Appendix F12
Option Characterization – System Operations

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1.0 Introduction

Modified system operations have been proposed to decrease demand, reduce evaporation losses, and improve efficiency within the Colorado River Basin (Basin). A number of system operations options were submitted for consideration in the Colorado River Basin Water Supply and Demand Study (Study). The submittals are summarized in appendix F2 and the original submittals are available via links from the electronic version of appendix F2 on the compact disc that accompanies this report and the version of appendix F2 on the Study website at http://www.usbr.gov/lc/region/programs/crbstudy.html.

Twenty four options related to System operations were received. These options consist of essentially three major overarching concepts:

- Evaporation Control Covers
- New Water Storage
- Modified Operation

These three concepts can be further grouped into three representative options for evaporation control covers, three representative options for new water storage and four representative options for Modify Operations. When potential yield of a representative option exceeds 200 kafy and the option is scalable, the representative option was characterized in progressive 200 kafy "steps". Figure F12-1 shows the general locations of options.

For the system operations category of options, only the options in the Evaporation Control Covers and New Water Storage underwent a characterization with ratings assigned to each criterion. Due to their technical and legal complexity, the options that comprise the Modify Operations group were not assigned ratings. However, available information on relevant criteria is discussed below.

This appendix summarizes the types of options received, the assumptions made and methods used to characterize the options, and the characterization results. Detailed description of the characterization criteria, approach, and rating guidance is provided in appendix F3.

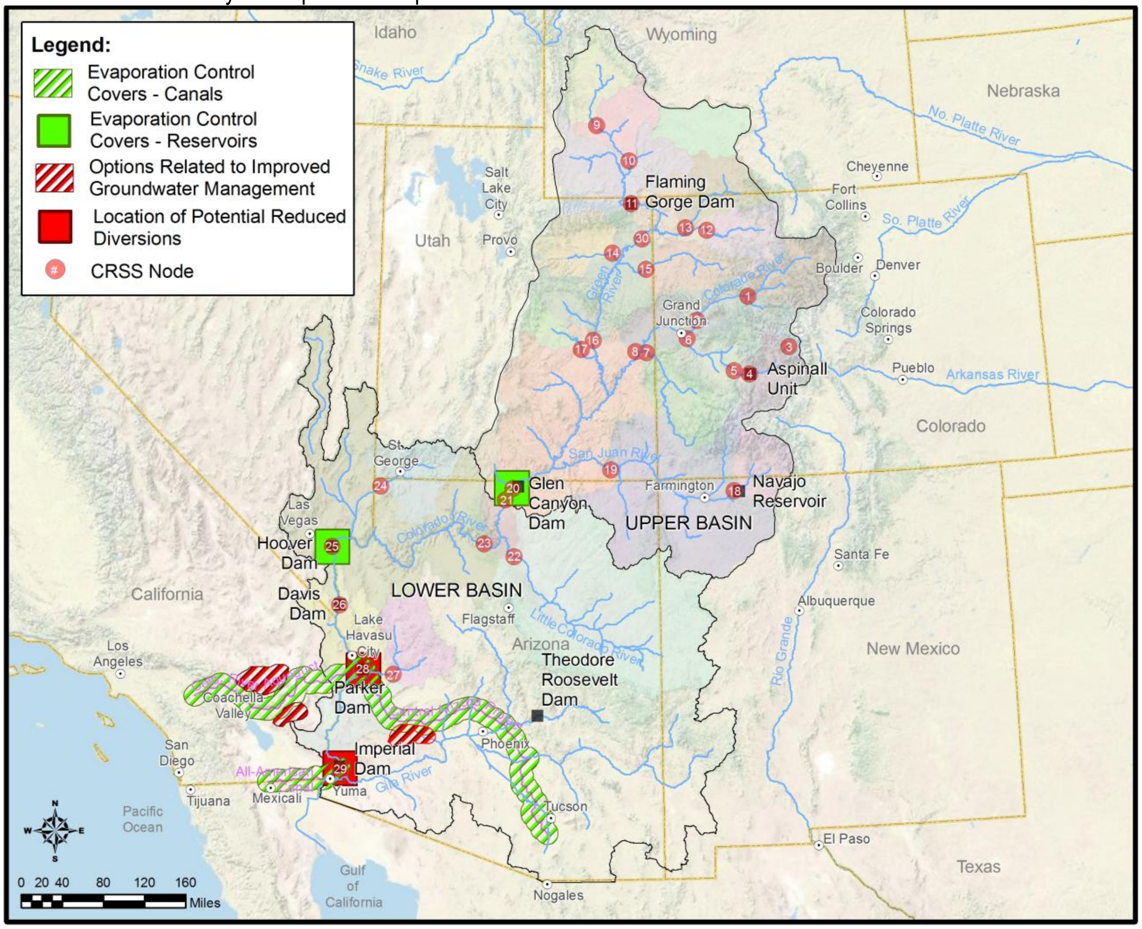
2.0 Evaporation Control Covers

This group of options includes physical and chemical methods to reduce evaporation from the major canals and reservoirs. Physical covers would incorporate solar photovoltaic panels to simultaneously reduce evaporation and generate electricity. Concepts involving chemical covers include the introduction of a chemical to the water surface of large reservoirs to reduce the evaporation rates of the reservoirs.

Based on these distinct concepts, three representative options were developed:

- Solar Panel Canal Covers
- Solar Panel Reservoir Covers
- Chemical Type Covers

FIGURE F12-1
General Locations of System operations Options within the Basin



2.1 Solar Panel Canal Covers

Solar panels covering the water surface of open canals were evaluated by estimating the water surface area and potential for reduced evaporation rates. The total water surface area of the largest canals (Colorado River Aqueduct, Central Arizona Project, and All American Canal) was estimated by reviewing aerial mapping. Next, evaporation rates from the canals were researched. Last, it was assumed that covering the canals as described in the options would reduce the current evaporation rate by 50 percent. However, pilot investigations would be needed to confirm and refine this assumed reduction as appropriate. The estimated potential water savings for installing solar panel covers over the major canals is approximately 18,000 acre-feet per year (afy).

The yield of this concept is highly dependent on the actual reduction in evaporation rates, and the overall costs are highly dependent on recovering some costs by selling energy. To better understand the potential of this option, a 3-year feasibility study, including a pilot program, should be considered. If deemed feasible and the concept was aggressively pursued, 2 years of permitting followed by 5 years of construction is plausible, totaling 10 years.

SPG Solar (2007) performed a pilot study and published the results showing that 3 acres of floatovoltaic (floating photovoltaic) coverage has an estimated capital cost of $5 million and generates about 1 megawatt of power. Assuming the photovoltaic panels have a 15-year life and are amortized at 4.125 percent, the annual cost of the $5 million installation is about $450,000. Assuming the power generated can be sold at $0.05 per kilowatt hour, the power generation is worth $135,000. Assuming 5 feet per year evaporation reduction, a very rough estimate of costs is $20,000 per acre-foot (af). Because the cost of this option is approximately 10 times more expensive than many other options, additional study was not performed to further refine the costs. However, renewable energy credits or higher energy prices could lower the cost per af. Conversely, additional costs for security to avoid theft of the photovoltaic panels would add costs to this concept.

In addition to yield, timing, and cost, the evaporation reduction options were characterized against several other criteria. Key considerations related to technical feasibility, permitting, legal, and policy were largely covered in the descriptions above related to estimating option timing. Permitting is expected to be substantially challenging for physical covers. Operational flexibility of this option is relatively low because the concept cannot be idled in particular years due to infrastructure and operational limits. Physical covers will pose additional maintenance challenges compared to open canals. The solar panel covers actually generate energy. In regard to hydropower, all concepts that reduce evaporation can later increase hydropower production. In general, those options that reduce evaporation most significantly have the most positive impact. Moderate improvements to water quality are anticipated for all evaporation reduction options because of higher canal flows that reduce salinity concentrations. Recreation may be influenced by all of the system evaporation reduction options, either through limiting recreational access or through unknown body contact restrictions. Conversely, reducing evaporation will likely result in a small increase in lake levels. Environmental impacts are highly variable between concepts, depending on potential changing operations or impacts related to covering water bodies. Socioeconomic impacts are difficult to fully assess because jobs will be created with all of these options, but there is also likely to be a combination of positive and negative impacts when considering more than just job creation. Without more-detailed assessments, neutral conditions were assumed for socioeconomics.

2.2 Solar Panel Reservoir Covers

Floating solar panel covers were also proposed to cover portions of the water surface of reservoirs to reduce evaporation. It was assumed that about 10 percent of the reservoir surface area in major reservoirs (Lakes Powell, Mead, and Havasu) could be covered, resulting in up to 200,000 afy of reduced evaporation using similar assumptions as those for canals.

Compared to the canal covers, an additional 5 years is anticipated to be required for the “floatovoltaic” concepts to address potential issues with covering the lakes in the severe Southwest environment and to minimize effects to recreation. This would bring the total time to implement to approximately 17 years. Cost estimates were developed as described for the canal covers, resulting in rough estimates of $15,000 per af. Reducing evaporation will likely increase lake levels and may positively influence shoreline recreational access. Other key criteria were similar to the canal covers option.

2.3 Chemical Type Covers

This concept includes introducing chemicals to large reservoirs (Lakes Havasu, Mead, and Powell) that reduce the evaporation rates of the reservoirs.

For this concept, it was assumed that evaporation-reducing chemicals would be added to Lakes Mead and Powell. The maximum reduction in evaporation is assumed to be 50 percent. However, pilot investigations would be needed to confirm and refine this assumed reduction as appropriate. Assuming the average evaporation from Mead and Powell is around 1.7 million acre-feet per year (mafy), this would result in about 0.85 mafy of evaporation savings. Because of the large areas being considered for this option and the need to fully evaluate feasibility of the option, it would be implemented in several phases. Characterization of this option was performed as increments of 200 thousand acre-feet (kaf) in order to capture issues of scale and other complexities of large-scale programs.

The yield of this concept is highly dependent on the actual reduction in evaporation rates and successful completion of the environmental review process. Because use of chemical covers to reduce evaporation is not common practice and the feasibility of this option has not been evaluated in the extreme environment and weather conditions of Lake Mead and Lake Powell, feasibility studies followed by pilot programs on smaller water bodies would be expected before attempted on any large scale. Also, extensive permitting would likely be required to show (with confidence) that adding the chemical to the water does not have negative impacts on water quality, public health, or the ecosystem. It was assumed that the studies and a small pilot-scale test could take place within 5 years. Next, a larger-scale pilot test of an additional 5 years may be required, followed by permitting and additional testing. Therefore, it could take 15 years before full-scale implementation.

This concept includes costs for airplanes, fuel, pilots, aircraft maintenance, and chemicals. Assuming chemical application every 10 days and two planes for chemical application, annual operation and maintenance is on the order of $38 million per year. Amortizing the cost of purchasing or leasing the airplanes ($3.8 million) and estimating the annual costs of the other cost items results in a rough estimated unit cost of about $100 per af. However, costs for monitoring to show that the chemicals do not negatively affect the aquatic ecosystem is not included.

In addition to yield, timing, and cost, the evaporation-reduction options were characterized against several other criteria. Key considerations related to technical feasibility, permitting, legal, and policy were largely covered in the descriptions above related to estimating option timing. Widespread application of chemical covers does not have a historical precedent to establish technical feasibility. Permitting is expected to be substantially challenging for chemical covers as well as for physical covers. Operational flexibility is related to the ability to idle the concept in wet years without negative consequences. Chemical covers therefore are shown as more operationally flexible than physical covers. Energy needs are relatively low for the chemical cover concepts. In regard to hydropower, all concepts that reduce evaporation in reservoirs can later increase hydropower production. In general, those options that reduce evaporation the most have the most positive impact. Other key criteria were characterized very similarly to the canal and reservoir cover options.

3.0 New Water Storage

This group of options involves the construction or expansion of reservoir projects in order to increase the amount of storage available on the system. There are two representative options in this group:

- New Water Storage
- Improved Groundwater Management

3.1 Pumped Storage – Central Colorado Project

The Central Colorado Project (CCP) proposes a high-altitude, off-river, pumped-storage facility concept. Union Park Reservoir would be located near the Continental Divide in Gunnison National Forest with a storage capacity of 1.2 maf. The reservoir would be capable of delivering water to the South Platte, Arkansas, and Rio Grande basins. It would be able to tie into the existing Fryingpan Arkansas Upper Colorado River Collection System and serve the communities in the central Front Range and Colorado Springs. The reservoir would be filled by pumping excess water during spring snowmelt months from existing Blue Mesa and Taylor Park reservoirs (Miller, 2007).

Storing 1.2 maf in the proposed high-altitude Union Park Reservoir instead of Lake Powell would result in some additional yield due to reduced losses from evaporation. Based on existing evaporation rates at each location, approximately 20,000 afy could be saved under ideal conditions.

All aspects of the proposed CCP are currently feasible from a technical standpoint. Overall feasibility investigation of the concept has already begun and could be completed within 3 years. However, construction of a new dam and modified flows in the upper reaches of the Basin would require significant permitting activities and preparation of an EIS. This proposed project has faced significant opposition for more than 30 years from Gunnison River Basin and other Colorado water users. The permitting process is expected to take a significant amount of time due to the strong and organized coalition of project opponents. Allowing for 7 years to complete the permitting process and 5 years to construct the facilities, the CCP would take approximately 15 years to implement.

According to the information provided in the option submittal, construction of the Union Park Reservoir would cost approximately $400 million. For the purposes of the Study, it was assumed that other facilities considered in the plan, including pipelines and pump stations between the new and existing reservoirs would cost an additional $200 million to construct. It was also assumed that the cost of operations would be significantly reduced by the revenue generated from energy production. Based on these assumptions and considering a yield of 20,000 afy, the unit cost of conserved water is approximately $2,250 per af.

Additional key criteria for the pumped storage CCP option include permitting, operational flexibility, and energy needs. No recent precedent exists for successfully permitting such a facility in the proposed region in the recent past, and the project has had significant organized opposition for more than 30 years. Although there are no technical feasibility issues with operational flexibility, the debt service for the capital costs would still be required in all years. This is problematic because a portion of the debt is proposed to be serviced by power-generating revenues, and power generation may be limited during high-flow years.

3.2 Reservoirs to Capture Unused Releases

This option concept is based on the recently constructed Warren H. Brock Reservoir System (Brock Reservoir). Between 2008 and 2010, Reclamation constructed an 8,000-af storage reservoir near Drop 2 of the All-American Canal in Southern California. The new reservoir stores Colorado River water that has been released from Parker Dam to meet downstream water orders but cannot be delivered for various reasons, such as changed weather conditions, high runoff into the river, or a number of other factors. In recent years, previous to the operation of Brock Reservoir, this water typically was not put to beneficial use within the United States due to the lack of sufficient storage capacity downstream of Parker Dam. Factors such as evaporation, transpiration by vegetation, channel storage, tributary flows, infiltration, weather conditions, unscheduled pumping from the river, variations in water user demands, and variations in return flows can significantly affect scheduled water deliveries and river regulation, thereby causing water to otherwise go unused in the United States and flow into the United Mexican States (Mexico). Although no specific sites were identified in the option submittal, it was proposed that additional reservoirs would be built to further improve the efficiency of the system.

Because specific locations have not been identified, the additional volume of water made available cannot be accurately estimated. Extensive evaluations would be required to calculate the potential cost and yield of additional reservoirs similar to the Brock Reservoir.

Based on the cost of the recently completed Brock Reservoir, this option is estimated to cost $500 per af.

Additional key criteria for this option include technical feasibility, timing, permitting, long-term viability, and operational flexibility. The design and construction of an additional storage reservoir is technically feasible – any such project would follow industry standards that require no new technologies. Identification of permitting issues, on the other hand, is challenging because an exact project has not been identified. Any new reservoir proposed by a federal agency would require compliance with the National Environmental Policy Act and Endangered Species Act; therefore this option scored low on timing and permitting. This option also scored low on long-term viability and operational flexibility because of the uncertainty in yield and the high capital costs that would be incurred even if no flows were captured in a given year and the system were idle. This concept was assumed to be neutral on recreation, socioeconomics, energy, and water quality.

3.3 Improved Groundwater Management

Current groundwater management practices within the Basin vary widely from state to state. This option would establish Basin-wide groundwater management practices that would control overdraft of groundwater resources to promote long-term sustainability; prevent groundwater pumping from depleting rivers, streams, springs, and other groundwater-dependent resources; and allow for underground storage of water supplies and strategic recharge of groundwater where possible.

Although careful management of groundwater is important for the overall benefit of the Basin, this option would not create any new supply and could reduce shorter-term available supply by decreasing dependence on unsustainable groundwater overdraft.

The time required to change current practices would vary by region. Groundwater curtailment plans typically require complementary plans for alternative water supply development or water conservation, and typically both. The Study assumed at least 5 years of feasibility analysis to develop such complementary plans. Many places in the Basin that have experienced significant groundwater level declines have local legal and permitting requirements in place to manage the limited groundwater supply. The submitted concept involves similar, but possibly more-aggressive management of the groundwater basins or extension of this management to all groundwater basins. Consequently, the Study assumed 3 years for permitting. Given at least 5 years for feasibility, 3 years for permitting, and assuming 2 additional years for implementation, benefits would be seen in at least 10 years.

Without specific details and project locations, the cost is difficult to estimate and would also likely vary by region. However, groundwater is typically an inexpensive supply source. The average cost of replacing low-cost groundwater with a higher-cost alternative was estimated at $2,000 per af.

There are trends towards curtailment of non-sustainable groundwater pumping; however, if this were to result in significantly increased costs or hardship, policy challenges would be anticipated. For these reasons, public acceptance is unknown. Consequently, this option scores low on the policy criterion. This option does score high on long-term viability, however, because it is envisioned that once an alternative supply becomes available, that supply will be used. Without additional details and study, this concept is considered fairly neutral for most other characterization criteria.

4.0 Modify Operations of Existing Reservoirs

This group of options includes changing operations to achieve a variety of improved efficiency goals and consists of a broad spectrum of individual options. The options predominantly involve modifying reservoir operations (reservoir operations), but also include groundwater management and storage.

From these concepts, six options were developed:

- Reduce Reservoir Evaporation
- Prioritize Lake Mead Storage
- Maximize Hydropower Generation
- Operating for Environmental Purposes

4.1 Reduce Reservoir Evaporation

Research shows evaporation at Lake Powell is 50 inches per year, 50 inches per year (Colorado River Consultants, 2008). Similarly, evaporation at Lake Mead is estimated to average approximately 80 inches per year (USGS, 2006). Therefore, it may be possible to preferentially store water in Lake Powell to some degree rather than Lake Mead and reduce evaporation. The reservoirs have different surface area-to-storage characteristics, and there are numerous other operational objectives that must also be considered. Based on these differences, it is not possible to perform simple calculations to estimate potential benefits of evaporation savings associated with revised operations.

Using the evaporation equations from the Colorado River Simulation System model for Lakes Powell and Mead, annual combined evaporation loss was computed for three total storage volumes – 16 million acre-feet (maf), 25 maf, and 33 maf (roughly 33, 50, and 66 percent of combined capacity). The distribution of those volumes was varied from (1) store as much as possible in Lake Mead to (2) store as much as possible in Lake Powell. As more water is stored in Lake Mead, the total evaporation increases. As more water is stored in Lake Powell, total evaporation is reduced. The difference between the two extremes ranges from 175,000 afy to about 300,000 afy, depending on the total volume distributed between the two reservoirs. This, however, does not represent the range of potential savings from reoperation. As a gross estimation, in accordance with the *Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (2007 Interim Guidelines [U.S. Department of the Interior (DOI), 2007]), total storage tends to be roughly balanced between the two reservoirs presently. As a result, reoperation from the current distribution to the "optimal for evaporation reduction" distribution could yield at most 100 to 200,000 afy depending on the total reservoir volume. Last, it is highly impractical that Lake Mead would be operated with as little water in storage as possible in favor of preferentially storing all water in Lake Powell. For perspective, it is likely that, at minimum, enough storage to generate power would be maintained. Reoperation from the current roughly 50/50 distribution to preferential storage in Lake Powell while maintaining the power pool at Lake Mead might yield 10,000 to 100,000 afy of reduced evaporation, but again, this is highly dependent upon the total volume at any given time.

Other studies have estimated between zero and 290,000 afy of savings may be possible depending on assumed operating scenarios and future hydrology conditions (Colorado River Water Consultants, 2008). Analysis completed as part of this study, based on area-capacity curves of the two reservoirs, suggests that the potential for water savings may range from less than 100,000 afy to almost 300,000 afy depending on how much "preferential" storage is permitted in Lake Powell.

The modification of Lakes Powell and Mead operations to reduce evaporation losses has significant legal and political implications. Any operational modifications could not occur until after 2026 when the 2007 Interim Guidelines expire. Furthermore, re-operating either reservoir solely to reduce evaporative losses is not consistent with either facility's authorized purposes.

This concept requires reoperation of the river system between Lake Powell and Lake Mead, but no new facilities. However, there would likely be significant costs associated with the changes in timing of water deliveries, hydropower generation, and ecological and recreational impacts. Due to their complexity, these costs were not estimated for the Study.

In addition to yield, timing, and cost, the evaporation reduction options were characterized against several other criteria. Key considerations related to technical feasibility, permitting, legal, and policy were considered in option timing. Hydropower generation, and the recipients of that generation, may be affected depending on how the operations are implemented.

4.2 Prioritize Lake Mead Storage

This group of options would designate Lake Mead as the primary water storage and distribution facility for the Upper and Lower basins. These concepts varied in their vision of Lake Powell. One option envisioned Lake Powell being maintained at the elevation level of 3,490 feet above mean sea level, allowing for continued power production, and otherwise being used for seasonal flow variations, flood control, and sediment distribution purposes. Another option considered the transfer of Lake Powell storage to groundwater aquifers, a sediment management program, and entertained the possibility of removing Lake Powell altogether. The concepts associated with decommissioning Glen Canyon Dam are outside the scope of the Study.

The prioritizing Lake Mead storage concept has extreme environmental, recreational, and policy issues. There would likely be significant public opposition to lowering Lake Powell resulting from impacts on legal obligations and policy objectives, because Lake Powell provides the mechanism for the Upper Basin to satisfy its compact obligations. Additionally, drawing down Lake Powell would result in reduced yield to the system. Losses due to evaporation would increase if additional water currently stored in Lake Powell were released to Lake Mead. The option to remove Lake Powell altogether would have significant negative impacts to the system because system storage would be dramatically reduced.

Changing the operations procedures at either Lake Mead or Lake Powell would not require any new facilities and is currently technically feasible. Time would be needed to establish new operational procedures and agreements among affected agencies and Reclamation, and to complete environmental permitting requirements. Assuming this process could be completed in 5 years and the revised operations completed in 2 years, modifications to operations that prioritize Lake Mead storage could take place in as few as 7 years. However, modifying the 2007 Interim Guidelines (DOI, 2007) is outside the scope of the Study, so this option was considered to be available in 2026, at the earliest.

Revisions to operations could affect other operating objectives. Lowering Lake Powell would have negative impacts on recreation on the lake, but could have positive impacts on recreation on the river through the Grand Canyon and on Lake Mead. This option was also characterized negatively with regard to operational flexibility and energy needs. Positive impacts of this group of options include potential impacts to river flows downstream of Glen Canyon Dam. Because of a more-natural flow regime, environmental conditions for that portion of the river could be potentially improved.

4.3 Maximize Hydropower Generation

Because of seasonal flow variations and year-to-year changes in hydrologic conditions, the hydropower generating reservoirs in the Basin often do not operate at optimal capacity. This concept proposes improving power generating efficiency in one of two ways. The first option would modify reservoir operations to reduce bypass flows, particularly at the Aspinall Unit, Crystal, Flaming Gorge, and Fontenelle reservoirs. Such operational changes could include a combination of changes to up- or down-ramp rates, timing of releases, and reservoir elevations. The second option would change reservoir operations to provide minimum elevations, ensuring that ability to generate power is consistently maintained.

Because the purpose of this concept is to maximize power-generating capacity, it has minimal effects on yield. Moving the location of storage to different reservoirs to provide the needed flexibility may result in negligible changes to evaporation losses. For the purposes of the Study, these options were considered to result in no new yield.

No new facilities would be needed, but time to negotiate and develop modified operation plans would be required. For the purposes of the Study, an implementation period of up to 10 years was assumed, including 3 years for feasibility, 3 years for permitting, and 4 years for implementation.

Because this concept does not create any new water supply and is based on modified operations the cost per af of yield has not been developed. Although it would not produce any additional supply, hydropower re-operation has the principal benefit of increasing power generation within the system. Otherwise, this concept is fairly neutral for most of the characterization criteria.

4.4 Operating for Environmental Purposes

This group of options involves modifying reservoir operations in order to provide a higher degree of river ecosystem and recreational benefits. These benefits would be generated by maintaining or restoring river flows, with potential modifications to the quantity or timing of flows, for example, on an hourly or daily basis. This concept involves the continued and adaptive operation of reservoirs in the Basin. Where benefits are provided within the current flow regimes, these options involve the development of legal and policy mechanisms that protect those regimes.

This concept would have minimal effects on yield, assuming no changes to operations on an annual basis. Changing flow regimes may result in negligible changes to evaporation losses. For the purposes of the Study, these options were also considered to result in no new yield.

This concept would require the institution of policies or formation of adaptive management work groups. National Environmental Policy Act and Endangered Species Act compliance would be required. Because of the broad nature of this group of options, the time required to formulate these mechanisms would vary. Formulation of an adaptive management work group could take 2 or more years, whereas environmental compliance might take 3 years resulting in benefits in 5 to 7 years. However, modifying the 2007 Interim Guidelines (DOI, 2007) is outside the scope of the Study, so this option was considered to be available in 2026, at the earliest.

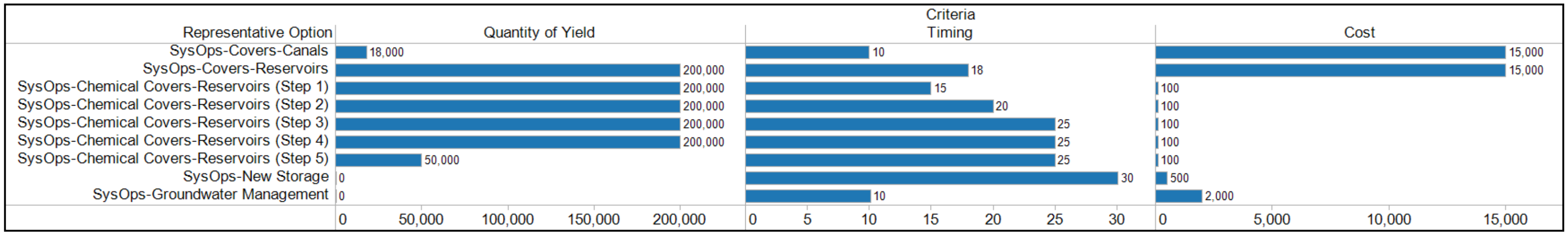
This concept scores positively for recreation, environment, and wildlife. However, it scores negatively for energy and the potential risk of lack of long-term commitment to revised operations.

5.0 Characterization Results

A summary of the characterization findings are shown in table F12-1. The top portion of the table shows the estimated quantity of yield, earliest timing of implementation, and estimated cost. The bottom portion of the table shows the 17 criteria and associated ratings (“A” through “E”) and is color-scaled. In general, “C” is typically designated as mostly neutral; “A” is largely positive; and “E” is largely negative. Refer to Appendix F3 for specific criteria descriptions and rating scales.

Notes providing detailed justification for each option criteria rating are available in electronic form on the accompanying compact disc and on Reclamation’s website at http://www.usbr.gov/lc/region/programs/crbstudy.html.

TABLE F12-1
Summary Characterization Ratings for System Operations Options



Representative Option	Quantity of Yield	Timing	Cost	Technical Feasibility	Implementation Risk	Long-Term Viability	Operational Flexibility	Permitting	Energy Needs	Energy Source	Other Environmental	Recreation	Socioeconomics	Policy	Legal	Hydropower	Water Quality
SysOps-Covers-Canals	E	B	E	C	C	B	D	C	A	A	A	C	C	A	A	C	B
SysOps-Covers-Reservoirs	D	C	E	C	D	D	E	D	A	A	C	D	C	D	D	A	B
SysOps-Chemical Covers-Reservoirs (Step 1)	D	C	A	E	D	D	A	E	B	D	D	D	C	D	C	A	C
SysOps-Chemical Covers-Reservoirs (Step 2)	D	C	A	E	D	D	A	E	B	D	D	D	C	D	C	A	C
SysOps-Chemical Covers-Reservoirs (Step 3)	D	D	A	E	D	E	A	E	B	D	D	E	C	D	C	A	C
SysOps-Chemical Covers-Reservoirs (Step 4)	D	D	A	E	D	E	A	E	B	D	D	E	C	D	C	A	C
SysOps-Chemical Covers-Reservoirs (Step 5)	E	D	A	E	D	E	A	E	B	D	D	E	C	D	C	A	C
SysOps-New Storage	E	D	A	A	B	E	D	D	B	C	D	C	C	A	B	C	C
SysOps-Groundwater Management	E	B	C	B	B	A	C	C	B	C	C	C	C	D	B	C	C

6.0 References

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