



Colorado's Water Supply Future



Colorado Water Conservation Board Strategies for Colorado's Water Supply Future

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Draft Report

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Acronyms

AF	acre-feet
AFY	acre-feet per year
AWWA	American Water Works Association
BOR	Bureau of Reclamation
BRT	Basin Roundtable
CBEF	Center for Business and Economic Forecasting
CBT	Colorado Big Thompson
CDSS	Colorado Decision Support System
CDWSU	Colorado Drought and Water Supply Update
cfs	cubic feet per second
CRSP	Colorado River Storage Project
CRWAS	Colorado River Water Availability Study
CUWCC	California Urban Water Conservation Council
CU&L	Consumptive Uses and Loss
CWCB	Colorado Water Conservation Board
EIS	Environmental Impact Statement
ELA	engineering, legal, and administrative
ESA	Endangered Species Act
fps	feet per second
FRICO	Farmers Reservoir and Irrigation Company
GHC	Government Highline Canal
gpcd	gallons per capita per day
GVIC	Grand Valley Irrigation Canal
HGL	hydraulic grade line
IBCC	Interbasin Compact Committee
IPPs	Identified Projects and Processes
KAF	thousand acre-feet
kwhr	kilowatt hour
M&I	municipal and industrial
MAF	million acre-feet
mg/L	milligrams per liter
NED	National Elevation Dataset
NEPA	National Environmental Policy Act
O&M	operations and maintenance
OWCDP	Office of Water Conservation and Drought Planning

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psi	pounds per square inch
RICD	recreational in-channel diversion
RO	reverse osmosis
SDO	State Demographer's Office
SMWSA	South Metro Water Supply Authority
SNWA	Southern Nevada Water Authority
SSI	self-supplied industrial
SWSI	Statewide Water Supply Initiative
TBM	tunnel boring machine
TDH	total dynamic head
TDS	total dissolved solids
TRT	Technical Roundtable
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
ZLD	zero liquid discharge

Section 1

Introduction

1.1 Background

The last decade has brought many changes to the State of Colorado. Even considering the recent economic recession, our state has experienced significant population growth, severe drought, increased emphasis on multiple uses of our water resources, and increased pressure on agricultural uses of water due to drought, urbanization, and purchase and transfer of agricultural water to new users.

To help understand and address these trends, the Colorado Water Conservation Board (CWCB) has undertaken a number of important initiatives. The CWCB is statutorily charged to conserve, protect, manage, and develop Colorado's water resources for current and future generations. In accomplishing this mission, the CWCB must help ensure that water is utilized to meet the needs of Colorado's citizens while protecting the environment.

In the last few years, state leaders and resource management agencies across the state have been increasingly focused on helping ensure that Colorado has an adequate water supply for its citizens and the environment. In 2003, the Colorado General Assembly authorized the CWCB to implement the Statewide Water Supply Initiative (SWSI). SWSI was a comprehensive identification of Colorado's current and future water needs and it examined a variety of approaches Colorado could take to meet those needs. SWSI implemented a collaborative approach to water resource issues by establishing SWSI roundtables. Roundtable is a term used to describe a group of people from which the state seeks input on water issues. Each roundtable's members have a broad range of geographical, professional, technical, and political expertise, such as water users, farmers, ranchers, water suppliers, industrial interests, and environmental and recreational groups. Nine roundtables were institutionalized in the 2005 Colorado Water for the 21st Century Act (House Bill 05-1177), which creates a voluntary, collaborative process to help the state address its water challenges. These include the eight major water basins (Arkansas, Colorado, Gunnison, North Platte, Rio Grande, South Platte, Southwest (San Juan/Dolores/San Miguel/Animas), and Yampa/White as well as the Denver Metro area.

The process is based upon the premise that Coloradans can work together to address the water needs within the state. The Act sets up a framework that provides a permanent forum for broad-based water discussions. It created nine Basin Roundtables and the Interbasin Compact Committee (IBCC).

In 2006, the IBCC established and the General Assembly ratified the IBCC's Charter. The Charter outlines the roles of the IBCC, one of which is to provide a "framework that creates incentives for successful deliberations, agreements, and their implementation." To help further this role, the IBCC embarked on a Visioning Process (described below).

Through the Visioning Process the IBCC, CWCB, and Basin Roundtables agreed to evaluate water supply strategies that could help address Colorado's water supply future. This report presents an analysis of three water supply strategies: conservation, agricultural transfers, and new water supply development, recognizing that no one strategy will meet future needs. Thus, water supply portfolios will be developed that will be a mix of water derived from conservation, agricultural transfers, and the development of new supplies from the Colorado River. It seeks to integrate many of the findings and recommendations of SWSI and SWSI Phase 2 with the ongoing work of the Basin Roundtables and IBCC. In particular it builds on the work of the SWSI 2 Conservation Technical Roundtable, the SWSI 2 Gap Technical Roundtable, and the Basin Roundtable's basin-wide water needs assessments.

This report is also part of a series of three reports that include a summary of the Basin Roundtables Nonconsumptive Needs Assessment Priority Mapping, the results of the Watershed Flow Evaluation Tool Pilot, and 2050 Municipal and Industrial (M&I) Water Needs.

1.2 IBCC/CWCB Visioning Process

During 2008, Colorado's water community embarked on a visioning process to address the following questions:

- If we let Colorado's water supply continue to evolve the way it is now, what will our state look like in 50 years?
- Is that what we want it to look like?
- If not, what can and should we do about it?

Discussions between the IBCC, the Basin Roundtables, and the CWCB generated the following statements:

- Colorado needs to provide an adequate water supply for our citizens and the environment. In doing so, the status quo approach to water supply will not lead to a desirable future for Colorado.
- Water supply in Colorado is transitioning from an era of undeveloped resources to an era of managing a more developed resource. Future water decisions will increasingly involve reallocating water between uses.
- Water is not an independent issue. Colorado's water supply future is tied to the larger economic, demographic, and cultural trends of our state.
- A range of strategies are needed to help meet our state's consumptive and nonconsumptive water supply needs. These include a combination of demand side strategies such as conservation, supply side strategies such as storage and agricultural transfers, and regional coordination strategies.

- The IBCC, CWCB, Basin Roundtables, and other stakeholders should work together to examine the trade-offs, risks, and uncertainties associated with different strategies and combination of strategies.
- A statewide Vision Statement should be developed in combination with an evaluation of water supply strategies.

The visioning process initiated by the IBCC to develop a statewide vision for Colorado's water supply future has three parts: 1) a Vision Statement; 2) Vision Goals; and 3) Water Supply Strategies. These terms are specifically defined as:

1. **Vision Statement** – This represents, in the broadest sense, the overall directive or mission. It describes "what" is to be achieved.
2. **Vision Goals** – These define the goals of the vision, and more importantly represent the benchmarks for the evaluation of strategies. The Vision Goals will play an important role in evaluating the performance of water supply strategies. This represents the "why" portion of the vision.
3. **Water Supply Strategies** – Strategies represent "how" we will achieve the Vision Statement. The performance of strategies is compared against the Vision Goals in order to see how well we are doing in achieving the overall Vision Statement. These strategies will lead to implementation.



Figure 1-1. Elements of the Visioning Process

The main rule is that the "what," "why," and "how" builds on each other, but are not redundant.

This visioning process is modeled after an integrated planning process and provides a path to sustainability. The elements of an integrated resource planning process involves active stakeholder participation, examines demand-side management as vigorously as supply options, incorporates multiple criteria in decisionmaking (e.g., reliability, cost, environment, quality of life, recreation, etc.), explores risk and uncertainty, and takes a long-term perspective (30 to 50 years).

This visioning process also employs elements of sustainability including finding the right balance between economic, environmental, and social needs; taking a holistic perspective; and consideration of the long-term. This visioning process promotes sustainable solutions because:

- It focuses on the long-term;

- It incorporates societal values;
- It takes a holistic, interconnected perspective; and
- It strives for balance in meeting multiple objectives.

1.2.1 Vision Statement and Vision Goals

The draft vision statement that the IBCC developed and will further refine as strategies are developed is "We envision a Colorado that balances municipal, industrial, agricultural, environmental, and recreational water needs and promotes cooperation among all water uses."

The IBCC also drafted vision goals. These Vision Goals are based on previous work by the IBCC, the CWCB Board, and other processes including: 1) responses to the IBCC Visioning Exercise, the SWSI Major Findings, the SWSI Objectives, Colorado State University's analysis of water beliefs and values, University of Denver's Colorado's Water Future Panel, and the IBCC's Guiding Principles (the CO 64 Principals).

These goals may individually conflict and may not always be accomplished. However, by evaluating all the goals together, more balanced water supply strategies can be achieved.

The IBCC drafted and discussed, but has not come to agreement on the following Vision Goals:

1. Meet M&I demands.
2. Meet agricultural demands.
3. Meet Colorado's environment and recreation demands.
4. Promote cooperation between water supply planners and land use planners.
5. Promote more cooperation among all Colorado water users.
6. Optimize existing and future water supplies by:
 - a. Minimizing non-beneficial consumptive use (evaporation, non-native phreatophytes, etc.).
 - b. Maximizing successive uses of legally reusable water.
 - c. Maximizing use of existing and new in-basin supplies.
7. Promote cost-effectiveness by:
 - a. Allocating costs to all beneficiaries fairly.
 - b. Achieving benefits at the lowest cost.
 - c. Providing viable financing mechanisms, including local, state, and federal funding/financing.
 - d. Mitigating third-party economic impacts.

8. Minimize the net energy used to supply water, including both the energy used and/or generated with raw water delivery, and the energy used for treatment.
9. Protect cultural values linked to water resources by:
 - a. Maintaining and improving the quality of life unique to each basin.
 - b. Maintaining open space.
10. Provide operational flexibility and coordinated infrastructure.
11. Promote increased fairness when water is moved between areas by:
 - a. Benefiting both the area of origin and the area of use.
 - b. Minimizing and mitigating the adverse economic and environmental impacts.
12. Comply with all applicable laws and regulations, meet all applicable compact obligations, protect compact allocations, and protect water rights including the right of water right owners to market their water, while recognizing some new institutions, organizations, or legislation may be needed to implement certain strategies.
13. Educate all Coloradoans on the importance of water, and the need to conserve, manage, and plan for needs of current and future generations.

1.2.2 Water Supply Strategies

The third part of a statewide vision for Colorado's water supply future is water supply strategies. During their May and August 2009 meetings, the IBCC discussed which water supply strategies may help meet our state's **consumptive** and **nonconsumptive** water supply needs. They agreed on a draft list of strategies for further evaluation. These included:

Demand Side Strategies

- Growth, Land Use, and Density Development
- M&I Conservation
- Agricultural Conservation (non-beneficial losses), Efficiency, and Alternative Cropping Patterns
- Reduction in Water Demands for Energy Development (Traditional and Renewable Energy)

Supply Side Strategies

- Reuse and Desalination
- Agricultural Transfers: Traditional Transfers and Alternatives to Traditional Transfers
- Optimizing/Rehabilitating Existing Storage and Delivery Systems

- New In-basin Storage that can Meet Multiple Consumptive and Nonconsumptive Needs
- Colorado River Compact Development
- Transbasin Diversions that Benefit the Area of Origin and the Area of Use
- Coordinated Reservoir Operations, Infrastructure Development, and Opportunities for Shared Infrastructure
- Colorado River Basin General Augmentation
- Integrated Management of Groundwater and Surface Water including the optimum use of groundwater and surface water supplies and the use of aquifer storage and recovery

At the July 2009 CWCB Board meeting, the CWCB Board reviewed this draft list and directed staff to begin describing and analyzing these strategies. Based on IBCC, Basin Roundtable, and CWCB direction, the CWCB staff began the development of these strategies in detail starting with **M&I Conservation, Agricultural Transfers, Colorado River Compact Development, and Transbasin Diversions** and use this information to begin to describe portfolios of projects indicating how Colorado might address its future water needs consistent with the vision and objectives developed by the IBCC, CWCB, and Basin Roundtables.

1.3 Report Purpose and Overview

The overall purpose of the report is to provide further details on this initial set of strategies. This report is a compilation of a series of technical memorandums that were developed to summarize technical work that was completed for the CWCB under various task orders. The objectives of the technical memorandums that have been compiled in this report are:

- Identify potential scenarios for Colorado's water supply future and associated water supply portfolios driven by the future scenarios
- Describe the M&I conservation strategy, agricultural transfer strategy, and new supply development strategy
- Present reconnaissance level cost estimates for the agriculture transfer and new supply development strategies
- Summarize the benefits, impacts, and opportunities of each strategy

1.3.1 Colorado's Projected M&I Water Needs

The strategies discussed in this report are intended to help meet Colorado's water supply needs under different future scenarios. Potential scenarios for Colorado's water supply future are based on future demands for water. Colorado's 2050 M&I water demands are discussed in detail in the CWCB report "State of Colorado 2050 Municipal and Industrial Water Use Projections" (2009). Due to the uncertainty with

projecting population 40 years into the future, low, medium, and high M&I water demands were estimated based on varying economic factors. The low, medium, and high M&I water demand projections are shown on Figure 1-2 (purple portion of chart).

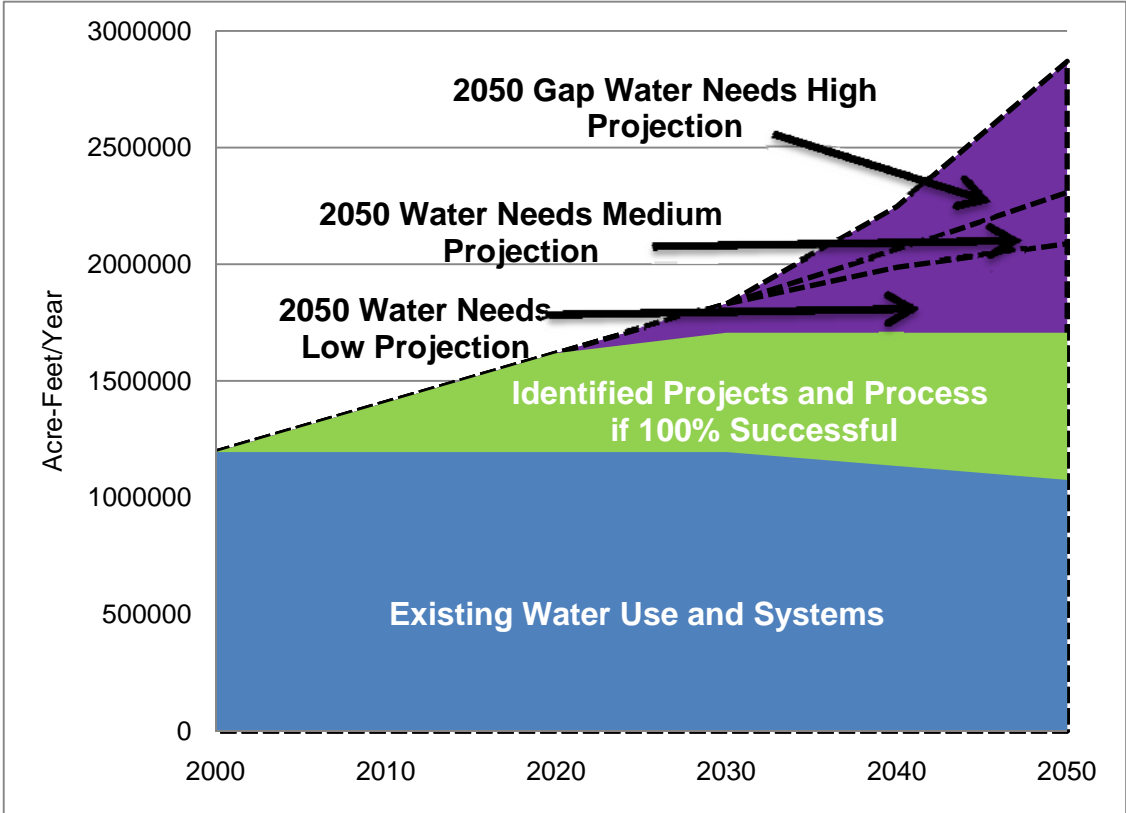


Figure 1-2. State of Colorado Projected M&I Water Needs

The purple portion of the chart can also be referred to as the M&I gap. The "gap" between Colorado's M&I supply and demand is dependent upon the success of projects, conservation plans, and other planning processes currently being pursued by water providers. These are referred to as Identified Projects and Processes (IPPs) and are represented in the green portion of Figure 1-2. To the extent these IPPs are successful, the strategies discussed in this report can be implemented further out in the future and need to account for less water. To the extent the IPPs are unsuccessful, these broader strategies will need to be implemented sooner and account for more of our future M&I needs. Figure 1-2 provides the estimated amount of water potentially provided by the SWSI IPPs. Some of the IPPs may or may not be successfully implemented by 2030. Because of the importance of the IPPs, CWCB is implementing an IPP database to track and monitor the progress of water provider's projects, conservation plans, and planning processes.

Figure 1-2 also shows that existing supplies are based on current demands being met by water providers through their current supplies and water system infrastructure.

One variable illustrated in Figure 1-2 is that due to climate change these supplies may decrease in the future. CWCB is in the process of modeling climate change in its Water Supply Availability Study and will provide information on this issue upon study completion. For now, Figure 1-2 shows a 10 percent decrease in supplies by 2050. In addition, these values assume that the current yield of groundwater in the major gap areas of the state will remain constant over the next 40 years. Groundwater yields in some areas have already experienced a decrease in yield and this issue may need to be examined in more detail in the future.

By the year 2050 under the high demand scenario, Colorado's gap between M&I supply and demand is expected to be 1,100,000 acre-feet (AF) growing from about 1,250,000 AF to about 2,870,000 AF assuming all identified projects and planning processes being pursued by water providers are 100 percent successful.

Under the low demand scenario assuming a 100 percent success rate of identified projects and planning processes Colorado's gap between M&I supply and demand is expected to be 320,000 AF. Total demand is expected to grow from about 1,250,000 AF to 2,100,000 AF.

All of the elements discussed above regarding Figure 1-2 may vary in the future. Instead of predicting one future condition for 2050, CWCB has developed five future M&I water demand and supply screening scenarios. These screening scenarios will drive the portfolio of solutions for Colorado's water supply future. The portfolio of solutions will contain a mix of M&I conservation, agricultural transfer, new supply development, and other strategies. Scenario development and the portfolio of solutions are discussed in **Section 2** of this report.

Section 3 will describe the conservation strategy after technical work for this strategy is completed.

The basic details of the agricultural transfer and new supply development strategies are discussed in **Section 4**. These strategies are defined by six concepts that have been discussed and studied by various entities throughout Colorado. All of these concepts would return water from various geographies to areas with significant 2050 water needs. The six concepts include:

Agricultural Transfer

- Middle and Lower South Platte River
- Middle and Lower Arkansas River

New Supply Development

- Green Mountain Reservoir
- Colorado River Return
- Yampa River
- Flaming Gorge Reservoir

For each of these concepts, a description of the key elements such as water source, conveyance, storage, and water quality are provided. Section 4 also includes a description of additional potential concepts that could be developed in smaller increments than the concepts listed above.

For all the strategies, **Section 5** discusses cost estimates. For the agricultural transfer and new supply development concepts listed above, reconnaissance level costs were developed based on previous efforts. The cost estimates include capital costs such as land acquisition, pumps, pipe, and treatment costs. Operation and maintenance costs were also estimated for each strategy. Operation and maintenance costs include energy, maintenance and replacement costs.

Section 6 discusses the benefits, impacts, and opportunities for each strategy, which was developed with feedback from the CWCB, IBCC, and the Basin Roundtables.

Section 7 will be developed based on recommendations from the CWCB and IBCC meetings.

Section 2

Scenarios for Colorado's Water Supply Future

2.1 Scenarios for Colorado's Water Supply Future Overview

Addressing Colorado's water supply future involves a number of important steps including: 1) identification of what is important to Coloradoans in the management and development of water; and 2) examining how water demand and supply may vary over the next several decades. The IBCC and CWCB Board have identified goals and objectives for water use and management through a "visioning process" and have provided direction for several water supply and demand scenarios. These

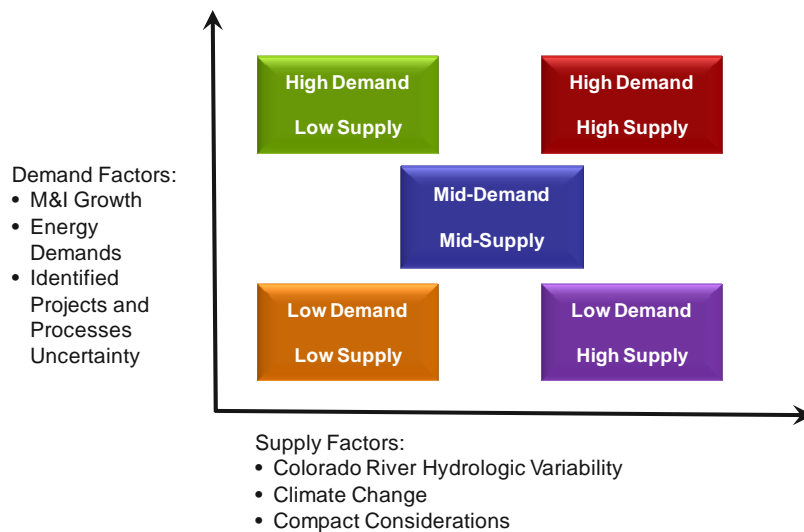


Figure 2-1. 2050 Statewide M&I Water Demand and Colorado River System Supply Scenarios

scenarios incorporate future M&I needs for water. Needs assessments that are currently ongoing examine demands for agricultural, energy, and nonconsumptive needs. As these components are further developed, they will be added to the scenario planning analyses.

Traditional planning efforts typically examine one predictive future. These scenarios are not intended to be forecasts of the future but are developed to represent *potential* future conditions

that may impact M&I water supply and demand. This approach was used because of the broad scale of this effort and because many factors are largely outside the control of water managers, such as population growth, oil shale development, and weather patterns. Five M&I water demand and supply futures were developed as screening scenarios for the year 2050 based on varying factors as shown in Figure 2-1. These screening scenarios are based on combining factors that may contribute to low, medium, and high statewide water demands and supplies available for new appropriation on the Colorado River System. The supply scenarios shown in Figure 2-1 are focused on the Colorado River system because the other major river systems in the state either have very limited water supplies and/or will be further developed as part of the IPPs and therefore there is limited ability to develop additional supplies within these river basins.

Over the next 40 years, several factors may vary statewide M&I water demands including population growth, energy development such as oil shale, and the success or failure of implementing the IPPs identified in the SWSI Phase 1 report (CWCB 2004). Similarly, factors that influence water supply include Colorado River hydrologic variability, climate change, and interstate compact considerations. This section includes narrative summaries that describe the factors that would contribute to low, medium, and high M&I water demands and supplies and estimates quantities of demands and supplies for each of the five screening scenarios. Finally, how these scenarios drive strategies for all of Colorado's future water supply needs (M&I, agricultural, environmental, and recreation) is summarized by describing how combinations of strategies can help meet Colorado future water supply needs.

2.2 Water Demands Narrative Summary

The following factors contribute to the low, medium, and high water demands depicted in Figure 2-1:

- Population growth and associated M&I water demands
- Energy demands for water specifically from oil shale development
- The amount of IPPs that are implemented by 2030

Population growth and associated demands are described in detail in CWCB's State of Colorado 2050 Municipal and Industrial Water Use Projections report (2009). The year 2050 population projections were estimated using the Colorado State Demographer's Office (SDO) and the Center for Business and Economic Forecasting (CBEF) models. The SDO/CBEF projections were only available through the year 2035. Population projections from 2035 to 2050 were based on extending and adjusting the SDO/CBEF forecasting models, equations, and algorithms. The SDO/CBEF business and economic model overview is shown in Figure 2-2. The basic assumption behind this model is that in addition to natural population growth (births and deaths) economic factors drive population growth. Because of the uncertainty in projecting economic conditions and employment levels in 2050, low, medium, and high population projections were developed. The following employment sectors and low, medium, and high factors driving these sectors were used in the forecasting model:

Traditional Basic Sectors

- Agriculture
- Government
- Mining
- Manufacturing
- Regional and National Services
- Tourism

Household Basic Sectors

- Retirees
- Wealth and Income
- Public Assistance
- Commuting/Employment

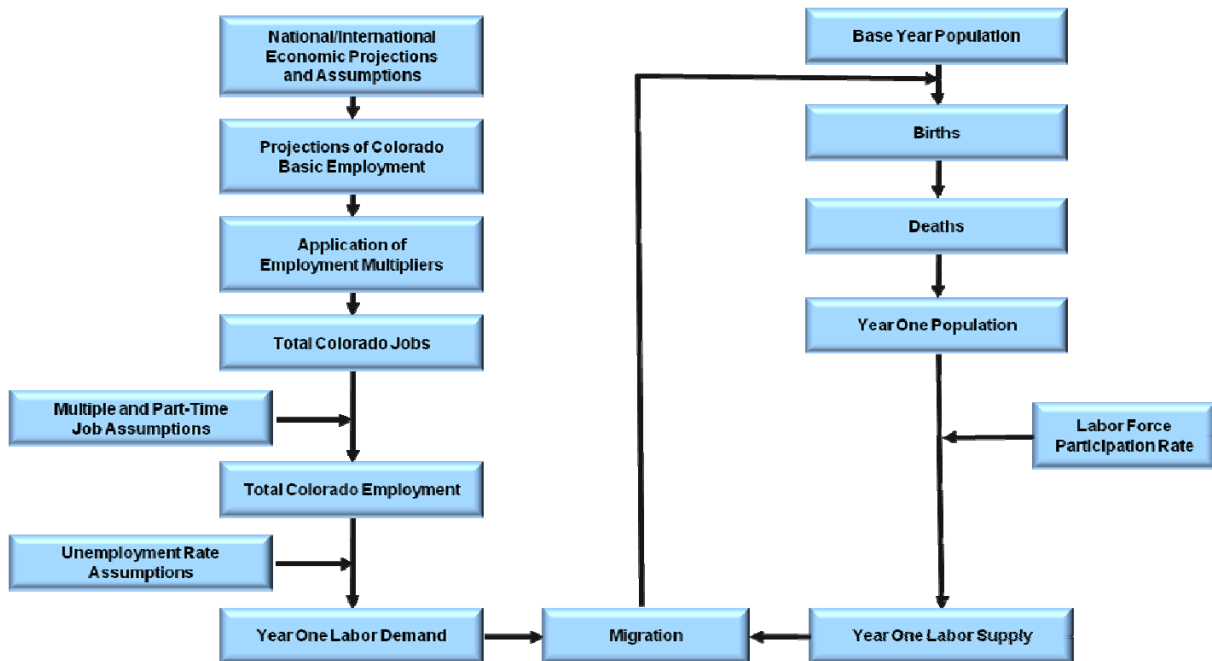


Figure 2-2. SDO/CBEF Population Projection Methodology

The population projections and water use data throughout the state were utilized to project low, medium, and high M&I water demands for 2050. The M&I water demand forecast used driver multiplied by rate of use approach. This is a commonly accepted forecast methodology that accounts for driving changes in water demand. For the M&I forecast, the driver is population and the rate of use is gallons per capita per day (gpcd). Thus, the population estimates developed for this update and the gpcd values determined through data collection are multiplied to estimate M&I demands. The statewide low, medium, and high M&I demands for water in 2050 are 1.8 million acre-feet (MAF), 2.0 MAF, and 2.2 MAF, respectively. Existing M&I demands are nearly 1.1 MAF (CWCB 2009).

Recent M&I projections also identified potential oil shale development as having large future water demands. This is based on a recent draft report for the Colorado, Yampa, and White River Basin Roundtables Energy Subcommittee that assesses the water needs in northwest Colorado for energy development. The report estimates water demands needed to support the extraction and production of natural gas, coal, uranium, and oil shale through 2050 (URS 2008). For purposes of the screening scenarios no development of oil shale was built-in for the low demand scenario, partial development of oil was included in the medium demand scenario, and full development of oil shale was incorporated into the high demand scenario. Total statewide M&I demands including oil shale and other self-supplied industrial (SSI) demands for the low, medium, and high screening scenarios are 2.1 MAF, 2.3 MAF, and 2.9 MAF, respectively (the range used to estimate the potential increase in oil shale and other self-supplied industrial demands is 300,000 to 700,000 AF).

The SWSI Phase 1 report summarized the IPPs that are required to help meet Colorado's 2030 water needs. Some of these IPPs are in the National Environmental Policy Act (NEPA) review and may not be successfully implemented. Other IPPs may face other issues such as legal, financial, or political concerns that may make their implementation difficult. The 2030 IPPs totaled 511,900 AF statewide. Figure 2-3 on the following page shows examples of the Arkansas, Colorado, and South Platte basins 2030 IPPs and demand gaps. The IPPs are broken out for those that are and are not under NEPA review. Based on reviewing IPPs across the state the following assumptions were made for the scenario analysis:

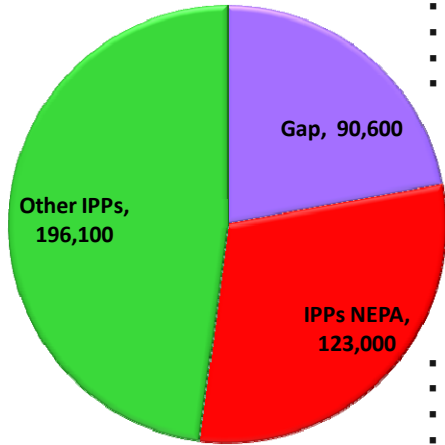
- The low M&I demand scenario assumed all of the IPPs will be implemented statewide
- The medium M&I demand scenario assumed 50 percent of the IPPs will be implemented statewide
- The high M&I demand scenario assumed 25 percent of the IPPs will be implemented statewide

In order to calculate the remaining 2050 M&I demands that would need to be met under the low, medium, and high scenarios, the existing demands and the assumed IPP success rates were subtracted from the total statewide demand including oil shale and other SSI needs. The remaining statewide M&I demands that will need to be met in the future for the low, medium, and high scenarios are: 320 thousand acre-feet (KAF), 790 KAF, and 1.4 MAF. Figure 2-4 shows this information graphically. As depicted, the low, medium, and high screening scenarios for 2050 M&I demand are calculated by subtracting existing demand and IPPs from the 2050 demand.

The IBCC and the CWCB have requested that water supply strategies be developed that address incremental portions of Colorado's future water needs. Multiple supply and demand side strategies will be formulated to help address Colorado's future water needs including, but not limited to, the use of Colorado's unallocated Colorado River water supplies, which are discussed in more detail below.

South Platte Basin

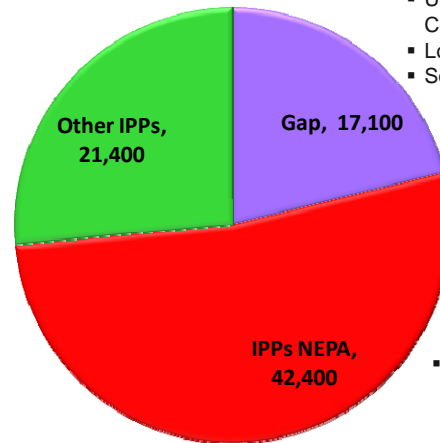
- South Metro Counties Rueter-Hess
- ECCV Northern Non-trib GW
- Denver Metro Counties
- Aurora Prairie Waters
- Thornton Poudre Pipeline
- Ag Transfers
- Gravel Lakes
- Northern Counties CBT acquisitions, ag transfers and local storage



- South Metro
- Denver Metro
- Northern
- Upper Mountain
- Lower Platte
- Moffat FIRMing
- Windy Gap FIRMing
- NISP
- Halligan-Seaman

Arkansas Basin

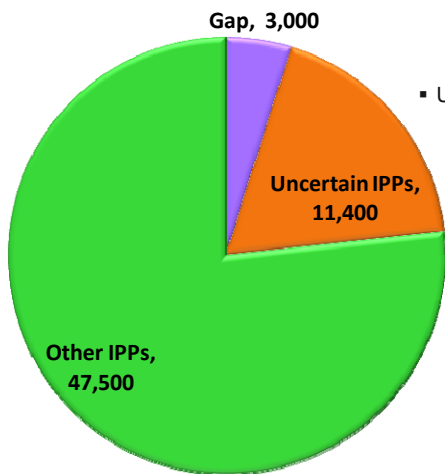
- Arkansas Valley Conduit
- Well augmentation
- Non-trib GW
- PSOP
- Existing water rights
- Agricultural Transfers



- Upper Arkansas
- Unincorporated El Paso County
- Lower Arkansas
- Southwestern Arkansas

Colorado Basin

- Pitkin County IPPs Existing Supplies
- Ruedi Reservoir
- Mesa County IPPs Existing Supplies, Ag Transfers, Ruedi/Wolford
- Jerry Creek Reservoir
- Garfield County IPPs Existing Supplies
- Ag Transfers
- Eagle County IPPs Existing Supplies
- Ag Transfers
- Eagle River Process



- UP CO

- Southern Delivery System

Figure 2-3. Examples of Identified Projects and Processes (acre-feet)

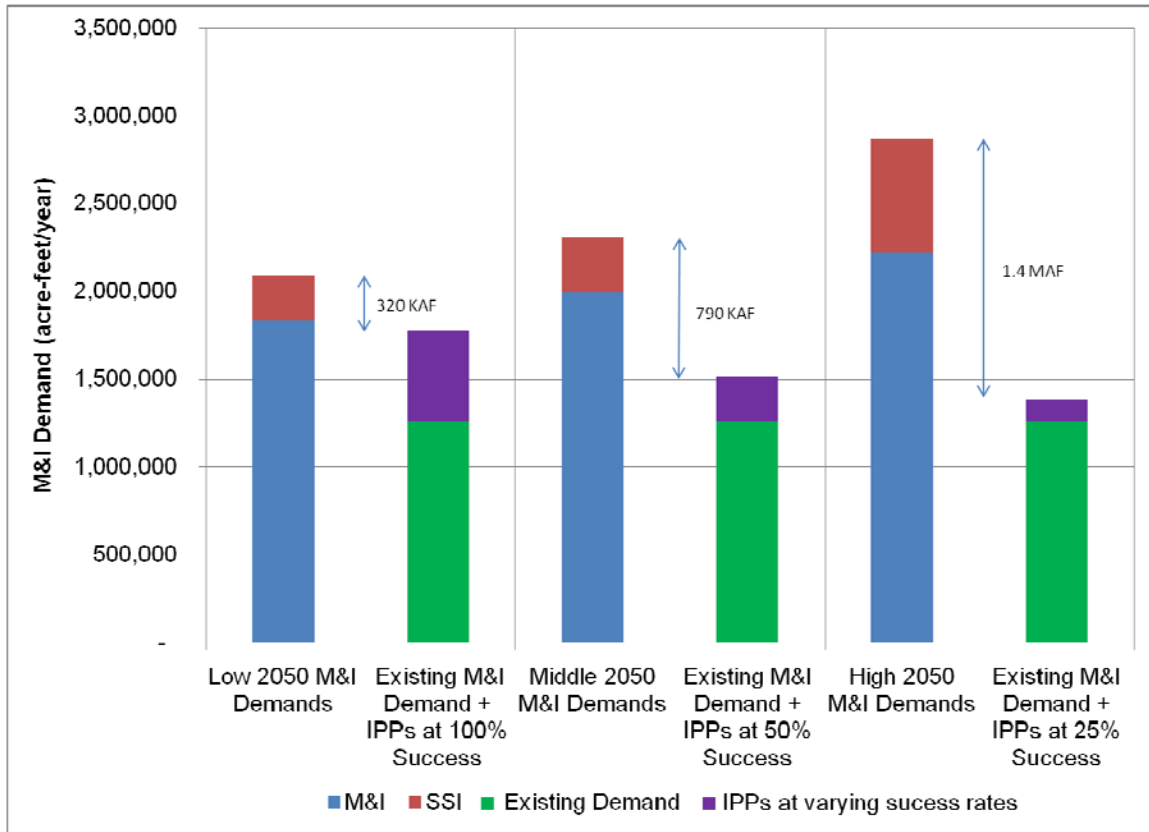


Figure 2-4. 2050 Water Needs Based on Varying M&I Demand Scenarios

2.3 Surface Water Supply Narrative Summary

Water supply varies over time and by location. Important factors that influence water supply availability include climate, legal, and operational considerations as well as the specific geographic location within the river basin. This section examines in general terms how these factors currently and may in the future affect water supply.

CWCB is currently conducting the Colorado River Water Availability Study (CRWAS). This study will provide a sophisticated analysis of where and when water is available in the Colorado River system. However, existing information on Colorado's compact entitlement and analysis by the Bureau of Reclamation (BOR) can provide a starting point. The CRWAS will help refine and provide additional detail on when and where Colorado River water is available

Following are some basic facts that describe Colorado's allocation of water supply under the Colorado River Compact (<http://cwcb.state.co.us/WaterSupply/InterstateCompacts/ColoradoRiverBasin/>), which are summarized in Figure 2-5:

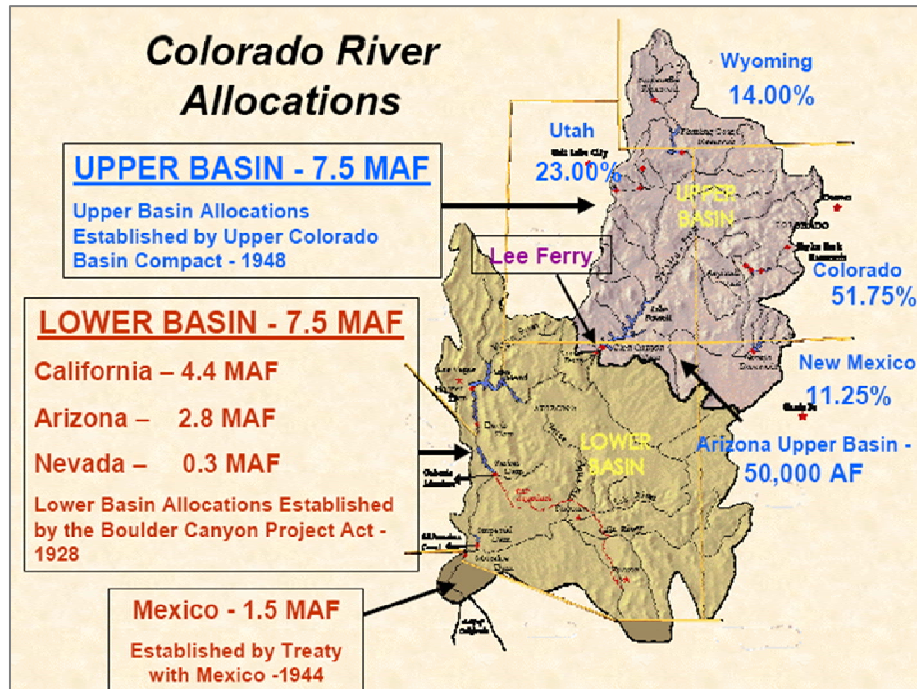


Figure 2-5. Colorado River Allocations

- The Colorado River was allocated to both the Upper Basin and Lower Basin states (divided at Lee Ferry, Arizona - a point in the mainstem of the Colorado River below Lake Powell approximately 1 mile below the mouth of the Paria River) and Mexico.
 - Upper Basin (Colorado, New Mexico, Utah, and Wyoming) apportioned 7.5 MAF per year
 - Lower Basin (Arizona, California, Nevada) apportioned 7.5 MAF, with right to develop one million additional acre-feet per year (AFY)
 - Treaty with Mexico provides for up to 1.5 MAF (.75 MAF each; Upper and Lower Basin), which is satisfied with system water in excess of 16 MAF (deficiencies are split 50-50 between basins)
 - States of the Upper Basin shall not cause the flow at Lee Ferry to be depleted below an aggregate of 75 MAF for any period of 10 consecutive years.
- The Upper Basin is allocated 7.5 MAF per year that is further allocated as described below under two basic scenarios, a *Full Supply* and a *Dry Supply*.
 - A *Full Supply* is reflective of a relatively wet period

- A *Dry Supply* is based on the BOR Hydrologic determination that includes the lowest 25 year period of record but not the most critical 12 year period of record (recorded flows not reconstructed flow records)

Table 2-1 Summary of Colorado's Allocation of the Colorado River for Discussion Purposes

State	Percent Allocation	Quantity Under Full Supply – 7.5 MAF	Quantity Under the Bureau of Reclamation (BOR) Hydrologic Determination – 6.0 MAF*
Colorado	51.75	3,855,375	3,079,125
New Mexico	11.25	838,125	669,375
Utah	23	1,713,500	1,368,500
Wyoming	14	1,043,000	833,000

* For discussion purposes the Hydrologic Determination of 6.0 is used versus the more recent determination of 6.2 MAF, which is adjusted based on a dynamic calculation of evaporation which allows for slightly higher consumptive use allocations.

Colorado recently updated its consumptive uses to incorporate high altitude growth coefficients for pasture grass and therefore consumptive uses, including agriculture, municipal, industrial, and transmountain diversions out of the Colorado River system, are 2,643,000 AF. It should be noted that available supply/remaining allocation as used here is simply the possible additional surface water supply that would be available after current and future consumptive uses are subtracted from the Table 2-1 values.

Utilizing this information produces the following results where the detailed calculations are below and summarized graphically in Figures 2-5 and 2-6.

- Full Supply (Allocation - Existing Consumptive Use = Remaining Allocation)
 - 3.855 MAF - 2.417 MAF = 1,438,000 AF Remaining Allocation using BOR CU&L
 - 3.855 MAF - 2.634 MAF = 1,221,000 AF Remaining Allocation using Colorado Decision Support System (CDSS) with High Altitude Crop Growth Coefficients
- Dry Supply (Allocation - Existing Consumptive Use = Remaining Allocation)
 - 3.079 MAF - 2.417 MAF = 662,000 AF remaining using BOR Consumptive Uses and Loss (CU&L)
 - 3.079 MAF - 2.634 MAF = 445, 100 AF remaining using CDSS High Altitude Crop Growth Coefficients

Currently, depending on the water supply planning scenario Colorado has between 445,000 AF and 1,438,000 of future water development opportunity on the Colorado River System.

Figure 2-6 illustrates the current level of consumptive uses in Colorado as contained in the latest version of the CU&L Report adopted by the BOR. This figure also demonstrates that Colorado's consumptive use of water is within Colorado's entitlement regardless of what entitlement limitation is compared against. It should also be noted that Colorado's entitlement does not change. However, if the flow at Lee Ferry changed, the hydrologic determination line can move up or down accordingly.

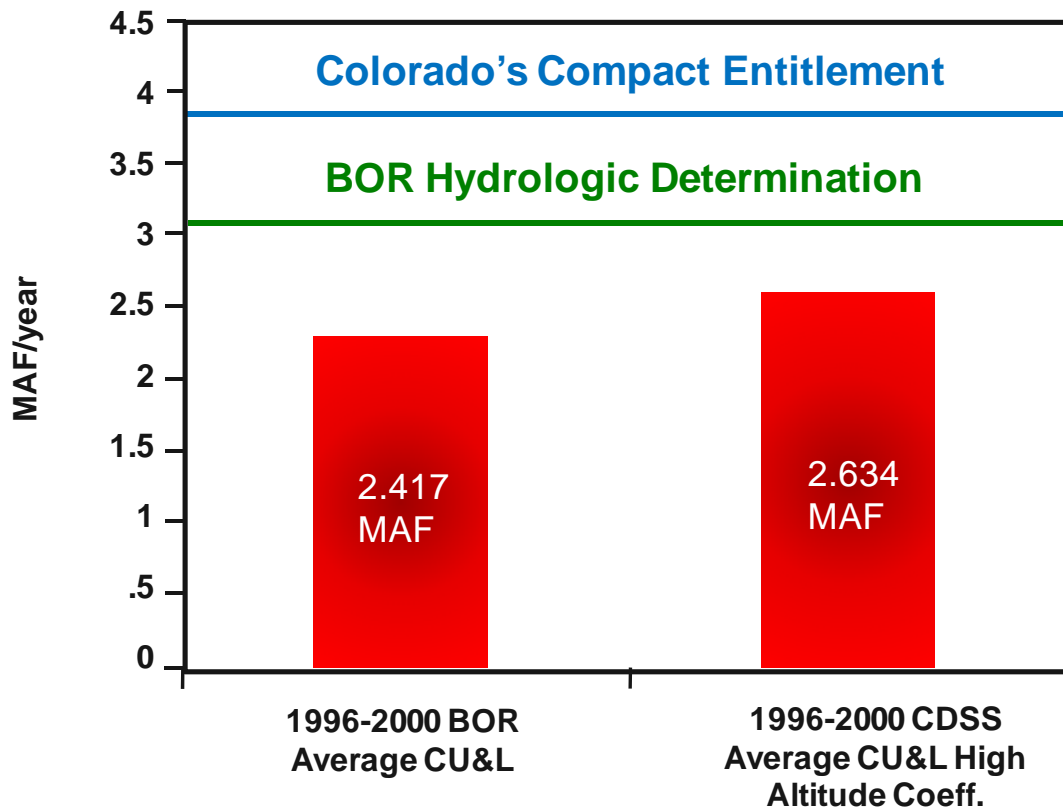


Figure 2-6. 1996-2000 State of Colorado River Depletions

Cursory level water supply screening scenarios representing low, medium, and high supplies were developed for the purposes of demonstrating the usefulness of this approach to future planning efforts. This work will be further defined after Phase I of the CRWAS is complete in late 2009.

The CWCB and IBCC requested that a range of water supply scenarios be described that explains how future hydrology may vary from the above ranges. Conservative estimates for the high and mid-supply screening scenarios were developed by taking roughly 60 percent of the available water identified above at the 1,221,000 and 445,000 AF levels. The low supply screening scenario was developed to represent the worst-case scenario.

- Low Supply screening scenario - 100,000 AF
- Mid -Supply screening scenario - 350,000 AF
- High Supply screening scenario - 700,000 AF

Finally it is important to clarify that this section focuses on the discussion of available water supply. The IBCC and CWCB have requested that the concepts or strategies that would beneficially use Colorado River water be developed in the following increments:

- 50,000 AF increment
- 100,000 AF increment
- 250,000 AF increment

These three increments of development are also well within Colorado's allocation of 445,000 to 1, 438,000 AF of Colorado River water. This is illustrated in Figure 2-7, which shows how the current development scenarios compare to the remaining entitlement available.

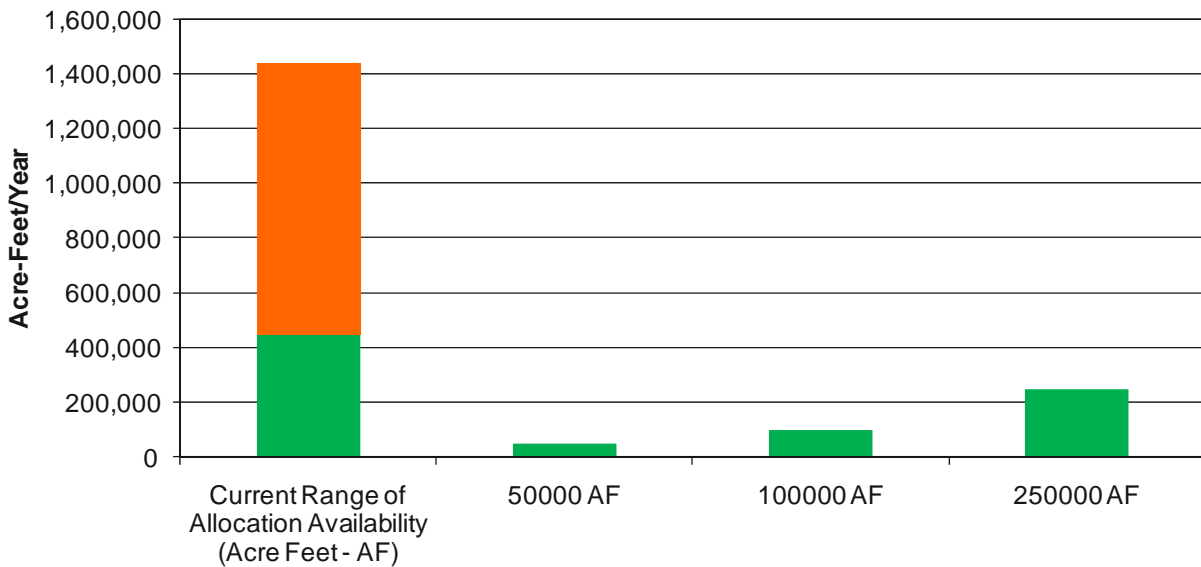


Figure 2-7. Colorado River Development is Within the Range of Colorado's Remaining Allocation

2.4 Scenarios for Colorado's Water Supply Future and Water Supply Strategy Portfolios

Figure 2-8 summarizes the amounts of water associated with each of the five screening scenarios based on discussion provided in Sections 2.2 and 2.3 describing the M&I Demand and Supply narratives. The next step the CWCB Board and IBCC have considered is the associated water supply strategy portfolios that could be developed to address each future scenario. For example, the high demand and low supply scenario indicates that a smaller increment of Colorado River water would be available to develop statewide and therefore additional emphasis on other strategies such as conservation and agricultural transfers would be needed to meet the M&I demand. Whereas a mid-supply and mid-demand scenario would involve a mix of: conservation, agricultural transfers, and development of some Colorado River water.

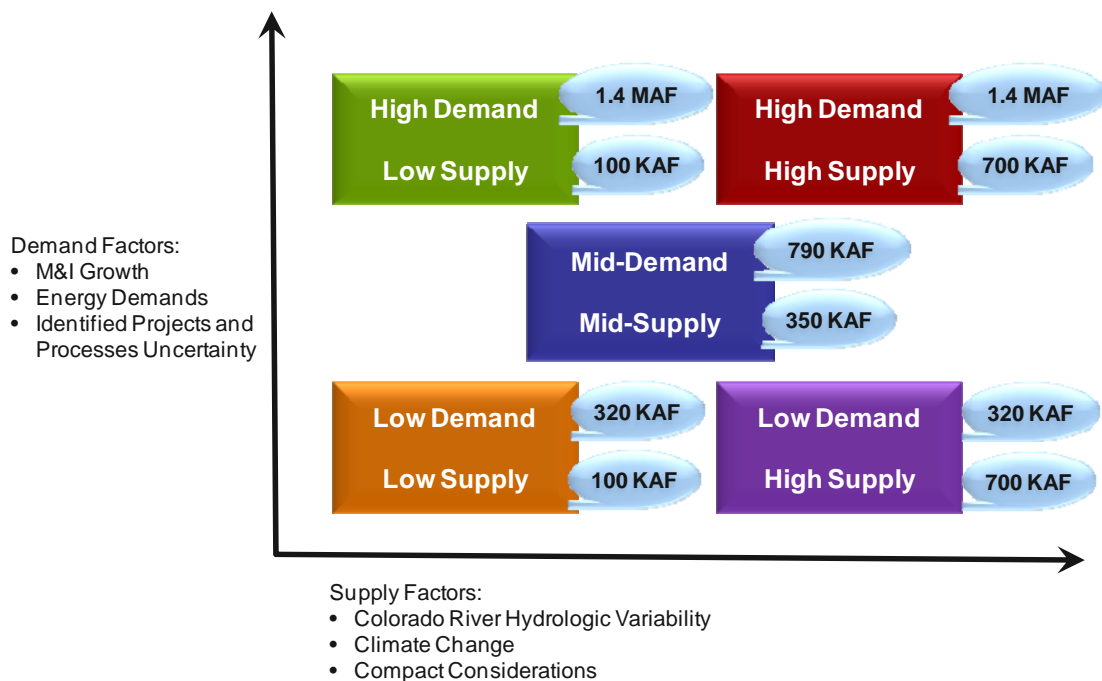


Figure 2-8. Colorado's M&I Water Demand and Supply Scenarios with 2050 M&I Water Demands and Colorado River System Supplies

To "build" these water supply strategy portfolios, CWCB developed a Microsoft *Excel* based tool that examines what-if scenarios based on the low, medium, and high M&I demand and water supply factors shown in Figure 2-8. The interface for this portfolio and trade-off tool is shown in Figure 2-9. The interface allows the user to vary the M&I demand and water supply scenario from low, medium, or high.

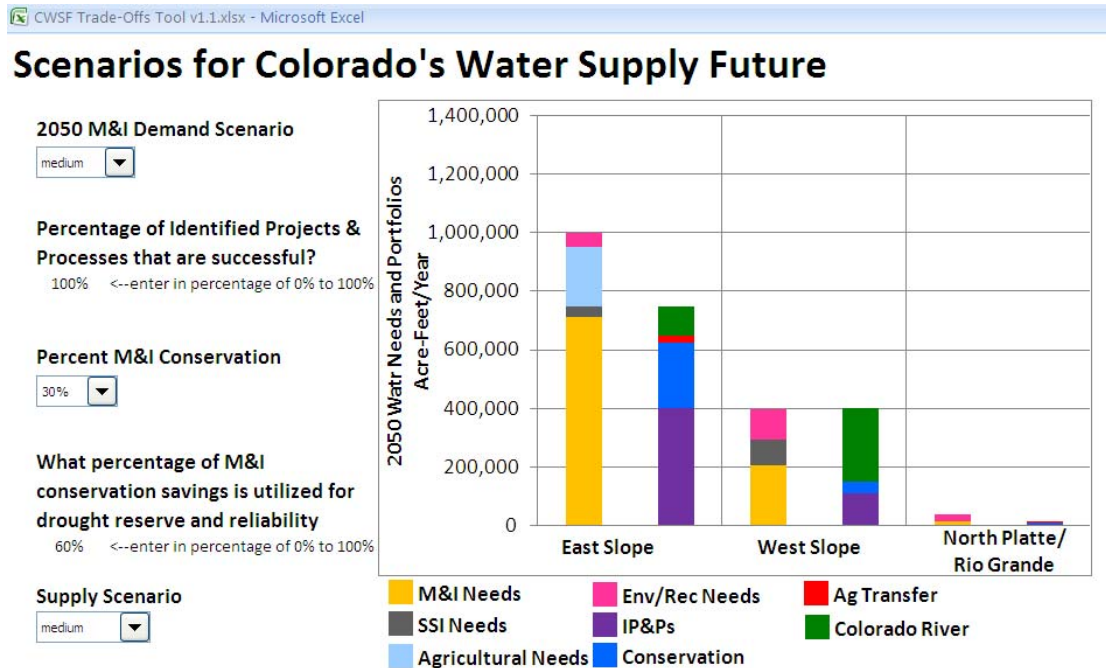


Figure 2-9. Colorado's Water Supply Future Portfolio and Trade-off Tool

Figure 2-10 illustrates the information generated from the portfolio and trade-off tool. The tool first predicts 2050 M&I and SSI water needs for Colorado's East Slope (Arkansas and South Platte Basins), West Slope (Colorado, Gunnison, Southwest and Yampa/White Basins), and North Platte/Rio Grande Basins. These M&I and SSI demands are circled in red on Figure 2-10. The M&I demands are the yellow portion of the bar and the SSI demands are the dark grey portion of the bar. The portfolio and trade-off tool currently has a "placeholder" for agricultural, environmental, and recreational needs and these are also illustrated in Figure 2-10. As these needs are further developed they can be incorporated into the tool. The low, medium, and high 2050 M&I and SSI water needs are derived directly from the 2050 M&I demand projections, which are summarized in Section 2.2 (CWCB 2009). For each low, medium, or high M&I demand scenario the existing 2008 demands were subtracted from the 2050 projects to estimate the 2050 M&I water needs.

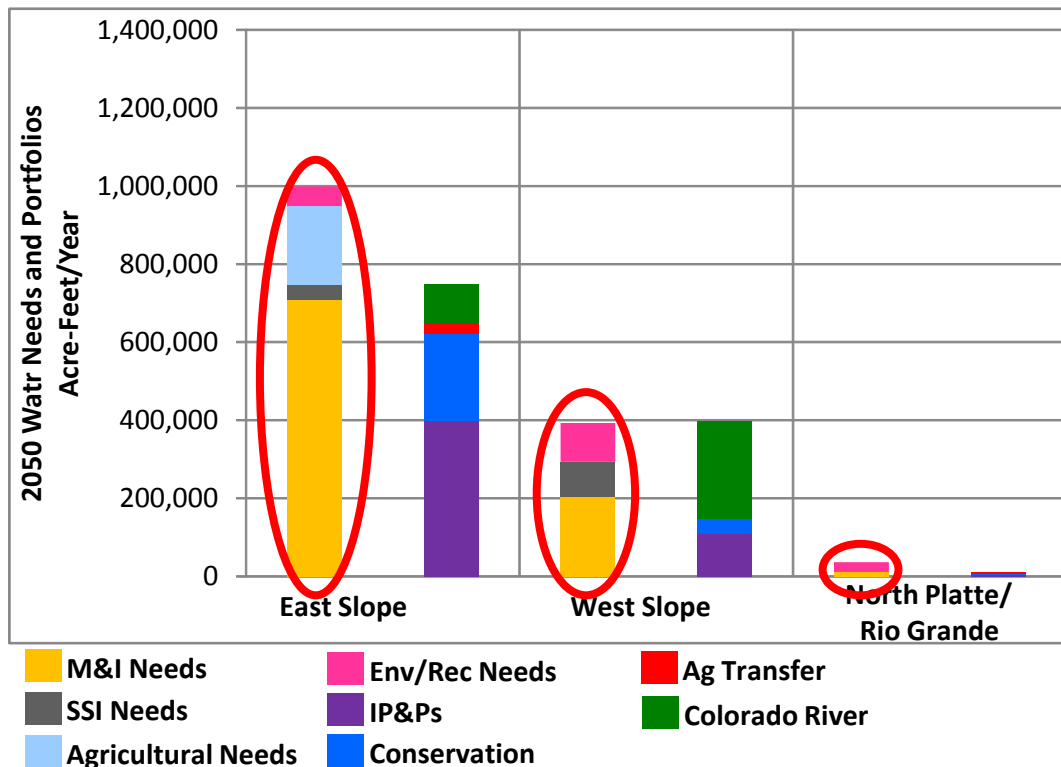


Figure 2-10. Example Output from the Portfolio and Trade-off Tool Showing 2050 Water Needs

Next, the portfolio and trade-off tool can assist the user in developing a portfolio to meet the 2050 water needs. The current version of the tool includes the following portfolio building blocks: IPPs, Conservation, Agricultural Transfers, and Colorado River system water. As further strategies for Colorado's water supply future are developed they could be included into this tool as appropriate. The black circles in Figure 2-10 shows where the portfolios are summarized in the tool's graphic output. The logic that the portfolio and trade-off tool uses to develop the portfolios is as follows:

- The user can specify the success rate of the IPPs and this is the first portion of the portfolio that is generated in the tool (purple portion of bars on Figure 2-11).
- The user can also specify the percentage of conservation from total M&I demands that will be achieved (20, 30, or 40 percent). This is shown as the blue portion of the bars on Figure 2-11. The user can also specify what percentage of future conservation will be utilized for drought reserve and reliability. The portion of conservation specified for drought reserve and reliability is subtracted from the total increment of conservation derived from the 20, 30, or 40 percent savings and this is what is displayed graphically on the output from the tool.

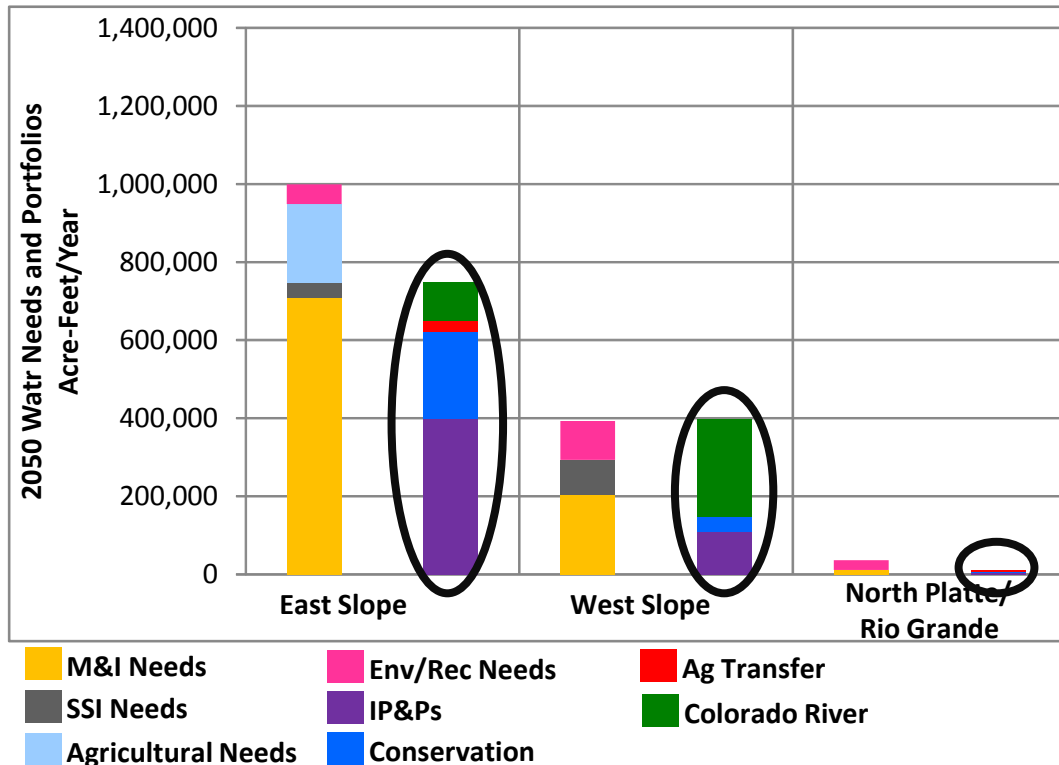


Figure 2-11. Example Output from the Portfolio and Trade-off Tool Showing Portfolios to Meet 2050 Water Needs

- The low, medium, and high screening supply scenarios for Colorado River system availability (100 KAF, 350 KAF, and 700 KAF) as discussed in Section 2.3 were used in the portfolio and trade-off tool. The tool assumes that under the low water supply scenario, 100 KAF of Colorado River system water would be available and that of this 100 KAF none would be available for the East Slope. For the medium supply scenario, the tool assumes 350 KAF of Colorado River system water would be available and that 100 KAF of the total would be available for the East Slope and 250 KAF would be available for the West Slope. Finally for the high supply scenario, the tool assumes 700 KAF of Colorado River system water would be available and that 250 KAF would be available for the East Slope and 350 KAF would be available for the West Slope. The allotment of Colorado River system water between the West Slope and East Slope was assumed for illustration purposes in the tool and could be refined in the future.
- Next, the tool subtracts from the 2050 M&I and SSI water needs the IPPs, conservation, and if available the Colorado River system amounts and the resulting increment of water is assumed to be generated from a traditional or alternative agricultural transfer of water.

- The portfolio and trade-off tool "meets" the M&I and SSI water needs first and if Colorado River system water is available in excess of the M&I and SSI needs it assumed to be available to meet agricultural, environmental and recreation needs.

For illustrative purposes, the portfolio and trade-off tool was used to develop preliminary portfolios for the five screening scenarios presented in Figures 2-1 and 2-8. For each screening scenario, conservation was assumed to achieve a 30 percent savings by 2050 and the percentage of conserved water used for drought and reliability was assumed to be 60 percent. The IPP success rate was assumed to be the same as the discussion in Section 2.2:

- The low M&I demand scenario assumed all of the IPPs will be implemented statewide
- The medium M&I demand scenario assumed 50 percent of the IPPs will be implemented statewide
- The high M&I demand scenario assumed 25 percent of the IPPs will be implemented statewide

The low demand/low supply screening scenario and resulting portfolio is shown in Figure 2-12. The portfolio resulting from this screening scenario for the East Slope is mainly comprised of IPPs (scenario assumes 100 percent success), conservation, and agricultural transfers. For the West Slope, the portfolio is based on IPPs, conservation, and Colorado River system supplies. The North Platte/Rio Grande portfolio is based on IPPs, conservation, and agricultural transfers. Please note that the agricultural, environmental, and recreational needs are illustrated as placeholders and will be revised in the future.

Figure 2-13 shows the 2050 M&I and SSI needs and portfolio to address these needs for the low demand/high supply scenario. The portfolio resulting from this screening scenario for the East Slope is mainly comprised of IPPs (scenario assumes 100 percent success), conservation and Colorado River system supplies. For this scenario on the East Slope, the total portfolio exceeds the M&I and SSI needs because of the Colorado River supplies. For the West Slope, the portfolio is based on IPPs, conservation, and Colorado River system supplies. The North Platte/Rio Grande portfolio is based on IPPs, conservation, and agricultural transfers. Please note that the agricultural, environmental, and recreational needs are illustrated as placeholders and will be revised in the future.

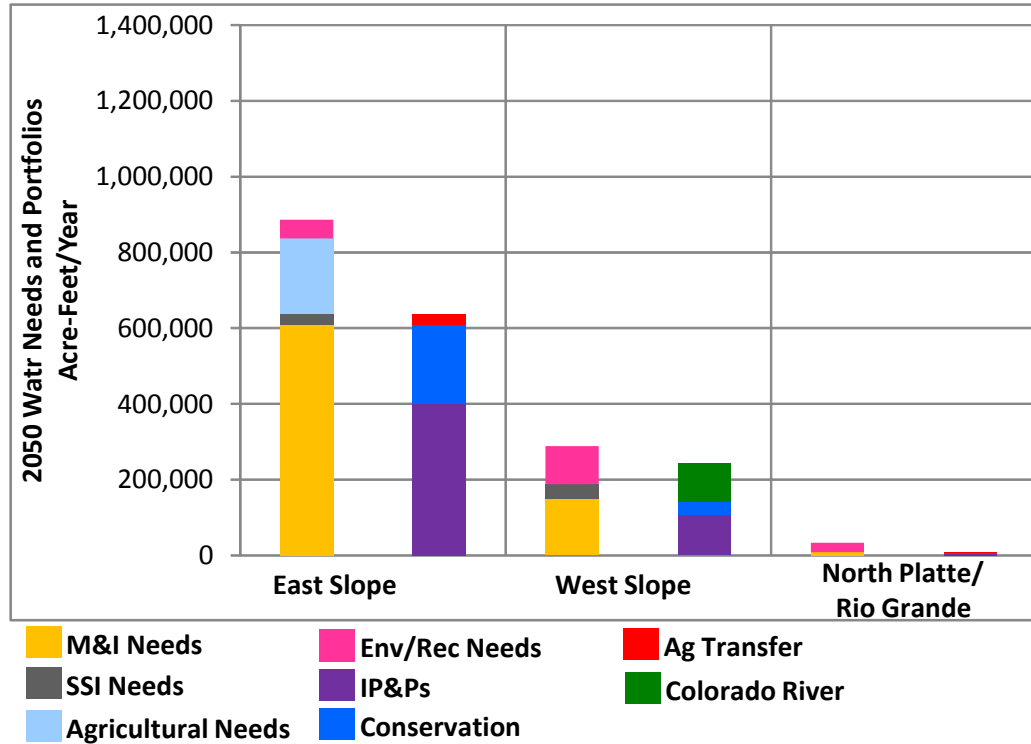


Figure 2-12. 2050 M&I Water Needs and Portfolio to Address Needs for Low Demand/ Low Supply Screening Scenario

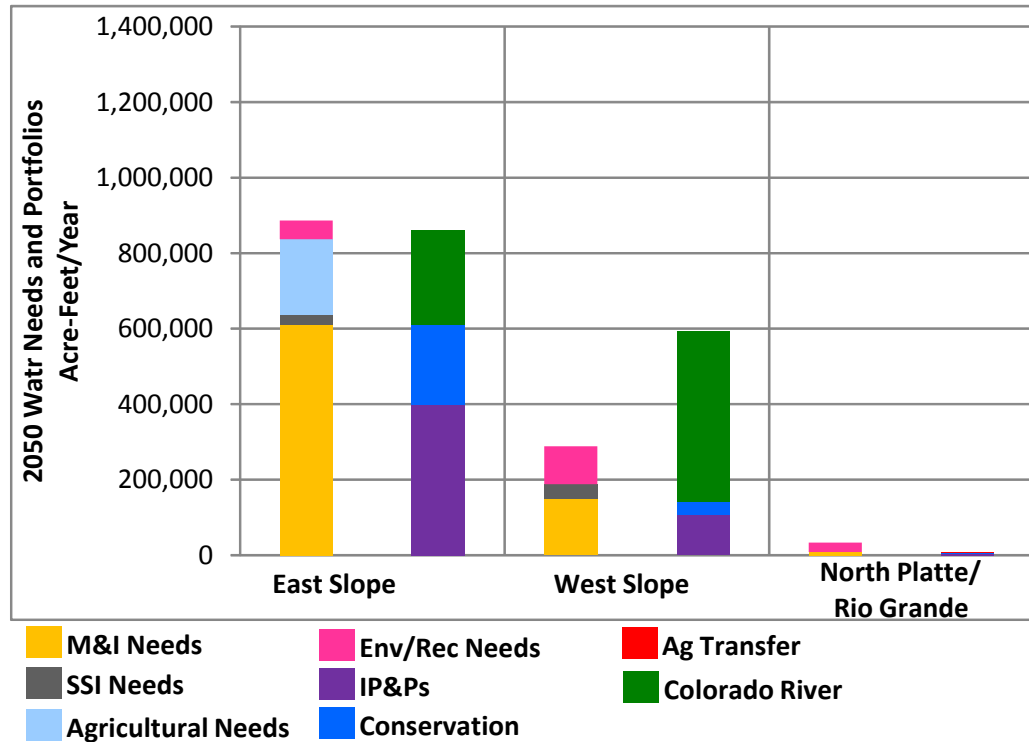


Figure 2-13. 2050 M&I Water Needs and Portfolio to Address Needs for Low Demand/ High Supply Screening Scenario

The medium demand/medium supply screening scenario and resulting portfolio is shown in Figure 2-14. The portfolio resulting from this screening scenario for the East Slope is comprised of nearly equal amounts of IPPs (scenario assumes 50 percent success), conservation, and agricultural transfers with a smaller portion Colorado River system supplies. For the West Slope, the portfolio is based on IPPs, conservation, and Colorado River system supplies. The North Platte/Rio Grande portfolio is based on IPPs, conservation, and agricultural transfers. Please note that the agricultural, environmental, and recreational needs are illustrated as placeholders and will be revised in the future.

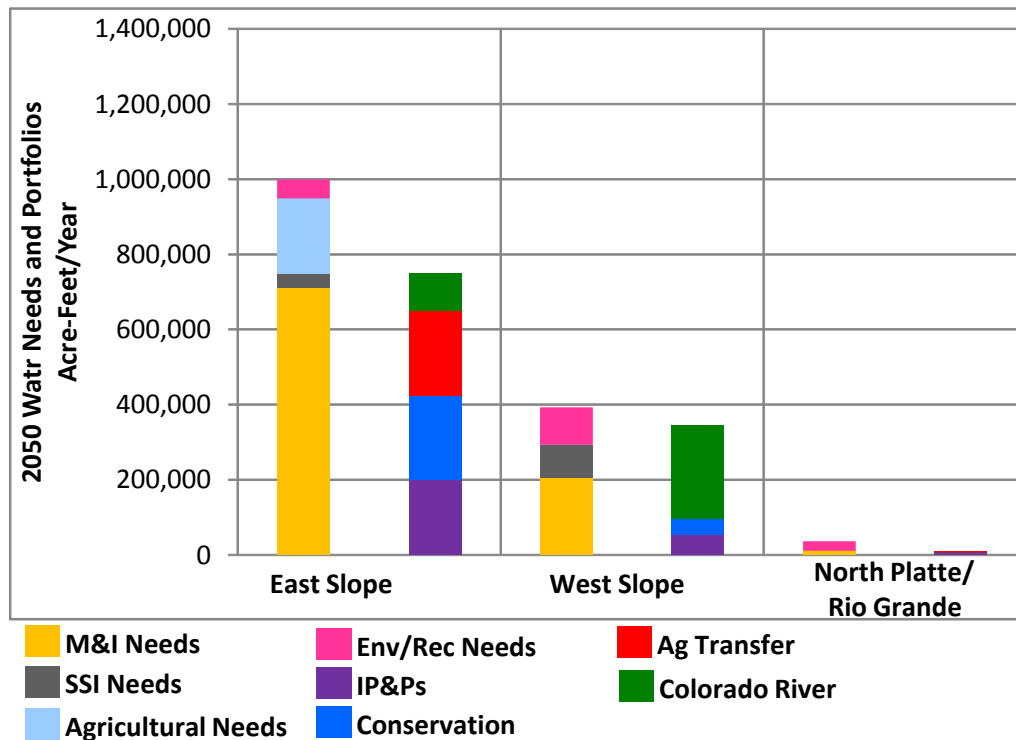


Figure 2-14. 2050 M&I Water Needs and Portfolio to Address Needs for Medium Demand/ Medium Supply Screening Scenario

Figure 2-15 shows the 2050 M&I and SSI needs and portfolio to address these needs for the high demand/low supply scenario. The portfolio resulting from this screening scenario for the East Slope is comprised of IPPs (scenario assumes 25 percent success), conservation, and agricultural transfers. For the West Slope, the portfolio is based on IPPs, conservation, agricultural transfers, and Colorado River system supplies. For the East Slope and West Slope, agricultural transfers would be the largest source of supply as part of this screening scenario. The North Platte/Rio Grande portfolio is based on IPPs, conservation, and agricultural transfers. Please note that the agricultural, environmental, and recreational needs are illustrated as placeholders and will be revised in the future.

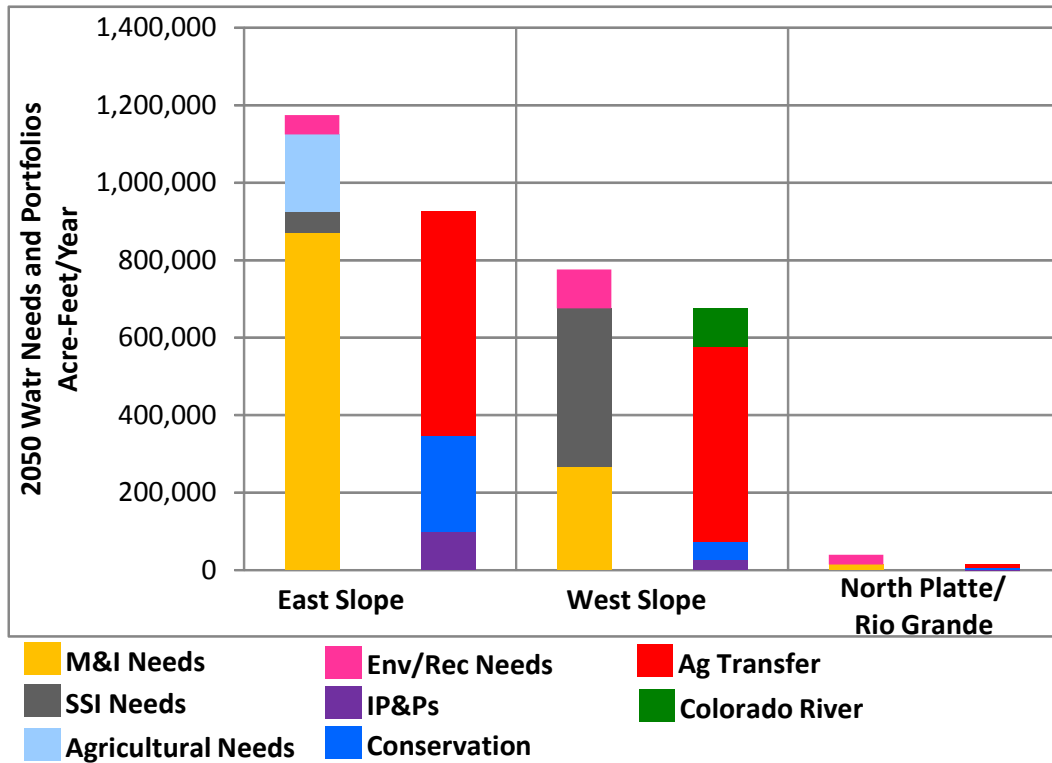


Figure 2-15. 2050 M&I Water Needs and Portfolio to Address Needs for High Demand/Low Supply Screening Scenario

For the high demand/high supply screening scenario, Figure 2-16 shows the 2050 M&I and SSI needs and portfolio to address these needs for the high demand/high supply scenario. The portfolio resulting from this screening scenario for the East Slope is comprised of IPPs (scenario assumes 25 percent success), conservation, agricultural transfers, and Colorado River system supplies. For the West Slope, the portfolio is based on IPPs, conservation, agricultural transfers, and Colorado River system supplies. The North Platte/Rio Grande portfolio is based on IPPs, conservation, and agricultural transfers. Please note that the agricultural, environmental, and recreational needs are illustrated as placeholders and will be revised in the future.

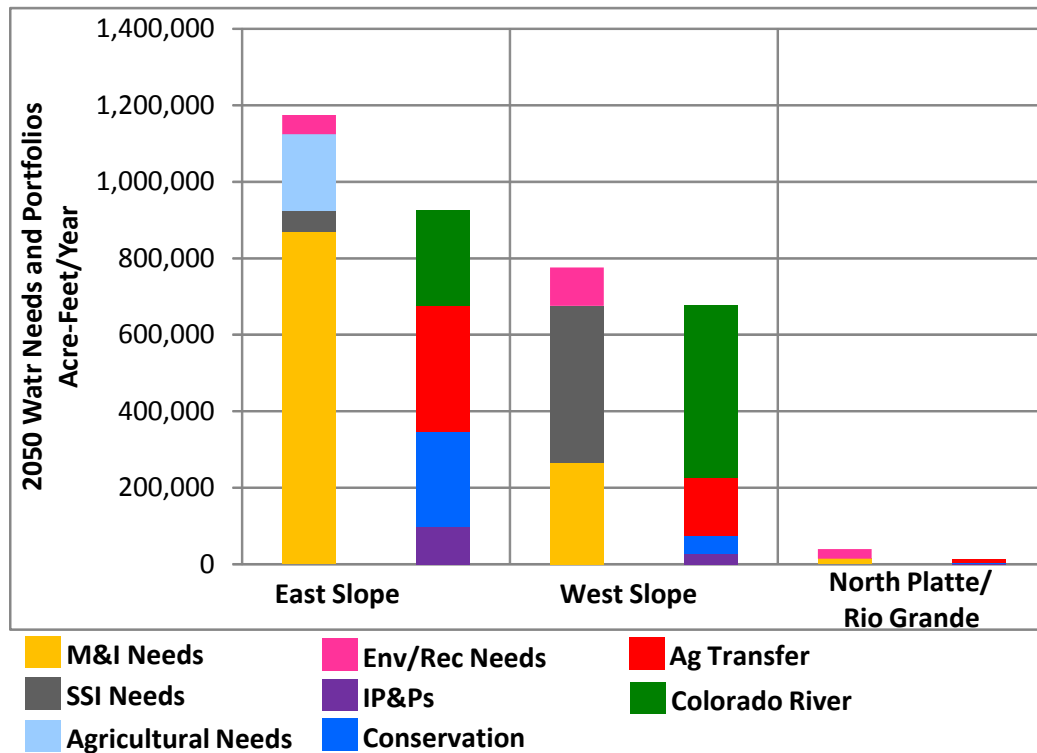


Figure 2-16. 2050 M&I Water Needs and Portfolio to Address Needs for High Demand/High Supply Screening Scenario

The remainder of this report will examine and describe several specific water supply strategies associated with the principle elements of the portfolios that can be utilized to address the future scenarios. This tool was developed because no single solution is likely to be successful in meeting all future needs. The critical building blocks or strategies that could be used to meet future needs will be described but the next steps are to assemble the strategies into implementable solutions that seek to balance the needs of the state as a whole and address the needs and concerns of individual stakeholders and interest groups. A critical part of that challenge is to begin to reach agreement on the specific targets or water supply yields and the most effective and implementable mix of each strategy.

Finally, another critical step is to identify how to maximize the implementability of the strategies or concepts. Several Basin Roundtables, the CWCB Board, and the IBCC have begun to look at what actions or activities would need to be included or added to the portfolios to garner broad support.

Section 3

M&I and Conservation Strategy

This section is under development.

Section 4

Agricultural Transfer and New Supply Development Strategies

4.1 Overview of Agricultural Transfer and New Supply Development Strategies

As part of the strategy development and evaluation for the agricultural transfer and new supply development strategies six concepts were considered. These concepts develop water supply in various locations and fall into two general categories:

- Traditional or alternative agriculture transfers from agricultural use to municipal use
- New water supply development from the Colorado River and/or its tributaries

The six water supply concepts are shown in Figure 4-1 below. There are two agricultural transfer concepts – one would deliver water from lower or middle Arkansas River to Reuter-Hess Reservoir and another that would deliver water from the lower or middle South Platte River downstream of Denver to the Brighton area. While agricultural transfers may occur on the West Slope, this study focuses on the East Slope because that is where the majority of past, present, and future transfers are likely to come from. On the West Slope, new appropriations, rather than acquisitions, are the primary focus. The four new water supply appropriation concepts that were studied are the Colorado River Return concept (also referred to as the Big Straw), Flaming Gorge concept, Yampa River concept, and Green Mountain Reservoir concept.

This report also builds on the recommendations set forth in SWSI Phase 2 from the Gap Technical Roundtable, which were as follows:

The mission of the Gap Technical Roundtable and a critical requirement of the Water for the 21st Century Act is to:

Foster cooperation among water suppliers and citizens in every water basin to examine and implement options to fill the gap between ongoing water planning and future water needs.

The Gap Technical Roundtable recommended the following strategies be evaluated:

1. Agricultural Transfers from the Arkansas and South Platte
2. Blue Mesa Pumpback
3. Colorado River Reconnaissance Study
4. Flaming Gorge Pipeline
5. Green Mountain Pumpback
6. Yampa Pumpback

The Gap Technical Roundtable recommended that the future work should evaluate the options using similar assumptions and the group suggested that a more detailed evaluation of the options be performed. Many of these items have been addressed and are included in this report. The general assumptions that were recommended by the Gap Technical Roundtable include:

- Delivery of similar water quality
- Common or comparable storage areas should be included for all options
- Common or comparable termination points should be included for all options
- There should be a range of water delivery; the suggested range was 100,000 - 175,000 - 250,000 AF

The Technical Roundtable also suggested the following evaluation elements be included:

- Include Capital and Operation and Maintenance costs as net present worth and annualized cost (infrastructure and operation and maintenance) and cost per AF
- Additional information should be developed that outlines some of the initial benefits, impacts, and attributes of the options
- Information and suggestions regarding base options (options that would be added to the major structural options) be obtained from the Basin Roundtables
- Conservation be considered in developing alternatives
- The CDSS be used to perform additional analysis of supply availability
- Additional information be included regarding existing storage and infrastructure opportunities
- Additional information be developed on storage requirements, miles of tunnels required, river crossings, permitting considerations (i.e., Federal Lands, Wilderness Areas, 1041 considerations, wetlands etc.)
- Refine and develop critical agricultural needs and solutions
- Identify environmental and recreational enhancements
- Refine and develop local basin projects and needs in conjunction with major structural options

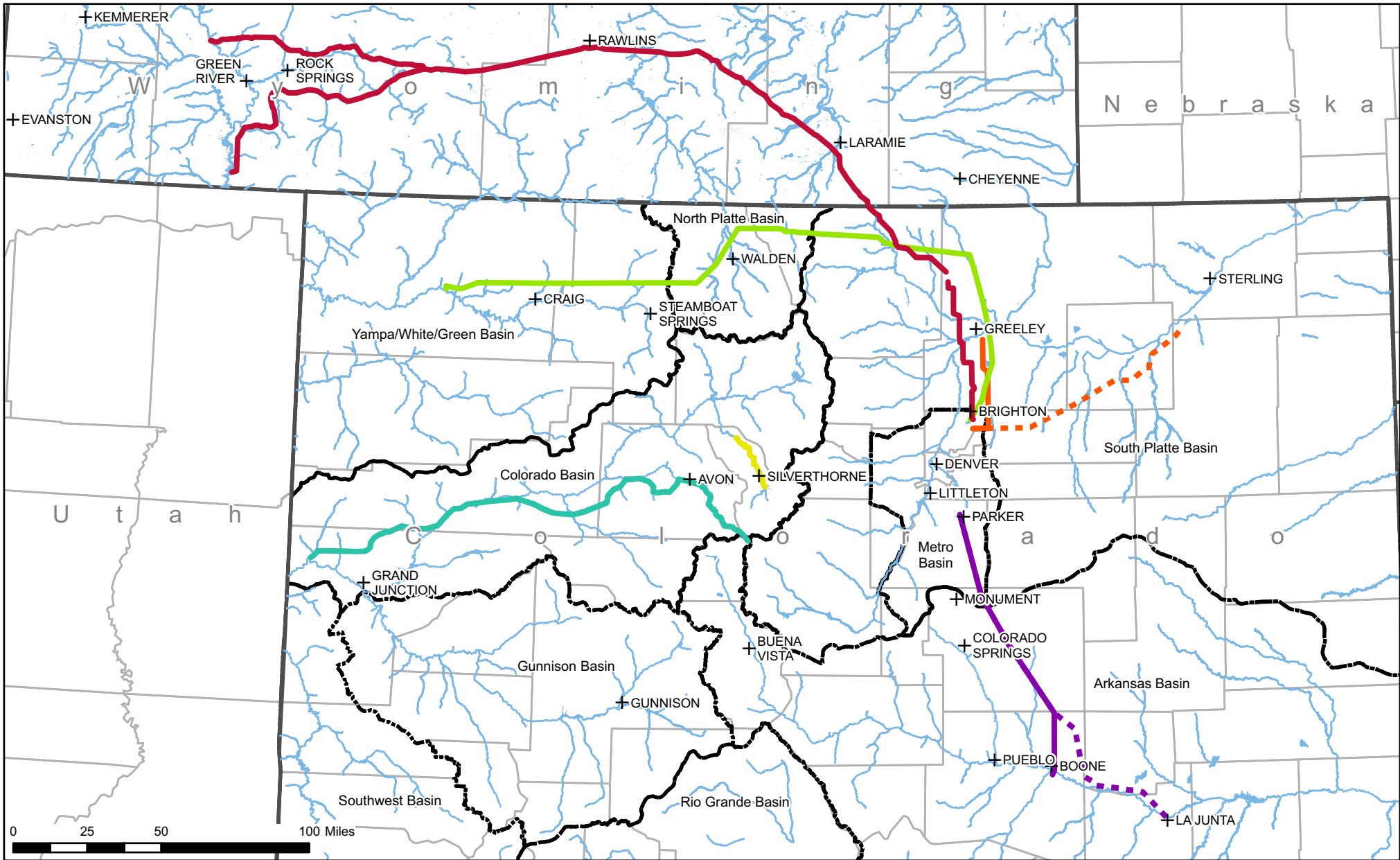


Figure 4-1. Overview of Agricultural Transfer and New Supply Development Concepts

Legend

- Colorado River Return Reconnaissance Study Concept
- Flaming Gorge Concept
- Yampa River Concept
- Middle South Platte Concept
- - - Lower South Platte Concept
- Lower Arkansas Concept 1
- - - Lower Arkansas Concept 2
- Green Mountain Concept
- Colorado Basins



DRAFT

The IBCC also asked for an evaluation of additional small-to-medium sized new water supply development projects. An initial list of additional smaller concepts is included in Section 4.3, but needs additional refinement.

The purpose of the information presented in this section is to provide basic information that is needed to begin strategy evaluation. This section describes each concept listed above and the important elements that would need to be considered when developing the concept such as water source, conveyance, storage, and water quality issues. Section 5 of this report provides reconnaissance level costs estimates for each concept presented in this section. Several recent studies were reviewed in preparing this report section. These include:

- Colorado River Return Reconnaissance Study (CWCB 2003)
- Blue River Pumpbacks and Wolcott Reservoir Alternatives Reconnaissance Study (Colorado River Water Conservation District et al. 2007)
- Arkansas River Renewable Water Economic Feasibility Study (Pikes Peak Regional Water Authority 2008)
- Rotational Land Fallowing-Water Leasing Program Engineering and Economic Feasibility Analysis (Lower Arkansas Valley Water Conservancy District 2007)
- Multi-Basin Water Supply Investigation (Northern Colorado Water Conservancy District 2006)
- Regional Water Master Plan (South Metro Water Supply Authority 2007)

In addition, recent information developed as part of the U.S. Army Corps of Engineers (USACE) Environmental Impact Statement (EIS) for the Regional Watershed Supply Project was reviewed (2009) (Flaming Gorge Concept). Because these studies were completed in different years, at varying levels of detail, and for different increments of water, a common set of engineering assumptions and costs were developed. The engineering assumptions are presented in the remainder of this section and the cost estimates are presented in Section 5. Again, the purpose of this analysis is to provide basic information to begin evaluating these agricultural transfers and new supply development strategies. Further evaluation beyond what is contained in this report – such as evaluating each strategy's ability to meet the IBCC's vision goals discussed in Section 1 – will be developed by CWCB in subsequent study efforts.

4.1.1 Agricultural Transfer and New Supply Development Strategies Potential Water Source

This section summarizes potential sources of water for both the agricultural transfer concepts and the new supply development concepts. For the agricultural transfer concepts, the potential sources of water include a traditional agricultural to municipal

water right transfers or an alternative agricultural transfer methods. For the new supply development concepts the water source would be developed by obtaining a new water right or contract for water from the Colorado River system.

4.1.1.1 Agricultural Transfer Potential Sources of Water Rights

Figures 4-2 and 4-3 show the potential water sources for the Arkansas and South Platte concepts. For the Arkansas River concept (Figure 4-2) two alignments were evaluated to deliver water from the lower Arkansas River to Reuter-Hess Reservoir in Parker, Colorado:

- Alignment 1 would divert water from the Arkansas River near Avondale, Colorado
- Alignment 2 would divert water from the Arkansas River near La Junta, Colorado

For the South Platte River concept (Figure 4-3) two alignments were evaluated to deliver water from the lower South Platte River downstream of Denver to the Brighton, Colorado area:

- Alignment 1 would divert water from the South Platte River near Greeley, Colorado
- Alignment 2 would divert water from the South Platte River near Sterling, Colorado

Meeting Colorado's future water needs through agricultural transfers may take a number of forms including:

- Acquisition and transfer by individual water providers and users.
- Acquisition and transfer on both a temporary and permanent basis. This may be accomplished via leasing and/or purchase.
- Examination and implementation of coordinated activities to meet the needs of multiple users both agricultural and new water uses.

These approaches and others will be utilized based on consideration of both river basin specific conditions and the needs and desires of those involved in the transactions. The discussion below examines some of the benefits and challenges that may be involved in the implementation of coordinated activities to help address Colorado's future water needs. It examines how agricultural transfers – both traditional purchase/transfer and alternative transfer methods – might be utilized to meet future needs.

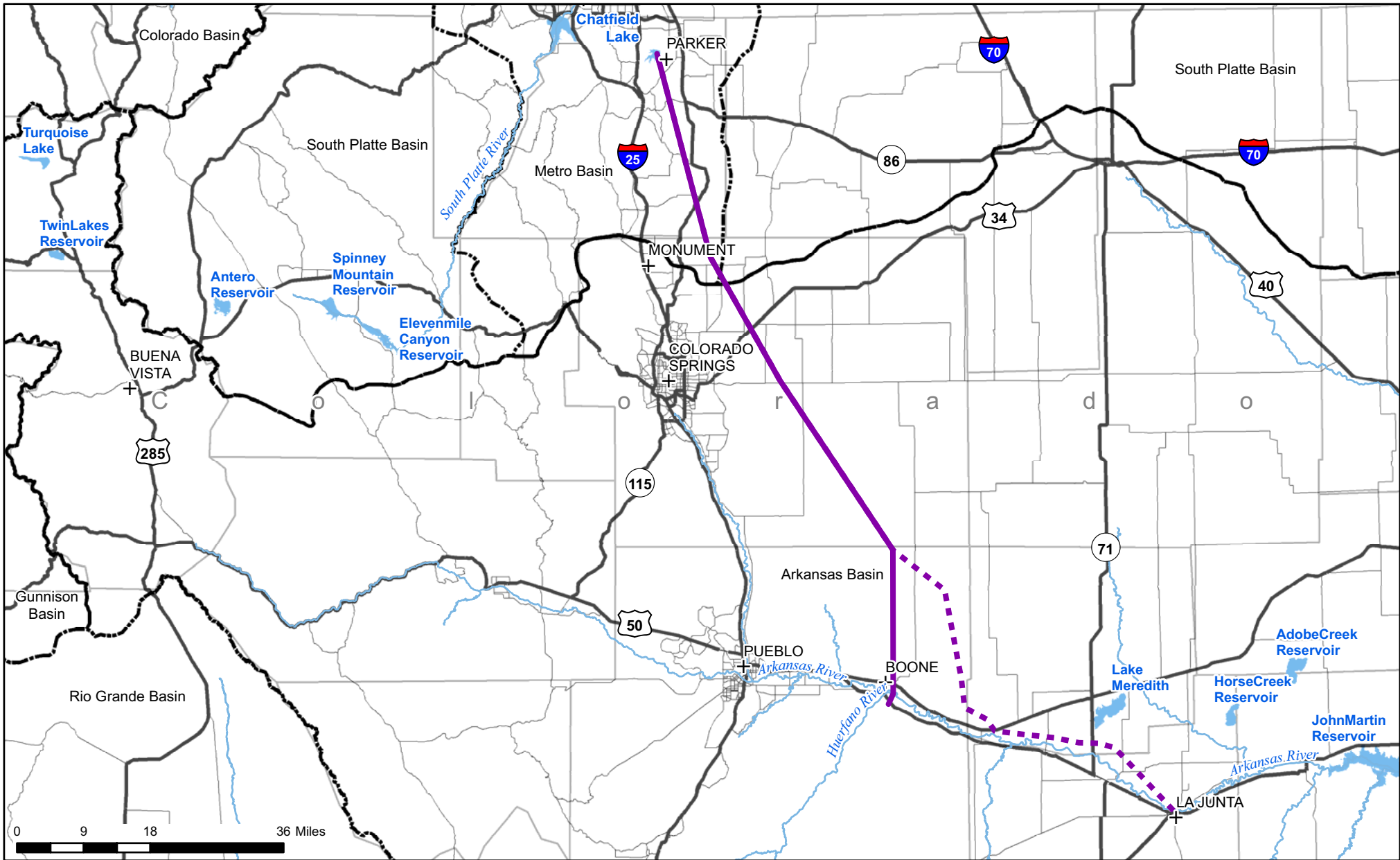


Figure 4-2. Arkansas River Agricultural Transfer Concept

Legend

- + Cities
- Highways
- Other Roads
- Rivers and Streams
- Lakes and Reservoirs
- Colorado Basins
- Lower Arkansas Concept 1
- Lower Arkansas Concept 2



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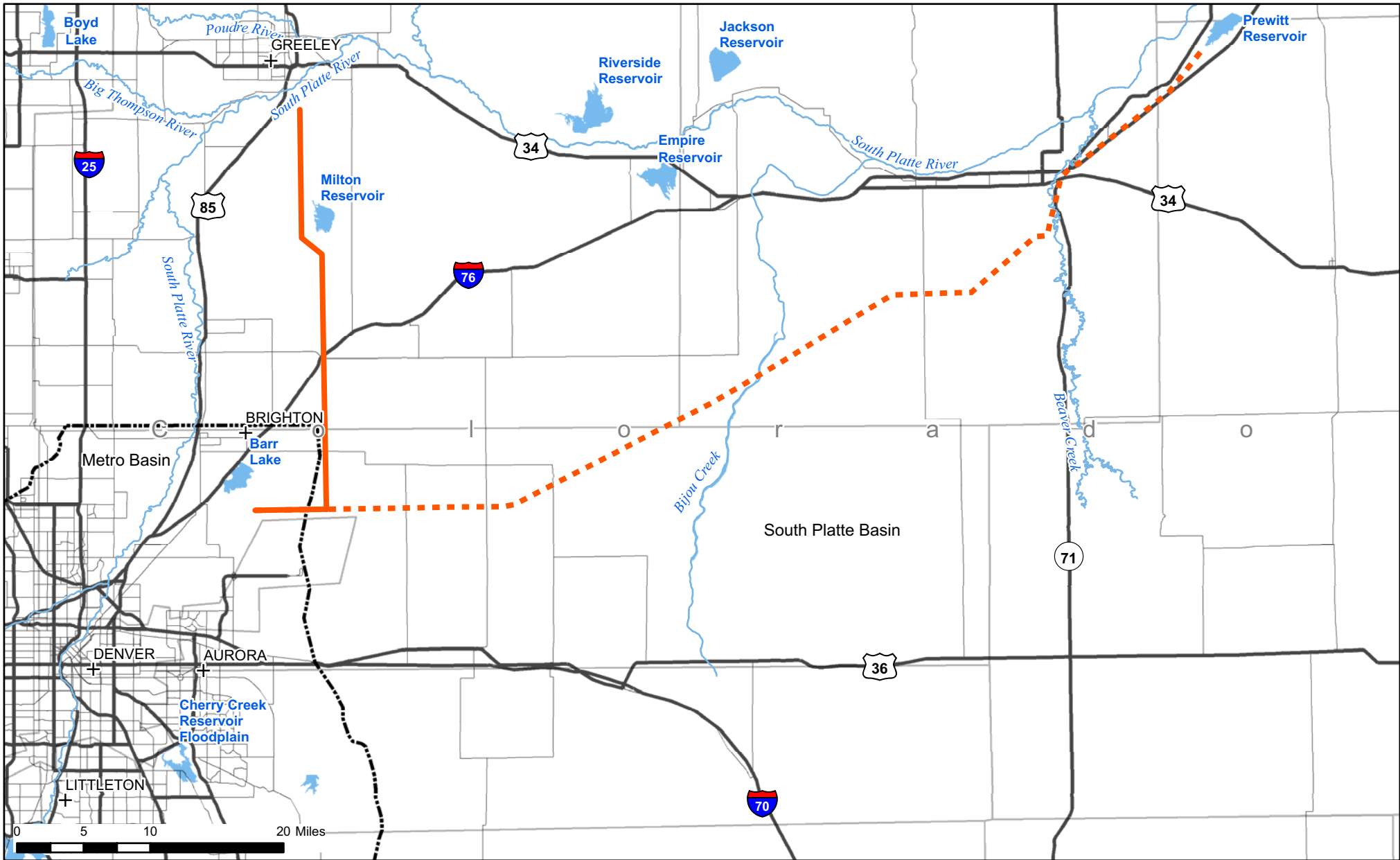


Figure 4-3. South Platte River Agricultural Transfer Concept

Legend

- + Cities
- Highways
- Other Roads
- Rivers and Streams
- Lakes and Reservoirs
- Colorado Basins
- Middle South Platte Concept
- Lower South Platte Concept



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Coordinated Acquisition and Transfer of Agricultural Water Rights

In Colorado the acquisition and transfer of water from agriculture to other uses has been and will continue to be an important source of future water supply. In order to cost-effectively meet future needs water providers examine the interrelationship of yield (seniority of water right), long-term reliability of the supply, the nature of the demand that needs to be met, cost, treatment, compatibility with their intake and delivery systems, and their overall water rights and infrastructure portfolio. Consequently, most water providers execute individual transactions that best match their unique needs.

From a broader statewide perspective the collective actions of multiple water providers can result in unintended consequences to the local community, the region, the state, and agriculture as a whole. However, there is not a readily identified institutional organization that could assume the roles associated with the financial, administrative, and organizational roles needed to approach agricultural water right transfers more holistically. A more coordinated effort in the identification and acquisition of agricultural water could have the benefits of:

- Preserving the most productive agricultural lands
- Maximizing the return on infrastructure investments
- Providing longer term certainty for both the water provider community and the agricultural community
- Avoiding/mitigating impacts to local communities, economies, and the environment
- Potential reduction in transaction costs due to economies of scale

The broader statewide perspective and coordinated efforts described above could have the potential impediments/impacts:

- Potential creation of a less dynamic and less nimble water transfer market
- Interference with existing transfer activities
- There are existing agricultural users that are not interested in remaining in agriculture who could be limited in their selling options
- Increased regulatory layers could be ascribed to agricultural transfers as a whole

These are a few of the key tradeoffs that present challenges for developing a more integrated and coordinated strategy for meeting Colorado's long-term water supply needs through transfer of agricultural water rights. Absent a concerted effort to address these tradeoff and challenges it seems likely that the result will be a steady loss of agriculture in a more piecemeal fashion.

As the broad suite of water supply concepts are developed there will be an opportunity to more precisely quantify the amount of water and corresponding number and location of agricultural acres that might be needed to meet future water

supply needs. A clear delineation of these quantities and their location is an essential first step to determine whether to, and if so how to, organize and administer a water supply strategy that more thoughtfully and sustainably provides a long-term water supply for M&I needs and maintains a strong agricultural economic base and food supply for Colorado and our nation.

Alternative Agricultural Transfer Methods

Conservative (low) estimates from the SWSI indicate that Colorado could see a reduction of almost 500,000 irrigated acres by the year 2030 with a major portion of those acres being lost in the Arkansas and South Platte Basins. An even larger loss of acreage may occur because of a lack of available supplies in the South Platte Basin and additional administration issues, such as the selling of partial water rights, the purchase of water rights associated with a central well, and reusing transferred rights to extinction. To more fully understand and help address this trend the CWCB has implemented several efforts to further investigate alternative agricultural transfer methods including:

- SWSI Phase 2 Technical Roundtable – Alternatives Agricultural Water Transfer Methods to Traditional Purchase and Transfer, findings and report available at <http://cwcb.state.co.us/IWMD/SWSITechnicalResources/SWSIPhaseIIReport/SWSIPhaseIIReport.htm>
- Providing Support to the Colorado Agricultural Water Alliance in the Preparation of a Draft February 1, 2008 report titled "Meeting Colorado's Future Water Needs – Opportunities and Challenges Associated with Potential Agricultural Water Conservation Measures" available at http://www.cwi.colostate.edu/other_files/Ag%20water%20conservation%20paper%20Oct%202016.pdf
- Providing Water Supply Reserve Account funding to the Arkansas Basin Roundtable to develop a September 10, 2008 report titled "Considerations for Agriculture to Urban Water Transfers: If you're going to do it, how to do it right" available at http://cwrri.colostate.edu/other_files/Ag_Urban_Report_Jan09.pdf
- Development and Implementation of an Alternative Agricultural Transfer Grant Program. For more information visit <http://cwcb.state.co.us/IWMD/AlternativeAgriculturalWaterTransfersGrantProgram/>

Each of the above resources provides valuable information to consider in the development of future water supply strategies associated with agricultural water use and transfers. Both traditional and alternative transfer methods can be implemented individually or through a more organized and systematic acquisition program as discussed above. In the end there will need to be a "political and social will" to pursue a more systematic acquisition program. It is hoped that the development and further definition of the water supply strategies discussed in this document will provide a

more clear direction on how to take the next steps for developing such a program and how that program can operate in conjunction and complimentary of other water supply strategies.

The remainder of this section will focus on summarizing the status of projects associated with CWCB's Alternative Agricultural Grant Program. For more information on the other topics visit the attached links.

The 2007 legislature passed Senate Bill 07-122, which authorized the CWCB to develop a grant program to further examine and develop alternative agricultural water transfer methods. The legislation also provided \$1,500,000 of funding for the program.

The specific authorizing legislative language is provided below.

SECTION 18. South Platte River and Arkansas River basins alternative agriculture water transfer sustainability grant program - appropriation. (1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the Colorado water conservation board, for the fiscal year beginning July 1, 2007, the sum of one million five hundred thousand dollars (\$1,500,000), or so much thereof as may be necessary, for the board to develop and implement a competitive grant program to advance various agricultural transfer methods as alternatives to permanent agricultural dry-up in the South Platte and Arkansas river basins, including but not limited to, interruptible water supply agreements, long-term agricultural land fallowing, water banks, reduced consumptive use through efficiency or cropping while maintaining historic return flows, and purchase by end users with leaseback under defined conditions. The board, in consultation with the basin water users, shall develop the detailed grant program design.

(2) The moneys appropriated in subsection (1) of this section shall remain available for the designated purposes until the project is completed.

In 2009 the legislature passed Senate Bill 09-125, which added additional funding for the grant program and extended the scope of the program to include all river basins in Colorado.

The specific authorizing legislative language is provided below.

SECTION 4. Continuation of the alternative agriculture water transfer sustainability grant program - appropriation. (1) In addition to any other appropriation, there is hereby appropriated, out of any moneys in the Colorado water conservation board construction fund not otherwise appropriated, to the department of natural resources, for allocation to the

Colorado water conservation board, for the fiscal year beginning July 1, 2009, the sum of one million five hundred thousand dollars (\$1,500,000), or so much thereof as may be necessary, for the board to continue to develop and implement a statewide competitive grant program to advance various agricultural transfer methods as alternatives to permanent agricultural dry-up, including interruptible water supply agreements, long-term agricultural land fallowing, water banks, reduced consumptive use through efficiency or cropping while maintaining historic return flows, and purchase by end users with leasebacks under defined conditions. Projects and programs in all drainage basins are eligible for funding.

(2) The moneys appropriated in subsection (1) of this section shall remain available for the designated purposes until they are fully expended.

Funding for the 2009 legislation became available on July 1, 2009. The following summary provides the status of projects that received funding from the 2007 legislation.

In May 2008 the CWCB reviewed the first round of grant applications and provided conditional approval for the following project:

- Lower Arkansas Valley Water Conservancy District – Super Ditch Company Project – \$320,000

In July 2008 the CWCB approved resubmitted applications for the following projects:

- Parker Water and Sanitation District – Lower South Platte Irrigation Research and Demonstration Project – \$477,500
- Farmers Reservoir and Irrigation Company (FRICO) – Alternative Water Transfers in the South Platte basin using the FRICO System Project – \$202,500

In November 2008 the CWCB reviewed the second round of grants and provided conditional approval of the following projects:

- Colorado Corn Growers – Development of Practical Alternative Agricultural Water Transfer Measures for Colorado Irrigated Agriculture Project – \$349,650
- Colorado State University (Southern Regional Extension Office) – Effects of Land Fallowing Study in the Lower Arkansas Valley – \$80,350
- High Line Canal Company – High Line Canal Water Leasing Project – \$70,000

Total funding allocated to date is \$1,499,500 (\$999,500 for May and July Projects; and \$500,000 for November Projects).

The results of these projects were not available at the time of the completion of this report. Each of the projects examine different aspects associated with developing a better understanding of how to implement alternative agricultural transfer methods ranging from technical, financial, legal, and institutional elements of completing these types of transfers. Alternate transfer methods include but are not limited to

interruptible supply agreement, water banks, long-term rotational fallowing, reduced consumptive use through efficiency or cropping, and purchase by end user with lease.

The results of these projects will be incorporated into the agricultural transfer strategy as they become available. CWCB hopes to work with the project sponsors to analyze "what would it take to make an alternative agricultural transfer program work in Colorado" and build the agricultural transfer strategy around that information. Once several projects are complete, the findings will be examined and a report written. The date of the Projects expected completion is provided below:

- Lower Arkansas Valley is expected to be complete in December of 2009
- Parker Water and Sanitation District is expected to be complete in December of 2010
- Farmers Reservoir and Irrigation Company is expected to be complete in December of 2009
- Colorado Corn Growers is expected to be complete in March of 2010
- Colorado State University is expected to be complete in December of 2012
- High Line Canal Company is expected to be complete in December of 2012

4.1.1.2 New Supply Development Potential Sources of Water Rights

Figures 4-4 through 4-7 below show the potential water sources for the Colorado River Return concept, Flaming Gorge concept, Yampa River concept, and Green Mountain Reservoir concept. For the Colorado River Return concept (Figure 4-4) water would be diverted out of the Colorado River near Grand Junction, Colorado and deliver water to the headwaters of the South Platte and Arkansas River Basins where existing infrastructure could divert supplies. The Flaming Gorge concept (Figure 4-5) would divert water out of Flaming Gorge Reservoir and Green River in Wyoming and deliver water to the Brighton, Colorado area. This concept potentially entails two diversion points:

- South diversion diverting directly from the existing Flaming Gorge Reservoir in the Green River close to the Utah Border
- North diversion upstream of the Flaming Gorge Reservoir

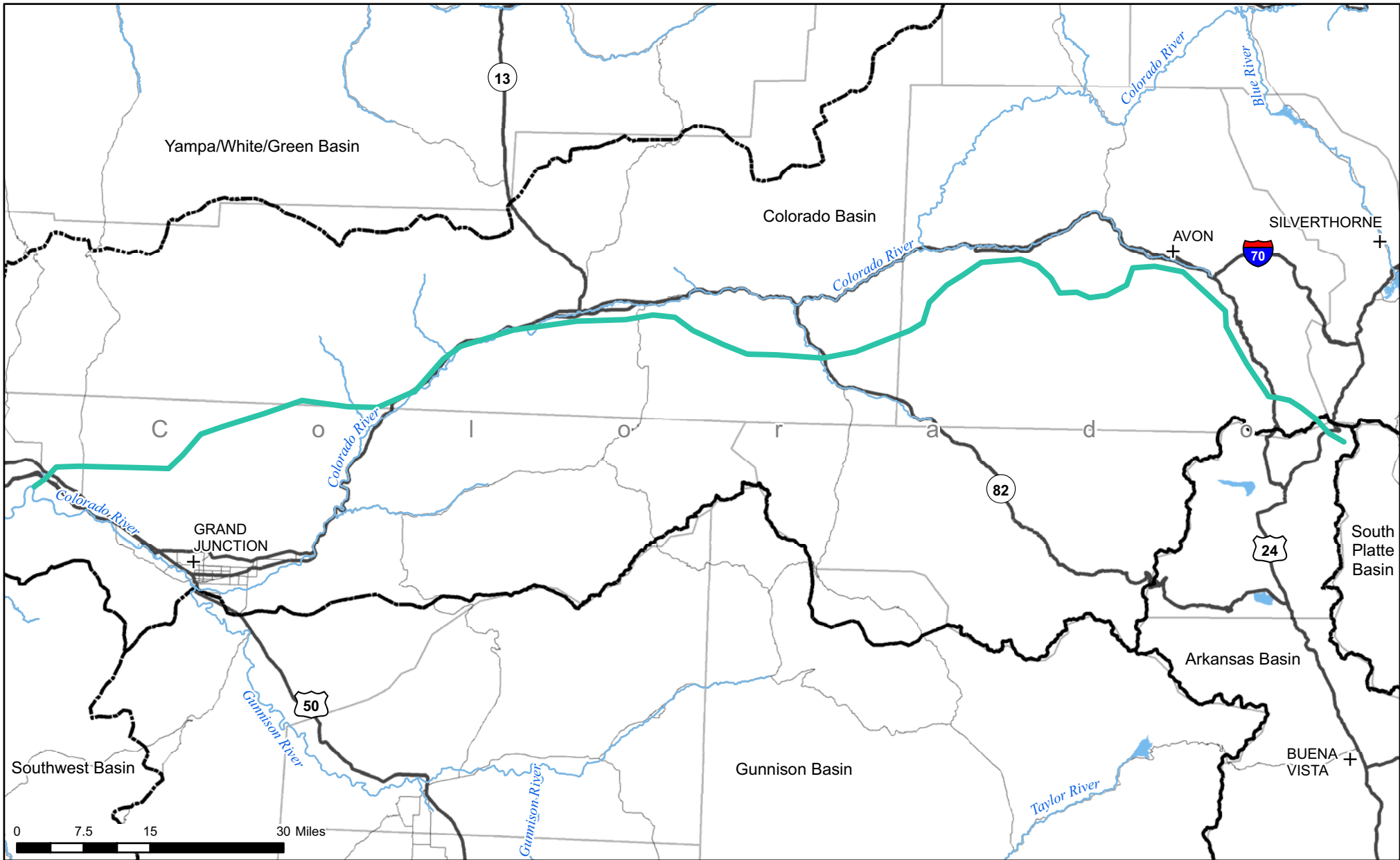


Figure 4-4. Colorado River Return New Supply Development Concept

Legend

- + Cities
- Highways
- Other Roads
- Rivers and Streams
- Lakes and Reservoirs
- Colorado Basins
- Colorado River Return Reconnaissance Study Concept



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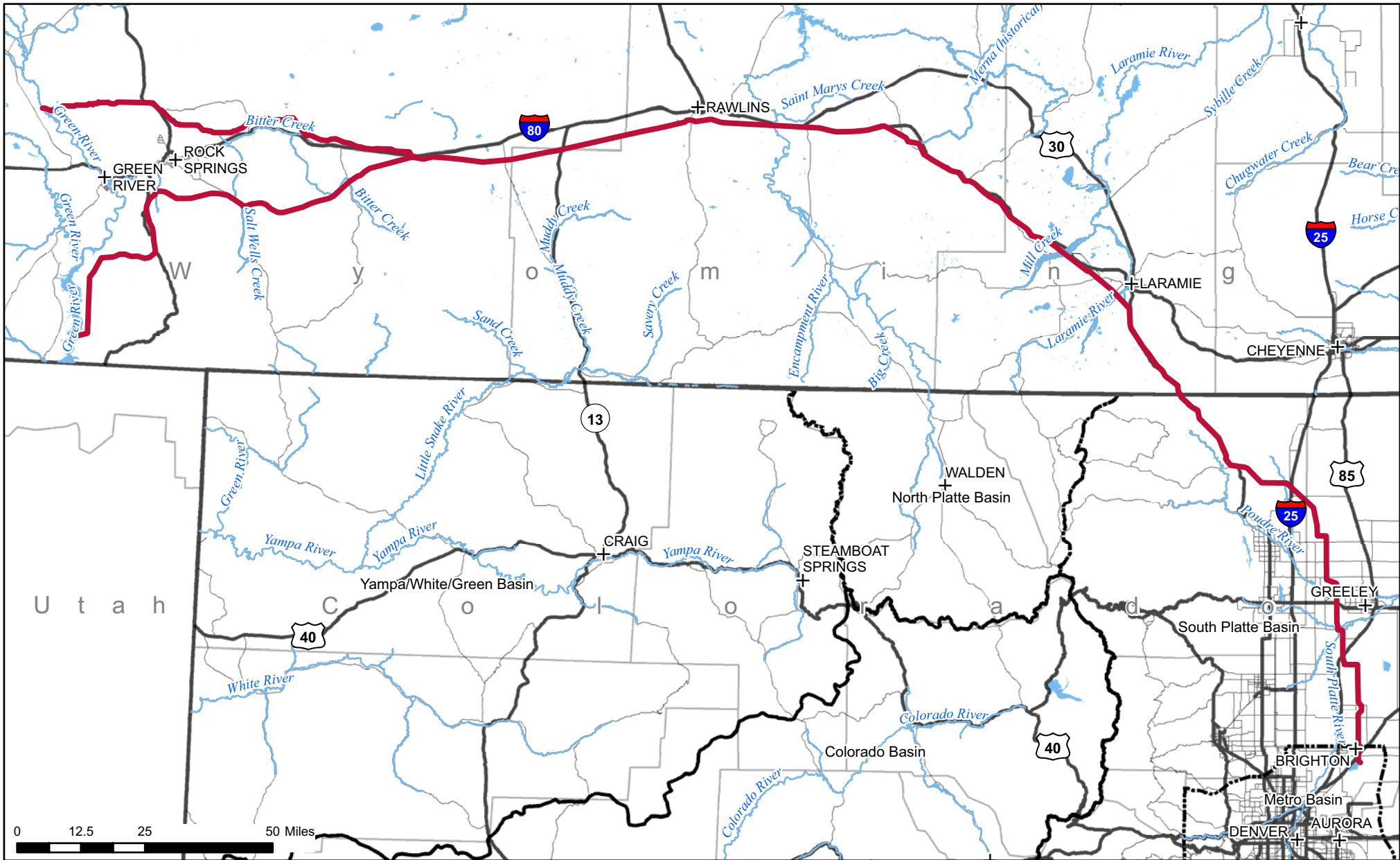


Figure 4-5. Flaming Gorge New Supply Development Concept

Legend

- + Cities
- Highways
- Other Roads
- Rivers and Streams
- Lakes and Reservoirs
- Colorado Basins
- Flaming Gorge Concept



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The Yampa River (Figure 4-6) concept would divert water from the Yampa River near Maybell, Colorado and deliver water to the Brighton, Colorado area. For the Green Mountain Reservoir concept (Figure 4-7), water would be pumped from Green Mountain Reservoir to the Blue River and delivered to Dillon Reservoir. Water would be moved to the South Platte Basin from Dillon Reservoir through existing infrastructure to the headwaters of the South Platter Basin.

4.1.2 Agricultural Transfer and New Supply Development Strategies Attributes Overview

The basic attributes of each concept are summarized in Table 4-1. For each concept, Table 4-1 describes the water source, conveyance and storage, water quality and treatment considerations, and the technical implementability issues. For the Lower South Platte and Lower Arkansas concepts, the cost of water rights are likely to decrease the further the downstream diversion is from urban areas; however, conveyance costs will increase the further the diversion is downstream. For the new supply development concepts except Flaming Gorge, the water supply acquisition would be a new appropriation. For Flaming Gorge, the water supply would be acquired through the BOR marketable pool. For both the Lower South Platte and Lower Arkansas concepts, reverse osmosis (RO) or advanced water treatment will be required due to source water quality. Similarly, the Colorado River Return concept would also require RO or advanced water treatment. The Green Mountain concept, Flaming Gorge concept, and Yampa River concept would not require advanced water treatment. Other important attributes are summarized in more detail in Table 4-1. Additional benefits, impacts, attributes, and opportunities identified by the IBCC, CWCB, and roundtables are provided in Section 6.

Preliminary alignments for all of the concepts were shown in Figures 4-1 through 4-7. These figures show several different termination points for the pipelines; however, it was assumed that the new water supply from all of these concepts will ultimately be delivered to the south metropolitan Denver region. A common point of delivery is important for meaningful comparison of these concepts based on a common set of assumptions, and the south metropolitan Denver region is predicted to have the largest water supply gaps by 2030 (CWCB 2004). The general alignments for all of the concepts shown above were determined in previous studies that were presented at the beginning of this section. In order to remain consistent with the previous studies, the previously studied concept alignments were used for this comparative analysis. Only minor modifications of these alignments were made during this engineering analysis.

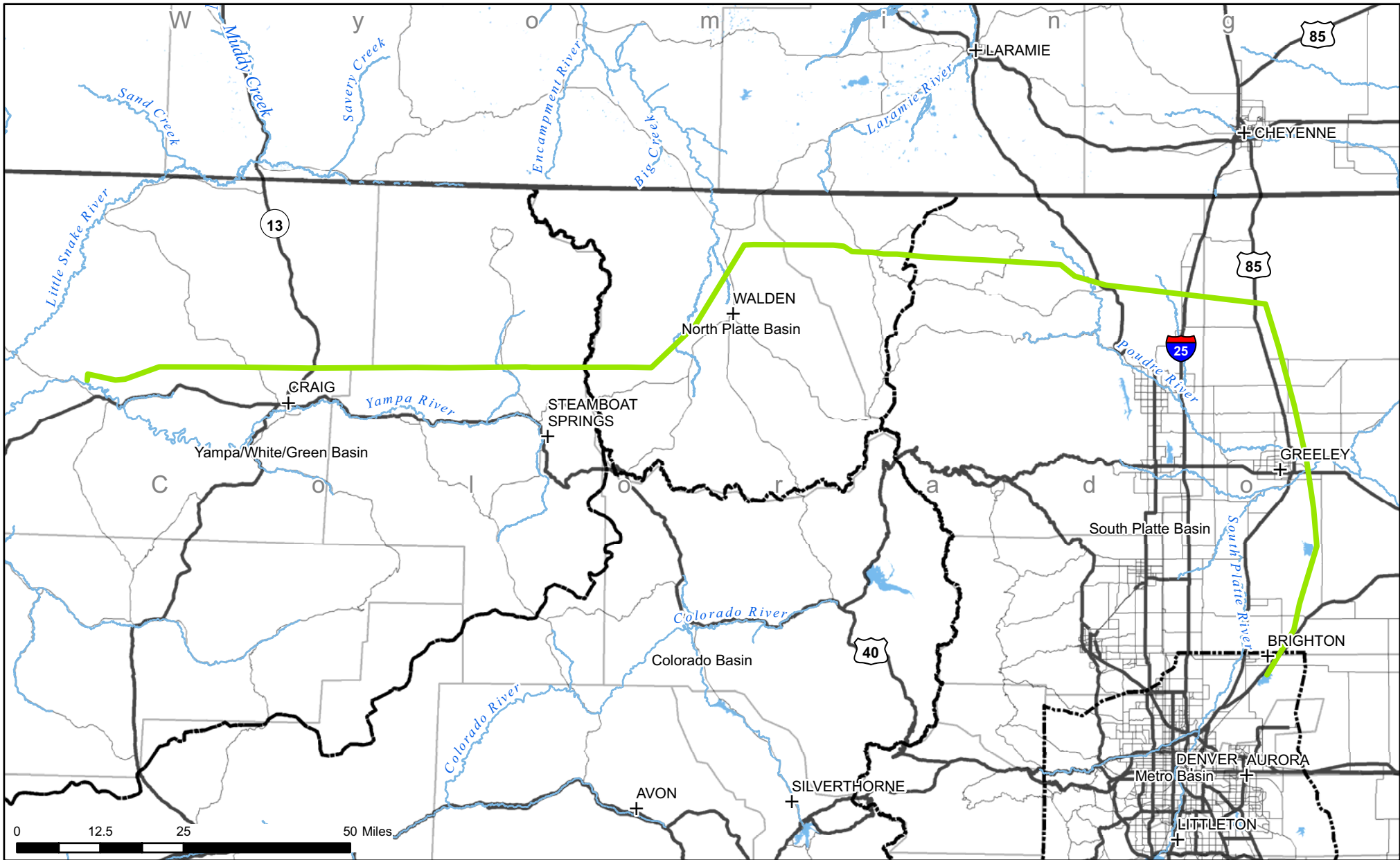


Figure 4-6. Yampa River New Supply Development Concept

- Legend**
- + Cities
 - Highways
 - Other Roads
 - Rivers and Streams
 - Lakes and Reservoirs
 - Colorado Basins
 - Yampa River Concept



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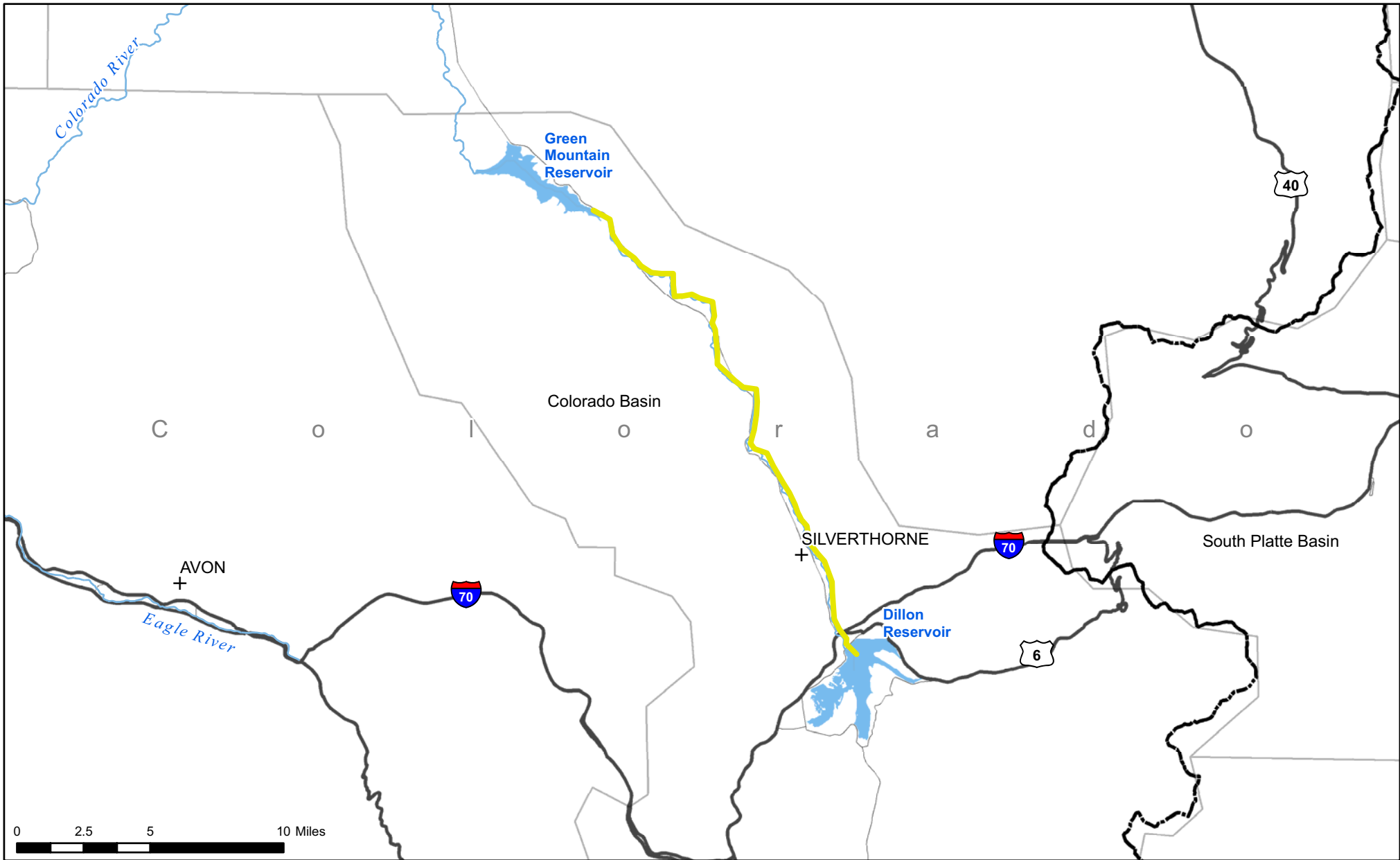


Figure 4-7. Green Mountain New Supply Development Concept

- Legend**
- + Cities
 - Highways
 - Other Roads
 - Rivers and Streams
 - Lakes and Reservoirs
 - Colorado Basins
 - Green Mountain Concept



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Table 4-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Lower South Platte	<ul style="list-style-type: none"> • South Platte agricultural water rights • Cost of water rights will likely decrease further downstream and away from urban areas 	<ul style="list-style-type: none"> • Water pumped 36 to 84 miles with static pumping requirement of 700 to 1,300 feet • Conveyance costs will increase the further downstream • Firming storage required 	<ul style="list-style-type: none"> • Water quality will decrease further downstream and treatment costs will increase • Expected Total Dissolved Solids (TDS) levels of 750 to 1,200 mg/L • RO or advanced water treatment will be required 	<ul style="list-style-type: none"> • If land is permanently dried up from an agricultural transfer will require revegetation • Recent water quality legislation allows water quality impacts for transfers over 2000 AF to be reviewed as part of an agricultural transfer (C.R.S. 37-92-305 (4)(a)(V))
Lower Arkansas	<ul style="list-style-type: none"> • Arkansas agricultural water rights • Cost of water rights will likely decrease further downstream and away from urban areas • LAWCD has formed the Super Ditch as an alternative to traditional agricultural transfer 	<ul style="list-style-type: none"> • Water pumped 96 to 133 miles with static pumping requirement of 3,100 to 3,600 feet • Conveyance costs will increase the further downstream • Firming storage required 	<ul style="list-style-type: none"> • Water quality will decrease further downstream and treatment costs will increase • Expected TDS levels of 750 to 2,000 mg/L • RO or advanced water treatment will be required 	<ul style="list-style-type: none"> • If land is permanently dried up from an agricultural transfer will require revegetation • Recent water quality legislation allows water quality impacts for transfers over 2000 AF to be reviewed as part of an agricultural transfer (C.R.S. 37-92-305 (4)(a)(V))
Green Mountain	<ul style="list-style-type: none"> • Blue River water in the Colorado River basin • Water would likely be a new appropriation unless Denver Water conditional rights can be used • New appropriation may require significant firming storage • Compact call and legal availability need to be resolved if a new appropriation 	<ul style="list-style-type: none"> • Water pumped 22 miles with static pumping requirement of 1,000 feet • Green Mountain storage will need to be replaced with other storage • Firming storage estimates vary significantly • Will depend on negotiations with Denver Water for terms of use of Dillon Reservoir and Roberts Tunnel • Conveyance on East Slope would be via South Platte River 	<ul style="list-style-type: none"> • Relatively high water quality • Conventional treatment technology 	<ul style="list-style-type: none"> • Landslides in Green Mountain Reservoir from reservoir drawdown may limit ability to fully use storage in reservoir

Table 4-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Yampa	<ul style="list-style-type: none"> • New water rights appropriation • Compact call and legal availability related to endangered fish need to be resolved for a new appropriation 	<ul style="list-style-type: none"> • Estimated 500,000 AF of West Slope storage would need to be constructed • East Slope storage also required • Would require approximately 250 miles of pipeline, with static pumping requirement of 5,000 feet • Pumping, pipeline, and tunneling required to deliver water to northern area of South Platte basin • Conveyance on East Slope would be via pipelines to the south Denver metropolitan area 	<ul style="list-style-type: none"> • Moderate water quality • Estimated water quality higher than Lower South Platte, Lower Arkansas, or Flaming Gorge • Conventional treatment technology 	<ul style="list-style-type: none"> • Constructible and permittable West Slope diversion, storage sites and pipeline routes need to be verified.
Flaming Gorge	<ul style="list-style-type: none"> • Contract with BOR for water from the Flaming Gorge marketable pool, to the extent the BOR is willing to acknowledge and contract out of the pool and it is not opposed by other Colorado River basin states • Compact call and legal availability and administration of depletions in Wyoming for use in Colorado need to be resolved 	<ul style="list-style-type: none"> • Volume of firming storage required will be dependent on terms of BOR contract • Limited Flaming Gorge storage may be available • Volume of firming storage is unknown • 357 to 442 miles of pipeline to the south Denver metropolitan area with static pumping requirements of 1,400 to 3,100 feet 	<ul style="list-style-type: none"> • Would likely require higher level of treatment than other West Slope options • TDS is higher than other West Slope options but lower than Lower South Platte or Arkansas • Conventional treatment technology 	<ul style="list-style-type: none"> • Constructible and permittable West Slope diversion, storage sites and pipeline routes need to be verified.

Table 4-1 Agricultural Transfer and New Supply Development Concept Attributes

Concept	Water Source/ Water Rights	Conveyance and Storage	Water Quality and Treatment Costs	Technical Implementability
Colorado River Return Reconnaissance	<ul style="list-style-type: none"> • New water rights appropriation • Compact call and legal availability need to be resolved for a new appropriation 	<ul style="list-style-type: none"> • West Slope storage would not be required • East Slope storage required • 179 miles of pipeline with static pumping requirement of 7,000 feet. • Conveyance on East Slope would be via South Platte and Arkansas Rivers 	<ul style="list-style-type: none"> • High TDS levels • Reverse osmosis or other advanced water treatment required • Potential water quality concerns related to temperature and other constituents with discharge to headwaters streams • Disposal of water treatment waste stream concentrate 	<ul style="list-style-type: none"> • Constructible and permittable West Slope diversion, storage sites and pipeline routes need to be verified.

As shown in the figure, the South Platte, Flaming Gorge, and Yampa alignments used in this study convey water to the Brighton area. It was assumed supplies could be conveyed from Brighton to the south metropolitan area, through shared future projects and/or existing projects such as the East Cherry Creek Valley Northern Pipeline and the City of Aurora Prairie Waters Pipeline. This reach of pipeline was not considered in this study as it does not help to differentiate between these three concepts and would be an equally small cost to any of the projects. The Arkansas alignments deliver to Reuter-Hess Reservoir near Parker in the south Denver metropolitan area. The Green Mountain project will convey water to the Denver area using existing Denver Water infrastructure within the South Platte Basin. Similarly, the Colorado River Return concept will convey water to the Denver area using the existing infrastructure within the Arkansas and South Platte River Basins.

4.2 Concept Size Options and Facility Requirements

With the exception of the Green Mountain concept, each of the agricultural transfer and new supply development concepts were evaluated based on three options:

- Option 1: delivery of 100,000 AFY constructed in a single phase
- Option 2: delivery of 250,000 AFY constructed in a single phase
- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

Key elements of each water supply concept were identified and evaluated using uniform assumptions to determine infrastructure requirements and sizing for the reconnaissance cost estimates. The assumptions and requirements of each concept are presented below for the following elements: water rights; firming storage; diversions; transmission facilities, including pipelines, tunneling, and pump stations; treatment facilities; and reuse infrastructure. Hydropower facilities were not considered for this report, nor electrical power substation and transmission facilities.

The maximum expected water supply yield from the Green Mountain concept is 68,600 AFY, which is less than the Option 1 delivery of 100,000 AFY. Therefore, it was the only concept that did not meet the minimum supply volume for this study and while compared against the other concepts, was not evaluated further with regards to water rights, diversion structures, firming storage, treatment, and reuse. However, Section 4.2.7 includes a summary of the reported transmission facilities that would be required for the Green Mountain water supply concept.

Flaming Gorge is the only concept with two diversion points – the north diversion and the south diversion, as introduced in Section 4.1. It was assumed that the south diversion can convey 150,000 AFY and the north diversion can convey 100,000 AFY. Given this assumption, Option 1 was sized and costed assuming only the north diversion pipeline is constructed, Options 2 and 3 were sized and costed assuming both the north and south diversion pipelines are constructed.

4.2.1 Water Rights

As discussed in Section 4.1, for the agricultural transfer concepts water would be transferred from agricultural use to municipal use. For the new supply development concepts new water rights would need to be acquired and for Flaming Gorge a contract would need to be established from the marketable pool. For the water supply development concepts, filing for a new water right would be required. The agricultural transfer concepts would require water rights purchase and obtaining the legal transfer of use, which require Colorado Water Court review.

4.2.2 Firming Storage

The availability of surface water supplies varies greatly in Colorado as annual water supplies are dependent upon the quantity of winter snowfall and the timing of the snowmelt in the spring and summer. Colorado's rivers typically have 2 to 4 months of elevated streamflows, which constitutes the window to divert and store the majority of available water supplies. Therefore, water storage is an important component of any water supply project, especially for large-scale, long-distance pipelines, as a future project would need to supply a relatively constant supply of water to the Front Range of Colorado to meet future demand needs.

As the availability of the river supplies comes within a few months, and municipal supplies are needed year round, a storage reservoir would, at a minimum, need to store almost the entire volume of each of the concept options. In addition, the quantity of snowfall varies greatly from year to year and storing excess water in wet and average years would help provide a reliable supply for dry and very dry years, when the full supply might not be available.

For the purpose of this planning level analysis it was assumed that a storage-to-yield ratio of 2:1 would be required for the agricultural transfer concepts. This assumption is based on the variability described above as well as variability between potential reservoir locations. As will be described in Section 5 the purchasing of senior agricultural rights was evaluated, which will help water supply reliability in dry and very dry years, when yields for junior users are often significantly curtailed. Thus, for both the Arkansas River concept and the South Platte River concept, the Option 1 storage volumes were evaluated at 200,000 AF and the Options 2 and 3 storage volumes were evaluated at 500,000 AF. Specific locations and reservoir sites were not evaluated for this analysis, as the location of the specific water rights purchased would greatly affect which reservoir locations would be optimal for future water supplies.

The firming storage requirements varied for the four new water supply development concepts. The Flaming Gorge concept South Diversion would divert water directly from the existing Flaming Gorge Reservoir and would not require additional firming storage. For the North Diversion of Flaming Gorge concept, it was assumed that a storage to yield ratio of 2:1 would be required and the storage volume for Options 1, 2, and 3 were all evaluated at 200,000 AF. Investigation of the Colorado River Return concept indicated that the diversion location would be below all Colorado existing

water rights, and anticipated flows in the Colorado River would be sufficient to divert water when needed. Thus firming storage would not be required, only operational storage, which was included in the transmission facilities (Section 4.2.3). It was assumed that a storage-to-yield ratio of 2:1 would be required for the Yampa River concept. The Yampa River concept Option 1 storage volume was evaluated at 200,000 AF and the Option 2 and 3 storage volumes were evaluated at 500,000 AF. Specific locations and reservoir sites were not evaluated for this analysis, as the location of the specific diversion location was not known, which would greatly affect which reservoir locations would be optimal for future water supplies.

4.2.3 Transmission Facilities

Transmission facilities consist of pipelines, tunnels, and pump stations. The basis for sizing each of these elements was review of the proposed supply and discharge locations, proposed general alignments for the conveyance facilities, and the development of a preliminary hydraulic grade line (HGL) based on the lift required to transfer the flows. Initial proximate locations for the pump stations were identified based on the topography along the proposed routes, maximum reasonable lifts for each pump station, and the trade offs of using tunnels through certain reaches rather than pump stations and pipelines. The initial sizing was based on the different lift and flow requirements. The results of this hydraulic analysis were used to determine pressure class requirements and tunneling lengths and depths. As noted in Section 4.1.2, alignments for each concept were selected from previous studies – one alignment was evaluated for each of the Flaming Gorge, Yampa River, and Colorado River concepts, and two alignments were evaluated for each of the Arkansas and South Platte concepts. Transmission facilities were evaluated separately for each scenario and for each alignment. Option 3 (250,000 AFY in two phases) was assumed to consist of two parallel pipelines with shared tunnels and pump stations.

All transmission facilities were sized to convey greater than the average selected target flow for each scenario, allowing for the total annual volume to be delivered if all infrastructure was available 90 percent of the time. Applying this peaking factor (1.1) allows the target annual volumes to be delivered despite downtime for routine maintenance and unexpected events such as pump station power outages.

4.2.3.1 Hydraulic Analysis

The alignments were brought into ArcGIS and were split into station points every 100 feet. The station points were then assigned an elevation based on the USGS National Elevation Dataset (NED) for Colorado and Wyoming. The elevation data were then used to make profiles for all of the alignments, which were used to complete the HGL analysis. HGLs were developed for each concept and are shown in Figures 4-8 through 4-15 below. The pipeline profile was assumed to follow the ground elevation, with approximately 8 feet of cover. The exception was where the ground surface required pipe slopes greater than 15 percent, in which case the pipeline was buried deeper to reduce slopes, or where tunnels were used instead of the pipelines.

**Figure 4-8. Hydraulic Grade Line
Arkansas Concept - Alignment 1**

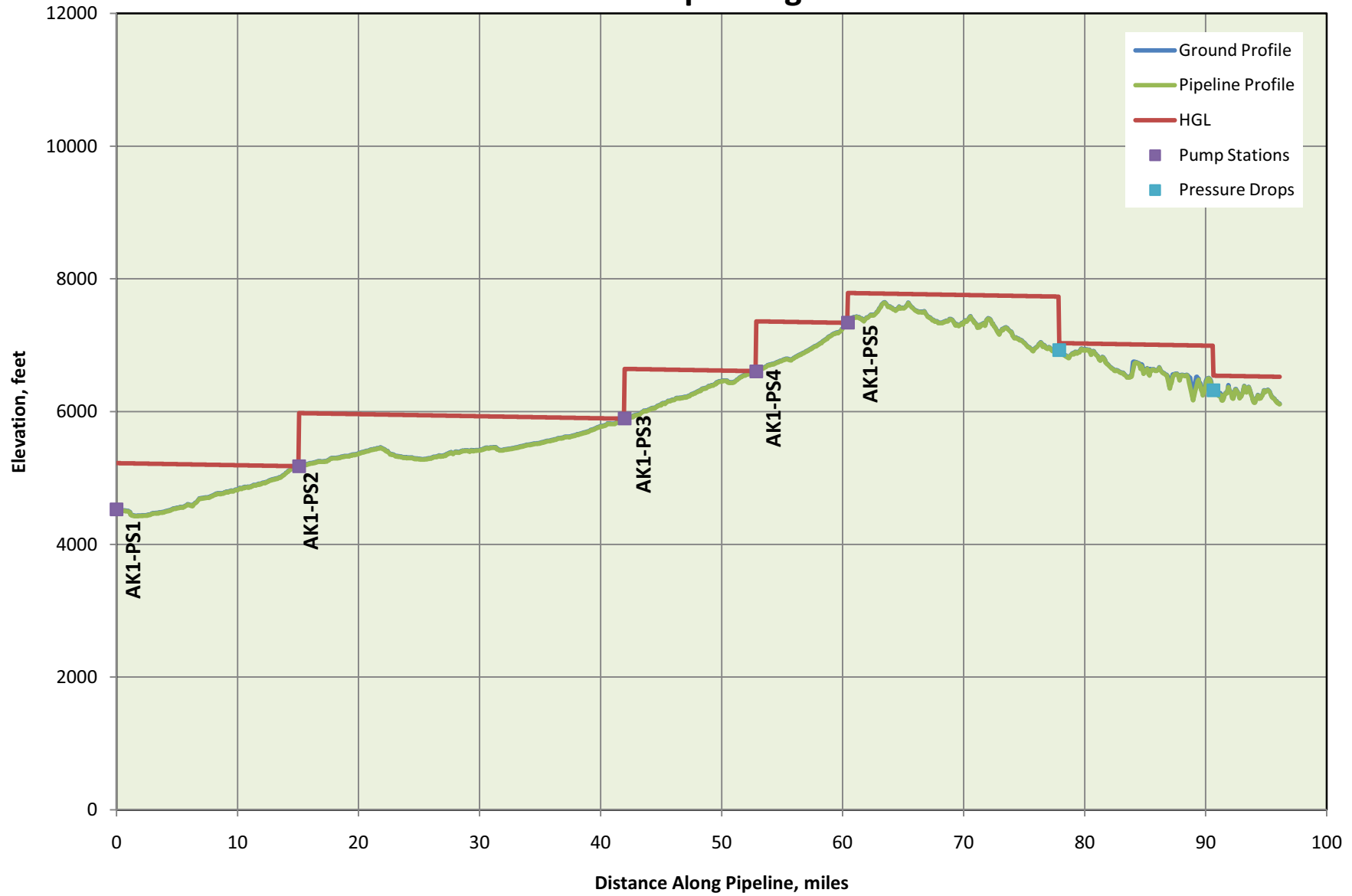
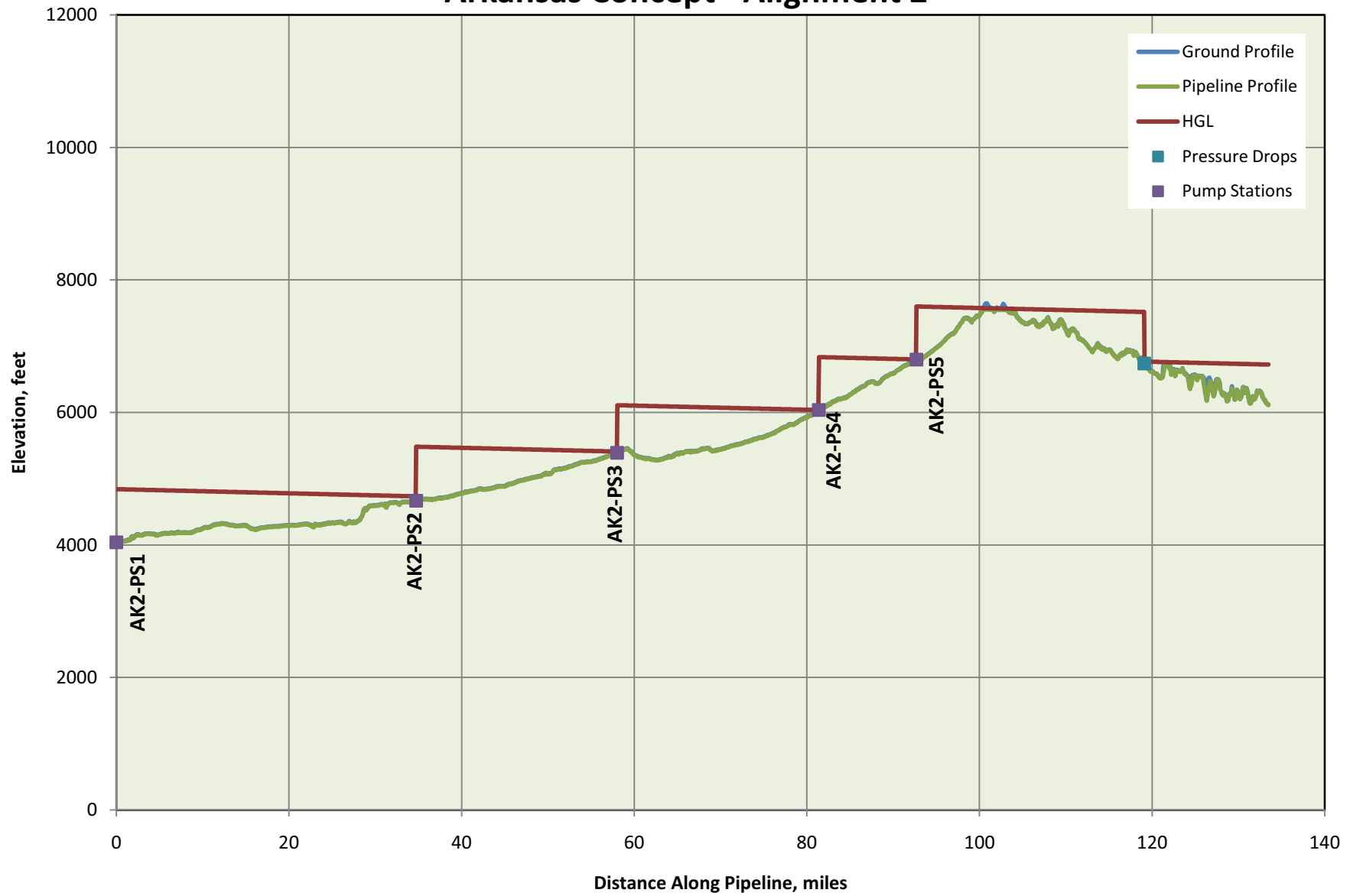
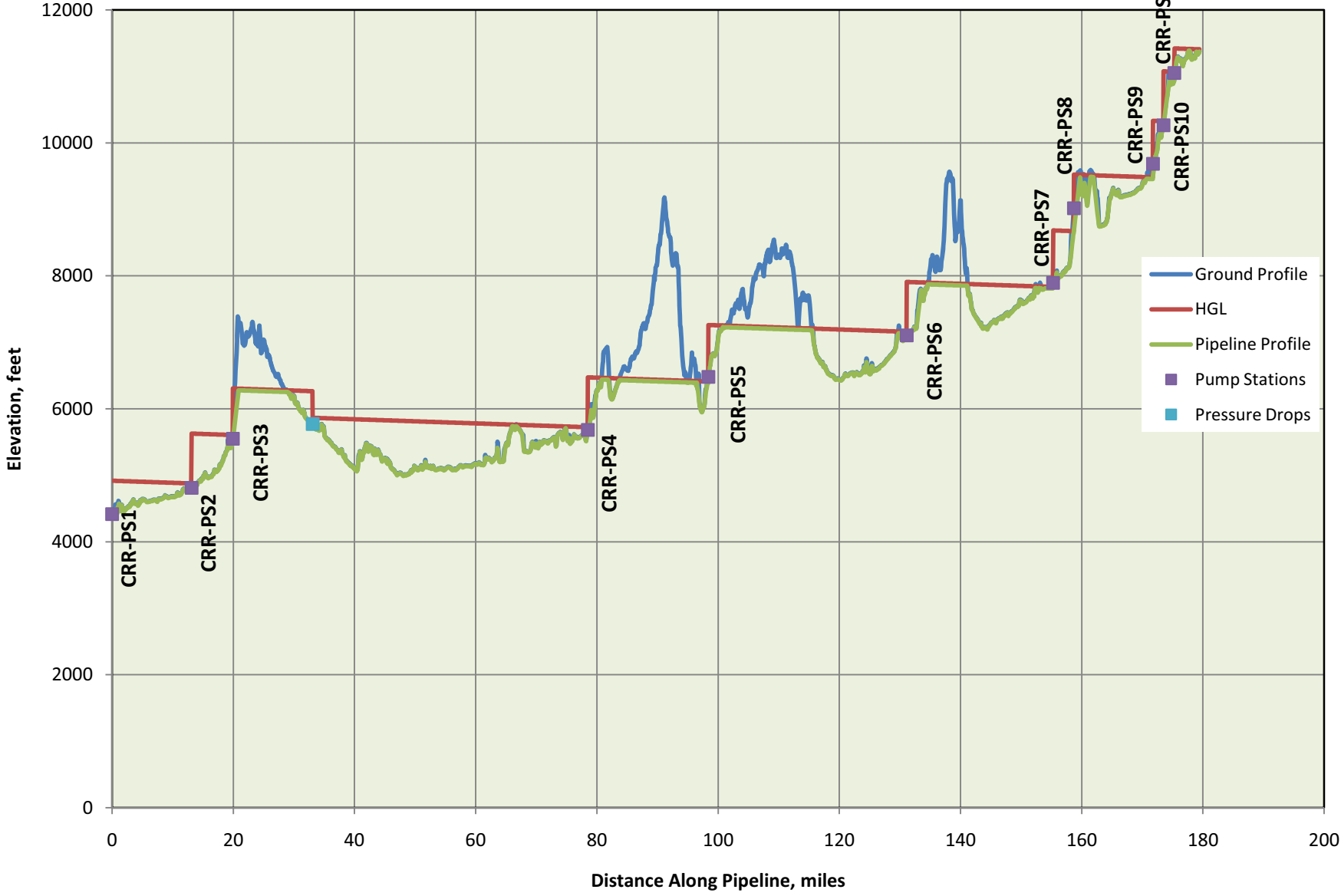


Figure 4-9. Hydraulic Grade Line Arkansas Concept - Alignment 2



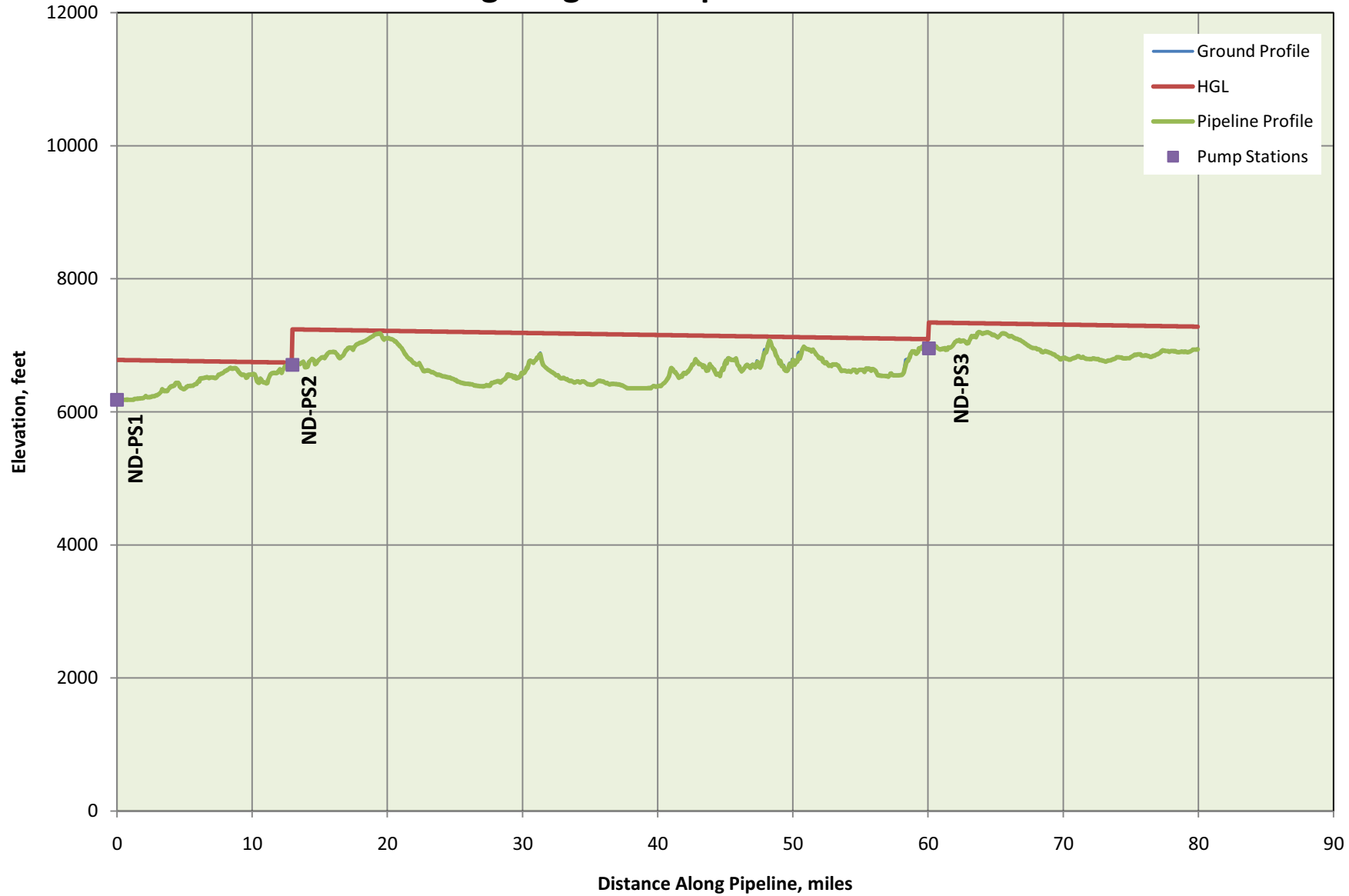
**Figure 4-10. Hydraulic Grade Line
Colorado River Return Concept**



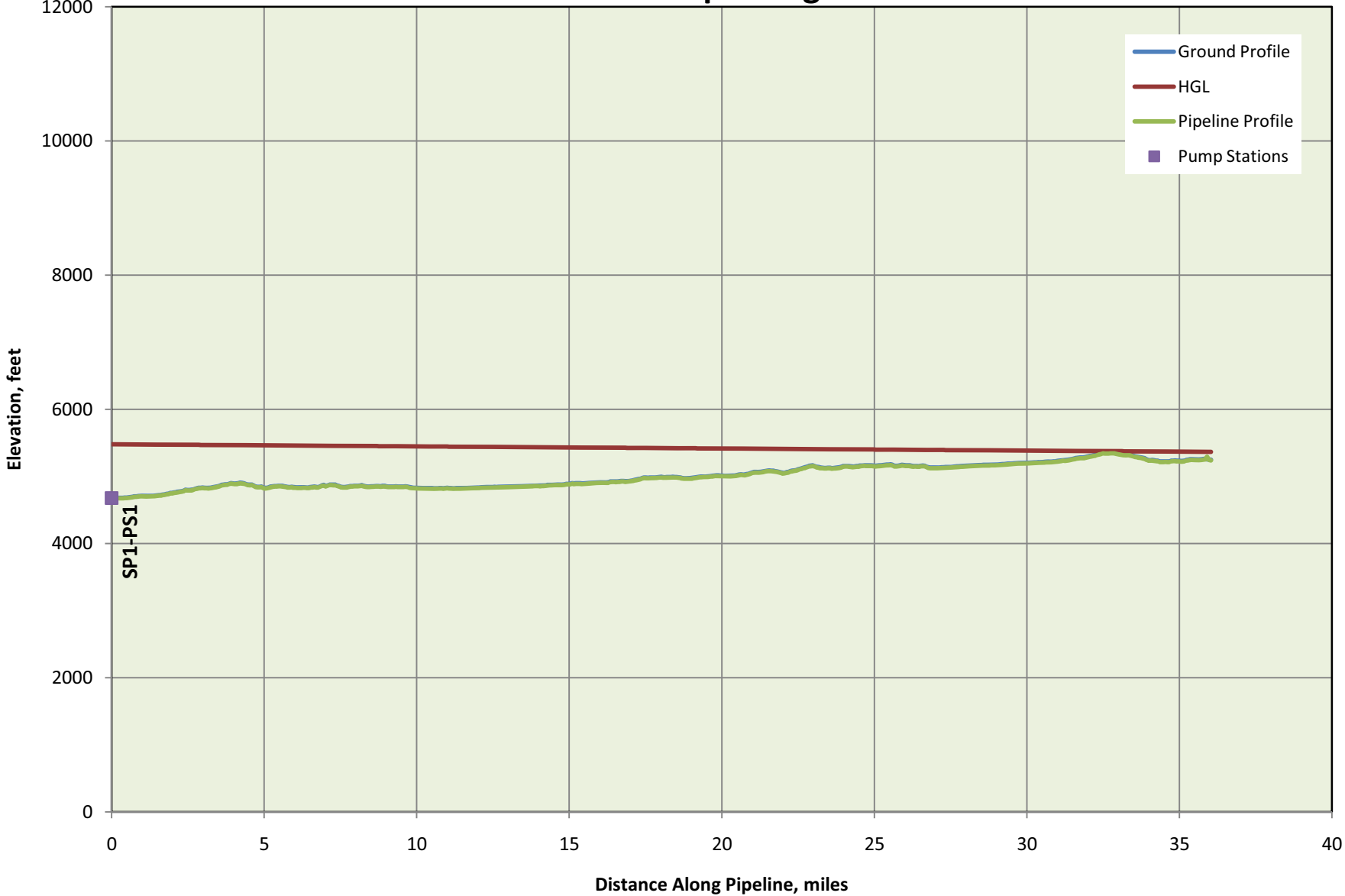
**Figure 4-11. Hydraulic Grade Line
Flaming Gorge Concept - South Diversion and Main Pipeline**



**Figure 4-12. Hydraulic Grade Line
Flaming Gorge Concept - North Diversion**



**Figure 4-13. Hydraulic Grade Line
South Platte Concept - Alignment 1**



**Figure 4-14. Hydraulic Grade Line
South Platte Concept - Alignment 2**

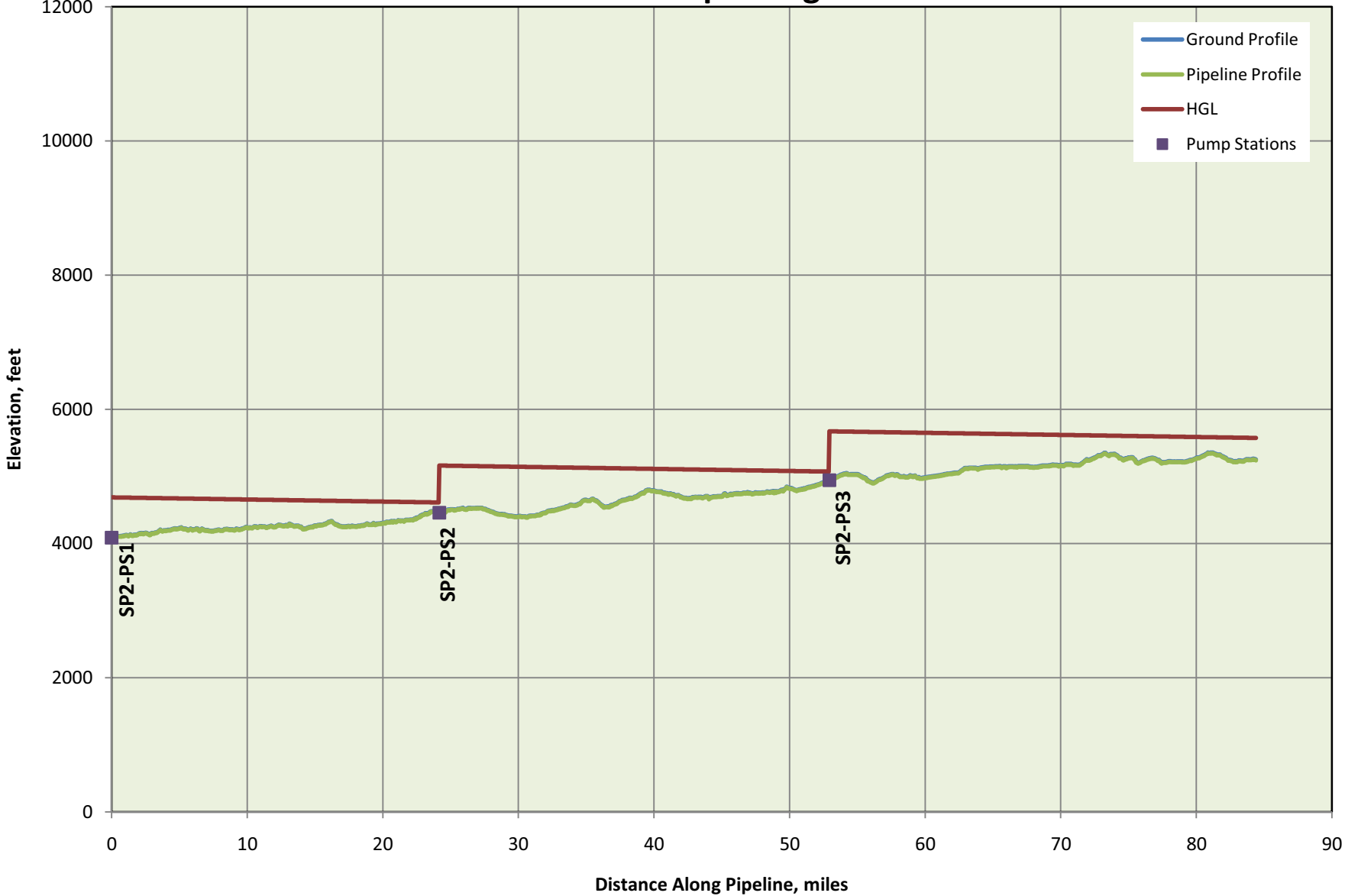
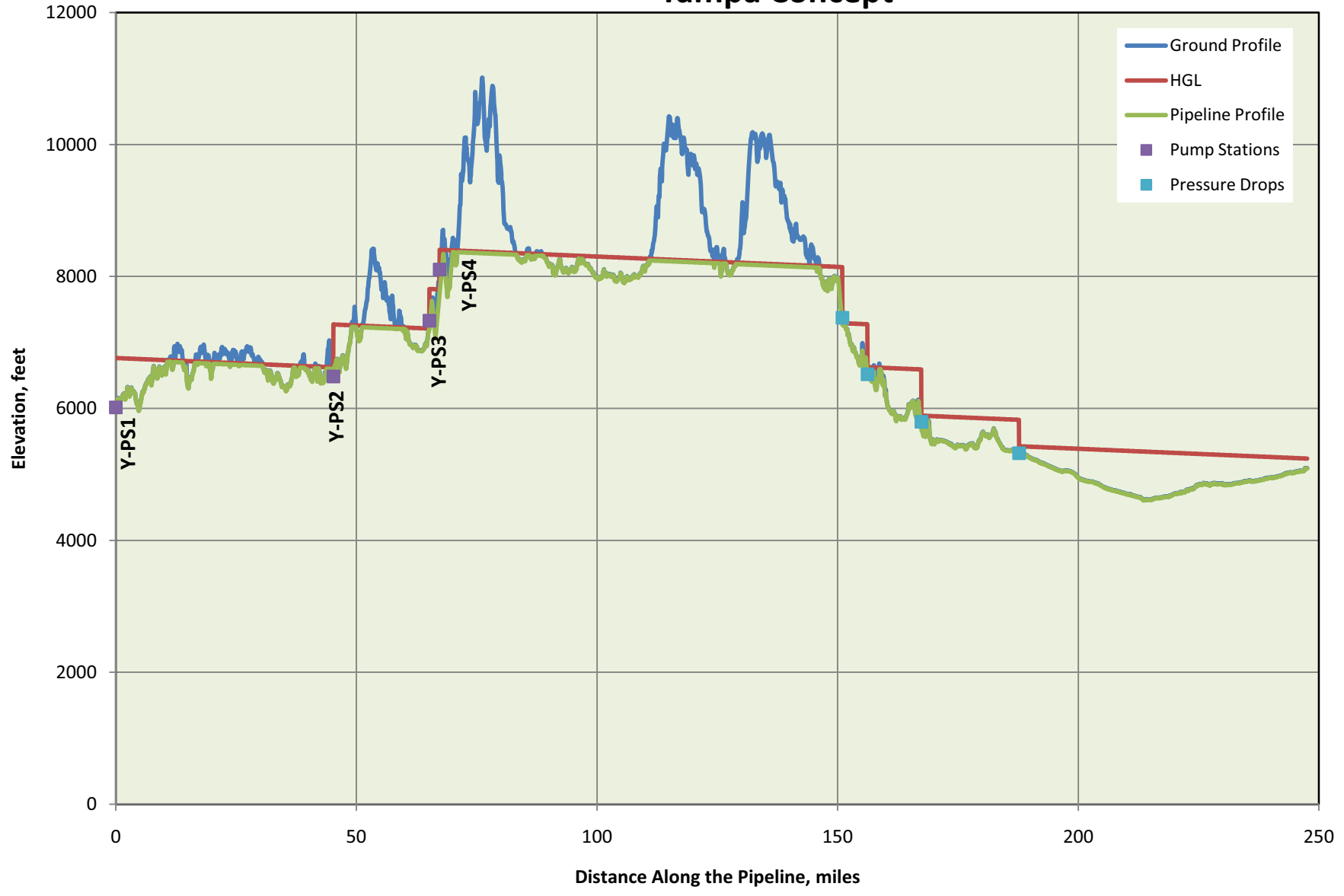


Figure 4-15. Hydraulic Grade Line Yampa Concept



The HGLs shown in Figures 4-8 through 4-15 were based on Option 2 (250,000 AFY in a single phase 114-inch pipe with the same peaking factor of 1.1 used to size the transmission facilities), the friction loss in the pipelines and tunnels estimated using the Hazen-Williams equation with a C-factor of 130. This C-factor is conservative for new pipe, but is a reasonable estimation of pipe conditions after 50 years, which is the anticipated project life. The HGL analysis was based only on one option because the difference in friction losses between options, which have similar velocities, is not significant. Where available (Yampa [Northern Colorado Water Conservancy District 2006], Flaming Gorge south diversion and main pipelines [USACE 2009] and Colorado River Return [CWCB 2003] concepts), pump station locations and total dynamic head (TDH) values were initially used from previous reports in order to approximate requirements for pumping as well as tunneling. Pump station locations and TDH values were then revised to maintain minimum pipeline pressures of 10 pounds per square inch (psi) and maximum pressures of about 350 psi while maintaining a reasonable balance between pumping and tunneling.

For some sections of the alignments the pressures needed to be reduced as the topography changed. The HGLs for each of the concepts are shown Figures 4-8 through 4-15. These are included to constrain pressures to reasonable values and used for the pressure class analysis. One possible way to accomplish the required reduction in head is through hydropower facilities, which were evaluated in previous reports for the Colorado River Return (CWCB 2003), Flaming Gorge (USACE 2009), and Yampa (Northern Colorado Water Conservancy District 2006) concepts. Pressure drop requirements are summarized in Table 4-2.

Table 4-2 Pressure Drop Summary

Concepts	No. Pressure Drop Facilities	Total head reduction (psi)	Total pressure blow-off (feet)
Arkansas 1	2	1,150	2,653
Arkansas 2	1	750	1,730
Colorado River Return	1	400	923
Flaming Gorge	4	2,500	5,768
Yampa	4	2,600	5,998

*Note: No pressure drop facilities were required for either South Platte alignment

Most of the concept alignments have widely varying slopes, which affects excavation or tunneling costs. The HGL analysis was also used to determine the portion of each alignment where ground slopes exceeded 10 percent. For this analysis an escalation factor was used to represent the increased difficulty for these reaches and the increased installation costs. Table 4-3 summarizes the percent of each alignment with ground slopes greater than 10 percent.

Table 4-3 Ground Slope Summary

Concept		Percentage of length with ground slope above 10%
Arkansas	Alignment 1	3
	Alignment 2	2
Colorado River Return		8
Flaming Gorge	Main Pipeline	4
	North Diversion Pipeline	4
	South Diversion Pipeline	4
South Platte	Alignment 1	0
	Alignment 2	0
Yampa		9

4.2.3.2 Pipelines

For planning purposes the pipelines were sized based on maintaining the flow velocity below 5.5 feet per second (fps) at the peak design flow of 1.1 times the average annual flow for each scenario. Table 4-4 shows the diameters and velocities for each scenario. All concepts are assumed to use the same flows and pipeline diameters. As discussed above, the Flaming Gorge concept south diversion was assumed to convey 150,000 AFY (Options 1 and 3) and the north diversion was assumed to convey 100,000 AFY (Options 2 and 3); all other concepts have a single diversion point. Each segment of pipeline was then evaluated to stay within 150, 250, or 350 psi class pipe pressure requirements, based on the difference between the HGL and the pipeline elevation. Table 4-5 summarizes pressure classes by pipeline.

Table 4-4 Pipeline Diameters and Velocities

Option	Capacity (AFY)	Peak Capacity (AFY)	Pipeline diameter (in)	Velocity, peak (fps)
1 and 3	100,000	110,000	72	5.4
2	250,000	275,000	114	5.4
3	150,000	165,000	90	5.2

Table 4-5 Pressure Classes

Concept		Pressure Class (%)		
		150 psi	250 psi	350 psi
Arkansas	Alignment 1	34	38	28
	Alignment 2	32	34	34
Colorado River Return		44	24	32
Flaming Gorge	Main Pipeline	35	42	23
	North Diversion Pipeline	29	47	24
	South Diversion Pipeline	20	49	31
South Platte	Alignment 1	40	22	39
	Alignment 2	24	52	25
Yampa		52	31	17

4.2.3.3 Pump Stations

Possible locations for the pump stations were based on identifying accessible locations for construction, and the maximum allowable pressure in the pipelines where tunnels were not used in-lieu of pumps and pipelines. Table 4-6 summarizes the number of pump stations and total required pumping head for each concept, and Table 4-7 shows the location and TDH of each pump station along each alignment. Pump station horsepower requirements were calculated for both peak and non-peak flows, as shown in Table 4-8. Horsepower calculations were based on an assumed combined pump and motor efficiency of 72 percent.

Table 4-6 Pump Station Summary

Concept		No. of Pump Stations	Total Pumping Head Requirements (ft)
Arkansas	Alignment 1	5	3,450
	Alignment 2	5	3,850
Colorado River Return		11	7,950
Flaming Gorge	Main Pipeline	2	1,300
	North Diversion Pipeline	3	1,350
	South Diversion Pipeline	3	1,650
South Platte	Alignment 1	1	800
	Alignment 2	3	1,750
Yampa		4	2,600

Table 4-7 Pump Stations

Concept		Pump Station ID	Distance Along Alignment (miles)	TDH (ft)
Arkansas	Alignment 1	AK1-PS1	0	700
		AK1-PS2	15	800
		AK1-PS3	42	750
		AK1-PS4	53	750
		AK1-PS5	60	450
	Alignment 2	AK2-PS1	0	800
		AK2-PS2	35	750
		AK2-PS3	58	700
		AK2-PS4	81	800
		AK2-PS5	93	800
Colorado River Return		CRR-PS1	0	500
		CRR-PS2	13	750
		CRR-PS3	20	700
		CRR-PS4	79	750
		CRR-PS5	98	850
		CRR-PS6	131	750
		CRR-PS7	155	850
		CRR-PS8	159	850
		CRR-PS9	172	850
		CRR-PS10	174	750
		CRR-PS11	175	350

Table 4-7 Pump Stations

Concept		Pump Station ID	Distance Along Alignment (miles)	TDH (ft)
Flaming Gorge	Main Pipeline	M-PS1	87	800
		M-PS2	167	500
	North Diversion Pipeline	ND-PS1	0	600
		ND-PS2	13	500
		ND-PS3	60	250
	South Diversion Pipeline	SD-PS1	0	650
		SD-PS2	19	600
SD-PS3		61	400	
South Platte	Alignment 1	SP1-PS1	0	800
		SP2-PS1	0	600
	Alignment 2	SP2-PS2	24	550
		SP2-PS3	53	600
Yampa		Y-PS1	0	750
		Y-PS2	45	650
		Y-PS3	65	600
		Y-PS4	67	600

Table 4-8 Total Pumping Horsepower Requirements

		Average (hp)			Peak (hp)		
		Option 1	Option 2	Option 3	Option 1	Option 2	Option 3
Arkansas	Alignment 1	75,000	188,000	188,000	85,000	212,000	127,000
	Alignment 2	84,000	209,000	209,000	95,000	237,000	142,000
Flaming Gorge		58,000	154,000	154,000	65,000	174,000	174,000
Colorado River Return		173,000	432,000	432,000	196,000	489,000	489,000
South Platte	Alignment 1	17,000	43,000	43,000	20,000	49,000	30,000
	Alignment 2	38,000	95,000	95,000	43,000	108,000	65,000
Yampa		57,000	141,000	141,000	64,000	160,000	160,000

4.2.3.4 Tunnels

The identification of where installation of tunnel reaches should occur rather than pipelines was also based on the HGL analysis. It was assumed that tunneling methods were used anywhere that the pipeline depth of bury was greater than 20 feet. As noted in Section 4.2.3.1, pump stations and tunneling for Colorado River Return, Flaming Gorge, and Yampa followed previous studies as closely as possible within the uniform hydraulic criteria used for this analysis. For the Arkansas and South Platte alignments, tunneling was kept to a minimum and only used in small areas of particularly steep slopes. This results in significantly less tunneling for these two projects than for Yampa or Colorado River Return, which is reasonable because the elevation gain and slopes of the South Platte and Arkansas concepts is significantly less than that of the Colorado River Return and Yampa concepts.

Tunnels longer than 3,000 feet were assumed to be constructed with a tunnel boring machine (TBM) and shorter tunnels were assumed to be constructed using hand mining methods. The 3,000 feet was used as the break point for this determination based on the unit cost analysis (see Section 5); 3,000 feet is the approximate length at which hand mining costs are equal to tunnel boring machine costs. Total tunnel lengths and average overburden depths for each pipeline are summarized in Table 4-9.

Table 4-9 Tunneling Summary

Concept		Total Tunnel Length (mi)	Average Tunnel Overburden (ft)	Max Overburden (ft)	Max Tunnel Length (mi)
Arkansas	Alignment 1	1	60	160	0.4
	Alignment 2	4	60	150	0.9
Colorado River Return		59	580	2,770	14.1
Flaming Gorge	Main Pipeline	3	70	210	0.8
	North Diversion	1	40	100	0.2
	South Diversion	13	140	250	11.3
Yampa		84	700	2,660	15.1

*Note: The South Platte alignments do not require tunneling

4.2.4 Diversions

Diversions were sized at five times the average annual flow for each scenario. Most of the diversion structures would be constructed off of the respective concept rivers, but as noted in Section 4.1, diversions are located in different places for different scenarios for the Flaming Gorge concept. Option 1 assumes all 100,000 AFY are drawn from the north diversion and Options 2 and 3 assume an additional 150,000 AFY from the south diversion. Conceptually the diversion structures would be used to convey available water supplies through the intake structure to the firming storage reservoir (if required as described in Section 4.2.2) where the first pump station for each concept (shown in Table 4-7) would begin the conveyance towards the specific concept delivery area.

4.2.5 Treatment

The raw water qualities vary widely between each of the described projects and therefore require various levels of treatment. For the purpose of this analysis, the main water quality parameter used to determine the required level of treatment to treat the raw water for potable municipal supply was total dissolved solids (TDS) in milligrams/liter (mg/L). Table 4-10 shows representative raw water TDS values for each of the analyzed projects.

Table 4-10 Representative Raw Water Supply TDS Values

Concept	Raw Water TDS (mg/L)
South Platte River (CDM 2007)	1,000
Arkansas River (CDM 2007)	1,200
Colorado River Return (CWCB 2003)	790
Flaming Gorge Reservoir (USACE 2009)	400
Yampa River (Northern Colorado Water Conservancy District 2006)	150

Waters with TDS less than 500 mg/L could be treated with conventional treatment, which could include flocculation and sedimentation, filtration, and disinfection. For this analysis the treated water quality TDS goal was 300 mg/L. For raw waters with TDS values greater than 500 mg/L advanced treatment would be required that includes flocculation and sedimentation, RO filtration, blending of bypass water, advanced oxidation/disinfection, and zero liquids discharge (ZLD) of membrane concentrate. As with conventional treatment, the final treated water quality TDS goal was 300 mg/L.

It was assumed that the regional supplies brought to the Front Range would be delivered with a maximum peaking capacity of 1.1 and a consistent supply would be available during the majority of each year. Periods of downtime would occur only during unexpected events and for required scheduled maintenance. Therefore, for water treatment facility sizing, it was assumed new regional supplies would be treated and used to meet municipal base demands and would not be used to meet peak demand, reducing the required plant capacity.

For water treatment sizing it was assumed that blend water would be available on the Front Range to reduce the TDS of the new regional supply, which would reduce the amount of RO filtration required on some of the regional supplies. The blend water was assumed to have a TDS of 300 mg/L and would be blended at a ratio of 30 percent blend water and 70 percent new regional supply. Table 4-11 below shows the raw water TDS, pre-treated blended TDS, treatment type, and facility size for Options 1, 2, and 3.

Table 4-11 Summary of Concept Water Qualities and Facility Sizing

Concept	Raw Water TDS (mg/l)	Pre-treated Blended TDS(mg/l)	Type of Treatment	Option 1 Capacity (mgd)	Option 2 Capacity (mgd)	Option 3 Capacity (mgd)
South Platte River	1,000	790	RO with ZLD	90	220	90 / 220
Arkansas River	1,200	930	RO with ZLD	90	220	90 / 220
Colorado River Return	790	643	RO with ZLD	90	220	90 / 220
Flaming Gorge Reservoir	400	370	Conventional	90	220	90 / 220
Yampa River	150	240	Conventional	90	220	90 / 220

The purpose of this simplified analysis using planning level facilities and assumptions described above allowed for the comparison of different treatment processes and cost analysis of the required treatment processes previously described in this section. It should be noted that detailed analyses of water quality, type of treatment, and facility sizing and layout will need to be completed if a regional water supply is selected in the future.

4.2.6 Reuse

In order to account for reuse, a generalized approach was taken to account for required infrastructure for both direct non-potable reuse and indirect potable reuse. The water supply provided by the new supply development concepts would be considered fully consumable and the historic consumptive use of the water supply provided by the agricultural transfer concepts would also be fully consumable. Because all of the water supplies would be fully consumable and the project supplies would be delivered to the same general Front Range area, the reused component of this analysis was not used to differentiate between the different water supply concepts. Instead, the reuse portion of the analysis was used to identify the planning level costs that will be required in the future to help meet the 2050 water needs in Colorado.

The reuse analysis assumed a maximum of 45 percent of the original water supply volume would be available for reuse as wastewater effluent (Town of Castle Rock 2008), which generally accounts for water supply transmission losses, water treatment losses, treatment losses, distribution losses, M&I consumptive use, and lawn irrigation return flows. Assuming wastewater effluent would meet water quality requirements it would be immediately available for direct non-potable supplies. Studies for individual municipalities would be required to plan and project individual municipal usage of available direct non-potable supplies. Volumes of wastewater effluent are fairly consistent throughout the year, while non-potable demands are primarily needed in the summer. Future analyses would include the infrastructure and storage required to deliver and firm non-potable supplies as well as the location and timing of major non-potable demands. For this report it was assumed that 10 percent of the available 45 percent would be used for single use non-potable demand to generally account for both single use direct non-potable demands and multiple use indirect potable demands. These percentages were arbitrarily selected to generally analyze the cost implications of reusing water supplies to the legal and practical extent possible. Detailed future analyses will be required to optimize how reusable water supplies are best used to meet future demands.

The remaining 90 percent of the 45 percent of reusable effluent would be used for indirect potable demand. The indirect potable supply could be used in a number of ways including diverting reusable effluent to municipal water supply storage facilities or discharging reusable effluent to a major river or tributary in the Front Range area for transportation to an alternate point of diversion with stream losses and used in similar fashion to extinction. For this analysis, it was assumed that reusable effluent would be discharged to a major river or tributary, subjected to a 7 percent

stream loss, and accounted for up to six times before being used to extinction. Table 4-12 below shows the expected direct non-potable and indirect potable reuse volumes for all of the concepts.

Table 4-12 Expected Direct Non-potable and Indirect Potable Reuse Volumes

Option	Annual Volume (AF)	Direct Non-Potable Reuse Volume (AF)	Indirect Potable Reuse Volume (AF)	Total Volume of Reuse Water (AF)
Option 1	100,000	4,500	60,300	64,800
Option 2	250,000	11,300	150,600	161,900
Option 3	100,000 / 250,000	4,500 / 11,300	60,300 / 150,600	64,800 / 161,900

The described methodology for reuse is simplistic, but future demands will require that fully reusable supplies are fully consumed to the practical extent possible. The projected volumes will be used for planning level costs as described in Section 5.

4.2.7 Summary of the Green Mountain Concept Transmission Facilities

The Green Mountain water supply concept would involve filing a new 300 cubic feet per second (cfs) water right on the South Platte River above Strontia Springs Reservoir and constructing a pipeline with required pump station(s) from Green Mountain Reservoir to Dillon Reservoir creating new supplies in Dillon Reservoir. This concept would require a reduction in Green Mountain's decreed volume, creating a storage pool in the reservoir to convey water to Dillon Reservoir, which once delivered to Dillon Reservoir could be conveyed through existing infrastructure to the Front Range. In addition, the Green Mountain Colorado Big Thompson (CBT) pool would have to be relocated to Wolcott Reservoir on Alkali Creek in the Eagle River basin. Based on the modeling and analysis completed to date [CWCB 2003] it is estimated the analyzed infrastructure and operations described above could produce up to 68,600 AFY.

4.3 Smaller Increment Concepts

As discussed at the beginning of this section, the concepts discussed in this report were evaluated based on the assumption that they could yield greater than 100,000 AF. The CWCB and IBCC directed CWCB staff to evaluate additional small-to-medium new water supply development projects (less than 100,000 AF). The purpose of developing additional smaller increment concepts is to examine the tradeoffs between combinations of smaller projects versus one or two larger projects. Table 4-13 is an initial draft list of small-to-medium projects. This list was developed through conversations with the River District, the Environmental Community, and a number of Front Range Water Providers.

Table 4-13 Additional Small-to-Medium Concepts

West Slope Supplies:	
Colorado Basin	Enhanced Green Mountain Pumpback <ul style="list-style-type: none"> • Grand Valley System Improvements • Increased yield for existing systems • Shoshone
	Wolcott Pumpback "Little Straw" - Wolcott Reservoir to Vail Pass 80 – 100K AF yield (Eagle Piney)
	Ruedi Pumpback Enhanced - Ruedi Pumpback coupled with Lime Creek addition
	Webster Hill Reservoir – Regulating reservoir 30K AF
Yampa Basin	Middle Yampa Pumpback - Elk River to tributary storage in the South Platte
	Mini Yampa - Four counties project. Diversion from Morrison and Service Creek into Northern's system
Gunnison	Taylor Reservoir - tunnel to Arkansas Basin with pumpback to enhance Taylor River flows
Wyoming Supplies:	
	Alt. Wyoming Project <ul style="list-style-type: none"> • Fontenelle Reservoir to South Pass • Tributaries of the Green or Yampa in central WY to South Pass
Front Range Supplies:	
Shared Infrastructure	Integration of Denver, Aurora, and S. Metro
	Integration of Northern and Denver
Increased Front Range Storage	Aquifer storage of Existing Reservoirs in South Platte
	Aquifer storage of reusable water in Designated Basins
	Gravel Lake storage - South Platte
	Estabrook Reservoir, 200,000 AF, wet year water (May be precluded by Platte River Agreement)
	Elevenmile Reservoir expansion
	Antero Reservoir expansion – 80K AF
Smaller Two Forks 345K AF	
Conjunctive Use	Optimization of Denver Basin Aquifer coupled with Interruptible Supply in Drought Years

The remainder of this section provides an overview of a subset of these additional smaller increment concepts. These overviews provide a starting point for discussions on which small-to-medium concepts warrant further analysis.

4.3.1 Colorado River Basin Enhanced Green Mountain with Grand Valley System Improvements

The BOR has completed system improvements on the Government Highline Canal (GHC) to reduce the amount of water needed to deliver water through the system since it was designed with turnouts that needed a full canal to be effective and thus carried water to the end of the long canal without use. The BOR installed automated check structures to allow the canal to be maintained at a full level without wasting water through the system. This saved about 15,000 AFY that is used to enhance the flows in the Colorado River in the critical 15 mile reach for Endangered Species Act (ESA) fish species.

It may be possible to accomplish additional system improvements on other canals in the valley such as the Grand Valley Irrigation Canal (GVIC), the other largest canal in the valley. It is uncertain if this canal is designed in the same manner as was the GHC so the savings are not as obvious unless they are proposing to convert to more

efficient irrigation systems. Since there are no compact issues or downstream water rights that would be impacted by decreased return flows associated with increased efficiency, there would be little if no opposition to such a proposal.

A pumpback from below the confluence of the Colorado River and Gunnison River to above the GHC (approximately 16 river miles) may merit analysis since it could provide water for the senior calling rights, and therefore reduce the amount of Green Mountain Reservoir that would need to be released for West Slope beneficiaries. This would then allow more of Green Mountain Reservoir space to be used for a Green Mountain Pumpback. It also may reduce the amount of water in the proposed Wolcott Reservoir that would need to be reserved for West Slope beneficiaries of Green Mountain Reservoir. Another benefit would be to provide water in the late summer and fall for the endangered fish species in the 15-mile reach and reducing the amount of water that would have to be released from Green Mountain Reservoir or Ruedi Reservoir as is now the situation.

To further develop this concept, coordination with East Slope and West Slope entities would need to occur to look at operational flexibility and possible benefits associated with removing or reducing the Shoshone call under various flow conditions.

4.3.2 Colorado River Basin Wolcott Pumpback

Denver Water originally filed for conditional water rights in the Eagle River basin for storage and a pumpback/collection system over Vail Pass to Dillon Reservoir. Some of these structures would be in the Eagle-Piney Wilderness Area and have not been pursued. The proposed Wolcott Reservoir is an off-channel reservoir that would serve as a replacement for some of the yield of Green Mountain Reservoir that would be used for the Green Mountain Pumpback. It may be possible to increase the size of Wolcott Reservoir to allow some pumpback over Vail Pass. Wolcott Reservoir would be filled by pumping from the Eagle Reservoir so there would be significant operational costs. Denver Water has indicated that it has stipulated to not construct the pumpback over Vail Pass for 40 years as part of the water court case dealing with the conditional water rights Denver owns in the Eagle River basin. This stipulation negates this option for the near future.

4.3.3 Colorado River Basin Enhanced Ruedi Pumpback

This concept would capture additional flows within the Lime Creek addition and pumpback water to the Boustad Tunnel for delivery to Twin Lakes Reservoir and the Arkansas River Basin. This would be a controversial project from an environmental perspective; however, the yield may be fairly significant since the Roaring Fork River joins the Colorado River below the Shoshone Power Plant call. If the Grand Valley Pumpback described above is constructed, the yield of Ruedi for transmountain uses would be enhanced since some of its purposes for ESA fish would be provided by the Grand Valley Pumpback.

4.3.4 Colorado River Basin Webster Hill Reservoir

This concept would include a regulating reservoir on the mainstem of the Colorado River with a volume of 30,000 to 40,000 AF. The location of this reservoir occurs in a critical habitat reach of the Colorado River. This reservoir would potentially increase the yield of water from Green Mountain Reservoir or a substitute reservoir since water in transit that is not needed due to rains causing a change in river conditions could be stored and then released when the need for water increases in the Grand Junction area.

4.3.5 Yampa River Basin Middle Yampa Pumpback

This concept has not been clearly described in previous study efforts but would appear to be a complex combination of a tunnel under the Continental Divide and Mt. Zirkel Wilderness Area and a pipeline across North Park and over the Medicine Bow Range to the headwaters of the Poudre River Basin. This could be an expensive project for a project of this size (i.e., less than 100,000 AF).

A possible alternative to this would be to deliver water to the North Platte system via the tunnel and exchange this water for an enhanced collection system on the Medicine Bow Range for delivery to the Poudre River basin. This would not violate the terms in the Nebraska vs. Wyoming federal decree. The yield may be limited due to runoff from the Medicine Bow Range into the Michigan River and its tributaries.

4.3.6 Yampa River Basin Mini Yampa

The Four Counties Project has or had conditional water rights from the Service and Morrison Creek basins into the Colorado River Basin. It would be a change of its purposes to deliver water to the Front Range via the CBT facilities but still may merit analysis. The water would be diverted by a collection system in the headwaters of the Yampa Basin and delivered by a pipeline to Granby Reservoir for delivery to the Front Range. A complication would be that it probably would obtain a water right junior to the recreational in-channel diversion (RICD) water right for Steamboat Springs and may limit its yield substantially.

4.3.7 Gunnison River Basin Taylor Reservoir

This project would require a pumpback from Blue Mesa and a contract for purchase of project water to have sufficient yield to be feasible since the yield at Taylor Park Reservoir is limited due to the senior Aspinall Unit calls. Previously, the water court found that the yield from this concept would be around 50,000 to 60,000 AF. It is likely that some of the pumpback would be used to enhance flows in the Taylor River. The tunnel costs and pumpback facilities costs could be significant for a project with a yield less than 100,000 AF. Additionally, the recently released draft programmatic biological opinion indicates only 25,000 AF is available for development above and below Blue Mesa, likely leading to legal water availability issues associated with this project.

4.3.8 Additional Wyoming Concepts

Fontenelle Reservoir is a part of the Seedskaadee Project, which is a participating Colorado River Storage Project (CRSP) project with an active storage capacity of 150,500 AF. It is used for M&I, hydropower, recreation, and fish and wildlife purposes. The State of Wyoming has purchased 120,000 AF of capacity for future uses including responding to a compact curtailment demand. The State of Utah evaluated this project years ago and decided it was not feasible to pursue. It would also require an analysis under the export statute for Wyoming, which is problematic. South Pass is located northeast of Fontenelle Reservoir on the Continental Divide. Water would have to be pumped with a lift of 1,500 feet over the pass and then would flow down the Sweetwater River, which is a tributary of the North Platte River. The Sweetwater River flows into Pathfinder Reservoir, which is one of the major reservoirs of the North Platte Project. It may be possible that water could be exchanged up the North Platte River to North Park where it could be pumped over the Medicine Bow Mountains to the Front Range. The costs per acre-foot of yield associated with a project of this limited size may be prohibitive.

It was also suggested to consider tributaries of the Green River or Yampa River in central Wyoming to South Pass. This would appear to require a collection system in the headwaters of the Big Sandy River and Green River along the Continental Divide on National Forest land. This concept has many potential issues including federal permits and the Wyoming export statute. The yield may also be limited by senior water rights on these rivers. It would deliver water down the Sweetwater River to Pathfinder Reservoir for exchange up the North Platte. Again, the cost per acre-foot of yield associated with a project of this size may be prohibitive.

4.3.9 Additional Front Range Storage

This section provides a brief analysis regarding enlarging the following reservoirs on the Front Range:

- Elevenmile Reservoir
- Estrabrook Reservoir
- Antero Reservoir
- Smaller Two Forks Reservoir

Enlarging Elevenmile Reservoir may not be technically feasible as this storage would be under a 2009 junior water right that would not yield water this high in the basin due to downstream calls. An estimate of firm yield of 1 AF for each 10 AF of storage space on the South Platte River near Chatfield Reservoir was included in Part Two of the South Platte Basin Roundtable Consumptive Needs Assessment Report (CWCB 2008). Likewise, the construction of Estrabrook Reservoir on the North Fork of the South Platte River would also be limited by its junior conditional water right even though it may be more senior than 2009. Denver Water may have a conditional right with an appropriation date in the 1950s or 1960s. The yield would be limited since the North Fork does not have a large drainage basin. Estrabrook Reservoir was intended

to be an alternative storage site for water delivered from Roberts Tunnel and Dillon Reservoir.

Antero Reservoir is decreed for 80,000 AF and was restricted to 20,000 AF due to a dam safety issue but has been recently repaired and the restriction removed. Any additional enlargement would have very limited firm yield.

Denver has maintained conditional water rights for a smaller Two Forks project. This could be as much as 345,000 AF. This reservoir would store water diverted through the Roberts Tunnel and may useful for storage of water from the Green Mountain Pumpback if Dillon Reservoir is limited by capacity or operational constraints.

Section 5

Reconnaissance Level Cost Estimates

5.1 Overview

Developing reconnaissance level costs is one element of the strategy evaluation process. Reconnaissance level costs were developed for the following water supply and delivery concepts:

1. Middle and Lower South Platte
2. Middle and Lower Arkansas
3. Colorado River Return
4. Yampa River
5. Flaming Gorge
6. Green Mountain Reservoir
7. Conservation

Costs were developed for the first five of these concepts for each of the three options outlined in Section 4:

- Option 1: delivery of 100,000 AFY constructed in a single phase
- Option 2: delivery of 250,000 AFY constructed in a single phase
- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

A unit cost-based methodology was used to develop capital costs for planning year 2009 for all concepts. Unit cost values and contingency factors for various project components were developed based on a variety of sources, including existing reports when available, a national construction cost database, data from other recent projects, and professional opinions. It is important to note these costs were developed for planning level comparison of concepts; it is not guaranteed that these costs will not vary from contractors' bids or final costs. However, these planning level costs are appropriate for the initial planning level comparison of future regional projects as well as in comparing the individual projects with one another on an equitable basis.

As discussed in Section 4, the Green Mountain concept is currently projected to yield less than 100,000 AFY and therefore reconnaissance level cost estimates were not updated for this concept. The most recent study summarizing costs for this concept are summarized in this section. Similarly, reconnaissance level costs were not updated for the Conservation Strategy. Cost estimates were developed as part of the SWSI Phase 2 effort and these are summarized in this section.

5.2 Green Mountain Concept Cost Estimates

The Green Mountain concept has been studied in previous efforts; cost estimates were developed and presented as part of the most recent study of the concept (Colorado River Water Conservation District et al. 2007). This study approximated the yield for the concept as 68,600 AF. The estimated total capital cost for the concept was \$687,000,000 or \$10,000/AF. The cost estimate does not include facilities to convey water to end users, water treatment costs, land acquisition, or mitigation.

5.3 Conservation Strategy Cost Estimates

As part of the SWSI Phase 2 Conservation and Efficiency Technical Roundtable effort, the roundtable developed cost estimates for the conservation measures identified as part of the study (CWCB 2007). The SWSI Phase 2 report states that the average cost to achieve the water conservation measures considered in the study is \$10,600/AF based on costs from the year 2007. The measures identified as part of the study ranged in cost from \$1,000 to \$2,000/AF. The SWSI Phase 2 study noted that conservation is a cost-effective strategy for most water providers. The CWCB is in the process of updating the cost estimates developed in SWSI Phase 2 and when this effort is completed, the revised cost estimates will be utilized in further evaluation of the conservation strategy.

5.4 Capital Cost Assumptions for the Agricultural Transfer and New Supply Development Strategies

Capital costs were developed for the following components of the agricultural transfer and new supply development concepts:

- Water rights
- Firming storage
- Transmission facilities (pipelines, tunnels, pump stations, diversions and appurtenances, and easements)
- Water treatment
- Reuse

The costs being presented in this section are based on feasibility level planning and sizing of facilities. Additional background and summary information is available in Appendix A. There are a significant number of unknown factors, or changes in the projects that will occur as they are further refined that cannot be specifically anticipated at this time. These factors include final alignments of transmission facilities, sizing and location of pump stations and storage facilities, market conditions at the time of construction, competitive bidding or negotiating terms, or other costs and mitigations associated with the concepts as they are further developed. To address this uncertainty we have included a contingency of 30 percent in the development of the capital cost estimates. In addition to the contingency, a factor for other soft costs including engineering, legal, and administrative (ELA) work has also

been included. The ELA factor is distinct from the contingency because it is intended to cover costs that are almost certain to be incurred, as opposed to inflating relatively certain costs to address uncertainty and variability. Estimated costs for environmental mitigation were not addressed as more detailed analyses will need to be completed to assess environmental impacts, as those future impacts will likely be very site-specific and vary greatly between all projects. However, the costs for necessary permitting work (including EIS, which are estimated to cost \$10 million per project [Peter 2009]) are included in the ELA costs. For the purposes of this planning effort the ELA factor was assumed to be 20 percent of the total pipeline and pump station capital cost. Including both the general contingency and ELA cost the total capital cost for pipelines and pump stations is increase by a total of 50 percent.

Due to the wide range of sources used in developing the different types of cost, for some of the facilities types the above contingencies and other soft costs were not included. Where they have not been included this has been specifically identified in the text.

There are a wide range of percentages that could be used for the contingency and ELA factors. These factors discussed above provide a reasonable basis for the comparison of the alternative concepts.

5.4.1 Water Rights

For the water supply development concepts, filing for a new water right would be required. The capital costs for the ELA work required to file for a new junior water right vary widely. It was assumed that a filing of a large regional project as described in this report would draw general opposition and would be required to go through Colorado Water Court as well as the Federal 404 Permit process, which would require an EIS (which is not included in the water rights cost, but is included in the legal costs of the pipeline costs) before permitting would be completed. It was estimated that \$4 million would complete the ELA costs for the water rights filing for each new water supply development regardless of project size (i.e., 100,000 AFY versus 250,000 AFY) (Cech, Frank, Helton, Ward, and Williamsen 2009).

For the agricultural transfer concepts, costs include the water rights purchase and obtaining the legal transfer of use, which require Colorado Water Court review. Costs for agricultural water transfer vary widely. Senior agricultural rights are more expensive than junior water rights and the physical location of the available supply will be important once individual entities in the future try to determine how specific ditch rights can be captured, exchanged, transferred, and used in their current system infrastructure. A survey of recent sale prices for a variety of junior and senior ditches within the South Platte and Arkansas River basins were analyzed (Cech, Frank, Helton, Ward, and Williamsen 2009). For this study it was assumed that senior agricultural water rights, which historically may not have been diverted in the Denver area, would be sold for \$15,000/AF of consumptive use in the South Platte River basin and \$7,000/AF of consumptive use in the Arkansas River basin. These unit costs include the ELA costs to convert the agricultural use to municipal use, but would

require firming storage and transmission pipelines to the Denver area, which are described below.

5.4.2 Firming Storage

Storage of diverted and delivered supplies would be required as discussed in Section 4.2.2 and capital cost estimates were based upon historic data collected from the Colorado Division of Water Resource Spreadsheet Database of new dams built in Colorado since 1995. The reservoirs analyzed for this study vary in size from 50,000 AF to 500,000 AF. The unit costs include the construction components of the dam, which include outlet works, reservoir clearing, and land acquisition. Estimated costs for environmental mitigation were not addressed as more detailed analyses will need to be completed to assess environmental impacts. Future impacts will likely be very site-specific and vary greatly between all projects. The unit cost is considered conservative and was not escalated as the unit cost accounts for expected economy-of-scale type cost savings in ELA costs as well as dam construction costs. The unit cost of \$1,000/AF was applied to diversion reservoirs, while Front Range delivery reservoirs had a unit cost of \$1,200/AF applied for costing purposes.

5.4.3 Transmission Facilities

Transmission facilities are a major component of the new supply development and agricultural transfer concepts. Transmission facilities include pipelines, diversions, appurtenances, tunnels, pump stations, and easements; diversion, appurtenance, and easement costs are included in overall pipeline costs for summary purposes. The unit costs for each facility type are discussed in the remainder of this section. Pipeline installation, land, and easement costs were separated into urban and rural components. The new supply development and agricultural transfer concepts were assumed to include 90 percent rural construction and 10 percent urban for these cost estimates presented in this section.

5.4.3.1 Pipelines

Pipeline unit costs were developed by analyzing nationwide and Colorado specific construction costs database and material unit costs. The database used a customized blend of labor, material, equipment, and subcontract components that are updated based on personnel experience and vendor surveys. The database is nationwide, but uses local material and labor rate costs. Labor is calculated based on assembly of a standard crew and standard labor productivities, which are adjusted to the nationwide labor union hourly rates.

Using this database, base unit costs for pipelines (not including tunnels) were developed for the 72-, 90-, and 114-inch diameter steel pipe required for the capacity of each option. Separate base costs are developed for urban and rural areas. These base unit costs assume straightforward installation, assuming ideal conditions for pipeline construction such as average soil conditions, no steep slope, easy site access, and no space constraints. These unit costs assumed 150 psi pressure class steel pipe,

with a steel price of \$1.25/pound. The base unit costs were then escalated to account for difficult or steep terrain and higher pressure classes.

To escalate for difficult terrain, two basic assumptions were made: productivity rates (feet of pipe laid per day) in "difficult" terrain were half of those assumed in the base costs; and productivity rates were two-thirds of the base in areas where ground slopes exceed 10 percent. The "difficult" terrain accounts for areas that present construction challenges such as access difficulties and difficult soil or rock conditions. The portion of the total unit base cost comprising installation was then escalated accordingly. All concepts were assumed to include 30 percent difficult terrain, the percentage of ground slope greater than 10 percent, which was determined for each alignment based on a GIS evaluation, as described in Section 4.2.3.1.

To escalate for pressure classes, manufacturers' data were used to determine the thickness of each pressure class for each diameter in order to determine the additional material requirements. The increase in unit cost of pressure class pipe above 150 psi was determined based on this additional material and the steel cost of \$1.25/pound used to develop the base unit cost in linear feet (\$/LF).

Table 5-1 shows base unit costs by diameter, the portion of the base unit costs attributable to installation, and the addition to unit costs for pressure class. The installation portion of the cost includes labor for tasks including excavation, welding, pipe cleaning, marking, testing, and backfilling, as well as equipment costs, but does not include repaving costs, or property or easement acquisition; these costs are included in the overall costs but are not escalated based on difficult or steep terrain.

Table 5-1. Base Unit Costs and Adjustments

Diameter (in)	Base Unit Cost - Rural (\$/LF)			Base Unit Cost - Urban (\$/LF)			Installation portion of base unit cost (\$/LF)	
	150 psi	250 psi	350 psi	150 psi	250 psi	350 psi	Rural	Urban
72	\$630	\$1,060	\$930	\$820	\$1,250	\$1,120	\$180	\$340
90	\$940	\$1,600	\$1,400	\$1,210	\$1,870	\$1,670	\$260	\$500
96	\$1,120	\$1,870	\$1,650	\$1,420	\$2,180	\$1,950	\$280	\$560
114	\$1,490	\$2,550	\$2,230	\$1,900	\$2,960	\$2,640	\$350	\$710

Final costs for each concept were developed based on these unit costs, the slope and pressure class characteristics for each alignment presented in Section 4, the installation assumptions presented in this section, and assuming that each alignment is 90 percent rural construction and 10 percent urban construction. Final adjusted unit costs, accounting for difficult terrain, steep areas, and pressure classes, are presented in Table 5-2.

Table 5- 2. Final Unit Costs by Concept

Concept		Option 1		Option 2		Option 3	
		Rural Unit Cost (\$/LF)	Urban Unit Cost (\$/LF)	Rural Unit Cost (\$/LF)	Urban Unit Cost (\$/LF)	Rural Unit Cost (\$/LF)	Urban Unit Cost (\$/LF)
Arkansas	Alignment 1	\$820	\$1,060	\$1,930	\$2,450	\$1,230	\$1,570
	Alignment 2	\$830	\$1,070	\$1,970	\$2,490	\$1,250	\$1,600
Colorado River Return		\$820	\$1,070	\$1,930	\$2,460	\$1,230	\$1,580
Flaming Gorge	Main Pipeline	\$810	\$1,050	\$1,910	\$2,440	\$1,910	\$2,440
	North Diversion Pipeline	\$820	\$1,060	\$820	\$1,060	\$ -	\$ -
	South Diversion Pipeline	\$ -	\$ -	\$1,270	\$1,620	\$1,270	\$1,620
South Platte	Alignment 1	\$820	\$1,070	\$1,950	\$2,470	\$1,240	\$1,580
	Alignment 2	\$820	\$1,060	\$1,940	\$2,460	\$1,230	\$1,580
Yampa		\$780	\$1,030	\$1,840	\$2,380	\$1,170	\$1,530

5.4.3.2 Tunnels

Combinations of unit costs were developed for tunneling. Per-tunnel and per-foot unit costs were developed for both tunnel boring machine and hand mining methods. The per-tunnel unit costs include mobilization, demobilization, and work shaft construction; the per-foot unit costs cover excavation and lining. Per-tunnel costs are applied to each discrete section of tunnel, so that each tunnel segment is separated from the next by portions of pipeline constructed with conventional excavation methods. As noted in Section 4, the two methods have the same cost at approximately 3,000 feet, so tunnels longer than 3,000 feet were assumed to be constructed with a TBM while shorter tunnels were assumed to be constructed using hand mining methods. Tunneling unit costs are presented in Table 5-3. These tunneling costs are increased by 5 percent in the final cost estimate to account for dewatering, power, and access road costs.

Table 5-3. Tunneling Baseline and Unit Costs

	Unit Costs (Excavation, Lining, Corrosion protection \$/LF)	Mobilization	Demobilization	Shafts	Total per-tunnel
		\$ / tunnel			
TBM	\$ 1,500	\$3,700,000	\$ 500,000	\$2,900,000	\$ 7,100,000
Hand-mine	\$ 3,300	\$ 260,000	\$ 110,000	\$1,300,000	\$ 1,600,000

5.4.3.3 Pump Stations

Pump station unit costs included the cost per horsepower for the construction of the pump station, with additional costs for land and operational storage. Pump station unit costs are summarized in Table 5-4. Pump station sizing was based on the peaked horsepower requirements presented in Section 4.2.3.3. Land costing assumes 3 acres of land per pump station, and maintains the assumption that 90 percent of the land is rural for each concept. For total pump stations per alignment, see Table 4-6. The total required storage volume is assumed to be 5 percent of daily flow

Table 5-4. Pump Station Cost Components

Cost Component	Unit	Cost
Pump Station Land - rural	\$/ac	\$7,000
Pump Station Land - urban	\$/ac	\$70,000
Storage Tank	\$/gal	\$0.67
Pump Station	\$/hp	\$1,200

5.4.3.4 Diversions and Appurtenances

Diversions were estimated to cost \$5,200 per cubic foot per day (cfs). As noted in Section 4, diversions were sized based on 5 times the average flow for each option. Appurtenances, such as pipe fittings, valves, vaults, and cathodic protection, were assumed to add an additional 5 percent to the total pipeline costs. Diversion and appurtenance costs are included in total pipeline costs.

5.4.3.5 Easements

It was assumed for costing purposes that all concept alignments would require both temporary construction easements and permanent maintenance access easements for their entire length. This assumption is conservative because portions of alignments following major roads may fall within existing right-of-ways. Unit costs for permanent easements were assumed to be one-half of the cost of purchasing land, and unit costs for temporary easements were assumed based on professional experience and judgment. The base costs for both temporary and permanent easements on a per-acre basis are provided in Table 5-5; final unit costs per linear foot are based on the per-acre costs and assumed widths that vary with pipeline diameter are presented in Table 5-6. The final per-foot cost for easements includes both temporary and permanent easement costs. Easement costs were not applied to tunnel lengths and are included in total pipeline costs.

Table 5-5. Easement Base Unit Costs

Cost component	\$/ac
Urban Permanent Easement	\$35,000
Rural Permanent Easement	\$3,500
Urban Temporary Easement	\$5,000
Rural Temporary Easement	\$ 2,000

Table 5-6. Final Easement Unit Costs

Pipeline Diameter (in)	Easement Width		Total Cost (\$/LF)	
	Temporary	Permanent	Urban	Rural
72	70	50	\$48	\$7
90	70	70	\$64	\$9
114	70	70	\$64	\$9

5.4.4 Water Treatment

Reconnaissance level treatment technology capital costs were developed based on knowledge of recently constructed and operating water treatment plants in Colorado. It should be noted that specific treatment processes and technologies vary based on water quality and costs may change based on detailed analyses of raw water quality and water treatment goals. For this report, the main focus was on reducing the TDS of treated water to 300 mg/L. Table 5-7 shows the base unit costs for the various levels

of treatment. Capital unit costs include buildings, treatment facilities, high service pump stations, operational storage, mechanical, and electrical facilities.

Table 5-7. Treatment Technology Base Capital Unit Costs

Treatment Technology	Cost (\$/gal)
Conventional Treatment	\$1.90
Reverse Osmosis	\$3.75
Zero Liquid Discharge	\$16.00
Disinfection of bypass water	\$1.00

For each water source, blended water supplies with TDS less than 500 mg/L were assigned the conventional treatment unit cost. For water sources with blended water supply TDS greater than 500 mg/L the percentages of water treated with RO and disinfected bypass were evaluated with a final treated TDS of 300 mg/L. It was assumed that only 15 percent of the RO volume would be concentrate and require further treatment with ZLD. Therefore, for each water supply an adjusted overall unit cost was calculated, specific to the raw water TDS concentrations. Higher TDS concentrations require more RO and consequentially more ZLD treatment. Table 5-8 shows the final treatment unit costs per project and are considered conservative and were not escalated.

Table 5-8. Final Treatment Capital Unit Cost per Concept

Concept	Raw Water TDS (mg/L)	Pre-treated Blended TDS (mg/L)	Type of Treatment	Treatment Unit Cost (\$/gal)
South Platte	1,200	1000	RO with ZLD	\$4.40
Arkansas River	790	1200	RO with ZLD	\$4.66
Colorado River Return	400	790	RO with ZLD	\$3.94
Flaming Gorge Reservoir	150	400	Conventional	\$1.90
Yampa River	0	90	Conventional	\$1.90

5.4.5 Reuse

It is difficult to assess the true costs of reuse as studies need to be completed on a municipality-by-municipality basis. The location and timing of available reusable effluent has to be coordinated with the location and timing of direct non-potable and indirect potable demands. Both direct non-potable and indirect potable demands require additional treatment requirements, conveyance infrastructure, and storage. Because water reuse will be required in the future to meet projected demands conservative unit costs were assigned, which were not escalated. It is important to note also that the levels of reuse are the same for all projects discussed in this report. Therefore, the reuse costing component will not help determine, which projects are more economically viable, but instead provides a planning level cost to reuse the legally available water to its physical extinction.

For direct non-potable reuse a unit cost of \$7,000/AF was used for costing and was based on a range of costs-of-services reported in the 2004-2005 Recycled Water System Master Plan Update for Denver Water (Denver Water 2005). The Master Plan Update looked at the required infrastructure to convey reused water to various non-potable demands within their system. The report indicated, "[t]hese costs-of-service are

relative, rather than absolute, and provide a benchmark by which to evaluate the economics of serving each customer" (Denver Water 2005).

For indirect potable reuse a unit cost of \$13,500/AF was used for costing and was based on a range of estimated provider costs for treating South Platte River supplies near the Brighton area and transporting the treated water to the South Metropolitan Denver area (South Metro Water Supply Authority [SMWSA] 2008). For this report is assumed that municipalities will discharge wastewater effluent in Front Range rivers and will build new large regional infrastructure to divert, retreat, and convey reusable supplies to municipalities. The SMWSA Mid-Term Water Delivery Project Plan (SMWSA 2008) costs included diversion, retreatment (RO with ZLD) and regional conveyance.

5.5 Operations and Maintenance Cost Assumptions

Operations and maintenance (O&M) costs were developed for each of the facility types described above. For some of the facilities – such as water rights and firming storage – annual lump sum amounts were estimated, where other facilities like treatment and reuse had unit costs per AF. In the case of the transmission facilities separate O&M costs were developed to differentiate the impacts of the cost of pumping.

5.5.1 Water Rights

For the transfer of agricultural rights to municipal use it was assumed that 25,000 acres would be dried up for every 50,000 AF of consumptive use. It was also assumed that two technicians would be required to oversee ELA compliance of the agricultural dry up and would earn \$50,000/year. Thus for Option 1 and Phase 1 of Option 3 an annual O&M cost of \$400,000/year was used and for Option 2 and Phase 2 of Option 3 an annual O&M cost of \$1,000,000/year was assessed. For new water right filings, it was assumed similar ELA costs would be required each year as the transfer of agricultural rights.

5.5.2 Firming Storage

For new supply development and agricultural transfer concepts it was assumed that an annual O&M cost of \$100,000/year would be incurred by each reservoir for general maintenance, reporting, and contributing annually to a general future improvements fund. Therefore, projects with both diversion and delivery reservoirs were assessed an annual O&M cost of \$200,000/year.

5.5.3 Transmission Facilities

Estimates of O&M costs were developed for the transmission facilities. Based on experience, pipeline, tunnel, and diversion structure maintenance was estimated at 0.5 percent of pipeline capital costs annually, applied to the overall project capital costs excluding pump stations. Pump station maintenance was estimated at 3 percent of capital costs annually, including only the capital cost of the pump stations.

Maintenance costs include the same 30 percent escalation factor for general contingencies used for capital costs, but do not include the 20 percent ELA cost.

Pump station operations cost was based on the brake horsepower calculations presented in Section 4, assuming a flat electric rate of 8 cents per kilowatt-hour (kwhr). This value of 8 cents/kwhr may be considered high for a typical flat billing rate; however, with many variable demand charges options during different times of the day and seasons of the year a slightly high flat hourly billing rate was intended to account for the highly variable demand and schedule charges, which are unknown at this time for larger commercial users.

5.5.4 Water Treatment

Planning level treatment technology O&M costs were developed based on knowledge of recently constructed and operating water treatment plants in Colorado. The unit costs include membrane replacement, power, chemicals, labor, overhead, insurance, lab work, and building utilities. Table 5-9 shows the base unit costs for the various levels of treatment.

Table 5-9. Treatment Technology Base Unit Costs

Treatment Technology	Cost (\$/Kgal)	Cost (\$/AF)
Conventional Treatment	\$0.30	\$100
Reverse Osmosis	\$0.70	\$230
Zero Liquid Discharge	\$4.00	\$1,300
Disinfection of bypass water	\$0.05	\$16

For each water source, blended water supplies with TDS less than 500 mg/L were assigned the conventional treatment unit cost. For water sources with blended water supply TDS greater than 500 mg/L the percentages of water treated with RO and disinfected bypass were evaluated with a final treated TDS of 300 mg/L. It was assumed that only 15 percent of the RO volume would be concentrate treated with ZLD. Therefore, for each water supply an adjusted overall unit cost was calculated, specific to the raw water TDS concentrations. Higher TDS concentrations require more RO and consequentially more ZLD treatment. Table 5-10 shows the final treatment unit cost per project and are considered conservative and were not escalated.

Table 5-10. Final Treatment O&M Unit Cost per Concept

Concept	Raw Water TDS (mg/L)	Pre-treated Blended TDS(mg/L)	Type of Treatment	Treatment Unit Cost (\$/Kgal)	Treatment Unit Cost (\$/AF)
South Platte	1,200	1000	RO with ZLD	\$0.88	\$285
Arkansas River	790	1200	RO with ZLD	\$0.94	\$305
Colorado River Return	400	790	RO with ZLD	\$0.76	\$250
Flaming Gorge Reservoir	150	400	Conventional	\$0.30	\$100
Yampa River	0	90	Conventional	\$0.30	\$100

5.5.5 Reuse

Reuse costs in general are difficult to assess as described in Section 5.4.5, and without specific understanding of how direct non-potable and indirect potable supplies will be used it is impossible to accurately assess projected costs. However, the retreatment of indirect potable supplies will be required; therefore, the indirect potable supply volumes were multiplied by the South Platte concept treatment annual O&M unit costs. While this methodology is a major simplification and does not assess pumping O&M costs, which may be large, the planning level costs for indirect potable supplies included retreatment.

5.6 Reconnaissance Level Costs

Reconnaissance level costs for each concept and option are summarized below. Appendix A presents the breakdown of each cost estimate into the various components of treatment, conveyance, water rights, reuse, and firming storage. Costs are presented for each of these concepts for each of the three options outlined in Section 4:

- Option 1: delivery of 100,000 AFY constructed in a single phase
- Option 2: delivery of 250,000 AFY constructed in a single phase
- Option 3: delivery of 250,000 AFY constructed with the first phase delivering 100,000 AFY and the second phase delivering the remaining 150,000 AFY

All costs are presented in 2009 dollars. Diversions, appurtenances, and easements are included in overall pipeline costs. All costs for option 3 are the total combined cost of both phases.

5.6.1 Capital Costs

The total capital costs were estimated for all water supply concepts and options based on the methodology described above. The summary of the capital costs is shown in Figure 5-1 below. Figure 5-1 shows that total capital costs are relatively similar for the concepts discussed in this analysis. Although the South Platte and Arkansas concepts require less length of pipeline and less pumping than the other concepts, the expense of purchasing and transferring senior water rights make the total capital costs comparable; see Appendix A for further detail.

Figure 5-2 below shows the unit capital costs (cost/AFY) of each concept. The per-AFY costs show the same trends between concepts as the capital costs, but highlight that cost differences on a per-AFY basis are minimal between all three Options. The Yampa and Colorado River Return projects show a greater difference in per-AFY capital costs, due to the significant tunneling requirements regardless of annual delivery capacity.

Figure 5-1. Summary of Total Capital Costs

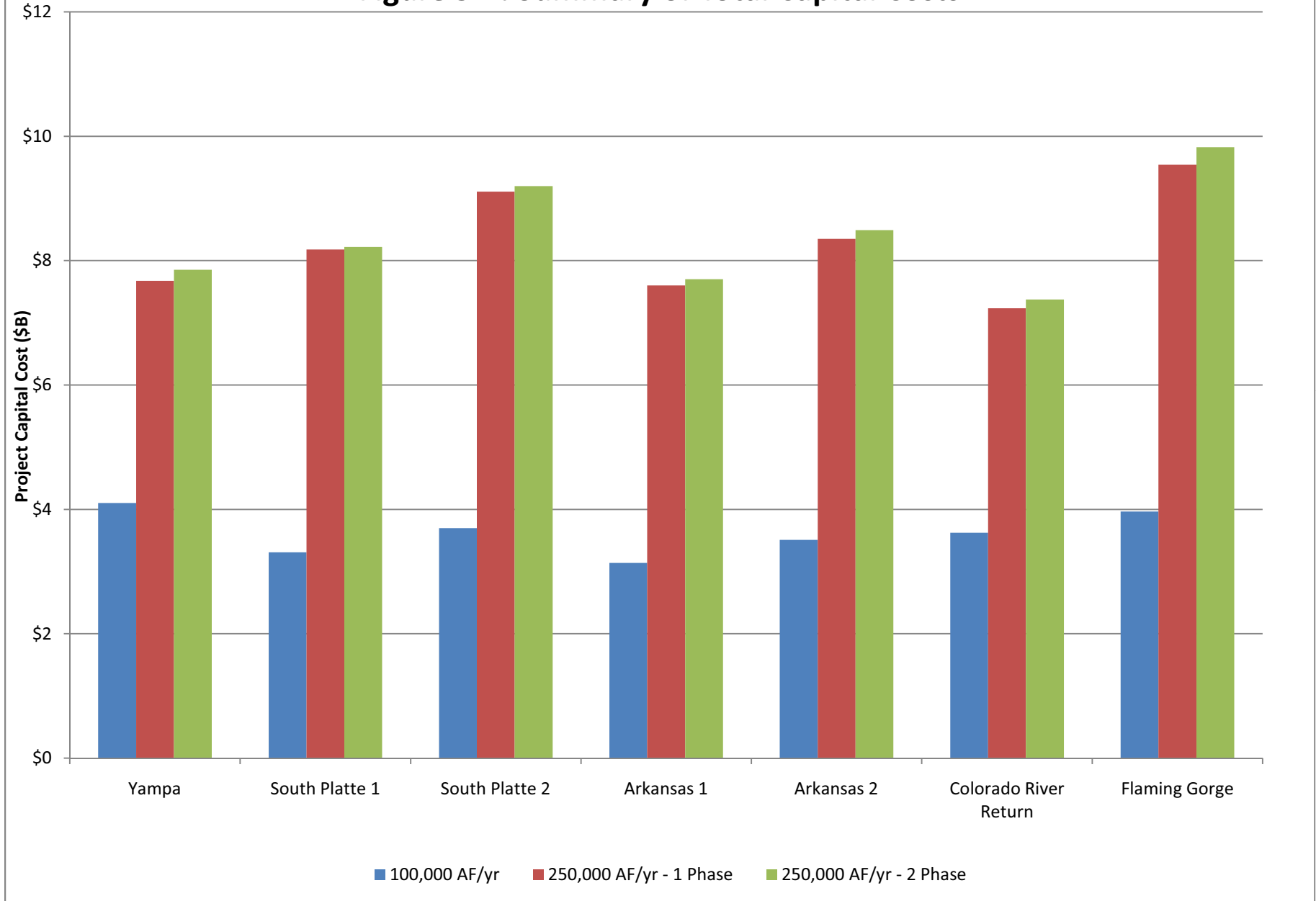
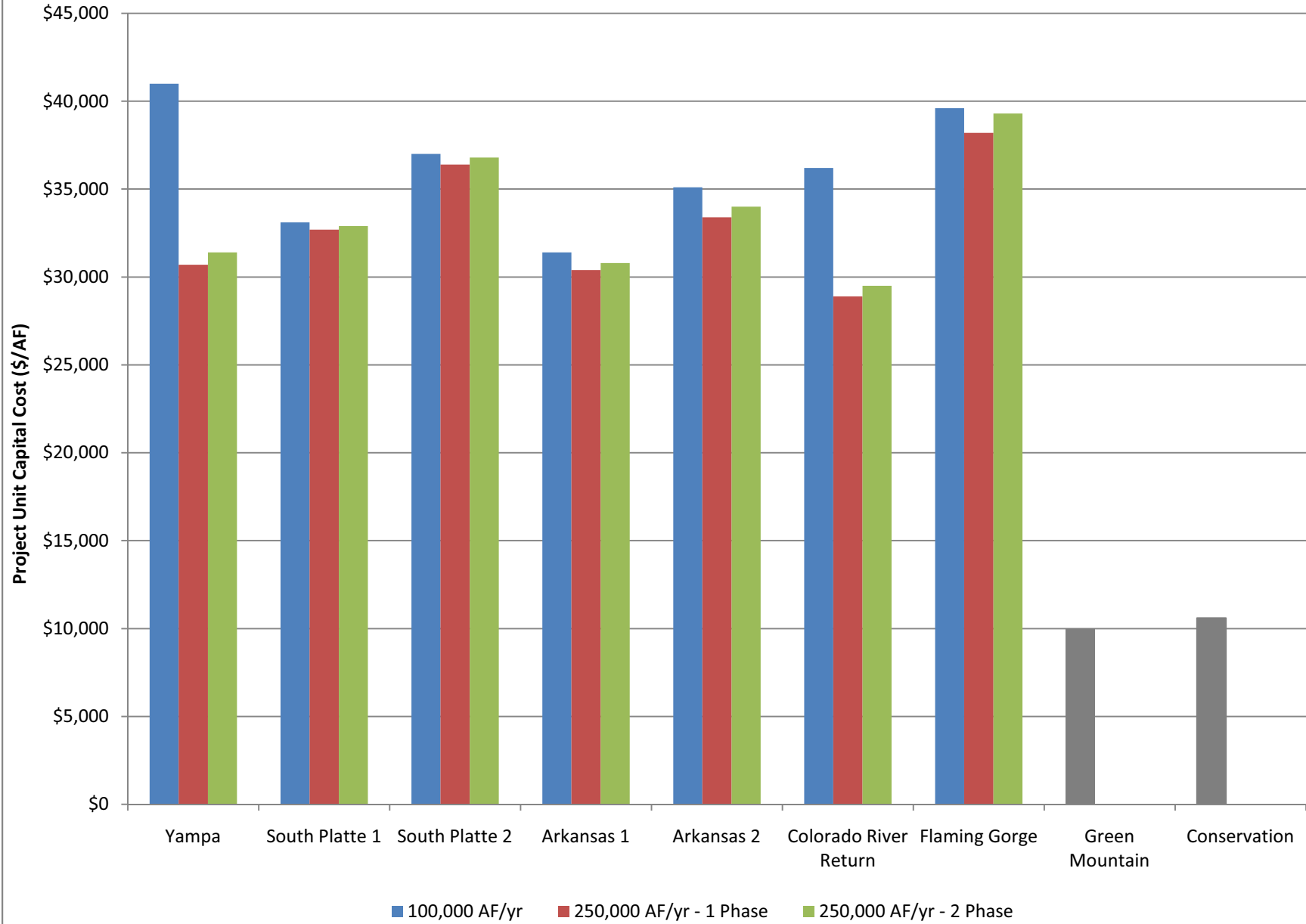


Figure 5-2. Summary of Total Capital Unit Costs



As depicted in Figures 5-1 and 5-2, the most expensive project to build at either 250,000 AF options would be Flaming Gorge, costing 30 to 35 percent more than Colorado River Return, the least costly. Colorado River Return and Yampa have a higher relative cost for option 1 (100,000 AF), with Yampa as the most expensive and Colorado River Return as the median. This is because tunneling costs do not change between options, and are therefore a bigger driver of cost in Option 1, which has a lower flow and thus lower costs for most of the associated infrastructure; the Yampa and Colorado River Return concepts have significantly more tunneling than other concepts.

Although the agricultural transfer concepts and the new supply development concepts are similar in total capital costs, the relative percentages of subcomponent capital costs vary significantly between the two concepts. Figure 5-3 below shows pie charts of the subcomponent capital costs for both the Middle South Platte concept (agricultural transfer) and the Yampa concept (new supply development) at 100,000 AF and 250,000 AF increments. Figure 5-3 shows that for agricultural transfer concepts the majority of the capital cost (regardless of project size) is comprised of water rights acquisition costs. Figure 5-3 also shows that the majority of new supply development concepts capital costs is associated with the transmission costs (pipelines and pump stations), although the relative percentage decreases as the project size increases.

5.6.2 Operations and Maintenance Costs

In order to evaluate the long-term costs of a regional water supply project, it is important to evaluate the estimated O&M costs. Figure 5-4 shows the expected total annual O&M costs of each concept. The significant variability between projects is due primarily to conveyance costs. Differences in water treatment requirements between conventional treatment (Yampa River and Flaming Gorge Reservoir supplies) and RO treatment with ZLD (South Platte River, Arkansas River, and Colorado River supplies) also contributes to this variation.

In order to better understand the differences between the annual unit O&M costs in cost per AFY were analyzed, as shown in Figure 5-5 below. The annual O&M unit costs generally do not vary between options, showing a minimal economy-of-scale savings. Slight increases in annual O&M unit cost between Options 2 and 3 are due to the maintenance of twice the distance of pipeline. The Colorado River Return project is the most expensive concept with the required pumping and advanced treatment.

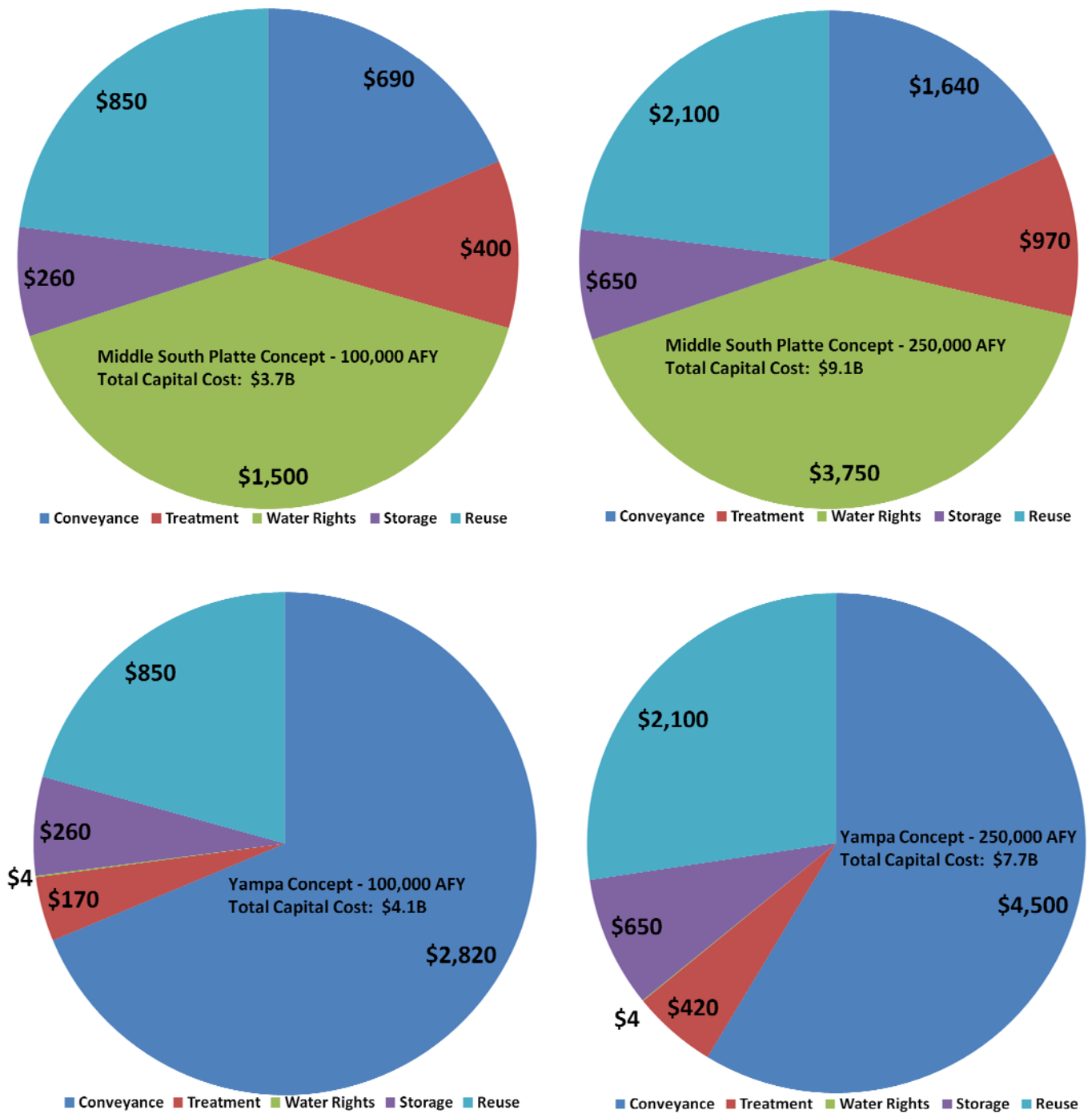


Figure 5-3. Comparison of Agricultural Transfer and New Supply Development Concepts Subcomponent Capital Costs

Figure 5-4. Summary of Total O&M Costs

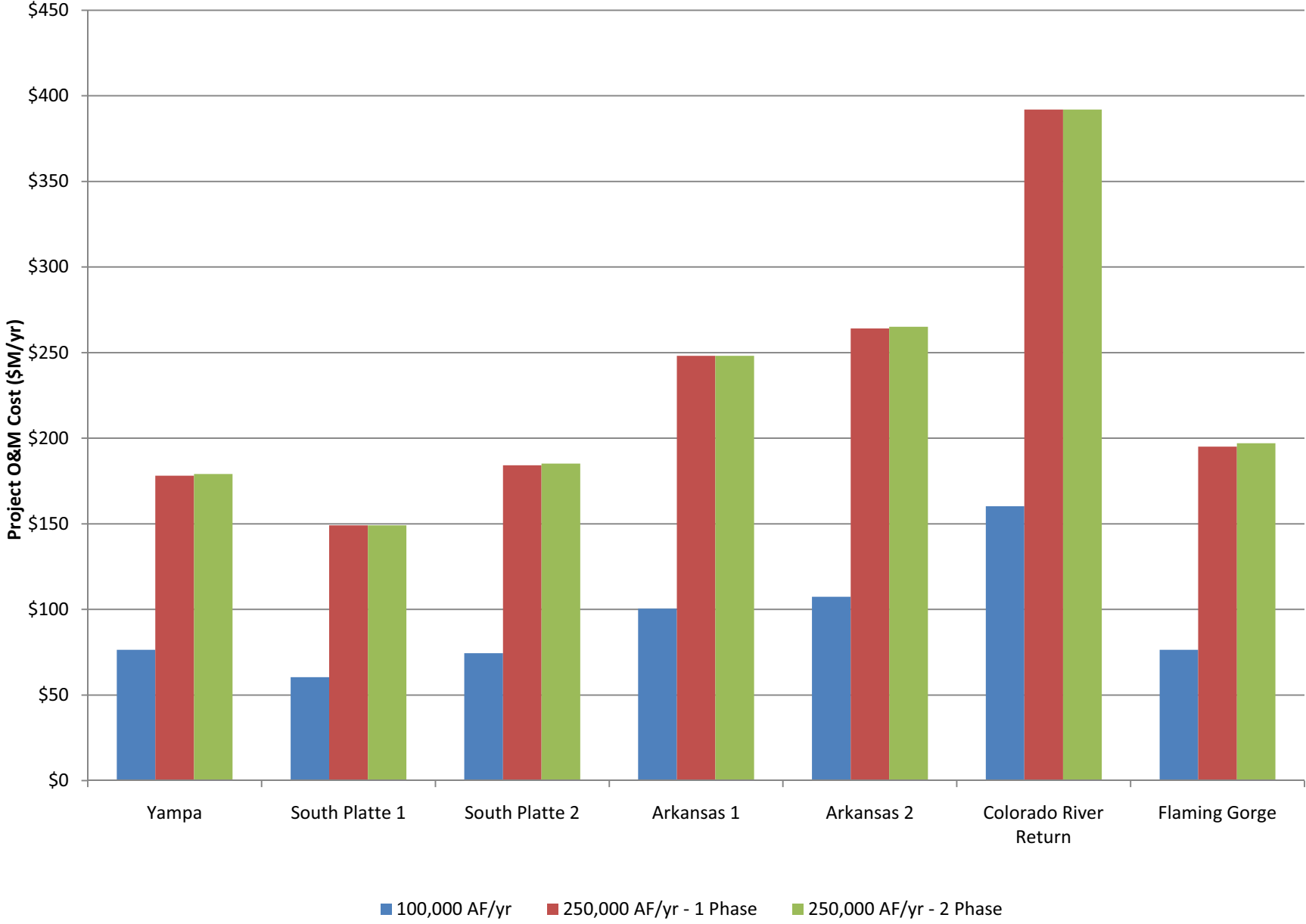
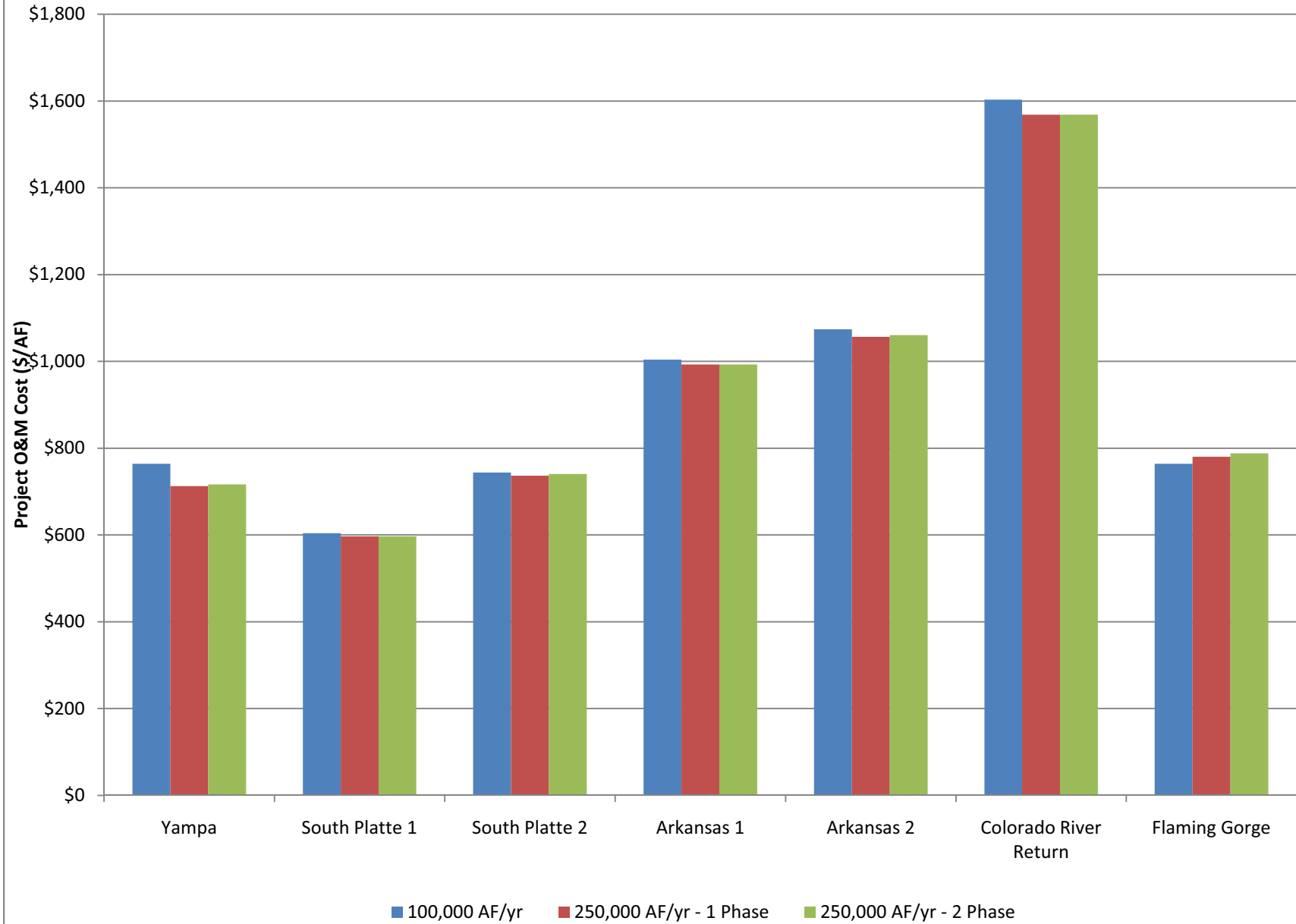


Figure 5-5. Summary of Total O&M Unit Costs



5.6.3 Life Cycle Costs

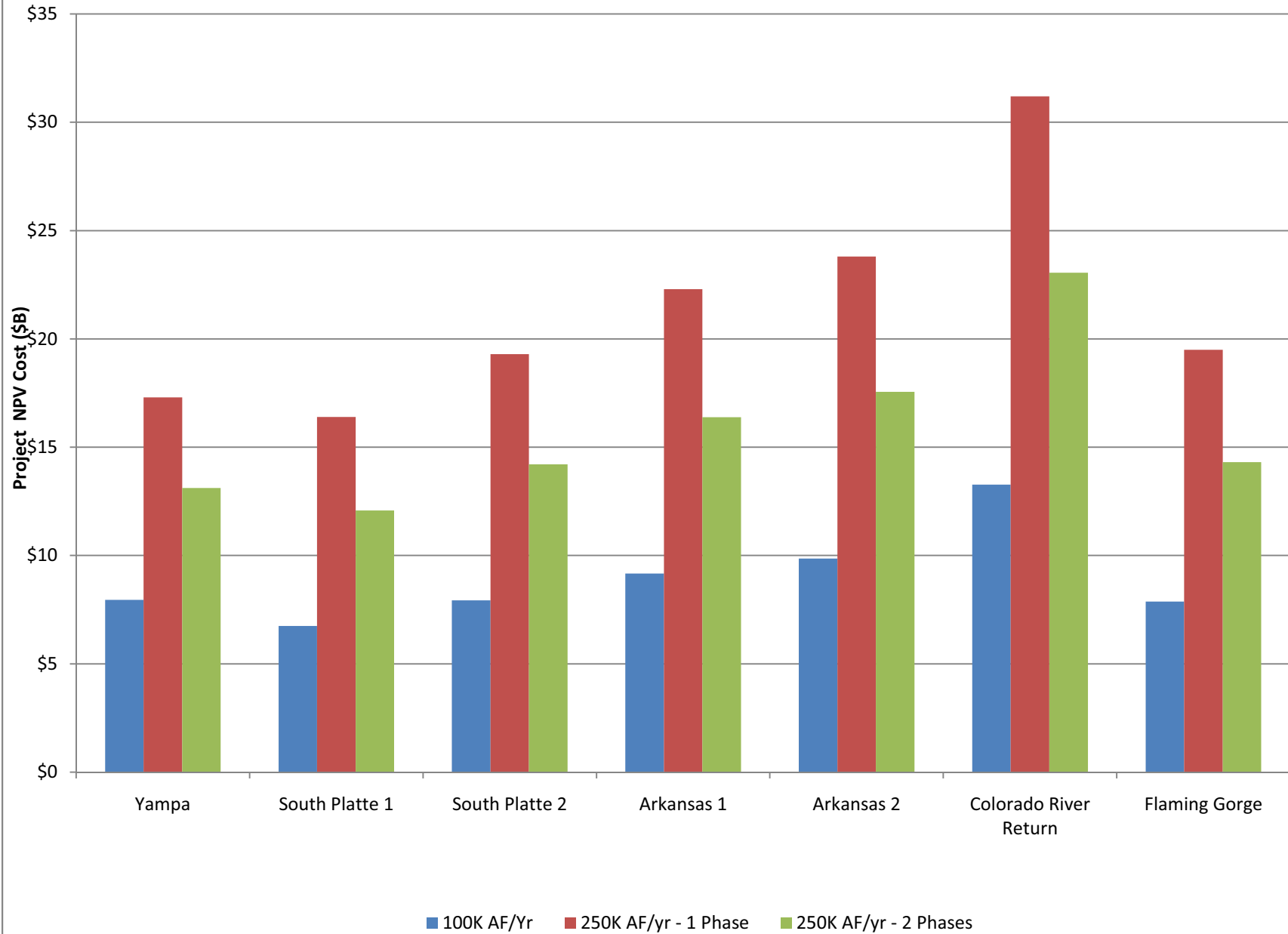
In addition to the development of capital, operations, and maintenance costs, life cycle costs for comparison of the options and concepts have also been developed. The life cycle costs allow comparison of not only the capital costs, but the operational costs associated with the alternatives, all brought back to a present worth value in order to evaluate the long range economic feasibility of each concept. The following key assumptions associated with life cycle cost development have been used for this analysis:

- Planning period – 50 years after completion of construction
- Present Worth – capital and operating costs brought back to 2009
- Capital costs expended in 2020, with O&M starting in 2021 for Options 1 and 2
- Capital costs expended in 2020, with O&M starting in 2021 for Phase 1 of Option 3 and 2040, with O&M starting in 2041 for Phase 2 of Option 3
- Discount rate, or cost of money – 6 percent
- Escalation
 - Capital items – 3 percent
 - Annual O&M – 3 percent
 - Energy – 5 percent
- 2009 Energy cost (\$/kwhr) - \$0.08

In addition to initial capital costs and annual operating cost, replacement costs were developed for the constructed facilities if the replacement was required during the 50-year planning period. The pipeline and pump station facilities (which included intake structures, pipelines, pump station structures, and surge structures) are primarily concrete and steel, which could have a useful life of 50 years. However, both the electrical and mechanical components of the pump stations would need to be replaced every 20 years (35 percent of the total capital cost), and it was assumed that this portion of the capital cost would be replaced twice in the 50-year planning period. Similarly the water treatment facilities have structures that are primarily concrete and steel and could have a useful life of 50 years. However, for water treatment facilities the electrical and mechanical equipment would need to be replaced every 25 years (50 percent of the total capital cost), and that portion of the capital cost was assumed to be replaced once in the 50 year planning period.

Based on total life cycle costs depicted in Figure 5-6 below, the most economically feasible alternative is the South Platte River Concept Alternative 1 and the most expensive alternative is the Colorado River Return Concept regardless of Option. It should be noted that, except for the Colorado River Return Concept, the water supply concepts are generally similar.

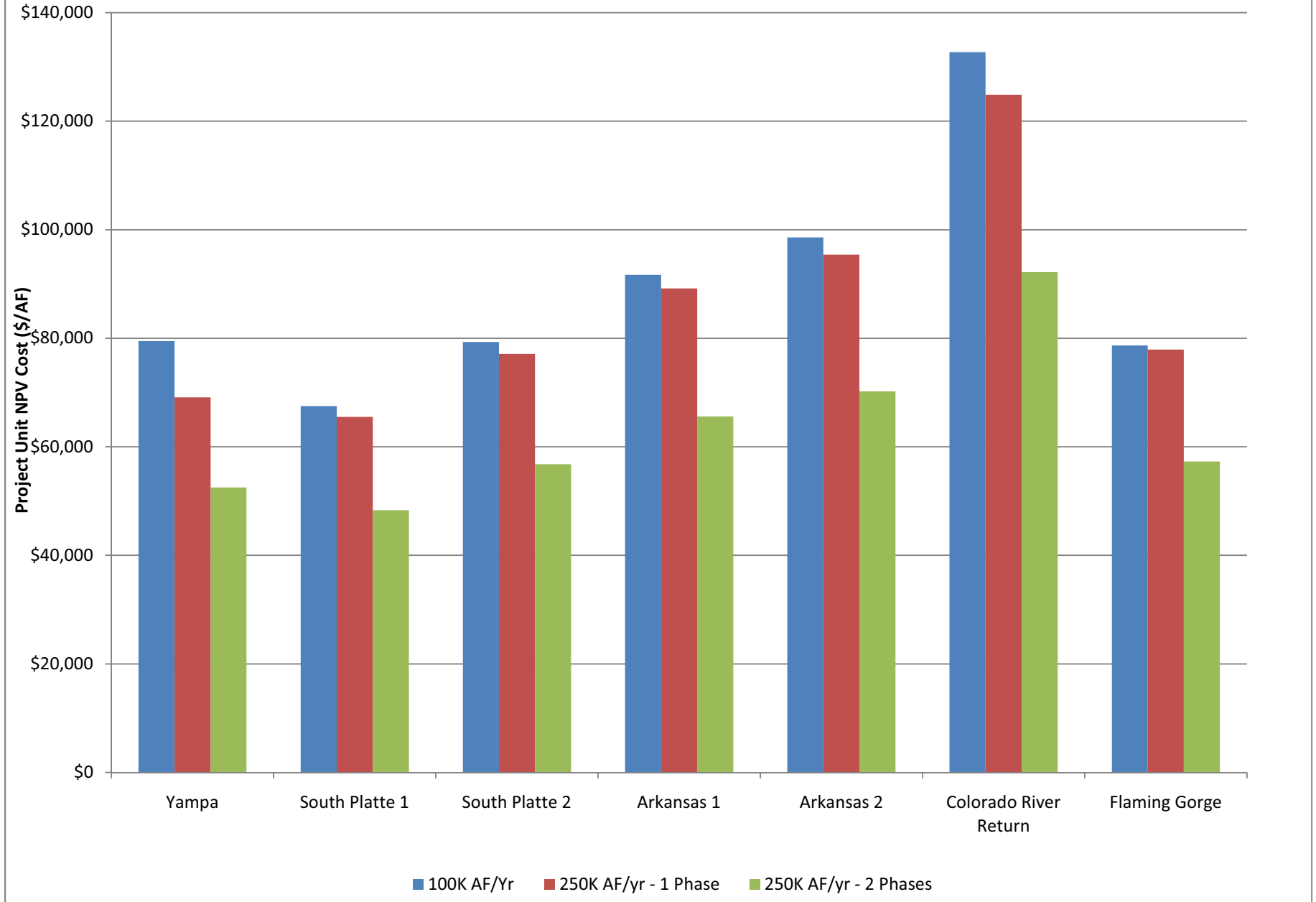
Figure 5-6. Summary of Total Life Cycle Costs



In the life cycle cost comparison, Option 3 (building a 250,000 AFY project in two phases) consistently has a lower present-day value than building the project in a single phase. This may seem counter-intuitive, but shows that if the entire present-day value for Scenario 3 was invested now and made an annual 5 percent return until the first phase was constructed and the remaining capital continued to receive an annual 5 percent return until the second phase was constructed, a smaller investment would have to be made now, than if the entire present-day value for Scenario 2 was invested. This illustration shows the power of investing money now and deferring the payment of large projects to a later date. However, in practice stakeholders would not likely invest the present-day capital values shown in Figure 5-7 below to construct a project in 2020 or 2040, as present capital would likely be used to fund immediate water resource needs. The life cycle unit costs show a similar perspective and are shown in Figure 5-7 below.

The life cycle unit costs also show the South Platte River Concept Alternative 1 being the most economically feasible and the Colorado River Return Concept being the most expensive. With the exception of the Colorado River Return Concept the Option 1 life cycle unit cost is between \$65,000/AF and \$95,000/AF and the Option 3 life cycle unit cost is between \$45,000/AF and \$65,000/AF.

Figure 5-7. Summary of Total Life Cycle Unit Costs



Section 6

Strategy Benefits, Impacts, and Opportunities

6.1 Introduction

The following section outlines benefits, impacts, and additional opportunities presented for each water supply strategy. A benefit is defined as something that adds overall value. An impact is defined as something that has a negative value. Opportunities are defined as what could be added to a project in order for it to move forward as a more viable strategy, and includes some mitigation measures.

Table 6-1 describes the benefits, impacts, and opportunities for each water supply strategy. These tables are a compilation of feedback received to date and are meant to be a "living document" that can be edited as the strategies are further refined.

Table 6-1. Benefits, Impacts, and Opportunities for Strategies

Benefits	Impacts	Opportunities
Conservation Strategy		
Cost effective water supply strategy	Potential reliability concerns	Use of interruptible supply agreements for system reliability could benefit agriculture
Reduces need for future development of new water supplies including transbasin diversions	Consideration of utilities financial model	Conserved water could be used to meet environmental/ recreational flows
Reduces need for future agricultural transfers	For higher levels of conservation, potential landscape impacts	Integration of municipal infrastructure
Instills a "water ethic" in Colorado citizens	New infrastructure will be needed to share conserved water	Agriculture interruptible supply agreements could be used to offset "demand hardening"
	New institutional arrangement will be needed to share conserved water	Consider state or local rule/statutory changes to give utilities more flexibility in integrating conservation into their financial models
	Not all conserved water can be put into new growth, and not all of it can be moved to the "gap" areas	Research to identify these impacts and potential state funding to help offset them
Agricultural Transfer Strategy		
<i>Lower South Platte Concept</i>		
Less reliance on additional deliveries from headwaters areas, thus minimizing streamflow impacts in environmentally sensitive areas	Water quality is poor and treatment costs (capital and O&M) are high	Potential to collaborate with remaining agricultural users to construct lower basin storage or recharge facilities to improve agricultural yields or provide for well augmentation
Reduces need for future development of new supplies including transbasin diversions	Disposal of treatment waste stream concentrate is a challenge and very costly	Shared infrastructure among water providers, resulting in economies of scale for capital and O&M

Table 6-1. Benefits, Impacts, and Opportunities for Strategies

Benefits	Impacts	Opportunities
<i>Lower South Platte Concept (cont.)</i>		
Potentially no net increase in depletions to the river system (assuming only the consumptive use portion is transferred)	Loss of irrigated acreage in production annually regardless of the type of agricultural transfer	Can provide for coordinated acquisition of agricultural rights for either a traditional or alternative transfer preserving higher quality/value agricultural production
	Significant energy requirements for pumping and water treatment	Conjunctive use with non-tributary groundwater can potentially improve the overall project operation
	Socio-economic impacts to rural communities	
<i>Lower Arkansas Concept</i>		
Less reliance on additional deliveries from headwaters areas, thus minimizing streamflow impacts in environmentally sensitive areas	Water quality is poor and treatment costs (capital and O&M) are high	Potential to collaborate with remaining agricultural users to construct lower basin storage or recharge facilities to improve agricultural yields or provide for well augmentation
Decreases the need for additional transbasin diversions	Transfer to South Metro Area may be of concern	Shared infrastructure among water providers, resulting in economies of scale for capital and O&M
No net increase in depletions to the river system	Disposal of treatment waste stream concentrate is a challenge and very costly	Can provide for coordinated acquisition of agricultural rights for either a traditional or alternative transfer preserving higher quality/value agricultural production
	Loss of irrigated acreage in production annually regardless of the type of agricultural transfer	Conjunctive use with non-tributary groundwater can potentially improve the overall project operation
	Significant energy requirements for pumping and water treatment	
New Supply Development		
<i>Green Mountain Concept</i>		
Reduces loss of irrigated acres in South Platte and Arkansas Basins	Potential for increased compact call	Delivery to North Fork of South Platte upstream of Denver Metro area for gravity delivery to Denver Water customers and other water providers
Utilization of Colorado's Colorado River compact entitlement	Additional in-basin storage	Protect or enhance Blue River flows
Additional flows in Upper South Platte	Diminished flows in rivers below proposed diversions with potential increases in TDS and other water quality impacts	Exchanges for additional flows in Colorado headwaters
Could be coordinated with Grand County streamflow management	Phosphorus levels in Dillon Reservoir	Multi-purpose storage for endangered species and other Colorado Basin needs
Potentially additional Grand Valley water supplies	Green Mountain Reservoir levels	Wolcott Reservoir for future west slope demands

Table 6-1. Benefits, Impacts, and Opportunities for Strategies

Benefits	Impacts	Opportunities
New Supply Development (cont.)		
<i>Green Mountain Concept (cont.)</i>		
Maintain Dillon Reservoir Levels	Streamflow impacts from Green Mountain Reservoir/Wolcott Reservoir Swap	Ability to exchange water for Summit County Municipal and Industrial purposes
Additional water supplies for the upper Blue River		
Blue River flow enhancement		
Additional west slope supplies		
Partial abandonment of some Eagle River rights		Recreation component for Wolcott Reservoir
<i>Yampa Concept</i>		
Reduces loss of irrigated acres in South Platte and Arkansas Basins	Potential for increased compact call	Multiple Front Range delivery locations
Utilization of Colorado's Colorado River Compact entitlement	Large energy requirements	West Slope and East Slope storage
Acceptable quality water source that may not require advanced water treatment processes	Endangered species on Yampa and Green Rivers	East Slope hydropower facilities
		Dinosaur National Monument located downstream of proposed diversion
	Exchanges for additional flows in Colorado headwaters	
		Infrastructure for irrigation of additional acres in Moffat County (20,000 to 30,000 acres of land could be irrigated)
		Water for future municipal development particularly in Steamboat and Craig. (Upper basin interests have previously secured about 60,000 acre-feet subordinations to protect future uses and they have indicated they would want a similar subordination or component of the project.)
		Operational agreements to benefit the endangered species recovery program
Operational agreements to maintain environmental and recreational flows on the lower Yampa		
<i>Flaming Gorge Concept</i>		
Reduces loss of irrigated acres in South Platte and Arkansas Basins	Potential impacts to endangered fish recovery program and other depletion issues on the Green River	Delivery to in-basin users for agricultural, augmentation, and instream flows
Acceptable quality water source that may not require advanced water treatment processes	Enlargement or construction of additional storage in South Platte or Arkansas	Exchanges for additional flows in Colorado headwaters
Utilization of Colorado's Colorado River Compact entitlement without impacting streamflows in Colorado	Large energy requirements	Conjunctive use with non-tributary Denver Basin aquifer in dry years
Allows water development while protecting environmental and recreational flows in Colorado	Potential for increased compact call	Aquifer storage and recovery terminal storage in the Denver Basin, Upper Black Squirrel, etc.

Table 6-1. Benefits, Impacts, and Opportunities for Strategies

Benefits	Impacts	Opportunities
New Supply Development (cont.)		
<i>Flaming Gorge Concept (cont.)</i>		
Diversifies the state's water supplies. (The Green River is north of the Colorado's current water supplies. Climate change models for the western U.S. indicate that precipitation may decrease in the Southwest and may increase in the North with the dividing line often splitting Colorado. Adding a more northerly water supply could mitigate potential risks from climate change.)	Complexity of water rights administration (compact call or dry years on the Green River)	Project can be configured to encourage certain density patterns, and/or landscaping
	Additional storage in the South Platte or Arkansas basins (surface water storage or underground storage).	Project can be configured to encourage different conservation measures
		Maximum utilization of fully consumable water either through M&I reuse or "second use" by east slope agriculture
		Operational agreements to benefit the endangered species recovery program
		Tie diversions to Lake Powell levels to avoid triggering a compact call
		Potential for small hydropower and use of renewable energy sources
<i>Colorado River Return System Concept</i>		
Reduces loss of irrigated acres in South Platte and Arkansas	Water quality is poor and treatment costs (capital and O&M) are high	Delivery to in-basin users for agriculture, domestic augmentation, and instream flows
Diverts below all major users in Colorado	Disposal of treatment waste stream concentrate is a challenge and very costly	Exchanges for additional flows in Colorado headwaters
Utilization of Colorado's Colorado River Compact entitlement without impacting streamflows in Colorado	Potential for increased compact call	Allows water development while protecting recreational and environmental flows in Colorado basin
Less reliance on additional deliveries from headwaters areas, thus minimizing streamflow impacts	Stream temperature, nutrients, and TDS in water after treatment will be different than streams receiving discharge from project	
Additional flows in upper South Platte, Arkansas, and Colorado Rivers, providing for additional environmental and recreational enhancement	Reduction of flows in the main stem Colorado River and the presence of federally listed fish species below the diversion	
Multiple basin delivery	Significant energy requirements	

6.2 Project Viability

In addition to providing feedback on the benefits, impacts, mitigation, and opportunities of each strategy, the Basin Roundtables, the IBCC, and the CWCB Board were asked to brainstorm around a specific question – *"What would it take to make these strategies and specific projects more viable?"*

The summary of feedback received to date is presented below. The feedback provided was done in an informal fashion and does not reflect consensus opinion of the roundtables. As with the table above, this feedback is expected to evolve as the strategies are further refined.

6.2.1 Conservation Strategy

Water Conservation at 20, 30, or 40 Percent

- Providers will need to rely on a wide mix of conservation practices to reach these levels. These include:
 - Water rates and incentives (tax incentives, rebates, rate structures, economic development incentives, cash for grass)
 - Education and technology (customer usage information, leak detection, public education, dry cooling technology)
 - Land use regulations (yard turf size limitations, public space turf allocation, turf fallowing, landscape codes, treat new development projects differently to reach 30 percent)
- Water planning elements will need to be included to make this a viable strategy:
 - Factor in demand hardening effects
 - Use saved water to increase supply reliability, environment climate change
 - Use interruptible agricultural supply contracts to address demand hardening
 - More efficient use of total supplies
- Statewide/regional efforts will be needed
 - Smaller utilities may need conservation assistance
 - Identify impacts on agriculture from potential reductions in return flow
 - Adopt uniform conservation goals east and west slope
 - Close loopholes allowing development with inadequate water supplies
 - Establish statewide efficiency reporting requirements
- Growth, land use, and water supply – Need to examine how Colorado grows as a way to reduce water needs
- The incorporation of demand management strategies to be planned or implemented prior to a transbasin project was also discussed statewide.

6.2.2 Agricultural Transfer Strategy

Arkansas Concept

- Alternatives to permanent dry up should be pursued (including rotational fallowing and long-term leases)
- Energy – pumping and treatment need alternative sources of energy
- Methods to deal with the waste stream needs to be identified
- Must include protection for smaller entities
- Build on Super Ditch Concept
- Concept should provide augmentation water for remaining agriculture in the Lower Arkansas
- Develop a focus on lower producing agricultural lands and identify these lands

- Identify what it takes to maintain rural economies
- Supplement this strategy with Tamarisk removal
- Protect environmental flows and consider ways to include environmental enhancements
- Integrate with Southern Delivery System and other existing infrastructure
- Construct additional storage

In addition the Arkansas Basin Roundtable produced a report titled *Considerations for Agriculture to Urban Water Transfers*. This report identified a framework for evaluating water transfers that addressed:

- Size of transfer
- Location of transfer
- Period of time to implement the transfer
- Point of diversion
- Time of diversion
- Means of conveyance
- Storage issues
- Water quality impacts
- Impact on environment
- Impact on recreation
- Economic impact on affected communities
- Noneconomic social impacts
- Local government interests
- Length of lease
- Frequency of transfer
- Considerations for transfers involving group

This report also identified the following potential opportunities:

- Transfer should consider not only immediate impacts but future impacts as well as cumulative impacts
- Consider amount, timing, and/or location of the transfer
- Consider economic development on former agricultural lands
- Consider viability to remaining shareholders of ditch companies from which transfers occurred
- Consider economic development assistance to affected communities
- Cooperation on developing infrastructure for treatment, conveyance, and storage of agricultural water converted to municipal use

South Platte Concept

- Alternatives to permanent dry up should be pursued
- Methods to deal with the waste stream need to be identified
- Include local storage for remaining agricultural use
 - Firm up lower river supplies and senior rights
 - Augmentation
 - Aquifer storage and recovery
- Cooperative effort - multiple stakeholders will need to be involved
- Endangered Species Act compliance must be maintained (three state agreement - Colorado, Nebraska, and Wyoming)
- Include resources for vegetative management (land re-seeding) and protection for the local environment
- Permanency of supply - lease terms must be specified
- Address local economic issues
 - Protect existing tax revenue and rural economies
 - Diversification of economy
 - Diversify crops
- Renewable energy could be used (e.g., wind, etc.)
- Assure receivers have mandatory water conservation (M&I/agriculture)
- Maintain return flows and groundwater levels
- Concept should not include tributaries; the source of water for this strategy should be the South Platte mainstem
- Additional storage for management/firming will be needed
- Maintain water fowl habitats and wetlands
- Maintain current flow regimes for fisheries

6.2.3 New Supply Development Strategy

Green Mountain Concept

- More storage for compensatory uses
 - Wolcott - west slope
 - Williams Fork reoperations
 - Phased approach
- Non-consumptive uses
 - Fish
 - Recreation
 - Protect flows below Kremmling
- Include components to address the Heeney Slide area
- Use existing infrastructure to the extent possible

- Administration and institutional issues will need to be addressed
- Use in conjunction with other strategies statewide
- Additional conservation for the end user should be mandatory
- Not just a Denver Water project; it needs to help address water supply issues in other areas of the Front Range

Flaming Gorge Concept

- Interstate cooperation: Colorado and Wyoming should work together to develop their respective Colorado River compact allocation
- Concept should be developed in the public forum not for profit or speculation
- It could be a federal/state partnership project utilizing CRSP Fund
- Needs to include protections to avoid a compact call
- The priority date could be an issue: is it the Flaming Gorge priority date or something else?
- Protect endangered species flow on the Green River
- Multiple Use Project
 - Upper Green River users (M&I and agriculture)
 - Involve Wyoming municipalities
 - Front Range municipalities
 - Return flows for agriculture or second use
 - Colorado River Basin exchange through existing systems to help meet west slope M&I uses and/or additional flows in the headwaters
 - Recreation – terminal storage reservoir
 - Environmental flows for South Platte
- Size - Look at maximum size considering compact entitlement and supply availability
- Energy - use renewable energy

Yampa Concept

- The protection of the future water development capability in the upper Yampa River basin, equivalent to 60,000 AF.
- The protection of the stability of the Programmatic Biological Opinion and ROD for the Yampa Plan on which many water users in the basin rely
- The protection of recreational usage of the River through Dinosaur National Monument
- The protection of water quality of the River
- The West Slope may expect significant conservation from east slope – does 1041 give them ability to ask for this?
 - Land use policy on project beneficiaries
 - Quality of life issues

- Yampa Basin has strong environmental/recreational interests
- The Yampa Basin may want some benefits from this concept for their basin – environmental, recreational, help meet demands from oil shale
- Multiple stakeholders needed to finance (federal involvement, Dinosaur National Monument)
- Water must be accessible for agricultural use
 - Overall cost to municipality must be cheaper than buy and dry
- Long-term financing needs to be made available
- Concurrent renewable energy projects to minimize any of energy needed to buy to move water up
- Recreational flows - flushing flows
- Limit timing of diversion (during high flow times)
- Concern is that once the project is built, agriculture on the west slope would be a target for dry up and a vehicle to move water would be there – this concept should limit the type of water that can be moved (i.e., not allow transferred agricultural rights to be moved through this project)
- Facilitate conditional water rights in that basin to be perfected, stored and conveyed within the basin
- Work through Colorado River Compact to assure Yampa Basin that right with Yampa project would be called out first
- Project beneficiaries closely work with Yampa Basin show commitment through tax proceeds – address this in potential operations
- Maybe build a larger west slope reservoir (600,000 AF instead of 500,000 AF) to protect environmental and recreational needs in times of shortage/drought
- Yield for increased irrigation for Yampa Basin

Colorado River Return Concept

- Project should not impact water users in Colorado River
- Political: storage, use public process; interstate water marketing
- The following recreational issues need to be resolved:
 - Use existing infrastructure
 - Find uses for chemicals removed
 - Zero liquid discharge needs to be addressed
- Issues associated with energy should be resolved:
 - Use renewable energy (solar/wind)
 - Provide energy to help pay for project
- Statewide financing needs to be available

- Should not harm endangered species – timing/storage solutions especially up in basin
- Basin of Origin:
 - Upper basin benefits municipal, industrial, environmental, and recreational needs
 - This could be exchanged and put pressure off Shoshone
- May be too expensive and have too many impacts when compared to other strategies

Section 7

Recommendations

This section will be completed after the June 2009 CWCB and IBCC meetings.

Section 8

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