Missouri River Recovery Management Plan and Environmental Impact Statement

Water Supply Environmental Consequences Analysis

Technical Report

August 2018

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Acronyms and Abbreviations

BiOp	Biological Opinion (amended in 2003)
DSS	Data Storage System
EQ	environmental quality (account)
ER	Engineering Regulation
ESA	Endangered Species Act
ESH	emergent sandbar habitat
H&H	hydrologic and hydraulic (model)
HC	human considerations
HEC	Hydrologic Engineering Center
M&I	municipal and industrial
MRRMP-EIS	Missouri River Recovery Management Plan and Environmental Impact Statement
MRRP	Missouri River Recovery Program
NED	national economic development (account)
O&M	operations and maintenance
OSE	other social effects (account)
P&G	1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies
POR	period of record
RAS	River Analysis System
RED	regional economic development (account)
ResSim	Reservoir System Simulation
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service

1.0 Introduction

The Kansas City and Omaha Districts of the U.S. Army Corps of Engineers (USACE), in cooperation with the U.S. Fish and Wildlife Service (USFWS), have developed the Missouri River Recovery Management Plan and Environmental Impact Statement (MRRMP-EIS). The purpose of the MRRMP-EIS is to develop a suite of actions that meets Endangered Species Act (ESA) responsibilities for the piping plover, the interior least tern, and the pallid sturgeon.

The purpose of the Water Supply Technical Report is to provide additional information on the impact analysis and results relevant to water supply that was completed for the MRRMP-EIS. Additional details on the National Economic Development (NED) methodology and results are provided in this technical report. The Regional Economic Development (RED) and Other Social Effects (OSE) are presented in the MRRMP-EIS, Chapter 3, Water Supply, Environmental Consequences section. No Environmental Quality (EQ) analysis was undertaken for water supply.

1.1 Summary of Alternatives

The MRRMP-EIS evaluates the following alternatives. A detailed description of the alternatives is provided in Chapter 2 of the MRRMP-EIS.

- **Alternative 1 – No Action.** This is the No Action alternative, in which the Missouri River Recovery Program (MRRP) would continue to be implemented as it is currently, including a number of management actions associated with the MRRP and 2003 Amended Biological Opinion (BiOp) compliance. Management actions under Alternative 1 include creation of early life stage habitat for the pallid sturgeon and emergent sandbar habitat (ESH), as well as a spring pulse for pallid sturgeon. The construction of habitat would be focused in the Garrison and Gavins reaches for ESH (an average rate of 164 acres per year) and between Ponca to the mouth near St. Louis for pallid sturgeon early life stage habitat (3,999 additional acres constructed).
- **Alternative 2 – USFWS 2003 Biological Opinion Projected Actions.** This alternative represents the USFWS interpretation of the management actions that would be implemented as part of the 2003 Amended BiOp Reasonable and Prudent Alternative (RPA) (USFWS 2003). Whereas Alternative 1 only includes the continuation of management actions USACE has implemented to date for BiOp compliance, Alternative 2 includes additional iterative actions and expected actions that the USFWS anticipates would ultimately be implemented through adaptive management and as impediments to implementation were removed. Considerably more early life stage habitat (10,758 additional acres constructed) and ESH (an average rate of 1,331 acres per year) would be constructed under Alternative 2 than under Alternative 1. In addition, a spring pallid sturgeon flow release would be implemented every year if specific conditions were met. Alternative 2 would also modify System operations to allow for summer flows that are sufficiently low to provide for early life stage habitat as rearing, refugia, and foraging areas for larval, juvenile, and adult pallid sturgeon.
- **Alternative 3 – Mechanical Construction**. The USACE would mechanically construct ESH at an average rate of 332 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from System

operations. The average annual construction amount includes replacing ESH lost to erosion and vegetative growth, as well as constructing new ESH. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 3. There would not be any reoccurring flow releases or pulses implemented under this alternative; however, should new information be learned through Level 1 and 2 studies over the next 9 years suggesting that spring discharges result in stronger aggregation of adult pallid sturgeon at spawning locations or increased reproductive success, a one-time spawning cue test could be implemented to provide additional information to support or refute this hypothesis. At the present time, it is assumed the test release would be similar to the timing, magnitude, duration, and pattern of the spawning cue included as a recurring release under Alternative 6.

- **Alternative 4 – Spring ESH Creating Release.** The USACE would mechanically construct ESH annually at an average rate of 195 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of an ESH-creating reservoir release in the spring. Alternative 4 would be similar to Alternative 1 (the No Action alternative), with the addition of a spring release designed to create ESH for the least tern and piping plover. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 4.
- **Alternative 5 – Fall ESH Creating Release**. The USACE would mechanically construct ESH annually at an average rate of 253 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. This amount represents the acreage necessary to meet the bird habitat targets after accounting for available ESH resulting from implementation of an ESH-creating reservoir release in the fall. Alternative 5 is similar to Alternative 1 (the No Action alternative), with the addition of a release in the fall designed to create sandbar habitat for the least tern and piping plover. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 5.
- **Alternative 6 – Pallid Sturgeon Spawning Cue.** The USACE would mechanically construct ESH annually at an average rate of 245 acres per year distributed between the Garrison, Fort Randall, and Gavins Point Reaches. In addition, the USACE would attempt a spawning cue pulse every three years in March and May. These spawning cue pulses would not be started and/or would be terminated whenever flood targets are exceeded. An estimated 3,380 acres of early life stage habitat for the pallid sturgeon would be constructed under Alternative 6.

1.2 USACE Planning Accounts

Human considerations (HC) evaluated in the MRRMP-EIS are rooted in the economic, social, and cultural values associated with the natural resources of the Missouri River. The effects to HC evaluated in the MRRMP-EIS are required under the National Environmental Policy Act and its implementing regulations (40 CFR 1500–1508). The 1983 Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (P&G) also served as the central guiding regulation for the economic and environmental analysis included within the MRRMP-EIS. Further guidance that is specific to the USACE is described in Engineering Regulation (ER) 1105-2-100, Planning Guidance Notebook, which provides the overall direction by which USACE Civil Works projects are formulated, evaluated, and selected for implementation. These guidance documents describe four accounts that were established to facilitate evaluation and display the effects of alternative plans:

- The NED account displays changes in the economic value of the national output of goods and services expressed in monetary units.
- The RED account registers changes in the distribution of regional economic activity (i.e., jobs and income).
- The EQ account displays non-monetary effect on significant natural and cultural resources.
- The OSE account registers plan effects from perspective that are relevant to the planning process, but are not reflected in the other three accounts. In a general sense, OSE refers to how the constituents of life that influence personal and group definitions of satisfaction, well-being, and happiness are affected by some condition or proposed intervention.

The accounts framework enables consideration of a range of both monetary and non-monetary values and interests that are expressed as important to stakeholders, while ensuring impacts are not double counted. The USACE planning accounts evaluated for water supply include NED, RED, and OSE.

1.3 Approach for Evaluating Environmental Consequences to Water Supply Access of the MRRMP-EIS

This evaluation assessed 59 municipal and commercial intakes located along the Missouri River and its reservoirs. While there are other intakes located throughout the System, including domestic and public water supply intakes, the analysis focused on those with sufficient information to evaluate potential impacts. When river flows and reservoir elevations fall below minimum operating requirements, intakes are unable to access water for municipalities, Tribes, commercial operations and others. This in turn can drive changes in costs to access water. The conceptual flow chart shown in Figure 1 demonstrates, in a stepwise manner, how changes to the physical conditions of the Missouri River and its reservoirs can lead to changes in costs of water supply access.

The evaluation of environmental consequences to water supply access was completed by evaluating how water supply intake operations would be affected by changes in river and reservoir conditions as modeled by the Hydrologic Engineering Center River Analysis System (HEC-RAS) and Reservoir System Simulation (HEC-ResSim) models developed by the Institute for Water Resources, HEC (Figure 2). Data from these models provided a profile of river and reservoir behavior at locations that approximately correspond to locations of water supply intakes, in the form of HEC-DSS (Data Storage System) flat files. River and reservoir behavior for each location were modeled over a period of 82 years, from 1930 to 2012. This analysis provided important inputs for the second step, the NED analysis, which estimated the change in water supply costs resulting from changes in access to water from the Missouri River. The following sections provide further details on the methodology.

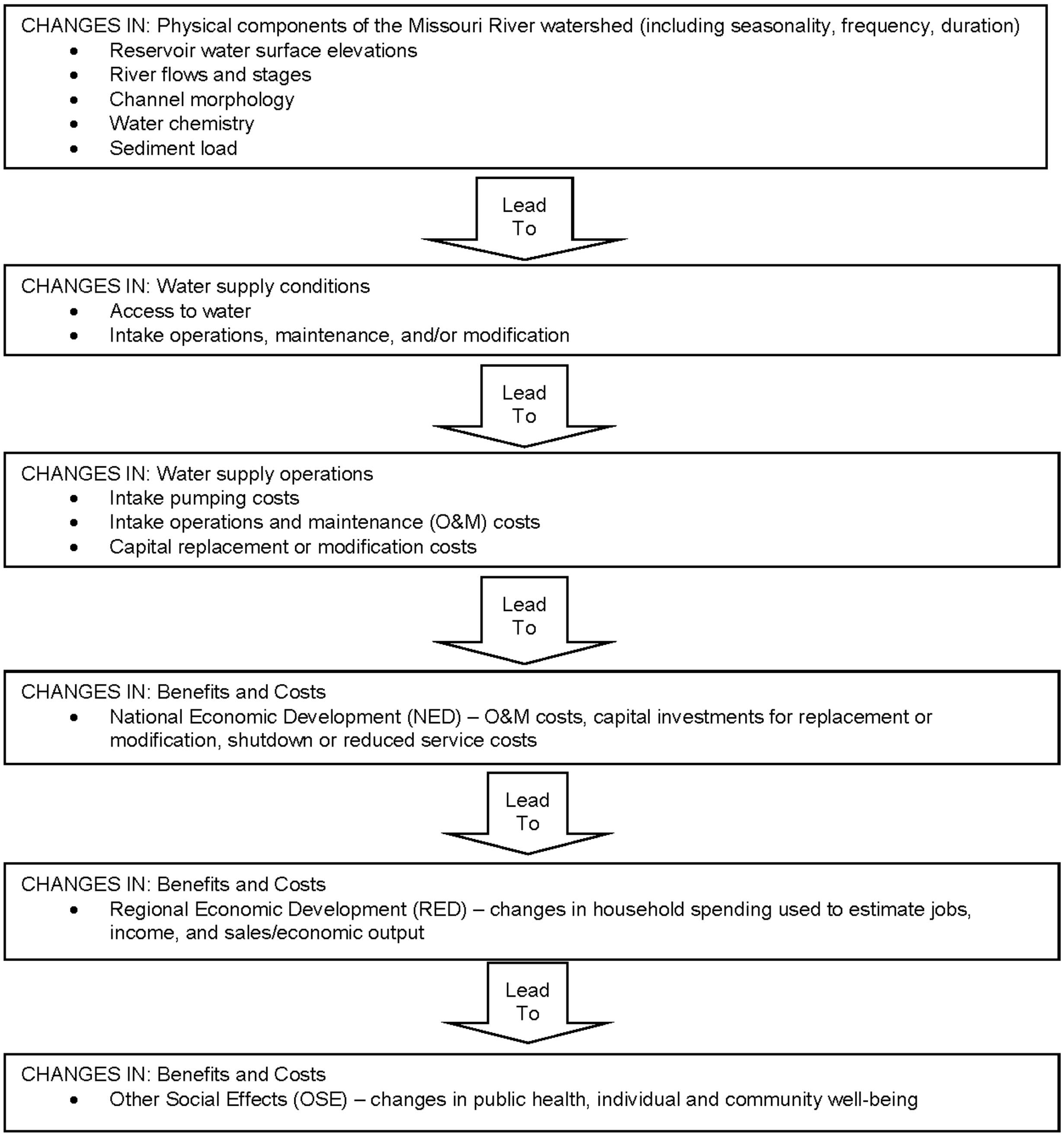

Figure 1. Flow Chart of Inputs Considered in Evaluation of Impacts to Water Supply Access

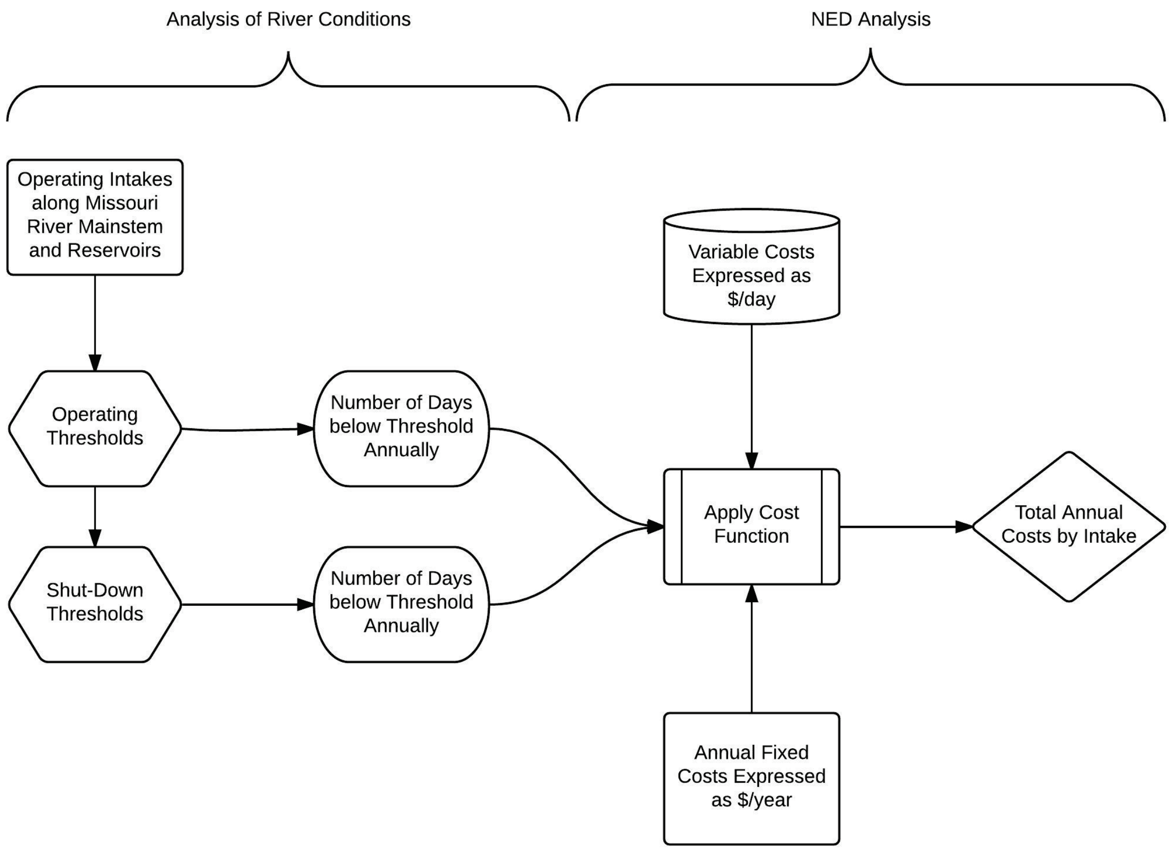

Figure 2. Approach for Evaluating Environmental Consequences to Water Supply Access

2.0 Assumptions, Limitations, and Risks

2.1 Assumptions and Limitations

In modeling the environmental consequences to water supply access from the MRRMP-EIS alternatives, the project team established a set of assumptions. The important assumptions used in the modeling effort are as follows.

- The river conditions analysis and economic analysis uses data from the hydrologic and hydraulic (H&H) modeling of the river and reservoir System. The analysis assumes that the H&H models reasonably estimate river flows and reservoir levels over the POR under each of the MRRMP-EIS alternatives including Alternative 1 (the No Action alternative).
- The river conditions analysis shows that impacts are expected to occur to water supply access under current System operations. Recent bed degradation is likely causing water

surface elevations to fall below critical thresholds in some locations.[1] Since these conditions exist under current System management, which are modeled with a 2012 channel geometry, water supply managers would need to improve intakes to address these issues. The analysis presented here does not attempt to evaluate intake modifications resulting from bed degradation issues, but instead focuses on changes in intake operations relative to Alternative 1, as a result of the action alternatives.

- Based on interviews with a representative sample of water supply managers it was assumed that water supply operations can adapt to small, infrequent changes in river flows and reservoir elevations under the MRRMP-EIS alternatives by using different-sized portable submersible pumps.

2.2 Risk and Uncertainty

Risk and uncertainty are inherent with any model that is developed and used for water resource planning. Much of the risk and uncertainty with the overall MRRMP-EIS is associated with the operation of the Missouri River System and the extent to which flows and reservoir levels will mimic conditions that have occurred over the POR. Unforeseen events such as climate change and weather patterns may cause river and reservoir conditions to change in the future and would not be captured by the HEC-RAS models or carried through in the water supply model described is this document. The project team has attempted to address risk and uncertainty in the MRRMP-EIS by defining and evaluating a reasonable range of plan alternatives that include an array of management actions within an adaptive management framework for the Missouri River. All of the alternatives were modeled to estimate impacts to municipal, tribal, and commercial water supplies.

Another source of uncertainty associated with the water supply analysis is predicting how water supply managers would react to long-term changes in river and reservoir conditions. The project team has utilized information from interviews with water supply managers to assess how adverse effects would affect operation of intakes. In all cases, the project assumed that submersible pumps would be used to adapt to changing conditions that are temporary in nature. However, in some cases, water supply managers may decide that it is more cost effective to make modifications to the intake to adjust to these conditions. For consistency across all water supply intakes, a standard approach of utilizing portable, submersible pumps were used. Some of these river conditions have not occurred in the recent past and therefore represent the anticipated operational response of a water supply managers to a hypothetical situation. However, while these operational responses may be reasonable under current conditions or in the near future, unforeseen conditions may arise that may alter the operational response to the adverse conditions

[1] For additional information on bed degradation please see section 3.2 River Infrastructure and Hydrological Processes in the MRRMP-EIS.

2.3 Geographic Areas

Water supply intakes are located all along the Missouri River and Mainstem reservoirs. The intakes evaluated were organized into two groups depending on their location. "upper basin" includes all intakes located above Gavins Point Dam, whereas "lower basin" includes those located below Gavins Point.

3.0 River Conditions Analysis

The purpose of the water supply river conditions analysis was to link H&H modeling efforts that simulate river and reservoir operations of the Missouri River under each of the MRRMP-EIS alternatives with economic analysis necessary to determine environmental consequences. The river conditions analysis used Microsoft Excel® to evaluate potential effects of changes in river flows, river stages, and reservoir elevations to water supply operations accessing water from the Missouri River.

The analysis evaluated how access to water supply would be affected by changes in river and reservoir conditions. As river flows and reservoir elevations fall below minimum operating requirements, intakes become unavailable to provide water to municipalities, Tribes, commercial operations and others. This in turn can require changes to how water supply providers access water including extending intakes or using submersible pumps on a temporary basis, which lead to an increase in costs for water supply providers. The river conditions analysis used outputs from H&H models developed by the USACE using specialized software to simulate river and reservoir operations for planning studies and decision support developed by the Hydrologic Engineering Center (HEC). HEC-RAS and HEC-ResSim data was used to provide a profile of river and reservoir behavior at locations that approximately corresponded to locations of water supply intakes, in the form of HEC-DSS flat files. River and reservoir behavior for each location were modeled over the POR.

The project team identified and evaluated 59 municipal and commercial intakes located along the Missouri River and its reservoirs that are expected to be operational during plan implementation for this analysis. For each of the intakes the project team evaluated the parameters described in Table 1. The NED analysis used the results river condition analysis: number of days below operating thresholds and the number of days below shut-down thresholds for each of the 59 intakes. The results were used to estimate changes in costs to water supply operations due to changes in river and reservoir operations from the MRRMP-EIS alternatives.

Table 1. Water Supply River Conditions Analysis Metrics

Metric	Performance Measure	Description
Metric 1 – Number of days river/reservoir levels fall below minimum access requirements for regular operation	Number of days	This measure is an estimate of the number of days in a calendar year that a water supply intake will not have access to water from either a river or reservoir. The focus of the metric is on operating conditions.
Metric 2 – Number of days river/reservoir levels falls below shutdown elevation.	Number of days	This measure is an estimate of the number of days in a calendar year that a water supply intake will not have access to water from either a river or reservoir. The focus of the metric is on shutdown conditions.

3.1 River Conditions Results

The primary purpose of the river conditions analysis was to better understand how each of the proposed alternatives might impact water supply access and to understand and describe the relationship between the Hydraulic and Hydrologic models and economic consequences. A summary of the river conditions analysis is discussed below for each alternative.

3.1.1 Alternative 1 – No Action (Current System Operation and Current MRRP Implementation)

Thirty-six of the 59 intakes experience adverse impacts associated with operating conditions under Alternative 1 with on average 71.4 days when water surface elevations fall below operating thresholds. In addition, 26 of the 59 intakes experience adverse impacts associated with shut-down elevations with on average 22.7 days per year when water surface elevations are below shut-down thresholds. Seasonal impacts modeled for Alternative 1 are summarized in Table 2. The table shows the highest number of impacts are incurring during the winter and fall months with the fewest impacts during the summer months.

Table 2. Alternative 1 River Condition Analysis – Seasonal Analysis

Alternative 1	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	35	34	31	24	36
Average Days Below Operating Thresholds	20.0	26.7	17.8	16.9	71.4
Number of Intakes Impacted in any year over the POR	25	21	21	17	26
Average Days Below Shut-Down Thresholds	7.5	8.7	6.6	4.7	22.7

The river condition analysis for the shut-down parameter for Alternative 1 is summarized in Figure 3 over the POR. The figure shows that in most years intakes in the upper and lower river are experiencing some impacts under Alternative 1. Many of these impacts are occurring during drought conditions such as during the 1930s, early 1960s and the 2000s. Many of these intakes are experiencing impacts related to degradation of the river bed, especially in the lower river. Degradation is discussed in more detail in the Section 3.2 of the FEIS.

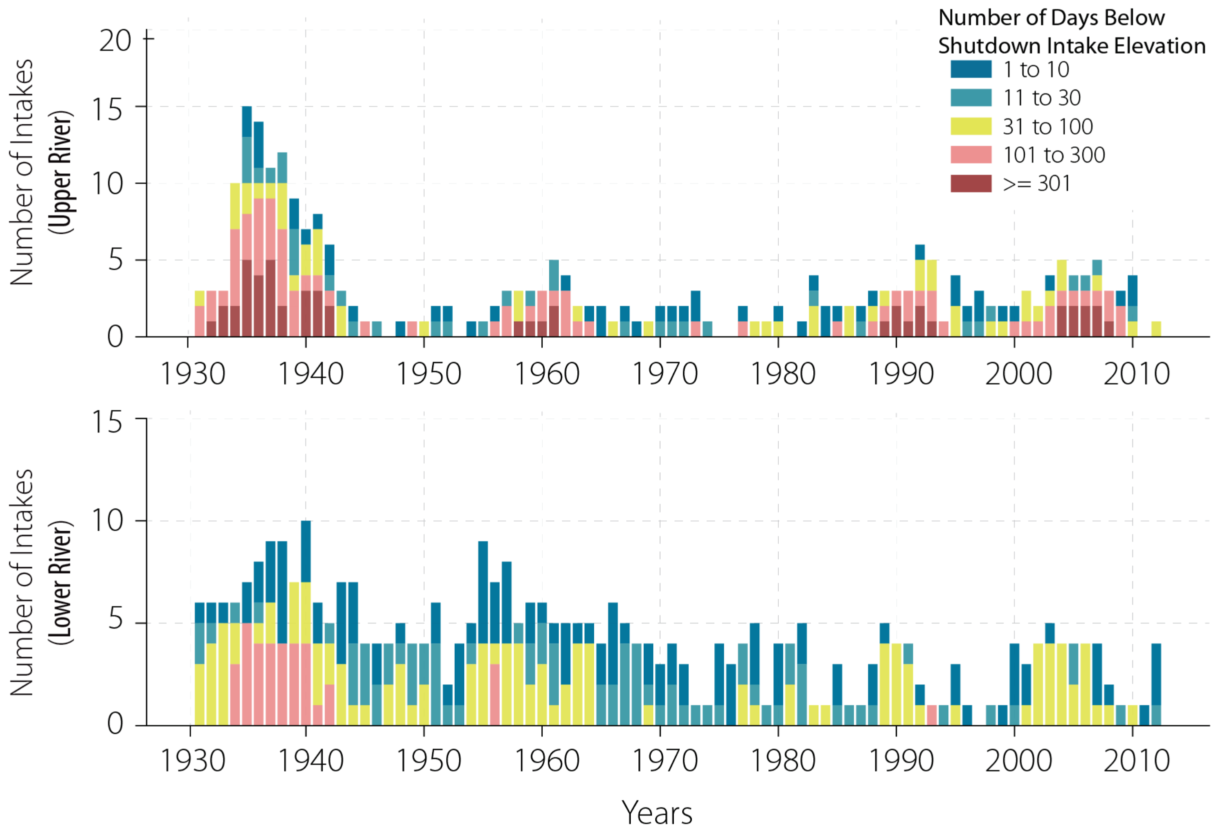

Figure 3. Number of Intakes and Days below Shut-Down under Alternative 1

3.1.2 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

The results of river conditions analysis on a seasonal basis is summarized in Table 3. Over the POR, thirty-seven intakes would experience impacts at some point under Alternative 2. On average, intakes would experience 69.7 days when water surface elevations fall below operating thresholds. There is one additional intake experiencing effects under Alternative 2 compared to Alternative 1. However, the average number of days below operating thresholds is slightly less under Alternative 2. In addition, 27 of the 59 intakes would experience impacts associated with shut-down thresholds under Alternative 2. On average, these intakes would experience 22.1 days when water surface elevations are below shut-down thresholds. This represents one additional intake showing impacts associated with shut-down thresholds with slightly less days of adverse impacts, on an annual basis. The impacts are highest during the winter and fall months but are slightly less than those under Alternative 1. Impacts in the summer months are slightly higher under Alternative 2 than under Alternative 1.

The river condition analysis for Alternative 2 are summarized in Figure 4 which shows the difference in the number of intakes and the days below shut-down conditions between Alternative 2 and Alternative 1 over the POR. The figure also distinguishes the intakes in the upper and lower river. Under Alternative 2, more intakes in the upper river have adverse impacts especially during modeled conditions (drought) similar to those in the 1930s and early

1960s. While additional intakes in the lower river also experience adverse conditions in several years, there are also a significant amount of years when intakes experience beneficial impacts in the lower river.

Table 3. Alternative 2 River Condition Analysis – Seasonal Analysis

Alternative 2	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	36	36	31	24	37
Change from Alternative 1	1	2	0	0	1
Average Days Below Operating Thresholds	19.3	25.3	17.8	17.4	69.7
Change from Alternative 1	-0.7	-1.3	-0.1	0.5	-1.7
Number of Intakes Impacted in any year over the POR	25	22	22	17	27
Change from Alternative 1	0	1	1	0	1
Average Days Below Shut-Down Thresholds	7.4	8.3	6.4	5.1	22.1
Change from Alternative 1	-0.1	-0.3	-0.3	0.4	-0.6

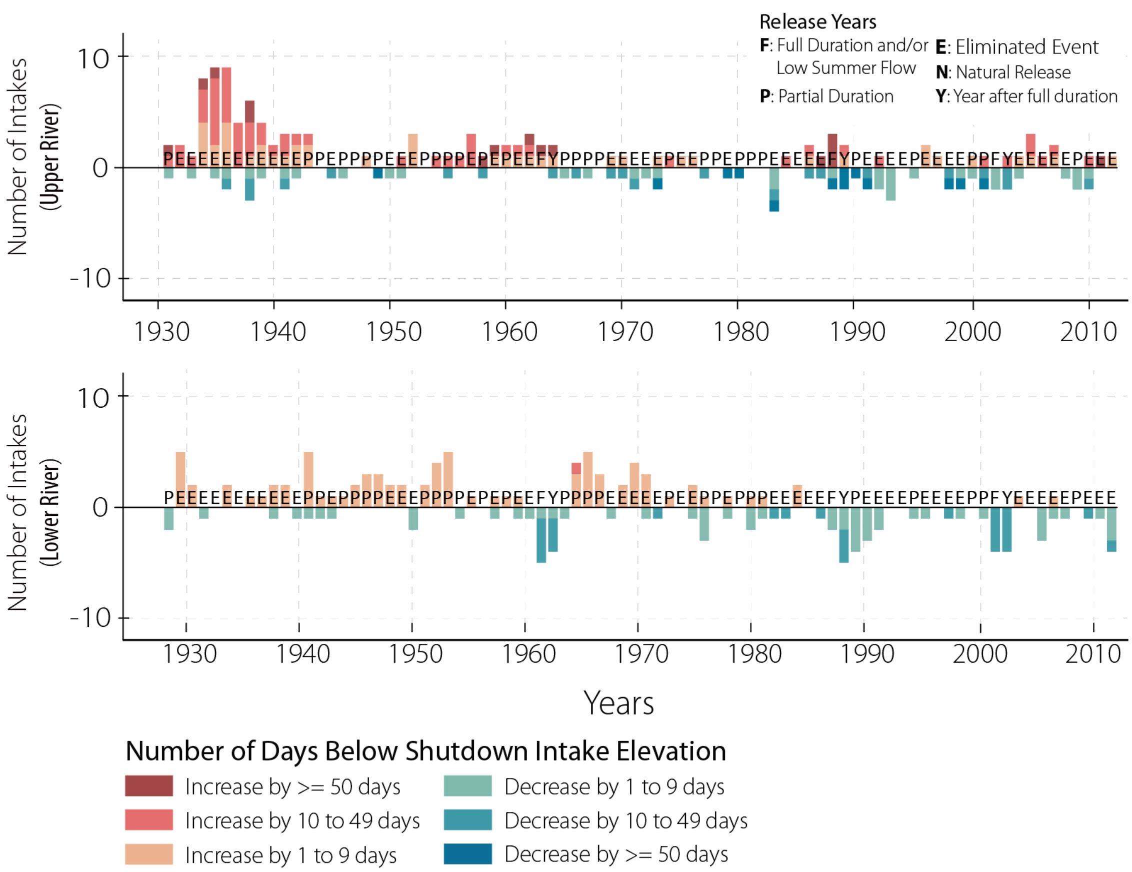

Figure 4. Number of Intakes with Changes in Number of Days below Shut-Down under Alternative 2 (Difference from Alternative 1)

3.1.3 Alternative 3 – Mechanical Construction Only

Over the POR, 36 intakes experience adverse impacts under Alternative 3. The average number days below operating conditions is 71.0, slightly less than under Alternative 1. Twenty-six intakes would experience adverse impacts associated with shut-down conditions with an average number of days below shut-down of 22.5, slightly less than Alternative 1. The seasonal impacts are summarized in Table 4. Under Alternative 3, impacts during the winter and fall appear to be higher than in the spring and summer with most seasons showing slightly lower number of days when water surface elevations are below operating thresholds compared to Alternative 1.

Table 4. Alternative 3 River Condition Analysis – Seasonal Analysis

Alternative 3	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	35	34	31	24	36
Change from Alternative 1	0	0	0	0	0
Average Days Below Operating Thresholds	19.8	26.6	17.8	16.8	71.0
Change from Alternative 1	-0.2	-0.1	-0.1	-0.1	-0.4
Number of Intakes Impacted in any year over the POR	25	21	21	17	26
Change from Alternative 1	0	0	0	0	0
Average Days Below Shut-Down Thresholds	7.4	8.6	6.6	4.6	22.5
Change from Alternative 1	-0.1	-0.1	0.0	-0.1	-0.2

Figure 5 summarizes the river conditional analysis for Alternative 3. This figure summarizes the difference between Alternative 1 and Alternative 3 in the number of intakes impacted and the number of days below shut down on an annual basis for both the upper and lower river. In both locations, the number of years with beneficial impacts is greater than the years with adverse impacts. More intakes in the upper river experience beneficial impacts in more years than intakes in the lower river, especially in drought years.

The one-time spawning cue test (Level 2) release that may be implemented under Alternatives 3 was not included in the hydrologic modeling for these alternatives because of the uncertainty of the hydrologic conditions that would be present if implemented. Hydrologic modeling for Alternative 6 simulates reoccurring implementation (Level 3) of this spawning cue over the wide range of hydrologic conditions in the period of record (POR). Therefore, the impacts from the potential implementation of a one-time spawning cue test release would be bound by the range of impacts described for individual releases under Alternative 6.

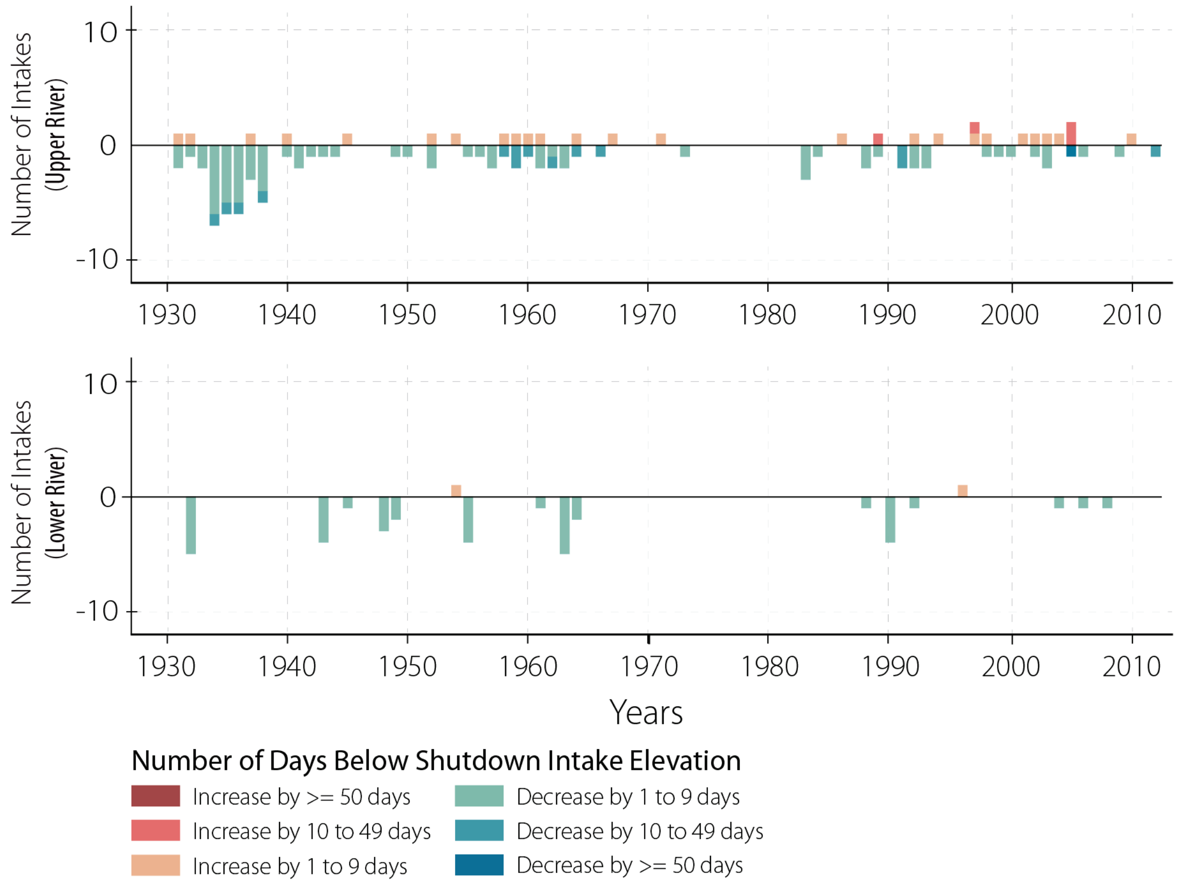

Figure 5. Number of Intakes with Changes in Days below Shut-Down Elevations under Alternative 3 (Difference from Alternative 1)

3.1.4 Alternative 4 – Spring ESH Creating Release

Over the POR, the one additional intake would experience impacts associated with operational thresholds in the winter under Alternative 4 as compared to Alternative 1 and the average number of days below operating conditions increases to 74.1; an increase of nearly three days on average. Twenty-eight intakes would experience adverse impacts associated with shut-down conditions with an average number of days below shut-down of 23.4; slightly higher than Alternative 1. The seasonal analysis is shown in Table 5. Impacts are slightly higher in all seasons under Alternative 4 with the exception of shut-down threshold during the spring season and the operating threshold in the winter which are the same as Alternative 1.

The river condition analysis for Alternative 4 is summarized in Figure 6. The figure shows that more intakes in the upper river are being adversely impacted under Alternative 4 relative to Alternative 1 than in the lower river. Though in both locations, the number of years with adverse impacts is greater than the number of the years of beneficial impacts. Impacts to intakes in the upper river are especially prevalent during the 1930s drought years.

Table 5. Alternative 4 River Condition Analysis – Seasonal Analysis

Alternative 4	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	35	35	31	24	36
Change from Alternative 1	0	1	0	0	0
Average Days Below Operating Thresholds	21.0	26.6	18.2	17.9	74.1
Change from Alternative 1	1.0	0.0	0.4	1.0	2.7
Number of Intakes Impacted in any year over the POR	26	22	23	19	28
Change from Alternative 1	1	1	2	2	2
Average Days Below Shut-Down Thresholds	8.0	9.0	6.6	4.9	23.4
Change from Alternative 1	0.5	0.3	0.0	0.3	0.7

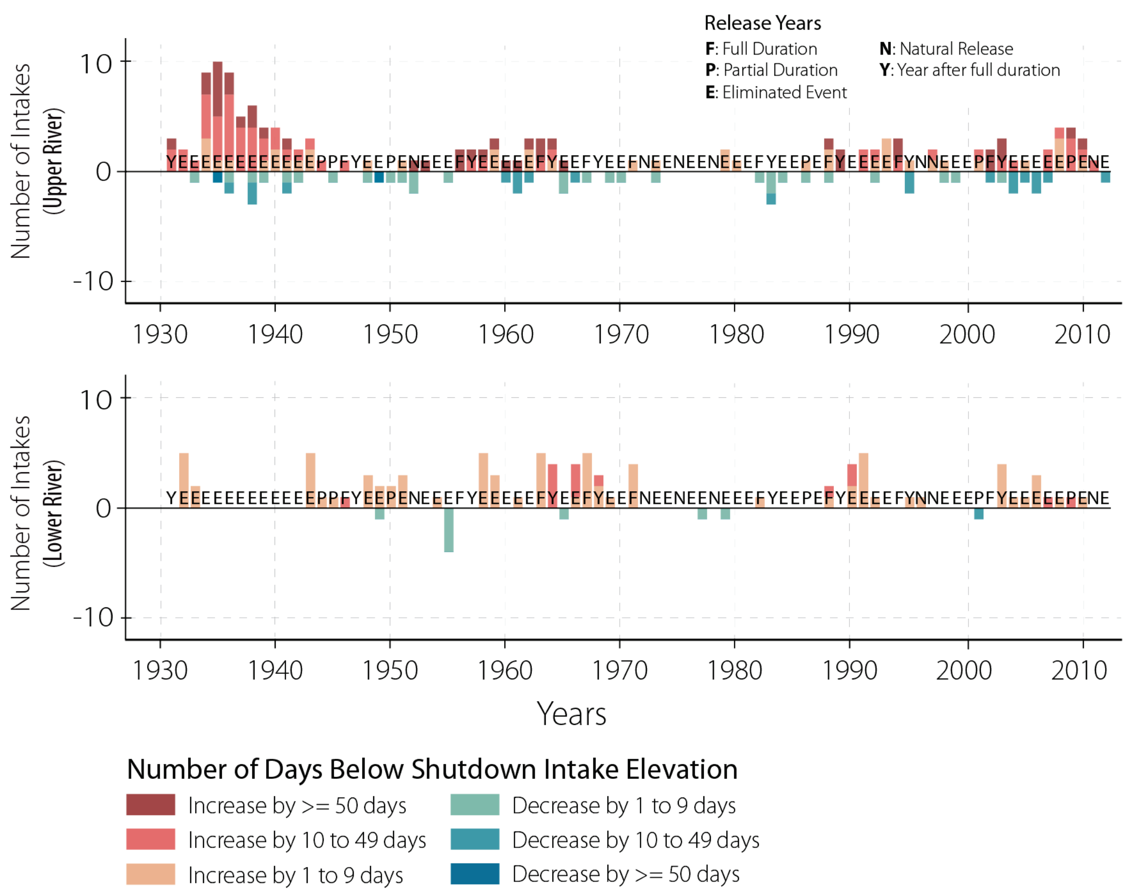

Figure 6. Number of Intakes with a Change in Days below Shutdown under Alternative 4 (Difference from Alternative 1)

3.1.5 Alternative 5 – Fall ESH Creating Release

Table 6 provides a summary of the river condition analysis for Alternative 5. Over the POR, one more intake would experience impacts associated with operational thresholds under Alternative 5 as under Alternative 1 (37) though the average number of days below operating conditions would decrease by 1.8 days to 69.6. Twenty-six intakes would experience adverse impacts associated with shut-down conditions with an average number of days below shut-down of 22.7, slightly less than Alternative 1. The seasonal analysis shows mixed results with some impacts increasing in certain seasons (winter) and decreasing in others (fall).

Figure 7 shows the annual impacts for intakes in both the upper and lower river. In both locations, the number of years with beneficial impacts is greater than the number of years with adverse impacts.

Table 6. Alternative 5 River Condition Analysis – Seasonal Analysis

Alternative 5	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	35	35	31	24	37
Change from Alternative 1	0	1	0	0	1
Average Days Below Operating Thresholds	19.8	26.0	18.0	17.0	69.6
Change from Alternative 1	-0.2	-0.7	0.2	0.1	-1.8
Number of Intakes Impacted in any year over the POR	25	20	21	17	26
Change from Alternative 1	0	-1	0	0	0
Average Days Below Shut-Down Thresholds	7.4	9.1	6.6	4.6	22.7
Change from Alternative 1	0.0	0.5	0.0	0.0	0.0

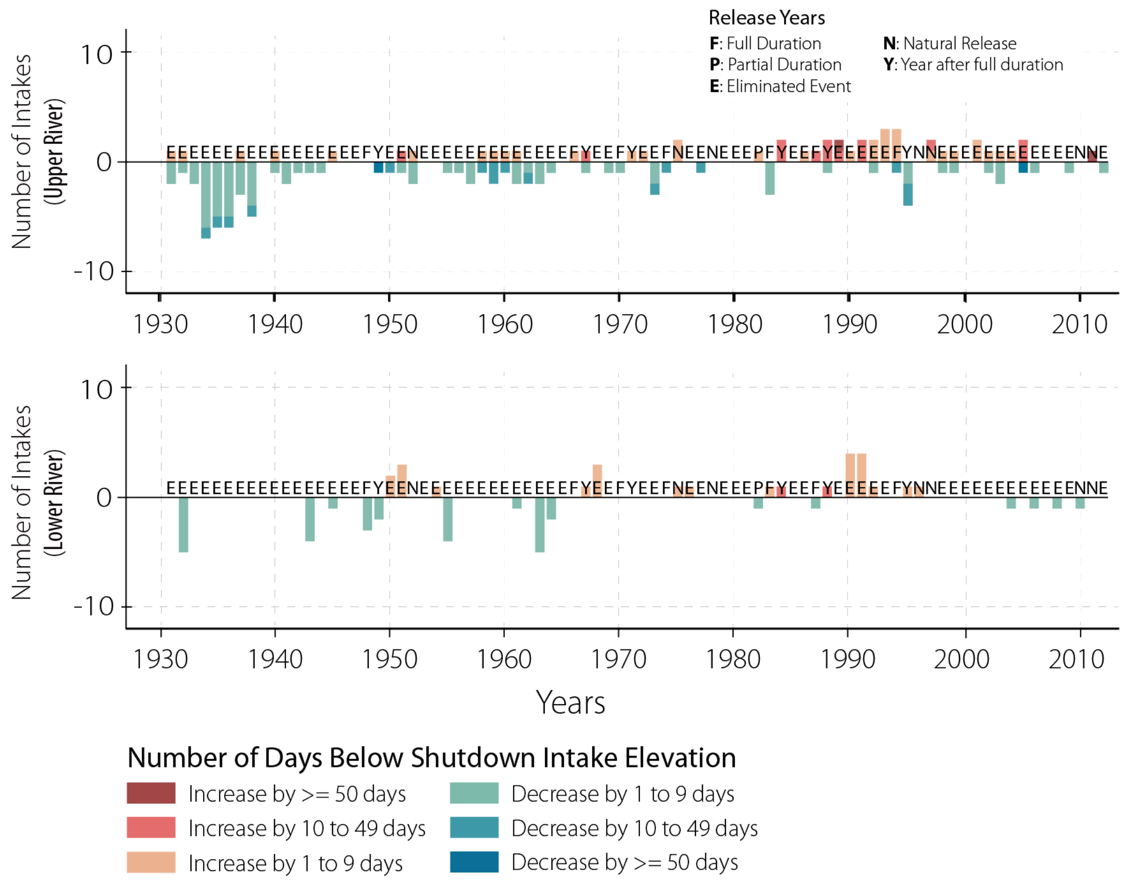

Figure 7. Number of Intakes with a Change in the Number of Days below Shut-Down under Alternative 5 (Difference from Alternative 1)

3.1.6 Alternative 6 – Pallid Sturgeon Spawning Cue

Over the POR, 36 intakes experience adverse impacts associated with operating conditions under Alternative 6, the same as Alternative 1. The average number days below operating conditions annually is 74.0 which is 2.6 days higher than under Alternative 1. Two additional intakes would experience adverse impacts associated with shut-down conditions under Alternative 6 with an average number of days below shut-down of 22.9, slightly higher than Alternative 1. Table 7 shows the seasonal analysis. In all seasons with the exception of the winter months, Alternative 6 shows slight increases in the number of days below operating thresholds compared to Alternative 1. For shut-down conditions, Alternative 6 results in a slight increase in days below shut-down conditions in the fall and summer and slight decreases in the winter and spring compared to Alternative 1.

Figure 8 shows the annual impacts for intakes in both the upper and lower river. In both locations, the number of years with adverse impacts is greater than the number of years with beneficial impacts. More intakes experience adverse impacts in the upper river, especially during the 1930s drought years than intakes in the lower river.

Table 7. Alternative 6 River Condition Analysis – Seasonal Analysis

Alternative 6	Season				Annual
	Fall	Winter	Spring	Summer	
Number of Intakes Impacted in any year over the POR	35	35	31	24	36
Change from Alternative 1	0	1	0	0	0
Average Days Below Operating Thresholds	20.6	26.6	18.6	17.8	74.0
Change from Alternative 1	0.6	0.0	0.7	0.9	2.6
Number of Intakes Impacted in any year over the POR	26	23	23	19	28
Change from Alternative 1	1	2	2	2	2
Average Days Below Shut-Down Thresholds	7.8	8.5	6.5	4.8	22.9
Change from Alternative 1	0.4	-0.2	-0.1	0.1	0.2

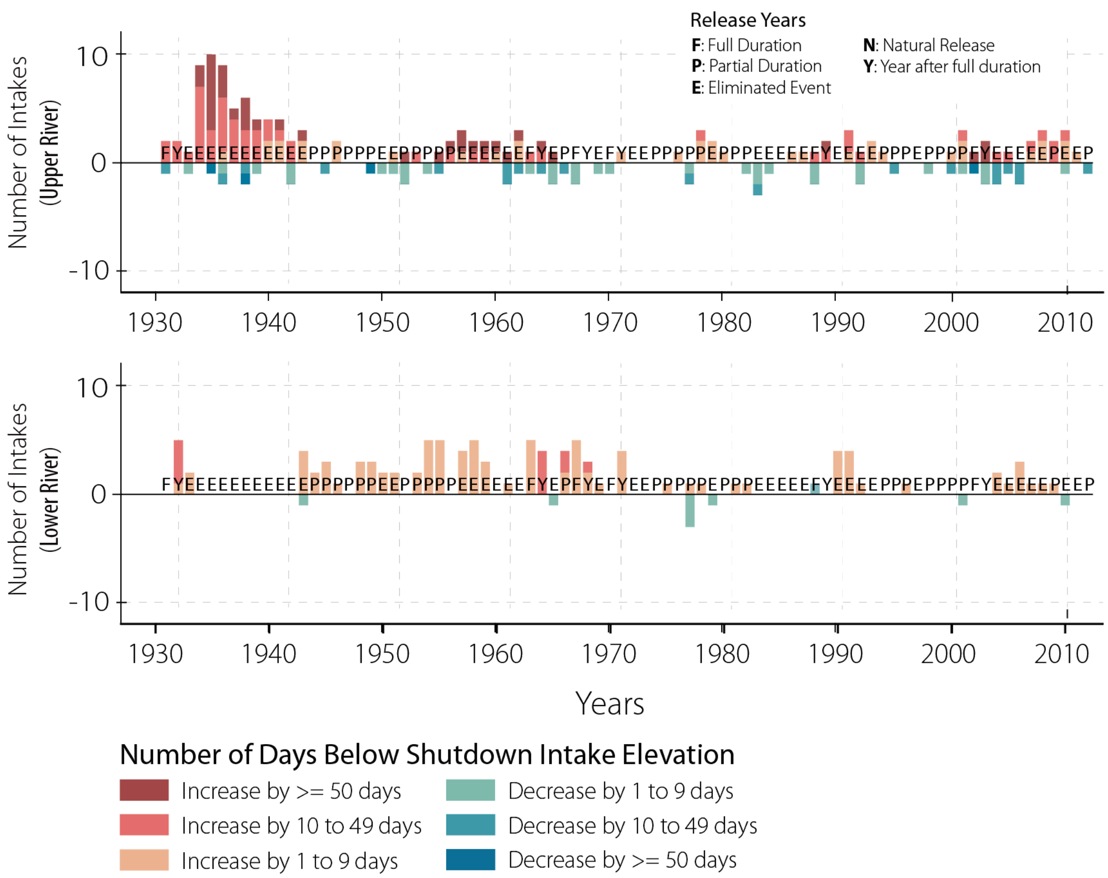

Figure 8. Number of Intakes with Changes in the number of Days below Shut-Down under Alternative 6 (Difference from Alternative 1)

4.0 Methodology

Water supply access is sensitive to changes in elevations of the Missouri River and reservoirs. As water flow/elevation falls below minimum access requirements, water intakes become unable to provide water for local municipalities, tribes, commercial operators, and others. Furthermore, a change in the cost of maintaining or operating intakes affects the residents and firms that rely on the intakes.

4.1 National Economic Development Approach

An Excel®-based economic analysis was developed that builds upon the river conditions analysis to evaluate the change in NED benefits for water supply access as a result of implementing the MRRMP-EIS alternatives. The NED analysis of water supply access was defined as changes in variable and fixed costs as a result of changing physical conditions along the Missouri River.

The river conditions analysis showed that water surface elevations would fall below both operating and shut-down elevations for many of the intakes evaluated under all the MRRMP-EIS alternatives as well as the Alternative 1. Modeling results for Alternative 1 indicate that water supply intakes, if they were to remain at existing elevations, would experience long-term, adverse impacts under continuation of current operations. These impacts would be due to frequent and prolonged instances when water surface elevations fall below critical operating thresholds (operating and shut-down). The modeling results show that 36 of the 59 intakes would experience on average 71.4 days when water surface elevations would fall below operating thresholds under Alternative 1. In addition, 26 of the 59 intakes would experience on average 22.7 days when water surface elevations are below shut-down elevations under Alternative 1. These impacts are occurring in both the upper and lower river and along riverine areas as well as reservoirs in the upper river though the reasons for these effects vary by location.

For the MRRMP-EIS alternatives, modeling results show that the annual average number of days that water surface elevations would fall below operating thresholds for water supply intakes would increase at most by three days across all the MRRMP-EIS alternatives compared to Alternative 1. The MRRMP-EIS alternatives would increase the annual average number of days below shut-down thresholds by less than one day. The project team concluded from the river conditions analysis that additional impacts would occur to water supply intakes under the MRRMP-EIS alternatives in various degrees but these impacts are considered incremental and temporary to those that are observed under the Alternative 1.

To support this assumption, the project team further evaluated how the MRRMP-EIS alternatives would impact river stage levels at certain points along the river. In other words, would any of the MRRP-EIS alternatives cause stage levels to fall below those experienced under Alternative 1. The implication is that if stages were lower under the MRRMP-EIS alternatives than under Alternative 1, water supply managers would likely consider additional intake improvements (extension or replacement). The project team reviewed the HEC-DSS[2] data to determine if stages were projected to be lower under any of the MRRMP-EIS

[2] Data Storage System.

alternatives for a sample of locations in the lower river (Sioux City, Jefferson City, Kansas City and St. Louis). Figure 9 summarizes the DSS data showing stage levels for Jefferson City for the years 1931–1942. Stage levels are lowest during these years over the POR for this location. The figure shows that at no point does any of the action alternatives cause stage levels to fall below those experienced under Alternative 1 at this location. Similar results are observed at the other locations evaluated. Additional figures are provided in Appendix A.

Given that the MRRMP-EIS alternatives are not expected to cause a decrease in river stages beyond those experienced under Alternative 1, it was concluded that the MRRMP-EIS alternatives would not result in additional intake modifications or replacements beyond what would be planned or undertaken under Alternative 1. Thus, the NED analysis for water supply access focused on estimating the incremental changes in operations under the action alternatives to address temporary increases in the number of days below shut-down or operational thresholds that would occur.

Interviews with water supply managers along with published information[3] provided some insight on how water supply managers may adjust to temporary changes in river or reservoir conditions, similar to those observed under the MRRMP-EIS alternatives. Operators indicated that when water surface elevations temporarily fall below operating elevations, submersible pumps can be used to pump water to collection basins or the intake and maintain operations. The project team used this information to estimate additional costs associated with conditions occurring under the MRRMP-EIS alternatives relative to Alternative 1 including the fixed and operating costs of submersible pumps needed to maintain operations at various water supply intakes along the river and reservoirs.

The NED analysis for water supply access was focused on the change in variable and fixed costs under each of the MRRMP-EIS alternatives to municipal and commercial water facilities. The following section explains the NED analysis in detail, including data sources and assumptions.

[3] A presentation provided by WaterOne dated August 15, 2007 indicates a temporary solution used to address low river flows was to rent pumps. This temporary approach was used prior to a $2 million investment in a low water level pumping facility could be completed (WaterOne 2007).

Figure 9. DSS Data showing stage levels under MRRMP-EIS Alternatives for Jefferson City, Missouri

4.1.1 Estimate Intake Capacity

In order to determine the size of the pumps that would be required at each intake location, the project team first needed to estimate the capacity of each of the 55 water supply intakes. Where possible, the project team obtained this information directly from water supply managers, especially commercial operators. Where this information was not available, the project team estimated daily water demand for each intake based on the population served which was obtained from the Master Manual and interviews with water supply operators and a daily per capita water usage rate. Per capita water usage rates were estimated for each state in the study area using data obtained from the U.S. Geological Survey (USGS 2000). For intakes where capacity values were unknown, the daily water use estimate was multiplied by the population served for each intake resulting in a daily capacity value.

4.1.2 Estimate Pumping Requirements for each Intake

Once the capacity for each intake was estimated, the project team used that information to determine the number and size of submersible pumps that would be needed to maintain each intake if water surface elevations fall below operating or shut-down levels under any of the alternatives. The project team contacted a manufacturing representative of Gorman-Rupp for information on their S-Series Submersible Dewatering Pumps (White 2016). These pumps come in a variety of sizes and horsepower and are routinely used for pumping water under conditions similar to those encountered by water supply managers along the Missouri River. Table 8 summarizes the pumps used for the analysis.

4.1.3 Estimate Pump Fixed Costs

The project team estimated an annual fixed cost for each pump used at each of the intakes. This fixed cost for each pump includes three components: (1) pump capital cost; (2) operations and maintenance (O&M) costs; and (3) permitting and regulatory requirements. Because it was assumed that the pumps would be used on a temporary basis (several days at a time), a daily fixed cost was estimated for each sized pump. The daily rate was estimated by annualizing the capital cost of each pump considering an average life expectancy of ten years, and a discount rate of ten percent.[4] This annual cost was then converted to a daily cost by dividing the annual rate by 365. The fixed cost for each pump also includes a cost for maintenance activities and environmental permits and regulatory requirements. These additional costs were estimated as ten percent of the annualized cost of the pumps. Table 8 summarizes the fixed costs for each pump size.

[4] This rate is expected to reflect the private cost of capital. In April 2018, the prime rate was estimated to be between 4.5 and 5.0 percent. Because the analysis is using a higher interest rate than the current private cost of capital, the fixed costs are higher than expected under current conditions. Using the higher interest rate may overstate the actual costs that would be incurred by operators but it does not change the comparison of alternatives because all are affected equally.

Table 8. Submersible Pumps Costs (2018 Dollars)

Submersible Pumps Model Number	Horse-power	Capacity (gpm)	Capital Cost (2018$) [a]	Useful Life	Daily Fixed Costs (2018$) [b]	Operations and Maintenance Costs (2018$) [c]	Environmental Permitting and Regulatory Costs (2018$) [c]
S4E1-E20	20	450	$13,333	8–12 years	$5.94	$216.99	$216.99
S4B1-E50	50	750–1,000	$19,997	8–12 years	$8.92	$325.44	$325.44
S6A1-E60	60	750–2,100	$23,056	8–12 years	$10.28	$375.22	$375.22
S6E1-E60	60	750–2,100	$29,256	8–12 years	$13.04	$476.13	$476.13
S12A1-E140	140	750–7,000	$31,169	8–12 years	$13.90	$507.26	$507.26

Notes: gpm = gallons per minute

a (White 2016)

b Daily fixed costs were calculated for each pump based on a 10-year life and discount rate of 10 percent.

c Estimated as ten percent of annual fixed costs.

Using the information on the intake capacity and the capacity of submersible pumps, the project team determined the appropriate size of pumps and number of pumps that would be needed to extend operations for each water supply intake. For some of the larger intakes, multiple pumps would be needed to extend operations.

4.1.4 Estimate Pump Variable Costs

After estimating the number and size of pumps for each water supply intake, the project team estimated the daily energy costs for each size pump. Based on the horsepower rating for each pump size, the team used the following calculation to show the energy requirements in watts:

$$1\ horsepower = 745\ watts$$

The number of hours each pump would operate was determined from the capacity of the pump and the amount of water that would need to be pumped per day. The calculation showing daily energy requirements per pump follows:

$$\frac{Water\ Amount\ (gallons)}{Pump\ Capacity\ (\frac{gallons}{hour})} * watts = watt/hours$$

The daily energy requirements were then converted to kilowatt/hours and multiplied by the average price for electricity ($/kWh) for the West North Central region of the United States as reported by the Energy Information Agency (EIA 2015). This resulted in an average energy cost per pump per day (2018 dollars).

4.1.5 Estimate Costs for Changing River Conditions under each Alternative

The project team used the variable and fixed costs for each pump with the river conditions analysis results to estimate the costs to access water under each alternative. As discussed above, the river conditions results indicated that several of the intakes evaluated would experience many instances when water surface elevations would fall below either operating or shut-down elevations under the Alternative 1. It is assumed that these operators would undertake some measures to modify or replace intakes that experience frequent operational impacts. However, in order to compare the MRRMP-EIS alternatives with Alternative 1, the project team applied the same assumptions of using submersible pumps when water surface elevations fall below operating conditions for Alternative 1. The costs were estimated using the following rules:

- For every day that water surface elevations fall below intake operating elevations, half of the daily energy costs per pump are applied (assumes intakes would still be operational when water surface elevations fall below operating thresholds but would not be as efficient)).
- For every day that water surface elevations fall below intake shut-down elevations, the daily energy costs per pump are applied.
- For every day that a pump is used, a daily fixed cost is applied.

These assumptions were applied to all 59 water supply intakes evaluated which resulted in an annual cost per alternative over the POR.

4.2 Regional Economic Development Methodology

The RED water supply evaluation included a qualitative discussion of impacts of the MRRMP-EIS alternatives. The project team utilized the results of the NED evaluation in describing potential RED effects. Because there were minimal changes in NED costs to access water for municipal and industrial (M&I) facilities, the analysis did not quantify potential changes in rates. However, because there is likely a small impact or an uncertain impact on rates, these impacts were described qualitatively.

4.3 Other Social Effects Methodology

Changes in water supply operations have a potential to cause other types of effects on individuals and communities. For example, if an alternative reduced or eliminated a facility’s ability to access the water, this could affect the local community in a number of ways, such as the community’s ability to grow and attract investment without a reliable water supply and a community’s sense of well-being. The water supply analysis used the results of the NED and RED analysis to determine the scale of impacts to the OSE account. Based on the NED and RED results, a qualitative assessment was included for other social effects to water supply. Data collected from water supply facilities and others was used to determine potential impacts to individual and community well-being, access to safe water sources, and economic vitality. Any changes to these areas of concern that would occur under MRRMP-EIS alternatives were examined to the extent possible. Any potential issues with water quality and treatment were considered a health and safety concern as well. Interviews with a sample of M&I water supply providers were conducted to inform the qualitative discussion of the social and public health effects possible under the MRRMP-EIS alternatives.

5.0 National Economic Development Evaluation Results

The NED analysis for water supply focused on the changes in operational and fixed costs as a result in changing physical conditions along the Missouri River. The results of the H&H modeling showed that water surface elevations would fall below both operating and shut-down elevations for many of the intakes evaluated under all the MRRMP-EIS alternatives including Alternative 1. The impact to water supply operators is an increase or decrease in costs associated with adapting to these changing conditions. Tables 9, 10, and 11 provide an overall summary of the NED analysis for each of the MRRMP-EIS alternatives. Table 9 summarizes the results for all of the water supply intakes in the basin over the POR. Total costs over this time period range from $47.4 million under Alternative 2 to $50.2 million under Alternative 4. Average annual costs range from $578,000 under Alternative 2 to $612,000 under Alternative 4. Relative to Alternative 1, Alternative 4 would result in the largest increase in costs (4.9 percent) or $28,000 greater on average per year, while Alternative 2 showed a reduction in average costs (1.0 percent) or just over $5,900.

Table 9. National Economic Development Analysis of MRRMP-EIS Alternatives to Water Supply Access (2018 Dollars)

All Locations	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Variable Costs	$39,904,978	$39,452,695	$39,657,152	$41,858,794	$39,986,483	$41,622,209
Fixed Costs	$7,982,099	$7,945,674	$7,935,662	$8,352,680	$7,997,534	$8,296,213
Total Costs	$47,887,077	$47,398,369	$47,592,815	$50,211,474	$47,984,017	$49,918,422
Difference in Total Costs from Alternative 1	NA	−$488,708	−$294,262	$2,324,397	$96,940	$2,031,345
Percentage Difference in Costs from Alternative 1	NA	−1.0%	−0.6%	4.9%	0.2%	4.2%
Annual Average Total Costs	$583,989	$578,029	$580,400	$612,335	$585,171	$608,761
Total Difference in Annual Average Costs from Alternative 1	NA	−$5,960	−$3,589	$28,346	$1,182	$24,772
Difference in Annual Costs per Intake	$9,898*	−$101	−$61	$480	$20	$420

Note: *Represents average annual costs for Alternative 1.

Table 10 summarizes the NED analysis for intakes in the upper river including Tribal intakes. Total costs ranged from $23.4 million under Alternative 3 to $25.2 million under Alternative 4. Relative to Alternative 1, Alternative 4 resulted in the greatest increase in costs (6.7 percent) or $19,300 on average per year. Alternatives 2 and 3 result in a small beneficial impact; reducing costs by one and 0.6 percent relative to Alternative 1.

Impacts of the MRRMP-EIS alternatives on intakes in the lower river varied slightly from those in the upper river as shown in Table 11. Intakes in the lower river tend to be larger in size than those in the upper river and these intakes experience higher costs when water surface elevations fall below operating thresholds. Total costs ranged from $23.9 million under Alternative 2 to $25.1 million under Alternative 6. Relative to Alternative 1, Alternative 6 resulted in the greatest increase in costs (3.5 percent) or $10,500 greater on average per year per intake in the lower river. Alternatives 2 and 3 resulted in a slight beneficial impact to water supply intakes in the lower river by lowering costs relative to Alternative 1.

Table 10. National Economic Development Analysis MRRMP-EIS Alternatives to Water Supply Access in the Upper River (2018 Dollars)

Upper Basin	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Variable Costs	$18,886,938	$18,796,947	$18,741,290	$20,194,641	$18,907,623	$19,850,562
Fixed Costs	$4,717,950	$4,727,615	$4,686,271	$4,992,950	$4,722,670	$4,923,685
Total Costs	$23,604,888	$23,524,562	$23,427,561	$25,187,591	$23,630,294	$24,774,247
Difference in Total Costs from Alternative 1	NA	−$80,326	−$177,327	$1,582,702	$25,405	$1,169,359
Percentage Difference in Costs from Alternative 1	NA	−0.3%	−0.75%	6.7%	0.1%	5.0%
Annual Average Total Costs	$287,864	$286,885	$285,702	$307,166	$288,174	$302,125
Total Difference in Annual Average Costs from Alternative 1	NA	−$980	−$2,163	$19,301	$310	$14,260
Difference in Annual Costs per Intake	$7,197*	−$24	−$54	$483	$8	$357

Note: *Represents average annual costs for Alternative 1.

Table 11. National Economic Development Analysis MRRMP-EIS Alternatives on Water Supply Access in the Lower Basin (2018 Dollars)

Lower Basin	Alt 1	Alt 2	Alt 3	Alt 4	Alt 5	Alt 6
Variable Costs	$21,018,040	$20,655,748	$20,915,863	$21,664,153	$21,078,859	$21,771,647
Fixed Costs	$3,264,149	$3,218,059	$3,249,391	$3,359,730	$3,274,864	$3,372,527
Total Costs	$24,282,188	$23,873,807	$24,165,254	$25,023,883	$24,353,723	$25,144,175
Difference in Total Costs from Alternative 1	NA	−$408,382	−$116,935	$741,695	$71,535	$861,986
Percentage Difference in Costs from Alternative 1	NA	−1.7%	−0.5%	3.1%	0.3%	3.5%
Annual Average Total Costs	$296,124	$291,144	$294,698	$305,169	$296,997	$306,636
Total Difference in Annual Average Costs from Alternative 1	NA	−$4,980	−$1,426	$9,045	$872	$10,512
Difference in Annual Costs per Intake	$15,585*	−$262	−$75	$476	$46	$553

Note: *Represents average annual costs for Alternative 1.

5.1 Alternative 1 – No Action (Current System Operation and Current MRRP Implementation)

Alternative 1 represents current System operations including a number of management actions associated with the MRRP and BiOp compliance. Management actions under Alternative 1 include creation of both shallow water habitat and ESH habitat and a spring plenary pulse or a bi-modal spring plenary pulse.

Modeling results under Alternative 1 indicate that if water supply intakes were to remain at their existing elevations they would experience long-term, adverse impacts compared to existing conditions. These impacts would be due to frequent instances when water surface elevations fall below critical thresholds (operating and shut-down). System operations under Alternative 1 would be the same as the current operations. However, as described in Section 3.1, Introduction, the impacts modeled do not account for the ability of water management to adapt to changing conditions on the System to serve authorized purposes, such as water supply. Also, the modeling does not account for what activities may be implemented in the future relative to bed degradation which may be influencing model results. This is because the 2012 river geometry used in HEC-RAS modeling reflects a level of bed degradation that was not present in prior years included in the POR analysis. These impacts are discussed in more detail in Section 3.2, River Infrastructure and Hydrological Processes, in the MRRMP-EIS. Given the frequency and duration of these periods where water surface elevations fall below critical operational thresholds, it is likely that water supply operators would need to make intake improvements, modifications, or relocation to adapt to changing conditions along the river. For more information on the impacts of bed degradation in the lower river please see *Missouri River Bed Degradation Study Technical Report* released by the USACE in May 2017.

The NED analysis for Alternative 1 is summarized in Table 12. Water supply intake operators along the Missouri River would incur an average annual cost of over $584,000 to adapt to changing conditions of the river. Average costs are higher in the lower river than in the upper river in part due to the size of the intakes, which would require larger pumps to move the required amount of water to the intake than for intakes in the upper river. Total annual costs for all 59 intakes evaluated range considerable over the POR from $78,300 to $2.3 million. The management actions that would occur under Alternative 1 would have negligible to small contribution to the costs to adapt to changing conditions on the Missouri River.

Table 12. Summary of National Economic Development Analysis for Alternative 1 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) [a]	$18,886,938	$21,018,040	$39,904,978
Total Fixed Costs (82-year POR) [b]	$4,717,950	$3,264,149	$7,982,099
Total Costs (82-year POR)	$23,604,888	$24,282,188	$47,887,077
Annual Average Total Costs	$287,864	$296,124	$583,989
Annual Average Total Costs per Intake	$7,197	$15,585	$9,898
Maximum Annual Costs	$765,490	$1,649,254	$2,326,102
Minimum Annual Costs	$52,816	$3,160	$78,345

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

5.2 Alternative 2 – USFWS 2003 Biological Opinion Projected Actions

The NED Analysis for Alternative 2 is summarized in Table 13. Water supply intakes along the Missouri River would incur on average a slight decrease in costs of $5,960 on average per year to adapt to changing conditions of the river relative to Alternative 1. Total annual costs range from $93,400 to $2.4 million. This represents an overall decrease in costs to access water of 1.0 percent over Alternative 1.

When evaluating the impacts of each of the MRRMP-EIS alternatives, it is helpful to examine the annual impacts. Figure 10 shows the annual NED impacts to water supply intakes in the upper and lower river. The graphic shows that intakes in the lower river are experiencing larger decreases in costs relative to Alternative 1 than intakes in the upper river. In five of the 82 years modeled, water supply access in the lower river would experience cost decreases of $90,000 or more relative to Alternative 1. These cost decreases are due to water surface elevations being higher than experienced under Alternative 1 during the fall or winter in certain years. These higher fall and winter flows correspond to years when there is a low summer flow. Water supply access in the upper river, including Tribal intakes also experience a smaller decrease in costs under Alternative 2. The difference in annual average costs from Alternative 1 for intakes in the upper river were −$980.

Table 13. Summary of National Economic Development Analysis for Alternative 2 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) a	$18,796,947	$20,655,748	$39,452,695
Total Fixed Costs (82-year POR) b	$4,727,615	$3,218,059	$7,945,674
Total Costs (82-year POR)	$23,524,562	$23,873,807	$47,398,369
Difference in Total Costs from Alternative 1	−$80,326	−$408,382	−$488,708
Percentage Difference from Alternative 1	−0.3%	−1.7%	−1.0%
Annual Average Total Costs	$286,885	$291,144	$578,029
Difference in Annual Average Costs from Alternative 1	−$980	−$4,980	−$5,960
Difference in Annual Costs per Intake	−$24	−$262	−$101
Maximum Annual Costs	$776,955	$1,651,173	$2,329,425
Minimum Annual Costs	$58,998	$6,272	$93,365

Notes:

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

Additional modeled results are shown in Figure 11. The differences in annual NED costs between Alternative 1 and 2 are plotted and color-coded based on the type of release occurring each year. This figure shows the results for water supply access in the lower river only. The results show that the greatest beneficial impacts to intakes in the lower river would occur in years when there is full release and a lower summer flow or the following years when a low summer flow event also would occur. These beneficial impacts are occurring during the winter or fall months when flows are slightly higher under Alternative 2 relative to Alternative 1 due to slightly higher System storage from the low summer flow events; during the winter and fall months, river flows tend to be at their lowest levels in the lower river. The beneficial impacts occurring in these years are outweighing adverse impacts occurring in other years resulting in an overall small decrease in costs.

Figure 12 shows the same data plot for intakes in the upper river for Alternative 2. There are less conclusive results of impacts to water supply access in the upper river. The results show beneficial impacts to water supply access during an eliminated release, year after full release and partial release relative to Alternative 1. However, the impacts would be much smaller than for intakes in the lower river. The annual increases in costs to access water in the upper river would be relatively small with the largest increase in annual costs of approximately $54,000 for all 40 intakes located in the upper river.

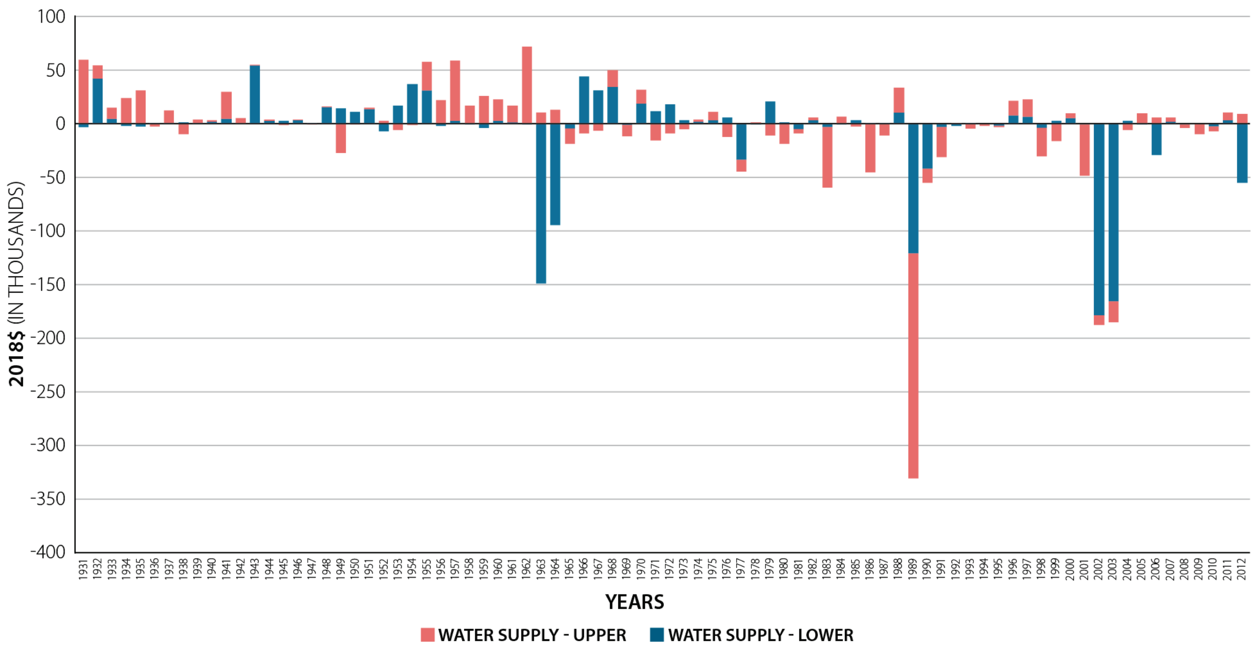

Figure 10. Annual Difference in Costs for Alternative 2 Relative to Alternative 1 for Intakes in Upper and Lower River (2018 Dollars)

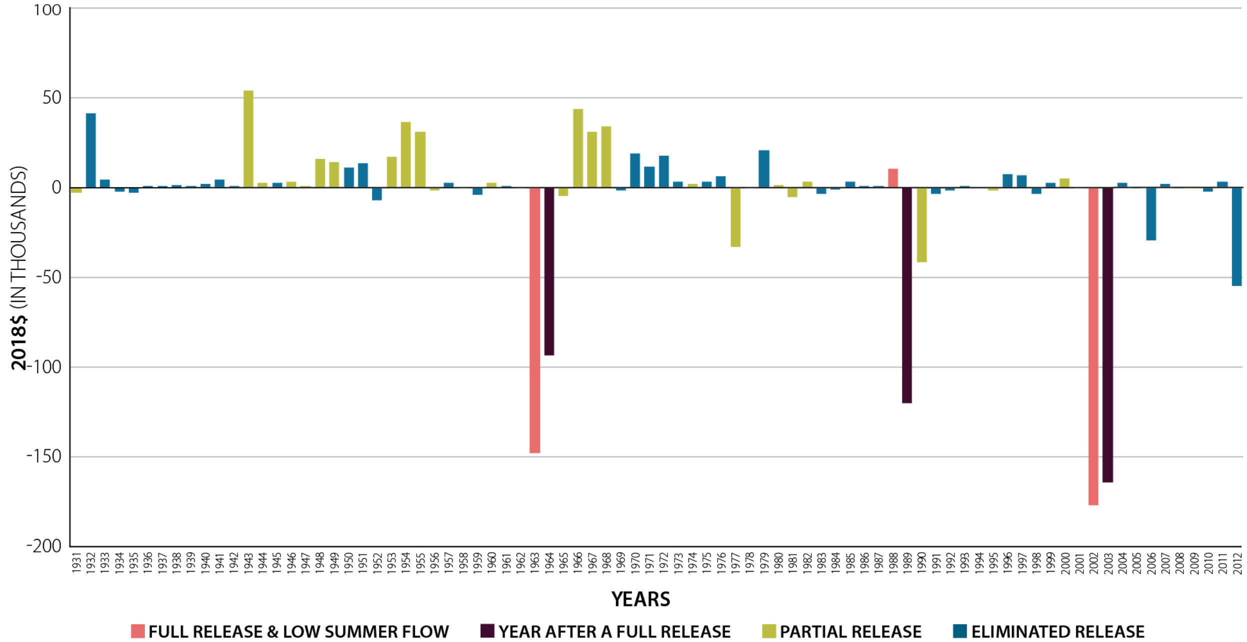

Figure 11. Difference Costs under Alternative 2 from Alternative 1 for Water Supply Access in the Lower River (2018 Dollars)

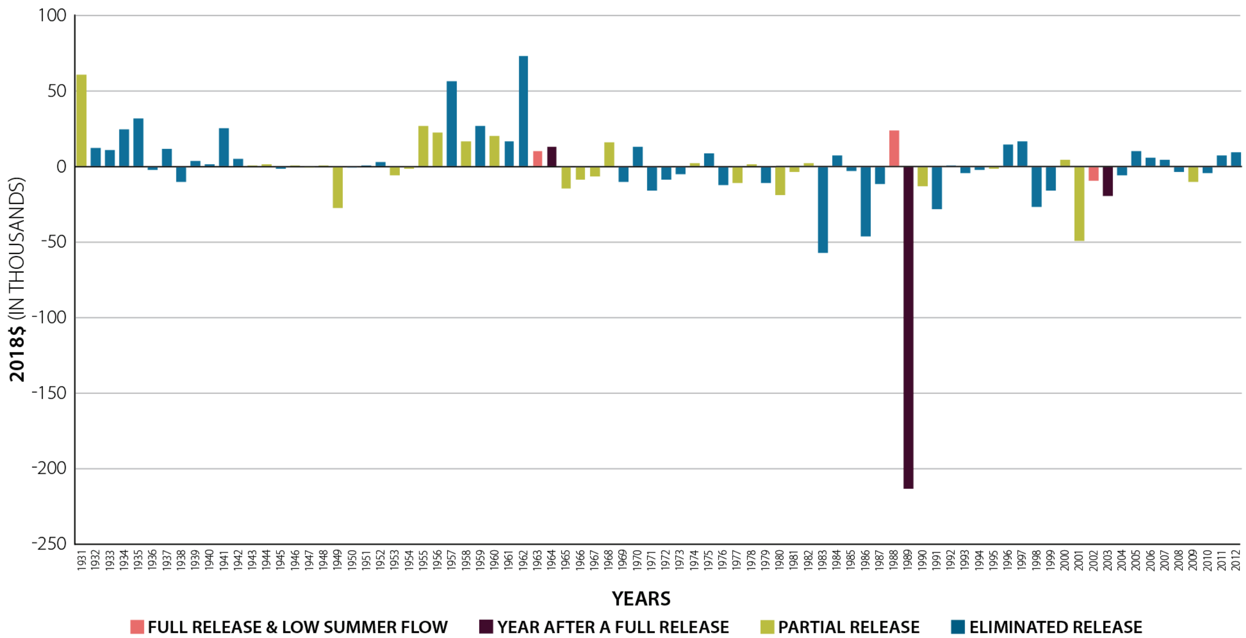

Figure 12. Difference in Costs under Alternative 2 from Alternative 1 for Water Supply Access in the Upper River (2018 Dollars)

5.3 Alternative 3 – Mechanical Construction Only

The NED results for Alternative 3 are summarized in Table 14. Overall, Alternative 3 would have a relatively small, beneficial impact on water supply access relative to Alternative 1. The modeling results show that intakes along the river would realize a decrease in average annual costs relative to Alternative 1 of $3,600 for all 59 intakes. Total costs for all water supply intakes would decrease by nearly $294,000 over the 82-year POR or a decrease of 0.6 percent from Alternative 1. More of the beneficial impacts would occur in the upper river.

Table 14. Summary of National Economic Development Analysis for Alternative 3 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) a	$18,741,290	$20,915,863	$39,657,152
Total Fixed Costs (82-year POR) b	$4,686,271	$3,249,391	$7,935,662
Total Costs (82-year POR)	$23,427,561	$24,165,254	$47,592,815
Difference from Alternative 1	−$177,327	−$116,935	−$294,262
Percentage Difference from Alternative 1	−0.75%	−0.5%	−0.6%
Annual Average Total Costs	$285,702	$294,698	$580,400
Difference in Annual Average Costs from Alternative 1	−$2,163	−$1,426	−$3,589
Difference in Annual Costs per Intake	−$54	−$75	−$61
Maximum Annual Costs	$765,156	$1,649,129	$2,325,851
Minimum Annual Costs	$54,597	$2,847	$73,840

Notes:

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

Figure 13 shows the annual NED impacts to water supply access in the upper and lower river. This graphic shows that intakes in both the upper and lower river are experiencing cost decreases in more years than cost increases for Alternative 3 relative to Alternative 1. In 61 of the 82 years modeled, water supply access in the upper river experience a decrease in costs while intakes in the lower river experience cost decreases in 29 years. Intakes in the upper river experience cost decreases greater than $5,000 in 13 of the 61 years with three years being greater than $15,000. Water supply access in the lower river appears to experience fewer beneficial impacts under Alternative 3 than intakes in the upper river. However, in four years the lower river intakes experience reductions in costs of greater than $15,000 relative to Alternative 1.

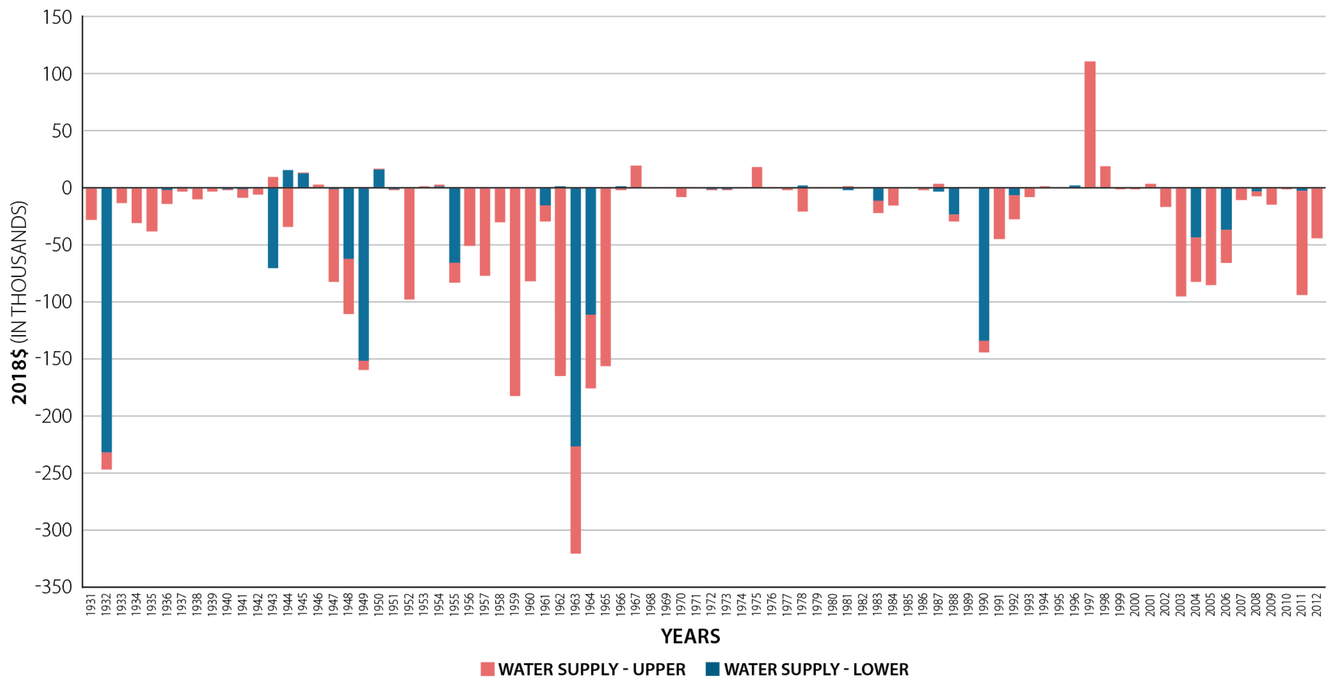

Figure 13. Annual Difference in Costs under Alternative 3 Relative to Alternative 1 for Water Supply Access in Upper and Lower River (2018 Dollars)

5.4 Alternative 4 – Spring ESH Creating Release

Alternative 4 focuses on developing ESH habitat through both mechanical and reservoir releases that would occur during the spring months. Both actions have the potential to affect water supply intakes. Alternative 4 is expected to have the largest, adverse impact on water supply intakes of any of the MRRMP-EIS alternatives.

The NED results for Alternative 4 are summarized in Table 15. On average, Alternative 4 results in adverse impacts on water supply access relative to Alternative 1. Over all locations, costs would increase by $28,300 on average per year an increase of 4.9 percent from Alternative 1. Alternative 4 has the largest impact on water supply access relative to Alternative 1 of any of the MRRMP-EIS alternatives and these impacts are occurring across both the lower and upper river. Annual costs range from $84,200 to $2.3 million.

Table 15. Summary of National Economic Development Analysis for Alternative 4 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) a	$20,194,641	$21,664,153	$41,858,794
Total Fixed Costs (82-year POR) b	$4,992,950	$3,359,730	$8,352,680
Total Costs (82-year POR)	$25,187,591	$25,023,883	$50,211,474
Difference from Alternative 1	$1,582,702	$741,695	$2,324,397
Percentage Difference from Alternative 1	6.7%	3.1%	4.9%
Annual Average Total Costs	$307,166	$305,169	$612,335
Difference in Annual Average Costs from Alternative 1	$19,301	$9,045	$28,346
Difference in Annual Costs per Intake	$483	$476	$480
Maximum Annual Costs	$782,299	$1,649,129	$2,342,390
Minimum Annual Costs	$54,597	$3,552	$84,205

Notes:

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

Figure 14 shows the annual NED impacts to water supply intakes in the upper and lower river. Change in average annual costs to water supply access relative to Alternative 1 is largest under Alternative 4 with intakes experiencing an increase in costs much more frequently under Alternative 4 than other MRRMP-EIS alternatives. The costs in the upper river are relatively large (greater than $50,000 in 18 years). Releases in combination with the onset of drought conditions similar to those in the 1960s and 2000s appear to result in the greatest increase in costs for water supply access. Differences in costs for water supply access relative to Alternative 1 under this alternative in the lower river over the POR range from a low of −$6,600 to a high of $78,500. Water supply access in the upper river is also experiencing increases in costs in over half the years during the POR relative to Alternative 1. Four of these years show an increase in costs greater than $100,000. Differences in costs for water supply access in the upper river over the POR would range from a low of −$25,000 to a high of $155,000.

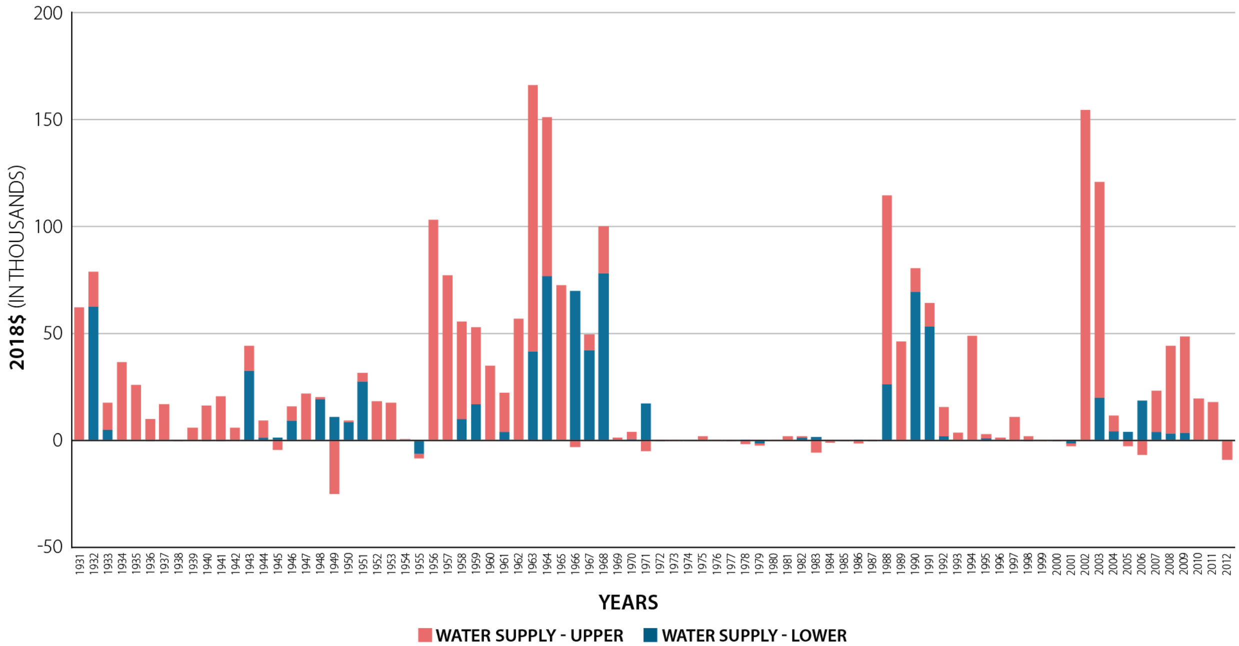

Figure 14. Annual Difference in Costs under Alternative 4 Relative to Alternative 1 for Water Supply Access in Upper and Lower River (2018 Dollars)

Figure 15 shows the difference in NED costs between Alternative 1 and Alternative 4 for the type of release occurring each year for the lower river. The results show that a year after a full release and years when releases are eliminated would result in the greatest increases in costs to access water in the lower river relative to Alternative 1. Impacts tend to occur during the winter or fall months when flows tend to be at their lowest levels in the lower river and the System is rebalancing to account for flow releases in the previous years.

Figure 16 shows the same data plot for intakes in the upper river for Alternative 4. Water supply access in the upper river appear to be affected most often under Alternative 4 during drought conditions (1930s, early 1960s, and mid-2000s). Drought conditions and its effects on reservoirs appear to be exasperated by a full release or the year after a full release. Full releases in the late 1950s and early 1960s, combined with drought conditions also appear to be driving increase in costs in the upper river. In the early 1990s and mid-2000s, again a full release event appears to cause adverse impacts to water supply access in the upper river. The adverse impacts are relatively large with the largest annual impact resulting in an increase in costs of approximately $155,000.

Table 16. Summary of National Economic Development Analysis for Alternative 5 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) [a]	$18,907,623	$21,078,859	$39,986,483
Total Fixed Costs (82-year POR) [b]	$4,722,670	$3,274,864	$7,997,534
Total Costs (82-year POR)	$23,630,294	$24,353,723	$47,984,017
Difference in Total Costs from Alternative 1	$25,405	$71,535	$96,940
Percentage Difference from Alternative 1	0.1%	0.3%	0.2%
Annual Average Total Costs	$288,174	$296,997	$585,171
Difference in Annual Average Costs from Alternative 1	$310	$872	$1,182
Difference in Annual Costs per Intake	$8	$46	$20
Maximum Annual Costs	$765,156	$1,649,129	$2,325,851
Minimum Annual Costs	$57,376	$4,063	$84,216

Notes:

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

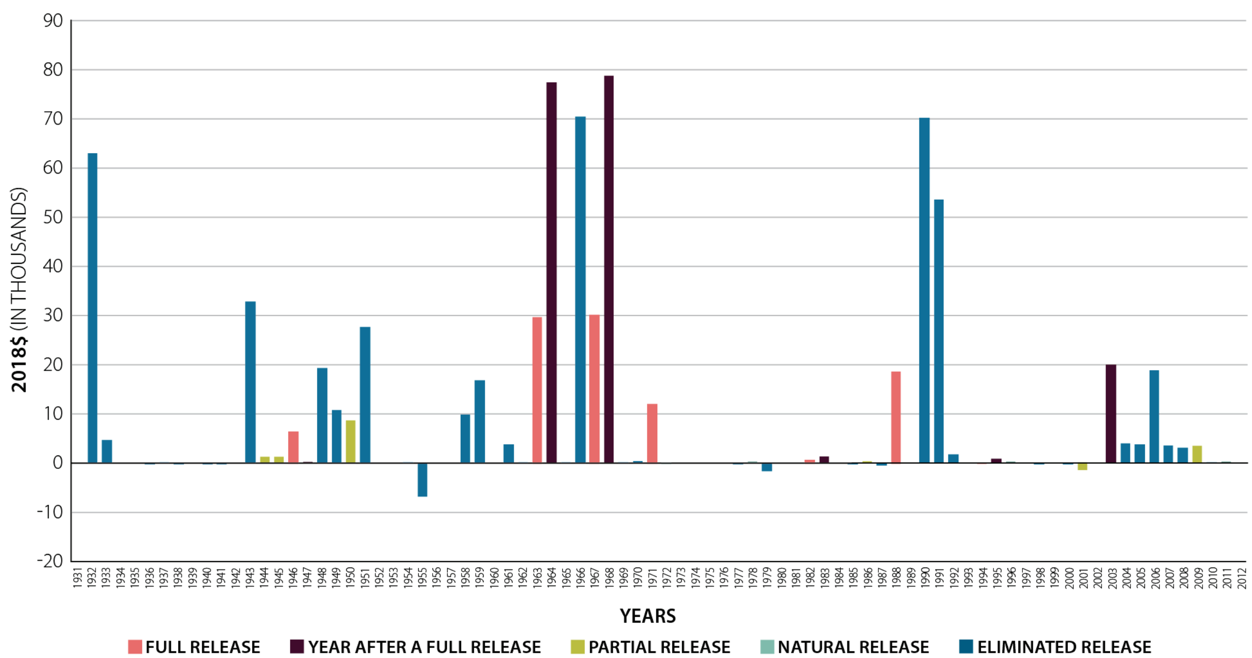

Figure 15. Difference in Costs under Alternative 4 from Alternative 1 for Water Supply Access in the Lower River (2018 Dollars)

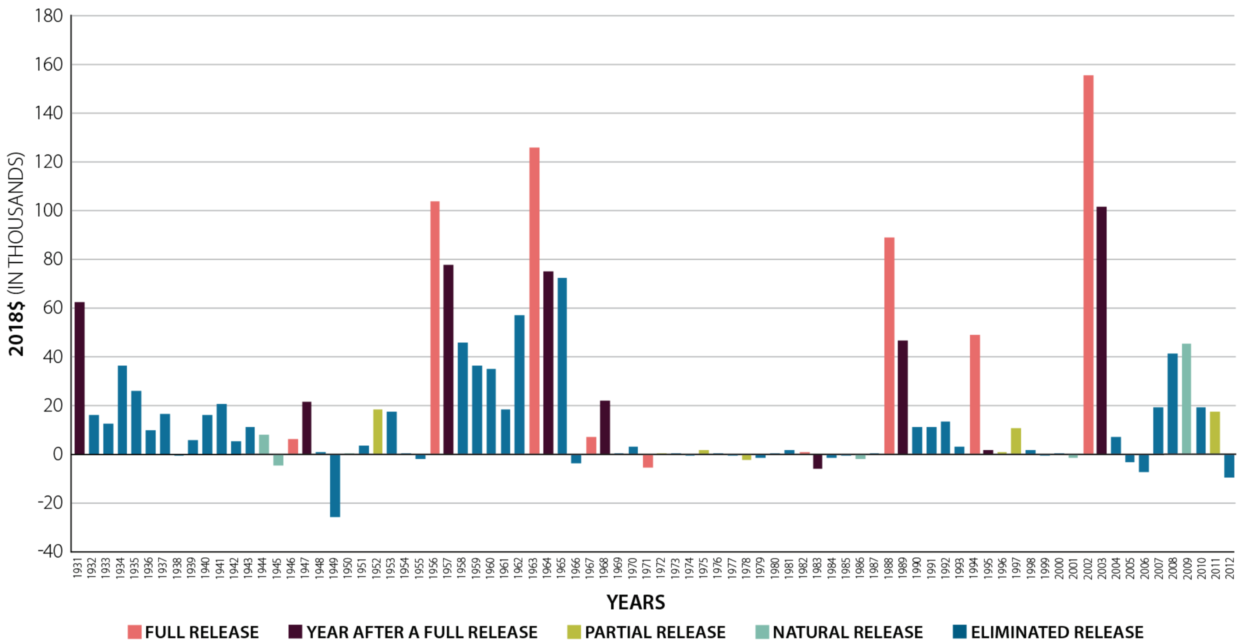

Figure 16. Difference in Costs under Alternative 4 from Alternative 1 for Water Supply Access in the Upper River (2018 Dollars)

5.5 Alternative 5 – Fall ESH Creating Release

Alternative 5 would focus on developing ESH habitat through both mechanical and reservoir releases that would occur during the fall months. Both actions have the potential to affect water supply intakes. The NED results for Alternative 5 are summarized in Table 16. Overall, Alternative 5 has a small, adverse impact on water supply intakes relative to Alternative 1. For all locations, average annual costs would increase by $1,200 or an increase of 0.2 percent from Alternative 1. Annual costs associated with adverse conditions along the river range from over $84,000 to $2.3 million under Alternative 5.

Figure 17 shows the annual NED impacts to water supply access in the upper and lower river. The graph shows that both the upper and lower river would experience about the same number years of cost increases as cost decreases under Alternative 5 relative to Alternative 1. Three years in the POR show cost decreases greater than $20,000 with the largest decrease occurring in 1949 of over $20,000.

Figure 18 shows the difference in NED costs between Alternative 1 and 5 for the type of release occurring each year in the lower river. The results show that the biggest adverse impacts are occurring in years when releases were eliminated or a year after a full release. However, cost decreases are also occurring in some years when releases are eliminated or a year after a full release; the magnitude of the cost decreases are not as great as the cost increases. Years when the largest adverse impacts are occurring (1951, 1990, and 1991) are due to the System rebalancing after events that occurred in previous years. Differences in annual costs for water supply access in the lower river ranged from a reduction in costs of $23,000 in 1932 to an increase in costs of $57,900 in 1990.

Figure 19 shows the same data plot for water supply access in the upper river for Alternative 5. Impacts to water supply access in the upper river are more adverse under Alternative 5 than in the lower river. Years with the greatest increase in costs occur in the late 1980s and early 1990s. Some of the years with the largest adverse impacts are occurring in years following a full release event and are the result of System rebalancing and changing reservoir elevations. In the late 1950s, early 1960s and mid-2000s, there are many years when eliminated releases are occurring and costs are higher for water supply access in the upper river under Alternative 5. Adverse impacts are relatively small with the largest impact resulting in an increase in annual costs of approximately $56,000 for intakes located in the upper river. Differences in annual costs over the POR range from a cost savings of nearly $25,700 in 1949 to a cost increase of $56,000 in 1995.

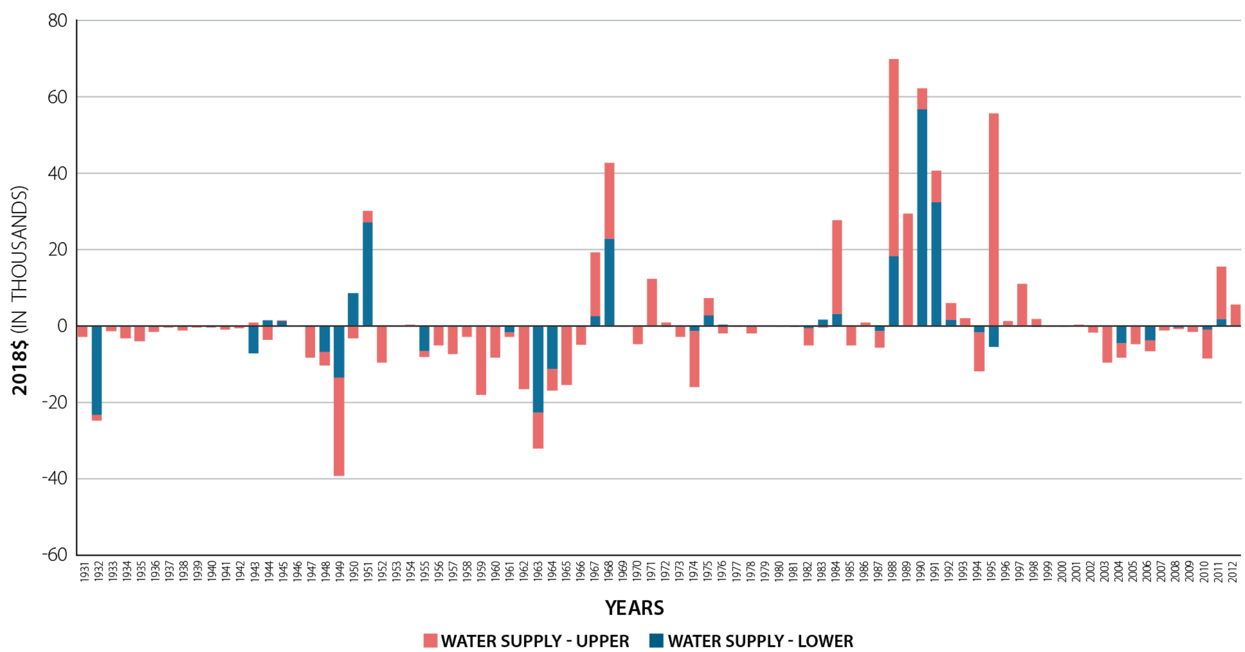

Figure 17. Annual Difference in Costs under Alternative 5 Relative to Alternative 1 for Water Supply Access in Upper and Lower River (2018 Dollars)

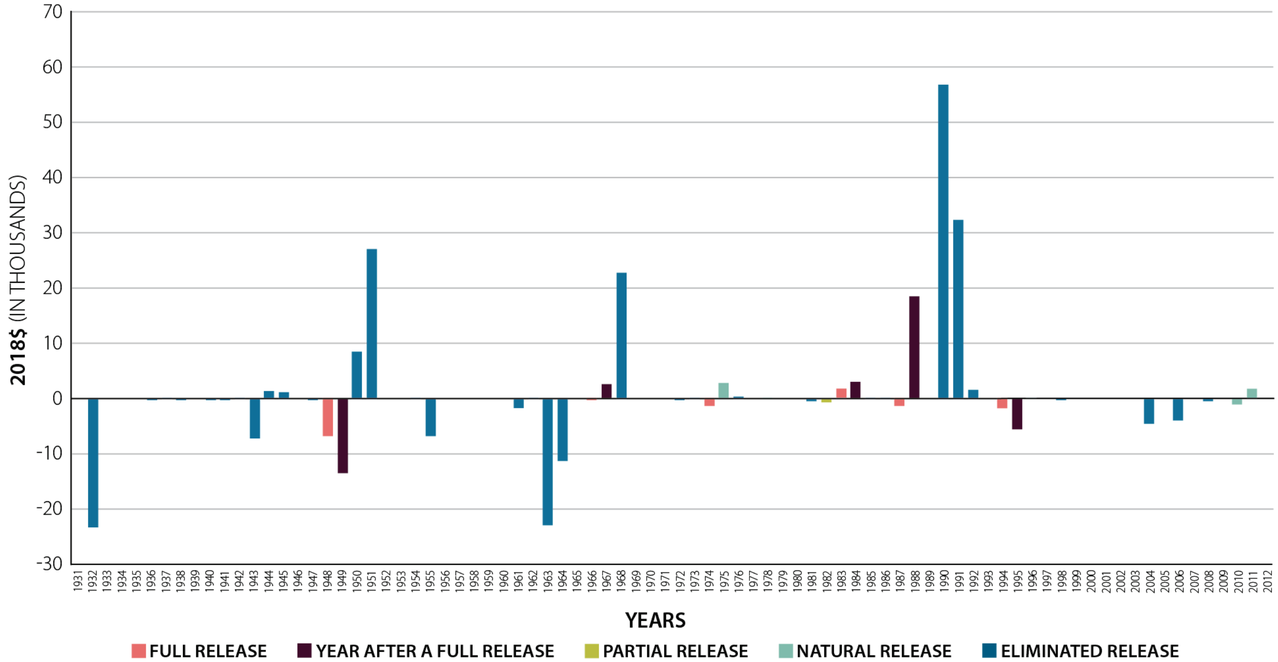

Figure 18. Difference in Costs under Alternative 5 from Alternative 1 for Water Supply Access in the Lower River (2018 Dollars)

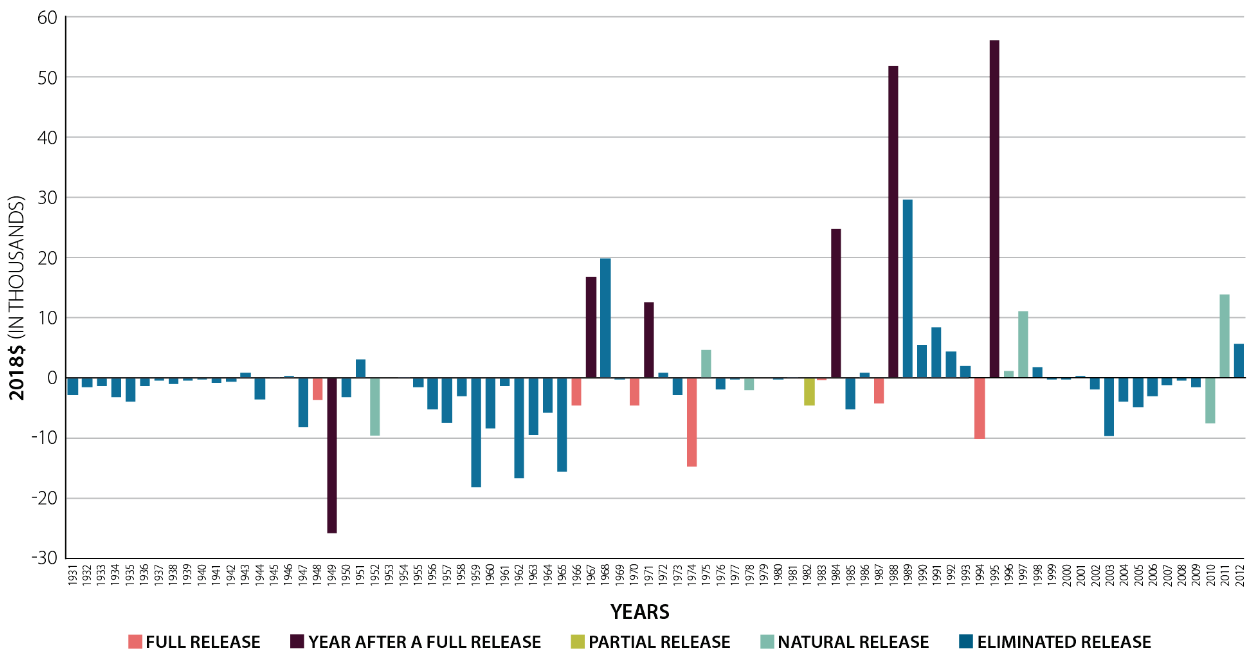

Figure 19. Alternative 5 Difference in Costs from Alternative 1 for Water Supply Access in the Upper River (2018 Dollars)

5.6 Alternative 6 – Pallid Sturgeon Spawning Cue

Alternative 6 includes actions that would develop ESH habitat through mechanical means and a spawning cue flow with bi-modal pulses that would occur in March and May. Both of these management actions have the potential to impact water supply intakes.

The NED results for Alternative 6 are summarized in Table 17. Overall, Alternative 6 has an adverse impact on water supply intakes relative to Alternative 1. For all locations average annual costs increase by $24,772 an increase of 4.2 percent from Alternative 1. Water supply access in both the upper and lower river experience increases in costs under Alternative 6. Annual costs range from over $77,000 to $2.3 million.

Table 17. Summary of National Economic Development Analysis for Alternative 6 (2018 Dollars)

Costs	Upper River	Lower River	All Locations
Total Variable Costs (82-year POR) [a]	$19,850,562	$21,771,647	$41,622,209
Total Fixed Costs (82-year POR) [b]	$4,923,685	$3,372,527	$8,296,213
Total Costs (82-year POR)	$24,774,247	$25,144,175	$49,918,422
Difference in Total Costs from Alternative 1	$1,169,359	$861,986	$2,031,345
Percentage Difference from Alternative 1	5.0%	3.5%	4.2%
Annual Average Total Costs	$302,125	$306,636	$608,761
Difference in Annual Average Costs from Alternative 1	$14,260	$10,512	$24,772
Difference in Annual Costs per Intake	$357	$553	$420
Maximum Annual Costs	$784,986	$1,649,129	$2,346,473
Minimum Annual Costs	$54,084	$4,063	$77,177

Notes:

a Variable costs in this context are those costs that change with amount of water that must be pumped at each intake.

b Fixed costs are those that do not change with pumping requirements and are based on the size and number of pumps being used on an annual basis at each intake.

Figure 20 shows the annual NED impacts to water supply access in the upper and lower river. The graph shows that water supply access in the upper and lower river are experiencing several years of cost increases under Alternative 6 relative to Alternative 1. Total annual costs range from a reduction in costs of nearly $25,000 to an increase in costs of over $140,700 for all intakes.

Figure 21 shows the difference in NED costs between Alternative 1 and 6 for the type of release occurring each year for intakes in the lower river. The results show that adverse impacts are occurring in years with all types of releases. The results also show adverse impacts to water supply access during years when releases are eliminated. One of the years with the largest adverse impacts is occurring the year after a full release (1968). However, the largest decrease in annual costs from Alternative 1 occurs in a year when there is a partial release (1977). Differences in annual costs for water supply access in the lower river range from a reduction in costs of $7,000 in 1977 to an increase in costs of $78,500 in 1968 relative to Alternative 1.

Figure 22 shows that access to water supply in the upper river appear to have more adverse effects under Alternative 6 than in the lower river. Similar to water supply access in the lower river, the impacts are associated with all the different types of releases. Costs increases are occurring in many more years than cost decreases relative to Alternative 1. Adverse impacts are resulting in an increase in costs on average per year of $14,300 for intakes located in the upper river. Differences in annual costs relative to Alternative 1 over the modeled POR range from a cost savings of $24,900 to an increase of nearly $117,000.

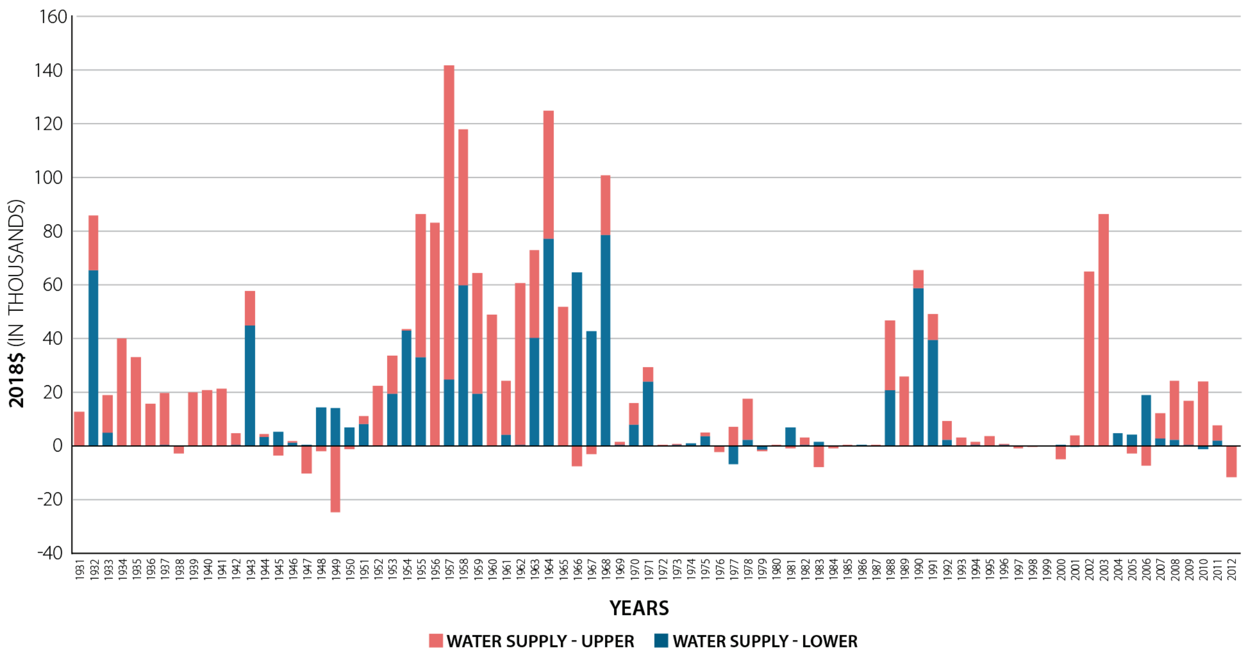

Figure 20. Annual Difference in Costs for Alternative 6 Relative to Alternative 1 for Water Supply Access in Upper and Lower River (2018 Dollars)

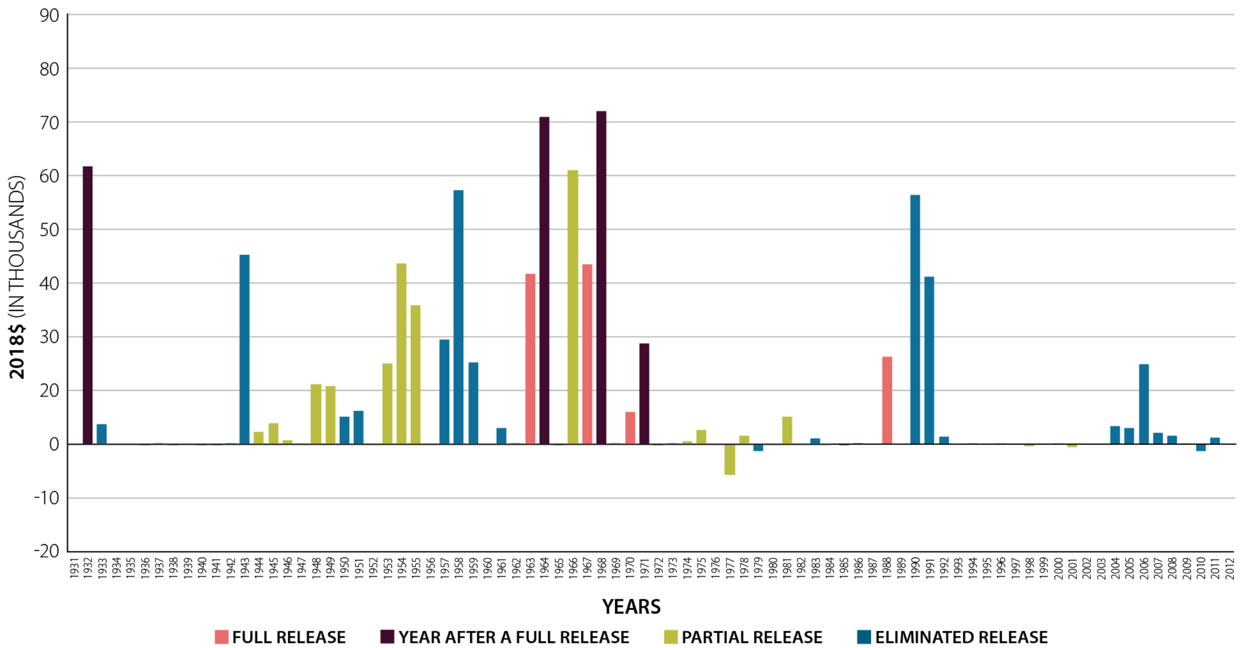

Figure 21. Difference in Costs under Alternative 6 from Alternative 1 for Water Supply Access in the Lower River (2018 Dollars)

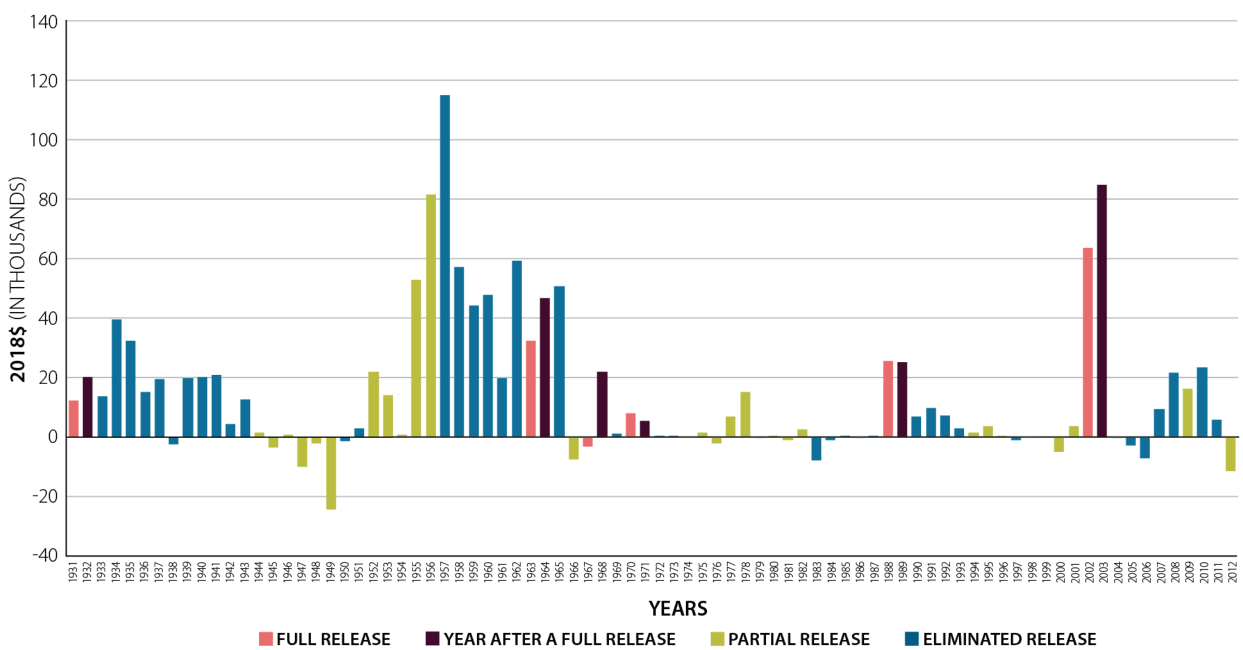

Figure 22. Difference in Costs under Alternative 6 from Alternative 1 for Water Supply Access in the Upper River (2018 Dollars)

6.0 Regional Economic Development Evaluation Results

The RED analysis focused on whether changes in costs to water supply intakes due to the MRRMP-EIS alternatives would have a measurable impact on water rates to local customers. A qualitative discussion of the RED impacts on water supply intakes is provided in Chapter 3 of the MRRMP-EIS.

7.0 Other Social Effects Results

The OSE analysis for water supply relied on the results of the NED and RED analysis to determine the scale of impacts that could occur to individual and community well-being, access to safe water sources, and economic vitality. A qualitative discussion of the OSE impacts on water supply intakes is provided in Chapter 3 of the MRRMP-EIS.

8.0 References

Institute for Water Resources, Hydrologic Engineering Center, Hydrologic Engineering Center River Analysis System (HEC-RAS) (http://www.hec.usace.army.mil/software/hec-ras/).

Institute for Water Resources, Hydrologic Engineering Center, Hydrologic Engineering Center Reservoir System Simulation (HEC-ResSim) (http://www.hec.usace.army.mil/software/hec-ressim).

U.S. Energy Information Administration, Table 5.6.A Average Price of Electricity to Ultimate Customers by End-Use Sector, by State, December 2015 and 2014 (Cents per Kilowatt-hour).

USFWS 2003. Amendment to the 2000 Biological Opinion on the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Bank Stabilization and Navigation Project, and Operation of the Kansas River Reservoir System.

USGS 2000 Estimated Used of Water in the United States in 2000. Table 5. Public Supply water withdrawals, 2000. Available at http://pubs.usgs.gov/circ/2004/circ1268/htdocs/table05.html

WaterOne 2007. Missouri River Bed Degradation and WaterOne's Intake Modifications, power point presentation, August 15, 2007,

White 2016. Personal Communication with Gregg White of Canyon Systems Inc. March 18, 2016.

Appendix A – Data Storage System Graphics

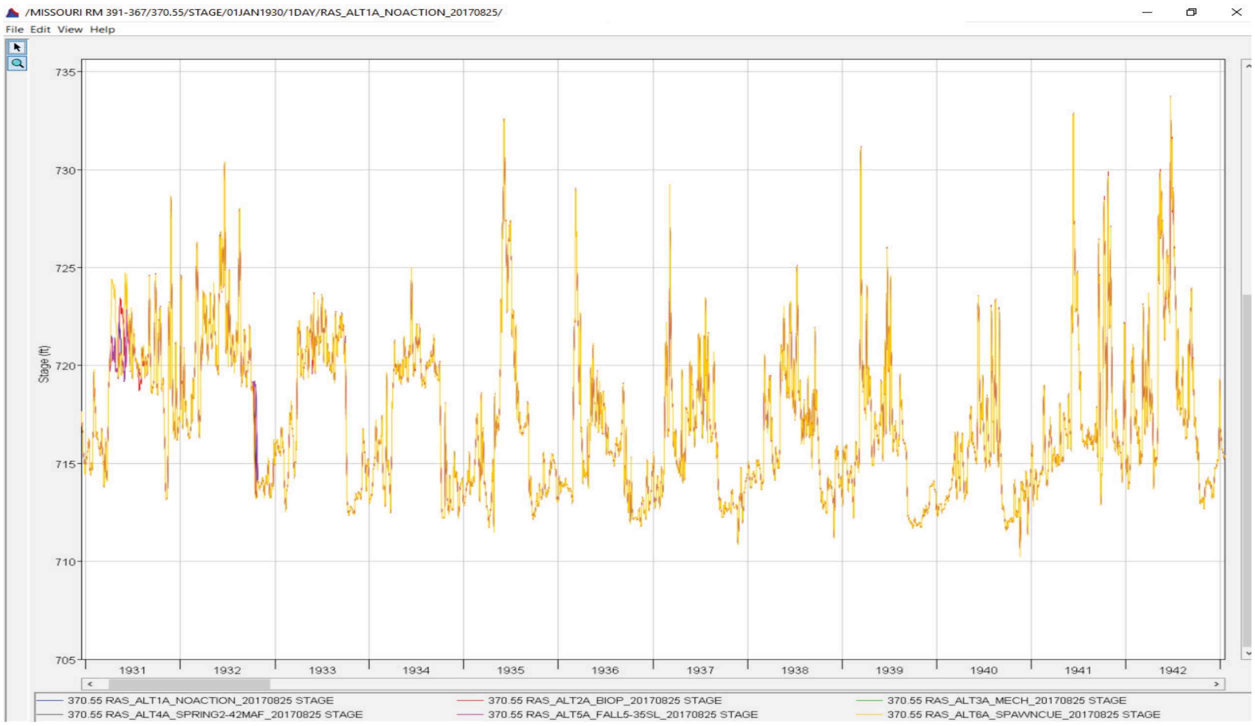

Figure A-1. Stage Levels for MRRMP-EIS Alternatives 1931–1942 for Kansas City, Missouri

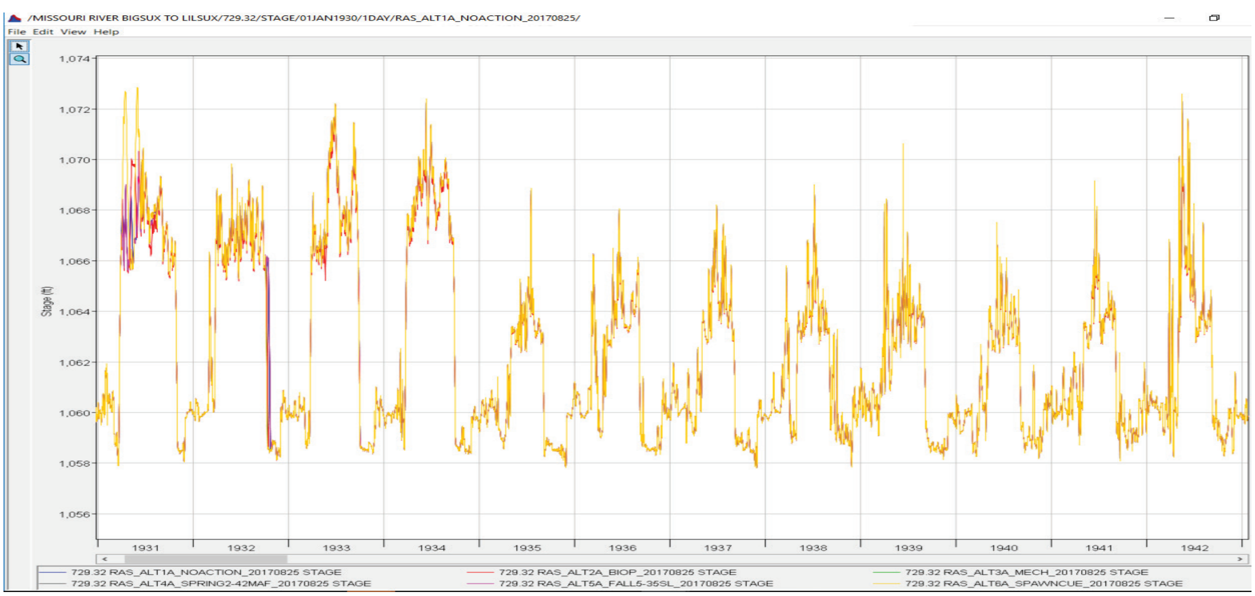

Figure A-2. Stage Levels for MRRMP-EIS Alternatives 1931–1942 for Sioux City, Iowa

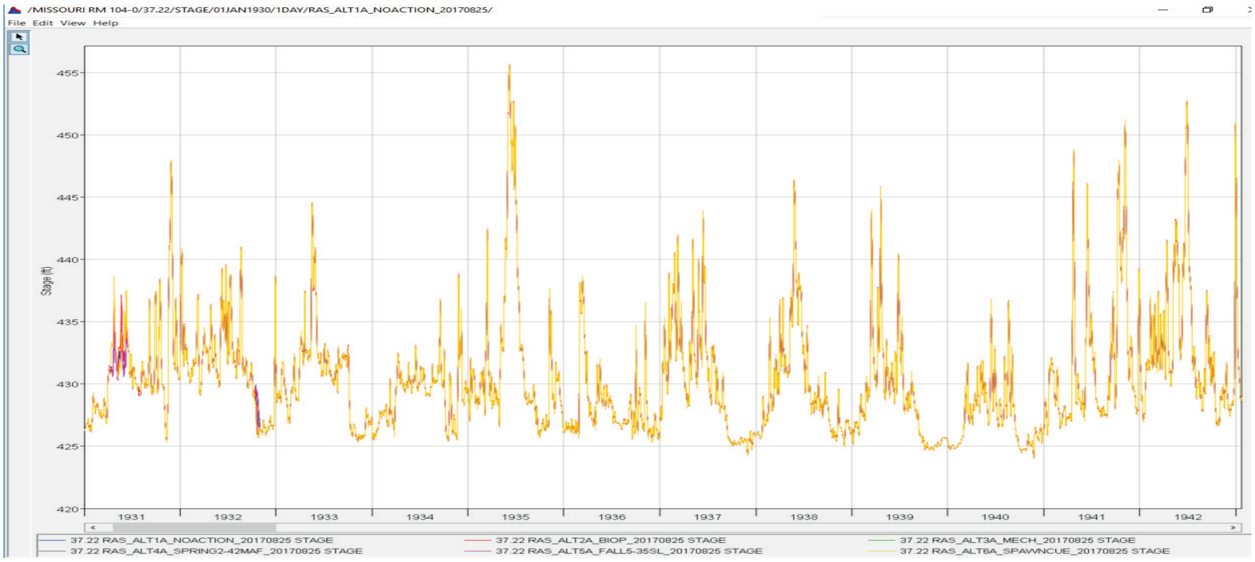

Figure A-3. Stage Levels for MRRMP-EIS Alternatives 1931–1942 for St. Louis, Missouri