WINDY GAP FIRMING PROJECT

Alternative Plan Formulation Executive Summary

Prepared by:

/ EDAW

Prepared for:
The Municipal Subdistrict of the Northern Colorado Water Conservancy District and Participants

• City of Broomfield
• City of Greeley
• City of Longmont
• City of Louisville
• City of Loveland
• Town of Erie
• Town of Superior
• Central Weld County Water District
• Platte River Power Authority

February 2003
# Table of Contents

## Introduction

- Regional Water Supply Needs ........................................................................ ES-1
- Current Windy Gap Project Facilities and Operations .................................. ES-1
- Dry-year Delivery Deficiencies ................................................................... ES-2
- Windy Gap Firming Project ........................................................................ ES-4

## Study Purpose and Approach

- Analyzing the Reliability of the Windy Gap Project .................................. ES-6
- Definitions of Water Supply Project “Reliability” ......................................... ES-6
- Factors Affecting Reliability ........................................................................ ES-7
- Model Selection and Applications ................................................................. ES-7
- WGFP Modeling Scenarios .......................................................................... ES-8

## Identification of Potential Elements

- Non-Structural and Institutional Elements .................................................. ES-10
- New Reservoir Elements ............................................................................ ES-11
- Existing Reservoirs and Gravel Pit Development ....................................... ES-11
- Aquifer Storage ............................................................................................ ES-11

## Phase I Element Screening

- Phase II Element Analysis ........................................................................ ES-13

## Phase III Formulation of Alternative Plans

- Comparisons of the Alternative Plans ........................................................ ES-17
- Operational Analysis ................................................................................ ES-19
- Plan 1. Lower Chimney Hollow Reservoir ................................................ ES-22
- Plan 2. Chimney Hollow and Jasper North (Alternative A) Reservoirs .... ES-22
- Plan 3. Chimney Hollow and Rawhide North Reservoirs ........................ ES-23
- Plan 4. Jasper North and Chimney Hollow Reservoirs .............................. ES-23
- Plan 5. Cactus Hill ................................................................................... ES-23
- Plan 6. Little Thompson Reservoir ............................................................. ES-23
- Plan 7. Jasper North and Rawhide North Reservoirs ................................ ES-24
- Cost Estimates .......................................................................................... ES-24
- Environmental Analysis .......................................................................... ES-25

## Summary ..................................................................................................... ES-27
Figures and Tables

Figure ES-1. Existing Windy Gap and C-BT Facilities............ ES-3
Figure ES-2. Three Phase Study Process ................................ ES-5
Figure ES-3. Elements Used in Alternative Plans ................. ES-18
Table ES-1. WGFP Models ......................................................... ES-8
Table ES-2. Storage Plan Summary ........................................ ES-16
Table ES-3. Short List of Alternative Plans ......................... ES-19
Table ES-4. Future Conditions Model Results ...................... ES-21
Table ES-5. Cost Summary for Storage Plans ....................... ES-24
Table ES-6. Summary Environmental Rating of Plans .......... ES-26
Introduction

This Alternative Plan Formulation Report addresses potential methods to enhance the reliability of water deliveries from the Windy Gap Project to meet current and future water demands. The report explains the need for the Windy Gap Firming Project (WGFP), identifies and evaluates potential project elements that might be used to meet the needs, and presents a short list of alternative plans for the WGFP. The report will be used by the WGFP Participants to select a proposed project (or projects) and initiate more detailed project planning and permitting activities.

Regional Water Supply Needs

The Northern Colorado Water Conservancy District (NCWCD or District) recently developed land-use-based regional water demand projections (NCWCD, February 2000). These projections document an increase in municipal demand of about 264,000 acre-foot (ac-ft) of water per year over the year 2000 water demand of 165,000 ac-ft per year within the urbanizing area of the district. All of the WGFP Participants, except for the Platte River Power Authority, are cities, towns, or domestic water districts located within this same regional study area.

The total demand for additional municipal and industrial water has continued to grow in spite of expanded water conservation and demand management programs. Individually, many users have implemented programs ranging from indoor plumbing retrofit programs to large-scale water reclamation facilities and non-potable irrigation systems. They have also explored regional integrated water supply projects, constructed interconnections between delivery systems, and cooperated in regional demand management programs.

The current reliability of municipal and industrial water supply systems is more of a concern than ever. This is evidenced by the broad water conservation and demand management programs implemented by Front Range water suppliers in response to unprecedented drought conditions in 2002. Additional concerns include potential interruptions in municipal water services due to major forest and range fires, biological and chemical contaminants, and terrorist activities. These and other factors have led to significant concerns with the long-term performance of existing and future water system components.

The Windy Gap Firming Project was developed in response to these needs and concerns. The purpose of the WGFP is to enhance the reliability of the existing Windy Gap water supply.

Current Windy Gap Project Facilities and Operations

The Windy Gap Project, which came on-line in 1985, consists of a diversion dam at the confluence of the Colorado and Frasier Rivers impounding a 450 ac-ft reservoir, and facilities (600 cfs pump station and pipeline) to pump water to Granby Reservoir. From there, the Windy Gap water is delivered through Colorado-Big Thompson (C-BT) Project facilities constructed by the U.S. Bureau of Reclamation. Using these C-BT facilities, Windy Gap water is pumped to Shadow Mountain Reservoir and is delivered through the Adams Tunnel to the east slope for holders of Windy Gap water allotments. The Municipal
Subdistrict of the Northern Colorado Water Conservancy District (Subdistrict) has a carriage contract with the NCWCD and the U.S. Bureau of Reclamation (Reclamation) for carriage of Windy Gap Project water by and through the C-BT Project facilities. The major Windy Gap and C-BT Project facilities are shown in Figure ES-1.

Planning studies for the Windy Gap Project were initiated in 1967 by a coalition of six northern Colorado cities (Boulder, Estes Park, Fort Collins, Greeley, Longmont, and Loveland) that saw a need to develop a new water source to meet the future needs of the rapidly growing northern Front Range of Colorado. Following completion and approval of an Environmental Impact Statement in 1981 and acquisition of 23 permits and licenses, construction on Windy Gap began in July 1981. The project was completed in 1985 and pumped its first water that spring. Recent growth along the Front Range has increased the reliance upon deliveries from the Windy Gap Project. This growth, coupled with extreme hydrologic conditions (a series of very wet years from 1995-1999 and a very dry sequence in 2001 and 2002) have highlighted the need for enhancing the reliability of the Windy Gap Project in terms of its ability to provide water in dry years.

**Dry-year Delivery Deficiencies**

Studies done prior to Windy Gap construction estimated that the average annual water deliveries from the Project would be 48,000 ac-ft per year, in addition to 3,000 ac-ft per year for the Middle Park Water Conservancy District. Actual project operations since 1985 have shown that average future water deliveries will be lower than 48,000 ac-ft per year because of several factors including:

- Windy Gap Project diversions are limited in dry years by senior water rights in the Colorado River drainage.
- Windy Gap Project diversions are limited in some other years by limited storage and conveyance capacity in the C-BT Project.
- Since Windy Gap is junior to C-BT, Windy Gap water initially stored in Granby Reservoir awaiting delivery to the East Slope is “spilled” during wet periods when Granby Reservoir is filled with C-BT water.
The Subdistrict and Windy Gap allottees have attempted to meet demands by integrating the operations of the C-BT and Windy Gap Projects as outlined in the Criteria for Integrated Operations of the Colorado-Big Thompson and Windy Gap Projects, which was adopted in 1991 by the District, Subdistrict, and Reclamation. As demands grow, and in certain hydrologic conditions, this integrated operation has proven to be problematic and will not allow full delivery of Windy Gap allotments.

**Windy Gap Firming Project**

Some owners of Windy Gap water need to improve the reliability of the Windy Gap water supply by “firming” the water deliveries from the project so that their full allotment can be delivered each year. The Windy Gap Firming Project (WGFP) is a new, cooperative regional endeavor to enhance the ability of the Windy Gap Project to meet water demands within the Subdistrict during a wide range of hydrologic conditions.

Nine entities participated in the financial sponsorship of this study, provided data on historic operations and future needs, and assisted the Subdistrict in making interim decisions in conducting the study. These “Participants” are Broomfield, Erie, Greeley, Longmont, Louisville, Loveland, Superior, Central Weld County Water District (CWCD), and Platte River Power Authority (PRPA). Several of the Participants need to firm Windy Gap water immediately, based on current demands and available supplies. Other Participants foresee a need to firm their Windy Gap water in future years based on projected growth in their water demands.

The WGFP will consider appropriate methods to provide a more reliable supply. The range of options includes structural options such as new or expanded reservoir storage capacity and non-structural options such as coordinated operation with the C-BT. Demand management strategies such as water conservation and reuse are not included as alternatives, but are incorporated into the overall demand projections and water needs of the individual participants.

Because of institutional constraints, including contractual and regulatory difficulties associated with changing the operation of existing projects, additional reservoir storage is a major focus of the study. The Participants initially estimated that 110,000 ac-ft of storage would be needed to increase the reliability of the project to required levels without any other operational improvements to Windy Gap Project in conjunction with C-BT operations. This estimate provided a starting point in the initial identification of the general types and sizes of options that should be considered and a yardstick against which the performance of other structural and non-structural alternatives could be measured.

The Windy Gap Project (river diversion, pump station, and pipeline to Granby Reservoir) was completed in compliance with the Final Environmental Impact Statement dated April 28, 1981 (FES 81-20) and associated local, state, and federal regulatory requirements. On-site and downstream environmental impacts were mitigated as set forth in the permit requirements and water rights decrees. **Nothing considered in the WGFP would alter in any way the existing legal authorities to divert water in accordance with Colorado water law and vested Windy Gap water rights.**

The study summarized herein demonstrates the consideration of a broad spectrum of methods to increase the reliability of the Windy Gap Project including water storage facilities as well as institutional and non-structural options.
Study Purpose and Approach

This study identifies, describes, and evaluates reasonable alternatives to enhance the reliability of the Windy Gap Project water supply based on engineering, technical, economic, environmental, and other relevant factors. The Subdistrict and the Participants previously evaluated several alternative dam and reservoir sites to store Windy Gap diversions. This study is broader in nature and encompasses a wide range of reasonable alternatives for firming the Windy Gap Project water supply.

Many of the alternative plans identified in this study may involve federal actions due to potential modifications of C-BT water storage and conveyance facilities and they may require environmental compliance with the National Environmental Policy Act (NEPA). NEPA requires that reasonable alternatives to a Proposed Action be explored and objectively evaluated. Therefore, this study will serve as a reference document in future permitting activities and in an Environmental Impact Statement (EIS), if one is needed for the alternative(s) selected by the Participants.

As shown in Figure ES-2, the study was conducted in three phases.

- Phase I identified a broad range of potential alternatives, or “elements,” and finished with a coarse screening of the elements. Elements that did not pass specific exclusion criteria were eliminated from further study.
- Phase II involved a more detailed analysis and comparative ranking of potentially feasible elements.
- In Phase III, comprehensive plans were comprised of one or more structural or non-structural elements with the goal of fully satisfying the Windy Gap water needs of the Participants.

**Figure ES-2. Three Phase Study Process**

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Formulate Long List of Project Elements</th>
<th>Exclusion Criteria</th>
<th>Potentially Feasible Elements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase 2</td>
<td>Potentially Feasible Elements</td>
<td>Element Comparison Criteria</td>
<td>Short List of Elements and Potential Plans</td>
</tr>
<tr>
<td>Phase 3</td>
<td>Potential Plans</td>
<td>Plan Comparison Criteria</td>
<td>Comparative Analysis of Plans</td>
</tr>
</tbody>
</table>
Analyzing the Reliability of the Windy Gap Project

A comprehensive water allocation computer modeling system is required to analyze the reliability of the Windy Gap Project and to estimate the amount of water that could be delivered by the project, especially during periods of drought. The determination of water deliveries during dry years or “firm” yield is dependent on the amount and timing of supplies, amount and timing of water needs or “demands,” reservoir storage contents, physical constraints in the water conveyance systems that vary with C-BT and Windy Gap operations, and routes by which water can be moved from one part of the system to another. A computer model that simulates these elements over a long time period and under changing hydrologic conditions is a necessary tool for this type of analysis.

To appreciate the need for, and the complexity of these models, the reader must first understand the definition of water project “reliability” and the factors that affect this reliability. The following two sections summarize these definitions and factors respectively. These sections are followed by descriptions of the models and the three types of scenarios evaluated using the models.

Definitions of Water Supply Project “Reliability”

The “reliability” of a water supply project is often measured in two ways:

1) **Average Year Reliability:** Reliability can be measured by the average amount of water that a project can deliver over a period of time considered representative of the long-term hydrology in the project area. The selected study period should include average, wet and dry years so that evaluations can be made on how well the project will operate in response to the widely varying rainfall and snowfall in areas like Colorado. The hydrologic period selected for this study starts a few years prior to a critical drought period to minimize impacts of starting reservoir contents. Most C-BT facilities, such as Granby, Carter Lake and Horsetooth came on line in the early 1950s so the study period used in this study began in 1950. The study period ended in 1996 because of dependence on the CDSS Historical Model (as discussed in the section titled “Model Selection and Applications”).

2) **Dry-Year Reliability:** Reliability can also be measured by the amount of water that a project can deliver during severe hydrologic conditions, typically a dry year or sequence of dry years. In estimating the dry-year reliability, one must consider how frequently the dry conditions will occur. A typical water supply project will be able to deliver much more water during the type of drought that one might expect once in every 10 years than a more severe drought that might be expected once in every 100 years. Typically, municipal and industrial (M&I) water suppliers must be more conservative and plan for more severe droughts than agricultural water suppliers. This is because M&I water shortages may compromise public safety and economic viability in the towns and cities. **For this study, alternatives are considered to provide a “firm” supply if deliveries can be made without shortages through a repeat of the historic hydrology from 1950 to 1996.**
Factors Affecting Reliability

For the Windy Gap Project, and other Colorado water supply projects, reliability is greatly affected by these factors:

- **Seniority of water rights.** In Colorado, and other western states, water is owned by the state and allocated to users with “water rights”. This right to use the water is administered by the state so that the earliest applications (that is, most “senior” water rights) get all of their water before any later applications (“junior” water rights) get theirs. Windy Gap is a relatively junior water right.

- **Magnitude of winter snowfall and rain from summer thunderstorms.** Approximately 70 percent of all runoff in the state is from snowfall melting in the spring and early summer. Approximately 70 percent of rainfall comes from short duration rain events (less than 6 hours) versus the lower intensity, longer duration storms occurring in areas with less dramatic topography than Colorado. In dry years, the available water supply is significantly reduced. In these types of years the yield of the Windy Gap water right is reduced because it is a relatively junior water right.

- **Rapid response of Colorado streams.** The same rugged topography that has such strong orographic effects on rainfall, results in rapid runoff in most Colorado streams and rivers. For projects to make much use of these high intensity, short duration stream flows, infrastructure must be designed so that it can be quickly operated, often from remote operations centers using Supervisory Control and Data Acquisition (SCADA) systems. This is especially true for projects with mostly off-channel storage which is being considered for the majority of WGFP plans, where peak flows must be quickly diverted from the streams.

- **The inclusion of “carry-over” storage.** The firm yield of a Colorado water supply project is often most significantly affected by the amount of storage it provides. “Carry-over” storage is the volume of water that can be “carried over” from a wet period to a dry period (to provide “firm” yield). Storage is often characterized as weekly, monthly, seasonal, yearly or long-term. In the case of the WGFP, long-term, that is, multi-year carry over storage is important. With Windy Gap’s relatively junior water rights, there are many years when the project is not allowed to divert any water because more senior water rights are entitled to the relatively little amount of water available. Therefore, multi-year carry over storage is needed for the Windy Gap project to offer reliable yield.

Model Selection and Applications

The two models used to evaluate storage plans and non-structural water management options that combine C-BT and Windy Gap project operations were the State’s Colorado Decision Support System (CDSS) and a Boyle Engineering Stream Simulation Model (BESTSM) applied specifically for this study. Table ES-1 describes the applications and key attributes of both models.
Table ES-1. WGFP Models

<table>
<thead>
<tr>
<th>Issue/ Model Used</th>
<th>Combined operations of C-BT and Windy Gap Projects/ Boyle Engineering Stream Simulation Model (BESTSM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colorado River Basin Water Availability/ Colorado Decision Support System (CDSS)</td>
<td>• Utilizes CDSS model results as input on monthly flows divertible by Windy Gap.</td>
</tr>
<tr>
<td></td>
<td>• Obtained close calibration with historic Granby Reservoir operations and Adams Tunnel diversions.</td>
</tr>
<tr>
<td></td>
<td>• Used to analyze a wide variety of historic and potential future C-BT operating scenarios and target reservoir levels, C-BT quota-setting polices and Windy Gap carriage contract interpretations.</td>
</tr>
</tbody>
</table>

WGFP Modeling Scenarios

Briefly, project simulations involved the development of three specific model scenarios.

1. Historical Modeling Scenario

The Historical Modeling Scenario uses BESTSM to simulate integrated C-BT and Windy Gap Project operations under historic hydrologic conditions. The geographic extent of the BESTSM Historical Model extends from the headwaters of the Upper Colorado River downstream to the Windy Gap diversion dam including Willow Creek on the west slope, as well as portions of the St. Vrain, Big Thompson and Cache la Poudre Rivers on the east slope. The BESTSM Historical Model is driven by historic Windy Gap and C-BT diversions from the Colorado River and Willow Creek and deliveries through the Adams Tunnel. It was calibrated and used to verify system parameters, estimated hydrology, and validate the way C-BT and Windy Gap operations were configured in the model.

2. Baseline Modeling Scenario

A predictive BESTSM Baseline Model was developed next, in which C-BT and Windy Gap project operations are rule-driven, rather than defined by historical values. C-BT and Windy Gap demands were configured in the BESTSM Baseline Model to simulate current conditions and operations imposed on historical hydrology. Baseline operations generally reflect existing WG and C-BT operating rules and facilities and historical quota setting policies. Concurrently, the State’s CDSS Baseline Model, which covers the entire Colorado River downstream to the state line, was updated to more accurately reflect C-BT operations. Use of the CDSS Baseline Model eliminated the need to extend the BESTSM Baseline Model downstream of the Windy Gap Diversion Dam and the need to include the Fraser River. The
CDSS Baseline Model was executed specifically to determine Fraser River inflows and the senior demand downstream of Windy Gap, which both impact the physical and legal availability of water at the Windy Gap diversion point. The BESTSM Baseline Model was executed first to examine the operation of the Windy Gap and C-BT Projects under current conditions. This depiction was a reference point for determining the baseline level of Windy Gap firm yield with no WGFP plan on-line. The BESTSM Baseline Model was then used to evaluate the operations and yield of each alternative plan. The BESTSM Baseline Model was executed for each plan to determine whether there is any additional yield associated with the plan or injury to C-BT as a result of integrated operations.

3. Future Conditions Modeling Scenario

The last step was to develop Future Conditions BESTSM and CDSS models, which reflect future conditions on the west slope imposed on historical hydrology. The CDSS Future Conditions Modeling Scenario was executed first to determine Fraser River inflows and the senior demand downstream of Windy Gap when Denver Water’s demands are increased to reflect potential future conditions. The future conditions Fraser River inflows and the senior demand downstream of Windy Gap were incorporated in the BESTSM Future Conditions Model, which was then executed for each plan to evaluate the impact on dry-year deliveries or firm yield.
Identification of Potential Elements

This study of the Windy Gap Firming Project began with the identification of potential opportunities that could enhance the dry-year reliability of the Windy Gap water supply. For purposes of this study, each potential opportunity is referred to as an element. Some elements, such as the largest storage elements could form single element plans, but most plans would likely consist of multiple elements, both structural and non-structural. The Phase I studies consisted of two primary steps – identification of possible elements and fatal flaw screening of the elements. The end result was a list of elements that would be used in the subsequent analyses and for forming alternative plans to increase the Windy Gap firm yield.

A broad study area was selected to allow the identification of a comprehensive list of potential elements. The study area encompassed the drainage basins that could reasonably supply water to the existing C-BT collection/distribution system without significant water rights issues, inter-basin water transfers, or costs. The major basins included within the geographic limits were the upper portion of the Colorado River basin on the west slope and the Cache la Poudre River, St. Vrain Creek, Big Thompson River, Upper and Lower Platte River and Clear Creek basins on the east slope. The geographic area was generally bounded by U.S. Highway 285 to the south; the Wyoming-Colorado state line to the north; the Colorado-Nebraska state line to the east; and the junction at the Blue River at Kremmling, Colorado to the west.

Element identification encompassed the reasonable types of elements within the study area that could be applied to the Windy Gap Firming Project. Windy Gap Participants were interviewed regarding current operations and any planned upgrades to facilities. The types of elements identified were categorized as follows:

- Non-structural and institutional opportunities;
- New reservoir sites;
- Existing reservoirs with enlargement potential; and
- Groundwater aquifer storage.

Non-Structural and Institutional Elements

The non-structural elements potentially applicable to firming existing Windy Gap water supplies primarily involve modifications to existing operations or improved integration of the C-BT and Windy Gap systems. Although these alternatives do not rely on significant new structural facilities such as dams and conveyance infrastructure, minor modifications to existing systems might be necessary to coordinate operations. Non-structural elements typically have some type of permitting requirements, but might be implemented faster because they do not rely on major new construction. The types of non-structural elements identified for the WGFP are:

- Unlimited borrowing of storage space from C-BT
- Limited borrowing of storage space from C-BT
- Modifying the Windy Gap Delivery Schedule
- Buying storage from C-BT Shareholders
- Individually operated storage in C-BT facilities
- Interruptible supply contracts
- Purchase/lease back arrangements and dry-year options on C-BT shares
- Integration with Denver Water’s raw water and treated water systems
- West Slope water purchases

New Reservoir Elements

A total of 125 new reservoir sites (element locations) were identified. Most of the sites were located on the East slope (108 sites) with 55 of the sites in the St. Vrain Basin. Eighteen sites were located in both the Cache la Poudre River and Clear Creek Basins. The Big Thompson River Basin contained 11 sites and the Lower South Platte River Basin contained six sites. Seventeen sites were identified on the West slope in the Colorado River Basin. The elements include both on- and off-channel sites and ranged in maximum capacity from 400 ac-ft to 1.96 million ac-ft. Most of the site capacities were estimated between 2,000 ac-ft and 80,000 ac-ft capacity. Twenty-one of the sites could store at least 110,000 ac-ft (the total capacity initially estimated by the Participants if the needed increase in firm yield came only from additional surface water storage).

Existing Reservoirs and Gravel Pit Development

Existing reservoirs with potential for enlargement were identified as potential elements regardless of ownership. Therefore, listing of a reservoir as a potential element does not imply nor guarantee availability, nor does it imply the willingness of the owner to participate in the Windy Gap Firming Project. A total of 31 existing reservoir sites were identified as potential elements for the Windy Gap Firming Project. At least one element was identified in each of the drainage basins, with the majority being within the St. Vrain River Basin.

Aquifer Storage

Aquifer storage and recovery (ASR) involves the placing of surplus surface water underground, for recovery at a later time when supplies are short. While ground water storage and recovery systems have been in operation around the country for many decades, general interest in ASR has intensified nationally, as the need to integrate use of surface water and groundwater resources has intensified. ASR offers a means for balancing supply and demand through the coordinated use of surface and ground
Two types of aquifer storage and recovery options were evaluated as part of this investigation: bedrock aquifers and alluvial aquifers.

**Bedrock Aquifers:** Bedrock aquifer storage and recovery appears to be impractical for this Project, given the hydrogeologic conditions and the annual storage targets. There were no significant bedrock aquifer storage opportunities for most of the participants. The Laramie-Fox Hills aquifer appears to be the only significant bedrock aquifer available to the southernmost participants (Erie, Louisville, Superior and Broomfield) for implementation of aquifer storage and recovery. Yields of existing wells in the Laramie Fox Hills are expected to be low, averaging about 25 gpm per well. Storage volumes achievable with such a system are unlikely to be greater than several hundred acre-feet per year, which is less than 1% of the project need of approximately 100,000 ac-ft.

**Alluvial Aquifers:** Alluvial aquifer storage may provide limited opportunities for the storage and recovery of modest volumes of water – storage volumes of up to several thousand acre-feet per year may be achievable with such a system. However alluvial storage is transient, generally difficult to control and vulnerable to water quality impacts from surface activities. Alluvial aquifer storage may warrant further evaluation, if it is determined in the future that a small program could, in some way, enhance the operational performance of one or more specific plans under consideration.
Phase I Element Screening

The purpose of Phase I screening was to identify elements with major flaws to allow the project team to focus on those elements with the greatest potential of successfully achieving the Project goals. All non-structural elements, groundwater storage opportunities, gravel pits and excavated storage ponds were carried forward as potential elements to Phase II. Exclusion criteria were developed and applied to each new and existing reservoir element on the long list. If an element did not pass any one of the exclusion criteria it was set aside from further consideration. A total of 67 elements were eliminated from further consideration as a result of the Phase I criteria. The remaining elements were carried forward for Phase II evaluations.

In general, several elements in the Cache la Poudre, St. Vrain and Big Thompson basins were screened based on their location in wild and scenic areas, wilderness areas, superfund sites or residential or other developments. All reservoir elements in Clear Creek, excepting Ralston Reservoir enlargement and Leyden Gulch Reservoir, were screened out because the cost and operational logistics of conveying water to and from these sites was judged to be prohibitive. The majority of west slope reservoirs were screened out because of the need to acquire new water rights. The Ralston and Leyden Projects were retained pending discussions with Denver Water about any possible joint use of the sites.

Phase II Element Analysis

In this phase, each element was subjected to qualitative and quantitative evaluations and to assess its suitability for inclusion in one or more plans that meet the goals of the WGFP. The evaluation included both environmental and resource impact issues and physical/technical considerations.

A numerical constraint score for each project element was developed through consideration of a series of land use, natural resource, and other evaluation criteria. Four categories of evaluation criteria were defined:

- Ecological
- Cultural and Visual Resources
- Land Use
- Regulatory

Each category of evaluation criteria typically includes a series of more specific factors. For example, the Land Use Category separately considers various types of land uses such as residential, agricultural, etc. For each evaluation criteria, a sliding scale of resource importance was defined, with higher values assigned to those resources or land uses protected by legislation or otherwise likely to generate controversy or agency and public concern. In addition to resource values, the project's potential degree of conflict was separately considered -- i.e. how would this land use or resource be affected by the project? This two-step process was designed to allow a separate consideration of each category so that a
situation where an important or sensitive resource is present would not automatically result in a high (negative) rating if that resource would not be substantially affected by the project. The overall guidelines for deriving a degree of conflict rating are provided below:

- **High** - Profound effect. Resource value being rated would be eliminated or significantly affected.
- **Moderate** - Moderate effect. Resource value being rated would be measurably affected (e.g. more than one acre).
- **Low** - Little effect.
- **None** - No effect.

After resource values and degree of conflict ratings were determined, an overall constraint rating was determined. By doing this type of analysis for each of the evaluation criteria, an overall score for each project element was derived. Obviously, reservoir sites or project elements with the greatest level of constraint would be those where several high resource values are present and development of the project would result in a high degree conflict with these resources.

Nine non-structural elements primarily involving modifications to existing operations or systems integration were evaluated. These do not rely on significant new structural facilities such as dams and conveyance infrastructure. As a result, environmental impacts and costs associated with these elements are not the key differentiators and the most effective criteria for comparing non-structural elements is potential firm yield. To determine which non-structural elements warranted modeling analyses, each element was evaluated with respect to its ability to firm the Windy Gap water supply. Non-structural elements that do not have the potential to firm the Windy Gap water supply were screened from further evaluation. The potentially beneficial and feasible non-structural elements advanced to Phase III were:

- Unlimited and Limited Borrowing from C-BT and Modifying Windy Gap Delivery Limitations (all involve delivery of C-BT water to Windy Gap allottees in lieu of Windy Gap water); and
- Buying Storage from C-BT Allottees and Individually Operated Storage in C-BT Facilities (all involve purchase of storage or establishing separate storage accounts in existing C-BT facilities such as Granby, Carter Lake and Horsetooth Reservoir).

## Phase III Formulation of Alternative Plans

Wide-ranging plans were formulated and evaluated in Phase III. These plans were based on several evaluation categories including environmental effects and cost. Initially, 18 representative plans were identified consisting of new and existing surface water storage elements. The plans include a broad range of types of storage sites, including new reservoirs and reservoir enlargements on the both sides of the Adams Tunnel. East Slope storage sites are located throughout the Project Participants’ service areas along the Front Range from Broomfield north to nearly Wyoming. The plans include single storage sites and multiple sites. Some plans were formulated because they performed well economically even though they performed only moderately well on environmental factors. Conversely, plans were formulated to
perform well environmentally even if the resulting unit costs per acre-foot of storage were relatively high. Table ES-2 lists the elements and storage volumes comprising these 18 alternative plans.

The bottom of Table ES-2 shows “Primary Formulation Factors.” The “x’s” and footnotes depict the areas or “factors” where each of the plans performed well, or the primary reason why the plan was considered. In summary, of the 18 plans:

- Six were formulated because they performed comparatively well in relation to environmental factors
- One was formulated because it performed comparatively well based on cost.
- Six included both east and west-slope storage
- One was formulated because it provides geographically distributed storage (attempts to place the storage in smaller facilities in proximity to the nine Project Participants)
- Three were formulated using two large east-slope reservoirs that provide illustrative alternatives to Chimney Hollow Reservoir
- One was formulated to provide storage on the northern end of the study area to match the initially anticipated storage needs of the northernmost Participant, PRPA.

It is important to note that this plan formulation process did not result in elimination of individual elements from further consideration. Rather, the process attempts to select the elements with the best characteristics (based on each criterion) and use these elements to formulate comprehensive plans that meet the WGFP needs. If further analysis indicates that one of the selected elements is not suitable for further evaluation, a similar element could be selected from the Phase II list and substituted into a plan. The goal of this process is to select the best elements and alternative plans – not to eliminate elements from any future consideration.

Additional information was developed for each of the 18 plans, including more detailed engineering layouts, a review of cumulative environmental/resource impacts, and estimated capital and operating costs. Initial operational modeling focused on plan performance (especially, average-year and dry-year water deliveries) for general categories of plans. For example, the performance of reservoirs on the west slope was compared with east slope reservoirs. In addition, the performance of east slope reservoirs located in the foothills (near C-BT delivery facilities) was compared with east slope reservoirs located on the plains (distant from C-BT delivery facilities). This information was used to evaluate each plan and compare plans to each other.

Non-structural and institutional elements, especially those related to the interrelationships between Windy Gap and Colorado-Big Thompson project operations, were not included as potential elements in this phase of the plan formulation and analysis because their performance must be quantified based primarily on enhanced yields. Gravel pit storage, alluvial aquifers and small capacity excavated storage were not included as potential elements in the formulated plans. These elements are not expected to account for more than about 10 percent of the total storage needed and were judged to have significant cost impacts to plans. These elements, however, may be feasible elements in addressing short-term needs. Therefore, they may serve well as the initial phase of a plan that may otherwise require a long lead time for
### Table ES-2. Storage Plan Summary (reservoir storage in ac-ft)

<table>
<thead>
<tr>
<th>ID</th>
<th>Element</th>
<th>Plan</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
<th>17</th>
<th>18</th>
</tr>
</thead>
<tbody>
<tr>
<td>102.3</td>
<td>Glade West</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>102.4</td>
<td>Glade East</td>
<td>114,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>Cactus Hill</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>121</td>
<td>Rawhide North</td>
<td></td>
<td></td>
<td>27,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>128</td>
<td>Big Windsor</td>
<td></td>
<td></td>
<td>32,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>Douglass</td>
<td></td>
<td></td>
<td>43,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>Upper Black Hollow</td>
<td></td>
<td></td>
<td>33,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>306.1</td>
<td>Lykins Gulch</td>
<td></td>
<td></td>
<td>27,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>365</td>
<td>Foothills</td>
<td></td>
<td></td>
<td>33,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>367</td>
<td>Left Hand Valley</td>
<td></td>
<td></td>
<td>27,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>372</td>
<td>Beaver</td>
<td></td>
<td></td>
<td>33,100</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>378</td>
<td>Marshall</td>
<td></td>
<td></td>
<td>27,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>401</td>
<td>Little Thompson G,H</td>
<td></td>
<td></td>
<td>30,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>406.1</td>
<td>Lower Chimney Hollow</td>
<td></td>
<td></td>
<td>40,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>410</td>
<td>Carter Lake</td>
<td></td>
<td></td>
<td>40,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>509</td>
<td>Spring Creek</td>
<td></td>
<td></td>
<td>27,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>602.0</td>
<td>Jasper North</td>
<td></td>
<td></td>
<td>36,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>602.1</td>
<td>Jasper North A</td>
<td></td>
<td></td>
<td>36,500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>627.1</td>
<td>Willow Creek A</td>
<td></td>
<td></td>
<td>21,600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>633</td>
<td>Jasper East</td>
<td></td>
<td></td>
<td>21,600</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Plan Storage (ac-ft) | 114,000 | 113,000 | 110,000 | 108,000 | 110,000 | 112,000 | 114,700 | 111,500 | 111,500 | 117,200 | 114,800 | 111,500 | 111,300 | 111,300 | 111,300 | 111,100 | 111,500 | 111,500 | 110,760

**Primary Formulation Factors**: (1) See discussion in text for explanation of “Plan Formulation Factors”.
(2) Large east slope reservoir with enough capacity – illustrative alternative to Chimney Hollow.
(3) Matches northern storage with the preliminary needs of the most northern Participant – PRPA.

(1) See discussion in text for explanation of “Plan Formulation Factors”
(2) Large east slope reservoir with enough capacity – illustrative alternative to Chimney Hollow.
(3) Matches northern storage with the preliminary needs of the most northern Participant – PRPA.
development, or in plans that could be staged to match the Participants’ near- and long-term demands (as these demands become better defined by the Participants and the Subdistrict).

In reviewing the performance of individual elements for inclusion in alternative plans, several general observations were noted, including the following three findings:

1. No elements performed exceedingly well both on cost and resource impacts. A few elements were found to perform reasonably well in satisfying multiple criteria and served as key elements in the plans.

2. A key issue for plains reservoirs is the ease of integrating a new storage facility with existing C-BT project operations. Ease of integration is not just the cost issue of physically connecting potentially remote facilities, it is also a factor in day-to-day flexibility in delivering water to a diverse group of project Participants located across the northern Front Range area of Colorado. The Project’s interaction with the C-BT system must be carefully integrated in average and wet years when the C-BT conveyance and storage systems are operating at, or near, capacity and also in drought years when C-BT and the Participant’s related facilities are potentially operating under reduced flows and pressure gradients. Remote and outlying facilities pose significant reliability issues and concerns in meeting the needs of the Project.

3. Storage west of the Adams Tunnel may enhance the overall storage to yield ratio (and, therefore, reduce the cost) of the Project. This is because Windy Gap diversions can be put immediately into storage without the potential of spilling Windy Gap water from Granby Reservoir when the Adams Tunnel is delivering C-BT water at capacity or is otherwise unavailable due to maintenance or other reasons. However, too much storage west of the Adams Tunnel, while being potentially more cost effective, may impact the reliability of the Project given the length of conveyance facilities needed to deliver water to the nine Participants.

Comparisons of the Alternative Plans

The same evaluation criteria utilized to rank individual project elements were also applied to overall project plans. The results of this analysis are shown in detail in the main report in relation to four categories of criteria: 1) Environmental Resource Rating; 2) Cost; 3) Institutional/Operational Issues; and 4) Staging Potential.

The storage plans discussed in the preceding section were reviewed and compared to one another to identify a short list of plans for a more detailed comparative evaluation. No single element or groups of elements stood out that would constitute obviously preferred plans that satisfied the goals of the project. From the 18 plans, seven plans were selected for the more detailed studies as summarized in Table ES-3.
Figure ES-3: Elements Used in Alternative Plans
Table ES-3. Short List of Alternative Plans

<table>
<thead>
<tr>
<th>Type of Plan</th>
<th>Plan No. and Storage Elements</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>East Slope Storage</td>
<td>Plan 1 – Chimney Hollow</td>
<td>All are single element plans that represent different types of sites – off channel, on channel and plains location, respectively</td>
</tr>
<tr>
<td></td>
<td>Plan 6 – Little Thompson</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Plan 5 – Cactus Hill</td>
<td></td>
</tr>
<tr>
<td>Primary East Slope Storage with supplemental West Slope Storage</td>
<td>Plan 2 – Chimney Hollow and Jasper North A</td>
<td>Chimney Hollow used as the representative east slope storage due to proximity of existing C-BT facilities and ease of distribution to all Participants</td>
</tr>
<tr>
<td></td>
<td>Plan 7 – Jasper North and Rawhide North</td>
<td></td>
</tr>
<tr>
<td>Primary West Slope Storage with supplemental East Slope Storage</td>
<td>Plan 4 – Jasper North and Chimney Hollow</td>
<td>Jasper North is the largest west slope element.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>East Slope Storage with supplemental outlying storage</td>
<td>Plan 3 – Chimney Hollow and Rawhide North</td>
<td>Combination of East Slope supplemental storage with a primary east slope storage</td>
</tr>
</tbody>
</table>

The elements included in the plans in Table ES3 were used in many of the formulated plans or best suited for the type of plan being evaluated. Therefore, they were selected based on ranking criteria as well as being ‘representative’ elements for the different types of plans (See Figure ES-2 Elements Used in Alternative Plans). The intent in this phase of the plan formulation was to evaluate the selected plans with respect to the modeling results and then consider alternative elements that may prove more suitable to the operating plan or replace a selected element that is determined to be less suitable after further evaluation.

The criteria previously utilized in the evaluation of individual elements and the initial 18 plans were expanded to further analyze each plan. The environmental category was expanded to include additional habitat quality parameters. Operations, specific water conveyance routes and pumping requirements, more detailed design layouts of the elements, and a refinement in the capital cost estimates were also included in the evaluations. The additional detail in the environmental evaluation and technical considerations enable a more comprehensive comparison of the selected plans and provide a better understanding of items that could impact any particular plan.

**Operational Analysis**

In addition to the seven plans discussed above, one non-structural element was modeled—buying storage from C-BT allottees. Comparisons of model results were made between the various plans to assess whether there is a significant marginal benefit to having East Slope versus West Slope storage, single or multiple reservoirs. Table ES-4 summarizes key results of the yield analysis under the future conditions scenario with full delivery of C-BT quotas. Chapter 6 of the main report provides additional information on the assumptions and scenarios presented below as well as other scenarios evaluated for each of the storage plans and for the non-structural element.
Assumptions that have a significant impact on results of the operational modeling include:

- Denver Water diversions from the Fraser River through the Moffat Tunnel. The water available for diversion at the Windy Gap Pumping Plant is extremely sensitive to how much water Denver will divert from the upper Fraser River in the future. The future conditions runs used in this study assume that Denver Water will expand east slope storage on its Moffat System and increase demand on that system by 15,000 ac-ft per year. This scenario is consistent with one of the scenarios provided by Denver Water for the UPCO study and was chosen to represent a potential worst-case with respect to Windy Gap. Windy Gap storage-to-firm yield ratios for the future condition are roughly 30% higher than for the baseline condition, which assumes no increases in Denver diversions.

- Interpretation of the Carriage Contract between the Subdistrict, District, and Reclamation. This contract specifies required “shrink” payments from Windy Gap to C-BT. This “shrink” payment requires that 10 percent of the Windy Gap water introduced into C-BT facilities is assigned to C-BT project ownership upon introduction as a condition for the use of C-BT facilities. The results shown in Table ES4 assume that no additional shrink will be paid to C-BT when water from an east-slope reservoir is re-introduced into the C-BT system for delivery.

- Ability to “preposition” C-BT water in a new east slope reservoir to make space available in Granby Reservoir for Windy Gap diversions. Prepositioning involves storing both C-BT and Windy Gap water in an east slope WGFP reservoir. By storing C-BT water in a WGFP reservoir, additional storage space is made available in Granby. As Windy Gap water is stored in Granby, it is transferred to the C-BT account and a commensurate amount of C-BT water in the WGFP reservoir is transferred to Windy Gap accounts.
### Table ES-4. Future Conditions Model Results

<table>
<thead>
<tr>
<th>Plan</th>
<th>Plan Description</th>
<th>Storage (ac-ft)</th>
<th>Units Firmed</th>
<th>Dry-Year Deliveries (ac-ft)</th>
<th>Storage Ratio&lt;sup&gt;1&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>1b</td>
<td>Lower Chimney Hollow</td>
<td>110,000</td>
<td>245</td>
<td>24,500</td>
<td>4.5</td>
</tr>
<tr>
<td>2</td>
<td>Lower Chimney (84,000 ac-ft) &amp; Jasper North Alt. A (36,500 ac-ft)</td>
<td>120,500</td>
<td>285</td>
<td>28,500</td>
<td>4.2</td>
</tr>
<tr>
<td>3b</td>
<td>Lower Chimney (110,000 ac-ft) &amp; Rawhide North (13,000 ac-ft)</td>
<td>123,000</td>
<td>215</td>
<td>21,500</td>
<td>5.7</td>
</tr>
<tr>
<td>4</td>
<td>Lower Chimney (44,500 ac-ft) &amp; Jasper North (79,000 ac-ft)</td>
<td>123,500</td>
<td>285</td>
<td>28,500</td>
<td>4.3</td>
</tr>
<tr>
<td>5</td>
<td>Cactus Hill</td>
<td>111,000</td>
<td>120</td>
<td>12,000</td>
<td>9.3</td>
</tr>
<tr>
<td>6b</td>
<td>Little Thompson</td>
<td>110,000</td>
<td>245</td>
<td>24,500</td>
<td>4.5</td>
</tr>
<tr>
<td>7</td>
<td>Jasper North (79,000 ac-ft) &amp; Rawhide North (13,000 ac-ft)</td>
<td>92,000</td>
<td>190</td>
<td>19,000</td>
<td>4.8</td>
</tr>
<tr>
<td>N/A</td>
<td>Purchase Storage from C-BT</td>
<td>20,000</td>
<td>45</td>
<td>4,500</td>
<td>4.4</td>
</tr>
</tbody>
</table>

<sup>1</sup> Total storage divided by dry-year deliveries

Note: Results presented above are without payment of reintroduction shrink payments to C-BT. Results for Plans 1, 3 and 6 include prepositioning of C-BT water in the WGFP reservoir—all other results are without prepositioning. Storage Ratio is calculated as Storage/Dry-Year Deliveries.

The seven alternatives were formulated in an attempt to fully meet the goals of the WGFP. However, not all alternatives fully satisfy the project goals. The number of Windy Gap units firmed, which is based on dry-year deliveries, varies for each plan depending on the storage ratio. Longmont and PRPA have requested fixed storage capacities of 16,000 ac-ft and 13,000 ac-ft, respectively. The remaining Participants have requested dry-year deliveries for 218 units (21,800 ac-ft/year). Because of the relationship between the storage ratio and the maximum available storage capacity at each site, the following plans cannot fully meet dry-year delivery requirements under the Future Conditions Scenario.

- **Plan 1b, Lower Chimney Hollow (110,000 ac-ft)** – This plan can firm approximately 245 units (65 units for Longmont and PRPA plus 180 of the 218 units owned by the remaining Participants) under the Future Conditions scenario. The plan can firm 305 units (87 units for Longmont and PRPA plus the full 218 units owned by the remaining Participants) under the Baseline Conditions scenario.

- **Plan 3b, Lower Chimney Hollow (110,000 ac-ft) and Rawhide North (13,000 ac-ft)** – This plan can firm approximately 215 units (50 units for Longmont and PRPA plus 165 of the 218 units owned by the remaining Participants) under the Future Conditions scenario. The plan can firm 285 units (67 units for Longmont and PRPA plus the full 218 units owned by the remaining Participants) under the Baseline Conditions scenario.

- **Plan 5, Cactus Hill Reservoir (110,000 ac-ft)** - This plan can firm approximately 120 units (32 units for Longmont and PRPA plus 88 of the 218 units owned by the remaining Participants) under the Future Conditions scenario. The plan can firm 165 units (43 units for Longmont and
Plan 6, Little Thompson (110,000 ac-ft) – This plan can firm approximately 245 units (65 units for Longmont and PRPA plus 180 of the 218 units owned by the remaining Participants) under the Future Conditions scenario. The plan can firm 305 units (87 units for Longmont and PRPA plus the full 218 units owned by the remaining Participants) under the Baseline Conditions scenario.

Plan 7, Jasper North (79,000 ac-ft) and Rawhide North (13,000 ac-ft) – This plan can firm approximately 190 units (60 units for PRPA and Longmont plus 130 units of the 218 units owned by the remaining Participants) under the Future Conditions scenario. The plan can firm 230 units (73 units for Longmont and PRPA plus 157 units owned by the remaining Participants) under the Baseline Conditions scenario.

Chapter 6 of the main report gives more detail on the operational performance of each plan for various scenarios and assumptions.

Plan 1. Lower Chimney Hollow Reservoir

This is a single element plan with storage on the east slope at the Chimney Hollow site. Water could be supplied via the existing Flatiron bypass or a new bypass, with a new pump station at Flatiron Reservoir or through a direct connection to Carter Lake. The plan does not require modifications to existing west slope Windy Gap or C-BT facilities.

The Lower Chimney Hollow site is located in Larimer County approximately five miles southwest of the City of Loveland. The site is in the adjacent valley west of Carter Lake on Chimney Hollow Creek, an intermittent drainage that flows through the site in a northerly direction. The Flatiron Power Plant borders the north end of the site. The largest reservoir and dam considered at the site would cover approximately 950 acres and store about 110,000 ac-ft of water. The only identified option for staging the construction of this plan is phased construction of the dam.

Plan 2. Chimney Hollow and Jasper North (Alternative A) Reservoirs

This plan consists of two elements with storage on the east slope and on the west slope. Water supply to the new east slope reservoir, Chimney Hollow will be as described in Plan 1. The west slope reservoir, Jasper North could receive water from a connection with the Windy Gap pipeline or through a direct connection to Lake Granby. Therefore, some modification to existing west slope Windy Gap or C-BT facilities will be required for this plan.

The location of the Lower Chimney Hollow site is as described under Plan 1. The dam crest elevation and reservoir level would be lowered to provide up to 84,000 ac-ft under this plan.

The Jasper North Alternative A site is a northern adjustment in the dam alignment shown in the Jasper North site identified under Plan 4. It is located in Grand County approximately five miles north of the Town of Granby. The site is about two miles west of Lake Granby. Most of the site is owned by NCWCD and is
currently operated as a working ranch with hay production and livestock grazing. Church Creek flows through the site. The reservoir and dam site would cover approximately 710 acres and have a storage capacity of 36,500 ac-ft of water.

**Plan 3. Chimney Hollow and Rawhide North Reservoirs**

This plan consists of two elements with the primary and supplemental storage on the east slope. Water supply to the primary east slope reservoir, Lower Chimney Hollow, will be as described in Plan 1. Water supply to the secondary storage facility, Rawhide North Reservoir, will be through Horsetooth Reservoir and a new pipeline between the reservoirs.

The Lower Chimney Hollow site is located as described under Plan 1. The Rawhide site is also located in Larimer County three miles west of the Larimer/Weld County line and eleven miles north of the Town of Wellington. The site is three miles west of Interstate 25 and is immediately north of the Rawhide Energy Project site. The site topography is relatively flat to gently rolling hills that would result in a shallow reservoir created by a dam with a long crest length. Vegetation consists of native short grass prairie. An intermittent, poorly defined branch of Coal Creek drains through the site. The reservoir could store up to 39,700 ac-ft of water, however, the capacity evaluated for this plan is only 13,000 ac-ft.

**Plan 4. Jasper North and Chimney Hollow Reservoirs**

This plan is a variation of Plan 2 with the primary storage being located on the West Slope with Chimney Hollow providing supplemental storage on the east slope. Water supply to the new reservoirs will be as described for Plan 2. The Lower Chimney Hollow site is as described under Plan 1. The Jasper North site is as described under Plan 2. The reservoir and dam site would cover approximately 1,080 acres and have a storage capacity of approximately 79,000 ac-ft.

**Plan 5. Cactus Hill**

This plan is a single element plan with storage on the east slope at the Cactus Hill site. No modifications would be required to the existing west slope Windy Gap or C-BT facilities. The Cactus Hill site is located in Weld County one mile east of the Weld/Larimer County line and three miles north of State Highway 14. The site consists of rolling grasslands and cultivated lands. Anheuser Busch owns most of the site and uses it for disposal of waste products from its nearby brewery. Black Hollow Creek flows through the site into Black Hollow Reservoir, which is ¼ mile south of the site. The proposed upper limits of the reservoir would cover approximately 3,050 acres and store 111,800 ac-ft of water. Staging options for this plan are limited to phased construction of the dam.

**Plan 6. Little Thompson Reservoir**

This plan is a single element plan with storage on the east slope and serves as an alternative to Plan 1. The storage site is on the Little Thompson River just upstream of the St. Vrain Supply Canal. It is located
primarily within Larimer County with a small portion of the right shoreline and reservoir just upstream of the dam extending into Boulder County. The site is approximately three miles northeast of the Town of Lyons and four miles north of State Highway 66. The reservoir and dam evaluated for this plan would cover approximately 1,250 acres and store about 110,000 ac-ft of water. Staging potential for this plan is limited to phased construction of the dam and spillway.

Plan 7. Jasper North and Rawhide North Reservoirs

This plan consists of two elements with the primary storage on the west slope and supplemental storage on the east slope. Water supply to the new east slope reservoir will be through Horsetooth Reservoir as in Plan 3. The west slope reservoir is the same as outlined in Plan 4 and will receive water directly from the Windy Gap Pump Station. The east slope reservoir is the same as outlined in Plan 3.

Cost Estimates

Table ES-5 summarizes the cost estimates for each plan, including capital costs for water storage and conveyance facilities and annual operating costs. In addition, equivalent total annual costs were computed by amortizing the capital costs over a 30-yr period at 5% interest. Unit costs are reported for both total storage and firm yield. A 30% contingency for construction and 30% allowance for design and administrative costs (permitting, etc.) were included.

Table ES-5. Cost Summary for Storage Plans

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Capital Costs ($ x Million)$</td>
<td>$199</td>
<td>$231</td>
<td>$241</td>
<td>$199</td>
<td>$91</td>
<td>$63</td>
<td>$148</td>
</tr>
<tr>
<td>Storage</td>
<td>$1,850</td>
<td>$2,050</td>
<td>$2,000</td>
<td>$1,750</td>
<td>$1,700</td>
<td>$1,700</td>
<td>$1,700</td>
</tr>
<tr>
<td>Conveyance</td>
<td>$3</td>
<td>$16</td>
<td>$3</td>
<td>$16</td>
<td>$98</td>
<td>$63</td>
<td>$11</td>
</tr>
<tr>
<td>Total Cost</td>
<td>$202</td>
<td>$247</td>
<td>$244</td>
<td>$215</td>
<td>$189</td>
<td>$193</td>
<td>$159</td>
</tr>
<tr>
<td>Total Storage (ac-ft)</td>
<td>110,000</td>
<td>120,500</td>
<td>123,000</td>
<td>123,500</td>
<td>111,000</td>
<td>110,000</td>
<td>92,000</td>
</tr>
<tr>
<td>Unit Cost ($/ac-ft)</td>
<td>$1,850</td>
<td>$2,050</td>
<td>$2,000</td>
<td>$1,750</td>
<td>$1,700</td>
<td>$1,750</td>
<td>$1,700</td>
</tr>
<tr>
<td>Dry-Year Deliveries (ac-ft)</td>
<td>24,500</td>
<td>28,500</td>
<td>21,500</td>
<td>28,500</td>
<td>12,000</td>
<td>24,500</td>
<td>19,000</td>
</tr>
<tr>
<td>Unit Cost ($/ac-ft)</td>
<td>$8,300</td>
<td>$8,700</td>
<td>$11,400</td>
<td>$7,500</td>
<td>$15,750</td>
<td>$7,900</td>
<td>$8,400</td>
</tr>
<tr>
<td>Annual Costs ($ x Million)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annualized Capital Cost$</td>
<td>$13.1</td>
<td>$16.1</td>
<td>$15.9</td>
<td>$14.0</td>
<td>$12.3</td>
<td>$12.6</td>
<td>$10.3</td>
</tr>
<tr>
<td>Annual Operations</td>
<td>$0.04</td>
<td>$1.1</td>
<td>$0.04</td>
<td>$1.2</td>
<td>$1.8</td>
<td>$1.8</td>
<td>$0.9</td>
</tr>
<tr>
<td>Total Annual Costs</td>
<td>$13.14</td>
<td>$17.2</td>
<td>$15.94</td>
<td>$15.2</td>
<td>$14.1</td>
<td>$14.4</td>
<td>$11.2</td>
</tr>
<tr>
<td>Unit Annual Cost of Dry-Year Deliveries ($/ac-ft)</td>
<td>$540</td>
<td>$600</td>
<td>$740</td>
<td>$540</td>
<td>$1,180</td>
<td>$600</td>
<td>$600</td>
</tr>
</tbody>
</table>
Capital Cost estimates include allowances for construction contingencies, design, administration, legal, environmental permitting and construction management costs.

Amortization: 30 years at 5%.

Environmental Analysis

Each alternative storage plan was evaluated in relation to the following five environmental categories of 1) Ecological; 2) Cultural; 3) Visual; 4) Recreational; and 5) Land Use. The scores ranged from zero to five (with zero being the most favorable; that is, the lower the score, the better the plan’s environmental performance). Scores were totaled for the five categories, but no overall score was computed given the differing numbers of criteria in each of the more general categories (for example, there were six criteria in the ecological category and only one in the cultural category). Therefore, the computation of a total score would have inherently implied that some categories were more important than others. A summary rating of the plans is shown below in Table ES6. Summary Rating of Plans.
### Table ES-6. Summary Environmental Rating of Plans

<table>
<thead>
<tr>
<th>Plan</th>
<th>Ecological</th>
<th>Cultural</th>
<th>Visual</th>
<th>Rec</th>
<th>Land Use</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Overall Habitat Rating</td>
<td>T&amp;E Species</td>
<td>Wetlands</td>
<td>Aquatic Habitat</td>
<td>Fens</td>
</tr>
<tr>
<td>Plan 1. Chimney Hollow</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Plan 2. Chimney Hollow &amp; Jasper North A</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Plan 3. Chimney Hollow &amp; Rawhide North</td>
<td>5</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Plan 4. Jasper North &amp; Chimney Hollow</td>
<td>5</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Plan 5. Cactus Hill</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Plan 6. Little Thompson</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Plan 7. Jasper North &amp; Rawhide North</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: Score shown for multiple element plans is the highest score for any one element or is based on the combined score for those criteria that can be totaled, e.g., total number of wetland acres or residences inundated.
Summary

The Windy Gap Firming Project Alternative Plan Formulation Report identifies more than a hundred non-structural and structural elements and systematically evaluates them based on technical issues, cost, and environmental impact considerations. Seven alternative water storage plans were formulated in an attempt to meet the dry-year delivery or storage goals of the WGFP as follows:

- Longmont and PRPA storage of 16,000 ac-ft and 13,000 ac-ft, respectively, regardless of storage ratio; and
- Remaining Participants dry year deliveries for 218 units or 21,800 ac-ft/yr.

The estimated cost and firm yield resulting from each are summarized in Table ES6. Summary Rating of Plans.

Not all of the plans fully satisfy the WGFP goals. Only Plans 2 and 4 (both include west slope storage) are able to make full dry-year deliveries in the Future Conditions scenario.

The ability to make full dry-year deliveries for the other plans (Plans 1, 3, 5, 6, and 7) is limited by combined storage capacity, operational constraints, and the available Windy Gap supply. Plan 1 (Chimney Hollow), Plan 3 (Chimney Hollow and Rawhide North), and Plan 6 (Little Thompson) are able, however, to make full dry-year deliveries under the Baseline Conditions scenario.

Each of the seven plans could be combined with non-structural measures, gravel pit storage, or excavated storage to provide additional delivery capacity or to provide a first stage project element that may be implemented sooner than the primary storage element.

The next step in the project is for the Participants to select a proposed alternative plan and initiate the federal permitting process. This report provides technical background for the Participants to make the selection. The final selection of a proposed alternative must be made by the Subdistrict and Participants after careful consideration of the information in this report and additional factors, including:

- **Baseline Condition vs. Future Condition.** Each Participant has a different water rights portfolio and some Participants may consider a project that can provide full dry-year deliveries under the Baseline Condition, but not in the Future Condition, to be acceptable. The selected alternative may be sized as a “hybrid” of the future conditions and baseline conditions.

- **Future Fraser River Basin Diversions.** The availability of water for diversion at the Windy Gap pumps in the future condition is directly related to an estimate of future Denver Water diversions from the Fraser River. Denver’s plans on the Fraser River will be reviewed in more detail, and that information will be provided to Participants to help select an alternative.

- **Carriage Contract Assumptions.** Assumptions made in the model regarding re-introduction shrink and pre-positioning are under review and should be carefully considered when selecting an alternative.