Seven states search for sustainable ways to augment the Colorado River system


On Dec. 13, 2007, U.S. Secretary of the Interior Dirk Kempthorne signed the Record of Decision: Colorado Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead. This decision is significant not only for what it will ultimately achieve, but also for what it already has achieved: “a remarkable consensus” among stakeholders about sharing water during drought and charting a water management course for the future, according to Kempthorne.

Before signing this decision at the Colorado River Water Users’ annual meeting in Las Vegas, Kempthorne praised the seven Colorado River Basin states — Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming (which will be referred to here as “the Seven States”) — for banding together to seek innovative solutions in a spirit of cooperation and compromise.

“As the Colorado River navigates a [nearly] 1500-mi [2400-km] journey down mountains, through canyons, and across desert landscapes, you have navigated the shoals of history,” Kempthorne said. “You have steered around the cataracts of litigation and acrimony. You have found the serene waters of partnership and cooperation.”

The states’ ongoing collaborative efforts with each other and with various federal agencies, including the U.S. Bureau of Reclamation, have received considerable attention elsewhere in the United States and in other parts of the world, Kempthorne noted.

“I am convinced that as other states — and other countries — struggle to resolve their water issues in the coming decades, they will look to
Eight years of drought have reduced the flow of the Colorado River and significantly lowered the water level in Lake Mead.

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this agreement as a model," Kempthorne said: "A way to embrace consensus rather than conflict. To conserve and share water rather than fight over water. To ensure that everyone walks away from the table as a winner."

This decision is only part of a story that began many years ago and has yet to unfold fully. A report published in March further demonstrates the Seven States' commitment to pursue long-term water supply augmentation for the Colorado River system. Prepared by the Colorado River Water Consultants — a joint-venture team of Black & Veatch (Kansas City, Mo.) and CH2M Hill (Englewood, Colo.) — for the Seven States, the Study of Long-Term Augmentation Options for the Water Supply of the Colorado River System is a first step in increasing the basin's water supplies.

Water Pressures

For millions of years, the Colorado River has flowed from the Rocky Mountains into the Gulf of California. This is the river that created the Grand Canyon. It originates as snowmelt, which enters the river via a series of tributaries and then winds its way south for 2330 km (1450 mi) as it drains 624,000 km² (241,000 mi²) of land.

Because of competing demands by Mexico and the Seven States, as well as competing consumptive, agricultural, industrial, environmental, and recreational uses, numerous formal agreements and acts focus on the rights to Colorado River waters. For example, the Colorado Compact of 1922 apportioned water-consumption rates among Upper and Lower Basin states. In addition, a 1944 treaty with Mexico guaranteed a minimum water flow to that nation under normal conditions. This is one of the most heavily regulated rivers, with the most complete allocation of its water of any river in the world.

In the past decade, hydrologists have determined that Colorado River allocations were based on an abnormally high base flow. The river now is drier and more prone to drought than it was in the early 1900s. The current 8-year drought is the worst in a century and one of the most severe in 500 years. Reservoirs that were brimming with water in 2000 have since lost half of their stored water. In 2002, flows were about 11 million m³ (2.9 trillion gal) below average.

Meanwhile, the population continues to expand rapidly; more than 35 million people now depend on Colorado River water for their lives.
and livelihoods, and another 29 million people are expected to depend on it by 2030.

**New Plan Needed**

In response to these pressures, the federal government, the Seven States, other public agencies, and other stakeholders are working to ensure that the Colorado River and its beneficial uses are protected. The U.S. Department of the Interior (DOI) oversees the management of the river's major reservoirs. DOI's Bureau of Reclamation administers river-related programs and policies.

In 2005, the Reclamation Bureau initiated an environmental impact statement process for *Colorado River Reservoir Operations: Development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead Under Low Reservoir Conditions*. In a Feb. 3, 2006, letter to former U.S. Secretary of the Interior Gale Norton, the Seven States responded by proposing several water operating and accounting procedures for the bureau to consider and the states to implement. The states also expressed their intention to jointly initiate a study for long-term augmentation of Colorado River system water supplies.

The Southern Nevada Water Authority agreed to fund the study, and the Seven States hired Colorado River Water Consultants to perform the technical analyses to be considered along with legal, environmental, and institutional factors. This analysis was completed in close coordination with both the states and the Reclamation Bureau's regional offices.

In a March 21, 2008, letter to Kempthorne (which accompanied the study report), the states emphasized the importance of long-term augmentation, given that conservation alone is insufficient and that the Colorado River is important to both local residents and the nation as a whole. A May 6, 2008, letter from Commissioner of Reclamation Robert Johnson to the Seven States stated DOI's and the Reclamation Bureau's readiness "to work with the Basin States to pursue these endeavors."

**Twelve Options Considered**

The study is part of the Seven States' overall efforts to manage the Colorado River and its resources proactively and to meet the needs of water users in the Colorado River Basin. The...
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L. WAREN/BLACK & VEITCH

project team evaluated 12 augmentation options
to gauge their feasibility, environmental viability, and potential benefit for water users in the southwestern United States. Some would yield new water supplies; others would reduce current consumption of Colorado River water.

The project team used an outreach program
to help confirm which options to study. They also convened a panel of experts to review the viability and completeness of the chosen options. The experts agreed that a beneficial long-term strategy would consist of some combination of these options.

All 12 options were evaluated based on the following eight parameters:

- location of water supply;
- quantity of water potentially available;
- water quality;
- technical issues;
- general reliability of supply;
- environmental issues;
- permitting; and
- cost per acre-foot.

Brackish water desalination. Brackish water typically contains between 1000 and 10,000 mg/L of total dissolved solids (TDS); its mineral content is between that of fresh water and ocean water. The project team focused on technologies for desalting groundwater, surface water, agricultural return flows, and drainage water. Team members identified two potential resources:

- retrofitting the Yuma (Ariz.) Desalting Plant
to treat water stored in a groundwater mound near Yuma; and
- using a previously untouched groundwater source in Riverside County, Calif.
A key technical consideration is that brine disposal is a significant issue, especially for inland sites.

Coalbed-methane-produced water. Coalbed methane is a natural gas associated with coal deposits; water is pumped out of the formation to produce gas from coalbed-methane wells. A coalbed-methane well typically produces 9.5 to 15 L/min (2.5 to 4 gal/min) of water with high TDS levels (2000 to 15,000 mg/L). Because this water has largely been viewed as a waste product, experience with its beneficial use is limited. Additional collection, treatment, and delivery systems would be required.

Coalbed methane is produced in four areas in the Colorado River Basin. The wide spacing of these wells and their distance from major Colorado River tributaries are important considerations.

Conjunctive use. Conjunctive use (water banking) is the coordinated management of surface water and groundwater so that their combined yield and reliability are greater than when managed independently. Typically, surface water is used during wet periods, and groundwater is used during dry spells. Water managers divert surplus flows of surface water (that are not needed to meet water supply or ecosystem needs) to recharge local groundwater basins for later withdrawal under peak, emergency, or drought conditions.

The Southern Nevada Water Authority has banked water in Nevada and participated in interstate banking in Arizona and California.

The project team focused on interstate options in the Lower Basin (Arizona, California, and Nevada). The team explored three options for developing more interstate water banking projects:
- Expand the Arizona Interstate Water Bank.
- Use established water banking programs in California.
- Create a major groundwater storage project in Southern California.

Ocean water desalination. The ocean is a reliable source of water but is much saltier than brackish water (the Pacific Ocean contains between 28,000 and 37,000 mg/L of TDS). Desalination is expensive, but unit costs are expected to decrease.

The project team developed a method to define a common cost approach, reviewed studies, conducted cost-sensitivity analyses, and developed cost comparisons. The technology evaluated was reverse osmosis preceded by a robust pretreatment process selected to address water quality, environmental, and permitting issues. The team considered co-locating a desalination plant with an existing power plant, looking closely at the amount of energy used, methods for addressing greenhouse-gas effects, and brine disposal options.

To date, only a few, relatively small ocean desalination plants have been built along the California coast, and these are used to augment supplies for California water agencies. Desalination facilities constructed to augment Colorado River water supplies would be used in California or Mexico to replace river water, thereby adding to the overall water supply and avoiding the costs of long-distance diversion.

Reduced water use for power generation. In thermoelectric power generation, significant volumes of water are used to cool power plants and remove waste heat from the power-generation cycle. Evaporative cooling is the most common cooling method used in the Colorado River Basin.

The project team investigated air-cooling methods, which would reduce water use, but found that converting to air-cooled systems would lower plant efficiency and increase capital costs. The team determined that this option should be addressed by individual states.

Reservoir evaporation control. The project team studied evaporation-control methods for Lake Mead and Lake Powell, the two largest reservoirs on the Colorado River. Team members evaluated several options, including chemical covers. Although chemical covers have reduced evaporation from pools and golf-course reser-
voirs, the team determined that Lake Mead and Lake Powell were too large; there were too many environmental, recreational, and permitting issues to merit further consideration.

Optimized reservoir operations are a prudent strategy already practiced at these lakes; nevertheless, the Seven States will continue operational studies for these reservoirs. In addition, the secretary of the interior signed a record of decision in December 2007 to adopt specific operating guidelines for lakes Powell and Mead through 2026.

River-basin imports. All potential river-basin import options have numerous technical, environmental, legal, and political obstacles. So, although the project team considered river-basin imports, determining their viability was beyond the scope of this study. More detailed analysis of political, legal, and socioeconomic factors in multiple basins will be required to understand fully the challenges of river-basin imports. In general, river-basin imports may bring a lot of water into the system, but stakeholders first must evaluate several issues, such as:

- environmental effects of reduced discharge from the exporting basin;

- potential effects on biological communities in both export and import basins;

- infrastructure requirements and conveyance facilities between export and import points;

- potential footprint effects of facility construction; and

- the need for high-voltage power facilities in remote locations.

The team's findings indicated that extensive permitting requirements were likely and that import reliability could be affected by in-stream flow requirements and intergovernmental agreements.

Stormwater storage. Although stormwater has been captured for flood-control purposes for many years, using this water to augment supplies is a more recent practice. It is now done extensively in Australia, Singapore, and some parts of the United States. With one exception, the project team found that this option would not benefit the Colorado River system significantly, because stormwater is already captured in the region's reservoirs.

The exception is the Gila River, which conveys stormwater runoff to the Colorado River. The project team evaluated the feasibility of storing stormwater at the Gila River's Painted Rock Dam and Reservoir, with a diversion canal to Imperial Dam. This option had been considered earlier by the Bureau of Reclamation. The issues included:

- unpredictable supply and annual yield;

- the construction (and related environmental impacts) needed to convey water and retrofit the dam for both storage and flood control; and

- water quality issues, such as pesticide contamination in the Gila River and algal growths that often cause anaerobic conditions in the reservoir.

Vegetation management. Salt cedar (tamarisk) is an aggressive, non-native shrub that some estimate could account for as much as 1.2 billion m$^3$ (1 million ac-ft) of water consumption in the basin — perhaps more, if its growth remains unchecked. The project team evaluated the relationship of non-native species to declining Colorado River flows; salt-cedar occurrence, spread, and control; and the sustainability of various controls. Team members found that appropriate salt-cedar controls could save water and provide substantial long-term biological, recreational, and fire-management benefits. Otherwise, uncontrolled salt-cedar growth could reduce water supply by as much as another 1.2 billion m$^3$/yr (1 million ac-ft/yr) by 2020.

The project team also evaluated existing forest-management practices and determined that they were sufficient.

Water imported via the ocean. The project team evaluated four methods for importing water from the ocean:

- an undersea pipeline from the Columbia or northern California Rivers;
- water tankers from Alaska;
- water barges from Alaska; and
- icebergs towed in from the Arctic.

For each method, the team identified the system components, required permits, costs, and special considerations. Technical issues included fuel consumption, undersea construction, bag integrity, and water loss. Each method could yield substantial volumes of water, although the amount potentially available from the Columbia River varies seasonally and is not well defined.

Water reuse. Water reuse is an effective way to conserve water, which typically is used once, treated, and then discharged to inland or coastal waterbodies. Urban and agricultural reuse projects help augment supplies by using recycled water rather than potable water. Agricultural reuse projects enable communities to recycle large volumes of water in controlled environments with limited public access.

Municipalities in the Colorado River Basin have conducted some urban reuse projects for decades, but many opportunities remain. Even though the treatment requirements can be ex-
tensive, the project team determined that reuse significantly improves water efficiency and that each state should address this option as part of its ongoing water-management efforts.

Weather modification. Most of the Colorado River Basin’s runoff comes from melting snow in Upper Basin watersheds. This snow largely accumulates at elevations above 2400 m (8000 ft) and becomes runoff between mid-May and mid-July.

Basin runoff could be increased by “seeding” clouds in the winter so they produce more snow. The seeding operation releases multitudes of embryonic ice nuclei that can convert supercooled cloud droplets to ice crystals, which, upon reaching an adequate size, fall to the ground as snowflakes. Experts believe that the snowflakes produced via seeding come from water droplets that otherwise would be lost to evaporation.

Although it is difficult to predict how much water could be gained and precisely where it would flow, cloud seeding holds promise. Prior investigations indicate that most of the runoff generated via cloud seeding would benefit the Upper Basin and later flow into Lake Powell for use in the Lower Basin.

Several states are sponsoring weather-modification programs.

Next Steps

The March 2008 report recognized but did not attempt to address legal, political, or policy factors. It also did not present recommendations, because the Seven States will select augmentation strategies after thorough consideration of many issues and interests.

The states will use this information to further evaluate long-term strategies for augmenting the Colorado River (see figure, above). The strategies carried forward will be coordinated among the Seven States, the Bureau of Reclamation, and other appropriate federal agencies.

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