Multi-Basin Water Supply Investigation

Executive Summary

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December 2006

Introduction

In 2003, the Colorado Water Conservation Board (CWCB) commissioned the Statewide Water Supply Initiative (SWSI). The SWSI evaluated projected municipal and industrial (M&I) water supply needs in Colorado through the year 2030. The results of this evaluation indicated that gross water use is expected to increase statewide by about 53 percent or 630,000 acre-feet per year (AFY) between 2000 and 2030. Presently, all but approximately 100,000 AFY of the new demand are projected to be met by proposed projects and by taking between 185,000 to 428,000 acres of irrigated agricultural land out of production.

Some water providers in the Denver metro area are investigating projects that would transfer water from irrigated agriculture within the Northern Colorado Water Conservancy District boundaries. NCWCD is interested in finding alternatives to agricultural dry-up. The purpose of this Multi-Basin Water Supply Investigation (MBWSI) is to identify facilities and associated potential costs for the transfer of water from rivers in northwest Colorado to the Front Range area to meet potential future water supply shortfalls.

The area considered for this investigation was limited to northwestern Colorado. The Colorado River Return Reconnaissance Study (also know as the Big Straw Study) evaluated a diversion from the main stem of the Colorado River below Grand Junction. North of the Colorado River, the White River yields approximately 500,000 AFY. North of the White River are the Yampa and Green Rivers. Both of these rivers yield approximately 1.5 million AFY. The Yampa River was chosen as the source of supply because there is sufficient quantity to provide at least 300,000 AFY of firm yield. In addition, the water quality of the Yampa River at Maybell is superior to water quality in the Green River below Flaming Gorge Reservoir and Colorado River below Grand Junction.

Water from the proposed project described in this report could be used within five river basins in Colorado, either directly or by exchange. In the case of the Yampa, North Platte and South Platte River basins, water could be directly used. In the case of the Arkansas basin, water could either be exchanged for Arkansas River water presently diverted by Aurora, or a pipeline could be extended over the Palmer Divide to provide direct deliveries to that basin. The upper Colorado River basin could also benefit from such a project by exchange. In this case, upper Colorado River water presently diverted by Front Range trans-mountain diverters could be exchanged for water received from the project.

The objective of this investigation is to determine whether there is a technically and economically feasible project configuration that would be able to divert water from northwestern Colorado to the Front Range area. This project, coupled with ongoing and consistent conservation measures, could help the state meet a substantial portion of its water needs in the 21st century. A consortium of entities and/or the State of Colorado will be required to fully evaluate and ultimately realize this project's potential.

This Executive Summary has been prepared by NCWCD based on the Multi-Basin Water Supply Investigation, December 2006 (Project 145218.100) prepared by Black & Veatch Corporation.

Water Supply

Water Quantity

The Yampa River basin drains an extensive area of northwest Colorado and southern Wyoming. The main stem of the Yampa River flows from its headwaters near the town of Yampa to its confluence with the Green River. Other substantial tributaries such as the Elk River and Little Snake River make up a large portion of the annual flow.

Figure ES-1 presents the historic annual flow at Maybell from 1917 to 2004. The annual flow was lowest in 1977 at 348,000 AFY and was highest in 1984 at over 2.2 million AFY. Flows average 1,130,000 AFY.

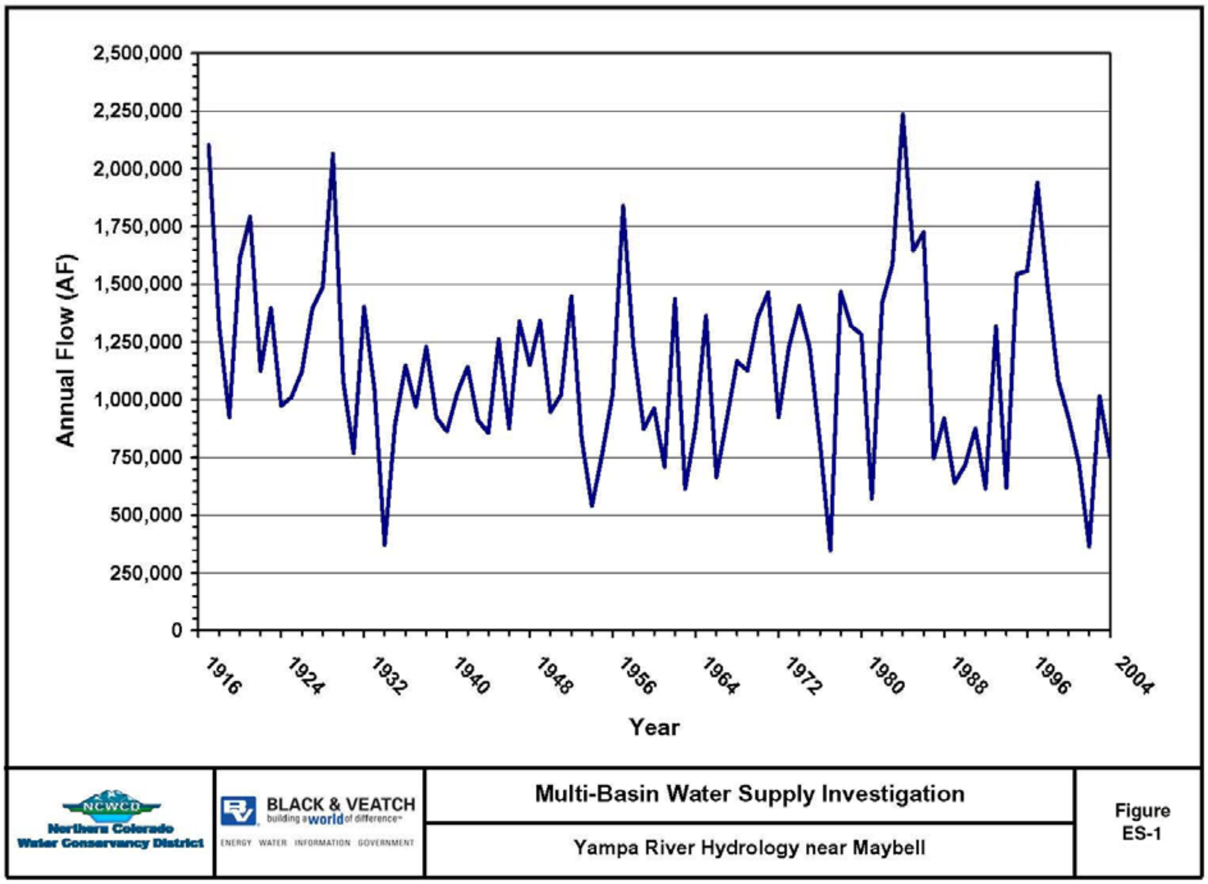


Figure ES-1

Flow at Maybell varies significantly over the year. Figure ES-2 presents the average monthly distribution of flows. During spring runoff, flows are often above several thousand cubic feet per second (cfs) on a consistent basis. However, for the remainder of the year, flow drops to several hundred cfs, with flows during drought periods sometimes falling below 100 cfs.

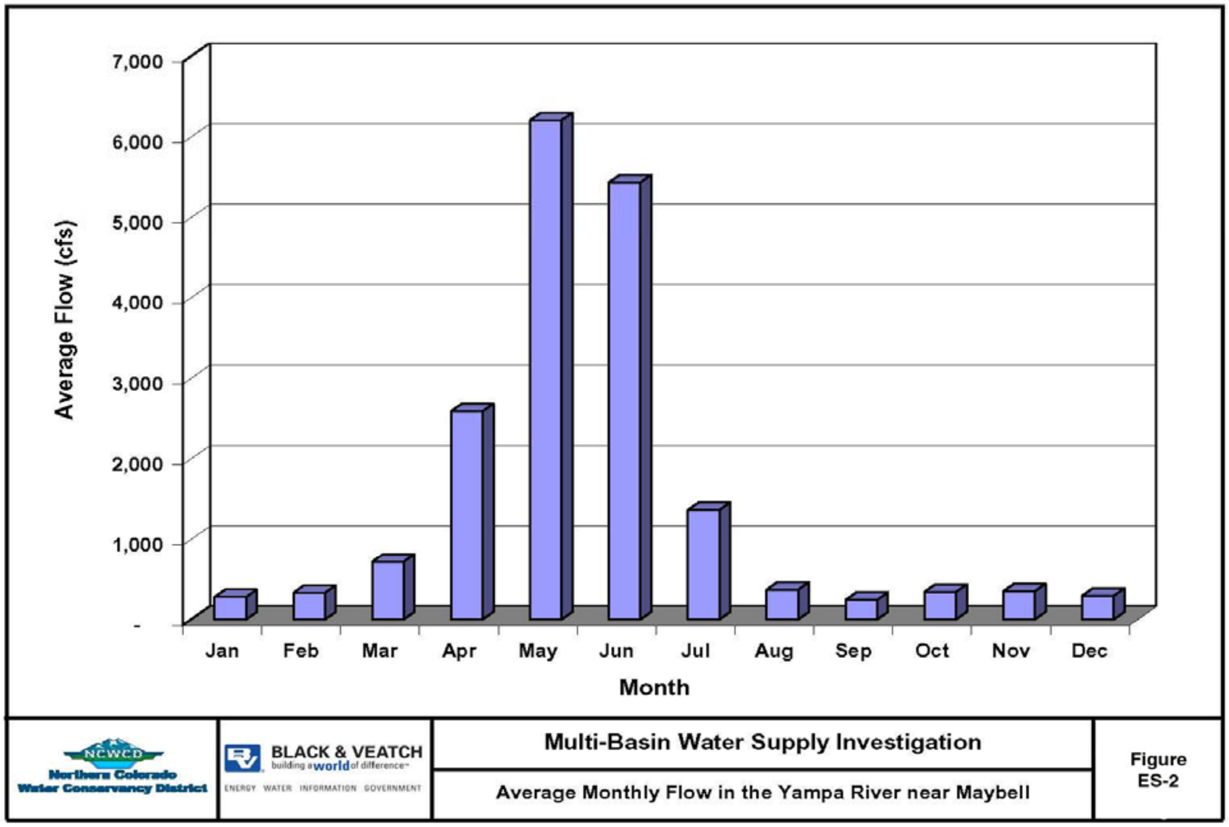


Figure ES-2

Diversion Constraints

The flow available for diversion from the Yampa River is constrained by the following:

- Colorado River Compact and Upper Colorado River Basin Compact.
- Endangered Species Act compliance on the Yampa River and Green River.

- Senior water rights upstream and downstream of the proposed diversion point.

The Colorado River Compact of 1922 allocated the flow of the Colorado River between Upper Basin States (Colorado, New Mexico, Utah, and Wyoming) and Lower Basin States (Arizona, California, and Nevada). In the simplest of terms, the Upper and Lower Basins were each entitled to develop and use 7,500,000 acre-feet of water annually. However, the Upper Basin must deliver 75,000,000 acre-feet to Lee Ferry, the dividing point between the Upper and Lower Basins, in any consecutive 10-year period. The Upper Colorado River Basin Compact of 1948 apportioned the Upper Basin's 7,500,000 AFY among Colorado (51.75 percent), New Mexico (11.25 percent), Utah (23 percent) and Wyoming (14 percent), with 50,000 acre-feet allotted to the portion of Arizona that lies within the Upper Basin above Lee Ferry. In addition, the 1948 Compact requires that Colorado will not cause the flow of the Yampa River at the Maybell gaging station to fall below a total of 5,000,000 acre-feet for any period of 10 consecutive years. The SWSI estimates that the amount of water available for development in Colorado under the 1922 and 1948 Compacts to be around 700,000 AFY. The potential operations described below do not violate the 1948 Compact requirement for flows below Maybell.

The U.S. Fish and Wildlife Service (Service) has listed the humpback chub, bonytail, Colorado pikeminnow, and razorback sucker as endangered under the Endangered Species Act (ESA). In 1988, the Secretary of Interior and the governors of Wyoming, Colorado, and Utah signed a Cooperative Agreement to implement the Recovery Implementation Program for Endangered Fish Species in the Upper Colorado River Basin. As part of this Recovery Program, the Service has issued a Final Programmatic Biological Opinion on the Management Plan for Endangered Fishes in the Yampa River Basin.

Implementation of the proposed project for diversions from the Yampa River will require compliance with the Colorado River compacts, as well as additional consultation with the Service regarding endangered fishes in the Colorado River Basin.

Potential Operations

The average annual flow at the Maybell gaging station is 1,130,000 acre-feet per year based upon data from 1917 to 2004. For planning purposes it was assumed that no diversions would take place that would reduce the flow in the Yampa River at the point of diversion to below 1,000 cfs. Considering this constraint, divertable flows generally occur in April through June with occasional flow availability in March and July.

It is assumed that deliveries from the west slope to the Front Range aqueduct would occur at a uniform rate over ten months. A reservoir near the point of diversion would provide for an equaling of aqueduct flows as well as firming of the supply in drought periods. For the purposes of this project, a firm yield of 300,000 AFY was evaluated. Approximately 500,000 acre-feet of storage and a corresponding maximum diversion rate of 2,000 cfs is required to provide for the firm yield. The flow to the Front Range is assumed to be 500 cfs over ten months. Preliminary analyses indicate that sufficient flows are available in the Yampa River to provide a 300,000 acre-foot firm yield, meet the potential flow requirements of the Colorado River compacts, and meet the flow needs of endangered species.

In addition to the western storage, a smaller eastern reservoir could also be constructed to provide for both scheduled and emergency outages in the aqueduct. For planning purposes, this reservoir would be sized to hold 75,000 acre-feet of water, which is approximately equivalent to two months of aqueduct delivery.

Water Quality

Water quality is an important consideration in evaluating water supply alternatives. If certain constituents are present in the water and, as a result, the supply does not comply with Environmental Protection Agency (EPA) primary and secondary standards, advanced treatment is often necessary. Ultimately, costly desalination treatment options such as reverse osmosis may be required.

While these treatment technologies continue to advance, large-scale inland brine disposal continues to be a difficult issue to overcome.

Because of the relative volume of water considered for this study, the Green and Yampa rivers were considered from a water quality perspective. The Green River is influenced by the 3.8 million acre-foot Flaming Gorge Reservoir. The dampening effect of Flaming Gorge Reservoir provides a nearly constant quality out of that reservoir. The water quality parameters studied include specific conductance, hardness, total dissolved solids (TDS) and sulfate. A summary of average water quality parameters in the Green River below Flaming Gorge and in the Yampa River at Maybell during the typical diversion season are shown in Table ES-1. The table shows that the Yampa River has significantly better water quality than the Green River.

Table ES-1

Water Quality in the Green and Yampa Rivers (Source: USGS)

Water Quality Parameter	EPA Standard Primary P)/ Secondary (S)	Yampa River at Maybell	Green River Below Flaming Gorge
Specific Conductance (ms/cm)	None	200	700
Total Dissolved Solids (ppm)	500 (S)	125	440
Hardness (ppm)	250 (S)	40	270
Sulfate (ppm)	250 (P)	20	200

Alignment Alternatives

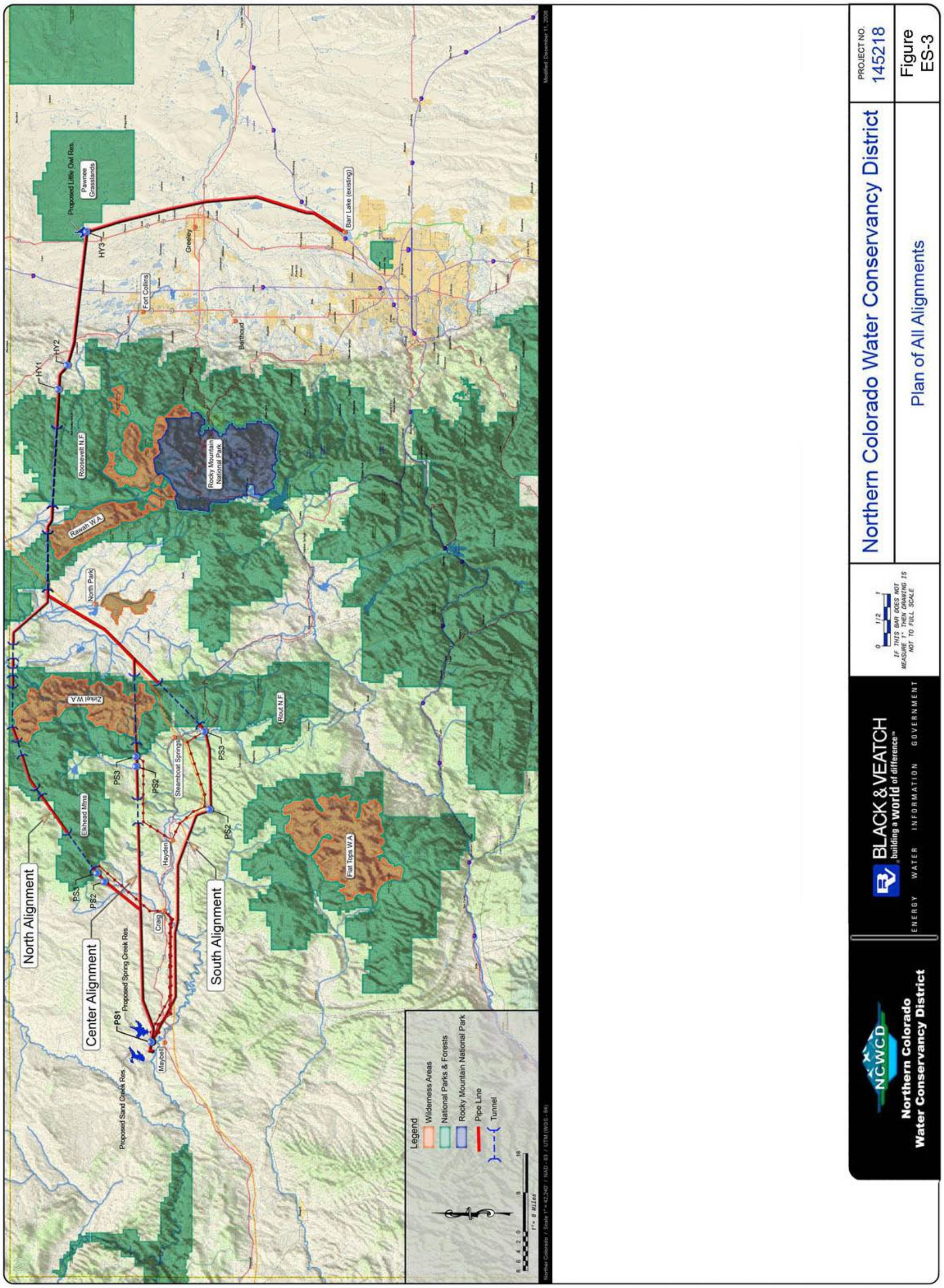
A delivery point near Barr Lake, northeast of Denver was selected as an appropriate termination point for each route because this location is central to several water supply plans for regional Denver water suppliers.

Several factors were considered when developing the potential alignments, including:

- Avoid wilderness areas.
- Avoid national parks.
- Minimize impacts to forest service lands.
- Minimize impacts to urban areas.
- Topography (balancing pipeline pressure, total pumping head, and tunnel length requirements).
- Utilize existing utility and/or transportation corridors, as appropriate.
- Proximity to high voltage power lines for power supply needs.
- Minimize total alignment length.

Three potential alignment options were developed for this investigation. Should this water supply concept be investigated further, it is expected that variations in the alignment alternatives presented herein will be identified and used as the basis for additional evaluations.

As shown on Figure ES-3, each alignment option includes west slope and east slope storage, pipeline and tunnel segments, west slope pumping stations, and east slope hydropower facilities.


Northern Colorado Water Conservancy District
Plan of All Alignments
PROJECT NO.
145218
Figure
ES-3
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building a world of difference
ENERGY WATER INFORMATION GOVERNMENT
Northern Colorado
Water Conservancy District
North Alignment
Center Alignment
South Alignment
Legend
Wilderness Areas
National Parks & Forests
Rocky Mountain National Park
Pipe Line
Tunnel

Figure ES-3

North Alignment

The North Alignment of the west segment passes through the Elkhead Mountain Range, north of the designated Zirkel Wilderness Area and just south of the Wyoming state line. As shown on Figure ES-4, this option requires tunnels to cross beneath both the Elkhead and Zirkel mountains. After exiting Routt National Forest, the north alignment crosses the far north portion of the North Park valley.

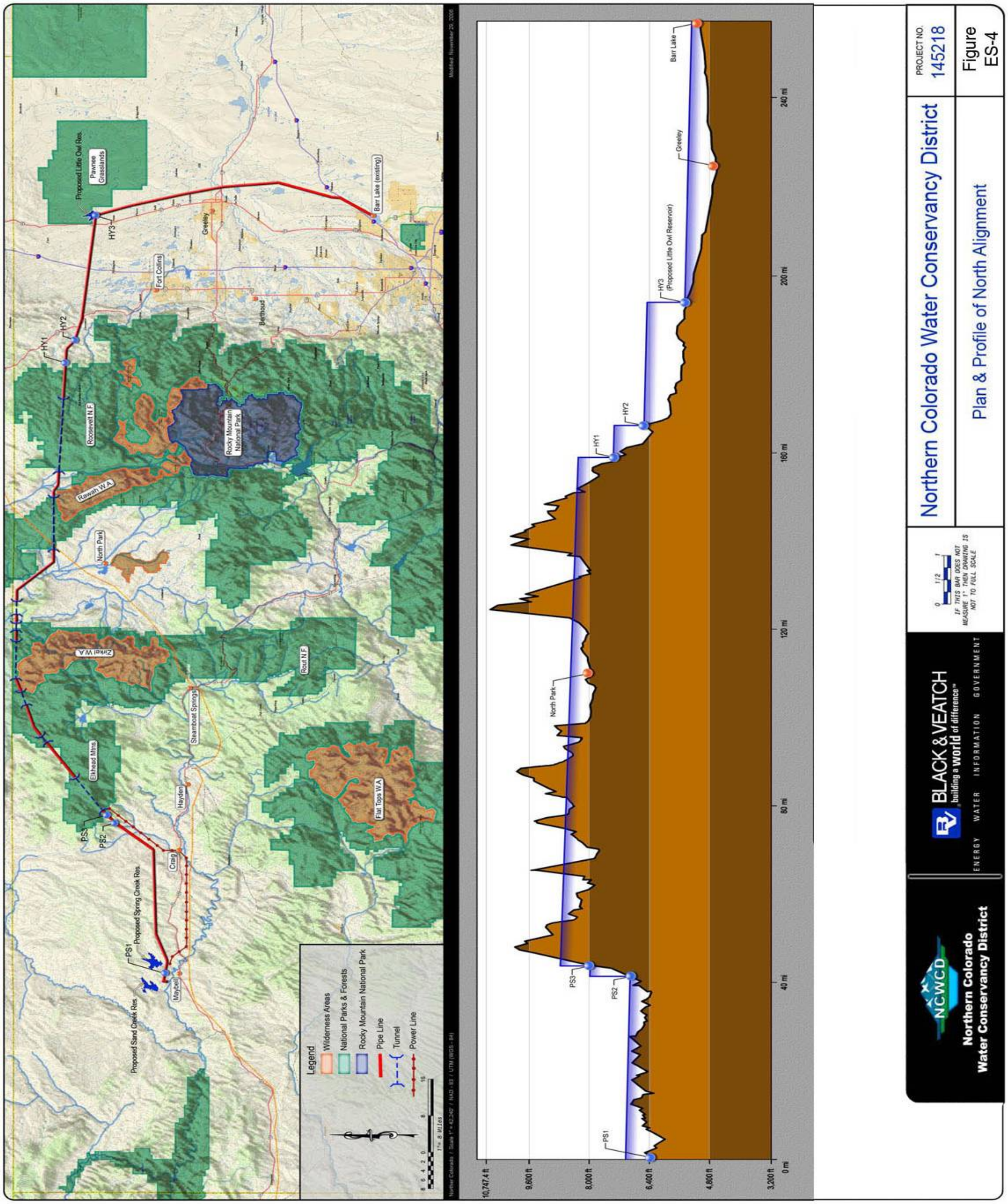
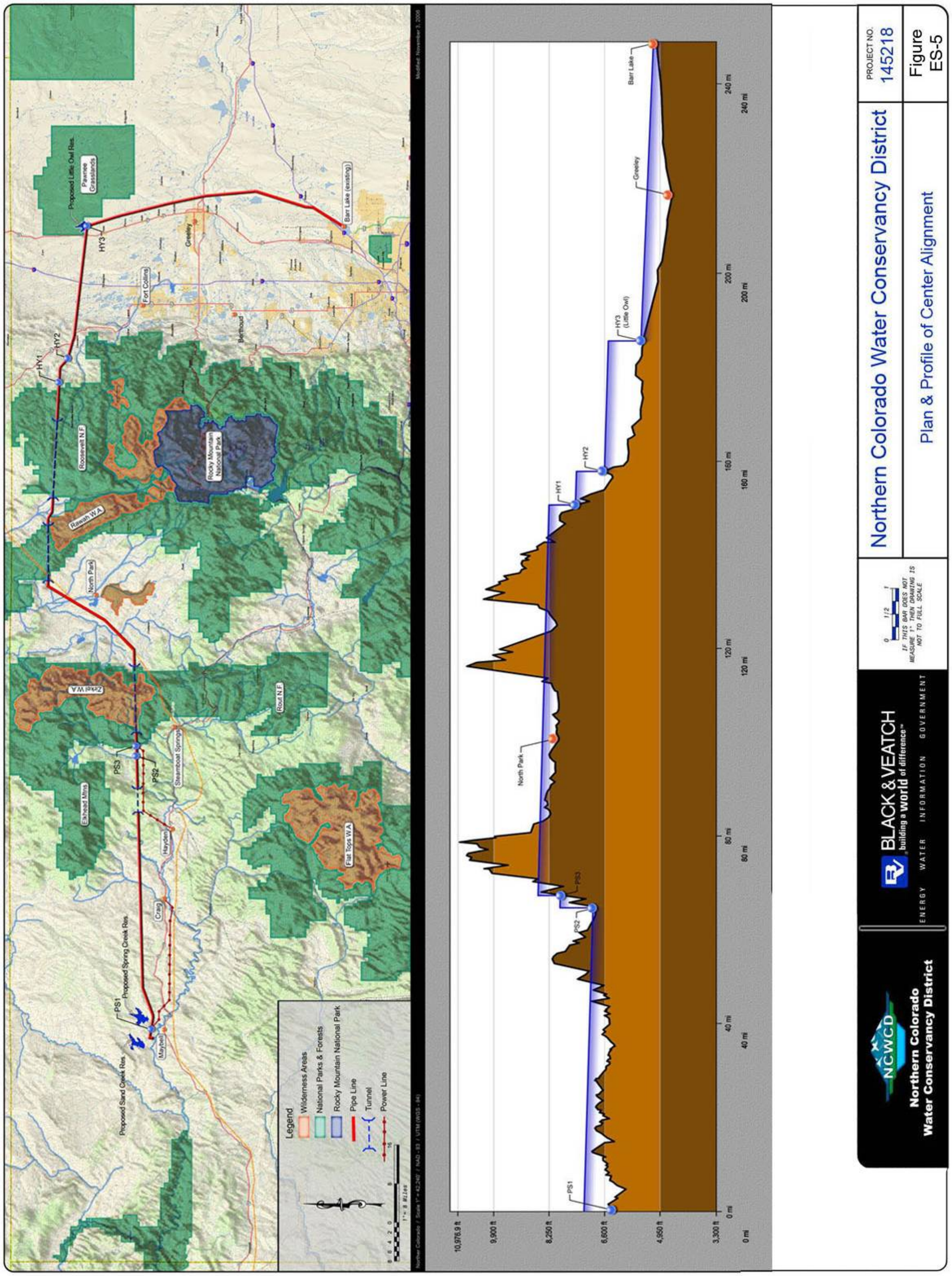

Northern Colorado Water Conservancy District
Plan & Profile of North Alignment
PROJECT NO.
145218
Figure
ES-4
BLACK & VEATCH
Northern Colorado
Water Conservancy District
Legend
Wilderness Areas
National Parks & Forests
Rocky Mountain National Park
Pipe Line
Tunnel
Power Line

Figure ES-4

Central Alignment

The Central Alignment of the west segment takes the most direct route from the diversion near Maybell to the North Park segment. It passes directly eastwards through Routt National Forest and crosses beneath the Zirkel Wilderness Area. As shown on Figure ES-5, tunneling would be utilized across the entire Zirkel Wilderness Area to avoid surface construction within the designated wilderness area. The North Park segment of this alignment parallels the existing high voltage power line across North Park.


Northern Colorado Water Conservancy District
Plan & Profile of Center Alignment
PROJECT NO.
145218
Figure
ES-5
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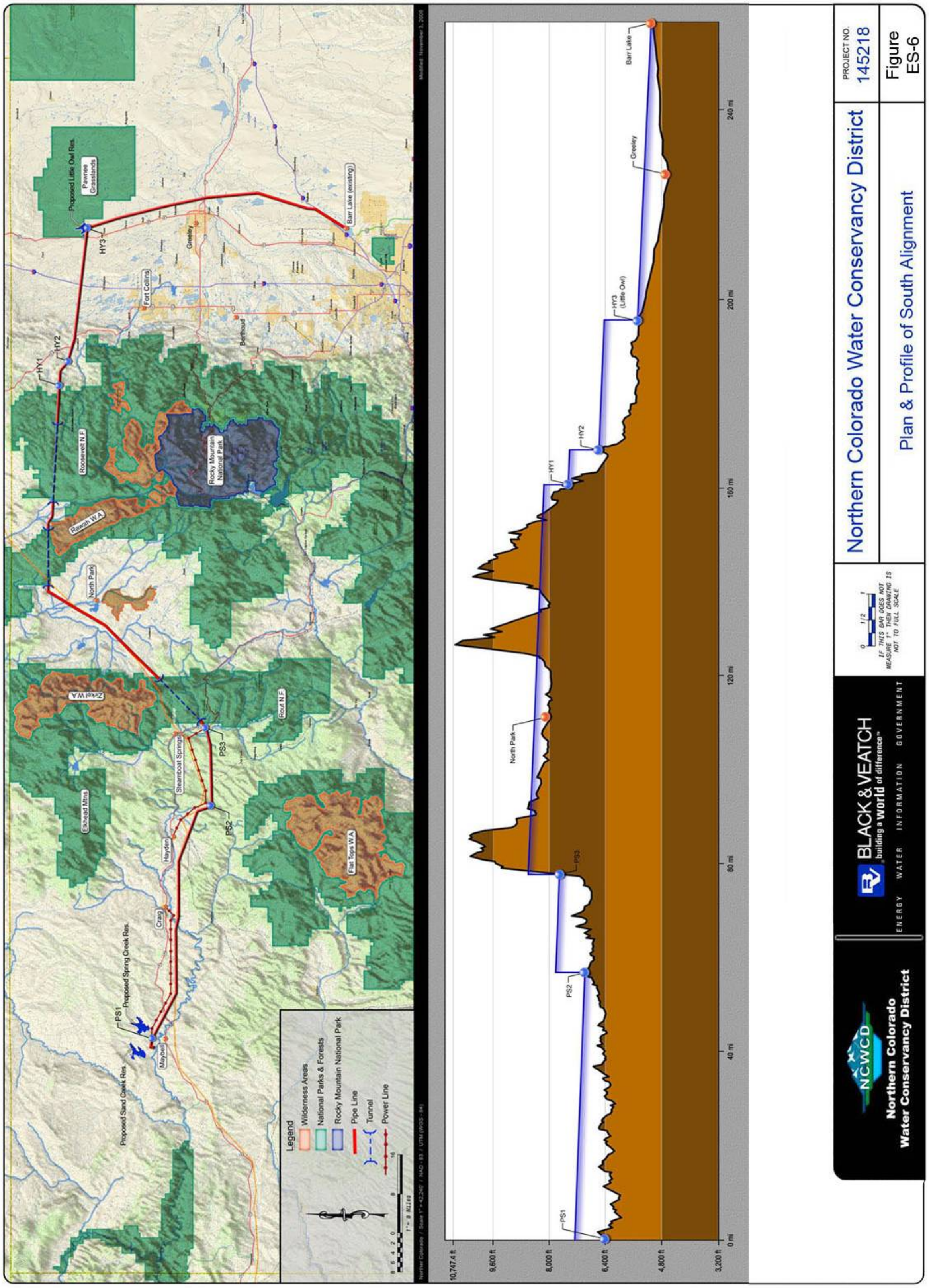
ENERGY WATER INFORMATION GOVERNMENT
Northern Colorado
Water Conservancy District
Legend
Wilderness Areas
National Parks & Forests
Rocky Mountain National Park
Pipe Line
Tunnel
Power Line
Rocky Mountain National Park
Roosevelt N.F.
Rawah W.A.
North Park
Zirkel W.A.
Routt N.F.
Steamboat Springs
Elkhead Mtns
Flat Tops W.A.
Hayden
Craig
Maybell
Proposed Sand Creek Res.
Proposed Spring Creek Res.
Proposed Little Owl Res.
Pawnee Grasslands
Barr Lake (existing)
Fort Collins
Greeley
Berthoud
PS1
PS2
PS3
HY1
HY2
HY3
HY3 (Little Owl)
North Park
Barr Lake
Greeley
10,976.9 ft
9,900 ft
8,250 ft
6,600 ft
4,950 ft
3,300 ft
0 mi
40 mi
80 mi
120 mi
160 mi
200 mi
240 mi

Figure ES-5

South Alignment

The South Alignment of the west segment parallels U. S. Highway 40 and the Yampa River for several miles, passes south of Steamboat Springs, and ultimately parallels the existing high voltage power line through Routt National Forest. As shown on Figure ES-6, this alignment also requires a tunnel to cross beneath the mountain range within Routt National Forest south of the Zirkel Wilderness Area. Similar to the central alignment, the North Park segment parallels the existing high voltage power line.


Northern Colorado Water Conservancy District
Plan & Profile of South Alignment
PROJECT NO.
145218
Figure
ES-6
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ENERGY WATER INFORMATION GOVERNMENT
Northern Colorado
Water Conservancy District
Legend
Wilderness Areas
National Parks & Forests
Rocky Mountain National Park
Pipe Line
Tunnel
Power Line
Barr Lake
Greeley
North Park
PS1
PS2
PS3
HY1
HY2
HY3
10,747.4 ft
9,600 ft
8,000 ft
6,400 ft
4,800 ft
3,200 ft
0 mi
40 mi
80 mi
120 mi
160 mi
200 mi
240 mi

Figure ES-6

A summary of the alignment alternatives is presented in Table ES-2.

Table ES-2

Alignment Alternatives Summary

Segments	Alignment Alternative		
	North	Central	South
Total Alignment Length	255 miles	250 miles	260 miles
Total			
- Total Pipe Length	208 miles	210 miles	227 miles
- Total Tunnel Length	67 miles	57 miles	45.5 miles
- Total Power Line Length	57 miles	58 miles	66 miles

Note, the total pipe length plus tunnel length is slightly longer than the total alignment length. This is because parallel 78-inch pipelines are assumed for the limited segments with working pressures above 500 psi, which doubles the pipe length within these limited segments.

Project Facilities

River Diversion Facilities

A diversion structure and pumping station would be required to convey Yampa River water to a new west slope raw water storage reservoir that would be located just north of Maybell. The diversion facility would only be operated when a minimum flow of 1,000 cfs can be maintained in the Yampa River downstream of the proposed diversion. The recommended west slope storage capacity is 500,000 acre-feet, the east slope storage capacity is assumed to be 75,000 acre-feet, and the maximum diversion rate is recommended to be 2,000 cfs.

Storage Reservoirs

The primary factors used for evaluating reservoir sites include:

- Avoiding known environmentally sensitive areas.
- Proximity to existing or known future mining operations.
- Minimizing distance from the river diversion to the west slope reservoir.
- Favoring sites with suitable soil characteristics for earthen dam foundations.
- Minimizing the amount of dam fill material required to meet storage objectives.
- Minimizing reservoir surface area.

Based on these factors, three sites were identified as shown on Figure ES-3. Zoned embankment (earthfill) dams are recommended for each of the three sites. A summary of the characteristics of these reservoirs are presented in Table ES-3.

Table ES-3 Summary of Potential Project Reservoirs			
Parameter	**Sand Creek Res.**	**Spring Creek Res.**	**Little Owl Res.**
Acre-feet	500,000	500,000	75,000
Dam Length (ft)	4,400	2,500	14,800
Dam Height (ft)	280	253	119
Res. Area (acres)	6,325	6,125	1,900
Embankment Vol (cy)	16,000,000	12,100,000	8,400,000

Pumping Stations

Pumping station locations were selected based on the system hydraulic profile for each alignment alternative. As shown on Figures ES-4 through ES-6, each alignment includes three pumping stations to provide the necessary energy to lift the water from the west slope storage reservoir to the tunnel segments that convey the water through the mountain ranges. The Yampa River Pump Station is designed for a maximum flow of 2,000 cfs. The remainder of the pump stations are designed for 500 cfs. Table ES-4 summarizes the operating conditions of the three pumping stations along the pipeline (referred to as inline pumping stations) for each alignment alternative.

Table ES-4

Operating Conditions for Inline Pumping Stations

Alignment	Pump Station #1		Pump Station #2		Pump Station #3		Total Alignment Power (hp)
	Pump Head (ft)	Station Power (hp)	Pump Head (ft)	Station Power (hp)	Pump Head (ft)	Station Power (hp)	
North	1,000	66,740	855	57,060	850	56,730	186,880
Central	1,050	70,080	850	56,730	850	56,730	184,540
South	925	61,730	925	61,730	925	61,730	185,190

A 60 acre-foot forebay at each pumping station would provide water storage for normal startup and shutdown operations, unscheduled outages of one or more pumps, and to balance minor differences between the discharges of the pumping stations.

Pipelines

Two alternatives were evaluated for the pipelines. The first would be a single pipeline capable of carrying the entire 500 cfs design flow rate. The second alternative would consist of two smaller diameter parallel pipelines. Initially, a smaller pipeline would carry half of the ultimate design flow (250 cfs). A second pipeline could be constructed in the future to meet the system target yield. The potential advantage of the phased approach is that 150,000 AFY could be delivered for a lower initial capital cost. The total capital cost for both pipelines would be slightly higher than the single pipeline approach. A 108-inch diameter pipe was selected for a single, one-stage pipeline. Two 78-inch parallel pipes are recommended for the two-stage project.

Tunnels

Tunnels would be required to cross the numerous mountain ranges and to avoid surface construction in designated wilderness areas. Since the minimum tunnel diameter depends on the tunnel boring equipment and not hydraulic requirements, phasing tunnel construction is not practical. Therefore, all tunnel segments were assumed to be constructed in a single phase at the recommended diameter. Considering both the tunnel boring equipment size and the potential hydraulic benefits associated with a design velocity of 6 fps, a 10-foot (120-inch) inside diameter tunnel is recommended (1 foot larger than the pipeline diameter).

Hydropower Facilities

A series of hydroelectric power plant facilities are recommended along the East Segment of the alignment. Table ES-5 summarizes the operating conditions associated with the proposed hydropower facilities.

Table ES-5

Hydropower Operating Conditions

	Hydro Station 1	Hydro Station 2	Hydro Station 3
Flow rate	500 cfs	500 cfs	500 cfs
Upstream head	740 ft	860 ft	830 ft
Tailwater head	20 ft	20 ft	20 ft
Rated capacity	36 MW	42 MW	40 MW

Cost, Schedule, and Conclusions

Costs

Both capital and annual operating costs were estimated for the project. Unit costs were utilized in developing component costs. The annual operating costs include labor for anticipated operating staff, maintenance, electricity, and the benefits of energy recovered from the hydropower plants.

Single Phase Implementation

The estimated capital, operation and maintenance, and energy costs for each of the three alignment options, assuming all of the facilities are constructed in a single phase, are presented in Table ES-6.

Table ES-6

Alternative Comparison and Costs (Single Phase)

	North	Central	South
Storage (AF)	575,000	575,000	575,000
Pipe (miles)	208	210	227
Tunnels (miles)	67	57	46
Pumping (hp)	294,000	297,000	299,000
Hydro (MW)	115	118	117
Capital Cost to N. Colorado	$3.29 Billion	$3.16 Billion	$3.22 Billion
- Unit Cost ($/AF)	$11,000 +/- per AF		
Capital Cost to Denver	$3.97 Billion	$3.82 Billion	$3.88 Billion
- Unit Cost ($/AF)	$13,000 +/- per AF		
Annual O&M Cost ($/AF)	$150+/- per AF		

Two Phase Implementation

The estimated capital, operation and maintenance, and energy costs for each of the three alignment options, assuming the facilities are constructed in two phases, are presented in Table ES-7.

Table ES-7
Alternative Comparison and Costs (Two Phase)

	North	**Central**	**South**
Storage (AF)	575,000	575,000	575,000
Pipe (miles)	198	202	222
Tunnels (miles)	61	53	44
Pumping Initial (hp)	182,000	180,000	183,000
Pumping Final (hp)	294,000	297,000	299,000
Hydro Initial (MW)	49	48	48
Hydro Final (MW)	115	118	117
Phase I Capital Cost to Denver	$2.95 Billion	$2.78 Billion	$2.66 Billion
- Unit Cost ($/AF)	$19,000 +/- per AF		
Total Phase I&II Capital Cost to Denver	$4.26 Billion	$4.11 Billion	$4.08 Billion
- Unit Cost ($/AF)	$14,000 +/- per AF		
Annual O&M Cost ($/AF)	$150+/- per AF		

Schedule

A proposed project schedule is presented on Figure ES-7. Based on the schedule presented herein, the proposed system could be operational by summer 2023. Five years have been allocated to solicit the interest of potential participants, further formulate the project, and identify the final participants. Another five years have been allocated to prepare the EIS and obtaining required permits. An estimated eight years would be required to design, bid, construct, and start-up the project.

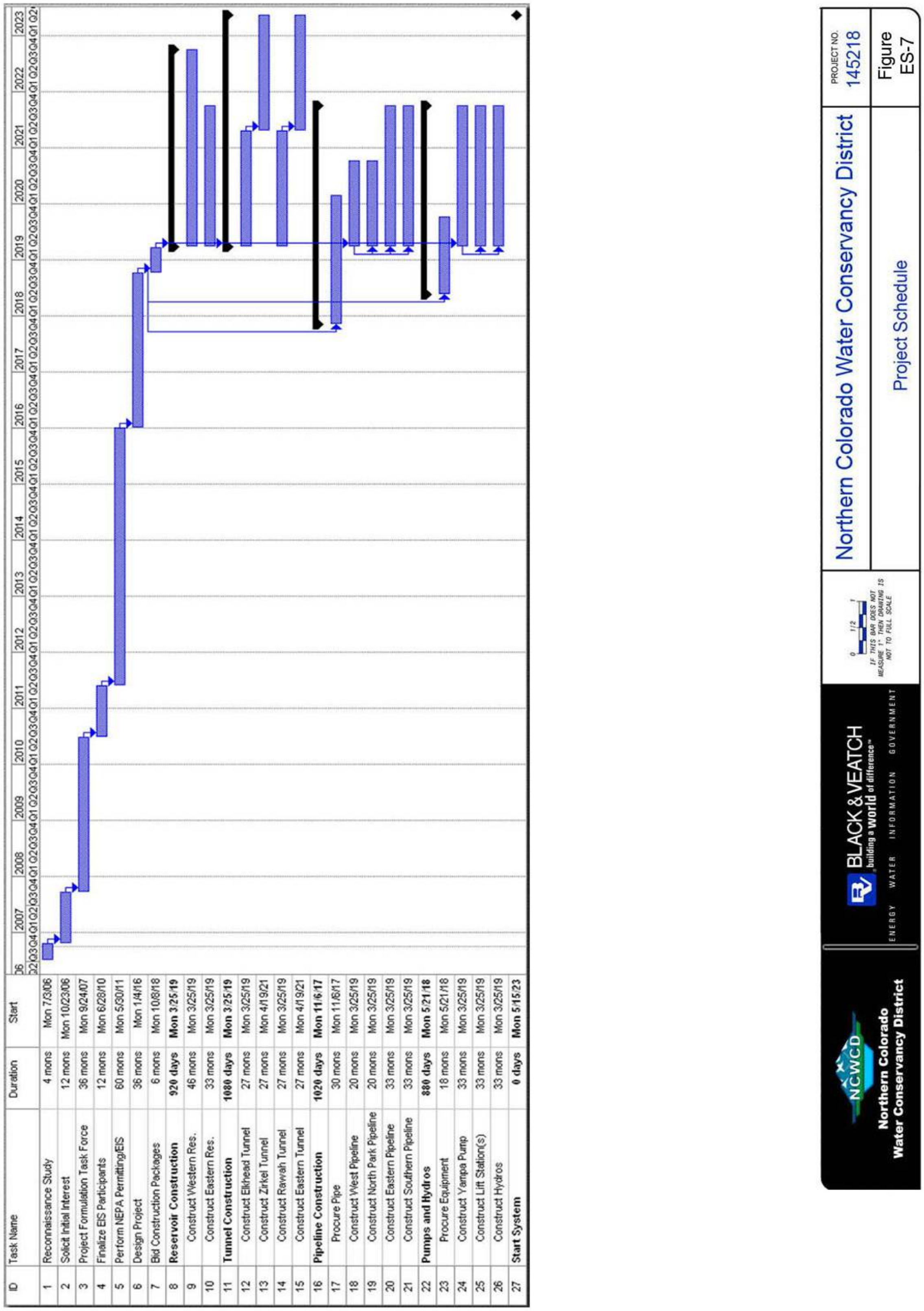
ID | Task Name | Duration | Start
1 Reconnaissance Study 4 mons Mon 7/3/06
2 Solicit Initial Interest 12 mons Mon 10/23/06
3 Project Formulation Task Force 36 mons Mon 9/24/07
4 Finalize EIS Participants 12 mons Mon 6/28/10
5 Perform NEPA Permitting/EIS 60 mons Mon 5/30/11
6 Design Project 36 mons Mon 1/4/16
7 Bid Construction Packages 6 mons Mon 10/8/18
8 Reservoir Construction 920 days Mon 3/25/19
9 Construct Western Res. 46 mons Mon 3/25/19
10 Construct Eastern Res. 33 mons Mon 3/25/19
11 Tunnel Construction 1080 days Mon 3/25/19
12 Construct Elkhead Tunnel 27 mons Mon 3/25/19
13 Construct Zirkel Tunnel 27 mons Mon 4/19/21
14 Construct Rawah Tunnel 27 mons Mon 3/25/19
15 Construct Eastern Tunnel 27 mons Mon 4/19/21
16 Pipeline Construction 1020 days Mon 11/6/17
17 Procure Pipe 30 mons Mon 11/6/17
18 Construct West Pipeline 20 mons Mon 3/25/19
19 Construct North Park Pipeline 20 mons Mon 3/25/19
20 Construct Eastern Pipeline 33 mons Mon 3/25/19
21 Construct Southern Pipeline 33 mons Mon 3/25/19
22 Pumps and Hydros 880 days Mon 5/21/18
23 Procure Equipment 18 mons Mon 5/21/18
24 Construct Yampa Pump 33 mons Mon 3/25/19
25 Construct Lift Station(s) 33 mons Mon 3/25/19
26 Construct Hydros 33 mons Mon 3/25/19
27 Start System 0 days Mon 5/15/23
2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023
Northern Colorado Water Conservancy District
NCWCD
BLACK & VEATCH building a world of difference
ENERGY WATER INFORMATION GOVERNMENT
IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO FULL SCALE
Northern Colorado Water Conservancy District
Project Schedule
PROJECT NO. 145218
Figure ES-7

Figure ES-7

Conclusions

The conclusions of this investigation are:

- The project is economically feasible and compares favorably to projects Denver metro suppliers are currently considering.
- The project provides a viable alternative to agriculture dry-up.
- Water could be provided to five basins - Yampa, North Platte, South Platte, Arkansas and Colorado.
- The project could provide a water supply which, when combined with conservation, could meet the state's water needs well into the 21st century.
- The project merits additional study and discussion and will require the cooperation of many entities and most likely the State of Colorado.
- The project could yield more than 300,000 AF of water annually.
- The project would only take Yampa River water that is currently flowing out of state.