2060. That imbalance can be as high as 6.8 million acre-feet when considering the drier water supply scenarios that primarily result from global climate model projections. "The Basin States include some of the fastest-growing urban and industrial areas in the United States," the study said. "At the same time, the effects of climate change and variability on the Basin water supply have been the focus of many scientific studies which project a decline in the future yield of the Colorado River. Increasing demand, coupled with decreasing supplies, will certainly exacerbate imbalances throughout the Basin."

A growing compendium of scientific evidence shows that global warming, primarily a result of increased concentrations of greenhouse gases in the Earth's atmosphere, is changing climate conditions. Since the late 19th century, observations indicate that global mean annual air temperatures have warmed 1.5 degrees Fahrenheit, according to several reports released by the Intergovernmental Panel on Climate Change.

"Temperatures are going to keep increasing and the trajectory we are on now is at the very high end," said Kathy Jacobs, director of the Center for Climate Adaptation Science and Solutions at the University of Arizona. "Because temperatures are increasing and because people have not fully understood the implications of that on river flows, the declines are likely to be higher than what people have historically estimated."

Jacobs, former director of the National Climate Assessment, spoke Sept. 29 at the Water Education Foundation's invitation-only, biennial Colorado River Symposium in Santa Fe, N.M. She described climate change not as some abstract notion that can be presented in several scenarios, but as a pressing problem that demands practical solutions local officials can incorporate into action.

"Given the magnitude of this problem, all of us should be highly mobilized," she said.

"There's been a general movement away from trying to educate the public [as a way to manage this issue] because the attention span is so incredibly short. What we really need to do is help, in specific decision contexts, give the kind of information that is credible, useful and timely for decision-makers at that scale of decisions."

The most recent National Climate Assessment in 2017 noted that while climate model simulations "suggest that droughts lasting several years to decades occur naturally in the southwestern United States," the region "is projected to experience significant decreases in surface water availability, leading to surface runoff decreases in California, Nevada, Texas, and the Colorado River headwaters even in the near term."

The increased heat is a significant factor in the expected reduction in river flows, authors Brad Udall with Colorado State University and Jonathan Overpeck with the University of Arizona (now at the University of Michigan) wrote in their 2017 research paper, *The 21st Century Colorado River Hot Drought and Implications for the Future.*

Farm fields under irrigation near Yuma, Ariz.

"Previous comparable droughts were caused by a lack of precipitation, not high temperatures," they wrote. "As temperatures increase in the 21st century due to continued human emissions of greenhouse gases, additional temperature-induced flow losses will occur. These losses may exceed 20 percent at mid-century and 35 percent at end-century."

As climate change causes air temperatures to increase, more water evaporates and soils dry out. This means less water reaches the river when the rain does arrive. Among their findings, the two scientists wrote that between 2000 and 2014 the Colorado River's flows declined to only 81 percent of the 20th century average, a reduction of about 2.9 million acre-feet of water per year. As much as one-half of that reduction can be attributed to the higher temperatures since 2000, the report said.

With so many people depending on the river, major water suppliers have joined forces to avoid painful cuts in deliveries. The pursuit of this cooperative and collaborative approach reflects an acknowledgement that, ultimately, the water rights system creates winners and losers in extreme circumstances.

"In the West, when you have first in time, first in right water rights, what that means is the last in time gets left out," said Brandon Goshi, manager of water policy and strategy for the Metropolitan Water District of Southern California (MWD). "That seems archaic. If it's a problem, then we have a problem we need to address together."

Natural variability, in combination with long-term changes in climate, will continue to influence conditions. However, even relatively small shifts in the average climate can substantially change the risk of extreme events such as heat waves, cold snaps, floods and drought.

"The issue of extreme events is here to stay, particularly those that are related to heat, and of course all extreme events at some level are related [to more energy in the atmosphere due to greenhouse gases]," Jacobs said.

The impacts on the natural environment from climate change are in addition to the decades of habitat loss that have occurred because of development and land conversion and the impact of invasive species that have altered habitat and, in some cases, contributed to the loss of native species.

"Climate change is projected to exacerbate habitat declines across the Basin, reducing water supply, raising temperatures and aridity, and disrupting phenology – the timing of seasonal natural phenomena such as spring floods, plant flowering, and insect hatching," according to a July 2017 report by the Audubon Society, *Water and Birds in the Arid West.* "Extreme conditions are likely to push organisms beyond what they can tolerate in parts of the arid southwest."

Devising effective climate change adaptation and mitigation policies can be difficult because of the need for people to coalesce around a unified strategy, Jacobs said.

"Everybody can look at the same set of facts and come up with a different conclusion and that is legitimate and normal," she said. "We all think because we look at the same facts, we should come up with the same conclusion and it doesn't always work that way. There are a lot of challenges for decision-makers … because it's outside the envelope of prior experience in many cases."

Because a stable and reliable water supply is so vital to the economy and livelihood of such a large and growing segment of the country, water agencies are trying to stay ahead of the curve to meet coming challenges.

In Southern California, where MWD receives one-half of its imported supply from the Colorado River, ensuring the robustness of water delivery systems at the micro and macro levels is a high priority. Uncertainty "is the name of the game" in a region affected by drought and regulatory restrictions on imported water supplies from Northern California.

A neighborhood in Las Vegas, which receives an average of just 4.3 inches of rainfall annually.

"Our approach to the uncertainty planning is the incorporation of a robust decision-making process to look at what the vulnerability of our [Integrated Resources Plan] is to the ranges of uncertainty in all these areas, including climate change," Goshi said.

The agricultural sector is vulnerable to climate change impacts as well. In a 2017 report, *Climate Change Vulnerability in the Food, Energy, and Water Nexus: Concerns for Agricultural Production in Arizona and its Urban Export Supply*, researchers at Arizona State University found that "climate change and increased resource demands are expected to cause frequent and severe strains" on water and energy systems, and that Arizona "is especially vulnerable" because of its hot and arid climate.

"Climate change creates a feedback loop by increasing temperature, necessitating more water and therefore energy use for crops, leading to further climate change," the report said. "An abundant food supply also creates feedbacks by increasing population growth, which causes further climate change and higher food demand."

The Climate Change Connection

In November 2017 the *Climate Science Special Report: Fourth National Climate Assessment* concluded that "based on extensive evidence, that it is extremely likely that human activities, especially emissions of greenhouse gases, are the dominant cause of the observed warming since the mid-20th century."

The report went on to say that annual trends toward earlier spring melt and reduced snowpack "are already affecting water resources in the western United States" and that assuming no change to current water resources management, "chronic, long-duration hydrological drought is increasingly possible before the end of this century."

Anyone living in the Southwest can tell you it's a dry place. Las Vegas receives 4.3 inches of rain annually. By contrast, parts of the Pacific Northwest receive more than eight times that amount.

Climate change affects the water cycle through less supply and storage from snowmelt, a greater percentage of precipitation coming as rain, earlier snowmelt and peak flows.

A growing data set is enabling scientists to flesh out how increasing temperatures are skewing normal weather events. "It's much easier for people, at least from a statistical perspective, to say whether or not individual events are connected to climate change," Jacobs said. "We are now starting to understand why these things are happening and how."

Climate change has brought "major declines" in snowpack, snow-water equivalent and snow cover in part due to

increases in surface temperature across all the mountain ranges in the West, Jacobs said, adding that the trend "seems like it's going to continue in a big way into the future."

Those conditions affect dam operations because of the need to plan for drought as well as more intense downpours that require stepped-up flood management.

From the environmental perspective, a higher evapotranspiration rate has implications for riparian areas because of reduced surface flows. "Climate change is affecting not only species and ecosystems, it's also affecting the services that ecosystems provide to us," Jacobs said. "Climate change, combined with other stressors, is overwhelming the capacity of ecosystems to buffer the effects of extreme events. The implications for biodiversity are huge and it's the area we are least capable of doing the kinds of adaptation that are required."

> *"This river is not in good shape today, despite the fact we have made progress and despite the fact this year was a somewhat normal year."*
>
> *– Jim Lochhead, CEO and general manager of Denver Water*

From the human perspective, extreme heat events, such as what Phoenix experienced in summer 2017, have reverberating effects, from straining the power grid to the grounding of commercial aircraft because the air is too hot to provide enough lift.

Arizona, which gets about 40 percent of its water from the Colorado River, has been working to buttress Lake Mead while looking toward the longer-term issue of climate change.

"Our focus has been mostly to target the issue of preventing shortage or, if we have to go into shortage, mitigating how bad the severity of a shortage impact is," said Mohammed Mahmoud, senior policy analyst with the Central Arizona Project (CAP). "In terms of climate change, … we are developing our own plan for a general strategy moving forward to address climate change and specifically adaptation."

Climate Change and the Colorado River Basin

Population in the seven Colorado River Basin states – Arizona, Nevada, California, Colorado, Utah, Wyoming and New Mexico – is expected to grow from 56 million to 94 million by 2050. Much of the water for cities and farms comes from Rocky Mountain snowmelt

The Colorado River is flanked by fall colors east of Glenwood Springs, Colo.

that feeds into the Colorado River as it winds 1,450 miles from its headwaters through the Southwest and into Mexico.

According to a 2014 report published by the Bulletin of the American Meteorological Society, *Understanding Uncertainties in Future Colorado River Streamflow*, recent studies that project streamflow changes in the Colorado River all show annual declines, but the magnitude of the projected decreases ranges from less than 10 percent to 45 percent by the mid-21st century. This is accounted for by "substantial evidence" that future Colorado River flow "will be reduced under the current trajectories of anthropogenic greenhouse gas emissions because of a combination of strong temperature-induced runoff curtailment and reduced annual precipitation."

Temperatures appear to have been playing a larger role than initially thought in reducing the flows of water down the Colorado River since the late 1980s, according to a 2016 study authored by scientists with the University of Arizona, University of Nevada and the U.S. Geological Survey (USGS).

Called *Increasing Influence of Air Temperature on Upper Colorado River Streamflow*, the study found that "recent droughts have been amplified by warmer temperatures that exacerbate the effects of relatively modest precipitation deficits." As a result, "continued warming temperatures will be an increasingly important influence in reducing future Upper Colorado River Basin water supplies."

Drought planning and heightened conservation measures are most often linked to the mega-population of the Southwest – Las Vegas, Southern California and Phoenix (with Tucson not far behind). However, a system crash also would adversely affect the rapidly growing Front Range in Colorado.

"We get half of our supply from the Colorado River, so if there is an upset on the river … and there's a curtailment in the Upper Basin … the entire Denver Front Range is at risk," Jim Lochhead, chief executive officer and general manager of Denver Water, said at the Symposium. "That's not a shortage, that's a curtailment. That's done. We are over; we are out of water."

> *"We don't have a supply problem, we have an allocation problem. There is little water allocated for nature and nature has very low priority."*
>
> *– Karl Flessa, professor of geosciences at the University of Arizona*

Lochhead said it's crucial that stakeholders not rest on their laurels and expect the coming winter to adequately replenish the snowpack.

"This river is not in good shape today, despite the fact we have made progress and despite the fact this year was a somewhat normal year," he said. "We are at a tipping point where we can achieve another spectacular success or we can fail miserably if we don't pull the pieces together and the pieces are sitting, frankly, right in front of all of us."

Researchers are scouring information to determine where the region has been climate-wise, and where it's going based on key data sources. Among the organizations is Reclamation, which in its *Colorado River Basin Water Supply and Demand Study* found that two-thirds of 112 future climate projections from a set of global climate models used by the Intergovernmental Panel on Climate Change show drying. One-third show no change or increases in Colorado River streamflow.

Reclamation believes that each degree Celsius of warming in and around the Colorado River could increase evaporation and evapotranspiration by as much as 3 percent. That is significant considering the 4.5 million acres of farmland irrigated with Colorado River water and the 35-40 million people in seven states who depend on the river for their municipal supply.

Meanwhile, ever-increasing and detailed data is pointing to a dramatically altered hydrologic future on the river, one that portends a new reality that will require the most stringent of drought contingency planning and most likely a change in water use practices.

Udall, who spoke at the Foundation's Santa Fe Symposium, told attendees that everyone is going to have to up their game to do more with less.

"Despite all the great work that's been done on drought contingency planning, this Basin is not doing enough to deal with the risk," he said during a panel discussion about the Basin's big picture, including future challenges. "We can adapt, we can reduce greenhouse gas emissions, and to the extent we do neither, we will suffer."

Udall acknowledged the thorny issue of perhaps reallocating or redistributing water in a basin where the Law of the River is sacrosanct.

"Most people in this community have shied away from mitigation, thinking it's too politically sensitive, that it's somebody else's problem," he said. "Mitigation is all of our problem. We have the policy tools and the technology to begin solving this meaningfully."

As climate change causes air temperatures to increase, more water evaporates and soils dry out.

The Environmental Connection

Adaptation is a way of life for the plants, birds, fish and wildlife in the Colorado River Basin, particularly the harsher desert regions. However, the advent of climate change has thrust a new threat level to some species already struggling to maintain viability.

"Climate change is exacerbating most of the pre-existing problems of the Colorado River," said Karl Flessa, professor of geosciences at the University of Arizona. "Among the ecosystem services provided by the river is the river water itself. As others have put it, we don't have a supply problem, we have an allocation problem. There is little water allocated for nature and nature has very low priority."

The effects are many and varied. According to the U.S. Geological Survey, ecosystem processes that keep soil carbon and nutrients available will be slowed. Alterations at the base of the food chain will reverberate upward. The expected loss of vegetation such as lichens, grasses and some trees will reduce populations of animals that depend on the quantity and quality of these plants for food and habitat, which will then affect their predators.

Animals that rely on free surface water also will be at risk, including grazing cattle that depend on the availability of grass and surface water. Insect outbreaks on drought-stressed plants will be more common and will likely lead to a dramatic increase in wildfires. Recovery after fire generally depends on water availability and thus is expected to be much slower than in the past.

Jacobs said it remains to be seen how the projected dryness in the Basin affects groundwater, though she alluded to California's rapid increase in groundwater pumping and subsequent overdraft in some regions in response to its most recent drought.

"Something not widely understood and not talked about very much is what the implications of climate change are for groundwater," she said. "They will be very different depending on the geology of the basins and whether the groundwater is fed by snowmelt. Obviously, there are places where there will be more intense precipitation, more flood flows and in these places, we could at least, on an annual basis, have more recharge."

> *"At some point in the next 10 years, we are going to wake up and go, 'Oops, we are way overshooting a safe and livable planet.'"*
>
> *– Brad Udall, Colorado State University*

Overall, however, it is likely that groundwater recharge across the Southwest will decline as surface flows decline.

Jacobs said aquatic systems and riparian areas already "on the brink" of crashing are especially vulnerable to climate change.

"There are a whole host of issues associated with aquatic systems," she said, citing reduced dissolved oxygen levels, increased pollutant concentrations caused by less than normal flow and reduced groundwater availability. An "underappreciated fact" is how groundwater supports habitat through its contribution to surface flows and its direct connection to trees and fauna.

Adjusting to a New Playbook

The Udall/Overpeck 2017 paper notes that "approximately one-third of the flow loss in the Colorado River is due to high temperatures now common in the Basin, a result of human-caused climate change," and that "as temperatures increase in the 21st century due to continued human emissions of greenhouse gasses, additional temperature-induced flow losses will occur."

The scenario is not an attractive one for the Basin, Udall said at the Symposium, calling a 3.6-degree Fahrenheit increase by 2100 a "living hell for water managers."

While climate change policy is shrouded by political influence, Udall said circumstances will eventually compel actions that help stem the tide of the negative impacts.

"At some point in the next 10 years, we are going to wake up and go, 'Oops, we are way overshooting a safe and livable planet,'" he said.

The extreme conditions could be met by techniques such as solar radiation management, a method of deliberate injection of particles into the stratosphere that aims to artificially cool the planet while trying to remove carbon dioxide and other greenhouse gases.

The problem with that, Udall said, is the possibility of the unintended side effects such as changes in the hydrologic cycle that lead to things such as increased monsoon activity.

There is "huge potential" to remove carbon from the atmosphere through forest management and increased agricultural development (also known as negative emissions), Udall said.

Living with Uncertainty

Scientists and "science translators" like Jacobs and Udall are adamant about the need for urgent response to climate change.

"There's this idea that climate change is going to gradually change things and that there will be plenty of time to make decisions when, in fact, the way we are experiencing it is through a series of extreme events that are very hard to predict. These are step changes as opposed to long-term trends," Jacobs said.

There are many challenges associated with connecting science and decision-making.

"People have referred to it as the 'Valley of Death' and bridging this gap is very challenging," Jacobs said. "Obviously scientists think differently than the rest of us … and trying to do the right thing in the context of institutions that are not set up to manage risk properly is really difficult."

Furthermore, she added, information about climate change is not getting

through to the public in meaningful ways.

"The knowledge that exists within the water management system doesn't get shared with academia as well as it should and vice versa," she said. "The giant gap between science and decision-making hasn't really been narrowing, despite the fact there have been significant investments in regional science and assessment," such as NOAA's Regional Integrated Sciences and Assessments and the DOI Climate Science Centers.

Flessa with the University of Arizona said it's important to keep the environmental impacts of climate change a high priority as time progresses.

"Much of the ecosystem damage to the river's habitats was already done by the time that climate change effects were added to the list of stressors. Yet, alas, we can make things worse – by building more dams, by diverting more water, by assigning a low priority to water that supports the semi-natural ecosystems that remain," he said. "Ecosystems that have already been compromised can't be expected to buffer yet more extreme events."

It is through such cooperative ventures as the Colorado River Interim Guidelines for Lower Basin Shortages that water agencies should be able to weather the brunt of expected supply shortages in a manner that avoids conflict, MWD's Goshi said, adding that "cooperative solutions" are preferable to water rights-based disputes.

Climate change response in the water sector is often couched as mitigation and adaptation. According to the Pacific Institute's Climate Change and Water, while "some degree of climate change is now unavoidable," an adaptation-focused approach "must be a central element of policy."

"Water managers and farmers around the world already implement a variety of technologies and practices to adapt to current climate and weather-related risks," the report said. "For example, water managers implement water conservation and efficiency measures to reduce their vulnerability to water supply constraints. Farmers shift the timing and types of crops grown according to seasonal weather forecasts."

Arizona, which plays an important role through its year-round crop production, will have to find ways to be resilient in the face of coming adversity.

"Arizona agriculture faces many challenges as the vulnerabilities of the food-energy-water nexus combined with anticipated effects of climate change lead to higher operating expenses, uncertainty regarding crop viability, and reduced availability of necessary resources," the ASU report said. "Many farmers may lack the financial resources or tolerance for increased costs to implement adaptations, but such measures may be necessary for agriculture to continue to thrive in Arizona."

For water agencies, the outlook has changed dramatically, even in less-than-predictable California. "There's a huge amount of uncertainty," Goshi said. "We live with it the same way that we live with the fact that we don't know what the population growth is going to be, and we don't know whether new local supplies – that were included in our Integrated Resources Plan or what the region has planned – are going to come to fruition."

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Calendar

January

24-25 **CWC 2018 Annual Convention**, sponsored by Colorado Water Congress, Denver, CO, http://www.cowatercongress.org/annual-convention.html

February

6-8 **Tamarisk Coalition's Riparian Restoration Conference,** Grand Junction, CO, http://tamariskcoalition.org/events/tcs-riparian-restoration-conference

8-9 **Annual Salinity Conference**, Multi-State Salinity Coalition (MSCC), Las Vegas, NV, http://multi-statesalinitycoalition.com/events/

22-23 **2018 Land & Water Summit**, sponsored by Xeriscape Council of New Mexico, Albuquerque, NM, http://xeriscapenm.com/

March

8-9 **Tribal Water in the Southwest**, sponsored by Law Seminars, Phoenix, AZ http://www.lawseminars.com/seminars/calendar.php

28 **Water Resources Research Center Conference**, "The Business of Water," Tucson, AZ, https://wrrc.arizona.edu/news/wrrc-conference-2018-business-water?page=1

April

11-13 **Water Education Foundation's Lower Colorado River Tour**, Las Vegas, NV, http://www.watereducation.org/water-tours

For more events, check out the Foundation's online calendar, www.watereducation.org/calendar. Have a future event to add to our calendar? Send it to Doug Beeman, dbeeman@watereducation.org.

California Unveils Long-Awaited Plan to Restore and Manage the Salton Sea

California state officials have embarked on a process to restore and manage the Salton Sea in an effort that helps to preserve the 2003 Quantification Settlement Agreement regarding the state's use of the Colorado River.

After much deliberation and public testimony, the State Water Resources Control Board revised its 2002 order that approved the long-term transfer of water from the Imperial Irrigation District (IID) to the San Diego County Water Authority, the Coachella Valley Water District and the Metropolitan Water District of Southern California.

The action was taken in recognition that, absent substantial action, the Salton Sea is doomed to an inevitable collapse, with disastrous ecological and public health ramifications.

IID has long sought a viable plan by the state to mitigate the effects of reduced agricultural runoff that have resulted in a dramatically receding shoreline and increased dust.

For IID, the state's action is a vindication of sorts after its lengthy campaign for action.

"In 2014, 12 years into the nation's largest ag-to-urban water transfer, IID found itself at a crossroad," according to a statement by IID General Manager Kevin Kelley. "Should it continue the QSA transfer of water out of the Imperial Valley, knowing that nothing was being done to protect the region from the public health and environmental threats posed by a dying Salton Sea? Faced with that hard question, the IID board had the courage to demand action from its partner, the state of California."

Absent state action, it was generally understood that IID had the ability to nullify the conditions of the water transfer.

Pressure to do something about the Salton Sea led to the 2015 creation of the Salton Sea Task Force and a series of public meetings in which representatives of Riverside County, the Coachella Valley and the Imperial Valley called upon officials to undertake immediate actions to address the looming crisis.

California's largest lake, the Salton

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Birds flock along the shore of the Salton Sea, an important link on the Pacific Flyway in southeastern California.

FEATURE

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Limits on groundwater pumping, water recycling and reuse, rainwater harvesting, and green infrastructure investment are being used to make the most of every drop of water in the Colorado River Basin. While conservation "is the place we have all jumped to historically and are jumping to again," increased efficiency means a loss of water to sometimes important places, Jacobs said.

"That's the story of the Salton Sea but it's also the story of groundwater recharge in many places," she said, noting that increased efficiency can actually reduce water supplies that support habitat. "Conservation can be a double-edged sword though it, of course, probably is the sharpest tool we've got," she said.

Because of the expected loss in surface water supplies, it's been suggested that using that vast space available underground is a practical strategy.

Jacobs said "the recovery part of that can be tricky; it only works in certain kinds of aquifers."

For its part, the National Audubon Society advocates incentives for water conservation in urban and rural areas, water banking, joint conservation funding agreements, and treaty agreements, as well as policy reforms "that provide the flexibility to make these approaches successful." Absent that, "local efforts to protect and restore rivers throughout the Basin are vulnerable."

The challenge presented by climate change mitigation and adaptation is daunting and requires an active rather than passive response, Flessa said.

"We do have the capacity to help ecosystems adapt, provide services and buffer extreme events," he said, meaning water managers would have to allocate water for natural systems in order to restore riparian, aquatic and estuarine habitats and national and international policies would need to be put in place to reduce the input of carbon dioxide into the atmosphere.

"I didn't say that it would be easy," he said. •

FROM THE HEADLINES

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Sea, is in jeopardy as less agricultural drain water and mitigation water from the Imperial Valley reaches it. The California Natural Resources Agency has used more than $80 million in voter-approved bond funds to restore habitat and suppress dust at the lake.

A new water bond that would provide $200 million for Salton Sea projects will go before voters in June 2018.

The state's Salton Sea Management Program explicitly says that restoration of the Salton Sea is "feasible" and that the state of California "will lead and coordinate management efforts" that will, among other things, result in as much as 30,000 acres of exposed playa covered by habitat and dust-suppression projects by Dec. 31, 2028.

The program's plan outlines annual targets for completion, beginning with 500 acres in 2018 and ramping up to 4,200 acres in 2028. The agreement further commits the state to creating a long-term plan beyond the initial 10 years.

"Successful management of a smaller but sustainable Salton Sea requires active support and participation from local, state and federal governing bodies, and stakeholders," said Felicia Marcus, chair of the State Water Resources Control Board. "The annual milestones give us a roadmap to pick up the pace, and the annual public meeting will maintain transparency and keep a light shining on this hugely important effort and on all of us."

An important link in the Pacific Flyway, the Salton Sea provides refuge and habitat for migratory birds. From a public health perspective, it was vital to prevent the exposed seabed from drying and blowing its hazardous contents into swirling dust storms.

Implementation of the QSA was contingent on the state's completion of a Salton Sea restoration plan. In 2007 a $9 billion comprehensive proposal was unveiled that included an extensive system of dikes, channels and pumps. The plan included saltwater ponds to provide habitat and dust control projects on sections of exposed lake bed.

Designing and implementing a practical and cost-effective response to the Salton Sea's problem has been a conundrum for more than a decade.

"The vast majority of plans, big and small, have been stymied by state-level gridlock, bureaucratic infighting, budget constraints, and the record-breaking drought," the National Audubon Society noted in a 2016 online publication, *"How Do We Save the Salton Sea?"* "Since the water-transfer deal was struck in 2003, only a few dozen acres of wetlands have actually been rebuilt."

The San Diego County Water Authority, the recipient of the transferred water, lauded the state's action. "This joint effort promotes the public interest by protecting public health and ensuring the continued delivery of conserved water for the benefit of our region, the state and the entire Colorado River Basin," said SDCWA General Manager Maureen Stapleton.

Kelley with IID said the Salton Sea plan "provides accountability and gives assurance to the residents of the Imperial and Coachella valleys that continued restoration efforts will remain in place for as long as the water transfers continue." •

– Gary Pitzer

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