TECHNICAL EVALUATION OF OPTIONS FOR LONG-TERM AUGMENTATION OF THE COLORADO RIVER SYSTEM

RESERVOIR EVAPORATION CONTROL

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ACRONYMS

AF	acre-feet
AFY	acre-feet per year
Basin	Colorado River Basin
Bureau	U.S. Bureau of Reclamation
CRWC	Colorado River Water Consultants
kWh	kilowatt hours
MI^2	square mile
MW	megawatts
NEPA	National Environmental Policy Act
Seven States	Seven Colorado River Basin States
TDS	total dissolved solids
UV	ultraviolet light

1.0 RESERVOIR EVAPORATION CONTROL

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1.1 SUMMARY AND PURPOSE

This discussion of reservoir evaporation control is one of a series of White Papers being prepared for the Seven Colorado River Basin States (Seven States). The purpose of the White Papers is to present evaluations of potential options to provide long-term augmentation of the water supply of the Colorado River system. This White Paper presents background information on the overall evaluation program, followed by a preliminary evaluation of the reservoir evaporation control option.

1.2 BACKGROUND

The Seven States have authorized Colorado River Water Consultants (CRWC) to provide a technical evaluation of long-term options. The States will supplement the technical evaluations with legal, administrative, and/or institutional considerations.

The White Papers are the first step in an iterative process to develop, screen, and evaluate options. Evaluation parameters will be applied progressively and will be developed in increasing detail as selected options become more promising. In parallel with White Paper development, the CRWC research team will meet with representatives of the Seven States and will refine the White Papers/develop new White Papers based on their input. White Paper results will be reviewed with a Technical Steering Committee comprised of delegates from the Seven States.

Each White Paper will present a brief overview of the option being evaluated, followed by discussions of history and viability of obtaining additional water from the source, location of supply, quantity of water potentially available, water quality, technical issues, general reliability of supply, environmental issues, permitting issues, and project costs. A list of reference documents for each White Paper will be included, and general findings and conclusions will be provided.

1.3 OVERVIEW OF OPTION

The evaluation in this White Paper addresses methods for evaporation control at the two largest Colorado River reservoirs: Lake Mead, located in southern Nevada, and Lake Powell, located in southern Utah and northern Arizona. The former covers 250 square miles behind Hoover Dam, and the latter covers 260 square miles behind Glen Canyon Dam. Both lakes are located in arid climates, with evaporation rates estimated to be 80 inches per year and 50 inches per year, respectively (United States Bureau of Reclamation [USBR] 2006b). This comes to an approximate loss of 1.7 million acre-feet per year (AFY) through evaporation for both reservoirs when Lake Powell is at elevation

3,700 feet (24.3 million AF) and Lake Mead is at elevation 1,221.4 feet (26.2 million AF).

The two methods considered to control evaporation are chemical covers and the use of preferential storage in Lake Powell. The more common chemical covers are alcohols that create a thin (i.e., molecular scale) barrier between the water and air. This thin layer reduces evaporation rates, but has minimal impacts on the diffusion of gas and the transmission of light into the water.

Evaporation control could also be achieved by managing changes between Lake Mead and Lake Powell. When the stored water in these reservoirs is significantly low, evaporation can be reduced by allowing all reductions in stored volume to be taken from Lake Mead. While maintaining a full Lake Powell, the lowering of Lake Mead would reduce the surface area and would reduce the water lost to evaporation for that stretch of the Colorado River.

Additional methods that were not considered include using physical covers, and taking advantage of reservoir shapes, elevations, or volumes of others reservoirs within the Colorado River system. Providing physical covers over reservoirs as large as Lake Mead and Lake Powell was deemed impractical. In addition to these two lakes, the system has six reservoirs with a volume greater than 100,000 acre-feet (AF). These are listed in Table 1. These reservoirs are managed in an optimized system, and the review of their operation is not within the scope of this work.

Table 1
Major Reservoirs in the Colorado River Basin

Reservoir	Volume Above Lowest Outlet (acre-feet)	Maximum Elevation (feet)
Blue Mesa	830,000	7519
Fontenelle	340,000	6506
Navajo	1,700,000	6102
Flaming Gorge	3,700,000	6049
Lake Powell	24,300,000	3700[1]
Lake Mead	26,100,000	1221[2]
Lake Mohave	1,800,000	650
Lake Havasu	620,000	450

Source: USBR, 2006
[1]Based on normal water surface elevation.
[2]Based on top of raised spillway gates.

1.4 HISTORY AND VIABILITY OF OBTAINING WATER FROM THIS SOURCE

1.4.1 Chemical Covers

Chemical covers have been used in domestic pools and golf course reservoirs to reduce water loss due to evaporation. One chemical cover manufacturer, WaterSavr™, has reduced evaporation in some applications by 10 to 40 percent. One project in Australia, which used chemical covers on two adjacent 10-acre reservoirs resulted in a 30 percent reduction in evaporation (Flexible Solutions, 2006). Additional study would be required to assess the application of chemical covers to reservoirs as large as Lake Mead and Lake Powell.

1.4.2 Preferential Storage in Lake Powell

The storage of water in the Colorado River system reservoirs is managed by the U.S. Bureau of Reclamation (Bureau) based on the annual Operating Plan transmitted by the Secretary of the Interior to the Governors of the Seven States.

1.5 LOCATION OF SUPPLY

The location of supply for this study is Lake Mead and Lake Powell.

1.6 AMOUNT OF WATER

The amount of water available depends on the surface area and the evaporation rate of each reservoir. The surface area of Lake Powell is 252 square miles (mi^2) at elevation 3,700 feet and has an estimated evaporation rate of 50 inches per year. This totals to a potential loss of approximately 672,000 AFY. The surface area of Lake Mead is 246 mi^2 at elevation 1,221 feet and has an estimated evaporation rate of 80 inches per year. This totals to a potential loss of approximately 1.1 million AFY. The combined evaporation from both reservoirs is estimated at 1.7 million AFY.

1.6.1 Chemical Cover

Using the WaterSavr™ product, a 15 percent decrease in the evaporation rate was assumed, which would result in water savings of up to 270,000 AFY.

1.6.2 Preferential Storage in Lake Powell

Using the same evaporation information described in Section 1.6, water recovery was estimated for various Lake Mead/Lake Powell operational scenarios. The Lake Powell option estimates the evaporation if Lake Powell were operated as full as possible while allowing the storage in Lake Mead to vary with water availability. The Lake Mead option estimates evaporation if Lake Mead were operated as full as possible while allowing Lake Powell to vary with water availability. The Combined Storage option estimates the evaporation if both Lake Powell and Lake Mead were operated to maintain similar storage volumes based on water availability. As shown in Table 2, almost 260,000 AF of water might be recovered in a year when Lake Mead is empty and Lake Powell is full compared to the Combined Storage option. This occurs at a total storage around 28 million acre-feet. As can be seen in Figure 1, this water savings is only for a specific stored water volume. The amount of water lost to evaporation is similar for any operational strategy when the reservoirs are full or when they are empty.

Table 2
Estimated Evaporation Rates at 28 Million AF

	Storage Strategy	
Evaporation by Reservoir	**Combined Storage**	**Preferential Storage in Lake Powell**
Lake Mead	600,000 AF	30,000 AF
Lake Powell	400,000 AF	710,000 AF
Total Evaporation	1,000,000 AF	740,000 AF

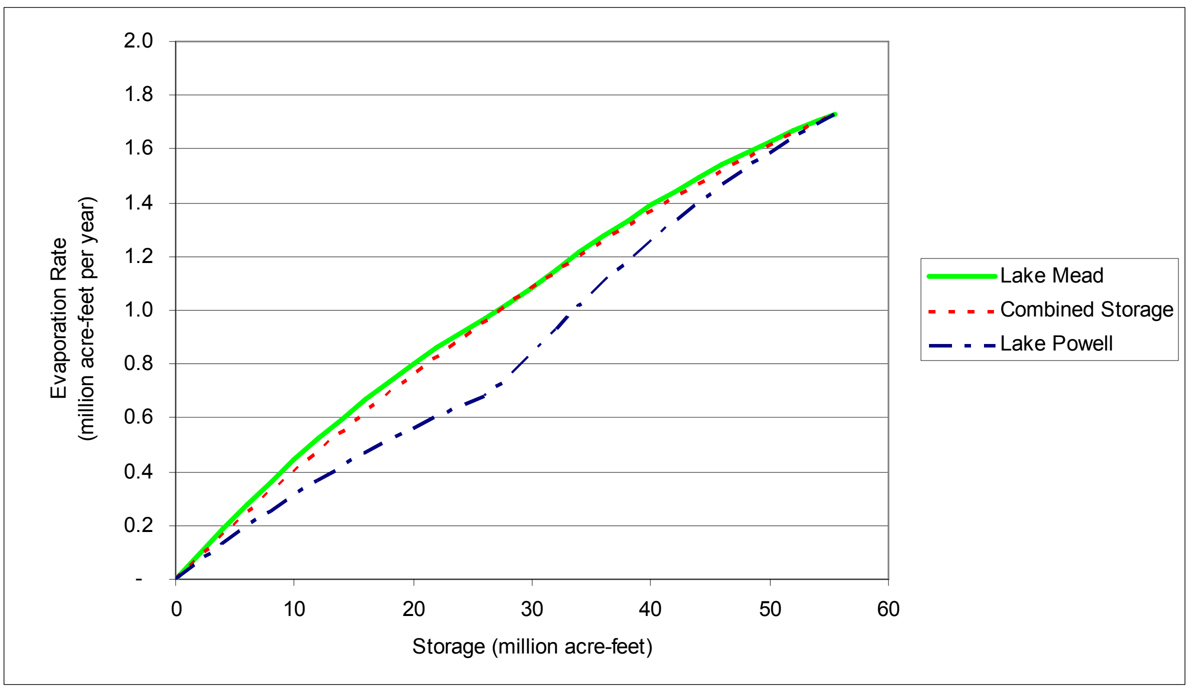

Figure 1 Estimated Evaporation Rates for Different Storage Scenarios

1.7 WATER QUALITY

1.7.1 Chemical Covers

The total dissolved solids (TDS) in a reservoir with chemical covers would be slightly lower than one without chemical covers. The dilution provided by the recovered water is greater than the solids in the chemicals added. Lower evaporation could be expected to raise the water temperature.

1.7.2 Preferential Storage in Lake Powell

Preferential storage in Lake Powell, could be expected to impact water temperature and slightly decrease the TDS in the downstream river.

1.8 TECHNICAL ISSUES

1.8.1 Chemical Cover

Chemical covers are applied in the form of a dry powder. The WaterSavr™ chemical cover uses non-soluble stearyl alcohol and cetyl alcohol to form the chemical barrier on the water surface. The alcohols are delivered in a calcium hydroxide mixture. The calcium hydroxide is not expected to significantly change the alkalinity of the water. While small reservoirs are treated by hand, the surface area of Lake Mead and Lake Powell would require many automated dispensers around the reservoir. It might require hundreds of dispensers to properly apply a complete chemical cover and to account for issues such as wind. Applying the chemical on the upwind side of the water body is expected to aid in dispersion. The properties of the chemical cover tend to allow it to spread to achieve a single monolayer. The longevity of the cover is affected by natural factors, such as sunlight (ultraviolet [UV] light), biological activity (aerobes), algae, and wind. Recreational activities, such as boating and water skiing, would also be a consideration.

1.8.2 Preferential Operation of Lake Powell

If Lake Powell is chosen as primary reservoir, Lake Mead would be drawn down to keep Lake Powell as full as feasible. However, because Lake Mead is a drinking water source, the Southern Nevada Water Authority (SNWA) would require additional pump stations at a lower elevation to continue to serve the Las Vegas Valley. A minimum water level would be required to continue to supply SNWA.

1.9 GENERAL RELIABILITY OF SUPPLY

1.9.1 Chemical Covers

Using chemical covers for reservoirs as large as Lake Mead and Lake Powell is not standard, and the water recovered from these reservoirs over the year would not be reliable. Additional studies would be required to understand the best application methods and the actual yield of the cover.

1.9.2 Preferential Storage in Lake Powell

Preferential storage in Lake Powell would provide predictable and reliable water supplies but only under specific conditions and only by reducing loss. Minimal additional water would be available when the two reservoirs are full. When the combined storage of the two reservoirs is near one half of capacity, the greatest water savings can be achieved. These water savings are expected to be repeated each year, but they will vary based on the water stored in each reservoir.

1.10 ENVIRONMENTAL ISSUES

1.10.1 Chemical Covers

Use of a chemical cover to reduce evaporation could slightly increase the temperature of the lake. This may be expected to impact some aquatic wildlife such as fish at the reservoirs or downstream.

The benefit of using a chemical cover is that TDS is reduced as a result of reducing evaporation. The solids added by a chemical cover are significantly less (approximately 5 percent) than the solids concentrated by evaporation. Chemicals used in the cover are relatively benign and biodegradable. Aerobic degradation is expected to occur on the surface where there is sufficient dissolved oxygen. An additional benefit is that the use of chemical covers could be discontinued during high supply years without significant impact on the ability to return to use of chemical covers during the next dry period. Nonetheless, the use of chemicals on such a large scale could be expected to create public concern over chemical handling and chemical hauling issues and chemical addition to the public water supply. Further study would be required for a lake the size of these two reservoirs to quantify the volume of chemicals required and to identify mitigation for chemical handling/hauling issues.

Any negative impact on recreational use, such as potential restrictions on body contact sports, also would generate public concern. Body contact was not considered in any of the referenced projects or studies. This is another area requiring additional study.
While the components of chemical covers do not adversely affect drinking water, the reservoirs are a source of drinking water. Current drinking water treatment processes are not expected to be impacted, but would require further study. The chemical cover could also impact animals that use the lake surface, but those impacts are not understood.

1.10.2 Preferential Storage in Lake Powell

Preferential storage in Lake Powell is likely to have some environmental impact. Recreational use of the empty reservoir would be substantially affected. Lake Mead is a popular recreational spot and attracts 6 to 8 million visitors per year (House of Representatives, April, 2006). Testimony at the House of Representatives suggested that the annual economic impact from Lake Mead exceeds $500 million. Although the lowering of Lake Mead would limit many of the current recreational uses such as house boating and water skiing. it might increase other recreational uses, such as rafting. Wildlife including fish and waterfowl would be impacted by this operation. It is expected that a significant National Environmental Policy Act (NEPA) process will be required to review preferential storage in Lake Powell.

1.11 PERMITTING

No specific permitting requirements have been identified for either method at this time. However, it is expected that requirements could emerge during a more detailed evaluation of reservoir evaporation control options.

1.12 COST

1.12.1 Chemical Covers

To provide a chemical cover application system, hundreds of shoreline applicators and the associated infrastructure will be required. While no cost studies for such a project have been completed, an order of magnitude estimate is provided here for planning purposes. Capital costs to provide shoreline applicators and chemical delivery infrastructure are estimated to be $20 million for each reservoir. An annual operating budget of the chemical cover application system is estimated to be about $60 million for each reservoir. Approximately $40 million dollars of that cost would be spent on the purchase of chemicals. The remaining cost would be for labor to operate and maintain the applicator system and the cost of managing the project, such as environmental monitoring, contracting, and mitigation. The cost of chemicals could be completely eliminated during wet years when chemical covers would no longer be required.

1.12.2 Preferential Storage in Lake Powell

The administrative cost of managing preferential storage in Lake Powell is expected to be minimal when compared to current operation. The major cost is elimination of power generation capacity. Hoover Dam (Lake Mead) has a total generating capacity of 2,079 megawatts (MW), and generated 3.2 billion kilowatt-hours (kWh) in 2005. Glen Canyon Dam (Lake Powell) has a total generating capacity of 1,296 MW kilowatts and generated 3.2 billion kWh in 2005. While preferential storage in Lake Powell would reduce the available revenue at Lake Mead, there would be an increase in the output of the power plant at Lake Powell.

Additional costs include infrastructure improvements at Lake Mead. Lake Mead is the drinking water source for the Las Vegas Valley. The cost of new pump stations, if Lake Mead were drawn down, could exceed $2.5 billion based on current pump station designs. Additional operational costs for electricity to pump the drinking water are estimated at $5 million per year. Additional costs that have not been quantified include the economic impact on recreation at both lakes and the capital cost to replace the temporary loss of electrical generation capacity.

1.13 REFERENCES

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1.14 CONCLUSION

White Paper findings are summarized in Table 3.

Table 3 Summary of Findings Related to Reservoir Evaporation Control Option		
Parameter	**Findings: Chemical Covers**	**Findings: Preferential Operation of Lake Powell**
Location of Supply	Lake Mead and Lake Powell	Lake Mead
Quantity of Water Potentially Available	270,000 AFY (at 15 percent evaporation reduction)	0 to 290,000 AFY (depending on stored volume)
Water Quality	Increased temperature, but reduced TDS	Lowered TDS downstream of Lake Powell
Technical Issues	Might not be practical at the scale proposed	Operational constraints
General Reliability of Supply	Generally predictable over a year, but unreliable during certain conditions such as high winds	Predictable, but limited to drought
Environmental Issues	Chemical usage issues Recreational impacts	Recreational impacts Significant NEPA review
Permitting Issues	Unknown	Unknown
Cost	$450/AF operation $20 million capital Unit costs $500/AF or greater	$344/AF operation (lost power generation) $2.5 billion capital Unit costs range from $1,000/AF to $2,000/AF depending on operating rules