



— BUREAU OF —
RECLAMATION

Verde Reservoirs Sediment Mitigation Study Appraisal Report

**Salt River Federal Reclamation Project, Arizona
Lower Colorado Basin Region**



Mission Statements

The U.S. Department of the Interior protects and manages the Nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated Island Communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms

4FRI	Four Forests Restoration Initiative
AC	acre
ACRD	asphalt core rockfill dam
ADEQ	Arizona Department of Environmental Quality
ADWR	Arizona Department of Water Resources
AF	acre-foot
AFY or AF/yr	acre-feet per year
AMA	Active Management Area
APE	Area of Potential Effect (cultural resources)
BC	benefit-cost
CAP	Central Arizona Project
CAPSAM	Central Arizona Project Service-Area Model
CDF	Confined Disposal Facility (for dredged materials)
CFS	cubic-feet per second
CO ₂	carbon dioxide
CRFD	concrete face rockfill dam
CWA	Clean Water Act
cy	cubic yard
cy/day	cubic yards per day
EIS	environmental impact statement
ESA	Endangered Species Act
ft	feet / foot
H-B HCP	Horseshoe-Bartlett Habitat Conservation Plan

IBA	Important Bird Area
IDC	interest during construction
ITP	Incidental Take Permit
KAF or kaf	thousand acre-feet
LF	linear foot
LS	lump sum
MAF	million acre-feet
MAFY or MAF/yr	million acre-feet per year
Mi	miles
MW	megawatt
NCS	New Conservation Space (Roosevelt Dam)
NED	National Economic Development
NEPA	National Environmental Policy Act
NMWSE	Normal Maximum Water Surface Elevation
NR	natural recharge
NRHP	National Register of Historic Places
NVS	New Verde Space (Bartlett Dam increased conservation capacity - does not include restored capacity lost to sedimentation and Phoenix Gatewater)
O&M	operations and maintenance
OPCC	Opinion of Probable Construction Costs
PMT	Project Management Team
PR&Gs	Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies
PROP	Project Reservoir Operations Planning (SRP short-term)
RCC	roller-compacted concrete

Reclamation	Bureau of Reclamation
ROW	river outlet works
RPM	Reservoir Planning Model (SRP long-term)
SCIF	SRP/CAP Interconnection Facility
SPD	Storage Planning Diagram (SRP)
SRFRP	Salt River Federal Reclamation Project
SRP	Salt River Project
SW	Surface Water
SY	square yard
TSG	Technical Support Group
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
VRSMS	Verde Reservoirs Sediment Mitigation Study



Executive Summary

The Verde Reservoirs Sediment Mitigation Study (VRSMS) is an appraisal level study conducted in accordance with Bureau of Reclamation Manual Directives and Standards CMP 09-01: *Water and Related Resources Appraisal and Special Studies*. The VRSMS evaluates alternatives to restore capacity lost at Horseshoe Reservoir on the Salt River Federal Reclamation Project (SRFRP) system to protect water supply resiliency and adapt facilities and operations for expected future conditions resulting from climate change. The VRSMS also examines opportunities to create additional benefits through the actions identified to resolve the problems caused by sedimentation at Horseshoe Reservoir.

The SRFRP, located near Phoenix, Arizona, includes a service area spanning portions of Maricopa, Gila, and Pinal Counties in central Arizona. The land within the project is furnished with water supplies from the Salt and Verde Rivers and from around 270 groundwater wells. The rivers are controlled by six storage dams, and a diversion dam constructed by the Bureau of Reclamation (Reclamation) that serves a system of canals, laterals, and ditches. The Salt River watershed contributes to Roosevelt Lake, Apache Lake, Canyon Lake, and Saguaro Lake. The Verde River watershed contributes to Horseshoe Reservoir and Bartlett Reservoir. Combined, the Salt-Verde watershed covers about 12,500 square miles in central and eastern Arizona. The study area for the VRSMS, along with the Salt and Verde watersheds, the Salt River Project (SRP) service area, and reservoirs, is shown in Figure ES-1.

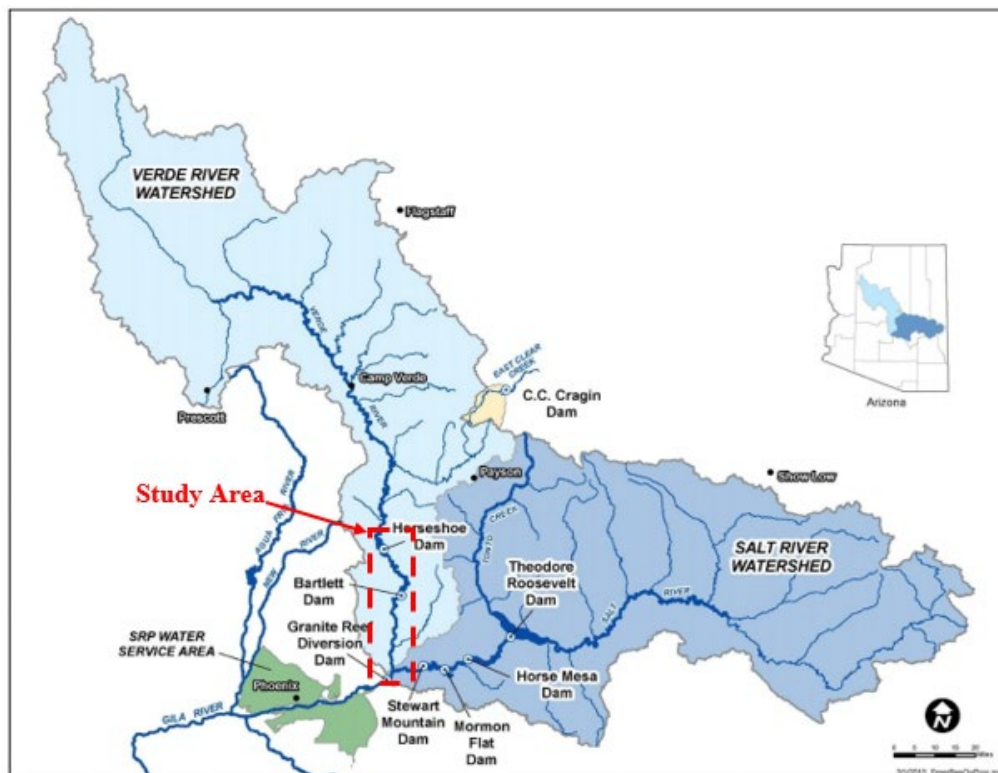


Figure ES-1. Salt and Verde watershed and Study area

Verde Reservoirs Sediment Mitigation Study Appraisal Report

The 2012 sediment survey at Horseshoe Reservoir showed that storage capacity in the reservoir had declined by 45,749 acre-feet since its construction in the 1940s. Most recent sediment surveys show that the storage capacity has declined at an average rate of 1,010 acre-feet per year (AFY) since 1979. At this rate, SRP and the City of Phoenix, which also has a stored water right in Horseshoe Reservoir (Phoenix Gatewater), will lose all water storage capacity in Horseshoe Reservoir around year 2110.

The VRSMS, with input from stakeholders, developed and evaluated alternatives to restore capacity lost at Horseshoe Reservoir due to sedimentation. Three action alternatives were developed that showed potential to restore lost storage capacity and mitigate future losses of storage capacity. These three action alternatives were compared to a Without Action alternative. The Sediment Removal alternative removes sediment from Horseshoe Reservoir using a variety of mechanical means to restore and maintain conservation storage capacity within the Verde River reservoir system. The Bartlett Modification 1 and Bartlett Modification 2 alternatives restore capacity lost at Horseshoe Reservoir through enlargement of Bartlett Dam and Reservoir by 97 feet and 62 feet, respectively. Both alternatives also create additional conservation capacity (New Verde Space, NVS). NVS in the Bartlett Dam Modifications does not include restored capacity lost from sedimentation in Horseshoe Dam or Phoenix Gatewater. Along with the larger reservoir, the alternatives consider re-operating the Verde Reservoir system from two smaller reservoirs with water conservation storage capacity to a single larger reservoir with all water conservation storage capacity. Horseshoe Dam would remain in place, but be operated as a run-of-river facility except during high inflow events to allow for sediment and flood management during the winter and spring runoff seasons.

Analysis of the alternatives using climate change adjusted hydrology and SRP's Reservoir Planning Model show that reduced availability of surface water storage capacity on the Verde River increases dependency on groundwater by SRP to meet the demands of contractors and water rights holders within SRP's water service area, despite significant decreases in total water demands on the SRFRP since 1980. Figure ES-2 shows the average annual surface water deliveries modeled for each alternative over the next 100 years. The Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study shows that the carryover capacity in the SRFRP river system, combined with conjunctive management of groundwater supplies, are needed for SRP to successfully manage water resources impacted by changes in climate (Bureau of Reclamation 2020). Preserving carryover storage in the SRFRP system is critical to managing the changes in timing and magnitude of precipitation and runoff events expected to come with changing climate conditions in the region. The relatively small size of the Verde River reservoir system results in excess flows from the Verde River that frequently spill from the reservoirs. As runoff events become larger in magnitude, sufficient storage capacity will be necessary to manage the events and put water supplies to beneficial use.

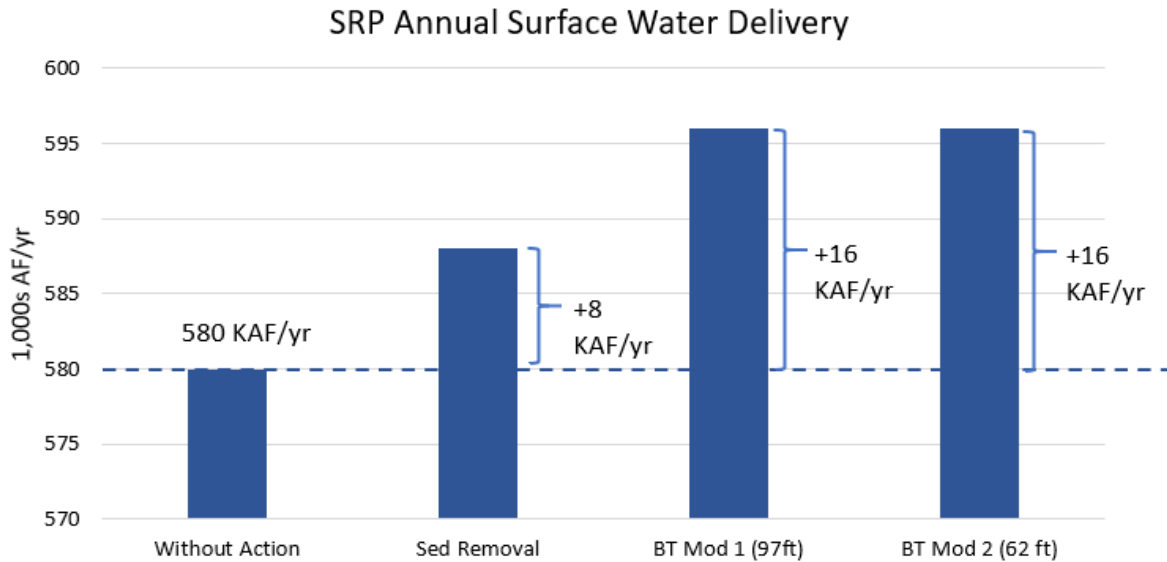


Figure ES-2. Modeled average SRP annual surface water deliveries (in thousands of acre-feet [KAF])

Projected water demand in the lower Colorado River Basin, including central Arizona, is expected to outpace available supply by 3 million acre-feet annually over the next century (Bureau of Reclamation 2012). Meanwhile, Arizona’s population is projected to grow to 18.3 million people by 2110, with water demand expected to grow from 6.9 million acre-feet per year (MAFY) to up to 10.5 MAFY in 2110 (Arizona Department of Water Resources 2014). Reclamation’s Colorado River Basin Report completed under Section 9503(c) of the SECURE Water Act identified modified reservoir system operations and new storage facilities similar to the Bartlett Modification alternatives as potential climate change adaptation strategies to address water supply vulnerabilities in the Colorado River Basin (Bureau of Reclamation 2016).

Changes in availability of Arizona’s Colorado River supply due to shortage, changing climate, and increased demands demonstrate a need for preserving and augmenting existing renewable water supplies in central Arizona. Though likely technically feasible, the mechanical removal of sediment to restore the water storage capacity for SRP and the City of Phoenix has direct and indirect costs that are estimated to outweigh the benefits. The two Bartlett Dam modification alternatives are expected to create benefits that outweigh the costs, with benefit-cost ratios of 3.5 and 2.2 for the 97-foot and 62-foot raise, respectively. The benefits estimated for the two alternatives include restored and new water supplies, hydropower, and avoided carbon dioxide emissions associated with hydropower production. Additionally, both dam modification alternatives have potential to create benefits related to environmental resources, recreational opportunities, water quality, flood control and safety of dams, but these benefits require further study to fully understand the magnitude of each. The dam modifications also have the potential to positively impact the regional aquifer if the water supply made available is used to offset regional groundwater pumping. Figure ES-3 shows the average annual net aquifer benefit associated with each Bartlett Modification for three scenarios of direct use or recharge of 25%, 50%, and 75% of NVS water yield.

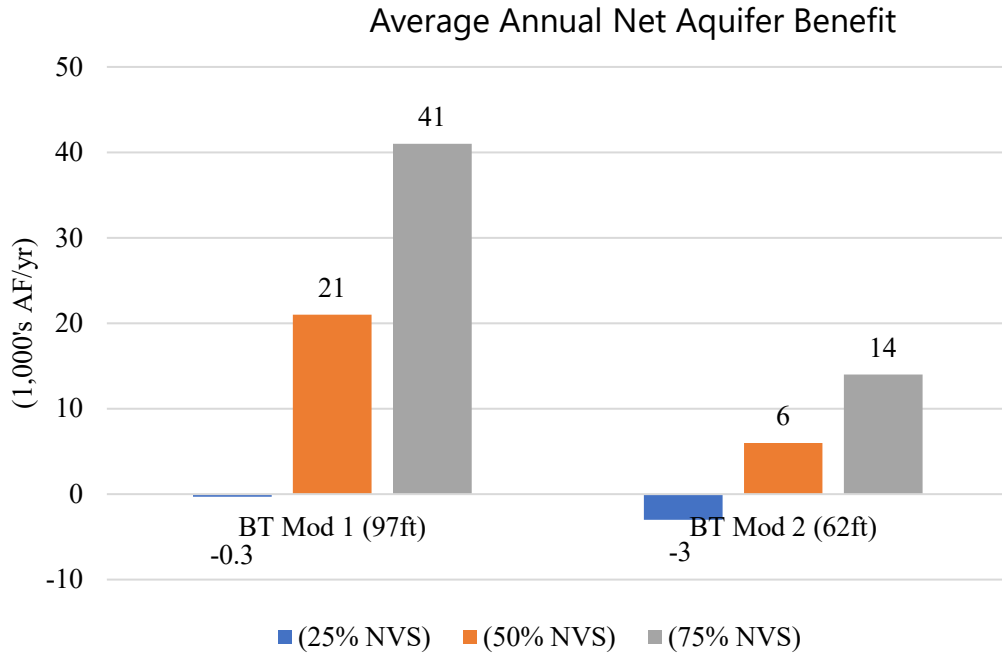


Figure ES-3. Net aquifer benefit for Bartlett Modification compared to Without Action

The environmental and cultural due diligence performed in this appraisal study indicates that the impacts to these resources would not preclude the Sediment Removal and Bartlett Dam modification alternatives from further consideration under feasibility. The effects to environmental and cultural resources for these two alternatives would need to be further evaluated in a feasibility investigation and a National Environmental Policy Act (NEPA) analysis. Implementation of Bartlett Modification 1 and 2 alternatives is expected to make available on average a water supply of 115,000 AFY and 60,000 AFY, respectively. Table ES-1 summarizes surface water yield for each alternative. These water supplies would otherwise be spilled if no action is taken and the continued loss of SRP's storage capacity is expected to result in increased SRP groundwater pumping. The City of Phoenix surface water credits created at Horseshoe Reservoir (Phoenix Gatewater) are expected to be 8,000 AFY less if either of the two Bartlett modification options is compared to the Without Action alternative. Further, the two Bartlett modification options create an opportunity to create new conservation storage space (NVS) that is expected to result in an average annual water yield (excluding restored capacity and Phoenix Gatewater) of 91,000 AFY and 36,000 AFY for Bartlett Modification 1 and 2, respectively. The additional supplies made available by these alternatives could create a net benefit to the regional aquifer of up to 41,000 AFY for the larger dam and 14,000 AFY for the smaller dam, in addition to an expected reduction of SRP groundwater pumping of 14,000 AFY.

Table ES-1: Summary of Modeled Surface Water Yield

Alternative	Change in Annual Phoenix Gatewater Accrual [AFY]	Change in Annual SRP SW Delivery [AFY]	NVS Average Annual Yield [AFY]	Annual Average SW Delivery Change from w/o action [AFY]
Without Action	-	-	-	-
Sediment Removal	3,000	7,000	-	10,000
BT Mod 1 (97 ft)	8,000	16,000	91,000	115,000
BT Mod 2 (62 ft)	8,000	16,000	36,000	60,000

Based on the findings of the appraisal-level analysis, the Bartlett Modification 1 (97-foot raise) and Bartlett Modification 2 (62-foot raise) alternatives appear to be viable. Both provide significant opportunity for increasing the beneficial use of water supplies from the Verde River and improve the water resiliency of central Arizona under changing climate conditions and water needs. Additional water supplies captured in the additional conservation space could be used to offset existing groundwater uses and/or reductions in the availability of Colorado River water during times of shortage.

The Sediment Removal alternative was scored the lowest in most criteria and stood to create the least benefits of the three action alternatives. Considerable uncertainty exists with the cost and implementation of this alternative because no sediment removal project of this magnitude has been completed at an inland reservoir. Additionally, the benefit-cost ratio of the alternative is estimated to be less than one, so the alternative is not recommended for further study at the feasibility level.

If no action is taken by Reclamation, it is expected that the sediment issues will continue to impact SRP and City of Phoenix conservation storage capacity, resulting in both entities turning to other more costly supplies to supplement lost surface water yields. SRP's most likely alternative supply will come from increased groundwater pumping.

Based on the findings of this appraisal study, it is recommended to:

- 1) Seek/confirm authority to initiate a feasibility study to determine the technical, environmental, economic, and financial feasibility of implementing one of the two Bartlett Modification alternatives to enable central Arizona to adapt water management to changing climate conditions.
- 2) Address topics identified in the VRSMS during the feasibility study process.
- 3) Develop cost-share agreements between Reclamation and potential beneficiaries for completing a feasibility study of Bartlett Dam modifications.



Drought impacts at Horseshoe Reservoir (SRP photo)

1 Introduction and Background

1.1 Introduction

The Verde Reservoirs Sediment Mitigation Study (VRSMS) is an appraisal level study conducted in accordance with Bureau of Reclamation Manual Directives and Standards *CMP 09-01: Water and Related Resources Appraisal and Special Studies* to help protect water supply resiliency and adapt facilities as operations for expected future conditions resulting from climate change. The VRSMS evaluates alternatives to restore lost capacity at Horseshoe Reservoir on the Salt River Federal Reclamation Project (SRFRP) system and also examines opportunities to create additional benefits through actions to resolve the sedimentation problems at Horseshoe Reservoir.

Information presented in this report is intended to inform and support planning by identifying potential future scenarios. These scenarios of future conditions should not be interpreted as a prediction of the future. The analysis provided in this report reflects the use of best available datasets and methods at the time of the study.

1.2 Project Sponsor

As the operator of the SRFRP, including Bartlett and Horseshoe reservoirs on the Verde River, and the entity responsible for water deliveries from that system, the Salt River Project (SRP) is the non-federal cost share partner and sponsor of this study.

1.3 Authority for the Study

Authority to conduct appraisal studies is found in the Reclamation Act of 1902.

1.4 Purpose of the Appraisal Study

Appraisal studies are used to determine the nature of water and related resource problems and needs, formulate and assess preliminary alternatives to address the problems, establish whether there is a Reclamation interest in working with partners to pursue a solution, and identify potential project beneficiaries. If a Reclamation interest exists and one or more viable alternatives are identified, then a completed appraisal report may recommend a feasibility study of a new Reclamation project or modification of an existing project.

1.5 Background and Study Area

The SRFRP, located near Phoenix, Arizona, includes a service area of about 248,000 acres spanning portions of Maricopa, Gila, and Pinal Counties in central Arizona. The land within the project is furnished with water supplies from the Salt and Verde Rivers and from approximately 270 groundwater wells. The rivers are controlled by six storage dams, and a diversion dam constructed by the Bureau of Reclamation (Reclamation) that serves more than 1,200 miles of canals, laterals, and ditches.

The Salt River watershed contributes to Roosevelt Lake, Apache Lake, Canyon Lake, and Saguaro Lake. The Verde River watershed contributes to Horseshoe Reservoir and Bartlett Reservoir. C.C. Cragin reservoir in the East Clear Creek watershed also contributes water to the Verde River watershed through a diversion that releases water into the East Verde River. Combined, the Salt-Verde watershed covers about 12,500 square miles in central and eastern Arizona as shown in Figure 1. The study area (also defined in Figure 1) for the VRSMS covers the geographic area spanning from the Verde River just upstream of Horseshoe Reservoir near Sheep's Bridge downstream to Granite Reef Diversion Dam on the Salt River below the confluence of the Salt and Verde rivers and approximately one mile on either side of the river along the river channel.

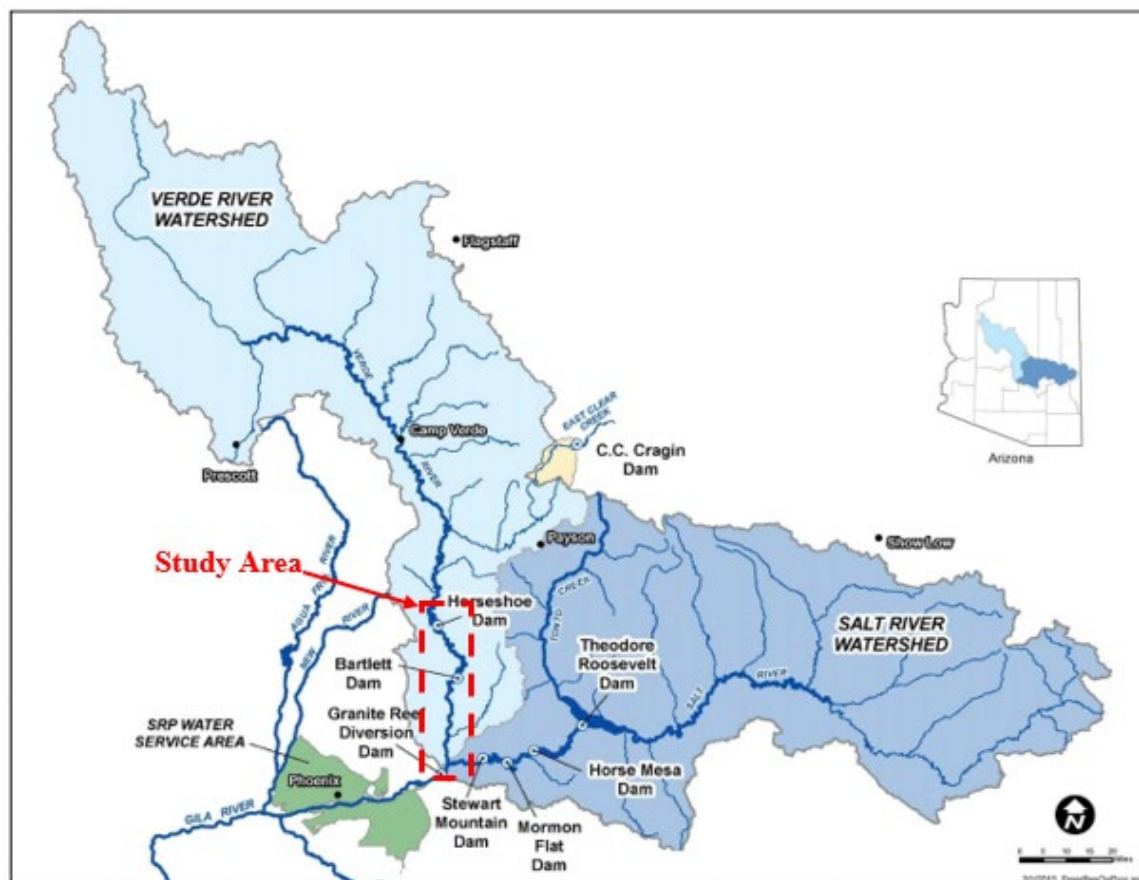


Figure 1. Salt and Verde watersheds and study area

The water stored in the Salt and Verde River watersheds provides approximately 40 percent of the municipal, industrial, and agricultural water supply to the Phoenix metropolitan area, the fifth largest city and the 12th largest metropolitan area in the United States. The SRFRP system is owned by Reclamation and is operated and managed by the SRP. SRP operates the six dams and reservoirs on the Salt and Verde rivers (see Table 1), as well as one on East Clear Creek. Total storage capacity on the Salt River system, including flood control and dam safety surcharges space, is more than 13 times greater than that of the Verde River system (Figure 2).

All four dams on the Salt River have hydropower-generation capabilities. Apache Lake, Canyon Lake, and Saguaro Lake are operated at relatively full levels year-round to maximize power generation. Roosevelt Lake levels fluctuate depending on Salt-Verde watershed runoff and water demand. Roosevelt is also the only dam operated by SRP with flood control space which is managed by SRP following the guidance of the Water Control Manual for Modified Roosevelt Dam, Salt and Gila Rivers, Arizona developed by the U.S. Army Corps of Engineers, Los Angeles District (1997). Bartlett and Horseshoe dams do not have significant hydropower generation capabilities.

Table 1. Verde and Salt River Dams and Reservoirs

Waterway	Reservoir	Dam
Verde	Horseshoe	Horseshoe
Verde	Bartlett	Bartlett
Salt	Roosevelt Lake	Modified Theodore Roosevelt
Salt	Apache Lake	Horse Mesa
Salt	Canyon Lake	Mormon Flat
Salt	Saguaro Lake	Stewart Mountain

Granite Reef Diversion Dam is located northeast of Phoenix downstream of the confluence of the Salt and Verde rivers. The Diversion Dam diverts water from the Salt River into the Arizona Canal on the north side of the Salt River and the South Canal on the south side. An interconnection with the Central Arizona Project (CAP) canal allows water to be delivered from the CAP into the South Canal. Once diverted into the Arizona and South canals, water is distributed through SRP's system of canals and laterals for delivery within the SRP water service area and to those with contracts to transport non-project water through the SRP system (Figure 3). The SRP canal and lateral system consists of more than 1,200 miles of canals and laterals. Along the canal and lateral system, SRP operates approximately 270 groundwater wells, which allow SRP to conjunctively manage surface water from the Salt and Verde rivers and groundwater from the aquifer underlying SRP's water service area on behalf of SRP customers, including city water treatment plants and residential and agricultural irrigation customers. SRP also operates the Granite Reef Underground Storage Project, New River Agua Fria Underground Storage Project, and the SRP Groundwater Savings Facility, which allow surface water supplies to be stored underground for future recovery.

TOTAL CONSERVATION STORAGE 2,292,904 AF

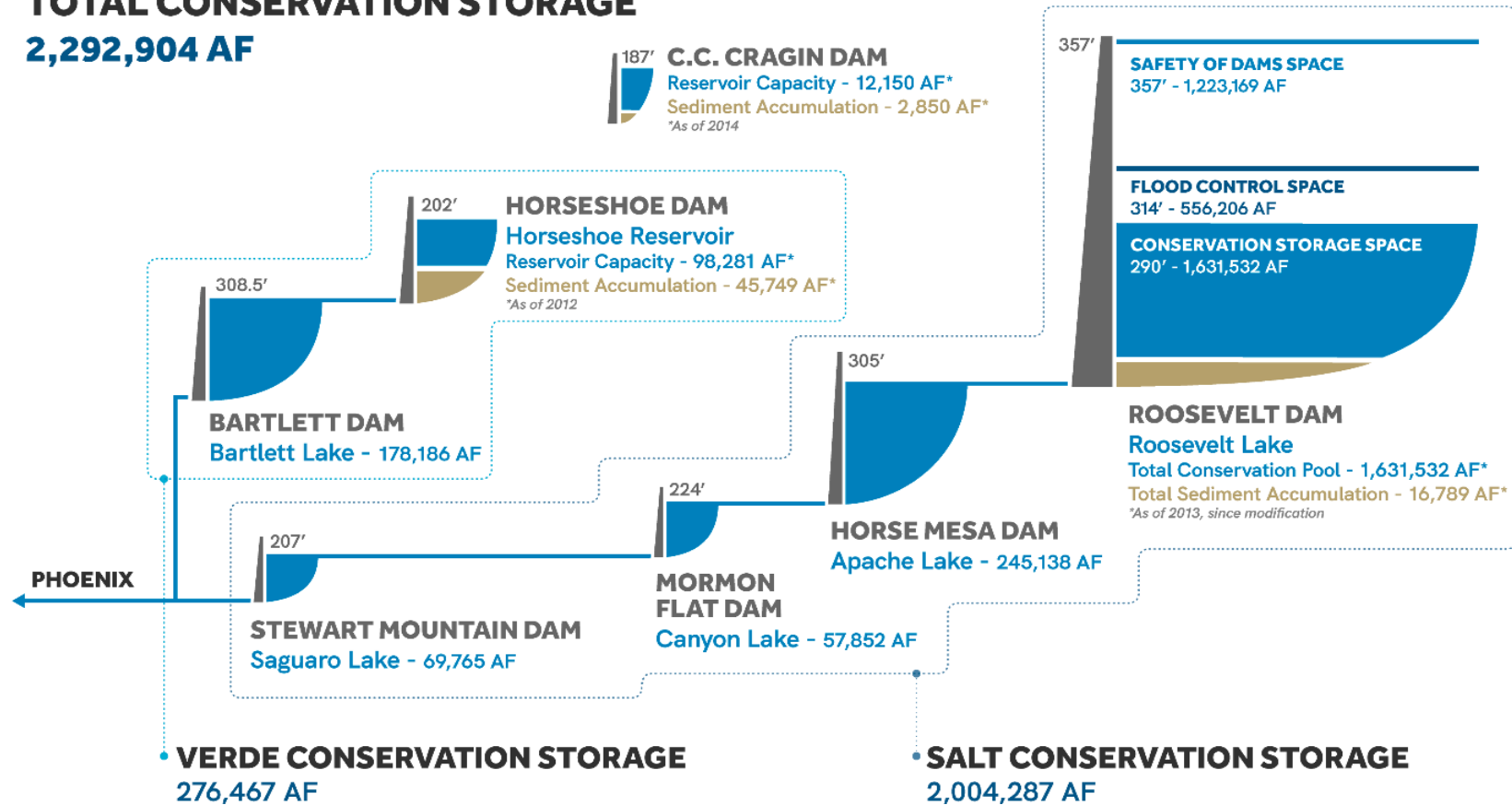


Figure 2. SRFRP dams and reservoirs storage capacities in acre-feet (AF)

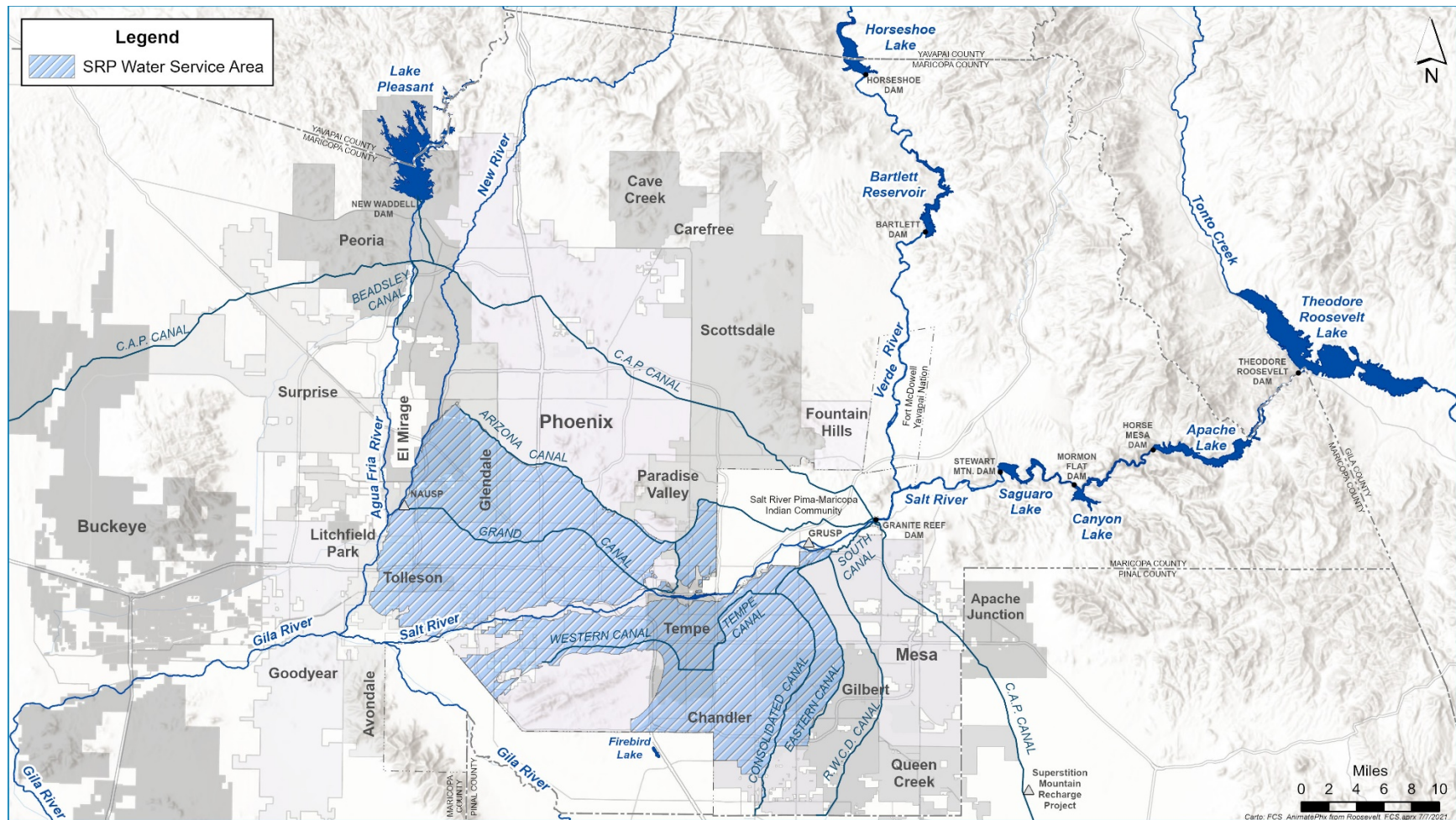


Figure 3. SRP water service area and water delivery Infrastructure

Horseshoe Reservoir provides water to water rights holders within SRP's water service area, certain contractors of the SRFRP, and to residents of the City of Phoenix. Following original construction of Horseshoe Dam between 1944-1946 by Phelps Dodge Corporation and the Defense Plant Corporation in fulfillment of a water exchange with SRP, the City of Phoenix invested in construction of flood gates in 1949 to increase the storage capacity of the reservoir for the benefit of residents of the City. The total storage capacity of Horseshoe Dam and reservoir in 1950 was 144,030 acre-feet (AF).

A 2012 LiDAR survey conducted by SRP estimated that approximately 45,749 AF of water storage capacity has been lost to sediment accumulation in Horseshoe Reservoir, reducing the water storage capacity to 98,281 AF. The capacity loss represents approximately one-third of the reservoir's original storage capacity and 15% of the total original storage capacity on the Verde Reservoir system. Today it is estimated that Horseshoe Reservoir loses an average of approximately 1,010 AF of storage capacity per year from sedimentation.

1.6 Study Period

The study period of the VRSMS has been defined as the 110 years from 2021 through 2130. For sedimentation, hydrologic, economic, and financial evaluations, each of the action alternatives are assumed to be constructed over a 10-year construction period from 2021 through 2030, and generate benefits over a 100-year period of analysis from 2031 through 2130. In accordance with the September 2016 Reclamation guidance document entitled *Time Based Adjustments in Reclamation Economic Analysis*, the point of reference selected for the present value calculations is the end of the construction period and beginning of the period of analysis. Costs and benefits are evaluated at the Fiscal Year 2021 Plan Formulation and Evaluation interest rate of 2.5%.

1.7 Study Methodology

1.7.1 Stakeholder Engagement Process

A broad range of stakeholders was invited to participate in or receive updates about the study, including municipalities, water service organizations, water regulatory agencies, tribal communities, and federal agencies (see Appendix A). General stakeholders' meetings were held every six weeks after the initial stakeholder kickoff meeting. The purpose of the general meetings was to provide progress reports regarding the study and to solicit feedback from the stakeholders on alternatives. Stakeholders were also provided opportunities to participate as Focus Group Members as described below to receive updates and provide input on specific technical areas of the study.

1.7.2 Study Organization

An organizational structure was developed to ensure the study was conducted in compliance with Reclamation Directives and Standards; all technical aspects of the study are evaluated and analyzed; and stakeholder input is incorporated into all stages of the study. This organizational structure is shown in Figure 4. It was the responsibility of the Project Management Team (PMT) to ensure the activities associated with the study were conducted in accordance with Reclamation Directives and Standards, and to establish and provide guidance to the Technical Support Group (TSG) which consists of representatives who provide input on specific technical areas. Focus Groups were

established to provide technical analysis and stakeholder input in the development of study products. Each Team Lead of the Focus Groups was also a member of the TSG. Stakeholders were encouraged to participate as Focus Group Members of any Focus Group for which they had an interest. Each Focus Group also had a Core Team which consisted of a small consortium of Focus Group members. The Core Team was responsible for developing the Focus Group deliverables, soliciting feedback from Focus Group Members, and providing progress updates to all stakeholders during general stakeholder meetings.

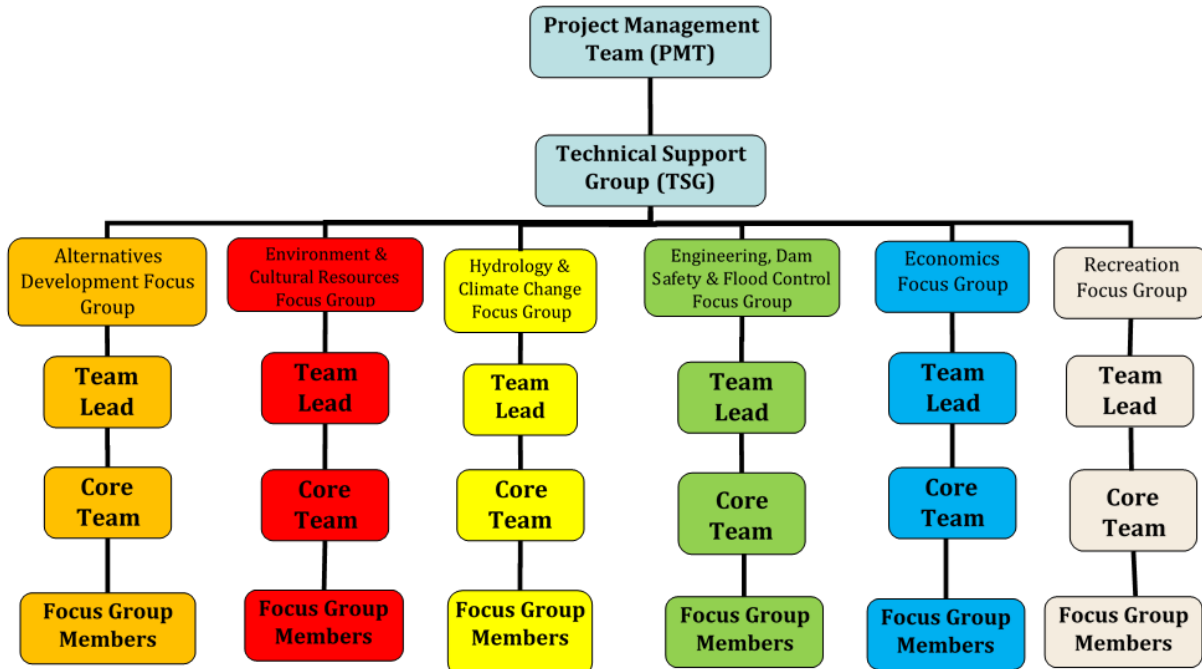


Figure 4. Study organizational structure

The purpose of each focus group is identified in Table 2.

Table 2. Focus Group Descriptions

Focus Group	Purpose
Alternatives Development	Formulate alternatives and evaluation criteria that demonstrate apparent potential to solve the problem and meet the needs of the study.
Hydrology and Climate Change	Formulate assumptions and evaluation criteria for existing hydrology, consider future impacts on hydrology due to climate change, and apply assumptions and considerations to water resource supplies for the alternatives.
Environmental and Cultural Resources	Gather existing data/information, formulate evaluation criteria, and evaluate the alternatives'

Focus Group	Purpose
	potential effects on and challenges related to environmental and cultural resources.
Engineering, Dam Safety, and Flood Control	Collect existing data, formulate evaluation criteria, and perform appraisal level analysis on the engineering design, dam safety, and flood control features of the alternatives.
Economics	Formulate evaluation criteria and analyze the economic and financial considerations of each alternative, including development of an appraisal-level assessment of costs and benefits.
Recreation	Collect existing data and perform appraisal level analysis on the recreation opportunities of the alternatives.

2 Statement of Problems, Needs and Opportunities

2.1 Problems

As of 2012, approximately 45,749 AF of water storage capacity has been lost to sediment accumulation in Horseshoe Reservoir. The capacity loss represents approximately one-third of the reservoir's original storage capacity and 15% of the total original storage capacity of the Verde Reservoir system. Today, it is estimated that Horseshoe Reservoir loses approximately 1,010 AF of storage capacity per year from sedimentation. The loss of capacity on a highly variable river system, coupled with the increase in hydrologic variability anticipated with climate change, creates concerns about future ability to meet the needs of the beneficiaries of the SRFRP and the City of Phoenix, both of which rely on water stored in Horseshoe Reservoir to meet water needs. Without action to restore lost carry-over storage capacity and mitigate against future storage losses at Horseshoe Reservoir, further dependency on groundwater is anticipated to meet customer demands during dry periods.

2.2 Needs

Restoring lost capacity and mitigating future sediment accumulation impacts on storage capacity at Horseshoe Reservoir can ensure that the SRFRP continues to fulfill its authorized purposes, especially in light of increasingly variable hydrologic conditions expected to result from climate

change. Central Arizona water users primarily rely on the water of the Salt, Verde, and Colorado Rivers. Future reductions in Colorado River water supplies resulting from extended drought highlight the need for maintaining the resiliency of the water supplies provided to central Arizona by the Verde River.

2.3 Opportunities

A number of options exist to mitigate current and future sedimentation impacts at Verde River reservoirs, including removal of sediment or constructing new, or modifying existing, dam facilities on the Verde River. Constructing new or modifying existing Verde River storage facilities creates opportunities to benefit users beyond original SRFRP beneficiaries through water supply, flood control, dam safety, recreation, hydropower, and environmental benefits. Creation of additional conservation storage presents an opportunity to provide new, renewable surface water supplies from flood waters that could be used to offset losses in supplies due to shortage on the Colorado River and reduce current and future dependency on the use of fossil groundwater in central Arizona. Section 7.13 provides an overview of the opportunities for each action alternative.

2.4 Federal Objective

According to the Council on Environmental Quality's *Principles, Requirements and Guidelines for Water and Land Related Resources Implementation Studies* (PR&Gs), "The Federal Objective, as set forth in the Water Resources Development Act of 2007, specifies that Federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by: (1) seeking to maximize sustainable economic development; (2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and (3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems (Council on Environmental Quality 2014)." The planning objectives developed for the Verde Reservoir Sediment Mitigation Study are consistent with this Federal Objective. In seeking to restore lost capacity and mitigate future losses of storage capacity due to sedimentation accumulation on Verde Reservoir system, the study seeks to encourage continued economic development in the Salt River Project's water service area. By enabling central Arizona to adapt water management to changing climate conditions, while limiting future groundwater capacity, the study aims to protect environmental resources by ensuring that water supplies in Verde and Salt River watershed are employed sustainably. Finally, by exploring opportunities to create additional project benefits, the study reflects national priorities, by developing recreational opportunities, providing habitat for fish and wildlife, and ensuring public safety.

The study further aligns with the PR&G's Guiding Principles of Healthy and Resilient Ecosystems; Sustainable Economic Development; Floodplains; Public Safety; and Watershed Approach. The study area outlined utilizes a watershed approach to evaluate alternative plans with an effort to ensure that conservation of surface water supplies leads to a management goal of safe-yield of groundwater. The objective of creating additional water supply benefits aims to align with the guiding principle of sustainable economic development, as it offers a means to sustainably meet water supply demands despite the increasing variability of hydrologic conditions due to the effects of

climate change. Finally, the exploration of opportunities to provide further fish and wildlife benefits and flood control benefits within the constraints of complying applicable Federal law and dam safety requirements aligns with the guiding principles of healthy and resilient ecosystems and public safety respectively. To ensure alignment with the PR&G Guiding Principle of Environmental Justice, at the feasibility level, the study team will make specific efforts to provide opportunities for effective public participation by minority, tribal, and low-income communities in the planning process. This will help ensure that the feasibility study identifies and avoids disproportionately high and adverse public safety, human health, or environmental burdens of alternative plans on these communities.

3 Existing Resources

3.1 Horseshoe Reservoir Sedimentation

The Verde River flows approximately 140 miles in a southeastward direction draining a 6,250-square-mile area of private, state, tribal, and U.S. Forest Service lands. Elevations within the watershed range from more than 12,600 feet in the San Francisco Peaks down to 1,300 feet at the Salt River confluence. The Verde River watershed is a mix of private and public lands with the majority of lands being under federal jurisdiction. The watershed has 45 different mapped land cover types including grassland, shrub habitat, forest, and riparian zones (U.S. Fish and Wildlife Service and Arizona Game and Fish Department 2011).

To support the VRSMS, HDR Inc. conducted research and analyses using soil conditions data provided by the U.S. Forest Service (USFS) to identify sources of sediment transport on the Verde River watershed. Based on antecedent soil conditions, a baseline for annual sediment production in the Verde River watershed was determined. The 6,250-square-mile Verde River watershed is estimated to produce approximately 4,600 AF of total sediment (suspended and bed-load) per year. The expected proportion of heavier bed-load sediments that could accumulate in a reservoir for a typical watershed is between 10% and 25% of total sediment production, with the remainder being suspended sediment that transports more easily in the water column and is less likely to settle in reservoirs. Table 3. Expected Annual Bed and Suspended Sediment for the Verde River Watershed shows the expected range of annual bed load sediment transport for the Verde River watershed based on soil conditions data.

Table 3. Expected Annual Bed and Suspended Sediment for the Verde River Watershed

	Total	Bed Load		Suspended Load	
Watershed Sediment Production Proportions		10%	25%	75%	90%
Annual Verde River Watershed Sediment Production (AF)	4,574	457	1,144	3,431	4,117

Periodic reservoir capacity surveys performed by SRP estimate sediment accumulation at a rate of approximately 1,010 AF of displaced water storage per year since 1979. Sediment surveys have not been conducted at Bartlett Dam since construction of Horseshoe Dam and there are no indications of significant sediment accumulation behind Bartlett Dam due to capture of sediment in the shallow and wide Horseshoe Reservoir. Figure 5 shows the results of periodic sediment surveys at Horseshoe Reservoir since construction in blue. The data points highlight the estimated storage capacity in the reservoir at the time of each survey. The black line shows a smoothed projection of sediment accumulation at a rate of approximately 1,010 AFY, based on the actual accumulations in Horseshoe Reservoir between 1979 and 2012. The upper dashed line shows a smoothed projection of sediment accumulation at a rate of approximately 750 AFY, based on the actual accumulations in Horseshoe Reservoir since construction. The lower dashed line shows a smoothed projection of sediment accumulation at the rate of change of sediment accumulations since construction starting with 1,010 AFY and accelerating by 50% every 15 years, as observed by historic sediment surveys shown by the blue line.

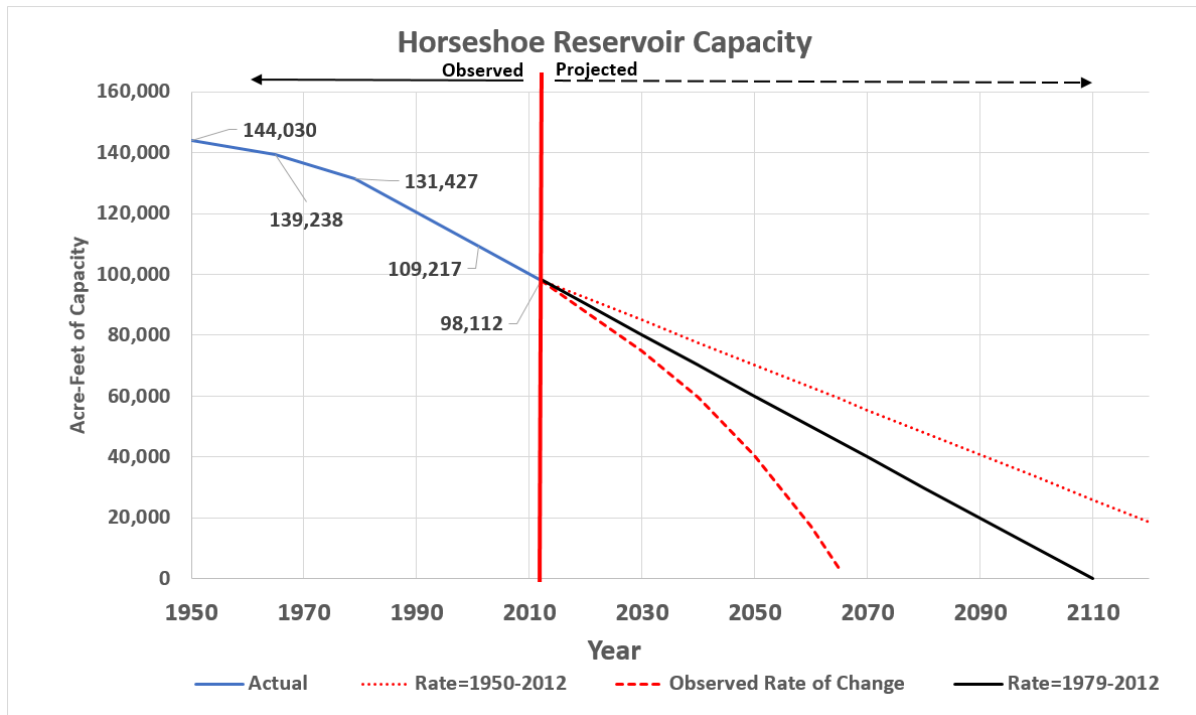


Figure 5. Historical and projected sedimentation in Horseshoe Reservoir

Though there is uncertainty in estimates due to the size of the Verde River watershed and limited historic sediment monitoring across the watershed, the observed sediment accrual rates in Horseshoe Reservoir since construction as shown in Table 4 are in the range of expected bed-load yield shown in Table 3. Expected Annual Bed and Suspended Sediment for the Verde River Watershed. For this study, future sediment accumulations are assumed to follow the black trendline in Figure 5, based on the historic accumulations over the last 40 years at Horseshoe Reservoir.

Table 4. Horseshoe Sediment Survey Results and Accumulation Rates

Year of Sediment Survey	Capacity (AF)	Annual Capacity Loss Rate to Sediment (AFY)
1950	144,030	
1965	139,238	(319)
1979	131,427	(558)
2001	109,217	(1,010)
2012	98,281	(994)

3.2 Verde Watershed Climate Change Expectations

Winter and early-spring rainfall and snowmelt generate the large majority of streamflow on the Salt and Verde Rivers, with approximately 71% of the annual streamflow occurring from December through April. Naturally occurring droughts and pluvials (wet periods) are a prominent part of the climate in the desert southwest (Lehner, Deser and Simpson 2018), with an irregular 63-year cycle in Salt-Verde streamflow (Murphy and Ellis 2019). The current multidecade drought in the Desert Southwest has been attributed to this natural variability (Lehner, Deser and Simpson 2018) and is the most severe in more than 600 years on the Salt-Verde (Murphy and Ellis 2019).

Climate change is expected to result in warmer temperatures and more variability in precipitation, with a slight decrease in Arizona winter precipitation that is expected to be small relative to natural variability (Easterling, et al. 2017). Recent research is suggesting that reduction in streamflow resulting from increased evaporative losses from the warming landscape will be less severe on the Salt-Verde than the Colorado River (Bureau of Reclamation 2020, Robles, et al. 2021). This temperature sensitivity to warming has been calculated as four to five times lower on the Salt-Verde than the Colorado River (Bureau of Reclamation 2020) with the decoupling of streamflow generation and peak potential evapotranspiration on the Salt-Verde being a contributing physical mechanism i.e., streamflow on the Salt-Verde is generated in the winter and early-spring, in contrast to the Colorado River with streamflow generated in the spring and early-summer (Robles, et al. 2021). Therefore, it is anticipated that the Salt-Verde will experience slight decreases in annual average streamflow, deeper droughts, and wetter pluvials (wet periods).

3.3 SRP Water Supplies and Deliveries

3.3.1 Water Supply

The Verde River drains an area of approximately 6,250 square miles and ranges in elevation from 12,600 feet in the San Francisco Peaks near Flagstaff, Arizona to 7,000 feet along the Mogollon Rim, to as low as 1,300 feet in the Sonoran Desert. From the Verde River's headwaters near Paulden, to its confluence with the Salt River, the Verde River follows an approximately 140-mile-long course. The Verde watershed consists of mixed coniferous and ponderosa pine forests in the higher elevations, pinon juniper ecosystems in the mid-elevations, and Sonoran Desert in the lower

elevations. The majority of the water supply that SRP manages on the Verde Reservoir system comes from winter precipitation and snowpack in the headwaters of the Verde watershed. The water supply is extremely variable.

Figure 6 depicts the monthly precipitation totals (in inches) and average runoff (in thousands of acre-feet [kaf]) produced on the Verde watershed. This Figure clearly demonstrates the importance of the winter season precipitation for the total water supply. The mean monthly inflow into SRP-operated reservoirs indicates that most of the runoff that results in streamflow occurs from February to April and very little occurs on average in the summer months of June, July, and August.

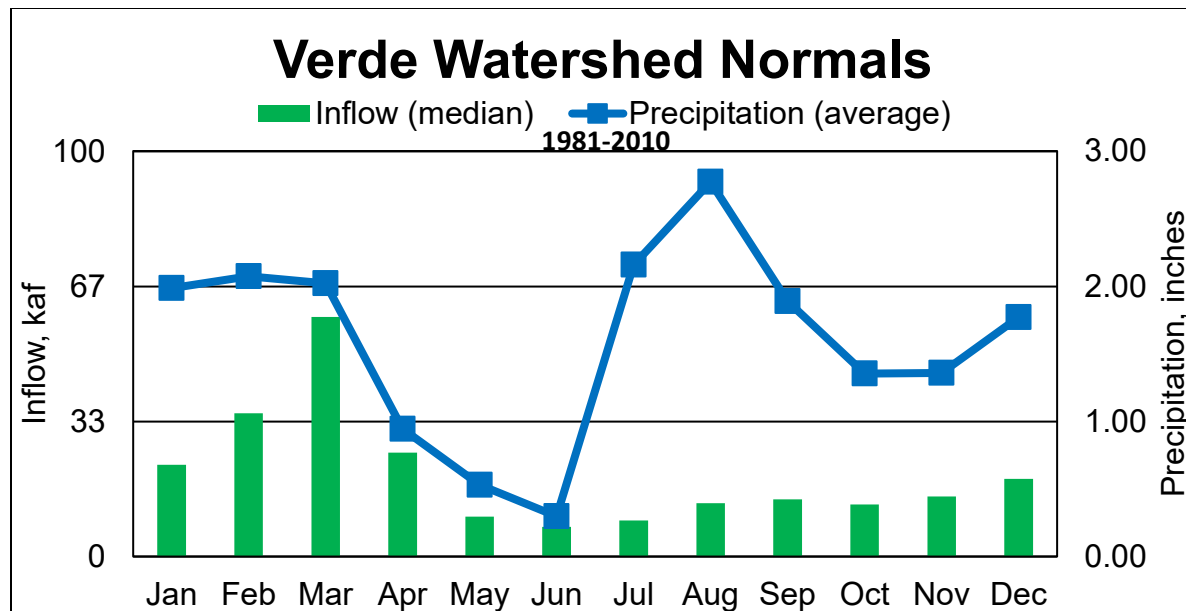


Figure 6. Verde watershed normals: average precipitation and median inflow (1981-2010)

Most of the analyses referenced in this report are from U.S. Geological Survey (USGS) gages (Table 5) which provide detailed data for inflows into the reservoirs (U.S. Geological Survey 2020).

Table 5. Gaged Data Available at Major Inflows in the Salt-Verde Watershed

USGS Gage, above reservoirs (inflow)		Gage ID	Data Record
Salt River	near Roosevelt	09498500	Oct 1913 to present
Tonto Creek	near Roosevelt	09499500	Oct 1913 to Dec-1940
Tonto Creek	above Gun Creek	09499000	Jan 1941 to present
Verde River	below Bartlett Dam	09510000	Oct 1913 to Oct 1938
Verde River	at Bartlett Reservoir	0950900	Oct 1938 to Dec 1945
Verde River	below Tangle Creek	09508500	Sep 1945 to present

3.3.2 Water Deliveries

SRP's conjunctive management of surface and groundwater resources has historically created a very reliable and steady supply of water for water rights holders within SRP's water service area. Figure 7 shows a 40-year snapshot of the variable surface water inflow and SRP's annual total deliveries. Surface water stored in the reservoirs and the availability of groundwater to augment surface water is key to maintaining a steady, reliable, and consistent water supply for the region.

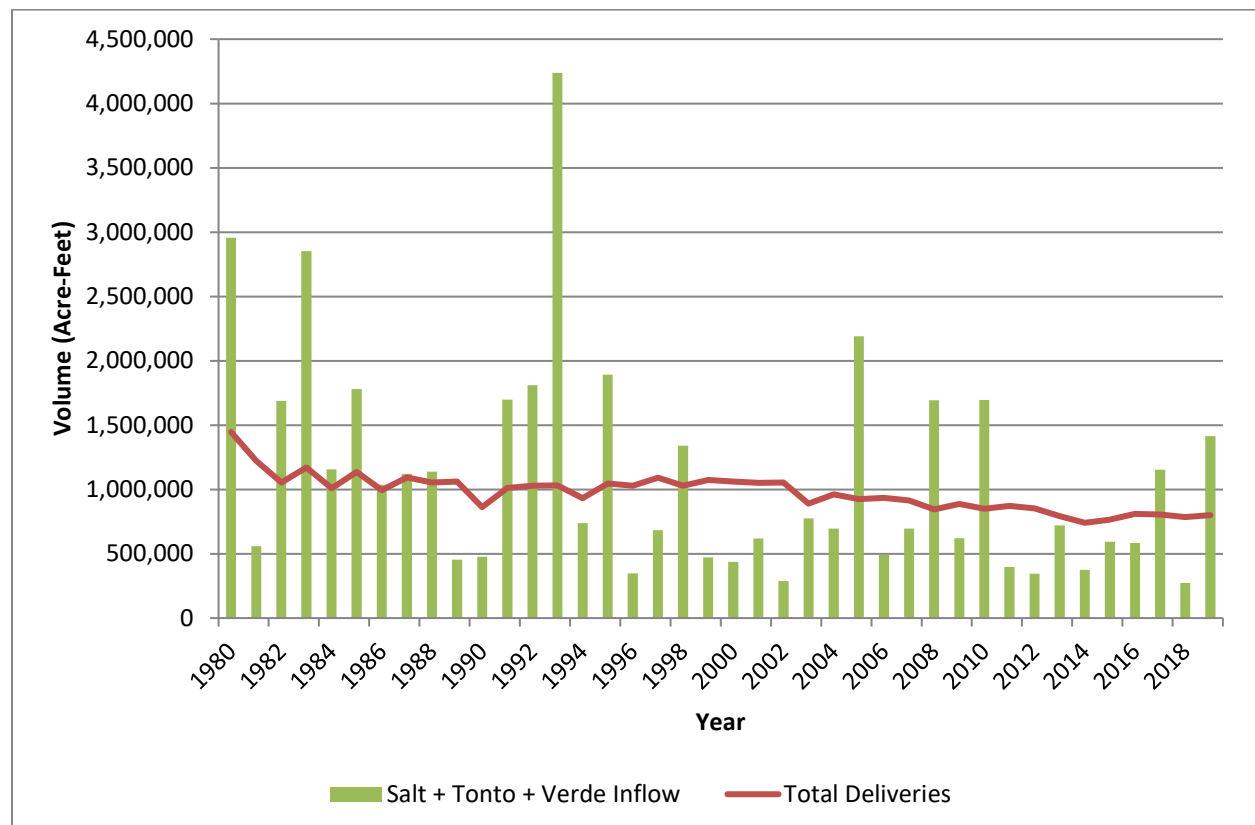


Figure 7. Total annual inflow into SRP reservoirs versus total annual water deliveries from 1980 through 2019

SRP water resources management is based on the conjunctive management of multiple sources of water to ensure an adequate supply of water to satisfy the demands of contractor and water rights holders within SRP's water service area. SRP uses a Project Reservoir Operations Planning (PROP) tool for short- to medium-term planning (1-3 years) for guidance. The PROP uses reservoir conditions at the end of the winter runoff season (May 1) to forecast monthly storage levels, surface water releases, and groundwater pumping for the remainder of the current year (May-December) and the following two calendar years. This is accomplished by using the Storage Planning Diagram (SPD) shown in Figure 8. The SPD provides a relationship between total reservoir storage, groundwater pumping production, and water allocation to manage water supplies based on the most severe drought identified in the tree-ring record dating back to the 14th century for the Salt River, Tonto Creek, and Verde River combined inflow (Phillips, et al. 2009). The red line in Figure 8 represents the storage level at which an SRP allocation is reduced from 3 AF/acre to 2 AF/acre. For longer term planning (30-50 years), SRP uses the Reservoir Planning Model (RPM).

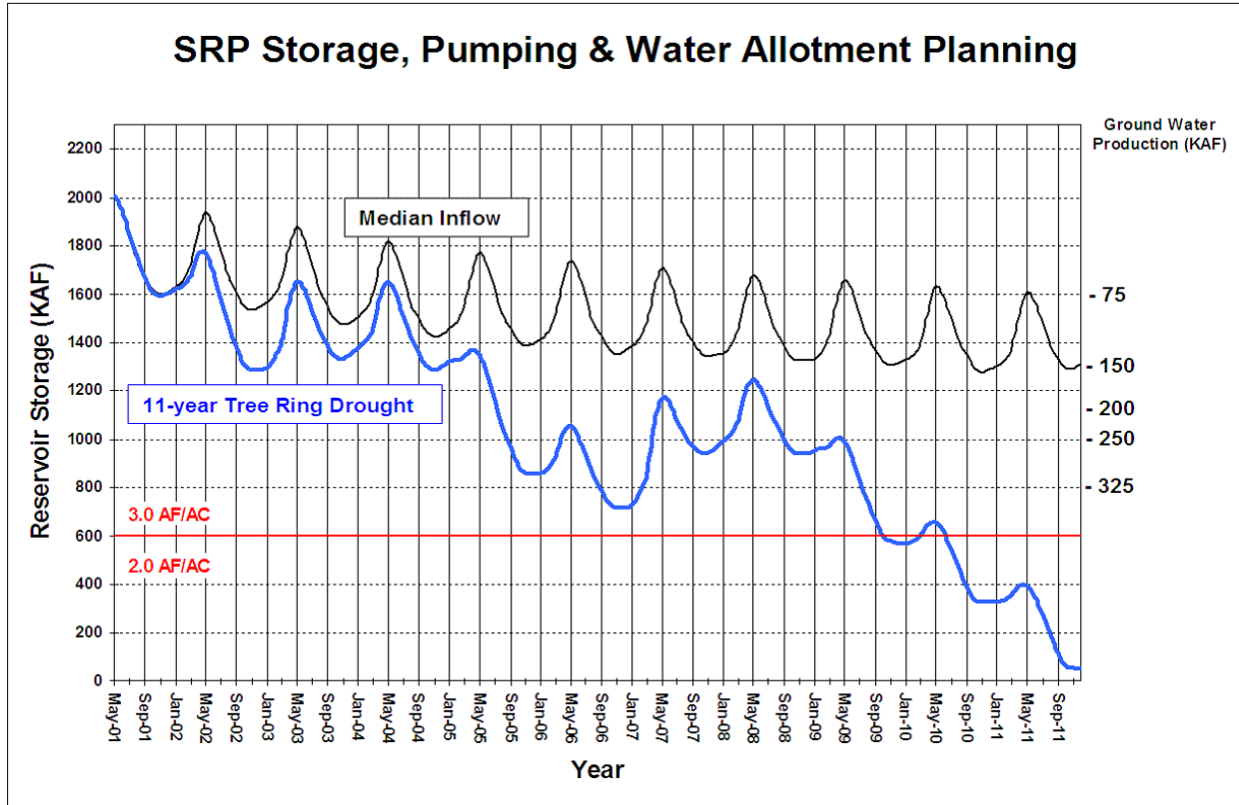


Figure 8. Storage planning diagram (Phillips, et al. 2009)

Groundwater supplements surface water delivery from the Salt-Verde system to the Phoenix metropolitan area. Managing the amount of groundwater pumping is critical for SRP reservoir storage planning. When storage is above 1.6 million acre-feet (MAF), groundwater pumping is at its minimum value of 75,000 acre-feet per year (AFY). As storage levels decrease, groundwater pumping increases. For reservoir operations planning, the maximum groundwater pumping capacity is set at 325,000 AFY.

3.4 City of Phoenix Water Supplies and Deliveries

The City of Phoenix meets its water needs through four main sources:

- Surface and groundwater delivered through SRFRP,
- Colorado River water delivered through the Central Arizona Project (CAP),
- groundwater pumped from City of Phoenix wells, and
- reclaimed water (treated wastewater effluent).

While the amount from each source varies year-to-year, water delivered through the SRFRP is approximately 50% of Phoenix's water supplies.

One of the water supplies delivered through SRFRP, but not considered part of Phoenix's SRFRP supply is Phoenix Gateway. In 1948 the City of Phoenix entered a contract with SRP and

Reclamation that established a stored water right resulting from the construction of spillway gates on Horseshoe Dam. Water accrued by the spillway gates constructed with City of Phoenix funding is referred to as Phoenix Gatewater. The physical storage capacity of Phoenix Gatewater was initially 76,130 AF, but due to sedimentation, Phoenix currently has approximately 65,077 AF of Phoenix Gatewater capacity. The City of Phoenix may accrue up to 150,000 AF of storage credits and can use 25,000 AF annually. Phoenix Gatewater can be approximately 20% of water supplied to the City of Phoenix from the SRFRP system.

3.5 Central Arizona Water Supplies and Future Need

The 1980 Arizona Groundwater Code recognized the need to manage the state's finite groundwater resources to support the growing economy. Areas with heavy reliance on groundwater were identified and designated as Active Management Areas (AMAs). The Phoenix AMA, which covers the central Arizona area (see Figure 9), has a primary management goal of safe-yield by the year 2025. Safe-yield is accomplished when no more groundwater is being withdrawn than is being replaced annually.

Central Arizona is characterized by a diverse mix of land and water use. Land use varies from heavily urbanized to agriculture with an increasing emphasis on municipal and industrial water uses. In central Arizona, especially the Phoenix AMA, agricultural water use has been declining as municipal water use has been rising over the past 25 years.

According to the Arizona Department of Water Resources, of the approximately 2.3 MAF of water used annually on average in the Phoenix AMA, approximately 1.6 MAF is surface water (CAP, SRP, and effluent) and approximately 800,000 AF is groundwater (Arizona Department of Water Resources 2021). Table 6 shows the breakout of water supply types to the Phoenix AMA / central Arizona in 2018. The largest type is groundwater, followed by Colorado River and surface water (Salt and Verde) supplies, with only a small portion provided by treated effluent.

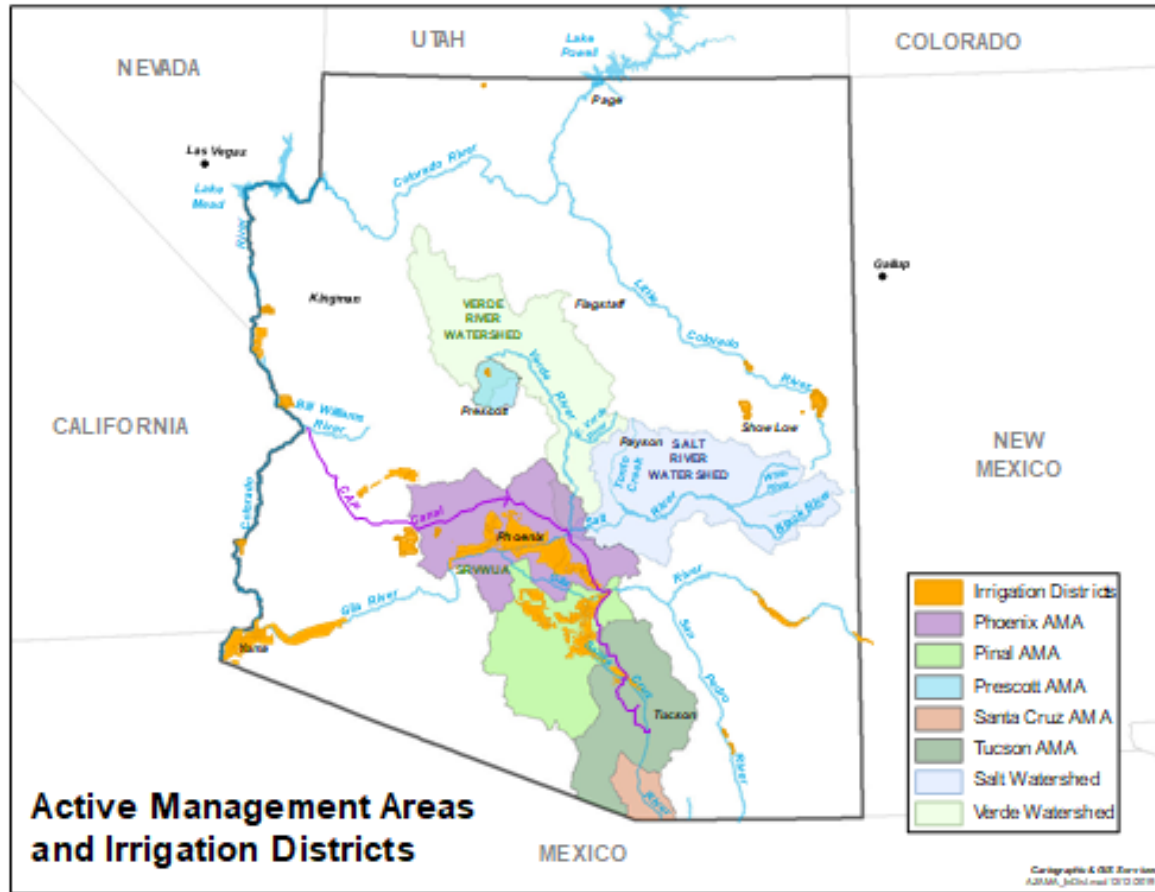


Figure 9. Arizona Active Management Areas. Phoenix AMA approximately represents central Arizona.

Table 6. Water Supply to the Phoenix AMA in Central Arizona in 2018 (Arizona Department of Water Resources 2021)

Supply Type	Supply Volume (AF)	Percentage of Total
Colorado River (CAP)	612,124	27%
Surface Water (SRP, etc.)	572,624	25%
Groundwater	805,027	36%
Effluent	258,891	12%

3.5.1 Central Arizona Future Supply

Published by ADWR in 2014, *Arizona's Next Century: A Strategic Vision for Water Supply Sustainability* (Strategic Vision) identified key priorities, timelines and action items needed to maintain sustainable water supplies for Arizona's future. This Strategic Vision states that, "The current challenge facing Arizona is that...water demands driven by future economic development are anticipated to outstrip existing supplies." (Arizona Department of Water Resources 2014) The Colorado River Basin Water

Supply and Demand Study (Bureau of Reclamation 2012) projected water demand in the Lower Colorado River Basin to exceed supply by up to 3 MAF annually over the next 100 years. Arizona's population was projected by the Water Resources Development Commission to grow to 10.5 million, 13.3 million, and 18.3 million people in 2035, 2060 and 2110, respectively, with water demand increasing from the current 6.9 MAFY to up to 10.5 MAFY in 2110. To reduce this supply and demand imbalance, ADWR is working closely with the 22 planning areas identified in the Strategic Vision to characterize issues that are resulting in these imbalances and develop strategies that are likely to be successful in addressing them.

The Strategic Vision also states, "While there may be viable local water supplies that have not yet been developed, water supply acquisition and/or importation will be required for some areas of the State to realize their growth potential....In order to avoid economic disruption, these efforts must begin immediately to ensure the long-term solutions are in place in advance of the need...." The Arizona Water Initiative, implemented in 2015, continues the work published in the Strategic Vision by joining ADWR and key stakeholders statewide to make progress on investigating long-term augmentation strategies for the State, and exploring additional water conservation opportunities for Arizona's sustainable future.

3.6 Environmental Resources in the Study Area

Environmental resources in the study area were grouped into 11 categories:

- Threatened and Endangered Species
- Bald and Golden Eagles
- Migratory Birds
- Other Terrestrial Species and Their Habitat
- Other Aquatic Species and Their Habitat
- Special Status Species
- Visual Resources
- Vegetation and Land Cover
- Jurisdictional Waters and Water Quality
- Air Quality
- Special Designations

These categories were identified by the Environmental & Cultural Resources Focus Group as the environmental resources with the greatest concern or importance within the study area. Below is a summary of each environmental category; a detailed description is found in Appendix B.

Seven species protected under the Endangered Species Act (ESA) occur or have the potential to occur in the study area (U.S Fish and Wildlife Service 2020). The ESA listed species identified include the razorback sucker (*Xyrauchen texanus*), Colorado pikeminnow (*Ptychocheilus lucius*), Gila topminnow (*Poeciliopsis occidentalis*), Southwestern willow flycatcher (*Empidonax traillii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), northern Mexican gartersnake (*Thamnophis eques megalops*), and the Arizona cliffrose (*Purshia subintegra*). The study area also includes critical habitat for the

razorback sucker and Southwestern willow flycatcher and recently designated critical habitat for yellow-billed cuckoo and northern Mexican gartersnake.

Bald eagles (*Haliaeetus leucocephalus*) and golden eagles (*Aquila chrysaetos*) occur or have the potential to occur within the study area. Both eagles are protected under multiple laws, including the Bald and Golden Eagle Protection Act. Of the two eagles, bald eagles are known to nest in the study area. Multiple migratory bird species occur or are likely present during their breeding seasons within the study area. These birds are covered under the Migratory Bird Treaty Act and/or other state and federal protections.

Other important environmental resources included in the analysis are species that provide recreational and economic value, nonnative sportfish, aquatic invasive species, a migration/movement corridor, and federal, tribal, and state special status species known or likely to occur in the study area.

Visual resources, which are defined as all seen areas from travel routes, use areas, and water bodies (U.S. Forest Service 1974), are also considered for the area. Management Area 1E of the Tonto National Forest Land Management Plan (1985) identifies a visual quality objective for a substantial portion of the study area and requires management for retention.

Nine vegetation communities and other land cover types along or near the Verde River have been identified in the study area. Additionally, three types of palustrine wetlands (forested, scrub-shrub, and emergent) and three types of streams (perennial, intermittent, and ephemeral) occur within the study area. These wetlands and other aquatic features may be regulated under Section 404 of the Clean Water Act (CWA).

The study area falls within Maricopa and Yavapai Counties. While no non-attainment or maintenance areas (subject to regulatory control of pollutant emissions under the Clean Air Act) occur within Yavapai County, Maricopa County has two non-attainment areas for particulate matter (PM-10) and ozone, and one maintenance area for carbon monoxide (Arizona Department of Environmental Quality 2020).

There are several areas with or being considered for special designation within the study area. The Tonto National Forest Draft Land Management Plan recommends establishing the Horseshoe Botanical Area to protect habitat for the Arizona cliffrose and other rare, endemic, sensitive, and at-risk plant species that occur on limestone outcrops near Horseshoe Reservoir (U.S. Forest Service 2019a, U.S. Forest Service 2019b). The Salt-Verde Ecosystem Important Bird Area (IBA) also occurs within the study area (Audubon n.d.). The Verde River portion of the IBA stretches from Childs, Arizona to the confluence with the Salt River. The Tonto National Forest's Mazatzal Wilderness is east and mostly adjacent to a portion of the study area from Sheep's Bridge to Bartlett Reservoir (U.S. Forest Service 1985, as amended, U.S. Forest Service 2019b). One recommended USFS wilderness area, referred to as Indian Butte, is immediately adjacent to, but outside the study area. The recommended wilderness area occurs west of Bartlett Reservoir, but is outside the boundary of Reclamation's land withdrawn for project purposes (U.S. Forest Service 2019a, U.S. Forest Service 2019b). Additionally, four grazing allotments are designated within the Tonto National Forest in the study area.

3.6.1 Current Environmental Measures

Existing operations and maintenance of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the Horseshoe-Bartlett Habitat Conservation Plan (H-B HCP) to mitigate for the incidental take of 16 species to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (U.S. Fish and Wildlife Service 2008, Salt River Project and ERO Resources Corp. 2008). The native species covered under the H-B HCP include the Southwestern willow flycatcher (“flycatcher”), yellow-billed cuckoo (“cuckoo”), bald eagle, razorback sucker, Colorado pikeminnow, Gila topminnow, spikedace (*Meda fulgida*), loach minnow (*Tiaroga cobitis*), roundtail chub (*Gila robusta*), longfin dace (*Agosia chrysogaster*), Sonora sucker (*Catostomus insignis*), desert sucker (*Catostomus clarki*), speckled dace (*Rhinichthys osculus*), lowland leopard frog (*Lithobates yavapaiensis*), northern Mexican gartersnake, and narrow-headed gartersnake (*Thamnophis rufipunctatus*). Covered bird mitigation efforts within the H-B HCP include the operation of Horseshoe Reservoir to support riparian vegetation and offsite acquisition and management of suitable nesting habitat. Minimization and mitigation efforts for covered native fish, frog, and gartersnake (“aquatic species”) include the operation of Horseshoe Reservoir to minimize non-native fish production, stocking of covered native fish, and supporting stream and water supply protection projects in the Verde River watershed. The Incidental Take Permit (ITP) issued by USFWS to SRP for the operation and maintenance of Horseshoe and Bartlett dams and reservoirs is valid for 50 years, spanning from 2008 to 2058.

3.7 Cultural Resources in the Study Area

The cultural resources study areas for each alternative assessed in this study were based on 200-foot buffers of the proposed Mullen Mesa stockpile and dredging operational areas for Sediment Removal, and digital elevation model contours for the 1,895-foot and 1,860-foot water elevations for the reservoir areas created by Bartlett Modifications 1 and 2, respectively. The cultural resources study areas also include a 2,026-foot contour for the reservoir area behind Horseshoe Dam. Data from previous cultural resources investigations in the study area were collected from Tonto National Forest, Reclamation, SRP, and AZSITE to calculate the number of acres that had been inventoried and identify the number of cultural resources that had been recorded. A list of these cultural resources data sources is provided in Appendix C.

The VRSMS study area is located along the lower stretch of the Verde River, an area known to have been extensively visited and settled by human beings for the past two millennia, if not longer. The study area was home to the ancient Huhugam, and more recently important to the Akimel O’odham, Hopi, Piipash, Western Apache, Yavapai, and Zuni groups. In the last 150 years, the study area was extensively developed by non-native peoples, primarily for the purposes of water reclamation. Human use of the study area has left an extensive and diverse assemblage of cultural resources across this landscape. Cultural resources are defined here in broad terms to include prehistoric and historical-period archaeological sites, historical-period buildings and structures, any known sacred sites, and natural features that have been the loci of human activities.

Horseshoe and Bartlett reservoirs have been the focus of prior cultural resources studies, particularly in support of the environmental review of the Central Arizona Project, Central Arizona Water

Control Study, and Reclamation's Safety of Dams program. Cultural resources surveys for these projects, conducted between the mid-1970s and early 1990s, resulted in the recording of hundreds of archaeological sites surrounding the reservoirs and along the Verde River between the two reservoirs.

The records search identified 236 cultural resources in the Bartlett Reservoir study area and 202 cultural resources within the Horseshoe Reservoir study area. A majority of the sites are attributed to pre A.D. 1500 Native American use of the lower Verde River valley. Pre A.D. 500 and post A.D. 1500 use by Native American groups is assumed, but likely underestimated due to the obvious and abundant architectural and material cultural remains from A.D. 500-1500. Some post A.D. 1870 cultural resources are assumed to be in the study area, including the dams and associated roads and facilities, the Horseshoe Dam construction camp, and sparse remnants of early homesteads. Bartlett Dam and Horseshoe Dam are listed on the National Register of Historic Places (NRHP) as part of the SRP multiple-property NRHP nomination. It is important to note that these data represent what is known to exist within the study area and are thought to be representative of the variety of cultural resources present; however, what is known is not necessarily the sum total of what exists.

3.8 Recreational Resources in the Study Area

Most recreation facilities in the study area are located at Horseshoe and Bartlett dams and reservoirs. Recreation activities include boating, fishing, water skiing, house boating, adaptive recreation, day use picnic areas, camping, paddle boarding, wildlife viewing, boat rentals, hunting, bicycling, motorless water sports, hiking, swimming, and horse riding. In addition to Bartlett Marina, recreation facilities in the area include a boat ramp, 12 camp sites with fire rings, picnic tables, and vault toilets. Dispersed shoreline camping is available at Bartlett Flat and RV camping is available at Yellow Cliffs. Boat launches are located at Yellow Cliffs, Bartlett Flat, and at Bartlett Marina. There are four ramadas with picnic tables and grills at Yellow Cliffs and a picnic area at Bartlett Flat.

Major recreation facilities are depicted in Figure 10 below.

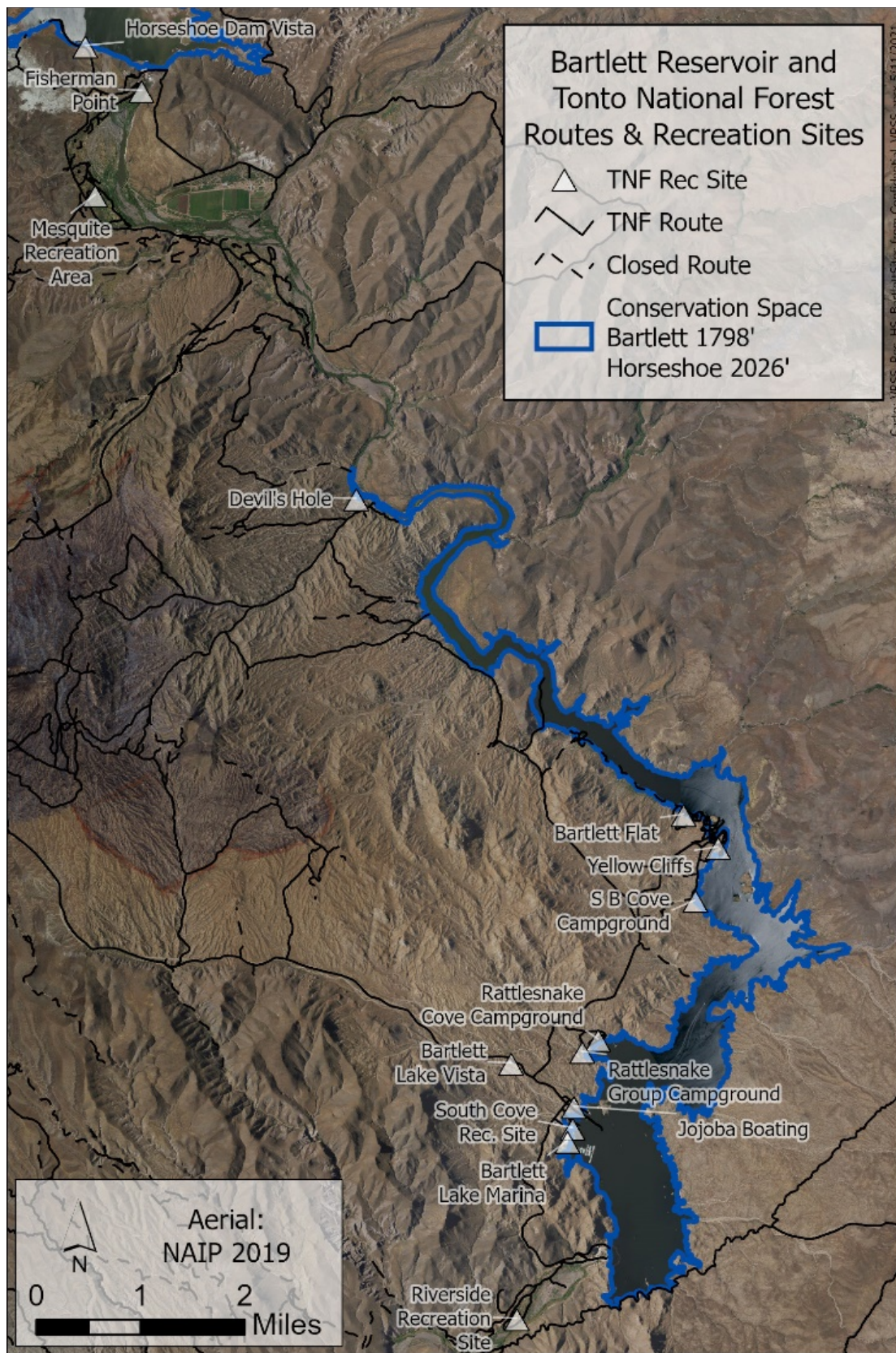


Figure 10. Bartlett Reservoir and Tonto National Forest routes and recreation sites

Low reservoir elevations at Bartlett Dam (< 1753 ft) can limit boat access at Bartlett Lake Marina and other reservoir boat ramps. At this elevation, only a few feet of ramp access remain, and the Marina must consider relocating docks and other facilities. When water levels reach 1757 ft, the Yellow Cliffs ramp and the ramp and dock are closed; this happens in most years. When Bartlett Reservoir approaches elevation 1747 ft, boat ramps can no longer reach the water and the Marina is forced to relocate its facilities.

In accordance with the existing H-B HCP, Horseshoe Reservoir is also typically drained from May to October, which has an impact to the limited amount of small horsepower boating already offered at Horseshoe Reservoir during those months.

3.9 Land Resources in the Study Area

Land within the study area encompassing the Horseshoe and Bartlett dam and reservoir sites is primarily owned by the United States and administered under the jurisdiction of the Bureau of Reclamation. The study area also includes approximately 500 acres of private inholdings between Bartlett Reservoir and Horseshoe Dam. Certain federal lands within the study area were first withdrawn from the public domain on December 14, 1901 for the Rio Verde Forest Reserve. Additional areas, including land within one mile of the Verde River were withdrawn on July 27, 1903, and December 14, 1904, under the Reclamation Act of 1902. Horseshoe and Bartlett dams and reservoirs are located on these Reclamation lands and managed for project purposes. Portions of these withdrawn lands that are not presently managed by Reclamation for project purposes are managed by the USFS pursuant to an agreement with Reclamation.

Areas within the study area, upstream of Horseshoe Dam, are also owned by the United States and managed by Reclamation and the USFS. Additionally, lands upstream of Horseshoe Dam have been designated for water and power purposes pursuant to the Arizona-New Mexico Enabling Act of 1910.

Land within the study area, but downstream of Bartlett Dam, is also owned by the United States and managed by Reclamation and the Forest Service. The United States holds the land underlying the Fort McDowell Yavapai Nation Reservation in trust for the benefit of the Fort McDowell Yavapai Nation. Lands located between Granite Reef Dam and the Fort McDowell Yavapai Nation Reservation along the Verde and Salt River were withdrawn on March 2, 1903, March 9, 1903, July 20, 1905, and April 15, 1918, pursuant to the Reclamation Act of 1902. These lands are also managed by the Bureau of Reclamation for project purposes and by the USFS pursuant to an agreement with Reclamation.

3.10 Water Rights in the Study Area

The right to beneficially use water from the Verde River is subject to the doctrine of prior appropriation. Numerous entities, including private, federal, state, and tribal water users claim the right to use water from the Verde River. These water users are located along the entire length of the river from its headwaters north of Prescott downstream to below its confluence with the Salt River in the Phoenix metropolitan area. These water users claim the right to use Verde River water under state and federal law (including through beneficial use prior to 1919), permits and certificates under

state law, existing court judgments or decrees, and federal reserved water rights. Claims made by these water users will eventually be confirmed in the Gila River General Stream Adjudication, a judicial proceeding in Maricopa County Superior Court to determine the extent and priority of all water rights in the Gila River system and its tributaries, including the Verde River (“Gila Adjudication”). Except for the tribal claims as described below, most claims to the use of water from the Verde River have not yet been adjudicated. The Gila Adjudication Court will eventually determine the attributes of each right to use water from the Verde River, including location and priority date for such use.

For certain Native American tribes, rights to the use of Verde and Salt river water have been adjudicated through Congressionally approved water rights settlements which have been approved by the Gila Adjudication Court. These Native American tribes are located downstream of Horseshoe and Bartlett dams and include the Fort McDowell Yavapai Nation and the Salt River Pima-Maricopa Indian Community. The Gila River Indian Community also has approved rights delivered in part through storage of water in the Verde River reservoir system. In addition to these settled claims, the Hualapai Tribe, Tonto Apache Tribe, and Yavapai-Apache Nation have asserted claims to water in the Verde River Basin. These tribes are all located upstream of Horseshoe and Bartlett Dams. The U.S. Department of the Interior has teams working to negotiate and settle the water rights claims asserted by these tribal nations.

3.11 Central Arizona Economy and Population Demographics

Maricopa County contains the majority of the Phoenix metropolitan area and is the focus of this section and the financial analysis in Appendix D. In 2018, Maricopa County’s approximately 2 million civilians¹ over the age of 16 worked in primary job sectors in similar proportion to the U.S. as a whole, as shown in Table 7 (Headwaters Economics 2020a). Ninety-eight percent of Maricopa County residents work within the county, which provides a positive indication of the county’s ability to support social services with business tax revenue.

Table 7. 2018 Employment by Major Job Sector

Job Sector	Maricopa County	United States
Management, Professional, & Related	38%	38%
Manufacturing	7%	10%
Finance, Insurance, & Real Estate	10%	7%
Education, Health Care, and Social Assistance	21%	23%
Travel and Tourism	17%	16%
Timber, Mining, and Agriculture	<1%	2%

Maricopa County’s population, employment, and personal income growth have all outpaced the national average substantially, with most of the growth occurring in the urban center of the county.

¹ Civilian population is defined as persons 16 years of age and older residing in the 50 states and the District of Columbia, who are not inmates of institutions (e.g., penal and mental facilities, homes for the aged), and who are not on active duty in the Armed Forces. (source: <https://fred.stlouisfed.org/series/CNP16OV#>)

Labor earnings have grown consistently, driven particularly by earnings growth in the services and construction sectors. The economy remained relatively resilient during periodic national recessions from February 1976 through February 2020 (Headwaters Economics 2020c). The Maricopa Association of Governments forecasts that Maricopa County population will increase from 4,436,900 in 2020 to 6,414,100 in 2055, and employment will increase from 2,236,400 in 2020 to 3,467,700 in 2055 (Maricopa Association of Governments 2019).

In Maricopa County, 77.6% of people identify as “white alone” compared to 72.7% for the U.S. However, Maricopa County has a higher percentage of people who identify as “American Indian or Alaska Native alone”, “some other race alone”, and “two or more races” compared to the U.S. In Maricopa County, 30.8% of residents identify as Hispanic or Latino (of any race) compared to 17.8% for the U.S. An estimated 82,699 Maricopa County residents self-identify as American Indian or Alaska Native.

‘Populations at Risk’ are defined as populations who are more likely to experience adverse social, health, and economic outcomes due to their race, age, gender, poverty status, and other socioeconomic measures. ‘Populations at Risk’ includes the percentage of Maricopa County’s civilian noninstitutionalized population living with a disability (11.1%) or without health insurance (11.1%). These factors tend to be correlated with other socioeconomic disadvantages but are not dramatically different from the U.S. as a whole (Headwaters Economics 2020d).

Income distribution in Maricopa County in 2018 was similar to the U.S., with a Gini Coefficient of 0.47 versus 0.48, respectively (where zero is perfect income equality and 1 is perfect income inequality). Overall, 14.7% of people and 10.6% of families in Maricopa County lived below the poverty line, similar to the U.S. as a whole.

Maricopa County’s housing base has a relatively recent median construction year (1990), and in comparison to household income, is slightly more affordable than the U.S. as a whole. Relative affordability of housing may positively affect families’ ability to pay for other necessities such as water.

4 Alternative Formulation

The alternatives to address the problem and need for the VRSMS were developed through the Alternatives Development Focus Group. Each potential alternative was screened for its likelihood to be realistically implemented and effective. Three action alternatives were developed that showed prospects to restore lost storage capacity and mitigate future losses of storage capacity to sedimentation in order to compare to a Future Without Action. In addition, a number of potential alternatives were considered, but not fully evaluated, in the appraisal study. The final alternatives are described in detail in Sections 4.1, 4.2, and 4.3; background on the alternatives not fully evaluated is provided in Section 4.3.4.

4.1 Without Action

The Without-Action alternative is a future scenario in which none of the alternatives identified are implemented. This alternative includes ongoing reservoir operations and maintenance, planned improvements, water supply planning using SRP's operational planning procedures and decision-making, as well as other foreseeable local management practices appropriate for comparison to action alternatives. This alternative assumes no planned intervention to restore or maintain capacity losses from sedimentation.

4.2 Sediment Removal

The sediment removal alternative looks at removing sediment from Horseshoe Reservoir to restore and maintain conservation storage capacity within the Verde River reservoir system. This alternative uses a variety of mechanical means including terrestrial heavy earth-moving equipment and aquatic dredging machinery to remove the sediment. Due to construction costs sensitivity to haul distances, the sediment disposal location is identified as the lands adjacent to Horseshoe Reservoir on Mullen Mesa.

4.2.1 Sediment Removal Alternative Overview

Removal of sediments can be accomplished using several different methods. The most cost-effective method is to use heavy earth moving equipment including scrapers, excavators, haul trucks, and similar equipment. Given the situation at Horseshoe Reservoir, where uncontrolled inflow from a very large watershed enters the reservoir annually, it is prudent to assume that a significant portion of the sediment removal would have to be done when water is in the lake and sediment is not dewatered, or "in the wet", and would require dredging of the sediment.

There are two basic types of dredging, hydraulic and mechanical. The hydraulic pipeline cutterhead dredge is the most commonly used hydraulic dredging vessel and is generally the most efficient and versatile. Because it is equipped with a rotating cutter apparatus surrounding the intake end of the suction pipe, it can efficiently dig and pump a wide range of alluvial materials and compacted deposits. Its advantages include relatively high production rates and relatively low cost per cubic yard for large projects. Its disadvantages are that its large, specialized equipment is difficult to move overland especially to remote locations. Additionally, it needs large volumes of water to operate, requires multiple boosters that can quickly drive up costs, experiences aggressive line wear due to pumping sand slurries, and requires a minimum requirement of six feet of water depth for a small dredge.

For Horseshoe Reservoir, the diameter of the dredge pipe would most likely be 16 inches or smaller; this size dredge typically produces less than 4,000 cubic yards per day (CY/day). As pipeline lengths increase, production will be reduced due to pumping pressures. Plus, a cutterhead dredge can only be used when there is water in the lake. If dredged water is not efficiently returned from the disposal site, there could be problems with insufficient water at the dredge for significant periods of time.

There are two primary types of mechanical bucket dredges, the clamshell (or grab) bucket dredge and the backhoe dredge. The excavated material is placed in scows or hopper barges that are towed to the placement areas. Buckets used on this type of dredge usually range in capacity from 1 to 30

CY. Bucket dredge production is a function of both the loading (excavation) and hauling components of its operation. The advantages of mechanical dredging are that the equipment is relatively available, more easily transported over land, and can operate in a variety of water depths/and or dry conditions. Additionally, multiple pieces of equipment can be working within close proximity to each other, tend to be more cost-effective for longer haul distances than hydraulic dredges, and placement areas can be much smaller. Disadvantages of mechanical dredges are relatively slow production, relatively high cost per cubic yard dredged, and development of locally high turbidity due to sediment disturbance. If mechanical dredging is used, the magnitude of the operation will be limited to the size of cranes that can be brought in overland. If the system is to be floated on a barge, it may be restricted by the size of the barge that can be brought and assembled onsite.

Although buckets as large as 50 CY have been used in the past, dredging at Horseshoe Reservoir would most likely utilize a dredge having a bucket of 3 to 5 CY. Production rates would depend on the dredging systems, i.e., the number of scows and/or trucks available, and the relative time to load/unload. Typically, a bucket dredge can produce 1,500 to 3,000 CY/day. This study assumes 45,749 AF of sediment would be removed from Horseshoe Reservoir.

Dredged materials are typically stored and dewatered in a Confined Disposal Facility (CDF). The CDF is constructed and designed to safely hold the volume of dredged material, as well as temporarily store water prior to it being returned to the originating water body. Excess water is normally returned to the originating water body if no contamination issues are present. Return water can either be pumped or gravity-drained back to the original water body. Constructed dikes form a confined surface area and the dredged sediments are pumped into this area hydraulically. The clarified water is usually discharged over a weir at a flow rate that is approximately equal to influent flow rate.

Dredging estimates are typically developed based on three general criteria: mobilization/demobilization, construction costs for the placement area, and cost/cubic yard of dredging. Mobilization costs are dependent on how far the equipment must be transported, the number of support vessels, and the cost of assembly. Placement area costs are normally limited to the cost of constructing the surrounding dikes and decant structure(s), but can also include special requirements for site lining for contaminated soils, return water considerations, and any special monitoring required. Unit costs for dredging are normally developed as a function of the complexity of the dredging operation and the distance to the placement area.

4.2.2 Sediment Removal Direct Cost Opinions

To assess potential costs, it is assumed some material could be seasonally excavated by conventional surface excavation methods, some by an excavator or clam shell, and some by a cutting head suction dredge. Figure 11 uses a Google Earth photo taken when the reservoir was nearly empty and displays three potential zones of sediment removal along with a nearby disposal area (that may or may not be available due to ownership or environmental constraints) to show the rough volumes and areas that could be expected. This conceptualization, along with the table below, supports a visualization of the magnitude of the effort required to excavate sediment from Horseshoe Reservoir.

Table 8 summarizes an appraisal-level Opinion of Probable Construction Costs (OPCC) based on approximately 73 million CY (45,749 AF) of sediment being removed and wasted very close-by,

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utilizing cutterhead suction dredging, barge-staged excavator dredging, and reservoir perimeter “dry” excavation that is presumed to utilize surface excavators and truck haul, and potentially some scraper use. Additional detail is provided in Appendix E for the procedures that produced the OPCC. The appraisal OPCC, before escalation, is approximately \$840 million or about \$18,000/AF of storage gained. To illustrate a potential best-case scenario, presuming the majority of the sediment can be removed with dry excavation methods, which is believed unlikely given Verde River basin hydrology and the difficulty in draining subsurface sediment, this Table presents a preliminary OPCC of approximately \$1.1 billion over an approximate 15-year program.

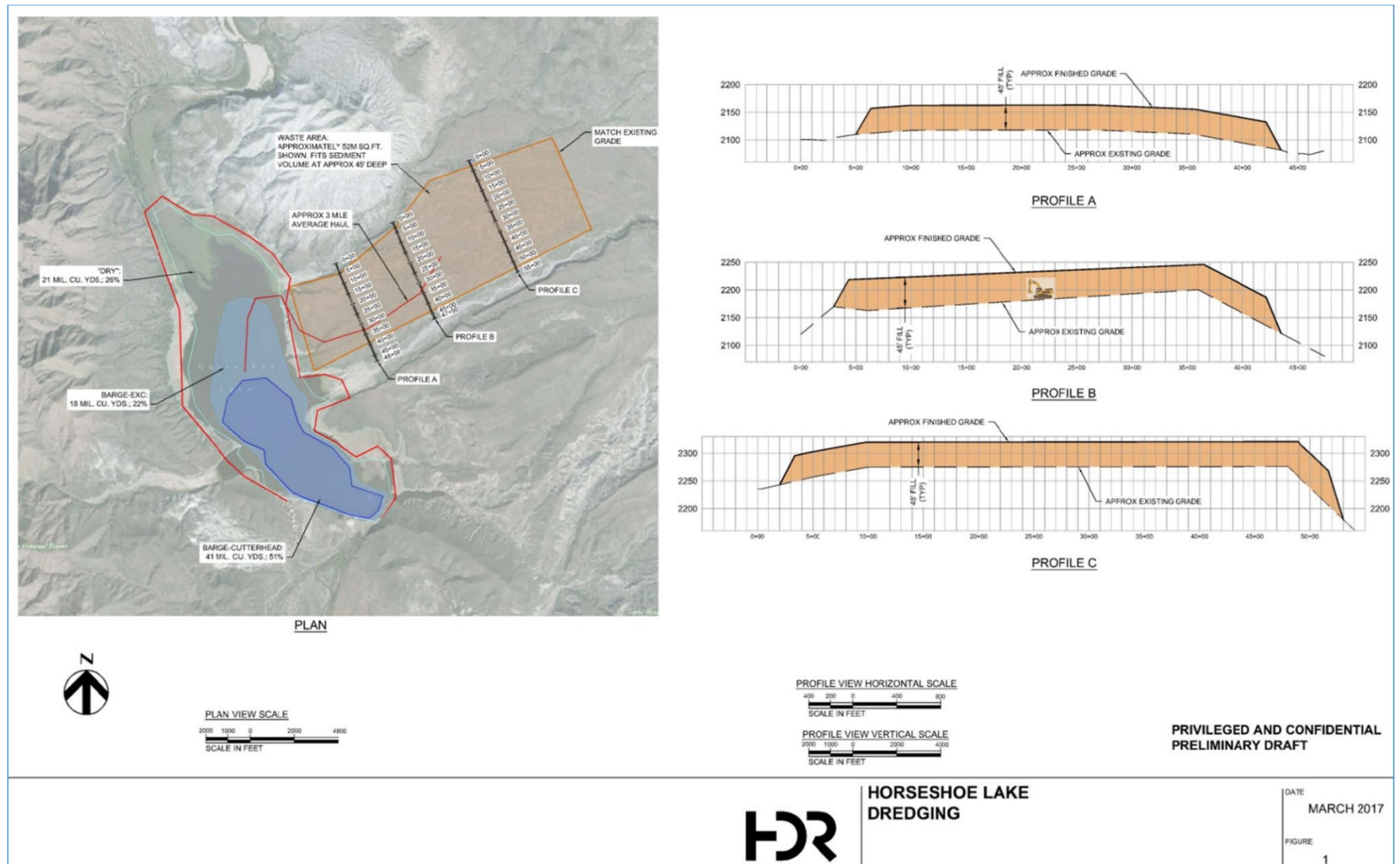


Figure 11. An illustrative concept for Horseshoe Reservoir sediment removal

Table 8. Preliminary Opinion of Probable Sediment Removal Cost

Description	Code	Quantity	Unit	Unit \$	Total \$
Diversion – Direct Cost ¹		1	Lump Sum (LS)	5,000,000.00	5,000,000
Diversion – Risk Cost ²		1	LS	2,000,000.00	2,000,000
Contractor Access, Staging, and Temp Works ³		1	LS	5,000,000.00	5,000,000
Clearing and Initial Site Work		1,500	Acre (AC)	2,000.00	3,000,000
Waste Area – Development		7,000,000	Cubic Yard (CY)	2.00	14,000,000
Temporary Holding and Dewatering Facilities ⁴		70,000	CY	25.00	1,750,000
Dewatering Allowance ⁵		3,750	Day	1,000.00	3,750,000
Sediment Excavation (Dry)		14,200,000	CY	3.00	42,600,000
Dredging (Excavator)		17,800,000	CY	8.00	142,400,000
Dredging (Cutterhead)		41,200,000	CY	10.00	412,000,000
Final Site Work and Reclamation ⁶		1,500	AC	2,500.00	3,750,000
Subtotal					635,000,000
Mobilization ⁷	2.30%	+/-		15,000,000	15,000,000
Subtotal with Mobilization					650,000,000
Contract Cost Allowances (sum of next two lines):	5%	+/-			30,000,000
Design Contingencies, 5% (+/-) ⁸					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
CONTRACT COST					680,000,000
Construction Contingencies ⁹	10%	+/-			70,000,000
FIELD COST (Price Level Jan 2017)					750,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	11%	+/-			86,000,000
CONSTRUCTION COSTS					836,000,000
Ref.: For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

NOTES:

1. Routing of river flow along reservoir banks, berms, etc. to isolate dry areas.
2. Seasonal and other interruptions where productivity is decreased.
3. Roads, launching stations, material transfers, etc.
4. Based on 2000 GPM, five days holding.

5. Flocculation agents, maintenance, etc.
6. Includes drainage construction.
7. Includes multi-year continuous operations.
8. The contingency is low considering that the design would be very different and reduced from the other storage options involving raised or new dams. Unlisted work represents work needed in considered scope, but not itemized at this level of detail. It should not be considered equivalent to the "design" contingency which reflects cost changes as the design evolves and the construction scope changes.
9. This contingency reflects post-award quantity changes, work scope changes, change orders, and low-grade disputes. Considering complex and multidisciplinary work on an existing facility and sensitive diversion considerations, we recommend considering a fairly typical 10 percent which is probably conservative.

4.3 Bartlett Modifications 1 and 2

The two Bartlett Modification alternatives propose to restore capacity lost at Horseshoe Reservoir through enlargement of Bartlett Dam and Reservoir downstream. Along with the larger reservoir, the Bartlett Modification alternatives consider re-operating the Verde Reservoir system from the current two water conservation to a single larger reservoir. Horseshoe Dam would remain in place, but operated as a run-of-river facility except during high inflow events to allow for sediment and flood management during the winter and spring runoff seasons. Horseshoe Dam operated as a run-of-river facility means that Horseshoe Dam release would match Verde River inflow until inflows into the reservoir exceed the river outlet works capacity (1,870 cubic feet per second [cfs]). At this point, Horseshoe Dam releases will be less than 1,870 cfs until water elevation reaches the spillway sill crest (2000 ft), at which point, release capacity increases.

4.3.1 Bartlett Modifications 1 and 2 Overview

Bartlett Modification 1 and 2 Alternatives include enlarging Bartlett Dam and Reservoir and re-operating the reservoir system to restore lost capacity, manage riparian and wetland habitat in Horseshoe Reservoir, mitigate future sediment impacts on storage capacity, create additional conservation storage, add flood control capacity and/or outlet works, enhance recreation opportunities, add hydropower generation, and increase dam safety. These alternatives identify a new dam constructed immediately downstream of (abutting) the existing Bartlett Dam. Bartlett Modification 1 is the larger of the two options with a Normal Maximum Water Surface Elevation (NMWSE) of 1895 ft, which is 97 feet higher than existing Bartlett Dam's NMWSE of 1798 ft. It would provide 628,000 AF of total storage capacity and increase total reservoir surface area to 7,015 acres. Bartlett Modification 2 has an NMWSE of 1860 ft, which is 62 feet higher than existing Bartlett Dam. Bartlett Modification 2 would provide 422,000 AF of total storage capacity and increase total reservoir storage surface area to 5,084 acres. Table 9 provides a summary of Bartlett Modifications 1 and 2 and Figure 12 and Figure 13 show the preliminary inundation area of each modification compared to existing Bartlett Reservoir.

Table 9. Summary of Bartlett Modification Alternatives

Alternative	Total Storage of New Reservoir [AF]	Restored Storage [AF]	Added Storage [AF]	Restored and Added Storage [AF]	Total Existing Verde Reservoir Storage as of 2012 [AF]	NMWSE [ft]	Reservoir Surface Area [acres]
Bartlett Modification 1	628,000	45,749	305,784	351,533	276,467	1895	7,015
Bartlett Modification 2	422,000	45,749	99,784	145,533	276,467	1860	5,084

Both alternatives move the remaining water storage rights from Horseshoe Reservoir into the modified Bartlett Reservoir. Horseshoe Reservoir could then be repurposed and operated to benefit habitat and species, provide flood control, and capture and manage sediment loads. The repurposed Horseshoe Reservoir could be operated as a run-of-river reservoir during lower flow times of year (May through December) when most transported sediment is suspended in the water column. This would allow habitat within the reservoir bottom to be managed for a more natural riparian ecosystem along the natural river channel. During winter and spring runoff periods (January-April) when larger storm and runoff events are capable of moving large amounts of bed-load sediment into the Verde Reservoir system, Horseshoe Reservoir would be operated to help route flood events, allowing flood water to be held in the reservoir to attenuate flood flows before entering the modified Bartlett Reservoir while also managing the movement of sediments downstream. Effective sluicing of sediments from Horseshoe Reservoir is expected to require high inflows to occur while the reservoir is drawn down. Modified reservoir operations made possible by the proposed Bartlett Modification alternatives would allow for Horseshoe to remain drawn down moving into the winter and spring runoff season, creating more opportunity for maintenance sluicing of sediment accumulations from Horseshoe Reservoir. The deep and narrow profile of Bartlett Reservoir offers potential for inducing density currents to convey sediment passed through Horseshoe Dam. The flood control pool would be expected to drain by late spring, allowing for re-establishment of river operations and habitat during summer, fall, and early-winter months.

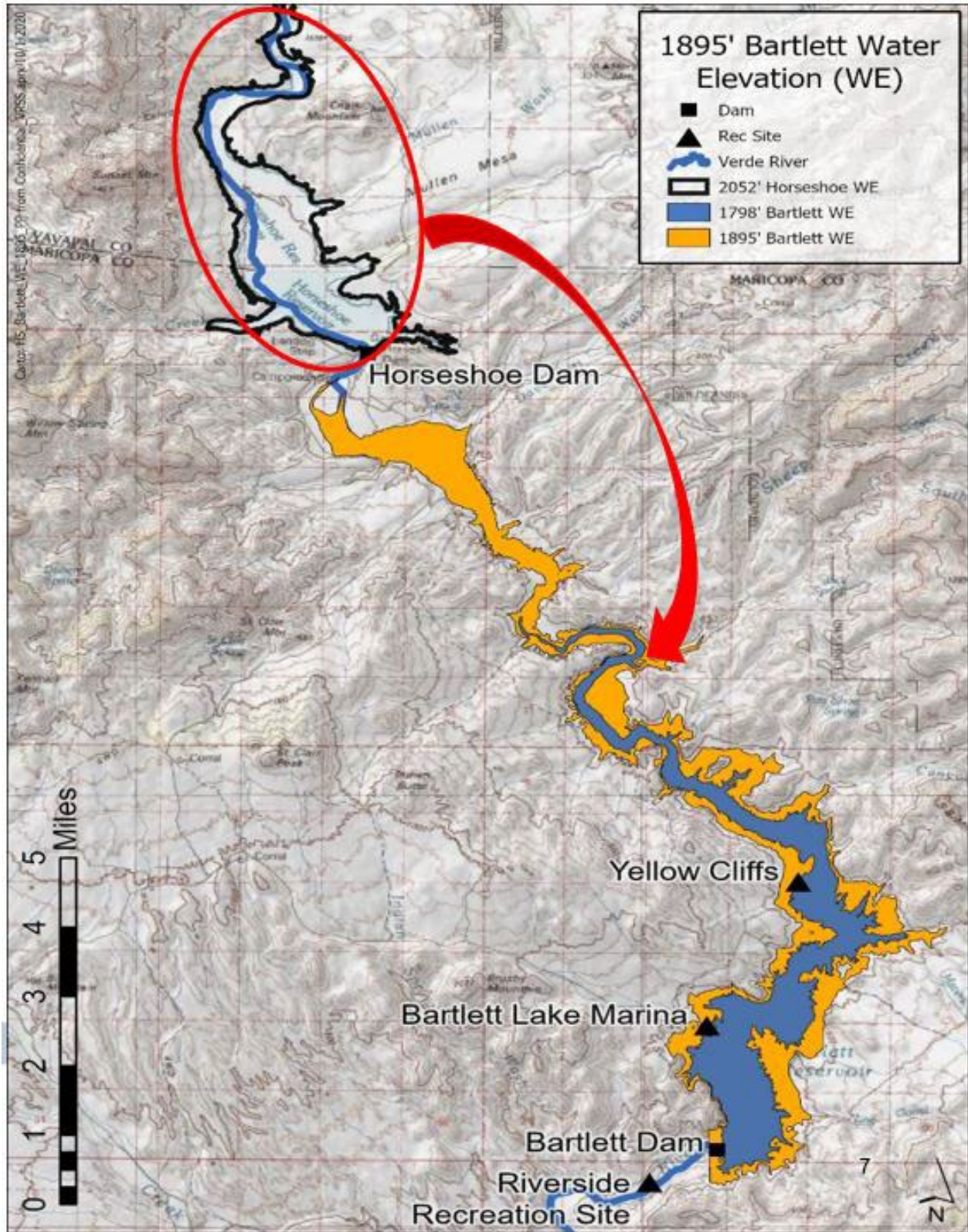


Figure 12. Bartlett Modification 1 (elevation 1895 feet) preliminary inundation area

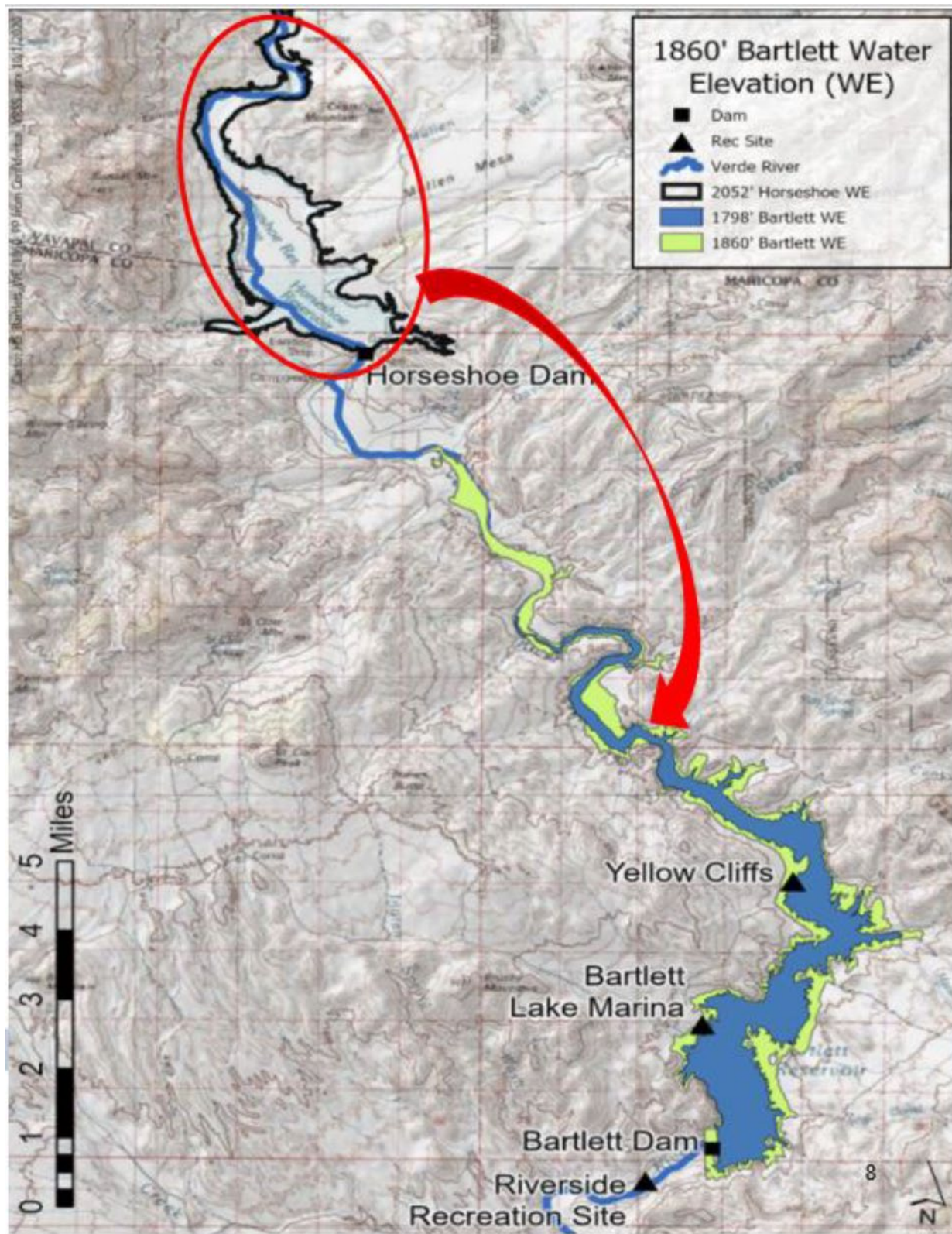


Figure 13. Bartlett Modification 2 (elevation 1860 feet) preliminary inundation area

4.3.2 Bartlett Modifications 1 and 2 Preliminary Design and Layout

Preliminary design and layout of Bartlett Modifications 1 and 2 have been considered for this appraisal study. Unless otherwise noted, Bartlett Modifications 1 and 2 are similar in design and layout, except for the difference in height and storage capacity between the two. Figure 15 shows the initial plan view of Bartlett Modification 1.

Both modifications are the construction of a new dam immediately downstream and abutting the existing Bartlett Dam. Should either alternative be recommended for feasibility, further analysis would need to be conducted to determine if the new dam would tie into the structure of the existing dam with infilling of the existing arches or designing the dam as a stand-alone structure. Either approach proposes using the existing dam as a cofferdam and extending existing outlets for river management during construction.

Initial design of Bartlett Modifications 1 and 2 is for a roller-compacted concrete (RCC) dam. RCC is now widely used for both new dams and for modifications to existing dams. RCC is placed with conventional earth moving equipment and conveyor systems allowing rapid placement of stiff concrete that can be compacted with heavy civil construction rollers. Fresh foundation rock will be needed to support either option, and will need to be excavated without compromising the integrity of the existing structure. This issue is lessened if the new construction completely fills in and ties together the existing dam and new dam section.

Bartlett Dam Modification 1 and 2 appurtenant structure initial designs assume passage of the same inflow design flood as the existing Bartlett Dam spillway structures. Either modification would use similar sized service spillways as existing, but with radial gates and energy dissipation accomplished with a flip bucket and plunge pool. Existing Bartlett Dam auxiliary spillways use fuse plug structures that are designed to erode in stages and increase flow release as water surface elevation increases. For the Bartlett Dam Modifications, the fuse plug spillways will be replaced with one of three options to pass a portion of the Probable Maximum Flood. The three auxiliary spillway options are labyrinth, composite labyrinth and fusegate, and ogee. All three options will require a lined chute or unlined channel to convey flood discharges to the downstream river channel. Should either Bartlett Dam Modification be carried forward to feasibility, further analysis would be required to determine the appropriate configuration. There is currently 22.6 feet of flood surcharge space available to the dam crest of existing Bartlett Dam. Either modification provides 25 feet of flood surcharge space and residual freeboard between the NMWSE and the raised dam crest.

Existing river outlet works (ROW) are used to pass normal water deliveries. The two existing conduits that make up the ROW would be extended through the new RCC dam section to the toe of the new dam for both Bartlett Modifications. Downstream of the dam, they would be combined into a single penstock and connect to an outlet structure located 1,200 feet downstream of the present ROW terminus. This would help protect outlet works from spillway discharge events. A small bypass valve may also be tapped into the larger outlet works penstock to discharge low flows into the stream channel immediately downstream of the new dam toe. There is also potential with either modification to increase the size of ROWs for increased use in flood flow releases to allow for maintenance sluicing and flushing of sediment through Bartlett Reservoir to maintain capacities within the reservoir system. Modifications to the existing intake tower at Horseshoe Dam to increase intake velocities could help improve passage of sediment from Horseshoe Reservoir into the modified Bartlett Reservoir for passage through Bartlett ROWs. The screening of low-level intakes

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at the Horseshoe Reservoir to increase sediment passage through increased water velocity is shown in Figure 14.

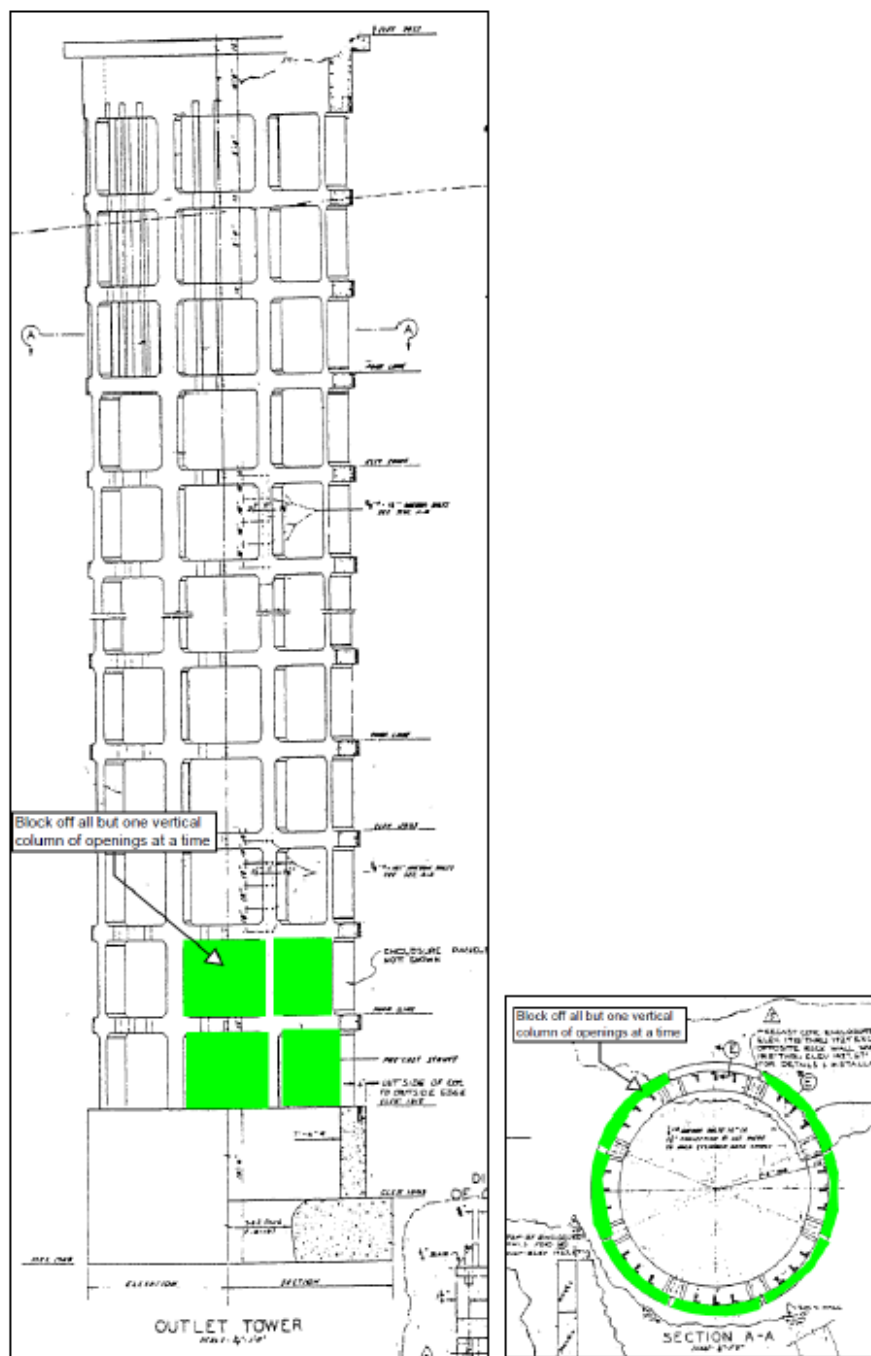


Figure 14. Horseshoe Dam outlet tower modification to enhance sediment sluicing and flushing

The Bartlett Dam site has previously been identified as a potential site for addition of conventional hydropower, and that is under consideration for each Bartlett Modification. Initial designs for both modifications have the powerhouse and generator at the outlet structure 1,200 feet downstream of the dam. At the powerhouse, the penstock will bifurcate to the turbine, and a large fixed cone or ring jet valve will discharge into the river channel. Details on potential hydropower capacity and a power generation economic analysis are provided in Appendix F.

Construction planning and sequencing play a critical role in the design and analysis of Bartlett Modifications 1 and 2. Flood routing during construction will likely rely on keeping the existing spillway in operation until enough of the new dam section and spillway are constructed to allow flood flows to be routed over the dam or through the spillway section. Figure 15 and Figure 16 show the preliminary plan view for Bartlett Modification 1 and 2, respectively.

4.3.3 Opinions of Probable Construction Costs

Appraisal-level estimates of probable construction costs were developed for the two Bartlett modification options and additional detail is provided in Appendix E. Table 10 provides a summary of costs for Bartlett Modification 1 and Table 11 shows a summary of costs for Bartlett Modification 2. Costs are based on previously executed field exploration programs, a work breakdown structure, a detailed construction sequencing plan, and schedule. Cost contingencies based on engineering judgement that consider factors such as the complexity of the work and level of supporting data available for estimating are also included.

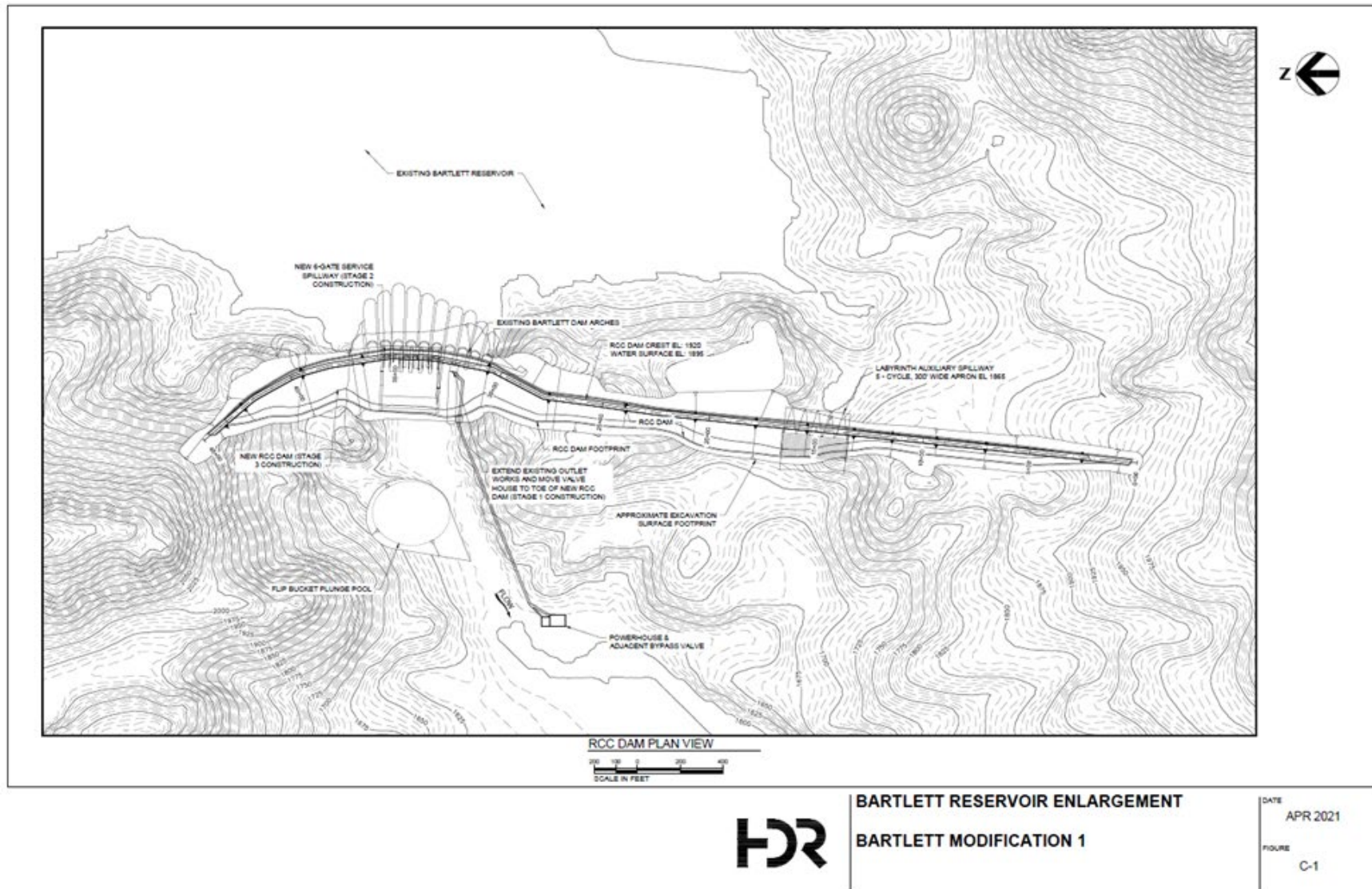


Figure 15. Bartlett Modification 1 preliminary plan view

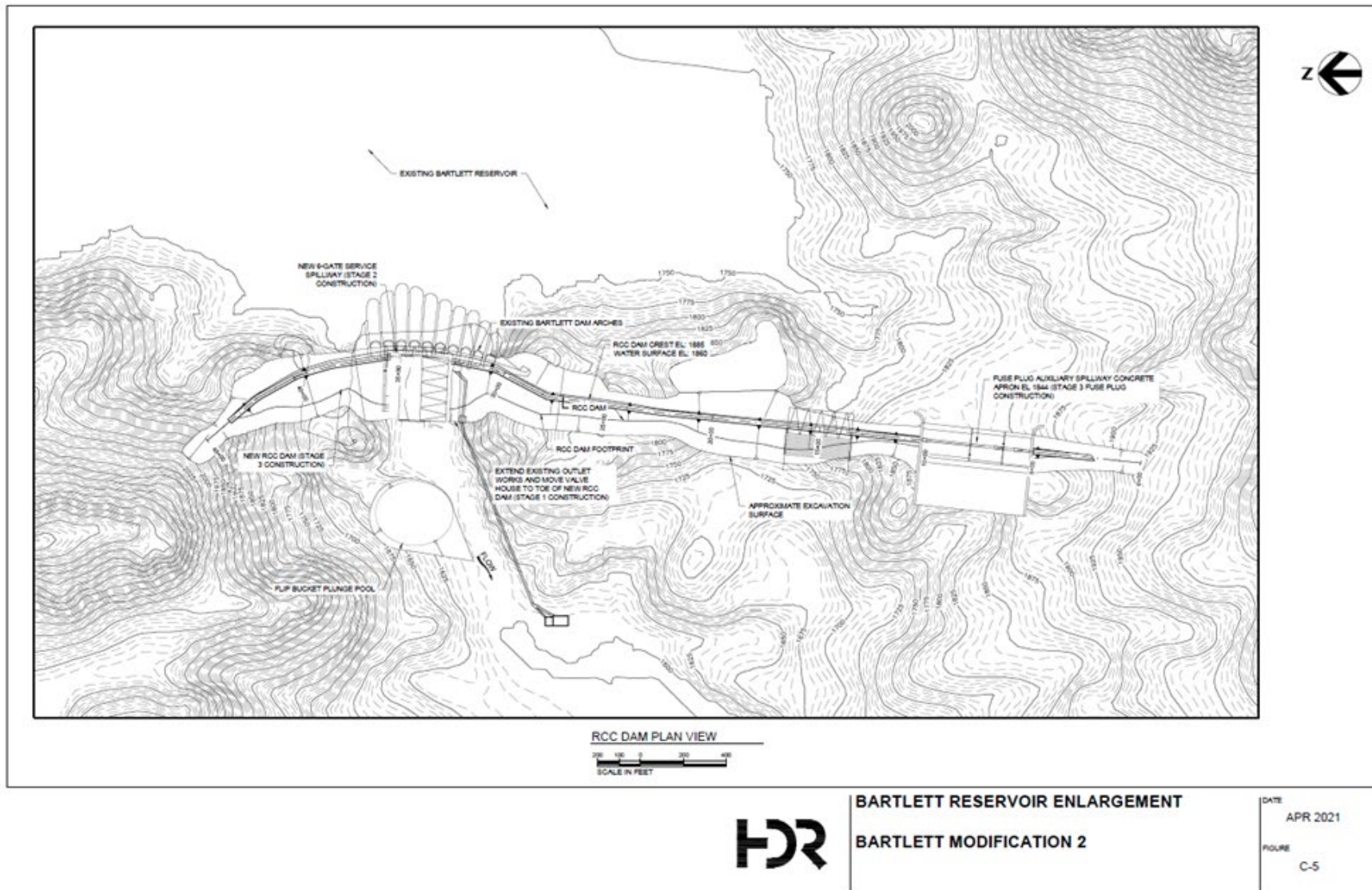


Figure 16. Bartlett Modification 2 preliminary plan view

Table 10. Appraisal-level Opinion of Probable Construction Costs for Bartlett Modification 1

Description	Code	Quantity	Unit	Unit \$	Total \$
1 WP1 - Transmission & Power Supply - Relocation		12,100	linear foot (lf)	300.00	3,630,000
2 WP2 - Project Access & Site Development					
2.2 Project Access Development		2.50	miles (mi)	1,550,000.00	3,875,000
2.3 Basic Staging Development		1	lump sum (ls)	2,100,000.00	2,100,000
3 WP3 - Dam Construction					
3.2 Site Development		1	ls	15,000,000.00	15,000,000
3.3 Site Restoration		24.0	acre (ac)	40,000.00	960,000
3.4 Existing Structure Demo		1	ls	5,500,000.00	5,500,000
3.5 Diversion & care of water (varies this configuration)		1	ls	27,275,000.00	27,275,000
3.6 Main Dam & integrated hydraulic structures					
3.6.1 Dam Foundation Preparation and Grouting		71,000	square yard (sy)	232.00	16,472,000
3.6.2 Dam earthworks		1,154,000	cubic yard (cy)	16.00	18,464,000
3.6.3 Dam body		2,117,500	cy	113.50	240,336,250
3.6.4 Dam Hydraulic Structures					
3.6.4.1 Service Spillway		1	ls	68,000,000.00	68,000,000
3.6.4.2 Low Level OW (varies this configuration)		1	ls	13,000,000.00	13,000,000
3.6.5 Spillway bridge		1	ls	1,390,000.00	1,390,000
3.6.6 Crest structures		1	ls	3,000,000.00	3,000,000
3.8 Auxiliary spillway construction		1	ls	28,000,000.00	28,000,000
3.11 Project electrical & instrumentation		1	ls	4,750,000.00	4,750,000
3.12 Administrative buildings		1	ls	1,050,000.00	1,050,000
Subtotal					453,000,000
Mobilization	6%	+/-			27,000,000
Subtotal with Mobilization					480,000,000
Contract Cost Allowances (sum of next two lines):	15%	+/-			70,000,000
Design Contingencies, 15% (+/-)					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
CONTRACT COST					550,000,000
Construction Contingencies	20%	+/-			110,000,000
FIELD COST (Price Level Jan 2018)					660,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	31%	+/-			200,000,000
CONSTRUCTION COSTS					860,000,000
Ref.: For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.					

Table 11. Appraisal-level Opinion of Probable Construction Costs for Bartlett Modification 2

Description	Code	Quantity	Unit	Unit \$	Total \$
1 WP1 - Transmission & Power Supply - Relocation		12,100	lf	300.00	3,630,000
2 WP2 - Project Access & Site Development					
2.2 Project Access Development		2.50	mi	1,550,000.00	3,875,000
2.3 Basic Staging Development		1	ls	2,100,000.00	2,100,000
3 WP3 - Dam Construction					
3.2 Site Development		1	ls	15,000,000.00	15,000,000
3.3 Site Restoration		24.0	ac	40,000.00	960,000
3.4 Existing Structure Demo		1	ls	5,500,000.00	5,500,000
3.5 Diversion & care of water (varies this configuration)		1	ls	21,275,000.00	21,275,000
3.6 Main Dam & integrated hydraulic structures					
3.6.1 Dam Foundation Preparation and Grouting		71,000	sy	183.00	12,993,000
3.6.2 Dam earthworks		1,154,000	cy	12.50	14,425,000
3.6.3 Dam body		1,442,500	cy	120.00	173,100,000
3.6.4 Dam Hydraulic Structures					
3.6.4.1 Service Spillway		1	ls	66,000,000.00	66,000,000
3.6.4.2 Low Level OW (varies this configuration)		1	ls	13,000,000.00	13,000,000
3.6.5 Spillway bridge		1	ls	1,390,000.00	1,390,000
3.6.6 Crest structures		1	ls	3,000,000.00	3,000,000
3.8 Auxiliary spillway construction		1	ls	19,400,000.00	19,400,000
3.11 Project electrical & instrumentation		1	ls	4,750,000.00	4,750,000
3.12 Administrative buildings		1	ls	1,050,000.00	1,050,000
Subtotal					362,000,000
Mobilization	5%	+/-			18,000,000
Subtotal with Mobilization					380,000,000
Contract Cost Allowances (sum of next two lines)	15%	+/-			60,000,000
Design Contingencies, 15% (+/-)					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
CONTRACT COST					440,000,000
Construction Contingencies	20%	+/-			90,000,000
FIELD COST (Unit Price Level Jan 2018)					530,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	31%	+/-			170,000,000
CONSTRUCTION COSTS					700,000,000
For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 & 09-03.					

4.3.4 Sediment Management and Operating Plan

To manage the capacity within Horseshoe and Bartlett reservoirs for the Bartlett Modification alternatives, a reservoir sediment management and operation plan at Horseshoe and Bartlett Dam may be implemented. The goal of the plan is to maintain the water yield of the reservoir system while minimizing the sedimentation in the reservoirs. A sediment management and operation plan may significantly reduce future sedimentation deposition rates in facilities to allow for sustainable management of sediment levels in the reservoir system and downstream of the reservoirs. The following provides a conceptual sediment management and operation plan for the Bartlett Modification Alternatives. This plan should be investigated and refined during feasibility when additional quantitative sedimentation data should be collected and analyzed. The sediment management plan also assumes the low level outlet works at Horseshoe Dam are improved as described above and shown in Figure 14 to improve sediment passage rates, and Modified Bartlett Dam has outlet works capable of sediment sluicing and flushing.

The sediment management plan and improved outlet works would be implemented in conjunction with modification of Bartlett Dam so that sediment management operations can be planned in concert with revised reservoir and flood operations identified for the new infrastructure. Sediment maintenance operations can be distilled into separate sluicing procedures for Horseshoe Dam and Modified Bartlett Dam.

At Horseshoe Dam, the modified reservoir system would allow for Horseshoe Reservoir to be operated seasonally with the following guidelines:

- Storage levels at Horseshoe Dam are minimal in early winter months before the late-winter and spring runoff season.
- Low storage levels would be maintained before high flow periods throughout winter to improve throughput of sediments moved by large flood events.
- During high flow events, the modified reservoir outlet works would be opened to full capacity (up to 1,870 cfs) to allow sediment-laden inflows to pass through Horseshoe Dam.
- If Horseshoe Reservoir elevations exceed the crest of the service spillways during an event, the spillways would be opened to allow continued passage of sediment.

Bartlett Dam's narrower geometry and steeper profile may allow for the inducement of density currents that carry sediment through the reservoir when it is full. Figure 17 and Figure 18 illustrate the difference between Horseshoe and Bartlett dam geometries as they relate to density currents. Sediment maintenance at Bartlett Dam may be operated with the following guidelines:

- Sediment sluicing would occur during high runoff years when Bartlett Reservoir is full or near full.
- As Modified Bartlett Reservoir reaches capacity from winter inflows, spill releases may be needed.
- Spill releases would first be made from high capacity, low level outlet works before opening service spillways. These releases may take advantage of density currents and allow sediment to sluiced through Bartlett Dam.

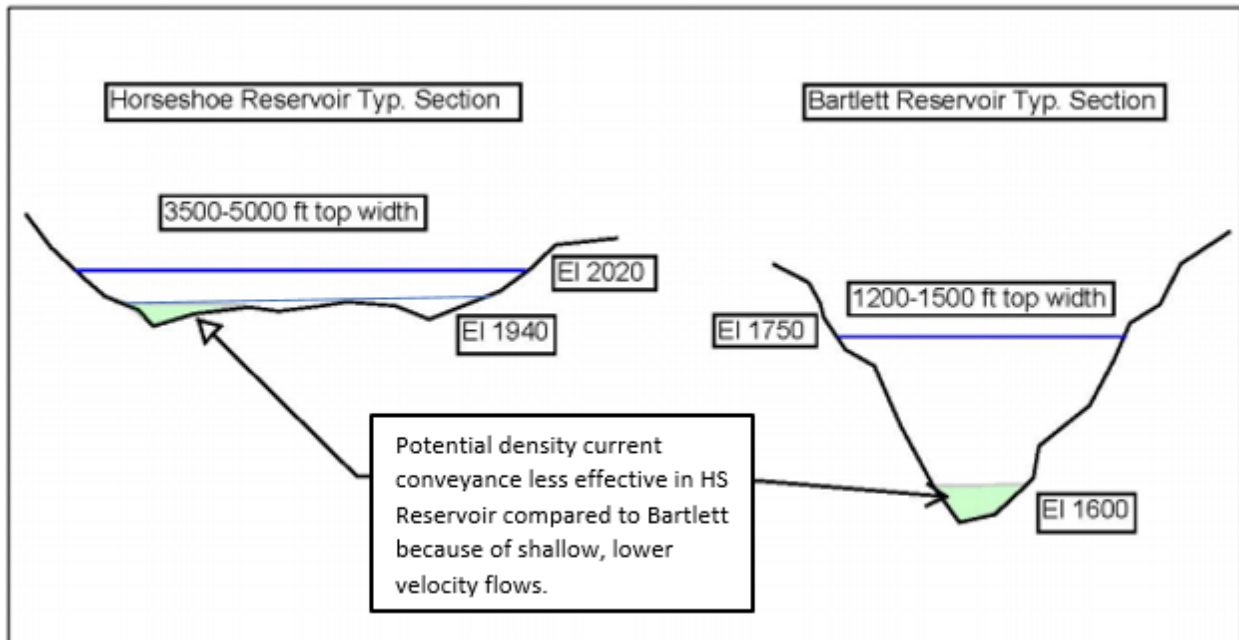


Figure 17. Bartlett and Horseshoe reservoirs sections

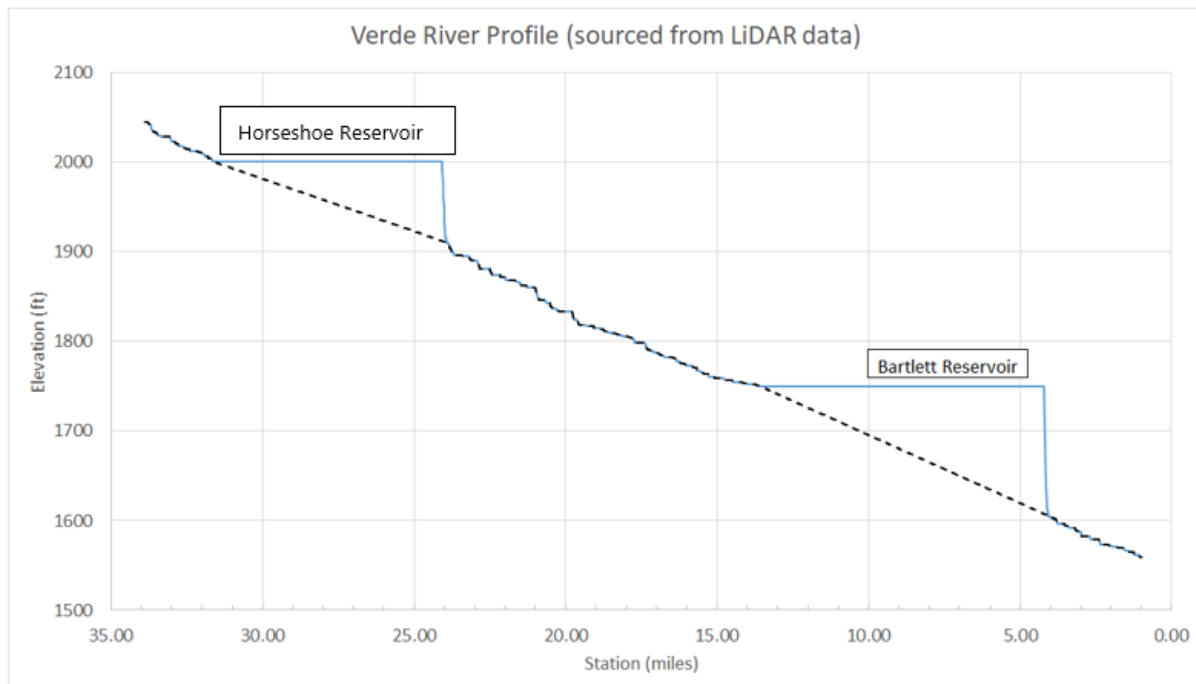


Figure 18. Verde River thalweg profile

The movement of sediments through the system that takes into account existing storage levels in the conservation pool of Modified Bartlett Reservoir would help reduce unnecessary water losses and utilize spill events (when total runoff exceeds reservoir capacity) to move sediments through the reservoir system. The sluicing plan would also take into account sediment inflow and outflow through the reservoir system to account for environmental considerations downstream of the reservoir system. The sluicing at Horseshoe and Bartlett dams might only occur once every several years depending on hydrologic and reservoir conditions, allowing the system to capture enough water for carryover to make water deliveries in dry years. Though significant sediment loads may not be sluiced annually, the sediment management plan will likely include the annual operations of the sluicing gates at both dams for short periods to ensure they are operational and do not become plugged with sediment buildup between sluicing events.

Detailed quantitative analysis performed at the feasibility level will provide more detail on sediment makeup through sampling and potential for sediment throughput through each reservoir based on hydraulic modeling. Without these components of a quantitative sediment analysis, the amount of sediment that may be successfully sluiced through Horseshoe Dam and Modified Bartlett Dam is uncertain and would be difficult to estimate without making overly simplified assumptions. The sluicing at Horseshoe Dam is unlikely to recover significant amounts of lost storage because of its broad, flat geometry, but may be more conducive with reducing future sedimentation in Horseshoe Reservoir to sustainable levels that extend the useful life of the reservoir for habitat and flood control operations. With its deeper, narrower geometry, sluicing and flushing sediment through Bartlett Dam may prove to be a successful management tool that prolongs the useful life of the reservoir system. If sediment sluicing through Modified Bartlett Dam proves to be unproductive, utilizing an enlarged Bartlett Dam and Reservoir as a sediment trap may also greatly extend the useful life of the entire Verde Reservoir system. No empirical evidence exists on the SRP system for expected increases in operations and maintenance expenses of the dam facilities resulting from implementation of the sluicing program, but further evaluation should be determined if facility designs are further evaluated at the feasibility level.

4.4 Alternatives Considered but Not Fully Evaluated

In addition to the without action and three action alternatives, several other potential alternatives were considered through the appraisal process, but ultimately screened out from full evaluation. Reservoir sluicing and flushing was considered, but identified as unlikely to restore capacity due to the physical characteristics of the Verde Reservoir system. Several options for land management actions across the watershed were also considered for reducing sediment inflows to preserve reservoir capacity. The greatest opportunity for reducing future sediment inflow was identified as reducing the risk of catastrophic wildfire, which is being addressed by a significant federal program already underway within the Verde River watershed and supported by Reclamation, SRP, and many of the beneficiaries of the SRFRP. The other land management opportunity that showed potential for reducing sediment was structural erosion control; however, a lack of data on efficacy and specific projects to implement resulted in a recommendation from the Alternatives Development Group to support the U.S. Forest Service and partners as they identify and implement projects, but not to include those actions in this appraisal study. Additional dam and reservoir alternatives were considered at a high level, but were screened from full consideration since the locations were more

costly and/or had less potential for creation of benefits. Sections 4.4.1, 4.4.2, and 4.4.3 provide further detail on the alternatives considered but not fully evaluated.

4.4.1 Reservoir Sluicing and Flushing

Reservoir sluicing and flushing aims to remove sediment build-up from, or pass sediment laden flows through, a reservoir by use of periods of high flow and floods. During high flow events, water is used to carry, scour, and entrain sediment accumulations in the water column to move through the reservoir outlet works. Sluicing and flushing of existing sediment accumulations in a reservoir requires low-level outlet works that can accommodate the high flows to successfully transport sediment from the reservoir. Deeper reservoirs with high capacity low-level outlet works can create strong enough currents that enable passage of accumulated sediment.

The small capacity river outlet works at Horseshoe Dam, combined with the shallow and wide reservoir created by the dam, are not conducive to successful sluicing or flushing efforts for restoring capacity (See Figure 17). Any attempts to flush sediment accumulations would require that Horseshoe Reservoir be drawn down substantially prior to a flood event in order to increase the ability to scour and entrain sediment in the water column, resulting in potential water loss to achieve sediment transport benefits. Even still, it is anticipated that only small amounts of sediment in the vicinity of the intake tower would allow for transport, making the effort ineffective for capacity restoration. An additional challenge for the Verde River reservoir system is that sediment would need to be transported through Horseshoe Reservoir and then Bartlett Reservoir to restore water storage capacity lost at Horseshoe. The sluicing gates at Bartlett have not been opened since the 1970s, creating substantial uncertainty about their functionality, especially in relation to closing the gates following a sluicing event. Because of these factors, it was not expected that reservoir sluicing or flushing would successfully meet the problem and need of this appraisal study and thus this alternative was not fully evaluated.

Though sluicing and flushing is not expected to meet the problem and need of this appraisal study, if modifications to Bartlett Dam and Horseshoe Dam are explored further in a feasibility study, consideration should be given to outlet structures and operations that could incorporate maintenance sluicing into reservoir operations plans to maintain storage capacities. The concept of leaving Horseshoe empty except during high flow and flood events enabled by the additional capacity created by the Bartlett Modification alternatives could allow for the creation of a less water-intensive sluicing maintenance program. A sluicing program could help extend the life of the Verde Reservoir system and reduce the rate at which Horseshoe Dam captures sediment in the proposed modified operational regime identified by the two Bartlett modification alternatives.

4.4.2 Watershed Sediment Management

The Alternatives Development Focus Group worked with the Hydrology and Engineering focus groups to evaluate existing sediment conditions on the Verde River watershed and to identify if opportunities exist for reducing overall sediment transport into Horseshoe Dam through landscape and watershed management activities to meet the problem and need of this project. The evaluation looked at four main types of land management actions on U.S. Forest Service lands across the Verde River watershed as shown in Figure 19. The four categories of management activities were: forest restoration and fuels reduction, structural erosion and sediment control measures, grazing management, and forest road and travel management.

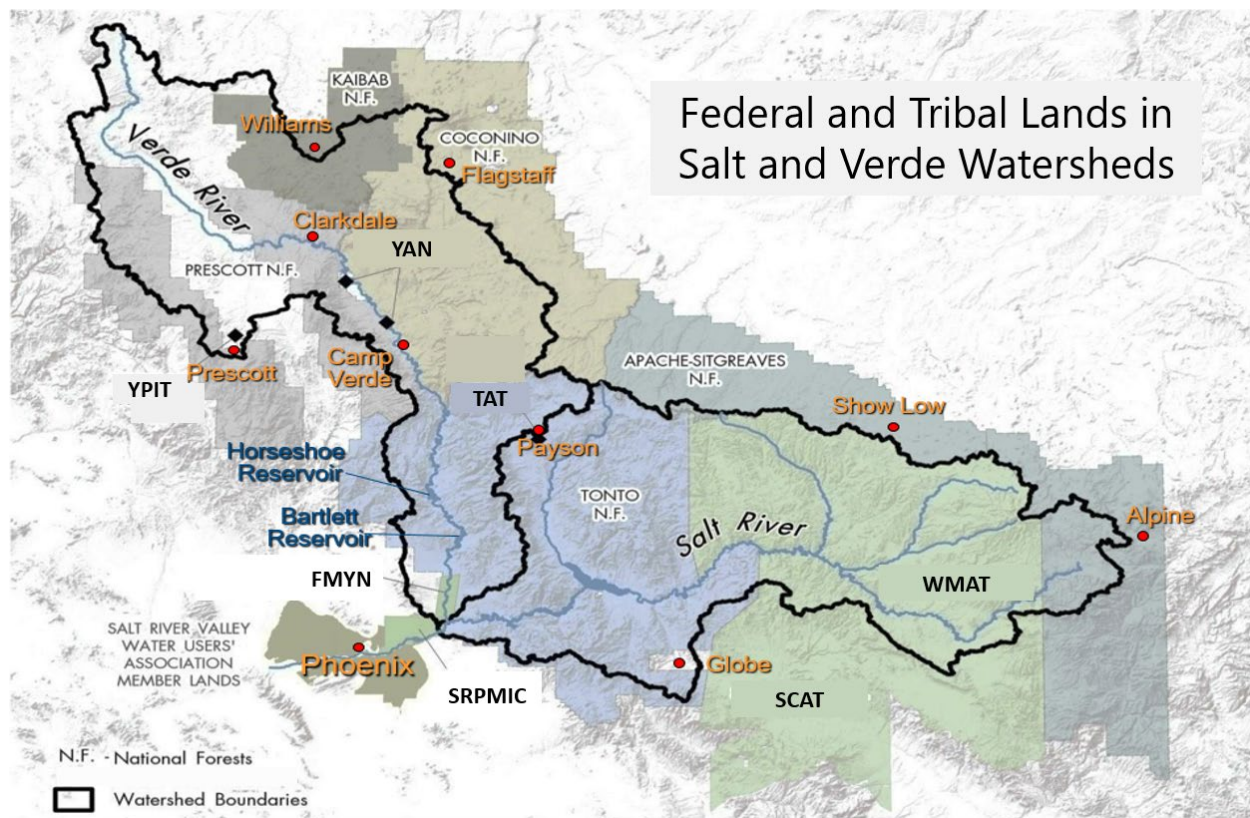


Figure 19. Federal and tribal lands within the Salt and Verde watersheds

Table 12 shows a summary of the potential annual reduction of sediment inflows into the Verde Reservoir system from each management action. Based on the research conducted by the Hydrology & Climate Change and Engineering, Flood Control, and Dam Safety focus groups in coordination with HDR Inc., the Alternatives Development Focus Group did not recommend including any watershed management activities for full evaluation through the appraisal report, but recommend continued support of forest restoration and fire risk reduction and consideration for supporting implementation of erosion control projects within the Verde River watershed. Further detail on the evaluation of the watershed sediment management actions is provided in Table 12.

Table 12. Summary of Sediment Reduction Efficacy and Expected Cost of Watershed Management Actions

	Total Potential Avoided Sediment Transport into Verde Reservoirs	Cost of Sediment Reduction in Verde Reservoirs
Grazing	N/A-- Need More Data	\$13,000/stream mile construction and \$130-\$430 per stream mile/year maintenance, \$2,200-\$10,700 per crossing Structure
Forest Road Maintenance and Decommissioning	6-14 AF/year bed load	\$8,230/mile for Level 3-5 Maintenance and \$1,949/mile for Level 2 Maintenance ¹
Catastrophic Wildfire Reduction	164-411 AF/year bed load	\$37,600-\$94,000/AF/year bed load
Structural Mitigation Measures	N/A-- Evaluate on Case-by-Case Basis	N/A-- Evaluate on Case-by-Case Basis

¹ Note: Estimating a cost per acre-foot of sediment reduction would require specific maintenance intervals and more detail on implementation and interval of maintenance recurrence.

4.4.2.1 Forest Restoration and Fuels Reduction

The Four Forests Restoration Initiative (4FRI) is a forest restoration initiative being led by four National Forests in northern Arizona, including three on the Verde River watershed—the Coconino, Tonto, and Kaibab National Forests. Uncharacteristic or catastrophic wildfire is identified as the single largest risk factor for contributing sediment to the Verde River watershed. Based on analysis included in the 2012 4FRI environmental impact statement (EIS), it is estimated that the ponderosa pine forests within the Verde watershed have the potential for producing 1,685 AF of sediment each year, with bed load sediment production ranging from 168 to 421 AF/year if the forests burn in uncharacteristic crown fires.

Fire history since construction of Horseshoe Reservoir indicates that Arizona’s large-scale, uncharacteristic crown fires have occurred outside of the Verde River watershed and are not likely a significant contributor to existing sediment loads in Horseshoe Reservoir, but rather represent a potential future risk to the Verde Reservoir system. Forest restoration and fuels reduction activities planned under the 4FRI program are designed to restore the ecological function of northern Arizona’s ponderosa pine forests to pre-settlement conditions and are likely to create many benefits for a diverse group of interests and stakeholders.

4.4.2.2 Structural Erosion and Sediment Control Measures

Structural mitigation measures appear to have the most promise for reducing sediment impacts to Verde River reservoir storage capacity; however, due to the geographic scale and volume of sediment impacting reservoir capacity, effectiveness must be considered on case-by-case basis as projects are developed within the watershed. Four projects currently being evaluated by the U.S. Forest Service and the Verde Watershed Restoration Coalition that are aimed at reducing erosion and sediment transport within the watershed are likely to provide some benefits to downstream reservoir capacity; however, the scale of these projects make it unlikely that evaluating them within

the appraisal study would have measurable impacts on extending the useful life of storage capacity within Verde River reservoirs.

Based on lack of project-specific information, the Alternatives Development Focus Group did not recommend that these projects be included for further evaluation in the appraisal study and recommended that beneficiaries of Verde River reservoirs consider supporting the implementation of these projects on a case-by-case basis. The use of Horseshoe Reservoir as a sediment trap appears to have significant promise to reduce sediment accumulation and extend the useful life of conservation storage capacity of the Verde Reservoir system by between 233 years and 437 years. Thus, the Alternatives Development Core Team suggested further evaluating the opportunity of using Horseshoe Dam as a sediment trap in the two Bartlett Modification alternatives.

4.4.2.3 Grazing Management

The information available on grazing management does not provide any indication of management opportunities that are not already being considered by the U.S. Forest Service to significantly reduce sediment impacts on Verde River reservoir storage capacity; therefore, the Alternatives Development Focus Group did not recommend any further evaluation of grazing management in the appraisal study. Since the Forest Service is tasked with managing the multiple uses of National Forest lands, the Alternatives Development Focus Group recommended that beneficiaries of Verde River reservoir storage track future grazing management activities in the Verde River watershed to identify if opportunities exist to improve management to prevent unnecessary sediment yield in the watershed while balancing other uses of National Forest lands.

4.4.2.4 Forest Road and Travel Management

Based on the information evaluated and the likelihood of sediment transport reduction benefits produced by changes in travel management, the Alternatives Development Focus Group does not recommend any further evaluation of benefits and impacts of implementation of these activities in the VRSMS appraisal study. Proper management of roads to prevent road degradation and reduce off-road travel is likely to prevent erosion, but the available information did not indicate that a significant reduction in sediment deposition in reservoirs could be achieved by improved management of forest roads across the watershed.

4.4.3 Other Reservoir Alternatives

Four additional dam sites with a total of seven different dams were evaluated and compared to the two Bartlett Modification options. All potential dam locations were compared to each other initially to screen out dam options that were less advantageous from full evaluation in the appraisal process to avoid redundant evaluation. Figure 20 below shows the approximate location of each of the four sites considered, with three located between Bartlett Dam and Horseshoe Dam (Intermediate Sites 1, 2, and 3) and one site located downstream of Bartlett Dam (Downstream Site). Several dam types and reservoir sizes were considered to compare construction and long-term operation and maintenance (O&M) costs as well as opportunities for creating additional benefits beyond restoration of capacity. Roller compacted concrete (RCC) dams are recommended for all dam sites, but Intermediate Site 1 was also considered for a concrete face rockfill dam (CFRD) and asphalt core rockfill dam (ACRD) due to complications of inundation of the downstream face of the new dam from the existing Bartlett Reservoir.

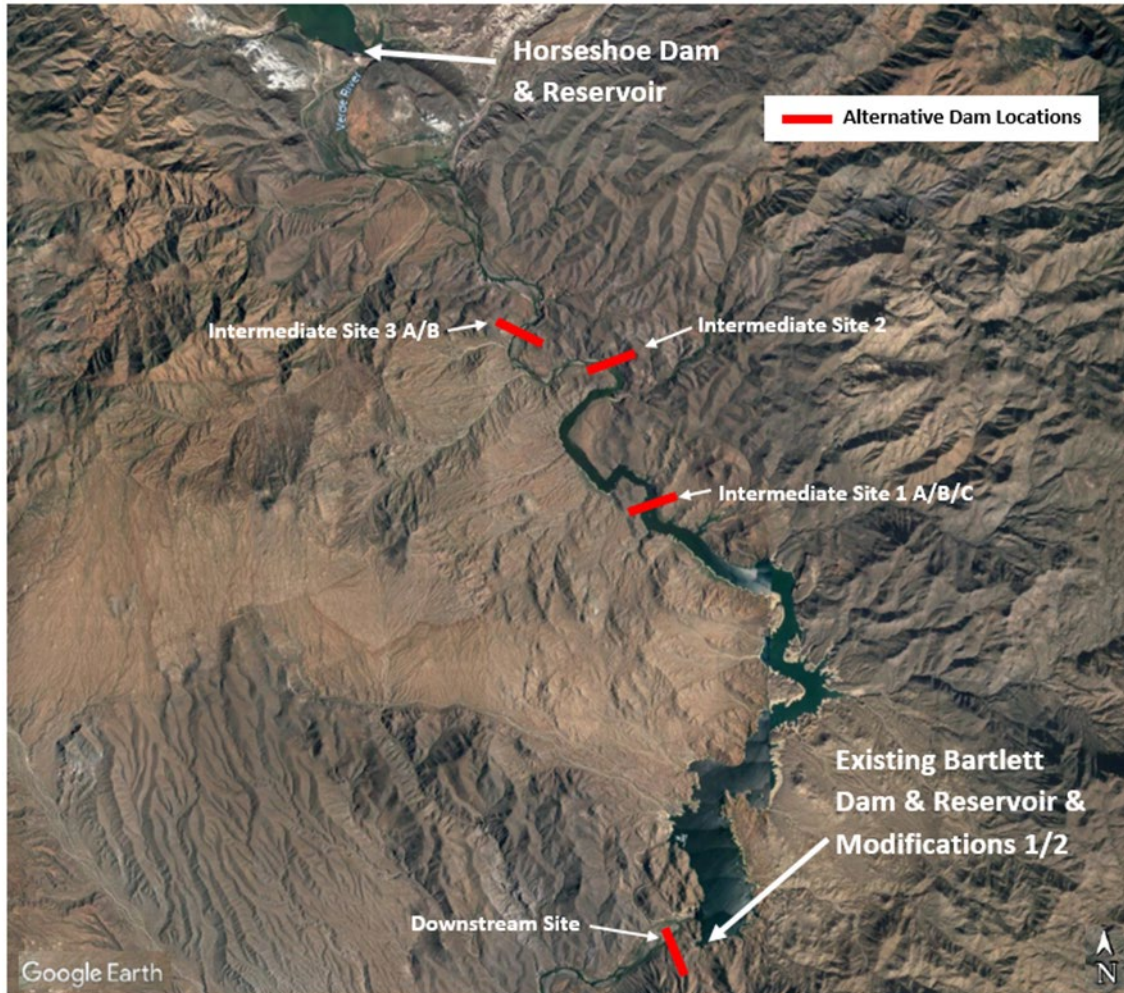


Figure 20. Alternative dam sites

The Downstream Site would function similar to the proposed system operations of the two Bartlett Modification alternatives and would have the same NMWSE as Bartlett Modification 1 (1895 ft). Each of the alternative dams except Intermediate Site 3B would result in moving water storage rights from existing Horseshoe Reservoir into a new larger reservoir created by the new downstream site. Intermediate Site 3B would only create enough capacity to restore what has been lost to sedimentation and would require Horseshoe Reservoir to remain in service as a conservation storage reservoir to maintain total system operational capacity.

All intermediate dams would back up to the downstream face of Horseshoe Dam with all but Intermediate Site 3B having the same NMWSE (1975 ft) as shown in Figure 21. Horseshoe Dam would remain in place for all intermediate dam options, creating operational challenges during flood and high flow operations for what would act, in effect, as a three-reservoir system. Additionally, keeping Horseshoe Dam in place would require substantial modification to its downstream face to accommodate the inundation and fluctuation of the intermediate reservoir. The NMWSE of the intermediate reservoir would also create hydraulic challenges for moving water from Horseshoe

downstream during certain times of the year due to the water elevations of the new reservoir being equal to or greater than that of Horseshoe Reservoir during large inflow events.

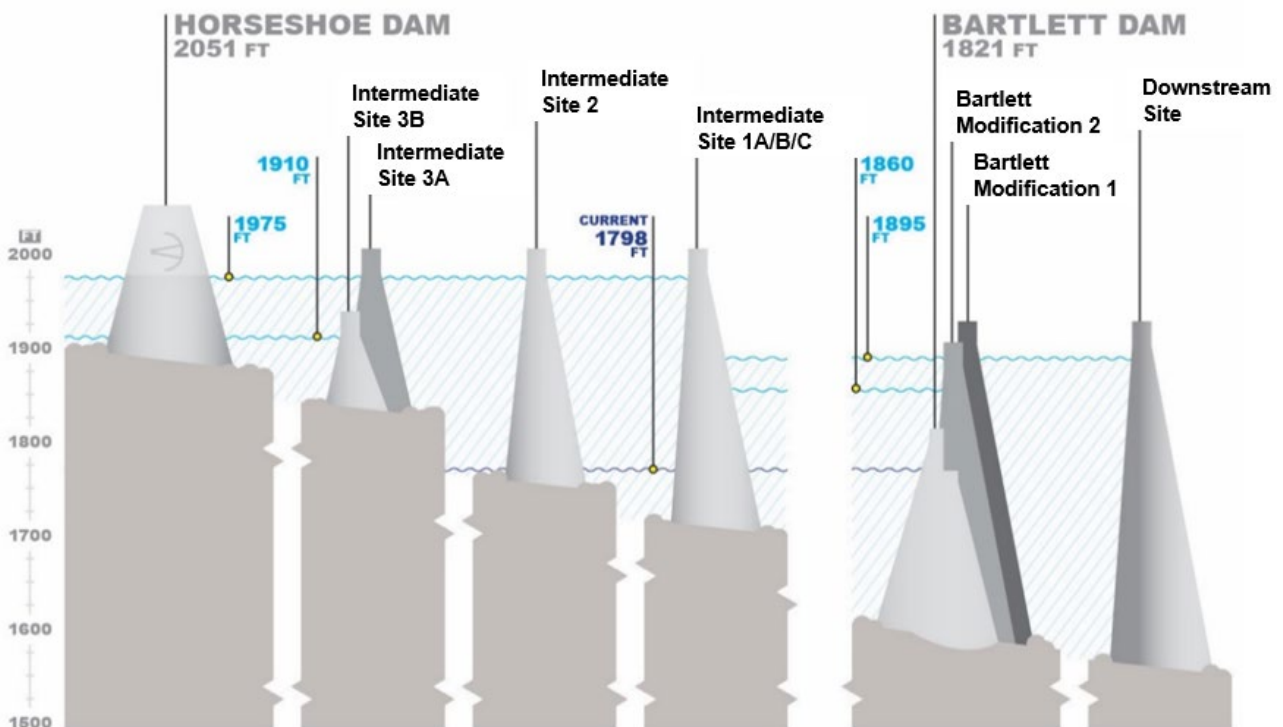


Figure 21. Alternative reservoir side profiles and NMWSE

Table 13 provides a comparison of key items that resulted in the screening out of each of the dam sites beyond Bartlett Modifications 1 and 2 from full evaluation in this appraisal report. The cost opinions included for comparison of water storage capacity costs were developed by HDR in support of this project to assist in initial screening of structural dam alternatives. The intermediate dam sites would add an additional reservoir to the system, creating operational challenges and inundating more land, while not creating any additional opportunities for new benefits beyond what would be created by the downstream locations, including Bartlett Modifications 1 and 2. The Downstream Site creates nearly identical benefits to Bartlett Modification 1, but requires a larger, more costly dam. Additionally, a new downstream dam site has greater uncertainty, both geologically and structurally, than modifying existing Bartlett Dam, so it was not further evaluated in the appraisal study.

Table 13. Dam Sites Not Fully Evaluated Compared to Bartlett Modifications 1 and 2

	Bartlett Mod 1/2	Downstream Site	Intermediate Site 1A/B/C	Intermediate Site 2	Intermediate Site 3A/B
Base Cost/AF Capacity Restored/Added	\$2,443 / 4,795	\$2,643	\$4,121 / \$4,356 / \$4,260	\$4,779	\$6,102 / \$7,820
Total Verde Reservoir Acreage	7,015 / 5,084 (~25% increase / ~10% decrease from current)	7,057 (~25% increase from current)	9,772 (~75% increase from current)	8,824 (~55% increase from current)	8,292 / 7,458 (48% /33% increase from current)
Number of Verde River Storage Reservoirs if Implemented	1	1	2	2	2 / 3
Total Verde Storage	628,000 AF / 422,000 AF	635,000 AF	557,000 AF	416,000 AF	364,000 AF / 337,000 AF
Potential Opportunities for New Benefits	Restored Capacity, Sediment Management, New Conservation Capacity, Habitat Management, Flood Control, Dam Safety, Hydropower, Increased Recreation Opportunities	Restored Capacity, Sediment Management, New Conservation Capacity, Habitat Management, Flood Control, Dam Safety, Hydropower, Increased Recreation Opportunities	Restored Capacity, New Conservation Capacity, Flood Control, Dam Safety, Increased Recreation Opportunities	Restored Capacity, New Conservation Capacity, Flood Control, Dam Safety, Increased Recreation Opportunities	Restored Capacity, New Conservation Capacity (excluding 3B), Flood Control, Dam Safety, Increased Recreation Opportunities

5 Alternative Evaluation Criteria and Metrics

5.1 Evaluation Criteria

The evaluation criteria for the VRSMS were developed in order to identify key areas of review and evaluation by each of the focus groups. The evaluation criteria were developed to evaluate an alternative's ability to meet the problem and need of the VRSMS based on guidance from Reclamation's Directives and Standards *CMP 09-01: Water and Related Resources Appraisal and Special Studies*, the Council on Environmental Quality's PR&Gs, as well as other federal water resources planning study guidance. The evaluation criteria are consistent with the direction of CMP 09-01 and the PR&Gs to evaluate each alternative for the applicability, acceptability, efficiency, effectiveness, and completeness of each alternative.

The evaluation criteria were assigned to the appropriate focus group for information collection and stakeholder input to develop an informed scoring of each alternative. The evaluation criteria for the VRSMS are listed below, along with a description of the scoring approach. Further background on the scoring of each alternative is provided in Section 7: Alternative Evaluation and Comparison. The evaluation criteria are scored by the focus groups based on expert judgement of the resources on a scale from 0 to 5, with the alternative expected to provide the strongest support for the criteria's objective being scored as a 5 and the alternatives expected to provide the least support for the criteria's objective being scored 0; the remaining alternatives are scored relative to the highest and lowest scoring alternative.

5.2 Evaluation Criteria for Considering Applicability

Applicability is defined by CMP 09-01 as the extent to which the alternatives align with Reclamation's interests, geographic jurisdiction, and authorized mission areas. The evaluation criteria used to consider the applicability requirement are described further below.

5.2.1 Applicability of Alternatives

Project Management Team

Reclamation projects are required to be completed within a defined geographic jurisdiction and authorized mission area. The purpose of this criterion is to evaluate if each alternative can be implemented by Reclamation as defined by Reclamation's jurisdiction and mission.

5.2.2 Enhances Water Management Flexibility

Focus Group – Alternatives Development

The ability for water managers in the region to be flexible while administering water resources is important, especially in the face of climate change and extended drought that may impact available

surface water for the region in the future. The purpose of this criterion is to evaluate if and to what degree each alternative enhances the flexibility of the tools used for water management. Water management tools include reservoir operations, water infrastructure, and other solutions.

5.2.3 Promotes Long-term Protection of Surface Water Supplies of the SRFRP and Contractors

Focus Group – Alternatives Development

Protecting existing surface water resources into the future is critical for the SRFRP to meet water supply obligations to its water rights holders and contractors. The purpose of this criterion is to evaluate if each alternative creates and promotes long-term security of existing water supplies over a 100-year planning period.

5.3 Evaluation Criteria for Considering Acceptability

Acceptability is defined by the PR&Gs as the viability and appropriateness of an alternative from the perspective of the Nation's general public and consistency with existing Federal laws, authorities, and public policies. It does not include local or regional preferences for particular solutions or political expediency. The evaluation criteria used to consider the acceptability requirement are described further below.

5.3.1 Potential Effects to Environmental Resources

Focus Group – Environmental and Cultural Resources

The purpose of this criterion is to evaluate each alternative based on the degree of potential effects to environmental resources.

5.3.2 Potential New Impacts to Cultural Resources

Focus Group – Environmental and Cultural Resources

The purpose of this criterion is to evaluate each alternative based on the degree of potential new impacts to cultural resources.

5.3.3 Applies Regional Perspective

Focus Group – Alternatives Development

Water supply resiliency in the future is not confined to the boundaries of a study area. Perspectives from the regional area potentially impacted by a project alternative play an important role in a successful alternative. The purpose of this criterion is to evaluate if and to what degree each alternative applies a solution that considers perspectives from the regional and watershed levels.

5.4 Evaluation Criteria for Considering Efficiency

Efficiency is defined by the PR&Gs as the extent to which an alternative alleviates the specified problems and realizes the specified opportunities at the least cost. The evaluation criteria used to consider the efficiency requirement are described further below. Additional information on economic efficiencies of alternatives is described in Section 8: Economic Analysis of Benefits and Cost.

5.4.1 Capital Cost Efficiency

Focus Group – Economics

The purpose of this criterion is to evaluate each alternative on its capital cost per acre-foot of capacity restored or added.

5.4.2 Operations and Maintenance (O&M) Cost Efficiency

Focus Group – Economics

The purpose of this criterion is to evaluate each alternative on its annual O&M cost per acre-foot of Verde River storage capacity.

5.4.3 Affordability

Focus Group – Economics

The likely affordability of the proportionate share of costs of an alternative will play an important role in an alternative's viability, especially in light of current federal budgets. Considering the lifecycle cost of an alternative relative to other options considered in the study as well as the options in the market of comparable benefits is important to evaluate the viability of an alternative. The purpose of this criterion is to help evaluate the financial viability of the alternative to beneficiaries.

5.5 Evaluation Criteria for Considering Effectiveness

Effectiveness is defined by the PR&Gs as the extent to which an alternative alleviates the specified problems and achieves the specified opportunities. The evaluation criteria used to consider the effectiveness requirement are described further below.

5.5.1 Effectiveness of Restored or Replaced Lost Surface Water Capacity on the Verde River

Focus Group – Hydrology and Climate Change

The purpose of this criterion is to evaluate the effectiveness of each alternative in restoring or replacing the 45,749 AF of storage capacity lost on the Verde River system due to sedimentation.

5.5.2 Mitigates Impacts to Capacity of Future Sediment Accumulation

Focus Group – Hydrology and Climate Change

The purpose of this criterion is to evaluate effectiveness of an alternative in mitigating or reducing the impact of sediment accumulation on Verde River reservoir capacity in the future, and if so, how effectively.

5.5.3 Reduces Future Groundwater Dependency

Focus Group – Hydrology and Climate Change

SRP conjunctively uses groundwater and surface water to supply water rights holders and contractors within its water service area. Reservoir storage levels are inversely related to the amount of groundwater pumped and delivered, including municipalities. Municipal water providers must meet safe yield groundwater pumping goals established through the Arizona Groundwater Management Act and provide an Assured Water Supply that is dependent on renewable supplies. The Phoenix Active Management Area (AMA) in central Arizona is currently working to create its 5th Management Plan, which will further define how water users can achieve safe groundwater yields by water users within the AMA. Under AMA rules, limits on groundwater pumping can be exceeded during drought times and may impede efforts to reach and maintain safe-yield. This criterion evaluates the efficacy of each alternative in reducing the region's dependency on groundwater in the future.

5.6 Evaluation Criteria for Considering Completeness

Completeness is defined by the PR&Gs as the extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects, including any necessary actions by others. It does not necessarily mean that alternative

actions need to be large in scope or scale. The evaluation criteria used to consider the completeness requirement are described further below.

5.6.1 Implementable

Focus Group – Engineering, Dam Safety and Flood Control

The scale and timeline of an alternative will dictate if it is within reason of meeting the problem and need. Practical engineering and design of each alternative is also an important consideration. The purpose of this criterion is to establish if an alternative can realistically be designed and implemented in a timeframe and at a scale that meets the problem and need.

5.6.2 Creates Opportunities for Additional Benefits to Water Supply, the Environment, Flood Control, Dam Safety, Recreation, or Hydropower

Focus Groups – All Focus Groups

Each alternative will address the problem and need, but can also create additional opportunities that benefit water supply, the environment, flood control, dam safety, recreation, or hydropower. Each of these six areas are within Reclamation’s authorized mission. The objective of this criterion is to evaluate if and to what degree each alternative provides additional benefits to each purpose. The overall score of each alternative was determined by the Project Management Team, considering the scoring and information on the potential opportunities identified by each focus group. Each focus group was responsible for evaluating opportunities for assigned purposes. The purposes evaluated by each focus group are assigned in Table 14 below.

Table 14. Focus Groups and Assigned Purposes for Evaluation

Purpose	Focus Group
Recreation	Recreation
Dam Safety	Engineering, Dam Safety and Flood Control
Flood Control	Engineering, Dam Safety and Flood Control
Hydropower	Economics
Environmental	Environment and Cultural Resources
Water Supply	Hydrology and Climate Change

5.7 Evaluation Metrics

The evaluation metrics for the VRSMS were developed by the focus groups to provide further detail and justification for the scoring for each focus group’s assigned Evaluation Criteria. The evaluation metrics were developed by each focus group to evaluate an alternative’s ability to meet the problem and need and to provide insight into stakeholder perspectives on the effectiveness and acceptability of each alternative. Evaluation of each alternative using the developed evaluation metrics is provided in Section 7: Alternative Evaluation and Comparison.

6 Hydrology Modeling and Results

6.1 Modeling Description

SRP’s Reservoir Planning Model (RPM) was used to assess the SRFRP reservoir system for the proposed alternatives over the period of analysis (2031 through 2130). The RPM is an application of OASIS (Operational Analysis and Simulation of Integrated Systems), a generalized water resources modeling platform that simulates the routing of water by solving a linear program. RPM is a mass

balance model created to evaluate the SRFRP reservoir system performance for a given set of demand, operating policies, and facilities over the historic inflow record and future predicted inflow. A detailed description of the RPM and assumptions used in the analysis are found in Appendix G.

RPM is operated on a monthly timestep. The duration of analysis for the RPM runs for the VRSMS alternative analysis is 106 water years to leverage the full historical gaged record at the USGS sites mentioned in Section 3.3. Local ungaged inflows for each simulation are also determined for Roosevelt Lake, the lower Salt River system, Horseshoe Lake, and Bartlett Reservoir using a correlation with gaged inflow.

In 2020 the Bureau of Reclamation, in a collaborative effort with Arizona State University and SRP, published a report that focused on the impacts of climate change on Salt-Verde streamflow and reservoir operations (Bureau of Reclamation 2020). In that study, two independent methodologies were used to assess the climate change impacts on future streamflow. The transient method involved physical hydrology modeling with inputs of future temperature and precipitation derived from Global Climate Model projections. The period-change method involved an exhaustive statistical analysis of historical streamflow, precipitation, and temperature records to adjust the distribution of historical streamflow based on projected 21st century climate.

For this appraisal study, aspects from both methods were leveraged to adjust the 106-year historical streamflow record (1914-2019) to produce a future record (2031-2136) based on changes in temperature, precipitation mean, and precipitation variability derived from Global Climate Model projections. The adjusted hydrologic record was then truncated to the period of analysis of 2031-2130 and was used in RPM to analyze all alternatives. The applied increase in temperature from 2031-2136 was around a 4 °C increase for both the Salt+Tonto and Verde. The applied change in mean precipitation was around a 4.5% decrease on Salt+Tonto watershed and around a 2.8% decrease on the Verde watershed. The change in precipitation variability was represented with an empirical cumulative distribution function with precipitation in the wettest years (above the 90th percentile) increased by 5%-10% and precipitation in the driest years (below the 10th percentile) decreased by 20%-30%. More details regarding the climate change adjusted streamflow record for projected changes in climate are available in Appendix H.

SRP's reservoir system is demand driven and demand is a major assumption for the RPM. Demand on the SRFRP system since 2016 has been between 725,000 and 775,000 AF/year. Historically, SRFRP system demand has been as high as 1.4 MAF/year but has declined since the 1980s. As agricultural acreage continues to be urbanized and residents continue water conservation practices, a demand of 725,000 AF/year is considered reasonable now and in the future, and was used in this analysis. The assumed demand for this analysis is lower than the assumed demand used in the Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study (Bureau of Reclamation 2020) because of recent data trends in the SRP water service territory. Other demands on the SRFRP reservoir system assumed in this analysis include Phoenix Gateway (25,000 AF/yr), deliveries from New Conservation Space (NCS) at Theodore Roosevelt Dam, other contracts and upstream diversions which are described in detail in Appendix G, as well as the new conservation storage capacity created by the two Bartlett Modification alternatives, referred to here as New Verde Space (NVS). The NVS in the Bartlett Dam Modifications is exclusive of the restored capacity lost from sedimentation or Phoenix Gateway (45,749 AF).

Other assumptions made in the RPM for this analysis and detailed in Appendix G include sedimentation, reservoir evaporation, demand distribution, reservoir river operations, minimum flow requirements, groundwater pumping, and river and reservoir losses.

6.2 Modeling Results

The RPM was used to assess changes in water yield from SRFRP reservoirs, the annual groundwater pumping needs of SRP's system, reservoir elevations, and dam releases. The output for the NVS was also used to provide scenario analysis for the estimated net benefits to the aquifer underlying the Phoenix Metropolitan Area resulting from changes in spill from SRP reservoirs and direct use or groundwater banking of NVS supplies. The following provide an overview of results that were used to evaluate alternatives.

6.2.1 Water Yield

Water yield values indicate the amount of water available to supply deliveries under each alternative, based on the modeled hydrology discussed in Section 6. Figure 22 shows Salt and Verde Reservoir surface water yield for each alternative. Since the Salt and Verde Reservoirs are operated as one system, the total surface water deliveries of the system are used when evaluating the surface water made available to SRP water rights holders by each of the alternatives. The surface water yield over the analysis duration shows increases in water yield for each action alternative compared to without action. The increase in yield is based on the change in available storage capacity on the Verde River. The highest water yield is produced by Bartlett Modification 1, followed by Bartlett Modification 2, and Sediment Removal. The increased yield results from availability of carryover storage capacity created by each alternative. The larger the total Verde River system capacity, the better positioned the system is to capture the highly variable hydrology of the Verde River, especially in wet years when more inflow is captured and stored.

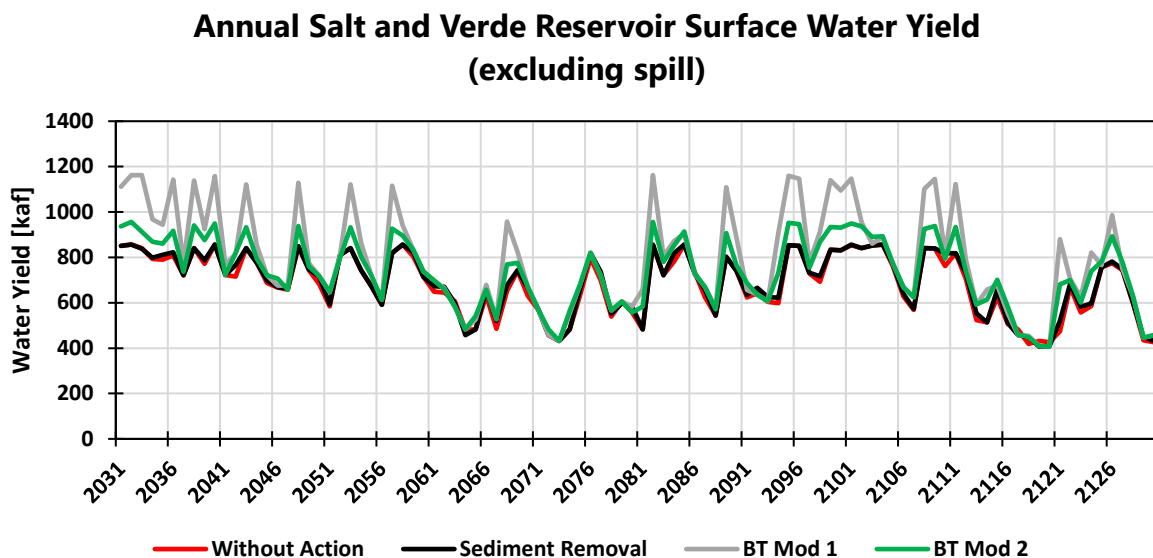


Figure 22. Annual Salt and Verde surface water yield

Figure 23 shows average annual surface water deliveries to contractors and water rights holders within SRP’s water service area for each alternative over the period of analysis (2031-2130). SRP surface water deliveries are impacted by the restored capacity lost to sedimentation in Horseshoe Reservoir and the continued sedimentation into the Verde River after each action alternative is complete. Bartlett Modifications 1 and 2 have higher increases in SRP surface water deliveries compared to the Sediment Removal alternative. Though all three action alternatives restore the 45,749 AF of capacity lost to sedimentation, Bartlett Modifications 1 and 2 use Horseshoe Reservoir as a sediment trap to mitigate sediment impacts to storage after project completion. The additional capacity created by Bartlett Modifications 1 and 2 is not being used for SRP surface water deliveries, but rather dedicated to new uses identified generally for this study as ‘NVS’. The addition of NVS results in the two Bartlett Modification alternatives providing the same amount of SRP surface water deliveries and Horseshoe Gatewater credits, while creating different deliveries to NVS end users.

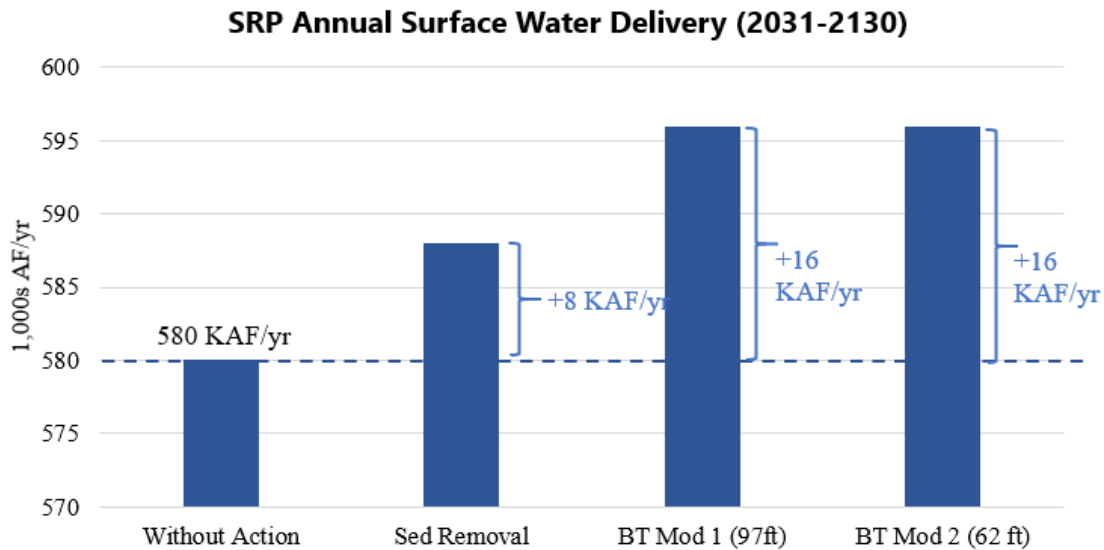


Figure 23. SRP modeled average annual surface water deliveries

Table 15 shows annual average values for change in each surface water delivery from the Without Action alternative during the study period (2031-2130). The maximum amount of Phoenix Gatewater that can be stored within SRP’s system at any time is 150,000 AF, and the maximum annual delivery of Gatewater is 25,000 AF. Similar to SRP surface water deliveries, the accruals of Phoenix Gatewater for the two Bartlett Modification alternatives are equal and higher than the Sediment Removal alternative as a result of Horseshoe Dam preventing sediment from entering the new modified Bartlett Reservoir. Bartlett Modification 1 has an NVS water yield 2.5 times higher than Bartlett Modification 2 due to the larger conservation storage capacity. No NVS yield is created by the Sediment Removal alternative since NVS is only created by the two Bartlett Modification alternatives.

Table 15. Summary of Modeled Surface Water Yield (2031-2130)

Alternative	Change in Annual Phoenix Gatewaywater Accrual [AFY]	Change in Annual SRP Surface Water Delivery [AFY]	NVS Average Annual Yield [AFY]	Annual Average Surface Water Delivery Change from w/o action [AFY]
Without Action	-	-	-	-
Sed Removal	3,000	7,000	-	10,000
BT Mod 1 (97 ft)	8,000	16,000	91,000	115,000
BT Mod 2 (62 ft)	8,000	16,000	36,000	60,000

6.2.2 SRP Groundwater Pumping

SRP conjunctively manages groundwater and surface water to make deliveries and relies on the Storage Planning Diagram (Figure 8) to make decisions on how much groundwater is pumped and delivered for a given year. Higher reservoir storage levels increase surface water deliveries and decrease groundwater pumping, and vice versa. For planning purposes, the maximum amount SRP will pump is 325,000 AF, with capacity to pump greater amounts in extreme conditions. The amount of SRP groundwater pumping is an indicator of the health of SRP's reservoir storage levels and surface water supply. Figure 24 shows average annual groundwater pumping results from the RPM analysis. The Without Action alternative has the greatest amount of average annual groundwater pumping because it has the least amount of surface water storage in the future. Both Bartlett Modifications 1 and 2 reduce groundwater pumping by 16 KAF/year compared to the Without Action alternative. Figure 24 and Figure 25 show how groundwater pumping is impacted with each alternative, but consider how the regional aquifer is impacted through longer durations of heavy SRP groundwater pumping and natural recharge.

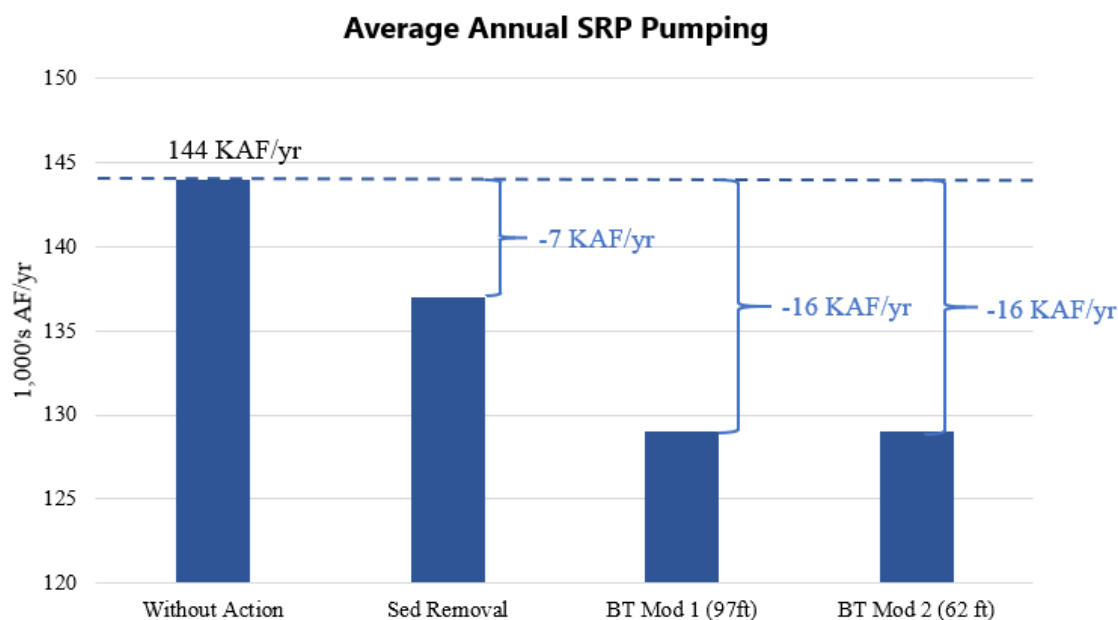


Figure 24. Modeled average annual SRP groundwater pumping

Long stretches of increased groundwater pumping may have negative impacts on aquifer health. Figure 25 shows the maximum 11-year cumulative SRP pumping volumes for each alternative. An 11-year duration was chosen because the worst drought identified in the paleohydrology determined from tree ring records was 11 years in duration (Phillips, et al. 2009).

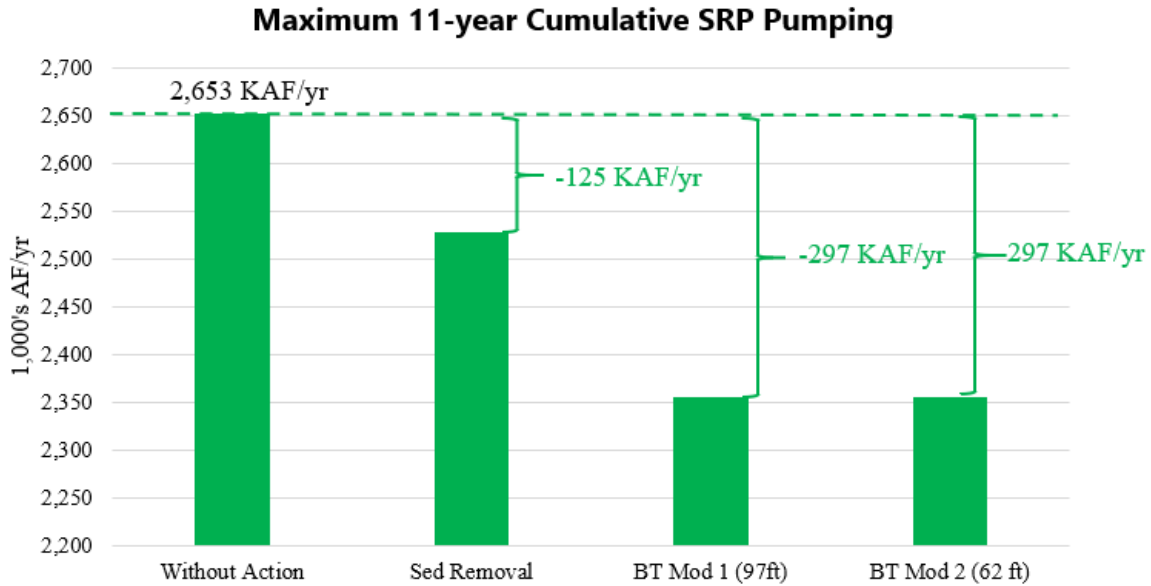


Figure 25. Modeled maximum 11-year cumulative SRP pumping from RPM analysis

6.2.3 Reservoir Elevations and Releases

Reservoir water surface elevations and releases are important information to consider on a reservoir system, especially when evaluating environmental and cultural impacts. Water surface elevations inform inundation area for each dam, while releases convey downstream impacts. Table 16 provides a summary of modeled Bartlett Dam elevations and shows modeled flow below Bartlett Dam. Seasonally, highest elevation and releases are reached for all alternatives during the December - February time periods when streamflow is highest from winter runoff. Bartlett Modification 1 involves the highest raise and has higher modeled water surface elevation and inundation levels than the other alternatives. Reservoir releases for the Bartlett Modification alternatives are higher than the other alternatives in the summer months because NVS deliveries are made in addition to SRP contractor and water rights holder demand. However, during the winter and spring months, the Bartlett Modification alternative releases are lower because less spill releases are made with the Bartlett Modification alternatives. Figure 26 shows the annual volume available from modeled runoff that would accrue to existing and restored storage accounts (SRP + Gatewater) and NVS Storage, and water in excess of storage capacity that would spill for the Bartlett Modification 1 alternative. The Bartlett Modification 2 alternative has a similar distribution, with spill volumes increasing and NVS yield decreasing by the approximate difference between the NVS storage capacity in each Bartlett modification alternatives (206,000 AF).

Table 16. Bartlett Dam Modeled Reservoir Water Surface Elevations

Bartlett Dam Modeled Reservoir Water Surface Elevations (Feet)				
		Dec - Feb	Mar - May	Jun - Aug
Without Action	25th Percentile	1764	1763	1759
	50th Percentile	1774	1791	1782
	75th Percentile	1791	1798	1798
	Max	1798	1798	1798
	Average	1777	1781	1776
Sediment Removal	25th Percentile	1766	1764	1760
	50th Percentile	1785	1792	1783
	75th Percentile	1785	1792	1783
	Max	1798	1798	1798
	Average	1780	1782	1778
Bartlett Modification 1	25th Percentile	1768	1778	1775
	50th Percentile	1806	1818	1810
	75th Percentile	1839	1866	1852
	Max	1895	1895	1895
	Average	1809	1825	1818
Bartlett Modification 2	25th Percentile	1768	1778	1777
	50th Percentile	1806	1818	1810
	75th Percentile	1833	1858	1852
	Max	1860	1860	1860
	Average	1805	1817	1813

Table 17. Modeled Flows Below Bartlett Dam

Modeled Average Daily Flows below Bartlett Dam (cfs)				
		Dec - Feb	Mar - May	Jun - Aug
Without Action	25th Percentile	109	109	109
	50th Percentile	355	522	111
	75th Percentile	520	1,116	111
	Max	14,111	13,089	1,277
	Average	836	948	214
Sediment Removal	25th Percentile	109	109	109
	50th Percentile	373	660	111
	75th Percentile	499	1,111	111
	Max	14,107	13,086	1,359
	Average	806	947	215
Bartlett Modification 1	25th Percentile	174	109	109
	50th Percentile	377	564	111
	75th Percentile	538	1,096	652
	Max	11,365	7,163	1,593
	Average	592	831	310
Bartlett Modification 2	25th Percentile	182	111	109
	50th Percentile	382	587	111
	75th Percentile	518	1,168	230
	Max	13,719	9,562	1,357
	Average	723	891	186

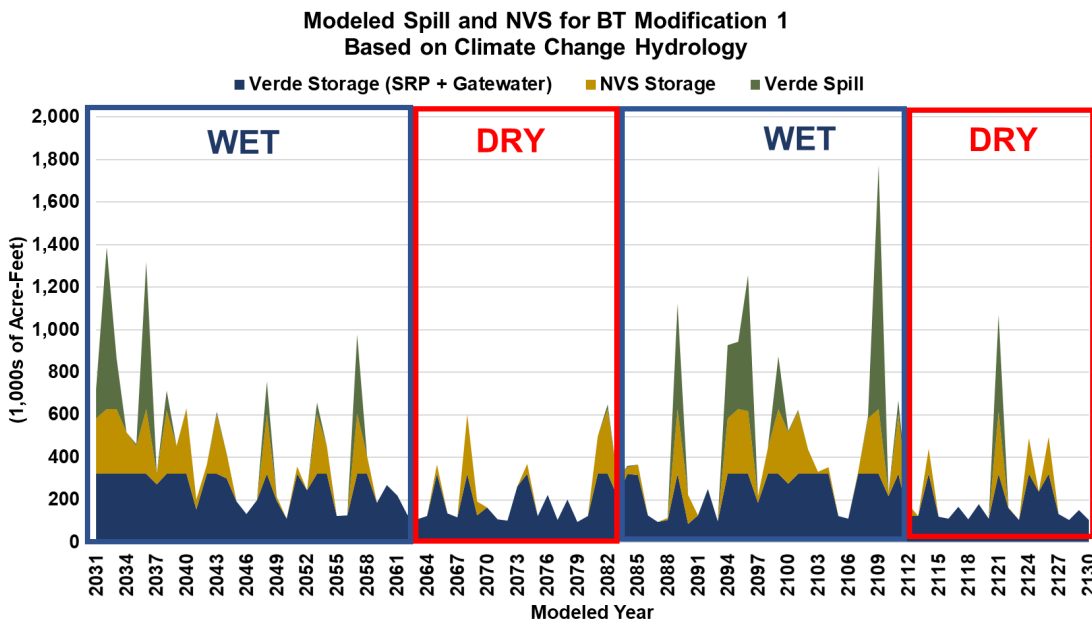


Figure 26. Water available for sluicing for Bartlett Modification 1

6.2.4 Net Aquifer Benefit

The RPM does not have the ability to directly assess regional groundwater pumping outside of the SRP service territory. However, regional aquifer health is an important consideration, especially with the amount of reliance central Arizona has on groundwater pumping. One way SRFRP reservoir operations does impact regional aquifer levels is from natural recharge in the Salt riverbed below Granite Reef Diversion Dam resulting from reservoir spills on the Salt and Verde rivers. The ADWR regional groundwater model for central Arizona (Salt River Valley Regional Model, 2008) uses a relationship to account for spill in the Salt River below Granite Reef Dam and natural recharge into the groundwater aquifer. By analyzing decades of spill and modeled natural recharge, this relationship can be approximated through a regression analysis by the following equation²:

$$NR = 2.7356 * Spill^{0.6218}$$

Where:

NR = Incidental Recharge

Spill = annual Granite Reef spill into the Salt River

Figure 27 shows the annual average spill determined from the RPM analysis and annual average natural recharge from spill using the equation above with spill at Granite Reef Dam as an input. On average, approximately 25% of observed spill over Granite Reef Dam is estimated to naturally recharge. As spill decreases with each alternative, less natural recharge occurs.

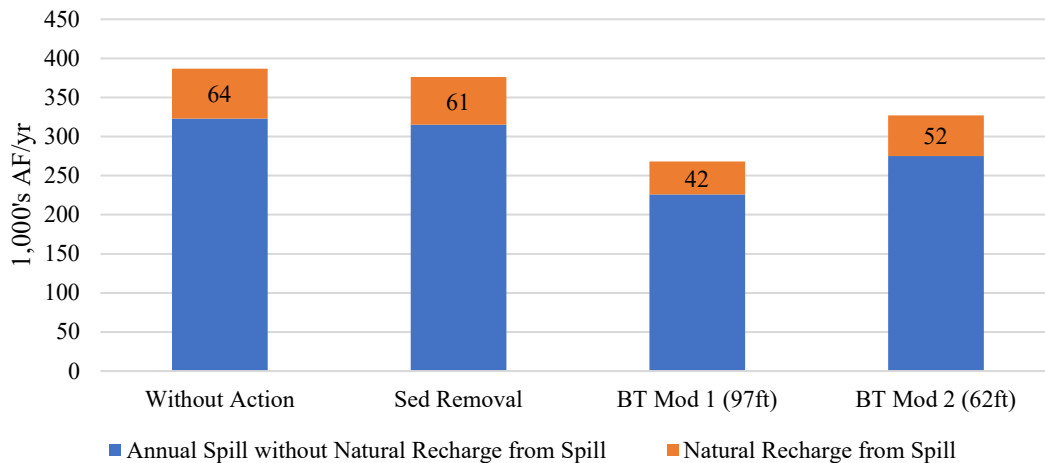


Figure 27. Average annual spill and natural recharge below Granite Reef Dam

Additional surface water supplies to central Arizona may also offset regional groundwater pumping. The NVS would be available for direct delivery and use or direct water banking in central Arizona. For this analysis and because of uncertainties of NVS usage in the future, three scenarios of NVS

² Arizona Department of Water Resources (ADWR) is currently evaluating spill impacts to natural recharge. The estimated amount in this analysis may change as the ADWR evaluation progresses.

deliveries are estimated to assess offsets to net groundwater pumping in the future. The three scenarios assume 25%, 50%, and 75% of NVS is either directly used to offset current groundwater demands or directly recharged and banked to offset future groundwater needs. Using NVS and estimated natural recharge for the Bartlett Modification alternatives, a net aquifer benefit is presented. Figure 28 shows the estimated change in average net aquifer benefit for the two Bartlett Modification alternatives compared to the Without Action alternative for three levels of NVS groundwater offset.

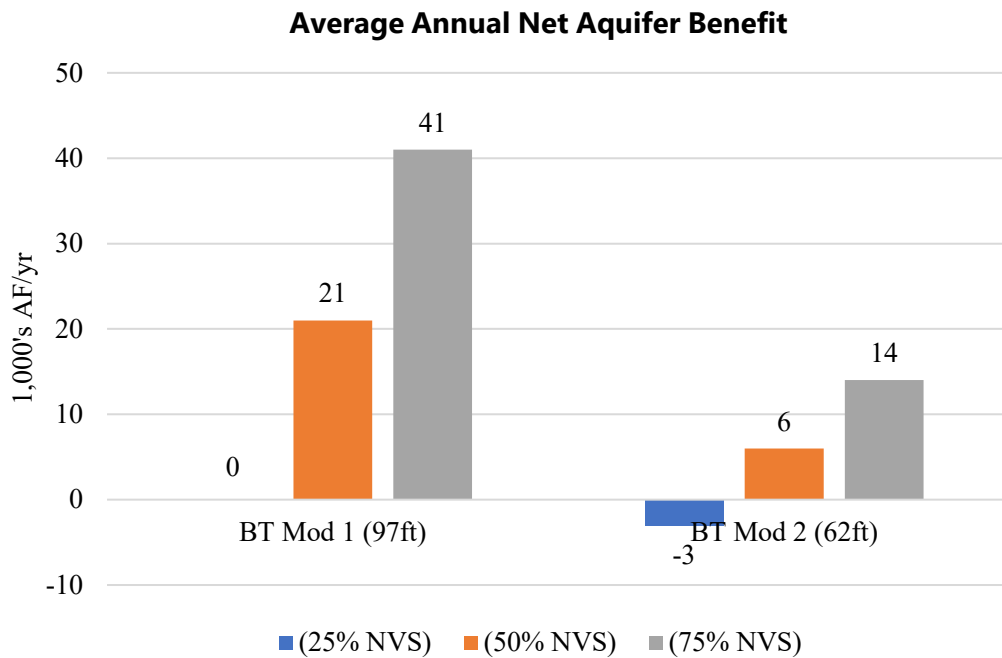


Figure 28. Estimated net aquifer benefit (2031-2130)

7 Alternative Evaluation and Comparison

The focus groups were tasked with collecting pertinent existing conditions data and information for the study area in order to assess each alternative based on the evaluation criteria. This section provides a description of the score, justification, and information used to compare each alternative based on the evaluation criteria.

Table 18 provides an overview of the scoring of the evaluation criteria for each alternative, with the alternative expected to provide the strongest support for the criteria's objective being scored as a 5 and the alternatives expected to provide the least support for the criteria's objective being scored 0; the remaining alternatives are scored relative to the highest and lowest scoring alternative. Each scored criterion was provided equal weight to produce an overall score based on the simple average of all criteria scores.

Table 18. Summary of Evaluation Criteria Scoring

Evaluation Criteria	Alternatives Score			
	Without Action	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
<i>Applicability</i>				
Applicability of Alternatives	Yes	Yes	Yes	Yes
Enhances water management flexibility	0	1	5	2
Promotes long-term protection of surface water supplies of the Salt River Federal Reclamation Project and Contractors	0	2	5	4
<i>Acceptability</i>				
Potential effects to environmental resources	5	0	2	2
Potential new impacts to cultural resources	5	3	0	1
Applies regional perspective	0	1	5	2
<i>Efficiency</i>				
Capital Cost Efficiency	5	0	4	3
Operations and Maintenance (O&M) Cost Efficiency	0	1	5	4
Affordability	2	0	5	4
<i>Effectiveness</i>				
Effectiveness of restored or replaced lost surface water capacity on the Verde River	0	5	5	5
Mitigates impacts to capacity of future sediment accumulation	0	3	5	4
Reduces future groundwater dependency	0	1	5	4
<i>Completeness</i>				
Implementable	0	1	4	5
Creates opportunities for additional benefits to water supply, the environment, flood control, dam safety, recreation, or hydropower	0	1	5	4
Overall Score (Average of all criteria scores)	1.3	1.5	4.2	3.4

7.1 Applicability of Alternatives

Following the alternatives development phase of the appraisal process, the PMT evaluated each alternative recommended by the Alternatives Development Focus Group for its applicability to Reclamation's areas of geographic jurisdiction and mission. All four alternatives were identified to reasonably be within Reclamation's mission to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public. The entirety of the area of the Without Action alternatives is contained within the geographic bounds of the Congressionally withdrawn lands described in Section 3.9. Initial review of lands affected by the Sediment Removal and two Bartlett Modification alternatives showed that most of the lands affected were within the geographic bounds of the Congressionally withdrawn lands. The exceptions to this finding were the private land inholdings between Bartlett and Horseshoe reservoirs that are expected to be impacted by the inundation created by Bartlett Modification 1 and portions of the sediment mound created by the Sediment Removal alternative outside of the withdrawn lands onto National Forest lands.

Alternative	Score	
	No	Yes
Without Action		X
Sediment Removal		X
Bartlett Modification 1		X
Bartlett Modification 2		X

7.2 Enhances Water Management Flexibility

The Alternatives Development Focus Group evaluated each alternative's ability to enhance water management flexibility based on the availability of surface water for use in water exchanges between users, and enhancements to central Arizona's ability to bank water underground for use during shortages of surface water supply. The increased variability expected from climate change will increase the need to have flexible infrastructure and operations to get water to end uses when it is needed. The alternatives with the greater ability to facilitate exchanges and enable groundwater banking were scored higher than the alternatives with lesser ability to facilitate exchanges and groundwater banking.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1						X
Bartlett Modification 2			X			

The focus group determined the scoring primarily based on the average annual yield of Phoenix Gateway and New Verde Space Water (detailed in Table 15), since SRP stored water is generally

not eligible for use outside the SRP water service area. In order to create a quantitative score, the focus group identified a scoring tool intended to objectively score each alternative based on the relative reduction in use of groundwater made possible. The scoring approach compares the calculated potential for groundwater reduction of each alternative to the alternative with the highest potential. Table 19 presents the conversion of percentage rank to the scoring range of zero to five.

Table 20 presents the data that was used to create the percentage score from the information in Table 15 and the resulting percentage score.

Table 19. Alternatives Development Focus Group Percentage Scoring Approach

Rating	Percentage Range
0	0-19% of Rating 5 total
1	20-39% of Rating 5 total
2	40-59% of Rating 5 total
3	60-79% of Rating 5 total
4	80-99% of Rating 5 total
5	100% (Provides most potential to meet evaluation criteria)

Table 20. Change in Availability of Surface Water by Alternative

Alternative	Annual Average SW Delivery Change from w/o action [kaf/yr]	Percent of Alternative with Highest Average SW Change
Without Action	-	0%
Sed Removal	10	9%
BT Mod 1	115	100%
BT Mod 2	60	52%

The focus group identified that all four alternatives have advantageous locations for delivering surface water to exchange and water banking locations due to the interconnections with the SRP system to multiple municipal systems and the conveyance facilities of multiple irrigation districts. Additionally, the Verde reservoirs are located upstream of a potential new delivery siphon currently being evaluated by SRP and CAP known as the SRP/CAP Interconnection Facility (SCIF) that would allow for movement of water from SRP's system into the CAP canal and upstream of the water treatment plants on the City of Phoenix system that interconnect with the Phoenix drought pipeline. The SCIF and the Phoenix drought pipeline would both create opportunities for increased water management flexibility in the future. The Alternatives Development team felt that the additional surface water supply made available by the Sediment Removal alternative provided slightly more water management flexibility than without action, due to the decreased use of groundwater by SRP.

7.3 Promotes Long-term Protection of Surface Water Supplies of the SRFRP and Contractors

The Alternatives Development Focus Group evaluated each alternative for the volume of surface water delivered to contractors and water rights holders within SRP's water service area, including tribes, and the City of Phoenix from the SRP system over the project period, as well as the useful life of the Verde reservoirs system conservation storage capacity as it is impacted by sediment accumulations in the future as described in Table 15. The alternatives with the largest annual surface water deliveries to SRP contractors and the longest useful life of storage capacity were scored higher and the alternatives with lower annual surface water deliveries to SRP contractors and shorter useful life were scored lower.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal			X			
Bartlett Modification 1						X
Bartlett Modification 2					X	

The larger storage capacity of the two Bartlett Modification options and reduced impacts of sediment on conservation storage capacity in the new Bartlett Reservoir resulting from use of Horseshoe Dam as a sediment trap resulted in higher scores for these two alternatives. Both dam modification alternatives are expected to produce the same annual surface water deliveries to SRP contractors as shown in Table 15, but Bartlett Modification 1 was scored higher due to the larger total reservoir size having a longer expected useful life of conservation storage capacity. The Sediment Removal alternative produces lower annual water deliveries than the dam modification alternatives due to sediment accumulations impacting water conservation storage capacity in the later portion of the study period following the initial removal of sediment. The Sediment Removal alternative has a longer estimated useful life of storage capacity than the without action, but substantially less than the two Bartlett Modification Alternatives. The Without Action alternative was scored the lowest due to the lowest surface water deliveries and shortest useful life of water storage capacity.

7.4 Potential Effects to Environmental Resources

The Environmental and Cultural Resources Focus Group evaluated each alternative, using the 11 categories described in Section 3.6, to identify potential environmental effects. The alternative that has the potential for the highest net benefits to environmental resources, or alternatively, the least negative effects to environmental resources was scored the highest (5). The alternative that produced the least net benefits, or alternatively has the greatest negative effects to environmental resources, was scored the lowest (0). The other alternatives were scored relative to the highest and lowest scored alternatives using a point spread approach. A brief description of the potential environmental issues and scoring justification is found below. A more detailed analysis of the potential environmental effects per alternative is found in Appendix I.

Alternative	Score					
	0	1	2	3	4	5
Without Action						X
Sediment Removal	X					
Bartlett Modification 1			X			
Bartlett Modification 2			X			

The analysis of the Without Action extends beyond the 50-year lifespan of SRP's Incidental Take Permit (ITP) to 2130, which is the end of the study period. The minimization and mitigation efforts of the H-B HCP are adaptive and accommodate for the changing ecosystem. Thus, the H-B HCP would continue under the Without Action alternative. Should operations of Horseshoe Dam change (e.g., to accommodate for sediment accumulation and reduction in water storage) and/or new species are listed, SRP would need to amend the H-B HCP. Once the 50-year term for the current ITP expires, SRP would need to seek a new ITP for ongoing operations of the Horseshoe and Bartlett dams and reservoir. Until that time, SRP would continue to manage water levels at Horseshoe Reservoir, conditional on other operation goals, to maximize riparian habitat during the nesting season for birds, maintain riparian vegetation at the upper end of the reservoir, and minimize the reproduction, recruitment, and survival of nonnative fish by rapidly drawing down the reservoir and minimizing carry-over storage. Implementation of the H-B HCP would continue to mitigate for effects to covered species under the current operation of the Horseshoe and Bartlett dams and reservoirs. Of those environmental categories that are not covered by the H-B HCP, there would likely be no net effects to Migratory Birds, Other Terrestrial Species and Their Habitat, the Arizona cliffrose, Visual Resources, Vegetation and Land Cover, and Special Designations. The Other Aquatic Species and Their Habitat category was the only category identified with the potential to have net negative effects. Based on this analysis and in accordance with the evaluation scoring criteria definitions, the Without Action alternative was scored a 5, because it had the least negative effects to environmental resources.

In considering both positive and negative effects for the Sediment Removal alternative, this alternative is likely to have greater negative effects to three environmental categories (i.e., three Threatened and Endangered Species, Visual Resources, and Jurisdictional Waters and Water Quality) and marginal negative effects to the remaining environmental categories. The Sediment Removal alternative would have greater negative effects to numerous environmental resources due to prolonged dredging and the impacts from the spoil area. In accordance with the evaluation scoring criteria definitions, this alternative has the greatest negative effects to environmental resources and scored a 0.

With the construction of a new dam, the corresponding expansion of the inundation zone, and the repurposing of Horseshoe Reservoir operations, Bartlett Modification 1 would likely have greater negative effects to bald eagles, marginal positive effects to Other Aquatic Species and Their Habitat, and marginal negative effects on the other nine environmental resource categories when considering both adverse and beneficial effects. When considering the downstream effects and compared to the Without Action Alternative, the RPM analysis indicated that average monthly flows below Bartlett Dam with the Bartlett Modification 1 Alternative would be reduced by 13%-29% in the winter and spring and increased by 45% in the summer.

Table 17 provides a summary of modeled flows below Bartlett Dam for each alternative. The overall reduction in flows or variability of those flows could reduce the establishment of native plants and trees, increase the abundance of non-native vegetation, decrease habitat suitability for wildlife, and increase fire risk. In general, Bartlett Modification 1 would negatively affect environmental resources in the short-term during construction and in the long-term through the modification to the reservoir elevations and changes in flows downstream of Bartlett Dam. Based on available information and in accordance with the evaluation scoring criteria definitions, Bartlett Modification 1 scored a 2.

The effects to environmental resources, including downstream effects, with the construction of Bartlett Modification 2 would closely resemble those described for Bartlett Modification 1. However, the decreased height of the dam would have a smaller inundation pool and consequently have slightly less negative effects to environmental resources. Based on this analysis and in accordance with the evaluation scoring criteria definitions, Bartlett Modification 2 scored a 2.

Avoidance, minimization, and/or mitigation would be required to address environmental effects for any of the action alternatives carried forward. If any alternative is carried forward to feasibility, all environmental resources would need to be examined thoroughly during the National Environmental Policy Act (NEPA) process. A list of potential, applicable environmental laws and regulations is found in Appendix J. Additionally, any change to SRFRP operations and maintenance would require a new or amended HCP to address incidental take of federally listed species and impacts on species of special concern.

7.5 Potential New Impacts to Cultural Resources

Each alternative was scored on a scale of 0 to 5. The alternative that is the most favorable to cultural resources because there would be no change in design and no new impacts to any cultural resources was scored the highest (5). The alternative that would have the most new impacts to cultural resources is the least favorable and was scored the lowest (0). The other alternatives were scored based on the number of cultural resources they could negatively impact.

Alternative	Score					
	0	1	2	3	4	5
Without Action						X
Sediment Removal				X		
Bartlett Modification 1	X					
Bartlett Modification 2		X				

Maintaining status quo at these dams and reservoirs would not result in new negative impacts to these cultural resources because they were already negatively impacted by dam construction, reservoir inundation, and later Safety of Dams work. For this reason, the Without Action alternative has the fewest potential negative impacts to cultural resources of all alternatives under consideration. In accordance with the evaluation scoring criteria definitions, the Future Without Action alternative was scored the highest (e.g., 5) and is the preferred alternative for cultural resources. Table 21 provides a summary of the cultural resources previously identified for each of the action alternatives.

Table 21. Existing Cultural Resource Information in Area of Action

Alternative	Study Area (acres)	Previously Inventoried in Study Area (acres and percentage)	Known Cultural Resources in Previously Inventoried Study Area (number)
Sediment Removal	1,577 acres	151 acres (9.5%)	60 sites
Bartlett Modification 1			
- Bartlett Reservoir	8,538 acres	6,265 acres (73%)	236 sites; Bartlett Dam
- Horseshoe Reservoir	3,284 acres	827 acres (25%)	188 sites; Horseshoe Dam
Total	11,822 acres	7,092 acres (60%)	424 sites; Bartlett and Horseshoe dams
Bartlett Modification 2			
- Bartlett Reservoir	6,365 acres	5,507 acres (87%)	152 sites; Bartlett Dam
- Horseshoe Reservoir	3,284 acres	827 acres (25%)	188 sites; Horseshoe Dam
Total	9,649 acres	6,334 acres (66%)	340 sites; Bartlett and Horseshoe dams

Based on the available data, the Sediment Removal alternative has the potential to result in negative impacts to at least 60 cultural resources. In accordance with the cultural resources scoring definitions, the Sediment Removal alternative was given a score of 3 because it has the potential to negatively impact a moderate amount of cultural resources.

Bartlett Modification 1 has the potential to result in new negative impacts to at least 424 cultural resources. In accordance with the cultural resources scoring definitions, the Bartlett 1 alternative was scored the lowest (e.g., 0) because it has the potential to adversely impact the largest amount of cultural resources and it has the greatest potential of any of the alternatives to negatively impact cultural resources.

Bartlett Modification 2 has the potential to result in new negative impacts to at least 340 cultural resources. In accordance with the cultural resources scoring definitions, the Bartlett 2 alternative was given a score of 1 because it has the potential to negatively impact a large amount of cultural resources.

If a feasibility study is initiated for any of the action alternatives, a Class III cultural resources inventory of the un-surveyed area is recommended, at a minimum. Compliance with Section 106 of the NHPA would be required prior to implementation of any action alternative.

7.6 Applies Regional Perspective

For the purpose of this evaluation criteria “regional” is defined as the area within the Verde River watershed, both upstream and downstream of the Verde River reservoirs, as well as the downstream areas connected to the SRP and CAP water service areas through infrastructure that could be impacted by changes resulting from the project. The Alternatives Development Focus Group used a watershed approach to evaluate/score each alternative’s relative ability to reduce groundwater

reliance and increase access to renewable water supplies, which are two common themes identified in local and statewide water policy and regulations. The main policy and statutory priorities identified to evaluate the regional perspective were the 1980 Groundwater Management Act and subsequent laws and regulations promoting reduced stress on aquifers, groundwater banking, and assurance of physical and legal availability of renewable water supplies to support economic development. Additionally, several recent Gubernatorial executive orders and State government-led committees prioritize ensuring that Arizona has the renewable water supplies available to sustainably support Arizona's economy. The alternative with the least potential to reduce unreplenished use of groundwater and least ability for putting to use renewable surface water supplies was scored 0 and the alternative with the most potential to reduce unreplenished use of groundwater and provide renewable surface water supplies was scored the highest. The focus group used information from Figure 24, Figure 25, Figure 27, and Figure 28 to evaluate the potential benefits to sustainable management of surface water and groundwater made possible by each alternative.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1						X
Bartlett Modification 2			X			

In order to create a quantitative score, the focus group identified a scoring tool intended to objectively score each alternative based on the relative reduction in use of groundwater made possible. The scoring approach compares the calculated potential for groundwater reduction of each alternative to the alternative with the highest potential. Table 19 presents the conversion of percentage rank to the scoring range of zero to five. Table 22 presents the data that was used to create the percentage score from the information in Figure 24 and Figure 28. Though the quantitative score for the Sediment Removal Alternative did result in a score of zero, the Alternatives Development Focus Group determined that the Sediment Removal alternative should be scored higher than the Without Action Alternatives, since removal of sediments is expected to help reduce groundwater use compared to taking no action.

Table 22. Groundwater Reduction Considerations for Quantitative Score

	SRP Pumping Change from w/o action [kaf/yr]	Potential GW Reduction based on Average Annual Net Aquifer Impact (50% NVS) [kaf/yr]	Total Potential GW Pumping Reduction (absolute value of GW Reduction + Net Aquifer Impact)	Percentage Score
Without Action	-	-	0	0%
Sed Removal	-7	-	7	19%
BT Mod 1	-16	21	37	100%
BT Mod 2	-16	6	22	59%

The focus group identified that the location of Verde River reservoirs is critical to the value created by the water supplies. Water supplies contained in Verde River reservoirs are delivered through gravity-fed canals into the SRP water system, which delivers water supplies directly to municipal water treatment plants and agricultural fields. The gravity fed system results in low operating and maintenance costs and reduces the likelihood of facility outages that impact system reliability. SRP's system is also interconnected into the conveyance facilities of several tribal and agricultural districts as well as the CAP canal. The location of the surface water supplies created by the reservoirs creates many opportunities for delivery of supplies to communities currently dependent on groundwater for meeting residential needs as well as communities that could be impacted by future shortages on the Colorado River. The water created by the New Verde Space in the two Bartlett Modification alternatives was considered an important and valuable opportunity to help meet water management goals in that the water supplies created could be used directly by beneficiaries or banked underground for future use.

7.7 Capital Cost Efficiency

This criterion was scored on the basis of each alternative's present value capital cost per acre-foot of restored / mitigated and additional capacity, with the lowest cost scored at 5 and the highest at 0. The metric that supports this criterion, shown in Table 23 on the following page, presents the relative present value investment cost of each acre-foot of reservoir system capacity that is restored, mitigated, or added by an action alternative. In evaluating future water supply acquisitions, these metrics could be compared to nominal per-acre-foot costs of acquiring a perpetual water right with a variable yield. Each alternative's capital cost estimates include economic adjustments to account for year of occurrence and interest during construction (IDC).

Alternative	Score					
	0	1	2	3	4	5
Without Action						X
Sediment Removal	X					
Bartlett Modification 1					X	
Bartlett Modification 2				X		

The Without Action Alternative has a capital cost of \$0; although it also provides no restored or mitigated capacity, the Economics Core Team felt that a score of 5 was most consistent with the literal definition of the criterion. The capital cost estimates include economic adjustments to account for year of occurrence and interest during construction (IDC) of the alternatives. The Sediment Removal Alternative is not cost-efficient, having the highest capital cost of any alternative and the least amount of capacity restored, mitigated, or added, so it was scored with a 0. Bartlett Modification 1 was the most capital-cost-efficient of the action alternatives, so it was scored with a 4 just behind the Without Action alternative. Capital costs of the Bartlett Modification 2 Alternative are the lowest of the action alternatives, but its slightly less favorable cost efficiency reflects that it adds significantly less capacity than Bartlett Modification 1, so it was scored with a 3.

Table 23. Capital Cost Efficiency Metrics

Criterion: Capital Cost Efficiency	Alternatives			
	Without Action	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Metrics				
Present Value of Dam Construction + IDC Cost	\$0	\$1,052,867,534	\$1,041,932,101	\$848,084,269
AF of Restored or Mitigated Capacity	-	45,749	45,749	45,749
AF of Additional Capacity	-	-	305,784	99,784
Present Value of Capital Cost/AF of Restored or Mitigated and Additional Capacity	\$0.00	\$23,014.00	\$2,963.97	\$5,827.44

7.8 Operations and Maintenance (O&M) Cost Efficiency

This criterion is scored on the basis of each alternative's annualized O&M cost per acre-foot of total Verde River storage capacity, with the lowest cost scored at 5 and the highest at 0. The metric that supports this criterion, shown in Table 24 on the following page, uses O&M and capacity data for the entire Verde River reservoir system (as estimated) to provide a comparison of the cost efficiency of all four alternatives on the same basis.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1						X
Bartlett Modification 2					X	

The O&M cost estimates based on SRP's financial planning provide \$786,546 annually for O&M at Bartlett and Horseshoe Dams over the near future, and that is assumed to continue under all alternatives; SRP does not expect a new facility to be more expensive to operate and maintain than the current facility based on currently available estimates. No replacement costs were included in these estimates as no reliable data was available to inform specific replacement items that would vary between the Without Action and action alternatives. If O&M costs are equal, the alternative with the least capacity has the poorest O&M Cost Efficiency. Even before adding SRP's implementation costs for the H-B HCP (\$309,000 per year) to the Without Action alternative's O&M costs, it had the poorest cost efficiency and was scored at a 0. (Note that the Without Action capacity is the rounded estimate of 2030 Verde River system capacity, which is modeled in 10-year increments.)

For the action alternatives, environmental and cultural mitigation costs are included in the construction cost estimate as part of non-contract costs, so the H-B HCP costs were not included here to avoid double-counting. Sediment Removal had the next lowest cost efficiency, in accordance with its capacity, so it was scored at a 1. Bartlett Modification 1, the most cost-efficient, received a score of 5, and the Economics Core Team felt that Bartlett Modification 2 was closer to Bartlett Modification 1 than Sediment Removal, so it received a score of 4.

Table 24. O&M Cost Efficiency Metrics

Criterion: O&M Cost Efficiency	Alternatives			
	Without Action	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Metrics				
Annualized Bartlett & Horseshoe Dams O&M Cost	\$1,095,546	\$786,546	\$786,546	\$786,546
Verde River Storage Capacity	268,000	322,000	628,000	422,000
Annualized O&M Cost/AF of Capacity	\$4.09	\$2.44	\$1.25	\$1.86

7.9 Affordability

The Affordability score considers the outcome of all the analyses described in Appendix D: Financial Analysis; alternatives with water supplies that are more affordable relative to others will be ranked higher and alternatives that are less affordable will be ranked lower. If the Economics Focus Group Core Team identified that an alternative's supply is unlikely to be affordable based on water provider and end user payment capacity as indicated by Bond Ratings, Debt Service Coverage Ratios, Unemployment, Property Values, Median Household Income, and Water Service Affordability, that alternative was ranked low to 0.

Alternative	Score					
	0	1	2	3	4	5
Without Action			X			
Sediment Removal	X					
Bartlett Modification 1						X
Bartlett Modification 2					X	

Appendix D provides additional detail for unquantified, quantified, and monetized metrics that support the scoring of this criterion. The socioeconomic indicators of Bond Ratings, Debt Service Coverage Ratios, Unemployment, Property Values, and Median Household Income do not vary between alternatives, and Reclamation would consider them to be at acceptable levels.

Sediment Removal, however, may result in costs (\$1,017 to \$1,096 per acre-foot) that are both potentially outside the ability of end users to pay and may not be competitive with costs of observed alternatives for water supply. As the least affordable, it was scored at a 0.

While the Without Action alternative creates no new water supply and therefore requires no immediate capital outlays, it has affordability implications. In the future, as entities lose reliable yield from the Verde River reservoir system, they would have to turn to other new sources of water which are expected to cost between \$175 and \$2,200 per acre-foot. Therefore, Without Action received a score of 2.

Estimated lifecycle costs of the Bartlett Modification 1 Alternative range from \$41 to \$102 per acre-foot of water yield, and costs of the Bartlett Modification 2 Alternative range from \$82 to \$166 per acre-foot of water yield; see Appendix D for a detailed description of these cost estimates, which vary between the SRP, Phoenix Gateway, and New Verde Space storage accounts. This is less than the average estimated per-acre-foot ability to pay of households in Maricopa County, and reasonably comparable to costs of wholesale water from other sources for M&I suppliers, both of which are further described in Appendix D. Bartlett Modification 1 costs may be reasonable for agricultural users within SRP's service area, who may be served from the SRP storage account. However, the estimated lifecycle costs of the New Verde Space water yield, at \$102 or \$166 per acre-foot (for Bartlett Modification 1 and 2, respectively) may be challenging for agricultural districts to justify, considering the average cost of water charged by central Arizona irrigation districts ranges from \$48 to \$66 per acre-foot in 2021. As the most affordable on a per-acre-foot basis, Bartlett Modification 1 was scored at a 5. Bartlett Modification 2, still expected to be affordable for M&I users but slightly less than Bartlett Modification 1, was scored at a 4.

8 Effectiveness of Restored or Replaced Lost Surface Water Capacity on the Verde River

This criterion is scored on a scale of 0 to 5. The alternative that restores or replaces the most surface water storage capacity on the Verde River system is scored the highest (5). The alternative that restores or replaces the least is scored the lowest, with alternatives that do not restore any capacity receiving a score of 0. All other alternatives are scored relative to the highest and lowest scored alternatives using whole number values between 0 and 5; multiple alternatives may be rated the same.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal						X
Bartlett Modification 1						X
Bartlett Modification 2						X

The Hydrology and Climate Change Focus Group assessed the total water storage capacity at Verde River reservoirs restored or replaced after alternative completion and the number of years it is expected to take to restore or replace at least 45,749 AF on the Verde system for each alternative. Based on the information available for the appraisal-level analysis, all action alternatives restore the

45,749 AF lost to sedimentation and are expected to take approximately ten years to restore or replace the capacity. Because of this, all three action alternatives were scored the same for effectiveness and the without action was scored the lowest.

8.1 Mitigates Impacts to Capacity of Future Sediment Accumulation

This criterion is scored on a scale of 0 to 5. The alternative that is the most effective in mitigating future sediment accumulation is scored the highest (5). The alternative that is least effective is scored the lowest, with an alternative that does not mitigate any future accumulation receiving a score of 0. All other alternatives are scored relative to the highest and lowest scored alternatives using whole number values between 0 and 5; multiple alternatives may be rated the same.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal				X		
Bartlett Modification 1						X
Bartlett Modification 2					X	

The Hydrology and Climate Change Focus Group evaluated the anticipated useful life of Verde Reservoir system capacity for each alternative to understand the relative capability of each alternative to mitigate future impacts of sediment accumulation to water storage capacity. The focus group defines the useful life for the Verde Reservoir System Capacity as the amount of time until it completely fills up with sediment. System capacity is the amount of conservation, or water supply, space in the system. Alternatives in which Verde Reservoir System Capacity has a longer useful life are deemed more effective. The focus group also considered the useful life for Horseshoe Reservoir, or the amount of time until it completely fills up with sediment. Sedimentation rates into Horseshoe Reservoir for each alternative are also assumed to be 1,010 AFY.

Table 25 shows metric data for this criterion. For simplicity at the appraisal-level, it was assumed that when Horseshoe Reservoir fills up, the sediment load will propagate into Bartlett Reservoir. Further study is suggested of the sediment accumulation and transport through the reservoir system if any alternatives are suggested for feasibility analysis. The anticipated useful life of the Verde Reservoir System Capacity was weighted 80% in the overall score because this metric directly applies to the water supply capacity of the Verde River reservoir system. The anticipated useful life of Horseshoe Reservoir was weighted 20%.

Table 25. Metric Data for Mitigates Impacts to Capacity of Future Sediment Accumulation Criteria

Alternative	Useful Life of Verde Reservoir System Capacity [years]	Useful Life of Horseshoe Reservoir [years]
Without Action	274	97
Sediment Removal	319	142
BTD Modification 1	711	97
BTD Modification 2	507	97

8.2 Reduces Future Groundwater Dependency

This criterion is scored on a scale of 0 to 5. The alternative that reduces groundwater dependency the most is scored the highest (5). An alternative is scored 0 if it has no potential to reduce groundwater dependency in the future. All other alternatives are scored relative to the highest and lowest scored alternatives using whole number values between 0 and 5; multiple alternatives may be rated the same.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1						X
Bartlett Modification 2					X	

The Hydrology and Climate Change Focus Group evaluated each alternative for reducing future groundwater dependency based on SRP groundwater pumping volume and estimated net impacts to regional groundwater aquifer from each alternative.

To understand the changes to SRP groundwater pumping, the focus group looked at the results of the reservoir planning model for average annual groundwater pumping and the maximum of 11-year cumulative groundwater pumping over the period of analysis (2031-2130) for the SRP system. The maximum 11-year pumping period was used because it is consistent with SRP water resource planning practice as 11-years is the length of most severe drought in the paleo record for the Salt and Verde River watersheds. Greater groundwater pumping volumes in the future indicate greater dependency on groundwater. The net impacts to the regional groundwater in the Phoenix Metropolitan Area is estimated by considering natural groundwater recharge from Salt and Verde spills and pumping offset by potential additional water supplies made available by each action alternative. See Section 6.2 for detailed explanation on estimation of net aquifer impact.

Figure 24 and Figure 25 in Section 6.2.2 show the estimates of SRP groundwater pumping and estimated net aquifer impact estimates for each alternative. Three percentages of use of NVS water were considered for groundwater offsets since it is unknown where any additional water made available by NVS would be used. The three percentages represent 25%, 50%, and 75% of NVS

water being used to directly offset groundwater pumping that is currently happening or required during future shortages of Colorado River water supplies. Ultimately, 50% NVS offset was used in this evaluation due to the uncertainty around NVS beneficiaries.

8.3 Implementable

This criterion is scored on a scale of 0 to 5. The alternative that addresses the problem and need with the most realistic design and can be implemented in a reasonable timeframe and scale is scored the highest (5). The alternative that does not is scored the lowest (0). All other alternatives are scored relative to the highest and lowest scored alternative using whole number values between 0 and 5. The Implementable selection metrics considered include geography, maintenance requirements, and geology. Uncertainty related to the completeness of the engineering design of each alternative is a major consideration for the Implementable evaluation. Completeness is defined as the extent to which an alternative provides and accounts for all features, investments, and/or other actions necessary to realize the planned effects. Below are the Implementable criteria scores for each alternative.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1					X	
Bartlett Modification 2						X

The Without Action alternative received the lowest score (0). It does not meet the problem and need as stated above.

The Sediment Removal alternative received a score of 1 for the Implementable criteria. It has the largest construction footprint and has the greatest uncertainty around the logistics of construction. Uncertainties associated with Sediment Removal are discussed in Section 9.3. The greatest uncertainties are the time needed to complete the sediment removal, dredging type (mechanical or hydraulic), and the maintenance requirements for the sediment mound. The construction footprint is large for this alternative, including suitable areas for additional access roads, material laydown areas, barge access, etc. The waste area alone will require an additional 1,194 acres of land for the long term.

Bartlett Modification 1 and 2 received a score of 4 and 5, respectively, for the Implementable criteria. Using the data collected in the scope of this appraisal study, initial dam design and construction considerations for the Bartlett Modification Alternatives are realistic, but with uncertainties common at the appraisal level. Engineering and construction uncertainties associated with the Bartlett Modification Alternatives are discussed in Section 9.6. Generally, more is understood about dam design and construction than a large scale, inland dredging project such as the Sediment Removal Alternative. Bartlett Modification 1 was scored lower than Bartlett Modification 2 because it will inundate the downstream toe of Horseshoe Dam during flood surcharge (above 1895 ft) events, possibly requiring modification to the Horseshoe Dam

downstream embankment. Bartlett Modification 1 is also a larger structure that will require more design and construction consideration. Geological and geotechnical constraints are not entirely unknown with the Modification Alternatives because the alternatives are sited at an existing dam site. Maintenance requirements for the Bartlett Modification Alternatives may be greater than Without Action in the short term, but unknown maintenance requirements may occur for the existing Bartlett Dam as it ages during the duration of analysis for the alternatives. For example, any usage of the existing auxiliary fuse plug spillway would require a large construction rebuild effort not currently accounted for. Both Bartlett Modification Alternatives will replace the auxiliary fuse plug spillway with an ogee crest or labyrinth spillway that does not require large maintenance or rebuild projects after use. Capacity maintenance infrastructure, i.e., sluicing, that will elongate restored and additional capacity may also be considered in feasibility for the Bartlett Modification Alternatives.

8.4 Creates Opportunities for Additional Benefits to Water Supply, Environmental Resources, Flood Control, Dam Safety, Recreation, or Hydropower

Each alternative may also create additional opportunities that benefit water supply, the environment, flood control, dam safety, recreation, or hydropower. Below is the score given to each alternative based on the opportunity created for these benefits. The scores are reflective of a quantitative and qualitative analysis of the opportunities provided by the Focus Groups. The sections below describe opportunities for each area.

Alternative	Score					
	0	1	2	3	4	5
Without Action	X					
Sediment Removal		X				
Bartlett Modification 1						X
Bartlett Modification 2					X	

8.4.1 Water Supply

Bartlett Modification 1 and 2 Alternatives feature the opportunity to provide additional water supply in excess of the restored capacity lost to sedimentation in Horseshoe Reservoir. Table 15 in Section 6.2.1 shows the additional average annual yield associated with the New Verde Space available for additional water supply.

8.4.2 Environmental

There are several environmental opportunities identified for Sediment Removal and Bartlett Modification alternatives. However, because of the great amount of uncertainty associated with the environmental impacts, environmental opportunities were not considered in the scoring table above. Below is a description of possible environmental opportunities for the alternatives.

For the Without Action Alternative, one opportunity exists. As sediment accumulates within Horseshoe Reservoir, sedimented areas may become wetlands or riparian areas, benefiting numerous riparian-obligated or aquatic-dependent species.

Several opportunities may exist for the Sediment Removal Alternative. An opportunity may be available to evaluate operational changes at Horseshoe that could potentially improve downstream hydrology to benefit native fish. The construction activities associated with the sediment removal at Horseshoe Reservoir may allow for the installation of check dams, which could double as fish barriers, to reduce sediment flow and/or assist with the recovery of native fish populations. Another opportunity exists for the management of the dredged material for environmental benefits.

The environmental opportunities associated with the Bartlett Modification Alternatives include increased flexibility in Horseshoe Reservoir to benefit native habitat and wildlife species and in Bartlett Reservoir to benefit sportfish species. There may also be an opportunity to create additional riparian habitat and to utilize a portion of the additional New Verde Space water supply for fish and wildlife purposes.

8.4.3 Flood Control

Consideration should be given to alternatives that provide the opportunity to attenuate peak flood flows downstream of Bartlett Dam that may impact the Phoenix Metropolitan Area. The Without Action Alternative would not provide additional storage space for flood control and no additional freeboard would be provided to help manage flood surcharges occurring above conservation space.

An estimated 45,749 AF of incidental water storage volume would be provided with the Sediment Removal Alternative. Though intentional flood control water storage capacity may not be provided with this alternative, the additional volume provided could be considered slightly advantageous for the flood control selection criteria. No additional freeboard would be provided with this alternative.

The Bartlett Modification 1 and 2 Alternatives propose constructing a new dam immediately downstream of and abutting the existing Bartlett Dam. The new dam would enlarge the Bartlett Reservoir system to restore lost capacity, mitigate future sediment impacts on storage capacity, add conservation storage, and increase flood control capacity and/or outlet works.

Approximately 352,000 AF for Bartlett Modification 1 and 146,000 AF for Bartlett Modification 2 of additional water storage capacity would be provided. Though intentional flood control water storage capacity may not be provided with the Bartlett Modification Alternatives, the additional volume provided could be considered significantly advantageous for the flood control selection criteria. An additional 25 feet of freeboard above the NMWSE would be provided with these alternatives; a portion of this freeboard could be dedicated for flood control.

There may also be an opportunity with the Bartlett Modification 1 and 2 Alternatives to use existing Horseshoe Dam and Reservoir to attenuate peak flows during flood events. Horseshoe Dam is expected to remain intact but have run-of-river operations using the river outlet works. During large inflow events, Horseshoe Dam will store inflows that exceed reservoir outlet work capacities until water elevations reach the spillway crests. For water elevations above the spillway crests, Horseshoe Dam spillway gates can be operated to attenuate peak flows and aid downstream flood operations.

8.4.4 Dam Safety

Though the removal of accumulated sediment from the Horseshoe Reservoir would restore approximately 45,749 AF of incidental water storage volume with the Sediment Removal Alternative, there would be no improvement to the existing safety of the dam. However, the dam was improved in the 1990s, so there is no associated negative risk regarding dam safety with the

selection of this alternative. After sediment removal, compromised storage space would be restored under this alternative, thus incidentally improving overall dam safety.

The Bartlett Modification 1 and 2 Alternatives propose constructing a new dam, outlets, gates, and auxiliary spillways immediately downstream of and abutting the existing Bartlett Dam. The new dam would restore lost capacity to the Bartlett Dam and Reservoir system and increase dam safety. Approximately 341,000 AF for Bartlett Modification 1 and 135,000 AF for Bartlett Modification 2 of incidental water storage capacity would be provided, which could be considered significantly advantageous for the dam safety selection criteria. This alternative would provide an additional 25 feet of freeboard above the NMWSE, which could also be considered advantageous for improving dam safety.

Though there are no Safety of Dams corrective actions identified for Bartlett Dam, there may be benefits from the Safety of Dam perspective of proactively replacing the nearly century-old structure with a dam of modern construction that meets all current engineering design and safety standards. Further study at feasibility could also evaluate the hydrologic changes that could occur with changing climates that may warrant improvements to outlet works, including replacing the existing fuseplug auxiliary spillway with spillways that are designed using current engineering practices.

8.4.5 Recreation Opportunities

The Recreation Focus Group examined the potential increase, decrease, or no change to availability of recreation opportunities based on changes to several factors, including miles of shoreline, acres of reservoir surface area, and accessibility to recreation opportunities. Based on these criteria, there would be no change in recreation opportunities for the Without Action and Sediment Removal alternatives.

The Bartlett Modification 1 and Bartlett Modification 2 alternatives would both have an increase in miles of shoreline, which could potentially result in more shoreline camping and camping from boat access. Both Bartlett Modification alternatives would also result in an increase in reservoir surface acres, and based on average capacity per surface area, more on-water activities could occur due to this increase. Some recreation facilities and access roads would likely be inundated with the increased elevation of Bartlett Lake and could potentially need to be relocated. With the projected increase in water and land-based recreation, changes to existing roads and parking would be necessary to accommodate the increased usage. When designing replacement facilities, consideration should be given to increased parking availability, road access to accommodate the potential increase in visitors, improved road surface or wider lanes, and addition of bike lanes for improved cyclist safety.

If hydropower were produced and made available to recreation sites, more amenities (i.e., restaurants, marinas, boat launches, camping cabins, etc.) and boat and watercraft rentals could be made available in response to increased recreation visitors.

Construction may impact several recreation areas around the reservoir. Evaluation of whether these areas can remain open during construction and how and when they may be impacted by higher water levels should be considered during the feasibility phase of the study.

8.4.6 Hydropower

There is opportunity for hydropower for the Bartlett Modification 1 and 2 Alternatives. A detailed description of possible benefits from hydropower are provided in Section 8.1.1.2 and Appendix F.

8.4.7 Federal Partnership Opportunities

There are potential opportunities for the Federal government, if authorized, to partner to acquire water supplies that could be used to meet current or future obligations. Many of these obligations are likely related to the settlement of Indian water rights claims.

9 Economic Analysis of Benefits and Cost

The purpose of a project plan is to identify a means to improve conditions in the human environment or to fill an existing or future need. Economic analysis is required as a part of the planning process to determine whether investments identified in the plan would generate benefits in excess of costs, and financial analysis is required to determine whether a plan could be funded. Because this study is conducted at an appraisal level, these analyses reflect what is achievable with the existing data, and are intended as a framework for a more detailed study if project planning proceeds to the feasibility level.

This section of the report describes methods, data sources, and results of the economic assessment. The results of the financial analysis are reflected in the Affordability criteria evaluation in Section 7.9, and the supporting analysis is included in Appendix D. Generally, the Sediment Removal alternative is not economically viable, and would be of questionable affordability. Bartlett Modifications 1 and 2 are estimated to produce benefits in excess of their costs, which are likely to fall within the beneficiaries' ability to pay.

9.1 Benefit-Cost Analysis

As described in the PR&Gs, "The objective of a national economic benefit-cost analysis is to evaluate the derived/estimated economic benefits and costs of an action and its effects on society." This section applies that guidance to compare and contrast future outcomes with and without each alternative, based on the estimated costs and benefits displayed in Table 26. Each subsection below will discuss an element of Table 26, which includes unquantified costs and benefits (represented by colors and symbols) that were identified by stakeholders through the focus group process. The color green with an ↑ symbol indicates stakeholder expectations for positive impacts, while red with a ↓ symbol indicates expectations for negative impacts. The color yellow with an ⇅ symbol reflects areas of uncertainty, or expectations by participants for both positive and negative impacts simultaneously, which could be clarified through additional study.

Table 26. Beneficial and Adverse Effects by Alternative (2021\$ as of the end of the construction period, EOY 2030)

Component	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Beneficial Effects			
Direct User Benefits			
Water Supply	\$ 296,220,000	\$ 3,760,570,000	\$1,891,920,000
Hydropower	\$ -	\$ 76,200,000	\$ 70,640,000
Recreation	↑	↑	↓
Flood Control	↓	↑	↑
Water Quality	↓	↑	↑
Subtotal	\$ 296,220,000	\$ 3,836,770,000	\$1,962,560,000
External Economies			
Avoided Social Cost of CO ₂	\$ -	\$ 25,500,000	\$ 23,140,000
Total Beneficial Effects	\$ 296,220,000	\$ 3,862,270,000	\$1,985,700,000
Adverse Effects			
Implementation Outlays			
Construction Costs	\$ 928,174,359	\$ 955,181,001	\$ 784,290,949
Interest During Construction	\$ 124,693,175	\$ 125,270,932	\$ 102,313,152
O&M	\$ 28,798,678	\$ 35,110,257	\$ 35,110,257
Subtotal	\$1,081,666,212	\$1,115,562,191	\$ 921,714,358
Associated Costs	\$ -	\$ -	\$ -
Other Direct Costs/Externalities			
Groundwater Loss	↓	↓	↓
Fugitive Dust	↑	↓	↓
Total Adverse Effects	\$1,081,666,212	\$ 1,115,562,191	\$ 921,714,358
Methods of Comparison			
Net Benefits	\$ (785,446,212)	\$ 2,746,707,809	\$1,063,985,642
Annualized Net Benefits	\$ (21,452,012)	\$ 75,017,750	\$ 29,059,447
Benefit-Cost Ratio	0.27	3.46	2.15

The PR&Gs “require an analysis of water projects in terms of the expected change in ecosystem service flows over time. Ecosystem goods and services are those things provided by nature that are of use to humans.” Many of Reclamation’s standard statutorily authorized project purposes, such as water supply, hydropower, and recreation, are ecosystem goods or services. VRSMS focus group and stakeholder sessions requested feedback on other identifiable ecosystem services and existing research, which this study could use to broaden our assessment of the effects of each alternative. The feedback received included references to the following sources:

- Auberle et al. (2009) deployed a survey tool on Verde River ecosystem services to 35 people knowledgeable about the watershed who identified nearly 500 qualitative values, mostly in

the categories of provisioning use and cultural use, which were intended to support future valuation studies.

- Gunkel et al. (2015) identified the unique aspects of reservoirs in semi-arid regions (Brazil), but with the exception of “carbon assimilation by biomass and sediments” the quantified or monetized ecosystem services align with existing Reclamation benefit categories.
- Hornung et al. (2019) linked various river and floodplain management measures to ecosystem services (Germany), characterizing flood retention areas and dams as having an ambiguous impact on many ecosystem services. However, dams were judged to have a strong positive effect on water supply, strong negative effects on mass flow/sediment regulation and habitat maintenance, and negative effects on soil formation in floodplains and local temperature regulation/cooling. Links to cultural services were judged to have weak scientific certainty.
- The Economics of Ecosystems and Biodiversity (TEEB, 2010) Valuation Database³ provides metadata and citations for a collection of ecosystem services research papers. For studies within the United States, it produces values for fresh water ecosystem goods and services that reflect existing Reclamation benefit categories; the one study on a desert ecosystem concerns willingness to pay for creating new national parks in desert areas of California, which was judged to be contextually irrelevant to the VRSMS study site.
- The Ecosystem Services Valuation Database (ESVD, 2020)⁴ is a follow-up to TEEB, with different studies for freshwater and desert ecosystems (one) in the United States, but similarly irrelevant or non-transferrable results.

Studies of the VRSMS alternatives at a greater level of detail could consider facilitating primary research to strengthen our understanding of additional ecosystem goods and services in the study area.

9.1.1 Calculation of Benefit Estimates

The PR&Gs describe how, “Economic values represent the utility (welfare or satisfaction) received or lost by an individual or society resulting from peoples’ preferences and their resource utilization. The general measurement standard of the value of goods and services is defined as the willingness to pay for each increment of output from a plan.” Reclamation benefit-cost analyses have traditionally categorized benefits by direct user benefits and indirect benefits or positive externalities.

9.1.1.1 Water Supply

The estimated economic benefits of the water supply that could result from the VRSMS action alternatives, relative to the Without Action alternative, are fully described in Appendix K and summarized in Table 27 below.

³ <http://www.teebweb.org>

⁴ <https://www.es-partnership.org/esvd/>

Table 27. Water Supply Benefits Summary

	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Total (100-Year) Estimated Water Supply Benefit	\$296,220,000	\$3,760,570,000	\$1,891,920,000
Annualized Water Supply Benefit (at 2.5% Discount Rate)	\$8,090,325	\$102,708,232	\$51,671,889
Annual Average Surface Water Delivery Change from Without Action (Acre-Feet per Year) ÷	10,000	115,000	60,000
Water Supply Benefit per Acre-Foot =	\$809	\$893	\$861
Present Value Lifecycle Water Supply Cost per Acre-Foot of Yield (Across all Storage Accounts) -	\$1,076	\$93	\$147
Water Supply Net Benefit per Acre-Foot =	-\$267	\$800	\$714

The water supply benefits were estimated based on the extent of future shortages in the region and the ability of each alternative to mitigate those future shortages for all users. This framework does not identify individual beneficiaries of the water supply created by the VRSMS action alternatives; instead, it uses a regional supply and demand framework to estimate the benefit for the region as a whole.

Under the Without Action conditions, renewable water shortages are anticipated in the region, which is expected to put upward pressure on the price of water, adversely affecting water users. Projections of annual supply and demand for central and southern Arizona, developed using the Central Arizona Project Service-Area Model (CAPSAM) as part of the West Salt River Valley Basin Study, are used to model the Without Action price effects associated with future water shortages. The water volume provided by each alternative, as modeled for the VRSMS, is then used to estimate the benefit of additional water supply, which comes from comparing annual price effects under the Without Action condition to price effects under each action alternative across a 100-year period of analysis from 2031 to 2130.

The benefit/cost analysis in Table 26 presents the water supply benefit estimate for each action alternative that corresponds to CAPSAM Scenario B and a price elasticity of demand of 0.5. Scenario B is characterized by a hot dry climate and intermediate urban growth, which was judged by the Economics Focus Group Core Team to be a reasonable set of assumptions across the range of possible future conditions. A price elasticity of demand of 0.5 is reasonably supported by literature, considering that the VRSMS is analyzing the benefits of wholesale water. The full range of water supply benefit estimates for each action alternative is provided in Appendix K, and present value lifecycle water supply costs per acre-foot are further described in Appendix D.

9.1.1.2 Hydropower

Reclamation's 2011 *Hydropower Resource Assessment at Existing Reclamation Facilities* identified existing Bartlett Dam as having reasonable potential for economically and financially viable hydropower

production. As part of the VRSMS, two installed generating capacities were evaluated – 6.1 megawatts (MW) and 10.6 MW, based on supporting analysis performed by HDR Inc. The two generating capacities were modeled by SRP staff in the Aurora production cost model to estimate benefits and avoided carbon emissions relative to a thermal powerplant. The results for the 10.6 MW facility are presented in Table 28; the full economic assessment is provided in Appendix F.

Grid-scale hydropower has never been justifiable as a stand-alone project at Bartlett Dam due to direct costs outweighing benefits over the economic recovery period for a private entity, which is exacerbated by the lack of local transmission interconnection. The economic analysis shows that there is potential for economical hydropower for all four alternatives; however, the Without Action and Sediment Removal alternatives have no proposed ground disturbance activities at the Bartlett Dam site, so these two alternatives were identified as non-viable by the Economics Focus Group due to larger barriers to initiating construction of a stand-alone power plant versus construction as part of a proposed dam modification. Bartlett Modification 1 shows the greatest opportunity for creation of overall benefits while Bartlett Modification 2 provides the second largest potential benefit. Since the two Bartlett Modification options already include significant ground disturbance activities at the dam site, hydropower could likely be cost-effectively integrated with construction and operations of those two alternatives (compared to the Without Action and the Sediment Removal alternatives).

Table 28. National Economic Development (NED) Benefits and Benefit-Cost (BC) Ratios for 10.6 MW Generating Facility (Excluding Social Cost of Carbon Dioxide [CO₂])

	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
NED Benefits (Millions)	\$66.65	\$76.20	\$70.64
BC Ratio	1.46	1.70	1.58

9.1.1.3 Recreation

A 2019 study by Southwick Associates for Audubon Arizona, The Economic Contributions of Water-related Outdoor Recreation in Arizona: A Technical Report on Study Scope, Methods, and Procedures, found that approximately 28 percent of Arizona residents engage in water-based outdoor recreation in the state, or about 1.5 million people, who collectively spend 48 million days outside per year. Reclamation's forthcoming West Salt River Valley Basin Study Economic and Trade-off Analysis provides more insight about the use of these data in economic benefit evaluation, combining them with consumer surplus estimates from the USGS Benefit Transfer Toolkit⁵ and Oregon State University's Recreation Use Values Database⁶ to derive consumer surplus per visitor day for 19 activities, many of which are potentially relevant to the VRSMS impact area. These draft values, which (on the median) range from \$13.80 for camping to \$142.80 for small game hunting, could be used to monetize impacts of the VRSMS alternatives if sufficiently detailed visitation data were available.

⁵ <https://sciencebase.usgs.gov/benefit-transfer/>

⁶ <http://recvaluation.forestry.oregonstate.edu/>

A study for the Arizona Game and Fish Department (Fedler, Anthony and Responsive Management for the Arizona Game and Fish Department 2014) surveyed licensed anglers about their angling-related travel and expenditures to estimate the economic impacts of fishing in Arizona for 2013. For Bartlett Lake, direct expenditures were reported as \$57,606,044, generating \$14,503,600 in salaries and wages, supporting 758 jobs, and producing \$2,971,126 in state tax revenue. Annual user days for the entire Verde River were reported as 592,263, but user days by site were not reported.

A feasibility-level study of the VRSMS alternatives should consider collecting primary data about recreation visitation in the area and further quantifying the economic effects of changes in recreation opportunities from the action alternatives.

9.1.1.4 Flood Control

The Bartlett Modification 1 and 2 Alternatives likely produce some economically significant flood control benefits, particularly in the context of dam safety. Flood control impacts were not estimated for this appraisal study, pending future work by Reclamation. The Bartlett Modification 1 and 2 Alternatives include use of Horseshoe Dam as a flood control structure, so those operations are reflected in the VRSMS hydrologic modeling, but future study should determine to what extent those operations help avoid structural damage or loss of life downstream.

9.1.1.5 Water Quality

Quantifying the water quality benefits of the action alternatives is challenging in scope; however, the Economics Core Team considered a 2005 City of Phoenix boil water event as a case study. On January 25, 2005, the City of Phoenix and Maricopa County issued a Boil Water Advisory for all areas served by the City of Phoenix water supply after heavy runoff into the SRP system resulted in water arriving at city water treatment plants with up to 40 times more turbidity (or suspended sediment) than is typical. Suspended sediments interfere with the water treatment process, harboring pathogens that can cause widespread waterborne illness. This event happened to coincide with an annual maintenance outage where water treatment plant capacity was already reduced and system flexibility was limited, producing what staff describe as a ‘perfect storm’. Ultimately, the Boil Water Advisory was in place for about two days.

The Economics Core Team reviewed a number of studies (Chyzheuskaya, et al. 2017, Wagner, Wallstrom and Onisko 2005, Ailes, et al. 2013) on the economic cost of boil water advisories, generally finding that one dollar per person per day is not an unreasonable value, making the economic cost of a boil water advisory \$1,000,000+ per day for the City of Phoenix. Chang (2016) summarizes research that “has established the criticality of electrical power and water services, for example, and the heightened vulnerability of certain population groups⁷ to infrastructure disruption. Omitting the socioeconomic impacts of infrastructure disruptions can lead to underinvestment in disaster mitigation.”

The increased Verde River storage capacity provided by the Bartlett Modification 1 and 2 Alternatives, and to a lesser extent by the Sediment Removal Alternative, has the potential to reduce the magnitude and frequency of future turbidity events by increasing retention time in the reservoir system and reducing peak flood events, enabling more sediments to settle out of the water column.

⁷ Chang (2016) further identifies these ‘certain population groups’ as “...the elderly, children, linguistic minorities, and low-income households.”

Additional storage on the Verde River could provide SRP with system-wide operational flexibility, potentially mitigating the impact of turbid runoff events on the Salt River system. The magnitude of the benefit is difficult to estimate at this time, considering water treatment plant improvements made by the City of Phoenix in and since 2005⁸, and the fact that not all heavy runoff events occur above Horseshoe or Bartlett Reservoirs. However, the *Verde River Watershed Report Card Methods Report on Data Sources, Calculation, and Additional Discussion* (March 2020) states that data collected by the City of Phoenix for the Val Vista Water Treatment Plant indicate that since 2007, an average of 0.88 “undesirable” turbidity events have occurred each year. It is not clear whether these undesirable events impose an operational cost that could be mitigated by the VRSMS action alternatives. Additionally, an estimate of the recurrence frequency of damaging or untreatable turbidity events, determined at a more detailed level of study, could be multiplied by the economic costs of boil water advisories to estimate end-user water quality benefits for the VRSMS alternatives.

9.1.1.6 Avoided Social Cost of Carbon Dioxide

The January 20, 2021 Executive Order on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis⁹ contains the following section on greenhouse gas emissions, which informed the VRSMS hydropower analysis:

“Sec. 5. Accounting for the Benefits of Reducing Climate Pollution. (a) It is essential that agencies capture the full costs of greenhouse gas emissions as accurately as possible, including by taking global damages into account. Doing so facilitates sound decision-making, recognizes the breadth of climate impacts, and supports the international leadership of the United States on climate issues. The “social cost of carbon”, “social cost of nitrous oxide”, and “social cost of methane” are estimates of the monetized damages associated with incremental increases in greenhouse gas emissions. They are intended to include changes in net agricultural productivity, human health, property damage from increased flood risk, and the value of ecosystem services. An accurate social cost is essential for agencies to accurately determine the social benefits of reducing greenhouse gas emissions when conducting cost-benefit analyses of regulatory and other actions.”

In February 2021, the Interagency Working Group on the Social Cost of Greenhouse Gases set interim values for the social cost of carbon dioxide. Installation of hydropower as part of a modification of Bartlett Dam would satisfy a portion of the SRP service area’s projected future power demand which otherwise may be met with fossil fuel generation. The projected reduction in emissions provides an indirect public benefit, independent of the direct use of power. The estimated avoided carbon emissions for a 10.6 MW facility and the associated monetized avoided social cost of carbon dioxide are provided in Table 29 and further discussed in Appendix F. Feasibility-level study of the VRSMS action alternatives should seek to monetize the greenhouse gas emission impacts, in terms of both benefits and costs, of all relevant construction and operation activities over the lifecycle of each alternative.

⁸ Some of the treatment plant improvements were made as a result of incoming water quality issues, representing a cost associated with the current state of river control. Not all treatment plants have the same capabilities as the upgraded Val Vista Water Treatment Plant.

⁹ <https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/20/executive-order-protecting-public-health-and-environment-and-restoring-science-to-tackle-climate-crisis/>

Table 29. Avoided Social Cost of Carbon Dioxide Emissions

	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Total Avoided Carbon Emissions (Metric Tons)	467,232	567,092	514,481
Avoided Social Cost of Carbon (Millions)	\$21.01	\$25.50	\$23.14

9.1.2 Calculation of Cost Estimates

9.1.2.1 Implementation Outlays

Implementation outlays include any expenses incurred by Federal or local participants in the implementation of a project. These may include construction and other development costs, investment costs and interest during construction (IDC), operation and maintenance (O&M) costs, and costs of environmental compliance.

In accordance with the September 2016 Reclamation guidance document entitled *Time Based Adjustments in Reclamation Economic Analysis*, the Study Period has been defined as the 110 years from 2021 to 2130, with a 10-year Construction Period from 2021 to 2030 and a 100-year Period of Analysis from 2031 to 2130. Streams of future costs identified as implementation outlays for each of the project alternatives were evaluated at the Fiscal Year 2021 Plan Formulation and Evaluation interest rate of 2.5%. One-tenth of the construction costs are assumed to be incurred in each year of the Construction Period. IDC is assessed on one-half of each year's annual construction expenditures and the sum of all previous years' expenditures and IDC accruals. Construction costs and IDC accruals are summed to the end of the Construction Period in 2030, while O&M costs projected over the Period of Analysis are discounted back to the same point in time. Table 26 identifies those present worth project costs in 2021\$ and compares them to present worth benefits as of the end of 2030 at the same price level. Construction and O&M costs were estimated as described in Sections 4 and 7.8, respectively. No replacement costs were included in these estimates as no reliable data was available to inform specific replacement items that would vary between the Without Action and action alternatives.

9.1.2.2 Associated Costs

If any non-project activities are required to achieve the full benefits of a project alternative (such as improvements to a privately-owned distribution system), these costs would be accounted for as associated costs. Further consideration should be given to associated costs for any alternatives considered at the feasibility level.

9.1.2.3 Other Direct Costs/Externalities

Although negative external effects could plausibly result from construction and operation of any of the project alternatives, Reclamation does not use a standard methodology to identify and quantify them. The necessity of gathering primary data to estimate externalities on a case-by-case basis makes this an impractical category for quantification or monetization at the appraisal level. However, stakeholder and focus group feedback reflected concerns in two areas that could be categorized as externalities.

Under the Without Action Alternative, increased groundwater pumping is expected to compensate for losses in surface water yield, resulting in regional groundwater loss and increased pumping costs. Groundwater pumping is discussed from a hydrology perspective in Sections 3.3.2 and 6.2.2, and feasibility-level study could potentially quantify and/or monetize the impacts of changes in groundwater pumping with and without each action alternative.

The exposed sediment mound created by the Sediment Removal Alternative has the potential to negatively impact local and/or regional air quality by generating fugitive dust (unless revegetated). The impact is likely small, compared to the sum of disturbed areas in the nearby metropolitan area, but could potentially be quantified with additional research.

9.1.3 Economic Evaluation of Alternatives

9.1.3.1 Net Benefits

Net Benefits are calculated as the difference between Total Beneficial Effects and Total Adverse Effects, and they must be positive for an alternative to be considered a desirable investment. The best alternative is that which maximizes Net Benefits; in this case, it is the Bartlett Modification 1 Alternative at \$2,746,707,809 (or \$75,017,750 annually). The Bartlett Modification 2 Alternative produces \$1,063,985,642 in estimated Net Benefits (or \$29,059,447 annually), but the Sediment Removal Alternative does not produce positive Net Benefits.

9.1.3.2 Benefit-Cost Ratio

The Benefit-Cost (BC) Ratio is calculated by dividing Total Beneficial Effects by Total Adverse Effects. A quotient greater than one would provide justification for selecting an alternative for further study. In this case, the Bartlett Modification 1 and 2 Alternatives have BC Ratios of 3.5 and 2.2, respectively. The Sediment Removal Alternative has a BC Ratio of 0.3 and is not recommended for further study.

10 Risk and Uncertainty

Assumptions were made in the appraisal study for each alternative to evaluate biological and cultural impacts, economics, engineering, recreation, reservoir operations, and hydrology as well as the requirements of CMP 09-01. Sound engineering, economic, and scientific judgement is the basis of the alternative analysis. However, due to data and information limitations at the appraisal level, many uncertainties could impact the results of evaluations. Risks and uncertainties associated with the alternatives recommended for feasibility study are described below consistent with the requirements of CMP 09-01. These risks and uncertainties are recommended to be further studied, refined, and identified for any feasibility study conducted on these alternatives.

10.1 Hydrology and Climate Change

Expected climate change impacts to hydrology are documented in Section 3.2, and the methodology used to adjust observed hydrology for warming temperatures, decreasing precipitation, and increasing precipitation variability is discussed in Appendix H. However, climate change impacts to

hydrology on the Verde River watershed are ultimately unknown. Uncertainty exists on the magnitude of warming and its impact on atmospheric conditions that drive precipitation type (rain or snow) and seasonal snowpack evolution. The degree and severity of climate change impacts on watershed vegetation, sedimentation, and hydrology are unknown. As climate change science progresses, it will be critical to continually assess impacts to the Verde Reservoir system.

10.2 Water Demand and Use

The SRFRP is a demand driven system and, as such, changes in demand in the future will impact reservoir storage, groundwater pumping, and surface water deliveries from the SRFRP reservoir system. This study assumes an SRP demand (excluding some contracts, NCS, and Phoenix Gateway) of 725,000 AF/yr. This assumption is based on trends in the SRP water service territory over the past decade, but there is uncertainty what the demand will look like over the next 100 years as urban infill occurs, agriculture acres are developed into urban and industrial uses, and water conservation technology and efforts advance. Further understanding of future demand in the SRP water service area will help advance water supply planning in the future.

10.3 Sedimentation Rate and Maintenance

Sedimentation into the Verde Reservoir system has averaged around 1,000 AF/yr since 1979 and this rate is assumed to continue in the analysis for this study. However, sedimentation is highly dependent on hydrology. As climate change impacts precipitation and Verde River flows in the future, sedimentation rates will follow. Land vegetation cover impacted by catastrophic wildfire and climate change will also impact sedimentation rates in the future. There is also uncertainty in the future as Horseshoe Reservoir continues to fill with sediment and the associated sediment loadings impact Bartlett Reservoir. This study assumed that Bartlett Reservoir will start filling with sediment after Horseshoe Reservoir completely fills in. A greater understanding of annual sedimentation loading, deposition, and composition into and through Horseshoe Reservoir and Modified Bartlett Reservoir through detailed quantitative analysis performed at the feasibility level will be needed to comprehend reservoir operations on the Verde system if Bartlett Modifications are implemented and the system is to be re-operated as proposed.

Managing sedimentation deposition in the new infrastructure for Bartlett Modification 1 and 2 Alternatives should also be considered. Outlet works for the Verde River dams capable of sluicing and the development of a sediment management operating program for the system under the Bartlett modifications alternatives may help reduce sediment accumulation in the future but could impact water supply deliveries and operations. Figure 26 shows that Bartlett Modifications 1 and 2 still have significant spill volume and flows in certain years that have potential for use to sluice excess sediments without impacting water supply. Such programs should be analyzed and studied further to evaluate opportunities to manage future sediment accumulations in a water sensitive manner. Feasibility level study should include a quantitative analysis of reservoir hydraulics and sediment composition with the purpose to evaluate the appropriate design of outlet and intake structures and operating conditions for implementing sluicing operations on the modified Verde Reservoir System.

Further study and information required for environmental permitting of sediment passage through the reservoir system will need to be explored if the Bartlett Modification alternatives are explored at the feasibility level. This may include monitoring efforts such as real time measurement of incoming sediment load (using turbidity to quantify sediment load); real time measurement of outgoing sediment load (using turbidity to quantify sediment load); bathymetric surveys performed at regular intervals; chemical testing of the sediment to assure that no naturally occurring or artificial contaminants were present, numerical modeling looking not only at the inflow and outflow in the reservoir but also where the sediment ends up downstream over time; and monitoring of the health of the stream as well as the aquatic life as described above

10.4 Reservoir Operations

Detailed system operations (e.g., river swap timing) have not been determined for the Bartlett Modification 1 and 2 Alternatives and will need to be considered. Operating one Verde Reservoir in conjunction with the Salt Reservoir system may deviate from current operations and impact activities such as dam maintenance and water transmission.

The beneficiaries of the NVS were not determined through the appraisal study. NVS user type and location may influence the timing of deliveries and the volume of NVS water that can be used to offset regional groundwater pumping. These unknowns may also impact overall (Salt and Verde) reservoir system operations. Further evaluation for timing of deliveries should be conducted if beneficiaries of NVS are identified.

10.5 Water Rights

Storing flood water in NVS and putting it to beneficial use requires a right to do so under state or federal law. Such rights could not conflict with prior vested water rights and would also be adjudicated in the Gila Adjudication.

10.6 Engineering and Construction

For Bartlett Modification 1 and 2 Alternatives, geological conditions immediately downstream of the existing Bartlett Dam and the location of a suitable borrow source for the roller compacted concrete are uncertainties that need to be investigated further. Additional geologic and geotechnical information will be required to determine dam cross-sections and to determine the excavation depths required to reach firm stable rock foundations, especially as it relates to the level of weathering in the coarse-grained granite located around Bartlett Dam. The level of weathering in rock may also impact excavation quantities and methods.

Bartlett Dam is in an area of Arizona recognized as having a low rate of seismicity. However, the seismic risk at Bartlett Dam with the Modification alternatives should be evaluated further. There may be an opportunity to exceed existing seismic loading demands with Bartlett Dam improvements, but a complete seismic loading analysis will need to be conducted.

Laboratory physical modeling or computer hydrologic model studies are recommended to minimize uncertainties regarding the calculated flow conditions of the service spillway, flip bucket, and plunge pool. The hydraulics and the erodibility of the rock for the service and auxiliary spillways need additional evaluation to confirm sufficient erosion resistance with selective excavation and armoring requirements, costs, and schedule implications. Sediment abrasion resistance measures should also be investigated for the reservoir outlet works design. Sediment abrasion resistance measures should also be investigated for the reservoir outlet works design. Additional maintenance requirements between Bartlett Modifications 1 and 2 have not been established and are recommended to support better evaluation of long-term costs between these two alternatives.

Uncertainty with dewatering during construction is typically high for modifications to existing dams. Most dewatering efforts will be in channel alluvium, but consideration for dewatering from water pools within the buttresses of the existing dam, and water from ROW releases flowing back upstream through the alluvium will need to be explored.

Further evaluation is needed to determine the integration between the existing structure and the proposed Bartlett Modification alternatives. Considerations should be taken for additional penetrations into the existing buttresses, effects of seasonal temperature fluctuations between the existing and proposed structure, and bonding between the two structures. Public protection risks will need to be evaluated during feasibility for the proposed modifications. These options must be risk neutral based on Reclamation's Dam Safety Public Protection Guidelines.

10.7 Environmental Resources

There are many environmental uncertainties to consider for the alternatives evaluated in this study. All environmental uncertainties will need to be analyzed in greater detail for each alternative moved forward to feasibility. Below are high level uncertainties identified in the appraisal process concerning environmental impacts.

There is limited survey data for many Threatened and Endangered species in the area, which creates uncertainty in the analysis of impacts for each alternative. Survey gaps exist for species such as the northern Mexican gartersnake, yellow-billed cuckoo, Southwestern willow flycatcher, Arizona cliffrose, razorback sucker, and Colorado pikeminnow. Complete survey data may be needed for full analysis of the alternatives moved into feasibility.

The extent (both temporal and magnitude) of potential adverse and beneficial impacts to habitat and species from the Bartlett Dam modifications or the repurposing of Horseshoe Reservoir is also unknown. The extent of potential downstream effects below Bartlett Dam are also unknown. However, it is anticipated that effects would incrementally diminish at or below Granite Reef Dam.

Additionally, it is uncertain if the repurposing of Horseshoe operations would result in a natural sinuosity that may impact plant species, wildlife habitat, and aquatic species. With modifications of the dam and repurposing of Horseshoe Reservoir, non-native species could establish and require management considerations. Additional information is also needed to investigate the potential for aquatic invasive species, e.g., quagga mussels, to establish if Bartlett Reservoir is enlarged. The uncertainty of NVS beneficiaries and their seasonal distribution of deliveries may also impact flows and environmental resources in the Verde River downstream of Bartlett Dam.

10.8 Cultural Resources

There are many risks and uncertainties for cultural resources. The entire Areas of Potential Effect (APE) for cultural resources is based on conceptual data and inundation areas using USGS topographic data. Without a well-defined APE, there is a risk that impacted acres have not been inventoried. A more detailed APE is recommended for the cultural resources analysis in feasibility.

Due to the level of analysis required for an appraisal study, a comprehensive collection, clean-up, review, and ground-truthing of all known cultural resources within this study area was not completed. It is possible that some sites have changed substantially or been destroyed since recordation. Historical-period buildings and structures, other than the two dams listed on the NRHP, were not included in the analysis. Areas that were previously inventoried may require resurvey, and recorded sites may require reassessment in feasibility. While 86 percent of the study area has been inventoried, the inventories are not all current and the data have not been ground-truthed. A more detailed cultural resources inventory may be necessary in feasibility.

There is also an unknown number of cultural resources significant to affiliated tribes within the study area (Traditional Cultural Properties and sacred sites). This analysis may omit some cultural resource types significant to affiliated tribes. Those resources not included will be addressed through formal tribal consultation.

10.9 Land Resources

A desktop review of the inundation zones for the two Bartlett Modification alternatives showed the bounds of both alternatives being within Reclamation withdrawn lands, with the exception of the private land inholdings between Bartlett and Horseshoe reservoirs. Private land inundation is expected from Bartlett Modification 1. Further evaluation of land ownership, jurisdiction, and impacts would be required to understand any necessary acquisition of lands to allow for implementation of either Bartlett Modification alternative.

10.10 Economics

The benefits estimates for increased water supplies for each action alternative are based on assumptions identified as reasonable by the Economics Core Team, using available information and study at the time of analysis. These assumptions should be assessed further in any feasibility level analysis. The actual benefits that result from a project being implemented will ultimately depend on many factors, such as future drought conditions, population growth, water efficiency improvements, price sensitivity, and policy decisions. No replacement costs were estimated for any of the alternatives in this appraisal study since reliable cost estimating information was not available that would allow for distinguishing between alternatives; further effort to estimate appropriate replacement costs should be made for any feasibility analysis of alternatives. Risks and uncertainty also exist about the future return on a hydropower investment at this facility, given the length of the planning period relative to recent and ongoing rapid change in the energy markets. If it is determined that a hydropower facility is a project component being recommended for study in feasibility, further analysis of effects on environmental and cultural resources for the recommended

design location of the powerhouse, outlet works, and transmission infrastructure, as well as the operations of the hydropower facility, will need to be performed.

11 Findings and Recommendations

11.1 Findings

Current research strongly suggests that the changing climate will bring drier and warmer conditions over time with greater variability in river flow and runoff for the Salt and Verde river watersheds. These conditions are expected to result in more extreme drought and pluvial periods. The 2012 sediment survey at Horseshoe Reservoir showed that storage capacity in the reservoir had declined by 45,749 AF since its construction in the 1940s, and has declined at an average rate of 1,010 AFY since 1979.

Modeling for this appraisal study shows that reduced availability of surface water storage capacity on the Verde River increases dependency on groundwater by SRP to meet the demands of contractors and water rights holders within SRP's water service area, despite significant decreases in total water demands on the SRP since 1980. The Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study shows that the carryover capacity in the SRFRP river system, combined with conjunctive management of groundwater supplies, are needed for SRP to successfully manage changes in climate (Bureau of Reclamation 2020). Preserving carryover storage in the SRFRP system is critical to managing the changes in timing and magnitude of precipitation and runoff events expected to come with changing climate conditions in the region. The relatively small size of the Verde River reservoir system results in excess flows from Verde River that frequently spill from the reservoirs and go unused. As runoff events become larger in magnitude, sufficient storage capacity will be necessary to manage the events and put water supplies to beneficial use.

Projected water demand in the lower Colorado River Basin, including central Arizona, is expected to outpace available supply by 3 million acre-feet annually over the next century (Bureau of Reclamation 2012). Meanwhile, Arizona's population is projected to grow to 18.3 million people by 2110, with water demand expected to grow from 6.9 MAFY to up to 10.5 MAFY in 2110 (Arizona Department of Water Resources 2014). Looking at opportunities to adapt to increased scarcity resulting from population growth and changing climate conditions, Reclamation's Colorado River Basin Report completed under Section 9503(c) of the SECURE Water Act identified modified reservoir system operations and new storage facilities similar to those identified in the Bartlett Modification alternatives as potential climate change adaptation strategies to address water supply vulnerabilities in the Colorado River Basin (Bureau of Reclamation 2016).

Changes in availability of Arizona's Colorado River supply due to shortage, changing climate, and increased demands show a need for preserving and augmenting existing renewable water supplies in central Arizona. Though likely technically feasible, the removal of sediment to restore the water storage capacity of SRP and the City of Phoenix has direct and indirect costs that are estimated to outweigh the benefits. The two Bartlett Dam modification alternatives are expected to create benefits that outweigh the costs, with benefit-cost ratios of 3.5 and 2.2 for the 97-foot and 62-foot

raise, respectively. The benefits estimated for the two alternatives include restored and new water supplies, hydropower, and avoided carbon dioxide emissions. Additionally, both dam modification alternatives have potential to create benefits to environmental resources, recreational opportunities, water quality, flood control and safety of dams, but these benefits require further study to fully understand the magnitude of each.

The environmental and cultural due diligence performed in this appraisal study indicates that the impacts to these resources would not preclude the Bartlett Dam modification alternatives from further consideration under feasibility. The effects to environmental and cultural resources for these two alternatives would need to be addressed in a feasibility investigation. Implementation of Bartlett Modification 1 and 2 alternatives are expected to create an additional water supply of 115,000 AFY and 60,000 AFY, respectively. If no action is taken, the opportunity to store and use these water supplies would be forgone and the continued loss of SRP's storage capacity would result in higher SRP groundwater pumping. The City of Phoenix surface water credits created at Horseshoe Reservoir are expected to be 8,000 AFY less if either of the two Bartlett modification options are not implemented. Further, the two Bartlett Dam modification options create an opportunity to develop new conservation storage space that is expected to result in an average annual water yield of 91,000 AFY and 36,000 AFY of renewable surface water for Bartlett Modification 1 and 2, respectively. The additional supplies could result in a net benefit to the regional aquifer of up to 41,000 AFY for the larger dam and 14,000 AFY for the smaller dam, in addition to an expected reduction of SRP groundwater pumping of 14,000 AFY.

11.2 Recommendations

Based on the findings of the appraisal-level analysis, the Bartlett Modification 1 (97-foot raise) and Bartlett Modification 2 (62-foot raise) alternatives appear to be viable and a draft feasibility plan of study has been prepared (Appendix L). Both meet the problem and need of the study and provide significant opportunity for increasing the beneficial use of water supplies from the Verde River and improve the water resiliency of central Arizona under changing climate conditions and water needs. The Sediment Removal alternative is not viewed to be a viable alternative for feasibility study due to low overall criteria scoring, uncertainty relating to the implementability of a sediment removal project of this magnitude at an inland reservoir, and the benefit-cost ratio being less than one. If no action is taken by Reclamation, it is expected that the sediment issues will continue to impact SRP and City of Phoenix conservation storage capacity, resulting in both entities turning to other more costly supplies to supplement lost surface water yields. SRP's most likely alternative supply will come from increased groundwater pumping. Additional water supplies captured in the additional conservation space could be used to offset existing groundwater uses and/or reductions in the availability of Colorado River water. Based on the findings of this appraisal study, it is recommended to:

- 1) Seek/confirm authority to initiate a feasibility study, based on the conclusions of this report, to determine the technical, environmental, economic, and financial feasibility, and impacts on ecological resiliency of implementing measures to restore capacity lost at Horseshoe Reservoir on the SRFRP system due to sedimentation. Additionally, explore opportunities to create additional project benefits, through modification of Bartlett Dam and nonstructural approaches, to enable central Arizona to adapt water management to changing climate conditions.

- 2) Address the following topics during the feasibility study process:
 - a. Identify interested beneficiaries and potential allocation of capacity created by the new storage facility and modified operation, including the appropriateness of dedicated safety of dam or flood control space on the Verde River reservoir system.
 - b. Identify appropriate climate change and hydrologic scenarios for evaluation of the proposed project and operational scenarios.
 - c. Identify appropriate seasonal water delivery scenarios for end users of the capacity created by the project to understand likely reservoir operating plans.
 - d. Evaluate facility modifications at existing Horseshoe Dam and designs for Modified Bartlett Dam needed to implement a water efficient sluicing program for maintaining reservoir capacities.
 - e. Evaluate options to maintain and enhance recreation opportunities in and around the reservoir area.
 - f. Evaluate opportunities for habitat improvement within the footprint of existing Horseshoe Reservoir.
 - g. Complete a constructability evaluation to provide a detailed analysis of possible construction phasing to reduce impacts to SRP operations and water yields during construction.
 - h. Complete a cost allocation to determine appropriate costs to be recovered under appropriate construction authorities.
 - i. Identify appropriate statutory authority, contracts, and agreements for funding, construction, and operation of any facilities identified for construction in feasibility study.
- 2) Develop cost-share agreements between Reclamation and potential beneficiaries for completing the feasibility study of Bartlett Dam modifications and other nonstructural approaches to restore capacity lost at Horseshoe Reservoir.

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13 Appendices

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Appendix B: Existing Environmental Conditions

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Appendix A: Stakeholder Organizations

Verde Reservoirs Sediment Mitigation Study

APPENDIX A Stakeholder Organizations

Agribusiness & Water Council of Arizona	City of Tolleson
Arizona Department of Environmental Quality	Environmental Defense Fund
Arizona Department of Water Resources	EPCOR
Arizona Beef Council	Flood Control District of Maricopa County
Arizona Game & Fish Department	Fort McDowell Yavapai Nation
Arizona Municipal Water Users Association	Friends of the Verde River
Arizona Public Service	Gallagher & Kennedy, P.A.
Arizona State Historic Preservation Office	Gila River Indian Community
Arizona State Land Department	Greater Phoenix Chamber
Arizona State University	Home Builders Association of Central Arizona
Arizona Trout Unlimited	Maricopa Audubon
Arizona Water Company	Montgomery & Interpreter, PLC
Arizona Wildlife Federation	Northern Arizona University
Audubon Society	Roosevelt Irrigation District
Bartlett Lake Marina	Roosevelt Water Conservation District
Buckeye Water Conservation & Drainage District	Rosette, LLP
Carefree-Cave Creek Chamber of Commerce	Salt River Pima-Maricopa Indian Community
Carefree Water Company	Sierra Club
Center for Biological Diversity	The National Audubon Society
Central Arizona Project	The Nature Conservancy
City of Apache Junction	Tonto Apache Tribe
City of Avondale	Town of Carefree
City of Buckeye	Town of Cave Creek
City of Chandler	Town of Gilbert
City of El Mirage	Town of Queen Creek
City of Glendale	Town of Wickenburg
City of Goodyear	University of Arizona
City of Mesa	U.S. Army Corps of Engineers
City of Peoria	U.S. Fish and Wildlife Service
City of Phoenix	U.S. Forest Service
City of Prescott	Valley Partnership
City of Scottsdale	West Valley Water Association
City of Surprise	Western Resource Advocates
City of Tempe	Yavapai-Apache Nation
	Yuma County Water Users' Association

Appendix B: Existing Environmental Conditions

Verde Reservoirs Sediment Mitigation Study
Appendix B
Existing Environmental Resources and Conditions

July 16, 2021

This report summarizes the existing environmental resources and conditions identified by the Environmental Subgroup of the Environmental and Cultural Resources Focus Group for the Verde Reservoirs Sediment Mitigation Study (VRSMS). The Environmental Subgroup has identified 11 environmental categories to evaluate against each alternative. Since this report will be utilized for the evaluation of potential environmental effects associated with the VRSMS alternatives, it was decided that even though a resource could be included in more than one of the environmental categories described below, it would only be considered in one of these categories. This ensured that there was not a duplicative evaluation occurring when applying the evaluation metric for the degree of potential effects to environmental resources. The information within these categories was obtained from existing literature, reports, and collected data. The information collected primarily focused on a geographic area (Study area) that spans from the Verde River just upstream of Horseshoe Reservoir near Sheep's Bridge downstream to the Granite Reef Diversion Dam on the Salt River and approximately one mile from the river's center east and west (Figure 1). If data was not available or was limited within the Study area, it was captured as a data gap.

1.0 Threatened & Endangered Species

Seven species listed as threatened or endangered (T&E) or experimental non-essential under the T&E Species List occur or have the potential to occur in the Study area [US Fish and Wildlife Service (USFWS) 2021].

Fish

The razorback sucker (*Xyrauchen texanus*), Colorado pikeminnow (*Ptychocheilus lucius*), and Gila topminnow (*Poeciliopsis occidentalis*) are listed as endangered under the Endangered Species Act (ESA) (Table 1). However, it is important to note that, in July 2021, USFWS proposed to downlist the razorback sucker from an endangered species to a threatened species.

Razorback suckers have been documented upstream of and within Horseshoe Reservoir [Arizona Game and Fish Department (AZGFD) 2021a]. Additionally, an individual razorback sucker was reported by an angler in the SRP canal suggesting they occasionally make their way through the Study area. They have been stocked upstream of Horseshoe Reservoir as recently as 2020 (SRP 2020). The Study area includes critical habitat for the razorback sucker. Critical habitat for the species encompasses Horseshoe Reservoir and the Verde River for about 120 miles upstream of the reservoir (59 FR 13374-13400).

Colorado pikeminnow have been stocked into the Verde River as recently as 2018 and is considered a nonessential experimental population (SRP 2019). It has been documented in Horseshoe and Bartlett reservoirs, but is considered functionally extirpated (AZGFD 2021a). There is no designated critical habitat for the Colorado pikeminnow in Arizona.

The Study area includes a one-mile, upstream stretch of Lime Creek from its confluence with Horseshoe Reservoir. A reproductive population of Gila topminnow is present in Lime Creek, a tributary to Horseshoe Reservoir (Tony Robinson, AZGFD, personal communication, April 11, 2019). The population of Gila topminnow found within Lime Creek occurs outside the Study area

and is located above a fish barrier found further upstream. No critical habitat has been designated for the Gila topminnow since its listing.



Figure 1. General vicinity map

In addition to these species, the Horseshoe - Bartlett Habitat Conservation Plan (H-B HCP), which covers the operation of Horseshoe and Bartlett dams and reservoirs, includes the endangered spikedace (*Meda fulgida*) and loach minnow (*Tiaroga cobitis*) (SRP 2008 and USFWS 2008). However, these species were not considered in this Study as there are no recent records of their presence in the Verde River and because the most downstream extent of their critical habitat is designated 32 miles upstream from Horseshoe Reservoir.

Table 1. ESA protected fish in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Gila topminnow	Poeciliopsis occidentalis	Shallow shorelines and slackwater areas of small streams, springs, and marshes	LE, SGCN 1A, H-B HCP	Not Present	Not Present	Not Present
Colorado pikeminnow	Ptychocheilus lucius	Turbid, deep, swift waters. Varies: from mainstem channels to slow backwaters of medium and large streams and rivers, sometimes around cover; prefer depths of a meter or more over sand, mud or gravel substrates in impoundments	LE, SGCN 1A, H-B HCP	Known	Rare	Unknown
Razorback sucker	Xyrauchen texanus	Main channel habitats used tend to be low velocity ones such as pools, eddies, nearshore runs, and channels associated with sand or gravel bars. Adjacent to the main channel, backwaters, oxbows, sloughs, and flooded bottomlands are also used.	LE (but recently proposed for downlisting), SGCN 1A, H-B HCP	Known	Unknown	Rare

Source: Arizona Game and Fish Department, September 8, 2020, Online Environmental Review Tool, Project ID: HGIS-12006

Notes: LE = federally listed endangered species

SGCN = State of Arizona Species of Greatest Conservation Need

H-B HCP = species covered by the H-B HCP

Known = species are known to occur in the area based on presence/absence surveys

Unknown = no presence/absence surveys exist, but there is suitable habitat found along or within portions of this location

Not Present = no survey detections or suitable habitat is present within this location

Rare = occasional detection.

Semi-Aquatic and Terrestrial Species

Two avian species and one reptile species protected under the ESA occur or have the potential to occur in the Study area: Southwestern willow flycatcher (*Empidonax traillii extimus*), yellow-billed cuckoo (*Coccyzus americanus*), and northern Mexican gartersnake (*Thamnophis eques megalops*) (Table 2). The cuckoo, flycatcher, and gartersnake are covered under the H-B HCP. An Information, Planning and Conservation System (IPaC) review of the Study area indicated California least tern (*Sterna antillarum browni*), Mexican spotted owl (*Strix occidentalis lucida*) and Yuma Ridgway's rail (*Rallus obsoletus yumanensis*) have the potential to occur within the area (USFWS 2021). However, all three species have been excluded from further consideration for the following reasons:

- There have been no confirmed records of Yuma Ridgway's rail along the lower Verde River or around the Salt River confluence in over 25 years (Troy Corman, AZGFD, personal communication, January 22, 2021). Additionally, suitable habitat for the species does not occur within the area under consideration.
- The least tern has not been documented along or near the Verde River (Troy Corman, AZGFD, personal communication, January 22, 2021).

- The Mexican spotted owl (*Strix occidentalis lucida*) occurs in the Tonto National Forest within designated critical habitat that is over 10 miles from the Verde River. Adult birds generally stay in the forested habitat; juveniles drop down into lower elevations when they fledge, but are not expected to be within the 1-mile distance from the Verde River (Troy Corman, AZGFD, personal communication, January 22, 2021).

Beginning in 2008 and occurring approximately every other year, SRP conducts flycatcher and cuckoo surveys at the upper end of Horseshoe Reservoir. Additionally, in 2013 and 2015, SRP surveyed the entire reach of the Verde River between Horseshoe and Bartlett dams for the Southwestern willow flycatcher (Marc Wicke, SRP, personal communication, January 13, 2021). Flycatcher surveys have also been conducted between Horseshoe Dam and Davenport Wash by the U.S. Forest Service (USFS) in 2011 (Greg Beatty, USFWS, personal communication, January 13, 2021). Arizona Game and Fish Department conducted a limited flycatcher survey in 2020 below Bartlett Dam near Needle Rock Picnic Area in the Tonto National Forest (Greg Beatty, USFWS, personal communication, January 13, 2021). Of the surveyed areas, Southwestern willow flycatchers have been documented breeding upstream of and within Horseshoe Reservoir, between Horseshoe Dam and Bartlett Dam, and below Bartlett Dam. Yellow-billed cuckoos have been recorded breeding north of Horseshoe Reservoir. Cuckoos have also been detected below Bartlett Dam near Needle Rock Picnic Area and Box Bar Recreation Area in the Tonto National Forest (Cornell Lab of Ornithology 2021). Suitable habitat for the cuckoo also occurs downstream of Horseshoe Dam and potentially along the length of the Verde River between Bartlett Dam and Granite Reef Dam.

It is unknown if the northern Mexican gartersnake occurs within the Study area. Suitable habitat for the northern Mexican gartersnake does exist within the perennial stream and wetlands along the Verde River between Horseshoe and Bartlett reservoirs and their tributaries and a segment of the river between Bartlett Dam and Granite Reef Dam.

Critical habitat has been designated in or near the Study area for all three species:

- Southwestern willow flycatcher - critical habitat is located along 4.2 miles of the Verde River just downstream of Horseshoe Dam and along 28.8 miles of the Verde River upstream of Horseshoe Reservoir (78 FR 344–534).
- Yellow-billed cuckoo - critical habitat has been designated along 4.5 miles of the river just downstream of Horseshoe Dam and approximately 33 miles upstream of Horseshoe Reservoir (86 FR 20798-21005).
- Northern Mexican gartersnake - Critical habitat for the northern Mexican gartersnake is designated in the Verde River watershed more than 55 miles upstream of Horseshoe Dam (85 FR 23608–23668).

Table 2. ESA-protected semi-aquatic and terrestrial animal species in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Yellow-billed cuckoo (Western distinct population segment)	<i>Coccyzus americanus</i>	Large blocks of riparian woodlands with broadleaf trees and shrubs or in arid or semiarid landscapes.	LT, FS S, SGCN 1A, H-B HCP, MBTA	Known	Unknown	Known
Southwestern willow flycatcher	<i>Empidonax traillii extimus</i>	Dense cottonwood/willow and tamarisk vegetation along rivers, streams, and wetlands	LE, SGCN 1A, H-B HCP, MBTA	Known	Known	Known
Northern Mexican gartersnake	<i>Thamnophis eques megalops</i>	Source area ponds and cienegas, lowland river riparian forests and woodlands, and upland stream gallery forests	LT, FS S, SGCN 1A	Unknown	Unknown	Unknown

Source: Arizona Game and Fish Department, September 8, 2020, Online Environmental Review Tool, Project ID: HGIS-12006

Notes: LE = federally listed endangered species

LT = federally listed threatened species

FS S = Forest Service sensitive

SGCN = State of Arizona Species of Greatest Conservation Need

MBTA = protected species under the Migratory Bird Treaty Act

H-B HCP = species covered by the H-B HCP

Known = species are known to occur in the area based on presence/absence surveys

Unknown = no presence/absence surveys exist, but there is suitable habitat found along or within portions of this location.

Plants

Arizona cliffrose (*Purshia subintegra*) is the only federally listed plant species that occurs within the Study area (Table 3). It is known to occur along or near the Verde or Salt rivers between Horseshoe Reservoir and Granite Reef Dam. Critical habitat has not been designated or proposed for the cliffrose. The species is known to primarily occur in four distinct areas in Arizona, each of which is considered a separate recovery unit (USFWS 1995). One of these recovery units identifies three areas surrounding Horseshoe Reservoir. Two of these areas are found above Horseshoe Dam while the remaining area occurs between Horseshoe and Bartlett dams. In 2019, the USFS surveyed these three areas and confirmed that the population is persisting (Drew Ullberg, USFS, personal communication, March 4, 2021).

Table 3. ESA-protected terrestrial plant species in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Arizona cliff rose	<i>Purshia subintegra</i>	Calcareous soils of upland limestone lakebed deposits and limestone outcrops.	LE, HS	Known	Known	Known

Source: Arizona Game and Fish Department, September 8, 2020, Online Environmental Review Tool, Project ID: HGIS-12006

Notes: LE = federally listed endangered species

HS = Highly Safeguarded: no collection allowed

Known = species have been recorded along or within portions of this location.

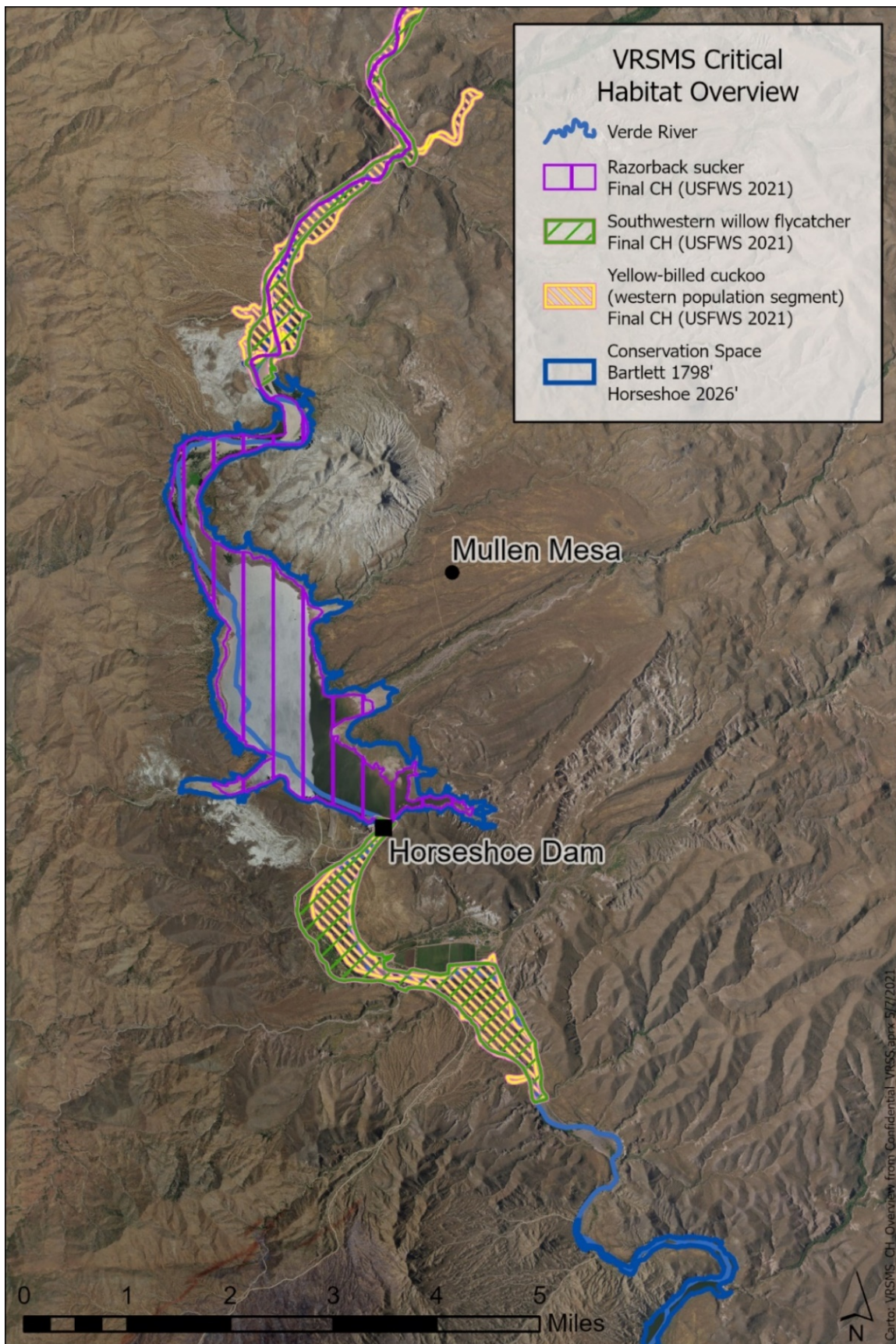


Figure 2. Proposed and designated critical habitat found within the Study area near Horseshoe Reservoir



Figure 3. Proposed and designated critical habitat found within the Study area near Bartlett Reservoir

Data Gaps

Known data gaps for T&E species include:

- Northern Mexican gartersnake - no surveys or monitoring studies have been conducted within the Study area.
- Yellow-billed cuckoo - there is limited survey data for this species. Surveys conducted focused primarily at or above Horseshoe Reservoir.
- Southwestern willow flycatcher - there is limited survey data for this species. Surveys conducted focused primarily at or above Horseshoe Reservoir, between Horseshoe and Bartlett Dams. One isolated survey was conducted near the USFS Needle Rock Picnic Area.
- Arizona cliffrose - limited survey data is available for this species. Surveys have been conducted within the Recovery Unit associated with Horseshoe Reservoir.
- Razorback sucker - there is little understanding as to how Horseshoe Reservoir Operations impact the species. Limited studies exist for the species.
- Colorado pikeminnow - there is little understanding as to how Horseshoe Reservoir Operations impact the species. Limited studies exist for the species.

2.0 Bald & Golden Eagles

Once protected under the ESA, bald eagles (*Haliaeetus leucocephalus*) have since been delisted. However, the bald eagle remains protected in the state under Arizona Revised Statute Title 17, federally under the Bald and Golden Eagle Protection Act, Migratory Bird Treaty Act, Lacey Act, Airborne Hunting Act, and the Convention on International Trade in Endangered Species of Wild Flora and Fauna, and tribally under Salt River Pima Maricopa Indian Community (SRPMIC) Tribal Ordinance SRO-359-2010. The bald eagle is also covered under the H-B HCP. AZGFD, along with various Federal agencies, tribes, and organizations on the Southwestern Bald Eagle Committee, have monitored bald eagle activity in Arizona, including around Bartlett and Horseshoe reservoirs, for many decades. The lower Verde River is the densest area of nesting bald eagles throughout the State of Arizona. The dense area of nesting bald eagles on the lower Verde River is aided by the diversity, accessibility, and continuity of prey resources (Stalmaster 1987 and Hunt et al. 1992) and the abundance of nesting locations in cottonwood trees. As of 2020, 13 breeding areas from Horseshoe Reservoir to Granite Reef Dam are known to be occupied by bald eagles. Of those, the Horseshoe breeding area is located above Horseshoe Dam; Yellow Cliffs, Sheep Creek, and Cliff are between Horseshoe and Bartlett dams; and Needle Rock, Bartlett, Box Bar, Fort McDowell, Doka, Sycamore, Rodeo, Orme and Granite Reef breeding areas are located below Bartlett Dam to above Granite Reef Dam (McCarty, Presler, and Jacobson 2020).

The AZGFD, along with the Southwestern Golden Eagle Management Committee, have monitored golden eagle (*Aquila chrysaetos*) activity in the state, including along the Verde and Salt rivers (McCarty, Presler and Jacobson 2020). One golden eagle breeding area has been documented northwest of Horseshoe Reservoir within the Study area (Kenneth Jacobson, AZGFD, personal communication, January 13, 2021). However, there is limited suitable habitat for nesting within the Study area for golden eagles (Kenneth Jacobson, AZGFD, personal communication, March 3, 2021).

Table 4. Eagles breeding in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Bald eagle	<i>Haliaeetus leucocephalus</i>	Large trees or cliffs near water (reservoirs, rivers, and streams) with abundant prey	SC, SGCN 1A, TS, H-B HCP, MBTA	Known	Known	Known
Golden eagle	<i>Aquila chrysaetos</i>	Open country; nest on rock ledges, cliffs, or in large trees	BLM S, SGCN 1B, TS, MBTA	Known	Not Present	Not Present

Note: SC = USFWS species of concern

BLM S = Bureau of Land Management sensitive

SGCN = State of Arizona Species of Greatest Conservation Need

TS = Tribal sensitive species (for many Tribes affiliated to the land)

MBTA = protected species under the Migratory Bird Treaty Act

H-B HCP = species covered by the H-B HCP

Known = eagle breeding areas occur within this location

Not Present = no known eagle breeding areas occur within this location

3.0 Migratory Birds

Table 5 presents a few of the migratory birds that are known or likely to be present during the breeding season (March 15 through September 15). The table does not include all the breeding birds found within the area; it instead only includes those that were identified using AZGFD's Environmental Online Review Tool (2020), USFWS' IPaC (2021), eBird (Cornell Lab of Ornithology 2021), iNaturalist (2021), and personal communications with Troy Corman at AZGFD (January 28, 2021). There are at least 20 migratory bird species found within the Study area during the breeding season. The summary table excludes those species (i.e. Southwestern willow flycatcher, yellow-billed cuckoo, bald eagle, white-winged dove, and mourning dove) that are covered under one of the other resource categories.

Table 5. Migratory birds associated with the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Adjacent to Bartlett Reservoir	Present Below Bartlett Dam
Gilded flicker	<i>Colaptes chrysoides</i>	Riparian woods and saguaro deserts	SGCN 1B, MBTA	Known	Known	Known	Known
American peregrine falcon	<i>Falco peregrinus anatum</i>	Near cliffs that support sufficient abundance of prey	SC, FS S, BLM S, SGCN 1A, MBTA	Known	Unknown	Known	Known
MacGillivray's warbler	<i>Geothlypis tolmiei</i>	Thickets of willow and alder, near stream bottoms or at edge of coniferous or mixed forest	SGCN 1B, MBTA	Known	Known	Known	Unknown
Virginia's warbler	<i>Leiostyris virginiae</i>	A ground nesting bird under a root or rock or clump of grass in open woodlands.	MBTA	Known	Unknown	Unknown	Unknown

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Adjacent to Bartlett Reservoir	Present Below Bartlett Dam
Gila woodpecker	Melanerpes uropygialis	Low-elevation deserts with woody plants large enough to provide nest sites, including areas with saguaro cactus and cottonwoods	SGCN 1B, MBTA	Known	Known	Known	Known
Abert's towhee	Melospiza aberti	Dense riparian brush	SGCN 1B, MBTA	Known	Known	Known	Known
Brown- crested flycatcher	Myiarchus tyrannulus	Tall sycamores or cottonwoods along streams; also found in open desert with large saguaros	SGCN 1C, MBTA	Unknown	Unknown	Unknown	Known
Lucy's warbler	Oreothlypis liciae	Mesquite along desert streams and washes; willows, cottonwoods	SGCN 1C, MBTA	Known	Unknown	Unknown	Known
Phainopepla	Phainopepla nitens	Riparian bird nests in willows and salt cedar	CCA, MBTA	Known	Known	Known	Known
Yellow warbler	Setophaga petechia	Wet, brushy areas such as willow thickets, field edges	SGCN 1B, MBTA	Known	Unknown	Known	Known
Arizona Bell's vireo	Vireo bellii arizonae	Lowland riparian areas with dense, low, shrubby vegetation	SGCN 1B, MBTA	Known	Known	Known	Known
Gray vireo	Vireo vicinior	Brushy mountain slopes, mesas, open chaparral, scrub oak, and junipers	FS S, SGCN 1C, MBTA	Known	Unknown	Known	Known
Great blue heron	Ardea herodias	Found in almost any aquatic habitat. Calm fresh waters or slow-moving rivers.	MBTA	Unknown	Known	Unknown	Known
Neotropic cormorant	Phalacrocorax brasilianus	Lakes or reservoirs. Dependent on the water levels creating island habitat	MBTA	Unknown	Known	Unknown	Unknown
Double-crested cormorant	Phalacrocorax auritus	Found in almost any aquatic habitat. Dependent on the water levels creating island habitat	MBTA	Unknown	Known	Unknown	Unknown

Note: FS S = Forest Service sensitive

BLM S = Bureau of Land Management sensitive

SGCN = State of Arizona Species of Greatest Conservation Need

MBTA = protected species under the Migratory Bird Treaty Act

Known = species are known to occur in the area based on survey/observation points

Unknown = no survey/observation points were recorded; however, suitable habitat is found along or within portions of this location.

Data Gaps

Not all of the listed species in Table 5 have been confirmed within certain reaches of the Study

area, but suitable habitat does exist within the Study area for these species.

4.0 Other Terrestrial Species and Their Habitat

This category includes terrestrial species not already identified under the T&E species, special status species, eagles, or migratory bird categories, and their habitat, and considers migration corridor(s) that are likely to occur within the Study area. The majority of the species in this category are terrestrial wildlife that provide economic and recreational importance as identified within AZGFD State Wildlife Action Plan (2012); however, the category also includes wintering waterfowl and a undescribed talusnail species has been detected near Bartlett Dam (Sorensen, Brock, and Scobie 2018).

Table 6. Terrestrial Wildlife and Their Habitat in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Adjacent to Bartlett Reservoir	Present Below Bartlett Dam
Gambel's quail	<i>Callipepla gambelii</i>	Dry, semidesert with tall shrubs; adjacent agricultural areas; residential areas with tall shrubs adjacent to water	SERI	Known	Unknown	Known	Known
White-winged dove	<i>Zenaida asiatica</i>	Brushlands, river woods, mesquites, saguaros, and suburban areas with trees	SERI; MBTA	Known	Known	Known	Known
Mourning dove	<i>Zenaida macroura</i>	Urban areas, agriculture fields, and open desert scrub habitats	SERI; MBTA	Known	Known	Known	Known
Mule deer	<i>Odocoileus hemionus</i>	Wide-ranging: grasslands, semideserts, scrublands, forests	SERI	Known	Known	Known	Known
Javelina	<i>Pecari tajacu</i>	Desert, chaparral, oak, grasslands	SERI	Known	Known	Known	Known
Mountain lion	<i>Puma concolor</i>	Desert mountains with broken terrain and steep slopes, along with dense vegetation, caves, rocky crevices that provide shelter	SERI	Known	Known	Known	Known
Bighorn Sheep	<i>Ovis canadensis mexicana</i>	Inhabit alpine meadows, grassy mountain slopes, and foothill country near rugged, rocky cliffs and bluffs	SERI	Unknown	Known	Unknown	Unknown
Undescribed talussnail	<i>Sonorella</i> sp.	Loose, talus slopes, rocky hillsides and ridges, and cracks and fissures of cliff faces.	Not yet designated	Unknown	Unknown	Known	Unknown

Note: SERI = State of Arizona Species of Economic and Recreation Importance

MBTA = protected species under the Migratory Bird Treaty Act

Known = species are known to occur in the area based on survey/observation points

Unknown = no survey/observation points were found; however, suitable habitat is found along or within portions of this location

Not yet designated = a possible new species that has been recorded but not yet designated by AZGFD

Movement/Migration corridors

The Verde and Salt rivers and their tributaries provide a migration and/or movement corridor for wildlife (AZGFD 2011, AZGFD 2013, and USFWS 2009). The riparian or xeroriparian habitats associated with these waterways provide an interconnected network of habitat for wildlife to move through.

Waterfowl

Every three years in January, waterfowl surveys are conducted in Bartlett Reservoir by AZGFD. The following waterfowl, which are protected under the Migratory Bird Treaty Act, were detected at Bartlett Reservoir in the winter of 2020: common goldeneye (*Bucephala clangula*), common mergansers (*Mergus merganser*), pied-billed grebe (*Podilymbus podiceps*), eared grebe (*Podiceps nigricollis*), Clark's grebe (*Aechmophorus clarkia*), horned grebe (*Podiceps auratus*), neotropical cormorant, double-crested cormorant, great blue heron, spotted sandpipers (*Actitis macularius*), belted kingfisher (*Megasceryle alcyon*), ring-billed gull (*Larus delawarensis*), common loon (*Gavia immer*), and surf scoter (*Melanitta perspicillata*) (Troy Corman, AZGFD, personal communication, March 26, 2021). No waterfowl surveys are conducted in Horseshoe Reservoir during the winter due to the low water level associated with the operations of this reservoir at this timeframe.

Data Gaps

Not all of the listed species in Table 6 have been confirmed within certain reaches of the Study area, but suitable habitat does exist within the Study area for these species.

5.0 Other Aquatic Species and their Habitat

This category includes aquatic species that are not T&E or special status species, and their habitat. Overall, this category includes sport fish and aquatic invasive species. The sportfish listed in Table 7 were identified in AZGFD's Bartlett Lake Fishes Management Plan (Gill 2019), but is not inclusive of all the sportfish.

Table 7 also includes aquatic invasive species (AIS). AIS is defined as any aquatic species that is not native to the ecosystem and whose introduction or presence may cause economic or environmental harm or harm to human health. AZGFD has established a list of 18 aquatic invasive species. The only known AIS currently present in the Study area is the apple snail (AZGFD 2021b). Annual removal efforts for the apple snail occur on a short section of the Verde River near the Salt River confluence and on the lower Salt River (Curt Gill and Andy Clark, AZGFD, personal communications, March 8, 2021). Other AIS that pose a threat are golden algae and quagga mussels. Golden alga was first identified in Arizona in April 2005 and has been confirmed in various public and private waters in the greater Phoenix area and in three reservoirs in the Tonto National Forest (Stewart et. al. 2011). Golden algae toxins, in high levels, are lethal to fish and can result in large-scale fish kills. Quagga mussels are capable of causing economic and ecological damage once they become established. Granite Reef Dam Forebay has quagga mussel populations. Quagga mussel veligers have been detected at Bartlett Reservoir, but not in the past few years (Sherri Pucherelli, Bureau of Reclamation, personal communication, February 2, 2021).

Table 7. Other aquatic species and their habitat in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Largemouth Bass	Micropterus salmoides	Prefer spawning areas with a firm bottom of sand, mud or gravel. Adult largemouth bass utilize submerged aquatic vegetation as cover to ambush prey and juvenile or young largemouth use aquatic weeds, tree limbs or submerged log or stumps as cover to escape predation. Dissolved oxygen is also an important hydrological condition essential to largemouth bass habitat.	Sportfish	Known	Known	Known
Flathead Catfish	Pylodictis olivaris	Prefer deep pools of streams, rivers, canals, lakes and reservoirs, where the water is turbid (cloudy) and the currents are slow.	Sportfish	Known	Known	Known
Black Crappie	Pomixis nigromaculatus	Prefer cover, such as such as vegetation, fallen trees or boulders. Often form schools in clear water among vegetation over mud or sand.	Sportfish	Unknown	Known	Unknown

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Apple Snail	Pomacea canaliculata	Thrive in slow-moving fresh water such including ponds, ditches, wetlands, and streams. Feed on a wide range of aquatic plants. Lay egg masses on solid surfaces 20" or less above water surface, with each mass containing 200-600 eggs. Eggs hatch in one to two weeks and release juveniles directly into surrounding environment. They have not been detected above Bartlett Reservoir.	AIS	Unknown	Unknown	Known
Quagga Mussel	Dreissena rostriformis bugensis	Quagga mussels inhabit freshwater rivers, lakes, and reservoirs. In North American populations, they are not known to tolerate salinities greater than 5 ppt (Spidle et al. 1995). Water temperatures of 28°C begin to cause significant mortality, and 32-35°C are considered lethal for dreissenid species (Antonov and Shkorbatov 1990, as cited in Mills 1996). The depth at which the mussels live varies depending on water temperature. They are not generally found in lakes near shore in shallow water due to wave action. The quagga mussel can inhabit both hard and soft substrates, including sand and mud, down to depths of 130 m and possibly deeper.	AIS	Unknown	Unknown	Unknown
Golden Algae	Prymnesium parvum	Golden alga was first identified in Arizona in April 2005. To date, golden alga has been confirmed in various public and private waters in the greater Phoenix area and in three reservoirs in the Tonto National Forest. Golden alga prefers more saline waters, which may help a bloom get started. Although factors such as water temperature and salinity are somewhat helpful in predicting lake conditions suitable for golden alga, there are also many documented exceptions in Arizona and other states.	AIS	Unknown	Unknown	Unknown

Note: Known = species are known to occur in the area based on survey/observation points

Unknown = no survey/observation points were found; however, suitable habitat is found along or within portions of this location.

6.0 Special Status Species

Special status species are sensitive species that are identified in wildlife and land management agency plans. Seventy special status species are known or likely to occur in the Study area (AZGFD 2020a); this value includes all the species found within the other environmental categories. However, not all the special status species found within the Study area are included in Table 8; those species that are identified within another environmental category were excluded. The information in Table 8 was obtained from the H-B HCP, AZGFD's Environmental Online Review Tool, including data from the Heritage Data Management System, and from USFS 1985b and 2019a.

Table 8. Special Status Species in the Study area

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Mammals						
Harris' antelope squirrel	<i>Ammospermophilus harrisi</i>	Rocky desert with cactus and shrubs	SGCN 1B	Known	Known	Known
Pale Townsend's big-eared bat	<i>Corynorhinus townsendii pallescens</i>	Day roosts found in mines and caves from desertscrub up to woodland and coniferous forests; night roosts may be in abandoned buildings; hibernate in cold caves, lava tubes, and mines mostly in uplands and mountains	SC, FS S, BLM S, SGCN 1B	Known	Known	Known
Allen's lappet-browed bat	<i>Idionycteris phyllotis</i>	Ponderosa pine, pinyon-juniper, Mexican woodland and riparian areas of sycamores, cottonwoods and willows; also captured in white fir and in Mojave desertscrub	SC, FS S, BLM S	Known	Known	Known
Western red bat	<i>Lasiurus blossevillii</i>	Riparian and wooded areas	FS S, SGCN 1B	Known	Known	Known
California leaf-nosed bat	<i>Macrotus californicus</i>	Sonoran desertscrub; primarily roosts in mines, caves, and rock shelters	SC, BLM S, SGCN 1B	Known	Known	Known
Arizona myotis	<i>Myotis occultus</i>	Summer: near water in ponderosa pine and oak-pine woodland; along permanent water in riparian areas in some desert areas, including the Verde River	SC, BLM S, SGCN 1B	Known	Known	Known
Fringed myotis	<i>Myotis thysanodes</i>	Deserts, grasslands, and woodlands	SC	Unknown	Unknown	Unknown
Cave myotis	<i>Myotis velifer</i>	Desertscrub of creosote, brittlebush, paloverde, and cacti; roosts in caves, tunnels, mineshafts, under bridges, and sometimes in buildings within a few miles of water	SC, SGCN 1B	Known	Known	Known
Yuma myotis	<i>Myotis yumanensis</i>	Varied upland and lowland habitats, including riparian, desertscrub, moist woodlands, and forests; prefer cliffs/rocky walls near water	SC, SGCN 1B	Known	Known	Known
Pocketed free-tailed bat	<i>Nyctinomops femorosaccus</i>	Desertscrub and arid lowland; roosts in high crevices in rugged canyons; may roost in buildings or under roof tiles	SGCN 1B	Known	Known	Known
Brazilian free-tailed bat	<i>Tadarida brasiliensis</i>	Desertscrub, coniferous forest, and coniferous woodlands	SGCN 1B	Known	Known	Known
Kit fox	<i>Vulpes macrotis</i>	Desertscrub, chaparral, and grasslands	SGCN 1B	Known	Known	Known
Southeastern river otter	<i>Lontra canadensis</i>	Reintroduced to the Verde River above Horseshoe Reservoir years ago, they inhabit the entire Verde River and reservoirs. They live in burrows made by other animals, rock formations, undercut banks, flood debris, and hollow tree logs.	SGCN 1B	Known	Known	Known
Fishes						
Longfin dace	<i>Agosia chrysogaster</i>	Pools with abundant cover. Also found in riffles.	SC, BLM S, SGCN 1B, H-B HCP	Unknown	Unknown	Unknown

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Desert sucker	<i>Catostomus clarkii</i>	Rapids/flowing pools of streams/ rivers primarily over bottoms of gravel- rubble with sandy-silt in the interstices	SC, FS S, BLM S, SGCN 1B, H-B HCP	Known	Known	Known
Sonora sucker	<i>Catostomus insignis</i>	Varied: warm-water rivers to trout streams	SC, FS S, BLM S, SGCN 1B, H-B HCP	Known	Known	Known
Roundtail chub	<i>Gila robusta</i>	Cool to warm water, mid-elevation streams and rivers where typical adult microhabitat consists of pools adjacent to swifter riffles and runs	SC, FS S, BLM S, SGCN 1A, H-B HCP	Known	Unknown	Unknown
Speckled dace	<i>Rhinichthys osculus</i>	Rocky riffles, runs, and pools of headwaters, creeks, and small to medium rivers: rarely in lakes	SC, BLM S, SGCN 1B, H-B HCP	Unknown	Unknown	Unknown
Reptiles						
Gila spotted whiptail	<i>Aspidoscelis flagellicauda</i>	Pinyon-juniper and oak woodlands, chaparral, and riparian woodland extensions into desert-grassland ecotones	SGCN 1B	Known	Unknown	Unknown
Variable sandsnake	<i>Chilomeniscus stramineus</i>	Upland desertscrub; washes or drainages with fine to coarse sand and leaf litter; can be above or below upland elevation	SGCN 1B	Known	Known	Known
Sonoran whipsnake	<i>Coluber bilineatus</i>	Upland desertscrub foothills and mountains, semidesert grassland, interior chaparral, Madrean evergreen woodland, Great Basin conifer woodland	SGCN 1B	Known	Known	Known
Tiger rattlesnake	<i>Crotalus tigris</i>	Upland desertscrub foothills/mountains, interior chaparral, Madrean evergreen woodland	SGCN 1B	Known	Known	Known
Sonoran Desert tortoise	<i>Gopherus morafkai</i>	Primarily rocky (often steep) hillsides and bajadas of Sonoran desertscrub but may encroach into desert grassland, juniper woodland, interior chaparral habitats, and even pine communities; washes and valley bottoms may be used in dispersal	CCA, FS S, BLM S, SGCN 1A	Known	Known	Known
Banded Gila monster	<i>Heloderma suspectum cinctum</i>	Sonoran Desert; undulating rocky foothills, bajadas, canyons	SC, SGCN 1A	Known	Known	Known
Reticulate Gila monster	<i>Heloderma suspectum suspectum</i>	Sonoran Desert; undulating rocky foothills, bajadas, canyons	SGCN 1A	Known	Known	Known
Gila monster	<i>Heloderma suspectum</i>	Sonoran Desert; undulating rocky foothills, bajadas, canyons	SGCN 1A	Known	Known	Known
Desert mud turtle	<i>Kinosternon sonoriense sonoriense</i>	Springs, creeks, ponds, waterholes of intermittent streams	BLM S, SGCN 1B	Unknown	Unknown	Unknown
Sonoran coral snake	<i>Micruroides euryxanthus</i>	Above flats in or near rocky or gravelly drainages, mesquite-lined washes, and canyons; upland desert/bajadas with diverse soil types	SGCN 1B	Known	Known	Known

Common Name	Scientific Name	Habitat	Status	Present Above Horseshoe Dam	Present Between Horseshoe and Bartlett Dams	Present Below Bartlett Dam
Regal horned lizard	<i>Phrynosoma solare</i>	Valleys and on rocky bajadas within Arizona upland desertscrub, Chihuahuan desertscrub, and semidesert grassland	SGCN 1B	Known	Known	Known
Saddled leaf-nosed snake	<i>Phyllorhynchus browni</i>	Upland desertscrub in association with alluvial soils and bajadas, sometimes Lower Colorado River desertscrub flats	SGCN 1B	Unknown	Known	Known
Bezy's night lizard	<i>Xantusia bezyi</i>	Crevice dweller of large rock outcroppings, cliff faces, and boulder fields, Arizona upland desertscrub, interior chaparral, and woodland communities	SGCN 1B	Unknown	Known	Known
Amphibians						
Arizona toad	<i>Anaxyrus microscaphus</i>	Upland desert and evergreen woodlands	SC, BLM S, SGCN 1B	Known	Known	Known
Sonoran desert toad	<i>Incilius alvarius</i>	Sonoran/Chihuahuan Desertscrub, Semidesert Grassland, Madrean Evergreen Woodland; breeds in temporary pools formed by monsoon rains	SGCN 1B	Known	Known	Known
Lowland leopard frog	<i>Lithobates yavapaiensis</i>	Sonoran Desertscrub, Great Basin Conifer Woodland, Madrean Evergreen Woodland; permanent/semipermanent water; riparian areas, ponds, cienegas, springs, cattle tanks, wetlands, and ditches	SC, FS S, BLM S, SGCN 1A, H-B HCP	Known	Known	Known
Insects						
Maricopa tiger beetle	<i>Cicindela oregona</i> Maricopa	Commonly on sandy stream banks and less commonly on gravels and clays along streambanks; may occur near seeps or reservoir banks	SC	Unknown	Unknown	Unknown
Plants						
Hohokam agave	<i>Agave murpheyi</i>	Benches or alluvial terraces on gentle bajada slopes above major drainages in desert scrub.	SC, FS S, BLM S, HS	Unknown	Unknown	Unknown
Cochise sedge	<i>Carex ultra</i>	Moist soil near perennially wet springs and streams; undulating rocky-gravelly terrain	FS S, BLM S	Known	Known	Known
Arizona agave	<i>Agave arizonica</i>	Open, rocky slopes and mesas in Sonoran desertscrub, chaparral, or juniper grassland.	HS	Unknown	Unknown	Unknown
Ripley wild buckwheat	<i>Eriogonum ripleyi</i>	Tertiary lakebeds on well-drained powdery soils derived from limestone, sandstone, or volcanic tuffs and ashes	SC, FS S, SR	Known	Unknown	Known
Senator Mine alumroot	<i>Heuchera eastwoodiae</i>	Found on moist shaded slopes in ponderosa pine forests and canyons	FS S	Known	Unknown	Unknown
Horseshoe deer vetch	<i>Lotus mearnsii</i> var. <i>equisolensis</i>	Desert scrub growing on late tertiary lacustrine deposits	FS S	Known	Known	Unknown
Rusby's milkwort	<i>Rhinotropis rusbyi</i>	Desert grassland and juniper woodland	FS S	Known	Unknown	Known

Note: CCA = U.S. Fish and Wildlife Service Candidate Conservation Agreement species
LE = federally listed endangered species

LT = federally listed threatened species
 SC = USFWS species of concern
 FS S = Forest Service sensitive
 BLM S = Bureau of Land Management sensitive
 SGCN = State of Arizona Species of Greatest Conservation Need
 HS = Highly Safeguarded: no collection allowed
 SR = Salvaged Restricted: collection only with permit
 H-B HCP = species covered by the H-B HCP
 Known = species are known to occur in the area based on H-B HCP, AZGFD's Environmental Online Review Tool, and USFS reports
 Unknown = no survey/observation points were found; however, suitable habitat is found along or within portions of this location.

Data Gaps

Not all of the listed species in Table 8 have been confirmed within the Study area, but suitable habitat does exist within the Study area for these species.

7.0 Visual Resources

Scenic character is defined as the combination of physical, biological, and cultural images that gives an area its scenic identity and contributes to its sense of place. It provides a frame of reference from which to determine scenic attractiveness and to measure scenic integrity (36 CFR 219.9). The Tonto National Forest is currently in the process of transitioning to using the scenery management system (SMS). The SMS provides a systematic approach for determining the relative value and importance of scenery in National Forest lands.

Currently, a Visual Management System is being used on the Tonto National Forest. Visual resources are defined as all seen areas from travel routes, use areas, and water bodies (USFS 1974). The Study area occurs within Management Area 1E of the Tonto National Forest Land Management Plan (1985). Management Area 1E encompasses the Verde River from Sheep Bridge south to the Tonto National Forest boundary and includes both Horseshoe and Bartlett reservoirs. The USFS visual quality objective for this management area is 'retention' which allows for management activities that are not visually evident.

Data Gaps

The Tonto National Forest is currently developing the various inventories required by SMS. Once the inventories are approved, the Forest Service will develop Scenic Integrity Objectives, which will guide the management of scenery resources.

8.0 Vegetation and Land Cover

An ecological system classification based on Lowrey et al. (2005) and the U.S. Geological Survey (USGS) (2005 and 2011) has been applied to accurately classify vegetation associations and other land cover types within the Study area. Classification of existing vegetation was achieved by a desktop analysis assessing the entire Study area, field-based accuracy assessments performed from prior helicopter and pedestrian surveys (i.e., on-the-ground surveys), and subsequent vegetation community boundary and classification revisions. Additionally, dominant and common plant species and species assemblages were documented based on prior field surveys.

Sonoran Paloverde-Mixed Cacti Desert Scrub

The Sonoran Paloverde-Mixed Cacti Desert Scrub ecological system occurs on hillsides, mesas and upper bajadas in southern Arizona. The vegetation is characterized by a three to 15-meter tall emergent tree layer of saguaro (*Carnegiea gigantea*) and/or a sparse canopy of xeromorphic deciduous and evergreen tall shrubs co-dominated by yellow paloverde (*Parkinsonia microphylla*) (USGS 2016). Within the Study area, this ecological system occurs on the high terraces of the Verde River and extend to the hillslopes and hilltops surrounding the Verde River

and Bartlett Reservoir. The density of saguaro cactus was observed to be highest on hillslopes with reddish colored soils. Other common community constituents observed within this system include burrobrush (*Ambrosia salsola*), velvet mesquite (*Prosopis velutina*), ocotillo (*Fouquieria splendens*), catclaw acacia (*Senegalia greggii*), triangle bur ragweed (*Ambrosia deltoidea*), fairyduster (*Calliandra eriophylla*), littleleaf ratany (*Krameria erecta*), pale desert-thorn (*Lycium palidum*), jojoba (*Simmondsia chinensis*), and a diverse array of cacti. The sparse herbaceous layer of this system is comprised of perennial grasses and forbs with annuals seasonally present and occasionally abundant.

The National Vegetation Classification (NVC) plant alliances and/or associations observed within the Sonoran Paloverde-Mixed Cacti Desert Scrub ecological system during field surveys include:

- *Ambrosia deltoidea* / *Simmondsia chinensis* Shrubland (CEGL000953)
- *Simmondsia chinensis* - *Parkinsonia microphylla* Shrubland (CEGL000983)
- *Acacia greggii* - *Parkinsonia microphylla* Shrubland (CEGL001340)
- *Carnegiea gigantea* / *Prosopis velutina* Wooded Shrubland (CEGL001389)

North American Warm Desert Wash

The North American Warm Desert Wash ecological system is restricted to intermittently flooded washes or arroyos that dissect bajadas, mesas, plains, and basin floors throughout the warm deserts of North America. Although these washes are often dry, they are defined by intermittent fluvial processes, which are often associated with rapid sheet and gully flow. This desert wash system occurs as linear or braided strips within desert scrub or desert grassland (USGS 2016). In the Study area, this system occurs within and along ephemeral drainages entering the Verde River and Bartlett Reservoir. Vegetation was observed to be variable within this system, ranging from sparse and patchy at steep upper reaches of the ephemeral drainages to moderately dense along and within lower reaches and in areas with a gentler gradient. Common shrubs and small trees observed in this system include burrobrush, catclaw acacia, velvet mesquite, arroyo willow (*Salix lasiolepis*), desertbroom (*Baccharis sarothroides*), mulefat (*Baccharis salicifolia*), Parish's desert-thorn (*Lycium parishii*), yellow paloverde, and blue paloverde (*Parkinsonia florida*).

The NVC plant alliances and/or associations observed within the North American Warm Desert Wash ecological system during field surveys include:

- *Acacia greggii* - *Parkinsonia microphylla* Shrubland (CEGL001340)
- *Prosopis velutina* - *Acacia greggii* Ruderal Shrubland (CEGL001388)
- *Acacia greggii* Wash Shrubland (CEGL005390)

North American Warm Desert Riparian Mesquite Bosque

The North American Warm Desert Riparian Mesquite Bosque ecological system consists of low-elevation (<1100 meters) riparian corridors found along streams in valleys of southern Arizona. Dominant trees typically include honey mesquite (*Prosopis glandulosa*) and velvet mesquite, both of which tap groundwater below the streambed when surface flows stop and are dependent upon the annual rise in the water table for growth and reproduction (USGS 2016). In the Study area, velvet mesquite is the dominant tree, forming dense thickets on lower terraces of the Verde River and tall shrublands on high terraces. Common shrubs observed within this system include burrobrush, yellow paloverde, mule fat, desertbroom, and catclaw acacia.

The NVC plant alliances and/or associations observed within the North American Warm Desert Riparian Mesquite Bosque ecological system during field surveys include:

- *Prosopis velutina* - *Acacia greggii* Ruderal Shrubland (CEGL001388)
- *Prosopis velutina* / *Muhlenbergia porteri* Ruderal Shrubland (CEGL001391)

North American Warm Desert Riparian Woodland and Shrubland

The North American Warm Desert Riparian Woodland and Shrubland ecological system consists of low-elevation (<1200 meter) riparian corridors along medium to large perennial streams throughout canyons and desert valleys of the southwestern United States. The vegetation is a mix of riparian woodlands and shrublands. A dynamic system, the plant species showing high fidelity within this system are dependent on annual or periodic flooding, associated sediment scour, and/or the annual rise in the water table for growth and reproduction. Accordingly, the dominant plant alliances and associations within this system vary with 1) the frequency, intensity, duration and timing of flow, including its often extreme inter-annual variability; 2) the relative contributions of rainfall, snowmelt, and diffuse groundwater and spring discharges to flow; 3) water temperature and chemistry; 4) channel substrate and form; 5) the extent of the hyporheic zone (ground-surface water interface/transitional area); and 6) drainage network connectivity. These latter conditions, in turn, vary with elevation, latitude and longitude, channel gradient, floodplain width (a function of topography and geology), and surrounding geology and land cover. In addition to the woodland and shrubland components of this system, sparsely vegetated alliances and associations are also common, representing an early seral state of this riparian system (USGS 2016).

Riparian forests are the dominant expression of the North American Warm Desert Riparian Woodland and Shrubland system within the Study area, with Goodding's willow providing the dominant overstory cover on low terraces and Fremont cottonwood (*Populus fremontii*) providing dominant overstory cover on high/abandoned terraces. Most riparian shrubland components of the system are comprised of sapling Goodding's willow but patches of narrowleaf willow (*Salix exigua*) and sparsely vegetated scour and depositional areas are common. The heterogeneity of this system contributes to high levels of structural heterogeneity within the riparian zones of the Study area. Other species observed within the Study area include yellow paloverde, blue paloverde, boxelder (*Acer negundo*), Arizona ash (*Fraxinus*

velutina), Arizona sycamore (*Platanus wrightii*), mule fat, desertbroom, velvet mesquite, burrobrush, arroyo willow (*Salix lasiolepis*), common buttonbush (*Cephalanthus occidentalis*), tamarisk (*Tamarix chinensis*), and a variety of aquatic and semi-aquatic grasses, sedges (*Carex* spp.), and rushes (*Juncus* spp.).

The NVC plant alliances and/or associations observed within the North American Warm Desert Riparian Woodland and Shrubland ecological system during field surveys include:

- *Populus fremontii* / *Baccharis salicifolia* Riparian Woodland (CEGL000941)
- *Populus fremontii* - *Salix gooddingii* Riparian Woodland (CEGL000944)
- *Populus fremontii* - *Salix gooddingii* / *Baccharis salicifolia* Riparian Forest (CEGL002683)
- *Salix gooddingii* Riparian Woodland (CEGL002743)
- *Tamarix* spp. Ruderal Riparian Shrubland (CEGL003114)
- *Baccharis salicifolia* Riparian Shrubland (CEGL003549)
- *Arundo donax* Riverbank Ruderal Wet Meadow (CEGL004101)
- *Salix exigua* / Barren Warm Desert Wet Shrubland (CEGL005655)

Introduced Riparian and Wetland Vegetation

The Introduced Riparian and Wetland Vegetation classification represents vegetation communities dominated (typically > 60 percent canopy cover) by introduced species. These are spontaneous, self-perpetuating, and not (immediately) the result of planting, cultivation, or human maintenance. Land occupied by introduced vegetation is generally permanently altered (converted) unless restoration efforts are undertaken. Specifically, land cover is significantly altered/disturbed by introduced riparian and wetland vegetation (USGS 2016). The dominant introduced riparian and wetland vegetation observed within the Study area is comprised several monotypic stands of giant reed (*Arundo donax*) located a short distance downstream of Horseshoe Reservoir.

Alluvium

The alluvium classification is technically a component of the North American Warm Desert Riparian Woodland and Shrubland ecological system (USGS 2016). However, it represents a unique early seral system-state and distinct habitat component and is consequently addressed separately here. The alluvium system state represents areas recently disturbed by depositional and scouring events of the Verde River. Its occurrence is limited to the Verde River floodway and it increases in prevalence in the areas immediately abutting the Verde River's active channel. Vegetation within this system-state is typically sparse and dominated by disturbance adapted species such as mule fat and desert broom.

The NVC plant alliances and/or associations observed within the alluvium classification of the North American Warm Desert Riparian Woodland and Shrubland ecological system during field surveys include:

- *Baccharis salicifolia* Riparian Shrubland (CEGL003549)
- *Salix exigua* / Barren Warm Desert Wet Shrubland (CEGL005655)

Undifferentiated Barren Land

Undifferentiated barren land has been classified as undisturbed lands with less than five percent overall perennial vegetation cover. The lack of vegetation cover within this classification is

typically correlated to undeveloped or otherwise poor soils and/or steep slopes. It does not include sites which could support vegetation community development but have been subject to recent disturbance (USGS 2016). The plant species found in undifferentiated barren land include some common highly adaptable weedy species but can also include species with special adaptations to unique site conditions, such as halophytes colonizing saline soil sites.

Open Water

Open water within the Study area includes Bartlett and Horseshoe reservoirs and the Verde River. (Refer to Water Factors for additional discussion.)

Agricultural Land/Cultivated Cropland

Areas used for the production of annual crops, such as corn, alfalfa, wheat, and cotton. Includes lands being actively tilled. There is an active agricultural operation approximately 1.3 miles south of Horseshoe Dam. Additionally, there are actively tilled fields paralleling the western bank of the Verde River within the Fort McDowell Yavapai Nation Reservation. Agricultural operations preclude the natural successional processes of vegetation community development (USGS 2016).

Invasive Plant Species

Invasive species that could occur within the Study area include but are not limited to the following species found in Table 9.

Table 9. Common invasive species found across Tonto National Forest

Russian knapweed (<i>Acroptilon repens</i>)	Weeping lovegrass (<i>Eragrostis curvula</i>)
Jointed goatgrass (<i>Aegilops cylindrica</i>)	Lehmann's lovegrass (<i>Eragrostis Lehmanniana</i>)
Tree of heaven (<i>Ailanthus altissima</i>)	Leafy spurge (<i>Euphorbia esula</i>)
Camelthorn (<i>Alhagi maurorum</i>)	Sweet resinbush (<i>Euryops subcarnosus</i>)
Giant reed (<i>Arundo donax</i>)	Dyer's woad (<i>Isatis tinctoria</i>)
Onionweed (<i>Asphodelus fistulosus</i>)	Kochia (<i>Kochia scoparia</i>)
Wild oats (<i>Avena fatua</i>)	Oxeye daisy (<i>Leucanthemum vulgare</i>)
Black mustard (<i>Brassica nigra</i>)	Dalmatian toadflax (<i>Linaria dalmatica</i>)
Asian mustard (<i>Brassica tournefortii</i>)	Yellow toadflax (<i>Linaria vulgaris</i>)
Rescuegrass (<i>Bromus catharticus</i>)	Purple loosestrife (<i>Lythrum salicaria</i>)
Ripgut brome (<i>Bromus diandrus</i>)	Yellow sweetclover (<i>Melilotus officinalis</i>)
Japanese brome (<i>Bromus japonicus</i>)	Oleander (<i>Nerium oleander</i>)
Red brome (<i>Bromus rubens</i>)	Globe chamomile (<i>Oncosiphon piluliferum</i>)
Downy brome (<i>Bromus tectorum</i>)	Scotch thistle (<i>Onopordum acanthium</i>)
Globe-podded hoary cress (<i>Cardaria draba</i>)	African rue (<i>Peganum harmala</i>)
Hairy white-top (<i>Cardaria pubescens</i>)	Buffelgrass (<i>Pennisetum ciliare</i>)
Plumeless thistle (<i>Carduus acanthoides</i>)	Fountain grass (<i>Pennisetum setaceum</i>)
Musk thistle (<i>Carduus nutans</i>)	Karoo bush (<i>Pentzia incana</i>)
Southern sandbur (<i>Cenchrus echinatus</i>)	Japanese knotweed (<i>Polygonum cuspidatum</i>)
Field sandbur (<i>Cenchrus spinifex</i>)	Sulfur cinquefoil (<i>Potentilla recta</i>)
Spotted knapweed (<i>Centaurea biebersteinii</i>)	Pyracantha (<i>Pyracantha</i> sp.)
Diffuse knapweed (<i>Centaurea diffusa</i>)	African sumac (<i>Rhus lancea</i>)
Malta starthistle (<i>Centaurea melitensis</i>)	Russian thistle (<i>Salsola kali</i> & <i>S. tragus</i>)
Yellow starthistle (<i>Centaurea solstitialis</i>)	Mediterranean sage (<i>Salvia aethiopsis</i>)

Rush skeletonweed (*Chondrilla juncea*)
Blue mustard (*Chorisporea tenella*)
Canada thistle (*Cirsium arvense*)
Bull thistle (*Cirsium vulgare*)
Field bindweed (*Convolvulus arvensis*)
White bietou (*Dimorphotheca cuneata*)
Common teasel (*Dipsacus fullonum*)
Russian olive (*Eleagnus angustifolia*)
Quackgrass (*Elymus repens*)

Arabian schismus (*Schismus arabicus*)
Mediterranean grass (*Schismus barbatus*)
Wild mustard (*Sinapis arvensis*)
Five-stamen tamarisk (*Tamarix chinensis*)
Smallflower tamarisk (*Tamarix parviflora*)
Salt cedar (*Tamarix ramosissima*)
Siberian elm (*Ulmus pumila*)
Periwinkle (*Vinca major*)

Data Gaps

Vegetation and land cover from just downstream of Bartlett Reservoir to Granite Reef Dam has not been field verified.

9.0 Jurisdictional Waters and Water Quality

There are wetlands and other aquatic features within the Study area that may be regulated under Section 404 of the Clean Water Act (CWA). Aquatic features that may be jurisdictional and within the federal government's authority to regulate under the CWA include territorial seas and traditional navigable water, perennial and intermittent tributaries, certain lakes and ponds, and impoundments of jurisdictional waters, and adjacent wetlands (USACE 2020a). Classification of aquatic resources (wetland, riverine, and open water systems) was conducted during a desktop analysis of the area from Horseshoe Reservoir to the Verde River below Bartlett Dam, field-based accuracy assessments performed from helicopter and pedestrian surveys (i.e., on-the-ground surveys) in 2018, and subsequent system boundary and classification revisions. In addition, dominant and common plant species and species assemblages were documented during field surveys and used to classify the mapped wetland system types. A description of the aquatic resources identified within the Study area is provided in the following sections.

Wetlands

The wetlands within the Study area are classified as palustrine; this classification includes all nontidal wetlands dominated by trees, shrubs, persistent and nonpersistent herbaceous plants, emergent mosses, or lichens (Cowardin et al. 1979). Palustrine wetlands also include aquatic habitats that are less than 20 acres in size, lack active wave-formed or bedrock shoreline features, have less than 6 feet of water at the deepest part, and have salinity due to ocean-derived salts below 0.5 percent.

Palustrine Forested Wetlands

Palustrine forested wetlands are characterized by a dominance of woody vegetation with a diameter at breast height (DBH) greater than or equal to three inches. Palustrine forested wetlands occur within the riparian corridor along the Verde River and in small pockets within intermittent tributaries of the Verde River. Goodding's willow and Fremont cottonwood are the dominant overstory species. Typical understory species include narrowleaf willow, mule fat, desertbroom, velvet mesquite, burrobrush, common buttonbush, tamarisk, and a variety of aquatic and semi-aquatic grasses, sedges, and rushes.

Scrub-Shrub Wetlands

Palustrine scrub-shrub wetlands are dominated by woody vegetation with a DBH of less than three inches. Woody vegetation used to classify scrub-shrub wetlands typically includes true

shrubs, young trees, and trees or shrubs that are small or stunted because of environmental conditions. Scrub-shrub wetlands occur within the riparian corridor spanning the Verde River and in small pockets within intermittent tributaries of the Verde River. Within the Study area, common shrubs of this wetland classification include narrowleaf willow, desertbroom, common buttonbush (*Cephalanthus occidentalis*), and tamarisk. The typically sparse herbaceous understory was observed to contain a variety of aquatic and semi-aquatic grasses, sedges, and rushes.

Palustrine Emergent Wetlands

Palustrine emergent wetlands are characterized by erect, rooted, herbaceous hydrophytes, excluding mosses and lichens. This vegetation is present for most of the growing season in most years. Palustrine emergent wetlands within the Study area are comprised primarily of introduced species. Wetlands occupied by introduced vegetation generally are permanently altered (converted) unless restoration efforts are undertaken. The dominant introduced riparian and wetland vegetation within the Study area is monotypic stands of giant reed (*Arundo donax*) located both within low-flow areas and along the fringe of the Verde River.

Streams

Stream features are broadly classified as either perennial, intermittent, or ephemeral based on flow regime. The definition of each of these classifications is provided below. Lateral extent of streams (riverine systems) is determined using stream geomorphology and vegetation response to the dominant stream discharge (USACE 2008). The upstream extent of riverine systems is generally defined as the point where the presence of bed and bank and an ordinary high-water mark ceases.

Perennial Streams

Perennial riverine features flow continuously year-round. Perennial streams are primarily supported by groundwater. Precipitation run-off is supplemental to stream flow and is not essential. Within the Study area, the perennial reaches include the Verde River perennial from Sheep's Bridge to approximately 6 miles downstream of Bartlett Dam, and the Salt River from the confluence with the Verde River downstream to the Granite Reef Diversion (ADEQ 2021c).

Intermittent Streams

Intermittent riverine features flow continuously during certain times of the year and more than in direct response to precipitation. Rainfall and snowpack melts supplement stream flow during dry periods. Within the Study area, the Verde River is intermittent from approximately 6 miles downstream of Bartlett Dam to the confluence with the Salt River (ADEQ 2021c).

Ephemeral Streams

Ephemeral riverine features flow only in direct response to precipitation. Within the Study area, ephemeral streams are characteristically linear or braided strips within desert scrub or desert grassland. Vegetation is variable, ranging from sparse and patchy at steep upper reaches of the ephemeral drainages, to moderately dense along and within lower reaches and in areas with a gentler gradient. Common shrubs and small trees observed in this system include burrobrush, catclaw acacia, velvet mesquite, arroyo willow, desertbroom, mulefat, Parish's desert-thorn, yellow paloverde, and blue paloverde. Ephemeral streams and washes are no longer regulated as jurisdictional waters under the Clean Water Act (USACE 2020a).

Open Water

The U.S. Army Corps of Engineers (USACE) classifies certain lakes, ponds, reservoirs, and impoundments of jurisdictional waters as non-wetland open water features (USACE 2020b). Open water features generally have no rooted-emergent or woody plant species present in

permanently inundated areas and the substrate is not technically defined as soil that would support vegetation (USACE 1987). Large reservoirs are classified as lacustrine systems, which include wetlands and deepwater habitats with all the following characteristics: 1) situated in a topographic depression or a dammed river channel; 2) lacking trees, shrubs, persistent emergents, emergent mosses, or lichens with greater than 30 percent areal coverage; and 3) total area exceeds 8 ha (20 acres) (Federal Geographic Data Committee 2013). Bartlett and Horseshoe reservoirs are the only lacustrine feature within the Study area.

Water Quality

The Arizona List of Unique Waters [Arizona Administrative Code R18-11-112(E)] and the Arizona 2016 and 2018 Section 303(d) lists of Impaired and Not Attaining Waters were reviewed to determine whether any unique or impaired waters are present. No Outstanding Arizona Waters (i.e. unique waters) occur within the Study area (State of Arizona 2019). Bartlett Reservoir has been identified as an impaired water under the Environmental Protection Agency's (EPA) Section 303(d) impaired waters list for mercury, and approximately 6.5 miles on the Verde River below Bartlett Dam is impaired for arsenic [[Arizona Department of Environmental Quality (ADEQ) 2017 and ADEQ 2021b].

Data Gaps

There is no approved Wetland and Jurisdictional Delineation from the USACE for the Study area. ADEQ is in the process of evaluating all options to protect Arizona surface waters not considered jurisdictional waters of the U.S. (WOTUS) under the Navigable Waters Protection Rule, dated June 22, 2020. When conferring with USACE on the VRSMS, the lower Verde River and portions of the Salt River down to Granite Reef Diversion Dam are anticipated to be jurisdictional (Kathleen Tucker, USACE, personal communications, February 2, 2021); therefore, it was assumed that construction activities would be occurring within the WOTUS.

10.0 Air Quality

Air quality is determined by the ambient concentrations of pollutants that are known to have detrimental effects on human health. Pursuant to the Clean Air Act (CAA), EPA has established National Ambient Air Quality Standards (NAAQS) for six air pollutants: ozone, airborne particulate matter (PM 10 and PM 2.5), carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead. Areas of the country with air quality that does not meet the standards are designated "nonattainment areas" by the EPA. The nonattainment designation subjects an area to regulatory control of pollutant emissions under the CAA so that attainment of the NAAQS can be achieved within a specified period. Areas that were in nonattainment, but are currently in compliance with NAAQS, are called maintenance areas.

The Study area falls within Maricopa and Yavapai Counties. While no non-attainment areas are designated within Yavapai County, Maricopa County has two, one for PM 10 and the other for ozone (ADEQ 2020). Within the Study area, the ozone non-attainment area spans from the middle of the Horseshoe Reservoir down to the Granite Reef Diversion Dam. The PM 10 non-attainment area stretches from Bartlett Reservoir to the Granite Reef Diversion Dam. Additionally, the portion of the Study area within the Fort McDowell Yavapai Nation Reservation is located in the Phoenix Carbon Monoxide Maintenance Area.

11.0 Special Designations

The Tonto National Forest Draft Land Management Plan recommends establishing the Horseshoe Botanical Area to protect habitat for the Arizona cliffrose and other rare, endemic, sensitive, and at-risk plant species that occur on limestone outcrops near Horseshoe Reservoir (USFS 2019a and 2019b). The Botanical Area would consist of two subareas, one located on the southwest side of Horseshoe Reservoir just west of Horseshoe Recreation and

Campground Area (between Horseshoe Dam and Lime Creek), and the other located at the north and northeast sides of the Reservoir at Chalk Mountain.

One Important Bird Area (IBA) occurs within the Study area: Salt-Verde Ecosystem IBA. The Verde River reach of the IBA occurs within the Study area; it stretches from Childs, Arizona to the confluence with the Salt River. The ornithological significance associated with this IBA is due to the density of bald eagle breeding areas along with the presence of various federally listed species and state species of conservation status (Audubon 2021).

The Tonto National Forest's Mazatzal Wilderness is east and mostly adjacent to a portion of the Study area, from Sheep Bridge to Bartlett Reservoir (USFS 1985 and USFS 2021). One recommended USFS wilderness area, referred to as Indian Butte, is immediately adjacent to, but outside the Study area. The recommended wilderness area occurs west of Bartlett Reservoir, but is outside the Bureau of Reclamation's withdrawn land boundaries (USFS 2019a and 2019b).

Four grazing allotments occur within the Study area on the Tonto National Forest (USFS 1975; USFS 1982; USFS 1985b).

Table 9. USFS grazing allotments in the Study area

Allotment Name	Occurs at or Above Horseshoe Dam	Occurs between Horseshoe and Bartlett Dams	Occurs below Bartlett Dam
Bartlett			x
St Clair		x	
Sears Club / Chalk Mountain	x	x	

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Appendix C: Cultural Resource Data Sources

Verde Reservoirs Sediment Mitigation Study

Appendix C: Cultural Resources Data Sources

Data from the following sources were used to calculate the number acres previously surveyed, identify the number of cultural resources previously recorded in the study area, and contextualize recorded cultural resources in relation to broader research themes. The following list was adapted from Hesse et al. 2021.

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Appendix D: Financial Analysis



— BUREAU OF —
RECLAMATION

Verde Reservoirs Sediment Mitigation Study

Appendix D: Financial Analysis

Salt River Project, Arizona

Interior Region 8: Lower Colorado Basin

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Verde Reservoirs Sediment Mitigation Study

Appendix D: Financial Analysis

Salt River Project, Arizona
Interior Region 8: Lower Colorado Basin

prepared by

Economics Focus Group Core Team
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Abbreviations

AF – Acre-Feet

CAP – Central Arizona Project

EPA – United States Environmental Protection Agency

M&I – Municipal and Industrial

NED – National Economic Development (benefits)

UOF – Use of Facilities (method of cost allocation)

SCRB – Separable Cost-Remaining Benefits (method of cost allocation)

SRP – Salt River Project

VRSMS – Verde Reservoirs Sediment Mitigation Study

1.0 Introduction

The primary purpose of the Verde Reservoirs Sediment Mitigation Study (VRSMS) action alternatives is water supply. Reflecting trends in central Arizona and future water demands, the majority of which are projected to be municipal and industrial (M&I), this financial analysis uses M&I-specific metrics guided by Reclamation Manual Directives and Standards WTR 11-02, *Title XVI Financial Capability Determination Process*, which is currently the only policy document reflecting the principles of Reclamation Technical Memorandum Number EC-2009-02, *Evaluating Economic and Financial Feasibility of Municipal and Industrial Water Projects*. The study's metrics reflect an analysis of bond ratings, debt service coverage ratios, socioeconomic indicators of the project region, water service affordability, water cost comparison, and a qualitative consideration of rate shock.

Because specific beneficiaries have not been identified for the water supply produced by the VRSMS action alternatives, the analysis has been adapted to broadly characterize the financial position of the ratepayers and M&I water purveyors throughout the potential beneficiary area (which varies slightly in these analyses according to the availability of data). Generally, there is broad financial capability to fund the Bartlett Modification 1 and 2 Alternatives, but there are affordability concerns with the Sediment Removal Alternative. The financial analyses documented in this appendix informed the scoring of each alternative under the Affordability evaluation criterion, which is described in Section 7.9 of the main report.

A discussion of irrigation ability to pay is contained in Section 2.9 of this appendix. The financial prospects for hydropower are discussed in Section 8.1.1.2 of the main report and Appendix F.

2.0 Financial Analysis

2.1 Bond Ratings

A primary analysis under WTR 11-02 reviews a project sponsor's bond rating or issuer credit rating and assigns it a High or Medium score for investment grade products, or an Unacceptable score for speculative products. For this study, ratings were retrieved from Standard and Poor's, Moody's, and/or Fitch Ratings, as applicable, either directly from the rating agencies' websites or as reported in water agencies' financial statements. The bond ratings of every water agency reviewed under this study (Apache Junction, Avondale, Buckeye, Cave Creek, Chandler, El Mirage, Gilbert, Glendale, Goodyear, Litchfield Park, Mesa, Paradise Valley, Peoria, Phoenix, Queen Creek, Scottsdale, Salt River Project [SRP], Sun City, Surprise, Tempe, Guadalupe, Tolleson, Tucson, Wickenburg, and the Water Infrastructure Finance Authority of Arizona) would be classified as High. This indicates that even under adverse conditions, the capability of these entities to meet their financial obligations is strong. The data are available upon request.

2.2 Debt Service Coverage Ratios

Calculation of debt service coverage ratios is normally performed along with a financial statement review as a part of primary financial analysis. That level of analysis for every M&I water purveyor in the metropolitan area was inconsistent with the objectives of financial analysis for the VRSMS, but debt service coverage ratios self-reported by each water purveyor were reviewed. In the context in which they were reported in each water purveyor's financial statements, all appeared to be positive indicators, but they were calculated in a variety of different ways, yielding numbers that are not comparable. Future analysis of a smaller pool of potential beneficiaries should make use of the standard debt service coverage ratio formula in WTR 11-02, which is Net Cash Operating Income divided by Annual Debt Service.

2.3 Unemployment Rate

A secondary financial analysis under WTR 11-02 covers socio-economic indicators for the project region, which vary in importance depending on the primary source of revenue for the project. The unemployment rate and median household income (see Section 2.4 below) are more important if the project is funded through fees and water charges. As shown in Figure 1 below, the unemployment rate for the Phoenix-Mesa-Scottsdale Metropolitan Statistical Area (MSA) has remained below the State of Arizona average with a declining or stable trend over the last 10 years, which is classified as "Good" in WTR 11-02.

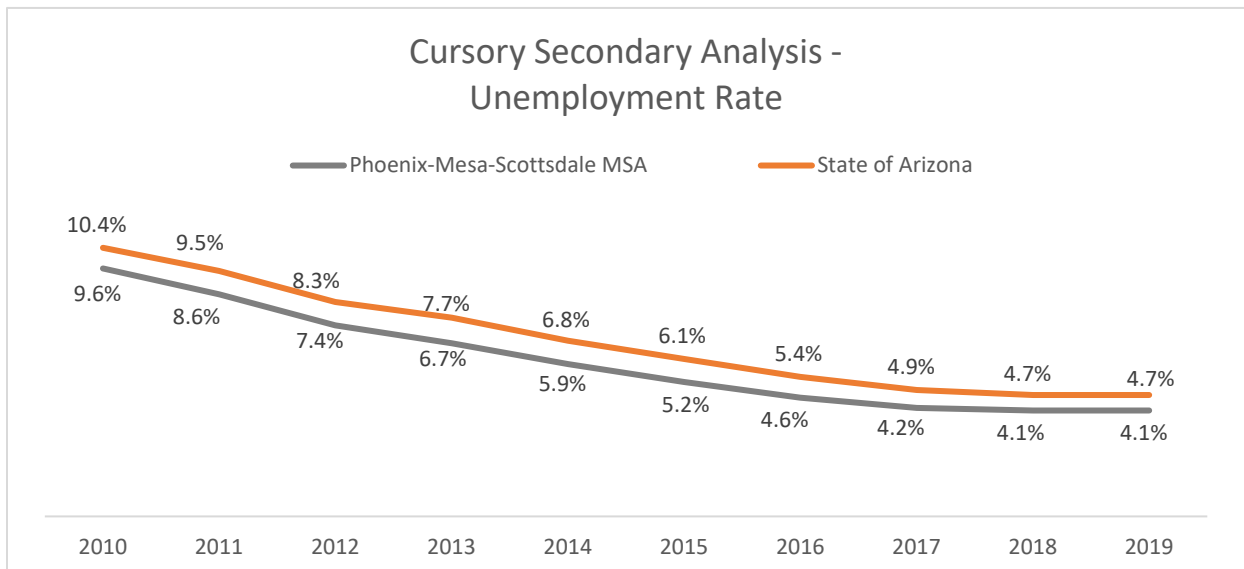


Figure 1. Cursory Secondary Analysis - Unemployment Rate (United States Bureau of Labor Statistics, 2020)

2.4 Median Household Income

Over the last 10 years, median household income for Maricopa County has remained within 25 percent of the State of Arizona average, with a stable or increasing trend, which is classified as “Medium” in WTR 11-02. Figure 2 below documents median household income for Maricopa County and the State of Arizona.

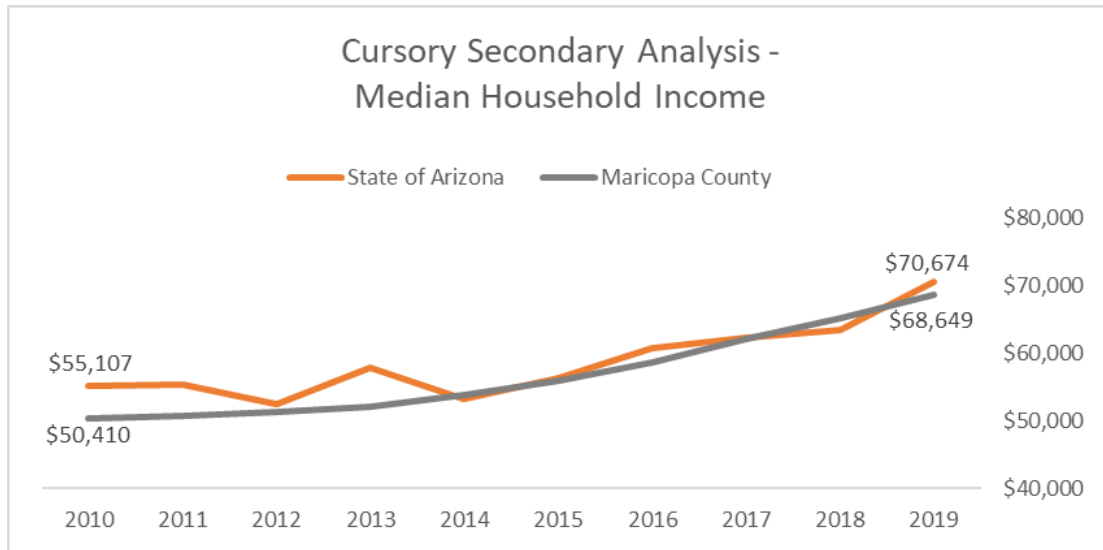


Figure 2. Cursory Secondary Analysis - Median Household Income (United States Census Bureau, 2020)

2.5 Property Values

Property values as a socio-economic indicator are particularly meaningful if the project is funded primarily through property-based assessments. As shown in Figure 3 on the following page, residential property values for Maricopa County over the last 10 years have remained above the State of Arizona average with a stable or increasing trend, which is classified as “Good” in WTR 11-02.

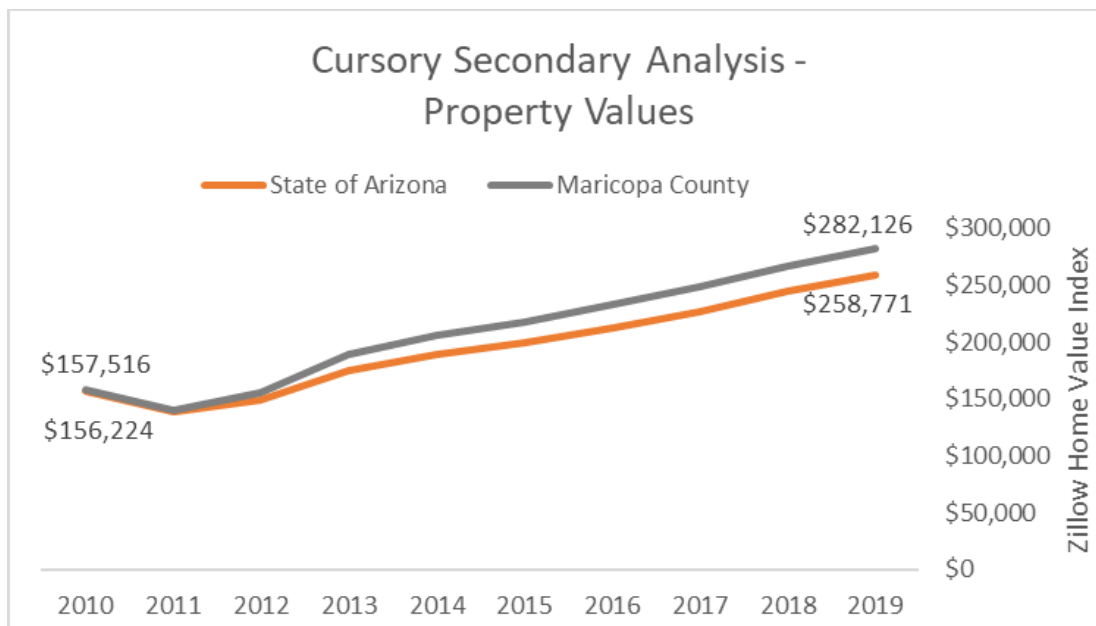


Figure 3. Cursory Secondary Analysis - Property Values (Zillow, 2020)

2.6 Water Service Affordability

As described in WTR 11-02 and (in more detail) in Technical Memorandum Number EC-2009-02, studies by the United States Environmental Protection Agency (EPA) suggest that household water supply costs in excess of 2.5 percent of median household income have the potential to inflict economic hardship. As shown in Table 1 on the following page, household water supply costs were estimated for 20 Phoenix-area water purveyors for which data were readily available. The Arizona Department of Water Resources provided 2019 annual average water use by household for each water purveyor, which was divided by 12 to derive monthly averages for which a cost could be calculated using each water purveyor’s volumetric rate schedule. The City of Phoenix, which has a rate schedule with seasonal variability, provided a monthly average household water supply cost estimate for this study. It should be noted that this analysis cannot accurately reflect the impact of the higher rate tiers which may only apply during certain months of the year. However, none of the M&I water purveyors reviewed for this study appear to have a rate structure that would result in water supply costs exceeding 2.5 percent of median household income for an average level of use in their service areas. This corresponds to a “Good” rating under WTR 11-02.

At a more detailed level of study, when prospective beneficiaries have been identified, this analysis should be repeated with the rate structures expected to be in effect during the with-project future, ensuring that project implementation isn’t expected to raise the beneficiary populations’ income burden percentage to an unacceptable level. Additionally, detailed ability to pay studies may be necessary.

Table 1. Water Service Affordability

Entity	Population Estimate, July 1, 2019 ¹	Monthly Service Charge	2020 Volumetric Tiered Charges ²									2019 Monthly Average Water Use by Household ³ in kGal	Estimated Annual Cost of Water	Median Household Income (in 2019 dollars), 2015-2019 ⁴	Income Burden Percentage
			Tier 1 Rate per kGal	Tier 1 Q (kGal)	Tier 2 Rate per kGal	Tier 2 Q (kGal)	Tier 3 Rate per kGal	Tier 3 Q (kGal)	Tier 4 Rate per kGal	Tier 4 Q (kGal)	Tier 5 Rate per kGal				
Cave Creek	5,838	\$ 53.79	\$ 3.09	10	\$ 4.64	20	\$ 6.96	30	\$ 10.44	50	\$ 15.66	11.13474749	\$1,079.46	\$83,787	1.29%
Litchfield Park	6,436	\$ 12.54	\$ 0.71	3	\$ 1.84	10	\$ 2.84	20	\$ 3.27	N/A	N/A	10.65134602	\$345.29	\$83,156	0.42%
Tolleson	7,372	\$ 26.85	\$ 3.72	10	\$ 3.93	30	\$ 4.70	N/A	N/A	N/A	N/A	8.016866981	\$546.15	\$45,952	1.19%
Paradise Valley	14,637	\$ 29.68	\$ 1.08	5	\$ 1.29	15	\$ 2.27	40	\$ 2.85	80	\$ 3.35	40.13556732	\$1,201.65	\$211,393	0.57%
El Mirage	35,753	\$ 19.77	\$ 3.55	5	\$ 3.91	15	\$ 4.31	25	\$ 4.73	N/A	N/A	5.450760035	\$471.39	\$58,216	0.81%
Sun City ⁵	37,499	\$ 11.50	\$ 0.74	1	\$ 1.08	3	\$ 1.69	9	\$ 1.92	12	\$ 2.18	10.55371095	\$318.67	\$40,586	0.79%
Apache Junction	42,571	\$ 31.93	\$ 3.88	4	\$ 5.48	10	\$ 6.05	N/A	N/A	N/A	N/A	4.868723422	\$626.53	\$45,653	1.37%
Queen Creek	50,890	\$ 18.33	\$ 1.77	10	\$ 2.37	20	\$ 2.96	N/A	N/A	N/A	N/A	10.85898323	\$429.36	\$105,729	0.41%
Buckeye	79,620	\$ 32.94	\$ 3.93	6	\$ 4.91	10	\$ 6.14	15	\$ 7.68	30	\$ 9.59	5.365781037	\$648.33	\$71,707	0.90%
Goodyear	86,840	\$ 18.44	\$ 2.15	6	\$ 4.27	12	\$ 6.42	30	\$ 10.31	N/A	N/A	6.688918534	\$411.38	\$83,866	0.49%
Avondale	87,931	\$ 11.87	\$ 1.21	5	\$ 1.93	9	\$ 2.84	13	\$ 4.45	N/A	N/A	7.960587423	\$260.45	\$61,825	0.42%
Surprise	141,664	\$ 28.82	\$ 1.89	10	\$ 1.89	20	\$ 1.89	N/A	N/A	N/A	N/A	7.425298891	\$514.25	\$69,076	0.74%
Peoria	175,961	\$ 16.09	\$ 1.18	4	\$ 3.11	10	\$ 4.41	20	\$ 4.87	N/A	N/A	8.07489899	\$401.80	\$75,323	0.53%
Tempe	195,805	\$ 15.70	\$ 1.80	6	\$ 2.49	12	\$ 3.65	20	\$ 4.61	40	\$ 5.10	7.940833044	\$375.99	\$57,994	0.65%
Glendale	252,381	\$ 14.40	\$ 2.52	6	\$ 3.15	15	\$ 4.42	30	\$ 6.26	N/A	N/A	11.24650017	\$552.56	\$55,020	1.00%
Gilbert	254,114	\$ 16.30	\$ 1.20	8	\$ 1.28	20	\$ 1.60	30	\$ 2.06	N/A	N/A	11.87890065	\$370.38	\$96,857	0.38%
Scottsdale	258,069	\$ 16.80	\$ 1.65	5	\$ 3.00	12	\$ 4.05	30	\$ 5.50	65	\$ 6.10	10.67691737	\$504.97	\$88,213	0.57%
Chandler	261,165	\$ 10.35	\$ 1.60	10	\$ 2.08	20	\$ 2.62	60	\$ 3.27	N/A	N/A	8.63520371	\$290.00	\$82,925	0.35%
Mesa	518,012	\$ 28.10	\$ 3.19	9	\$ 4.79	18	\$ 5.77	24	\$ 6.46	N/A	N/A	6.969082947	\$489.14	\$58,181	0.84%
Phoenix ⁶	1,680,992	\$ 6.03	Varies	Varies	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.464339291	\$450.60	\$57,459	0.78%

¹ Resident population and net change (V2019), U.S. Census Bureau, Population Estimates Program (PEP)

² Assembled by SRP staff as part of this study, December 15, 2020; kGal=1,000 gallons

³ Based on 2019 residential demand (AF) divided by total housing units, personal communication received from Arizona Department of Water Resources, January 25, 2021

⁴ Median Household Income: U.S. Census Bureau, American Community Survey (ACS) 5-Year Estimates

⁵ Population from 2010 Census; 2019 estimate not available

⁶ 2020 average bill calculated by City of Phoenix, received via personal communication 2/1/2021

Reclamation's Yuma Desalting Plant Special Study Water Market Analysis (2020), completed as part of a broader forthcoming Yuma Desalting Plant report, estimates a range of ability to pay values per household for counties in the southwestern United States, aggregating that ability to pay to the county level and converting it to a wholesale equivalent ability to pay per acre-foot of domestic water supply. The Water Market Analysis reviews methodological bases for measuring household ability to pay for water that address criticism by Manuel Teodoro (2018) of EPA's median household income methodology.¹ The analysis takes living expenses and poverty rates into consideration as suggested by Teodoro, deriving an affordability threshold for water from data used in the analysis.

For Maricopa County, the Water Market Analysis produced an estimate of total household ability to pay of \$1,509,364,000 to \$2,342,209,000 per year. The relevance of this county aggregate ability to pay is limited because not every household would bear the cost of implementing one of the VRSMS action alternatives. However, in comparison, the annualized present value lifecycle costs of the VRSMS action alternatives range from approximately \$25,000,000 to \$30,000,000 per year. To present household ability to pay for Maricopa County on a per-acre-foot retail basis, the Water Market Analysis divided ability to pay per household by estimated household water use; these values were suggested to be further converted to a wholesale basis using an estimated raw water supply cost percentage of 35.27%, resulting in estimates of wholesale ability to pay per acre-foot between \$700.11 and \$1,646.09. As described in the following section on cost comparison to alternative sources of supply, and shown in Table 4, the water supplies created by the Bartlett Modification 1 and 2 Alternatives are not currently estimated to cost more than \$166 per acre-foot of water yield, although the Sediment Removal Alternative costs are estimated at more than \$1,000 per acre-foot of yield which potentially exceeds household ability to pay as calculated in the Water Market Analysis.

2.7 Comparison of Alternative Sources of Supply

As part of a secondary analysis, WTR 11-02 prescribes a comparison between rates for feasible alternative sources of water and rates for water under the proposed project. Where proposed project rates are competitive with or below rates for alternative sources of water, a "Good" rating would be assigned. Without identifying specific beneficiaries and their interest in specific volumes of water, rates could not be analyzed. However, the Economics Core Team compiled cost information for recent water acquisition transactions and conceptual alternatives for creation of new water supplies that have the following characteristics in common with the VRSMS action alternatives:

- Perpetually (or 100-year) renewable water source
- Legally available
- Physically connected to the lower Colorado River basin

¹ Incidentally, Manuel Teodoro in *Measuring Household Affordability for Water and Sewer Utilities* (Journal AWWA, January 2018: 110:1) assesses household water and sewer affordability for Phoenix, AZ using his proposed methodology, finding that Phoenix had the most affordable water and sewer service of the 25 largest US cities he studied in 2017.

Those transactions and alternatives, which include estimated Central Arizona Project (CAP) wheeling charges where appropriate (but not beneficiary-specific financing, overhead, or operational costs), are summarized below in Table 2. They are intended to be interpreted as representative costs to acquire the next increment of water in central Arizona, not as average costs associated with those sources of water supply.

Table 2. Cost Comparison of Alternative Sources of Water Supply

Water Source	Representative Transactions and/or Source of Estimates	Estimated Cost per Acre-Foot¹, Including Delivery Charges to Central Arizona
CAP Indian and/or M&I Priority Water Lease	Central Arizona Project Water Lease Among the United States of America, the San Carlos Apache Tribe, and the Town of Gilbert, Arizona; Lease Agreement for CAP Water Between City of Chandler and the Gila River Indian Community	\$175-\$210
Reallocated CAP Non-Indian Agricultural (NIA) Priority Water	85 FR 34232, June 3, 2020; 86 FR 4119, January 15, 2021; CAWCD website.	\$230
Colorado River Mainstream Transfer	Transfer of Fourth Priority mainstream Colorado River water from GSC Farm, LLC to Town of Queen Creek	\$320
Central Arizona Groundwater Replenishment District (CAGRD) Enrollment	https://www.cap-az.com/documents/departments/finance/Final-CAGRD-2020-21-2025-26-Water-Rate-Schedule.pdf	\$700-\$740
Inland or Ocean Desalination	https://new.azwater.gov/sites/default/files/Long-Term%20Water%20Augmentation%20Options%20final.pdf ; Bureau of Reclamation Yuma Desalting Plant Special Study Water Market Analysis, forthcoming	\$690-\$2,200
Recycled/Effluent Water	Agreement for Development of Effluent Recharge Facility, Effluent Disposal and Purchase and Sale of Effluent between CAWCD and Liberty Utilities; https://new.azwater.gov/sites/default/files/Long-Term%20Water%20Augmentation%20Options%20final.pdf	\$75-\$1,800

¹ Water acquisitions may include a combination of upfront and annual or per-acre-foot charges. Significant assumptions were necessary in the development of these estimates, including assumptions about the future availability of water, which may result in underestimation of these costs. Data are available upon request.

The cost per acre-foot of water yielded by each of the VRSMS action alternatives varies by storage account (SRP, Phoenix Gatewater, and New Verde Space) in accordance with each account's size and operational priority. While the Sediment Removal Alternative's costs are specific to water supply, the overall project cost of the Bartlett Modification 1 and 2 Alternatives may consist of both

dam and powerplant costs that would need to be allocated among the water supply and hydropower purposes using a cost allocation method such as Separable Cost-Remaining Benefits (SCRB), which weighs the economic benefits accruing to each purpose. At this level of study, there is considerable uncertainty about other beneficial purposes, such as flood control and recreation, that may be quantified in the future and bear a portion of the project costs. Additionally, the operating criteria for the Salt and Verde River reservoirs would be expected to change in the future under the Bartlett Modification 1 and 2 Alternatives, which could significantly change the estimated distribution of benefits between hydropower and water supply, affecting the cost allocation. To avoid setting expectations at this time for the future allocation of costs, this study equates dam costs with the water supply purpose and powerplant costs with the hydropower purpose. The powerplant costs described in Section 8.1.1.2 of the main report and Appendix F can be characterized as separable costs, which would be the minimum cost assigned to hydropower in a SCRB allocation. Therefore, if hydropower is pursued as a project purpose, the water supply costs presented here would be overstated and the hydropower costs would be understated.

Taking the Bartlett Modification 1 and 2 dam costs as water supply costs, the Use of Facilities (UOF) method is then used to allocate water supply costs between storage accounts for all three VRSMS action alternatives. As described in Reclamation's Economics Guidebook, the UOF assigns costs based on the physical characteristics of project features (in this case, capacity of each storage account). Because physical measures of use are "complicated by variability of use over time, fluctuations of head, peak periods of use, conflicting demands, and inapplicability of a common measure to all project purposes," the UOF is "limited, generally, to use in suballocating costs assigned to a NED component by another method among groups of beneficiaries sharing in a common purpose." Discussions will continue during the review period of this study and during future studies about the best measure to characterize the relative benefit provided by each storage account.

Table 3 on the following page displays the UOF calculations. For all alternatives, 34,696 AF has been identified as the amount of SRP capacity to be restored, and 11,053 AF has been identified as the amount of Phoenix Gatewater capacity to be restored. Using the Sediment Removal Alternative as an example,

$$\begin{aligned} &34,696 \text{ AF of SRP Restored Capacity} / 45,749 \text{ AF of Total Restored Capacity} = \\ &76\% \text{ of capacity restoration benefitting SRP} \end{aligned}$$

The total Sediment Removal Alternative costs of \$1,081,666,212 are then assigned 76% to SRP Restored Capacity (\$820,334,671) and 24% to Phoenix Gatewater Capacity (\$261,331,540).

The Bartlett Modification 1 and 2 Alternatives provide additional water storage capacity referred to as New Verde Space capacity, which reduces the proportion of project costs borne by SRP Restored Capacity and Phoenix Gatewater Capacity.

Table 3. Allocation of Dam Costs by Capacity Type - Use of Facilities Method

Allocation of Dam Costs by Capacity Type - Use of Facilities Method	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
AF of SRP Restored Capacity	34,696	34,696	34,696
Percentage	76%	10%	24%
Allocated Present Value Construction + IDC	\$798,493,780	\$102,837,788	\$202,188,725
Allocated Present Value O&MR Costs	\$21,840,891	\$2,842,404	\$6,865,789
Allocated Costs Subtotal	\$820,334,671	\$105,680,193	\$209,054,515
AF of Phoenix Gateway Restored Capacity	11,053	11,053	11,053
Percentage	24%	3%	8%
Allocated Present Value Construction + IDC	\$254,373,754	\$32,760,724	\$64,410,652
Allocated Present Value O&M Costs	\$6,957,787	\$905,496	\$2,187,214
Allocated Costs Subtotal	\$261,331,540	\$33,666,220	\$66,597,866
AF of New Verde Space (Additional) Capacity	-	305,784	99,784
Percentage	0%	87%	69%
Allocated Present Value Construction + IDC	\$0	\$906,333,589	\$581,484,891
Allocated Present Value O&M Costs	\$0	\$25,050,777	\$19,745,675
Allocated Costs Subtotal	\$0	\$931,384,367	\$601,230,566
Total Capacity Restored or Additional	45,749	351,533	145,533
Percentage	100%	100%	100%
Present Value Dam Construction + IDC	\$1,052,867,534	\$1,041,932,101	\$848,084,269
Present Value Dam O&M Costs	\$28,798,678	\$28,798,678	\$28,798,678
Total Costs	\$1,081,666,212	\$1,070,730,779	\$876,882,947

Because the objective of developing this information is to assess affordability, the costs allocated to each storage account under each alternative are divided by the estimated water yield from each account (acre-feet of delivery from SRP Restored Capacity, acre-feet of Phoenix Gateway accrual, and acre-feet of delivery from New Verde Space). More information about hydrologic modeling is found in Section 6 of the main report. As shown in Table 4 on the following page, costs per acre-foot range from \$41 for Phoenix Gateway Accrual under Bartlett Modification 1 to \$1,096 for delivery from SRP Restored Capacity under the Sediment Removal Alternative. It should be noted that these costs are presented for a 100-year benefit period. Analysis performed by individual water providers may use a different period of benefits accrual, which would alter the estimated cost per acre-foot. However, the 100-year period of analysis would not be unreasonable for municipal water providers in Arizona since the State of Arizona's Assured Water Supply program requires water providers to prove that water supplies are legally and physically available for 100 years.

Table 4. Estimated Costs per Acre Foot for Each Action Alternative

Estimated Cost per Acre Foot of Action Alternatives	Alternatives		
	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Present Value Lifecycle Costs Allocated to SRP Restored Capacity	\$820,334,671	\$105,680,193	\$209,054,515
Total Acre-Feet of Delivery from SRP Restored Capacity	748,300	1,552,500	1,530,800
Present Value Lifecycle Costs per Acre-Foot of Delivery From SRP Restored Capacity	\$1,096	\$68	\$137
Present Value Lifecycle Costs Allocated to Phoenix Gateway Restored Capacity	\$261,331,540	\$33,666,220	\$66,597,866
Total Acre-Feet of Phoenix Gateway Accrual	257,000	816,000	812,000
Present Value Lifecycle Costs per Acre-Foot of Phoenix Gateway Accrual	\$1,017	\$41	\$82
Present Value Lifecycle Costs Allocated to New Verde Space (Additional) Capacity	\$0	\$931,384,367	\$601,230,566
Total Acre-Feet of Delivery from New Verde Space (Additional) Capacity	-	9,128,300	3,612,700
Present Value Lifecycle Costs per Acre-Foot of Delivery From New Verde Space (Additional) Capacity	N/A	\$102	\$166

Based on these results, the Bartlett Modification 1 and 2 Alternatives compare favorably to other sources of future water supply (see Table 2 on page 7), and this is a strong contribution to the study's assessment of financial viability.² Allocating a portion of the Bartlett Modification 1 and 2 dam costs to hydropower would further reduce these costs, but is heavily contingent on further study of hydropower economics.

Focus group members provided feedback that the \$0 upfront cost of the Without Action Alternative is misleading, since entities who progressively lose water supply under that alternative would have to invest in other sources of new supply to supplement lost supplies.

2.8 Rate Shock

As described in WTR 11-02, a rate shock analysis is valuable to assess potential negative public reactions to the magnitude of estimated changes in water rates (not necessarily the rate levels themselves). Studies by the EPA suggest that water rate increases of 100 to 200 percent may indicate questionable affordability and increases greater than 200 percent may be unaffordable.

² Like the cost estimates in Table 2, these estimates do not include any beneficiary-specific operational or overhead costs, and represent delivery of water at Granite Reef Diversion Dam.

At a more detailed level of study, the study team would engage with prospective project beneficiaries to review rate design for the with-project future and ensure that rate shock is not a concern. Generally, rate shock might be more likely for a beneficiary with a small water portfolio, a small customer base, and a relatively large acquisition of water at a significantly higher cost than its current portfolio. The impact of rate shock may differ depending on how water costs are distributed among tax revenues, water rates, and other sources of revenue.

2.9 Irrigation Payment Capacity

Reclamation Manual D&S PEC 11-01, *Irrigation Ability-to-Pay Analyses*, provides the basic requirements and framework for conducting analyses to determine the ability of contractors to pay for their share of project construction costs allocated to irrigation. Those analyses are outside the scope of the VRSMS, but that is not considered to be a significant risk to this financial viability assessment because the irrigation component of the water supply provided by the VRSMS alternatives is thought to be small and probably contained within SRP surface water deliveries where some cost recovery flexibility exists.

For a cursory analysis, SRP staff supporting the VRSMS provided a summary of 2021 end-user water rates per acre-foot for irrigation deliveries in various central and southern Arizona irrigation districts, as shown in Figure 3 below.

PRICE PER AF COMPARISON TO OTHER DISTRICTS AS OF 2021

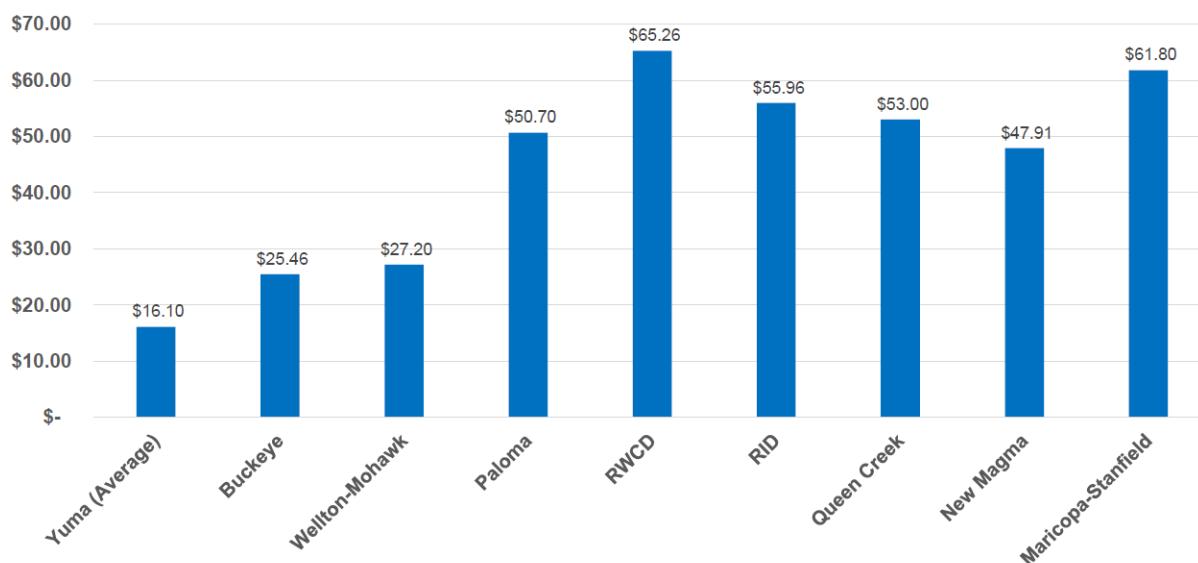


Figure 3. Irrigation Rate Comparison

These water rates are generally around or below the VRSMS action alternatives' estimated per-acre-foot costs to restore SRP's lost surface water delivery capacity (see Table 4 on page 10), which don't include additional delivery and overhead costs that would be assessed by an irrigation district. Estimated costs for the New Verde Space water are considerably higher.

Irrigation districts frequently have access to subsidized or other low-cost water sources, probably making the VRSMS alternatives financially unattractive for irrigation. Historically, allocations of CAP water and costs to irrigation districts resulted in a number of bankruptcies during a downturn of the Arizona agricultural economy, ultimately leading to widespread relinquishment of CAP agricultural priority water entitlements in exchange for debt forgiveness. Future studies should carefully assess the impacts of the VRSMS alternatives on irrigation rate-payers and the relationship between irrigation and M&I water uses in demonstrating an alternative's financial feasibility.

3.0 Conclusion

Table 5 below summarizes the results of this financial analysis. Any of the VRSMS action alternatives would be undertaken in an environment of socioeconomic indicators that Reclamation considers acceptable under Reclamation Manual Directives and Standards WTR 11-02. Additionally, Maricopa County households are estimated to possess the ability to pay for either of the Bartlett Modification 1 or 2 Alternatives, which are both cost-competitive with other sources of new M&I water supplies. The Sediment Removal alternative, however, may result in costs per AF that are potentially outside the ability of end users to pay and are not competitive with costs of observed alternatives for water supply. The Without Action Alternative also has affordability implications, as entities lose reliable yield from the Verde River reservoir system and turn to new sources of water at an increased cost.

Table 5. Financial Analysis Summary

Financial Analysis Summary	Alternatives			
	Without Action	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Metrics				
Bond Ratings	High	High	High	High
Debt Service Coverage Ratios	High	High	High	High
Unemployment	Good	Good	Good	Good
Median Household Income	Medium	Medium	Medium	Medium
Property Values	Good	Good	Good	Good
Water Service Affordability	Good	Poor	Good	Good
Cost Comparison to Alternative Sources of New Supply	N/A	Poor - Not competitive with costs of observed alternatives	Good - Reasonably comparable to costs of other water sources	Good - Reasonably comparable to costs of other water sources

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Appendix E: Appraisal Design and Cost Opinion Summary

Technical Memorandum

Date: Monday, August 16, 2021

To: Ron Klawitter and Andrew Volkmer, SRP

From: HDR Engineering

Subject: **Verde Reservoirs Sediment Mitigation Study –
Appraisal Design and Cost Opinion Summary**

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1. Introduction

This memorandum summarizes the development of appraisal-level designs and opinions of probable construction costs (OPCCs) for the three alternatives in the Verde Reservoirs Sediment Mitigation Study (VRSMS). One alternative would remove and dispose of sediment accumulated in Horseshoe Reservoir. The other two alternatives involve modifying Bartlett Dam and Reservoir.

2. Horseshoe Reservoir Sediment Removal

The section discusses removal and disposal of 45,749 acre-feet (AF) (approximately 73 million cubic yards [CY]) of sediment from Horseshoe Reservoir. Although there are cases where this magnitude of sediment has been moved over a period of years in coastal and riverine settings, there are no known similarly-sized examples of such a large-scale sediment removal project from an inland reservoir.

Removal of sediments can be accomplished using several different methods. The most cost-effective method is to use heavy earth moving equipment including scrapers, excavators, trucks, and similar equipment. Using earth moving equipment requires that the reservoir be drawn down far enough and long enough that the work can be done essentially “in the dry”. Scrapers require relatively dry ground; excavators and trucks can be used in wetter conditions. Both types of operations would benefit from drainage and water control systems that would need to be constructed as the reservoir is drawn down annually. Given the situation at Horseshoe Reservoir, where the uncontrolled inflow from a very large watershed enters the reservoir annually, it is prudent to assume at this appraisal-level of analysis that a significant portion of the sediment removal would have to be done “in the wet” and would require dredging of the sediment.

2.1. Dredging Methods

Two primary types of dredging equipment are considered: cutterhead dredges with suction lines and mechanical dredges. Both types would likely be needed for full removal of the Horseshoe Reservoir sediments. They are described below.

If a cutterhead dredge is used, it would need to be brought in by trucks, in pieces, and assembled on site. This would require a location for a crane to lift the pieces into position and place the assembled dredge into the water. Dredge components transported overland are typically restricted in size due to roadway limitations. The remote location of Horseshoe Reservoir will present significant challenges in mobilizing a large dredge. Due to requirements of the Bartlett-Horseshoe Habitat Conservation Plan (HCP) for annual dewatering of the reservoir during summer months, the dredge would also have to be removed seasonally or sit idle over the winters thereby driving up the cost of the sediment removal.

A large cutterhead dredge can have a discharge pipe on the order of 30 inches (in) in diameter and a total installed capacity in excess of 12,000 horsepower (hp). These dredges can move more than 40,000 CY of material per day in some conditions. However, given the constraints of

bringing equipment to, and operating within Horseshoe Reservoir, the dredge pipe would most likely be 16 inches or smaller and the total installed horsepower would be less than 2,000 hp, depending on discharge distance and elevation change. Dredges of this size typically produce less than 4,000 CY/day (2.5 AF/day). As the pipeline length increases, production will be reduced. A cutterhead dredge can only be used when there is sufficient water in the lake. Also, if dredged water is not efficiently returned from the disposal site to the reservoir, there could be problems with lack of required water depth at the dredge for significant periods of time. Water quality requirements and potential management strategies may also raise important permitting, cost, and scheduling concerns.

There are two primary types of mechanical dredges, the clamshell (or grab) bucket dredge (commonly called a *bucket dredge*) and the backhoe dredge. The bucket dredge is so named because it uses a bucket to excavate the material to be dredged. Different types of buckets can fulfill various types of dredging requirements. Typical bucket types include the clamshell, orange-peel and dragline; these can usually be interchanged to suit operational requirements. The vessel can be positioned and moved within a limited area using anchors and/or spuds. The material excavated can be placed in barges that are towed to the placement areas. Buckets used on this type of dredge usually range in capacity from one to 30 CY. The crane is mounted on a flat-bottomed barge, on fixed-shore installations or on a crawler mount.

Bucket dredge production is a function of both the loading (excavation) and hauling components of its operation. Production rates while loading depend on several factors: the size and weight of the bucket, the operating characteristics of the bucket, the type of material to be excavated, the face thickness or bank height of the material, operator efficiency and the bucket cycle time. Operating characteristics affect the bucket's fill factor (the decimal equivalent of the percent volume of bucket actually filled) and include the bucket weight, bucket shape, closing edge configuration (toothed or smooth) and closing action. A complete bucket cycle time is defined as the time required to lower the open bucket to the bottom, mechanically grab the material, close the bucket and then raise, position and release the bucket either over a waiting barge or to the side (sidecasting). Twenty to thirty cycles per hour are typical, but large variations exist in production rates because of the variability in depths and materials being excavated. The effective working depth is limited to about 100 feet (ft). Smaller bucket dredges typically do not dredge denser materials while a larger bucket may require structural enhancement (for example, thicker plates to withstand rock excavation).

The bucket dredging process usually requires that excavated material be hauled to a placement site by a hopper-type barge with bottom doors, a split-hull type barge or a flat-deck barge modified to carry the dredged material. The material is unloaded using gravity dump methods where possible or by a hydraulic unloader. Material moved by barges may require an additional clamshell to unload onto shore or trucks to haul to a placement site or sites. If the clamshell/dragline is used on shore, it may be possible to directly place the material onto a truck to be hauled directly to the placement site.

Advantages of mechanical dredges include:

- Can remove sediment with minimal water.
- Equipment is relatively available and more easily transported over land.
- Equipment can work in variety of water depths/and or dry conditions.
- Multiple pieces of equipment can be working within close proximity to each other.
- Tend to be more cost-effective for longer haul distances than hydraulic dredges.
- Placement areas can be much smaller.

Disadvantages of mechanical dredges include:

- Relatively slow production.
- Relative cost per cubic-yard dredged can be high.
- Can develop locally high turbidity.

For the use of mechanical dredging at Horseshoe Reservoir for sediment removal, the magnitude of the operation will be limited to the size of cranes that can be brought in overland. If the system is to be floated on a barge, it may be restricted by the size of the barge that can be brought and assembled onsite. Although buckets as large as 50 CY have been used in other types of settings, dredging at Horseshoe Reservoir would most likely utilize a dredge having a bucket of three to five cubic yards. Production rates would depend on the dredging systems, i.e. the number of barges and trucks that can be economically used in this setting, and the cycling time to load and unload. Typically, a bucket dredge can produce 1,500 to 3,000 CY/day.

2.2. Dewatering Methods

Dredged materials are typically dewatered in a Confined Disposal Facility (CDF). The CDF is constructed and designed to safely hold the volume of dredged material, as well as temporarily store water prior to it being returned to the originating water body. Excess water is normally returned to the originating water body if there no contamination issues. Return water can be either pumped or gravity-drained back to the original water body.

A CDF must be designed and operated to provide adequate initial storage volume and surface area to hold the dredged material solids during an active filling operation and, if hydraulically filled, to retain suspended solids such that clarified water is discharged. The site must be large enough to meet both short-term storage capacity requirements during filling operations and long-term requirements for the anticipated life of the site. Sufficient surface area and dike height with freeboard must be available for retention of fine-grained material to maintain effluent water quality. When the dredged material is initially deposited in the CDF, it may occupy several times its original volume. The settling process is a function of time, but the sediment eventually consolidates to its in-situ volume, or less if desiccation occurs. Adequate volume must be

provided during the dredging operation to contain the total volume of sediment to be dredged, accounting for any volume changes during placement. Procedures to evaluate the required surface area and volume during active filling operations, to estimate effluent suspended solids concentrations and to design other features for CDFs are described in USACEs *EM 1110-2-5025 Dredging and Dredged Material*.

The site conditions must allow for construction of structurally and geotechnically sound retaining dikes for effective containment of ponded water and dredged material. For near-shore sites, the dike face may be exposed to erosional forces due to currents and wave action, and some form of armor protection must be considered.

Capacity requirements are dependent on the volume and type of material. Fine-grained sediment typically “bulk” by retaining water during the dredging process. Coarse-grained sediments (sand and larger) drain more freely and do not normally bulk and require additional capacity. Fine-grained sediments (clays and silts) typically require 1.5 times their in-situ volume in the placement area (*USACE EM 1110-2-5025*).

The size and type of CDF that could be used for Horseshoe Reservoir would be dependent on type of dredge and how material is delivered. The CDF site would need to be sized for the amount of material to be placed and how long it would take to dry. For dredging efficiency, several smaller sites may have advantages over one large one. With the large potential size (or sizes) of the CDF(s) for Horseshoe Reservoir sediment removal, the design will need to be carefully considered and the construction carefully monitored considering the potential for both local and large-scale slope failures and would likely require continuing long-term monitoring and management costs.

2.3. Cost Data for Dredging Operations

Dredging estimates are typically developed based on three general cost components, mobilization/demobilization, construction costs for the placement area and cost per cubic yard of dredging. Mobilization costs are dependent on the size of the equipment, how far the equipment must be transported, the number of support vessels and the cost of assembly. Placement area costs are normally limited to the cost of constructing the surrounding dikes and decant structure(s), but can also include special requirements for site lining for contaminated soils, return water considerations and any special monitoring required for both engineering and environmental considerations. Unit costs for dredging are normally developed as a function of the complexity of the dredging operation and the distance to the placement area.

Navigation projects in major rivers and coastal areas that have well-established dredging and placement areas normally cost between three and ten dollars per cubic yard. As projects get more complicated or longer disposal distances are involved, the costs can exceed \$20/CY for these types of projects. Specialty projects, sediment clean up, lake dredging and some marsh restoration projects can exceed \$100/CY. One recent reservoir sediment removal project for Denver Water (*Raitt and Cochran, 2017*) has shown that specialized inland reservoir dredging can exceed \$80/CY.

2.4. Preliminary Opinions of Probable Construction Costs

A preliminary overview of the potential costs of restoring Horseshoe Reservoir water storage capacity by removing accumulated sediment is presented below.

To assess potential costs, it is assumed some material could be seasonally excavated by conventional surface excavation methods, some by an excavator or clam shell and some by a cutting head suction dredge. Figure 1 presents a Google Earth photo taken when the reservoir was nearly empty with three potential zones of sediment removal and a nearby disposal area to show the rough volumes and areas that could be expected. This conceptualization helps with the visualization of the massive undertaking that would be required to excavate the sediment accumulated to date in Horseshoe Reservoir.

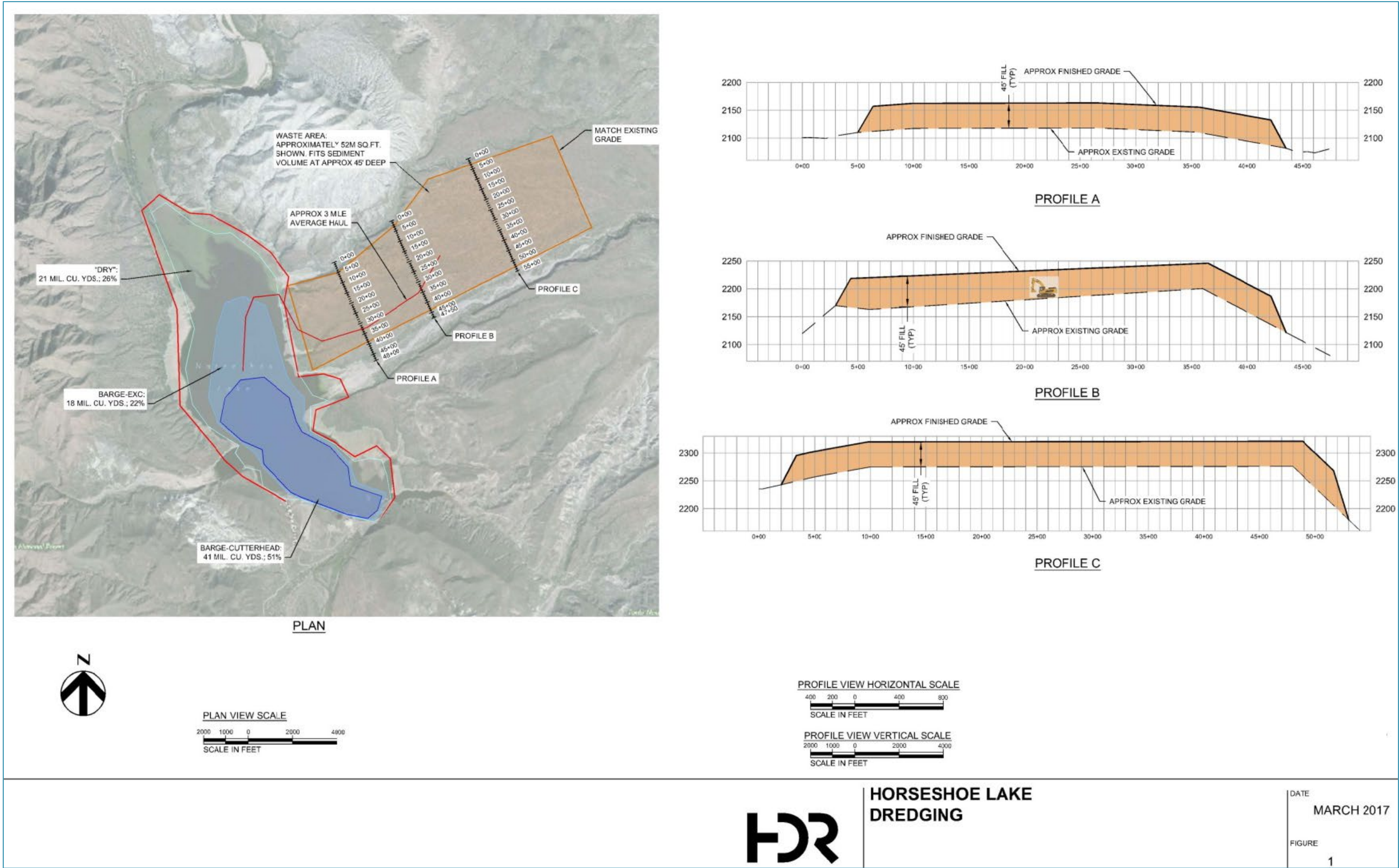


Figure 1. An Illustrative Concept for Horseshoe Reservoir Sediment Removal

Table 1 shows the appraisal-level OPCC to remove and dispose of the latest estimate of Horseshoe Reservoir sediment accumulation (45,749 AF or approximately 73 million CY) using Reclamation cost estimating guidelines. The OPCC, at January 2017 price levels, is approximately \$836 million or about \$18,300/AF of restored storage space. This illustrates a *potential best-case scenario*, considering that: 1) it is based on the assumption that a single close-by disposal area is available and 2) no known sediment removal program for an inland reservoir has ever been attempted to deal with the volume of sediment accumulated to date in Horseshoe Reservoir.

Table 1. Preliminary Opinion of Probable Sediment Removal Cost

Description	Code	Quantity	Unit	Unit \$	Total \$
Diversion – Direct Cost ¹		1	Lump Sum (LS)	5,000,000.00	5,000,000
Diversion – Risk Cost ²		1	LS	2,000,000.00	2,000,000
Contractor Access, Staging, and Temp Works ³		1	LS	5,000,000.00	5,000,000
Clearing and Initial Site Work		1,500	Acre (AC)	2,000.00	3,000,000
Waste Area – Development		7,000,000	CY	2.00	14,000,000
Temporary Holding and Dewatering Facilities ⁴		70,000	CY	25.00	1,750,000
Dewatering Allowance ⁵		3,750	Day	1,000.00	3,750,000
Sediment Excavation (Dry)		14,200,000	CY	3.00	42,600,000
Dredging (Excavator)		17,800,000	CY	8.00	142,400,000
Dredging (Cutterhead)		41,200,000	CY	10.00	412,000,000
Final Site Work and Reclamation ⁶		1,500	AC	2,500.00	3,750,000
Subtotal					635,000,000
Mobilization ⁷	2.30%	+/-		15,000,000	15,000,000
Subtotal w/Mobilization					650,000,000
Contract Cost Allowances (sum of next two lines):	5%	+/-			30,000,000
Design Contingencies, 5% (+/-) ⁸					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
Contract Cost					680,000,000
Construction Contingencies ⁹	10%	+/-			70,000,000
Field Cost (Price Level Jan 2017)					750,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	11%	+/-			86,000,000
Construction Costs					836,000,000

Ref.: For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.

NOTES:

1. Routing of river flow along reservoir banks, berms, etc. to isolate dry areas.
2. Seasonal and other interruptions where productivity is decreased.
3. Roads, launching stations, material transfers, etc.
4. Based on 2000 GPM, five days holding.
5. Flocculation agents, maintenance, etc.
6. Includes drainage construction.
7. Includes multi-year continuous operations.
8. The relatively low contingency is used considering that the design is straightforward compared to the more challenging design of the Bartlett Modification alternatives that require the complex integration of multiple engineering disciplines and consideration of challenging construction sequencing and risk management strategies during the design process.
9. This contingency reflects post-award quantity changes, work scope changes, change orders, and low-grade disputes.

2.5. Summary and Recommendations

Sedimentation within Horseshoe Reservoir has greatly impacted the reservoir's water storage capacity. There are several well-established methods to remove the sediment through use of earth moving equipment, hydraulic dredging, and mechanical dredging. However, these methods have never been known to be used to remove sediment in an inland reservoir to the magnitude required to restore lost capacity in Horseshoe Reservoir.

The preliminary opinions of potential sediment removal costs presented here appear to be very high in comparison to the costs per acre foot of water storage created through the construction of new dams and reservoirs in the western U.S. Furthermore, it is believed that the basis of this initial OPCC including, but not limited to, sediment removal rates, disposal location, dewatering costs, environmental and water quality management costs, contingency factors and other factors, tend to make a sediment removal program as presented herein for an initial appraisal-level screening process appear more feasible than would actually be the case. The information shown above presents major issues to overcome to remove and dispose of this sediment successfully and reliably.

3. Bartlett Modification 1 and 2 Alternatives

In the early and mid-1980s, the Central Arizona Water Control Study (CAWCS) evaluated many alternatives to address dam safety issues at Salt and Verde River basin dams, including flood passage. It also addressed potential needs for additional water storage in the two river basins. The CAWCS and other studies led to the implementation of major modifications to existing dams including Roosevelt Dam on the Salt River and Bartlett and Horseshoe Dams in the Verde River Basin.

The modifications to the Bartlett and Horseshoe Dams in the mid-1990s brought them into compliance with Reclamation dam safety standards. Periodic dam safety reviews are conducted in accordance with Reclamation's procedures and the available information supports that these dams remain in compliance with current standards. There are no known major upgrades or repairs currently required on either dam, making today's situation different from conditions that required upgrades in the mid-1990s when new conservation storage was added in Roosevelt Lake and new auxiliary spillways were constructed at Bartlett and Horseshoe Dams. There have, however, been major advances in dam design and construction technologies since the new features were selected in the early 1990's. These include advancements in roller-compacted concrete (RCC) dams and labyrinth-crested overflow spillways, both of which are incorporated into the appraisal-level designs presented below for the two Bartlett Modification alternatives.

To develop the two Bartlett Dam modifications presented herein, many other options and design/construction/operational factors were considered including:

- Modifications of the existing dams/reservoirs and new storage sites downstream of Bartlett Dam and between the existing Bartlett and Horseshoe Dams based on a variety of factors including topography and geology.

- Practical range of reservoir capacities.
- Suitability of alternative types of dam construction.
- Geology and construction material availability.
- Structural considerations.
- Hydraulic considerations (including flood management during and after construction).
- General environmental constraints and opportunities.

Each of these factors, and others, should be evaluated in more detail in a feasibility study, if one is conducted.

Presented below are several factors that directly affect the design of the Bartlett Modification 1 and 2 alternatives evaluated in this appraisal study.

3.1. RCC Construction

RCC is now widely used for both new dams and for modifications to existing dams. As its name implies, roller-compacted concrete or “RCC” is placed with conventional earth moving equipment and conveyor systems, allowing rapid placement of low-slump (stiff) concrete that can be compacted with the types of rollers used in heavy civil construction. RCC typically has a lower cementitious content than conventional concrete but can attain sufficient compressive strength for typical dam applications. Fly ash is used to replace a portion of the cement resulting in lower heat of hydration and therefore, lower thermal stress development in massive dam applications. In addition, RCC is often placed nearly continuously thereby reducing construction duration and costs. For an RCC dam to be selected, the foundation rock at the site needs to be relatively strong and uniform, and suitable aggregates should be available in relatively close proximity to avoid large hauling costs and environmental impacts. As discussed below, the geologic conditions at and near the Bartlett Modification 1 and 2 alternatives sites are believed to be suitable for RCC materials.

Primary Factors Considered in Selecting RCC for Appraisal-level Design of the Bartlett Modifications

- Ease and speed of construction - RCC is placed with conventional earth moving equipment and conveyor systems allowing rapid placement of low-slump (stiff) concrete compacted with rollers used in heavy civil construction.
- Smaller footprint and less ground disturbance than an embankment dam.
- Best for flood passage – service spillway can be placed over the top of the dam, often significantly reducing construction cost and spatial disturbance.
- A relatively strong and uniform foundation is available at the Bartlett Modification site – further geotechnical exploration would be needed for a Feasibility Study.
- Economical sources of aggregates for the RCC are expected to be available nearby.

Key factors considered in the appraisal-level engineering layouts of the Bartlett Modification 1 and 2 alternatives included:

- Availability and cost of required construction materials.
- Foundation geology and suitability.
- Spatial requirements and interfaces with the existing dam structures.
- Flood passage options and cost.
- Management of river flows during construction.
- Construction risks including relative risk of cost increases, potential project failure modes, potential shifts in the risk profile for the Verde River basin dams and other factors.

3.2. Site Location

For the purposes of this appraisal study, it has been assumed that a new RCC structure would need to be built on the downstream side of the existing Bartlett Dam. This new construction might be designed to act either as an integrated structure with the existing arches providing the lower portion of the upstream water-tight barrier or the new dam might be designed to be very close to the existing dam but not rely on the existing dam for water retention or any structural support. To provide a reasonably conservative appraisal OPCC, this study assumes that the new construction would be immediately downstream of the existing dam, but there would be no long-term structural reliance on the existing dam. The existing dam may be left in place or partially removed as determined in any future phases of design work.

3.3. Water Management during Construction

For the Bartlett Modification 1 and 2 alternatives, construction flooding risk may be partially managed through potential flood attenuation provided by the existing Bartlett Dam and Reservoir if the reservoir can be managed at relatively low elevations during the construction period. Management of river flows during construction using existing facilities eliminates the need for construction of a new diversion tunnel that would increase costs and lengthen the overall construction period. Management of potential flood flows during construction is an important risk management consideration and drove the development of a conceptual construction sequencing plan for the Bartlett Modification alternatives even at this early appraisal-level design (see Section 4.6 below).

3.4. Regional Geology and Seismicity

3.4.1. REGIONAL PHYSIOGRAPHIC AND GEOLOGIC SETTING

The site of the Bartlett Modification alternatives lies within the Lower Verde River valley of central Arizona; within the Transition Zone Province (see Figure 2 below). The Transition Zone is described as the geologic area between the higher elevation Colorado Plateau to the

northeast and the Basin and Range Province to the southwest. Its name reflects that it exhibits characteristics of both the Colorado Plateau and the Basin and Range such as crustal extension and normal faulting as well as zones of relatively flat-lying un-deformed rocks (Brand and Stump, 2011). The Transition Zone accommodates the difference in crustal extension between the Basin and Range Province and the Colorado Plateau.



Figure 2. Geographic provinces in Arizona. Approximate location of Bartlett Dam is shown by the red square. Bartlett Dam and the Quaternary faults within 100 km (Figure 3) are in the Transition and Basin and Range zones. (Revised Probabilistic Seismic Hazard Analysis and Ground Motion Time Histories for Bartlett Dam, Technical Memorandum No. 85-833000-2014-02; Reclamation, 2013)

The Lower Verde Valley is recognized as a half-graben, bounded to the west by a north-south striking east dipping normal fault. North of the vicinity of the Bartlett Modification site, this fault accounts for as much as 1.5 kilometers (km) of downward offset to the east. The cumulative offset across the Lower Verde Valley in the vicinity of the site is accommodated by a series of down-to-the east normal faults (Ferguson, 1999). The Tertiary deposits are tilted due to this normal faulting as shown on the photograph below.



Photograph 1. Tilted Tertiary Sequence in the Lower Verde River Valley north of Bartlett Dam

Rock types mapped at the site and between Bartlett and Horseshoe Dams include Proterozoic granite that varies from a coarse grained K-spar rich granite to a fine grained plagioclase granite (as described in the *Bartlett Dam Construction and Modification Reports*). Tertiary volcanics including basalt, tuff, and pyroclastic flows; Tertiary sedimentary rocks and Quaternary alluvial, alluvial fan, landslide and colluvium deposits are also present. Some of the older alluvial deposits are as much as 350 to 400 ft above the current Verde River level (Cook *et al*, 2010).

3.4.2. Seismicity

The site of the two Bartlett Modification alternatives lies within an area of Arizona recognized as having a low rate of seismicity (Wong *et al*, 2000). A seismic hazard investigation and updated Probabilistic Seismic Hazard Analysis (PSHA) loadings and Ground Motion time histories were completed for Bartlett Dam by Reclamation (*Revised Probabilistic Seismic Hazard Analysis and Ground Motion Time Histories for Bartlett Dam, Technical Memorandum No. 85-833000-2014-02; Reclamation, 2013*). The memorandum's Summary states:

"In this study, the Quaternary faults present within 100 km of the dam {Bartlett Dam} were reviewed, and a field investigation of Horseshoe fault was completed. The local fault characteristics were updated as a result of this work. {see Figure 3 below from Reclamation 2013}

*Movement along the range-bounding Horseshoe fault considered to be normal in past studies (Pearthree, 1996b; Piety and Anderson, 1990; Wong *et al.*, 2000b) was updated to include both normal and oblique components of movement on the fault. This change*

was based on field observations, including the geomorphology of the fault trace, the exposed fault plane in bedrock, and the presence of apparent laterally-offset drainages along the trace, as well as recent regional studies on the overall tectonic stress regime in the region that indicate some strike-slip component of stress in an extensional environment (Kreemer et al., 2010; Lockridge et al., 2012).

The loadings presented in this study supersede previous results. The PSHA loadings have changed slightly from the report by Wong and others (2000). The PHA values have increased slightly, while the 1.0-sec SA has decreased. The table below compares the 2000 values to the current study.”

Table 2. Summary of Peak Horizontal Acceleration (PHA) and 0.2-second and 1.0-second Spectral Acceleration (SA) values from the previous study (Wong et al., 2000) and Reclamation study (Reclamation, 2013)

	Previous Loadings (Wong et al., 2000)		Updated Loadings (Reclamation, 2013)	
	10,000 yr return period	10,000 yr return period	10,000 yr return period	10,000 yr return period
PHA	0.19 g	0.32 g	0.21 g	0.37 g
0.2-sec SA	n/a	n/a	0.53 g	0.94 g
1.0-sec SA	0.16 g	0.27 g	0.10 g	0.19 g

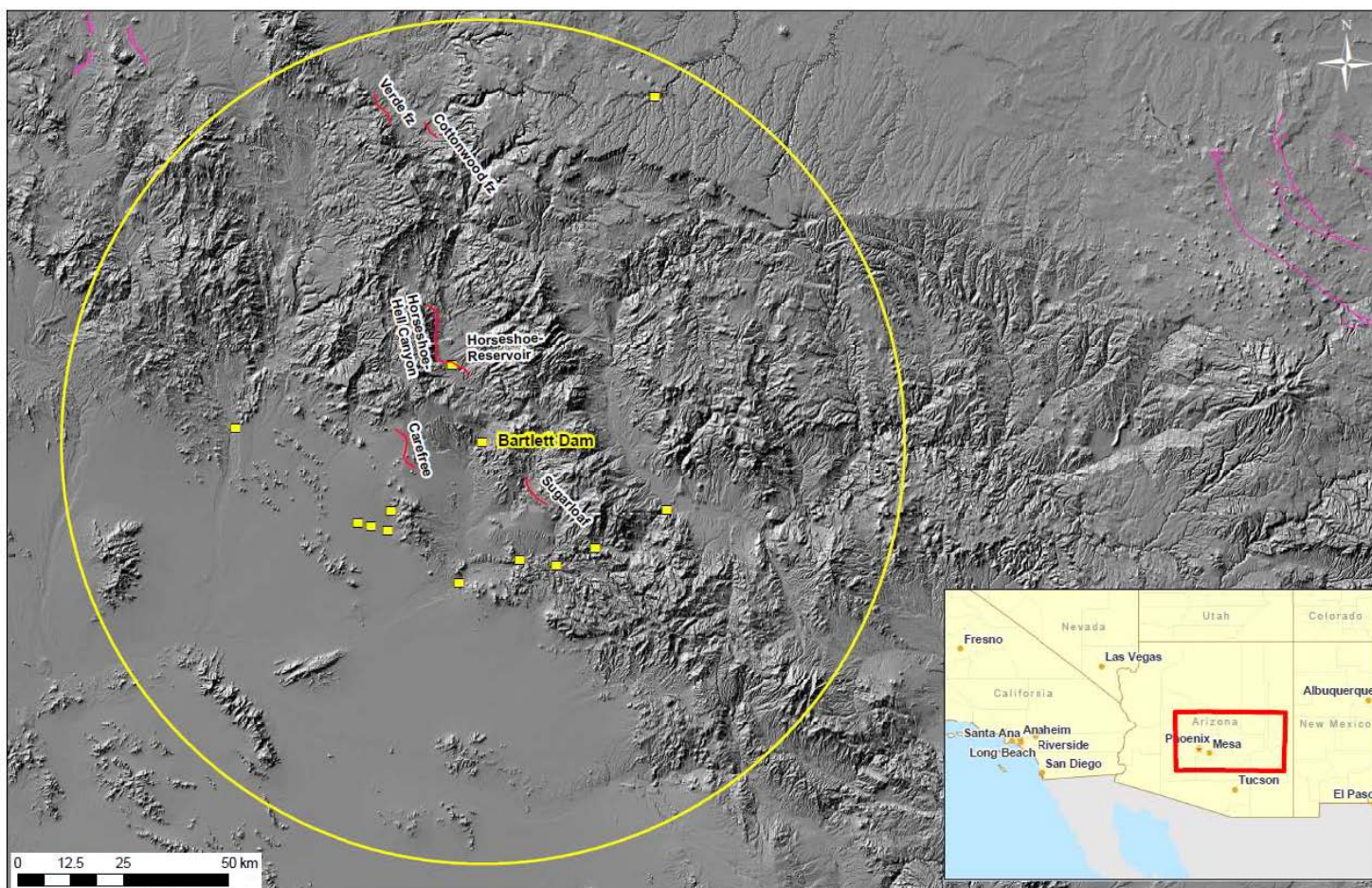
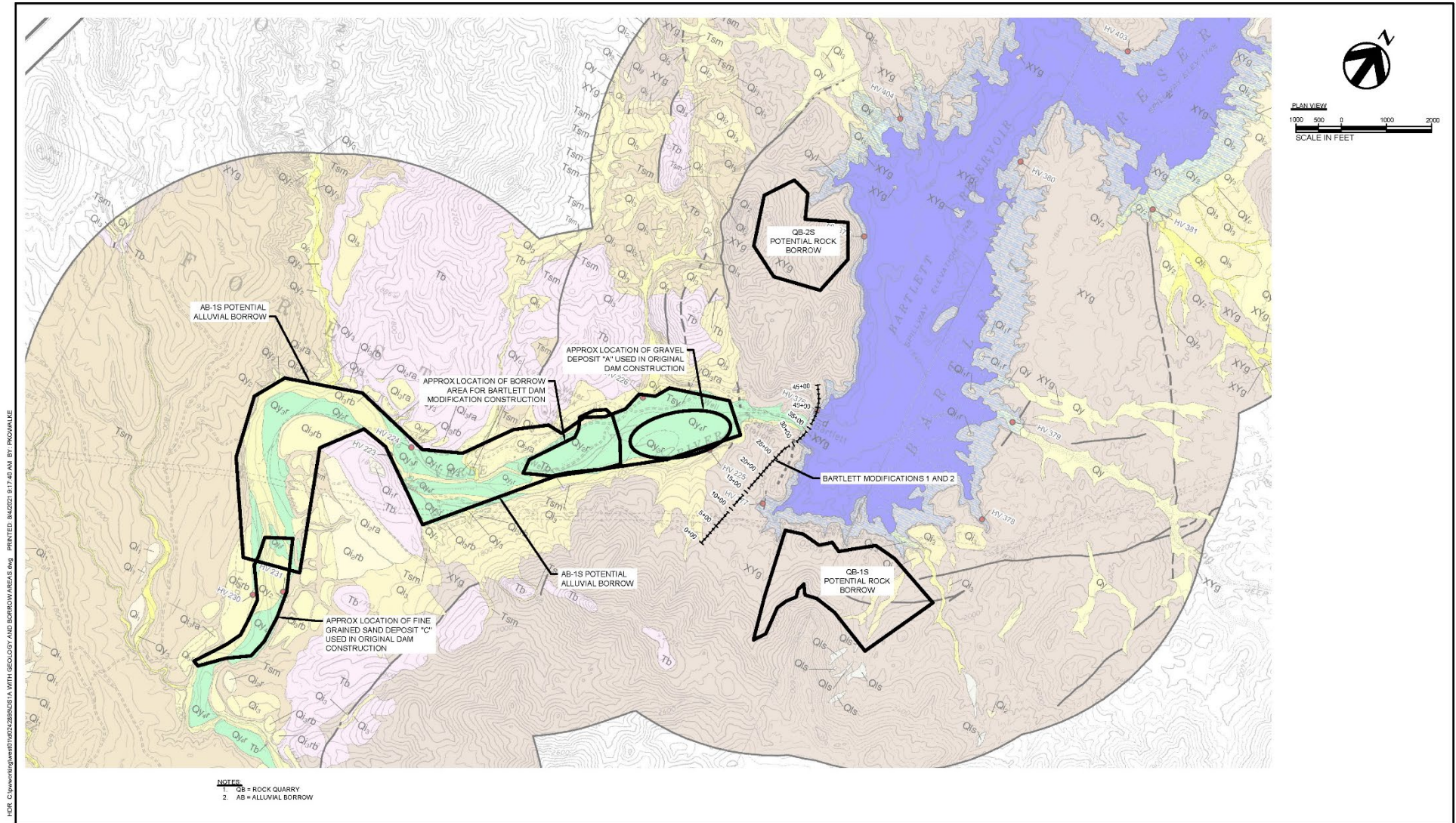


Figure 3. Location map of Bartlett Dam in central Arizona. Yellow circle denotes a 100 km radius around Bartlett Dam. The red lines are the mapped Quaternary faults from the USGS Quaternary fault and fold database located within 100 km of the dam. Pink lines are mapped Quaternary faults located >100 km from Bartlett Dam. (Revised Probabilistic Seismic Hazard Analysis and Ground Motion Time Histories for Bartlett Dam, Technical Memorandum No. 85-833000-2014-02; Reclamation, 2013)

3.5. Site Geology

The *Arizona Geological Society Publication Surficial Geologic Map of the Verde River Corridor, Central Arizona* (Cook et al, 2011) is a compilation of previous geologic mapping efforts and presentation of data acquired during recent mapping. It is used as the basis for appraisal-level assessment geologic conditions for the Bartlett Modification alternatives. The surface geology of the area is shown on Figure 4 (*Geologic maps from Cook et al, 2010*).



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SITE GEOLOGY AND POTENTIAL BORROW AREAS

DATE
AUG 2021

FIGURE
1J

Figure 4. Geology and Potential Borrow Areas near Bartlett Dam

3.5.1. Geologic Conditions

The Bartlett Modification 1 and 2 alternatives alignment includes the area immediately downstream of the existing Bartlett Dam. The alignment lies on Proterozoic granite (map unit XYg). Significant data regarding the granite was collected during initial construction of the Bartlett Dam and during construction of the modification in the mid 1990's. The granite is coarse- to fine-grained, with silicic dikes and shear zones within it. The shear zones in this granite unit are identified as ductile shears that occurred after emplacement (*Skotnicki and Leighty, 1998*) meaning that they are not a product of the current seismic setting. The contacts between zones of fine-grained and coarse-grained granite are generally tight and fused. However, some open fractures were reported in the 1996 report *Construction Geology for Bartlett Dam Modifications and Auxiliary Spillway*. The coarse-grained granite is moderately hard to hard and slightly fractured when slightly weathered to fresh. The fine-grained granite is hard and moderately fractured when slightly weathered to fresh.

Four predominant joint sets were identified during geologic mapping and drill hole logging during the Bartlett Dam Modification that have variable strike but are steeply dipping. Another low angle dipping set was also identified. Weathering along the joints was reported to vary between the coarse- and fine-grained granite. Joints in the coarse-grained granite are reported to be intensely weathered with iron oxide coating or clean. Joints in the fine-grained granite are clean or coated with iron and manganese oxide. A fault was mapped during construction of the left gravity section. The fault zone was measured at approximately one foot thick and was observed to be intensely weathered. Based on information in the previous construction reports, fine- and coarse-grained granite would provide a preferable RCC dam foundation. Excavation of moderately to intensely weathered granite would be required to reach the appropriate foundation conditions. Kinematic analysis of discontinuities including joints, shear zones, faults and lithologic contacts would be required to properly design excavation slope geometry. Photograph 2 shows an example of the closely spaced fractures in the fine-grained granite.



Photograph 2. Closely Spaced Fractures in the Fine-Grained Granite at the Bartlett Dam

Late Pleistocene alluvial fan and terrace deposits, described as weakly consolidated sands and gravels, are located left of the river channel. Recent river alluvium, including flood channel and terrace deposits, was described as unconsolidated sand, gravel and silt and are present within the current river channel. These materials would require complete excavation after river diversion along with excavation of weathered granite underneath the river channel in order to reach acceptable foundation conditions.

3.5.2. Other Geologic Hazards

Other geologic hazards include landslides and flood related debris flows. Based on existing geologic map data and AZGS Landslide Susceptibility Map

(http://azgeology.azgs.az.gov/sites/azgeo.azgs.az.gov/files/article_files/fig1-adem-landslide-incidence-susept.jpg), the risk of landslides is low for the Bartlett Modification alternatives.

Mapped landslide units (QIs) east of the Bartlett Modification alignments are limited and landslide potential is limited on the weathered granite surface left of the alignments. However, there may be landslide units that are not fully mapped upslope of the mapped units.

Flood-related debris flow is possible with sufficient rainfall, slope geometry to concentrate flow and debris that can be mobilized. A case of flood-related debris flow is not known to exist in the vicinity of the alignments but should be considered at least a remote possibility in the Verde River basin and tributaries.

Reservoir induced slope stability issues are possible if the Tertiary sedimentary rocks and middle to early Quaternary alluvial sequences that are at elevations above current river flood

elevations could be inundated. Based on the fact that Tertiary sedimentary rocks are primarily conglomerate and sandstone, and Quaternary deposits are largely sand and gravel, large scale slope stability issues would not be anticipated. However, localized slope failures could be expected upon reservoir filling and upon reservoir fluctuation during operation.

Construction hazards related to geology include excavation-induced slope stability problems. The number of discontinuities including joints, shear zones and faults within the Proterozoic granite; the number and orientation of flow and depositional contacts within the Tertiary volcanic and sedimentary rocks and the unconsolidated nature of Pleistocene alluvial fan deposits all have the potential to present excavation slope stability hazards. Use of existing data and further study to assess the number and orientation of discontinuities, and contacts of lithologic units would be required to properly engineer a foundation excavation and minimize slope instability hazards.

3.6. Construction Materials

Quaternary alluvium was successfully used as concrete aggregate for the Bartlett Dam construction and modification. The Holocene (present to 8,000 years old) historic river terrace deposits (Qy_{3r}) and flood channel and low terrace deposits (Qy_{4r}) have significant gravel and larger size content. Figure 4 shows the location of the aforementioned deposits (labeled AB-1S) that have potential use as aggregate material (with processing) for the Bartlett Modifications.

Another potential source of aggregate is the Proterozoic granite. The granite has coarse-grained and fine-grained units and is the most predominant rock type in the area of the Bartlett Reservoir. The granite is approximately 50% - 70% feldspar, 20% - 40% quartz and trace to 10% biotite. The granite would need to be slightly weathered to fresh, requiring any overburden of weathered granite and surface deposits to be removed to quarry a consistent rock quality. One potential limitation of the coarse-grained granite is the large feldspar crystals. The role of these large crystals, in terms of durability and in achieving a consistent and acceptable aggregate size through crushing operations, would require investigation prior to using it as an aggregate source. Locations of potential granite source locations are presented on Figure 4 (QB-1S and QB-2S). Assessment of the granite in future design phases should include crushing, processing, and laboratory testing to assess the suitability of the granite for aggregate.

3.7. Layouts of Alternatives

Layouts of the potential Bartlett Dam Modification alternatives including the dams' appurtenances (diversion systems, spillways, river outlets and potential for hydropower plant) are discussed in this section and are presented on Figure 5 and Figure 6. These preliminary layouts are based on reviews of available information and site visits. It is understood that the existing dam and appurtenances comply with current dam safety standards following the 1994-1996 dam raise, service spillway modifications and addition of a new auxiliary spillway. Reclamation's periodic inspections and performance reviews indicate that Bartlett Dam appears to be well constructed and maintained and has operated successfully for more than 70 years. The selected seismic loads for this location are relatively low as discussed above and Reclamation's analyses and instrumentation reviews do not indicate significant concerns with

the safety of the existing structure. The appraisal-level layouts of the dams include 0.8H:1V downstream slopes; 10V:1H upstream slopes; 24-foot-wide crest with a 25-foot-high chimney section. Foundation excavation, up to 45 feet deep, through weathered rock was assumed. A double-line grout curtain with holes at 20-foot spacings and tertiary holes for 50% of the length was included. The depth of the holes varies with the height of the dam along its length. No reliance was made on the foundation treatments for the existing dam. Allocations were also included in the cost opinions for other seepage and stability measures including blanket and consolidation grouting, drainage holes and gallery and localized treatments of potential fissures and shear zones. General factors affecting project layouts include:

- **Bartlett Dam and appurtenances meet current safety requirements.** These appurtenances, including the outlet works systems, primary gated spillway, and auxiliary fuse plug spillway, are believed to meet current dam safety standards based on the available information. There were no conditions cited in the available reference materials that would require major upcoming expenses that would be avoided or offset with a new dam or major dam raise. The options configured for this Study maintain, at a minimum, the same flood passage capability as the current Bartlett Dam appurtenances.
- **No opportunity for another vertical raise of the dam.** The 1994-1996 raise was accomplished with a vertical extension of the arches, buttresses, and gravity end sections. However, there was no increase in the normal operating pool level and no sustained increased water loads on the dam. A significant additional raise using a similar approach is not considered feasible.
- **Interface with the existing dam.** There are both potential benefits and significant challenges associated with infilling the existing dam arches to develop an integrated dam structure, the assessment of which requires additional geotechnical exploration beyond the scope of this appraisal-level study. Reasonably conservative assumptions are used in the selection of an appropriate dam cross section and foundation treatment allowances to develop preliminary cost opinions presented herein.
- **Optimized dam layouts are possible.** The dam layouts presented herein show the RCC section continuing the full length of the left abutment past the auxiliary spillway. Other arrangements could also be considered. For example, a composite dam with the main RCC gravity dam section transitioning an earth core rockfill dam close to the existing Bartlett left abutment thrust block, could also be considered.
- **The existing level of flood control and flood passage capability must be maintained or enhanced with a raise of the existing dam.** The preliminary OPCC reflects both a new service spillway at the maximum section of the dam and a new RCC overflow auxiliary spillway along the left abutment. Future engineering evaluations should determine if full flood routing capacity can be provided over the maximum section of the dam.
- **Reservoir outlet and management of reservoir levels.** The preliminary OPCCs presented here include cost allocations for modifications to the existing outlet works

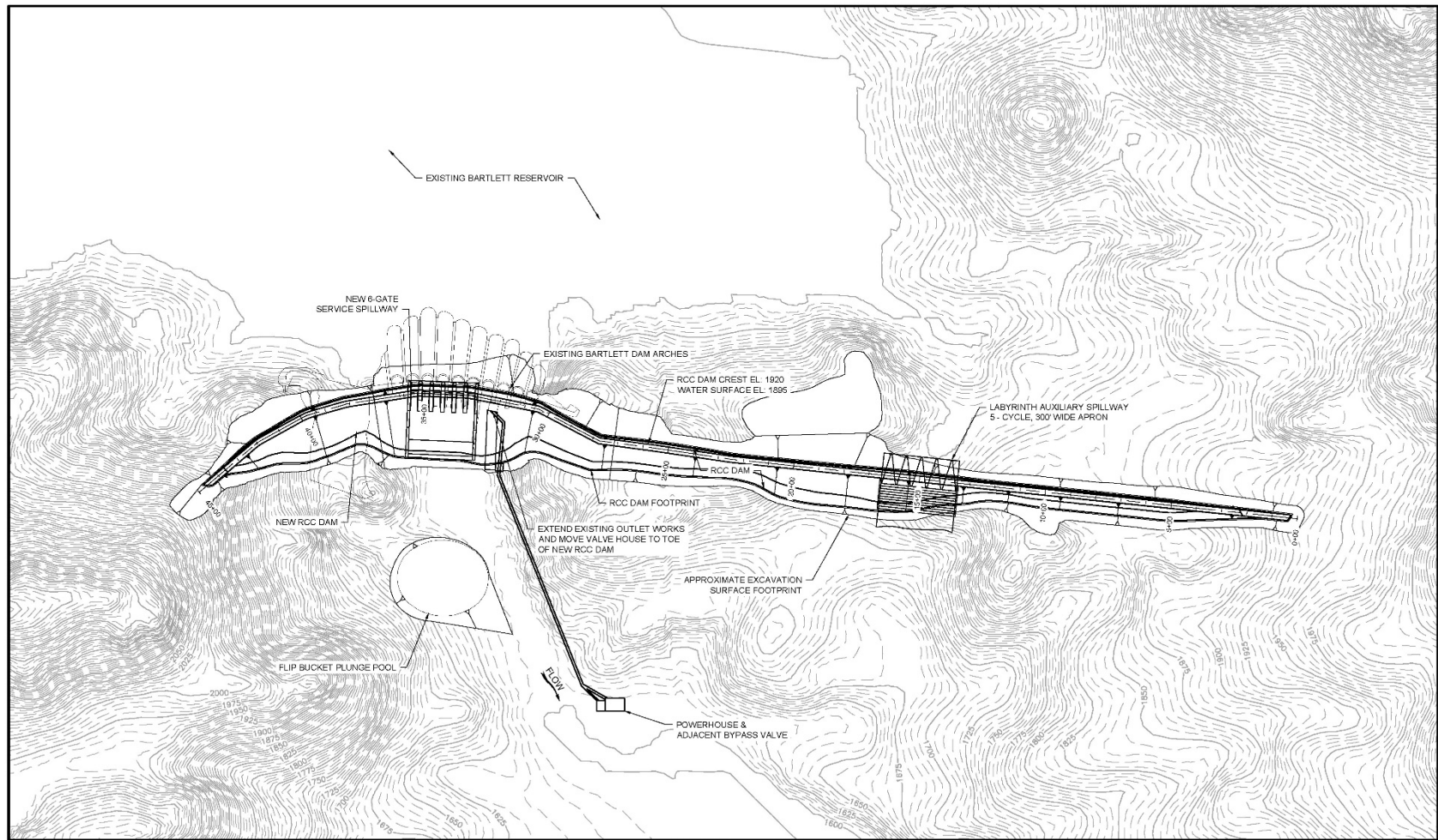
system, as well as construction of new downstream flow control facilities. Temporary reduction in reservoir storage levels and/or possible modifications to the outlets may be needed to increase diversion flow rates to manage potentially damaging spills during construction. Diversion costs are based on utilizing and extending the existing outlet works through the work area.

- **Spillway use for flood routing during construction.** Continued availability of the existing spillway may be needed until enough of the new dam section and spillway are constructed to allow routing flood flows over the dam or through the new spillway section. In addition to the construction costs for the diversion and permanent works, the preliminary OPCC reflects the impacts of challenging construction sequencing and risk mitigation costs.
- **Environmental considerations.** The location and extent of environmental effects of the Bartlett Modification alternatives are affected by whether the borrow areas for the RCC aggregates can be located within previously disturbed areas. Future phases of study should address these types of issues in more detail.

The appraisal-level project layouts presented herein were prepared using existing information. Design data investigations in the future should include: geologic mapping, detailed joint surveys, drill holes along the proposed dam alignment, around the dam footprint, at the auxiliary spillway location and within the proposed plunge pool to determine foundation characteristics (depth to rock, depth of weathering, etc.). Packer tests should be performed in the drill holes to determine permeability and an instrumentation plan should be developed for the drill holes. Additionally, an investigation program should be conducted to delineate aggregate and other borrow sources. Reservoir mapping should be conducted to identify if there are areas of potentially significant landslides or other geologic hazards.

The interface between the existing dam of the new construction will also need to be thoroughly considered. Considerations should include the following:

- The potential for introduction of stress concentrations in the RCC due to the penetration of the existing buttresses. This is chiefly of concern for a partially integrated structure.
- Effects of seasonal temperature fluctuations on the interface between the existing structure and the potential new one. The existing Bartlett Dam is an extremely thin structure and is therefore subject to various stress states due to seasonal temperature variations.
- Means of ensuring a bond between the existing and proposed concrete structures.
- The constructability of an integrated dam raise will need to be further evaluated, as these alternatives have risks related to public protection as well as construction schedule and construction cost risks.



RCC DAM PLAN VIEW

200 100 0 200 400
 SCALE IN FEET

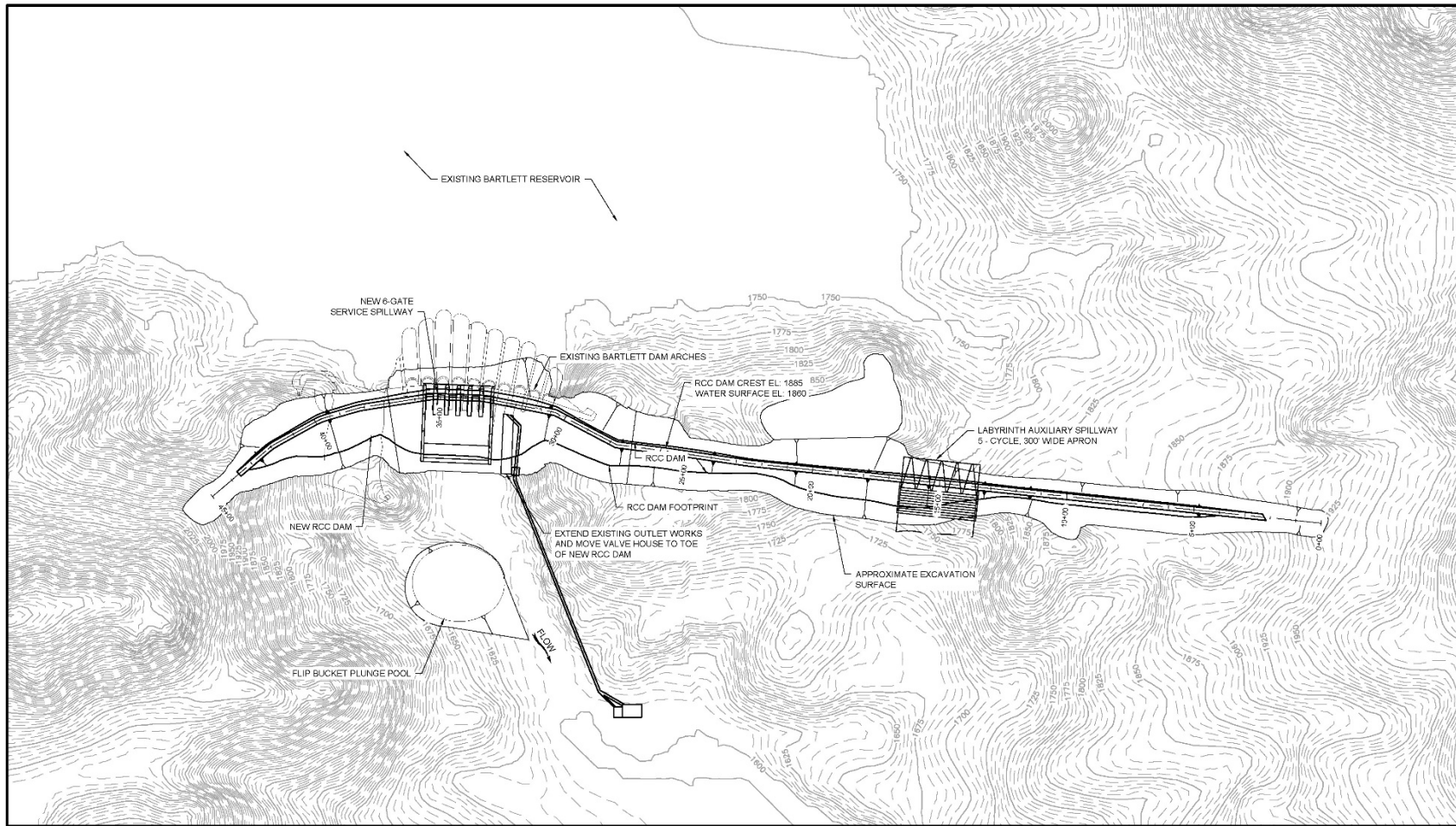


VERDE RESERVOIRS SEDIMENT MITIGATION
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BARTLETT MODIFICATION 1 - PLAN

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Figure 5. Bartlett Modification 1 Preliminary Layout



RCC DAM PLAN VIEW



VERDE RESERVOIRS SEDIMENT MITIGATION
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Figure 6. Bartlett Modification 2 Preliminary Layout

3.8. Spillways

3.8.1. Service Spillway

For the purposes of this appraisal-level study, the three existing 50-ft-wide by 50-ft-high fixed-wheel (Stoney) gates are assumed to be replaced by radial gates of similar size and capacity. The current service spillway is designed to pass a peak routed discharge of 287,500 cfs at reservoir water surface (RWS) elevation 1821.0 per Reclamation's 2018 Comprehensive Review (CR) report. This report cites a peak reservoir design inflow of 562,000 cfs for the probable maximum flood (PMF). Energy dissipation for this system would be accomplished with a flip bucket and plunge pool. Matching the hydraulic performance characteristics of the potential new and the existing service spillway requires that the hydraulic performance of the auxiliary spillway also be consistent with the existing facilities to pass the same PMF inflow design flood. Feasibility-level design should consider the amplification of loading that will occur with a higher dam for the most seismic loadings as discussed in Section 3.4.2.

3.8.2. Auxiliary Spillway

Three alternative crest types, in addition to replacement with a fuseplug spillway, were considered for the auxiliary spillway. Each one was configured to pass a peak discharge of 274,500 cfs: the difference between the 562,000 cfs peak reservoir inflow and the service spillway design discharge of 287,500 cfs cited above. This approach is conservative at this stage of appraisal-level design. It assumes no reduction in the peak design discharge requirement resulting from attenuation of the peak reservoir inflow. Reclamation's 2018 CR cites peak design discharge of 261,700 cfs for the current fuseplug system at an RWS elevation of 1820.2; slightly lower than the elevation cited for the peak service spillway discharge in the preceding. The three additional types of spillway crests that were considered are:

- labyrinth
- composite labyrinth and fusegate
- ogee

These alternatives were reviewed in terms of their physical size, construction cost, replacement cost, operational predictability, and compatibility with an RCC modification to the existing dam. All three alternatives for the crest-control structure will require either a lined chute or unlined channel to convey flood discharges to the downstream river channel. The cost opinions include allowances for a concrete apron extending across the full width of each alternative for 50 ft downstream of the apron and for up to 200,000 CY of rock excavation and armoring (up to 32,000 CY RCC) to shape an unlined channel extending to the river. This is considered a reasonable approach to defining appraisal-level layouts and cost based on the available existing information related to the erodibility of the flowpath downstream of the existing auxiliary spillway fuseplugs. Future feasibility study programs, if conducted, will need to assess the erodibility of the underlying rock in relation to the flow velocities, depths, and durations for the design discharge. The cost of labyrinth crest option was incorporated in the overall OPCC for the two Bartlett Modification alternatives presented in Section 4 below.

Reclamation's Public Protection Guidelines and sound engineering practice dictate that any risks during the construction of dam modifications be minimized and that there is no increased risk following a dam modification compared to pre-modification conditions. Therefore, maintaining sufficient flood routing capacity during construction is an important consideration. An overview of a potential construction phasing for the new service spillway and auxiliary spillway is below, followed by descriptions of the three alternative types of crest structures considered for the auxiliary spillway. Bartlett Modification 1 is used in the descriptions of the alternative crest structures below.

Flood Flow Capacity during Spillway Construction

An important consideration for the design and construction of the Bartlett Dam raise including the new auxiliary spillway structure will be the ability to pass large flood events during the transition phase following closure and permanent modification of the existing service spillway, completion of the new service spillway, and completion of the new auxiliary spillway. It is currently assumed that the service spillway will retain full functionality while the center portion of the new dam is constructed within and downstream of the buttresses of the existing dam. While the new service spillway section and left abutment section is under construction, the existing low level outlet works would be used to pass low to moderate flows through the new outlet works penstock leading to the new powerhouse (if hydropower generation is included) 1,200 ft downstream of the dam, while the existing service spillway would be used to manage flood flows in excess of the capacity of the two 72-inch-diameter outlet valves. The auxiliary spillway labyrinth sections would not be constructed until the new service spillway is functional and available for flood passage. Once the new service spillway is complete and functional, the auxiliary labyrinth crest sections would be completed prior to dam raise, and at the same time as the existing service spillway is decommissioned and the right abutment section of the raised dam is completed. Section 4.6 provides additional detail on management of flood flows during potential construction phasing.

Labyrinth Crest Structure

This alternative consists of a 300-ft-wide labyrinth spillway with five complete cycles, each of which is approximately 60 ft wide, 116 ft long as measured along the crest, and 30 ft in height above the apron. Passing a 274,500 cfs peak design discharge for the auxiliary spillway requires about 21 ft of head over the weir crest elevation of 1,895 ft for Bartlett Modification 1. A dam crest at elevation 1,920 ft results in four feet of residual freeboard above the maximum estimated reservoir elevation of 1,916 ft. The total effective crest length of the five-cycle labyrinth is approximately 720 ft, based on the magnification factor derived from empirical discharge equivalent curves provided in Reclamation's design guidelines for labyrinth spillways (Reclamation). The 21-ft maximum driving head combined with the four-foot residual freeboard and the 30-ft weir height necessitates a base apron elevation of 1,865 ft, or about 55 ft below the proposed dam crest elevation of 1,920 ft. The apron extends across an RCC pedestal jutting into the reservoir from the upstream face of the RCC dam and through the RCC dam section to the downstream face. The total length of the apron from upstream to downstream is approximately 126 ft. The approach conditions to the labyrinth sections will be improved by the auxiliary spillway's extension into the reservoir, optimizing its capacity and providing stable flow

conditions over the labyrinth cycles. Guide walls approximately 25 ft in height would extend downstream of the dam crest on either side of the spillway to contain the spill discharge. Downstream of the RCC toe, a discharge apron approximately 50 ft in length would extend down the slope, with guide walls on either side to direct the flow. Beyond the apron, limited excavation and RCC armoring are assumed to be necessary to protect the most vulnerable reaches of the steeply sloping natural channel guiding emergency spillway flow to the river below. The discharge exit location for the auxiliary spillway channel is shown several hundred feet downstream of the potential new hydroelectric powerhouse. While current judgment suggests the spill channel rock would be sufficiently erosion resistant with selective excavation and armoring, the erodibility of the auxiliary spillway discharge channel needs to be evaluated early in design to confirm design requirements, cost, and schedule implications.

Composite Labyrinth and Fusegate Crest Structure

This alternative consists of a three-cycle, 180-ft-wide labyrinth of similar design as described above, but only 45-ft-high, adjacent to two, 120-ft-wide Fusegates (@Hydroplus) separated from the labyrinth section by a dividing guide wall. The apron beneath the labyrinth section would be at elevation 1,875 ft, while the apron for the Fusegates would be at about elevation 1,860 ft. The total effective length of the labyrinth section as calculated using the magnification factor applied from Reclamation guidance would be about 288 ft. The Fusegate effective crest length based on the magnification factor derived from Reclamation guidance would be about 300 ft. The Fusegate tipping reservoir elevations have not been estimated, but the full discharge capacity of the labyrinth with both Fusegates failed is about 250,000 cfs with a reservoir elevation of 1,915 ft. However, replacing the Fusegates in their design position would require either a large cofferdam upstream of the Fusegate apron or drawing down the reservoir to elevation 1,860 ft. Similar to the labyrinth spillway described above, the composite spillway would be contained by guide walls on either side of the discharge chute and apron, extending roughly 50 ft beyond the toe of the proposed RCC dam section. Spillway flow would pass down the natural valley to the river channel below. No preliminary design figures were prepared for this alternative since the labyrinth-only option is believed to provide greater operational reliability and lower capital cost of construction and does not require replacement costs or reservoir drawdown associated with Fusegates. Auxiliary spillway channel considerations would be the same as the labyrinth-only alternative.

Ogee Crest Structure

This alternative consists of a simple ogee crest spillway at crest elevation 1,895 ft that would require a total width of about 773 ft. The downstream discharge chute would terminate roughly 50 ft downstream of the RCC dam section toe, as for the labyrinth spillway and the composite spillway designs described above. However, the natural topography in the spillway exit area likely would result in the flow splitting to pass on both sides of the downstream natural high point, necessitating considerably more discharge channel cost than the narrower labyrinth options. The discharge capacity of the simple ogee crest would be roughly 250,000 cfs at reservoir elevation 1,915 ft. While this alternative provides a simple ogee crest section, and lower unit discharge down the natural valley slope, the extended width of crest was significant,

and this option was not evaluated further. No preliminary design figures were prepared for this alternative.

3.9. Outlet Works and Hydropower Penstock

Although other options were considered for the outlet works design, the River Outlet Works (ROW) and bypass system are located far enough downstream to provide protection from service spillway discharge events. A small bypass valve could be tapped into the larger outlet works penstock to discharge low flows into the stream channel immediately downstream of the new dam toe. The valve and operator will be protected from service spillway flows by a robust valve control house with protected personnel access from the left abutment to the valve house. The large-diameter (108 in) outlet works penstock would continue along the left channel bank to the new powerhouse location approximately 1,200 ft downstream of the toe of the new RCC dam. Any location nearer to the new service spillway would be vulnerable to high-flow spill events, given the close proximity to the service spillway flip bucket and plunge pool. The three sluice gates for the existing low-level outlets have not been used since 1977 and are no longer operable. Future design studies should determine whether this system should be repaired and extended or permanently plugged, depending on the need for sediment maintenance at Bartlett Dam.

The two existing 72-inch diameter conduits that make up the ROW would be extended through the new RCC dam section to the toe of the new dam. Downstream of the dam, they would be combined through a wye into a single nine-foot-diameter steel penstock to provide a cross sectional flow area about 10% greater than currently exists to manage head loss in the lengthened penstock without exceeding the maximum flow velocity through the existing 72-inch-diameter conduits. The conduit would connect to a powerhouse and outlet structure location about 1,200 ft downstream of the present terminus. The remaining length of the large penstock would be encased or buried in an excavated trench in rock along the left channel bank to protect it from the river in the case of large spill events. At the terminus of the large penstock, a powerhouse structure would serve as both the primary low to moderate flow bypass valve outlet and a hydropower generation plant whenever flows will permit. At the powerhouse, the penstock will bifurcate to the turbine and to a large, fixed cone or ring jet valve discharging into the river channel. The bypass valve will also provide transient attenuation and pressure relief in the event of turbine load rejection runaway condition, eliminating the need for a separate surge chamber in the system. A concrete valve house and control system would be constructed to protect it from high river flows. The sizing and layout of the powerplant and the potential energy generation is presented in the next section.

3.10. Hydropower

There have been several previous preliminary assessments of adding conventional hydropower at the Bartlett and Horseshoe Dams, including occasional interest of private developers exploring potential Lease of Power Privilege (LOPP) arrangements. LOPP is a contractual right given to a non-federal entity to use a Reclamation asset for electric power generation. The power generation must be consistent with Reclamation's project purposes and must not impair

the efficiency of water deliveries or negatively affect any other Reclamation project purpose. It must also be a risk-neutral modification.

Non-federal entities seeking to utilize a Reclamation asset would be required to obtain either a Reclamation LOPP or FERC License – but not both. Previous explorations of conventional hydropower generation have not moved forward, likely due to a combination of the capital costs and permitting challenges associated with new electrical transmission lines. Connecting relatively small-capacity plants to the high-voltage power lines passing immediately below and along the left abutment of Bartlett is not practical.

For the purposes of this appraisal-level study, a new hydropower facility was located approximately 1,200 ft downstream of the dam and would be fed water from a penstock extending from existing river outlet works conduits. A range of installed capacities for a new hydropower plant were evaluated. Based on assumed economic parameters, the most viable installation would be on the order of six to ten megawatts (MW) when costs of new electrical service (transmission) costs are included. Transmission is the most significant driver of cost and, therefore, economic viability for the facility

A high-level cost opinion for a 5.5 MW facility was developed and is presented in Table 3. The basis for the cost opinion, including generating equipment, was bids and/or construction on similarly-sized hydropower installations including sites in remote areas.

Table 3. Construction Cost Opinion for a 5.5 MW Hydroelectric Plant

Feature	Item	Cost
Powerhouse	Earthwork/Water	\$200,000
	Structure	\$1,250,000
	Mechanical BOP	\$330,000
	Electrical BOP	\$880,000
Penstock	Material	\$430,000
	Install	\$480,000
Generating Equipment	Equipment	\$5,800,000
	Install	\$820,000
Switchyard		\$320,000
Transmission/Fiber		\$8,700,000
Subtotal		\$19,210,000
Contingency (40%)	—	7,680,000
Total		\$26,890,000

Cost opinions were then developed for a wider range of installed capacities through scaling of the 5.5 MW facility costs as follows:

- Per Installation (powerhouse structure, earthwork, and balance of plant mechanical and electrical, switchyard, and transmission)
- Per kW (generating equipment)
- Per Penstock Diameter Squared (penstock material and installation)

The results of this process are shown in Table 4 below.

Table 4. Hydropower Plant Capital and O,M&R Cost Opinions

Design Discharge (cfs)	Capacity (kW)	Penstock Diameter (ft)	Capital Cost (\$Millions)	O,M&R Cost (\$ per year)
50	760	3.0	17.8	100,000
100	1,520	4.0	19.2	105,000
200	3,050	5.5	22.1	116,000
300	4,570	6.5	24.9	126,000
400	6,100	7.5	27.7	137,000
500	7,620	8.0	30.5	147,000
600	9,140	9.0	33.4	158,000
700	10,670	9.5	36.1	168,000
800	12,190	10.5	39.1	179,000
900	13,720	11.0	41.9	190,000
1000	15,240	11.5	44.7	200,000

Operations, maintenance and replacement (O,M&R) costs for the plant are estimated to be on the order of \$100,000 - \$200,000 per year. This estimate is based on HDR's proprietary database of capital and O,M&R costs obtained by HDR from owners/operators of hydroelectric projects in operation and from quotes provided through sponsors of projects in the planning, permitting, design and construction phases across the U.S. The opinions of probable O,M&R costs for the Bartlett Modification alternatives were developed using this database focusing on similarly-sized plants including both recently-constructed plants and aging plants. The estimate also is based on the assumptions that the hydropower facility will:

1. be remotely operated and in conjunction with the operations of the other existing Salt and Verde River water storage and hydropower facilities and

2. only be constructed as part of one of the Bartlett Modification alternatives and so the on-site personnel assigned to maintain the dam will also maintain the hydropower plant as a small part of their normal routines.

Typical O,M&R costs can be heavily dependent on labor costs and on the accessibility of the facility. The estimated capital cost of the hydropower facility that might be constructed in association with one of the two Bartlett Modification alternatives is approximately three to four percent of the total capital costs for these alternatives. Therefore, it is reasonable to expect that the labor costs for maintaining the hydropower facility would be a small component of the alternatives' overall annual labor cost. The resulting O,M&R costs are shown in Table 4.

4. Cost Opinions and Constructability

4.1. Approach

The method used to develop each alternative's costs included the following steps:

1. Select dam axis alignments and generate existing ground profiles for them.
2. Identify a reasonably conservative cross section configuration for each dam taking into account the likely foundation conditions, construction materials, key static and seismic loading conditions and other factors.
3. Estimate nominal excavation depths and the degree that they would vary along the entire dam base.
4. Select type, locate, and size the hydraulic structures, and diversion and cofferdam components.
5. Develop additional typical cross sections to generate major component quantities.
6. Generate work categories and a work breakdown structure (WBS) that encompasses the alternatives and provides a thorough basis to apply quantities and pricing for each alternative. The WBS was comprised of approximately 300 work elements that roll up into the 18 major items shown in the cost summary tables later in this section.
7. Generate work quantities and considerations to guide price selection for each work item.
8. Generate a composite RCC unit cost for each alternative, by considering a sub-WBS and variability between alternatives.
9. Price each alternative's WBS.
10. Select and apply "below-the-line" contingencies and factors that reflect Reclamation's approach to developing total project costs from direct construction costs. (*Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03*)
11. Generate various summaries to facilitate comparison between alternatives.

12. Evaluate differences and variability between alternatives and develop line-item low- and high-cost ranges for each item and each alternative. The range in costs presented below reflect the summation of all the individual ranges in each cost item rather than applying say a percent difference at the end.
13. Generate summary information and metrics.

4.2. Key Cost Components

Presented below are overviews of selected cost components that either have a large impact on bottom-line construction costs or have significant cost escalation risks.

4.2.1. River Diversion and Care of Water During Construction

Both Bartlett Modification alternatives require low-level outlet works releases during construction to maintain downstream flow requirements and appropriate reservoir levels to aid in management of normal and flood flows into the reservoir. They also will require tailwater management, likely through construction of a downstream cofferdam. Dewatering of dam foundation and structure excavations will also be needed. In addition to these direct costs, the contractor's bids will also include diversion and flood management risk costs reflecting both sequence- and impact-related costs. For example, sequence impacts relate to foundation excavation, treatment, and grouting. The impact costs relate to the discontinuity, loss of economy and, potentially, remobilization costs associated with breaking work into sequences, phases, and perhaps smaller components. Risk costs are less tangible than direct costs but are often a significant consideration in the development of contractor bids.

4.2.2. Project Access and Site Development

For each Bartlett Modification alternative, a cost has been developed for additional new access, improving existing access, creating needed project construction roads, river crossings and site staging areas.

4.2.3. Demolition

The cost opinion for each modification alternative contains an allowance for demolition of existing facilities, e.g., existing dam crest modifications and the service and auxiliary spillway removals.

4.2.4. Foundation Preparation

Foundation excavation costs include common excavation and followed by rock excavation, generally priced as blasted rock excavation. Excavation depths have been chosen for each alignment, recognizing the central valleys typically require deeper excavation. Average excavation depths have been assumed to be on the order of 30 to 45 ft with up to half of that being weathered or unsuitable rock. Allowances for dental concrete, foundation grouting, and dam and foundation drains are also included.

4.2.5. RCC Dams

RCC costs depend on material type and quality; mix design; mixing; placing a delivery, which is highly dependent on the dam height and volume; plant location; delivery approach; and both vertical and volumetric productivity. For example, if in future design phases, it is decided that RCC should be placed to completely fill in the existing arch sections, this placement is more costly than long and wide lifts without constraints. The cost of mobilizing and setting up the plant(s) and delivery system(s) is very similar between the two alternatives. Since Bartlett Modification 2 is the smaller alternative, it has a higher unit cost because the same fixed costs for both alternatives are applied to the smaller total volume of RCC. Finally, “RCC” in each estimate is considered to be not only the roller compacted concrete, but also the facing systems, gallery, internal drain systems, contraction joints, etc., which all contribute to a composite RCC pricing. For the raise options, consideration has been given to separate line-item costs for the infill of the buttresses upstream of the new dam’s cross section.

4.2.6. Hydraulic Structures

Line items addressing hydraulic structures include modifications to the existing Bartlett Dam river outlet works, where applicable, and new outlet works construction, new service spillway, and an auxiliary spillway. Each alternative includes a service spillway and a separate auxiliary spillway with unit costs applied to excavation, concrete, gates, RCC foundations and supplemental chute excavation. The labyrinth crest option for the auxiliary spillway was used in the cost opinions both Bartlett Modification alternatives.

4.3. Contingencies and Factors

Each estimate reflects each alternative’s “Total Direct Construction Cost - before contingencies” followed by several “below-the-line” factors building to a total opinion of probable cost. Shown and described below, these factors are necessary to generate a realistic understanding of total project costs, beginning with project planning, final design, construction oversight, permitting and other administrative costs along with appropriate design and construction contingencies that reflect the level of project development, site characterization and inherent design and construction risks.

4.3.1. Estimate and Design Contingencies

These contingencies are consistent with Reclamation’s design and procurement contingencies and represent an allowance for costs that become more developed and defined as the level of design evolves. For example, an early estimate might assume an uncontrolled spillway and, as the design evolves, gated spillway control is deemed necessary. A design contingency is intended to allow for this cost increase and the magnitude of the contingency would decrease as the design process evolves from the current appraisal level through feasibility and final design levels.

4.3.2. Construction Contingency

This contingency considers the costs a project is likely to incur after award of a construction contract. It addresses work quantity increases, changes in scope, change orders, and low-grade

dispute resolution associated with differing site conditions or requirements. Each alternative has been assigned a construction contingency to reflect relatively high-risk construction components related to major river diversion and management and to complex and multi-disciplinary work requirements. It is important to recognize this contingency would not necessarily decrease as the design evolves but may even increase as the understanding of anticipated bid and post-award conditions improves.

4.3.3. Non-contract Costs

The subtotal costs prior to this factor represent the costs of construction, first bid and then the final quantity, change and dispute costs. The non-contract cost line adds a factor for environmental and other permitting costs, site characterization, studies, design, and construction management, etc. that have not yet been individually estimated. The “non-contract” costs should not be considered a contingency, but the real costs of preparing for and monitoring construction. Non-contract costs were developed based on Reclamation’s guideline (*Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03*).

4.3.4. Escalation

Escalation has not been evaluated in this analysis and costs are considered to represent a price points as presented in the cost opinion tables.

4.4. Cost Risks

For each line-item in the WBS, a low and high range was generated to reflect factors that could drive the costs up or down from the Base Cost. Judgment was applied to the base pricing to reflect low and high ranges from a starting point of 80% of the base cost for the low end and 120% of the base cost for the high end. An illustrative example is the spillway plunge pool impact basin where the low-end cost is for an unlined pool excavated or eroded to resistant rock. The high-end cost reflects the potential that it may be determined in future design phases that a heavily reinforced concrete lining is appropriate. This is an example where applying uniform percentages across all cost items to obtain low and high estimates is not appropriate for highly specialized dam construction. In summary, the aggregate differences in the low to high ranges for the two Bartlett Modification alternatives range from a low of approximately 76% to a high of 133% between the options.

An overview of the major design and construction risks that were taken into account in developing the construction cost opinions for the two Bartlett Modification alternatives is presented in Table 5.

Table 5. Summary of Risk Issues Considered in the Appraisal Designs and Cost Opinions

Component	Risk Overview
Interface of New Dam with the Existing Dam Structure	Potentially high risk and requiring continued attention in future design phases. Rehabilitation of existing sluicing system or design and construction of a new system may be needed with measures to control potential excessive wear on gates and valves from abrasive sediment.
Construction Sequencing	Construction sequencing effects on the efficiency and continuity of work. Multiple construction packages will likely be needed to perform the eight currently identified stages of construction.
Diversion and Care of Water	High risk typical of dam construction but is a lesser risk for RCC dam construction than for embankment dams. Passing Bartlett spill events during construction will require carefully planned construction sequencing and reservoir management.
Dam and Foundation Stability	Relatively well-known foundation conditions for an appraisal-level design considering previous field exploration and construction programs. Additional investigation needed to better define conditions extending farther downstream and along the extended abutments. Complex structural behavior but lower seismic loadings than many other areas in the U.S.
Variable Foundation Conditions	Potential variability in foundation excavation requirements including stabilization of steep slopes.
Work Scope Complexity	Complex, multi-disciplinary design, and construction is required. Limited upstream access and marine operations necessary for some work.
Environmental Compliance	Existing Habitat Conservation Plan and potential new requirements may affect design details and construction sequencing and duration.
Recreational Uses	Marina modifications will be required, and types of recreational uses and access locations may be affected during construction.
Site Access and Infrastructure Relocations	Site access limitations and haul road construction. Relocations include an existing high-voltage transmission line. Verde River crossings will be required.
Interface with the Existing Horseshoe Dam and its Reservoir Operations	Stability of the existing upstream embankment will increase with continued sediment accumulation, but modifications will be needed to the existing outlet system. Additional slope stabilization may be needed for the downstream embankment to address partial inundation and Bartlett reservoir fluctuations.

4.5. Reclamation Public Protection Guidelines

Reclamation's Public Protection Guidelines and sound engineering practice dictate that any risks during the construction of dam modifications be minimized and that there is no increased risk following a dam modification compared to pre-modification construction conditions. The Bartlett Modification alternatives would require major construction work at the existing Bartlett

Dam including its appurtenances. This includes extensive excavation and treatment of the foundation and abutments adjacent to and adjoining the existing structure. This appraisal-level study has not addressed the excavation details and methodologies or the degree to which the reservoir may need to be lowered during construction. This study does, however, identify, at a preliminary level, potential stages in construction sequencing to increase confidence in the technical and economic feasibility and the overall cost risks associated with this work. The next section describes a staged construction process with schematics depicting potential sequencing options. This is followed by the appraisal-level opinions of probable construction costs as these costs are affected by public protection and risk management requirements and strategies.

4.6. Construction Sequencing

Constructability issues are considered here at an appraisal level of detail to support evaluation of: 1) alternative approaches to the facility layouts; 2) potential fatal flaws from technical and safety perspectives and 3) preliminary OPCCs. This section presents a potential eight-step process for the required construction activities; which relies on using the existing service spillway as long as possible, followed by a period late in construction where spill flows, reduced if possible by Bartlett and Horseshoe storage reductions during construction, are routed through the new auxiliary spillway alignment. The eight steps are presented on Figure 7 and Figure 8 for the Bartlett Modification 1 alternative. Descriptions of each step follow the figures. Environmental management and mitigation programs would be conducted throughout all stages of the work program.

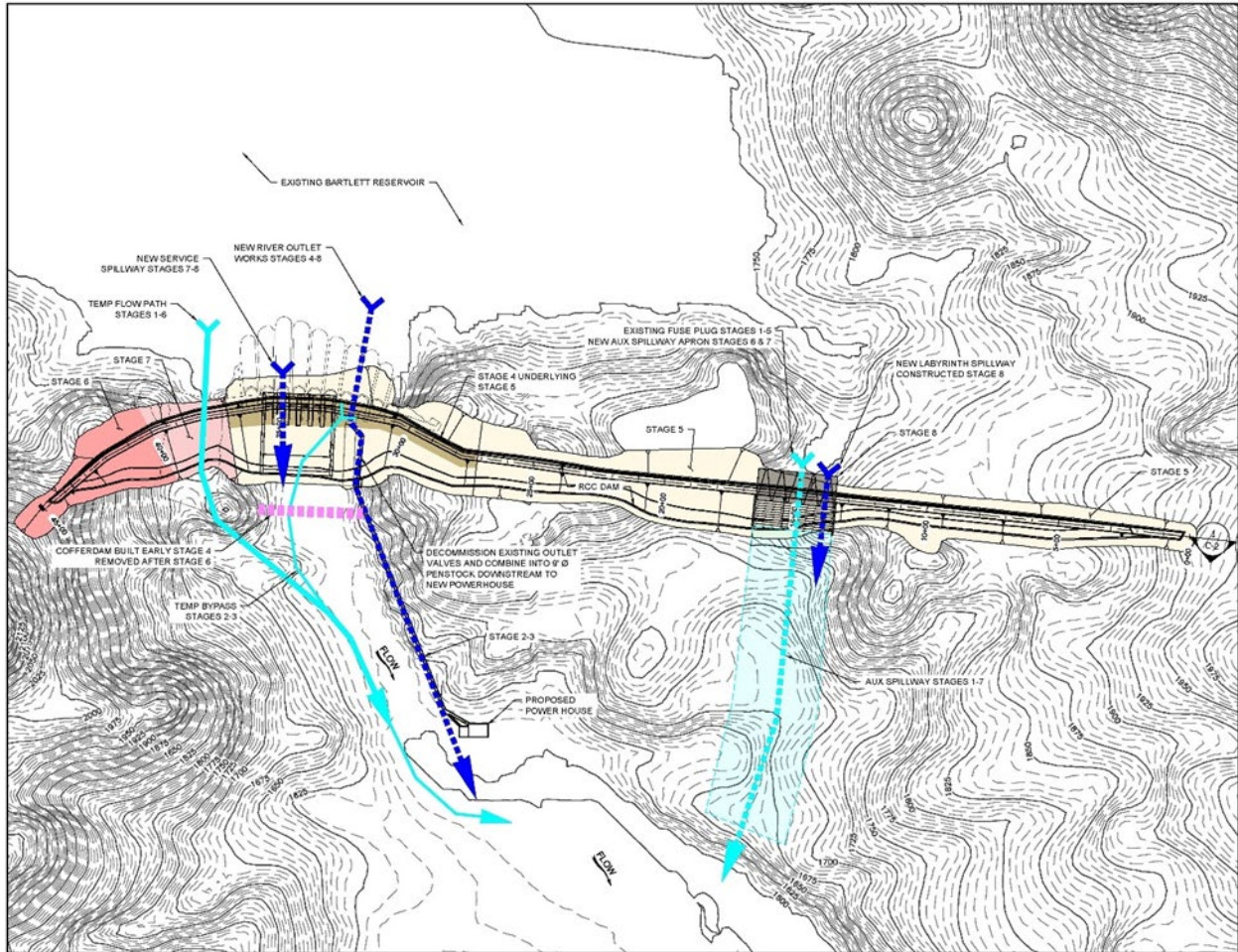


Figure 7. Construction Sequencing – Plan View

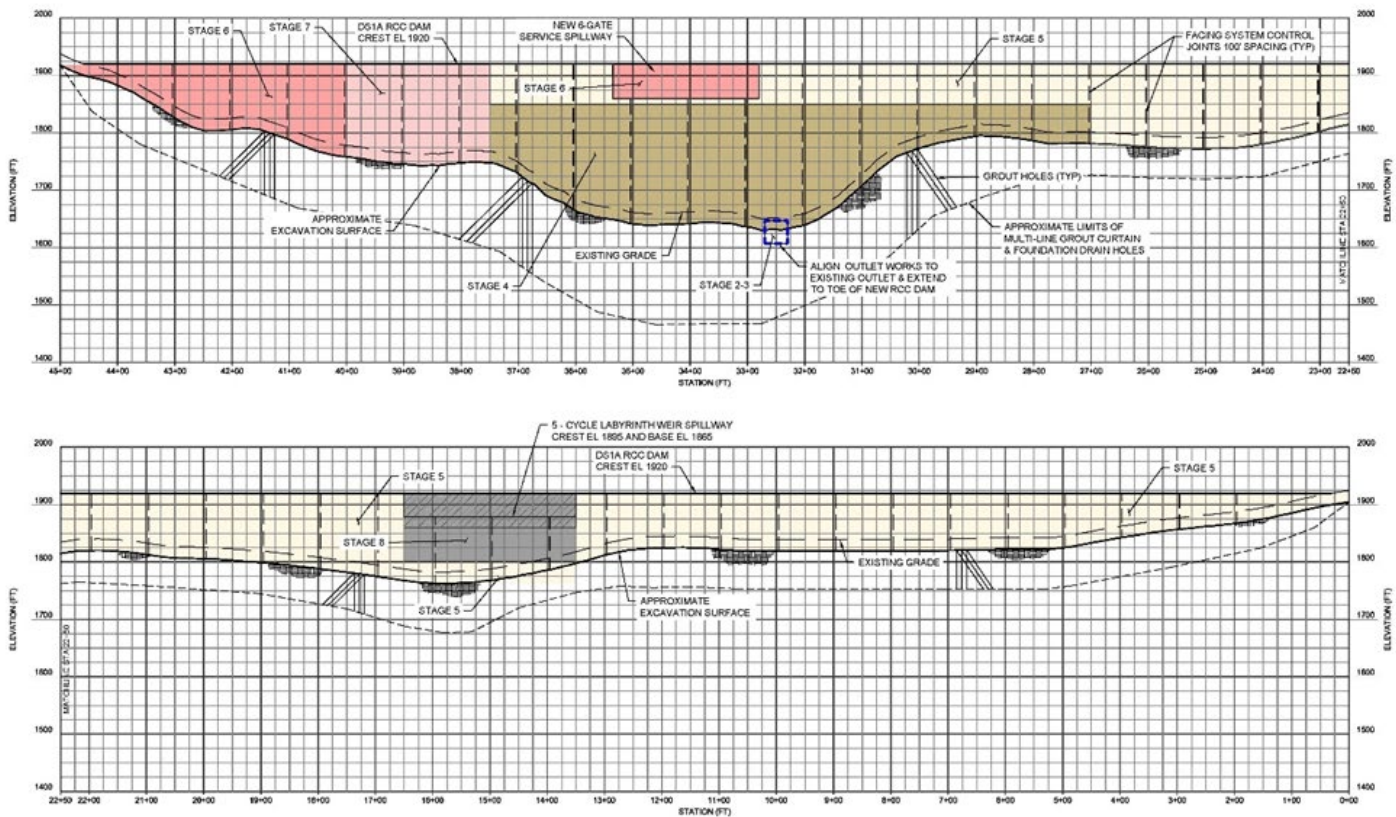


Figure 8. Construction Sequencing – Elevation View

- Stage 1 – Site access, construction facilities and borrow development.** Construct contractor and owner offices, equipment and material staging areas, access roads to both abutments including river crossing. Develop borrow area(s) and perform test blasting and crushing to produce materials meeting construction specifications. Relocation of the existing electrical transmission line should also occur in Stage 1, unless previously completed. If conventional hydroelectric power is included, the new transmission line can be constructed in this stage or be deferred to later stages. The existing ROW, service spillway and auxiliary spillway remain in service.
- Stages 2 and 3 – Outlet extension, valve house, and power house construction.** Either in a single stage or in two stages, construct new valve house downstream of future dam toe, construct modifications to the River Outlet Works intake, if necessary, and extend and encase the outlet pipe. If included, construct powerhouse and connection penstock. If hydro-mechanical, electrical and control equipment are pre-ordered, installation can occur, but can also be deferred to later stages. Channel the river to the right side of the valley (looking downstream) to isolate left bank for outlet extension and construction of aforementioned structures. A side channel cofferdam may be needed depending on desired level of protection and on depth of excavation required for valve house and potential powerhouse and dewatering needs. Dam foundation

excavation can begin in areas not affected by tailwater or spill events. The existing service and auxiliary spillways remain in service to provide flood routing protection of the existing dam and construction activities.

- **Stage 4 – Tailwater cofferdam and dam construction to crest of existing dam** (Station 27+00 to 37+50 to El. 1821). Construct cross-valley tailwater cofferdam. Excavate and prepare central valley and left abutment thrust block foundation, including drilling and grouting. Construct RCC dam/buttness and left thrust block to the crest of the existing dam. Begin preparing the auxiliary spillway discharge channel for potential use in later phases leaving the existing fuseplugs in place. Reservoir releases will be made through the new outlet works configuration for the remainder of construction. The existing service and auxiliary spillways remain in service to provide flood routing and protection of the existing dam and construction activities. The possibility of managing the Salt and Verde River systems to lower the elevation of Bartlett Reservoir during all, or portions of this and later stages should be fully considered in potential future studies.
- **Stage 5 – Left wing excavation and construction.** (Station 0+00 to 37+50). Complete foundation excavation and treatment including drilling and grouting. Complete final preparations of the auxiliary discharge channel for potential flood routing releases. Prepare left wing foundation and construct RCC dam from Station 16+50 to 27+00, El. 1770 to 1821, then replicate for left end of dam from Station 0+00 to 13+50, leaving out the auxiliary spillway portion of the dam above elevation 1800. Then raise the dam from Station 27+00 to 37+50 to El. 1920 the (new dam crest). The existing service and auxiliary spillways remain in service.
- **Stage 6 – Right wing excavation and construction (Station 40+00 to 45+00) and start new service spillway.** Remove existing auxiliary spillway fuse plugs. Cofferdam right wing, if necessary, right of the existing dam/service spillway face. Excavate and prepare right wing of dam foundation and perform foundation treatment, including drilling and grouting. Construct right wing RCC dam to El. 1920 the (new dam crest). Begin to construct new service spillway gates and bridge. Flood flows, in part, would be routed through the service spillway if required, but primarily through the auxiliary spillway apron (El. 1800) and discharge channel (prior to construction of the labyrinth crest). Flood routing protection could be enhanced, if necessary, by reservoir level management during construction when possible.
- **Stage 7 – Complete right wing RCC (Sta. 37+50 to 40+00) and finish new service spillway.** Bulkhead existing service spillway and remove existing service spillway crest control structure including gates. Finish installing gates and constructing new service spillway bridge. Excavate and prepare remaining right-wing foundation and construct remaining RCC to dam crest. Flood flows would be routed through the auxiliary spillway apron and discharge channel (prior to construction of the labyrinth crest), aided by reservoir level management during construction, when possible.

- **Stage 8 – Finish auxiliary spillway.** Construct RCC apron to elevation 1865 and the construct the labyrinth crest structure. Flood flows would be managed by managing the reservoir level, making use of the enlarged reservoir capacity up to auxiliary spillway apron and using the new service spillway.

The sequencing of dam construction in the central valley during Stages 4 and 5, and then completion of the dam in the right abutment area during Stage 6 will require further structural and thermal analyses and evaluations to configure the dam in such a manner that effective foundation treatment, crack control strategies, seepage control, as well as load transfer through the curved gravity section of the dam are achieved. These additional structural analyses and evaluations as well as construction details should be further developed in any subsequent feasibility design development.

The preliminary construction cost opinion assumes four work packages for this alternative; 1) transmission and power supply relocation; 2) project access and site development; 3) dam construction and 4) site improvements and potential off-site mitigation measures. The overall construction duration may last up to eight years with pre-construction activities including site access, site development and transmission line relocation requiring the first two years and final environmental mitigation and site improvements the last year. It is estimated that the construction of the enlarged dam and its appurtenances could take approximately four to six years.

4.7. Cost Opinions

Appraisal-level OPCCs for Bartlett Modification 1 and 2 alternatives are presented at April 2020 price levels. Table 6 presents a high-level comparison of the two alternatives in two parts: 1) pertinent data on their size and scope and 2) cost parameters including direct construction costs and total costs including contingencies and non-contract costs. Neither of the OPCCs presented in Table 6 and Table 7 below are escalated to either an estimated construction start nor a construction mid-point given the preliminary status of this work. In addition to the base cost opinion, Table 6 provides a probable low and probable high estimate range that was developed, as described above, as the summation of the low and high cost ranges for each of the approximate 300 elements in each estimate.

Table 6. Pertinent Data and Preliminary Cost Opinions (April 2020 Price Levels)

Bartlett Alternatives	Modification 1	Modification 2
Pertinent Data		
Normal Maximum Water Surface Elevation (NMWSE)	1,895	1,860
Dam Crest Elevation	1,920	1,895
Total Storage Capacity at NMWSE	628k AF	422k AF
Restored and Added Storage Capacity at NMWSE ⁽¹⁾	351k AF	146k AF
Project Costs		
Direct Construction Costs - before contingencies/factors	\$453 M	\$362 M
Total Base Construction Cost - including contingencies, non-contract costs	\$860 M	\$700 M
Low End Project Cost (from Total Base Cost)	\$655 M	\$530 M
High End Project Cost (from Total Base Cost)	\$1,140 M	\$930 M
Low to high range as percent of base (%)	76 – 133	76 – 133
Total Base Cost per AF of Total Storage (\$/AF)	\$1,400/AF	\$1,700/AF
Total Base Cost per AF of Added Storage (\$/AF)	\$2,450/AF	\$4,800/AF

1. Restored and Added storage includes restoration of 45,749 AF of sediment accumulation in Horseshoe Reservoir – for additional information, see Reclamation's Verde Reservoirs Sediment Mitigation Study Appraisal Report

The cost opinions presented above were based on:

- Developing eight-part construction sequencing strategy described in the preceding section that focused on maintaining adequate operational and flood management capabilities of the outlet works and spillways for the entire construction duration while minimizing impact to active work.
- Preparing and evaluating a detailed (~100 tasks) appraisal-level construction schedule to validate the sequencing strategy and better understand cost impacts and risk.
- Assessing key risk areas included foundation and abutment excavation risk, aggregate materials sourcing and processing, and the diversion and sequencing impacts of building the new facility while maintaining operational and flood releases. This program, including assessment of foundation preparation and material sourcing risk triggered a deeper foundation allowance, increased right abutment excavation, increased commercial supply of conventional concrete fine aggregate, and increased the length of relocated

transmission line to provide a greater buffer around a potential quarry site. The outlet works was extended farther downstream to better accommodate safe use, and isolation during construction.

Additional key assumptions and considerations affecting the development of the Bartlett Modification alternatives are presented in Table 7 below. Per Reclamation's Directives and Standards related to cost estimating, a contingency for environmental permitting and compliance of five percent is included as a component of the Non-Contract Cost line item.

Table 7. Appraisal-level Opinion of Probable Construction Costs for Bartlett Modification 1

Description	Code	Quantity	Unit	Unit \$	Total \$
WP1 - Transmission & Power Supply – Relocation		12,100	linear foot (lf)	300.00	3,630,000
WP2 - Project Access & Site Development					
Project Access Development		2.50	miles (mi)	1,550,000.00	3,875,000
Basic Staging Development		1	lump sum (ls)	2,100,000.00	2,100,000
WP3 - Dam Construction					
Site Development		1	ls	15,000,000.00	15,000,000
Site Restoration		24.0	acre (ac)	40,000.00	960,000
Existing Structure Demolition		1	ls	5,500,000.00	5,500,000
Diversion & Care of Water		1	ls	27,275,000.00	27,275,000
Main Dam & Hydraulic Structures					
Dam Foundation Preparation and Grouting		71,000	square yard (sy)	232.00	16,472,000
Dam - Earthworks		1,154,000	cubic yard (CY)	16.00	18,464,000
Dam- Body		2,117,500	CY	113.50	240,336,250
Dam - Hydraulic Structures					
Service Spillway		1	ls	68,000,000.00	68,000,000
Low Level Outlet		1	ls	13,000,000.00	13,000,000
Spillway - Bridge		1	ls	1,390,000.00	1,390,000

Description	Code	Quantity	Unit	Unit \$	Total \$
Crest structures		1	ls	3,000,000.00	3,000,000
Auxiliary Spillway		1	ls	28,000,000.00	28,000,000
Project Electrical & Instrumentation		1	ls	4,750,000.00	4,750,000
Administrative Buildings		1	ls	1,050,000.00	1,050,000
Subtotal					453,000,000
Mobilization	6%	+/-			27,000,000
Subtotal with Mobilization					480,000,000
Contract Cost Allowances (sum of next two lines):	15%	+/-			70,000,000
Design Contingencies, 15% (+/-)					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
Contract Cost					550,000,000
Construction Contingencies	20%	+/-			110,000,000
Field Cost (Jan 2018)					660,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	31%	+/-			200,000,000
Construction Costs					860,000,000

Ref.: For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 and 09-03.

Table 8. Appraisal-level Opinion of Probable Construction Costs for Bartlett Modification 2

Description	Code	Quantity	Unit	Unit \$	Total \$
WP1 - Transmission & Power Supply - Relocation		12,100	lf	300.00	3,630,000
WP2 - Project Access & Site Development					
Project Access Development		2.50	mi	1,550,000.00	3,875,000
Basic Staging Development		1	ls	2,100,000.00	2,100,000
WP3 - Dam Construction					
Site Development		1	ls	15,000,000.00	15,000,000
Site Restoration		24.0	ac	40,000.00	960,000
Existing Structure Demolition		1	ls	5,500,000.00	5,500,000
Diversion & Care of Water		1	ls	21,275,000.00	21,275,000
Main Dam & Hydraulic Structures					
Dam Foundation Preparation and Grouting		71,000	sy	183.00	12,993,000
Dam - Earthwork		1,154,000	cy	12.50	14,425,000
Dam - Body		1,442,500	cy	120.00	173,100,000
Dam - Hydraulic Structures					
Service Spillway		1	ls	66,000,000.00	66,000,000
Low Level Outlet		1	ls	13,000,000.00	13,000,000
Spillway Bridge		1	ls	1,390,000.00	1,390,000
Crest Structures		1	ls	3,000,000.00	3,000,000
Auxiliary Spillway		1	ls	19,400,000.00	19,400,000
Project Electrical & Instrumentation		1	ls	4,750,000.00	4,750,000
Administrative Buildings		1	ls	1,050,000.00	1,050,000
Subtotal					362,000,000
Mobilization	5%	+/-			18,000,000
Subtotal with Mobilization					380,000,000
Contract Cost Allowances (sum of next two lines)	15%	+/-			60,000,000



Description	Code	Quantity	Unit	Unit \$	Total \$
Design Contingencies, 15% (+/-)					
APS, 0% (+/-), Type of procurement: Undetermined - Appraisal-level study					
Contract Cost					440,000,000
Construction Contingencies	20%	+/-			90,000,000
Field Cost (Jan 2018)					530,000,000
Non-Contract Costs (Ref. Table 10-1, Reclamation Cost Estimating Handbook)	31%	+/-			170,000,000
Construction Costs					700,000,000

For summary rounding and terminology, see Reclamation Manual, Directives and Standards FAC; 09-01, 09-02 & 09-03.

Table 9. Preliminary OPCCs - Key Assumptions and Considerations

#	Key Assumptions/Considerations
1	Work is divided into several work packages (WPs) to reflect a multi-phased or multi-contract project delivery approach. For example, Bartlett Modification 1&2 alternatives include: WP1 - Transmission and Power Supply/Relocation; WP2 - Project Access and Site Development; and WP3 - Dam Construction.
2	An "unlisted" work item is included in each work package's direct construction costs at 2.5%.
3	"Below-the-line" factors are the same for each option; design contingency 20%, construction contingency 15%, non-contract costs 25%; no project financing costs or escalation to start or mid-point of construction are included.
4	All costs are presented at April 2020 price levels.
5	Access road improvements include pioneering, excavation and fills, drainage structures, barrier, and base gravel, and do not include asphalt or other paving.
6	Verde River crossings are included.
7	Existing demolition allowances are included for Bartlett Crest modifications, Bartlett existing outlet modifications and Bartlett Dam service and auxiliary spillways.
8	Marine work staging and mobilization are included to support Bartlett Dam outlet works modifications and demolition and raise construction.
9	A line item is included for general diversion flood risk during dam construction.
10	An allowance for seepage cutoff is included with the high range at 150% of the base case considering the sequencing evaluation and the limited exposure period where the primary tailwater cofferdam is critical.
11	Grouting was estimated based on an assumed average 75-foot depth; and the planned grouting effort extends across the central valley, rather than relying on the original construction's grout curtain. Other assumptions include: foundation preparation - grouting; double curtain with 100% secondary and 50% tertiary holes and 0.75 bg/lf takes for the primary RCC and rockfill dam foundations. Extensive consolidation grouting has been assumed for the RCC dam foundations. Single curtain with 50% secondary and 25% tertiary holes and .75 bag/lf takes have been assumed for saddle dam foundations, without consolidation grouting.
12	RCC slopes are assumed at 0.1:1 upstream and 0.8:1 downstream. Composite pricing includes: mixing, delivering, placing 285# cement/fly ash mix; a test section; 2.5-feet thick conventional concrete upstream and downstream faces; partial mix temperature control; drainage features; vertical control joints; partial lift bedding for cold joints; a buttress surcharge for placement and increased unit costs for high tertiary crushing and screening of aggregate, segmented construction, higher cement and fly ash costs, and higher cooling costs than was used in previous estimates for the Bartlett Modification alternatives.

#	Key Assumptions/Considerations
13	The auxiliary spillway costs include excavation and partial armoring of the chute and preparing the chute for spill use before the service spillway is taken out of service.
14	The LLOW configuration assumes establishing discharge control near the downstream toe of the new dam along with OW extension fully downstream to the powerhouse location to provided needed flexibility and protection during construction. The OW system I includes line items for supplemental structure excavation and stabilization; intake, encasement and outlet concrete; pressure pipe; and three, six-foot diameter steel outlet pipes, each with a 72 in fixed cone valve; trash/debris racks and miscellaneous building systems. A line item is also included for upstream modifications.
15	The service spillway includes an RCC base; 275-feet wide, six each, 30-foot width x 42-foot height radial gates, a flip bucket. An allowance has been included for shaping the plunge pool totaling 500k CY.

Appendix F: Hydropower Benefits Estimation



— BUREAU OF —
RECLAMATION

Verde Reservoirs Sediment Mitigation Study

Appendix F - Hydropower Benefits Estimation

Salt River Project, Arizona
Interior Region 8: Lower Colorado Basin

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Verde Reservoirs Sediment Mitigation Study

Appendix F - Hydropower Benefits Estimation

Salt River Project, Arizona
Interior Region 8: Lower Colorado Basin

prepared by

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Abbreviations

AF – Acre-Feet

BT 1 – Bartlett Modification 1 Alternative

BT 2 – Bartlett Modification 2 Alternative

EIA – United States Energy Information Association

EO – Executive Order

MW – Megawatts

NED – National Economic Development (benefits)

NPV – Net Present Value

O&M – Operation and Maintenance

PV – Present Value

SRP – Salt River Project

VRSMS – Verde Reservoirs Sediment Mitigation Study

1.0 Introduction

Reclamation's 2011 *Hydropower Resource Assessment at Existing Reclamation Facilities* identified existing Bartlett Dam as having reasonable potential for economically and financially viable hydropower production. As part of the Verde Reservoirs Sediment Mitigation Study (VRSMS), two installed generating capacities were evaluated—6.1 megawatts (MW) and 10.6 MW, based on supporting analysis performed by HDR Inc. The two generating capacities were modeled by Salt River Project (SRP) staff in the Aurora production cost model¹ to estimate benefits and avoided carbon emissions relative to a thermal power resource.

2.0 VRSMS Hydropower Assessment

2.1 Modeling Approach

National Economic Development (NED) benefits are estimated using the systems approach for the hydropower opportunity as the avoided costs to the power system of constructing a hydropower generating unit relative to the most likely alternative thermal generating source (Bureau of Reclamation Economics Guidebook). Following the Economics Guidebook, a production cost model is used to evaluate the avoided costs to SRP's power system over the period 2021-2050, and a straight-line approach with no price inflator is used to estimate costs for the remainder of the study period (2051-2130). Additionally, for consistency with Executive Order (EO) 13990, the NED benefits also include an estimated avoided social cost of carbon resulting from the operation of the hydropower facility rather than a thermal generating facility. In accordance with the September 2016 Reclamation guidance document entitled *Time Based Adjustments in Reclamation Economic Analysis*, the point of reference selected for the present value calculations is the end of the construction period and beginning of the period of analysis; in this case the point of reference is end of year 2030.

Consistent with the Economics Guidebook, the alternative thermal resource is identified as a portion of a simple cycle natural gas peaking plant. The production cost model assesses SRP's system load (demand) and available generating capacity (supply) along with hourly electricity market prices and market electricity availability (supply) to economically optimize dispatch of available SRP generating units and market purchases in order to estimate the operating costs of meeting SRP system load. Modeling outputs for power system operation and maintenance (O&M) costs, capital expenditures, and wholesale market net revenue were used to estimate the change in costs to the system over the modeling period. The change in capital and O&M costs and wholesale net revenue from the base case (portion of capacity of a simple cycle natural gas unit equivalent) to the hydropower cases are used as the NED benefits estimate as the avoided cost to SRP's power system,

¹ The Aurora by Energy Exemplar production cost model is used for modeling the scenarios. This is the standard production cost model used by SRP in resource and financial planning activities and is a widely used model in the electric utility industry for financial and resource planning.

using federal assumptions for period of analysis and discount rate². Equations 1 and 2 below show the calculation for NED Benefits.

Equation 1: Net Avoided System Costs

Net Present Value (NPV) Production Cost Benefits = NPV ($C_{\text{hydro}} + O\&M_{\text{hydro}} - C_{\text{NatGas}} - O\&M_{\text{NatGas}} + \Delta O\&M_{\text{system}} + \Delta \text{MarketTransNetRev}$)

Where:

C_{hydro} = Capital Cost of hydro facility

$O\&M_{\text{hydro}}$ = Lifecycle O&M of hydro

C_{NatGas} = Capital cost of alternative natural gas facility

$O\&M_{\text{NatGas}}$ = Lifecycle O&M of alternative natural gas facility

$\Delta O\&M_{\text{system}}$ = Change in overall O&M costs of the power system

$\Delta \text{MarketTransNetRev}$ = Change in net revenue (sales less purchases) for wholesale electric market transactions from the power system

Equation 2: NED Economic Benefits

NED Benefits = NPV Production Cost Benefits – PV($C_{\text{hydro}} + O\&M_{\text{hydro}}$) + PV Avoided Social Cost of Carbon)

2.2 Modeling Assumptions

Two different generator capacities were evaluated using the production cost model and compared to the equivalent portion of capacity of a simple cycle natural gas unit³. The two hydropower facility capacities evaluated were a 10.6 megawatt (MW) hydropower plant (34% annual capacity factor⁴) and a 6.1 MW hydropower plant (42% annual capacity factor⁵) as the upper and lower bound of installed capacity based on facility head and water release rates. Though slightly smaller or larger facilities could be installed on existing or modified Bartlett dams, smaller facilities would result in frequent generator bypasses when water deliveries exceed hydropower penstock capacity, and larger

² Federal guidelines for period of analysis, discount rates, and alternative generating resources are not necessarily consistent with those used by SRP or other power utilities; therefore, the results of this economic analysis and any associated decision to invest in the construction of a hydropower facility would vary by utility.

³ The costs, capacity, and energy production of a portion of a newly constructed simple cycle natural gas generating unit were used. Simple cycle natural gas generators are produced in capacity increments larger than the small hydropower generators being evaluated in this study, so a portion of the costs associated with a new facility is considered to be able to evaluate the opportunity with similar capacities.

⁴ Annual capacity factor based on hydropower viability analysis performed by HDR Inc to support the VRSMS. Monthly capacity factors distributed based on Reservoir Planning Model (RPM) modeling for Bartlett Mod 1.

⁵ Annual capacity factor based on hydropower viability analysis performed by HDR Inc to support the VRSMS. The annual capacity factor is scaled down as a function of reduction in water deliveries between BT Mod 1 and BT Mod 2 ($(337\text{k}/372\text{k}) \cdot 46\%$) = 42%. Monthly capacity factors distributed based on RPM modeling for Bartlett Mod 1.

facilities would have smaller operating seasons and ranges due to the small releases from Bartlett Dam during summer months.

Table 1 below shows the capital and O&M costs estimated for the hydropower and thermal generating facilities. Figure 1 shows the monthly capacity factor for each hydropower facility, showing generation dependent on water deliveries from Bartlett Dam. For the appraisal level analysis, monthly reservoir operations and deliveries were assumed to follow existing SRP operating plans, with most deliveries from the Verde System occurring during fall and spring months.

Table 1: Facility Cost and Operating Assumptions

	10.6 MW Hydropower Generator	10.6 MW of Simple Cycle Natural Gas Facility	6.1 MW Hydropower Generator	6.1 MW of Simple Cycle Natural Gas Facility
Capital Costs (2020\$)	\$36.1 Million ⁶	\$9.6 Million	\$27.7 Million ⁷	\$5.5 Million
Annual Operating and Maintenance Costs (2020\$)	\$168,400/year	\$368,626/year	\$136,800/year	\$329,178/year

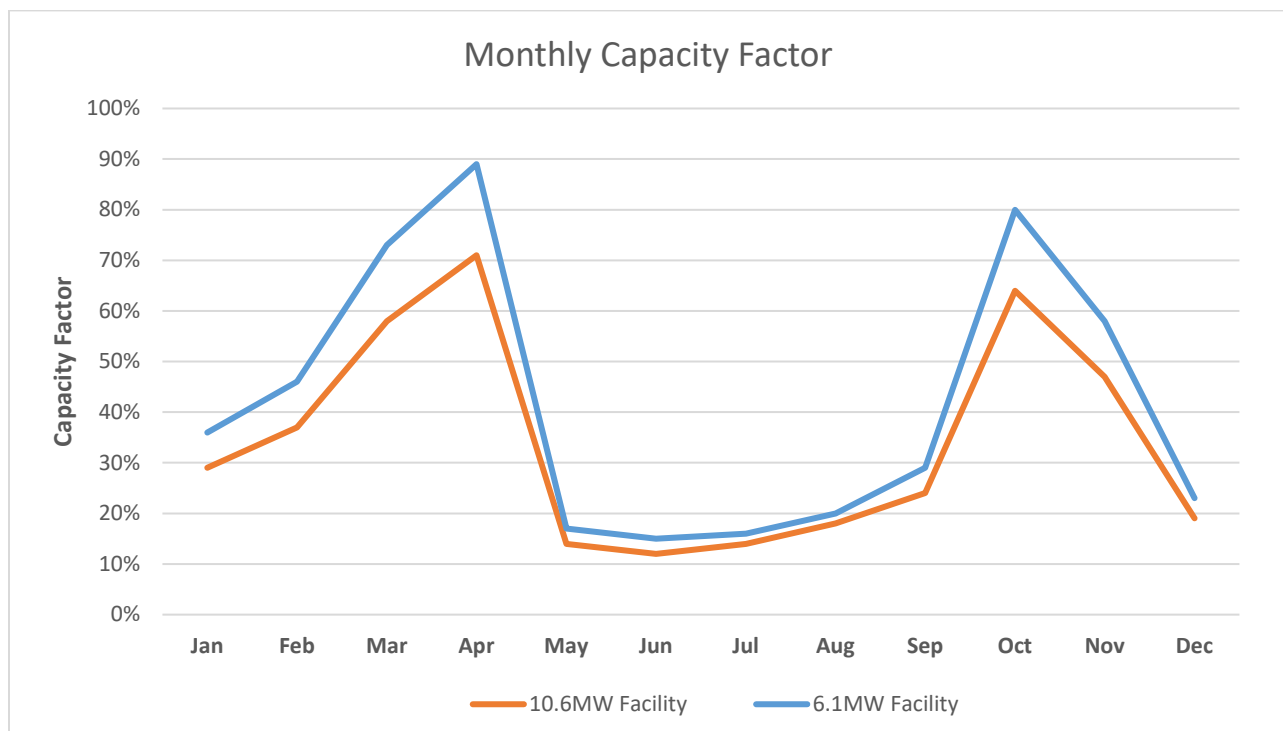


Figure 1: Monthly Operating Capacity Factor

⁶ Costs based on hydropower viability analysis performed by HDR Inc to support the VRSMS — total capital costs, including transmission costs, less debt service.

⁷ Costs based on hydropower viability analysis performed by HDR Inc to support the VRSMS — total capital costs, including transmission costs, less debt service.

The natural gas price forecast used as an input into the production cost model came from the Energy Information Administration's⁸ 2020 natural gas price forecast. The production cost model produces hourly electricity market clearing prices for the Palo Verde market hub using natural gas prices as an input for the modeling period ending in 2050. The real forecasted prices are shown in Figure 2. The annual cost savings are assumed constant after 2050 with no price escalation of electricity market prices due to the lack of a forecast for the remainder of the study period. A net present value (NPV) analysis is performed for the period of analysis 2021-2130, with construction of the hydropower facilities and associated expenditures occurring between 2027 and 2030. The hydropower facilities are estimated to begin generation in 2031 and remain in operation through the end of 2130⁹. The 2021 Federal water resources planning rate of 2.5% is used as the discount rate.

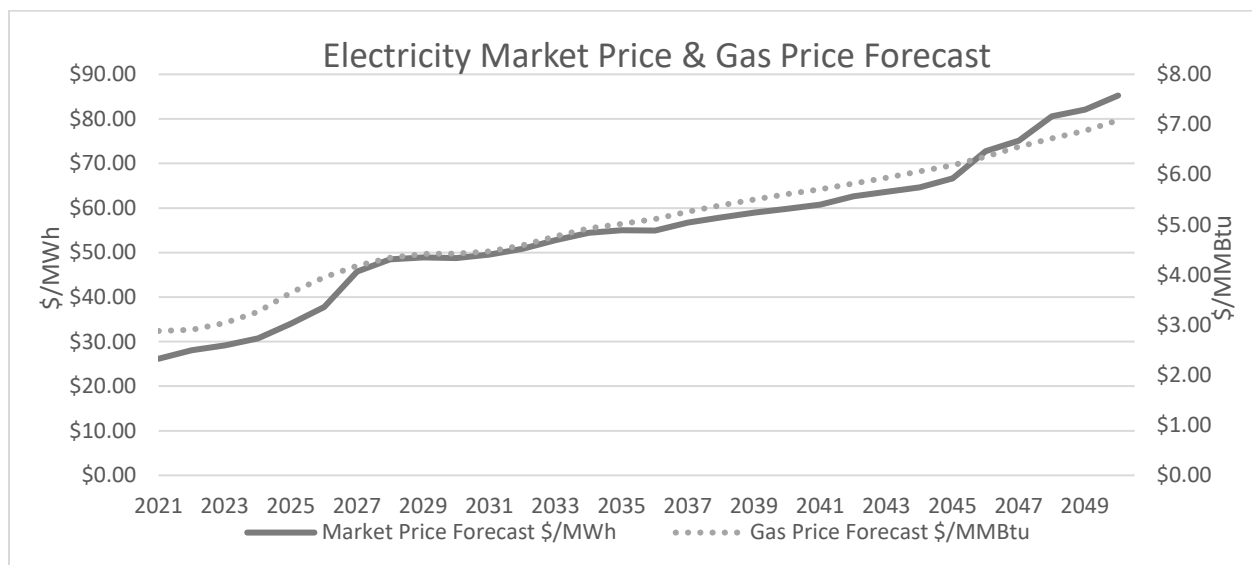


Figure 2: Electricity Market and Natural Gas Price Forecasts

The production cost model is used to estimate benefits directly for the two generator sizes using modeled water deliveries for the Bartlett Modification 1 (BT 1) Alternative and Bartlett Modification 2 (BT2) Alternative for the 10.6 MW and 6.1 MW generating facilities, respectively. The production cost model runs for each of the facilities were compared to a base case model scenario that included the equivalent generating capacity provided by the simple cycle natural gas facility. The only change between the modeled base cases and the modeled hydropower facility cases were the change in the generating resource and associated cost and operating characteristics from the simple cycle natural gas facility to the hydropower facility. Due to the data and time intensity of running the production

⁸Market prices obtained for the Henry Hub market trading node.

<https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2020&region=1-0&cases=ref2020&start=2018&end=2050&f=A&linechart=ref2020-d112119a.3-3-AEO2020.1-0~ref2020-d112119a.38-3-AEO2020.1-0&map=ref2020-d112119a.4-3-AEO2020.1-0&ctype=linechart&sourcekey=0> (10:25:56 GMT-0700 (Mountain Standard Time), February 2, 2021)

⁹ A 100-year useful life for a hydropower generator is reasonable due to the robust design and simple operation of francis turbines. For this analysis, no replacement cost is assumed for either the natural gas generator or the hydropower facility. Though regular maintenance activities are likely to enable a 100-year life of a hydropower generator, the same is not true for a combustion turbine, which generally would have a maximum useful life of 30 to 40 years.

cost model, the benefits for each of the remaining alternatives were estimated by scaling the output of the production cost model based on total water deliveries from each alternative. Table 2 below shows the factors used to scale the direct and indirect benefits for each alternative based on the percentage of annual water deliveries¹⁰ relative to the water deliveries of BT 1 and BT 2.

Table 2: Production Cost Model Benefits Scaling Factors

	% of Deliveries BT1 (10.6 MW Facility)	% of Deliveries BT2 (6.1 MW Facility)
Without Action	80%	88%
Sediment Removal	82%	91%
BT Mod 1	100%	110%
BT Mod 2	91%	100%

2.3 Modeling Results

The production cost model estimates changes in costs as well as changes in carbon emissions resulting from different resource portfolios. For this analysis, the change in direct costs and the monetized change in carbon dioxide emissions are estimated as the potential NED benefits resulting from hydropower installation in conjunction with each alternative. The results of this analysis are presented below.

2.3.1 Production Cost Model Results

Tables 3 and 4 below show the benefit and cost estimates for the 6.1 MW and 10.6 MW generating facilities, respectively. The NPV of system operating costs with the hydropower facility is shown in line (A), which is the output of the production cost model. The life cycle costs of the hydropower facilities are removed from the NPV in order to estimate the present value of benefits for inclusion in the calculation of NED benefits below. The PV of benefits is estimated as the avoided costs of system operations if a simple cycle natural gas facility were installed, rather than the similarly sized hydropower facility. The majority of the benefits are created by the low annual operating and maintenance costs of the hydropower facility.

Table 3: 6.1 MW Generating Facility (\$Millions)

	Metric	Without Action	Sediment Removal	BT 1	BT 2
(A)	PV Net Benefits (Estimated Prod Cost Model)	\$28.15	\$29.64	\$41.12	\$35.07
(B)	Cap Cost of hydro (HDR)	\$(29.56)	\$(29.56)	\$(29.56)	\$(29.56)
(C)	Lifecycle O&M (PV of 2031-2130 HDR @ 2.5%)	\$(5.13)	\$(5.13)	\$(5.13)	\$(5.13)
(D)	PV of Costs (B+C)	\$(34.69)	\$(34.69)	\$(34.69)	\$(34.69)
(E)	PV of Direct NED Benefits (A-D)	\$62.84	\$64.33	\$75.81	\$69.76

¹⁰ Annual water deliveries do not include spill volumes since spill events would not be expected to move through hydropower penstocks.

Table 4: 10.6 MW Generating Facility (\$Millions)

	Metric	Without Action	Sediment Removal	BT 1	BT 2
(A)	PV Net Benefits (Estimated Prod. Cost Model)	\$19.45	\$20.82	\$31.37	\$25.81
(B)	Cap Cost of hydro (HDR)	\$(38.52)	\$(38.52)	\$(38.52)	\$(38.52)
(C)	Lifecycle O&M (PV of 2031-2130 HDR @ 2.5%)	\$(6.31)	\$(6.31)	\$(6.31)	\$(6.31)
(D)	PV of Costs (B+C)	\$(44.83)	\$(44.83)	\$(44.83)	\$(44.83)
(E)	PV of Direct NED Benefits (A-D)	\$64.28	\$65.65	\$76.20	\$70.64

2.3.2 Carbon Benefits

The carbon benefits are estimated as avoided carbon dioxide emissions from the simple cycle natural gas facility compared to generation using non-carbon emitting hydropower, as well as an estimated average carbon rate per MWh of power purchased on the market each year. The carbon benefits are modeled directly in the production cost model for the 10.6 MW and 6.1 MW generating facilities through the end of the modeling period of 2050. The scaling factors in Table 2 were then used to estimate the total avoided carbon emissions for each alternative. Table 5 below shows the total estimated avoided carbon emissions for each alternative, for both the 6.1 MW and 10.6 MW facilities.

Table 5: Total Metric Tons of Avoided Carbon (2031-2130)

	Without Action	Sediment Removal	BT 1	BT 2
6.1 MW Facility	562,116	578,159	701,727	636,626
10.6 MW Facility	454,267	467,232	567,092	514,481

The Interagency Working Group on the Social Cost of Greenhouse Gases, U.S. Government provided estimates of the social cost of carbon in February 2021 in response to EO 13990, which were used to estimate the benefits of avoided carbon emissions provided by installation of a hydropower facility in lieu of a thermal facility. Table 6 on the following page shows the annual estimated social cost per metric ton of carbon emitted on an annual basis from 2031 through 2050. These values enabled the study team to monetize the metric tons of carbon emissions avoided each year. The annual avoided emissions and social cost of carbon are assumed to be constant after 2050 until the end of the study period (2130). Table 7 shows the present value of the avoided social cost of carbon for each of the alternatives. Following the direction of EO 13990, the avoided social cost of carbon is included in the estimate of NED benefits.

Table 6: Social Cost of Carbon

Year	Social Cost of Carbon \$/Metric Ton
2031	\$ 90.84
2032	\$ 92.21
2033	\$ 93.57
2034	\$ 94.93
2035	\$ 96.30
2036	\$ 97.66
2037	\$ 99.02
2038	\$ 100.39
2039	\$ 101.75
2040	\$ 103.11
2041	\$ 104.45
2042	\$ 105.79
2043	\$ 107.12
2044	\$ 108.46
2045	\$ 109.79
2046	\$ 111.13
2047	\$ 112.46
2048	\$ 113.80
2049	\$ 115.14
2050	\$ 116.47

Table 7: PV of Avoided Social Cost of Carbon (\$Millions)

	Without Action	Sediment Removal	BT Mod 1	BT Mod 2
6.1 MW Facility	\$24.55	\$25.25	\$30.64	\$27.80
10.6 MW Facility	\$20.43	\$21.01	\$25.50	\$23.14

2.3.3 NED Benefits & Benefit-Cost Ratio for Hydropower

The NED benefits are estimated for the hydropower opportunity for each of the alternatives by adding the PV of modeled benefits from the production cost model and the PV of the avoided social cost of carbon. Tables 8 and 9 below provide the total NED benefits estimate and the benefit-cost (B-C) ratio for the 6.1 MW and 10.6 MW generating facilities, respectively. Based on this analysis, all four alternatives have potential for creating economic benefits from hydropower facilities. Reclamation's 2011 *Hydropower Resource Assessment at Existing Reclamation Facilities* identified existing Bartlett Dam as having reasonable potential for economically and financially viable hydropower production. However, the Without Action and Sediment Removal alternatives likely have larger barriers to constructing a hydropower facility than the Bartlett modification alternatives, since neither alternative has planned ground disturbing activities at the Bartlett Dam site where the facility would be constructed. Several uncertainties exist for the economic viability of hydropower for all alternatives and are described further below.

Table 8: NED Benefits and B-C Ratios for 6.1 MW Generating Facility

	Without Action	Sediment Removal	BT Mod 1	BT Mod 2
NED Benefits (Millions)	\$87.38	\$89.58	\$106.46	\$97.56
B-C Ratio	2.52	2.58	3.07	2.81

Table 9: NED Benefits and B-C Ratios for 10.6 MW Generating Facility

	Without Action	Sediment Removal	BT 1	BT 2
NED Benefits (Millions)	\$84.71	\$86.67	\$101.70	\$93.78
B-C Ratio	1.89	1.93	2.27	2.09

2.4 Uncertainties and Opportunity for Further Study

Initial modeling shows that, based on Reclamation guidance for assessing the NED benefits of hydropower as part of the two Bartlett Modification options, it is likely that an economical hydropower facility could be installed. Uncertainties exist based on level of detail of the alternatives at the appraisal level, and differences between Reclamation’s assumptions for evaluating hydropower resources and the assumptions that power utilities would use to evaluate the same investment. Further detail is provided below, included the expected impact (+/-) on the NED benefits presented here.

Timing of water deliveries (+): The timing of water delivery releases from BT Mods 1 and 2 were assumed to follow the same monthly delivery pattern as SRP’s current operations—primarily delivering water from Verde River reservoirs during the fall and spring run-off months, while water deliveries during summer months primarily come from the Salt River reservoirs. If additional storage capacity is added to the Verde Reservoirs system, the delivery from this New Verde Space (NVS) would likely follow a delivery pattern with peak deliveries occurring during summer months. Since energy values tend to be highest during the hot summer months in Phoenix and hydropower generation is dependent on water deliveries, investigation of either of the BT Mod alternatives at the feasibility level should further refine the timing of planned water deliveries to provide a refined input for the hydropower generating timing. If more water deliveries and associated hydropower generation were to occur during summer months, the benefits of the hydropower facility would increase.

Alternative Generating Resources (+/-): Following existing Reclamation guidance, this analysis used a simple cycle natural gas facility as the most likely alternative thermal generating source. Power utilities have a number of alternative generating resource alternatives beyond thermal resources, each with tradeoffs between generating profile, dispatchability, carbon intensity, and lifecycle costs. If an alternative is investigated further at feasibility, the assumptions for the most-likely generating

resource should be evaluated further to ensure that the Federal assumptions for the economic analysis are consistent with current industry practice.

Period of Analysis (-): Fast-moving changes in the electricity industry and the advances in technology for generating resources limit the accuracy of assumptions made for a 100-year period of analysis. A shorter period of 30 to 40 years is generally more realistic for evaluating cost recovery for justification of investment in power resources. If further study is conducted at the feasibility level, further attention should be paid to the period of analysis for the hydropower resource and the assumed replacement costs of the most likely alternative thermal generating resource. Shortening the period of analysis will have negative impacts on the present value of benefits due to the large capital investment.

Discount Rate (-): The water resources planning rate (2.5%) is likely lower than the cost of capital of most power utilities. Electricity markets continue to have slimmer margins between the costs of generating resources and local marginal prices for market purchases. The use of the water resource planning rate is probably not appropriate for making the decision as to whether a hydropower facility would be an economical investment for a power utility. If a feasibility study is conducted, the discount rate applied for determining the feasibility of installing a hydropower unit should be evaluated further. A larger discount rate is expected to decrease the NED Benefits, and reduce the justifiable economic expenditure for a hydropower facility.

Operating and Maintenance Costs (-): The assumed annual O&M costs of approximately 0.5% of initial capital investment estimated by HDR in support of this study based on market data may be low. Further evaluation of equipment and overhead costs should be evaluated if a project configuration that includes hydropower generation is considered in a feasibility study. Annual O&M costs may range as high as 1.5% to 2.5% of initial capital investment, which would have a negative effect on the net benefits created by the hydropower resource and have bearing on the economic feasibility of the resource.

Timing of a Decision on Hydropower (+/-): The economics of the electric power industry are changing rapidly with influences on both the supply and demand side. It is recommended that all economic assumptions used in a feasibility study for hydropower facilities be revisited regularly and validated at the end of the feasibility study process to ensure that the assumptions have not become obsolete.

Production Cost Model Runs (+/-): Scaling results from the production cost model based on annual water deliveries is a reasonable assumption for an appraisal-level screening analysis; however, if any of the alternatives are to be evaluated at the feasibility level, it is suggested that the production cost model be run for each alternative to provide more precision to the analysis of potential benefits.

3.0 Conclusion

This analysis shows that there is potential for economical hydropower as part of all four VRSMS alternatives; however, the Without Action and Sediment Removal alternatives have no proposed ground disturbance activities at the Bartlett Dam site, resulting in larger barriers to initiating

construction of a stand-alone power plant. Bartlett Modification 1 shows the greatest opportunity for creation of overall benefits while Bartlett Modification 2 provides the second largest potential benefit. Since the two Bartlett Modification options already include significant ground disturbance activities at the dam site, hydropower could likely be cost-effectively integrated with those two alternatives if electricity market economics permit.

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Appendix G: Reservoir Planning Model Detailed Description

Verde Reservoirs Sediment Mitigation Study

Appendix G Reservoir Planning Model

SRP's Reservoir Planning Model (RPM) was used to assess the SRP Reservoir System (System) for each alternative in the Verde Reservoirs Sediment Mitigation Study (VRSMS). Since the Verde Rivers reservoirs and Salt River reservoirs are operated as one system to make shareholder and contract water deliveries, it is critical to evaluate the entire system even if infrastructure modifications only occur on one side of the system. The RPM is an application of OASIS (Operational Analysis and Simulation of Integrated Systems), a generalized water resources modeling platform that simulates the routing of water by solving a linear program. OASIS is a mass balance model. It was created to evaluate System performance for a given set of demands, operating policies, and facilities over the historic inflow record and future predicted inflow.

In total, the model has approximately 80 nodes and 90 connecting arcs. There are six reservoir nodes, 25 withdrawal nodes, 15 on- and off-project demand nodes, and other miscellaneous nodes to account for inflows, minimum flow requirements, reservoir evaporation and seepage, and other points of interest. The three lower Salt River reservoirs are operated as one because they are maintained around 95 percent capacity year-around due to hydrogeneration operations. Using mass balance and continuity, RPM routes water through the System using goals and constraints based on reservoir operations policies and demands on a monthly time-step. Monthly stream flows for a reference period and future period for the U.S. Geological Survey (USGS) stream gages, are input to RPM at nodes. Using a relationship with flows at these nodes, local inflows for each simulation are determined for Roosevelt Lake, the lower Salt River system, Horseshoe Lake, and Bartlett Reservoir. After inflows are determined and input to the RPM, the model is run, and output is used in alternative criteria evaluation.

RPM is operated on a monthly timestep. The duration of analysis for the RPM runs in this study is 106 years. This duration was chosen because the historical gaged record at the USGS sites is October 1913-present. Observed monthly records from October 1913 through September 2019 (106 water years) were adjusted for climate change as described in the climate change section and projected forward 106 years.

Demand Assumptions

The following SRP system demand scenarios are used for the RPM demand on the SRP system. The RPM consolidates all water uses for SRP's service area plus contractual deliveries outside the service area into one demand node. This demand node excludes New Conservation Storage, Fort McDowell Yavapai Nation (FMYN), Phoenix Gateway, and upstream demands. Each of these accounts have separate demand nodes in RPM. Those demands are also identified below.

725,000 AF/year

Demand on the SRP System since 2016 has been between 725,000 and 775,000 AF/year. Historically, SRP system demand has been as high as 1.4 million AF/year, but has declined since

the 1980s. As agriculture acres continue to urbanize and residents continue water conservation practices, a demand of 725,000 AF/year is considered reasonable now and in the future.

New Conservation Space (NCS) Demand

New Conservation Space (NCS) is 272,500 AF of storage in Modified Roosevelt Reservoir that six municipalities (NCS Cities) own and use. Despite NCS being on the Salt Reservoir system, NCS demand has an impact on the Verde Reservoirs because the SRP Reservoirs are operated as one system. NCS demand for these cities was assumed to be equivalent to the volume outlined in their Assured Water Supply designation. The City of Phoenix indicated to use full NCS demand (if available). The following annual NCS demands for each city are assumed for the VRSMS RPM analysis.

Chandler = 8,100 AF/yr
Glendale = 8,100 AF/yr
Mesa = 12,500 AF/yr
Phoenix = 136,250 AF/yr
Scottsdale = 8,100 AF/yr
Tempe = 4,200 AF/yr

New Verde Space (NVS) Demand

As expressed in the Strategic Vision (ADWR, 2014), large increases in water need across central Arizona are expected in the future. Based on this, it is assumed beneficiaries of the New Verde Space (NVS) will use the annual volume of accrual in its entirety every year. The water supply may be used in several ways, including supporting water uses currently dependent on fossil groundwater, firming supplies for lower-priority Colorado River water, or to support other water supply and demand imbalances.

Phoenix Gateway Demand

The City of Phoenix has indicated the following for annual Phoenix Gateway demand, if available.

Gateway Demand = 25,000 AF/year

Fort McDowell Yavapai Nation (FMYN) Demand

The RPM analysis is set based on the FMYN/SRP agreement and uses the following for demand.

FMYN Demand = 7,200 AF/year

Upstream Demand

A few demands occur upstream of the reservoirs and are accounted for in the RPM analysis. The RPM analysis is set based on these agreements and uses the following demand (White Mountain Apache and San Carlos Apache tribes) from naturalized flow upstream of the reservoirs.

WMAT = 25,800 AF/year
SCAT = 7,300 AF/year

Demand distribution

The current monthly demand over the year is not constant and is modeled as a pattern in the RPM model. Table 1 shows how annual demand is distributed over 12 months in the System. This demand pattern is used in the RPM model for all simulations and future years. This demand distribution was also assumed for the New Verde Space for the Bartlett Modification 1 and 2 alternatives.

Table 1: Monthly distribution of annual demand

Month	Percentage of Annual Demand
January	3.9%
February	4.4%
March	6.5%
April	9.5%
May	11.1%
June	13.1%
July	13.5%
August	12.9%
September	8.8%
October	7.3%
November	6.3%
December	2.9%

Other RPM Assumptions

Sedimentation

The Horseshoe Reservoir capacity curve has been extrapolated using recent sediment surveys at Horseshoe Reservoir. The annual sedimentation rate pulled from this curve and used in the RPM modeling is 1,010 AF/year. With this rate and without action, Horseshoe Reservoir completely fills up with sediment by 2110. In the Without Action alternative, after Horseshoe Reservoir completely fills up, the same sedimentation rate starts impacting Bartlett Dam storage. In the RPM, stage-storage curves used to represent each reservoir are not temporally dynamic. Therefore, sedimentation impacts to Horseshoe and Bartlett reservoirs for the duration of the modeling period were applied every ten years.

Reservoir and River Operations

For the Without Action alternative, river and reservoir operating rules in the RPM follow current operations. Much of the reservoir operations are handled by model weighting. Figure 1 shows the priority of weighting in the model as described below. Storage (above dead storage) in the reservoirs is weighted lower than the demands at Granite Reef Diversion Dam; therefore, water will be released to meet demands before storage needs are evaluated. Demands upstream of the reservoirs have higher weights than storage to prevent shortages upstream to fill storage downstream. Evaporation, seepage, and river loss are all weighted higher than storage and

downstream demands to prioritize counting those physical losses before any operational decisions are made.

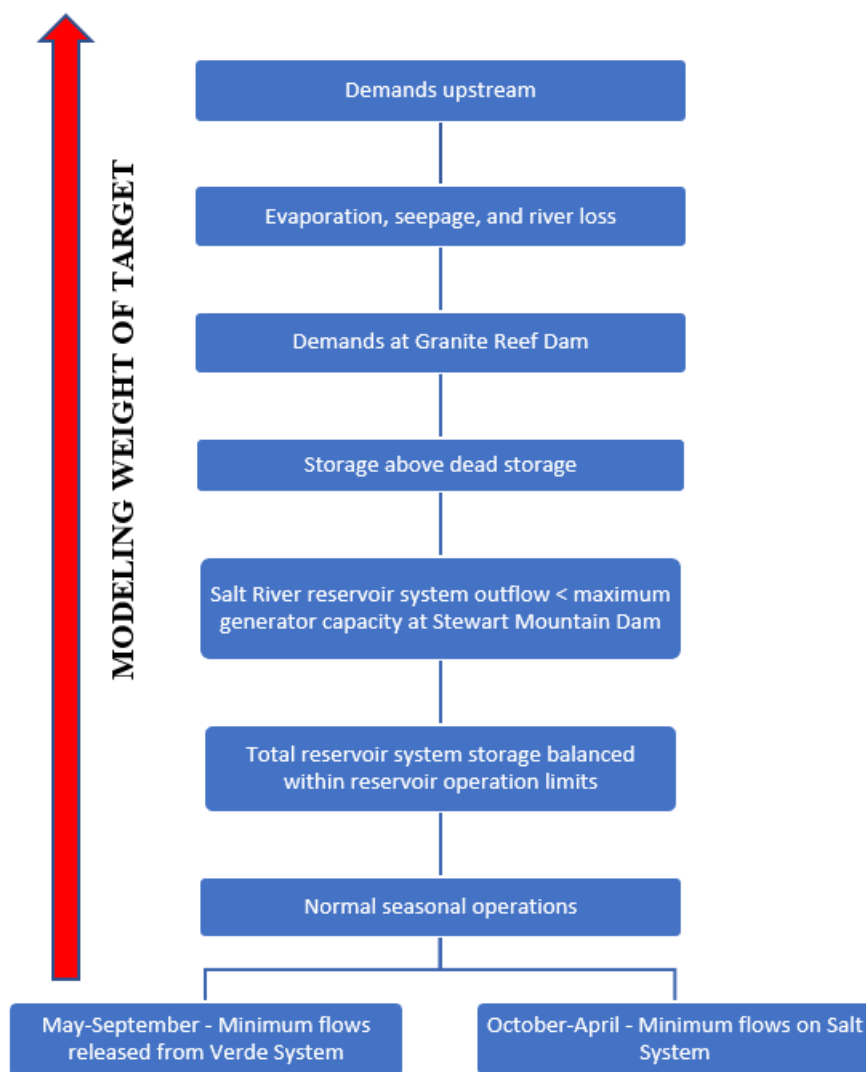


Figure 1 - Operations order of modeling target weights

The river system used to meet demands is then determined. First, targets for normal seasonal operations are set. From May through September, a target is set on the Verde River reservoir system to limit flows to the minimum release, so the model will try to make demand releases from the Salt River reservoir system. From October through April, the inverse is targeted (minimize Salt River outflows, making demand releases from the Verde River reservoir system). Once the normal targets are set, some additional qualifiers are defined. A target is set for the Salt River reservoir system outflow not to exceed the maximum generator capacity at Stewart Mountain Dam. The weight on this target is higher than the seasonal norms, so if a demand

release would cause lower Salt River outflows to exceed the generator capacity, the balance above the maximum would be attempted to be released from the Verde River reservoir system.

Additionally, targets are defined to keep a balance between the total storage in each reservoir system, defined by operating limit rule curves. Each system has a target that discourages storing water above the operating limit, so if one system is above the operating limit and one is at or below it, the demand release from the System will be adjusted appropriately to try to operate to the curves. The weight for these targets are slightly higher than the normal seasonal targets, but much lower than the weight for actual storage in the reservoirs, so the effect will be to shift demand releases between the two reservoir systems when needed, but not to release water in excess of demand from storage.

Minimum Flow Requirement

For the Verde system, the minimum outflow from Bartlett Dam is 100 cfs per paragraph 16 of the January 15, 1993 Settlement Agreement for the Fort McDowell Yavapai Nation (FMYN) Water Rights Settlement, plus any water deliveries to FMYN. For the Lower Salt River, the minimum outflow is set to 8 cfs. These minimum flow requirements are used for all alternatives.

Groundwater Pumping

The maximum pumping capacity is 325,000 AF/year. Minimum and maximum groundwater pumping values keep pumping within certain limits. It is assumed for the RPM analysis that minimum pumping will be about 65,000 AF. As storage levels decrease, groundwater pumping increases. Maximum and minimum groundwater pumping values apply to all alternatives.

Central Arizona Project (CAP) Exchanges

CAP exchanges and inflows have been removed from the RPM for the model runs performed in simulations conducted for this analysis. Although the SRP system can exchange water with the CAP system, these exchanges are not guaranteed to be available for SRP use and not considered for the appraisal level of analysis.

River and Reservoir Loss

River loss is computed by multiplying a constant for annual loss by the monthly fraction of evaporation for both rivers. This volume is forced into a designated loss node at the confluence of the Salt and Verde rivers. Reservoir seepage is computed by multiplying the beginning of month storage (since the wetted area does not change significantly month to month) by a seepage constant that is specific to each river system. River and reservoir loss computation methods do not change across the alternatives.

Hydrology – Climate Change Impacts

In early 2020 the Bureau of Reclamation published a report (USBR, 2020) that resulted from a collaborative effort among the Bureau of Reclamation, Arizona State University and the Salt River Project and focused on the impacts of climate change on Salt-Verde streamflow and reservoir operations. In that study, two independent methodologies were used to assess the climate change impacts on future streamflow. The transient method involved physical hydrology modeling with inputs of future temperature and precipitation derived from Global Climate Model projections. The period-change method involved an exhaustive statistical analysis of historical

streamflow, precipitation, and temperature records to alter the distribution of historical streamflow based on projected 21st century climate.

For this appraisal study, aspects from both of these methods were leveraged to alter the 106-year historical streamflow record (1914-2019) to produce a future record (2031-2136) based on changes in temperature, precipitation mean, and precipitation variability derived from Global Climate Model projections. The applied increase in temperature from 2031-2136 was +4 °C for both the Salt+Tonto and Verde. The applied decrease in mean precipitation was -4.5% on Salt+Tonto watershed and -2.8% on the Verde watershed. The change in precipitation variability was represented with an empirical cumulative distribution function with precipitation in the wettest years (above the 90th percentile) increased by 5%-10%, and precipitation in the driest years (below the 10th percentile) decreased by 20%-30%. The projected change in the average annual Salt-Verde streamflow between 1914-2019 and 2031-2136 was -25.4 kaf or about -2.2% which is expected given higher temperatures driving increased evaporative losses from the landscape and decreased mean precipitation. There was a decrease in streamflow in 79% of the years but for about 10% of the years, annual streamflow was increased by more than 100 kaf. One would expect deeper droughts and wetter pluvials with increased precipitation variability. More details regarding altering the 1914-2019 streamflow record for projected changes in climate are given in Appendix H.

Reservoir Evaporation

Reservoir evaporation is computed by multiplying a monthly evaporation coefficient determined for each reservoir by the surface area of that reservoir for each month. The computed evaporation is removed from the storage at each reservoir node in RPM.

Reservoir evaporation for this analysis was also modified to account for climate change. The Hamon equations for potential evapotranspiration are effectively a very simplified version of the Penman-Monteith equations requiring only average temperature as the meteorological variable (Allen et al., 1998; Svoma and Gantzer, 2016). Monthly temperature records available from the National Center for Environmental Information for Sky Harbor International Airport from 1950-2019 were input to the Hamon equations to derive a historical baseline for potential evapotranspiration. To be consistent with the methods deriving the climate change impacts on Salt-Verde streamflow, a linear increase in future temperature reaching 4 °C by 2136 (see Appendix H) was extrapolated from the observed record. These temperatures were applied to the Hamon equations to produce future potential evapotranspiration. To alter the resulting time series of potential evapotranspiration to better estimate lake evaporation, the seasonal scaling factors given in table 12, page 114 of Allen et al. (1998) were applied to account for the seasonal changes in heat storage in an open water body. Finally, the average monthly lake evaporation estimates from 2031-2136 were divided by the 1950-2019 monthly averages to create monthly scale factors representing the monthly change in lake evaporation from present to future climate. These scale factors were multiplied by the monthly evaporation rates currently in the Reservoir Planning Model.

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Appendix H: Future Streamflow on the Salt-Verde

Verde Reservoirs Sediment Mitigation Study

Appendix H: Future Streamflow on the Salt-Verde

A1: Introduction

The methods for adjusting historical records of Salt-Verde streamflow based on projected changes in temperature and precipitation are described along with a brief summary of results. Salt+Tonto and Verde streamflow (Figure A1) records from water years 1914-2019 provide the baseline for comparison to derived future streamflow, 2031-2136. Section A2 provides a general overview of challenges in using climate change projections for planning studies. Section A3 discusses the use of temperature sensitivities and precipitation elasticities as an alternative to physical hydrologic modeling. Section A4 details the derivation of future changes in temperature and precipitation that are used to adjust the streamflow record. Section A5 briefly describes the results of the climate change analysis.

A2: Challenges in Using Projections of Future Climate for Planning Studies

Phase 5 of the Coupled Model Intercomparison Project (CMIP5; Taylor et al., 2012) provides a set of projections of future climate from Global Climate Models (GCMs) from numerous institutions worldwide. The Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (AR5) and other global, regional, and national assessments are largely based on output from CMIP 5 (Taylor et al., 2012). GCMs simulate climate at large spatial scales, $\sim 100 \text{ km} \times \sim 100 \text{ km}$ resolution, which is not adequate for planning studies about the impacts of climate change on water resources (Pierce et al., 2014), especially for watersheds that are $\sim 30,000 \text{ km}^2$ and span a wide range in elevations. Therefore, downscaling is required for most impact studies. The two main types of downscaling are dynamical downscaling and statistical downscaling. Dynamical downscaling uses higher resolution regional climate models nested within a portion of the coarse resolution GCM. Statistical downscaling applies statistical relationships between coarse resolution model output and observations to translate the large-scale information to a smaller scale. A significant disadvantage of statistical downscaling is that relationships between the large and small scales may change in the future. This is not a problem for dynamical downscaling, but the computational expense of dynamical downscaling is larger than statistical downscaling by orders of magnitude. This limits the climate change analysis to a small portion of CMIP5 suite. In addition, dynamically downscaled output often needs to be bias corrected before practical application (Pierce et al., 2014).

A3: Temperature Sensitivity and Precipitation Elasticity

Translating changes in temperature and precipitation to changes in streamflow is challenging given the complexities of streamflow generation (USBR, 2020). Even after significant effort for bias correction and model calibration, large biases can remain, limiting the utility for planning studies (USBR, 2020). Moreover, equifinality (Her et al., 2019) reduces confidence in hydrologic model output, making the computational expense of complex physical hydrologic models an even more unattractive feature, particularly if biases remain after calibration. Therefore, empirically derived temperature sensitivities and precipitation elasticities are indispensable tools for planning projects. Applying the sensitivities and elasticities to the historical inflow record eliminates the challenges from bias in the baseline period for climate change planning studies.

The temperature-streamflow sensitivity is,

$$S_t = \frac{\Delta Q}{Q} / \Delta T \quad (1)$$

where ΔQ is the change in seasonal streamflow, Q is an initial seasonal streamflow, and ΔT is the change in seasonal average temperature ($^{\circ}\text{C}$). The temperature-streamflow sensitivity (S_t) is most easily interpreted as the percent change in streamflow per change in unit temperature, but has the mathematical units of $^{\circ}\text{C}^{-1}$ (USBR, 2020). The precipitation-streamflow elasticity is,

$$\varepsilon_p = \frac{\Delta Q}{Q} / \delta \quad (2)$$

where

$$\delta = \frac{\Delta P}{P} \quad (3)$$

and ΔP is the change in seasonal total precipitation and P is an initial seasonal total precipitation. The precipitation-streamflow elasticity (ε_p) is most easily interpreted as the ratio between the percent change in streamflow and the percent change in precipitation, but is unitless (USBR, 2020).

A4: Adjusting Streamflow Records for Future Conditions

A4.1: Applying Temperature Sensitivities and Precipitation Elasticities

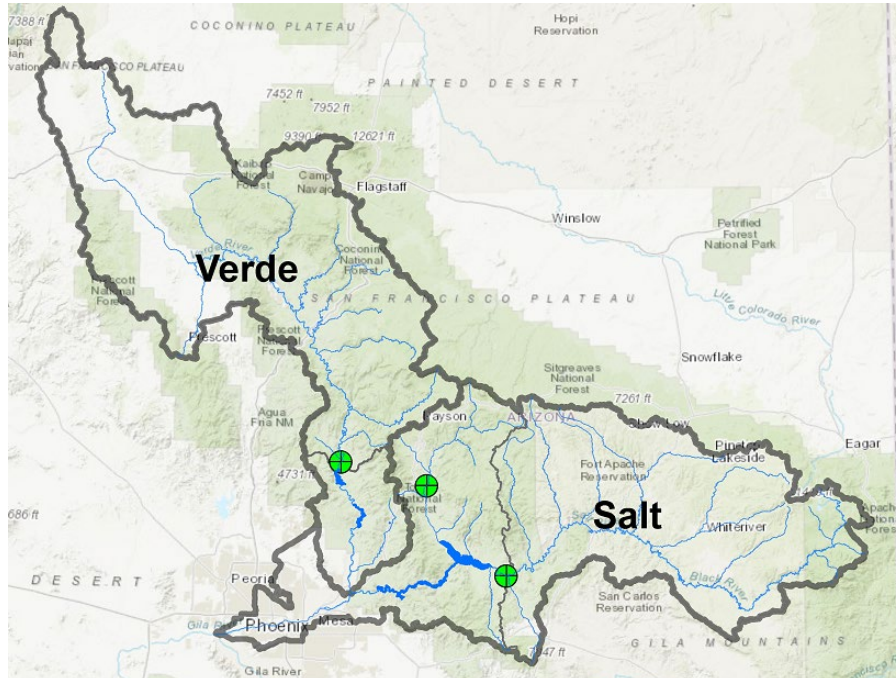


Figure A1: The Salt and Verde River basins and the three streamflow gages (green symbols) used to quantify inflow into Horseshoe Lake (Verde) and Roosevelt Lake (Salt). The thick gray lines represent the basin boundaries and the thin gray lines further delineate the contributing drainage areas for the Salt River and Verde Rivers into Roosevelt and Horseshoe Lakes respectively.

For the Salt+Tonto and Verde streamflow records (Figure A1), S_t and ε_p were found to vary considerably from summer to winter and between wet years and dry years (Murphy, 2016; USBR, 2020). Equations for S_t and ε_p used in this study are given in Murphy (2016) on pages 286-288. The equations were derived through an exhaustive investigation of the three-dimensional space relating streamflow response to temperature and precipitation. The S_t and ε_p are given separately for October through April and May

through September. For example, S_i for the October-April period represents the percentage change in total streamflow during October-April per unit change in average temperature during October-April and $\mathcal{E}_p$ represents the ratio between the percent change in total streamflow during October-April and the percent change in total precipitation during October-April. It is important to emphasize again that S_i and $\mathcal{E}_p$ are applied seasonally, and therefore, sub-daily, daily, and monthly changes in streamflow characteristics arising from more rainfall at the expense of snowfall with warming are not determined. Therefore, impacts to operations arising from shorter time scale changes in streamflow are not considered in this study. The cold season temperature sensitivity (S_i) does, however, indirectly quantify the impacts of temperature on rainfall/snowfall partitioning and total seasonal streamflow, as warmer (colder) winters would be expected to be less (more) snow dominated.

The 1914-2019 Salt+Tonto and Verde streamflow records (Figure A1) were adjusted by applying temperature sensitivities and precipitation elasticities by the following process:

$$\Delta Q_T = ([1 + S_T]^{\Delta T} - 1)Q \quad (4)$$

$$\Delta Q_P = \delta \mathcal{E}_p (Q - Q_{base}) \quad (5)$$

where ΔQ_T is the change in seasonal streamflow due to change in temperature (ΔT), ΔQ_P is the change in seasonal streamflow due to change in precipitation (δ), and Q_{base} is the seasonal total baseflow (Murphy, 2016). The change in seasonal streamflow due to changes in precipitation and temperature ($\Delta Q_{T,P}$) was given by:

$$\Delta Q_{T,P} = \Delta Q_T + \Delta Q_P \quad (6)$$

A4.2 Future Changes in Temperature and Precipitation and Adjusting the Streamflow Record

Inter-model uncertainty in CMIP5 is a significantly larger source of uncertainty than the uncertainty contained in the parameter space of hydrologic models (Her et al., 2019). The spread in the CMIP5 projections arises from a number of sources of uncertainty including natural variability of the climate system, future carbon dioxide emission scenarios, and sensitivity to increased carbon dioxide. There are also model differences in the skill in reproducing large spatial and temporal patterns in temperature and precipitation (Anagnostopoulos et al., 2010). Therefore, an ensemble approach determining a mid-point in the range of projected changes is an appropriate first step in examining the climate change signal in the CMIP5 suite.

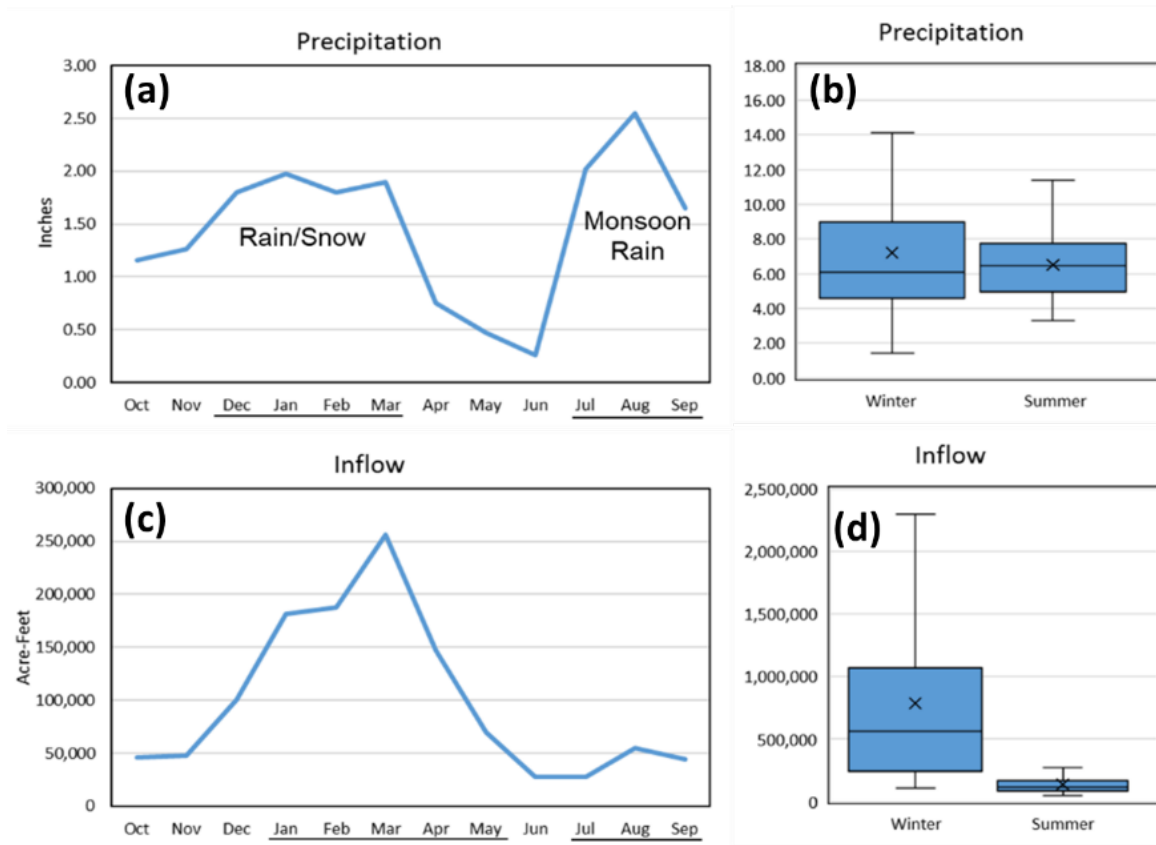


Figure A2: Monthly Salt-Verde watershed average precipitation (a) and total reservoir inflow (c). Seasonal distribution of precipitation (b) and total reservoir inflow (d).

Considering the need for an ensemble approach and the computational limitations of dynamical downscaling (Pierce et al., 2014), statistical downscaling was the chosen method to produce small-scale climate change information. Therefore, the Localized-Constructed-Analogs CMIP5 (LOCA-CMIP5) statistically downscaled dataset was used (Pierce et al., 2014). For the Salt-Verde watersheds, the LOCA-CMIP5 dataset has substantial large positive biases in monsoon season precipitation (USBR, 2020). Given that most of the Salt-Verde streamflow is generated in the winter and early-spring (Figure A2) and the values of the empirical temperature sensitivities (S_t) and precipitation elasticities ($\mathcal{E}_p$) for the Salt-Verde (Murphy, 2016; USBR, 2020), changes in temperature and precipitation outside of the monsoon season (e.g., Oct-May) are expected to have the greatest impact on future streamflow.

To quantify the projected climate change impact on temperature and precipitation, the average change in temperature (ΔT_{full}) and precipitation (ΔP_{full}) in the 64 LOCA-CMIP5 projections was calculated separately for the Salt+Tonto and Verde (Figure A3). The LOCA-CMIP5 time series span 1950-2099. The periods 2090-2099 and 1990-1999 were chosen to calculate ΔT_{full} and ΔP_{full} as this was assumed to be the best representation of change over the 2031-2136 period. In the absence of other information (e.g., projected carbon dioxide concentration in the 22nd century and LOCA-CMIP5 projections in the 22nd century) this is a reasonable assumption to quantify ΔT_{full} and ΔP_{full} over a ~100 year period from the early 21st to the early 22nd century. The choice of ten-year periods versus

thirty-year periods (e.g., 1970-1999 and 2070-2099) is justifiable because internal climate variability would be expected to be negligible when averaging 64 simulations. Given the previously mentioned issues with the monsoon season climate in the LOCA-CMIP5 data, Oct-May was chosen to calculate ΔT_{full} and ΔP_{full} . It should be noted that results were not sensitive to calculating ΔT_{full} and ΔP_{full} separately for summer and winter. This is not surprising given a relatively small portion of annual streamflow is generated from monsoon season precipitation (Figure A2).

The future temperature anomaly was given by:

$$T'_{f,y} = -T'_{h,1914} + T'_{h,y-117} + \frac{\Delta T_{full}}{106}(y - 2030) \quad (7)$$

where $T'_{f,y}$ is the temperature anomaly (°C) in the future period f (2031-2136) at year y , and $T'_{h,1914}$ and $T'_{h,y-117}$ are the observed seasonal temperature anomalies during historical period h , (1914-2019), for 1914 and $y-117$ respectively. The anomalies are relative to the 1990-2019 average seasonal temperature and the spatial average from the monthly 4 km PRISM dataset (Daly et al., 1994) of the given watershed was used as the historical record. The change in temperature applied to Equation 4 for a given year in the future period ($\Delta T_{f,y}$) was given by:

$$\Delta T_{f,y} = T'_{f,y} - T'_{h,y-117} \quad (8)$$

The complete temperature anomaly time series with the linear climate change up to ΔT_{full} is displayed in Figure A4.

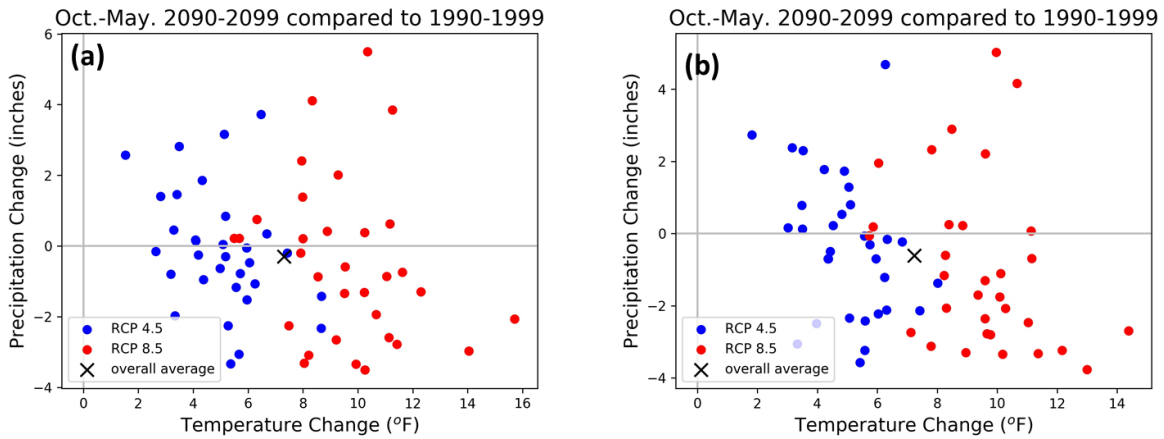


Figure A3: Late-21st century changes in total winter precipitation and average temperature for the Verde (a) and Salt+Tonto (b) basins for 64 LOCA downscaled simulations from the Coupled Model Intercomparison Project Phase 5 (CMIP5).

To apply a linear change in mean seasonal precipitation up to ΔP_{full} the following scale factor ($\delta_{1,f,y}$) was first calculated for each year y in the future period f :

$$\delta_{1,f,y} = \left(\frac{\Delta P_{full}}{\bar{P}_h} - 1 \right) \frac{\Delta T_{f,y}}{\Delta T_{full}} \quad (9)$$

where $\bar{P}_h$ (in.) is the average seasonal total precipitation of the 64 LOCA-CMIP5 time series during the 1990-1999 time period in Figure A3. The future precipitation adjusted only for the change in the mean was given by:

$$P1_{f,y} = P_{h,y-117} \delta_{1,f,y} \quad (10)$$

where $P_{h,y-117}$ is the observed seasonal total precipitation during historical period h , (1914-2019), in

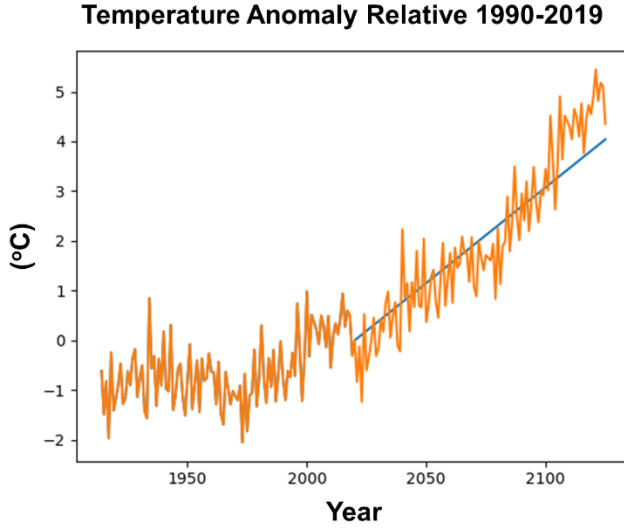


Figure A4: Salt-Verde historical and future Oct.-May average temperature anomaly (orange line) with linear future warming from climate change (blue line).

year $y-117$. To derive $P_{h,y-117}$, the spatial average from the monthly 4 km PRISM dataset (Daly et al., 1994) of the given watershed was used as the historical record.

Empirical quantile mapping was used to adjust the historical precipitation record for projected changes in precipitation variability. Empirical quantile mapping is a common bias correction technique for precipitation output from numerical weather prediction models and GCMs (Cannon et al., 2015). This method can be applied in a similar fashion to represent the change in precipitation variability from a current time period to a future time period. For example, using the inverse cumulative distribution function

(CDF), $F_f^{-1}\{F_h[\cdot]\}$, (Cannon et al., 2015) relates precipitation in the current time period to the future time period, where F_h and F_f are the CDFs of precipitation in the current and future periods, respectively. Since the statistical distribution function of Salt-Verde precipitation is unknown and extremes are very impactful on the Salt-Verde reservoir system, F_h and F_f were determined empirically and thus a lookup table represents the transfer function. For the changes in mean temperature and precipitation, a linear change from 2031-2136 was assumed. To apply a change in variability in a similar fashion, F_h and F_f would need to vary year-by-year from 2031-2136. For the sake of simplicity and to represent the broad late 20th century to late 21st century change in precipitation variability, F_h and F_f were determined through comparison of 2050-2099 and 1950-1999. Therefore, the initial lookup table had 3200 entries, 50 years multiplied by 64 LOCA-CMIP5 projections. To apply the lookup table to the 106-year historical record, a lookup table with 106 entries was created by smoothing the original lookup table. This was done by binning the original lookup table into 106 groups of approximately equal size (~30) and averaging the bins.

A second scale factor ($\delta_{2,f,y}$) to apply the change in the precipitation variability is calculated as:

$$\delta_{2,f,y} = \frac{F_f^{-1}\{F_h[P_{h,y-117}]\}}{P_{h,y-117}} \quad (11)$$

where F_f^{-1} is the inverse empirical cumulative distribution function for seasonal precipitation total in the 2050-2099 future period, F_h is the empirical cumulative distribution function for seasonal

precipitation total in the 1950-1999 in the historical period, h , and $P_{h,y-117}$ is the observed seasonal precipitation total for year $y-117$, where y is a year in the period 2031-2136. Applying this scale factor (Equation 11) to the historical precipitation time series,

$$P2_{f,y} = P_{h,y-117} \delta_{2,f,y} \quad (12)$$

results in a new future precipitation time series, $P2_{f,y}$. The time series $P2_{f,y}$ has a mean precipitation that is different than $P1_{f,y}$, and does not correspond to ΔP_{full} in Figure A3 because of the different time periods analyzed in the LOCA-CMIP5 data. To address this, a final scale factor was calculated ($\delta_{f,y}$)

$$\delta_{f,y} = \delta_{2,f,y} \frac{\overline{P1}_{f,y}}{\overline{P2}_{f,y}} \quad (13)$$

where $\overline{P1}_{f,y}$ and $\overline{P2}_{f,y}$ are the averages of the $P1_{f,y}$ and $P2_{f,y}$ time series respectively, and the final future precipitation time series was given by:

$$P_{f,y} = \delta_{f,y} P_{h,y-117} \quad (14)$$

and are displayed in Figure A5. Finally, the historical inflow record adjusted for climate change is a result inserting $\Delta T_{f,y}$ and $\delta_{f,y}$ into Equations 4-6, to produce a change in streamflow that varies by year:

$$\Delta Q_{T,P,y} = \Delta Q_{T,y} + \Delta Q_{P,y} \quad (15)$$

where $\Delta Q_{T,P,y}$ is the change in streamflow in year y relative to year $y-117$ (where y is a year in the period 2031-2136) due to changes in streamflow from temperature-sensitivity $\Delta Q_{T,y}$ and precipitation-elasticity $\Delta Q_{P,y}$.

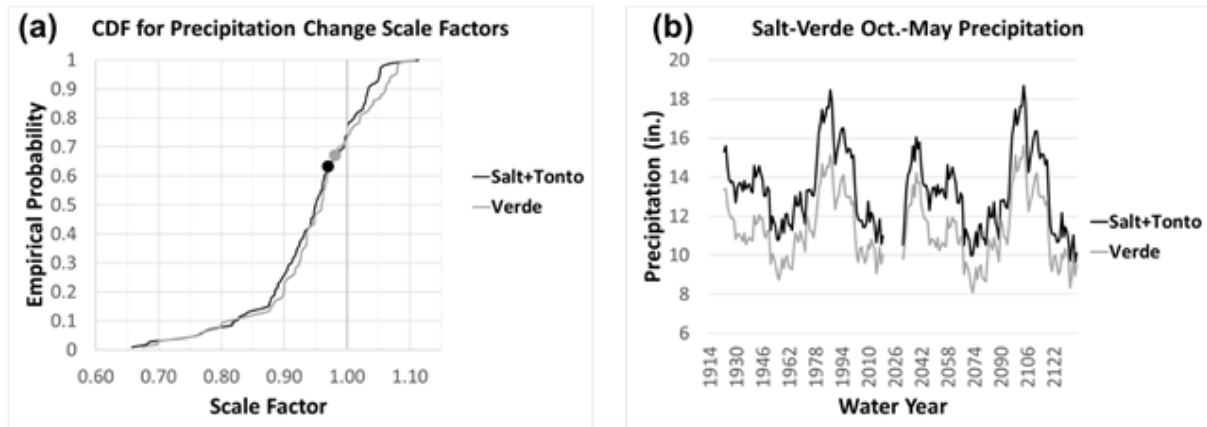


Figure A5: Changes in precipitation variability represented by cumulative distribution functions for $\delta_{f,y}$ (a) with the changes in the mean precipitation also displayed (circles). The historical and future seasonal precipitation (b) are related by the scale factors in panel (a) through Equation 14. The annual values in (b) are smoothed with a 10-year running average.

A5: Future Streamflow

After applying $\Delta T_{f,y}$ and $\delta_{f,y}$ to Equations 4-6, the difference in the average Salt-Verde Oct.-May precipitation between 1914-2019 and 2031-2136 is -0.31" or about -2.5% (Figure A6). The

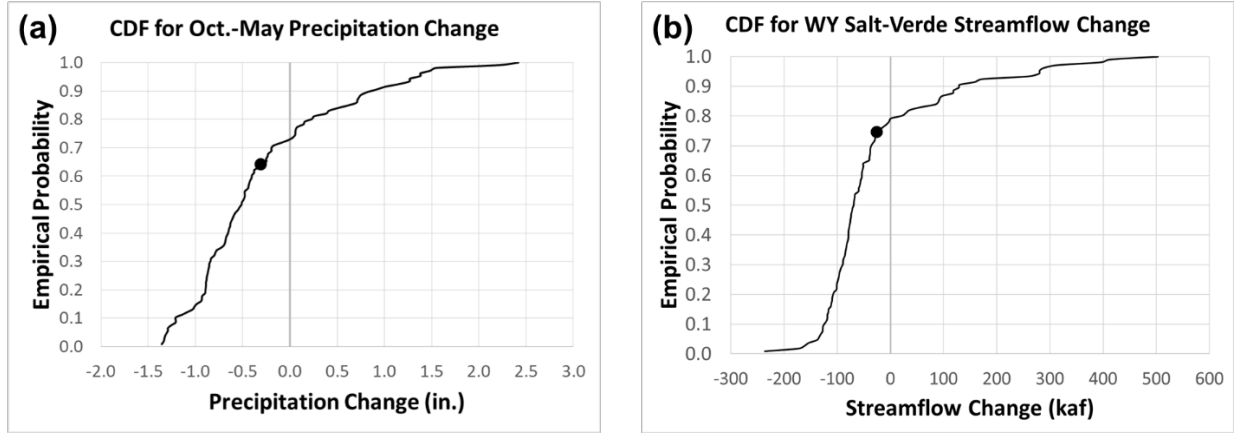


Figure A6: Cumulative distribution functions displaying differences in the historical precipitation (a) and streamflow (b) records and the historical records adjusted for climate change with the change in the means given by black circles.

difference in the average water year streamflow between 1914-2019 and 2031-2136 is -25.4 kaf or about -2.2% (Figure A6). This suggests that the increased precipitation in the extreme wet years derived from the LOCA-CMIP5 data (Figure A5a) results in increased streamflow during those years that slightly overcomes the decrease in mean precipitation, e.g., in ~10% of the years, water year streamflow is increased by more than 100 kaf (Figure A6). The decrease in mean streamflow due to increased temperature is evident from comparing the percentile of the no change value (i.e., zero line) between Figure A6a and Figure A6b. For example, water year streamflow is decreased in ~79% of the years while precipitation is only decreased in ~73% of the years (Figure A6). Lastly, the decrease in average streamflow (-2.2%) is less than what is expected from the impact of increased temperature alone on the Upper Colorado River Basin (Vano et al., 2012; Vano and Lettenmaier, 2014). This is in part because the temperature sensitivity (S_T) on the Salt-Verde average streamflow is $\sim 1.2\% \text{ } ^\circ\text{C}^{-1}$ (USBR, 2020) while S_T on Colorado River average streamflow is reported to be $\sim 6.5\%$ (Vano et al., 2012; Vano and Lettenmaier, 2014). The physical mechanisms responsible for this difference need further exploration but recent research suggests that the Salt-Verde is less sensitive to warming because the streamflow occurs earlier in the year (e.g., January-April) when the potential for evaporative losses from the landscape is limited (Robles et al., 2020). The complete 1914-2136 time series of total annual Salt-Verde streamflow is displayed in Figure A7.

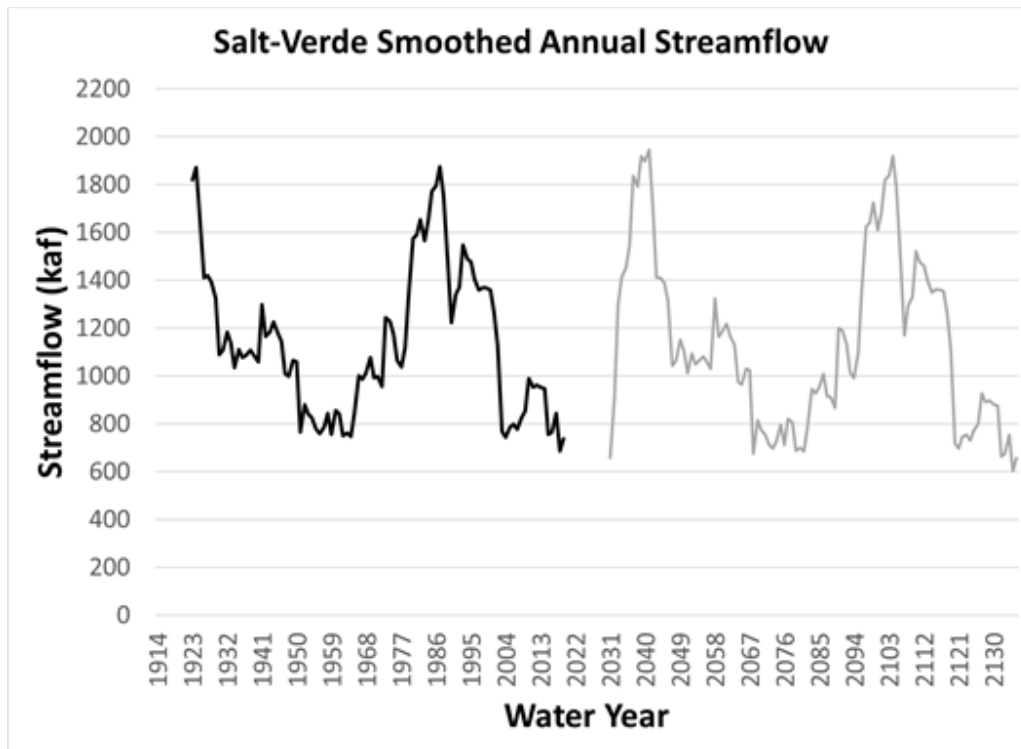


Figure A7: Historic total Salt-Verde streamflow (black line) and historical observations adjusted for climate change (gray line). The annual values are smoothed with a 10-year running average.

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Appendix I: Environmental Considerations Metrics Narratives

Verde Reservoirs Sediment Management Study
Appendix I - Environmental Considerations
Metric Narratives Appraisal Study Alternatives

Category for Evaluation	Without Action	Sediment Removal	Bartlett Mod 1	Bartlett Mod 2
Threatened & Endangered Species				
Gila Topminnow	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for the incidental take of 16 species, including the Gila topminnow, to the maximum extent practicable, and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). Based on the continual implementation of the HCP, the Without Action would not likely have a change in effects on Gila topminnow.	The nearest population of Gila Topminnow occurs in Lime Creek, a tributary to Horseshoe Reservoir. The Horseshoe-Bartlett HCP includes existing mitigation, including a fish barrier, to protect the population from the effects of reservoir operations and production of nonnative fish that compete and prey upon Gila Topminnow. Gila topminnow is not known to occur within the areas proposed for sediment removal. It is anticipated that the existing population in Lime Creek, above the fish barrier, would not be affected by the movement of sediment downstream.	The Gila topminnow is not found within Bartlett or Horseshoe reservoirs, the Verde River between these two reservoirs, or in the Verde and Salt rivers below Bartlett Dam. Thus, the proposed Bartlett Dam alternatives would have no effect on the topminnow. The proposed repurposing of Horseshoe Reservoir operations is not anticipated to benefit the Gila topminnow because the habitat conditions needed by the topminnow would not result from the proposed run-of-river operations.	The Gila topminnow is not found within Bartlett or Horseshoe reservoirs, the Verde River between these two reservoirs, or in the Verde and Salt rivers below Bartlett Dam. Thus, the proposed Bartlett Dam alternatives would have no effect on the topminnow. The proposed repurposing of Horseshoe Reservoir operations is not anticipated to benefit the Gila topminnow because the habitat conditions needed by the topminnow would not result from the proposed run-of-river operations.
Colorado Pikeminnow	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including the Colorado pikeminnow, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). The Colorado pikeminnow is considered a 10(j) non-essential experimental population and was last stocked in the Verde River upstream of Horseshoe Reservoir in 2018. There are no current plans to continue to stock the pikeminnow, and there is no viable population in the reservoirs due to non-native fish. To	Colorado pikeminnow in the Verde River are considered a 10(j) non-essential experimental population and have been collected in Horseshoe Reservoir. This experimental population is considered functionally extirpated from the area. The last stocking effort was approximately 50 miles upstream of the project area at Beasley Flats in 2018, and AZGFD does not plan on stocking in the future. Any existing fish in the reservoir may be affected by the removal of sediment due to habitat loss, hydraulic entrainment, release of contaminants, sedimentation, suspended sediment, and underwater noise. However, due to the low numbers of Colorado	In the Verde River, the USFWS designated the Colorado pikeminnow a 10(j) non-essential experimental population under the Endangered Species Act. Surveyors have collected pikeminnow in Horseshoe and Bartlett reservoirs; however, the USFWS considers this experimental population functionally extirpated from the area. The construction of a new dam and the corresponding raising of the reservoir is unlikely to impact the 10j population. A more natural flow regime, associated with the repurposing of the Horseshoe operations, could benefit native fish, but because of interactions with nonnative fish, it is difficult to say whether it would benefit native species, such as the Colorado pikeminnow. There is no proposed or existing critical habitat for the species in the study area.	In the Verde River, the USFWS designated the Colorado pikeminnow a 10(j) non-essential experimental population under the Endangered Species Act. Surveyors have collected pikeminnow in Horseshoe and Bartlett reservoirs; however, the USFWS considers this experimental population functionally extirpated from the area. The construction of a new dam and the corresponding raising of the reservoir is unlikely to impact the 10j population. A more natural flow regime, associated with the repurposing of the Horseshoe operations, could benefit native fish, but because of interactions with nonnative fish, it is difficult to say whether it would benefit native species, such as the Colorado pikeminnow. There is no proposed or existing critical habitat for the species in the study area.

Category for Evaluation		Without Action		Sediment Removal		Bartlett Mod 1		Bartlett Mod 2
		comply with the H-B HCP, SRP conducts a rapid drawdown each year to minimize non- native species in Horseshoe Reservoir. Based on the continual implementation of the HCP, the Without Action would have no change in effect on Colorado pikeminnow.		pikeminnow in the system, the effects are likely to be marginal. There is no proposed or existing critical habitat for the species in the study area.				
Razorback Sucker		Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including the razorback sucker, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). Designated critical habitat for the razorback sucker occurs within Horseshoe Reservoir and the Verde River upstream of the reservoir. Currently, no viable population exists within the Study area. Based on the continual implementation of the H-B HCP, the Without Action Alternative would have no change in effect on razorback suckers.		Razorback sucker designated critical habitat occurs within the area under consideration for sediment removal. AZGFD stocked razorback suckers approximately 50 miles upstream of the study area near Beasley Flats most recently in 2020. This alternative would likely have negative effects on critical habitat identified in Horseshoe Reservoir. Any existing fish in the reservoir may be affected by the removal of sediment due to habitat loss, hydraulic entrainment, release of contaminants, sedimentation, suspended sediment, and underwater noise. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the razorback sucker.		Razorback sucker designated critical habitat occurs within a portion of the area under consideration for this alternative. Critical habitat for the razorback sucker encompasses Horseshoe Reservoir and the Verde River upstream of the reservoir. AZGFD stocked the razorback suckers approximately 50 miles upstream of the project area near Beasley Flats in 2020. A more natural flow regime, associated with the repurposing of the Horseshoe operations, would benefit native fish, but because of interactions with nonnative fish, it is difficult to say whether or not it would benefit native species, such as the razorback sucker. The expansion of Bartlett Reservoir would likely result in an increase in nonnative fish abundance in the reservoir; however, the nonnative fish community currently in Bartlett Reservoir is large enough to prevent establishment of the razorback sucker.		Razorback sucker designated critical habitat occurs within a portion of the area under consideration for this alternative. Critical habitat for the razorback sucker encompasses Horseshoe Reservoir and the Verde River upstream of the reservoir. AZGFD stocked the razorback suckers approximately 50 miles upstream of the project area near Beasley Flats in 2020. A more natural flow regime, associated with the repurposing of the Horseshoe operations, would benefit native fish, but because of interactions with nonnative fish, it is difficult to say whether or not it would benefit native species, such as the razorback sucker. The expansion of Bartlett Reservoir would likely result in an increase in nonnative fish abundance in the reservoir; however, the nonnative fish community currently in Bartlett Reservoir is large enough to prevent establishment of the razorback sucker.
Yellow-billed cuckoo		Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including the yellow-billed cuckoo, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). The yellow-billed cuckoo occurs in the northern reaches of Horseshoe Reservoir. Critical habitat is designated upstream of Horseshoe		Within areas surveyed for the species, yellow-billed cuckoos occur in the upper end of Horseshoe Reservoir. Physical disturbance around Horseshoe may alter occupied habitat and would interfere with their breeding season (i.e., prolonged noise/construction activity would deter nesting). This would likely have negative effects on the cuckoos. Newly designated critical habitat does not occur within the area of disturbance for this alternative. It is unknown how sediment transport may affect the		It is unknown if yellow-billed cuckoos breed below Horseshoe Reservoir, but they have been recorded between Bartlett and Granite Reef dams. Suitable habitat exists downstream of Horseshoe Dam and potentially along the length of the Verde River between Bartlett Dam and Granite Reef Dam. Designated critical habitat occurs above Horseshoe Reservoir and along 4.5 miles of the Verde River just downstream of Horseshoe Dam. Therefore, the physical disturbance associated with the inundation would alter suitable and designated critical habitat for the cuckoo by reducing foraging opportunities and inundating potential nest trees, and it could result in an increase in exotic vegetation, such as tamarisk. If cuckoos nest near the dam site, noise, dust and light disturbance associated with construction could also interfere with nesting. These impacts would have negative effects on the cuckoos. However, the		It is unknown if yellow-billed cuckoos occur below Horseshoe Reservoir, but they have been recorded between Bartlett and Granite Reef dams. Suitable habitat exists downstream of Horseshoe Dam and potentially along the length of the Verde River between Bartlett Dam and Granite Reef Dam. Designated critical habitat occurs above Horseshoe Reservoir and along 4.5 miles of the Verde River just downstream of Horseshoe Dam. Therefore, it is likely that the physical disturbance associated with the inundation would alter suitable and designated critical habitat for the cuckoo by reducing foraging opportunities and inundating potential nest trees, and it could result in an increase in exotic vegetation, such as tamarisk. If cuckoos nest near the dam site, noise, dust and light disturbance

Category for Evaluation	Without Action	Sediment Removal	Bartlett Mod 1	Bartlett Mod 2
	Reservoir near Sheeps Bridge and between Horseshoe and Bartlett reservoirs. The H-B HCP manages riparian habitat between the two reservoirs and in Horseshoe Reservoir to benefit covered species. Additionally, the cuckoo has benefited from the riparian habitat maintained from the continual release of flows downstream of Bartlett Dam. Based on the continual implementation of the H-B HCP, the Without Action Alternative would have no change in effect on yellow-billed cuckoo.	proposed critical habitat below Horseshoe Dam. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the cuckoo. For instance, if construction activities occurred outside of their breeding season, this would reduce the potential negative effects to the cuckoo.	cuckoo could benefit from the proposed repurposing of Horseshoe Reservoir operations, as habitat within the reservoir bottom could be restored to a more natural riparian ecosystem along the river channel. Periodic inundation could also create nesting habitat below Horseshoe Dam. Based on the water model, Bartlett Mod 1 would only be at the max elevation (1895 feet) 17 percent of the time over the 110-year period evaluated. The expansion and/or creating of suitable habitat in Horseshoe Reservoir, although beneficial, would occur over time. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease cuckoo habitat suitability, and increase fire risk. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the cuckoo. For instance, if construction activities occurred outside of their breeding season, this would reduce the adverse effects to the cuckoo.	associated with construction could also interfere with nesting. These impacts would be expected to have negative effects on the cuckoos. However, the cuckoo could benefit from the proposed repurposing of Horseshoe Reservoir operations, as habitat within the reservoir bottom could be restored to a more natural riparian ecosystem along the river channel. Periodic inundation could also create nesting habitat below Horseshoe Dam. Based on the water model, Bartlett Mod 2 would be at the max elevation (1860 feet) 30 percent of the time over the 110-year period evaluated. The expansion and/or creating of suitable habitat in Horseshoe Reservoir, although beneficial, would occur over time. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease cuckoo habitat suitability, and increase fire risk. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the cuckoo. For instance, if construction activities occurred outside of their breeding season, this would reduce the negative effects to the cuckoos.
Southwestern willow flycatcher	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including the Southwestern willow flycatcher, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). Critical habitat for the flycatcher occurs upstream of Horseshoe Reservoir near Sheeps Bridge and downstream of Horseshoe Dam, between the two reservoirs. Additionally, the flycatcher has benefited from the riparian habitat maintained from the continual release of flows	The Southwestern willow flycatcher nests and occurs upstream of and within Horseshoe Reservoir. Physical disturbance within Horseshoe Reservoir could alter occupied or suitable habitat. With a prolonged construction period, it is anticipated that the noise and human activity could interfere with breeding by deterring nesting. This is likely to have negative effects on the flycatcher. No designated critical habitat occurs with the area of disturbance. It is unknown how sediment transport may affect critical habitat below Horseshoe Dam. Endangered Species Act compliance would be required. Avoidance, minimization, and/or	The Southwestern willow flycatcher nests and occurs upstream of and within Horseshoe Reservoir, within a few miles downstream of Horseshoe Dam, and below Bartlett Dam near Needle Rock Picnic Area in the Tonto National Forest. Designated critical habitat occurs above Horseshoe Reservoir and along 4.2 miles of the Verde River just downstream of Horseshoe Dam. Under this alternative, designated critical habitat would be inundated below Horseshoe Dam with the expansion of Bartlett Reservoir. The physical disturbance associated with the inundation would alter suitable, occupied, or designated critical habitat for the flycatcher by reducing foraging opportunities, inundating nest trees, and it would likely result in an increase in exotic vegetation, such as tamarisk. The flycatcher could however benefit from the proposed repurposing of Horseshoe Reservoir operations as the habitat within the reservoir bottom could be restored to a more natural riparian ecosystem along the river channel. Periodic inundation could also create nesting habitat below Horseshoe Dam. Based on the water model, Bartlett Mod 1 would only be at the max elevation (1895 feet) 17 percent of	The Southwestern willow flycatcher nests and occurs upstream of and within Horseshoe Reservoir, within a few miles downstream of Horseshoe Dam, and below Bartlett Dam near Needle Rock Picnic Area in the Tonto National Forest. Designated critical habitat occurs above Horseshoe Reservoir and along 4.2 miles of the Verde River just downstream of Horseshoe Dam. Under this alternative, designated critical habitat would be inundated below Horseshoe Dam with the expansion of Bartlett Reservoir. The physical disturbance associated with the inundation would alter suitable, occupied, or designated critical habitat for the flycatcher by reducing foraging opportunities, inundating nest trees, and it would result in an increase in exotic vegetation, such as tamarisk. The flycatcher could however benefit from the proposed repurposing of Horseshoe Reservoir operations as the habitat within the reservoir bottom could be restored to a more natural riparian ecosystem along the river channel. Periodic inundation could also create nesting habitat below Horseshoe Dam. Based on the water

Category for Evaluation	Without Action	Sediment Removal	Bartlett Mod 1	Bartlett Mod 2
	downstream of Bartlett Dam. Based on the continual implementation of the H-B HCP, the Without Action Alternative would have no change in effect on southwestern willow flycatcher.	mitigation could be required to address effects to the flycatcher. For instance, if construction activities occurred outside of their breeding season, this would reduce the adverse effects to the flycatcher.	the time over the 110-year period evaluated. The expansion and/or creating of suitable habitat in Horseshoe Reservoir and immediately below Horseshoe Dam, having both positive and negative effects, would occur over time. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease flycatcher habitat suitability, and increase fire risk. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the flycatcher. For instance, if inundation occurred outside of their breeding season, this would reduce the negative effects to the flycatcher.	model, Bartlett Mod 2 would be at the max elevation (1860 feet) 30 percent of the time over the 110-year period evaluated. The expansion and/or creating of suitable habitat in Horseshoe Reservoir and immediately below Horseshoe Dam, having both positive and negative effects, would occur over time. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease flycatcher habitat suitability, and increase fire risk. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the flycatcher. For instance, if inundation occurred outside of their breeding season, this would reduce the negative effects to the flycatcher.
Northern Mexican Gartersnake	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including the northern Mexican gartersnake, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). To comply with the H-B HCP, SRP conducts a rapid drawdown each year to minimize non-native species in Horseshoe Reservoir to remove non-native fish, which prey on the snakes. It is unknown if the northern Mexican gartersnake occurs in the Study area. However, suitable habitat does occur within the perennial stream and wetlands along the Verde River between Horseshoe and Bartlett reservoirs and its tributaries and a segment of the Verde River between Bartlett Dam and Granite Reef Dam. There is no designated critical habitat	Due to the lack of surveys in Horseshoe Reservoir and its tributaries, it is unknown if the northern Mexican gartersnake is present. Suitable habitat does occur within the area of disturbance; therefore, negative effects to the northern Mexican gartersnake are possible. There is no designated critical habitat within Horseshoe Reservoir. Surveys would need to be performed to detect the snake. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the northern Mexican gartersnake.	It is unknown if the northern Mexican gartersnake occurs in the study area. However, suitable habitat does occur within the perennial stream and wetlands along the Verde River between Horseshoe and Bartlett reservoirs and its tributaries and a segment of the Verde River between Bartlett Dam and Granite Reef Dam. Therefore, negative effects to the northern Mexican gartersnake are possible. There is no designated critical habitat within the study area. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flooding and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease gate snake habitat suitability, and increase fire risk. Surveys would need to be performed to detect the snake. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the northern Mexican gartersnake.	It is unknown if the northern Mexican gartersnake occurs in the study area. However, suitable habitat does occur within the perennial stream and wetlands along the Verde River between Horseshoe and Bartlett Reservoirs and its tributaries and a segment of the Verde River between Bartlett Dam and Granite Reef Dam. Therefore, negative effects to the Northern Mexican gartersnake are possible. There is no designated critical habitat within the study area. Surveys would need to be performed to detect the snake. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flooding and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, decrease gartersnake habitat suitability, and increase fire risk. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the northern Mexican gartersnake.

Category for Evaluation	Without Action	Sediment Removal	Bartlett Mod 1	Bartlett Mod 2
	within the project area. Based on the continual implementation of the H-B HCP, the Without Action would have no change in effect on northern Mexican gartersnake.			
Arizona Cliffrose	The Arizona cliffrose occurs along the Verde River between Sheeps Bridge and Granite Reef Dam. The plant occurs primarily on calcareous soils of upland limestone lakebed deposits and limestone outcrops. One recovery unit for the Arizona cliffrose occurs within the Study area. This recovery unit is subdivided into three areas surrounding Horseshoe Reservoir. Two of these areas are found above Horseshoe Dam while the remaining area occurs between Horseshoe and Bartlett dams. Current dam operations avoid effects to Arizona cliffrose. Therefore, it is anticipated that the Without Action would have no effect on Arizona cliffrose.	Based on existing survey data, the location of the spoil area (on Mullen Mesa) for the proposed dredging effort would have an adverse effect on the cliffrose as a population occurs within the vicinity (between Deadman Creek and Chalk Mountain). Depositing the spoils on or near this site would likely have negative effects on the cliffrose. This alternative would have negative effects on one subarea of the cliffrose recovery unit. Endangered Species Act compliance would be required. Avoidance, minimization, and/or mitigation could be required to address effects to the plant. For instance, the plants could be marked, buffered, and protected from the deposition and blowing dust. It is unknown how the dredging or sediment transport may affect other populations surrounding Horseshoe Reservoir.	The Arizona cliffrose occurs along or near the Verde or Salt rivers between Horseshoe Dam and Granite Reef Dam. It occurs primarily on calcareous soils of upland limestone lakebed deposits and limestone outcrops. One recovery unit for the Arizona cliffrose occurs within the area, subdivided into three areas surrounding Horseshoe Reservoir. Two of these areas occur above Horseshoe Dam while the remaining area is between Horseshoe and Bartlett dams. Based on the maximum inundation elevation (1895') for the raising of Bartlett Dam, the one subdivided area of the Recovery Unit (found below Horseshoe Dam) would not be affected. However, there is a potential for cliffrose and their habitat to be inundated between Horseshoe and Bartlett dams. It is unknown how the repurposing of Horseshoe Dam operations would affect the three subdivided areas of the Recovery Unit. It is also unknown what the downstream effects would be to the cliffrose found below the new Bartlett Dam. Endangered Species Act compliance could be required if the cliffrose is found within the areas of disturbance for the new Bartlett Dam construction. Avoidance, minimization, and/or mitigation could be required to address effects to the plant.	The Arizona cliffrose occurs along or near the Verde or Salt rivers between Horseshoe Dam and Granite Reef Dam. It occurs primarily on calcareous soils of upland limestone lakebed deposits and limestone outcrops. One recovery unit for the Arizona cliffrose occurs within the area, subdivided into three areas surrounding Horseshoe Reservoir. Two of these areas are found above Horseshoe Dam while the remaining area occurs between Horseshoe and Bartlett dams. Based on the maximum inundation elevation (1860') for the raising of Bartlett Dam, the one subdivided area of the Recovery Unit (found below Horseshoe Dam) would not be affected. However, there is a potential for cliffrose and their habitat to be inundated between Horseshoe and Bartlett dams. It is unknown how the repurposing of Horseshoe Dam operations would affect the three subdivided areas of the Recovery Unit. It is also unknown what the downstream effects would be to the species found below the new Bartlett Dam. Endangered Species Act compliance would be required if the cliffrose is found within the areas of disturbance for the new Bartlett Dam construction. Avoidance, minimization, and/or mitigation could be required to address effects to the plant.

Bald and Golden Eagles	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including bald and golden eagles, to the maximum extent practicable and ensures that incidental take will not appreciably reduce the likelihood of the survival and recovery of these species in the wild (USFWS 2008). The Without Action Alternative would maintain periodic flooding consistent with the natural hydrologic regime that favor the persistence of bald eagle nesting habitat. The cold water release from Bartlett Reservoir during the late winter and early spring, periodic flooding, and reduced flows in late spring and summer, following the natural hydrologic regime, favor the persistence of native suckers and an overall diversity of native and exotic fish that are available as prey for eagles. Based on the continual implementation of the H-B HCP, the Without Action Alternative will have no change in effect on bald and golden eagles.	There would be minimal negative effects to bald eagle prey, noise/human activity disturbance, and possible disturbance to eagles trying to acquire prey. However, there is uncertainty to what degree these effects may have on eagles without more information. There would likely be tribal cultural interests associated with these effects. There are no known nesting bald eagles within Horseshoe Reservoir, only in the cliffs above Horseshoe Reservoir and between Horseshoe and Bartlett dams. There are no current known bald eagle-built nests in trees within the Horseshoe Reservoir conservation space or below Horseshoe Dam, but eagles frequently build new nests and have built them in trees in these areas in the past. Two bald eagle nesting platforms occur in the conservation space at the upper end of the reservoir, but eagles have yet to use them. Bald eagles nesting on the platforms, in a tree within the conservation space, or below Horseshoe Dam may be disturbed from noise/human activities or the inundation of nests and/or nest trees. There are no effects to golden eagles expected as they are not known to nest near reservoirs but in cliff faces at higher elevations. Compliance with the Bald and Golden Eagle Protection Act may be required and could result in mitigation. Avoidance and/or minimization measures could be implemented to reduce effects to the bald eagles during their breeding season.	There could be greater negative effects to bald eagles from this alternative. The lower Verde River is the densest area of nesting bald eagles throughout the State of Arizona. It is anticipated that the increased storage associated with Bartlett Mod 1 would provide a new and more abundant/reliable/accessible food source for nesting bald eagles between Horseshoe and Bartlett dams, but would likely have negative effects on the riparian habitat and prey resources for nesting bald eagles found below Bartlett Dam. The new conservation space for Bartlett Reservoir would extend into areas where eagles previously used large cottonwood nest trees for nesting and foraging. Water storage would likely diminish or eliminate bald eagle nesting or foraging opportunities from these trees in the future. It is anticipated that the increased Bartlett storage would improve bald eagle foraging habitat and productivity for possibly three existing bald eagle pairs between Horseshoe and Bartlett dams. By altering the hydrologic regime below Bartlett Dam through the reduction in winter and spring flows and an increase in summer flows, it is anticipated that there would be a slow degradation of the riparian habitat below Bartlett Dam and that there would be changes to the native fish abundance from further alteration to the hydrologic regime. It is anticipated that there would likely be negative effects to at least seven breeding areas (Bartlett, Needle Rock, Box Bar, Fort McDowell, Doka, Sycamore, and Rodeo sites). It is uncertain whether the proposed changes would alter the Orme and Granite Reef breeding areas because of their reliance on the Salt River and Tempe Town Lake. The effects to eagle habitat, as water travels farther downstream past the dams, likely diminishes. Thus, it is difficult to gauge how the hydrologic changes associated with this alternative would affect the bald eagle territories found farther downstream below Granite Reef Dam. The breeding areas found below Granite Reef Dam have currently been altered dramatically based upon Salt and Verde River dam operations, so further changes may not be as noticeable compared to the last 100 plus years of water regulation. There are likely tribal cultural interests associated with all the above effects. Because no golden eagles rely on Verde River sources, nest near construction activities, or rely on aquatic Verde River resources, it is expected that there would be no effects from this alternative to golden eagles. Compliance with the Bald and Golden Eagle Protection Act and any legal protections for the bald eagle on tribal lands that may be impacted would be required and would likely result in mitigation. Avoidance and/or minimization measures could occur to reduce	There could be greater negative effects to bald eagles from this alternative. The lower Verde River is the densest area of nesting bald eagles throughout the State of Arizona. It is anticipated that the increased storage associated with Bartlett Mod 1 would provide a new and more abundant/reliable/accessible food source for nesting bald eagles between Horseshoe and Bartlett dams, but would likely have negative effects on the riparian habitat and prey resources for nesting bald eagles found below Bartlett Dam. The new conservation space for Bartlett Reservoir would extend into areas where eagles previously used large cottonwood nest trees for nesting and foraging. Water storage would likely diminish or eliminate bald eagle nesting or foraging opportunities from these trees in the future. It is anticipated that the increased Bartlett storage would improve bald eagle foraging habitat and productivity for possibly three existing bald eagle pairs between Horseshoe and Bartlett dams. By altering the hydrologic regime below Bartlett Dam through the reduction in winter and spring flows and an increase in summer flows, it is anticipated that there would be a slow degradation of the riparian habitat below Bartlett Dam and that there would be changes to the native fish abundance from further alteration to the hydrologic regime. It is anticipated that there would likely have negative effects to at least seven breeding areas (Bartlett, Needle Rock, Box Bar, Fort McDowell, Doka, Sycamore, and Rodeo sites). It is uncertain whether the proposed changes would alter the Orme and Granite Reef breeding areas because of their reliance on the Salt River and Tempe Town Lake. The effects to eagle habitat, as water travels farther downstream past the dams, likely diminishes. Thus, it is difficult to gauge how the hydrologic changes associated with this alternative would affect the bald eagle territories found farther downstream below Granite Reef Dam. The breeding areas found below Granite Reef Dam have currently been altered dramatically based upon Salt and Verde rivers dam operations, so further changes may not be as noticeable compared to the last 100 plus years of water regulation. There are likely tribal cultural interests associated with all the above effects. Because no golden eagles rely on Verde River sources, nest near construction activities, or rely on aquatic Verde River resources, it is expected that there would be no effects from this

				impacts to the bald eagles during their breeding season and to avoid potential disturbances to their nest or perch sites.	alternative to golden eagles. Compliance with the Bald and Golden Eagle Protection Act and any legal protections for the bald eagle on tribal lands that may be impacted would be required and would likely result in mitigation. Avoidance and/or minimization measures could occur to reduce impacts to the bald eagles during their breeding season and to avoid potential disturbances to their nest or perch sites.
Migratory Birds	Sedimentation accumulation could result in changes to riparian vegetation in and surrounding Horseshoe Reservoir. The Horseshoe-Bartlett HCP manages the riparian habitat for covered species using light detection and ranging (LiDAR) in aerial imaging of vegetation to identify vegetation trends in the Study area. The data is integrated with a breeding habitat model for the management of covered species. This management practice benefits riparian obligate bird species. SRP would continue to manage water levels at Horseshoe Reservoir, conditional on other operation goals, to maximize riparian habitat during the nesting season for birds and maintain riparian vegetation at the upper end of the Horseshoe Reservoir. The gradual decline and eventual total loss of water storage capacity within the Horseshoe Reservoir may have negative effects on certain migratory bird species found at or below Horseshoe Dam.	Migratory birds would likely be negatively affected by the physical disturbances to their habitat (either surrounding or within the Horseshoe Reservoir). Construction activities could also interfere with their breeding season. Fish and Wildlife Coordination Act and Migratory Bird Treaty Act compliance would be required and could result in mitigation. Avoidance and/or minimization measures could reduce effects to the birds.	Migratory birds would likely be negatively affected by the physical disturbance to their habitat from the construction of the dam or within the inundation area associated with the new Bartlett Dam. The modification would inundate riparian, wetland, upland habitat, and agricultural lands. Noise, dust and light disturbance associated with construction could interfere with nesting for certain species found in or within the surrounding habitat to the construction activities. Beneficial effects associated with this alternative include an increase in open water habitat for waterfowl at Bartlett and a potential increase in riparian habitat found downstream of Horseshoe Dam due to periodic inundation. Riparian obligate species could also benefit from the repurposing of Horseshoe Reservoir operations as habitat within the reservoir bottom would be restored to a more natural riparian ecosystem along the river channel. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of nonnative species like tamarisk, and increase fire risk. Tamarisk can provide vegetation for open cup nesting birds. However, a decrease in larger willows and cottonwoods reduces opportunities for cavity nesting birds and larger raptors or herons. Fish and Wildlife Coordination Act and Migratory Bird Treaty Act compliance would be required and could result in mitigation. Avoidance and/or minimization measures could reduce effects to the birds. For instance, the timing for filling the new reservoir could occur outside the breeding season for the majority of these species.	Migratory birds would likely be negatively affected by the physical disturbance to their habitat from the construction of the dam or within the inundation area associated with the new Bartlett Dam. The modification would inundate riparian, wetland, and upland habitat. Noise, dust and light disturbance associated with construction could interfere with nesting for certain species found in or within the surrounding habitat to the construction activities. Beneficial effects associated with this alternative include an increase in open water habitat for waterfowl at Bartlett and a potential increase in riparian habitat found downstream of Horseshoe Dam due to periodic inundation. Riparian obligate species could also potentially benefit from the repurposing of Horseshoe Reservoir operations as habitat within the reservoir bottom would be restored to a more natural riparian ecosystem along the river channel. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and trees, increase the abundance of tamarisk, and increase fire risk. Tamarisk can provide vegetation for open cup nesting birds. However, a decrease in larger willows and cottonwoods reduces opportunities for cavity nesting birds and larger raptors or herons. Fish and Wildlife Coordination Act and Migratory Bird Treaty Act compliance would be required and could result in mitigation. Avoidance and/or minimization measures could reduce effects to the birds. For instance, the timing for filling the new reservoir could occur outside the breeding season for the majority of these species.	
Other Terrestrial Species and Their Habitat	Some terrestrial species have benefited from the riparian habitat maintained from the continual release of flows downstream of Bartlett Dam and these benefits would continue with the current	The species of economic and recreation importance (SERI) could be negatively affected by the noise/human activity disturbances from the construction activities	The species of economic and recreation importance (SERI) could be negatively affected by the noise/human activity disturbance from the construction activities and the alteration to the surrounding habitat. Riparian and upland habitat along with some agricultural fields would be	The species of economic and recreation importance (SERI) would likely be negatively affected by the noise/human activity disturbance from the construction activities and the alteration to the surrounding habitat. Riparian and upland habitat	

	operations of the dams and reservoirs. Overall, there would be slight benefits, but in general the species of economic and recreation importance (SERI), wintering waterfowl, undescribed talussnail, and migration/movement corridor along the Verde River would not be affected by the Without Action Alternative.	and the alteration to the surrounding habitat (i.e., around the reservoir and on Mullen Mesa). Adjacent habitat and shoreline access is anticipated to be available during construction. The SERI are likely to avoid the areas of active construction. Wintering waterfowl may also be negatively affected by the noise/human activity disturbances from the construction activities. This project would result in minor negative effects to the migration corridor found along the Verde River. More information is needed on the undescribed talussnail. Should the talussnail occur within the area impacted by construction, it would likely have a negative effect on the species. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures could be implemented to reduce effects to SERI, wintering waterfowl, and the migration corridor.	inundated, thereby reducing cover and the prey base or food source for the SERI. The SERI are likely to avoid the areas of active construction and inundation. Wintering waterfowl may also be negatively affected by the noise/human activity disturbances from the construction activities; however, wintering waterfowl would benefit long-term from the increase in open water habitat at the reservoir. This project would likely result in minor negative effects to the migration corridor found along the Verde River. The repurposing of Horseshoe Reservoir operations could benefit wildlife; this would offset some of the negative effects to the SERI. More information is needed on the undescribed talussnail. Should the talussnail occur within the area impacted by construction, it would have a negative effect on the snail. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and increase the abundance of tamarisk, decreasing habitat suitability for SERI and wintering waterfowl, and increasing fire risk. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures could be implemented to reduce effects to SERI, the undescribed talussnail, wintering waterfowl, and the migration corridor.	would be inundated, thereby reducing cover and the prey base or food source for the SERI. The SERI are likely to avoid the areas of active construction and inundation. Wintering waterfowl may also be negatively affected by the noise/human activity disturbances from the construction activities; however, wintering waterfowl would benefit long-term from the increase in open water habitat at the reservoir. This project would likely result in minor negative effects to the migration corridor found along the Verde River. The repurposing of Horseshoe Reservoir operations could benefit wildlife; this would offset some of the negative impacts to the SERI. More information is needed on the undescribed talussnail. Should the talussnail occur within the area impacted by construction, it would have a direct negative effect on the species. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants and increase the abundance of tamarisk, decreasing habitat suitability for SERI and wintering waterfowl, and increasing fire risk. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures could be implemented to reduce effects to SERI, wintering waterfowl, the undescribed talussnail, and the migration corridor.
Other Aquatic Species and Their Habitat	To comply with the Horseshoe - Bartlett HCP, SRP conducts a rapid drawdown each year to minimize non-native species, including sportfish species, in Horseshoe Reservoir. Sediment accumulation and the consequent reduction in water storage at Horseshoe may have a negative effect on the sportfish population found within Bartlett Reservoir and downstream of Bartlett Dam.	Long-term sediment removal could cause habitat loss, hydraulic entrainment, release of contaminants, sedimentation, suspended sediment, and underwater noise. There is a potential for this to be a negative effect to sportfish and the prey resources they rely upon. However, it is anticipated that this would only have small negative effects on these species as sportfish population are reduced at Horseshoe due to current operations. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for	The raising of the water level in Bartlett Reservoir would likely create a "new lake" effect that would benefit fish species occurring in Bartlett Reservoir and would increase the amount of habitat available for sportfish. The change in the flow regime and potentially cooler waters would have a beneficial effect on certain sportfish species. Quagga mussel veligers have been detected in Bartlett Reservoir, but have not established. Further investigation is needed to understand whether increasing reservoir levels at Bartlett would create an environment that quagga mussel population could establish. Current Horseshoe operations are designed to disrupt spawning of sport fish for the protection of native aquatic species. It is unknown how the repurposing of Horseshoe Dam operations will affect sportfish and AIS. The downstream effects from this alternative to sportfish and AIS are also unknown.	The raising of the water level in Bartlett Reservoir would likely create a "new lake" effect that would benefit fish species occurring in Bartlett Reservoir and would increase the amount of habitat available for sportfish. The change in the flow regime and potentially cooler waters would have a beneficial effect on certain sportfish species. Quagga mussel veligers have been detected in Bartlett Reservoir, but have not established. Further investigation is needed to understand whether increasing reservoir levels at Bartlett would create an environment such that quagga mussel population could establish. Current Horseshoe operations are designed to disrupt spawning of sport fish for the protection of native aquatic species. It is unknown how the repurposing of Horseshoe Dam operations will affect sportfish and AIS. The downstream effects from this alternative to sportfish and AIS are also unknown.

Special Status Species	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. As part of that compliance, SRP implements the 2008 Horseshoe-Bartlett HCP to mitigate for incidental take of 16 species, including several special status species (USFWS 2008). Based on the continual implementation of the HCP, the Without Action would have no change in effect on these special status species. The other special status species would also benefit from the ongoing management of the HCP. The gradual decline and eventual total loss of water storage capacity within the Horseshoe Reservoir may have a negative effect on certain special status species found at or below Horseshoe Dam. However, the minimization and mitigation efforts of the H-B HCP are adaptive and accommodate for the changing ecosystem.	During the duration of the sediment removal, special status species may be displaced or killed. The lands within and surrounding Horseshoe Reservoir provide habitat for special status species (of reptiles, amphibians, fish, insects, gastropods, plants, and small and large mammals), all of which may be impacted to varying degrees. The primary effect of the project on wildlife resources would be the loss of small mammals, herpetofauna, fish, gastropods, and plants due to construction activities. Most avian species and medium sized to large mammals would be capable of avoiding the construction area. Construction would also displace species into the surrounding habitat. Noise-related disturbances associated with construction could also have negative effects on wildlife. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures should be implemented to reduce effects to special status species. It is unknown how sediment transport may impact downstream species and their habitat.	During the dam construction and with the inundation associated with the new dam, the action may displace or kill special status species. The lands within and surrounding Bartlett Reservoir provide habitat for special status species (of reptiles, amphibians, fish, insects, gastropods, plants, and small and large mammals), all of which would be affected to varying degrees. The primary effect of the project on special status species would be the loss of small mammals, herpetofauna, fish, gastropods, and plants within proximity to the construction activities or the new inundation zone. Most avian species and medium sized to large mammals would be capable of avoiding the construction area. Construction would also displace species into the surrounding habitat. Noise-related disturbances associated with construction could also have negative effects on wildlife. The increased inundation level could provide an opportunity for nonnative species to displace native species within the reservoir. Riparian- and aquatic-dependent special status species could benefit from the repurposing of the Horseshoe Reservoir operations. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants, increase the abundance of tamarisk, decrease habitat suitability for riparian-obligate or aquatic-dependent species, and increase fire risk. Additionally, the further alterations to the hydrologic regime can reduce the variety of river habitat that native fish use and increase nonnative fish habitat, resulting in potentially more competition and predation effects to native fish species. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures should be implemented to reduce effects to special status species.	During the dam construction and with the inundation associated with the new dam, the action may displace or kill special status species. The lands within and surrounding Bartlett Reservoir provide habitat for special status species (of reptiles, amphibians, fish, insects, gastropods, plants, and small and large mammals), all of which would be affected to varying degrees. The primary effect of the project on special status species would be the loss of small mammals, herpetofauna, fish, gastropods, and plants within proximity to the construction activities or the new inundation zone. Most avian species and medium sized to large mammals would be capable of avoiding the construction area. Construction would also displace species into the surrounding habitat. Noise-related disturbances associated with construction would also have a minor effect on wildlife. The increased inundation level would provide an opportunity for nonnative species to displace native species within the reservoir. Riparian- and aquatic-dependent special status species could benefit from the repurposing of the Horseshoe Reservoir operations. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants, increase the abundance of tamarisk, decrease habitat suitability for riparian-obligate or aquatic-dependent species, and increase fire risk. Additionally, the further alternations to the hydrologic regime can reduce the variety of river habitat that native fish use and increase nonnative fish habitat, resulting in potentially more competition and predation effects to native fish species. Fish and Wildlife Coordination Act compliance would be required should this alternative be recommended for feasibility. Avoidance and/or minimization measures should be implemented to reduce effects to special status species.
Visual Resources	The existing infrastructure is already a part of the existing visual landscape. Over the next century, sediment would continue to accumulate in Horseshoe Reservoir. This increase in sediment and	The sediment removal alternative would have negative effects on the scenic quality of the landscape. The landscape would be altered at Horseshoe Reservoir	The new dam construction and changes to the landscape associated with the expansion of Bartlett Reservoir would have a minor negative effect on visual resources. Physical, biological, and cultural impacts would occur, thereby negatively affecting the scenic character of the area. The	The new dam construction and changes to the landscape associated with the expansion of Bartlett Reservoir would have a minor negative effect on visual resources. Physical, biological, and cultural impacts would occur, thereby negatively affecting the

	reduction in the storage capacity would eventually alter the visual landscape. However, it is unknown if the incremental changes in the scenic character would meet the Forest Service's visual management objectives and if those changes would enhance the visual character of the area.	through a long-term dredging effort that would result in a 2-mile long by 1- mile wide spoil area on Mullen Mesa. Physical, biological, and cultural impacts would occur, thereby negatively affecting the scenic character of the area. The potential changes to the scenic character would not meet the current Tonto National Forest's visual management objective for the associated management area.	potential changes to the scenic character would not meet the current Tonto National Forest's visual management objective for the associated management area.	scenic character of the area. The potential changes to the scenic character would not meet the current Tonto National Forest's visual management objective for the associated management area.
Vegetation and Land Cover	SRP utilizes light detection and ranging (LiDAR) in aerial imaging of vegetation to identify vegetation trends within a portion of Study area. The data is integrated with a breeding habitat model for the management of species covered in the HCP. Continuing with current operations would result in an ongoing loss in the conservation space at Horseshoe Reservoir and in the overall storage capacity on the Verde River. The landscape would be altered at Horseshoe Reservoir as sediment accumulates and storage capacity decreases. Sedimentation accumulation would affect the vegetation surrounding the reservoir and could result in changes to stream and floodplain morphology upstream of Horseshoe Dam. However, there is not enough information to adequately determine the type of vegetation that would occupy the new landscape. The Without Action Alternative would likely increase vegetation cover adjacent and between the reservoirs, but the vegetation that would dominate the landscape is unknown.	Part of Horseshoe Reservoir has been managed to maintain riparian habitat for listed and migratory birds. The proposed activity would likely have negative effects on riparian vegetation and open water found at Horseshoe Reservoir. Avoidance and/or minimization measures could be implemented to reduce impacts to the riparian areas. Sonoran Paloverde-mixed cacti desert scrub habitat on Mullen Mesa would be disturbed. Invasive species would likely establish within areas of disturbance and would need to be managed. Overall, it is anticipated that these adverse effects to the habitat would be marginal.	The vegetation and land cover would change as riparian (i.e., North American warm desert washes, North American warm desert riparian mesquite bosques, North American warm desert riparian woodland and shrubland, and introduced riparian and wetland vegetation), upland habitat (i.e., Sonoran paloverde-mixed cacti desert scrub), and agricultural lands (specifically the KA Ranch) are inundated at Bartlett Reservoir. Invasive species would likely establish within areas of disturbance and would need to be managed. The repurposed Horseshoe Reservoir could allow for riparian habitat within the reservoir bottom to be restored to a more natural riparian ecosystem along the natural river channel. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants, increase the nonnative plant abundance, and increase fire risk. In considering the effects to the vegetation from the new inundation level and the repurposing of Horseshoe Reservoir, this alternative could have a marginal negative effect.	The vegetation and land cover would change as riparian (i.e., North American warm desert washes, North American warm desert riparian mesquite bosques, North American warm desert riparian woodland and shrubland, and introduced riparian and wetland vegetation) and upland habitat (i.e., Sonoran paloverde-mixed cacti desert scrub) are inundated at Bartlett Reservoir. This inundation would be to a lesser extent than that of Bartlett Mod 1. Invasive species would likely establish within areas of disturbance and would need to be managed. The repurposed Horseshoe Reservoir could allow for riparian habitat within the reservoir bottom to be restored to a more natural riparian ecosystem along the natural river channel. Further altering the hydrologic regime below Bartlett Dam by reducing winter and spring flows and increasing summer flows can reduce the establishment of native plants, increase the nonnative plant abundance, and increase fire risk. In considering the effects to the vegetation from the new inundation level and the repurposing of Horseshoe Reservoir, this alternative could have a marginal negative effect.

Jurisdictional Waters and Water Quality	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. Maintenance and planned improvements would comply with the Clean Water Act, when applicable. However, the gradual accumulation of sediment could impact water quality in reservoir systems and create water quality issues at downstream treatment plants.	Extensive dredging would occur within the waters of the United States (WOTUS) to remove approximately 50,000 acre-feet of sediment within Horseshoe Reservoir. Dredging would result in high turbidity due to the sediment disturbance. This could result in an extensive adverse effect to the WOTUS. The water from the dredged material that is temporarily stored in a Confined Disposal Facility would either be pumped or gravity-drained back to the lake if no contamination issues are present. It is not known at this time how contaminated water would be addressed. Clean Water Act (Section 404, 401, and 402) compliance would be required. Permit applicants must take all appropriate and practicable steps to avoid and minimize adverse impacts to WOTUS. Compensatory mitigation for unavoidable impacts may be required to ensure that an activity requiring a Section 404 permit complies with Section 404(b)(1) Guidelines.	The new dam would impound waters within the lower Verde River, just downstream of the existing Bartlett Dam. The impoundment would inundate a perennial reach of the Verde River, adjacent palustrine wetlands, and certain portions of intermittent and ephemeral streams leading into the reservoir. The new dam would increase the depth and width of Bartlett Reservoir. However, by having the new dam downstream and abutting the existing dam, the existing dam could be utilized as a cofferdam. An extension of the existing outlets would allow for ongoing river management during construction. Flood routing during construction would likely depend on keeping the existing spillway in operation until enough of the new dam and spillway are constructed. It is also important to note that this alternative includes moving the remaining un-silted storage capacity from Horseshoe Reservoir into the modified Bartlett Reservoir and repurposing Horseshoe Reservoir operations to benefit habitat and species, flood control, and sediment capture. Overall, the new dam would likely result in negative effects to the WOTUS. Clean Water Act (Section 404, 401, and 402) compliance would be required. Permit applicants must take all appropriate and practicable steps to avoid and minimize adverse impacts to WOTUS. Compensatory mitigation for unavoidable impacts may be required to ensure that an activity requiring a Section 404 permit complies with Section 404(b)(1) Guidelines.	The new dam would impound waters within the lower Verde River, just downstream of the existing Bartlett Dam. The impoundment would inundate a perennial reach of the Verde River, adjacent palustrine wetlands, and certain portions of intermittent and ephemeral streams leading into the reservoir. The new dam would increase the depth and width of Bartlett Reservoir. However, by having the new dam downstream and abutting the existing dam, the existing dam could be utilized as a cofferdam. An extension of the existing outlets would allow for ongoing river management during construction. Flood routing during construction would likely depend on keeping the existing spillway in operation until enough of the new dam and spillway are constructed. It is also important to note that this alternative includes moving the remaining un-silted storage capacity from Horseshoe Reservoir into the modified Bartlett Reservoir and repurposing Horseshoe Reservoir operations to benefit habitat and species, flood control, and sediment capture. Overall, the new dam would likely result in negative effects to the WOTUS. Clean Water Act (Section 404, 401, and 402) compliance would be required. Compensatory mitigation would be required to offset any unavoidable adverse effects. Permit applicants must take all appropriate and practicable steps to avoid and minimize adverse impacts to WOTUS. Compensatory mitigation for unavoidable impacts may be required to ensure that an activity requiring a Section 404 permit complies with Section 404(b)(1) Guidelines.
Air Quality	Existing operations of Horseshoe and Bartlett dams and reservoirs requires continual compliance with federal, state, and local laws and regulations. Ongoing operations (i.e., water supply planning and deliveries) would have no effect on air quality. Although maintenance activities and planned improvements may result in short term impacts, compliance with the air quality regulations would be required. The emissions associated with these actions are not expected to exceed the de minimus thresholds for criteria pollutants. Based on continual operations, the Without Action	Construction for this alternative would occur within one non-attainment area for ozone. There would be a temporary increase in dust and vehicular emissions during construction. Compliance with federal, state, and local air quality laws and regulations would be required. It is important to note the following: Section 176(c) of the Clean Air Act prohibits Federal entities from taking actions in nonattainment or maintenance areas which do not conform to the State Implementation Plan (SIP) for the attainment and maintenance of the national ambient air quality standards (NAAQS). A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a Federal action equals or exceeds thresholds set forth in 40 CFR 93.153(b).	Construction for this alternative would occur within two nonattainment areas, one for PM10 and the other for ozone. There would be a temporary increase in dust and vehicular emissions during construction. Compliance with federal, state, and local air quality laws and regulations would be required. It is important to note the following: Section 176(c) of the Clean Air Act prohibits Federal entities from taking actions in nonattainment or maintenance areas which do not conform to the State Implementation Plan (SIP) for the attainment and maintenance of the national ambient air quality standards (NAAQS). A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a	Construction for this alternative would occur within two non-attainment areas, one for PM10 and the other for ozone. There would be a temporary increase in dust and vehicular emissions during construction. Compliance with federal, state, and local air quality laws and regulations would be required. It is important to note the following: Section 176(c) of the Clean Air Act prohibits Federal entities from taking actions in nonattainment or maintenance areas which do not conform to the State Implementation Plan (SIP) for the attainment and maintenance of the national ambient air quality standards (NAAQS). A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a

	Alternative would have no effect on air quality.	of the national ambient air quality standards (NAAQS). A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a Federal action equals or exceeds thresholds set forth in 40 CFR 93.153(b).		
Special Designations	Several special designated areas are located within the Study area; however, none of these sites are affected by the current maintenance and operation of Horseshoe and Bartlett dams and reservoirs. Over time the continual accumulation of sediment in Horseshoe Reservoir may alter the surrounding landscape and thus potentially affect avian species found within the IBA. However, it is difficult to determine what the potential, incremental benefits or negative effects would be to the IBA, grazing allotments, or the proposed Horseshoe Botanical Area. The adjacent designated and recommended wilderness areas are not anticipated to be affected. Consequently, the Without Action Alternative is not expected to have effects on special designated areas.	1) It is expected that there would be long-term negative effects to Sears Club/Chalk Mountain grazing allotment. The spoil area, which is 2-miles long and 1-mile wide, would need to be closed to grazing during construction. 2) Overland routes for delivering the dredging equipment are not known at this time. Avoidance and mitigation measures would need to be employed for the proposed Horseshoe Botanical Area, which is broken up into two subareas that surround Horseshoe Reservoir. Without these measures, it is anticipated that the two subareas for the Horseshoe Botanical Area, could be negatively affected by overland access. Negative effects to surrounding vegetation at Horseshoe Reservoir are anticipated to occur for the overland access and with the extensive dredging effort. These effects on the vegetation would have a negative effect on avian species found within the IBA. There are no anticipated effects to the Mazatzal Wilderness or the recommended Indian Butte Wilderness Area.	There would be a small negative effect to the forage within Sears Club/Chalk Mountain, St Clair, and Bartlett grazing allotments. A general area of disturbance for constructing the dam is not known at this time; only the locality for the new dam site, the expected inundation area associated with the new dam, a powerhouse, and generator at the outlet structure are known. The maximum elevation of inundation, though anticipated to occur infrequently, would be 1895 feet. Based on the water model, the median annual elevation is 1827 feet. Negative effects to vegetation found along the Verde River below Horseshoe Dam and to the surrounding vegetation at Bartlett Reservoir are anticipated as a result of the increased inundation level. This effect on vegetation would have a negative effect on certain avian species found within the IBA between Horseshoe and Bartlett Dams, thereby likely having a negative effect on a portion of the IBA between Horseshoe and Bartlett Dams. However, the avian species found within the IBA above Horseshoe Dam would benefit from the repurposing of Horseshoe Reservoir operations. Both subareas of the proposed Horseshoe Botanical Area are not anticipated to be affected by the construction and inundation associated with Bartlett Mod 1. The maximum inundation level (1895 ft) for Bartlett Reservoir would be close in proximity to the lower subarea for the proposed Horseshoe Botanical Area, but it would not inundate it. It is unknown how the repurposing of Horseshoe Dam operations would affect the two subareas of the proposed Horseshoe Botanical Area. There are no anticipated effects to the Mazatzal Wilderness Area or the recommended Indian Butte Wilderness Area.	1) There would be a small negative effect to the forage within Sears Club/Chalk Mountain, St Clair, and Bartlett grazing allotments. A general area of disturbance for constructing the dam is not known at this time; only the locality for the new dam and the expected inundation area associated with the new dam, a powerhouse, and generator at the outlet structure are known. The maximum elevation of inundation, though anticipated to occur infrequently, would be 1860 feet. Based on the water model, the median annual elevation is 1822 feet. Adverse effects to vegetation found along the Verde River below Horseshoe Dam and to the surrounding vegetation at Bartlett Reservoir are anticipated as a result of the increased inundation level. This effect on vegetation would have a negative effect on certain avian species found within the IBA between Horseshoe and Bartlett dams, thereby having an adverse effect on a portion of the IBA between Horseshoe and Bartlett dams. However, the avian species found within the IBA above Horseshoe Dam would benefit from the repurposing of Horseshoe Reservoir operations. Both subareas of the proposed Horseshoe Botanical Area are not anticipated to be affected by the construction and inundation associated with Bartlett Mod 2. The maximum inundation level (1860 ft) for the Bartlett Reservoir would not be close in proximity to the lower subarea for the proposed Horseshoe Botanical Area. It is unknown how the repurposing of Horseshoe Dam operations would affect the two subareas of the proposed Horseshoe Botanical Area. There are no anticipated effects to the Mazatzal Wilderness Area or the recommended Indian Butte Wilderness Area.

Note: For all 4 alternatives, SRP would continue to maintain a minimum flow in the Verde River below Bartlett Dam by releasing no less than 100 cubic feet per second of water from Bartlett Dam at all times, plus the amount of water necessary to satisfy any diversion between Bartlett Dam and the confluence of the Salt and Verde Rivers, including diversions by Rio Verde and Fort McDowell Indian Community.

Rules of the Road

1. If data gaps were identified, best known information was considered when approximating effects for a resource. For instance, if there was no survey data for a species, habitat suitability was utilized for approximating effects to that species.
2. Unless explicitly described in the alternative descriptions, mitigation considerations were not applied to the evaluation of effects. If it is anticipated that mitigation could be required due to Federal or State regulations, the corresponding narrative for the score captured this information.
3. When considering the net sum of both negative and positive effects to a resource, effects associated with construction were weighted heavier than those that would occur over time with mitigation. This approach aids in the red flag review of the environmental considerations associated with these alternatives. It also assists when trying to apply a single score value for dynamic effects (i.e., effects occurring over time and space).
4. Under the Without Action Alternative, maintenance and planned improvements at Horseshoe, Bartlett, and Granite Reef would continue to comply with federal, state, and local laws and regulations.

Category for Evaluation	Appraisal Study Alternatives			
	Without Action	Sediment Removal	Bartlett Modification 1	Bartlett Modification 2
Threatened & Endangered Species				
Gila Topminnow	-	3	3	3
Colorado Pikeminnow	-	3	3	3
Razorback Sucker	-	2	3	3
Yellow-billed cuckoo	-	1	2	2
Southwestern willow flycatcher	-	1	2	2
Northern Mexican Gartersnake	-	2	2	2
Arizona Cliffrose	3	1	2	2
Bald & Golden Eagles	-	2	1	1
Migratory Birds	3	2	2	2
Other Terrestrial Species and Their Habitat	3	2	2	2
Other Aquatic Species and Their Habitat	2	2	4	4
Special Status Species	-	2	2	2
Visual Resources	3	1	2	2
Vegetation and Land Cover	3	2	2	2
Jurisdictional Waters and Water Quality	-	1	2	2
Air Quality	-	2	2	2
Special Designations	3	2	2	2
Metric: All Environmental (mean score)	2.86	1.82	2.24	2.24
Criteria: Score	5	1	2	2

Metric Environmental Scoring Definitions

Metric Scoring definitions

- Existing operations of Horseshoe and Bartlett Dams and Reservoirs requires continual compliance with federal, state, and local laws and regulations. A part of those federal regulations includes the ongoing implementation of SRP's Habitat Conservation Plan.
- 1 In considering both beneficial and adverse effects, the net sum of these effects would **likely** result in **greater** negative effects.
- 2 In considering both beneficial and adverse effects, the net sum of these effects would **likely** result in **marginal** negative effects.
- 3 In considering both beneficial and adverse effects, there **would likely be** no impacts.

4	In considering both beneficial and adverse effects, the net sum of these effects would likely result in marginal positive effects.
5	In considering both beneficial and adverse effects, the net sum of these effects would likely result in greater positive effects.

Evaluation Criteria Scoring Definitions

Scoring (0-5) – This criterion is to be scored on a scale of 0 to 5. Scores for each alternative should be relative to other alternatives. The alternative that has the potential for highest net benefits to these resources, or alternatively, the least negative effects to these resources should be scored the highest (5). The alternative that produces the least net benefits, or alternatively has the greatest negative effects to these resources should be scored the lowest (0). All other alternatives should be scored relative to the highest and lowest scored alternative using whole number values between 0 and 5, multiple alternatives may be rated the same.

Criteria Scoring Approach/Methodology

A mathematical approach was used to compare the metric mean scores for each alternative. This approach provided an overall criterion score for each alternative. The criterion was scored on a scale of 0 to 5. The alternative that is the most favorable to the environmental resources was scored the highest (5). The alternative that is the least favorable to the environmental resources was scored the lowest (0). The other alternatives were scored relative to the highest and lowest scored alternatives using a point spread approach.

Scoring Justification

The mathematical approach allowed for the application of the metric mean scores for each alternative while also considering a point spread approach. In doing so, it allowed for a relative comparison among the alternatives. It is important to note that the metric provided a mean score for all the environmental categories under consideration per alternative, and the criteria allowed for a relative comparison between the alternatives. The qualitative narratives provided in the metric demonstrated a net sum approach, which was important to acknowledge in order to decide which alternative was more or less favorable to environmental resources.

Appendix J: Potential Applicable Environmental Laws and Regulations

Verde Reservoirs Sediment Mitigation Study

Appendix J Potential Applicable Environmental Laws and Regulations

Ecosystem disruptions have the potential for both adverse and beneficial effects to environmental resources in the Study area. If the alternatives are carried forward to feasibility, all federal, state and local environmental laws and regulations would need to be adhered to. Some of the most prominent laws and regulations are listed below.

Laws and Regulations	Regulating Entity	Requirement/Notes
Bald and Golden Eagle Protection Act	USFWS	Unlawful to “at any time or in any manner” “take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import” any bald or golden eagle alive or dead, “or any part, nest, or egg thereof.”
Clean Air Act	EPA	The Clean Air Act requires that any Federal entity engaged in an activity that may result in the discharge of air pollutants must comply with all applicable air pollution control laws and regulations (Federal, State, or local). It also directs the attainment and maintenance of NAAQS for six different criteria pollutants including carbon monoxide, ozone, particulate matter, sulfur oxides, oxides of nitrogen, and lead. A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a federal action equals or exceeds thresholds set forth in 40 CFR 93.153(b).
Clean Water Act	U.S. Army Corps of Engineers, Arizona Department of Environmental Quality, and Environmental Protection Agency	Clean Water Act strives to restore and maintain the chemical, physical, and biological integrity of the nation's waters by controlling discharge of pollutants. The basic means to achieve the goals of the CWA is through a system of water quality standards, discharge limitations, and permits. Section 404 of the CWA identifies conditions under which a permit is required for actions that result in placement of fill or dredged material into waters of the United States. In addition, a 401 water quality certification and 402 National Pollutant Discharge Elimination System (NDPES) permit are required for activities that discharge pollutants to waters of the U.S.
Endangered Species Act	USFWS	The ESA provides protection for plants and animals that are currently in danger of extinction (endangered) and those that may become so in the foreseeable future (threatened). Section 7 of this law requires Federal agencies to ensure that their activities do not jeopardize the continued existence of threatened or endangered species or adversely modify designated critical habitat.

Laws and Regulations	Regulating Entity	Requirement/Notes
Fish and Wildlife Coordination Act	USFWS and Arizona Game and Fish Department	The FWCA provides a procedural framework for the consideration of fish and wildlife conservation measures in Federal water resource development projects. Coordination with the USFWS and Arizona Game and Fish Department are required on all Federal water development projects.
Migratory Bird Treaty Act	USFWS	Unless permitted, it is unlawful to “pursue, hunt, take, capture, kill, attempt to take...any migratory bird, any part, nest, or any product”.
National Environmental Policy Act	Federal agency with a federal nexus	NEPA requires federal agencies to complete an environmental review prior to undertaking a ‘major federal action’ that may ‘significantly’ affect the quality of the human environment.
National Historic Preservation Act (NHPA)	Federal agency with a federal nexus	Federally funded undertakings that have the potential to affect historic properties are subject to Section 106 of the NHPA. Under this act, Federal agencies are responsible for the identification, management, and nomination to the National Register of Historic Places of cultural resources that would be affected by Federal actions. Consultation with the Advisory Council on Historic Preservation and the State Historic Preservation Office / Tribal Historic Preservation Office is required when a Federal action may affect cultural resources on, or eligible for inclusion on, the National Register.

Appendix K: Water Supply Benefit Estimation



— BUREAU OF —
RECLAMATION

Verde Reservoirs Sediment Mitigation Study

Appendix K: Water Supply Benefit Estimation

Salt River Project, Arizona
Interior Region 8: Lower Colorado Basin

Mission Statements

The Department of the Interior conserves and manages the Nation's natural resources and cultural heritage for the benefit and enjoyment of the American people, provides scientific and other information about natural resources and natural hazards to address societal challenges and create opportunities for the American people, and honors the Nation's trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities to help them prosper.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Verde Reservoirs Sediment Mitigation Study

Appendix K: Water Supply Benefit Estimation

Salt River Project, Arizona

Interior Region 8: Lower Colorado Basin

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Abbreviations

ADWR – Arizona Department of Water Resources

AF – Acre-Feet

AMA – Active Management Area

AWBA – Arizona Water Banking Authority

AWS – Assured Water Supply

CAGRD – Central Arizona Groundwater Replenishment District

CAP – Central Arizona Project

CAPSAM – Central Arizona Project Service-Area Model

CAWCD – Central Arizona Water Conservation District

CBA – Cost Benefit Analysis

CPI – Consumer Price Index

CS – Consumer Surplus

ft - foot or feet

HU – Housing Unit

IDC – Interest During Construction

KAF – Thousand Acre-Feet

LTSC – Long-term storage credit

M&I – Municipal and Industrial

OM&R – Operation, Maintenance, and Replacement

PV – Present Value

SRP – Salt River Project

VRSMS – Verde Reservoirs Sediment Mitigation Study

WSRV – West Salt River Valley

WTP – Willingness to Pay

1.0 Introduction

The benefit of additional renewable water supply depends on several factors. For the purpose of the Verde Reservoirs Sediment Mitigation Study (VRSMS), an appraisal-level benefit estimate is calculated based on projections of renewable water supply and demand in the central/southern Arizona region and the potential for future water supply and demand imbalances (shortages). In this framework, the benefit of additional water supply is based on the extent of future shortages in the region and the ability of each alternative to mitigate those future shortages. Shortages may arise from reduced water supply, increased water demand, or a combination of both. The benefit estimate includes municipal, industrial, and agricultural uses of renewable water (CAP, SRP, local surface water, and effluent). The estimate does not include non-market benefits such as those associated with ecosystem services and recreation, nor effects associated with impacts to groundwater aquifers. Multiple projections of future supply and demand are evaluated, each reflecting a different extent of future renewable water shortages in the region. These projections serve as “what if” scenarios to demonstrate the range of potential benefits that might result from the new water supply provided by each alternative considered for the VRSMS.

A shortage is defined as a situation where the quantity demanded exceeds the quantity supplied at the going price. In other words, a shortage reflects a gap between supply and demand. When this happens for a good or service, such as renewable water, it puts upward pressure on price, adversely affecting water users. To quantify the water supply benefit for each alternative, future regional price effects are evaluated by comparing conditions Without Action to conditions under each action alternative. Shortages in renewable supplies are primarily anticipated for municipal and industrial (M&I) users, while agricultural users are expected to continue to rely heavily on groundwater into the future. Nonetheless, many agricultural users also depend on renewable water, meaning they too are likely to be affected by future M&I shortages in the region.

This framework does not identify the particular beneficiaries of additional water supply, but rather, uses a regional supply and demand framework to estimate the benefit for the region as a whole. Under the Without Action conditions, renewable water shortages are anticipated in the region, which is expected to put upward pressure on the price of water. In this setting, the benefit of additional water supply is calculated based on the extent that future shortages and price changes are reduced. This captures the direct benefit for those that will ultimately receive the new water, as well as the indirect benefit for the region as a whole from keeping prices down. In other words, those not expected to experience a shortage or receive any of the new supply provided by an alternative will nonetheless benefit from reduced regional shortages and upward pressure on regional water prices. The water supply benefit estimates provided here therefore encompass both direct and indirect benefits for municipal, industrial, and agricultural users across the central/southern Arizona region.

2.0 Overview of Estimation

The first step in calculating the water supply benefit is to estimate the Without Action price effects associated with future water shortages. Projections from the Central Arizona Project Service-Area

Model (CAPSAM) of annual water supply and demand in the central/southern Arizona region (Maricopa County, Pinal County, and Pima County) are used to model the Without Action price effects associated with future water shortages. This model is discussed in detail in Section 3.1. The water volume provided by each alternative is then used to estimate the benefit of additional water supply, which comes from comparing annual price effects Without Action with price effects under each action alternative across a 100-year period. Shortages are modeled for the three-county region, which depend on future drought conditions on the Colorado River as well as population growth and conditions in the local area. The water supply volume for each alternative is based on hindcast modeling of surface water yield for the Salt and Verde river systems modeled for the VRSMS. Water yield is therefore modeled based on local watershed conditions while the shortage volume is based on numerous conditions within the broader region.

A 10-year implementation time for planning and construction is assumed for each alternative, from 2021-2030, meaning 2031 is the first year that benefits begin. To estimate water supply benefits, three CAPSAM supply and demand scenarios are assessed for a 100-year period (2031-2130) with each reflecting a different magnitude of water shortages across time. The projections encompass groundwater and surface water availability under varied climate conditions and water demand under varied growth rates, spatial growth patterns, and assumptions of future water-use efficiency. The model also accounts for the major legal and regulatory elements of Arizona's elaborate water management framework. The CAPSAM projections end in 2060, so for the purpose of the VRSMS, these projections are linearly extrapolated to 2130 in order to estimate a 100-year benefit consistent with the 100-year lifecycle assumed for each alternative and used to estimate lifecycle costs (see Appendix D for more details). The average annual growth in renewable water demand and renewable water shortages from 2021-2060 is used to project shortages for the period 2061-2130.

It is important to note that these projections do not reflect any official projection of future supply and demand in the region, but rather, represent a range of plausible "what if" scenarios based on the best available information at the time of the VRSMS. A benefit range is therefore provided where the low-end estimate reflects the minimum plausible benefit and the high-end estimate reflects the maximum plausible benefit. A "recommended" benefit estimate is also provided which is considered to be the most consistent with assumptions used throughout the VRSMS. In practice, it is impossible to know the true benefit of increased water supply since it will ultimately depend on several unknown factors, such as future drought conditions, population growth, water efficiency improvements, price sensitivity, and policy decisions. By varying some of these key parameters, the true benefit is expected to fall somewhere between the low-end and high-end estimates.

In addition to different supply and demand scenarios, different price sensitivities are also assessed to generate a range of benefit estimates. Price sensitivity is captured by the price elasticity of demand which reflects how users change their quantity demanded from changes in price. Price elasticity of demand is discussed in detail in Section 4.1. The range of price effects across CAPSAM scenarios represents uncertainty in future water shortages associated with population and climate conditions, while the range across price elasticity of demand characterizes uncertainty in future price sensitivity for water users. Water supply benefits are largest with low price sensitivity under a hot dry climate and rapid outward growth, and smallest with high price sensitivity under historic climate and slow compact growth.

Annual benefits vary from year-to-year, differing based on the renewable shortage volume and water volume provided by each alternative. Annual benefits are discounted and summed across the 100-year period to derive a benefit estimate from the perspective of the beginning of the period of analysis. If an alternative provides more water than is necessary to offset the annual shortage volume, it is assumed that additional water is used to create long-term storage credits (LTSCs) to help address future water shortages. An alternative would be to allow prices to decrease in “surplus” years, but this is not realistic nor consistent with historical prices in the region, which have been steadily rising across time.

Absent significant changes in renewable supplies, the region will be heavily dependent on groundwater pumping to meet projected future demand. Much of that groundwater use is subject to Arizona’s Assured Water Supply (AWS) rules which require offsetting replenishment. CAPSAM treats this portion of unmet demand as groundwater pumping that is subject to AWS rules, recognizing that it is yet to be determined how that pumping might get offset with renewable supplies in the future. To estimate the benefit of new renewable water provided by each alternative, this unmet portion of demand is treated as the shortage volume for renewable supplies. This is done to capture Arizona’s existing legal framework which requires future municipal demand to be met by directly using renewable supplies or through offsetting groundwater use with renewable supplies.

3.0 Future Supply and Demand

In support of the West Salt River Valley (WSRV) Basin Study, the Central Arizona Water Conservation District (CAWCD) used CAPSAM to model regional supply and demand for 2020-2060 for each major water user in central/southern Arizona (Seasholes, 2019). CAPSAM produces projections for 80 public and private water utilities accounting for more than 99 percent of the demand in the municipal sector, 23 Agricultural Irrigation Districts and other Grandfathered Irrigation Rights, 12 Tribes and Tribal Districts, and over 20 other user categories including the Central Arizona Groundwater Replenishment District (CAGR), Arizona Water Banking Authority (AWBA), and industrial users such as mines and power plants. Because there are important regional interactions among water supply and demand, water supply benefits are estimated based on the full three-county model. As previously mentioned, these projections are intended to serve as “what if” future scenarios to demonstrate the range of potential benefits that might result from the new water supply provided by each alternative. See Seasholes (2019) for more details on the development of the CAPSAM projections and assumptions used for the WSRV Basin Study.

3.1 CAPSAM

CAPSAM simulates a wide range of future conditions, including variable rates and patterns of growth, shortage impacts, effluent reuse, aquifer recharge and recovery, and complex supply portfolio management decisions. The model accounts for numerous sources of water supply and the major elements of Arizona’s elaborate legal and regulatory framework that affect the availability and accounting of those supplies. As a systems model, CAPSAM generates different supply and demand conditions and then approximates how water users might respond to changing conditions. Many of

the future responses are influenced by the set of laws, rules, rights, and practices that comprise water management in the region. Like any model, CAPSAM simplifies phenomena that have many layers of additional complexity. For example, while CAPSAM simultaneously simulates supply and demand for more than 100 entities, it does not model the distribution of those supplies and demands within an individual water provider or irrigation district. Exceptions include distinguishing between Salt River Project (SRP) on and off project demands, and the location of urbanizing agricultural land. In addition to complexity, future supply and demand encompass several elements of uncertainty, so CAPSAM strikes a balance between unmanageable complexity and unreasonable simplification.

The model tracks the total legal and physical supply availability for several water supply types in each projection year. Supply categories include effluent, SRP water, Central Arizona Project (CAP) water, local surface water, and groundwater, many of which are further divided into subcategories. The supply of LTSCs and groundwater allowances are also tracked, with debits and credits occurring through time. The model includes deliveries to irrigation districts as in-lieu groundwater (indirect recharge) and to direct recharge projects. CAGR membership is also included, and it is assumed that supplies are limited by currently known CAGR resources. The model also simulates transfers, leases, exchanges, reallocations, and priority conversions, which includes only existing or currently proposed transactions. Lastly, in the process of fulfilling annual demands, CAPSAM makes projections of effluent use. This effluent use includes non-potable reclaimed distribution (i.e., “purple pipe”) and any recovered effluent that is indirectly satisfying potable demand (i.e., water that is physically groundwater, but legally effluent).

For the VRSMS, attention is placed on CAPSAM Scenarios B, D, and F from the WSRV Basin Study. All of these scenarios constrain the use of renewable supplies to those that are in-hand or part of existing plans, therefore capturing the Without Action conditions used to evaluate the benefit of increasing renewable water supply. The scenarios differ in the rate of population growth, spatial distribution of growth, water use efficiency, and climate-related factors such as the magnitude and frequency of shortage to the CAP, crop evapotranspiration, and SRP and local surface water availability. Municipal demand varies among the scenarios, but per-capita use generally trends downward to reflect observed long-term trends associated with improvements in water use efficiency and societal tastes and preferences. Agricultural demand is based on cropped acres, crop mix, consumptive use, and irrigation efficiency. Gradual improvements in agricultural efficiency are also included in each scenario.

Scenario B uses the official mid-series growth rate developed by the Arizona Office of Economic Opportunity and the official growth pattern developed by the Maricopa Association of Governments. The scenario also reflects a hotter, drier future. This includes lesser declines in household water use, increased crop consumptive use, and large Colorado River water shortages. This scenario is most consistent with the assumptions used throughout the VRSMS and is therefore used for the “recommended” benefit estimate. Scenario D simulates a more aggressive rate of growth coupled with a regional growth pattern that is weighted more heavily towards suburban and exurban areas. Like Scenario B, climate factors reflect a hotter, drier future, but a higher proportion of the housing units in agricultural areas are placed on active agricultural land compared to Scenario B. This scenario reflects the most rapid population growth and adverse climate conditions. Scenario F is based on historic climate conditions and simulates a lower rate of growth and a spatial pattern

of growth that places a greater proportion of housing units within the existing urban core rather than existing agricultural land. Scenario F also includes a more aggressive rate of decline in household use and higher irrigation efficiencies.

To help differentiate the effects of observed long-term declines in water use from future growth-related trends, CAPSAM separately considers existing and new municipal demand. Existing municipal demand represents baseline water use, as reported to the Arizona Department of Water Resources (ADWR) in the most recent Annual Report. New demand is simulated on the basis of housing units (HUs) that are projected to be built in each water provider's service area. Demand includes the use from the housing unit itself as well as a fraction of the ancillary demands (e.g., new parks, commercial land uses, etc.). CAPSAM spatially distributes HUs among water providers based on a geographic reference projection of housing units by provider, by time. The geographic projections are based on growth modeling that incorporates a large number of factors, including demographic data from the U.S. Census, construction data, planned developments, land uses, employment patterns, and transportation infrastructure. To evaluate alternative growth patterns, CAWCD contracted with Applied Economics to develop a socioeconomic model for the region.

The growth patterns used under these different scenarios were developed by varying key assumptions that affect the relative distribution of housing units. Some of the key factors included relative proximity to transportation infrastructure and existing development, how quickly planned but unbuilt development takes place, relative willingness to commute to employment centers, and land use capacity factors. Three of the spatial scenarios are ultimately used; "Baseline" (Scenario B) mirrors the officially adopted growth pattern by the Maricopa Association of Governments, "Outward Growth" (Scenario D) doubles the employment travel time factor and places a greater proportion of housing units in the western portion of the region, and "Compact" (Scenario F) halves the travel time and places a greater proportion of the growth in the Phoenix area and portions of the metro area.

Because the footprint of irrigated agriculture cannot expand (other than on tribal lands), population growth can result in significant urbanization of agricultural land with a subsequent reduction in irrigation demand. As new housing units are projected, reduction in agriculture acreage is calculated based on the average density of surrounding urban uses. CAPSAM also simulates agricultural demand based on a number of factors that affect agricultural use. These include crop mix by irrigation district, changes in efficiency, substitution of higher water use crops, and changes in consumptive use due to climate change. CAPSAM includes assumptions about tribal water use, including on-reservation use (predominantly irrigation), off-reservation storage, and off-reservation leasing. Leased tribal supplies are included in individual water provider portfolios.

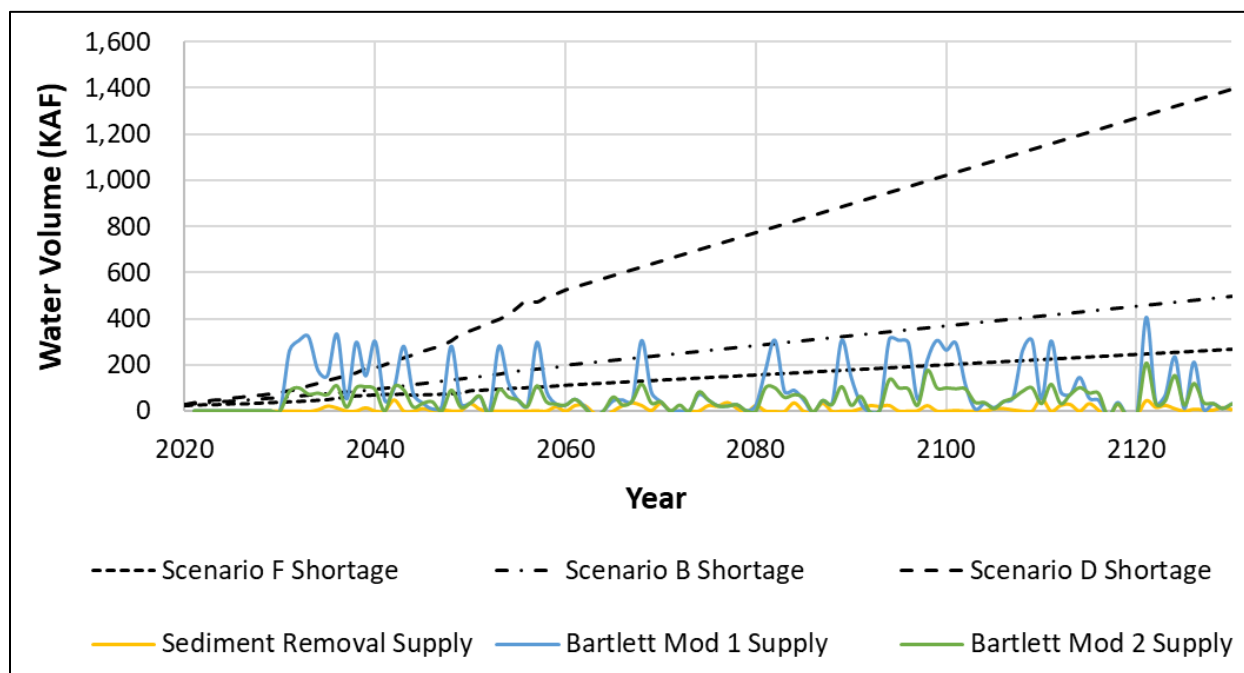
3.2 Renewable Water Projections

To estimate the benefit of additional renewable water supply, information from CAPSAM is combined with estimates of water yield for each alternative considered for the VRSMS. CAPSAM is used to identify the expected shortage volume in each year under different supply and demand scenarios. The annual water volume provided by each alternative is then used to evaluate how each alternative helps reduce future shortages. Water yield for each alternative is based on hindcast

modeling of local conditions on the Salt and Verde rivers, so it is important to note that yield is not intended to reflect particular years or future conditions, but rather, capture the cyclical nature of the watershed as historically observed across time. The water volume and associated benefit is therefore not attributable to any particular year. Instead, the benefit estimate is best understood as a 100-year total that captures the cyclical nature of the watershed and annual variations in water yield over time.

A 10-year implementation time for planning and construction is assumed for each alternative. This period is modeled from 2021-2030, meaning 2031 is the first year that benefits begin to accrue. As such, water yield is modeled as starting in the year 2031. From the hydrologic hindcast modeling, 105 years of water volume was provided, so the first 100 years are used to measure the 100-year benefit from 2031-2130. The CAPSAM projections end in 2060, so for the purpose of the VRSMS, these projections are linearly extrapolated to 2130 in order to estimate a 100-year benefit consistent with the 100-year lifecycle assumed for each alternative and used to estimate lifecycle costs. The average annual growth in renewable water demand and renewable water shortages from 2020-2060 is used to project shortages for the period 2061-2130. Figure 3.1 shows the renewable water projections used to estimate benefits. This includes the shortage volume under CAPSAM Scenarios B, D, and F as well as the water supply volume provided by the three action alternatives: Sediment Removal, Bartlett Modification 1, and Bartlett Modification 2.

Figure 3.1 – Renewable Water Projections, 2020-2130



By the end of the period (2130), Scenario B is expected to result in a shortage volume of about 500 thousand acre-feet (KAF), Scenario F is expected to result in a shortage of 270 KAF, and Scenario D is expected to result in a shortage of 1,400 KAF. From 2031-2130 this corresponds with an average annual shortage of 285 KAF under Scenario B, 159 KAF under Scenario F, and 764 KAF under Scenario D. Meanwhile, Sediment Removal is projected to provide an average annual yield of

about 9 KAF, Bartlett Modification 1 is projected to provide an average of 110 KAF per year, and Bartlett Modification 2 is projected to provide an average of 54 KAF per year.

As shown in Figure 3.1, in some cases the water yield provided by an alternative is expected to exceed the regional shortage volume during the early part of the period. For these years, it is assumed that water beyond the shortage volume is used to create long-term storage credits (LTSCs) to help offset future water shortages. The alternative would be to allow prices to decrease in “surplus” years, but this is not realistic nor consistent with historical prices in the region, which have been steadily rising across time. Given the cyclical nature of water yield, all “new LTSCs” are modeled as being used by the end of the period to offset shortages, meaning the 100-year benefit estimates encompass the entire yield provided by each alternative across the period.

4.0 Methodology

The demand for water represents the maximum willingness to pay (WTP) for water, which also reflects the marginal benefit derived from each unit of water. When users pay a price below their WTP, they receive a monetary gain known as consumer surplus (CS). This gain is calculated according to the area under the demand curve, above the price paid by users. This means that price changes affect CS, all else equal. To quantify the water supply benefit for each alternative, price changes and subsequent changes in CS are measured within the central/southern Arizona region.

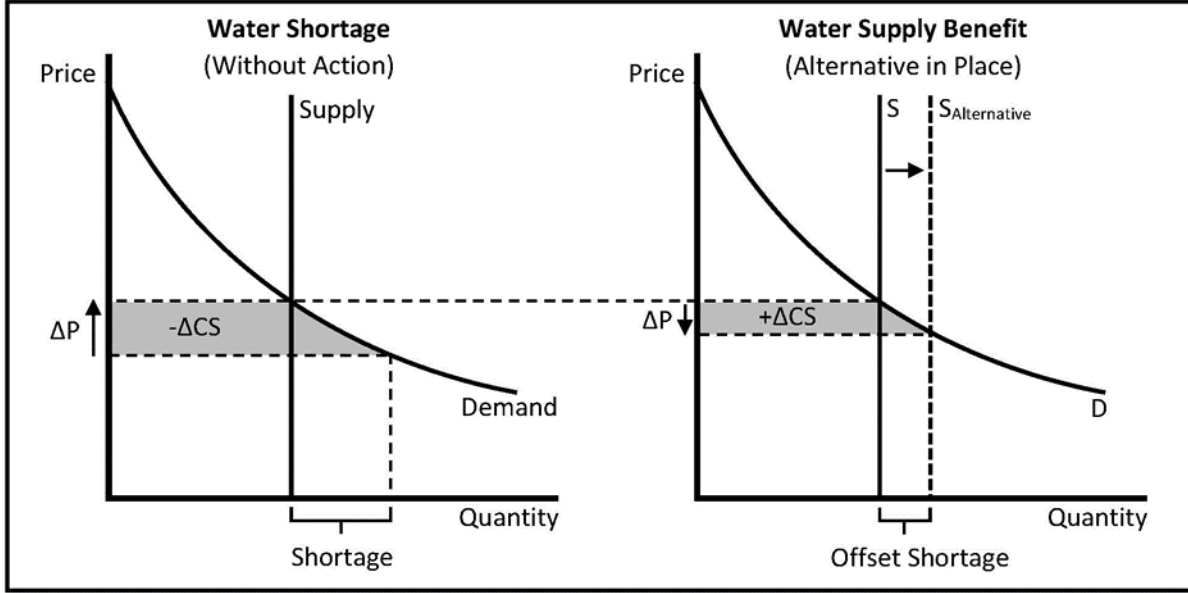
The price final users pay for water, or the retail price, varies greatly depending on location and the type of end use. For example, the price paid for potable water in part reflects the value added from water treatment and delivery to users, resulting in a higher price than is paid for raw untreated water. In order to evaluate the benefit of raw water provided by each alternative, and to analyze various uses of water simultaneously, it is necessary to focus on wholesale demand and the price of raw water, rather than final water demand and retail prices. For this analysis, water shortages and price effects for renewable supplies are assessed at the wholesale level based on regional supply and demand in central/southern Arizona, meaning benefit estimates for water supply are measured for raw water, prior to any treatment, delivery, or other factors that might add to the value of that water.

For many goods and services, the supply curve slopes upward, reflecting that producers are willing and able to provide more of the good or service at higher prices. However, the supply of water in the region is limited, due to physical availability as well as regulatory restrictions. Aggregate water supply for the region is therefore assumed to be fixed, or perfectly inelastic, which is reflected by a vertical supply curve. A perfectly inelastic supply is a reasonable assumption where the quantity of a good or service is relatively fixed, as with water availability in Arizona. Under this framework, changes in CS can be measured using information on: (1) the size of shortage; (2) the price elasticity of demand; and (3) the WTP for raw water. The change in CS with versus without an alternative in place is then used to quantify the water supply benefit for each alternative.

Shifts in supply and demand cause adjustments in price, reflecting either a shortage (upward pressure on price) or a surplus (downward pressure on price). Under the CAPSAM projections, regional water demand is expected to grow significantly, and supply is expected to remain relatively fixed,

with limited renewable water supplies and restrictions on groundwater pumping. This is expected to lead to growing water shortages over time and put upward pressure on the price of renewable water in the region. The left-hand graph in Figure 4.1 illustrates a shortage in renewable supplies, which can result from a decline in supply, increase in demand, or a combination of both. Regardless of the cause, shortage puts upward pressure on price and decreases CS, as depicted in the left-hand graph.

Figure 4.1 – Water Shortage and Water Supply Benefit



The change in price (P) associated with a shortage is calculated for each year (t) according to Equation 4.1, which is a function of the price elasticity of demand (ϵ_D), shortage volume (S), and the current quantity of renewable water use (Q).

$$\Delta P_t = \left(\frac{S_t}{Q_t + S_t} \right) \left(\frac{1}{\epsilon_D} \right) \quad (4.1)$$

This equation states that price changes are a function of renewable shortages, measured as a proportion of total renewable use, and the shape of regional water demand, which is defined by the price elasticity of demand. The price elasticity of demand is assumed to remain fixed across the study period. Annual changes in CS are calculated according to Equation 4.2.

$$\Delta CS_t = -(\Delta P_t)(Q_t) + 0.5(\Delta P_t)(S_t) \quad (4.2)$$

The first term in Equation 4.2 captures the shaded rectangle area shown in Figure 4.1, while the second term approximates the shaded triangle area assuming a linear hypotenuse (i.e., a linear demand between the new and old price).¹ An increase in renewable water from implementing an alternative will offset some of the shortage and reduce upward pressure on price, generating a positive change in CS as shown in the right-hand graph of Figure 4.1. The water supply benefit for each alternative is measured

¹ A geometric approximation is required since the functional form of demand is unknown, meaning integration cannot be used to calculate CS changes. For small incremental changes, this simplification has minimal influence on estimation.

by comparing annual changes in CS Without Action to CS changes with an action alternative in place, as shown in Equation 4.3.

$$Benefit_t = \Delta CS_{With_t} - \Delta CS_{Without_t} \quad (4.3)$$

To calculate the present value (*PV*) of benefits across the 100-year period of analysis, annual benefits from Equation 4.3 are summed according to Equation 4.4, which employs a classic exponential discounting method where the discount rate (*r*) reflects the fiscal year 2021 *Federal Water Resources Planning Rate*² of 2.5% and the base year (*t*=0) is the first year that benefits accrue (2031).³

$$PV = \sum_{t=0}^{99} \frac{Benefit_t}{(1+r)^t} \quad (4.4)$$

As previously mentioned, changes in CS depend on the size of annual shortages, price elasticity of demand, and WTP for raw water. CAPSAM is used to provide information on the annual shortage volume under different supply and demand scenarios. The following sections discuss the values used for the price elasticity of demand and WTP for raw water in the region.

4.1 Price Elasticity of Demand

Price elasticity of demand measures the relationship between the price of water and the quantity demanded. This captures the shape of the demand curve, reflecting how consumers alter their water use when price changes. More formally, it measures how a percent-change in price leads to a percent-change in the quantity demanded. This is measured as a ratio, as shown in Equation 4.5. To estimate water supply benefits, the elasticity of demand is used to measure the relationship in the opposite direction, determining how quantity (a water shortage) affects price, which was previously shown in Equation 4.1. It is assumed that demand is isoelastic, meaning that price elasticity is constant across all parts of the demand curve.⁴ This allows the measure of elasticity to be applied across different levels of water use and across various price levels.

$$\varepsilon_D = \frac{\% \Delta Q}{\% \Delta P} \quad (4.5)$$

The elasticity of demand is generally negative, reflecting that demand is downward-sloping due to an inverse relationship between price and the quantity demanded. As such, it is common practice to take the absolute value for easier interpretation. An absolute value is therefore reported throughout this analysis. In this case, the elasticity of demand ranges from 0 to infinity. An elasticity of 0 implies no relationship between price and the quantity demanded. An elasticity of 1 (unit-elastic) implies that

² The *Federal Water Resources Planning Rate* can be found on the Federal Register at: <https://www.federalregister.gov/documents/2020/12/11/2020-27294/change-in-discount-rate-for-water-resources-planning>

³ Benefits are assumed to occur at the beginning of the year, meaning the first year of benefits is not discounted.

⁴ In practice, price elasticity of demand can vary for several reasons. For example, at different levels of water use, at different prices, at different levels of income, and across different seasons. However, the level of detail provided by CAPSAM does not permit for these differences to be captured, and modeling varied elasticities would add significant complexity with minimal added value for an appraisal-level estimate as provided here.

there is a one-to-one relationship, meaning a one-percent change in price corresponds with a one-percent change in the quantity demanded (and vice versa). An elasticity between 0 and 1 (inelastic) means the quantity demanded changes less than the percent-change in price. This is often the case for water demand, since water is a necessity with no close substitutes, meaning the quantity demanded is minimally influenced by changes in price. An elasticity greater than 1 (elastic) means the quantity demanded changes more than the percent-change in price. This reflects consumption that is more responsive to price changes, which is often associated with non-essential goods and services with several close substitutes.

The elasticity of demand tends to vary across time, with a more inelastic relationship between price and quantity in the short-run, and a more elastic relationship in the long-run. This is because in the long-run consumers have more time to adjust their behavior and respond to changes in price. For example, there is more time for residential users to shift towards more efficient appliances, industrial users towards more efficient production, and agricultural users towards more efficient irrigation. Since this assessment is focused on long-term effects across a 100-year period, a long-run elasticity is most applicable.

The economics literature has an extensive number of studies that measure the elasticity of demand for water. The overwhelming majority of this work has focused on residential water demand, with less attention on agricultural demand and very little research looking at commercial and industrial demand. Studies have also tended to focus on short-run estimates, with only a handful providing long-run estimates. The economics literature was reviewed to identify the most relevant estimates of long-run demand elasticity for the study area. There have been several meta-analyses conducted that survey the economics literature, along with a handful of individual studies that examine water demand in Arizona.

The earliest meta-analysis, Espey et al. (1997), reviewed 24 journal articles published between 1967 and 1993 encompassing 124 elasticity estimates. They found that 90% of the estimates were between 0 and 0.75, with an average short-run elasticity of 0.51 and a median of 0.38. Short-run elasticities were found to range from 0.03 to 2.23, while long-run elasticities were more elastic, ranging from 0.1 to 3.33 with a median of 0.64. Later, Dalhuisen et al. (2003) examined 64 studies and 314 estimates between 1963 and 2001. They found an average elasticity of 0.41 and a median elasticity of 0.35, with long-run estimates generally more elastic by 0.28. Worthington and Hoffman (2008) examined 37 studies from 1980 to 2006, many of which were outside of the United States. They found that price elasticity ranged from 0 to 0.5 in the short run, and 0.5 to 1 in the long run. The most recent meta-analysis of residential water demand, Sebri (2014), examined 100 studies encompassing 638 estimates from 2002-2012. They found an average price elasticity of 0.37 and a median elasticity of 0.29, with long-run elasticities that were more elastic by 0.2.

These meta-analyses highlight the extensive literature that has developed around estimating the price elasticity of residential water demand. These studies indicate that price elasticity is generally inelastic and that long-run elasticities tend to be more elastic. That said, the estimates vary across studies for several reasons, many of which are associated with conditions in the study location. The most relevant estimates are therefore those that are most applicable to the VRSMS area. There have been a handful of studies that estimate price elasticity for residential water demand in Arizona. However, many of these studies are outdated and utilize the same dataset to focus on the Tucson area (e.g.,

Young, 1973; Agthe and Billings, 1980; Billings and Agthe, 1980; Agthe et. al, 1986; and Agthe and Billings, 1987). One exception, Klaiber et al. (2012), examined residential water demand in the Phoenix metropolitan area, focusing on how price responsiveness varies with season and drought conditions. Another exception, Yoo et al. (2014), also estimated demand in Phoenix, expanding on methods used by Klaiber et al. (2012) to focus on water availability and climate change.

Klaiber et al. (2012) found an elasticity of 1.54 in the winter and 0.68 in the summer when conditions were normal, falling to 1.17 in the winter and 0.3 in the summer when conditions were dry. Yoo et al. (2014) found a short-run elasticity of 0.66 and a long-run elasticity of 1.55. These estimates are notably larger (more elastic) than past estimates, from both the Tucson area and economics literature more broadly. This could be due to Phoenix water users being more responsive to price changes than other areas, or due to water users becoming more responsive to price changes over time. It could also be due to the sample used, variables included, or modeling assumptions and methods. Realistically, it is likely that a combination of these factors is responsible for the larger estimates. The estimates from these recent studies are arguably the most applicable to the study area. That said, both of these studies focus on residential demand for a single provider (Phoenix) and there are several limitations with their data and estimation methodology.

All studies mentioned thus far have focused solely on residential water demand, which is only one portion of municipal demand. Although residential demand constitutes the majority of municipal use, commercial use is also important, and may respond uniquely to price changes. Furthermore, since regional demand is modeled for municipal, industrial, and agricultural demand together in this study, it is important to consider how industrial and agricultural users may uniquely respond to price changes. Unfortunately, there has been minimal work on commercial and industrial water demand, and no known estimates of elasticity near the VRSMS area. The few studies that exist do however suggest that demand elasticities are unique for commercial and industrial uses. Surveys of this literature are available in Renzetti (2002), Brosa (2004), and Worthington (2010). Early studies suggested that commercial use is the most inelastic, followed by residential use and then industrial use, but more recent work has been mixed on this ordering.

For agricultural demand, past work suggests that agricultural users tend to be less price-sensitive than M&I users, which may be partly due to differences in use, as well as differences in price. One meta-analysis, Scheierling et al. (2006), examined 24 studies consisting of 73 estimates in the U.S. from 1963 to 2004. The mean price elasticity was 0.48, with a median of only 0.16. Elasticity estimates ranged from 0 to 1.97. Few studies estimated long-run elasticities, but the authors noted that long-run elasticities were generally more elastic, just as with other water uses. There have been several studies that examine irrigation water demand in western states (e.g., Howe et al., 1971; Heady et al., 1973; Hexem and Heady, 1978; Frank and Beattie, 1979; Gisser et al., 1979; Ogg and Gollehon, 1989; Moore et al., 1994; and Hendricks and Peterson, 2012), but only a handful of studies that examine agricultural water demand in Arizona. Focusing on Arizona, Kelso et al. (1973) found elasticities ranging from 0 to 1.01, while Ayer and Hoyt (1981) found a range of 0.06 to 1.45. Unfortunately, there have not been any elasticity estimates in Arizona in recent years.

Rather than relying on any single study and estimate of elasticity, it was deemed most appropriate to test a probable range of elasticities to demonstrate how the benefit of increased water supply varies with future price sensitivity. This is also necessary since demand is modeled for municipal, industrial,

and agricultural use together. Testing a range further helps to address the fact that past price sensitivity may not be a great predictor of future price sensitivity. For each CAPSAM scenario, an inelastic demand ($\epsilon_D=0.5$), unit-elastic demand ($\epsilon_D=1$), and elastic demand ($\epsilon_D=1.5$) is tested. The range of price effects across CAPSAM scenarios represents uncertainty in future water shortages associated with population and climate conditions, while the range across price elasticities characterizes uncertainty in future price sensitivity for water users. The combination of these two factors is used to provide a range of probable benefits associated with each alternative.

For the purpose of conducting a cost-benefit analysis (CBA) for the VRSMS, a “recommended” benefit estimate is provided, which assumes inelastic demand ($\epsilon_D=0.5$). The price elasticity estimates in the economics literature are based on final retail demand, and there are no known estimates for wholesale demand for raw water. That said, wholesale demand for raw water used by municipal systems is likely to be more inelastic than retail demand for several reasons. For one, only a portion of a municipal system’s cost is attributed to raw water, while other costs such as treatment, delivery, and administrative costs are also part of the price that gets passed on to final users. Also, some water revenues may come from fees and taxes, not solely from charges for use. Municipal systems also operate under different incentives than final users, generally with the goal of obtaining raw water supplies to fulfill final demands, with minimal control over the quantity demanded, other than from passing along costs and altering price structures; for example, using increasing block-pricing to increase price signals at higher levels of use.

All these features imply that a change in the price of raw water is likely to generate less of a quantity response for wholesale demand relative to retail demand. This makes the benefit estimates under inelastic demand the most applicable for CBA and the framework used to estimate raw water supply benefits for the VRSMS. Inelastic demand ($\epsilon_D=0.5$) is therefore assumed for the “recommended” benefit estimate, while additional benefit estimates are also provided to show the full range of potential benefits under varied price sensitivity and future conditions.

4.2 Willingness to Pay

In Arizona, the regional demand curve for raw water is unknown. This means that WTP for different quantities of water is also unknown. In general, water providers typically operate as a regulated natural monopoly, meaning they charge prices based on their average cost of provision. However, this price does not necessarily reflect WTP, and instead represents a lower-bound, while true WTP is defined as the maximum that users would pay. When it comes to water, there are several reasons why WTP is likely to be higher than prices charged based on cost; for example, the existence of non-market value, public good characteristics, externalities, and policies which affect price. This means that using a price based on cost to calculate changes in CS would provide a lower-bound estimate for the water supply benefit of each alternative. To provide a more accurate estimate, regional LTSC transactions are used to proxy WTP for a unit of renewable water in Arizona.

The observed transactions for LTSCs provide a reasonable proxy for WTP as they are a tool to meet renewable requirements under Arizona’s AWS Program, meaning a LTSC for an AF of raw water roughly reflects a user’s WTP for a unit of renewable water. An alternative would be to use a

benefit-transfer approach to proxy the WTP for a unit of water. However, after surveying the literature, no studies or estimates exist within the study area, and there are no studies that the VRSMS team felt would be suitable for benefit-transfer to the study area due to the complexity and uniqueness of Arizona's water management framework. It was therefore determined that LTSC transactions reflect the best available data to proxy WTP for a unit of renewable water in the central/southern Arizona region. In many instances, LTSCs represent the most likely alternative supply for M&I users to supplement shortages in water supplies from the Colorado, Salt, and Verde river systems.

For reference, the City of Phoenix states in its 2020 water rate schedule that users within city limits are charged \$183 per AF to cover raw water costs, and users outside the city are charged \$274 per AF.⁵ This can be thought of as the average price that Phoenix pays for a unit of raw water, which is unique to its particular water portfolio and access to renewable supplies. Given that Phoenix has a diverse and secure water portfolio, it is likely that other municipal providers in the region pay a higher price for raw water, which depends on their particular water portfolio and access to renewable supplies. It would therefore not be reasonable to assume that the price Phoenix pays for raw water is generalizable to what others in the region pay. On the other extreme, municipal users with less secure water portfolios and minimal or no access to renewable supplies must rely on the CAGRDR to offset groundwater use and comply with Arizona's AWS requirements. For 2020/2021 the CAGRDR rate is \$742 per AF of replenishment for users in the Phoenix Active Management Area (AMA).⁶ This means that municipal users in the region have a WTP anywhere from \$183 to \$742 for a unit of raw renewable water, depending on their particular circumstances.

A formal market for renewable water supplies does not exist in Arizona, but a growing number of transactions between willing buyers and sellers of LTSCs has become more regular and has been well documented in Arizona (Bernat et al., 2020). These LTSCs are tracked by ADWR for each authorized entity and remain with the entity until the credit is either recovered for use or transferred voluntarily to another entity. Review of data from ADWR published on November 30th, 2020 for the Phoenix, Pinal, and Tucson AMAs show a total combined LTSC balance of nearly 13 million AF between approximately 177 accounts. The historically observed transactions of LTSCs and the large volume of LTSCs in the three AMAs make it reasonable to expect that transactions for these supplies will continue, if not become more frequent in the future.

To determine the average transaction price for a LTSC and proxy WTP for a unit of renewable water in the region, publicly available LTSC transactions were queried from the CAGRDR⁷ and AWBA.⁸ In total, 38 transactions were identified for the period 2008-2020. Nearly one million AF of LTSCs were conveyed by these transactions between state agencies, tribes, municipal providers, industrial users, and investment firms. These observed transactions provide a reasonable sample size of data to proxy WTP for the purpose of the VRSMS. That said, unlike LTSCs, the water stored under the VRSMS alternatives is renewable, meaning that benefit estimates based on LTSCs may underestimate the true benefit. Figure 4.2 shows the 38 transactions on a price per AF basis,

⁵ Water rates for Phoenix are available at: <https://www.phoenix.gov/waterservices/customerservices/rateinfo>

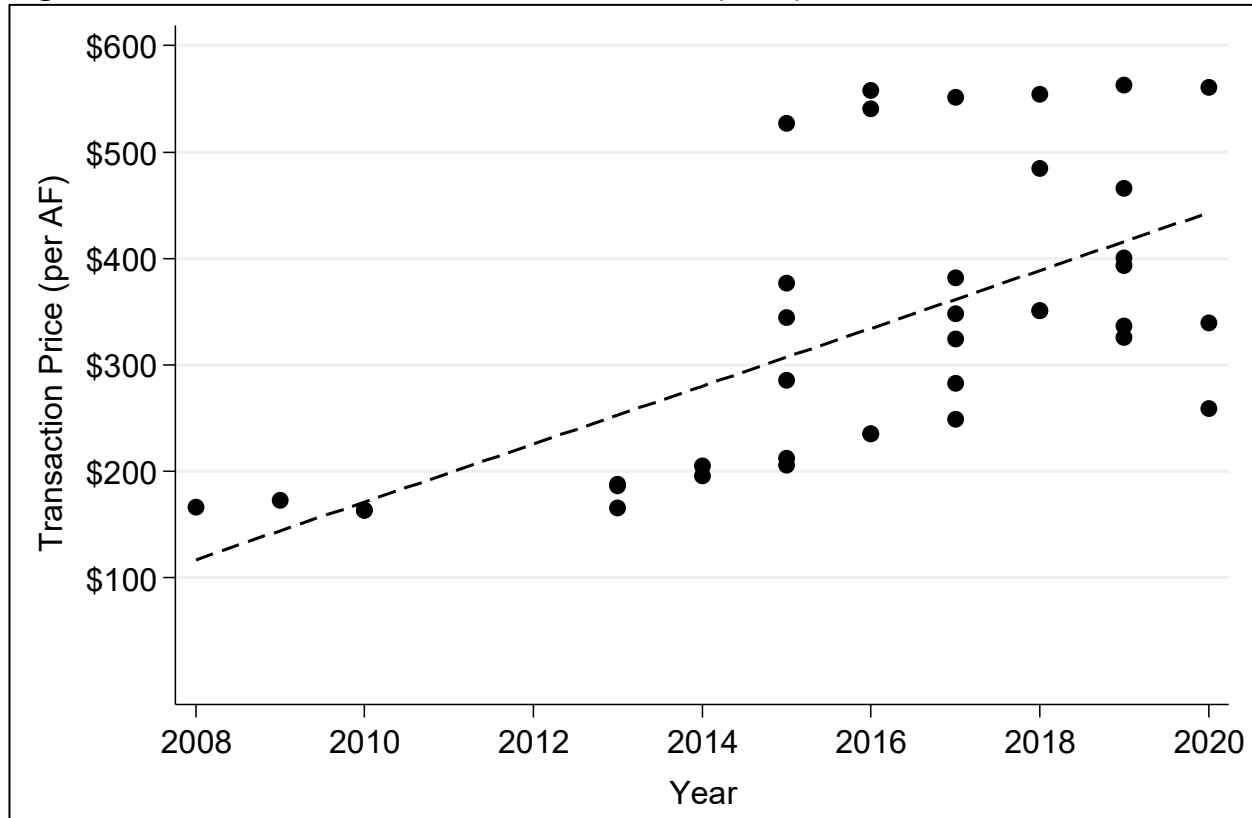
⁶ CAGRDR water rates are available at: <https://www.cap-az.com/departments/finance/water-rates>

⁷ CAGRDR transactions are available at: <https://www.cagrdr.com/water-supply-program/agreements-and-acquisitions>

⁸ AWBA transactions are available at: <https://waterbank.az.gov/agreements>

including an estimated well pumping cost⁹ per AF for recovery of the LTSCs, all of which are adjusted to \$2021 using the Phoenix-Mesa-Scottsdale consumer price index (CPI) for all urban consumers.¹⁰

Figure 4.2 – LTSC Transaction Prices for 2008-2020 (\$2021)



As shown in Figure 4.2, there is an upward trend in real LTSC transaction prices across the period. This is likely due to growing water scarcity across time. For the purpose of estimating water supply benefits for the VRSMS, the average LTSC transaction price is used solely for the start of the study period (2021) to proxy WTP. As previously discussed, future prices and changes in CS are then modeled based on the expected shortage volume and assumptions for price elasticity of demand. To bring the observations shown in Figure 4.2 to a 2021 perspective, the VRSMS economics core team decided that the trend across time should be used to adjust past LTSC transactions.¹¹ This was done with a simple linear regression to identify the slope of the trend line shown in Figure 4.2. The results indicate that real transaction prices increased approximately \$27.15 per year from 2008-2020 (R-

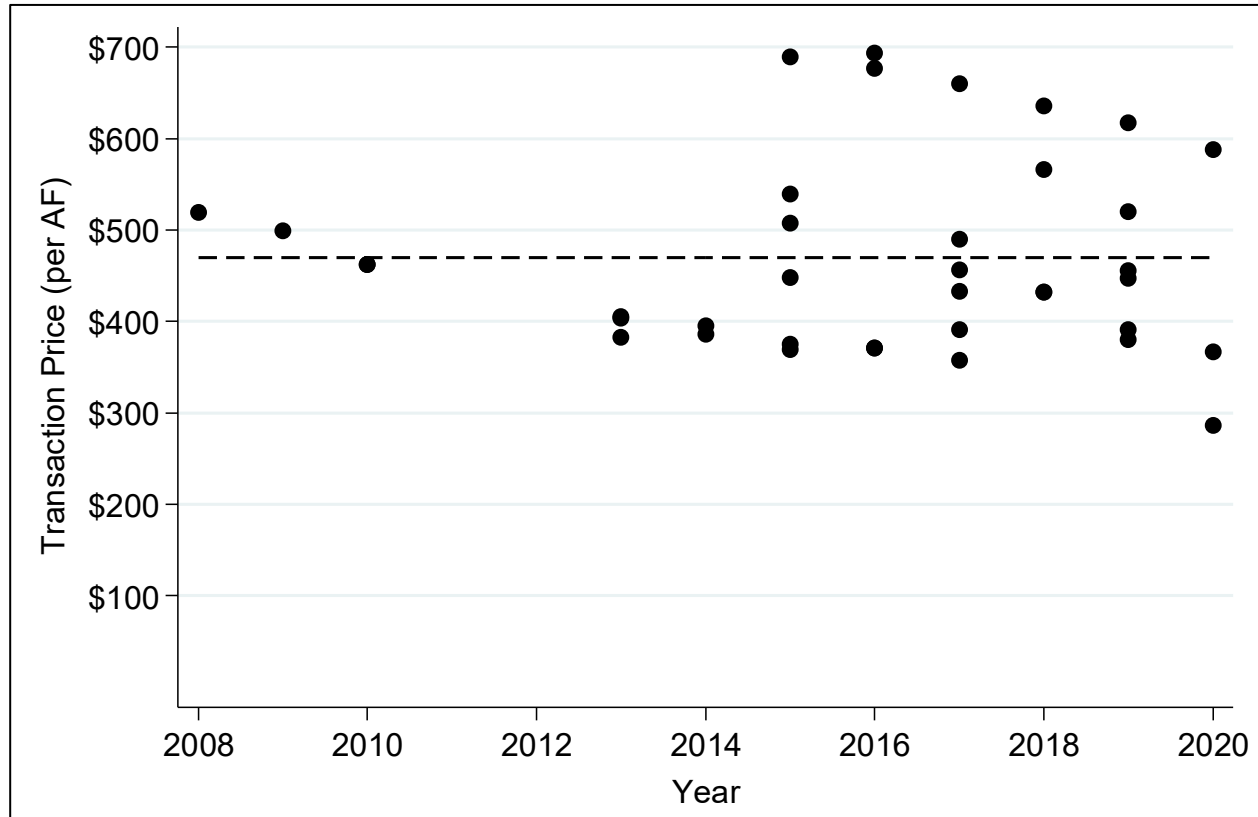
⁹ Some transactions included contractual prices for recovery of groundwater through a well system, while others do not. Where a contractual recovery rate was identified, that rate was added to the price per AF of the LTSCs since physical pumping of groundwater is necessary to put a LTSC to use and therefore would be expected to be included in a purchaser's WTP. For transactions with no defined recovery rate, a rate of \$98 per AF (2020\$ and then adjusted) was assumed based on the cost of OM&R + Electricity for pumping groundwater within SRP's well system. This cost was identified as a reasonable assumption for regional long-term well operation and replacement costs for pumping groundwater.

¹⁰ CPI data for the Phoenix-Mesa-Scottsdale region is available at: <https://www.bls.gov/cpi/regional-resources.htm>

¹¹ An alternative would be to shorten the period to remove some of the past transactions, but it was determined that reducing the number of observations was not desirable and these observations should remain in the sample.

squared=0.39, P-value=0.000, n=38). This is used to adjust transactions to a 2021 perspective. Figure 4.3 shows the resulting time-adjusted transaction prices. As shown, the adjustment removes the trend across time.

Figure 4.3 – Time-Adjusted LTSC Transaction Prices (\$2021)



To proxy WTP for the start of the study period in 2021, the time-adjusted average LTSC transaction price is used. Table 4.1 provides the summary statistics for LTSC transactions before and after the time adjustment. As shown, prior to adjusting for time, the average is about \$333 per AF, with a median of \$331 per AF. This suggests that there is little to no skew in the distribution of the 38 LTSC transactions used. After adjusting for time, the average is approximately \$470 per AF, which is used to proxy WTP for a unit of raw renewable water in 2021. For the time-adjusted transactions, the minimum is \$286, and the maximum is \$694. The time adjustment also reduces the variance of the observations, with the standard deviation falling from about \$135 to \$106.

Table 4.1 – Summary Statistics for LTSC Transactions per AF (\$2021)

Statistic	Sample Observations	Time-Adjusted Observations
Average	\$332.93	\$470.13
Median	\$331.25	\$447.92
Minimum	\$163.25	\$286.15
Maximum	\$563.19	\$693.71
Standard Deviation	\$134.66	\$105.64

5.0 Benefit Estimates

For each alternative, benefits are estimated under CAPSAM Scenarios B, F, and D as well as under different price elasticities of demand by comparing conditions Without Action to conditions under each action alternative. The range of price effects across CAPSAM scenarios represents uncertainty in future water shortages associated with population and climate conditions, while the range across price elasticities characterizes uncertainty in future price sensitivity for water users. The combination of these two factors is used to provide a range of probable benefits associated with each alternative. For the purpose of CBA, a “recommended” benefit estimate is provided which reflects Scenario B and inelastic demand ($\epsilon_D=0.5$). This was chosen since Scenario B is most consistent with the assumptions used throughout the VRSMS and since a change in the price of raw water is likely to generate less of a quantity response for wholesale demand relative to retail demand. An upper bound and lower bound is provided around the recommended estimate by holding elasticity constant and varying the climate and growth scenario. All benefit estimates are from the perspective of when benefits first begin to accrue (2031 base year) and discounted using the 2021 *Federal Water Resources Planning Rate* of 2.5%.

Table 5.1 shows the 100-year water supply benefit for Sediment Removal of 73 million cubic yards. The 100-year benefit ranges from about \$99 million (Scenario F and elasticity=1.5) to \$335 million (Scenario D and elasticity=0.5). This reflects the full range of uncertainty around future climate, growth, and price sensitivity. For the recommended estimate, the benefit for Sediment Removal is estimated at \$296 million with a lower bound of \$289 million and an upper bound of \$335 million.

Table 5.1 – 100-Year Benefit for Sediment Removal (millions, \$2021)

Price Elasticity of Demand	Climate and Growth Scenario		
	Scenario F	Scenario B	Scenario D
1.5	\$99.05	\$101.36	\$115.99
1	\$147.54	\$151.04	\$172.36
0.5	\$289.08	\$296.22	\$335.30

Table 5.2 shows the 100-year water supply benefit for Bartlett Modification 1, a 97-ft raise. The 100-year benefit ranges from about \$1.1 billion (Scenario F and elasticity=1.5) to \$4.4 billion (Scenario D and elasticity=0.5). This reflects the full range of uncertainty around future climate, growth, and price sensitivity. For the recommended estimate the benefit for Bartlett Modification 1 is estimated at about \$3.76 billion with a lower bound of \$3.2 billion and an upper bound of \$4.4 billion.

Table 5.2 – 100-Year Benefit for Bartlett Modification 1 (millions, \$2021)

Price Elasticity of Demand	Climate and Growth Scenario		
	Scenario F	Scenario B	Scenario D
1.5	\$1,102.63	\$1,286.81	\$1,535.87
1	\$1,642.48	\$1,917.49	\$2,282.24
0.5	\$3,218.08	\$3,760.57	\$4,439.80

Table 5.3 shows the 100-year water supply benefit for Bartlett Modification 2, a 62-ft raise. The 100-year benefit ranges from about \$622 million (Scenario F and elasticity=1.5) to \$2.2 billion (Scenario D and elasticity=0.5). This reflects the full range of uncertainty around future climate, growth, and price sensitivity. For the recommended estimate, the benefit for Bartlett Modification 2 is estimated at about \$1.9 billion with a lower bound of \$1.8 billion and an upper bound of \$2.2 billion.

Table 5.3 – 100-Year Benefit for Bartlett Modification 2 (millions, \$2021)

Price Elasticity of Demand	Climate and Growth Scenario		
	Scenario F	Scenario B	Scenario D
1.5	\$621.76	\$647.39	\$754.56
1	\$926.18	\$964.68	\$1,121.24
0.5	\$1,814.63	\$1,891.92	\$2,181.22

In general, for each alternative, the benefit range varies more across price elasticity of demand than across CAPSAM scenarios. This suggests that future price sensitivity and how users respond to changes will be important in shaping the true benefit of additional water supply. That said, demand is likely to be fairly inelastic, and there is notable variation across CAPSAM scenarios, indicating that the extent of future shortages is also important in shaping the benefit of additional water supply. Table 5.4 provides the recommended benefit estimates for each alternative as well as the lower and upper bounds, which reflect different climate and growth scenarios while holding price elasticity constant. In general, the variation in benefits across alternatives is proportionate to the water volume provided by each alternative. This means that Bartlett Modification 1 provides the largest water supply benefit, followed by Bartlett Modification 2 and then Sediment Removal.

Table 5.4 – 100-Year Water Supply Benefit for Each Alternative (millions, \$2021)

Alternative	Recommended Estimate	Lower Bound Estimate	Upper Bound Estimate
Sediment Removal	\$296.22	\$289.08	\$335.30
Bartlett Modification 1	\$3,760.57	\$3,218.08	\$4,439.80
Bartlett Modification 2	\$1,891.92	\$1,814.63	\$2,181.22

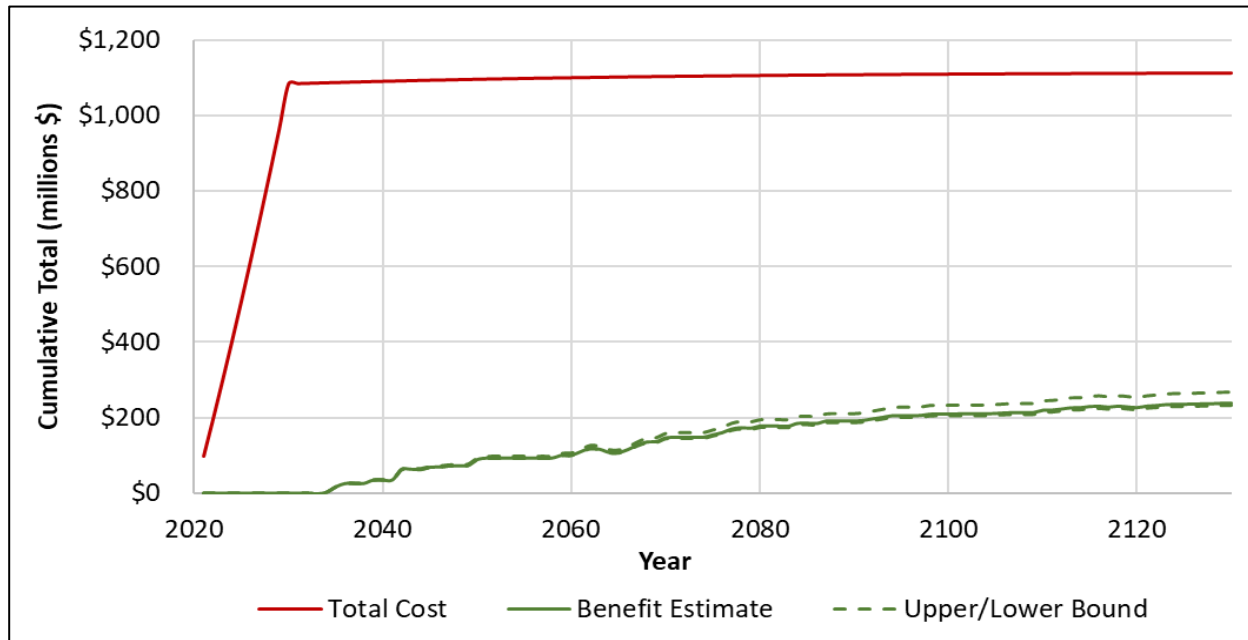
These estimates reflect inelastic demand ($\epsilon_D=0.5$) with the recommended estimate based on Scenario B, the lower bound based on Scenario F, and the upper bound based on Scenario D.

6.0 Breakeven Analysis

The breakeven point refers to the time required for the benefit of an alternative to cover the cost, sometimes referred to as the payback period. In this section, the breakeven point is evaluated based on construction cost; operation, maintenance, and replacement (OM&R) cost; and the benefit of additional renewable water supply. The breakeven point presented here therefore does not include all costs and benefits associated with each alternative, but rather, reflects the time it would take for the water supply benefit to cover capital and OM&R costs. This is intended to provide additional information on the economic viability of each alternative. Cost-benefit ratios and a formal CBA that includes the “recommended” water supply benefit estimate, as well as other considerations, are provided elsewhere as part of the VRSMS (see Appendix D for more details).

Construction cost is assumed to be evenly split across the 10-year construction period (2021-2030) and includes interest during construction (IDC) to capture the opportunity cost of the construction expenses that are incurred before each alternative begins to produce benefits (see Section 8.1.2 of the main report for more details). Once construction is complete, OM&R costs are modeled for the period 2031-2130 to reflect an assumed 100-year lifecycle for each alternative. Figure 6.1 shows the cumulative total cost (construction and OM&R) and the recommended water supply benefit for Sediment Removal across the period. As shown, the benefit estimate is well below the estimated cost, meaning there is not a breakeven point across the period evaluated.

Figure 6.1 – Breakeven Point for Sediment Removal



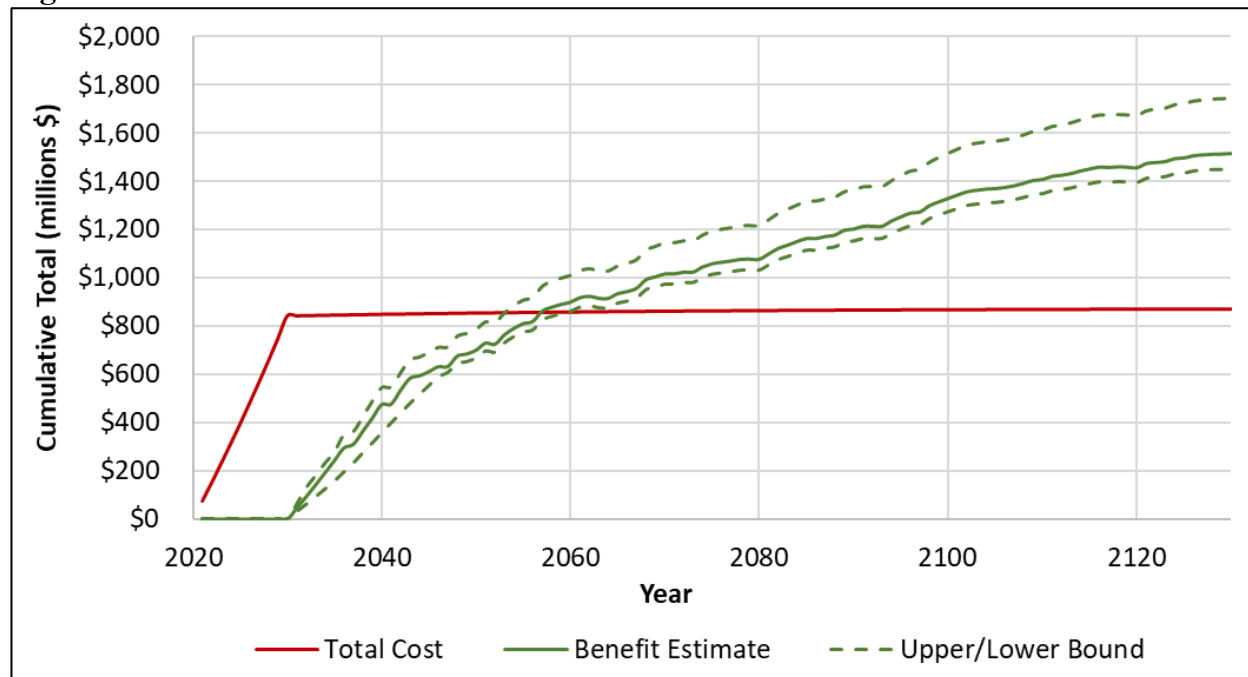
Looking at Bartlett Modification 1, Figure 6.2 shows the expected breakeven point under the recommended benefit estimate. The breakeven point is in 28 years (2049) with a lower bound of 37 years and an upper bound of 21 years. This indicates that across the period, the renewable water supply benefit for Bartlett Modification 1 is expected to cover the construction and OM&R costs.

Figure 6.2 – Breakeven Point for Bartlett Modification 1



Looking at Bartlett Modification 2, Figure 6.3 shows the expected breakeven point under the recommended benefit estimate. The breakeven point is in 37 years (2057) with a lower bound of 40 years and an upper bound of 33 years. This indicates that across the period, the renewable water supply benefit for Bartlett Modification 2 is expected to cover the construction and OM&R costs.

Figure 6.3 – Breakeven Point for Bartlett Modification 2



As shown by these figures, Bartlett Modification 1 and Bartlett Modification 2 are expected to break even across the period. Meanwhile, Sediment Removal is not expected to break even across the period. That said, these alternatives come with additional costs and benefits that are not reflected here (e.g., for hydropower), meaning the true breakeven point is likely to differ from that presented here. Future analysis is therefore warranted to determine the true breakeven point for each alternative considering all costs and benefits.

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Appendix L: Draft Feasibility Study Plan of Study



— BUREAU OF —
RECLAMATION

Appendix L

DRAFT Verde Reservoirs Sediment Mitigation Feasibility Plan of Study



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DEFINITIONS AND ACRONYMS

ADWR - Arizona Department of Water Resources

AF - acre-feet

Appraisal Level Study - The level of analysis and data collection needed to initially determine the nature of water and related resource problems and needs in a particular area, formulate and assess preliminary alternatives, determine Reclamation interest, and recommend subsequent actions.

AZGFD - Arizona Game and Fish Department

CAGRD - Central Arizona Groundwater Replenishment District

CAP - Central Arizona Project

CAWCD - Central Arizona Water Conservation District

Cooperating Partners - federal agencies, tribes, state agencies, local governments, municipal and industrial water users, irrigation districts, agricultural improvement districts, and water users' associations.

ESA – Endangered Species Act

FWCA - Fish and Wildlife Coordination Act

M&I - Municipal and Industrial

MOU – Memorandum of Understanding

NEPA - National Environmental Policy Act

NHPA - National Historic Preservation Act

PMP - Project Management Plan

PMT – Project Management Team

POS - Plan of Study

PR&G – Principles, Requirements and Guidelines

Reclamation - Bureau of Reclamation

Report of Findings - summary Appraisal Study

Study Area - The area of the Verde River where sedimentation issues exist and potential alternatives can be implemented.

SRFRP - Salt River Federal Reclamation Project

SRP - Salt River Project. Collective reference to the Salt River Project Agricultural Improvement and Power District, a political subdivision of the State of Arizona, and the Salt River Valley Water Users' Association, an Arizona territorial corporation, who collectively operate the Salt River Project System. The local study partner.

Salt River Project System - refers to the facilities owned by the United States, under the administrative jurisdiction of the Bureau of Reclamation, and operated and maintained by SRP pursuant to contract.

SRP Water Shareholders - water users in the Salt River Valley who own land within the Salt River Reservoir District and who are entitled to the delivery of water from the Salt River Project System.

SRVWUA - Salt River Valley Water Users' Association

TSG - Technical Support Group

USFWS - United States Fish and Wildlife Service

USFS - United States Forest Service

VRSMS – Verde Reservoirs Sediment Mitigation Study

1. INTRODUCTION

1.1. PURPOSE AND SCOPE OF STUDY

The Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study strongly suggests that the changing climate will bring drier and warmer conditions over time with greater variability in river flow and runoff for the Salt and Verde river watersheds (Bureau of Reclamation, 2020). These conditions are expected to result in more extreme drought and pluvial periods. The 2012 sediment survey at Horseshoe Reservoir showed that storage capacity in the reservoir had declined by 45,749 AF since its construction in the 1940s, and has declined at an average rate of 1,010 AFY since 1979.

Beginning in July 2020, the Bureau of Reclamation (Reclamation), in partnership with the Salt River Project (SRP), conducted the Verde Reservoirs Sediment Mitigation Study (VRSMS). The objective of the VRSMS was to conduct an appraisal study to examine potential alternatives to resolve the issue of loss storage capacity due to sediment accumulation in the Verde Reservoir system. Modeling for the VRSMS showed that reduced availability of surface water storage capacity on the Verde River increases dependency on groundwater by SRP to meet the demands of contractors and water rights holders within SRP's water service area, despite significant decreases in total water demands on the SRP since 1980. The Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study shows that the carryover capacity in the Salt River Federal Reclamation Project (SRFRP) reservoir system, combined with conjunctive management of groundwater supplies, are needed for SRP to successfully manage changes in climate (Bureau of Reclamation 2020). Preserving carryover storage in the SRFRP system is critical to managing the changes in timing and magnitude of precipitation and run-off events expected to come with changing climate conditions in the region. The relatively small size of the Verde River reservoir system results in excess flows from the Verde River that frequently spill from the reservoirs and mostly go unused. As run-off events become larger in magnitude, sufficient storage capacity will be necessary to manage the events and put water supplies to beneficial use.

Projected water demand in the lower Colorado River Basin, including central Arizona, is expected to outpace available supply by 3 million acre-feet annually over the next century (Bureau of Reclamation 2012). Meanwhile, Arizona's population is projected to grow to 18.3 million people by 2110, with water demand expected to grow from 6.9 MAFY to up to 10.5 MAFY in 2110 (Arizona Department of Water Resources 2014). Looking at opportunities to adapt to increased scarcity resulting from population growth and changing climate conditions, Reclamation's Colorado River Basin Report, completed under Section 9503(c) of the SECURE Water Act, identified modified reservoir system operations and new storage facilities similar to those identified in the Bartlett Modification alternatives as potential climate change adaptation strategies to address water supply vulnerabilities in the Colorado River Basin (Bureau of Reclamation 2016).

Changes in availability of Arizona's Colorado River supply due to shortage, changing climate, and increased demands show a need for preserving and augmenting existing renewable water

supplies in central Arizona. Though likely technically feasible, the removal of sediment to restore the water storage capacity of SRP and the City of Phoenix has direct and indirect costs that are estimated to outweigh the benefits.

The purpose of this study is to conduct a feasibility analysis of the alternatives recommended in the VRSMS appraisal report. The two Bartlett Dam modification alternatives are expected to create benefits that outweigh the costs, with benefit-cost ratios of 3.5 and 2.1 for the 97-foot and 62-foot raise, respectively. The benefits estimated for the two alternatives include restored and new water supplies, hydropower, and avoided carbon dioxide emissions. Additionally, both dam modification alternatives have potential to create benefits to environmental resources, recreational opportunities, water quality, flood control and safety of dams, but these benefits require further study to fully understand the magnitude of each.

The environmental and cultural due diligence performed in the appraisal study indicated that the impacts to these resources would not preclude the Bartlett Dam modification alternatives from further consideration under feasibility. The effects to environmental and cultural resources for these two alternatives would need to be addressed in this feasibility study. Implementation of Bartlett Modification 1 and 2 alternatives are expected to create an additional water supply of 115,000 AFY and 60,000 AFY, respectively. If no action is taken, the opportunity to store and use these water supplies would be forgone and the continued loss of SRP's storage capacity would result in higher SRP groundwater pumping. The City of Phoenix surface water credits created at Horseshoe Reservoir are expected to be 8,000 AFY less if either of the two Bartlett modification options are not implemented. Further, the two Bartlett Dam modification options create an opportunity to develop new conservation storage space that is expected to result in an average annual water yield of 91,000 AFY and 36,000 AFY of renewable surface water for Bartlett Modification 1 and 2, respectively. The additional supplies could result in a net benefit to the regional aquifer of up to 41,000 AFY for the larger dam and 14,000 AFY for the smaller dam, in addition to an expected reduction of SRP groundwater pumping of 14,000 AFY.

1.2. PROJECT SPONSOR(S) AND PARTNERS

As the operator of the Salt River Project System, including Bartlett and Horseshoe reservoirs on the Verde River, and the entity responsible for operation, maintenance, and water deliveries from that system, SRP is a partner and co-sponsor of this study with the Bureau of Reclamation. Additionally, through the VRSMS appraisal study process, several local entities, including agricultural, tribal, and municipal water users have identified interest in being a non-federal sponsor of the feasibility report. See Section 8.2 of this Plan of Study (POS).

This plan of study will be modified to identify additional study partners based on authorization and partner interest received.

1.3. AUTHORITY FOR THE STUDY

The Bipartisan Infrastructure Law (statutory name of Infrastructure Investment and Jobs Act of 2021), Public Law 117-58, provides the authority to conduct this feasibility study.

1.4. DESCRIPTION OF THE STUDY AREA AND PROJECT

The SRFRP, located near Phoenix, Arizona, includes a service area of about 248,000 acres spanning portions of Maricopa, Gila, and Pinal Counties in central Arizona. The land within the project is furnished with water supplies from the Salt and Verde Rivers and from approximately 270 groundwater wells. The rivers are controlled by six storage dams, and a diversion dam constructed by Reclamation that serve more than 1,200 miles of canals, laterals, and ditches.

The Salt River watershed contributes to Roosevelt Lake, Apache Lake, Canyon Lake, and Saguaro Lake. The Verde River watershed contributes to Horseshoe Reservoir and Bartlett Reservoir. C.C. Cragin reservoir in the East Clear Creek watershed also contributes water to the Verde River watershed through a diversion that releases water into the East Verde River. Combined, the Salt-Verde watershed covers about 12,500 square miles in central and eastern Arizona as shown in Figure 1. The study area (also defined in Figure 1) for the VRSMS covers the geographic area spanning from the Verde River just upstream of Horseshoe Reservoir near Sheep's Bridge downstream to Granite Reef Diversion Dam on the Salt River below the confluence of the Salt and Verde rivers and approximately one mile on either side of the river along the river channel.

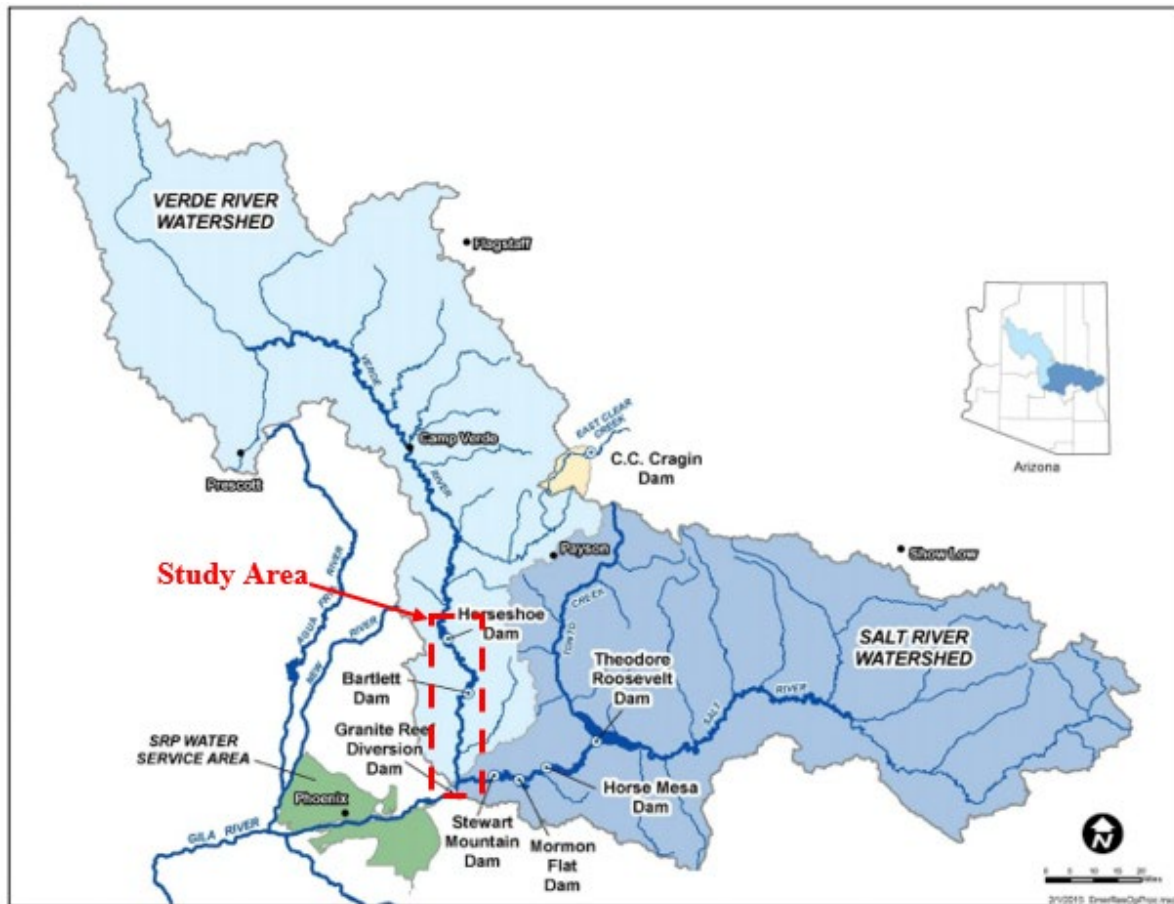


Figure 1. Salt and Verde watersheds and study area

The water stored in the Salt and Verde River watersheds provides approximately 40 percent of the municipal, industrial, and agricultural water supply to the Phoenix metropolitan area, the fifth largest city and the 12th largest metropolitan area in the United States. The SRFRP system is owned by Reclamation and is operated and managed by the SRP. SRP operates the six dams and reservoirs on the Salt and Verde rivers, as well as one on East Clear Creek.

Total storage capacity on the Salt River system, including flood control and dam safety surcharges space, is more than 13 times greater than that of the Verde River system (Figure 2).

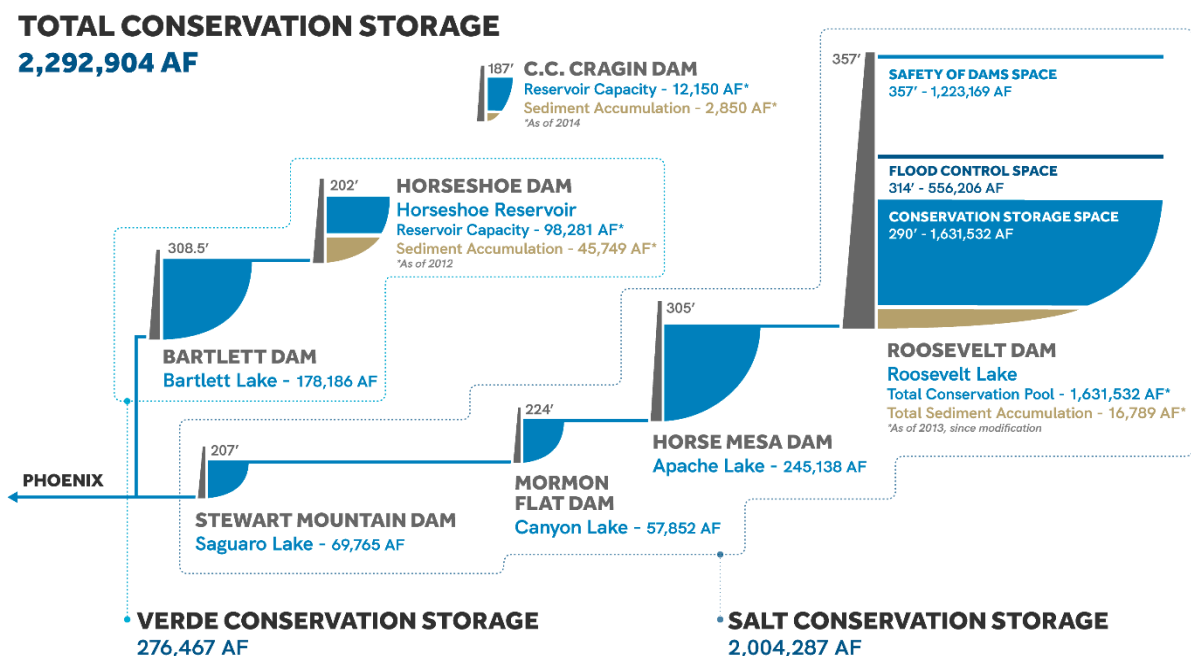


Figure 2. SRFRP dams and reservoirs storage capacities

All four dams on the Salt River have hydropower-generation capabilities. Apache Lake, Canyon Lake, and Saguaro Lake are operated at relatively full levels year-round to maximize power generation. Roosevelt Lake levels fluctuate depending on Salt-Verde watershed runoff and water demand. Roosevelt is also the only dam operated by SRP with flood control space which is managed by SRP following the guidance of the Water Control Manual for Modified Roosevelt Dam, Salt and Gila Rivers, Arizona developed by the U.S. Army Corps of Engineers, Los Angeles District (1997). Bartlett and Horseshoe dams do not have significant hydropower generation capabilities.

Granite Reef Diversion Dam is located northeast of Phoenix downstream of the confluence of the Salt and Verde rivers. The diversion dam diverts water from the Salt River into the Arizona Canal on the north side of the Salt River and the South Canal on the south side. An interconnection with the Central Arizona Project (CAP) canal allows water to be delivered from the CAP into the South Canal. Once diverted into the Arizona and South canals, water is distributed through SRP's system of canals and laterals for delivery within the SRP water service area and to those with contracts to transport non-project water through the SRP system (Figure 3). The SRP canal and lateral system consists of more than 1,200 miles of canals and laterals.

Along the canal and lateral system, SRP operates approximately 270 groundwater wells, which allow SRP to conjunctively manage surface water from the Salt and Verde rivers and groundwater from the aquifer underlying SRP's water service area on behalf of SRP customers including city water treatment plants and residential and agricultural irrigation customers. SRP operates the Granite Reef Underground Storage Project, New River Agua Fria Underground Storage Project, and the SRP Groundwater Savings Facility, which allow surface water supplies to be stored underground for future recovery.

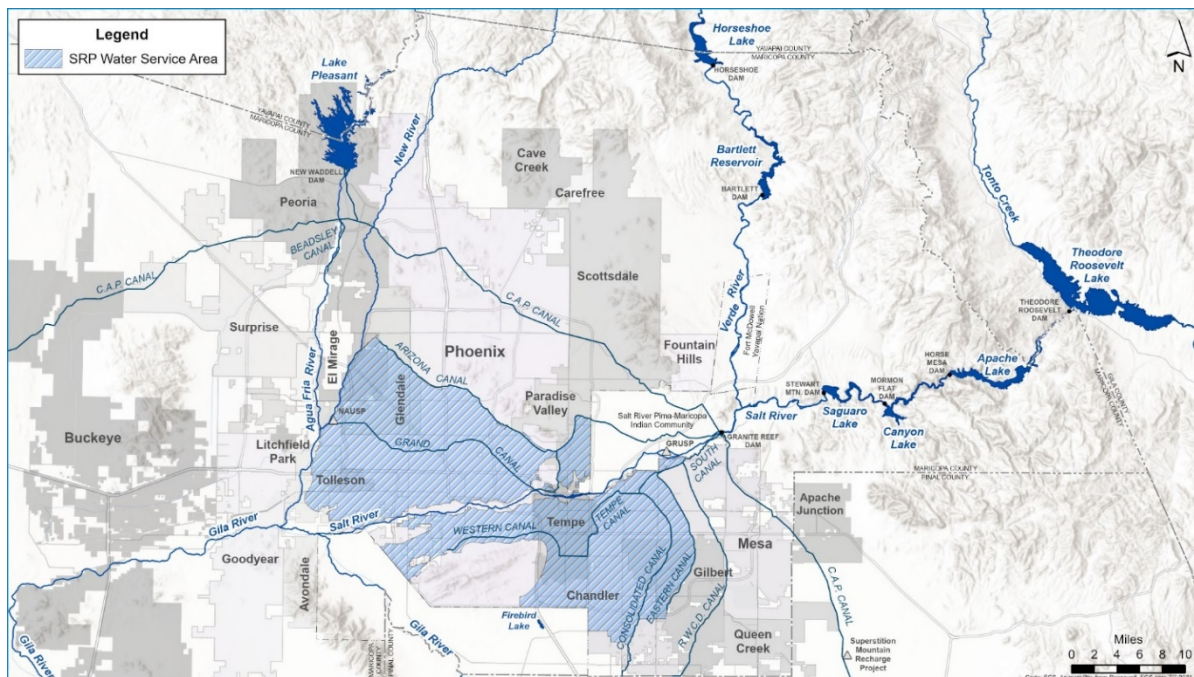


Figure 3. SRP water service area and water delivery Infrastructure

1.5. PREVIOUS AND CURRENT STUDIES

U.S. Army Corps of Engineers Central Arizona Water Control Study (1980s) – Investigation of Salt and Verde River Watersheds to address dam safety, flood control, potential for additional storage and multi-purpose uses.

Bureau of Reclamation Comprehensive Review Reports – Bartlett and Horseshoe Dams

Bureau of Reclamation, Salt and Verde River Reservoir System SECURE Reservoir Operations Pilot Study, 2019 – Conducted as part of Reclamation's reservoir operations pilot initiative which focused on identifying innovative approaches to improve water management strategies in the western United States.

Verde Reservoirs Sediment Mitigation Study Appraisal Report - preliminary investigations into options to address lost storage capacity to sedimentation and manage future sediment accumulation in Horseshoe Reservoir.

1.6. STUDY MILESTONES

The following are the high-level milestones for the Study. These will be further defined in the Project Management Plan (PMP) and will be revised as needed throughout the course of the study.

- Prepare Plan of Study and Cost Share Agreement
- Develop Project Management Plan
- Select plans for feasibility study
- Conduct feasibility scoping
- Regional Director's first interim review
- Conduct alternative analyses
- Regional Director's second interim review
- Value Planning Study
- Net public benefits plan
- Select preferred alternative
- Recommended Plan
- DEC Review and Policy Compliance Review
- Prepare Draft Feasibility Report (an Environmental Impact Statement (EIS) accompanies the Feasibility Report throughout the approval process)
- Regional Director's Final Review
- Regional Director's Draft Feasibility Report
- Commissioner's Draft Feasibility Report
- Secretary's Draft Report
- Review by Office of Congressional Affairs
- Review by Office of Management and Budget
- Approved Final Feasibility Report submitted to Congress as Secretary's Recommendation

2. SCOPING

2.1. PROBLEMS AND OPPORTUNITIES

Because of sedimentation, Horseshoe Reservoir's capacity has been reduced by approximately 46,000 acre-feet since it was placed in service in 1949. The lost capacity reduces available storage capacity for City of Phoenix and SRP's water shareholders. The VRSMS evaluated alternatives for restoring capacity and mitigating future impacts of sediment on the Verde River reservoirs as well opportunities for creating additional benefits of water supplies, flood control, dam safety, the environment, recreation, and hydropower. Through the VRSMS, it was identified that the State of Arizona has prioritized the use of renewable water supplies such as surface water over non-replenished groundwater sources. Growth in central Arizona, combined with future expectations for availability of Colorado River water supplies made available to central Arizona via the CAP canal, create an expected need for additional renewable water supplies that

can be put to use to benefit the region and relieve demand on non-renewable groundwater supplies.

The VRSMS identified that two viable alternatives may exist for restoring capacity and managing future sediment loadings in the system. The two alternatives identified were Bartlett Modification 1 and Bartlett Modification 2, modifications to existing Bartlett Dam that would raise the reservoir elevation at full pool by 97 or 62 feet, respectively. The Bartlett Dam modification alternatives were identified to create opportunities to expand water conservation capacity, improve flood routing and safety capabilities on the Verde River, improve aging facilities for dam safety purposes, increase recreational opportunities at Bartlett Lake, install grid-scale hydropower at Bartlett Dam, as well improve habitat and sediment management at Horseshoe Dam and Reservoir. The feasibility study would elaborate on the analysis of opportunities in the VRSMS for increasing benefits created by the Verde River reservoir system for the purposes of water supply, hydropower, dam safety, flood control, environmental, and recreation.

2.2. FEDERAL OBJECTIVE

The planning objectives developed for this feasibility study shall be consistent with the Federal Objective as set forth in the Water Resources Development Act of 2007 and shall align with the guiding principles of the Principles, Requirements and Guidelines (PR&Gs) of Healthy and Resilient Ecosystems; Sustainable Economic Development; Floodplains; Public Safety; Environmental Justice; and Watershed Approach. To ensure alignment with the PR&G Guiding Principle of Environmental Justice, the study team will make specific efforts to provide opportunities for effective public participation by minority, tribal, and low-income communities in the planning process. This will help ensure that the feasibility study identifies and avoids disproportionately high and adverse public safety, human health, or environmental burdens of alternative plans on these communities.

2.3. PLANNING OBJECTIVES

Through a process of stakeholder, partner, and public input, the project management team will formulate planning objectives against which to evaluate alternative plans to meet the identified problems, needs, and opportunities in the study area.

2.4. PLANNING CONSTRAINTS

Through a process of stakeholder, partner, and public input, the project management team will formulate planning constraints on developing alternative plans to meet the identified problems, needs, and opportunities in the study area.

3. EXISTING RESOURCE AND FUTURE CONDITIONS

The VRSMS included data collection from existing data and reports. As part of the feasibility study, data collection will extend to conducting analysis, studies, surveys, etc., to obtain the

detailed data necessary to complete the feasibility analysis and design. This includes, but is not limited to:

- General maps showing proposed structure site, existing buildings, utilities, construction access roads, laydown yards, storage areas, sources of construction materials, recreation areas, etc.
- Topographic map
- General description of local conditions
- Foundation investigations
- Geologic investigations
 - Geologic mapping
 - Detailed joint surveys
 - Drill holes along proposed alignment and plunge pool to determine
 - depth to rock
 - depth to weathering
 - Packer tests on drill holes to determine permeability
 - Instrumentation plan on drill holes
- Construction materials investigations
 - Material sources, etc.
- Hydrologic investigations
 - Climate change hydrology
 - Continue to develop hydrology datasets that reflect impacts to climate change based on most recent science
 - Determine set of hydrology series that bound the high and low climate change estimates
 - Water demand study
 - New Verde Space demand distribution
 - Develop monthly demand distribution for New Verde Space water
 - Identify appropriate range (high, low, and expected value) of future demands for remainder of system (SRP shareholder, contractors, etc.)
 - Identify change in groundwater use (SRP and central Arizona)
- Seismic investigations
 - Same as above, obtain and use latest available study
- Reservoir investigations (area capacity tables, sediment study)
 - Sedimentation rate
 - Collect and use LiDAR data to refine estimate of current sedimentation of Horseshoe Reservoir
 - Sediment sampling program
 - Collect sediment samples from Horseshoe and Bartlett reservoirs to characterize physical and chemical properties of sediment to use in hydraulic modeling and development of preliminary sediment management plans.
 - Collect in-situ or estimate sediment loading above Horseshoe Dam
 - Reservoir hydraulic modeling
 - Build hydraulic model of Verde River system necessary to model

sediment transport of sluicing and flushing alternatives through the reservoir system

- Sediment management plan
 - Use modeling data to develop sediment management plan for Horseshoe and Bartlett reservoirs

3.1. SURFACE AND GROUNDWATER QUANTITY

The VRSMS identified existing SRP water supplies and deliveries. Most of the water supply that SRP manages on the Verde Reservoir system comes from winter precipitation and snowpack in the headwaters of the Verde watershed. The water supply is extremely variable. Figure 4 depicts the monthly precipitation totals and average runoff produced on the Verde watershed.

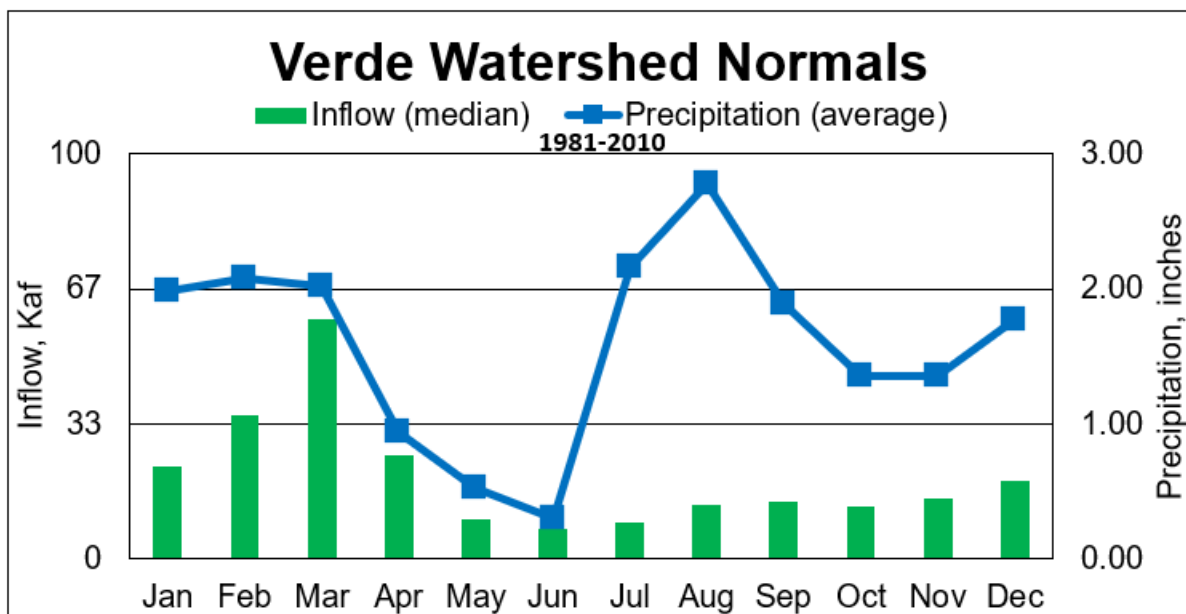


Figure 4. Verde watershed normals: average precipitation and median inflow (1981-2010)

Climate change is expected to result in warmer temperatures and more variability in precipitation, with a decrease in Arizona winter precipitation. It is anticipated that the Salt-Verde will experience slight decreases in annual average streamflow, deeper droughts, and wetter pluvials (wet periods).

SRP's conjunctive management of surface (seven reservoirs) and groundwater resources (around 270 groundwater wells) has historically created a reliable and steady supply of water for water rights holders within SRP's water service area. Figure 5 shows a 40-year snapshot of the variable surface water inflow and SRP's annual total deliveries. Surface water stored in the reservoirs and the availability of groundwater to augment surface water is key to maintaining a steady, reliable, and consistent water supply for the region.

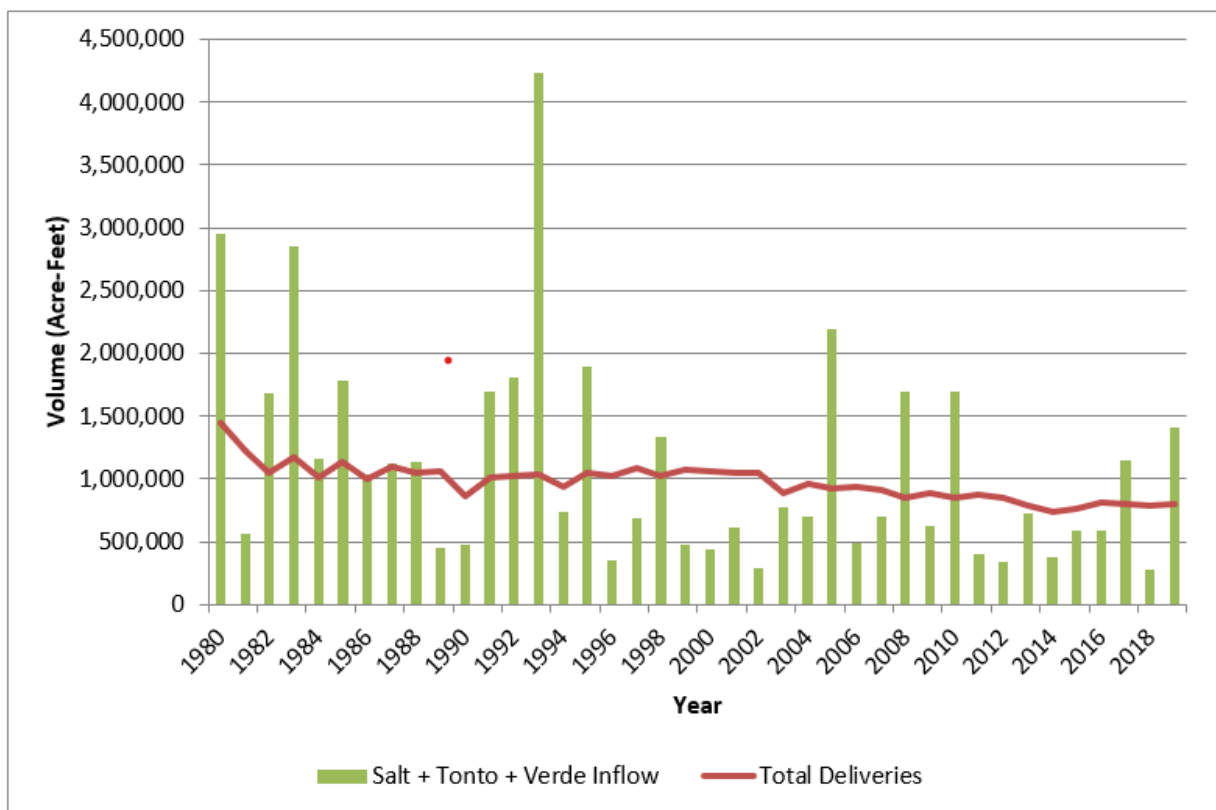


Figure 5. Total annual inflow into SRP reservoirs versus total annual water deliveries from 1980 through 2019

The VRSMS feasibility analysis will continue collecting and analyzing future and existing surface and groundwater supplies. Areas of focus include:

- **Climate change hydrology:**
Continue to develop hydrology data sets that bound the high and low climate change impacts based on most recent science.
- **Water demand:**
Develop monthly demand distribution for the New Verde Space water supply, identify appropriate range of future demands for remainder of system, and identify any change in groundwater use.
- **Reservoir operations:**
Refine reservoir operational modeling time-steps to evaluate and plan reservoir operation with Bartlett Modification alternatives, including habitat opportunities at Horseshoe Reservoir, and potential sediment management plan.

3.2. WATER SUPPLY INFRASTRUCTURE

SRP operates seven storage dams, and a diversion dam constructed by the Reclamation that serves a system of canals, laterals, and ditches. The Salt River watershed contributes to Roosevelt Lake, Apache Lake, Canyon Lake, and Saguaro Lake. The Verde River watershed contributes to Horseshoe Reservoir and Bartlett Reservoir. East Clear Creek watershed contributes to C.C. Cragin Reservoir. Combined, the Salt-Verde watershed covers about 12,500 square miles in central and eastern Arizona. SRP also operates around 270 groundwater well within the SRP service area to supplement surface water supplies. The Salt and Verde watersheds, the SRP service area, and reservoirs, is shown in Figure 6.

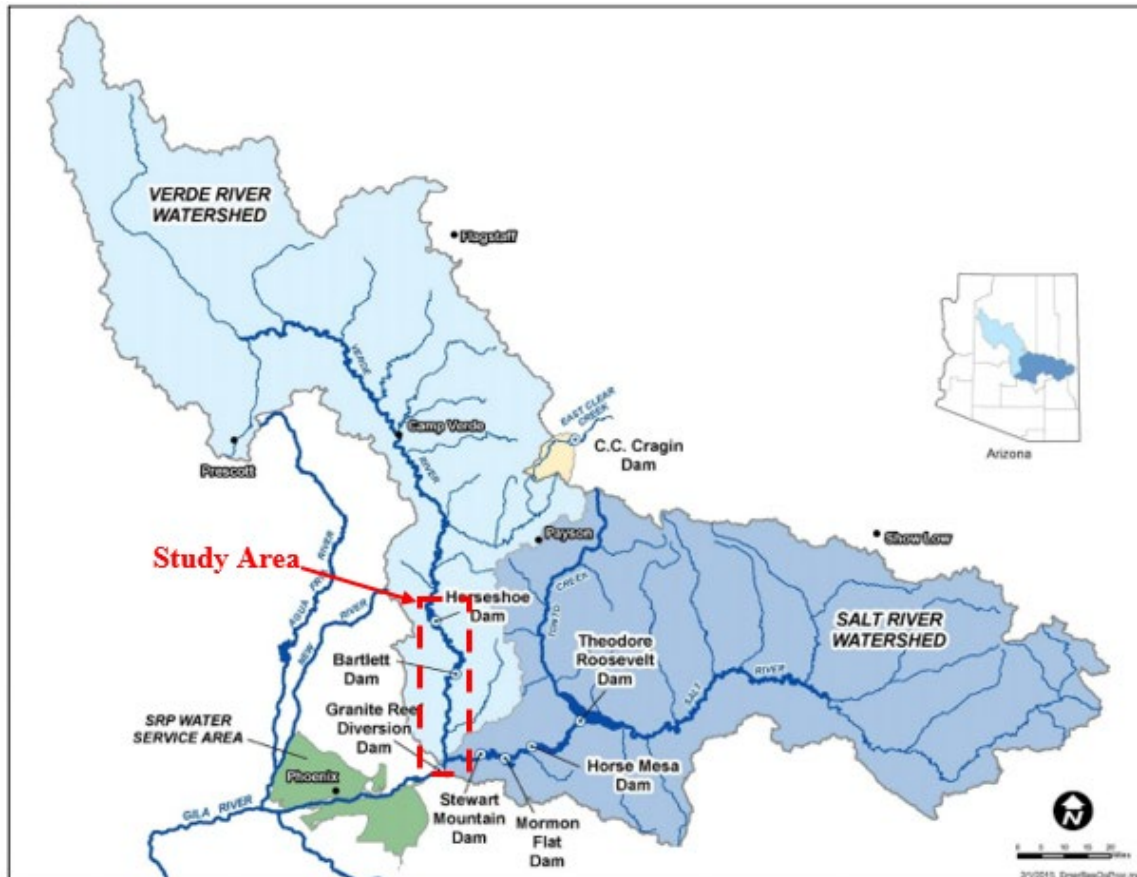


Figure 6. Salt and Verde watershed and Study area

The VRSMS investigated two alternatives to modify Bartlett Dam to restore capacity lost at Horseshoe Reservoir due to sedimentation, and increase storage capacity. Both alternatives move the remaining water storage rights from Horseshoe Reservoir into a modified Bartlett Reservoir. Horseshoe Reservoir could then be repurposed and operated to potentially benefit habitat and species, provide flood control, and manage sediment loads. Table 1 shows a summary of the two modification alternatives.

Table 1. Summary of Bartlett Modification Alternatives

Alternative	Total Storage of New Reservoir [AF]	Restored Storage [AF]	Added Storage [AF]	Restored and Added Storage [AF]	NMWSE [ft]	Reservoir Surface Area [acres]
Bartlett Modification 1	628,000	45,749	305,784	351,533	1895	7,015
Bartlett Modification 2	422,000	45,749	99,784	145,533	1860	5,084

The Bartlett Dam Modification Feasibility study will investigate and analyze the design of the two Bartlett Dam Modification alternatives identified in the VRSMS. Foundation, geology, construction considerations, seismic risk, and security risk will all be assessed. Cost estimates from the VRSMS will be refined.

Sedimentation rate analysis, sediment sampling to characterize physical and chemical properties, and reservoir hydraulic modeling will be conducted to assist development of a sediment management plan.

3.3. SURFACE AND GROUNDWATER QUALITY

This feasibility analysis will document the quality of the surface and groundwater resources and any impacts from the feasibility alternatives, including development of a sediment management plan. During this study, identification of permits needed for implementation of any proposed actions will occur.

3.4. LAND RESOURCES

Land within the area encompassing the Horseshoe and Bartlett dam and reservoir sites is primarily owned by the United States and administered under the jurisdiction of Reclamation. The VRSMS area also includes approximately 500 acres of private inholdings between Bartlett Reservoir and Horseshoe Dam. Certain federal lands within the study area were first withdrawn from the public domain on December 14, 1901, for the Rio Verde Forest Reserve. Additional areas, including land within one mile of the Verde River, were withdrawn on July 27, 1903, and December 14, 1904, under the Reclamation Act of 1902. Horseshoe and Bartlett dams and reservoirs are located on these Reclamation lands and managed for project purposes. Portions of these withdrawn lands that are not presently managed by Reclamation for project purposes are managed by the U.S. Forest Service (USFS) pursuant to an agreement with Reclamation.

Areas within the study area, upstream of Horseshoe Dam, are also owned by the United States and managed by Reclamation and the USFS. Additionally, lands upstream of Horseshoe Dam have been designated for water and power purposes pursuant to the Arizona-New Mexico Enabling Act of 1910.

Land within the study area, but downstream of Bartlett Dam, is also owned by the United States and managed by Reclamation and the USFS. The United States holds the land underlying the Fort McDowell Yavapai Nation Reservation in trust for the benefit of the Fort McDowell Yavapai Nation. Lands located between Granite Reef Dam and the Fort McDowell Yavapai Nation Reservation along the Verde and Salt rivers were withdrawn on March 2, 1903, March 9, 1903, July 20, 1905, and April 15, 1918, pursuant to the Reclamation Act of 1902. These lands are also managed by the Bureau of Reclamation for project purposes and by the USFS pursuant to an agreement with Reclamation.

In the VRSMS, a desktop review of the inundation zones for the two Bartlett Modification alternatives showed the bounds of both alternatives being within the Reclamation withdrawn lands, with the exception of the private land inholdings between Bartlett and Horseshoe reservoir. The private land inundation is expected from Bartlett Modification 1. Further evaluation of land ownership, jurisdiction, and impacts would be required to understand any necessary acquisition of lands to allow for implementation of either Bartlett Modification alternative.

Additional analysis to determine the project area based on evaluation of the likely areas receiving direct benefits from the project will need to be performed in the feasibility study to identify the appropriate project area and the lands required to be analyzed beyond those directly impacted by the footprints of the structural alternatives.

3.5. ENVIRONMENTAL RESOURCES

A feasibility study would constitute a major federal action. Per the Council of Environmental Quality regulations on National Environmental Policy Act (NEPA) and the Department of Interior's NEPA Guidance, an EIS must be completed within two years unless a senior agency official of the lead agency approves a longer period in writing and establishes a new time limit. This timeframe spans from the issuance of the Notice of Intent to the Decision Document. At least a 30% design is recommended to proceed with NEPA. A full detailed description of the proposed alternatives, operational scenario, access routes, lay down areas, and borrow sources would be required to proceed with NEPA compliance. Environmental considerations that would occur prior to and during the NEPA process include those addressed by the National Historic Preservation Act (NHPA) and Endangered Species Act (ESA). Fish and Wildlife Coordination Act (FWCA) compliance would also be required. Reclamation plans on using the NEPA document, rather than a separate report, for compliance, but will need to confirm with U.S. Fish and Wildlife Service. Implementation would occur post-decision document.

Environmental resources in the study area were grouped into 11 categories for the VRSMS:

- Threatened and Endangered Species
- Bald and Golden Eagles
- Migratory Birds
- Other Terrestrial Species and Their Habitat
- Other Aquatic Species and Their Habitat
- Special Status Species

- Visual Resources
- Vegetation and Land Cover
- Jurisdictional Waters and Water Quality
- Air Quality
- Special Designations

These categories were identified as the environmental resources with the greatest concern or importance within the VRSMS study area. A detailed description is found in Appendix B of the VRSMS Appraisal Report.

There is limited survey data for many threatened and endangered species in the area, which creates uncertainty in the analysis of impacts for each alternative. Survey gaps exist for species such as the northern Mexican gartersnake, yellow-billed cuckoo, Southwestern willow flycatcher, Arizona cliffrose, razorback sucker, and Colorado pikeminnow. A survey plan should be developed to identify data gaps and plan for closing any necessary gaps to facilitate a full analysis of the alternatives moved into feasibility.

As action alternatives are developed in more detail at the feasibility-level, there will be a need for identification of baseline conditions and complete analyses to support expected requirements for compliance with the NEPA and other applicable environmental statutes, such as the NHPA, FWCA, ESA, Migratory Bird Treaty Act (MBTA), Clean Water Act (CWA), Clean Air Act (CAA), and the Bald and Golden Eagle Protection Act (BGEPA). The following subsections provide a high-level overview of environmental compliance activities that will occur during the feasibility process as well as scoping of additional environmental compliance that would need to occur following congressional authorization and before construction activities could commence, assuming a project is found feasible and authorized for construction.

- MBTA compliance would be required. A permit, if required, must be obtained prior to construction.
- CWA (Section 404, 401, and 402) compliance would be required. An individual permit under Section 404 of the CWA is anticipated. A permit must be obtained prior to construction.
- CAA compliance would be required. A conformity determination is required for each criteria pollutant or precursor when the total direct and indirect emissions of the criteria pollutant or precursor in a nonattainment or maintenance area caused by a Federal action equals or exceeds thresholds set forth in 40 CFR 93.153(b). Compliance with state and local air quality laws and regulations would also be required.
- BGEPA compliance would be required. (It is unknown how long this will take to complete - no permits have been issued to date in Arizona). A permit, if required, must be obtained prior to construction.

3.6. ECONOMICS

The economic analysis for the VRSMS identified the net benefits for the Bartlett Modification 1 Alternative at \$2,746,713,573 (or \$75,017,908 annually) and for the Bartlett Modification 2 Alternative at \$1,063,991,406 (or \$29,059,604 annually). The Bartlett Modification 1 and 2 Alternatives have benefit-cost ratios of 3.5 and 2.1, respectively. The benefits evaluations included quantitative analysis of water supply, hydropower, and avoided carbon emissions from installation of hydropower generating facility. The VRSMS identified potential benefits and costs for recreation, flood control, water quality, environmental effects (positive and negative), and dam safety modifications, but did not have data available for quantitative analysis.

The benefits estimates for increased water supplies for each action alternative are based on assumptions identified as reasonable by the VRSMS Economics Core Team, using available information and study at the time of analysis. These assumptions should be assessed further in any feasibility level analysis. The actual benefits that result from a project being implemented will ultimately depend on many factors, such as future drought conditions, population growth, water efficiency improvements, price sensitivity, and policy decisions. Risks and uncertainty also exist about the future return on a hydropower investment at this facility, given the length of the planning period relative to recent and ongoing rapid change in the energy markets. Table 2 identifies major milestones and initial information and tasks for achieving the major milestones.

Table 2. Project Milestones and Prerequisites

Major Milestone	Initial Prerequisites
Pursuant to Section VIII.B. of 707 DM 1 Handbook, consult with the Office of Policy Analysis to discuss the scope and nature of a planned Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies (PR&Gs) analysis	Brief Reclamation Law Administration Division
Conduct a benefit-cost analysis	Develop construction/OM&R/greenhouse gas estimates Identify project beneficiaries Develop an operational regime Identify ecosystem services, supported by biological/physical primary research Identify and quantify project benefits, which may include water supply, recreation, hydropower, flood control, water and/or air quality, and fish & wildlife
Allocate costs	Identify statutory authority that would be used for construction Determine Federal participation Collect information necessary to conduct a Separable Costs Remaining Benefits cost allocation (for example, multipurpose without and single purpose alternative cost estimates) in compliance with PEC P01 and PEC 01-02 Quantify benefits

Major Milestone	Initial Prerequisites
Conduct financial analysis/ability to pay studies	Identify contractual structure Develop funding plan
Conduct regional economic impact and/or other social assessments	

Economic and financial analyses for the feasibility study will be conducted in accordance with the following specific documents, as they may apply:

- PR&Gs
- Reclamation Technical Memorandum Number EC-2009-02, Evaluating Economic and Financial Feasibility of Municipal and Industrial Water Projects
- Bureau of Reclamation Economics Guidebook
- RM Policy CMP P09, Water and Related Resources Planning
- RM Policy P14, Peer Review of Scientific Information and Assessments
- RM Policy PEC P01, Final Cost Allocations
- RM Policy PEC P07, Allocation of Operation, Maintenance and Replacement Costs
- RM D&S CMP 09-02, Water and Related Resources Feasibility Studies
- RM D&S PEC 01-02, Project Cost Allocations
- RM D&S PEC 11-01, Irrigation Ability-to-Pay Analyses
- RM D&S FIN 06-31, Interest Rates for Interest During Construction and Interest on Investment

3.7. SOCIO-ECONOMIC CONDITIONS

Effort for this task should not exceed that which is necessary to identify issues which could potentially eliminate an alternative plan, or that would significantly increase overall project costs by significantly increasing mitigation costs above a standard estimation factor.

- As needed, identify and describe baseline, existing, and forecasted social conditions using existing information.
- As needed, identify potential social impacts of each alternative.
- As needed, identify potential mitigation for adverse social impacts as appropriate.

3.8. RECREATION

Current and changing recreation conditions will be analyzed to evaluate how each alternative affects the quantity and quality of the recreation experience in impacted areas.

3.9. WATER RIGHTS

The right to beneficially use water from the Verde River is subject to the doctrine of prior appropriation. Numerous entities, including private, federal, state, and tribal water users claim

the right to use water from the Verde River (both upstream and downstream of the Verde River reservoirs). These water users claim the right to use Verde River water under state and federal law (including through beneficial use prior to 1919), permits and certificates under state law, existing court judgments or decrees, and federal reserved water rights. Claims made by these water users will eventually be confirmed in the Gila River General Stream Adjudication, a judicial proceeding in Maricopa County Superior Court to determine the extent and priority of all water rights in the Gila River system and its tributaries, including the Verde River (“Gila Adjudication”). Except for the tribal claims as described below, most claims to the use of water from the Verde River have not yet been adjudicated. The Gila Adjudication Court will eventually determine the attributes of each right to use water from the Verde River, including location and priority date for such use.

For certain Native American tribes, rights to the use of Verde River water have been adjudicated through Congressionally approved water rights settlements which have been approved by the Gila Adjudication Court. These Native American tribes are located downstream of Horseshoe and Bartlett dams and include the Fort McDowell Yavapai Nation and the Salt River Pima-Maricopa Indian Community. The Gila River Indian Community also has approved rights delivered in part through storage of water in the Verde River reservoir system. In addition to these settled claims, the Hualapai Tribe, Tonto Apache Tribe, and Yavapai-Apache Nation have asserted claims to water in the Verde River Basin. These tribes are all located upstream of Horseshoe and Bartlett Dams. The U.S. Department of the Interior has teams working to negotiate and settle the water rights claims asserted by these tribal nations.

Storing flood water in the new conservation capacity identified by the two Bartlett Dam modification alternatives and putting it to beneficial use requires a right to do so under state or federal law. Such rights could not conflict with prior vested water rights (either upstream or downstream of the reservoir). Additional water stored behind the dam would require entities storing and beneficially using such water to obtain a right under Arizona law through an administrative process with the Arizona Department of Water Resources (ADWR). The process includes such entities applying for a permit to appropriate such water under Arizona Revised Statute (A.R.S.) 45-152. Under A.R.S. 45-153, the Director of ADWR is required to approve applications made in proper form and where the proposed water use does not conflict with vested water rights, is not a menace to public safety, or is not against the interests and welfare of the public.

4. ALTERNATIVE FORMULATION

The alternatives recommended for feasibility in the VRSMS Appraisal Report will be included as alternatives to be evaluated as part of this study. Additional alternatives may be identified during the analysis and will be considered and evaluated if they meet the purpose and need of the study. The following is the list of alternatives from the VRSMS Appraisal Report that were recommended for further study.

- A no action alternative (no change to existing infrastructure or management)
- Bartlett Dam 1 Alternative

- Including potential operational alternatives
- Including potential design alternatives
- Bartlett Dam 2 Alternative
 - Including potential operational alternatives
 - Including potential design alternatives

Each alternative considered in the feasibility study will also be evaluated for the opportunity to create new benefits such as:

- Flood Control
- Water Supply
- Operational Flexibility
- Hydropower Generation
- Environmental Enhancement Benefits

The feasibility study team will develop criteria for screening alternatives to be considered at the feasibility level and focus on solutions that are practicable, feasible, and likely to meet planning objectives. The VRSMS performed an initial screening of alternatives to identify those viable for feasibility study. Those alternatives identified as viable will be further refined to determine appropriate variations and additions that may improve efficacy in meeting project objective. Those alternatives considered in the VRSMS appraisal analysis, but not found viable, may be used for context in the feasibility study to show the range of alternatives considered, but not fully evaluated during the feasibility analysis.

5. ALTERNATIVE EVALUATION AND COMPARISON

Alternatives will be evaluated based on a methodology to be developed by the Project Management Team (PMT) in consultation with the feasibility study team. The alternatives will be evaluated for: applicability, effectiveness, costs and benefits, environmental impacts, and risk and uncertainty, and in accordance with Reclamation and federal requirements (such as CMP 09-02 and the PR&Gs). Evaluation criteria may be updated and modified based on input from stakeholders.

6. CONSULTATION AND COORDINATION

Consultation and coordination with local, state, tribal and federal agencies will occur throughout the study period. Consultations and coordination for NEPA, ESA, NHPA, intergovernmental compliance and agreements will be directed by appropriate Reclamation staff in accordance with all applicable laws and policies. Public engagement during the study period is anticipated to include several direct stakeholder meetings as identified by Reclamation or SRP. The stakeholder list from the VRSMS will be used to develop the stakeholder team for this feasibility study as well as others identified as potentially interested by the project team. The consultation and coordination activities will be described in detail in the PMP.

7. FINDINGS AND RECOMMENDATIONS

A Feasibility Report documenting the completed results and findings of the feasibility study will be prepared, as well as an EIS. The feasibility report will include necessary elements as identified in CMP 09-02. A Summary of Findings Report of the feasibility analysis will be produced which documents the basis for the recommendations, including the comparative performance and impacts of the selected and rejected alternatives.

8. STUDY ORGANIZATION

8.1. LEAD ENTITY

Bureau of Reclamation - A Reclamation study manager will manage and direct Reclamation and Cooperating Partner activities, and coordinate/facilitate the participation of other entities and interested publics.

8.2. OTHER ENTITIES AND PUBLICS

SRP, as the operator of the Salt River Project and operator of Horseshoe and Bartlett reservoirs, is the local study co-sponsor. In addition, a consortium of local entities made up of municipal, agricultural, and tribal water users in central Arizona are working together to develop a formal coalition of study sponsors. The consortium consists of many partners working to execute a Memorandum of Understanding (MOU) and non-federal cost share agreement for supporting the feasibility study if federal authorization and funding is provided. The MOU and the non-federal sponsors' cost share agreement is expected to be executed by December 2021. The non-federal sponsors intend to develop a steering committee to provide unified input to the Project Management Team of the feasibility study.

Additional study partners will be identified through the execution of the non-federal costs share agreement and as the study progresses if additional interest is identified.

8.3. PROJECT MANAGEMENT TEAM (PMT)

8.3.1. Structure

The PMT is comprised of the project managers for Reclamation and SRP.

8.3.2. Responsibilities

The PMT will perform the activities associated with the study, such as gathering existing data, assisting the Technical Team, and writing the final report. The PMT will have the following specific duties on this study:

- Identify, nominate and approve members of the Technical Support Group (TSG), and appoint them by letter.
- Develop the feasibility plan of study through coordination with the TSG.
- Review the alternatives and formally select the preferred plan or plans.
- Formulate and coordinate public outreach activities.
- Ensure that the feasibility study components and overall study report meet the requirements of CMP 09-02, including necessary Reclamation reviews and approvals.
- Document the study results with preparation of draft and final reports.
- Participate in periodic meetings.

8.4. TECHNICAL SUPPORT GROUP (TSG)

8.4.1. Structure

The TSG will be comprised of individuals from Reclamation, SRP, or other organizations to be determined that are necessary to support the technical analysis required to complete the feasibility study. These individuals will be formally invited by the PMT. If the PMT determines other personnel are essential to the team, they will be formally invited to join the TSG.

8.4.2. Responsibilities

The TSG will write the evaluation criteria for the alternatives. Evaluation criteria will include engineering, economic, legal requirements, environmental and all other applicable constraints. The TSG will also review, evaluate, and recommend the alternatives to the PMT. The TSG will have the following specific duties on this study:

- Determine and write the evaluation criteria for the alternatives.
- Provide leadership and management of subtasks within their area of subject matter expertise to support the overall feasibility study process.
- Provide technical information and data as needed and requested by the PMT.
- Provide technical reviews of work products provided by the TSG at the direction of the PMT and in accordance with the agreed upon schedules. Study reports will be reviewed for technical accuracy and adherence to the purpose and needs of the study and provide comments and recommendations.
- Participate in periodic meetings.
- Gather the existing reports.
- Update existing reports, if necessary.
- Gather any additional technical data that is needed.
- Develop viable alternatives that meet the study purpose and needs.
- Recommend peer reviews as necessary.

9. DELIVERABLES

9.1. PREPARATION OF REPORTS

Draft and final reports will be prepared documenting the results of the study and the recommended plan. This includes documenting the analyses of existing and future alternatives and associated potential impacts, alternatives considered and eliminated from further consideration, and recommendations and conclusions regarding a preferred set of alternatives having the highest potential for meeting the purpose and needs of the study.

9.2. PREPARATION OF SUPPORTING DOCUMENTS

All technical disciplines will generate supporting documents as appropriate to cover the details of their individual evaluations.

9.3. COORDINATION ACTIVITIES

The coordination activities will be described in detail in the PMP.

10. PROJECT MANAGEMENT PLAN

A PMP will be developed in accordance with CMP 07-01. The PMP will be a living document and will be updated in accordance with the Change Management Plan identified in the PMP.

11. REFERENCES

- Arizona Department of Water Resources. (2014). *Arizona's Next Century: A Strategic Vision for Water Supply Sustainability*. Retrieved from https://drought.unl.edu/archive/plans/Water/state/AZ_2014.pdf
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- Easterling, D. R., Kunkel, K. E., Arnold, J. R., Knutson, T., LeGrande, A. N., Leung, A. R., . . . Wehner, M. F. (2017). Precipitation change in the United States. *Climate Science Special Report: Fourth National Climate Assessment, 1*, 207-230. (D. J. Wuebbles, D. W. Fahey, K. A. Hibbard, D. J. Dokken, B. C. Stewart, & T. K. Maycock, Eds.) Washington D.C.: U.S. Global Change Research Program. doi:10.7930/J0H993CC
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