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

COLORADO RIVER BASIN IMPORTS AND EXPORTS TECHNICAL MEMORANDUM

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Purpose

The Seven Colorado River Basin States (Seven States) have authorized Colorado River Water Consultants (CRWC) to provide a Technical Evaluation of Options for Long-Term Augmentation of the Colorado River System (Project). This Technical Memorandum (TM), one of a series of TMs being prepared as part of the Project, presents results of an evaluation of the technical feasibility of importing water from adjacent drainage basins into the Colorado River Basin (Basin).

Scope

The TMs are the second step in an iterative process to develop, screen, and evaluate long-term water supply augmentation options. The TMs build upon and expand on preliminary studies developed during the initial weeks of the evaluation process.

Based on input received during the October 2, 2006 Expert Panel Workshop and the October 20, 2006 Technical Committee meeting, it was determined that the information presented in the Imports and Exports White Paper sufficiently addressed the concepts presented in that paper. Therefore, this TM will not further elaborate on the previously evaluated concepts, but will instead break down the summary of historic exports from the Basin and evaluate the feasibility of additional concepts for importing water into the Basin. Specifically, this TM will focus on the following:

- This TM will provide a more detailed listing of exports by summarizing the historic exports of each of the main diversion projects within the Basin.

- This TM will not evaluate ways to reduce Basin exports because options for reducing exports are being evaluated as stand alone concepts in other TMs.

- This TM will evaluate the following concepts for increasing Basin imports:

    1) Divert from the Snake River in Wyoming to North Horse Creek, which is a tributary near the headwaters of the Green River.

    2) Divert from the Bear River in Utah or Wyoming to Ham's Fork Creek, which is tributary to the Green River.

    3) Divert from Clark's Fork of the Yellowstone River in Wyoming or Montana to the headwaters of the Green River.

4) Divert from the Mississippi River downstream of the Ohio River to the Navajo River (evaluated for benchmarking purposes).

Findings

Table ES-1 summarizes the findings of this TM.

Table ES-1
Summary of Findings Related to Water Import Options

Parameter	Findings
Location of Supply	Snake River, Bear River, Clark's Fork of the Yellowstone River, and the Mississippi River downstream of the Ohio River.
Quantity of Water Potentially Available	33,000, 50,000, 75,000, and 675,000 acre feet per year (AFY) from the Snake, Bear, Clark's Fork, and Mississippi Rivers, respectively.
Water Quality	Water quality from all sources considered is generally good and in some cases excellent.
Technical Issues	River diversions, pipes, pumps and tunnels are all well established technologies. However, each alternative would require new high voltage power supplies in relatively remote locations.
General Reliability of Supply	Reliability of the supply depends primarily on the water rights and interstate compact agreements made.
Environmental Issues	Environmental issues include the effect of reduced river discharge on biological communities, especially anadromous fish species, and impacts due to construction of facilities.
Permitting Issues	Extensive permitting would be required. Key permit issues may include construction within National Forests and obtaining a favorable record of decision on the Environmental Impact Statement.
Cost	Capital and annual cost information is presented in Section 3 of this TM. An independent memorandum calculates the unit cost of these alternatives and compares the findings to other augmentation concepts.

Conclusions

If the costs presented herein are competitive with other options being investigated, the institutional and environmental feasibility of these concepts should be investigated.

1.0 INTRODUCTION

1.1 Overview

This section describes Project objectives, briefly discusses the program framework within which the evaluation of long-term augmentation options is proceeding, and presents overall Project methodology. Also provided is a brief description of how this TM is organized, a list of abbreviations and acronyms used, and information about the references cited herein.

1.2 Project Rationale (Objectives)

Separate studies and investigations have projected an increase in demands for Colorado River system water and a reduction in long-term runoff of the Colorado River. As part of their proactive response to this scenario, the Seven States have authorized CRWC to provide a technical evaluation of long-term augmentation options. The States will supplement the technical evaluations with legal, administrative, and/or institutional considerations. All phases of the evaluation are being conducted in close coordination with the States and with the two regional offices of the U.S. Bureau of Reclamation (Bureau).

1.3 Other Ongoing Water Management Efforts

The evaluation of long-term options focuses on both previously-identified concepts and applications of new technology or management options. The evaluation was begun in parallel with the Bureau's development of Lower Basin Shortage Guidelines and Coordinated Management Strategies for Lake Powell and Lake Mead under Low Reservoir Conditions. It also should be noted that each of the Seven States has comprehensive water management programs. Concepts being developed under these independent programs will not be evaluated through the Seven States process.

1.4 Methodology

Evaluation of options is an ongoing and iterative process. In the first phase of the evaluation, White Papers were generated for 12 potential long-term augmentation options developed by CRWC in concert with the Seven States. In parallel with White Paper preparation, the CRWC team met with representatives of each State, the Bureau's two regional offices, and other interested parties. A password-protected Project Website was developed, an Expert Panel was convened, and a workshop was held with the Project's Technical Committee. The workshop focus was on the 12 White Paper options and three additional options suggested by the Expert Panel. Grouped by the purpose they achieve and the benefit provided, the initial options were:

- Firm up supply/reduce shortages: Conjunctive use, reservoir evaporation control, vegetation management, weather modification, stormwater storage, and additional storage.

- New supplies. Basin imports/reduction of exports through exchanges, brackish water desalination, coal bed methane produced water, seawater desalination, and water imports using ocean routes.

- Increase water use efficiency/exchange. Reduction of power plant consumptive use, agricultural and urban water reuse, agricultural and urban transfers, and accelerated urban water conservation.

During the workshop with the Technical Committee and a subsequent meeting with the Project Principals, six options were selected for more detailed evaluation at the TM level: brackish water desalination, conjunctive use, ocean water desalination, stormwater management, river imports and exports, and vegetation management. This TM describes an evaluation of the technical feasibility to import water from other drainage basins into the Colorado River Basin.

1.5 Technical Memorandum Organization

This TM is organized by the following sections:

- Executive Summary
- Introduction
- Technical Discussion of Alternatives
- Costs

1.6 Abbreviations and Acronyms

The following abbreviations and acronyms are used in this TM.

AF	acre-foot
AFY	acre-feet per year
Basin	Colorado River Basin
Bureau	United States Bureau of Reclamation
CDWR	California Department of Water Resources
Cfs	cubic feet per second
CRA	Colorado River Aqueduct
CRWC	Colorado River Water Consultants
M&I	municipal and industrial
MWD	Metropolitan Water District of Southern California
n/a	not applicable
O&M	operations and maintenance
Project	Technical Evaluation of Options for Long-Term Augmentation of the Colorado River System
RO	reverse osmosis
Seven States	Seven Colorado River Basin States

SWP	California State Water Project
TM	technical memorandum
U.S.	United States

1.7 References

Wyoming State Engineer's Office, 1973: Wyoming Water Planning Program.

Wyoming State Engineer's Office, 1972: Water and Related Land Resources of the Big Horn River Basin, Wyoming.

Snake River Compact, 1949: Idaho and Wyoming Interstate Compact.

Sunrise Engineering, 2003: Snake/Salt River Basin Plan for the Wyoming Water Development Commission.

Shields, John, Interstate Streams Engineer for the Wyoming State Engineers Office, November 28, 2006 phone conversation with Klint Reedy, lead author of the Colorado River Basin Imports and Exports Alternatives Technical Memorandum.

Prairie, James R., Hydraulic Engineer for the United States Bureau of Reclamation Upper Colorado Region, 1971-2006: Upper Basin Consumptive Uses and Losses Spreadsheet.

United States Bureau of Reclamation Lower Colorado River Water Accounting, 1986-2002: Lower Basin Decree Accounting Spreadsheet.

United States Geological Survey - http://waterdata.usgs.gov/nwis/, 2006: Daily Stream Flow Recordings.

Black & Veatch, 2006: Unit Cost Memorandum for the Multi-Basin Water Supply Investigation prepared for the Northern Colorado Water Conservancy District.

DeLorme Topo 6.0, 2006: Electronic USGS Topographic Mapping Software.

2.0 TECHNICAL DISCUSSION

2.1 Overview

This section presents the evaluation criteria and summarizes the findings presented in the preliminary studies of Colorado River Basin Imports and Exports. The potential options were evaluated with respect to location of supply, quantity of available water, water quality, technical issues, reliability, environmental and permitting issues, and cost.

The Technical Committee determined that the preliminary studies on Basin Imports and Exports provided sufficient information on the import concepts evaluated. The preliminary study findings are summarized in Table 2-1.

Table 2-1
Summary of Preliminary Findings Related to Imports and Exports Option

Parameter	Findings
Location of Supply	Columbia River, Klamath River, Snake River, Missouri River, or the Great Lakes are potential locations of supply.
Quantity of Water Potentially Available	The Snake River may have less than 1 million AFY of available water. All other identified sources are expected to have a minimum of 1.3 million AFY potentially available.
Water Quality	All identified sources have high quality water suitable for municipal water use. Impacts of varying water qualities on aquatic species would need to be further evaluated.
Technical Issues	All of the potential projects identified herein include the construction and long term operation of very large infrastructure systems, which could provide challenges. However, similar facilities have been constructed in the past and continue to be operated.
General Reliability of Supply	The reliability of all supplies could be limited by in-stream flow requirements and intergovernmental agreements.
Environmental Issues	Extensive environmental evaluations typical of all large infrastructure projects would be required.
Permitting Issues	Multi-State and Federal permits would be required for a large transbasin diversion project. Historically, these permits have proven difficult to acquire for similar projects.
Cost	Present worth costs of the water supplies were not calculated. The most affordable project identified requires an initial capital investment of $5 billion and annual costs of $25 million. The most expensive project identified requires $35 billion in initial capital and annual costs of $900 million.

2.2 Detailed Listing of Basin Exports

Table 2-2 summarizes exports of water from the Upper Basin by state for the years 1971 through 2004. As shown in Table 2-2, Colorado has the greatest number and quantity of diversions and has historically averaged roughly 500,000 AFY of diversions while New Mexico operates only one diversion and averages approximately 90,000 AFY.

Table 2-3 summarizes exports of water from the Lower Basin by state for the years 1986 through 2002. As shown in Table 2-3, California has the greatest quantity of diversions and has historically averaged roughly 4,500,000 AFY while annual diversions by Mexico averaged approximately 2,500,000 AFY. Future diversions by California will be somewhat lower as California's Colorado River Water Use Plan limiting diversions to 4,400,000 AFY in normal years, when water apportioned to but unused by Arizona and Nevada is not available, is now in effect.

It should be noted that the information presented in Tables 2-2 and 2-3 is based on data provided by the Bureau's Upper Colorado Regional Office and Lower Colorado Regional Office. Because these are two different offices with different data management systems, the readily available historic periods are different. However, both tables provide an accurate summary of historic diversions over the past several decades.

Table 2-2
Upper Colorado River Basin - Export Summary[1]

State	Diversion Facility	Average Annual Diversion (AFY)	Maximum Annual Diversion[2] (AFY)	Minimum Annual Diversion[2] (AFY)	Percent State Total
Colorado	Alva B. Adams Tunnel	228,553	293,373	158,095	46
	Roberts Tunnel	59,209	140,745	0	12
	Moffat Tunnel	55,278	91,720	23,437	11
	Charles H. Boustead Tunnel	47,628	110,132	0	10
	Twin Lakes Tunnel	39,071	63,758	8,382	8
	Homestake Tunnel	24,834	59,869	0	5
	Grand River Ditch	17,914	25,196	4,980	4
	Hoosier Pass Tunnel	8,670	13,749	2,362	2
	Busk-Ivanhoe Tunnel	5,473	9,845	2,450	1
	16 Other Diversions	10,461	26,753	1,690	2
	State Total	**497,092**	**653,126**	**368,608**	**100**
New Mexico	Azotea Tunnel	89,833	164,125	6,302	100
	State Total	**89,833**	**164,125**	**6,302**	**100**
Utah	Strawberry Tunnel	37,516	90,409	0	32
	Syar Tunnel (SWU)	25,032	80,873	0	22
	Duchesne Tunnel	22,290	40,873	0	19
	Syar Tunnel (CUP)	19,359	69,261	0	17
	Ephraim Tunnel	2,564	5,470	0	2
	Fairview Tunnel	2,161	4,471	0	2
	Spring City Tunnel	1,922	3,595	0	2
	Strawberry - Willow Cr	1,406	3,823	42	1
	11 Other Diversions	3,806	5,433	765	3
	State Total	**116,056**	**173,187**	**20,471**	**100**
Wyoming	Hog Park Diversion	10,407	23,524	2,482	85
	Continental Divide	1,030	1,040	690	8
	Ranger Ditch	495	500	330	4
	Broadbent Supply Ditch	247	2,898	0	2
	State Total	**12,179**	**25,314**	**4,022**	**100**
	Upper Basin Totals	**715,453**	**864,229**	**518,942**	**n/a**

[1]Values are based on data provided from the Bureau for the years 1971 through 2004.

[2]Maximum and minimum values shown above the total line are for specific diversions. Values below the total line are the maximum and minimum values for the state as a whole.

Table 2-3 Lower Colorado River Basin - Export Summary[1]					
State	**Diversion Facility**	**Average Annual Diversion (AFY)**	**Maximum Annual Diversion[2] (AFY)**	**Minimum Annual Diversion[2] (AFY)**	**Percent State Total**
California	Imperial Irrigation District	2,981,246	3,159,609	2,572,659	66
	Metropolitan Water District – Colorado River Aqueduct (MWD – CRA)	1,216,437	1,300,203	994,373	27
	Coachella Valley Water District	333,637	369,685	309,367	7
	Total	**4,531,320**	**4,755,655**	**4,075,856**	**100**
Mexico	Mexico	2,536,577	5,192,772	1,505,334	100
	Total	**2,536,577**	**5,192,772**	**1,505,334**	**100**
	Lower Basin Total	**7,067,897**	**9,948,427**	**5,581,190**	**n/a**

[1]Values are based on date provided from the Bureau for the years 1986 through 2002. Recent implementation of the California's Colorado River Water Use Plan will reduce average and maximum diversions in that state in the future.

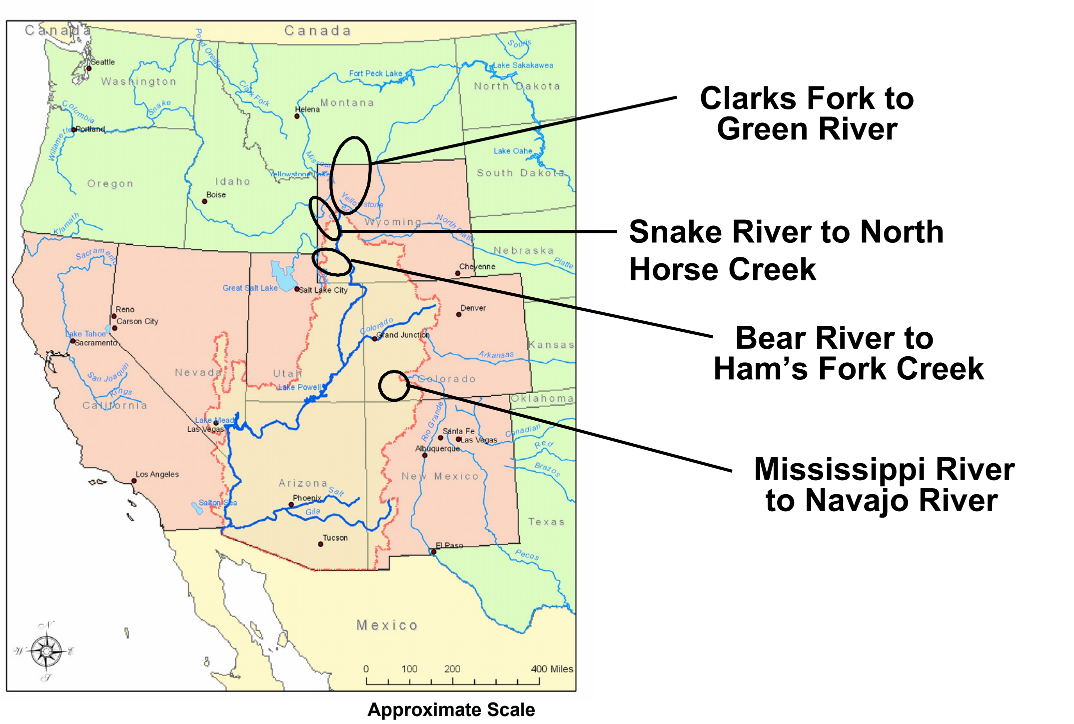
[2]Maximum and minimum values shown above the total line are for specific diversions. Values below the total line are the maximum and minimum values for the state as a whole.

2.3 Development of Basin Imports Alternatives

Based on input from the Technical Committee, four potential import alternatives were developed for evaluation as part of this TM:

- Snake River Basin in Wyoming to the Green River Basin in Wyoming
- Bear River near the Utah/Wyoming border to the nearest Green River tributary.
- Clark's Fork of the Yellowstone River to the Green River Basin.
- Mississippi River below confluence of the Ohio River to the nearest tributary of the San Juan River Basin.

The approximate locations of these alternatives are shown on Figure 2-1 and discussed in more detail below.



Colorado River Basin Diversion Alternatives

The Seven Colorado River Basin States

Figure 2-1

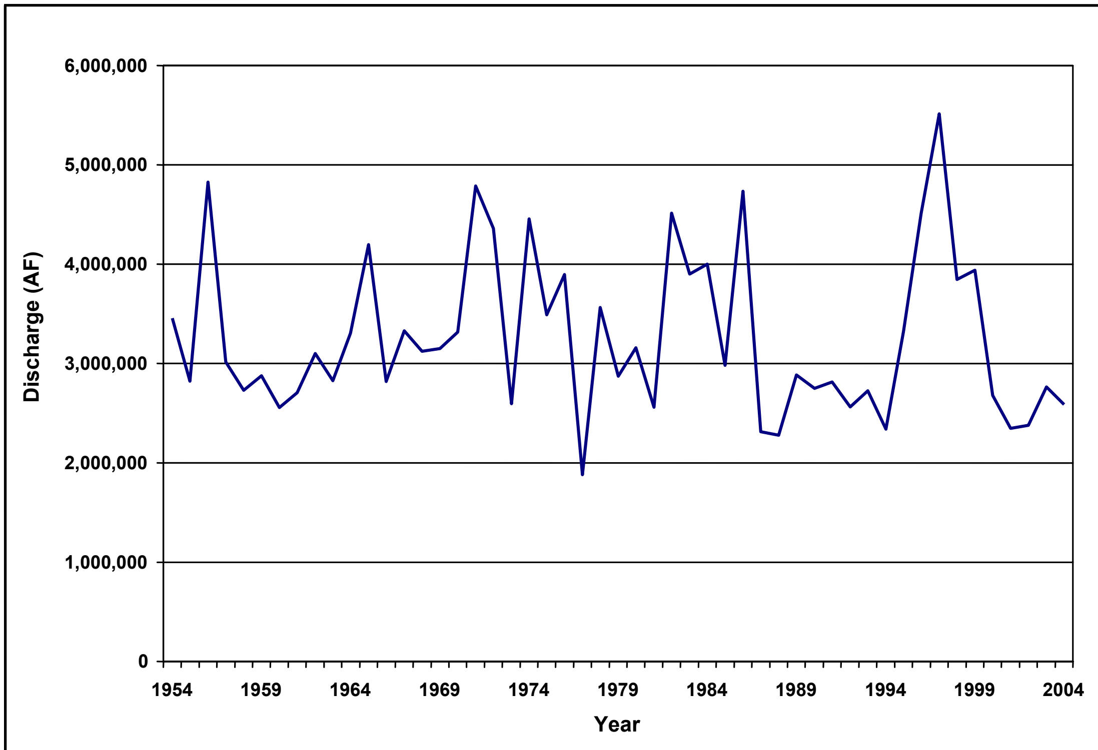
2.3.1 Snake River to North Horse Creek

This import alternative involves diverting water from the Snake River and delivering it to the Green River Basin. Under this alternative, water would be pumped from Palisades Reservoir over the basin divide to Horse Creek, which is tributary to the Green River.

Water quality in the Snake River at the proposed diversion point is considered to be good as a municipal and industrial (M&I) source water.

2.3.1.1 Water Supply

According to the Snake River interstate compact, Wyoming has rights to deplete four percent of the annual flow in the Snake River at the state line. Figure 2-2 presents the historic Snake River yields above Palisades Reservoir near Alpine, Wyoming (USGS Stream Gage 13022500). The details of Wyoming's allocation are defined in Article III - A of the Snake River Compact and these details are summarized in the Snake River/Salt River Basin Plan (Sunrise Engineering, 2003).



Historic Snake River Flows above Palisades Reservoir near Alpine, WY

The Seven Colorado River Basin States

Figure 2-2

The following summarizes the compact as written in the Snake River/Salt River Basin Plan:

> "Four percent of the waters of the Snake River basin are allocated to Wyoming for direct diversion or storage. The first half or 2 percent of the compact allocation can be diverted or stored without any storage space replacement requirement. Wyoming shall provide replacement storage space equal to one-third of any additional use under the second half of the 4 percent allotment. It is estimated that Wyoming's 4 percent share at the Wyoming-Idaho border is approximately 200,000 AFY. One-half is approximately 100,000 AF and one-third of this amount is 33,000 AFY of storage space."

This is the amount of storage allocated to Wyoming in Palisades Reservoir.

Table 2-4 summarizes Snake River yield and storage information.

Table 2-4 Snake River Available Yields and Storage			
Parameter	**Snake River Flow Subject to Allocation**[1]		
	Dry Year[2]	**Normal Year**	**Wet Year**[3]
Total Flow Available	2,815,967	4,407,501	6,081,299
Initial Allocation (2 Percent)	56,319	88,150	121,626
Total Allocation (4 Percent)	112,639	176,300	243,252
Current Depletions	(22,772)	(21,758)	(22,011)
Remaining Allocation	89,867	154,542	221,241

(1)Values based on Table III-13 of the Snake River/Salt River Basin Plan.

(2)Flow is greater than driest year shown on Figure 2-3. The Basin Plan indicates that revised operation of upstream reservoirs will result in additional water being released in dry years.

(3)Note this is greater than the 5 million AFY value reference in the Article III summary.

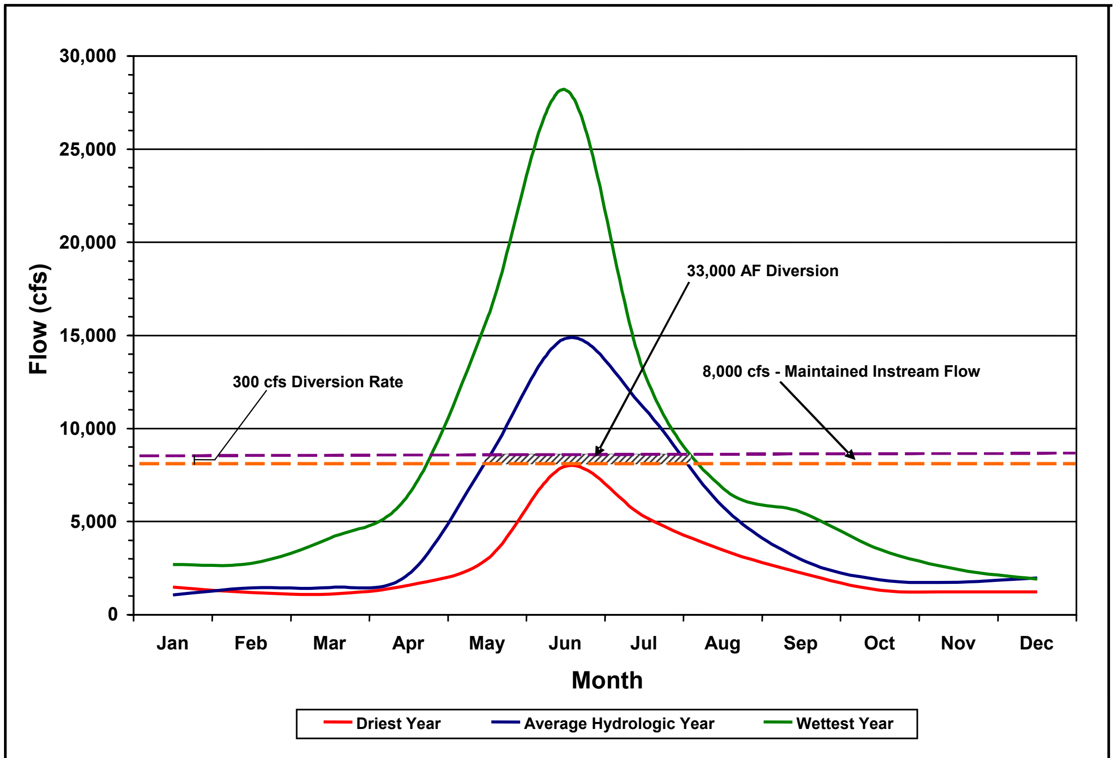
18,600 acre-feet (AF), 29,100 AF, and 40,100 AF of storage in Palisades Reservoir would be required for dry, normal, and wet years, respectively.

Based on these values, the 2003 Snake River/Salt River Basin Plan estimates approximately 90,000 AFY, 155,000 AFY, and 221,000 AFY is available to Wyoming in dry, normal, and wet years, respectively. However, because a large portion of this water is available during only a few brief months, storage would be required to realize these yields. Because Wyoming has been allocated 33,000 AFY of storage in Palisades Reservoir and because that storage is not currently being used to meet compact requirements, a yield of 33,000 AFY was selected for this investigation. Additional flows could be realized if new storage was constructed upstream of Palisades Reservoir.

2.31.2 Infrastructure Requirements

Palisades Reservoir was selected as the diversion location because utilizing this facility would eliminate the need for new diversion facilities and the potentially available storage would reduce the size of the required transbasin facilities.

Figure 2-3 presents the annual distribution of Snake River flows above Palisades Reservoir. As shown on Figure 2-3, peak flows generally occur between the months of May and August. It was assumed that the 33,000 AF of storage space not currently used to meet compact requirements with Idaho could be used to capture the peak May through August flows and the new conveyance facilities would deliver the stored water to the Green River Basin over an 11-month period. This would leave one month per year that the system could be shut down for annual maintenance. However, is should be noted that the storage space in Palisades Reservoir not currently used to meet compact requirements with Idaho is tied up in a long-term agreement with the Wyoming Game and Fish Department, where water from Palisades Reservoir is transferred to Jackson Lake via exchange agreements and released for the benefit of wild trout downstream of Jackson Lake.

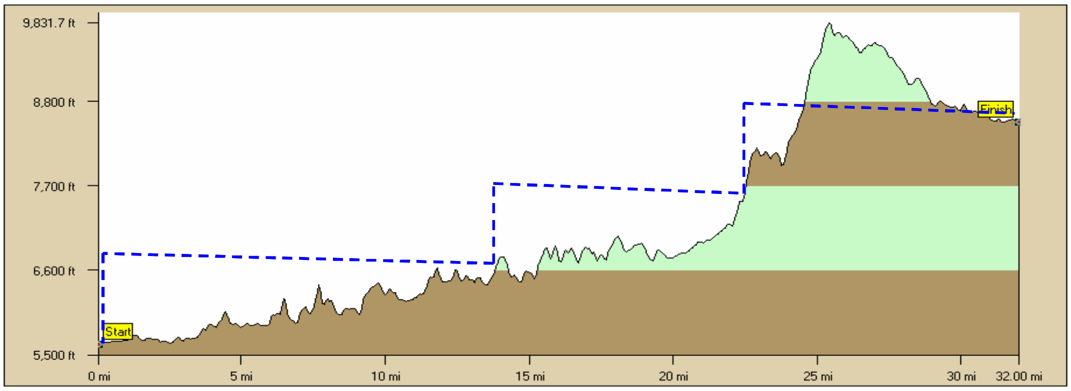


Snake River Proposed Diversion Operation

The Seven Colorado River Basin States

Figure 2-3

Figure 2-4 shows the profile of the proposed aqueduct alignment. The components associated with the alignment include three pumping stations, 26 miles of 36-inch diameter pipe, and approximately 6 miles of tunnel.



Alignment Features
- **3 pump stations**
- **26 miles of 36 -inch diameter pipe**
- **6 miles of tunnel**

Palisades Reservoir to North Horse Creek Profile

The Seven Colorado River Basin States

Figure 2-4

2.3.1.3 Concept Cost Summary

Table 2-5 lists the estimated capital and operations and maintenance (O&M) costs associated with the infrastructure requirements for the Snake River to North Horse Creek alternative.

Table 2-5
Cost Summary for the Snake River to North Horse Creek Alternative

Component	Capital Cost (million $)	Annual O&M Cost ($)	Annual Electricity Cost ($)
Three pumping stations	30.7	615,000	10,300,000
36-inch diameter pipeline	75.1	150,000	n/a
Tunnel	105.8	529,000	n/a
Total	**211.6**	**1,294,000**	**10,300,000**

2.3.1.4 Institutional and Political Considerations

The following is a list of institutional and political considerations associated with implementation of this alternative. This list is preliminary based on limited conceptual information and may be incomplete.

- The 33,000 AF of storage space in Palisades Reservoir assumed to be available is currently tied up in a long-term agreement with the Wyoming Game and Fish Department and the operational approach to Palisades Reservoir would require revisions and approvals from all stakeholders for the storage space to be used for an out-of-basin diversion.

- Wyoming may choose to exercise the right to use the water before allowing the water to be diverted for consumption out of the State of Wyoming.

- Article IV of the Snake River Interstate Compact states the following, "No water of the Snake River shall be diverted in Wyoming for use outside the drainage area of the Snake River except with the approval of Idaho; and no water of any tributary of the Salt River heading in Idaho shall be diverted in Idaho for use outside the drainage area of said tributary except with the approval of Wyoming."

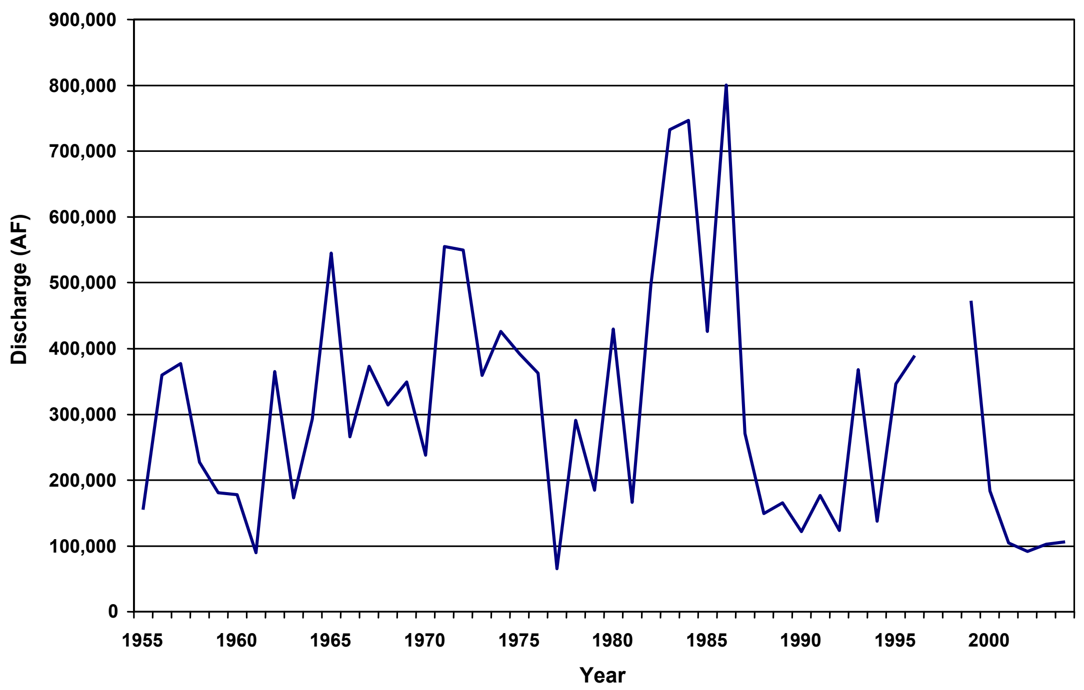
2.3.2 Bear River to Ham's Fork Creek

This import alternative involves diverting water from the Bear River and delivering it to the Green River Basin. Under this alternative, water would be diverted and pumped from Bear River over the basin divide to Ham's Fork Creek, upstream of Lake Viva Naughton.

2.3.2.1 Water Supply

Various locations were considered for diversion from the Bear River. Based on review of stream gage data, there is sufficient yield in the Bear River directly downstream of Smith's Fork to consider it as a diversion location. Figure 2-5 presents the historic Bear River yields below Smith's Fork near Cokeville, Wyoming (USGS Stream Gage 10038000).

As with the previously described alternative, water quality in the Bear River at the proposed diversion point is considered to be good as a M&I source water.



Historic Flow in Bear River below Smith's Fork

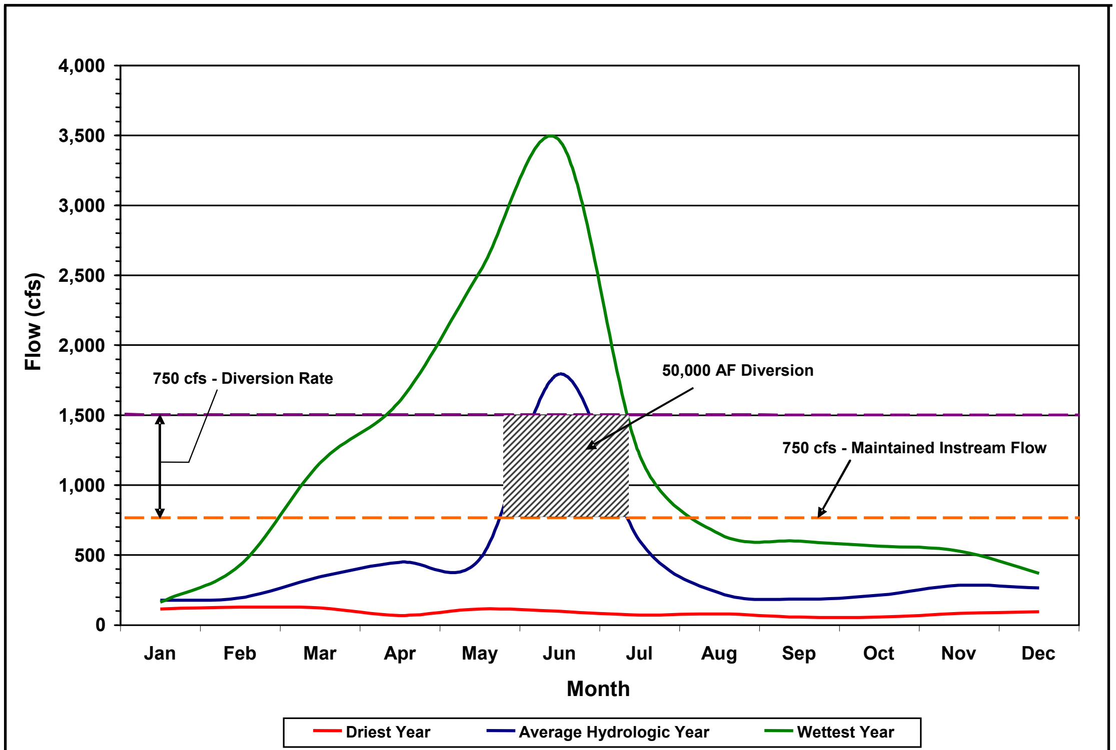
The Seven Colorado River Basin States

Figure 2-5

2.3.2.2 Infrastructure Requirements

Figure 2-6 presents the annual distribution of Bear River flows below Smith's Fork and presents one possible river diversion operational scheme. As shown, peak flows generally occur between the months of May and July. Based on the average hydrologic year, a river diversion structure with a capacity of 750 cubic feet per second (cfs) could capture and divert 50,000 AF over those months, while leaving a minimum of 750 cfs in the river.

A new storage reservoir that could store the diverted volume of 50,000 AF could possibly be located on one of the tributaries to Smith's Fork. If constructed, the transbasin conveyance facilities could be sized to deliver the target yield of 50,000 AF over an 11-month period, assuming 1 month per year is allotted for annual maintenance. This would result in a design capacity of the transbasin conveyance facilities of 75 cfs. Alternatively, it may be feasible to design the conveyance facilities to match the capacity of the river diversion facilities and avoid both the cost and environmental permitting requirements of the reservoir.



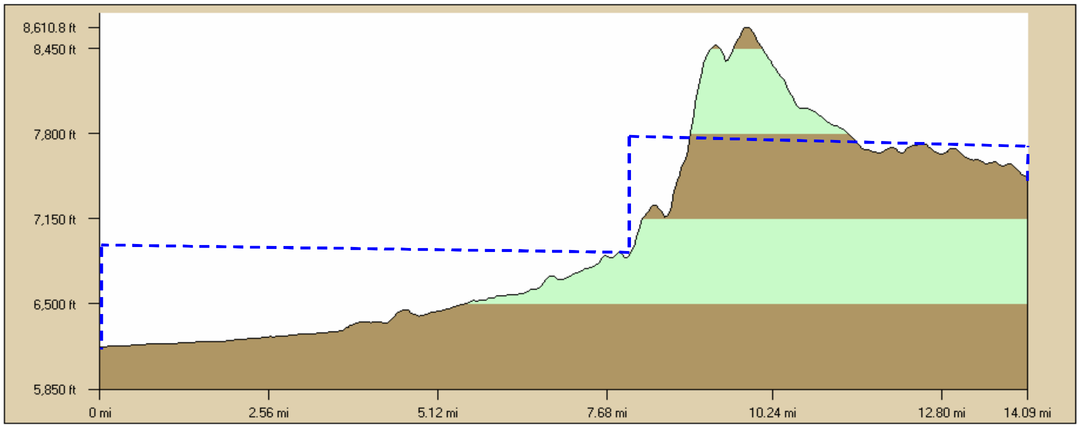
Bear River Proposed Diversion Operation

The Seven Colorado River Basin States

Figure 2-6

Figure 2-7 shows the profile of the proposed aqueduct alignment. The components associated with the alignment include two pumping stations, one hydropower station, 11.5 miles of 132-inch diameter pipe, and approximately 2.5 miles of tunnel.

As shown on Figure 2-7, less than 15 miles of conveyance facilities are required to deliver Bear River water to the Green River Basin. Because of this relatively short distance and because the feasibility of a new storage facility is unknown, it was assumed that regulatory storage would not be provided and that the conveyance facilities would be sized to match the full 750 cfs capacity of the diversion facilities. If warranted, future studies could evaluate the feasibility and cost benefit of providing storage near Smith's Fork.



Alignment Features
- **2 pump stations**
- **1 hydropower station**
- **2.5 miles of tunnel**
- **11.5 miles of 132 -inch diameter pipe**

Bear River to Ham's Fork Creek Profile

The Seven Colorado River Basin States

Figure 2-7

2.3.2.3 Concept Cost Summary

Table 2-6 lists the estimated capital and O&M costs associated with the infrastructure requirements for the Bear River to Ham's Fork Creek alternative.

Table 2-6
Cost Summary for the Bear River to Ham's Fork Creek Alternative

Component	Capital Cost (million $)	Annual O&M Cost ($)	Annual Electricity Cost ($)
Diversion	5.0	n/a	n/a
Two pumping stations	116.8	2,336,000	14,000,000
Hydropower station	28.9	722,000	(2,000,000)
132-inch diameter pipeline	121.6	243,000	n/a
Tunnel	48.3	242,000	n/a
Total	**320.6**	**3,543,000**	**12,000,000**

2.3.2.4 Institutional and Political Considerations

The following is a list of institutional and political considerations associated with implementation of this alternative. As with the other concepts identified in this TM, this list is based on limited conceptual information and may be incomplete.

- Agreements with all stakeholders would be required, including Utah and Wyoming.

- The minimum instream flow value shown on Figure 2-6 is based on review of hydrology information only. Detailed biology studies would be required to determine the actual instream flow requirements and diversion limitations.

2.3.3 Clark's Fork to Green River

This import alternative involves diverting water from Clark's Fork of the Yellowstone River in Wyoming and delivering it to the Green River Basin. Two routes were developed for this alternative. Option 1 minimizes construction within National Forest lands and in areas that may be deemed environmentally sensitive. Option 2 investigates the straightest route to the headwaters of the Green River. Consideration was also given to diverting water from Clark's Fork to the Snake River and then from the Snake River to the Green River. However, the headwaters of the two rivers are within 50 miles of each other. Consequently, this analysis assumed a direct delivery to the Green River Basin.

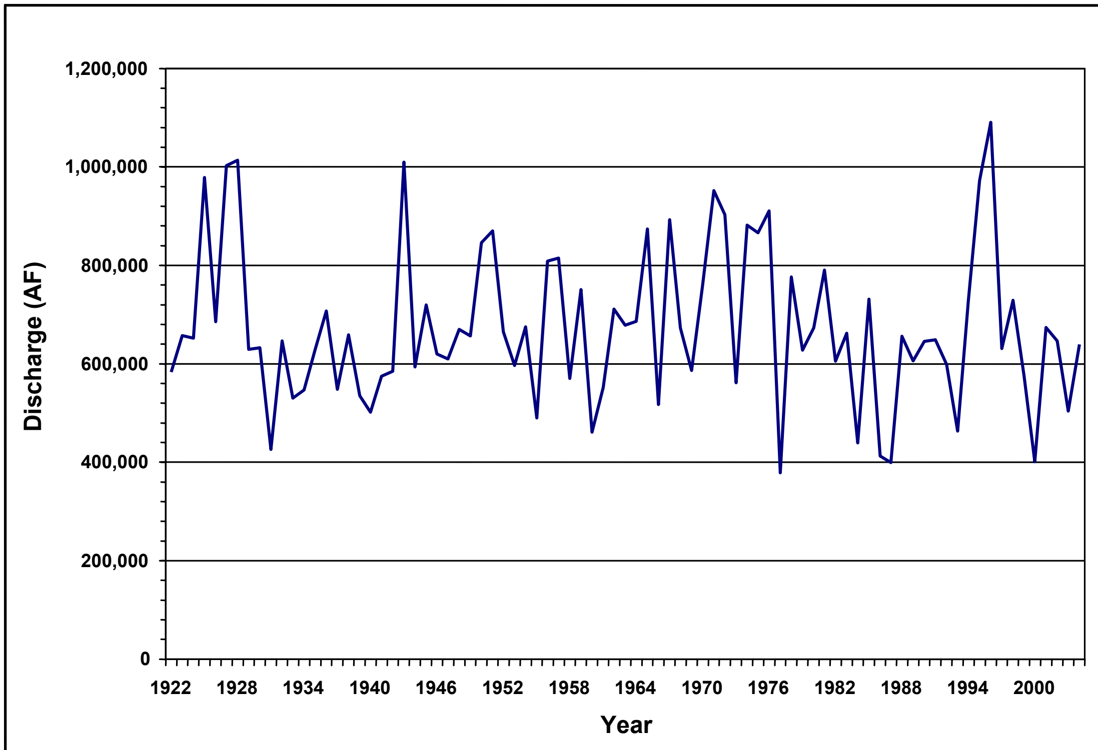
2.3.3.1 Water Supply

Wyoming is allocated 60 percent of the depletable yield of Clark's Fork, and Montana is allocated the other 40 percent. According to the 1973 Wyoming Water Plan, Wyoming's 60 percent allocation is 428,400 AF in an average year. Currently, very little water is depleted from this river basin. However, based on conversations with John Shields, State of Wyoming Interstate Streams Engineer, this river has been designated wild and scenic and diverting significant volumes for out-of-basin depletion may not be feasible.

For this study, it was assumed that 75,000 AFY (approximately 20 percent of Wyoming's depletable allocation) could be exported to the Green River Basin. This is an arbitrary value and additional studies should be performed to determine a yield acceptable to the current stakeholders of Clark's Fork water. In addition, if additional water could be diverted, a better economy of scale (unit cost of water) would be realized.

Figure 2-8 presents the historic Clark's Fork yields near Belfry, Montana (USGS Stream Gage 06207500).

As with the previously-described alternative, water quality in the Clark's Fork of the Yellowstone River at the proposed diversion point is considered to be good as a M&I source water.



Historic Flow in Clark's Fork of the Yellowstone River

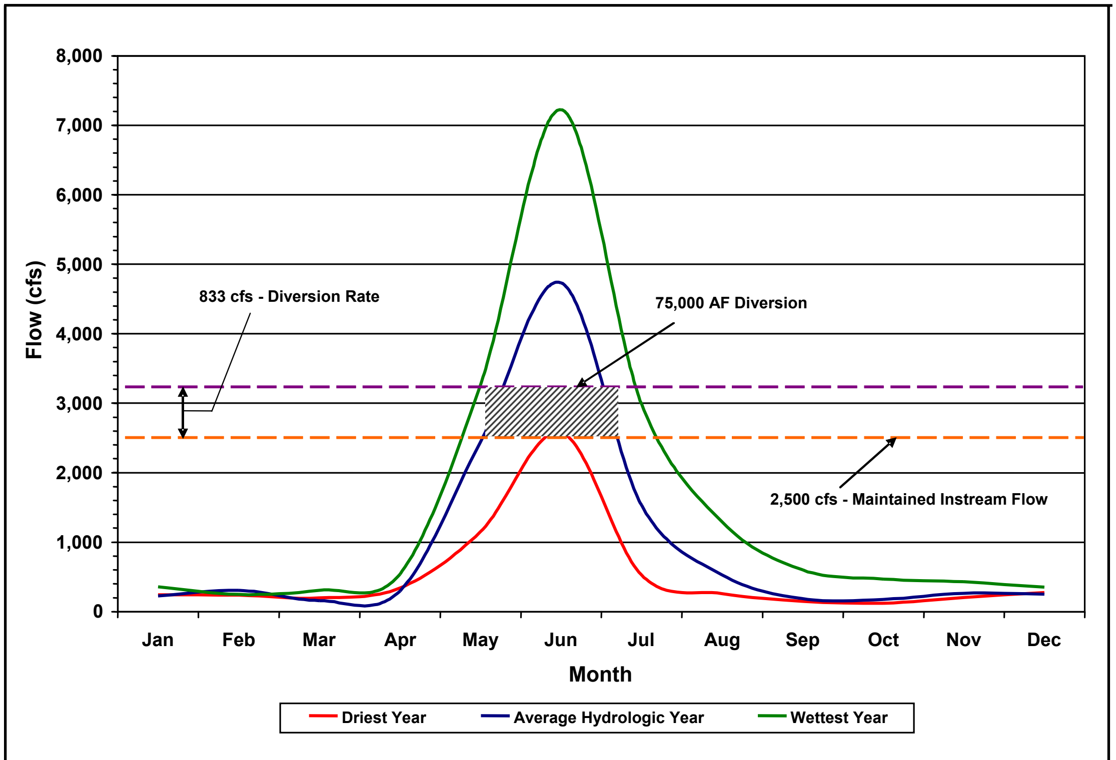
The Seven Colorado River Basin States

Figure 2-8

2.3.3.2 Infrastructure Requirements

Figure 2-9 presents the annual distribution of Yellowstone River flows near the Wyoming state line. As shown, peak flows generally occur between the months of May and July. Based on the average hydrologic year, a river diversion structure with a capacity of 833 cfs could capture and divert 75,000 AF over those months, while leaving a minimum of 2,500 cfs in the river.

Buffalo Bill Reservoir is located approximately 45 miles from the potential Clark's Fork Diversion point. This existing reservoir has approximately 605,000 AF of usable storage. Buffalo Bill Reservoir could be used to provide operational storage and reduce the size of the conveyance facilities downstream of the reservoir. However, storage agreements would be required with all Buffalo Bill Reservoir stakeholders.

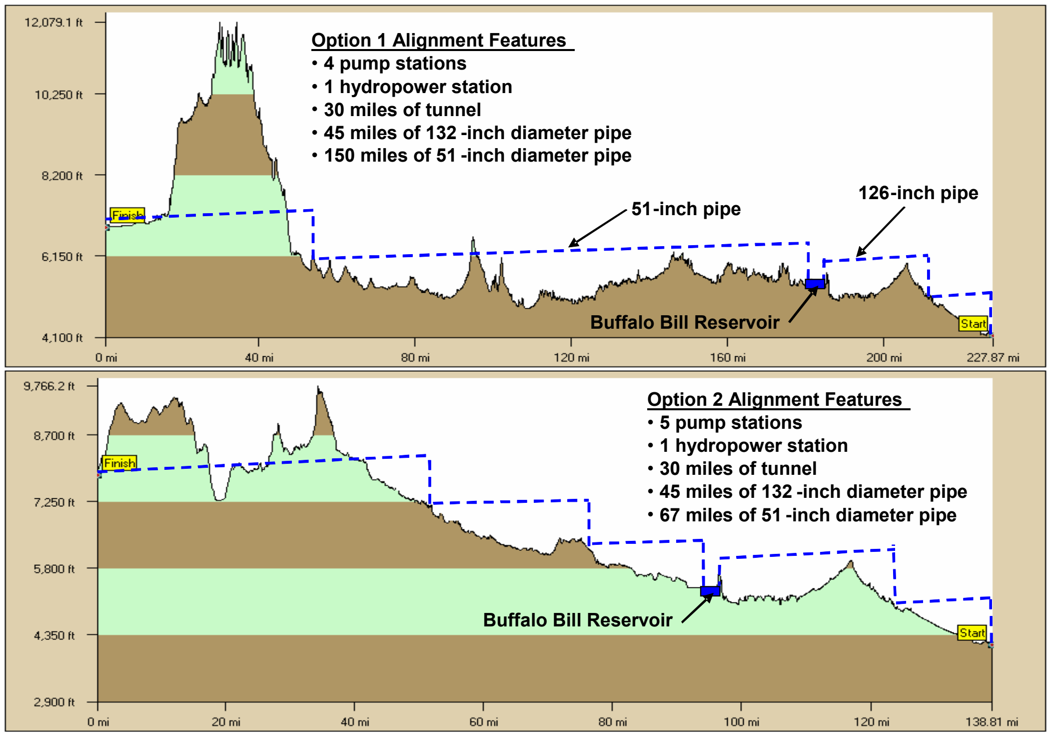


Clark's Fork Yellowstone River Proposed Diversion Operation

The Seven Colorado River Basin States

Figure 2-9

Figure 2-10 presents the profiles for the alignment for both options. Option 1 includes four pumping stations, one hydropower station, 45 miles of 126-inch diameter pipe, 150 miles of 51-inch diameter pipe, and approximately 30 miles of tunnel. Option 2 includes five pumping stations, one hydropower station, 45 miles of 126-inch diameter pipe, 67 miles of 51-inch diameter pipe, and approximately 30 miles of tunnel.



Clark's Fork to Green River Profiles

The Seven Colorado River Basin States

Figure 2-10

2.3.3.3 Concept Cost Summary

Table 2-7 lists the estimated capital and O&M costs associated with the infrastructure requirements for Option 1 of the Clark's Fork to Green River concept.

Table 2-7
Cost Summary for the Clark's Fork to Green River Option 1 Concept

Component	Capital Cost (million $)	Annual O&M Cost ($)	Annual Electricity Cost ($)
Diversion	5.0	n/a	n/a
Four pumping stations	160.9	3,219,000	37,200,000
Hydropower station	39.4	985,000	(8,600,000)
132-inch diameter pipeline	458.1	875,000	n/a
51-inch diameter pipeline	617.2	1,234,000	n/a
Tunnel	565.5	2,828,000	n/a
Total	**1,846.2**	**9,141,000**	**28,600,000**

Table 2-8 lists the estimated capital and O&M costs associated with the infrastructure requirements for Option 2 of the Clark's Fork to Green River concept.

Table 2-8
Cost Summary for the Clark's Fork to Green River Option 2 Concept

Component	Capital Cost (million $)	Annual O&M Cost ($)	Annual Electricity Cost ($)
Diversion	5.0	n/a	n/a
Five pumping stations	168.3	3,368,000	40,500,000
Hydropower station	39.4	875,000	(8,600,000)
132-inch diameter pipeline	458.1	541,000	n/a
51-inch diameter pipeline	270.6	985,000	n/a
Tunnel	548.2	2,741,000	n/a
Total	**1,489.7**	**8,510,000**	**31,900,000**

2.3.3.4 Institutional and Political Considerations

The following is a list of institutional and political considerations associated with implementation of this alternative. As mentioned previously, this list is preliminary based on limited conceptual information and may be incomplete.

- Yellowstone River Basin Interstate Compact – Article 10 requires approval of both Montana and Wyoming to agree to any out-of-basin diversions.
- Past concepts have been rejected in Federal Court.

2.3.4 Mississippi River to Navajo River (Tributary to the San Juan River)

To provide a relative comparison of the cost of the three concepts presented above, a Mississippi River concept was also investigated. Specifically, this import alternative involves diverting water from the Mississippi River downstream of the fork of the Ohio River and delivering it to the Navajo River, which is a tributary to the San Juan River.

2.3.4.1 Water Supply

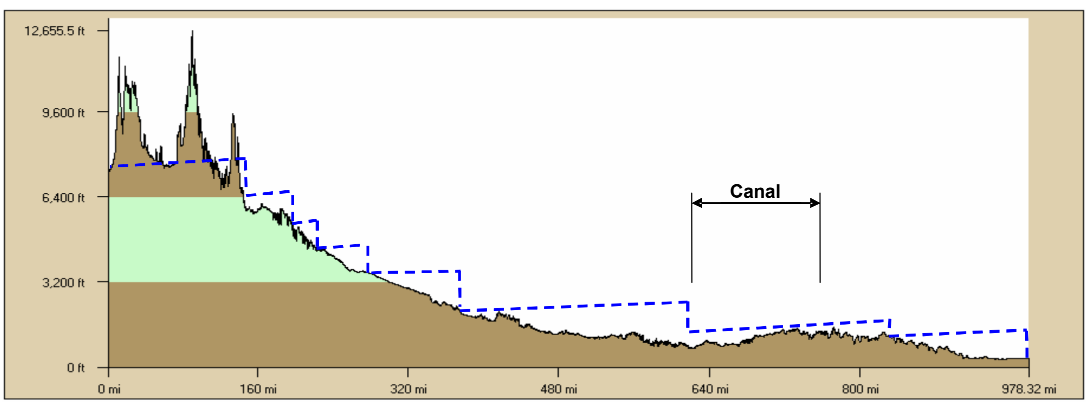
The diversion location was selected at a point along the Mississippi River downstream of the confluence with the Ohio River. At this point, it is assumed that there is sufficient water to meet Mississippi River navigation requirements and that excess water would be available for diversion to the Basin. A diversion rate equal to the capacity of a single 144-inch pipe, which is equal to 1,000 cfs or 675,000 AFY, was selected. This yield was selected based on the capacity of a 144-inch pipe, which is believed to be the largest feasible pipe size considering manufacturing constraints at the anticipated operating pressures and constraints associated with the logistics of delivering the pipe to the installation locations. Additional yield could be realized if parallel pipelines were provided.

The water quality in the Mississippi River is not of the same high quality as the other mountain water sources investigated herein. However, it is of acceptable quality for a municipal water source with conventional water treatment.

2.3.4.2 Infrastructure Requirements

It was assumed that sufficient flow is available in the Mississippi River downstream of the Ohio River and that a conventional river pumping station could be utilized for the diversion. It was also assumed that 1,000 cfs would be available for diversion all year long and therefore no regulatory storage would be required.

Figure 2-11 shows the plan and profile of the proposed aqueduct alignment associated with this concept. The components associated with the alignment option include seven pumping stations, 110 miles of canal, 775 miles of 144-inch diameter pipe, and approximately 85 miles of tunnel.



Alignment Features
- **7 pump stations**
- **110 miles of canal**
- **85 miles of tunnel**
- **775 miles of 144 -inch diameter pipe**

Mississippi River to Navajo River Profile

The Seven Colorado River Basin States

Figure 2-11

2.3.4.3 Concept Cost Summary

Table 2-9 lists the estimated capital and O&M costs associated with the infrastructure requirements for the Mississippi River to Navajo River alternative.

Table 2-9
Cost Summary for the Mississippi River to Navajo River Concept

Component	Capital Cost (million $)	Annual O&M Cost ($)	Annual Electricity Cost ($)
Diversion	5.0	n/a	n/a
Seven pumping stations	783.9	15,679,000	483,000,000
144-inch diameter pipeline	8,922.2	17,844,000	n/a
Canal	99.4	199,000	n/a
Tunnel	1,556.8	7,784,000	n/a
Total	**11,367.3**	**41,506,000**	**483,000,000**

2.3.4.4 Institutional and Political Considerations

The following is a list of institutional and political considerations associated with implementation of this concept. As mentioned previously, this list is preliminary based on limited conceptual information and may be incomplete.

- Coordination and approval from a large number of stakeholders would be required.
- With approximately 1,000 miles of aqueduct length, construction impact mitigation could be significant.
- With a total project cost exceeding $10 billion, federal financing may be required.

3.0 COSTS

Table 3-1 summarizes and compares the capital and O&M cost estimates for each of the import alternatives. Cost estimates were developed based on the following assumptions:

- Capital costs will be financed at an interest rate of 5 percent.

As shown in Table 3-1, the cost associated with the Snake River and Bear River alternatives are comparable and both alternatives have the lowest lifetime unit cost. Both of the Clark's Fork options and the Mississippi River alternative have comparable lifetime unit costs, which are more than double those of the Snake River and Bear River alternatives.

Table 3-1
Cost Summary for the Import Alternatives

Parameter	Import Alternative				
	Snake River	Bear River	Clark's Fork Option 1	Clark's Fork Option 2	Mississippi River
Yield (AFY)	33,000	50,000	75,000	75,000	675,000
Capital Cost ($ Millions)	$212	$321	$1,846	$1,490	$11,367
O&M ($ Millions/yr)	$1.29	$3.54	$9.14	$8.51	$41.50
Electricity ($ Millions/yr)	$10.30	$12.00	$28.60	$31.90	$483.00
Unit Cost ($/AF)	$770	$730	$2,100	$1,830	$1,870