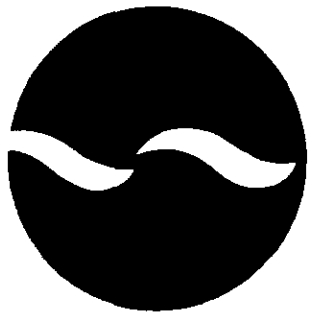
Metropolitan Water Supply Investigation
Final Report

Report to the
Colorado Water Conservation Board

January 1999

Hydrosphere Resource Consultants, Inc.
HRS Water Consultants, Inc.
Mulhern MRE, Inc.
Spronk Water Engineers, Inc.



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LIST OF ABBREVIATIONS AND ACRONYMS

CBT	Colorado-Big Thompson Project
cfs	cubic feet per second
Convention	Colorado Water Convention
CWCB	Colorado Water Conservation Board
DCWRA	Douglas County Water Resource Authority
EIS	Environmental Impact Statement
EPA	U.S. Environmental Protection Agency
FRICO	Farmers Reservoir and Irrigation Company
IRP	Integrated Resource Planning Process
MWSI	Metropolitan Water Supply Investigation
PACSM	Platte and Colorado Simulation Model
PMT	Project Management Team
POS	Plan of Study
SACWSD	South Adams County Water and Sanitation Department
SRCAS	Southern Regional Cooperative Action Study
TAC	Technical Advisory Committee

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Executive Summary

The Metropolitan Water Supply Investigation (MWSI) was initiated by Governor Romer and the Colorado General Assembly in 1993 to explore cooperative solutions to future metropolitan Denver area water supply needs that would minimize the conflicts often associated with development of large scale water supply infrastructure such as transbasin diversion projects. The primary focus of the MWSI was the analysis of supply-side options involving the cooperative use, operation and/or linkage of existing water supply systems in a manner that would enhance water yields. By design, the MWSI did not explore new water development projects involving significant new infrastructure, nor did it examine the potential savings from additional water conservation programs.

The MWSI identified and evaluated cooperative water supply options in four primary categories:

- **conjunctive use**
- **effluent management**
- **interruptible supply arrangements**
- **other system integration opportunities**

The MWSI demonstrates that cooperative water supply options exist with respect to conjunctive use, effluent management, and other system integration opportunities to help meet a large part of the anticipated future needs in the major geographic sub-regions[1] of the metropolitan Denver area. For several reasons, interruptible supply arrangements between farmers and cities appear less promising at this point in time.

The cooperative options, as examined in this investigation, would not require construction of new transbasin diversion facilities, though additional transbasin diversions using existing facilities and water rights could be necessary to fully realize the potential of conjunctive use in the South metro sub-region and other system integration options available to the Northwest metro sub-region. Reusable return flows associated with increased transmountian diversions in turn help to expand cooperative options in the area of effluent management. Improvements to the existing water storage and distribution infrastructure serving the metropolitan area would be necessary, but such improvements would not entail major new on-stream reservoirs.

[1] For purposes of understanding how cooperative water supply options can function, the metro Denver area is best viewed as a collection of geographic sub-regions defined by their primary sources of supply. These sub-regions are referred to in this report as the Denver Central, the South metro, the City of Aurora, Northeast metro, and Northwest metro. Cooperative water supply options vary between sub-regions due to each region's unique water supplies and water development history.

While each water supply category evaluated in the MWSI appears to present significant, technically feasible cooperative opportunities, each also raises several issues that present serious obstacles to implementation without considerable additional work.

The table below summarizes the MWSI's findings.

Cooperative Supply Category	Supply or Yield Potential	Actions Items/Unresolved Issues
Conjunctive Use	up to 60,000 acre-feet of surface water yield under example project analyzed	South Platte and Blue River stream depletions Water right constraints Feasibility of long-term, large scale recharge IGA's among participants Balancing groundwater depletions with increased use of surface waters
Effluent	up to 120,000 acre-feet of excess reusable return flows; specific project yields were not investigated	Relatively high costs Public acceptance of potable reuse Effects of exchanges on water quality Effects on instream flows
Interruptible Supply	up to 190,000 acre-feet of interruptible supply; specific project yields were not investigated	Would require major institutional changes Impacts to agricultural communities Geographic/cost considerations
Other System Integration Opportunities	up to 20,000 acre-feet of yield under example projects analyzed	Water right constraints IGA's among participants Federal action (Chatfield storage reallocation)

COOPERATIVE WATER SUPPLY OPPORTUNITIES

Conjunctive Use would involve the linkage of groundwater systems currently serving communities in parts of Douglas and Arapahoe counties with the Denver Water system. Water available from the Denver system in average and wet years could be used to meet demands and for recharge of Denver Basin aquifers. Groundwater sources would be used to meet demands not fully satisfied by surface water sources and during periods of drought. For the example project analyzed, conjunctive use arrangements could yield up to 60,000 acre-feet per year to meet new demands or reduce existing groundwater pumping from the Denver Basin aquifers.

Conjunctive use presents a promising solution to continued dependence upon non-renewable groundwater resources by the growing communities in the South metro sub-region. Conjunctive use also raises several unresolved questions. To the extent that a conjunctive use project would rely on additional transmountain diversions from existing facilities and water rights, this would raise objections from West Slope interests. However, the operational flexibility inherent in a conjunctive use project could allow for mitigation of some impacts while still generating significant yield. Other issues and uncertainties associated with conjunctive use include changes in water rights, the feasibility of large-scale recharge over the long term, and the challenges associated with securing required intergovernmental cooperation among potential conjunctive use participants.

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Effluent Management involves cooperative and coordinated approaches for utilizing metro Denver area providers' reusable return flows. The metro Denver area currently generates reusable return flows in excess of its current reuse needs of approximately 80,000 acre-feet per year. These undeveloped reusable return flows are projected to increase to more than 120,000 acre-feet per year under providers' current plans as the metro Denver area grows.

Significant cooperative effluent management opportunities exist in all of the metro Denver area sub-regions. However, full use of reusable return flows would eventually require development of additional storage below the Metro wastewater plant and extensive implementation of potable reuse. Relatively high costs, public acceptance, intergovernmental coordination, and effects on water quality and instream flows also are issues of concern.

Interruptible Supply would involve cooperative arrangements with agricultural water users along the Front Range that would give cities the right to use agricultural water during times of drought in exchange for financial compensation to farmers. This report provides an overview of possible types of interruptible supply arrangements, estimates of gross supply potential, and discussion of perceived barriers to implementation. The total amount of dry year, high quality water supply potentially available for interruptible supply arrangements is approximately 190,000 acre-feet. This supply estimate does not reflect the potential competing needs of long-term (beyond 2020) future growth in the Northern Front Range. Example projects involving this source and specific project yields were not investigated.

During the course of analysis, awareness of major legal, institutional, political, geographical, and infrastructure barriers to using this supply in the metro Denver area emerged. These barriers exist for each of the cooperative water supply categories evaluated in the MWSI, but are especially pronounced and evident with respect to the Interruptible Supply category. Without additional work and dialogue between the metro Denver area and northern Front Range farmers and communities over the next three to five years, interruptible supply arrangements do not appear to be promising water supply options for the metro Denver area at this time.

Other Systems Integration Opportunities identified in the process of conducting the MWSI are the focus of ongoing studies involving the Northeast and Northwest sub-regions and Chatfield Reservoir. Other cooperative approaches identified but not investigated include possible development of joint storage for regulation of supply from the Windy Gap and Moffat systems, and creation of a market for water saved through conservation initiatives. These ideas will likely be the subjects of future investigations by interested parties.

THE BROADER BENEFITS OF THE COLLABORATIVE MWSI PROCESS

The MWSI has been both a technical evaluation of cooperative water supply opportunities and a continuing process of dialogue, mutual education, joint inquiry, and collaboration among over 60 Front Range water providers and representatives of other key stakeholders including environmental organizations, agriculture and the West Slope. While this diverse group has focused principally on the opportunities and limitations associated with the four cooperative water supply categories, participants also developed and shared considerable information regarding the future water needs of the metro Denver area and individual water providers' plans that are in place for meeting those needs.

This information, summarized in the table and text below by sub-region, provides valuable context that enhances understanding of the roles and benefits of the cooperative water supply opportunities evaluated through the MWSI.

Sub-region	Projected Future Water Demand, AF	Basis of Projection	Reasonably Certain Future Supply, AF (1)	Future Unmet Needs, AF (2)	Applicable Cooperative Supply Opportunities (3)
Denver Central Sub-region	454,000 (4)	build-out	410,000	14,000 to 44,000 (5)	conjunctive use with South sub-region, effluent management with Northeast sub-region, system integration with Northwest sub-region and Aurora
South Metro Sub-region	127,000	build-out	127,000	0	conjunctive use with Denver, effluent management within Cherry and Plum Creek basins
City of Aurora	105,000 (6)	2030	75,000	30,000 (6)	effluent management with Northeast sub-region, coordinated reservoir operations with Denver
Northeast Metro Sub-region	125,000	build-out	61,000 to 100,000 (7)	25,000 to 64,000 (7)	system integration and effluent management among Denver, Aurora, Brighton, South Adams County WSD, Thornton and the Barr Lake companies
Northwest Metro Sub-region	100,000	build-out	90,000	10,000	system integration with Denver, effluent management within Clear Creek and Big Dry Creek basins
Total	911,000		763,000 to 802,000	79,000 to 148,000	

(1) Based on their planning efforts to date, water providers have a relatively high degree of confidence in these supplies.
(2) Providers have a relatively lower degree of confidence in their plans to meet these needs, based on uncertainty factors and the comparatively longer time frames before these supplies would be needed.
(3) Cooperative supply opportunities could be used to meet future unmet needs or as an alternative to reasonably certain future supplies.
(4) Includes Denver Water and Englewood; includes Denver Water's 30,000 AF safety factor.
(5) Based on the expected range of Denver Water's future safety factor.
(6) Includes Aurora's 10,000 AF planning reserve.
(7) Depending on the degree of implementation of Thornton's Northern Project.

The table illustrates that most Denver area water providers have planned for the future very well and currently have strategies in place to meet projected water needs to the year 2030 and in some cases considerably beyond that date. As described further below, the cooperative water supply opportunities evaluated in the MWSI could supplement or partially replace the plans individual water providers already have in place.

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The Denver Central Sub-region is comprised of the Denver Water Combined Service Area, including the City and County of Denver, 75 fully dependent contract providers, and over 20 partial supply contracts; the City of Englewood; and other small providers in the Bear Creek basin. The main sources of supply available to the this sub-region consist of native South Platte River water, transmountain diversions from the Blue, Fraser and Williams Fork Basins and water reuse. Non-tributary groundwater is available but not used to any significant degree. Water conservation measures also are in place and serve to reduce demand.

Denver's Near Term resource strategy, as developed in its Integrated Resource Planning process, is projected to yield 401,000 acre-feet compared to a raw water demand at build-out of 445,000 acre-feet, including a 30,000 acre-foot safety factor. Assuming that Denver is successful in implementing its Near Term strategies, Denver has a remaining need of 14,000 acre-feet to 44,000 acre-feet, depending on its safety factor. Denver anticipates meeting this remaining need through additional water conservation, potable reuse and development of additional supplies through the use of its water rights, which could be achieved by Denver alone or through cooperative actions with others. Denver has sufficient potential yield from its own water rights to meet its build-out needs and obligations. Denver has not yet chosen a specific long-term water supply strategy, and remains interested in additional water conservation, effluent management, conjunctive use, and additional surface storage to meet its long-term needs.

The City of Englewood, included in this sub-region, does not anticipate significant growth in its water demands and has sufficient existing water supplies to meet its ultimate future water needs, projected to be about 8,500 acre-feet per year.

The South Metro Sub-region includes the water provider members of the Douglas County Water Resource Authority[2] and other small providers in Douglas and Arapahoe Counties. Throughout this sub-region, Denver Basin groundwater is the primary source of supply.

The build-out water demands for this sub-region are projected to total about 127,000 acre-feet per year (exclusive of those providers supplied by Denver and Aurora). Water providers in this sub-region have sufficient decreed groundwater rights, surface supplies, reuse/augmentation plans and contract deliveries to meet their projected build-out needs. There is no significant unmet need projected for this sub-region, assuming that Denver Basin groundwater will continue to be used as a major water supply source.

However, the sub-region is actively working to increase the renewable portion of its water supplies by employing effluent management approaches that would maximize the reuse of its groundwater return flows, and by acquiring additional surface supplies. The

[2] The water provider members of the Douglas County Water Resource Authority include Arapahoe County Water & Wastewater Authority, Centennial Water & Sanitation District, Parker Water & Sanitation District, East Cherry Creek Valley Water & Sanitation District, Town of Castle Rock, Roxborough Park Water & Sanitation District, Stonegate Village Metro District, Inverness Water & Sanitation District, Meridian Metro District, Castle Pines Metro District, Castle Pines North Metro District, Cottonwood Water & Sanitation District, North Douglas County Water & Sanitation District, Pinery Water & Sanitation District, Donala Water District and Willows Water District

region is particularly interested in expanding the roles of reuse and conjunctive use of surface and groundwater as ways to reduce its future use of Denver Basin groundwater.

The City of Aurora currently meets its water needs through a combination of changed irrigation rights, transmountain diversions, alluvial and nontributary wells, water reuse and water conservation.

Aurora has not yet projected an ultimate or build-out demand for its service area. Instead, Aurora anticipates future population growth to average 50,000 people per decade with an associated increase in water demands of 10,000 acre-feet per decade. Aurora therefore projects a total water demand of 95,000 acre-feet by the year 2030. Aurora has plans in place to meet its projected year 2010 demands with acquired Arkansas basin agricultural rights, additional effluent reuse, rehabilitation of its Cherry Creek alluvial wells, and other minor projects.

Aurora's plans for meeting its needs beyond the year 2010 include the Eagle River Conjunctive Use Project (in cooperation with the City of Colorado Springs), the South Park Conjunctive Use Project, and additional water reuse. Aurora is participating in cooperative planning activities of effluent management in the Northeast Metro sub-region described below. Aurora is also working with Denver Water to explore cooperative opportunities involving those entities' existing South Platte reservoirs.

The Northeast Metro Sub-region includes Thornton, South Adams County Water & Sanitation District and Brighton. Also included in this sub-region are the irrigation companies associated with the Burlington Ditch/Barr Lake system (the Barr Lake Companies). The water supply sources currently available to municipal providers in this sub-region include municipal and changed irrigation rights on the South Platte and Clear Creek, alluvial and nontributary wells, and exchange rights.

The long-term municipal water demands for this sub-region are projected to be about 125,000 acre-feet per year. Most of this demand is associated with the build-out demands of the City of Thornton. Providers in this sub-region have plans in place to meet between 60,000 to 100,000 acre-feet of this need. This range is due to uncertainties about the ultimate degree of implementation and associated yield of Thornton's Northern Project.

Current planning efforts are focused on meeting 20,000 to 40,000 acre-feet of the remaining needs for this area, which are primarily associated with anticipated growth in Brighton and the South Adams County Water and Sanitation District. Denver and Aurora are also involved in these planning efforts because of their interest in water reuse opportunities and because portions of their service areas are located in this sub-region. Current planning efforts are focused on development of storage facilities, maximizing exchanges and finding uses for Aurora's and Denver Water's presently undeveloped supplies of reusable effluent. Providers are particularly interested in addressing water quality problems associated with municipal diversions located downstream of most of the urbanized metro Denver area. Options under consideration include development of additional gravel pit storage capacity and use of storage capacity in Barr Lake and the Beebe Draw under cooperative arrangements with the Barr Lake Companies.

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The Northwest Metro Sub-region includes Arvada, Broomfield, the Consolidated Mutual Water Company, Golden, Northglenn, Westminster and other small providers in the Clear Creek basin. The water supply sources currently available to this sub-region consist primarily of Clear Creek municipal rights and changed irrigation rights and partial service contracts with Denver Water, which are mostly satisfied via deliveries from the Moffat Tunnel Collection System.

The long-term water demands for this sub-region are projected to be about 100,000 acre-feet per year. Most of the sub-region's projected increase in water demand is associated with anticipated growth in Arvada and Broomfield. Providers in this sub-region have plans in place to meet about 90,000 acre-feet of this need. Cooperative planning efforts for meeting the remaining 10,000 acre-feet of need in this sub-region are focused upon coordinated use and sharing of existing or new storage and conveyance facilities and expanded reuse.

Within each of these sub-regions, cooperative water supply approaches could play an important role in meeting future water supply needs in a manner that could potentially reduce the costs and environmental permitting risks associated with other options.

RECOMMENDATIONS

1. It is recommended that a continuing state-sponsored cooperative supply planning forum be established.

The MWSI has improved communication, mutual understanding and cooperation between metro Denver area water providers, West Slope interests and environmental interests. Is has resulted in several ongoing collaborative studies which are designed to increase water supplies in mutually acceptable ways. It has also had a major effect upon other ongoing planning efforts addressing issues of critical importance to the metro Denver area's water supplies. These include:

- Quadrant investigations of various cooperative water supply opportunities
- The Platte River Cooperative Agreement and EIS process
- The Upper Colorado River Basin Study
- The Colorado River Endangered Fish Species Water Availability Study
- The Chatfield Reservoir Reallocation Feasibility Study
- The USFS's South Platte Wild & Scenic Study and associated negotiations.
- The Northern Regional Water Coalition's investigation of long-term future M&I water needs of the Northern Front Range

These studies and planning efforts are proceeding independently, but are highly interrelated and deal with complex issues that affect numerous parties. It is therefore recommended that a continuing state-sponsored forum be established to serve the following functions:

- Coordination and integration among interested parties regarding these interrelated studies and planning efforts.
- Provide an opportunity for parity to be maintained between large and small providers and other interest groups; facilitate open discussion and resolution of issues and concerns, thereby reducing the potential for litigation
- A forum for addressing State policy issues and access to state agency technical expertise
- An opportunity for regular and periodic updating of the MWSI database

This may be best accomplished by regular periodic meetings convened by an appropriate state agency such as the Colorado Water Conservation Board.

2. It is recommended that the MWSI database be periodically updated through a state-coordinated effort as part of the continuing state-sponsored forum.

The MWSI has resulted in development of a relatively comprehensive and detailed database base on metro Denver water supply providers and their water supply systems. This database has improved the understanding of the overall operation and interplay between metro area water supply systems and the status of individual providers' planning efforts. For example, information from this database was used to formulate Colorado's Plan for Future Depletions pursuant to the Platte River Cooperative Agreement. This database should be maintained and periodically updated so that it continues to be useful for cooperative municipal water supply planning and assessment of regional and basin-wide issues. Ultimately this database should be incorporated into the South Platte Decision Support System.

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1. Introduction

1.1. PREFACE

This report documents the Metropolitan Water Supply Investigation (MWSI) which was initiated in the fall of 1993 following authorization of the investigation by the Colorado General Assembly and formation of the Front Range Water Forum under an Executive Order (see Appendix 1) issued by Governor Roy Romer. The results of the MWSI can be characterized as consisting of two critical elements:

1) The establishment of a process and practice of cooperative technical collaboration and communication between metro Denver area water providers; and

2) The preliminary investigation of several potential cooperative water supply opportunities.

The MWSI was intended to encourage discussions and provide technical support for cooperative water supply initiatives in a manner that would be complementary to and compatible with the water supply planning efforts of individual water providers. The MWSI was not intended to substitute for or compete with these individual efforts.

It is important to note that the water supply opportunities discussed in this report involve the use of facilities and water rights that are currently owned by individual water providers, and in most cases would affect other water-dependent interests. Implementation of any of these water supply opportunities would be at the discretion of the relevant entities and would depend upon voluntary cooperation between affected parties.

Several of the cooperative water supply opportunities described in this report are the subject of more detailed ongoing investigations of technical, environmental and institutional issues. Specifically, these efforts include:

1. The Southern Regional Cooperative Action Study, which is examining the hydrologic and operational aspects of conjunctive use of surface and groundwater systems in southern parts of the metro area. Phase 1 of this Study has been completed.
2. The Northeast Regional Cooperative Action Study, which is examining the operational, water rights and hydrologic aspects of a cooperative regional potable water supply project in the northeast quadrant of the metro area.
3. The Northwest Regional Cooperative Action Study, which is examining options for integrated management of storage and conveyance facilities in the northwest quadrant of the metro area, including reservoir enlargements and new storage.

These investigations are described in Section 3.2.4.3, Systems Integration Study Results of this report and in Appendix 7.

The information provided in this report should be useful to local, state and federal officials and the general public in understanding the possibilities and limitations associated with cooperative water supply planning for the metro Denver region. The authors believe that the information provided in this report and the Executive Summary will be useful in the following ways:

- As a background and educational document for state and local officials that may not be directly involved in water supply planning and development;
- As a preliminary investigation for use by water providers in their evaluation of water supply opportunities;
- As a reference document and point of departure for future investigations; and
- As a reference document for other interested parties that could be involved in or impacted by the implementation of the subject water supply options (e.g. environmental organizations, western slope interests, federal and state permitting agencies).

1.2. BACKGROUND

In January of 1993, Governor Roy Romer and the Colorado Department of Natural Resources convened the first Colorado Water Convention. The Convention focused on issues related to Front Range water supply planning and interbasin transfers of water.

The Governor voiced deep concerns about the heavy economic and social costs of "water supply planning through litigation." He cited the fact that over $80 million had been spent in unsuccessful litigation and permitting efforts by various water interests in the previous decade, including Two Forks, Union Park, AWDI and others.

The Governor also spoke about concerns and controversy associated with transmountain diversions. Others emphasized the potential adverse effects of exports on local communities and their water supplies, water quality, water-based recreation and environmental values. Some participants spoke of the need for new legislative protection for basins of origin against further exports of water.

Discussion at the Convention suggested that a cooperative approach to water supply planning, focusing on better use of already-developed water supply systems, may be needed; that only by being sensitive to multiple perspectives could workable ideas emerge; that further sacrifice on the part of West Slope, agricultural and environmental interests could not reasonably be expected until the metro Denver area had first "put its own house in order" through more reliance on water conservation, reuse, conjunctive use, and other means of full and efficient utilization of existing systems.

The Convention also focused on a "systems integration" approach to water supply planning. This approach envisioned a cooperative and inclusive water supply planning process to supplement the ongoing effort of individual water providers. Several potential water supply options were highlighted including the proposed Barr Lake Plan, the Northern Colorado Water Conservancy District's Southern Water Supply Pipeline, conjunctive use of surface and groundwater, interconnection and coordinated operation of individual water supply systems, pooling and sharing of supplies, and regional management of systems.

Many conference participants felt that the State of Colorado could fill a unique role in advancing cooperative water supply solutions by acting as a facilitator and coordinator, offering the technical expertise available within state agencies, and providing financial support.

1.3. MWSI ORIGINS AND OBJECTIVES

Conference participants' overall response to the cooperative possibilities raised was generally positive. Based on this response, the MWSI was initiated under the joint leadership of the State Legislature and the Governor. The 1993 Session of the General Assembly authorized the Colorado Water Conservation Board (CWCB) to spend up to $450,000 to investigate opportunities for enhanced coordination in meeting the water supply needs of the metropolitan Denver area.

During the summer of 1993 the Colorado Department of Natural Resources formulated a preliminary scope of study for the MWSI. This scope of study targeted three specific water supply opportunities:

1. The Barr Lake Plan, as suggested by the owners of the Burlington Ditch system that serves agricultural lands to the northeast of the metro Denver area;
2. Integration of the water supply systems of the metro Denver area and the northern Front Range via the Northern Colorado Water Conservancy District's proposed Southern Water Supply Pipeline; and
3. Conjunctive use of non-tributary Denver Basin groundwater with surface water supplies systems.

The overall focus of the investigation was to be a cooperative analysis of these supply side opportunities. The preliminary scope of study did not include projections of future water demands, which had been addressed in previous studies including the Metropolitan Denver Water Supply Environmental Impact Statement. Also excluded from the MWSI's scope of study were investigations of new water development projects or of the potential of additional water conservation savings. It was felt that these topics had already been studied in prior efforts.

As originally conceived, the MWSI was expected to achieve three primary objectives:

1. Development of a technically facilitated planning process designed to foster collaborative planning efforts among water users while taking advantage of existing areas of information and expertise;
2. Development of sufficient analytical capability to evaluate the water supply yield and operational aspects of a variety of relatively complex water supply opportunities; and
3. Conduct the specific technical investigations as needed for evaluation of a Barr Lake Plan, the Southern Water Supply Project, and the conjunctive use of non-tributary groundwater and surface water supply systems.

As the investigation evolved, these objectives were refined and modified as described in Section 2, MWSI Process and Scoping.

By December of 1993 the state retained a team of consultants led by Hydrosphere Resource Consultants, Inc. to manage and carry out the technical investigations. The consulting team also included ECI, Inc., HRS Water Consultants, Inc., Mulhern MRE, Inc. and Spronk Water Engineers, Inc.

2. MWSI Process

2.1. MANAGEMENT

In October of 1993, Governor Roy Romer issued an Executive Order (Appendix 1) creating the Front Range Water Forum, comprised primarily of elected officials, water managers, and community leaders from the Front Range and the West Slope. Forum members were asked to nominate representatives to serve on a Technical Advisory Committee (TAC). The Governor, the Colorado Water Conservation Board and several key state legislators encouraged the Forum and the TAC to take leadership roles in the MWSI. The Forum's role was to consider any public policy issues that might arise from the investigation, while the TAC was charged with technical oversight and guidance of the investigations. The TAC consisted primarily of members with expertise in metro Denver area water supply systems and water issues. The TAC directed the initial scoping of the investigations, provided technical guidance during the investigations and facilitated collection of information.

The Governor's Executive Order also directed the Executive Director of the Department of Natural Resources to appoint a Project Management Team (PMT) consisting of representatives from state agencies having interest or expertise in the subject matter of the investigation. The PMT originally included representatives from the Colorado Water Conservation Board, the Colorado Division of Water Resources, the Colorado Division of Wildlife, the Colorado Division of Parks and Outdoor Recreation, the Colorado Department of Public Health and Environment and the Colorado Department of Agriculture. The primary purpose of the PMT was contract administration and coordination of the State's involvement in the MWSI process. The PMT was later restructured to include several key TAC members in order to serve as a TAC steering committee.

Members of the Front Range Water Forum are listed in Appendix 2, Technical Advisory Committee Members are listed in Appendix 3 and Project Management Team Members are listed in Appendix 4.

2.2. MWSI PHASES

As originally conceived, the MWSI was to be implemented in four relatively conventional planning phases designed to define specific objectives, gather data, develop a modeling capability, and evaluate promising water supply options.

1. Scoping (Phase I) - The purpose of this phase was to specifically define study objectives and work tasks. In addition, the Scoping phase was to identify data needs, data sources, and the technical issues to be addressed.

2. Information Development (Phase II) - This phase was designed to inventory and gather relevant information and data and evaluate the analytical tools available for analysis of water supply options. In addition, this phase included the initial formulation, refinement and screening of targeted cooperative water supply opportunities.
3. Modeling (Phase III) - This study phase was to develop the analytical capability needed to evaluate the individual and combined yield potential and operational aspects of a variety of water supply options including the targeted opportunities.
4. Opportunities Evaluation (Phase IV) - This phase was to investigate the water supply options coming out of Phases II and III in terms of their yield and operational implications, facilities requirements and costs, potential environmental impacts and potential institutional issues.

2.2.1. Phase I Scoping

During the Scoping phase of the MWSI, it became apparent that most TAC members were uncomfortable with the process of cooperative planning involving numerous parties. It was felt that this tension came from a combination of factors including a history of competition among water providers for limited supply; suspicions about possible state "hidden agendas" in the MWSI; uncertainties about how to structure and conduct cooperative planning efforts that focused on existing systems; turf issues such as the need to protect existing supplies; and uncertainties about how the results of cooperative water supply planning would be used.

Because of these factors, the TAC recommended that the MWSI emphasize the process, discussions and information gathering necessary to establish and improve working relationships, and not "target" specific water supply projects for study. This required an incremental approach that would allow TAC members to exchange "comfortable" levels of information about their respective water supply systems, identify and understand each others' issues and concerns, and evaluate cooperative planning opportunities on a gradual and incremental basis. Although this process would require more time than expected, it was expected to produce valuable working relationships and, accordingly, was judged to be a worthwhile investment.

At a two day retreat held in April 1994, TAC members agreed that their primary mission would be to assist and guide state agencies and consultants in the selection and analysis of opportunities to achieve better coordination of existing water supply systems. The TAC also agreed to assist in communicating the status of the MWSI to Forum members and other interested parties and to serve as a clearinghouse for the exchange of information and ideas between its members, state agencies and the consultant team.

During the retreat the TAC agreed that the MWSI should focus on four broad conceptual categories of water supply options: conjunctive use; effluent management; interruptible supply arrangements; and other systems integration opportunities. TAC work groups

were established to develop scopes of work, coordinate information gathering efforts, and oversee the consulting team's efforts in each of these areas. Later in the process, a fifth work group was established to oversee efforts related to the possible use of Chatfield Reservoir for water supply storage purposes. Members of each work group are listed in Appendix 5.

These conceptual water supply categories are described as follows:

- **Conjunctive Use** – This category is defined to include arrangements which would achieve coordinated use of the metro Denver region's surface systems and groundwater systems in a manner that would allow more efficient use of each resource than could be attained by separate and independent use.
- **Effluent Management** – This category focuses on ways to increase regional water supplies through reuse and exchanges of reusable effluent in a manner that would be compatible with the water quality management plans of the Metro Wastewater Reclamation District and others.
- **Interruptible Supply Arrangements** – This category involves ways to achieve voluntary short-term transfers of water supplies, such as those associated with agricultural, industrial, and instream flow water rights, to meet municipal needs in times of shortage, without permanent reallocation of water uses.
- **Other Systems Integration Ideas**– This was originally designed as a "catch-all" category to allow for ongoing brainstorming efforts by the TAC and exploration of promising ideas that might emerge from discussions regarding the first three categories. Work within this category included developing information, maps and tools to facilitate discussions and brainstorming sessions regarding possible linkage of water supply and distribution systems so as to more fully utilize regional water supplies. Part of this effort was to assist the consulting team in coordinating the efforts of the other work groups and in identifying areas of overlap.

In order to enhance the level of trust and working relationships between its members, the TAC informally agreed to discussion ground rules as summarized below.

- Members would seek to identify and involve all interested stakeholders;
- Members would identify and communicate issues and concerns as early in the process as possible;
- Agreement to study certain options would not commit anyone to implementation of such options;
- Public representation of any TAC position would not be permitted without review and approval of the entire group;
- Work products would be drafted by small groups followed by review and comment by the entire group;
- Opinions expressed by TAC members would be considered as individual opinions, not for attribution, and not assumed to be the position of any agency unless expressly identified as such;

- Effort would be made to work toward group consensus, with fallback to consensus among affected parties; and
- The Assistant Director of the Colorado Department of Natural Resources, would serve as the primary point of contact with the news media.

The Phase I scoping process was completed in August of 1994 with TAC approval of a Phase II Plan of Study (POS). The Phase II POS included an extensive inventory of existing information, formulation of water supply options under four conceptual categories of water supply sources, and development of a Phase III POS.

An important element of the POS related to the formulation of water supply options was the TAC's desire that the early phases of the MWSI not be unduly constrained by legal and institutional barriers to possible opportunities. This was intended to encourage creative thinking and brainstorming about the technical feasibility of various options. The TAC recognized that there could be potential legal and institutional barriers associated with all four categories of sources, and the POS included efforts to identify and disclose these issues.

The TAC also decided that the objectives of the MWSI's original modeling phase (Phase III) might be best met by taking advantage of existing models in order to minimize new model development efforts. The TAC included an inventory of available modeling tools as part of the MWSI's Phase II POS.

It was also determined that the MWSI would not involve the development of new water demand forecasts but would instead rely upon previous studies such as the Denver Metropolitan Water Supply EIS and forecasts developed by individual water providers.

The TAC's selection of categories of water supply sources to be studied was based upon a desire to learn more about cooperative approaches that more effectively utilize water available to existing systems without construction of major new storage or collection facilities. While the TAC considered many other options for study including demand management and new surface water development proposals, these options were not included in the study due to several considerations. Generally, options that were eliminated were not consistent with the concept of cooperative utilization of existing systems and facilities, were already being pursued or implemented by individual water providers, and/or had already been investigated in other previous or ongoing studies.

2.2.2. Phase II Investigations

The initial efforts under Phase II involved the collection of available data and information relevant to each of the conceptual water supply sources described above. This effort included numerous TAC work sessions where study participants presented overviews of their individual water supply systems, existing and future water demands, plans for meeting future needs, and issues and concerns. The information gathered through this process was compiled in a series of technical memoranda, which were provided to TAC members during Phase II.

Throughout the MWSI process, as TAC members learned more about each others' water supply systems, new ideas for cooperative opportunities emerged which required redirection of study efforts and gathering of additional information. While this approach caused significant delays, it was necessary for maintaining flexibility throughout the MWSI so that work plans could be formulated and modified as necessary in response to the TAC's deliberations.

As the MWSI evolved in response to direction from the TAC during Phase II, the originally anticipated approach was modified to include more analysis and the formulation of conceptual designs in the area of conjunctive use than was originally anticipated. While under the original POS these efforts would have taken place during Phase IV of the MWSI, the overall thrust of the MWSI did not change. However, this shift in the focus resulted in some reduction in the Phase II efforts originally anticipated for the areas of effluent management and systems integration.

The Phase II inventory of available models concluded that the MWSI's analytical approach for yield and operational purposes would be to rely on Denver's Platte and Colorado Simulation Model (PACSM) as a basic analytical tool and to develop "model extensions" for further MWSI investigations. This decision was based on two basic factors: the importance of the operation of Denver's system when considering cooperative water supply options, and Denver's position of openness with respect to availability of PACSM model data and assumptions. This resulted in a collaborative effort with Denver in the use, review and refinement of PACSM during the remainder of the MWSI process. Additional models, designed to run as "extensions" of PACSM, were developed by the MWSI as parts of specific investigations. A description of PACSM is provided in Appendix 6.

Efforts under the Phase II of the MWSI were substantially completed in August of 1995 with the publication of numerous Phase II task memoranda, four summary reports specific to each conceptual water supply category, and a Draft Phase III POS which was finalized in October of 1995.

2.2.3. Phase III Investigations

The Phase III POS included a mix of work areas designed to advance the treatment of effluent management to a level comparable to the Phase II analysis of conjunctive use options. The PMT felt that more detailed studies in the area of conjunctive use were not necessary with the exception of some additional model runs to evaluate certain conjunctive use scenarios. In addition, Phase III included efforts to increase the level of TAC discussions regarding other systems integration ideas. As with the previous phases of the MWSI, the TAC wanted to retain flexibility so that efforts could be re-directed as needed in response to new information and changing priorities.

In the area of conjunctive use, additional model runs were completed using the model developed in Phase II (with some minor modifications). These model runs were designed to produce analyses in the following areas:

- scenarios that do not involve borrowing and/or recharge;
- use of alternative sources of surface water supply;
- sensitivity of yields to various levels of demand in the Denver Water service area; and
- sensitivity of yields to peaking storage availability.

Based upon the modeling results, the alternative sources of surface water supply, and resulting return flows, potential environment impacts and permitting issues were generally identified. It was anticipated that early awareness of environmental concerns would be useful for purposes of formulating specific conjunctive use proposals and for identifying interested parties and potential approaches to mitigation.

In the Phase III POS, it was also anticipated that the consulting team would provide technical support for a conjunctive use demonstration project to test the concepts of recharge, borrowing and payback and to provide assistance in the establishment of operating rules and accounting requirements. However, there was no activity under this task, and it was concluded that it would not be feasible to implement such a demonstration project within the time frame for completion of the MWSI.

Phase III investigations of effluent management included refinements to the Phase II inventory of reusable supplies , development of a reusable return flow model and database, estimation of future levels of reusable return flows, and collaboration with Denver Water to refine estimates of future exchange potential. These efforts involved analyses of water rights and reusable supplies owned by several water providers that were not included in PACSM. Phase III work in this area also addressed the potential for pooling of reusable effluent and altering the timing of use of reusable sources in order to increase the reliability of reusable return flows for substitution and reuse purposes.

In the area of interruptible supply, the Phase II report provided an overview of concepts, alternative approaches, and a regional quantification of agricultural supplies that could conceptually be made available for such arrangements. The Northern Colorado Water Conservancy District expressed concerns that the Phase II draft report "overemphasizes the potential for water transfers from the Northern Front Range to the Denver Metropolitan area." While the intent of the interruptible supply concept was to protect and continue existing water uses by allowing only temporary transfers, Northern municipal water providers were concerned about the need to reserve adequate water supply for growth within their area and the potential economic, social, and environmental impacts. In response to these concerns, the Phase III POS included further study of perceived barriers to interruptible supply. This was to address perceptions and underlying causes of barriers and approaches to overcoming such barriers. However, as Phase III proceeded, the PMT felt that additional analysis of these issues should be postponed pending regional planning efforts to be undertaken by Northern municipal water providers. A Northern Regional Water Coalition has subsequently been formed to undertake these efforts. Ultimately, the MWSI did not study interruptible supply arrangements beyond Phase II. In the area of interruptible supply, this report therefore includes only an updated version of the Phase II report.

Under the direction of the TAC, Phase III of the MWSI included a concentrated high-level strategic examination of other systems integration possibilities. The primary objectives of this effort included: 1) providing an opportunity for additional mutual education regarding water supply systems from the perspectives of different geographic sub-regions; 2) establishment of a safe clearinghouse for discussion of cooperative water supply ideas and information; and 3) possible establishment of forums for continued discussion of cooperative planning effort that would endure beyond the conclusion of the MWSI. This part of the investigation was implemented through a series of six regional brainstorming meetings as described below.

- **Denver/Aurora** – This meeting focused on the central portion of the metro Denver area and on its two largest water supply systems. These were addressed in one session due to their common elements including extensive transbasin supplies, major South Platte reservoirs, and a principal diversion point at Strontia Springs Reservoir.
- **Cherry Creek/Plum Creek** – This meeting focused on the metro Denver water providers that are primarily dependent on Denver Basin groundwater as a water supply source. Other major elements specific to this region include a high level of interest in reuse and augmentation plans involving the surface flows and alluvial aquifers of Cherry Creek and Plum Creek.
- **Northwest Quadrant** - This sub-region includes the water providers obtaining their primary supplies from Clear Creek and Denver's Moffat Tunnel Collection System. South Boulder Creek, Ralston Creek and Coal Creek are also included in this sub-region.
- **Northeast Quadrant** - This sub-region includes the South Platte River from Chatfield Reservoir to the St. Vrain confluence and the lower portions of Bear Creek, Cherry Creek and Clear Creek. This sub-region includes most of the metro area's effluent management opportunities and associated water quality issues. This region receives major inflows from urban stormwater runoff, lawn irrigation return flows and wastewater discharges.
- **Northern Front Range** - This sub-region includes the South Platte below the St. Vrain confluence and the Boulder, St. Vrain, Big Thompson and Cache La Poudre basins. Most of the agricultural water use in the South Platte basin occurs within this sub-region and most of this sub-region is located within the Northern Colorado Water Conservancy District.
- **West Slope** – This meeting yielded valuable information concerning a number of systemic issues and policy perspectives that need to be considered regarding systems integration opportunities as they affect existing and future transbasin diversions and West Slope water management issues such as endangered fish, instream flows and water quality.

While the Phase III systems integration discussions were underway, the Denver Board of Water Commissioners adopted a new Resource Statement that directed their staff to explore cooperative actions with water suppliers outside the Denver Water service area (see Appendix 8.) The Resource Statement also suggested a process for the development and consideration of cooperative actions on a sub-regional basis that would encourage

suburban water suppliers to coordinate their efforts so as to avoid piecemeal fragmented planning. To the extent that individual members of the TAC were interested in more detailed investigations in any of the study areas, it was anticipated that such investigations could take place through cost sharing arrangements with the state. It was anticipated that these investigations would provide the basis for continuing discussions beyond the conclusion of the MWSI and could possibly lead to the implementation of cooperative projects.

2.2.4. Phase IV Sub-Regional Studies

In consideration of these factors, the PMT decided that the originally planned Phase IV effort to develop and evaluate conceptual design plans should take place in these sub-regional planning efforts. This would allow water suppliers from each of the sub-regional areas to have a more direct involvement with the formulation of conceptual plans in conjunction with continuing the cooperative communication and coordination process established under the MWSI. To facilitate this effort, the CWCB authorized the use of funds originally budgeted for Phase IV, on a matching basis, for sub-regional planning efforts.

2.3. COORDINATION WITH OTHER STUDIES / PROCESSES

Another critical factor that influenced the evolution of the MWSI was its relationship with other studies and planning processes that were ongoing at the beginning of the MWSI or initiated while the MWSI was underway. These related studies and planning processes included the following:

- When the MWSI was initiated, the **Metro Wastewater Reclamation District** was engaged in extensive **effluent management studies** that included the analysis of water management options such as exchanges and reuse.
- **Denver Water** was in the early stages of implementing an **Integrated Resource Planning Process (IRP)** to identify and evaluate alternative water supply planning strategies. In conjunction with this effort a new raw water supply planning model for the Denver system (PACSM) was developed as a tool for evaluation of new water supply sources and system management alternatives.
- The **Arapahoe County Water Resource Authority,** the **Douglas County Water Resource Authority, Denver Water** and **Aurora** were involved in studies of non-tributary groundwater resources that included investigations of recharge potential and potential interconnection with surface water facilities in order to facilitate **conjunctive use of surface and groundwater resources.**
- **Mayor Wellington Webb** was in the process of initiating a planning effort for revitalization of the urban South Platte River corridor that included plans to address **urban South Platte instream flow and water quality issues.**

- The **Colorado Department of Natural Resources** and several South Platte water users were involved in extensive negotiations with the U.S. Department of the Interior and the States of Wyoming and Nebraska aimed at addressing **Platte River endangered species** issues. These negotiations resulted in the Platte River Endangered Species Cooperative Agreement. Data and analytical tools developed for the MWSI became the basis for Colorado's Plan for Future South Platte River Depletions.
- The **Colorado Department of Natural Resources** and several Colorado River water users continued their involvement in the **Colorado River Recovery Implementation Program** throughout the course of the MWSI.
- The **Colorado Division of Water Resources** and the **Colorado Water Conservation Board**, in response to direction from the General Assembly (Senate Bill 96-74), initiated the **Denver Basin and South Platte River Basin Technical Study**. The primary purposes of this investigation were to investigate the adequacy of existing replacement/relinquishment requirements for Denver Basin wells and the impacts of conservation, water reuse, conjunctive use and runoff from impervious surfaces on water rights and water supplies. In addition, investigations were initiated to estimate the economic life of the Denver Basin Aquifers (Senate Bill 96-153).
- In conjunction with the MWSI, the **Colorado Water Conservation Board** initiated discussions with the **U.S. Army Corps of Engineers** to investigate the feasibility of allocation or **reallocation of Chatfield Reservoir storage** for water supply purposes.
- The **U.S. Forest Service** began conducting a **Wild and Scenic Rivers Program Eligibility Study** for the South Platte River above Denver.

Each of these efforts was designed to address specific problems or objectives for the individual sponsoring agencies and each contributed unique information to the MWSI. In several cases, the MWSI provided important information and analytical capabilities that were critical for the success or continued progress of these other studies and planning processes.

3. MWSI Results

3.1. BASIN-WIDE OVERVIEW

Throughout the MWSI process, a variety of information was collected from water providers in the metro Denver area. This included maps of service areas, estimates of existing and future service area populations, levels of water use, major facilities, water supply sources and reusable water supplies. This information was used as input to several investigations conducted as part of the MWSI. Similar information was collected on municipal water use in the remainder of the South Platte Basin as part of the Denver Basin and South Platte River Basin Technical Study (the Senate Bill 96-74 Study). Information related to West Slope issues and concerns was also collected.

Taken together, this information provides a useful overview of the municipal water supply situation in the South Platte Basin and a contextual basis for understanding cooperative actions, their advantages and disadvantages. Several aspects of this compiled information are presented in the following sections. With respect to future populations and water demands, the MWSI did not attempt to project or reconcile future water demands on a local or regional level. Information presented on future population, water use, and water supply plans are simply that supplied by individual water providers and the State of Colorado.

3.1.1. Water Supply Service Area Regions

When considering the municipal water supply needs of the metro Denver area of Colorado, it is useful to think in terms of three water supply service area regions as shown in Figure 1 below, each characterized by its geography, its history and its unique set of water supply circumstances and opportunities.

3.1.1.1. Central Service Area Region

This region consists of Adams, Clear Creek, Denver, Gilpin, Jefferson and Park Counties, and that portion of Arapahoe County served by Aurora. The region includes the following water providers: Denver Water (including 76 fully dependent contract providers within its combined service area), Aurora, Thornton, Westminster, Arvada, Consolidated Mutual Water Company, Englewood, Northglenn, South Adams County Water & Sanitation District, Golden, Coors, Public Service Company, Brighton and several minor water providers within the upper South Platte, upper Clear Creek and upper Bear Creek basins.

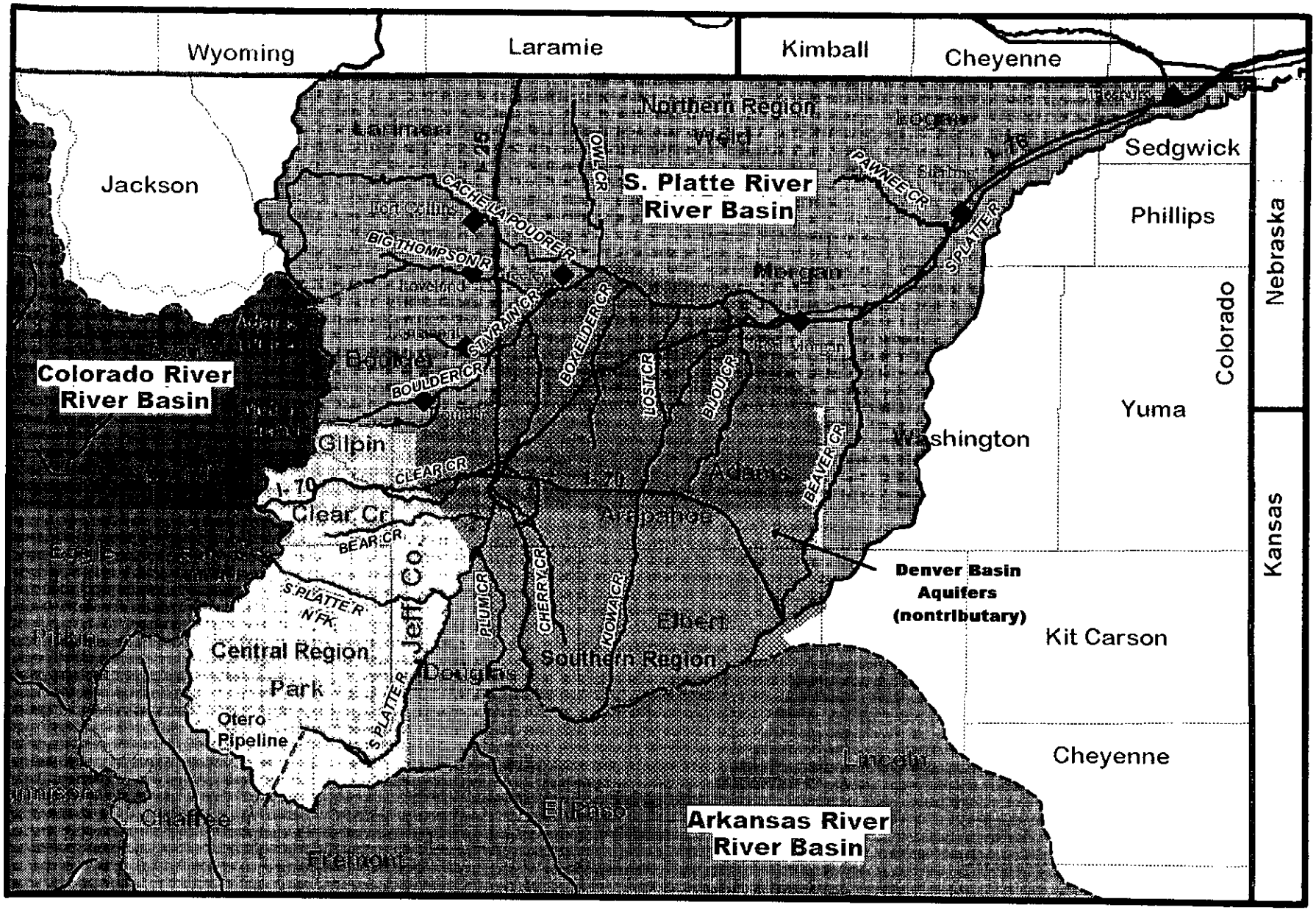

Figure 1: South Platte River Basin Water Supply Service and Source Regions

Prepared for the Colorado Water Conservation Board, Colorado Department of Natural Resources by
Hydrosphere Resource Consultants, 1002 Walnut Street, Suite 200, Boulder, CO 80302

This region has ready access to water supplies from the South Platte River and Clear Creek and a relatively high percentage of the region's water supplies come from transbasin imports, primarily from the Colorado River Basin, via Denver's and Aurora's water systems. Providers in the region own most of the senior water rights and storage facilities on these stream systems within the region. Municipal water supply in the region is heavily influenced by the Denver Water system, which serves the City and County of Denver and provides full or partial water supply to over 90 other suppliers.

Although much of this region is situated over a portion of the Denver Basin aquifers, the region relies almost completely on surface water supplies. There is relatively little agricultural water use remaining in the region.

3.1.1.2. North Service Area Region

This region consists of Boulder, Larimer, Logan, Morgan, Sedgwick, Washington and Weld Counties. The region contains more than 50 municipal water providers and rural domestic water districts including Fort Collins, Boulder, Longmont, Loveland, Greeley, Lafayette, Louisville, Superior, Broomfield and Fort Morgan.

This region has ready access to surface waters of Boulder Creek, the St. Vrain River, the Big Thompson River, the Cache la Poudre River and the South Platte River below Denver. Water providers within this region also have access to water from the Colorado-Big Thompson (CBT) and Windy Gap projects and most providers rely to some degree on water from these projects.

The North region relies almost completely on surface water supplies including tributary groundwater, and relatively little of the region is located over significant parts of the Denver Basin aquifer. Agriculture has historically accounted for the vast majority of water use in this region and will continue to comprise the bulk of the region's water use in the future. Because of the legal availability of CBT and Windy Gap water and the large amount and proximity of agricultural water, municipal water supplies are relatively plentiful in this region compared to the Central, South and West Slope headwater regions.

The Northern Colorado Water Conservancy District (Northern), along with its Municipal Subdistrict, plays a leadership role in regional water supply policy and planning. During recent years there has been a great deal of concern about pending and potential future transfers of agricultural water rights from areas within the North Region to cities in the northern tier of the Central Region. In response to these concerns, Northern has convened a Northern Regional Water Coalition in order to conduct studies and policy discussions to evaluate current and future water needs within the North Region. Northern has also adopted policies to limit the transfer of water from the Colorado-Big Thompson and Windy Gap projects to areas outside of District and Subdistrict boundaries, and to discourage the transfer of native base supplies outside of this region.

Nonetheless, the North region is a significant potential water supply source for metro Denver area water providers who can legally acquire existing irrigation rights and new

water rights in the North Region and transfer them to municipal use outside of the North region. A recent example is the City of Thornton's Northern Project.

3.1.1.3. South Service Area Region

This region consists of portions of Douglas County and that part of Arapahoe County not served by Aurora. The region includes sixteen water providers including Parker Water & Sanitation District, Centennial Water & Sanitation District, the Town of Castle Rock, East Cherry Creek Water & Sanitation District and several smaller water districts. These providers are members of the Douglas County Water Resource Authority (DCWRA), formed by Douglas County for the purpose of facilitating cooperative regional water supply planning for the region. The region is situated directly over the most productive portion of the Denver Basin aquifer system. Conversely, the region is characterized by relatively little surface water availability.

Significant urban development in this region began approximately 20 years ago. By this time most of the flow of the South Platte River had already been appropriated. The region's other major surface tributaries, Cherry Creek and Plum Creek, have relatively small and erratic flows. Consequently most of the region's water providers rely on nontributary Denver Basin groundwater as their sole or principal supply. During recent years, the DCWRA and its individual water provider members, in cooperation with local government, have been working to minimize their long-term reliance on Denver Basin groundwater through open space and land use planning efforts and implementation of reuse and augmentation plans.

3.1.2. Water Source Regions

Municipal water supplies for the metro Denver area are currently obtained from three distinct water source regions: the South Platte River basin (including the Denver Basin aquifers), the Colorado River basin and the Arkansas River basin as shown in Figure 1. Metro Denver area providers will continue to look to each of these three source regions for their future supplies.

3.1.2.1. South Platte River Basin

Metro Denver area providers obtain approximately 60% of their water supplies from the South Platte River basin. These include municipal direct flow rights and storage rights, changed irrigation rights, Denver Basin groundwater and alluvial groundwater rights, and reuse of water from South Platte rights. Irrigation rights were first changed to municipal use as irrigated lands within the metro Denver area became urbanized. More recently, irrigation rights have been acquired from more distant areas, including the South Park region of the upper South Platte Basin, portions of the Big Dry Creek basin and South Platte Basin in Adams and southern Weld Counties, and the Cache La Poudre basin in northern Weld County.

Metro Denver area providers will continue to look to the South Platte River basin for a major portion of the future water supplies. Based on an inventory of water supply plans, approximately 45% of the metro Denver area's future water supplies will be obtained from South Platte Basin water sources. These include additional South Platte Basin surface water development, conversion of in-basin irrigation rights, Denver Basin groundwater use and reuse of these sources.

There are several areas of concern related to additional development of South Platte Basin water sources. The presence of threatened and endangered species on the Platte River in Nebraska continues to be a major area of concern. Colorado has entered into a Cooperative Agreement with the U.S. Department of Interior and the States of Nebraska and Wyoming to implement recovery efforts for these species and their associated habitats. Under this Cooperative Agreement, Colorado is developing a plan to mitigate the impacts of new water-related activities in Colorado on the species and their habitats through the use of reregulation storage at the Tamarack Project, located along the South Platte River near Julesburg.

Large scale conversion of irrigation rights, particularly from agricultural lands located far from urban areas, have raised concerns about impacts to agricultural economies and local government tax bases. The majority of irrigated agriculture in the basin is located within the boundaries of the Northern Colorado Water Conservancy District. As discussed above, Northern has adopted policies to discourage the transfer of native base supplies outside of this region.

Increased reliance on Denver Basin groundwater as a principal supply by some water providers in Douglas and Arapahoe Counties has raised concerns about the long-term sustainability and economic viability of this groundwater resource. While the amount of groundwater in storage in these aquifers is vast, natural recharge of these aquifers is believed to be very limited. As future groundwater pumping increases, aquifer levels are expected to decline. There is a concern that this may lead to higher pumping costs, the eventual need for additional wells and reduced supplies. Groundwater-dependent providers have recognized this problem and are actively working to increase the renewable portion of their water supplies.

Water quality in the South Platte and its tributaries has been significantly affected by agricultural and municipal water use and land use. Development of additional South Platte Basin water supplies will put further stresses on water quality in the basin.

Upstream of the metro Denver area, the South Platte River is a major aquatic habitat and recreational amenity. Construction of water supply reservoirs has inundated several reaches of river and created significant flatwater recreational opportunities. The operation of water supply systems has substantially altered the character and flow regime of much of the remaining free-flowing portions of the river. There is a significant concern among recreational users, natural resource management agencies and environmental interests that further development and future operations of water supply systems do not unreasonably impair existing aquatic environmental and recreational values. This issue is being addressed in the U.S. Forest Service's Wild and Scenic Rivers Program Eligibility Study for the South Platte River above Denver.

3.1.2.2. Colorado River Basin

The Colorado River Basin has been a major source of water supply for agricultural and municipal water users since the early 1900's. South Platte Basin municipal and industrial water providers obtain about 30% of their existing water supply from the Colorado River Basin. The areas that are most relevant to this investigation include the Colorado River mainstem in Garfield and Mesa Counties and its headwater tributaries located in Grand, Summit, and Eagle Counties.

Water supply sources for the Colorado River headwater counties consist primarily of the Colorado, Fraser and Williams Fork Rivers in Grand County, the Blue River in Summit County, the Eagle River in Eagle County. Access to water supplies from these sources in Grand, Summit and Eagle Counties is limited primarily by the relative seniority of water rights for transbasin diversions, and (during the late summer and winter low-flow months) by the water rights of the Shoshone hydropower plant located downstream in Glenwood Canyon on the Colorado River main stem. For all of the headwater counties, water rights held by the Colorado Water Conservation Board for protection of instream flows are a limiting factor during periods of drought and seasonal low-flows.

Water users in Garfield and Mesa Counties have access to water supplies from the Colorado River main stem and its tributaries, while water users in Gunnison, Montrose, Mesa and Delta Counties have ready access to supplies from the Gunnison River and its tributaries.

Growing water demands throughout the West Slope consist primarily of municipal uses. In the headwater counties, water demands for snowmaking and winter domestic use have grown rapidly during recent years resulting in an increased need for local water supply storage facilities. In both the headwater and main stem counties agricultural lands and water rights are rapidly being converted to urban and municipal uses.

Water management activities and water supply availability are affected by the presence of several endangered fish species in the Colorado River near Grand Junction. A recovery implementation program has been created to address the needs of these species. This program must consider the flow requirements of the endangered species, existing and future in-basin water uses and transbasin diversions. The goal of the program is to allow for future water development under Colorado's compact entitlement while recovering the endangered species. Real and perceived trade-offs between these competing uses have resulted in considerable controversy within the program.

There are also several water quality concerns within the basin related to transbasin diversions. Transbasin diversions selectively divert higher quality headwater sources, resulting in higher concentrations of dissolved solids and certain pollutant constituents at lower elevations in the basin. Some transbasin diversions (primarily the CBT project and Denver's Moffat and Roberts collection systems) have also significantly reduced winter season flows in several areas, which has reduced available dilution flows for wastewater treatment facilities in headwater locations.

3.1.2.3. Arkansas River Basin

The waters of the Arkansas River Basin currently constitute a relatively small water supply source for the metro Denver area. The City of Aurora is the only metro Denver area provider that diverts native water supplies from the Arkansas basin. Aurora diverts Arkansas water via its Otero pump station, which it also uses to divert water imported into the Arkansas from the Colorado River basin. Until recently, Aurora's diversions of Arkansas supplies have been less than 1,000 acre-feet per year to date, consisting of its water rights from two small ranches in the upper Arkansas basin. In the past five years Aurora has begun using up to 8,000 acre-feet of its recently transferred water rights from the Colorado Canal and the Rocky Ford Ditch. Aurora's ultimate diversions under these projects are expected to be approximately 14,000 acre-feet per year.

3.1.3. Metro Denver Area Water Supply Service Areas

As defined in this report, the metro Denver area includes both the Central and South Service Area Regions as described above. Municipal water supply in the metro Denver area is provided by a combination of cities, counties and special purpose water districts. Figure 2 shows the service areas of the major water providers in the metro Denver area. Over 98% of municipal and industrial water use in metro Denver is represented by the 26 water providers shown in the figure. Denver Water is the largest water supplier, providing exclusive supply to the City and County of Denver and by contract to 76 other cities and water districts. Denver also provides partial water supply to 15 other providers. A list of Denver Water's contract obligations to other providers is shown in Table 1.

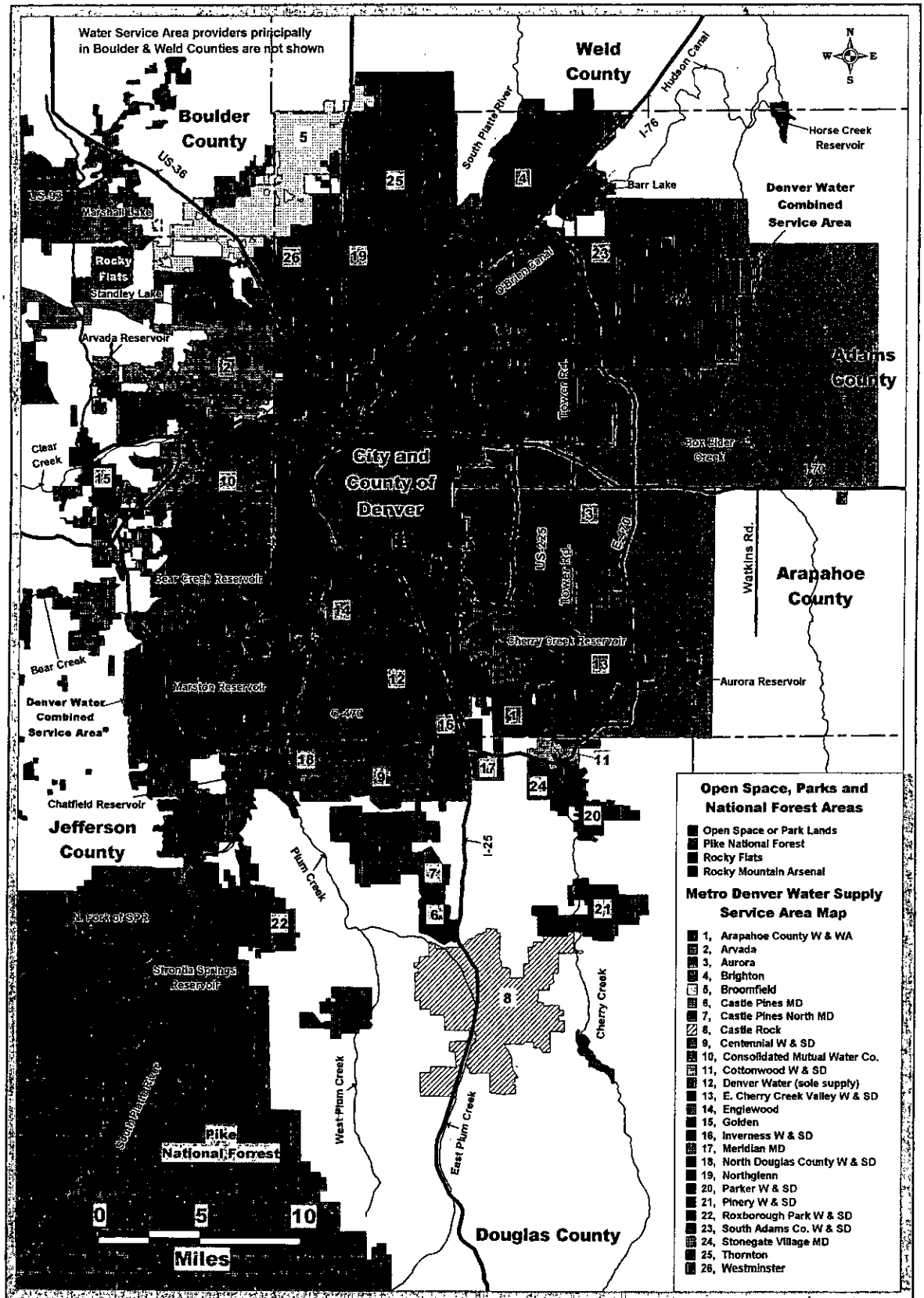

Figure 2

January 1999

Metropolitan Water Supply Investigation

State of Colorado - Water Conservation Board - Dept. of Natural Resources

HYDROSPHERE

Note: Service Area Boundaries are Approximate

Figure 2: Major Service Areas of Major Water Providers in the Metro Denver Area

Table 1: Denver Water Contract Obligations

Entity	Type	1996 Consumption, Acre-Feet
Agricultural Ditches	SCR	199
Alameda WSD	RB	194
Alameda WSD	MM	304
Antero	SCR	500
Arvada	SCR	16,512
Bancroft-Clover WSD	MM	5,742
Bear Creek WSD	RB	2,306
Bennet Bear Creek Farm	TS	212
Berkeley MD	RB	842
Bonvue WSD	MM	52
Bow-Mar WSD	MM	303
Brookridge Heights	TS	140
Broomfield	SCT	5,300
Canitoe WSD	RB	79
Castlewood Water	RB	2,921
Centennial WSD	SCR	3,291
Charlou Park Water	TS	61
Cherry Creek Valley WSD	MM	2,014
Cherry Creek Village WSD	MM	552
Cherry Hills Farm	RB	297
Cherry Hills Heights W&S	TS	59
Cherry Hills North W&S	TS	147
Cherry Hills SubD Water	RB	41
Cherry Hills Village	TS	599
Cherrymoor South WSD	MM	98
Cherrymor WD	TS	33
City-Wash. Parks/Denver CC	SCR	0
Colo Div of Parks & Rec	RB	32
Colorado Academy	RB	44
Columbine WSD	TS	430
Consolidated Mutual	MM	10,329
Consolidated Mutual	SCR	0
Continental Oil/Conoco	RB	834
Country Homes Metro	RB	154
Crestview WSD	MM	2,526
Devonshire Heights WS	TS	171
E. Cherry Hills WUA	RB	110
East Cherry Creek WSD	SCR	0
Edgewater	MM	810
Englewood (City Ditch)	SCR	0
Englewood, Other	SCR	0
Fairmont Cemetery	SCR	0
Fehlmann Sub WD	TS	10
Fitzsimmons/RM Arsenal	SCT	1,200
Glendale	MM	953
Grant WSD	TS	291
Green Mountain WSD	MM	6,565
Greenwood Village	TS	395
Havana WSD	TS	1,136
Hi-Lin WSD	TS	154
High View WD	MM	542
Hillcrest WSD	TS	283
Holly Hills WSD	TS	433
Inverness WSD	MM	304

MM = Master Meter (treated)
TS = Total Service (treated)
RB = Read & Bill (treated)
SCR = Special Contract/Raw
SCT = Special Contract/Treated

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Table 1: Denver Water Contract Obligations (Continued)

Entity	Type	1996 Consumption, Acre-Feet
Ken-Caryl WSD	MM	2,847
King, Lloyd J	TS	9
Lakehurst WSD	MM	2,440
Lakewood	MM	760
Littleton	TS	7,431
Lochmoor WSD	TS	46
Long Lakes	SCR	0
Loretto Heights Resub Water	TS	91
Mansfield Heights WSD	TS	203
Meadowbrook WSD	MM	500
Miscellaneous	SCR	0
Mountain View	RB	69
N. Lincoln WSD	RB	71
North Pecos WSD	MM	391
North Table Mountain	SCR	0
North Washington Street WSD	MM	2,874
Northgate WD	MM	21
Others: Cherry Hills CC, etc.	SCR	0
P&CRSPPA Rollover Taps	SCR	0
Panorama Park	TS	29
Phillips Petroleum	RB	1
Platte Canyon WSD	RB	3,564
PSCO/Arapahoe	SCR	7,260
PSCO/Cherokee	SCR	6,450
Rocky Flats (EG&G)	SCR	0
S. Sheridan WSD	RB	434
S.University Plaza Wtr Assn	TS	46
SE Englewood WD	TS	8,120
Sheridan	TS	893
South Adams County WSD	MM	292
Southgate WSD	RB	8,298
SW Cherry Hills WD	RB	456
SW Metro WSD	RB	5,970
SW Plaza MD	TS	49
SW Suburban Denver	TS	1,242
Valley WD	MM	1,583
Westminster	SCR	0
Wheatridge WD	MM	3,139
Willowbrook WD	MM	1,410
Willows WD	RB	868
Willows WD	MM	853
Total		**135,460**

MM = Master Meter (treated)
TS = Total Service (treated)
RB = Read & Bill (treated)
SCR = Special Contract/Raw
SCT = Special Contract/Treated

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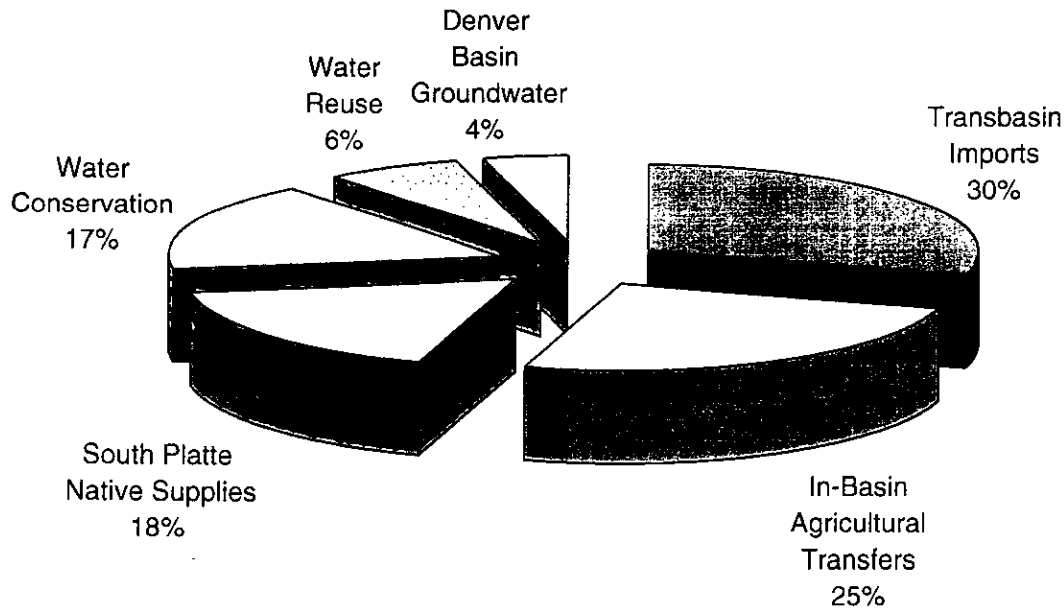
3.1.4. Water Management Strategies

For the purpose of the Basin-Wide Overview, it is useful to consider the universe of possible water management strategies available to municipal water providers as fitting into six categories, including five supply-side strategies and one demand management strategy (water conservation), which are described below. Individual water providers utilize these strategies to varying degrees according to their individual circumstances and opportunities. All of these strategies can be implemented through cooperative actions as well as through individual efforts. The relative role of each of these strategies in meeting the existing municipal and industrial water supply needs of the South Platte Basin is shown in Figure 3.

Figure 3: Existing Municipal & Industrial Water Supply, South Platte Basin of Colorado



3.1.4.1. Native South Platte Supplies

This source includes water supplies diverted from native South Platte surface flows under municipal water rights. At the time when significant urban development began on the Front Range, most of the reliable flow of the South Platte had already been appropriated for irrigation use. Consequently municipal water supplies from this category depend

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heavily upon storage because most of the remaining native supply occurs only during periods of high flows.

This source constitutes approximately 18% of the South Platte Basin's existing municipal water supply. Future opportunities for additional development of native South Platte flows will require some form of additional storage. Storage opportunities include new surface storage reservoirs, enlargements of existing surface reservoirs, reallocation of space in flood control reservoirs and groundwater storage via recharge.

3.1.4.2. In-Basin Agricultural Transfers

This source includes water supplies derived from acquisition of water supplies originally used for irrigation purposes within the South Platte Basin. As Front Range cities began to develop, they typically acquired irrigation rights that diverted within or adjacent to their urban service areas. More recently, municipal providers have acquired irrigation rights on a larger scale, often changing the location of use of those rights by several miles. As an example, over 30,000 acre feet of irrigation rights in the South Park area of the Upper South Platte Basin have been acquired and changed to municipal use by metro Denver area providers, principally Aurora and Thornton. As another example, the Colorado-Big Thompson project, completed in the 1950's, originally provided supplemental water supplies primarily to agricultural users within the South Platte Basin. Over the last 40 years, a significant amount of this supply has been acquired and changed to municipal use in accordance with the policies and rules of the Northern Colorado Water Conservancy District.

This source constitutes approximately 25% of South Platte Basin's existing municipal water supply. Future opportunities for additional in-basin agricultural transfers largely exist in the Northern Region, which is where most of the remaining irrigated agriculture is located.

3.1.4.3. Trans-Basin Imports

This source includes supplies imported from the Colorado, Arkansas and North Platte River basins. Transbasin import of water into the South Platte Basin for municipal purposes began in 1936 with the completion of the Moffat Tunnel. Existing transbasin diversion projects providing municipal and industrial supplies to the South Platte Basin include the Colorado-Big Thompson and Windy Gap projects; Denver's Roberts Tunnel and Moffat Tunnel collection systems; Aurora's diversions from the Homestake, Twin Lakes and Busk-Ivahoe projects via the Otero pump station; the Grand River Ditch: the Berthoud Pass Ditch: the Boreas Pass Ditch: and the Vidler tunnel. Transbasin diversions from the Colorado basin into the South Platte Basin currently average about 430,000 acre-feet per year. About 38% of this amount, or about 162,000 acre-feet, is diverted for municipal and industrial purposes within the metro Denver area.

Imported water currently provides approximately 30% of the South Platte Basin's municipal water supply. Supplies from this source are expected to increase in the future through more intensive use of existing water rights and facilities. New storage capacity,

obtainable by enlarging existing reservoirs, building new reservoirs or storage in aquifers under a conjunctive use project could be used to regulate water from additional transbasin diversions.

3.1.4.4. Water Reuse

This source includes supplies derived from legally reusable return flows through exchanges, plans of augmentation and direct reuse. Generally speaking, municipal water providers have the right to reuse to extinction the return flows resulting from municipal use of imported sources, Denver Basin groundwater sources and the historically consumed portion of changed irrigation rights. Water reuse has become a significant source of municipal supply only within the last 25 years. Water reuse currently provides approximately 6% of the basin's municipal water supply. Supplies from this source are expected to increase in the future as municipal providers make more use of exchange and direct reuse opportunities.

3.1.4.5. Denver Basin (Nontributary) Groundwater

Pumping of Denver Basin (nontributary) groundwater has become a significant municipal water source only within the last 20 years. Its principal area of use is within Douglas and Arapahoe Counties where municipal water providers and individual domestic, industrial and irrigation users have found it to be a readily available and relatively inexpensive source. Denver Basin groundwater currently provides approximately 4% of the South Platte Basin's municipal water supply. Supplies from this source are expected to increase in the future as municipal providers in the South service area region increase their use of existing well decrees. Future growth in Denver Basin groundwater use may be reduced significantly if a conjunctive use project is implemented.

3.1.4.6. Water Conservation

Water conservation includes all measures designed to reduce water demands of end users and to encourage wise water use. As used in this report, water conservation includes education, incentives, rates, meters, xeriscape, restrictions, water-efficient fixtures, appliances and irrigation systems, ordinances, etc. It has been estimated that water conservation currently results in a 17% reduction in municipal water demand basin-wide.

It is expected that water conservation will play an increasingly important role in meeting future water demands as voluntary conservation programs are pursued more extensively by water providers, as water-efficient fixtures and appliances become more commonplace, and as water conservation-oriented water rate structures are increasingly used.

Individual providers have historically made water conservation decisions in the metro Denver area. In other areas of the U.S., water conservation has been approached at a regional level. For example, under the CALFED program to address water supply and environmental issues in California's Bay Delta area, a regional 'Best Management

Practices' approach has been taken to water conservation. Under this approach, individual providers have agreed to implement an agreed-upon package of water conservation practices.

3.1.5. Existing Conditions

During the course of the MWSI and the Denver Basin and South Platte Basin Technical Study (SB74 Study), water use inventory information was collected for all major water providers in the South Platte Basin. This information included service area populations, raw water uses, and general mix of water supply sources used by each provider or provider group.

Based on the inventory information collected during various phases of the MWSI, the 1996 service area population, water use, and average existing mix of water supply sources for South Platte Basin municipal providers are shown in Table 2. The existing water supplies of metro Denver area providers are briefly summarized by sub-region in the following sections.

This information is provided as a general reference point for average conditions. The relative roles of individual water sources change considerably from year to year, primarily in response to variations in native South Platte River flows. During dry years, providers rely more heavily on transbasin imports, Denver Basin groundwater and releases from storage. In wet years, native South Platte supplies play a more prominent role.

3.1.5.1. Denver Central Sub-Region

The Denver Central sub-region is comprised of the Denver Water Combined Service Area, including the City and County of Denver, 75 fully dependent and over 20 partial supply contract providers; the City of Englewood and other small providers in the Bear Creek basin. The main sources of supply available to the this sub-region consist of South Platte municipal water rights and changed irrigation rights, transmountain diversions from the Blue, Fraser and Williams Fork Basins and water reuse.

Denver Water obtains its native South Platte supplies from numerous municipal direct flow rights and from storage rights associated with its South Platte Reservoirs, principally Cheesman Reservoir, Eleven-Mile Reservoir, Marston Reservoir, Gross Reservoir, and its storage account in Chatfield Reservoir. Denver also diverts under changed irrigation rights that were previously used to irrigate lands in the vicinity of Chatfield Reservoir. Denver's transbasin supplies include its diversions from its Moffat Tunnel and Roberts

Table 2: Existing Municipal Water Use in the South Platte Basin (1996 Demand Conditions)

Region/Water Provider	Service Area Population	Raw Water Supply, af/year [1]	Native South Platte Supplies	In-Basin Agricultural Transfers	Trans-Basin Imports	Water Reuse	Denver Basin Ground-water	Estimated Water Conservation Savings [1]
Central Region								
Denver Water [3]	1,000,000	265,000	99,000	23,000	130,000	13,000	0	61,000
Aurora [4]	255,000	60,000	500	30,000	24,000	4,500	1,000	12,000
Thornton	82,000	19,000	3,000	13,000	0	3,000	0	4,500
Westminster	100,000	21,000	3,000	15,000	0	3,000	0	4,700
Arvada [5]	98,000	(included in Denver's supplies)						
Broomfield [6]	34,000	(included in Denver's supplies)						
Englewood	30,000	8,500	1,000	5,500	2,000	0	0	2,000
Golden/Coors [7]	16,000	11,000	2,000	7,000	0	2,000	0	1,000
S. Adams County W&SD	22,000	5,500	0	2,500	0	2,100	900	1,300
Brighton	17,000	4,000	500	1,500	0	2,000	0	1,000
Northglenn	29,000	5,000	0	2,500	400	2,100	0	1,200
Con. Mutual (non-DW) [8]	26,000	4,000	1,000	3,000	0	0	0	
Misc. Central [9]	50,000	6,000	2,500	2,500	0	0	1,000	1,000
Total Central	1,759,000	409,000	112,500	105,500	156,400	31,700	2,900	89,700
South Region								
Arapahoe County W&WA	1,500	1,100	200	0	0	300	600	200
Castle Pines MD	2,000	500	0	0	0	0	500	100
Castle Pines North MD	2,000	600	0	0	0	0	600	100
Castle Rock	15,000	3,300	0	0	0	200	3,100	700
Centennial/N. Douglas Co.	45,000	10,500	7,600	400	0	900	1,600	2,400
Cottonwood W&SD	2,500	600	0	0	0	100	500	100
E. Cherry Cr. Valley W&SD	21,000	5,300	300	0	0	300	4,700	1,200
Inverness W&SD [10]		1,400	300	0	0	400	700	300
Meridian MD [10]		1,000	0	0	0	0	1,000	200

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Table 2: Existing Municipal Water Use in the South Platte Basin (1996 Conditions) (continued)

Region/Water Provider	Service Area Population	Raw Water Supply, af/year	Native South Platte Supplies	In-Basin Agricultural Transfers	Trans-Basin Imports	Water Reuse	Denver Basin Ground-water	Estimated Water Conservation Savings (2)
Parker W&SD	15,000	3,200	0	0	0	700	2,500	700
Pinery W&SD	7,500	1,900	500	1,000	0	100	300	400
Roxborough Park (11)	3,000	(included in Aurora's supplies)						
Southgate (12)		(fully served by Denver)						
Stonegate Village MD	4,500	1,000	0	0	0	0	1,000	200
Willows WD (non-DW) (13)	11,500	2,600	0	0	0	0	2,600	600
Misc South (14)	9,000	2,000	100	0	0	0	1,900	500
Total South	139,500	35,000	9,000	1,400	0	3,000	21,600	7,700
Total Metro Denver Area	1,898,500	444,000	121,500	106,900	156,400	34,700	24,500	97,400
North Region (15)	676,000	194,000	25,000	80,000	83,000	6,000	0	18,500
South Platte Basin Totals	2,574,500	638,000	146,500	186,900	239,400	40,700	24,500	115,900

(1) Raw water supplies include raw water delivery losses.
(2) Water conservation savings are not included in Raw Water Deliveries. Water conservation savings were estimated by extrapolating savings from metering and other conservation measures in the Denver Water service area to other metro Denver water supply service areas.
(3) Figures include the City & County of Denver, 75 suburban distributors with Total Service, Read & Bill or Master Meter Accounts, and over 20 Fixed/Special Contract commitments. Population and water use figures do not include Arvada, Broomfield, Centennial and Englewood, which are accounted for elsewhere.
(4) Raw water deliveries Include contract deliveries to Roxborough Park Metro District
(5) Arvada currently receives nearly all of its water from Denver under a 19,660 AF special raw water contract
(6) Broomfield currently receives all of its water from Denver under a 6,500 AF special treated water contract.
(7) Includes approximately 7,000 AF of industrial water use by Coors Brewing Company
(8) Consolidated Mutual Water Company currently receives about 70% of its water from Denver under a Master Meter contract.
(9) Includes municipal water uses in Clear Creek, Gilpin and Park counties and in the mountain portions of Jefferson county.
(10) Inverness and Meridian serve primarily commercial and industrial uses; population figures are therefore not shown.
(11) Roxborough Park receives all of its water from Aurora under a raw water contract.
(12) Southgate is fully served by Denver under a read and bill treated water contract; population and raw water use figures are included in Denver's.
(13) Willows receives about 60% of its water from Denver under treated water contracts. IN the future Willows will be fully served by Denver.
(14) Includes small providers in Douglas and Elbert Counties.
(15) Includes Fort Collins, Boulder, Greeley, Longmont, Loveland, Lafayette, Louisville, Superior, 27 smaller municipalities, 16 rural domestic water districts, and municipal water users in Logan, Sedgwick and Washington counties.

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Tunnel collections systems. Denver's supplies derived from water reuse include its effluent exchanges from the Metro and Bi-Cities wastewater plants to its upstream points of diversion and storage. Denver does not currently use any Denver Basin groundwater sources. Denver's water conservation efforts include a recently completed metering of its entire service area, a water conservation-oriented rate structure and 18 other educational and voluntary programs.

The City of Englewood obtains its native South Platte supplies from changed irrigation rights previously used to irrigate lands below Chatfield Reservoir and from storage rights associated with McLellan Reservoir. Englewood's transbasin supplies include its deliveries from the Ranch Creek collection system under a contract with Denver water and from Boreas Pass Ditch. Englewood does not currently use any Denver Basin groundwater sources or reuse water.[3]

3.1.5.2. South Metro Sub-Region

The South Metro sub-region includes the water provider members of the Douglas County Water Resource Authority[4] and other small providers in Douglas and Elbert Counties.

Throughout this sub-region, Denver Basin groundwater is the primary source of supply for most providers. One exception is the Centennial Water & Sanitation District, which currently obtains most of its supplies from surface sources via Centennial's own water rights and contract deliveries from Englewood and Denver Water. Also, the Roxborough Park Metro District currently obtains its entire supply from Aurora under a raw water delivery contract. Most of the other providers within this sub-region have alluvial wells in the Cherry Creek or Plum Creek drainages and augmentation plans that allow them to use some of their reusable groundwater return flows to increase their alluvial well pumping.

3.1.5.3. City of Aurora

The City of Aurora currently meets its water needs through a combination of South Platte changed irrigation rights and municipal rights, transbasin diversions, alluvial and nontributary wells, water reuse and water conservation.

[3] While the City of Englewood is discussed in the MWSI report for the purpose of providing a complete overview, it should be noted that Englewood did not participate in the MWSI process.

[4] The water provider members of the Douglas County Water Resource Authority include Arapahoe County Water & Wastewater Authority, Centennial Water & Sanitation District, Parker Water & Sanitation District, East Cherry Creek Valley Water & Sanitation District, Town of Castle Rock, Roxborough Park Water & Sanitation District, Stonegate Village Metro District, Inverness Water & Sanitation District, Meridian Metro District, Castle Pines Metro District, Castle Pines North Metro District, Cottonwood Water & Sanitation District, North Douglas County Water & Sanitation District, Pinery Water & Sanitation District, Donala Water District and Willows Water District

Most of Aurora's changed irrigation rights were formerly used to irrigate ranches in the South Park area of the Upper South Platte. Aurora's South Platte municipal rights are associated with its Spinney Mountain Reservoir and its intake at Strontia Springs. Aurora's transbasin supplies include its diversions from its interests in the Homestake, Twin Lakes and Busk-Ivanhoe projects, and its acquired agricultural water rights from the Arkansas River Basin, principally its Rocky Ford Ditch and Colorado Canal rights. Aurora's supplies derived from water reuse include its effluent exchanges from the Metro wastewater plant to its upstream points of diversion and storage, direct reuse on several parks and golf courses, and augmentation of its Cherry Creek alluvial wells. Aurora uses a small amount of its Denver Basin groundwater resources for irrigating parks and golf courses and for reservoir evaporation replacement. Aurora's policy on development of Denver Basin groundwater is to reserve their primary use for drought protection. Aurora's water conservation efforts include a water conservation-oriented rate structure and several educational and voluntary programs.

3.1.5.4. Northeast Metro Sub-Region

The Northeast Metro sub-region includes Thornton, South Adams County Water & Sanitation District (SACWSD) and Brighton. The water supply sources currently available to this sub-region include municipal and changed irrigation rights on the South Platte and Clear Creek, alluvial and nontributary wells, and exchange rights.

Thornton owns shares in several upper and lower Clear Creek irrigation companies as well as in the Standley and Barr Lake divisions of the Farmers Reservoir and Irrigation Company (FRICO). Thornton's municipal rights are centered around its East and West gravel lakes facilities located near the Burlington Ditch headgate. Thornton also has several important exchange rights between the Metro wastewater plant and its diversion points on Clear Creek and at the Burlington Ditch.

SACWSD diverts most of its supplies from South Platte alluvial wells that are augmented by SACWSD's water rights associated with the Burlington Ditch system. SACWSD also uses a small amount of Denver Basin groundwater from its deep wells. SACWSD has recently reached an agreement with Denver Water that will provide SACWSD with a 4,000 acre-foot treated water supply for partial replacement of and blending with its tributary wells, which have experienced ongoing water quality problems.

Brighton diverts its supplies from alluvial South Platte wells that are augmented with water from Brighton's shares in several South Platte Irrigation ditches.

3.1.5.5. Northwest Metro Sub-Region

The Northwest Metro sub-region includes Arvada, Broomfield, the Consolidated Mutual Water Company, Golden, Northglenn, Thornton, Westminster and other small providers in the Clear Creek basin.[5]

[5] While the City of Golden is discussed in the MWSI report for the purpose of providing a complete overview, it should be noted that Golden did not participate in the MWSI process.

The water supply sources currently available to this sub-region consist primarily of Clear Creek municipal rights and changed irrigation rights, partial service contracts with Denver Water, which are mostly satisfied via deliveries from the Moffat Tunnel Collection System, and exchanges on Clear Creek, Ralston Creek and Big Dry Creek. Most of the changed irrigation rights are associated with the Church Ditch, the Farmers Highline Canal and the Standley and Marshall divisions of FRICO.

3.1.6. Future Conditions

As part of the Phase III of the MWSI, individual water providers presented summaries of their future water supply plans during the regional brainstorming meetings. This information was compiled and completed via follow-up discussions with individual providers or reliance on existing published sources. Based on this inventory of water supply plans currently in place, the future service area populations, expected future water uses, and future water supply plans for South Platte Basin municipal water providers are shown in Table 3. Only those future supplies judged to be reasonably certain are shown. Water providers have a relatively high degree of confidence in their ability to develop these supplies. Proposed water sources were grouped into the six categories of water management strategies previously discussed. The planning horizons presented in this table are as defined by individual providers. In some cases, these horizons correspond to an ultimate or "build-out condition, while in other cases they refer to a certain date. No attempt was made to reconcile individual providers' population projections with regional or state population projections. The State of Colorado's population projections by water supply service area region for the year 2020 are shown for comparison purposes.

It should be noted that providers' projections of future water needs and their plans to meet those needs are not precisely known. There are several dimensions of uncertainty involved in water supply planning related to permitting, costs, environmental impacts, public acceptance and water rights issues. This uncertainty is one of the primary factors behind the investigation of cooperative water supply concepts in the MWSI.

Table 3 shows that water providers in the South Platte Basin are currently planning to meet the projected water demands of approximately 4,200,000 people. Most providers are planning to meet the projected ultimate or 'build-out' water demands for their

Table 3: Future Water Supply Plans for South Platte Basin Municipal Water Providers

Region/Water Provider	Projected Future Service Area Population	Basis of Projection	State of Colorado Population Projection (Year 2020)	Projected Future Raw Water Deliveries, af/year	Reasonably Certain Future Supply, AF (1)	Native South Platte Supplies	In-Basin Agricultural Transfers	Trans-Basin Imports	Water Reuse	Denver Basin Ground-water	Estimated Water Conservation Savings (2)
Central Region											
Denver Water (3)	1,350,000	build-out		387,000	385,000	110,000	27,000	191,000	57,000	0	89,000
Aurora (4)	400,000	2030		95,000	75,000	500	30,000	39,000	4,500	1,000	14,000
Thornton (5)	378,000	build-out		93,300	45,000	7,000	18,000	7,000	13,000	0	14,000
Westminster (Non-DW) (6)	116,000	build-out		24,500	23,800	3,000	16,000	1,000	3,800	0	4,000
Arvada (Non-DW) (7)	130,000	build-out		6,400	4,000	500	2,500	0	1,000	0	1,000
Broomfield (Non-DW) (8)	70,000	build-out		17,500	10,000	0	0	6,000	4,000	0	3,000
Englewood	35,000	build-out		8,500	8,500	1,000	7,000	500	0	0	1,000
Golden/Coors (9)	40,000	build-out		15,000	15,000	3,000	9,000	0	3,000	0	2,000
S. Adams County W&SD	50,000	2040		16,000	10,000	2,000	2,500	2,000	2,000	1,500	3,000
Brighton	64,000	2040		16,000	6,000	0	3,000	0	3,000	0	3,000
Northglenn	38,000	build-out		6,500	5,000	0	2,500	400	2,100	0	1,000
Con. Mutual (non-DW) (10)	33,000	build-out		8,000	6,000	2,000	4,000	0	0	0	1,000
Misc. Central (11)	80,000	various		10,000	10,000	2,500	3,500	1,000	1,000	2,000	3,000
Total Central	2,784,000		2,416,800	703,700	603,300	131,500	125,000	247,900	94,400	4,500	139,000
South Region											
Arapahoe County W&WA	18,000	build-out		9,100	8,900	1,800	0	0	4,500	2,600	1,500
Castle Pines MD	9,000	build-out		2,200	2,200	500	0	0	600	1,100	400
Castle Pines North MD	11,000	build-out		2,700	2,700	0	0	0	800	1,900	400
Castle Rock	128,000	build-out		32,000	30,000	1,000	0	0	3,000	26,000	5,100
Centennial/N. Douglas Co.	102,000	build-out		25,500	25,500	8,000	400	0	4,000	13,100	4,100
Cottonwood W&SD	8,000	build-out		2,000	2,000	300	0	0	600	1,100	300
E. Cherry Cr. Valley W&SD	62,000	build-out		15,500	15,500	1,000	0	0	2,500	12,000	2,500
Inverness W&SD (12)		build-out		2,400	2,400	300	0	0	1,000	1,100	400
Meridian MD (12)		build-out		2,000	2,000	0	0	0	1,000	1,000	300
Parker W&SD	109,000	build-out		27,300	27,300	400	0	0	8,300	18,600	4,400

Region/Water Provider	Projected Future Service Area Population	Basis of Projection	State of Colorado Population Projection (Year 2020)	Projected Future Raw Water Deliveries, af/year	Reasonably Certain Future Supply, AF (1)	Native South Platte Supplies	In-Basin Agricultural Transfers	Trans-Basin Imports	Water Reuse	Denver Basin Ground-water	Estimated Water Conservation Savings (2)
Pinery W&SD	20,000	build-out		5,100	5,100	300	0	0	2,000	2,800	800
Roxborough Park (13)		build-out	(included in Aurora's supplies)								
Southgate (14)		build-out	(fully served byDenver)								
Stonegate Village MD	6,000	build-out		1,500	1,500	0	0	0	500	1,000	200
Willows WD (15)		build-out	(fully served byDenver)								
Misc South (16)	12,000	various		3,000	3,000	0	0	0	500	2,500	500
Total South	485,000		310,800	130,300	128,100	13,600	400	0	29,300	84,800	20,900
Total Metro Denver Area	3,269,000		2,727,600	834,000	731,400	145,100	125,400	240,900	123,700	89,300	159,900
North Region (17)	1,000,000	2020	1,041,600	290,000	290,000	35,000	114,000	126,000	15,000	0	18,500
South Platte Basin Totals	4,269,000		3,769,200	1,124,000	1,021,400	180,100	239,400	373,900	138,700	89,300	178,400

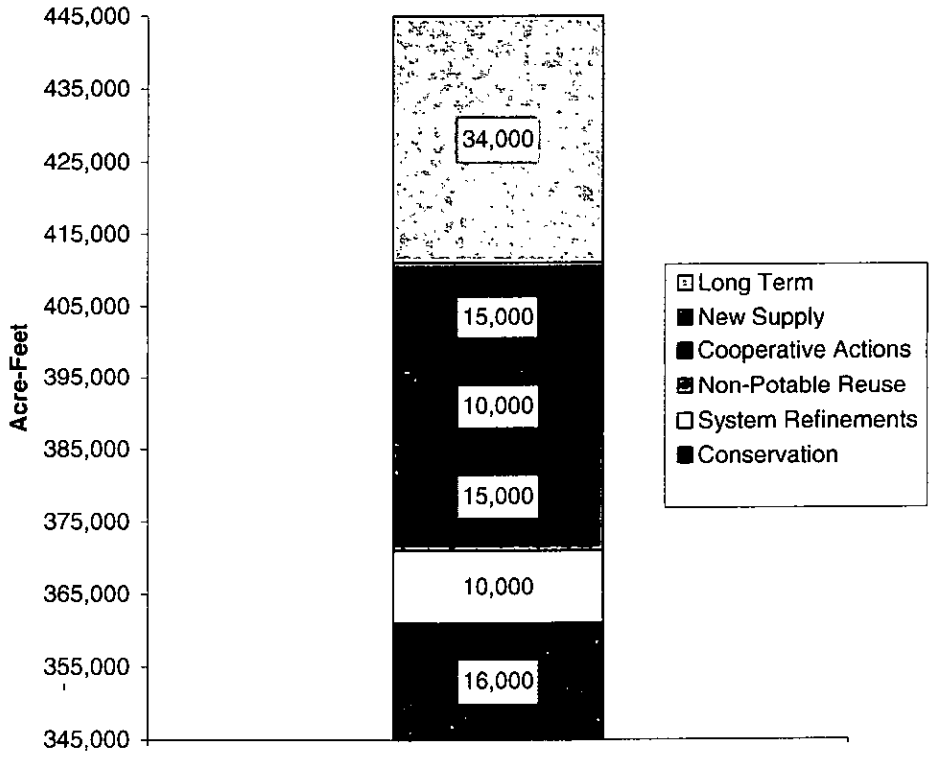
(1) Based on their planning efforts to date, water providers have a relatively high degree of confidence in these supplies.
(2) Water conservation savings are not included in Raw Water Deliveries.
(3) Figures include the City & County of Denver, 75 suburban distributors with Total Service, Read & Bill or Master Meter Accounts, and 13 Fixed/Special Contract commitments. Population and water use figures include portions of Arvada, Broomfield, and Westminster, based on raw water contract commitments. Projected future raw water deliveries include raw water system losses but do not include Denver's 30,000 AF safety factor.
(4) Deliveries include contract deliveries to Roxborough Park Metro District and raw water system losses, but do not include Aurora's 10,000 AF planning reserve.
(5) Thornton's reasonably certain future supply estimate includes only a portion of the yield of its Northern Project; if the full potential yield of the Northern Project is included, Thornton's future supply would increase to approximately 83,000 acre-feet.
(6) Westminster will receive 4,500 acre-feet of raw water from Denver in the future under a special raw water contract
(7) *Arvada will receive 19,660 AF of raw water from Denver in the future under a special raw water contract*
(8) Broomfield will receive 6,500 AF of treated water from Denver in the future under a special treated water contract
(9) Includes approximately 7,000 AF of industrial water use by Coors Brewing Company
(10) Consolidated Mutual Water Company will receive about 70% of its water from Denver under a several contracts.
(11) Includes municipal water uses in Clear Creek, Gilpin and Park counties and in the mountain portions of Jefferson county.
(12) Inverness and Meridian serve primarily commercial and industrial uses; population figures are therefore not shown.
(13) Roxborough Park is assumed to receive its future water supplies from Aurora under a raw water contract.
(14) Southgate is fully served by Denver under a read and bill treated water contract; population and raw water use figures are included in Denver's.
(15) Willows will be fully served by Denver under a read and bill treated water contract; population and raw water use figures are included in Denver's.
(16) Includes small providers in Douglas and Elbert Counties.
(17) Includes Fort Collins, Boulder, Greeley, Longmont, Loveland, Lafayette, Louisville, Superior, 27 smaller municipalities, 16 rural domestic water districts, and municipal water users in Logan, Sedgwick and Washington counties.

respective service areas. The future water supply plans of metro Denver area providers are briefly summarized by sub-region in the following sections.

3.1.6.1. Denver Central Sub-Region

Denver Water estimates that the firm annual yield of its existing system is about 345,000 acre-feet. Through its Integrated Resource Planning (IRP) process, Denver Water has developed a Near-Term resource strategy which will employ a combination of 66,000 acre-feet of water conservation, minor system refinements nonpotable reuse, cooperative actions with others and new supply development to meet its projected needs through the year 2030 to 2040, depending on the size of Denver's safety factor. Denver's Near-Term Strategy is shown in Figure 4 below.

Figure 4: Denver Water's Near-Term Strategy



Denver has not yet decided on its long-term options, although it has identified additional water conservation, potable reuse, conjunctive use and new supply development as options.

3.1.6.2. South Metro Sub-Region

Water providers in this sub-region anticipate additional use of their groundwater rights, surface supplies, reuse/augmentation plans and contract deliveries to meet their projected build-out needs. There is no significant unmet need projected for this sub-region, assuming that Denver Basin groundwater will continue to be used as a major water supply source.

However, the sub-region is actively working to increase the renewable portion of its water supplies by employing effluent management approaches that would maximize the reuse of its groundwater return flows, and by acquiring additional surface supplies. The region is particularly interested in expanding the roles of reuse and conjunctive use of surface and groundwater as ways to reduce its future use of Denver Basin groundwater.

3.1.6.3. City of Aurora

Aurora has not yet projected an ultimate or build-out demand for its service area. Instead, Aurora anticipates future growth to average 50,000 people per decade with an associated increase in water demands of 10,000 acre-feet per decade. Aurora therefore projects a future water demand of 95,000 acre-feet by the year 2030, which includes a 10,000 acre-foot planning reserve . Aurora has plans in place to meet its projected year 2010 demands with acquired Arkansas basin agricultural rights, additional effluent reuse, rehabilitation of its Cherry Creek alluvial wells, and other minor projects.

Aurora's plans for meeting its needs beyond the year 2010 include the Eagle River Conjunctive Use Project (in cooperation with the City of Colorado Springs), the South Park Conjunctive Use Project, and additional water reuse. Aurora is participating in cooperative planning activities of effluent management in the Northeast Metro sub-region described below. Aurora is also working with Denver Water to explore cooperative opportunities involving those entities' existing South Platte reservoirs.

3.1.6.4. Northeast Metro Sub-Region

The long-term future water demands for this sub-region are projected to be about 120,000 acre-feet per year. Most of this demand is associated with the City of Thornton. Providers in this sub-region have plans in place to meet about 100,000 acre-feet of this need.

Current planning efforts are focused on meeting the remaining 20,000 acre-feet of needs for this area, which are primarily associated with anticipated growth in Brighton and the South Adams County Water and Sanitation District. Denver and Aurora are also involved in these planning efforts because portions of their service areas are located in this sub-region. Current planning efforts are focused on development of gravel pit storage facilities, maximizing exchanges and finding potential uses for Aurora's and Denver Water's excess supplies of reusable effluent. Providers in this sub-region are

particularly interested in addressing water quality problems associated with municipal diversions located downstream of most of the urbanized metro Denver area.

3.1.6.5. Northwest Metro Sub-Region

The long-term future water demands for this sub-region are projected to be about 100,000 acre-feet per year. Most of the sub-region's projected increase in water demand is associated with anticipated growth in Arvada and Broomfield. Providers in this sub-region have plans in place to meet about 90,000 acre-feet of this need. Cooperative planning efforts for meeting the remaining 10,000 acre-feet of need in this sub-region are focused upon coordinated use and sharing of existing or new storage and conveyance facilities and expanded reuse.

3.2. WATER SUPPLY OPPORTUNITIES

As discussed in Basin-Wide Overview, the MWSI focused on five areas of investigation: conjunctive use, effluent management, interruptible supply arrangements with agricultural water users, other systems integration concepts and Chatfield Reservoir. The results of each of these investigations are presented and discussed below.

3.2.1. Conjunctive Use

3.2.1.1. Background

Conjunctive use is defined as the coordinated use of surface water and groundwater resources and systems to produce a larger and more reliable combined supply than could be generated from either source alone.

Conjunctive use was probably first used as a deliberate water management strategy in Colorado in the 1950's along the lower South Platte and Arkansas Rivers where farmers began using alluvial wells to supplement their surface diversions. Well pumping took advantage of water stored in the alluvial aquifers of the stream, and the alluvial aquifers would refill during subsequent high flow periods.

In the 1970's and 1980's Arapahoe and Douglas County providers became interested in conjunctive use for individual wells. The Willows Water District/Denver Water and the Centennial Water & Sanitation Districts initiated pilot studies which involved injecting potable surface water into deep aquifers via conventional water supply wells during periods when pumping from those wells was not needed. These studies evaluated the feasibility of water recharge, storage and retrieval for the purpose of reducing long-term declines in groundwater levels.

The metro Denver water community's interest in conjunctive use as a potentially large scale water supply source has its roots in Denver's long-standing plans to build Two Forks reservoir and in the more recent development of municipal wells in the Denver Basin aquifers.

In the early 1980's Two Forks was seen as the answer to Denver's future water supply needs. Over 100,000 acre-feet per year of storable flows remained in the South Platte above Denver and in the Blue River at Dillon and Two Forks was thought to be the perfect storage site for capturing these flows. While the project would have evaporation losses, would have major environmental and recreational impacts and would require more than 1,000,000 acre-feet of storage capacity to develop less than 100,000 acre-feet of yield, Two Forks was seen as the only way to effectively capture these flows.

The U.S. EPA's rationale for veto of the project in 1990 was based on EPA's beliefs that the project caused unacceptable environmental impacts and that practicable alternatives with less adverse impacts existed. Use of Denver Basin groundwater as a supply to be used in conjunction with surface supplies was one of the alternatives mentioned by EPA.

Development of Denver Basin groundwater began in earnest in the 1980's with the rapid growth within southern Arapahoe and Douglas Counties. For many water providers in this region, the Denver Basin represented the only available major water supply. Wells could be easily developed into plentiful aquifers. The State's newly enacted SB5 regulations clarified ownership issues and facilitated well development by water districts in the area. As growth continued in the region, Denver Basin groundwater became the principal water supply.

However, many of these providers were concerned about relying on Denver Basin groundwater as an exclusive supply over the long term. Natural recharge to the aquifers was assumed to be quite limited. Providers were concerned that water levels in wells would decline over time, leading to higher pumping costs, the eventual need for additional wells and reduced supplies.

In the early 1990's, Arapahoe and Douglas County providers recognized the desirability of using excess "wet year" surface supplies to meet their demands and to recharge aquifers, thereby augmenting their groundwater supplies and substantially prolonging the life of their groundwater resources (Mulhern, 1993). Thus the concept of conjunctive use in a metro Denver setting was born. The most obvious source of these "wet year" surface supplies would be the storable flows that remained in the South Platte above Denver and in the Blue River at Dillon.

More recently, the City of Aurora has become interested in the potential of conjunctive use as applied to local aquifers in mountain settings as a way to regulate runoff supplies available to junior water rights. Aurora has filed water rights applications for the Eagle River and South Park conjunctive use projects.

Conjunctive use was therefore identified early on in the MWSI as a major area of interest on the part of TAC members.

3.2.1.2. Conceptual Description of Conjunctive Use

Conjunctive use as a water management strategy can take several forms. Common to all forms is the use of groundwater and the storage function of aquifers to supplement and/or regulate surface supplies. Both alluvial and Denver Basin groundwater systems can be employed in a conjunctive use strategy. The following descriptions pertain to a conjunctive use strategy applied to the metro Denver region and the Denver Basin aquifer system, since this is the region's largest groundwater source.

When there are divertible surface water supplies legally available, a conjunctive use system would capture and utilize these surface supplies, and would utilize Denver Basin groundwater to meet the demands at times when surface supplies are not available. By jointly using surface water and groundwater supplies and systems, opportunities exist to develop new yield and to prolong the life of groundwater resources. While the concept of conjunctive use is interesting, there are issues and concerns associated with conjunctive use that are discussed at the end of this section.

Direct Use of Surface Water, Groundwater Back-Up

Under the simplest form of a conjunctive use plan, groundwater providers would use surface flows when legally available during runoff periods and would rely on wells during periods when surface flows were unavailable. This arrangement would extend the physical life of aquifers.

This arrangement historically occurred between Denver Water and the Willows Water District. Since the mid-1980's, Denver supplied surface water to Willows on a temporary and interruptible basis. Willows used the water supplied by Denver to meet its demands in those years, thereby reducing its reliance on its deep wells, which were its principal source of supply. (Denver and Willows have subsequently entered into an agreement under which Denver eventually will supply all of the potable water in Willows' service area.)

Direct Use of Surface Water With Groundwater Recharge

Groundwater recharge could be added to this basic conjunctive use arrangement. In this case, available surface water in excess of that needed to meet demands would be treated to potable standards and injected into aquifers via wells. This would increase the capture of surface flows and would replenish aquifers. Recharged water could then be pumped and used at a later time.

The Centennial Water and Sanitation District is already practicing this form of conjunctive use. Centennial uses available surface water from its surface water rights, its augmentation plan, its surface water contract interests, and from spot sales of water from Denver in order to minimize pumping of Denver Basin wells. In 1996, an above average year, Centennial met over 90% of its municipal demand from surface supplies and recharged approximately 500 acre-feet of surface water into its Denver Basin wells.

The Willows Water District and Denver Water, in conjunction with the U.S. Bureau of Reclamation, have also conducting pilot scale groundwater recharge studies as part of the Bureau's High Plains Aquifer Recharge Demonstration Project.

Conjunctive Use With Borrowing and Groundwater Recharge

A more comprehensive conjunctive use plan would require the coordinated operation of surface water and groundwater systems. Under this arrangement, groundwater supplies would serve as a drought-year supply for both groundwater and surface water systems. This would allow groundwater users to be served exclusively by surface water – both from runoff and from water released from surface reservoirs - during wet and average years. This would create greater draw-downs of surface reservoirs, allowing them to capture a greater amount of surface water during runoff periods. Under this mode of operation, water users relying on surface reservoirs could be exposed to additional risk of not refilling reservoirs in the event of drought. But this risk would be alleviated by the ability to supplement the surface water system with groundwater during droughts, thereby "paying back" the water "borrowed" from surface reservoirs. This type of a conjunctive use arrangement would require considerable cooperation among participating groundwater and surface water providers.

The surface water captured under a conjunctive use plan could be used to offset existing groundwater use and extend the life of existing non-tributary groundwater-dependent supplies. This would also stabilize future pumping costs, which would otherwise increase as aquifer levels decline. To the degree that a conjunctive use plan is designed for this purpose, the potential for "new yield" from that conjunctive use plan decreases. At the same time however, the long term operations, maintenance and replacement costs would be lower because of less aquifer decline.

Alternatively, the surface water captured under a conjunctive use plan could be temporarily stored in aquifers and used to produce additional firm yield. Under this latter approach, conjunctive use is similar to new reservoir construction except that the additional storage space is achieved by using the storage capacity of aquifers.

A conjunctive use plan could also be designed to address a combination of both purposes: offsetting existing groundwater uses and generating new yield.

3.2.1.3. Surface Water Availability

Information was gathered on surface water supplies potentially available for conjunctive use. Based on TAC guidance, potential surface water supplies that met the following criteria were assumed:

1. They would be divertible by metro Denver area providers under new or existing water rights.

2. There must be surface supply in excess of the amount needed to meet demands and fill existing reservoirs.

3. They would rely on existing surface water collection and importation facilities.

Based on a review of existing information, several sources of potential surface supplies were initially identified and considered. These included:

1. Denver's unused divertible supplies from the South Platte and Colorado basins, including South Platte free river water.

2. Aurora's unused divertible supplies from the Arkansas and Colorado basins.

3. Water from the Colorado-Big Thompson and Windy Gap projects.

4. Excess surface water from local tributaries such as Cherry and Plum Creeks, during precipitation events.

5. Excess South Platte flows occurring below Denver,

6. First use of South Platte irrigation rights.

Denver's Unused Divertible Supplies

In most years, more water is available to Denver Water's collection system and water rights than can be delivered or stored. Denver's "unused divertible" supplies are one potential source of surface water that could be used in a conjunctive use plan. The amount available would be subject to Denver's future needs and water development plans, water rights constraints, environmental concerns and West Slope issues.

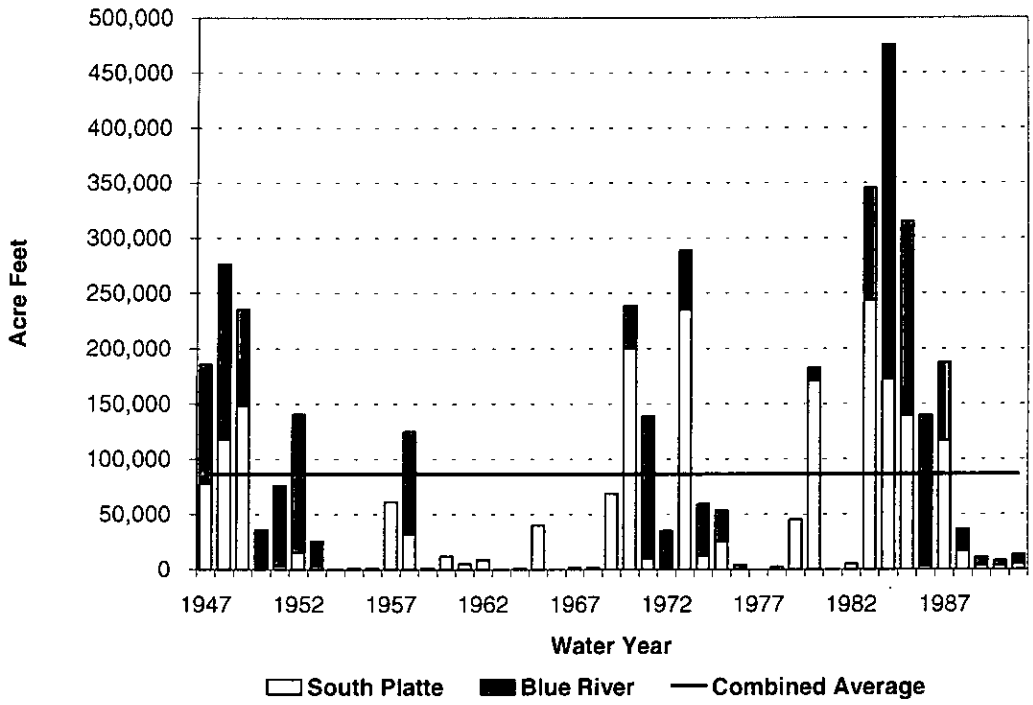
When Phase II of the MWSI began exploring conjunctive use, Denver was beginning its Integrated Resource Planning (IRP) process and its current PACSM model was not complete. An initial estimate of Denver's unused divertible supplies was therefore obtained from earlier Denver modeling studies done as a part of the Two Forks EIS. This initial estimate was based on monthly data and showed Denver's unused divertible supplies as averaging 85,000 acre-feet per year over the 1947 - 1974 period of hydrologic record. These supplies represented combined South Platte, Blue River and Fraser River flows divertible under Denver's water rights in excess of Denver's system needs at an assumed demand level of 335,000 acre-feet per year, which corresponded to the estimated safe yield of Denver's existing system at that time. This estimate was used in the MWSI's Phase II Conjunctive Use Summary Report.

During Phase III of the MWSI, a revised estimate of Denver's unused divertible supplies was developed using data from Denver's PACSM model. This second estimate was based on daily data and showed Denver's unused divertible supplies from the Blue and South Platte Rivers (excluding the Fraser River) plus free river water as averaging approximately 87,000 acre-feet per year over the 1947 through 1991 period of hydrologic

record. These flows are shown in Figure 5. This estimate reflected the operation of Denver's system at a safe yield of 395,000 acre-feet per year, which corresponded to Denver's Near-Term strategy as first developed in Denver's IRP process. At that time, Denver's Near-Term strategy included several system refinements, new supply projects, nonpotable reuse and conservation programs. (The primary reason for the slight increase in estimated unused divertible supplies in spite of a higher demand level for Denver is the inclusion of the years 1975 – 1991 in Denver's model studies. These years contained exceptionally large runoff seasons.)

This second estimate was used in the Southern Regional Cooperative Action Study (SRCAS), and was done as a follow-on study to the overall MWSI. Denver's unused divertible surface supplies from the South Platte and Blue River would have several major advantages in a conjunctive use arrangement. They represent a high quality supply that could be diverted at Strontia Springs, close to the major areas of municipal use of Denver Basin groundwater. As discussed in the following sections, most of this supply could be effectively regulated using existing surface reservoirs under a conjunctive use arrangement. However, it should be noted that the availability of this supply would be subject to Denver's future plans, water rights constraints, environmental/permitting considerations and West Slope concerns.

Figure 5: Denver's Unused Divertible Supplies South Platte and Blue Rivers Near-Term Scenario



Aurora's Unused Divertible Supplies

The City of Aurora has water rights in three transbasin diversion systems in the Colorado River basin and in several ditch companies and ranches in the Arkansas River basin. The divertible yields of these rights increase considerably in high runoff years. An initial analysis was conducted of Aurora's potentially unused divertible supplies as part of Phase II of the MWSI. This analysis revealed that, under future demand conditions and considering Aurora's current storage facilities, Aurora would have sufficient demand and storage capability to fully use these supplies under all but very wet conditions. In addition, Aurora is pursuing additional storage options to regulate these remaining flows. For these reasons, this MWSI did not examine this surface water supply source further.

Water from the Colorado-Big Thompson and Windy Gap Projects

The Colorado-Big Thompson Project was constructed by the U.S. Bureau of Reclamation for the primary purpose of providing a supplemental water supply from the Colorado River to lands within the Northern Colorado Water Conservancy District for irrigation, municipal, industrial and other beneficial uses. The Project has operated for over forty years according to water rights decrees, contractual agreements between the United States

Prepared for the Colorado Water Conservation Board, Colorado Department of Natural Resources by
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and the District, policies established by the District, and operating practices of the Bureau.

The Windy Gap Project was constructed by the Municipal Subdistrict of the Northern Colorado Water Conservancy District, with the agreement and cooperation of the District and the United States, to provide an additional independent water supply of at least 48,000 acre feet (AF) per year from the Colorado River to municipal and industrial water users located within the Subdistrict by more fully using the capacity of CBT Project facilities. The Windy Gap Project was completed in 1985. Its operation is subject to water rights decrees; a Carriage Contract between the United States, the District and the Subdistrict; an integrated operations plan; individual participant allotment contracts and various policies established by the Subdistrict.

The potential availability of CBT and Windy Gap project water for conjunctive use was initially examined using information from previous modeling studies.

CBT Project Water

CBT project water is allocated to District water users based upon their ownership of CBT units and an annual quota set by the District Board. All CBT units are owned and actively used by water users in the District; in that sense there is no "excess" quota water available for conjunctive use. In addition, District policies and Federal repayment contracts prohibit the use of CBT project water outside the boundaries of the District.

Occasionally the District Board also makes "non-charge" CBT water available to water users within the District. Non-charge water is issued when anticipated runoff makes a spill from Granby Reservoir imminent. Non-charge water is provided on a first come-first serve basis to all water users in the District who can that water to immediate beneficial use; ownership of CBT units is not required. Non-charge water has only been issued in ten years since the CBT project began operations, although large amounts of non-charge water (over 120,000 acre-feet) have been delivered in individual years. Given that non-charge water is not owned by individual water users, it could be considered as a potential surface supply for conjunctive use.

However, the same prohibition of use of CBT project water outside District boundaries applies. Also, delivery of meaningful amounts of non-charge water into the metro Denver area would require major new storage and conveyance facilities. For these reasons it was concluded that CBT project water would not be available as a potential surface supply for conjunctive use in the metro Denver area. However, non-charge water could be used in a conjunctive use arrangement within the Northern Colorado Water Conservancy District boundaries.

Windy Gap Project Water

The Windy Gap project was designed to provide an average supply of 48,000 acre-feet per year to project participants. The project began operating in 1985, and is currently operating at less than 50% of capacity. However, full use of Windy Gap project water by

current project participants is expected to ultimately occur. It was therefore concluded that Windy Gap water could potentially be available for conjunctive use only as an interim source. District and Subdistrict Board policies effectively prohibit the use of Windy Gap water outside of District boundaries. Major new storage and conveyance facilities would be needed to deliver this supply into the metro Denver area. For these reasons this source was not studied further.

Local Tributaries

The potential availability of surface flows from Cherry and Plum Creeks was briefly examined using historical stream flow records and call data. This analysis revealed that an average of 4,000 to 5,000 acre-feet of excess surface flow could be available, but that these flows would occur extremely sporadically and would require storage capacity in excess of 50,000 acre-feet for regulation. This source was not investigated further because of the relatively small yield, the need for major storage in rapidly developing areas. This source could be incorporated into a larger conjunctive use plan, especially if new surface storage were available in off-stream locations or via flood control storage reallocation at Cherry Creek and Chatfield reservoirs.

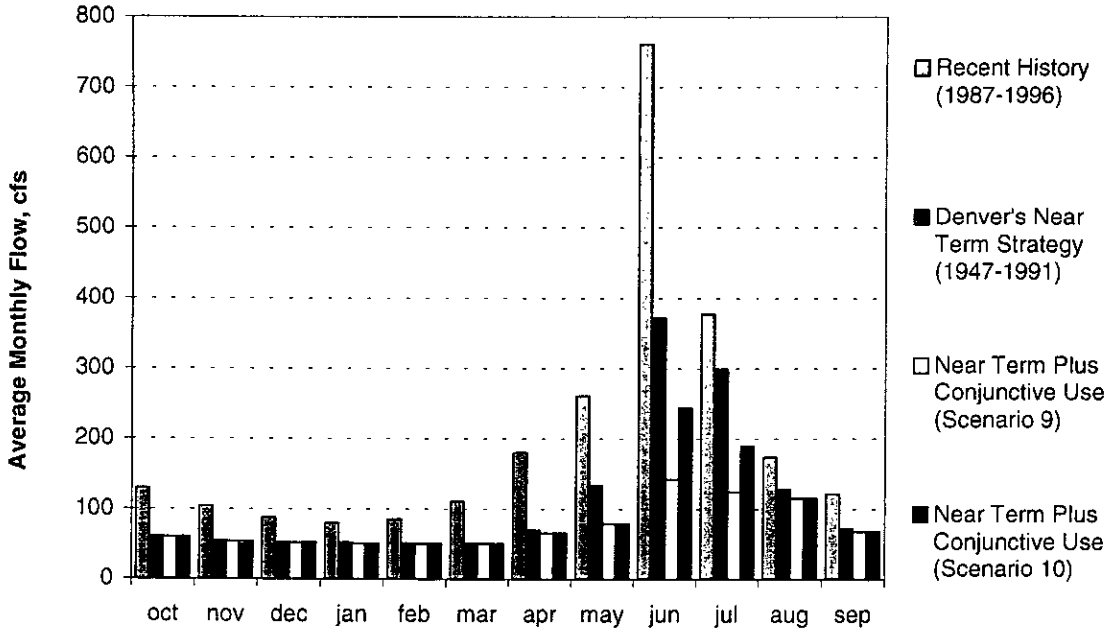
South Platte Flows Below Denver

The South Platte River below Denver has significantly more surface water potentially available for conjunctive use than at upstream locations due to urban return flows (wastewater and lawn irrigation returns), surface flows from local tributaries, and stormwater runoff from urban areas.

The potential availability of South Platte flows below Denver was examined under future conditions as reflected in Denver's Near-term scenario. Excess flows at the Burlington Ditch and at the Henderson gage were estimated taking into account existing irrigation uses and future municipal uses as reflected in PACSM. These two locations were examined because the Burlington Ditch is a major conveyance structure that could be used to divert additional surface supplies under a conjunctive use arrangement, and the Henderson gage reflects virtually all of the metro Denver region's return flows. Estimates of excess South Platte flows below Denver are shown in Figure 6.

This source represents a major potential surface supply available for a conjunctive use plan. However, it is located much farther from the Denver Basin groundwater users in the region and from existing surface water reservoirs other than Barr Lake. Therefore major conveyance and storage facilities would be needed to make use of this supply in a conjunctive use manner, except possibly for those municipal providers and water uses located in the northeast quadrant of the metro Denver region. In addition, the water quality of this supply shows the effects of return flows from a major urban region and therefore this source is not in great demand as a municipal supply among metro Denver providers. Consequently the MWSI did not initially examine conjunctive use concepts using this water supply. The potential for using this supply is being considered in the

Figure 6: Blue River Below Dillon Reservoir



The example conjunctive use plan would also increase stream flows in reaches conveying water diverted from the Blue River and water "borrowed" from Denver's reservoirs. Stream flows in the South Platte below Cheesman would generally increase during the August through April period in most years while stream flows in the North Fork South Platte below Grant would generally increase year round. There would be considerable flexibility as to when these flow increases could occur. This would allow for flow management to address fishery and recreational needs in the augmented reaches.

Endangered Species

There could be endangered species concerns related to the surface water depletions in both the South Platte and Colorado River basins would occur as part of a conjunctive use project. These would be similar in nature to surface water depletions that would result from a new surface water storage project. Cooperative agreements are in place in both basins to address the needs of the endangered species while allowing for continued development of water resources in Colorado.

Effects on Reservoir Recreational Levels

Conjunctive use plans involving borrowing arrangements with Denver would result in an overall decrease in storage in Denver's reservoirs on a year round basis. This decrease

under a first use arrangement with downstream irrigation rights. However, it is possible that the yield of a conjunctive use project could be enhanced by considering potential first use arrangements as another source of surface supply.

3.2.1.4. Groundwater and Aquifer Availability

Two potential groundwater resources were identified as part of the MWSI's study of conjunctive use concepts: the Denver Basin nontributary aquifer system and the Beebe Draw alluvial aquifer system. These two aquifer systems are the largest groundwater resources within reasonable proximity to the metro Denver area.

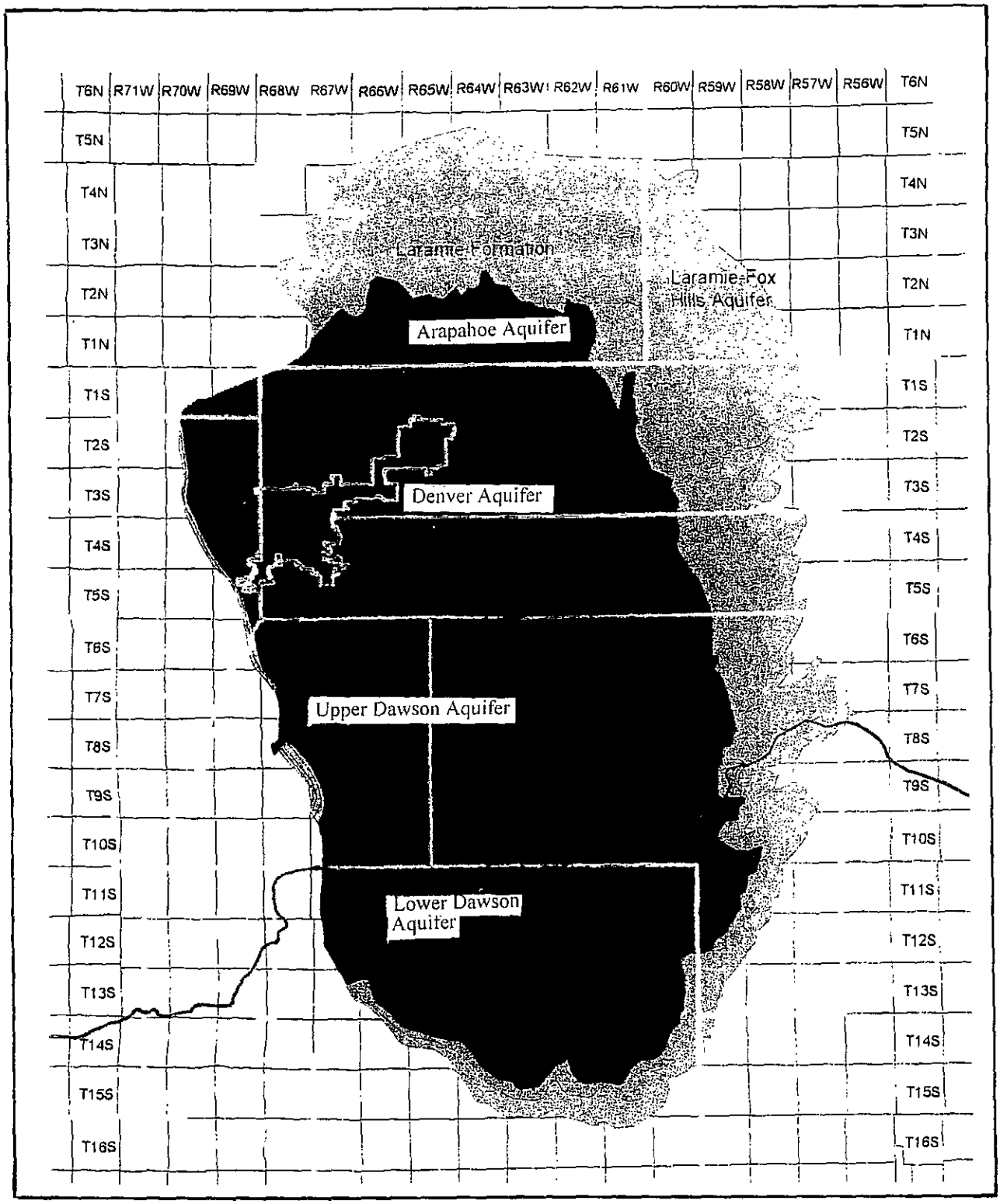
There are enormous differences between these two aquifer systems from the perspective of a conjunctive use project for the metro Denver area. While both aquifers are essentially nontributary with respect to South Platte River surface flows, the Denver Basin aquifers are much deeper, geographically much more extensive (underlying about 6,800 square miles compared to 300 square miles for the Beebe Draw), and have much more water in storage. Artificial recharge of the Denver Basin aquifers would require use of well injection, while the Beebe Draw could be recharged via surface ponds. The water quality of the Denver Basin aquifers is generally better than Beebe Draw aquifers.

There are other groundwater resources that could potentially be used in conjunctive use arrangements, such as the alluvial aquifers of Lost Creek and Box Elder Creek and aquifers in the South Park area of the Upper South Platte.

Denver Basin Aquifers

The Denver Basin groundwater basin underlies approximately 6,700 square miles as shown in Figure 7. It extends from Greeley in the north to Colorado Springs in the south and from the Front Range in the west to the high plains in the east. In ascending order the Denver Basin aquifers include the Laramie-Fox Hills, Arapahoe, Denver and Dawson aquifers. There is an enormous amount of water in storage in the Denver Basin aquifers, approximately 467 million acre-feet, 300 million acre-feet of which is recoverable (Robson, 1987). The total amount of recoverable water in the five county metro Denver area is estimated to be approximately 150 million acre-feet, with approximately 40 million acre-feet beneath Douglas County alone (Van Slyke, 1993). The areas of greatest aquifer thickness and best well production occur in southwestern Arapahoe and northern Douglas Counties. The water quality of the Denver Basin aquifers is generally good.

Aquifer Map of the Denver Basin



Legend

Denver Basin Aquifer
- Arapahoe Aquifer
- Denver Aquifer
- Fault
- Laramie Formation
- Laramie-Fox Hills Aquifer
- Lower Dawson Aquifer
- Upper Dawson Aquifer
- Township/Range

Division Boundary
County Boundary

WATER RESOURCES

Existing (1996) levels of use of Denver Basin groundwater were estimated to be approximately 57,000 acre-feet per year. About 50% of this is due to municipal use with the rest attributed to irrigation, livestock & domestic, and industrial uses. Over 50,000 gpm (over 80,000 acre-feet per year) of municipal well capacity is currently developed into the Denver Basin aquifers, primarily within Douglas County (HRS, 1997).

Two pilot programs for recharging water into the Denver Basin have been undertaken by the Willows Water District in cooperation with Denver Water, and by the Centennial Water & Sanitation District. These projects have successfully injected and stored treated surface water into the Denver and Arapahoe aquifers. Both studies have stressed the importance of injecting high quality treated surface water which is chemically compatible with the native groundwater. There have been varied results with respect to well hydraulic issues; one pilot program has experienced hydraulic head build-up during reinjection, while the other program has found an increase in well efficiency over time.

Recharge (injection, storage and recovery) into the Arapahoe aquifer at pilot levels has been shown to be viable. Additional research and review of these projects will be required to evaluate the long term effects of injection and recovery operations at higher levels on wells and the aquifer, the long term well maintenance costs, and the applicability of recharge to other aquifers in the Denver Basin.

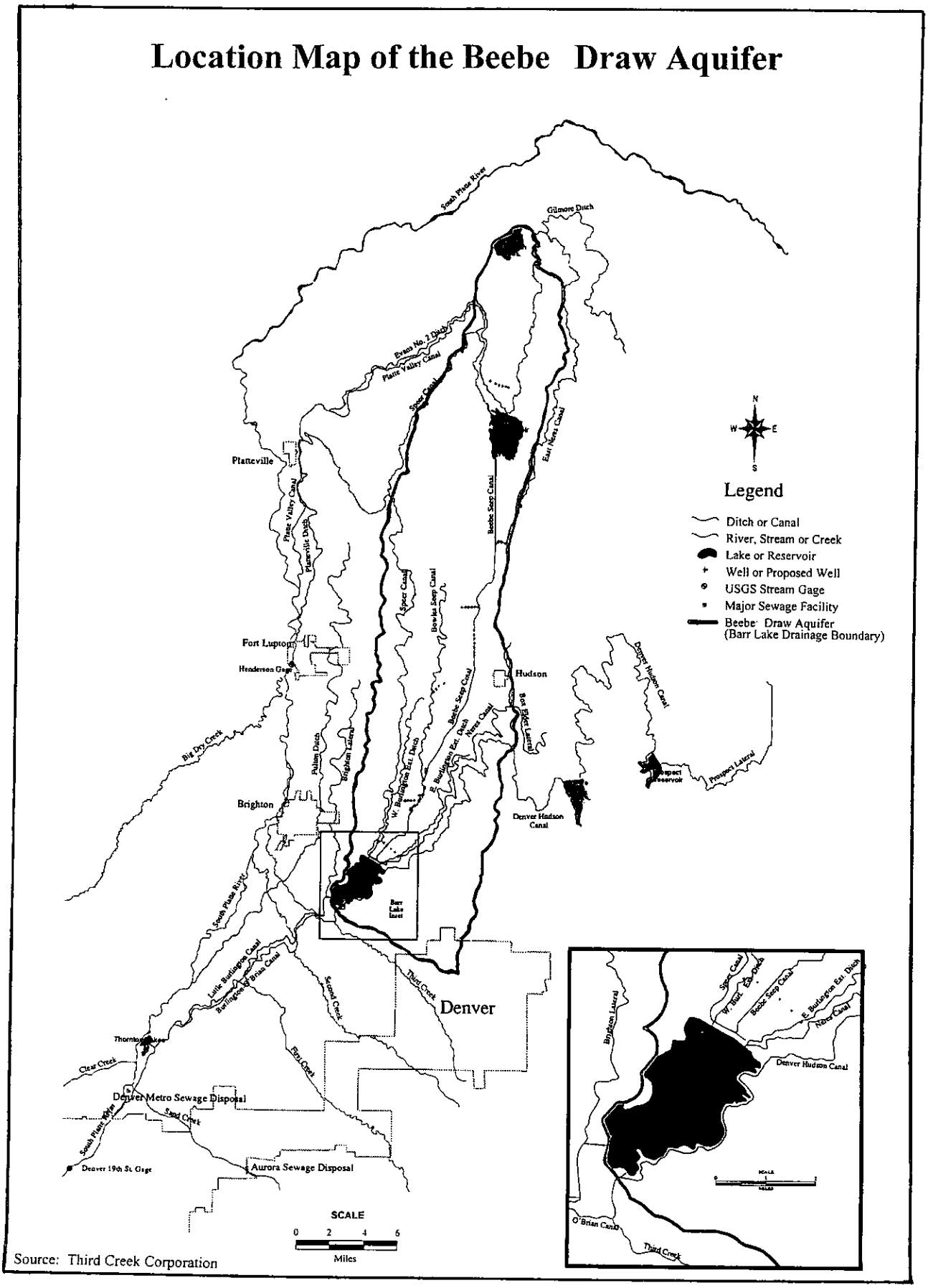
The Denver Basin aquifer system was included in the MWSI's conceptual examination of conjunctive use because of the size and extent of the aquifer system, the significant municipal reliance on the aquifer system, and the proximity of existing municipal well fields to the South Platte River.

Beebe Draw

The Beebe Draw aquifer was examined as a potential groundwater resource for conjunctive use arrangement for several reasons: 1) it is located relatively close to the northern part of the metro Denver area, 2) it is part of the Barr Lake irrigation system, and 3) the irrigation companies associates with the Burlington Ditch and Barr Lake are interested in a cooperative arrangement with Denver area municipal providers as expressed in the Barr Lake Plan, a multi-purpose water management concept document produced by the companies. The Barr Lake Plan incorporates the water rights, storage and conveyance facilities of the Farmers Reservoir and Irrigation Company, the Burlington Ditch Reservoir and Land Company, and the Henrylyn Irrigation District (the "Companies").

Beebe Draw is a shallow (up to 100 feet thick) alluvial aquifer located between Barr Lake and Milton Reservoir, as shown in Figure 8. It is geologically isolated between the South Platte River on the west and Box Elder Creek on the east. Hydrogeologically it is an extinct paleochannel of the South Platte. The total storage capacity of the aquifer is estimated to be between 1 and 2 million acre-feet. The aquifer is relatively porous, with well capacities as high as 2,000 gpm. The major sources of supply to the aquifer are

Location Map of the Beebe Draw Aquifer



Source: Third Creek Corporation

seepage from Barr Lake return flows from irrigation within the Draw and precipitation. The aquifer is currently at or near its storage capacity with discharges to the surface accumulating in Beebe Seep, a surface drainage running north to Milton Reservoir. The aquifer is currently used for supplemental irrigation. Existing use of the aquifer is not precisely known but is estimated to be small compared to the aquifer's storage capacity.

The aquifer has several water quality problems, primarily associated with elevated levels of dissolved manganese and nitrate. These problems reflect historical supply sources to the aquifer and local irrigation practices. The MWSI's initial investigations suggest that more active use of the aquifer coupled with changes in water quality management practices in the Draw could improve the water quality of the aquifer over time.

The Companies have an augmentation plan that can utilize the storage potential of the Beebe Draw aquifer for recharge and storage of surface supplies and delivery to irrigation and municipal uses. The Companies envision that the aquifer, combined with Barr Lake, have sufficient storage capacity to meet the Companies' irrigation needs while also providing a major new municipal supply to the metro Denver area.

The MWSI examined the potential use of the Beebe Draw aquifer for storage and subsequent use of water in a conjunctive use arrangement. Background data were reviewed concerning water occurrence in the aquifer. These data suggested a total unsaturated volume in the aquifer of approximately 83,000 acre-feet. This represents the total available storage capacity in the aquifer under current levels of use.

A groundwater flow model was used to simulate the response of the aquifer to recharge under several scenarios. Potential recharge sites were selected on the basis of sufficiently low transmissivity, adequate unsaturated thickness, and location away from Beebe Seep in order to minimize rapid loss of water to the surface. The analysis showed that up to 13,000 acre-feet of the aquifer's existing storage capacity could effectively be used for recharge, storage and subsequent withdrawal of water. The balance of the aquifer's storage capacity is located in areas with very high transmissivity, minimal unsaturated thickness, or where recharged water would rapidly emerge at the surface.

It is possible that a program of more intensive use of the aquifer would significantly increase the useful storage capacity of the aquifer for conjunctive use purposes. This would require a more elaborate modeling study addressing the well facility and operational aspects of such a management regime as well as the effects on existing surface irrigation uses and well uses, changes in supply to Milton Reservoir, and aquifer water quality. Such a study was beyond the scope of the MWSI.

The Beebe Draw aquifer is located relatively far from most groundwater-dependent Denver area providers. Therefore major conveyance facilities would be needed for providers outside of the northeast quadrant of the metro Denver area to make use of this supply in a conjunctive use manner.

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3.2.1.5. Analytical Approach

The MWSI analyzed an example conjunctive use project that focused on the southern metro Denver area, involving DCWRA member providers and Denver Water. This example was selected because of the importance of Denver basin groundwater use in the southern metro Denver area. A large-scale regional example project was investigated because of widespread interest in conjunctive use among DCWRA providers, and because Denver Water's Resource Statement contained guidelines for cooperative actions which encouraged the consolidation of water supply proposals at regional or sub-regional levels. The MWSI's analysis focused on the physical water availability, operational, facilities and potential yield aspects of a conjunctive use project. It did not address in detail the water rights, environmental impacts, facility costs or implementation aspects of such a project.

The central premise in the MWSI's example conjunctive use plan was that a new pipeline from Denver's Conduit 26 could be used to deliver surface water to DCWRA groundwater providers where it could be used directly, stored in new reservoirs, and recharged into Denver Basin aquifers via well fields. The pipeline could also be used to deliver surface water and groundwater back to Denver at the Foothills treatment plant when needed. The surface water captured under this arrangement could provide water to new development or could be delivered to existing users, thereby reducing existing levels of pumping from Denver Basin aquifers.

Conjunctive use could be implemented with or without "borrowing" water from Denver's reservoirs. Each of these two concepts can be explained and simulated via relatively straightforward operating rules.

In the "without-borrowing" concept, surface water would be diverted from the river and delivered to DCWRA providers only during high flow periods when Denver's unused divertible supplies were directly available. During other periods, water would be withdrawn from Douglas County reservoirs and pumped from Denver Basin wells to meet demands.

In the "with-borrowing" concept, surface water would also be released from Denver's Cheesman, Eleven-Mile and Dillon reservoirs ("borrowed") to meet additional demands, to fill Douglas County reservoirs and to recharge Denver Basin aquifers. In this manner additional space would be created in Denver's reservoirs to more effectively capture surface flows in subsequent years. Borrowing from Denver's reservoirs would occur only when Denver's reservoirs were above a specified "storage trigger" level, and the cumulative amount borrowed ("the debt") would be tracked. If Denver's reservoirs subsequently refilled completely, the debt to Denver would be erased. If Denver's reservoirs only partially refilled, the debt to Denver would be the amount borrowed or the reservoir capacity that was not refilled, whichever was less. If Denver's reservoirs fell below the storage trigger, borrowing would cease and the debt to Denver would be paid back with deliveries from Douglas County storage or from well pumping to Denver's Foothills water treatment plant via the new pipeline within a specified "repayment

period". Borrowing would be subject to a limit based upon the systems' ability to repay Denver within the specified payback period.

A simple model of these types of conjunctive use arrangements was developed during Phase II of the MWSI. This model used estimates of Denver's unused divertible supplies obtained from Denver's earlier modeling studies done as a part of the Two Forks EIS, as discussed previously. The model was used to initially explore the operational dynamics of a large-scale conjunctive use plan and to generally determine whether a conjunctive use approach could be effectively used to develop new water supplies and extend Denver Basin aquifer life. Potential yield, net effects on aquifer storage levels, and relationships between critical operational and facilities variables were explored. Based on the model results, conceptual costs for an example large-scale conjunctive use project combined with a regional treated water delivery system were developed to determine whether such a concept was within the realm of basic feasibility. The MWSI's Phase II analyses of conjunctive use are discussed in detail in the MWSI Phase II Conjunctive Use Summary Report.

A more detailed investigation of the operational and yield aspects of conjunctive use is being conducted in the Southern Regional Cooperative Action Study (SRCAS). This study is using more recent estimates of Denver's unused divertible supplies and is simulating the potential operations of Denver's reservoirs in a more detailed manner. While this study has explored the operational possibilities of conjunctive use in more detail, several dimensions of feasibility, including water rights, environmental impacts, institutional arrangements and costs remain to be examined.

More refined analysis will be required to meaningfully determine the feasibility, yield potential and operating rules of any specific conjunctive use plan. Significant technical, legal, institutional and environmental issues remain to be addressed. The reader is referred to Section 3.2.1.7, Issues and Concerns for a discussion of these issues.

3.2.1.6. Results of Conjunctive Use Investigations

CAVEAT: It should be noted that the study results presented and discussed below are preliminary and conceptual in nature.

MWSI Phase II Analysis

The MWSI's Phase II analysis focused on conjunctive use options "with borrowing," and explored the sensitivity of yield results to varying rates of aquifer recharge capability, and surface water borrowing limits. Alternate sets of runs were made to maximize surface water capture assuming either: 1) no net depletion of the groundwater aquifers; or 2) a 300-year aquifer life (i.e. an average annual net depletion of one-three hundredth ($1/300^{th}$) of the groundwater available beneath the service areas of participating groundwater providers.

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The results of the Phase II modeling showed a potential yield of up to 60,000 acre-feet could be attained annually from a conjunctive use arrangement with no net depletion of the aquifer. This yield increased to 73,000 acre-feet assuming that a 300-year aquifer life could be tolerated.

The following assumptions were made in these Phase II analyses.

- All of Denver's estimated 85,000 acre-feet of unused divertible supplies (including Blue River, South Platte and Moffat supplies) were treated as a single inflow to Denver's system, available for conjunctive use, divertible at Strontia Springs and storable in Denver's reservoirs.
- All of Denver existing raw storage (505,000 acre-feet) was treated as a single reservoir, available for borrowing and capable of capturing Denver's unused divertible supplies.
- A borrowing storage trigger of 200,000 acre-feet (Denver's total storage level below which borrowing is suspended).
- A borrowing limit of 100,000 acre-feet.
- DCWRA providers' combined well pumping capacity of 9,000 acre-feet per month (equal to peak month demand for 60,000 AF per year).
- Well recharge capacity of 4,500 acre-feet per month (equal to 50% of well pumping capacity) is feasible over the long term.
- A new 12,000 acre-feet peaking reservoir in Douglas County.
- A new pipeline of unlimited capacity from Conduit 26 to DCWRA providers.

Under the simplifying assumptions made in this Phase II analysis, the results suggested that conjunctive use could be a source of significant new yield. The important roles of aquifer recharge and of borrowing-pay back arrangements with Denver's surface reservoirs in capturing additional surface supplies became obvious. The results of the Phase II studies were sufficiently positive to warrant further investigation, which is occurring in the Southern Regional Cooperative Action Study (SRCAS).

Southern Regional Cooperative Action Study

The conjunctive use analyses undertaken in the SRCAS relied on a more detailed model and more refined assumptions and data regarding Denver's unused divertible supplies, surface water reservoirs available for borrowing and facility capacities. The model included a more detailed representation of Denver's upper South Platte and Blue River systems and DCWRA providers. Cheesman, Dillon and Eleven-Mile reservoirs were modeled separately and were considered as the only Denver reservoirs available for potential inclusion in a conjunctive use plan. Daily estimates were obtained of Denver's unused Blue River and South Platte divertible supplies under Denver's Near-Term water use scenario. These supplies were split into those portions occurring tributary to Dillon, Cheesman, Eleven Mile, and Strontia Springs. Model runs explicitly reflected capacity constraints for all new and existing pipelines and reservoirs in the system.

Conjunctive Use Without Borrowing or Recharge

An initial series of scenarios was explored representing a simplified version of conjunctive use. In these scenarios, surface flows could be used to meet DCWRA provider demands and to fill new off-stream Douglas County reservoirs, but no aquifer recharge capability or "borrowing" agreements with Denver was assumed. These scenarios reflect relatively conservative assumptions regarding cooperation between Denver Water and DCRWA providers and the use of Denver's system. The following assumptions were reflected in these scenarios.

- Operation of Denver's system under its Near-Term resource strategy (as defined at that time) with a raw water demand of 395,000 acre-feet per year.
- Normal operation of Denver's reservoirs (no borrowing).
- Denver's unused divertible supplies from its South Platte and Roberts systems (averaging 87,000 acre-feet per year under its new PACSM modeling) would be available for conjunctive use.
- Denver would use its unused divertible supplies to meet DCRWA providers' demands and to fill new off-stream storage only when the yield of Denver's water rights exceeded its own needs.
- No recharge of Denver Basin aquifers.
- DCWRA provider well pumping capacity sufficient to meet peak month demands.

The results of the no-borrowing, no-recharge analyses are summarized in Table 4.

Table 4: Results of No-Borrowing, No-Recharge Scenarios

Scenario	Demand Level, af/yr.	New Pipeline Capacity, cfs	New Reservoir Capacity, af	Average Surface Water Deliveries, af/yr	Average Groundwater Deliveries, af/yr
1	25,000	60	0	9,900	15,100
2	25,000	100	25,000	15,000	10,000
3	25,000	200	80,000	20,200	4,800
4	60,000	200	80,000	25,500	34,500

A demand level of 25,000 acre-feet per year corresponds to DCWRA providers' existing municipal use of Denver Basin aquifers. Scenarios with this demand level illustrate the potential benefit of an arrangement where DCWRA providers would use Denver's unused surface supplies to reduce existing groundwater pumping in their service areas and to fill off-stream storage. Under these scenarios it was assumed that there would be no net water supply benefit or impact to Denver's system. Obviously a conjunctive use arrangement such as this would require some other form of compensation to Denver for use of its water rights and facilities.

The scenario with a 60,000 acre-foot demand level shows that, as DCWRA providers' demands increase or if new yield to Denver is required as part of the arrangement, a conjunctive use plan without borrowing or aquifer recharge capabilities would not be as effective in reducing Denver Basin groundwater use.

Without additional on-stream storage capacity (which could be created by a borrowing program with Denver or by building new on-stream reservoirs) the ability of a conjunctive use project to capture unused surface supplies would be limited by the capacity of the new pipeline to Douglas County. Even a 200 cfs capacity pipeline would be of limited value because much of Denver's unused divertible supplies occurs during relatively brief periods of extremely high flows.

Without groundwater recharge capability, even 80,000 acre-feet of new off-stream storage would be of limited value in a large scale conjunctive use project due to the 17-year critical period (1953-1969) between significant amounts of available surface supplies under future demand conditions, as shown in Figure 5. In order to effective regulate much of Denver's remaining unused divertible supplies, additional storage considerably in excess of 80,000 acre-feet would be required.

Conjunctive Use With Borrowing and Recharge

A second series of scenarios was developed to explore a conjunctive use including a borrowing arrangement with Denver and recharge of Denver Basin aquifers. These scenarios reflect a more integrated approach to conjunctive use, requiring more cooperation between Denver Water and DCRWA providers and significant changes in the operation of Denver's system. The following assumptions were reflected in these scenarios.

- Operation of Denver's system under its Near-Term resource strategy (as defined at that time) with a raw water demand of 395,000 acre-feet per year.
- Denver's unused divertible supplies from its South Platte and Roberts systems (averaging 87,000 acre-feet per year) would be available to meet DCRWA providers' demands, fill new off-stream storage, recharge aquifers, and could be captured in Denver's reservoirs.
- Denver would allow borrowing from Dillon, Cheesman and Eleven Mile Canyon Reservoirs, subject to borrowing triggers, and would capture its unused divertible supplies in these reservoirs using the storage capacity created by borrowing.
- A borrowing storage trigger of 250,000 acre-feet (Denver's total storage level below which borrowing is suspended).
- Payback of Denver deficit required within two years after storage trigger reached.
- Payback can be made with either surface water or groundwater.
- DCWRA providers' well pumping and water treatment capacity of 9,000 acre-feet per month (equal to peak month demand for 60,000 AF per year).

- Well recharge capacity of 6,000 acre-feet per month (equal to 67% of well pumping capacity) is feasible over the long term.

The results of the "with-borrowing" scenarios are shown in Table 5. These results suggest that adding the ability to borrow from Denver storage and the ability to recharge Denver Basin aquifers would greatly increase the effectiveness of a conjunctive use plan in capturing additional surface supplies.

Table 5: Results of With-Borrowing Scenarios

Scenario	Demand Level, af/yr	New Pipeline Capacity, cfs	New Reservoir Capacity, af	Aquifer Recharge Capacity, cfs	Average South Platte Deliveries, af/yr	Average Blue River Deliveries, af/yr	Average Net Groundwater Deliveries, af/yr
5	60,000	0	0	0	0	0	60,000
6	60,000	100	0	0	15,000	17,000	28,000
7	60,000	100	55,000	0	16,000	20,000	24,000
8	60,000	200	80,000	0	18,000	20,000	22,000
9	60,000	200	80,000	100	22,000	30,000	8,000
10	60,000	200	80,000	100	28,000	20,000	12,000

The borrowing and payback arrangement would provide sufficient drought protection to Denver to allow for greater seasonal draw-downs of some of its reservoirs. Reliable payback to Denver could be assured because DCWRA providers would have excess well capacity during off-peak months of dry years that could be used to pay back Denver with groundwater. Greater seasonal draw-downs of some of Denver's existing reservoirs would greatly increase those reservoirs' ability to capture surface supplies because most of Denver's unused divertible supplies are tributary to Dillon, Cheesman and Eleven Mile reservoirs.

The ability to recharge Denver Basin aquifers greatly enhances the effectiveness of a conjunctive use arrangement because the amount of aquifer storage available in the Denver Basin is vastly greater than what could be built as new surface storage. For example, the total use of groundwater storage occurring in Scenario 9 above over the 45-year hydrologic modeling period was greater than 800,000 acre-feet, more than ten times the available off-stream surface storage capacity in Douglas County. Also, there would be no evaporation losses to or water quality degradation in water stored in the aquifers. Both of these factors are crucial given the long periods between major occurrences of Denver's unused divertible supplies as shown in Figure 5. Consequently recharge capability appears to be relatively more valuable than new surface storage beyond a relatively small operational level.

The results also show that considerable flexibility could exist in a conjunctive use plan regarding the relative amounts of surface supplies captured from the Blue River versus the South Platte River. While some additional Blue River waters would be needed in order to maximize the yield of a conjunctive use project, capture of most of Denver's unused divertible Blue River supplies would not be necessary for attainment of

significant yields. This is illustrated in Scenarios 9 and 10 in Table 5 above. In Scenario 9, water was borrowed proportionately from Dillon, Cheesman and Eleven Mile reservoirs based on their respective storage contents. Because Dillon comprises about 60% of the total storage, most borrowing came from Dillon and most of the capture of Denver's unused divertible supplies occurred at Dillon. In Scenario 10, an operating rule was imposed that required borrowing to occur preferentially from Cheesman and Eleven Mile. Consequently, most of the surface water captured was South Platte water. From a total systems perspective Scenario 10 was slightly less efficient at minimizing net groundwater withdrawals, but it significantly reduced the depletive impacts to the Blue River.

The results of these analyses show that the yield from a conjunctive use plan could be used to meet the water needs of new development or to offset existing groundwater uses, or a combination of both.

The SRCAS is ongoing at the time of this report and these results are subject to further refinement. Details of these analyses can be found in the SRCAS – Phase 1 Report.

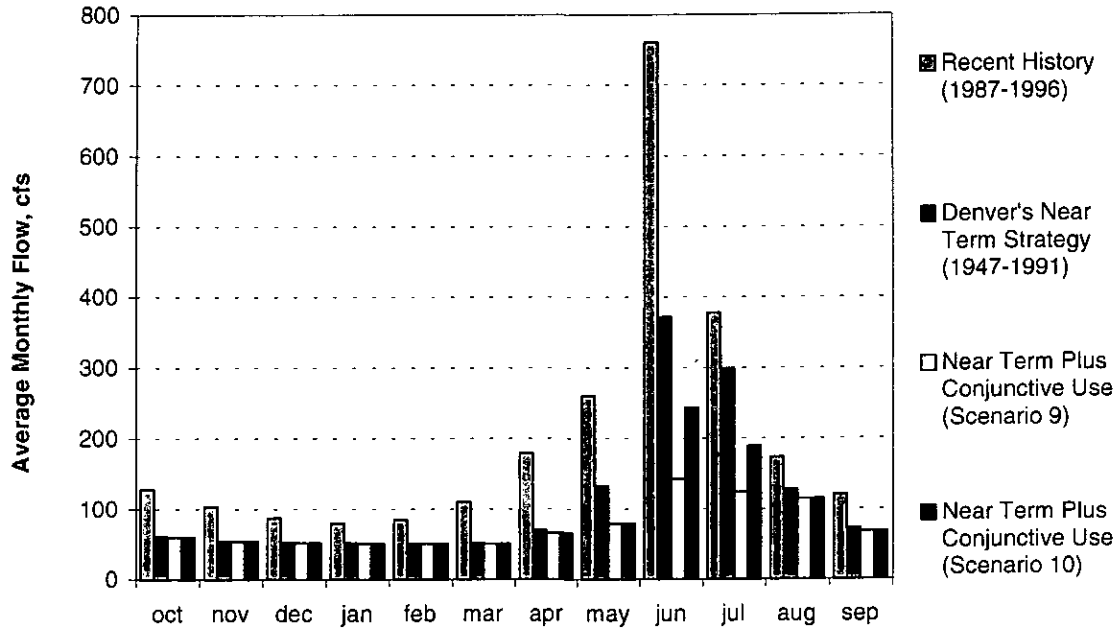
3.2.1.7. Issues and Concerns

The conjunctive use investigations done to date under the MWSI have focused on the hydrologic, operational and facilities aspects of conjunctive use as a potential water supply source. However, there are numerous potentially serious issues and concerns that have been identified in the course of these investigations that will require further analysis and resolution before any notion of feasibility can be entertained. A high level of cooperation between DCWRA providers, Denver Water and West Slope interests would be required. While it was beyond the scope of the MWSI to address these issues and concerns, they are identified and briefly discussed below.

Effects on stream flows

A conjunctive use project would result in the same type of depletive and accretive effects on stream flows as a new off-stream surface water reservoir project. The stream segments affected would depend on the configuration of the conjunctive use project. The example conjunctive use plans examined in the MWSI involved Denver's unused divertible supplies from the Blue and South Platte Rivers. Depletions to stream flows would therefore occur in both rivers, primarily during the months of May through July. The depletive effects of two example large scale conjunctive use projects (Scenarios 9 and 10 in Table 5 above) on the Blue River below Dillon are shown in Figure 9 below.

Figure 9: Blue River Below Dillon Reservoir



The example conjunctive use plan would also increase stream flows in reaches conveying water diverted from the Blue River and water "borrowed" from Denver's reservoirs. Stream flows in the South Platte below Cheesman would generally increase during the August through April period in most years while stream flows in the North Fork South Platte below Grant would generally increase year round. There would be considerable flexibility as to when these flow increases could occur. This would allow for flow management to address fishery and recreational needs in the augmented reaches.

Endangered Species

There could be endangered species concerns related to the surface water depletions in both the South Platte and Colorado River basins would occur as part of a conjunctive use project. These would be similar in nature to surface water depletions that would result from a new surface water storage project. Cooperative agreements are in place in both basins to address the needs of the endangered species while allowing for continued development of water resources in Colorado.

Effects on Reservoir Recreational Levels

Conjunctive use plans involving borrowing arrangements with Denver would result in an overall decrease in storage in Denver's reservoirs on a year round basis. This decrease

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would be most pronounced in the fall, winter and early spring seasons as water would be delivered to end users, to off-stream surface storage and for aquifer recharge. In the late spring and summer seasons additional surface flows would be captured in most years and reductions in reservoir levels would be relatively minor. Figure 10 and Figure 11 below illustrate the changes in storage contents for Dillon and Cheesman/Eleven Mile reservoirs that would occur under an example large scale conjunctive use project that borrowed from both Dillon and Cheesman/Eleven Mile (Scenario 9 in Table 5 above). Again, flexibility could exist for managing reservoir level reductions among Denver's reservoirs. This could be done by limiting the seasons in which borrowing would occur and by preferentially borrowing from reservoirs with the lowest recreational value. Figure 12 and Figure 13 illustrate changes in Dillon and Cheesman/Eleven Mile storage under Scenario 10, in which borrowing occurred preferentially from Cheesman and Eleven Mile Reservoirs. Under this scenario, reductions in reservoir contents attributable to a conjunctive use project were isolated to Denver's South Platte reservoirs. There was no change in Dillon contents attributable to the conjunctive use project.

Water Rights

MWSI analyses to date have focused on the hydrologic, operational and facilities aspects of conjunctive use. Water rights were not considered except in Denver Water's estimates of its unused divertible supplies, developed for the purposes of MWSI analyses. Generally speaking, Denver's estimates of these supplies included all water that Denver could develop under its absolute water rights and its conditional Two Forks rights, assuming that Denver had the necessary storage facilities and the necessary municipal demand to use such water. The use of these water rights as envisioned in the MWSI's analysis of conjunctive use would require changes of water rights including a change of the conditional Two Fork storage rights.

The use of such supplies under the example conjunctive use plan previously discussed would include storage in new off-stream reservoirs, recharge and storage in Denver Basin aquifers, refilling of Denver's existing reservoirs, and delivery to municipal end users in both Douglas County and Denver's existing service area. There are conflicting opinions about whether such uses would be consistent with Denver's existing decrees, and whether or not changes in water rights or new water rights would be required in order to use the supplies in the manner illustrated. The amount of unused divertible supplies available to a conjunctive use project may vary from what was assumed in the MWSI analyses depending upon water rights constraints.

Figure 10: Conjunctive Use Scenario 9
Effects on Dillon Reservoir Contents

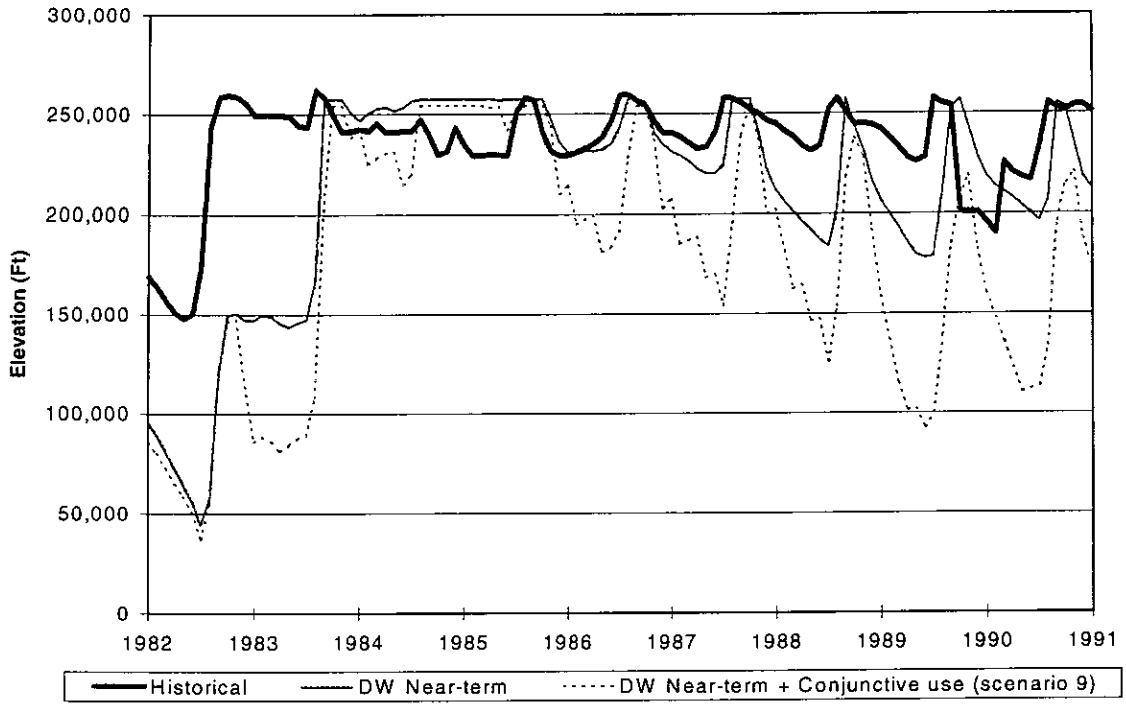

Figure 11: Conjunctive Use Scenario 9
Effects on Cheesman/11 Mile Reservoir Contents

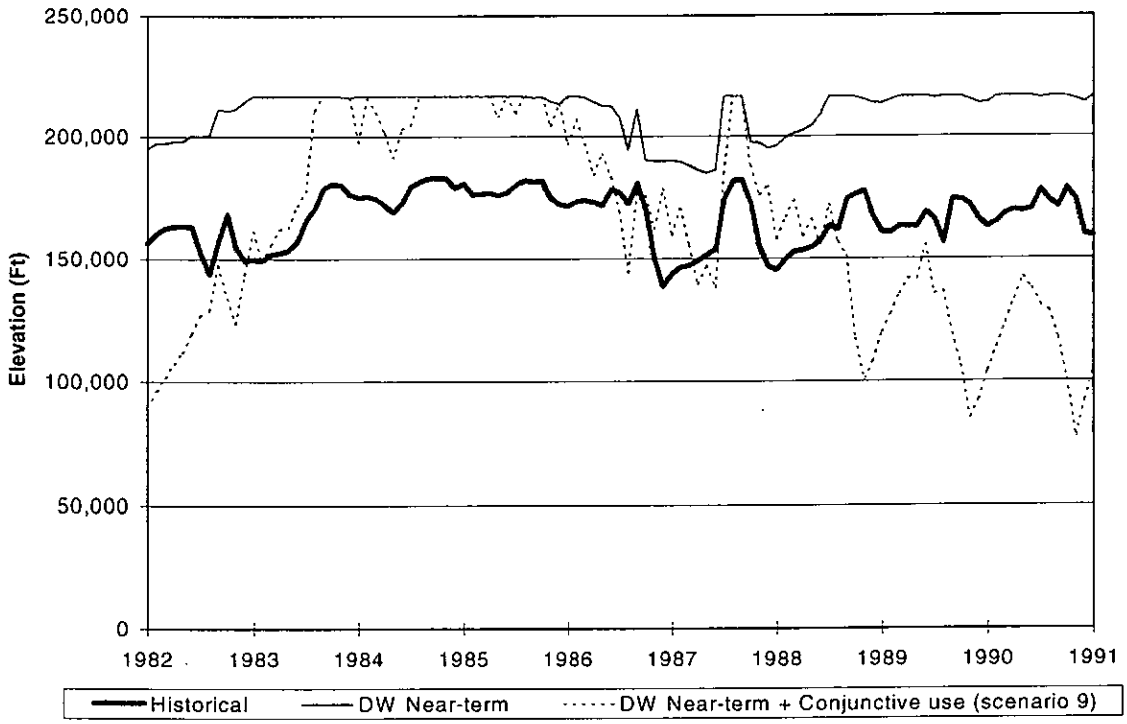

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Figure 12: Conjunctive Use Scenario 10
Effects on Dillon Reservoir Contents

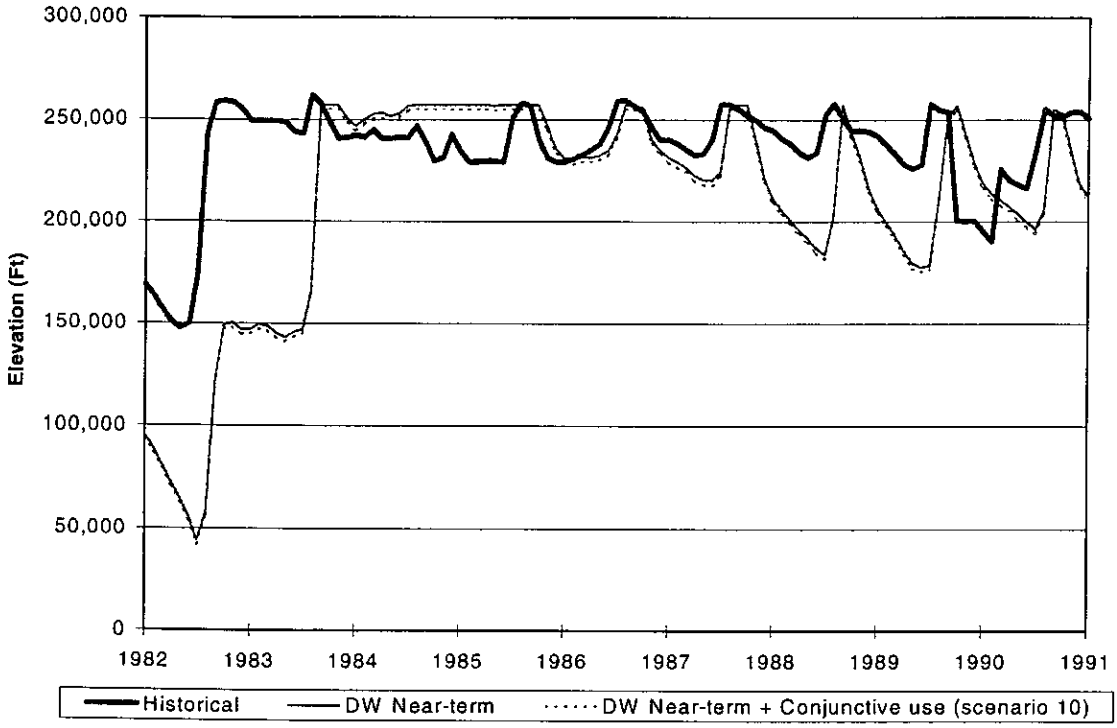
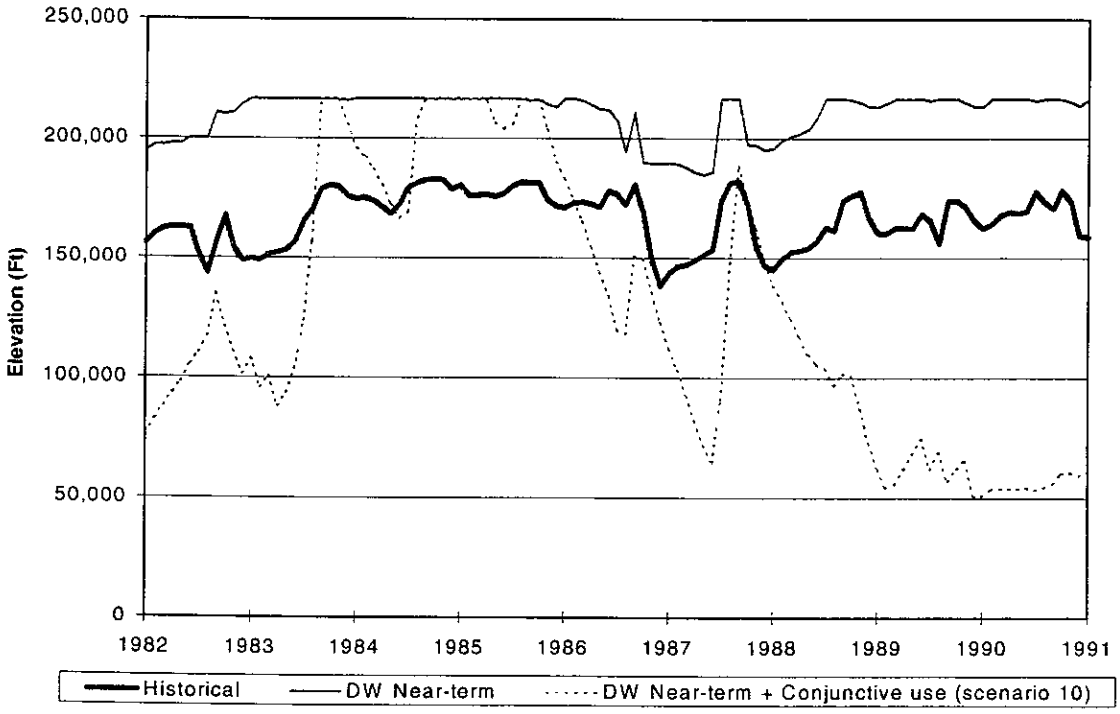


Figure 13: Conjunctive Use Scenario 10
Effects on Cheesman/11 Mile Reservoir Contents



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Some TAC members have voiced several water rights-related concerns regarding conjunctive use as illustrated in the MWSI. These concerns are summarized below:

- There is a concern that Denver's Blue River decrees require that Denver reuse to extinction the municipal return flows derived from its Colorado River water imports within legal limitations and subject to economic feasibility; otherwise Denver's Blue River diversions can be correspondingly decreased. There is a concern that this should be a prerequisite to any use of Blue River water for conjunctive use purposes.
- There is a concern that Denver's Blue River decrees limit Denver's use of its Blue River supplies to municipal purposes within Denver's metropolitan area, defined as such an area as is reasonably integrated with the development of Denver. There is a concern that municipal uses within Douglas County do not meet this "metropolitan area" definition.
- There is a concern that any applications for new Blue River water rights for conjunctive use purposes as illustrated in the MWSI analyses would have to meet the test of need. Given the amount of Denver Basin groundwater available to DCWRA providers, can the need for Blue River water be demonstrated?
- If a new Blue River water right were needed for conjunctive use purposes, would it yield any appreciable amount of water given the United States' Green Mountain Reservoir hydropower right for 1,726 cfs? Could a power interference provision be obtained?
- How would water rights for a conjunctive use project relate to instream flow rights for Colorado River endangered fish species?

While there are conflicting opinion about each of these concerns, resolution of these and other water rights issues would be required before any finding of conjunctive use feasibility could be made. Negotiations among affected parties would almost certainly be part of this process.

Feasibility of Long-Term, Large-Scale Recharge

Recharge of Denver Basin aquifers has been demonstrated on a small-scale level by the Willows Water District in cooperation with Denver Water and by the Centennial Water & Sanitation District. These two providers have injected over 2,500 acre-feet of treated water into the Arapahoe and Denver aquifer of the Denver Basin over the last seven years. Both projects have concluded that injection, storage and recovery of treated surface water in the Denver Basin is technically and economically feasible.

There are, however, some remaining unknowns regarding long-term and large-scale use of aquifer recharge via well injection as a regional water management technique. The long-term effects of injection and recovery operations on wells and aquifers and the associated long-term well maintenance costs have not been fully evaluated. Additional research will be required to evaluate the potential for future problems. In particular,

additional data review and analyses should be performed to evaluate the effect injection water temperature has on injection and pumping well hydraulics.

Aquifer recharge to date has been limited to the Arapahoe and Denver aquifers. The possibility of recharge in the Dawson and Laramie-Fox Hills aquifers would have to be studied in order to determine the storage and recovery potential in those aquifers.

The available storage space in the Denver Basin aquifers is also a potential management concern. While the volume of groundwater in the Denver Basin is enormous – over 400 million acre-feet – the available storage capacity in the Denver Basin aquifers in Douglas County area is relatively limited because the aquifers are currently virtually full. The Final Report of Willows' Denver Basin Aquifer Recharge and Demonstration Project includes an estimate of 500,000 acre-feet of available injection storage capacity in the four Denver Basin aquifers, based on existing conditions (Halepaska, 1997). A large-scale conjunctive use project such as that analyzed in the MWSI would require an aquifer storage capacity for recharge of surface water of almost double this amount. It may therefore be that a conjunctive use project would have to be phased in over time in order to allow for additional aquifer space to be created through continued well pumping.

Control of Recharged Water

Concerns have been voiced regarding the certainty that recharged water would remain available in the aquifers over a long period of time. Well interference effects could occur between providers participating in a conjunctive use plan and adjacent water users relying exclusively on groundwater. If the Dawson aquifer were used for recharge storage and withdrawal it may be difficult to prevent some of the stored water from emerging into surface drainages, and individual household wells may be affected.

In addition, a number of legal and institutional issues related to the use and management of Denver Basin aquifer storage must be addressed. While landowners have been granted the right to develop water from the Denver Basin aquifers underlying their property, the question of who is entitled to use empty underground storage space has not been addressed by the Colorado State Legislature, the State Engineer, or the courts. How will storage space within the aquifer formations be allocated between competing rechargers? What kind of safeguards will be required to insure that recharged water can be extracted without injury to adjacent well owners within the area affected by recharge? What regulatory and institutional arrangements will be necessary to properly monitor and administer recharge programs (White, 1995)? All of these issues point to the desirability of having a regionally managed conjunctive use plan.

West Slope Concerns

There are several concerns that have been voiced by West Slope TAC members, in addition to the water rights concerns outlined above, regarding conjunctive use as examined in the MWSI. These relate to water quality, future West Slope water supply needs, Colorado River endangered species concerns, aquatic impacts and recreational impacts.

The West Slope believes that Denver's Blue River decrees do not allow for use of Blue River water in the manner envisioned in a conjunctive use plan, and that any new decrees for such purposes would have to be subject to the West Slope's future water needs. Furthermore the West Slope questions the legitimacy of need for Blue River water to serve Douglas County given the large amounts of Denver Basin groundwater available to Douglas County water providers.

The West Slope contends that further reductions in runoff season flows resulting from conjunctive use would have deleterious effects on water quality in the Grand Valley area with respect to salinity. A variety of salinity-sensitive crops comprise a major part of the agricultural economy in that region.

The West Slope is concerned that its ability to meet its future water supply needs, particularly in Summit, Grand and Eagle Counties, would be seriously impaired by additional Blue River diversions under Denver's existing decrees unless some form of allowance or compensation were included as part of a cooperative conjunctive use plan.

The West Slope is concerned that any water-related obligations toward the ultimate resolution of Colorado River endangered species issues be borne fairly by water providers exporting water from the Colorado Basin as well as in-basin users.

Finally, the West Slope is concerned about the cumulative impacts to cold water fisheries, reservoir-based recreation and whitewater recreation that could result from a large scale conjunctive use project combined with Denver's newly adopted Near-Term water supply strategy.

All of these concerns have previously been raised during the Two Forks Reservoir EIS and permitting process. At that time, Two Forks was seen as a single project that would have significant impacts to the Blue River and Dillon Reservoir. In comparison, Denver's newly adopted Near-Term water supply strategy combined with a large scale conjunctive use project as examined in the MWSI would have cumulative effects to the Blue River that would be similar, although not as large, as Two Forks.

Groundwater Sustainability

A conjunctive use plan as examined in the MWSI would require the participation of Denver Water as the primary surface water provider and DCWRA providers as the primary owners of groundwater resources and well facilities. Both entities are concerned with the issue of Denver Basin groundwater sustainability.

While DCWRA providers have decreed groundwater rights in excess of their projected build-out demands (Mulhern, 1996), they recognize that it is desirable to minimize long-term reliance on groundwater as a principal supply due to increased future well development and pumping costs. They see conjunctive use as a way to incorporate surface supplies into their systems, thereby greatly extending aquifer life. However they generally do not believe it is necessary to achieve a state of no net withdrawal of groundwater.

Denver Water has a somewhat different perspective. The Denver Water Board's Resource Statement, adopted October 15, 1996, contains guidelines for cooperative actions with metropolitan water suppliers outside the Board's service area. These guidelines state that a cooperative action proposal "is most likely to receive consideration by the Board if it ensures that groundwater resources are sustainable if the proposal relies on groundwater." While Denver does not explicitly define what is meant by sustainable, Denver is concerned about cooperative arrangements that may have open-ended liabilities regarding Denver's future water supply service obligations. Denver is therefore interested in seeing how DCWRA providers' ultimate water demands would be sustainably met under a conjunctive use arrangement.

At the other end of the groundwater sustainability debate are certain West Slope interests, which believe that Douglas County's large amounts of legally and economically groundwater should be used in preference to additional diversion of Blue River water. These West Slope interests question how DCWRA providers can demonstrate a legitimate need for additional Colorado River water given the adequacy of their decreed groundwater rights. In general, the West Slope believes that Denver Basin groundwater is sufficient to provide an economical and reliable water supply for a considerable period of time before additional Colorado River water should be used under a conjunctive use plan. The West Slope also believes that DCWRA providers should maximize their use of local surface supplies, including wastewater reuse and alluvial wells via augmentation plans, prior to relying on Colorado River water.

Well Interference Effects

Under a conjunctive use plan with borrowing from Denver, DCWRA providers would pump their Denver Basin wells more intensively during payback periods. This result could have localized physical effects on domestic exempt wells in the upper Denver Basin formations. However, Senate Bill 5 does not guarantee water levels to well owners.

Under a regional conjunctive use plan, the existence of non-participating providers interspersed with participating providers could result in inequitable benefits to the "non-players" in the form of increased well levels due to recharge. This potential effect points to the desirability of a regional approach to conjunctive use which would addresses the water supply needs of all significant providers in the region.

3.2.2. Effluent Management

3.2.2.1. Background

Effluent management as a water supply source consists of the use of legally reusable municipal return flows via exchanges, plans of augmentation, nonpotable reuse and potable reuse programs. Reuse of municipal return flows has long been recognized as a

potentially significant water supply source. Its importance was highlighted in Denver's Blue River decrees, which include a stipulation requiring Denver to reuse, to the degree economically and legally feasible, the municipal return flows from its Colorado River water supplies; otherwise Denver's Blue River diversions could be reduced.

While less than 10% of the metro Denver area's existing water supply is derived from effluent management, most providers envision an increased role for effluent management in meeting their future water needs. As part of the MWSI, a comprehensive analysis was conducted of the water supply potential associated with cooperative approaches to effluent management.

3.2.2.2. Conceptual Definitions

Effluent management is defined as any arrangement that utilizes municipal return flows to increase municipal water supplies. This can be accomplished in two ways: return flows can be physically reused for nonpotable and potable purposes, and return flows can be reused under various substitution or exchange arrangements.

Typically, when water is used for municipal purposes, less than 50% of the water used is actually consumed. The water not consumed returns to the stream in the forms of wastewater, return flows from irrigation of lawns, parks, and golf courses, and subsurface losses from the treated water distribution grid.

Municipal return flows must be legally reusable in order to effectively increase water supply. Under Colorado water laws, reusable water available to metro Denver area water providers can generally come from five sources as described below.

1. Water imported to the South Platte or its tributaries from another river basin
2. Nontributary groundwater from the Denver Basin Aquifers.
3. The historically consumed portion of water rights changed from one use to another, such as from irrigation to municipal use.
4. Water diverted under a water right that has been decreed to allow for reuse.
5. Water diverted under an exchange or plan of augmentation that has reusable water as its source of supply (i.e. reusable water can be reused to extinction).

Broadly speaking, water reuse can be accomplished either by substitution arrangements, by nonpotable reuse or by potable reuse.

Substitution involves the use of reusable return flows as a source of substitute supply to downstream water rights in order to allow for what would otherwise be out-of-priority diversions at another location, which may be upstream or downstream of the source of substitute supply. The substitute supply must be suitable in quality and quantity to prevent injury to water rights receiving the substitute supply. Examples of substitution include water exchanges, plans of augmentation, first use agreements and water trades.

Substitution is the most common form of municipal return flow reuse in the metro Denver area today.

Substitution opportunities are limited primarily by the exchange potential in a given stream segment between the point of substitute supply and the point of diversion. Exchange potential is defined as the minimum continuous flow occurring between the point of substitute supply and the point of diversion that is in excess of intervening water rights requirements, during a period of downstream water calls. (For the purposes of this study, exchange potential is assumed not to exist during "free river" conditions). Exchange potential varies considerably over time as a function of stream flows and call conditions.

Substitution also includes the use of reusable return flows to meet the return flow requirements associated with water rights change decrees under plans of augmentation.

Nonpotable reuse is defined as directly supplying appropriately treated effluent to meet a nonpotable water demand such as irrigation of parks or golf courses, industrial process water or power plant cooling water. Nonpotable reuse arrangements can be used to meet water demands within a provider's service area or to supply water to another provider under a contractual arrangement.

In order to adequately address water quality and public health concerns, nonpotable supplies must usually be treated to relatively high water quality standards. The State of California's "Title 22 Standards," which result in water suitable for full body contact, are generally recognized as the standard for most forms of nonpotable reuse.

In the metro Denver area, nonpotable reuse has not yet been widely used as a water supply source, being thus far limited to irrigation of several parks and golf courses in the southern metro area. Currently the City of Aurora, the Arapahoe County Water & Wastewater Authority and the Inverness Water & Sanitation District all used treated wastewater to irrigate parks and golf courses within their service areas. However, most water providers plan to increase their nonpotable reuse activities in the near future. Most notable is Denver Water's nonpotable reuse plan, which will provide 15,000 acre-feet of nonpotable supply to several areas in the northeast part of Denver Water's service area, including Denver International Airport and Public Service Company's Cherokee thermal electric power plant. The City of Aurora is also planning to expand the capacity of its Sand Creek Reclamation Plant (which supplies tertiary treated effluent for irrigation in its service area) from 2.5 MGD to 5 MGD.

Potable reuse is defined as the direct introduction of highly treated wastewater into a municipal supply system as part of that system's planned operations. Wastewater treated for potable reuse typically undergoes several stages of advanced wastewater treatment processes that redundantly ensure the reliable production of water that exceeds Safe Drinking Act standards. Such water is sometimes referred to as "repurified" water. Repurified water is typically blended with other potable sources to further ensure reliability of quality.

Not included in the potable reuse definition are situations where conventionally treated wastewater effluent comprises a portion of the stream flow or alluvial aquifer supply that is drawn upon by a municipal water supply system. Most of the municipal water supply systems in the metro Denver water are already in this situation.

Potable reuse has not yet been implemented in the metro Denver area due to cost and public acceptability reasons. However, potable reuse has been implemented in other parts of the country and has been demonstrated to be technical and institutionally feasible on a large-scale basis.

While water reuse has primarily been done for purposes of increasing water supplies, direct reuse arrangements have occasionally been implemented for the primary purposes of economically disposing of treated wastewater and to recycle nutrients.

3.2.2.3. Analytical Approach

The MWSI's effluent management investigations covered both Phases II and III of the MWSI. Initial background information was collected in Phase II. Additional information was collected, a regional database of reusable effluent resources was developed, and preliminary analyses of effluent management opportunities were conducted in Phase III.

Phase II Background Information Collection

Background information was collected and reviewed in Phase II in order to establish an analytical baseline, to identify data gaps and to understand the differences in assumptions and approaches taken by individual providers in previous studies of effluent management. This background information step resulted in the compilation of the following categories of information:

- Stream flow data for selected gages in the metro Denver area;
- Estimates of ungaged gains from urban stormwater return flows to the South Platte River through Denver;
- Diversion and water distribution records for the Burlington Canal/Barr Lake system;
- Diversion records for other District 2 ditch systems;
- Evaporation data for Cheesman, Eleven-Mile and Antero reservoirs;
- Key agreements and water rights decrees that affect the South Platte River in the reach from Strontia Springs Reservoir to the upstream end of Water District 2;
- Historical South Platte River call records;
- Water quality information related to municipal effluent reuse; and
- Information on treatment technologies related to various effluent uses.

This information was used to quantify existing exchange potential, relative priorities of exchange water rights among water providers and water quality aspects of water reuse opportunities. This information was distributed to the TAC as a series of Phase II work task memoranda.

Phase III Studies

Phase III studies included development of a comprehensive effluent management database and municipal return flow model, analysis of remaining exchange potential under anticipated future conditions, assessment of direct nonpotable and potable reuse opportunities, and an assessment of effluent storage requirements. Additional study of these issues is continuing in the Northeast Quadrant Cooperative Action Study, described in Section 3.2.4.3, (Northeast Region Opportunities and Issues).

Effluent Management Database

An effluent management database was developed in Phase III to provide a comprehensive and consistent coverage of reusable return flow sources and reuse plans for all metro Denver area municipal water providers. Information was gathered from individual providers for existing and projected future conditions in the following areas:

- Average monthly treated water delivery patterns;
- Reusable water supplies and average monthly delivery patterns specific to those supplies; and
- Plans and commitments for reusable return flows.

Providers were consulted to ensure accurate interpretation of the collected data, their current reuse practices and future reuse plans. Existing reusable supplies and reusable return flows for each water provider were estimated using 1993 and 1994 operational data. Future levels of reusable supplies were estimated based on best available planning data, decrees and individual provider's reuse plans. These estimates were later updated for the SB 96-74 study to reflect 1996 uses and have been incorporated into this report.

Municipal Return Flow Model

Reusable municipal return flows were quantified for each major provider or provider group on an average monthly basis using a municipal return flow model patterned after a Denver Water lawn return flow study for the Cherry Creek basin (Denver Water, 1994).

For each provider or provider group, average monthly treated water deliveries were divided into indoor and outdoor components based on the assumption that December through February deliveries were exclusively for indoor uses. Monthly amounts in excess of this winter season average were assumed to be for outdoor uses.

Indoor uses were assumed to result in 5% consumptive use and 95% return flow in the form of wastewater (Wheeler, 1974; Wright, 1987). Outdoor uses were assumed to be used 97% for irrigation and 3% for other outdoor uses. Irrigation uses were assumed to result in 80% consumptive use, 18% subsurface return flows, and 2% surface return flows. Other outdoor uses were assumed to be 100% consumptive (Denver Water, August 1994). Subsurface return flows from irrigation use were assumed to reach the stream system on a steady basis, based on average distances to streams and typical subsurface hydrogeologic conditions for the metro Denver area.

Reusable return flows, in the forms of wastewater and lawn irrigation return flows, were calculated based on the average monthly percentage of treated water deliveries that were comprised of reusable supplies. The results of this model were incorporated into the effluent management database for each major provider or provider group.

Analysis of Remaining Exchange Potential

Remaining exchange potential is the exchange potential remaining in the river after the exercise of existing exchange rights at expected future levels. Remaining exchange potential under expected future conditions was estimated in order to assess the water supply potential of additional effluent management opportunities beyond those planned by individual providers under their respective rights.

Exchange potential on the South Platte was quantified between the Metro Wastewater outfall and four upstream locations: the Burlington headgate, Chatfield Reservoir, Strontia Springs Reservoir and Cheesman Reservoir. Exchange potential was also examined between the Burlington ditch headgate and upstream locations in order to assess the potential role of the Burlington Ditch in cooperative water supply arrangements.

Remaining exchange potential under future conditions was quantified using output data from Denver Water's Near-Term PACSM model scenario along with other information sources. Denver's Near-Term scenario is described in Appendix 8. It reflects Denver's and Aurora's full use of their respective South Platte effluent exchange rights at future demand levels. It does not reflect Thornton's exchanges between Metro and the Burlington Ditch headgate and Clear Creek. The effects of these exchange rights on remaining were estimated using water rights information obtained from Thornton.

Exchange potential in the Clear Creek, Cherry Creek and Plum Creek basins was also assessed using information from previous studies. Finally, the subject of substitution opportunities involving water supplies in the Northern Front range was briefly examined.

Assessment of Reuse Opportunities

Individual provider plans for nonpotable and potable water reuse were assessed during development of the effluent management database. The effects of these plans were accounted for in developing regional estimates of reusable return flow supplies and demands.

Assessment of Effluent Storage Requirements

An initial examination was made of the need for additional storage capacity for regulation of reusable return flows. This was done by comparing the patterns of occurrence of all reusable return flow supplies available at Metro to South Platte exchange opportunities and projected nonpotable reuse demands.

3.2.2.4. Results of Effluent Management Investigations

Reusable Supplies and Return Flows

Municipal and industrial water use in the metro Denver area presently generates about 261,000 acre-feet of return flow annually; 227,000 acre-feet as wastewater discharges and 34,000 acre-feet as lawn irrigation return flows. Of this total return flow, about 133,000 acre-feet per year is legally reusable. Based on providers' water supply plans for development of additional water sources over the next thirty to fifty years, the reusable return flow supply is expected to increase to about 267,000 acre-feet per year. While over 70% of the existing reusable return flow is associated with the water rights owned by Denver Water and Aurora, most suppliers have some water rights that generate reusable effluent. Existing and estimated future reusable water supplies and reusable return flows are summarized in Table 6 below. Water providers with significant amounts of reusable supplies are individually discussed in the following sections.

Table 6: Metro Denver Area Reusable Supplies and Return Flows (Acre-Feet Per Year)

	reusable supply (1)		reusable wastewater	
provider	present	future (2)	present	future
Denver Water	87,000	161,000	50,000	95,000
Aurora	50,000	70,000	26,000	38,000
Douglas County (3)	27,000	117,000	11,000	46,000
Thornton	9,000	45,000	5,000	24,000
Westminster	6,000	8,000	4,000	5,000
Arvada	4,000	5,000	1,000	2,000
Other (4)	22,000	40,000	11,000	18,000
Subtotal	205,000	446,000	108,000	228,000
Reusable LIRF's (5)			25,000	40,000
Total	205,000	446,000	133,000	268,000

(1) Treated water production
(2) Includes reasonable certain supplies
(3) Includes all Douglas County Water Resource Authority providers
(4) Includes Brighton, Broomfield, Englewood, Golden/Coors, Northglenn, SACWSD and miscellaneous providers
(5) Lawn irrigation return flows

Denver Water

Denver Water's existing reusable water supplies consist of its Blue River diversions, water diverted by Denver under Englewood's Cabin/Meadow Creek rights, water diverted under Denver's effluent exchange rights, and consumable water from irrigation rights which have been changed to municipal use.

Denver's Blue River diversions comprise the majority of its reusable supplies. Denver's PACSM modeling studies show that, under existing demand levels, Denver's use of Blue River water would average approximately 63,000 acre-feet per year over the 1947-1991 period of hydrologic record (Denver Water, 1997). Denver's use of Blue River water is expected to grow to approximately 128,000 acre-feet per year by the year 2030 as Denver's combined service area demands increase to 401,000 acre-feet per year under its Near-Term resource strategy (Denver Water, 1997).

Denver's decrees for its Blue River water rights stipulate that Denver must exercise due diligence in attempting to maximize its reuse of water from the Colorado River system "through exchange or otherwise" in order to minimize Denver's reliance on Blue River diversions (Consolidated Cases, 1955). Consequently Denver has reused a growing portion of its Blue River-derived return flows via exchange of reusable effluent since 1976. Based on Denver's PACSM modeling studies, Denver's use of its effluent

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exchanges would average about 22,000 acre-feet per year under existing demands conditions, and are expected to increase to over 40,000 acre-feet per year in the future. Denver has also conducted extensive investigations of potable and nonpotable water reuse and is in the process of implementing a 15,000 acre-foot nonpotable reuse project to serve a variety of municipal irrigation and industrial purposes in the northeast portion of Denver's service area.

The quantity of reusable supply available to Denver varies considerably from year to year based on runoff conditions. During extremely wet years, Denver's divertible supplies under its South Platte rights are greater and Denver's Blue River diversions and reusable effluent supplies are consequently smaller.

Denver is currently prohibited from reusing most of the water diverted from its Moffat system under its water rights in the Fraser and Williams Fork Basins because of a 1940 Agreement with the Consolidated Ditches of Water District 2. In that agreement Denver agreed not to reuse Moffat system supplies as consideration for not making evaporation releases from its mainstem South Platte reservoirs. The potential for Denver to lease, purchase or otherwise acquire the ability to reuse its Moffat system supplies under a modification or termination of the 1940 Agreement was not explored as part of the MWSI.

City of Aurora

Virtually all of Aurora's water supplies are legally reusable. Aurora's existing reusable water supplies include its imports from the Colorado River via the Homestake, Twin Lakes and Busk-Ivanhoe projects; its Arkansas River Basin water rights; its numerous South Platte Basin irrigation rights which have been changed to municipal use on a consumable basis; its Denver Basin groundwater supplies; its augmented Cherry Creek well rights; and its effluent exchange rights (Aurora, 1992).

Aurora's reusable supplies are expected to grow significantly in the future as Aurora increases its use of its existing Colorado Basin rights, its recently acquired Arkansas Basin irrigation rights (Colorado Canal and Rocky Ford Ditch), its Denver Basin groundwater rights and its South Platte exchange rights.

Since most of Aurora's water rights are reusable, Aurora's reusable supplies do not vary significantly in average and dry years. In wet years, Aurora usually makes more use its junior in-basin rights, which results in a decrease in Aurora's reusable supply. However, Aurora is not required to use its junior in-basin rights preferentially over its transbasin supplies or its changed irrigation rights.

Douglas County Water Resource Authority

The Douglas County Water Resource Authority (the Authority) is comprised of 14 water providers with service areas in Douglas County and portions of southern Arapahoe County. The Authority includes virtually all water providers located south of Denver Water's combined service area, except for Aurora and Englewood. Based on 1996 water

use data from individual providers, current water use by DCWRA members, other than treated water provided by Denver, averages approximately 32,000 acre-feet per year (HRS, Mulhern, 1997). Approximately 75% of this amount, about 24,000 acre-feet per year, is from reusable water sources including nontributary Denver Basin groundwater and fully augmented surface water.

Douglas County's reusable supplies are expected to grow in the future as providers increase their use of Denver Basin groundwater and pursue additional water supplies.

The quantity of reusable supply available to DCWRA providers varies slightly from year to year based on runoff conditions. During wet years, DCWRA providers use a proportionately greater amount of surface water, thereby reducing their use of Denver Basin groundwater.

City of Thornton

Most of Thornton's water rights are irrigation rights that have been changed to municipal use on a consumable basis. These include irrigation rights in the Upper South Platte Basin, the Clear Creek Basin, the Big Dry Creek Basin, the Burlington Ditch system and the Cache La Poudre basin (Thornton, 1996). Consequently, most of Thornton's municipal supplies are reusable. Thornton's reusable supply is expected to increase significantly in the future as Thornton fully utilizes its existing water rights portfolio and develops its Northern Project water supplies.

City of Westminster

Westminster derives its existing reusable water supply from irrigation rights that have been changed to municipal use on a consumable basis. These include irrigation rights in the Clear Creek, Big Dry Creek and Coal Creek Basins (Metro Wastewater, 1994). Westminster's reusable supply is expected to increase in the future as Westminster fully utilizes its existing water rights portfolio and develops or acquires additional water supplies.

City of Arvada

The City of Arvada has seven water court approved plans of augmentation which allow it to reuse all of its water supplies except for its raw water lease from Denver Water. While most of Arvada's existing water supply comes from its raw water contract with Denver Water, Arvada does have some reusable water supply from changed Clear Creek and Ralston Creek irrigation rights and reuse leases (Metro Wastewater, 1994; Aurora, 1992). Arvada's reusable supply is expected to increase in the future as Arvada more fully utilizes its existing water rights portfolio and develops or acquires additional supplies.

Other Providers

Other metro Denver area water providers with significant amounts of reusable effluent include Brighton, Broomfield, Englewood, Golden, Northglenn and South Adams County Water & Sanitation District.

Brighton's water supply currently comes from alluvial wells along the South Platte River. Brighton owns shares in the Burlington, FRICO-Barr, and Fulton Ditch companies which have been changed to municipal use on a consumable basis. Brighton uses these supplies as augmentation for its alluvial wells.

Broomfield's reusable supplies consist of its 5,600 acre-feet of Windy Gap Project water. While Broomfield currently uses only a small portion of its Windy Gap supplies, this use is expected to grow to the full 5,600 acre-feet level within the next 25 years.

Englewood's reusable supplies consist of its transbasin imports from the Boreas Pass Ditch and from its Ranch Creek system, and the historically consumed portion of South Platte irrigation rights which it has changed to municipal use.

The reusable water supplies of the City of Golden and Coors Brewing Company consist of the historically consumable portion of South Platte irrigation rights which have been changed to municipal and industrial use, plus some small amounts of transbasin diversion water.

The South Adams County Water & Sanitation District's (SACWSD) reusable supplies consist of its shares in the Burlington and Wellington companies, which it has changed to municipal use for augmentation purposes, and its Denver Basin groundwater rights. SACWSD currently uses both of these supplies as augmentation water for its alluvial wells.

Levels of Reuse

Existing levels of reuse were quantified through a review of individual water providers' water use accounting records, review of an effluent reuse questionnaire developed by the Metro Wastewater Reclamation District (Metro Wastewater, 1994) and discussions with individual providers. For each provider or provider group, existing levels of reuse were characterized in terms of substitution and direct reuse on an average monthly basis. Levels of reuse vary to some degree from year to year, with higher levels reuse occurring during average and below average years when yields from South Platte rights are relatively less and reusable supplies from transbasin and Denver Basin groundwater sources are relatively greater.

Planned future levels of reuse were quantified based on individual providers' future reuse plans, and on provider responses to the Metro effluent reuse questionnaire.

Ultimate potential reuse levels were quantified regionally based on future levels of reusable supplies under the assumption that all of these reusable supplies could

potentially be reused. While this assumption may not currently be realistic in terms of economics and technical and institutional feasibility, ultimate potential reuse levels were estimated to illustrate the future water supply potential of this source.

Metro Denver water providers are currently diverting approximately 53,000 acre-feet per year via various substitution arrangements involving reusable return flows, and are directly reusing another 1,000 acre-feet for urban irrigation purposes. About 80% of existing reuse is in the form of South Platte and Clear Creek exchanges; the balance consists primarily of augmentation for alluvial wells in the Cherry Creek and Plum Creek Basins.

Future plans for effluent reuse over the next 30 to 50 years total about 171,000 acre-feet per year. This figure is comprised of substitutions of about 134,000 acre-feet and direct reuse of about 37,000 acre-feet per year. Future substitutions will include increased levels of South Platte and Clear Creek exchanges, and augmentation plans and substitutions for both surface water diversions and alluvial wells in the Cherry Creek, Plum Creek, Big Dry Creek, Beebe Draw and Cache La Poudre Basins . Future plans for direct reuse envision a relatively dramatic increase compared to current levels. Most of the planned direct reuse activities involve irrigation and industrial process water applications in newly developing areas where dual water distribution infrastructure can be cost effectively implemented.

Future substitution plans will exhaust virtually all of the exchange opportunities on the South Platte between the Burlington and Strontia Springs, especially if some level of instream flow protection along the South Platte through metro Denver is assumed.

Ultimate levels of reuse potentially could exceed 500,000 acre-feet per year, assuming that providers: 1) develop the full amount of reusable supplies currently included in their water supply plans; 2) obtain decrees to reuse all of their legally reusable return flows; 3) use to extinction all of their legally reusable supplies via substitution, nonpotable reuse and potable reuse; and 4) have sufficiently large demands for water.

Existing and estimated future levels of reuse are summarized in Table 7 below. The reuse plans of individual providers are discussed in the following sections.

Prepared for the Colorado Water Conservation Board, Colorado Department of Natural Resources by
Hydrosphere Resource Consultants, 1002 Walnut Street, Suite 200, Boulder, CO 80302

Table 7: Summary of Effluent Reuse Plans (Acre-Feet Per year)

	Current Use Direct			Planned Future Use Direct		
Provider(s)	Subst.	Reuse	Total	Subst.	Reuse	Total
Denver	22,000	0	22,000	42,400	15,000	57,400
Aurora	5,800	400	6,200	8,200	7,000	15,200
Douglas County (1)	2,400	600	3,000	23,500	3,500	27,000
Thornton	3,000	0	3,000	24,500	4,000	28,500
Westminster	3,700	0	3,700	4,900	1,500	6,400
Arvada	500	0	500	1,900	3,300	5,200
Other (2)	15,900	0	15,900	28,600	3,000	31,600
Totals	53,300	1,000	54,300	134,000	37,300	171,300

(1) Includes all Douglas County Water Resource Authority providers
(2) Includes Brighton, Broomfield, Englewood, Golden/Coors, Northglenn, SACWSD and miscellaneous providers

Denver Water

As part of its Near-Term resource strategy, Denver Water plans to increase its effluent exchanges and to implement its nonpotable reuse project. By the year 2030, Denver's effluent exchanges and related plans of augmentation on the South Platte will average approximately 34,000 acre-feet per year. Denver's nonpotable reuse project will deliver approximately 15,000 acre-feet per year of treated reusable wastewater effluent to a variety of nonpotable uses in the vicinity of Stapleton, Rocky Mountain Arsenal and Denver International Airport (Denver Water, 1997).

Beyond the Near-Term, Denver Water is expected to have a surplus of remaining reusable return flow. Denver is therefore considering further expansions to its nonpotable reuse project as well as potable reuse options. Denver's long term water supply strategies are only preliminary at this point. Denver's long term nonpotable reuse plan contemplates an additional 9,000 acre-feet per year of nonpotable deliveries to several industrial water users. Denver is also considering various potable reuse options ranging in yield from 4,000 acre-feet per year to over 25,000 acre-feet per year, and the possible sale of portions of its reusable return flows to other metro Denver area municipal water providers.

Aurora

Aurora currently reuses approximately 6,200 acre-feet per year of reusable wastewater. Most of this reuse (4,000 acre-feet) is in the form of augmentation for Aurora's alluvial Cherry Creek wells. The remainder is composed of Aurora's Metro effluent exchanges (1,800 acre-feet), and direct reuse for irrigation of three parks and the Aurora Hills golf course (400 acre-feet). Aurora also leases portions of its reusable effluent to other metro area providers (Aurora, 1992).

Aurora's future reuse plans total about 15,000 acre-feet per year and include additional effluent exchanges, increased augmentation for Aurora's Cherry Creek wells, and additional nonpotable and potable direct reuse. Aurora may also continue to lease portions of its reusable effluent under short term arrangements to other metro area providers in the future (Aurora, 1992).

Douglas County Water Resource Authority Providers

Douglas County water providers are focused on maximizing use of their Denver Basin groundwater supplies through direct reuse and augmentation plans. Direct reuse is generally accomplished by treatment of wastewater and use of the effluent for irrigation of golf courses and parks. Augmentation plans in the area generally contemplate more extensive use of tributary water from alluvial groundwater in the Cherry Creek, Plum Creek and South Platte Basins with replenishment of these waters with return flows from nontributary sources.

Douglas County providers are currently reusing approximately 3,000 acre-feet per year, primarily through augmentation plans. Approximately 600 acre-feet of this total is being directly reused by the Inverness Water & Sanitation District and the Arapahoe Water and Wastewater Authority for golf course irrigation.

In the future Douglas County providers generally plan to increase their reuse of return flows from Denver Basin groundwater as their first use of this water supply source grows. Based on current water supply plans for the region it is expected that total reuse by Douglas County providers will grow to approximately 13,200 acre-feet per year by the year 2020. Long term plans contemplate approximately 27,000 acre-feet per year of reuse (Mulhern, 1998).

Thornton

Thornton currently reuses approximately 3,000 acre-feet per year for make-up of return flow obligations associated with Thornton's water rights portfolio.

Thornton's future reuse plans include use of its conditional South Platte and Clear Creek exchange rights, various direct reuse opportunities in its future service area, and return of reusable effluent to the Cache La Poudre Basin as part of Phases II and III of Thornton's Northern water supply project. Based on current estimates, Thornton will be reusing approximately 12,000 acre-feet per year of water by the year 2020. Thornton's long term future reuse plans under its Northern water supply project contemplate reuse of over 28,000 acre-feet per year, primarily by substitution (Thornton, 1996).

Westminster

Westminster currently reuses approximately 3,700 acre-feet per year for exchanges and make-up of return flow obligations associated with its water rights portfolio.

In the future Westminster's reuse plans include expanded make-up of return flow obligations and use of exchange rights, and irrigation of golf courses, parks, greenbelts municipal and commercial landscaping within its future service area. Based on current estimates, Westminster will be reusing approximately 6,400 acre-feet per year of water by the year 2020 (Metro Wastewater, 1994).

Arvada

Arvada currently reuses approximately 500 acre-feet per year for exchanges and make-up of return flow obligations associated with its water rights portfolio.

Arvada's future reuse plans include extensive direct reuse of reusable effluent for irrigation of parks, golf courses and landscaping in both its existing Clear Creek service area and its proposed Jefferson Center located in the upper Coal Creek Basin. Based on current estimates, Arvada will be reusing approximately 5,200 acre-feet per year of water by the year 2020 (Metro Wastewater, 1994).

Other

The City of Brighton currently reuses about 3,500 acre-feet per year for augmentation of its alluvial wells along the South Platte River. Brighton's future levels of reuse are expected to increase to about 13,000 acre-feet per year as its use of alluvial wells grows and it acquires additional augmentation supplies (MWSI, 1997).

All of Broomfield's current water supply comes from its treated water contract with Denver Water; Broomfield therefore does not reuse any of its existing water supplies. In the future Broomfield plans to use its 5,600 acre-feet of Windy Gap Project water and plans to directly reuse approximately 3,000 acre-feet per year for irrigation of golf courses, parks, greenbelts, etc. by the year 2030 (MWSI, 1996).

The City of Northglenn currently obtains about 2,100 acre-feet of its supply under a reuse agreement with FRICO. This arrangement is expected to continue into the future.

The City of Englewood currently reuses approximately 1,000 acre-feet per year for exchanges and various augmentation plans. Its future levels of reuse are not expected to increase significantly.

The City of Golden and the Coors Brewing Company currently reuse approximately 5,000 acre-feet per year for exchanges, make-up of return flow obligations and augmentation of wells. Future levels of reuse by Coors and Golden are expected to increase to approximately 6,000 acre-feet per year.

The South Adams County Water & Sanitation District (SACWSD) currently reuses about 4,500 acre-feet per year for augmentation of its South Platte alluvial wells. While SACWSD's future water supply plans are currently uncertain, SACWSD's future levels of reuse are expected to grow to about 6,000 acre-feet per year in response to future increases in its service area demands (MWSI, 1997).

Exchange Potential

South Platte

Historically, reuse has been implemented by metro area providers primarily through exchanges and plans of augmentation. The yield of these arrangements is limited by the exchange potential on the river between the point of substitute supply and the point of diversion. Exchange potential is difficult to quantify because it varies as a function of stream flows, diversion levels and call conditions[6]. As the metro Denver area grows, exchange potential will tend to diminish, because as the overall levels of wastewater discharge and urban runoff increases, the effects of downstream calls on upstream water rights are reduced. This trend effectively increases the yield of upstream water rights, but reduces exchange potential and the associated yield of some exchange rights.

As a part of Phase II of the MWSI, two previous investigations of exchange potential were examined, one conducted by W.W. Wheeler & Associates and one by Cheryl Signs Engineering. Both of these studies examined exchange potential under historical conditions. The Wheeler reported an exchange potential on the South Platte River between the Burlington ditch headgate and Strontia Springs of approximately 44,000 acre-feet per year over the historical period of 1947 through 1974 . The Signs study reported an exchange potential on Clear Creek between the mouth of Clear Creek and the Croke Canal of approximately 22,000 acre-feet per year for a similar period. Neither of these studies assumed any instream flow requirements along their respective exchange reaches. Maintenance of a minimum stream flow in either case would reduce the available exchange potential.

During Phase III of the MWSI, exchange potential under future conditions (i.e. remaining exchange potential) was estimated using results from Denver modeling studies and other data sources. These estimates reflect future uses of exchange rights and plans of augmentation by metro Denver area water providers. The results of these studies are summarized in Table 8.

These studies indicate that the historical exchange potential on the South Platte between Metro and locations upstream of the Burlington Ditch will be largely exhausted by future exercise of exchange rights and plans of augmentation.

It should be noted that these estimates do not reflect any instream flow requirements for the South Platte River through Denver. Instream flow requirements would further reduce remaining exchange potential above the Burlington Ditch. Exchanges reduce the stream flow between the downstream point of substitute supply and the upstream point of diversion. When all exchange opportunities on a given river reach are being exploited, there would be a zero flow point somewhere in the intervening stream reach. If an

[6] Exchanges are sometimes done during free river conditions for the purpose of storing reusable effluent in upstream reservoirs.

instream flow requirement were enforced between the Metro wastewater plant and Chatfield Reservoir, the yields of exchange rights would be correspondingly reduced.

Table 8: Results of Phase III Exchange Potential Analysis

Remaining Exchange Potential Between Metro And Strontia Springs (Acre Feet)

Condition	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average	0	0	200	600	500	700	300	300	0	200	300	100	3,200
Wet	0	0	600	800	900	900	400	0	0	300	200	300	4,400
Dry	0	0	0	100	100	100	0	400	100	100	200	0	1,100

Remaining Exchange Potential Between Metro And Chatfield (Acre Feet)

Condition	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average	0	0	300	700	500	800	400	400	0	200	300	100	3,700
Wet	0	0	700	1,100	1,000	1,100	400	0	0	300	200	300	5,100
Dry	0	0	0	100	100	100	0	400	100	100	200	0	1,100

Remaining Exchange Potential Between Metro And Burlington (Acre Feet)

Condition	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average	100	400	3,000	5,100	2,500	2,700	1,200	600	600	2,200	3,900	1,700	24,000
Wet	300	900	5,900	5,600	3,500	3,100	1,000	0	0	600	5,600	1,500	28,000
Dry	0	0	0	400	500	500	1,600	1,200	2,100	2,200	3,400	900	12,800

Remaining Exchange Potential Between Metro And Burlington Plus Free River at Burlington (Acre Feet)

Condition	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Average	1,400	1,700	3,500	5,800	3,000	5,100	6,400	32,500	24,100	9,500	7,600	2,300	102,900
Wet	14,300	11,900	9,600	8,900	5,100	8,300	17,000	58,700	20,100	9,600	27,600	5,200	196,300
Dry	0	0	0	400	500	500	1,600	2,100	2,200	3,400	5,400	1,100	17,200

In contrast, the remaining exchange potential between Metro and the Burlington Ditch is significant, particularly when viewed in combination with estimates of remaining "free river" water at the Burlington. This is due to the combined effects of urban stormwater runoff, lawn irrigation return flows and upstream wastewater discharges, which result in a greater and more continuous flow in the South Platte River below the Cherry Creek confluence. However, the water quality of this stream reach reflects the influences of these sources, making exchanges in this reach relatively less desirable.

Clear Creek

Based on a review of existing planning studies, it was clear that the exchange potential between Metro and municipal points of diversion on Clear Creek will also be largely exhausted by existing exchange rights in the basin. Because of this, no quantitative estimates of remaining exchange potential in Clear Creek were developed.

Cherry Creek/Plum Creek

Substitution opportunities in the Cherry Creek and Plum Creek basins are not as dependent on exchange potential defined by surface stream flows, due to the physical nature of the alluvial groundwater features of these basins. For example, it is estimated that Cherry Creek above Cherry Creek Reservoir has an alluvial storage capacity of about 25,000 acre-feet. Significant volumes of groundwater are in storage in the alluvium irrespective of surface flow conditions. Reusable effluent can therefore be used to augment pumping from alluvial wells. Viewed from this context, the substitution

opportunities in the Cherry Creek and Plum Creek basins are significant, particularly given the largely reusable nature of the municipal water supplies (Denver Basin groundwater) in these basins.

Water providers in these basins are actively working toward maximizing their individual substitution opportunities related to Cherry Creek and Plum Creek. The potential for coordinated management of Cherry Creek and Plum Creek substitution opportunities on a regional level is also under discussion as part of the Southern Regional Cooperative Action Study.

Substitution Opportunities Involving the Northern Front Range

Phase II of the MWSI briefly considered substitution opportunities involving water supply systems located on South Platte tributaries to the north of the metro Denver area. For example, surplus reusable effluent from the metro Denver area could be regulated in downstream surface storage and delivered as a substitute supply during the irrigation season into ditches in the Big Thompson and Cache La Poudre basins. A portion of the water normally diverted by those ditches could then be delivered south to the metro Denver area via some combination of existing CBT project facilities and/or a new delivery pipeline. The infrastructure requirements for this type plan have not been studied.

However, numerous concerns were voiced by Northern water interests about the limited supply of high quality mountain runoff and the equity of allowing a portion of that resource to be delivered to water providers in the metro Denver area. The Northern Colorado Water Conservancy District Board of Directors has also emphasized that CBT Project facilities are not available to be used for the delivery of water outside of District or Subdistrict boundaries. Legal and institutional constraints exist that preclude such used of CBT Project facilities for such purposes. Further, such substitution arrangements would constitute a diminishment of the high quality "base supply" to the Northern Front Range region. This factor is also a major concern to the area.

Because of these concerns, cooperative substitution opportunities involving the northern Front Range were not examined further in Phase III of the MWSI.

Assessment of Reuse Opportunities

The current reuse plans of individual providers were surveyed and are reflected in the discussions above. Denver Water's 15,000 acre-foot nonpotable reuse project addresses all of the currently foreseeable nonpotable reuse needs of the northeast metro Denver area. Providers will probably identify additional nonpotable reuse opportunities as their respective service areas develop over the long-term. Areas with particular promise, due to locally available wastewater sources and the overall nature of expected future land uses, include the northeast metro Denver area surrounding DIA, the Big Dry Creek basin and the Cherry Creek and Plum Creek basins. However, infrastructure costs for nonpotable reuse projects are usually extremely high unless they are incorporated into the

initial plans and designs of newly developing areas. "Retrofitting" an already developed area for nonpotable reuse is usually cost prohibitive (San Diego County Water Authority, 1995).

Given the size of the projected excess of reusable return flows for the region and the limited opportunities for further substitutions upstream of Chatfield, a regional potable supply project combining potable reuse and exchanges from the Metro wastewater plant to the Burlington Ditch appears to be the most promising way to beneficially use this reusable resource for municipal purposes. Conceptually, this project could make use of two physical sources: diversions via the Burlington ditch under free river conditions or exchange of reusable effluent, and direct pumping of reusable effluent from Metro.

Such a project is the primary subject of analysis in the Northeast Regional Cooperative Action Study (see Section 3.2.4.3 and Appendix 7. Major areas of study include hydrology/operations, effluent storage and conveyance requirements, water quality and treatment aspects, locations and sizes of participants' delivery areas, and the degree to which such a new supply would be physically integrated with existing treated water systems. This last concern relates to the operational advantages of additional water source blending. It would also help address public acceptability concerns.

The technical and political feasibility of potable reuse of wastewater has been demonstrated on a large-scale basis in the U.S. A plant in Fairfax County, Virginia, has repurified water for human consumption since 1978 without any health problems. The City of San Diego and the San Diego County Water Authority are proposing to construct a 20-MGD water repurification facility to treat reclaimed wastewater from San Diego. Repurified water would be blended with imported supplies in a raw water reservoir and conveyed to the San Diego's Alvarado filtration plant. There, the water would undergo additional filtration and disinfection before being introduced into the City's potable water delivery system. Ongoing feasibility studies have been favorable and, pending approval from regulating agencies, implementation of the project could begin as early as 2000.

Assessment of Effluent Storage Requirements

The amount of effluent storage that will be needed to regulate effluent supplies is dependent on the amount of future substitution and reuse activities and the number of participants involved.

Denver Water has determined that it will need approximately 12,000 acre-feet of effluent storage to maximize its exchange yields at 34,000 acre-feet per year and to reliably deliver 15,000 acre-feet of nonpotable reuse water. In making this determination Denver assumed that it would be using only its own reusable effluent as a physical source for its nonpotable reuse project. In formulating this plan study Denver assumed that it would use its reusable effluent produced at Metro as a sole supply for its exchanges and its nonpotable reuse plan.

As part of Phase III analyses, the potential benefits of considering effluent storage requirements from an integrated perspective was explored. A storage requirements

analysis was conducted which considered three physical supplies and three demands under future conditions. Available supplies included Denver's reusable effluent, Aurora's reusable effluent, and free river supplies on the South Platte at the Burlington Ditch. These three supplies were used to meet Denver's and Aurora's exchange opportunities and to supply Denver's 15,000 acre-foot nonpotable reuse project, assuming varying amounts of available effluent storage.

The results of this analysis indicated that the total effluent storage requirement for meeting these three demands would be reduced to less than 3,000 acre-feet. This analysis illustrates the potential benefit of considering effluent storage requirements from an integrated perspective.

The Northeast Quadrant Cooperative Action Study is expanding on this preliminary storage requirements analysis. The reusable effluent supplies and the effluent-related demands of Denver, Aurora, Thornton, Brighton and South Adams County W&SD will be considered. A storage requirement of 30,000 AF to 60,000 AF northeast regional potable supply project will also be addressed.

3.2.2.5. Issues and Concerns

Cost

Potable reuse of effluent is a relatively costly option from both a capital and O&M perspective. Cost estimates in 1995 for San Diego County Water Authority's proposed water repurification project suggested an annual cost, including capital and O&M, of approximately $1,000 per acre foot of water produced (San Diego County Water Authority, 1995). These costs did not include any raw water storage facilities.

The costs of a potable supply project using a combination of Metro effluent and diversions from the South Platte River upstream of the Metro wastewater plant may not be significantly lower. This is because the water quality of the South Platte River below Denver is highly variable due to upstream wastewater discharges, stormwater events and other forms of non-point source pollution. Designing a potable supply project to accommodate such influent water quality variability would be particularly challenging.

However, in areas where tertiary treatment of wastewater effluent is already required and where the water quality of the receiving stream is relatively high, the costs of potable reuse may be relatively lower. One such example is the Cherry Creek basin above Cherry Creek Reservoir.

Public Acceptance of Potable Reuse

Direct potable reuse of wastewater is still extremely uncommon in the U.S. In places where it has been implemented or seriously considered, public acceptance has been generally favorable provided that adequate research, education, monitoring and oversight

activities have been done. Public acceptance of potable reuse in the metro Denver area has not been explored.

Blue River Decree Issues

There are multiple interpretations of Denver's Blue River Decrees. The West Slope's interpretation is that the Blue River decrees require Denver to fully reuse the municipal return flows derived from its Colorado River water imports within legal limitations and subject to economic feasibility; otherwise Denver's Blue River diversions can be correspondingly decreased. Denver's future reuse and exchange plans currently result in Denver having over 40,000 acre-feet of unused reusable effluent remaining after considering Denver's existing and proposed exchanges and nonpotable reuse project. Denver's options for increasing its reuse appear to be limited to potable reuse options, because Denver will exhausted its feasible exchange and nonpotable reuse options. The costs associated with potable reuse may be seen as economically infeasible, particularly given Denver's other supply and demand management choices.

Instream Flow Issues

Instream flow requirements between points of effluent release and upstream points of diversion would be a limiting factor for future exchange potential. Below Strontia Springs Dam downstream the old Last Chance Ditch headgate above Chatfield Reservoir, federal permit conditions require Denver Water to bypass 60 cfs during the period of May 15th through September 15th and 30 cfs during the period of September 16th through May 14th. Denver has access to approximately 10,000 acre-feet of storage in Chatfield Reservoir for use in recapturing bypass flows that are in excess of flows required to meet downstream calls, but Denver's opportunities to exchange water recaptured in Chatfield back up to Strontia Springs are limited by Chatfield operational constraints designed to protect Chatfield recreational uses.

At the present time, there is no formal instream flow protection requirement for the South Platte River below Chatfield Reservoir. However, in conjunction with ongoing efforts to improve the South Platte corridor through Denver, Englewood, and Littleton, work is currently underway to develop and improve recreational amenities, wildlife habitat, and scenic values. Part of this effort includes an analysis of the amount of instream flow that may be necessary to maintain water quality, aquatic habitat, scenic values, and recreational activities such as rafting and kayaking. Instream flow requirements for the South Platte below Chatfield will reduce exchange potential.

West Slope Concerns

West Slope water interests do not want to see instream flows in the urban South Platte maintained at the expense of increased diversions from the West Slope.

The West Slope is also concerned that the value of reusable water to water providers under an effluent management scenario will result in providers choosing to divert

transmountain water when native South Platte water is available and that transmountain diversion will increase while native South Platte water goes unused.

Water Quality Issues

The primary water quality considerations associated with exchanges are the potential impact of increased upstream diversions on water quality in the South Platte River through the exchange reach in the metro area and the impacts of pumping effluent directly into agricultural irrigation ditches. Exchanges to upstream points of diversion could substantially reduce instream flows below Chatfield Dam during certain times of the year. These stream flow reductions would also reduce the assimilative capacity of the stream resulting in higher concentrations of pollutants from point sources and nonpoint sources. The greatest exchange potential occurs during the spring and early summer when stream flows are highest and thus there is a substantial amount of dilution water available. It is not likely that exchanges would substantially impact the operation of downstream wastewater treatment plants because effluent limits for those plants are typically based upon low stream flow conditions when there is little or no exchange potential.

However, water rights holders downstream of the point of exchange diversions (i.e. downstream of Chatfield) are concerned about the effect of exchanges on the suitability of their water supplies. This issue has been raised in the Water Court under the grounds of water quality-related injury. This in turn raises another issue: should water quality be regulated both by the Colorado Water Quality Control Commission and in the Water Courts in piecemeal fashion?

Metro Wastewater Reclamation District Perspective

The Metro Wastewater Reclamation District's plant located on the South Platte River just north of Denver, treats approximately 70% of the effluent from the metro Denver area. The Metro District has indicated a willingness to cooperate with effluent management proposals that result in reductions in the amount of effluent discharged directly to the South Platte River during certain critical periods (April through October) and proposals that do not increase the District's treatment costs. The Metro District believes that use of wastewater effluent for agriculture and urban irrigation appears to be a particularly beneficial way for society to recycle nutrients. Metro has conducted a study of water supply-related effluent management strategies to improve the water quality downstream of its discharge (Metro Wastewater, 1994). The Metro District has also submitted a series of working papers which provide details from the District staff's perspective on effluent management issues and possibilities (Metro Wastewater, 1996).

Agricultural Perspective

For agricultural water users, the primary concern associated with effluent management is the potential environmental and economic impacts on crop production, public health, and worker safety associated with the use of effluent as an irrigation supply. Acceptable

water quality requirements for various agricultural applications are not well defined and continue to be the subject of much debate. The primary general constituents of concern for irrigated agriculture in treated wastewater effluent are pathogenic organisms, nutrients, salinity and trace elements. In many cases, the water quality of irrigation water desired by some agricultural interests is better than the stream standards for agricultural use as set by the Colorado Water Quality Control Commission, upon which the level of treatment of wastewater discharges is partially set.

3.2.3. Interruptible Supply Arrangements with Agriculture

3.2.3.1. Background

This part of the MWSI examines the public policy, technical, institutional, and economic issues associated with interruptible supply arrangements (ISA's). Although the gross South Platte Basin dry-year supply potential for such arrangements under existing supply conditions is estimated as approximately 495,000 acre-feet, the feasibility or yield of such arrangements with respect to any particular ditch system or water right was not evaluated. This section of the report is a summary of these findings.

The MWSI Phase II draft report provided an overview of concepts, alternative approaches, and a regional quantification of agricultural supplies that could conceptually be made available for such arrangements. Review comments on the draft report prepared by the Northern Colorado Water Conservancy District expressed concerns that the report overemphasized "the potential for water transfers from the Northern Front Range to the Denver Metropolitan area." While the intent of the interruptible supply concept is to maintain existing water uses by allowing only temporary transfers, northern water users are concerned about the need to reserve an adequate long-term water supply for growth within their area. They are also concerned about the potential economic, social, and environmental impacts of water transfers from agricultural to municipal uses.

In response to these concerns, the Phase III POS included further investigation of perceived barriers to ISA's. This was intended to address perceptions and underlying causes of barriers and possible approaches to overcoming such barriers. However, as Phase III proceeded, the PMT felt that additional analysis of these issues should be postponed pending regional planning efforts to be undertaken by northern Front Range water providers. Ultimately, the MWSI did not study ISA's beyond Phase II. This section of the report therefore includes only the material presented in the Phase II report with review comment revisions.

3.2.3.2. Conceptual Definitions

The concept of Interruptible Supply involves the voluntary short-term transfer of existing water supplies to meet municipal need, without permanent reallocation of water uses.

The goal of such arrangements is to protect irrigation rights from permanent acquisition pressures and allow for creative and cooperative uses while protecting water rights.

From a purely economic standpoint (based upon ability to pay), the value of interruptible supply arrangements lies in being able to temporarily allocate water from lower valued uses to higher valued uses (in this case municipal treated water supplies) during times of shortage. Potential sources of existing lower valued water supplies for ISC arrangements could theoretically include agricultural, industrial, and instream flows water rights within a geographic area encompassing both the front range and west slope. In addition, potential supplies could include raw water used for urban irrigation. For example, a municipality could have an interruptible supply contract with the urban irrigation portion of a ditch supply.

In the western United States, estimates of the direct marginal value productivity of water in irrigation range from about $10 to about $75 per acre-foot, whereas in the municipal sector, the value of water ranges from $300 to $500 per acre-foot (Young, 1984). This would indicate the possibility of potentially significant economic benefits to agricultural water users associated with the ability to periodically make irrigation water available to municipalities.

Along the Front Range, the greatest use of water for agricultural purposes occurs in the northern Front Range area (to the north of the Boulder/Weld County line). In addition, in many areas along the northern Front Range, agriculture developed much earlier than urbanization. The water rights associated with agriculture are thus typically senior to the water rights for municipal uses, which limit the dry year yield available to municipal water supply systems. Therefore for purposes of this study, the initial focus is on temporary transfers of water from agriculture to municipal use.

Traditional ways of expanding municipal water supplies have included the direct purchase of agricultural water rights. Initially, these transfers of agricultural water rights to municipal use occurred incrementally as urbanized areas expanded onto surrounding agricultural lands. Since land use changes and water transfers occurred simultaneously in relatively small increments, the effects of such transfers were not considered to be significant (MacDonnell and Rice, 1994).

More recently, the types of permanent transfers have changed. Two major differences are 1) water rights acquisitions can now include agricultural lands which are far-removed from the municipality buying the rights; and 2) the amounts of water transferred are sometimes in much larger blocks than before (MacDonnell and Rice, 1994). In some cases, cities have had to look farther to meet the demands of increased growth. With these changes has come an increase in the level of controversy surrounding the transfers. The permanent dry-up of farmland brings with it a multitude of issues and concerns regarding the potential for adverse economic, social, and environmental impacts.

Specifically, cities and municipal water users in the areas where interruptible supply opportunities may exist have voiced strong concerns and, in some cases, opposition to the transfer of waters out of their natural basins to the metro area in this manner. Northern

Colorado has invested enormous resources in developing and protecting a diversified economy that includes a significant irrigated agriculture component. These irrigated lands are not only important from an economic perspective but also provide important open space and wildlife habitat. The water supplies used to irrigate these lands also provide a source of drought protection for northern Front Range municipalities and water providers. Northern Front Range water users are concerned that the transfer of water supplies to the metro Denver area could cause significant adverse effects in northern Colorado (Wilkinson, 1996).

However, if temporary transfers could be structured so as to result in minimal adverse impacts on the affected areas with appropriate mitigation of impacts and compensation to the interests involved, then interruptible supply arrangement could be beneficial to both the agricultural community and front range municipal water providers.

The arrangements between the parties must be structured to meet their respective specific needs and would generally include provisions to address issues such as the following:

- The amount of water and associated water rights to be transferred;
- The time frame in which water would be transferred;
- The circumstances under which a transfer would be triggered;
- The mechanism for physical delivery of the water transferred;
- The requirements for advance notice of when a transfer will be necessary;
- The overall term of the contract;
- The price and payment arrangements (including price adjustments over time)[7]; and
- Environmental and third party impacts.

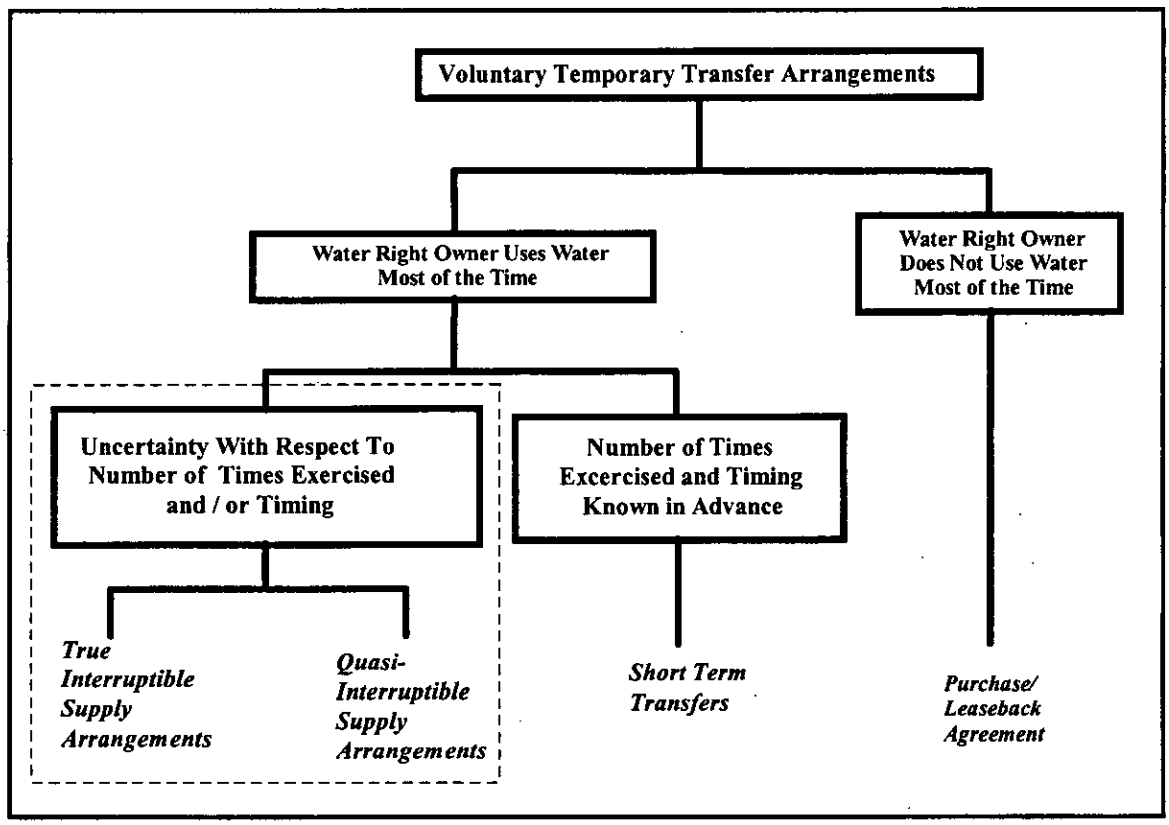
Note that there are various mechanisms through which temporary transfers may occur. Agreements can be made directly between parties or the transfer may be facilitated through the use of a water bank - an intermediary that seeks to bring together buyers and sellers. Under direct agreements between municipal water providers and agricultural water users, the agricultural entity may be an individual farmer or farmers, a ditch company, a water user's association, or a water conservancy district representing a group of irrigators.

Figure 14 has been developed to illustrate the relationship between various voluntary temporary transfer arrangements and how interruptible supply arrangements fit into this overall hierarchy. The first distinguishing factor is "who actually uses the water, most of the time." Under purchase/leaseback agreements, the owner of the water right is not the primary user of the water. The focus of this study, however, is on arrangements where the owner of the water right uses the water most of the time while the primary user of the water retains ownership.

[7] Typically, there is an option price (the payment from the buyer to the seller for having the option) and exercise price (the payment made during a year that the option is exercised).

The next distinguishing factor is the level of uncertainty involved in the agreement. Sometimes, arrangements are made where the number of times the transfer will occur and when it will occur are known (although the precise amount of water to be transferred may not be known at the time the agreement is made - this depends on the actual amount of water available to the water right owner). These arrangements are often made for the subsequent one or even two-year period, and are typically referred to as "short-term transfers." This type of arrangement is in contrast to agreements where there is uncertainty with regards to the number of times the transfer will be exercised and/or the year when the transfer(s) will take place. The agreement may be made for transfers to occur for a specified number of times, with some mechanism in place to determine exactly when the transfers will occur (Quasi-Interruptible Supply Arrangements). The years that the transfer will occur is not known at the onset of the contract. Or, the agreement may be that transfers will happen on the occurrence of some "trigger" (e.g., precipitation level, stream flow, snowpack, storage conditions, etc.). In this situation, both the number of transfers and the timing of such transfers are unknown at the beginning of the contract. These types of arrangements, are known as "true interruptible supply arrangements" and are typically more long term than quasi-interruptible supply arrangements. The focus of this study are the arrangements which fall within the dashed box displayed in Figure 14.

Figure 14: Relationships Between Various Temporary Transfer Arrangements



Under either direct arrangements or a banking approach, there can be many advantages to grouping several individual entities under one organization. These approaches allow

increased flexibility so that individual impacts can be reduced via rotation of affected lands within organization boundaries or prioritization of lands based upon their productivity. Also, if a buyer only needs to negotiate with one entity (e.g., an irrigation district), transaction costs can be substantially reduced. Procedures could be established through banking or direct agreements so that individual farmers could volunteer to be interrupted during a certain period of time in a manner similar to the Conservation Reserve Program. In addition, this type of coordination could provide the basis for innovative water management schemes that could allow greater flexibility in meeting contract obligations in a manner that would reduce impacts. A detailed description of water banks and how they work can be found in MacDonnell, et al., 1994.

Under interruptible supply arrangements, ownership of the water can either be retained by the agricultural entity or transferred to the municipal water user and leased back to the agricultural user (purchase/leaseback agreements). Under either type of arrangement, the water would be used most of the time for agricultural purposes. From the perspective of a municipal water provider, there are certain advantages and disadvantages associated with either approach. An interruptible supply agreement without transfer of the water will be less expensive than outright purchase, which often must include purchase of the irrigated lands. However, such agreements must be for a limited term, so the municipality must have a strategy for replacement of the supply at the end of the term if the contract cannot be extended. Purchasing the agricultural water rights at the end of the term may be more expensive and could involve bidding against other water users.

From the perspective of an agricultural water user, there are also advantages and disadvantages to either retaining ownership of the water rights or purchase/leaseback arrangements. Retaining ownership of both the water rights and the associated irrigated lands allows agricultural to continue their operations in the farming business while realizing additional revenues that would not otherwise be available. However, under an interruptible supply agreement, their water rights would be encumbered during the term of the agreement and could not be sold. One advantage of a purchase/leaseback arrangement is that the agricultural party can recover much of its capital investment while continuing to farm.

Under any type of interruptible supply agreement the level of uncertainty regarding the frequency of interruption is a critical issue. Arrangements can be structured so that the number of times the transfer will occur and when it will occur are known (although the precise amount of water to be transferred would be up to the discretion of the water right owner and would depend on the amount of water available to the water right owner). These arrangements are often made for the subsequent one or even two year period, and are typically referred to as "short-term transfers." This type of arrangement is in contrast to long-term agreements where there is uncertainty about the number of times the transfer will be exercised and/or the year when the transfer(s) will take place. The agreement may be made for transfers to occur for a specified number of times, with some mechanism in place to determine exactly when the transfers will occur. The years that the transfer will occur are not known at the onset of the contract because of the difficulty in forecasting the timing droughts. This type of agreement must include some type of "trigger" based

upon conditions such as precipitation level, stream flow, snowpack, and/or storage reservoir levels.

3.2.3.3. Sources of Water Supplies

From a purely economic standpoint, the value of interruptible supplies arrangements lies in being able to temporarily allocate water from lower valued uses to higher valued uses (in this case municipal treated water supplies). Potential sources of existing lower valued water supplies for ISC arrangements could include agricultural, industrial, and instream flows water rights within a geographic area encompassing both the Front Range and West Slope. In addition, potential supplies could include raw water used for urban irrigation. For example, a municipality could have an interruptible supply contract with the urban irrigation portion of a ditch supply. The potential supply of water from agricultural interests far surpasses the amount of water available from other sources. Therefore for purposes of this study, the initial focus is on temporary transfers of water from agriculture to municipal use. It should again be noted that northern Front Range cities, municipalities, and water purveyors are very concerned about any potential transfer of water out of their natural basins for use in the metro area, and do not feel that those resources should be considered as a significant source of future water for the metro Denver area.

3.2.3.4. Information Development

Information development for investigation of arrangements with agricultural water users involved a literature search and an inventory of South Platte River water diversion records for purposes of developing of an estimate of the gross supply potential. The literature search focused on previous investigations related to public policy, technical, institutional and economic issues associated with interruptible supply arrangements.

Previous Studies on Interruptible Supply Contracts

There have been several studies done regarding interruptible supply contracts under the Prior Appropriation System of the West, most of which have been written from an economic perspective. One study in particular (Pinnes, 1994) is focusing on issues surrounding the formulation of such a program for the Northern Colorado Water Conservancy District. This particular study is being conducted for the specific purpose of increasing the dependability the water yield from Windy Gap in dry years. The reader is referred to the Pinnes report and others listed in the References Section of this report for additional details.

Although there has been significant interest in interruptible supply arrangements, there are only a few actual implementations. The arrangements and studies described below are from Pinnes (1994) and MacDonnell and Rice (1994) and are organized into the categories of "true interruptible supply arrangements" and "quasi-interruptible supply arrangements." A summary of these examples can be found in Table 9.

Table 9: Summary of Interruptible Supply Arrangement Studies and Implementations

Ex. No.	Buyer	Purpose of Transfer	Seller	Seller Type	Type of Arrangement	Implementation or Study/Proposal	Duration of Contract	Trigger
1	MWD	Municipal	Dudley Ridge Irrigation District	Agriculture	True ISC	Implementation	1 year	SWP Deliveries to MWD
2	MWD	Municipal	Santa Clara Irrigation District	Agriculture	True ISC	Implementation	1 year	SWP Deliveries to MWD
3	MWD	Municipal	Palo Verde Irrigation District	Agriculture	True ISC	Study	35 yr (proposed)	N/A
4	MWD	Municipal	Areias Dairy Farm	Agriculture	Quasi-ISC	Close to Implement.	15 years	Mun. Discretion (7 times)
5	EBMUD	Municipal	Various Irrigators	Agriculture	True ISC	Study	N/A	CA State Index = Crit. Dry
6	Grand Junction	Municipal	Redlands	Industrial	True ISC	Implementation	Open Ended	Municipal Discretion
7	A City in Utah	Municipal	Farmers	Agricultural	True ISC	Implementation	25 years +	Municipal Discretion
8	Denver Area Municipalitie	Municipal	Fort Lyon Canal Co.	Agriculture	True ISC	Study	N/A	N/A
9	Fish & Wildlife Service	Environment	Truckee-Carson Irrigation District	Agriculture	True ISC	Study	N/A	N/A
10	State of Texas	Environment	Water Users of Edwards Aquifer	Ag. / Mun.	True ISC	Study	N/A	Aquifer Level
11	Yakima River Trustees	Environment	Yakima	Ag. / Mun.	True ISC	Study	N/A	N/A

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True Interruptible Supply Arrangements and Studies

MWD/Dudley Ridge: The Metropolitan Water District (MWD) in California had an agreement with the Dudley Ridge Water District (District) for a portion of the District's 1993 allocation of State Water Project (SWP) water. MWD agreed to buy (at $125/AF) all of the District's SWP water above the amount requested by the District's water users, if MWD's allocation of SWP water was 50% or less of its entitlement. The agreement gave MWD a conditional obligation to buy the water, but even if the trigger condition occurred, if the District farmers requested their full allocation, no water would be transferred. Since only 17% of the land within the district's service area was irrigated in 1992 (recent water shortages had already caused much land to be fallowed), this contract could be viewed by the irrigators as a mechanism for drought survival. The trigger condition did not occur in 1993, thus no water was transferred.

MWD/Santa Clara: MWD entered into a contract with the Santa Clara Valley Water District for a portion of its 1993 SWP entitlement, similar to the MWD/Dudley Ridge agreement. Again, the trigger condition did not occur and no water was transferred.

City in Utah: Around 1960, a city in Utah paid $25,000 for the right to take a farmer's entitlement of 5 cfs, whenever it wanted. During each year the option was exercised, the city paid $1,000 and provided 300 tons of hay to the farmer. During the first 25 years of the contract, the option was exercised 3 times. This example was documented by Clyde, 1986, where the name of the city was not disclosed. The author has since passed away and an investigation to uncover the parties involved in this agreement has not been successful (Pinnes, 1995).

Fort Lyon Canal Company Study: Interruptible supply arrangements were considered, but not recommended, as part of a study commissioned by the Colorado Water Conservation Board to transport water from the Fort Lyon Canal Company in the Arkansas River basin to the metro Denver area. Issues in this situation included 1) farmers were unsure as to whether or not permanent damage would result due to land fallowing, 2) future uncertainties and the intent by some farmers to leave agriculture without limitations made this type of agreement unattractive, and 3) conveyance facilities were not in place to transport the water to a new use.

FWS/Stillwater Wildlife Refuge: The Environmental Defense Fund (EDF) and The Nature Conservancy (TNC) have proposed interruptible supply strategies for transferring water from the agricultural community to the Stillwater Refuge, operated by the Fish and Wildlife Service. A source of funding has been an obstacle in the advancement of this plan.

Edwards Aquifer: EDF has made a proposal to manage the Edwards Aquifer in southern Texas using interruptible supply contracts. The sellers would include all users of the aquifer and the trigger is proposed to be the aquifer level. This scheme has not been pursued by the state legislature, which has been mandated to develop a management plan for the aquifer.

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Grand Junction/Redlands: In 1979, the City of Grand Junction entered into an open-ended contract with Redlands Water and Power Company. At the discretion of the City, Redland's water can be diverted to the City. The point of diversion for the two entities is nearly at the same location on the river. An annual payment is made by the City to the Water and Power Company for this option. When a transfer occurs and as a result, Redlands is required to purchase power, the City must compensate Redlands over and above any losses incurred. The City is responsible for all transaction costs related to the transfer application. In the past 15 years, the option has never been exercised.

MWD/PVID: Negotiations have taken place between MWD and the Palo Verde Irrigation District (PVID) for a long-term interruptible supply arrangement. These negotiations started in the mid-1980's. The proposed contract had a length of 35 years and included an initial payment in addition to a payment when the option was exercised. Due to concerns on the part of PVID farmers, a two-year land fallowing agreement was made in order to assess the impacts of short-term transfers. During 1993-1994, 93,000 AF/year of water was transferred and approximately 22% of the cropped acreage was fallowed. Initial results show that third-party impacts have been minor, probably due in part to the fact that fallowed acreage was a small fraction of a much larger agricultural region (Pinnes, 1994).

EBMUD: Interruptible supply contracts were pursued by the East Bay Municipal Utility District (EBMUD) with irrigation water users in the late 1980's. The proposed trigger was conditions when a year was classified as "critically dry," according to the State's supply index. Issues involved in these negotiations include 1) opposition to transferring any water for municipal use (even if temporary), 2) low price, 3) concerns about potential loss of water rights, and 4) salt water intrusion into the aquifer if groundwater were used as a replacement supply (Pinnes, 1994). These options are not currently being pursued.

Yakima River Basin: EDF has proposed interruptible supply arrangements in order to maintain minimum instream flows on the Yakima River (Willey and Diamant, 1994). Funding has been a major issue for this effort.

Quasi-Interruptible Supply Arrangements and Studies

MWD/Areias Dairy Farm: A 15-year agreement between MWD and the Areias Dairy Farm involves the transfer of water from the dairy farm to MWD in any seven of the 15 years, at MWD's discretion. When water is transferred, the dairy farm is expected to fallow its land. MWD will pay $175/AF to the dairy farm and $25/AF to an environmental restoration fund, as mandated by the CVPIA (Central Valley Project Improvement Act). As of 1994, this agreement was in the public review stage. This arrangement is not a true interruptible supply arrangement since the number of times the transfer will occur is known at the onset of the agreement.

3.2.3.5. Purchase/Leaseback Arrangements

Although the focus of this study is on the potential for interruptible supply agreements in the study area, it is beneficial to understand purchase/lease back agreements that have taken place. Two such arrangements have been developed in the metro Denver area.

Denver Water: In 1963, Denver entered into forty-year contracts with two ranchers, by which it acquired rights to water from the Williams Fork River. One of the rights was for 110 cfs and the other for 3 cfs. The sellers used the water to grow feed for their livestock, so when the city exercised its option, payments were intended to compensate the ranchers for the purchase of alternative feed. The ranchers paid a specified amount for rent over the forty-year period and the city paid the ranchers a certain amount during years in which it exercised its option to use the water. The amount depended on if all or a portion of the water was optioned. Denver had to give notice no later than March 10 if all water for the upcoming irrigation season would be taken, and by June 15 if all or a portion of the water would be taken starting July 1 (Pinnes, 1994).

City of Boulder: In 1994, the City of Boulder purchased shares of the Lower Boulder Ditch and entered into a lease back arrangement with the seller. The seller has a perpetual right to delivery of the irrigation water, subject to the City's right to take the water in time of shortage. Boulder has agreed to take the water only in times of shortage, but the City has the discretion to determine the existence of this type of situation. The City anticipates exercising its option once every 20 to 30 years and is required to give at least two weeks' notice of the proposed interruption. The farmer does not pay rent to the City and the amount the City must pay to the farmer in the event of water being taken depends on when notice was given. If notice is given before May 1, the City must pay ditch company assessments for that year. If after May 1, Boulder must reimburse the farm for losses resulting from the interruption (Pinnes, 1994). Thus far, the City has not exercised its option.

3.2.3.6. Conditions for Successful Arrangements

Five factors impacting the success of interruptible supply agreements are discussed below.

Economic Benefits

From the buyer's viewpoint, interruptible supply agreements can be seen as an economical way to secure additional water supplies during dry-year shortfalls. The outright purchase and maintenance of water rights can be expensive. From the viewpoint of the agricultural community, ISC arrangements can be viewed, in some cases, as a way to economically survive a drought.

One of the first cost-related issues which must be determined up front is how the transferred water would be transported to the new use. In some cases, the infrastructure may already be in place, minimizing the importance of this issue. This issue may be moot if, for example, both parties involved share a common storage reservoir (e.g.,

Standley Reservoir). If, however, new facilities would need to be built and maintained, the cost of such facilities could make the arrangement cost prohibitive. It may be very difficult to justify the construction and maintenance of new conveyance facilities, particularly if those facilities are intended to be used relatively infrequently. An additional aspect of the economic viability of ISC arrangements is that of transaction costs. Resources required in order to put the contract in place can be costly. If the alternative to meeting municipal needs via interruptible supply contracts is the direct purchase of the agricultural water rights, however, conveyance costs and transaction costs may be approximately the same for both alternatives. In this case, conveyance and transaction costs do not impact the economic analysis comparing the two alternatives.

Reliable Source of Supply

A critical aspect of ISC contracts is the degree of certainty that a certain amount of water will be available for transfer when the option is exercised. If reasonable level of certainty does not exist, the contract will be useless.

Both Parties See Benefits

As with any voluntary agreement, each party involved must see some type of benefit to having an interruptible supply arrangement in place. All of the previous examples have been initiated by the proposed buyer (or an organization representing the buyer's needs). The buyer in most cases has some goal such as: 1) dealing with a short term shortage (as in the case of MWD/Dudley Ridge and MWD/Santa Clara which were precipitated by a recent drought); 2) dealing with an immediate mandate of some sort (e.g. mandate to develop a management plan for the Edwards Aquifer); or 3) addressing the security of long-term supplies. Cooperation in the development of such agreements are often facilitated when the seller 1) agrees with the overall principle of temporary transfers, especially for municipal purposes and 2) sees this type of arrangement as being the "lessor of two evils" or as having minimal risks. Note that in many of the examples mentioned in Section 4, a willingness on the part of the seller was at least partially based on concerns of future events. In the Yakima example, farmers were concerned that they would, in the future, lose some of their water to salmon in any event, and they preferred to do so in a way that yields an economic benefit to them (Pinnes, 1994). In addition, the minimal risk involved in the MWD/Dudley Ridge and MWD/Santa Clara agreements resulted in a higher level of willingness to enter such agreements on the part of the irrigators.

Minimal Agricultural Operational Issues

Site-specific operational issues on the part of the seller need to be considered when looking into the feasibility of an ISC arrangement. A specific farm operation must look at how it would deal with a temporary absence of all or a portion of its irrigation supply - Can it switch to another water supply? Can it switch to alternative crops? Can the farm temporarily refrain from the production of crops and avoid long-term problems? In the case of transferring a portion of a larger entitlement, would flow reductions impact irrigation operations on otherwise "non-impacted" areas of the farm? How many

consecutive seasons could a transfer occur before "temporary impacts" start to look like "permanent impacts?" These issues are very site-specific and would need to be considered on a case-by-case basis.

Minimal Third Party Impacts

There are several potential third-party impacts which may result from exercising dry-year options. Some of these impacts are discussed below. In each case, there is a need to somehow recognize threshold damage issues - How much and how often can supplies be interrupted before significant impacts occur either to the region or individual third-parties or entities? These issues will need to be explored on a case-by-case basis, using information from past experiences.

Environment

Potential environmental impacts include 1) dust and wind erosion of fallowed land, 2) impacts on groundwater if groundwater pumping increases as a result of transfers, and 3) impacts on ecosystems such as wetlands which may occur as a result of altered water use patterns.

Local Economic Impacts

Interruptible supply agreements may have economic impacts on individuals and on the local community. In some cases (e.g. the MWD/Dudley Ridge example), the use of options were seen as a way for irrigators to economically survive the drought. Contracts can be set up so that during a year when an option is exercised, the seller ends up in a better economic condition than would have occurred had no contract been in place. This impact can positively affect sales tax revenues for the community.

Unemployment may rise, however, during these same years. The impacts of unemployment will depend on levels of mechanization of the affected crops. Preliminary investigations in the MWD/PVID case indicate less than 1% of the valley's work force was laid off due to the program (Pinnes, 1994). Local economic impacts due to increased unemployment can be minimized through programs which compensate affected individuals directly or through payments by the buyer to an agency responsible for the distribution of social service funds.

Other local economic issues include the impacts on local businesses which support agricultural activities. This impact has not been quantified. With regards to overall economic impact on the community, the degree of impact is highly dependent on the significance of the seller in the region as a whole. If, as in the case of MWD/PVID, the affected area is small compared to the surrounding agricultural regions, impacts on the region will be minimized. Impacts are also minimized if the affected land is distributed over a larger geographical area, versus concentrated in one area.

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Injuries to Other Individual Entities

As with any water transfer, injuries to other water right owners needs to be analyzed. Impacts due to changes in return flows and water quality need to be considered. In addition, potential impacts to an affected ditch company (e.g., decreases in operational efficiency due to reduced canal flow) need to be studied. These issues need to be investigated on a case-by-case basis.

3.2.3.7. Specific Contract Terms

Parties can make the contracts as simple or as complicated as necessary to meet their specific needs. Key issues which need to be determined include:

- Price and payment arrangements (including price adjustments over time)[8];
- Overall length of the contract;
- Amount of water to be transferred;
- How a transfer will be triggered; and
- How much notice will be necessary.

Other additional contract terms should be considered by the parties to address issues that are difficult or impossible to anticipate. Several examples are listed below.

Renegotiation Clause: This clause allows the contract to be reopened and renegotiated prior to termination in order to address unforeseen circumstances.

Right of First Refusal: This provision allows the seller to sell the water rights supporting the contract before contract termination. The buyer, however, is given the right to match the offered price. In some cases, a maximum purchase price is set in order for the buyer to be comfortable dealing with the chances of short term spikes in water prices (Michelsen, 1988).

Force Majeure: In the event of uncontrollable circumstances which result in a party not fulfilling their part of the contract, this clause relieves each party of contract obligations.

Arbitration Clause: An arbitration clause describes the procedures to deal with contract disputes.

[8] Typically, there is an option price (the payment from the buyer to the seller for having the option) and exercise price (the payment made during a year that the option is exercised).

3.2.3.8. Other Contractual and Procedural Considerations

Group or Individual Arrangements

Arrangements can be made with an individual farmer or farmers or the seller can be a ditch company, water user's association, or conservancy district, representing a group of irrigators. There can be many advantages to grouping several individual entities under one organization. First of all, individual impacts can be reduced via rotation of affected lands within organization boundaries. Secondly, if the buyer only needs to negotiate with one entity (e.g., an irrigation district), transaction costs can be substantially reduced. Third, a unifying agency can be responsive to changing productivity issues and be arranged so that ISC obligations are met by interrupting less productive lands, all other things being equal.

In some cases, it may make sense to set up some type of unifying organization (representing several different entities) in order to facilitate cooperation and negotiations. Procedures could be set up so that individual farmers could volunteer to be interrupted. Such "take it or leave it" programs are not foreign to the agricultural community (e.g., the Conservation Reserve Program). In addition, this type of 'clearinghouse' could implement innovative water management schemes that could be flexible and help distribute the impacts of meeting contract obligations.

Transaction Procedures and Resources

In an ideal setting, the legal process one would go through to set up an interruptible supply contract would be simple, to minimize transaction costs, and yet involve enough detail to ensure that the appropriate level of "homework" is done up front. Three levels of complexity have been identified as potential legal transaction mechanisms. These are described below in order of decreasing complexity.

Water Court: This is the highest cost option and requires the most involvement.

Temporary Substitute Supply Agreements: It may be feasible to set up some types of contracts using the course of temporary substitute supply agreements. This option would require lower transaction costs than going to water court. Using this mechanism for ISC may result in more scrutiny than usual, however, since the option may only take place during periods of drought. The maximum overall length of time for temporary substitute supply agreements needs to be explored, along with other details, in order to determine whether or not this mechanism would be suitable for ISC arrangements.

Do Nothing: In some cases, the geographical arrangement between the two parties is such that the seller need only 'not divert' and the buyer directly receives the benefit. In this case, no legal action is required for the non-use of a water right which greatly simplifies the transaction.

Technical, economic, and legal resources are required to set up an ISC arrangement. These transaction costs could be significant and the agricultural community has access to fewer resources for investigating these aspects from their perspective. This discrepancy

can provide a disincentive for irrigators to enter ISC negotiations. One way to overcome this would be to set up some type of impartial, third-party financial aid source to assist irrigators in acquiring these services. Although the private sector has supplied this type of support in the past, through water brokers, there are trust issues. In addition, the cost of services from the private sector can significantly increase transaction costs.

3.2.3.9. Supply Source Considerations

The issues described in Section 4 are very site-specific and depend on specific arrangements set up in the contract. Therefore, it is difficult to talk about hypothetical examples and to simplify the analysis in a generic sense. There are a few differences in buying from a direct-flow dominated system and a storage dominated system, however. Direct flow rights are much more variable than systems dominated by storage rights. With storage rights, there can be much more certainty as to quantity and users have more flexibility regarding timing of use. Storage based systems which are shared between potential buyers and sellers have the added benefit of not having to deal with additional conveyance issues. The timing of deliveries and quantity available for transfer from storage dominated systems is also a function of reservoir operations. Contracts can be set up for a fixed amount of water, where the reservoir would need to be operated so that the fixed amount were available if the option were exercised. An alternative would be to contract for an amount available over a fixed amount. This type of agreement would require reservoir operations to be specified.

3.2.3.10. Economic Considerations

A number of studies have looked at the economic impacts of interruptible supplies. Michelsen and Young (1993) and Clark and Abt (1993) have used examples in Northern Colorado as an example to illustrate the economic benefits of such arrangements. These analyses were done from the perspective of the municipality. Using 1988 data, Michelsen and Young estimated present value benefits of ISC arrangements versus the direct purchase of the water right. The results indicate that ISC arrangements are economically viable over a large range of conditions.

Data used for computing base case conditions included:

Contract Life	20 years
Probability of Exercising the Option	1:20
Cost Incurred During Year Option is Exercised	$90/year[9];
Water Right Purchase Cost	$600/AF;
Appreciation of Water Right Purchase Cost	2%/year;
Share Assessment Costs	$12/AF/year;
Discount Rate[10]	4%/year.

For either alternative (ISC or direct purchase), the water needs to be physically delivered to the municipality. In many cases, the cost of additional conveyance facilities would be the same for either alternative. In their analysis, Michelsen and Young assumed that costs for conveyance and transaction costs[11] were the same between the two alternatives and could therefore be neglected.

Using the values above, it was determined that the maximum price that a city could afford to pay a farmer to hold an option contract is $295/AF. Under this base case, as long as the negotiated option price is $295/AF or less, ISC contracts are more economically attractive than the direct purchase of the water right. Michelsen and Young varied the values listed above to determine how sensitive present value benefits were to these parameters. The results are displayed in Table 10. For most of the conditions, the present value benefits are positive and significant. Two key parameters are the appreciation of water right purchase costs and the discount rate - both of which can be difficult to predict. Michelsen and Young did not address possible conveyance costs that may be associated with the physical conveyance of the water to the municipality.

[9] Value for a 1:20 year drought water supply, using average crop prices

[10] Reflecting tax-free municipal bond rates

[11] Note that in the analysis done by Clark and Abt, the transaction costs for the direct purchase alternative were significantly higher than transaction costs incurred for an ISC arrangement. This would make ISC contracts even more attractive than illustrated by Michelsen and Young.

Table 10
(Maximum Option Price Which A Municipality Can Pay and Still Benefit Over Purchasing the Water Right)
(1988 $/AF)

Parameter Value		Interest Rate		
		3%	4%	5%
Water Right Appreciation (percent / year)	0%	379	428	467
	2%	218	295	357
	3.5%	51	157	244
	5%	-170	-5	93
Farmer Offering Price / Excercise Cost ($/AF)	40	255	329	389
	90	248	295	357
	135	184	264	329
Water Right Purchase Cost ($/AF)	400	182	231	269
	600	218	295	357
	1000	289	424	533
Timing of Option Excercise (Year Excercised)	1st	198	270	328
	10th	218	295	357
	20th	235	315	380
Expected Frequency	1:4	-50	50	133
	1:5	17	112	189
	1:10	151	234	301
	1:20	218	295	357
	1:50	258	332	391

3.2.3.11. South Platte River Basin Supply Potential

It is estimated that in 1985 there were 917,640 acres of irrigated land within the South Platte River Basin in Colorado with associated irrigation water usage of about 2,850,000 acre-feet. Consumptive use of water in the irrigation sector in 1985 is estimated to have been about 1,400,000 acre-feet (USGS, 1989)

The Front Range region within the South Platte River Basin has been divided into ten sub-basins in order to estimate gross potential supplies in the region. These sub-basins are displayed in Figure 15. Potential gross agricultural supplies in each of these basins are shown in Table 11.

It is important to note that entities to the north of the metro Denver area do not feel that their region should be identified as a source of significant future water supply for the metro area. Many cities, municipalities, and domestic water purveyors that are located within or adjacent to vital irrigated agricultural areas look to these supplies to sustain the

irrigated agricultural economy in their area and as a source of water as urban and suburban growth encompasses previously irrigated lands (Wilkinson, 1996).

Figure 15: Sub-Basins of the Northern Front Range Region

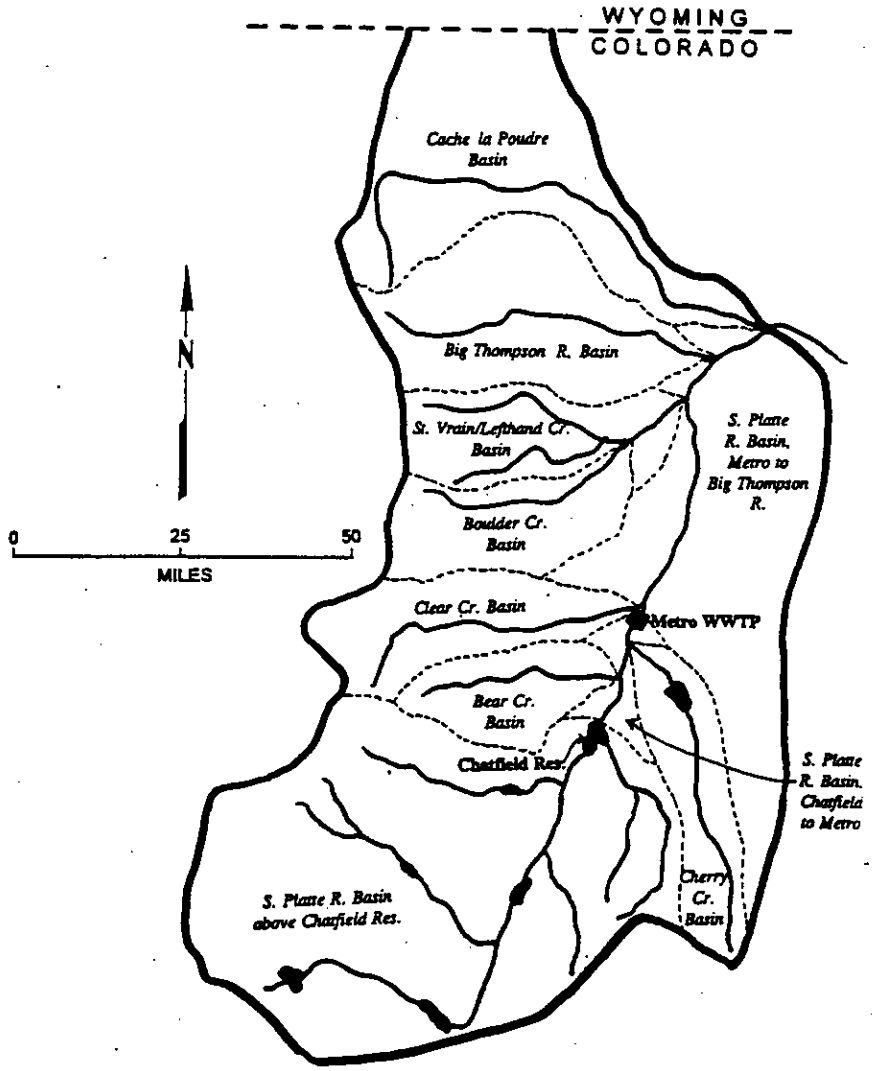

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Table 11: Estimate of Gross Supply Potential for Interruptible Supply Arrangements by Sub-Basin

Sub-Basin	Average Annual Dry Year Supplies Owned by Agriculture With Diversions Above Greeley (3)	Average Annual Clean Dry Year Diversions Owned by Agriculture in AF (4)
South Platte above Chatfield (5)	8,000	8,000
Bear Creek	~0 (6)	~0 (6)
Cherry Creek	~0 (6)	~0 (6)
Clear Creek	13,000 (7)	4,000 (7)
South Platte (Chatfield to Metro)	54,000	0
South Platte (Metro to Big Thompson)	151,000	0
Boulder Creek	49,000	24,000
St. Vrain / Left Hand	49,000	37,000
Big Thompson	73,000	47,000
Cache La Poudre	111,000	74,000
TOTAL:	495,000	190,000

NOTES:
(1) These numbers are estimates. Only major ditches have been considered.
(2) Numbers listed may include ditch diversions that serve areas within a municipality's planning area.
(3) Annual Dry Year Diversions based on data from
1954, 1955, 1963, 1964, 1966, 1977 and 1981 (except St. Vrain does not include 1977 or 1981)
(4) "Clean" means diversion does not occur downstream of a major WWTP
(5) 'S. Platte Above Chatfield' includes S. Park ditches (including N.F. S. Platte) which are expressed as depletions, not diversions
(6) ~0 = Insignificant
(7) Average annual for period of record (Dry year numbers not readily available, values not included in total)

3.2.3.12. Issues and Concerns

Geographic Considerations

Geographically, most of the available supply lies to the north of the metro Denver area. Interruptible supply contracts involving the use of these supplies in the metro area would involve the development of additional conveyance facilities, which would be relatively costly and could be politically problematic from the perspectives of affected local governments. For example, Boulder County has adopted land use regulations under state statues governing areas and activities of statewide concern (1041 regulations).

Because of their location and geographic extent, existing CBT facilities have been viewed by some as a possible system for conveyance of ISC water to the metro Denver area. However, it is the position of the District that the facilities of the CBT and Windy Gap Projects are legally dedicated to the sole use of water users within the District and Subdistrict boundaries and may not be used for the benefit of the metro area.

Agricultural Community Concerns

There is some degree of mistrust of municipal water interests on the part of some members of the agricultural community within the study area. As discussed previously, under Other Contractual and Procedural Considerations, these arrangements are facilitated when the seller agrees with the overall principle of temporary transfers, especially for municipal purposes. In order to successfully develop a contract, some of

this mistrust may need to be reduced and contracts set up so that both parties view the arrangement as a "win-win." Again, contracts need to be set up so that both parties are comfortable with the arrangement. There are no fixed rules.

Concerns on the part of some in the agricultural community and reasons for mistrust and skepticism vary. These include:

- Strong beliefs that water should be kept for agricultural use instead of municipal use and that temporary transfers are precursors to permanent transfers;
- Concerns of legal consequences of such transactions. Uncertainty over whether or not an arrangement could result in forfeiture for non-use or in loss of priority;
- Farmers prefer short-term arrangements. Long term arrangements sought by municipalities are sometimes viewed as limiting one's future alternatives;
- Knowing that the agricultural community has very few resources to evaluate and negotiate potential ISC deals and that municipalities have far greater resources, there is the sense that municipalities would have an unfair advantage; and
- Due to past experiences and perceptions, there is a genuine mistrust of municipalities by some in the agricultural community.

Some of these concerns are shared by several Northern municipal water providers.

CBT System "Wheeling"

Delivery of ISC water from northern agricultural areas to the metro Denver area would require additional conveyance facilities. Because of their location and geographic extent, the CBT project facilities may be usable to help convey ISC water to the metro area, thereby reducing the length of any new conveyance facilities. Under this concept, reduced diversions by the ditch systems participating in the ISC arrangement could be "exchanged" into the CBT Project system by reducing concurrent CBT deliveries to non-participating entities and allowing the ISC water to be diverted by those entities as a substitute supply. This would result in increased CBT system storage which could then be used as a delivery source to the metro area from Carter Lake via a new pipeline. This operational scheme would have to be developed so as to avoid impacts to CBT and Windy Gap deliveries and there are a number of institutional and operational issues that would have to be addressed and resolved.

The NCWCD Board of Directors, which is responsible for operating the system, has taken the position that CBT Project facilities are not available for "wheeling" water outside the District or Subdistrict. Legal and institutional barriers exist that currently preclude the use of these facilities for such uses. Any such use of CBT Project facilities would require significant legal and institutional changes and would require the consent of the District and the Bureau of Reclamation.

Relationship Between ISC and Other Water Supply Options

From the metropolitan Denver perspective, interruptible supply contracts serve the same purpose as conjunctive use scenarios - they both supplement when surface supplies are inadequate. In areas where exchanges of effluent could be made or ISC options could be exercised, since the effluent is already there, it may not make sense to impact agricultural land through ISC contracts. When comparing ISC opportunities to other alternatives, it may be important to factor in potential conveyance costs. If the conveyance costs are approximately the same, as it could be when comparing ISC to the direct purchase of agricultural lands, this impact can be neglected in the economic analysis. On the other hand, if interruptible supply contracts are being compared to other alternatives, then potential ISC conveyance costs could seriously reduce or eliminate any economic benefits of ISC arrangements.

3.2.4. Systems Integration

3.2.4.1. Conceptual Definitions

The concept of systems integration involves the cooperative use or enhancement of several water supply systems in a manner designed to synergistically increase or maximize total combined yields. Conjunctive use of surface and groundwater systems, coordinated approaches to effluent management, and interruptible supply arrangements discussed in other parts of this report are all specific examples of systems integration. The TAC's original reason for including this separate systems integration section in the MWSI was to create a "catch-all" category for ideas that were not adequately developed for inclusion in the study at the time of initial scoping. System integration efforts throughout the MWSI were also intended to stimulate creative thinking and generate ideas for cooperative water supply opportunities.

Phases II and III of the MWSI included several TAC and Work Group "brainstorming" meetings, including a series of brainstorming sessions designed to focus on specific areas and water supply systems. The MWSI systems integration effort was intended to address a number of procedural and substantive objectives that were identified by TAC members including the following:

- Create an information inventory on current water supply systems service areas, facilities, system yields, water rights portfolios, etc., that would be useful to further individual and cooperative planning efforts;
- Provide an opportunity for mutual education regarding the water supply systems and the perspectives of individual water providers and geographic sub-regions of the metro Denver area;
- Establish a forum where cooperative water supply ideas and information could be brought forth and openly discussed;

- Explore at a strategic level a number of market-related ideas involving investment in water conservation programs, pooling or interim leasing of water rights or reuse credits, etc.;
- Explore the potential utility of raw water or treated water interconnections or coordinated operations between individual water supply systems;
- Identify areas of mutual concern (such as maintenance of instream flow and/or water quality conditions in a critical stream reach) and conceptual approaches for addressing concerns; and
- Consider possible establishment of a continuing forum for periodic discussions and informal cooperative planning efforts among metro area water providers that would exist beyond the life of the MWSI.

Follow-up studies of systems integration opportunities identified during this process are currently underway through three separate regional cooperative investigations. This chapter of the MWSI report provides a description of the process employed to generate ideas, a summary of the results of this process, descriptions of several key systems integration opportunities, and the descriptions of relevant cooperative studies that are now in progress.

3.2.4.2. Information Development

Identification of systems integration opportunities required collection of information about individual water supply and distribution systems and mutual education of individual water providers regarding each others' systems. The first step in this process was to develop a framework for the information needed and the format for its presentation. This framework was intended to provide consistency in the type of information and level of detail required for different water supply systems.

Information about water supply systems was gathered through meetings with individual water providers to prepare for a series of presentations to the TAC. Information developed through this process included the following:[12]

- **Hydrology and Water Quality Information**
  1. Major streams and aquifers
  2. Characterization of surface flows
  3. Surface water/groundwater interactions
  4. Areas of particular water quality concerns
- **Water Supply Systems Information**

[12] Much of this information is presented in other sections of this report as needed for discussion of specific Systems Integration opportunities.

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1. Maps showing the water supply service areas within each sub-region, surface water diversion points, raw water reservoirs, wells, raw water lines, water treatment plants, major treated water reservoirs, wastewater treatment plants, major raw water collection and conveyance lines, and treated water mains over 18." (Physical and political reference points such as highways, streams, county and municipal boundaries were also included.)
2. Tabulated descriptions of the capacities of listed facilities
3. Overview descriptions of system operations including seasonal sequence of water sources used, operational responses to dry year and wet year conditions
4. Summary of water rights portfolios
5. Estimates of system average and safe yields

- **Water Uses and Conservation Practices**
  1. Current levels of water use
  2. Municipal and agricultural (if applicable) water conservation programs
  3. Estimated per capita use levels.

- **Water Resource Needs and Plans**
  1. Population and water demand projections
  2. Plans for new water supply development
  3. Plans for new distribution facilities
  4. Status of land use planning as related to water supply planning activities

- **Interactions With Other Areas**
  1. Perceived effects of system operations on upstream, downstream and out-of-basin water users and interests
  2. Perceived effects of other sub-regions' water supplies and operations
  3. General status of cooperative relationships within each sub-region and with other sub-regions

- **Perceptions of System Integration Opportunities**
  1. Ideas regarding linkages, coordination of operations or other possible Systems Integration options
  2. Areas where sub-regions or individual providers may have something to offer with respect to spill capture, reuse and reallocation opportunities
  3. Areas of concern regarding regional System Integration opportunities being discussed by others

Each of the brainstorming meetings focused on a particular geographic sub-region of the metro Denver area with presentations made by relevant water supply management entities within that sub-region, followed by discussion of perspectives, ideas for cooperative endeavors, and issues of concern.

The geographic sub-regions were designed to encompass contiguous areas that share or compete for water supplies from certain sections of the South Platte River, its tributaries, or imported sources. Based upon this approach, the meetings were organized to focus upon the following geographic sub-regions:

1. **Denver Water System/Aurora Water System** – The water supply systems of these two providers are unique given their size and geographic scope which includes transbasin diversions from the Colorado and Arkansas Basins, South Platte Basin sources, and distribution facilities throughout the metro area. These systems also have unique opportunities for synergy in the South Park area where both entities have major storage facilities and numerous water rights and where Aurora's transbasin imports enter the South Platte.

2. **Cherry Creek and Plum Creek (Southern Region)** – This sub-region includes the Cherry and Plum Creek basins upstream of Cherry Creek and Chatfield Reservoirs. These basins are characterized by relatively erratic and small surface flows, significant alluvial aquifers and large supplies of Denver Basin groundwater beneath them. Each basin contains a major flood control reservoir, which presents both problems and opportunities regarding water supply and water quality. Most municipal water supply systems within this sub-region are highly reliant on Denver Basin groundwater and reuse of surface water through plans of augmentation. Levels of groundwater use are growing relatively rapidly due to population growth pressures. Major water providers include Aurora, the Arapahoe County Water & Wastewater Authority, Castle Pines Metro District (MD), Castle Pines North MD, the Town of Castle Rock, Centennial Water & Sanitation District (W&SD), Cottonwood W&SD, East Cherry Creek Valley W&SD, Inverness W&SD, Meridian MD, North Douglas County W&SD, Parker W&SD, Pinery W&SD, Roxborough Park MD, Stonegate Village MD and Willows WD. All of these providers except Aurora are members of the Douglas County Water Authority.

3. **Clear Creek/Moffat System (Northwest Region)** – This sub-region includes the water providers obtaining their primary supplies from Clear Creek and Denver's Moffat Tunnel Collection System. South Boulder Creek, Ralston Creek and Coal Creek are also included in this sub-region. Several raw water delivery and storage systems have existing and potential interconnections within this sub-region: the Standley and Marshall divisions of FRICO; Denver Water's Moffat delivery system; portions of Boulder's and Public Service Company's (PSCO) systems; and the southern portion of the CBT/Windy Gap projects. Water management in this region is highly evolved and relies heavily on exchanges and Standley Lake operations. Major water providers include Arvada, Boulder, Broomfield, Consolidated Mutual Water Company,

Coors, Denver Water, FRICO, Golden, Northglenn, PSCO, Superior, Thornton and Westminster.

4. **South Platte Urban River: Chatfield Reservoir to the St. Vrain Confluence (Northeast Region)** – This sub-region includes the South Platte River from Chatfield Reservoir to the St. Vrain confluence and the lower portions of Bear Creek, Cherry Creek and Clear Creek. This sub-region represents the major portion of the metro area's effluent management "universe" and associated water quality issues. The region receives major inflows from urban stormwater runoff, lawn irrigation return flows and wastewater discharges. Major water users with points of diversion or exchange rights in this sub-region include Aurora, Brighton, the Burlington Companies, Centennial W&SD, the Consolidated Ditches of District 2, Denver Water, Englewood, PSCO, South Adams County W&SD and Thornton. Other entities with water-related interests include the Metro Wastewater Reclamation District, Rocky Mountain Arsenal, the Urban Drainage & Flood Control District, the Corps of Engineers, the City of Littleton and the Colorado Divisions of Wildlife and State Parks.

5. **Northern Front Range and Lower South Platte (Northern Region)** – This sub-region includes the South Platte below the St. Vrain confluence and the Boulder, St. Vrain, Big Thompson and Cache La Poudre basins. Most of the agricultural water use in the South Platte Basin occurs within this sub-region and most of this sub-region is located within the Northern Colorado Water Conservancy District. This area is supported by native and imported surface water supplies of over 1,000,000 AF per year coupled with surface storage capacity of over 1,000,000 AF. Major sub-region members include Boulder, Estes Park, Fort Collins, Greeley, Longmont, Loveland, the Northern Colorado Water Conservancy District (NCWCD), the Bureau of Reclamation, Saint Vrain and Left Hand Water Conservation District, the Platte River Power Authority, and several district water users associations, rural domestic water districts and ditch companies.

6. **West Slope** – There are a number of systemic issues and political perspectives that need to be considered regarding systems integration opportunities as they affect existing and future transbasin diversions and West Slope water management issues. In addition, there may be some synergistic benefits to the metro Denver area and the West Slope associated with some opportunities. This meeting was hosted by the West Slope participants of the TAC and focused on developing a Colorado River basin-wide perspective on systems integration opportunities and concerns. Major sub-region members included the Colorado River Water Conservation District, counties, cities, irrigation, industrial and recreational water users and environmental interests within the Colorado River basin.

3.2.4.3. Systems Integration Study Results

The sub-regional meetings produced an abundance of inventory data and identified several opportunities for cooperative water supply plans as well as concerns about the potential impacts of such plans on local water-related interests. The inventory data have been summarized and presented in previous sections of this report. The opportunities and concerns identified in each of the meetings are described below.

Denver/Aurora Opportunities and Issues

The Denver Water combined service area consists of the City and County of Denver and 75 suburban contract distributors. Current annual water demand for the combined service area is about 265,000 acre-feet. Denver Water estimates that the firm annual yield of their system is about 345,000 acre-feet, resulting in a current surplus supply of about 80,000 acre-feet per year. This supply should be sufficient to meet future demands through the year 2013. (This assumes Denver would continue to require a safety factor of 30,000 acre-feet). The Board of Water Commissioners has adopted a policy to plan for meeting future demands within a fixed combined service area, but not to enlarge the combined service area by creating new outside distributors.

Denver Water's Integrated Resource Planning (IRP) process has estimated additional future water needs of 100,000 acre-feet per year, or a total of 445,000 acre-feet, by the year 2045. This projection includes a 30,000 acre-feet as a "safety factor" as insurance against risks associated with potential loss of yield from catastrophic occurrences, faulty projections or regulatory requirements. The results of the IRP process indicate that the additional 100,000 acre-feet of supply needed for demands beyond 2013 can be met through conservation, reuse, system refinements, cooperative arrangements with other regional water providers and development of some of its conditional water rights (Denver Water, 1997).

Partially in response to the interest and concerns voiced in these sub-regional meetings, the Denver Water Board adopted a Resource Statement that directs Denver Water staff to evaluate potential cooperative actions that may be proposed by other metro area water suppliers (Denver Water, 1995). The Board's Resource Statement encourages metro area water suppliers to coordinate and consolidate proposals initiating from the same geographic region or sub-region. It also clearly states that such proposals must be responsive to Denver's interests and to West Slope, environmental and permitting concerns. In response to Denver's Resource Statement, providers within three geographic sub-regions have entered into cooperative agreements to investigate specific "systems integration" water supply opportunities.

The City of Aurora currently encompasses about 130 square miles with an estimated population of 260,000 residents. Aurora's current annual water demand is approximately 50,000 acre-feet. The average annual yield of the Aurora water supply system, including its recently changes Rocky Ford Ditch and Colorado Canal rights in the Arkansas basin, is estimated at about 76,000 acre-feet per year from surface water supply sources in the South Platte, Colorado and Arkansas River Basins. Aurora also has access to substantial Denver Basin groundwater, which is mostly reserved for drought or emergency uses.

Aurora expects future growth to average 50,000 people per decade with an associated increase in water demands of 10,000 acre-feet per decade. Plans to meet these future demands include the Eagle River/Camp Hale Conjunctive Use Project (in cooperation with the City of Colorado Springs and the West Slope), the South Park Conjunctive Use Project, expanded effluent reuse, possible cooperative arrangements with Denver Water and other purchases.

The Denver/Aurora water supply systems are currently linked at Strontia Springs Reservoir in Waterton Canyon, which serves both systems as their primary point of diversion for South Platte supplies and water imported from the Blue River, Eagle River and Arkansas River Basins. Discussions are currently underway between Denver and Aurora regarding possible arrangements to more effectively utilize their respective Upper South Platte storage facilities including Antero, Eleven Mile, Spinney Mountain and Cheesman Reservoirs. Because these discussions have not involved other water providers, they have proceeded independently of the MWSI.

Opportunities under investigation include enlargement of Antero Reservoir wherein Aurora could store water imported from the Colorado and Arkansas Rivers in Antero. This additional storage would enhance the yield of Aurora's collection systems and more effectively utilize storage at Antero, where the water supply yield to Denver is limited by Denver's junior storage rights and the relatively small physical yield of the watershed tributary to Antero. Since the discussions between Aurora and Denver Water have not been part of the MWSI process, detailed information regarding these opportunities is not available for inclusion in this study.

Southern Region Opportunities and Issues

The service areas for water providers in the southern region of the metro area, including northern Douglas County and south central Arapahoe County, currently encompass approximately 134 square miles, of which 37 square miles is developed. Current (1996) annual demands are approximately 37,000 acre-feet and are expected to increase to approximately 146,000 acre feet. Southern area providers are planning to meet existing and future demands through expanded use of Denver Basin groundwater, surface water sources, and reuse of legally available return flows.

Southern area providers are increasingly relying on direct reuse and augmentation plans in the Cherry Creek and Plum Creek basins to allow for increased pumped from alluvial wells. Effluent discharged to Cherry Creek and Plum Creek generally receives advanced wastewater treatment, and under augmentation plans, serves to recharge the alluvium and replace out of priority pumping from tributary aquifers. The alluvium provides both storage and water quality benefits through filtration and dilution of water that is pumped to municipal systems.

Through the Douglas County Water Authority, southern area providers are participating in a cooperative action investigation with Denver Water to further examine the conjunctive use concepts described previously in this report for the purpose of reducing their reliance on Denver Basin aquifer sources. The Southern Regional Cooperative Action Study (Phase I) has reached a preliminary conclusion that up to 60,000 acre feet of

potential additional yield could be cooperatively developed through conjunctive use (Hydrosphere, 1998). This could be used to offset existing Denver Basin groundwater pumping or to provide new water supply taps. Further study of a potential conjunctive use project is planned by both Denver Water and the Authority.

It is important to note that Douglas County has also adopted land use strategies to manage growth and urbanization. These strategies include down-zoning and the use of County open space sales tax revenues and GoCo grants to acquire an open space buffer between Castle Rock and Colorado Springs. Downzoning and open space acquisition efforts over the past 10 years have resulted in a 10% reduction in the County's build-out population estimates (Sullivan, 1997). The County recognizes the importance of land use planning and is working closely with utilities to coordinate water and sewer service needs with land use and zoning decisions.

Northwest Region Opportunities and Issues

The northwest sub-regional group includes the cities of Arvada, Broomfield, Westminster and the Consolidated Mutual Water Company. In cooperation with Denver Water and the State of Colorado, this group is engaged in a study to define the potential additional yield that could be cooperatively developed through interconnections and cooperative use of storage facilities at one or more locations in the northwest area. Northwest water supply systems, seasonal operations for wet/average/dry years, participants' relevant water rights, and major system facilities including diversion points, canals, pipelines, reservoirs, treatment plants, principal treated water distribution lines and interconnections are being examined to identify critical linkages, capacities and bottlenecks. An operational analyses will be conducted to help identify constraints and opportunities including the following:

- Attention will be focused on identifying storage levels in major reservoirs and levels of use of major conveyance facilities. Opportunities associated with periods of unused storage and conveyance capacity within individual systems will then be identified.

- Monthly time series estimates of unused supplies available under the participating parties' water rights will be developed including estimates of supplies from the Moffat and Gumlick Tunnels, South Boulder Creek, Coal Creek, Ralston Creek and Clear Creek. Opportunities associated with these unused supplies will be identified.

- Opportunities associated with reusable supplies and unused Clear Creek exchange potential (which may exist due to insufficient storage or individual exchange supplies) will be identified.

- An analyses will be conducted to look at how unused supplies could be "firmed" from a regional perspective by delivery to demand locations or to available storage capacity using existing and assumed future interconnections. Initial analyses would focus on the regional opportunities associated with existing systems.

- The benefits of additional storage capacity at Standley, Gross, Leyden Gulch and other locations will be examined.

The results of this study will be used by the Northwest Provider Group and by Denver Water to evaluate potential cooperative water supply actions.

Northeast Region Opportunities and Issues

The northeast group of water suppliers includes Aurora, Brighton, the Burlington Companies, Denver Water, Metro Wastewater Reclamation District, South Adams County Water & Sanitation District, and Thornton. In cooperation the State of Colorado, this group is engaged in further study of cooperative water development opportunities on the South Platte River below Denver.

Each of the participants has specific areas of interest in relation to this study. Denver Water is interested in raw water storage facilities needed to maximize the yield of its South Platte exchange rights and its 15,000 acre-foot nonpotable reuse project. Denver is also interested in finding potential uses for its 45,000 acre-feet of reusable effluent remaining after its exchange rights and nonpotable reuse project. This could take the form of additional nonpotable reuse, sale of reusable effluent credits to others, or participation in a Northeast regional potable supply project to meet a portion of its long term demands.

Aurora is interested in exploiting ways to utilize any remaining exchange potential up to Strontia Springs and Spinney Mountain Reservoir and finding uses for its remaining reusable effluent (approximately 40,000 acre-feet). This may include possible participation in a northeast potable supply project to serve future demands in the northern portion of its future service area east of DIA.

Thornton owns approximately 12,000 acre-feet of gravel pit storage on both sides of the South Platte River below the Burlington Ditch, and its 30 MGD Columbine treatment plant is located adjacent to its gravel lakes. Thornton is committed to full use of its South Park rights, Burlington Ditch rights and effluent exchange rights, all of which involve diversion at the Burlington Ditch. In addition Thornton anticipates developing additional gravel pit storage facilities along the South Platte between Denver and Greeley to maximize the yield of its Northern Project. As the largest municipal diverter of surface water from the South Platte below Denver, Thornton is interested in addressing water quality problems associated with municipal diversions directly downstream of the metro Denver area. Thornton may be interested in participating in a cooperative Northeast potable supply project that could serve as an efficient and reliable means of utilizing its water rights.

Brighton and SACWSD are interested in additional water supplies for their respective future service areas, located north of the Rocky Mountain Arsenal, DIA and Barr Lake. While neither of these entities has significant amounts of reusable return flows, each is interested in participation in a cooperative Northeast potable supply project.

The Burlington Companies are concerned with preserving the value of their water supply assets. They are interested in any cooperative projects that would make use of their water rights, storage and conveyance facilities to provide additional municipal supplies while fairly compensating the Companies and preserving the viability of irrigated agriculture in the Burlington service area.

The Metro Wastewater Reclamation District is responsible for a variety of water quality issues related to dissolved oxygen, ammonia and flow fluctuations on the South Platte River below Denver (Segment 15) associated with its wastewater discharges. Metro is currently anticipating several significant capital expenditures to address these problems in the near future. Metro would be interested in participating in cooperative water supply projects that would help address Metro's water quality concerns in a cost effective and timely manner.

The Northeast Cooperative Action Study is building upon these interests and on effluent management and systems integration concepts previously identified in the MWSI. Specifically, the study is focusing on the raw water storage requirements, hydrology, water rights, operations and water quality aspects of the following contemplated actions:

- Developing the remaining exchange opportunities between the Burlington Ditch and Chatfield Reservoir and upstream locations, using the participants' reusable return flows, subject to water quality and urban South Platte instream flow issues.

- Optimizing the delivery of nonpotable water from the Metro plant for appropriate uses. The "trade potential" of other providers participating with Denver in a nonpotable reuse plan in trade for additional potable water supplies from Denver Water are areas of particular mutual interest.

- Developing a new regional potable municipal supply project diverting from the South Platte River at or below the Burlington Ditch. This project would utilize both reusable return flows and free river water and would be designed to serve a portion of the long-term future needs of each of the Northeast participants.

- The potential for integrating the perceived downstream storage needs of each of the Northeast participants and of "pooling" participants' reusable return flow sources in order to reduce the need for additional downstream storage is of particular interest.

- The potential role of the Burlington Ditch/Barr Lake/Beebe Draw system in providing storage and conveyance capacity in each of these options is also of particular interest.

Northern Region Opportunities and Issues

This sub-region includes the South Platte below the St. Vrain confluence and the Boulder, St. Vrain, Big Thompson and Cache La Poudre basins. Most of this sub-region is located

within the Northern Colorado Water Conservancy District. The principal municipal water providers in this region include Fort Collins, Boulder, Greeley, Longmont and Loveland. There are also several relatively large rural domestic water providers in this area. Surface water supplies in this region are significant, including over 800,000 acre-feet of native flows plus approximately 300,000 acre-feet of transbasin imports on an average annual basis. Most of the agricultural water use in the South Platte Basin occurs within this sub-region, with approximately 1,000,000 acres of irrigation.

Several system integration opportunities between the Northern region and the metro Denver area were initially identified. These included interruptible supply and substitution arrangements with irrigated agriculture, purchase and delivery of Windy Gap supplies to northern metro Denver area providers via the Carter Lake pipeline, participation in joint storage projects for regulation of Windy Gap and Moffat system supplies with use of CBT facilities to deliver Moffat supplies to the Denver area.

However, there were strong concerns voiced by many of the region's water users regarding water transfers out of the region to the metro Denver area. Northern Colorado greatly values its diversified economy that includes a significant amount of irrigated agriculture. The Northern region's water supply helps support the region's irrigated agriculture, open space and wildlife resources and acts as a source of drought protection for northern municipalities. Northern municipal water providers are relying on interruptible supply and substitution arrangements for their own drought protection and future growth purposes and do not feel that these options are available to the metro Denver area. In addition, current District and Subdistrict regulations limit the delivery of Windy Gap water to areas within the Northern region.

One system integration opportunity has remained of mutual interest: possible joint participation by Denver Water and the Municipal Subdistrict in a new storage facility for regulation of Windy Gap and Moffat system waters at the proposed Jasper Reservoir site below Willow Creek Reservoir. This concept is being examined by the Subdistrict and Denver. Both entities are interested in additional storage capacity for their respective water rights. This concept would involve delivery of Moffat supplies to Denver's service area via a pipeline from Carter Lake.

West Slope Opportunities and Issues

The West Slope was considered a sub-region from the perspective of understanding West Slope water issues and the effects of transbasin diversions. A meeting was convened by the Colorado River Water Conservation District to discuss these issues. In attendance were representatives from Grand, Summit and Eagle Counties, the Northwest Colorado Council of Governments, the Colorado River District, and Grand Valley irrigation and municipal interests. The major issues discussed included West Slope water needs and the impacts of transbasin diversions on West Slope water supply, water quality, fisheries, recreational and endangered species issues. Background information and a historical perspective of transbasin diversion project development were provided. The River District also provided a review of the legal issues associated with development of new transbasin diversion projects and expanded use of existing projects. These issues are

discussed in more detail on other sections of this report, which deal with specific water development opportunities.

Colorado's Plan for Future Depletions

As part of Phase III of the MWSI, a spreadsheet tool was developed to articulate and illustrate Colorado's plan for addressing future growth in municipal and industrial water use in the South Platte Basin of Colorado from the perspective of the Platte River endangered species.

The Colorado plan links the anticipated impacts of water development to increases in human population. It considers the interaction of six basic water supply source categories - those defined in Chapter 4 - that will be used to serve new population and associated development. Some of these sources will increase flows in the South Platte River while others will decrease flows. Based upon the water supply plans of individual water providers in the basin, the overall effect of supplying new growth will be to increase South Platte flows on an average basis. Flows in the fall, winter and spring will increase and flows in the summer will decrease. To mitigate this effect, Colorado will implement new water regulation projects, like the Tamarack project, to shift river flows back to the summer period.

The illustrative tool relied on several sources of information previously collected as part of the MWSI. Subsequent refinements to this spreadsheet tool have been made by Hydrosphere as part of a separate contract with the Platte River Project.

Water Conservation Marketing

This concept involves the creation of a market for water saved through implementation of conservation measures. This type of market could take many different forms, so the ideas presented in here are intended only to introduce the concept and stimulate discussions.

While most metro area water suppliers have implemented water conservation programs during the last decade, there remain many water conservation measures that have not been broadly pursued. One of the reasons that some conservation measures have not been implemented is the concern that reductions in consumption could reduce operating revenues resulting in rate increases. Another reason for not implementing conservation measures is that some water suppliers have more than adequate supplies and no need to conserve at this time. In addition, there may be some suppliers that have access to sources of supply that are less costly than additional conservation measures.

One possible opportunity for further encouraging the implementation of conservation measures would be to create a market for water conservation savings. This market would provide a mechanism to allow one water supplier to fund the implementation of conservation measures within the service area of another supplier in exchange for the right to make use of a portion of the water saved. Organization of this type of a market could take place as follows:

- Interested Front Range water suppliers would meet and develop a comprehensive list of water conservation "BMPs;"
- Each supplier would evaluate their individual water supply system needs to determine which water conservation measures would be appropriate for their system and customers;
- Each individual supplier would also determine which water conservation measures should be implemented internally and which measures could be made available to the "market" (participation in the market would be entirely voluntary);
- A clearinghouse or bulletin board would be established for purposes of facilitating the exchange of information between water suppliers;
- Water suppliers would provide information to the clearinghouse or bulletin board about water conservation measures that could be made available to the market. This information could including a prospectus on the cost of implementing a given conservation measure, the estimated water savings, and the potential "yield" to other water suppliers that may wish to invest in its implementation;
- Water suppliers in need of new supplies could then tender offers to those which are making conservation measures available to the market; and
- The specific terms of transactions would be negotiated between the interested parties.

The primary goal of this type of arrangement would be to create a flexible entrepreneurial environment where any water utility could offer to implement a conservation measure and share a portion of the water saved in exchange for funding. The funds could be sufficient to fully or partially offset the direct cost of implementing the conservation measure plus any potential reduction in revenues associated with a lower level of water consumption. The sharing of the water saved could be on a permanent or interim basis depending upon the needs of the utilities involved in the transaction.

3.2.5. Chatfield Reservoir

3.2.5.1. Background

Chatfield Dam and Reservoir is located on the South Platte River about 8 miles southwest of Denver in Douglas and Jefferson Counties. The dam was completed in 1973 by the U.S. Army Corps of Engineers (COE) for flood control purposes as part of the Tri Lakes Project which also includes Bear Creek and Cherry Creek Reservoirs. Chatfield is a rolled earthfill dam with a maximum height above the streambed of 147 feet and a crest

length of 13,057 feet. The total capacity of the reservoir is approximately 336,000 acre-feet, and the reservoir at capacity would cover a surface area of about 6,245 acres.

Under current operations, the State of Colorado controls operations of the storage pool below elevation 5,432 feet MSL (28,150 acre-feet) and is committed by contract with the COE to maintaining a pool above 5,423 feet MSL (20,000 acre-feet) for recreation, fish, and wildlife purposes. Denver Water is permitted to make use of 10,000 acre-feet of storage space within the conservation pool between the elevations of 5,423.8 and 5,432 feet MSL and is committed to use its best efforts to maintain at least 20,000 acre-feet (5,426.94 feet MSL) in the pool from May 1 through August 31 for recreation. All of the remaining storage capacity in the reservoir (approximately 308,000 acre-feet) is operated by the COE for flood control purposes. Current operational releases to the South Platte below Chatfield are limited to the inflows of up to 5,000 cfs.

Numerous metro area water providers have expressed interest in using storage space in the Chatfield, Cherry Creek and/or Bear Creek Reservoirs for water supply purposes. These entities include Denver Water, Aurora, Castle Rock, Englewood, Thornton, Centennial Water and Sanitation District, and others. The Colorado Division of Parks and the Colorado Division of Wildlife have also indicated an interest in the use Chatfield storage for water supply purposes and management of instream flows for environmental and recreational purposes. The MWSI identified a need for additional water supply storage to most effectively implement several of the water supply options being investigated.

3.2.5.2. Conceptual Definitions

Efforts of the Chatfield Work group under the MWSI were focused primarily upon Chatfield for several reasons related to its potential importance as a water supply facility. As an existing facility with a large amount of mainstem South Platte River storage capacity, the possibility of reallocation of storage could be more practicable and cost effective than the development of new storage reservoirs. It has a significant additional supply that is not physically available to upstream storage and diversion facilities such as Strontia Springs, Cheesman, Spinney Mountain, and Eleven Mile. Chatfield's proximity to several key metro area water supply systems including Denver, Aurora, the Douglas County water providers is also an important factor. There are similar advantages associated with the potential use of Bear Creek Reservoir for water supply regulation.

The allocation of additional storage space in Chatfield to water supply purposes could occur either through a reallocation of storage currently reserved for flood control or recreation or through the allocation of storage found to be in excess of what is needed for flood control. Under either scenario, COE regulations require extensive investigations to determine the technical, economic, and environmental feasibility of allocation or reallocation of storage for water supply. An environmental assessment or environmental impact statement (EIS) including an assessment of recreational impacts, along with consultation under Section 7 of the Endangered Species Act, would also be required. In addition, water users would be required to enter into a contract with the federal

government for the repayment of costs associated with the storage space that would be utilized for water supply purposes.

3.2.5.3. Information Development

Under Phase II of the MWSI, information was compiled regarding the availability of storage in Chatfield Reservoir, the procedural steps required to make storage available to metro area water providers, and the issues associated with allocation or reallocation of storage for water supply purposes. Potential water supply related uses for storage space in Chatfield were identified. The Chatfield Work Group and the Colorado Water Conservation Board initiated discussions with the COE and have developed a detailed scope of work for the required technical and environmental studies.

Information regarding the contractual arrangements between the federal government and the State of Colorado related to Chatfield, reservoir operations, regulatory requirements related to reallocation of storage, conditional water rights decreed to entities interested in water supply storage at Chatfield, and environmental and recreational issues and concerns was compiled and review by the consulting team.

The Chatfield Reservoir project was originally authorized under the Flood Control Act of 1950 (64 Stat. 175). The Act was later modified to allow the COE to reassign a portion of the storage space to joint flood control and conservation purposes including storage for municipal, industrial, and agricultural water supply, subject to a finding of feasibility and economic justification (100 Stat. 4168).

The COE's authority for reallocation of storage is also governed by Title III of the Water Supply Act of 1958, as amended (72 Stat. 319). Under that Act, reallocations are limited to 15% of total storage capacity or 50,000 acre-feet, whichever is less, provided that the reallocation does not "seriously affect" the purposes for which the project was authorized. Reallocations of storage in excess of these limits require the approval of Congress.

In discussions with the Colorado Water Conservation Board and the Chatfield Work Group, the COE has outlined their procedural requirements for the reallocation of storage from flood control to water supply purposes. The Chatfield Work Group has also facilitated the development of a detailed reallocation feasibility study scope of work, a checklist for compliance with applicable statutes and regulations, a plan for funding the feasibility study process, and a plan for the assignment of responsibilities to the State, the COE, and potential participants. Both the State of Colorado and the COE have secured funding for the feasibility study and are planning to start work on the study by the end of 1998. It is currently estimated that completion of the feasibility study will require 2 to 3 years and cost approximately $1.7 million.

As currently planned, the feasibility study will address the following topics:

- The amount of flood control storage required at Chatfield and Bear Creek must be reevaluated using updated meteorological information and the new inflow design criteria;

- Analysis of existing and proposed alternative operations of Chatfield for combined flood control and water supply purposes including potential changes to downstream flows, reservoir pool elevations, water supply consequences, flood control impacts, environmental impacts, and recreational impacts;
- Analysis of water supply needs and alternatives for meeting those needs;
- Analysis of alternatives and costs including an assessment of the financial capability of project participants;
- National Environmental Policy Act (NEPA) compliance documentation (an EIS); and
- Section 7 consultation as required under the Endangered Species Act.

3.2.5.4. Results

In addition to the information gathering efforts described above, a preliminary list of potential water supply-related uses for storage space in Chatfield Reservoir was developed. These potential uses are based primarily on storage needs related to the investigations of conjunctive use, effluent management and systems integration. It should be noted that several of the options listed below could utilize Chatfield storage on a seasonal basis so as to minimize or avoid the need for reallocation of storage now reserved for flood control purposes.

- **Point of diversion for water supply (Denver Water, Centennial, Englewood, southern metro area Counties, Aurora)** - Chatfield is currently located downstream from the primary points of diversion for Denver Water and Aurora. The ability to divert water directly from storage in Chatfield to Denver's and Aurora's water supply treatment and distribution systems would enhance all of the additional functions described below. This could also benefit other water providers under cooperative arrangements.
- **Development of storable flows** - Preliminary modeling results indicate that storable South Platte and Plum Creek flows currently available at Chatfield average over 50,000 acre-feet per year. The water supply yield of additional storage at Chatfield would be subject to several factors including operational restrictions to protect flood control and recreational pools, water rights and degree of integration with providers water supply systems. Preliminary modeling suggests that additional long-term water supply storage at Chatfield in the range of 5,000 to 40, 000 acre-feet could produce yields of 2,000 to 8,000 acre-feet respectively. In addition, the ability to utilize carryover storage in Chatfield could free-up space in other reservoirs, such as Dillon, thus enhancing the yield of existing facilities.

- **Short term staging for recharge/conjunctive use** – Operational modeling of conceptual scenarios for conjunctive use of surface and Denver Basin groundwater systems identified the need for some surface water storage to meet peak demands and for regulation of supplies for recharge of groundwater systems. The location of Chatfield would be ideal for fulfilling this function.
- **Exchange-related storage (such as Denver Water/Burlington)** - The availability and amounts of reusable effluent and exchange potential at existing intakes for Denver and others do not always coincide with uses or destination storage for the water exchanged. Also, the exchange potential at Chatfield is considerably more reliable than at upstream points of diversion. The ability to exchange water into storage or to alternative points of diversion at Chatfield may enhance exchange yields to individual providers or under cooperative arrangements.
- **Reregulation of Denver Water's Waterton releases** - Denver Water is required to maintain 60 cfs summer and 30 cfs winter instream flows below Strontia Springs Dam. When these bypass flow requirements are greater than the amount of water being called past Strontia Springs, Denver Water can store the difference at Chatfield. However, because of certain restrictions on the way this storage can be used, Denver Water cannot always recover this water. This situation could be remedied by changes in the rules governing this storage and the ability to divert water from Chatfield directly to the Denver treatment and distribution system.
- **Reregulation of Plum Creek basin reusable return flows** - With the urbanization of the Plum Creek basin above Chatfield, there will be an increase in reusable effluent from use of Denver Basin groundwater. The ability to store and reregulate these reusable return flows could be an important source of water for exchange and augmentation.
- **Regulation of South Platte urban instream flows** - The Cities of Denver, Englewood, and Littleton have all identified the need to improve instream flow conditions through the metro Denver area in order to improve aquatic habitat, aesthetic conditions, water quality, and recreational potential. The use of storage at Chatfield to regulate and reregulate flows will most likely be critical to meeting urban instream flow objectives.

3.2.5.5. Issues and Concerns

The possible reallocation of storage at Chatfield Reservoir raises a number of institutional, environmental, and recreational issues that must be addressed. These issues include but are not necessarily limited to the following:

Availability of Storage for Reallocation - The preliminary analysis conducted by the COE has concluded that there may not be storage available for reallocation at Chatfield without structural or operational modifications. Such modifications could include enlarging the spillway, raising the height of the dam or increasing the limit on releases.

However, based upon discussions with the COE regarding the reallocation of storage in Chatfield Reservoir, it appears that there are several options that may become available

depending on the outcome of the studies related to the COE's Water Control Manual. A critical factor in determining if storage space is available for reallocation will be downstream constraints that could restrict the amount of water released during a flood event. Such constraints would include bridges and other structures that could be effected by high flows. It is possible that many of these potential constraints have been removed or reduced with infrastructure improvements during the last ten years (or could be removed) and that this may allow for releases greater than the current 5,000 cfs restriction. For every 1,000 cfs that can be released over and above the existing 5,000 cfs constraint, it may be possible to reduce flood storage requirements by approximately 10,000 acre-feet. For example, if the release restriction could be increased to 8,000 cfs, it may be possible to reduce the flood control storage requirement by 30,000 acre-feet, thereby making this space available for water supply purposes.

Another factor that could have an affect on the amount of flood storage required at Chatfield is the assumption used by the COE regarding the potential for Probable Maximum Flood (PMF) attenuation by upstream reservoirs. In their preliminary evaluation of Chatfield using the new inflow design criteria, the COE assumed there would be no flood attenuation by upstream reservoirs. The COE seems willing to reconsider this assumption. However, such attenuation "credit" may require constraints on the water supply operations of these reservoirs, which could potentially nullify any gain in yield from additional Chatfield storage.

Other options for use of water supply storage at Chatfield could include the use of storage space within the pool currently administered by the State of Colorado and the use of storage in the flood control pool during seasons when there is little or no flood risk. The COE indicated that these options could also be investigated in their study.

Flood Control Tradeoffs – While the reallocation of storage at Chatfield from flood control to water supply would be beneficial to metro area water uses, it could increase the risk of downstream damages from flooding. The social and economic implications of this type of tradeoff will be evaluated in the feasibility study.

Determination of How Reallocated Storage Would be Used - The availability of storage in Chatfield and possibly Bear Creek Reservoirs could be important to some of the water supply options currently being considered in the MWSI including conjunctive use of surface and groundwater and effluent management. However, many different and sometimes competing water users have acquired conditional decrees for the use of water supply storage at Chatfield. The Colorado Division of Parks has sought COE authorization to utilize 752 acre-feet of temporary storage in Chatfield which would be used to assist Parks in maintaining the permanent recreation pool in Cherry Creek Reservoir by providing an alternative source of evaporation replacement water. Storage at Chatfield and Bear Creek could be beneficial to efforts to maintain adequate instream flow levels from Chatfield Dam downstream through the metro area. Thus, there is potential for conflicts between competing uses of water supply storage in these facilities. Under terms of the contract between the COE and State, the Colorado Water Conservation Board has the authority to approve the manner in which any storage made available for water supply purposes is allocated to individual water users.

Environmental and Recreational Impacts - At this time the normal pool in Chatfield Reservoir is maintained at about 26,643 acre-feet at an elevation of about 5,432 feet. Impacts to recreational facilities maintained by the Colorado State Parks would begin to occur at an elevation of about 5,434 feet with storage of 29,985 acre-feet. In addition, the heronry located on the south side of the reservoir and wetlands on the south and west shorelines would be impacted at this elevation. Thus, an increment of only about 3,000 acre-feet of additional storage would result in environmental and recreational impacts that may require mitigation. Increases in reservoir fluctuation or drawdowns during the summer within the 10,000 acre-feet pool allocated to Denver Water may also adversely affect recreational and natural resource features at Chatfield. While flood control events would result in similar impacts, which could be of significantly greater magnitude, these impacts are expected to occur less frequently than would be the case with flood control events.

In order to achieve 20,000 acre-feet of water supply storage at Chatfield, the surface elevation of the reservoir must be raised to an elevation of approximately 5,444 feet, which is about 12 feet above the existing normal pool. At this level, all of the boat ramps, the swim beach and bathhouse, beach concessions, and many of the shelters and picnic areas would have to be relocated.

According to Colorado State Parks, mitigation of impacts to the swim beach, heronry, boat ramps and access to the west side of the park would be "difficult, if not impossible," but no studies have been conducted to assess mitigation possibilities. Such assessments would be part of a feasibility report. Potential wetland impacts have not been quantified. Further site specific investigations would be required to specifically quantify and qualify these impacts and mitigation options. Operational changes associated with water supply storage could also affect water quality both in the reservoir and downstream.

Section 7 Consultation - The COE has been conducting intermittent discussions during the last several years with the U.S. Fish and Wildlife Service regarding endangered species issues associated with the Tri-Lakes reservoirs. Section 7 issues will be included in the studies associated with revising and updating the Water Control Manual. Section 7 consultation would also be required for reallocation of storage to water supply purposes. Coordination or consolidation of these efforts may be advisable if a reallocation process is to be initiated. To the extent such consultations determine that reservoir operations adversely affect endangered species occurring downstream in Nebraska, the recently negotiated Cooperative Agreement and Proposed Species Protection Program for the Central Platte should be relied upon for required mitigation.

Repayment Costs - The methodology for determining repayment cost requirement is delineated in the Code of Federal Regulations. The methodology that is most likely applicable to Chatfield and Bear Creek is based upon the construction replacement cost of the project multiplied by the ratio of storage reallocated to total storage. Operational costs and any direct costs associated with the reallocation process are also factored in to the equation. The COE estimates that the current cost of storage at Chatfield would be about $1,200 per acre-foot and at Bear Creek about $2,800 per acre-foot. These costs appear to be competitive when compared to the cost of developing new water storage facilities.

4. Conclusions and Recommendations

The Metropolitan Water Supply Investigation has explored cooperative solutions to future metro Denver area water supply needs under the direction of a Technical Advisory Committee appointed by the Governor's Front Range Water Forum. The Investigation process involved extensive consultation and data sharing between metro Denver area water providers, representatives of several northern Front Range water interests, West Slope water interests and citizen conservation organizations. From this process, a relatively clear picture has emerged regarding some cooperative approaches that could potentially play a significant role in meeting future water needs, and the unresolved issues that must be addressed through ongoing cooperative planning processes.

4.1. COOPERATIVE WATER SUPPLY OPPORTUNITIES

Cooperative water supply approaches could play an important role in meeting future water supply needs in a manner that could potentially reduce the costs and environmental permitting risks associated with other options. Overall conclusions related to water supply opportunities examined in the MWSI are discussed below.

4.1.1. Conjunctive Use

Conjunctive use of surface and groundwater supply systems is a classic example of an opportunity for the integration of water supply systems in a manner that provides better utilization of existing systems and potentially significant synergistic benefits through enhanced yield. The MWSI considered example conjunctive use arrangements involving the South metro sub-region in conjunction with the Denver Water system. Assuming that Denver's unused divertible supplies from its Blue River and South Platte water rights were available, a conjunctive project could yield up to 60,000 acre-feet per year. This water could be used to meet new demands or to reduce existing groundwater pumping from the Denver Basin aquifers.

Conjunctive use provides a promising opportunity for developing significant additional water storage capacity without the on-site direct impacts of large surface water storage facilities. Conjunctive use also raises several unresolved questions. To the extent that a conjunctive use project would rely on additional transmountain diversions using existing facilities and water rights, this likely would engender concerns among West Slope residents. However, the operational flexibility inherent in a conjunctive use arrangement could allow for mitigation of most impacts while still generating significant yield. Other issues and uncertainties associated with conjunctive use include changes in water rights, the feasibility of large-scale recharge over the long term, and the challenges associated with securing required intergovernmental cooperation among potential conjunctive use participants. Additional diversions from the Blue River are of particular concern to West

Slope interests, who have expressed the view that the metro Denver area must first maximize its use of in-basin supplies, including Denver Basin groundwater, conservation and reuse, before any additional diversions from the West Slope occur. Though West Slope and Front Range water interests have conflicting opinions regarding these issues, collaborative investigations are being planned to learn more about these concerns and possible solutions.

4.1.2. Effluent Management

Effluent management opportunities involving substitutions, non-potable reuse and potable reuse appear to be viable options for utilizing metro Denver area providers' reusable return flows to increase water supplies. The metro Denver area currently generates excess reusable return flows of approximately 80,000 acre-feet per year. These excess reusable return flows are projected to increase to more than 120,000 acre-feet per year under providers' current plans as the metro Denver area grows.

Significant opportunities for cooperative effluent management strategies exist in all of the metro area sub-regions. In the South metro sub-region and the Aurora service area, reusable return flows can be used in conjunction with local surface water and alluvial groundwater to develop alluvial well augmentation plans and for irrigation of parks, golf courses and other irrigated areas in new development.

In the Central metro sub-region, Denver's non-potable reuse project could serve as the foundation for regional non-potable and potable reuse strategies. Exchanges between the Metro wastewater plant and Chatfield Reservoir could be increased through the expanded use of Chatfield Reservoir as a point of diversion and storage for municipal water systems.

Significant opportunities for nonpotable reuse exist in Big Dry Creek basin of the Northwest metro sub-region, due to locally available wastewater sources and the overall nature of expected future land uses.

However, given the amount of excess reusable return flows and the limited opportunities for further substitutions, a regional potable supply project combining potable reuse and exchanges from the Metro wastewater plant to the Burlington Ditch appears to be the most promising way to use this reusable resource for municipal purposes. Conceptually, this project could make use of two physical sources: diversions via the Burlington ditch under free river conditions or exchange of reusable effluent, and direct pumping of reusable effluent from Metro.

The ability to use the significant amount of reusable return flow remaining in the basin will be largely contingent on the region's cost of water supplies. Public acceptance, intergovernmental coordination, and effects on water quality and instream flows are also issues of concern. It appears that potable water reuse could ultimately become an economically viable option, given the costs and permitting uncertainties of other water supply options. However, the West Slope is also concerned that the potential value of

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reusable water to water providers under effluent management scenarios would result in providers choosing to divert transmountain water when native South Platte water is available and that transmountain diversions will increase while native South Platte water goes unused.

4.1.3. Interruptible Supply

The availability of water for interruptible supply is limited primarily to arrangements with agricultural water supply systems to the north of the metro Denver area. In the South Platte Basin in 1985 there was over 2,800,000 acre-feet of water used irrigation, primarily in areas to the north of metro Denver. This includes a dry year yield of about 190,000 acre-feet per year of relatively high quality water that is diverted upstream of major wastewater treatment plants. While the potentially available supply for interruptible supply arrangements to the north of the metro area appears to be large, there are significant legal, institutional, geographical, and practical barriers to implementation. The MWSI analysis of these issues was suspended by the PMT pending the completion of regional planning efforts by northern Front Range water providers.

Northern Colorado water providers have shown considerable vision and foresight in securing that region's water supply. The Northern Colorado Water Conservancy District is currently conducting a study to update water demand projections for future municipal, rural domestic, industrial and agricultural needs within the District. Northern water users are concerned about the need to reserve an adequate long-term water supply for growth within their area and would therefore like to complete this study before further exploring cooperative opportunities with metro Denver area water users.

During Phase II of the MWSI the following issues of concern to northern Front Range Water Users and perceived barriers to interruptible supply arrangements were identified:

- Northern Front cities consider water transfers from agriculture to be a potential source of supply for serving their future growth.
- Water users expressed concerns about the potential economic, social, and environmental impacts of water transfers from agricultural to municipal uses.
- Because of the large number of small water users within the region to the north of the metro Denver area, the complexity of arrangements necessary for implementation and the associated transaction costs are much higher than would be the case if there were only one or a few large water users.
- Water rights administration and potential injury issues associated with the changes in water rights that would be required for interruptible supply arrangements could be very high.

- Because of the geographic location of agricultural water supply systems, there would be significant costs associated with conveyance facilities.

Further investigations would be necessary to fully understand these and other potential concerns, the underlying causes of barriers and possible approaches to overcoming such barriers.

4.1.4. Other Systems Integration Opportunities

The concept of systems integration involves the cooperative use or enhancement of several water supply systems in a manner designed to synergistically increase or maximize total combined yields or operational efficiencies. Through the MWSI efforts involving the exchange of water supply systems information between water providers and brainstorming, several ideas for cooperative approaches were identified but not studied in detail. These systems integration opportunities include:

- Ongoing studies involving the Northeastern and Northwestern metro area sub-regions are investigating effluent management options and coordinated use of existing storage and conveyance facilities and possible cooperative development of additional storage.

- Joint storage projects for regulation of Windy Gap and Moffat system supplies with use of C-BT facilities to deliver Moffat supplies to the Denver area will be the subject of future discussions between Denver, Northern and other interested parties.

- Creation of a market for water saved through implementation of conservation measures is a concept that deserves further discussion and consideration.

- There will be significant additional conservation and reuse opportunities remaining in the South Platte basin. Most of the conservation savings currently anticipated are simply the result of extrapolating savings from existing programs into the future. Significant potential for further savings will remain, due primarily to several factors beyond our control. For instance, the industry-wide move to more efficient water using appliances and plumbing fixtures has yet to make a big difference in our existing water use but will over the next 30 or 40 years as old less efficient fixtures are replaced.

While the water supply yields associated with these options were not quantified in this study, preliminary estimates indicate that their water supply potential could be in the range of 30,000 to 50,000 acre-feet per year.

4.2. ADEQUACY OF METRO DENVER AREA SUPPLIES

Metro Denver area water providers currently have more than adequate water supplies for meeting existing demands and are in the process of refining and implementing plans to

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meet projected water demands beyond the year 2030. The sources of supply for meeting current and future demands vary between different geographic sub-regions within the metro area. These sub-regions, their existing supplies, and their estimated unmet future demands are summarized below.

- **The Denver Water Combined Service Area** includes the City and County of Denver, 75 fully dependent contract providers, and over 20 partial supply contract providers. The primary sources of supply available to the Denver Water System consist of native South Platte River water, transmountain diversions from the Blue, Fraser and Williams Fork Basins and reuse. As determined through its Integrated Resources Planning Process, Denver Water's Near Term resource strategy is projected to yield 401,000 acre feet compared to an ultimate raw water demands of 445,000 acre feet, which includes a 30,000 acre-foot safety factor. Assuming Denver is successful in implementing its Near Term Strategy, Denver would have a remaining future need of 14,000 acre-feet to 44,000 acre-feet, depending on the size of its safety factor. Denver anticipates meeting this remaining need through water conservation, reuse, system refinements, additional supplies, and cooperative actions with others.

- **The South Metro Sub-region** includes the water provider members of the Douglas County Water Resource Authority and the Arapahoe County Water and Wastewater Authority. Throughout this sub-region, Denver Basin groundwater is the primary source of supply. There are no significant unmet needs projected for this region, assuming that Denver Basin groundwater will continue to be used as a major water supply source. However, the region is actively working to increase the renewable portion of its water supplies by maximizing reuse of its groundwater return flows and acquiring additional surface supplies. The region is particularly interested in expanding the roles of reuse and conjunctive use of surface and groundwater as ways to reduce its future use of Denver Basin groundwater.

- **The City of Aurora** currently estimates the average annual yield of its water supply system at about 75,000 acre-feet per year from water supply sources in the South Platte, Colorado and Arkansas River basins. Aurora anticipates future growth to average 50,000 people per decade with an associated increase in water demands of 10,000 acre-feet per decade. In addition, Aurora has a policy of maintaining a 10,000 acre-foot planning reserve. Plans to meet these future demands include conjunctive management projects in the Eagle River Basin (in cooperation with the City of Colorado Springs and the West Slope) and in South Park. Aurora is also participating in the cooperative planning activities of the Northeast metro sub-region described below.

- **The Northeast Metro Sub-region** includes Aurora, Thornton, South Adams County Water & Sanitation District and Brighton. The water supply sources currently available to this sub-region consist primarily of the mainstem of the South Platte, Clear Creek, and Big Dry Creek. Assuming the full development of Thornton's Northern Project, this region has a future unmet need of approximately 20,000 acre-feet per year, associated with anticipated growth in Brighton, South Adams County Water and Sanitation District, and the northern portion of Aurora's service area.

Current planning efforts are focused on the development of gravel pit storage facilities, maximizing exchanges and finding potential uses for Aurora's and Denver Water's excess supply of reusable effluent. Thornton is particularly interested in addressing water quality problems associated with municipal diversions directly downstream of the discharge from the Metro Wastewater Treatment Plant.

- **The Northwestern Metro Sub-region** includes Arvada, Broomfield, areas served by Consolidated Mutual Water Company, Northglenn, Thornton and Westminster. The water supply sources currently available to this sub-region consist primarily Clear Creek and partial service contracts with Denver Water which are mostly satisfied via deliveries from the Moffat Tunnel Collection System. This sub-region has an unmet need of approximately 10,000 acre-feet per year, associated with anticipated growth in Arvada and Broomfield. Cooperative planning efforts for this sub-region are focused upon coordinated use and sharing of existing or new storage and conveyance facilities and expanded reuse. Denver's Moffat system is currently under-utilized due to east slope storage limitations. If additional storage can be made available in the northwestern region through cooperative use of existing storage or development of new facilities, Denver may gain more flexibility in the use other parts of its system, with possible metro-wide benefits. Storage could come through operational synergies with FRICO's Marshall system (which is storage rich but water short), through expansion of existing facilities such as Standley Lake or Gross Reservoir, or construction of off-mainstream facilities such as the Leyden Gulch reservoir site.

4.3. OVERVIEW OF WATER SUPPLY STRATEGIES

Metro Denver area water providers are currently relying upon a combination of six supply source categories to meet their existing and future needs. Metro Denver area water supply plans in place generally address planning horizons beyond the year 2030, and in most cases reflect providers' projected ultimate or 'build-out' service area demands. The combined source categories under planned future conditions are shown in Figure 16.

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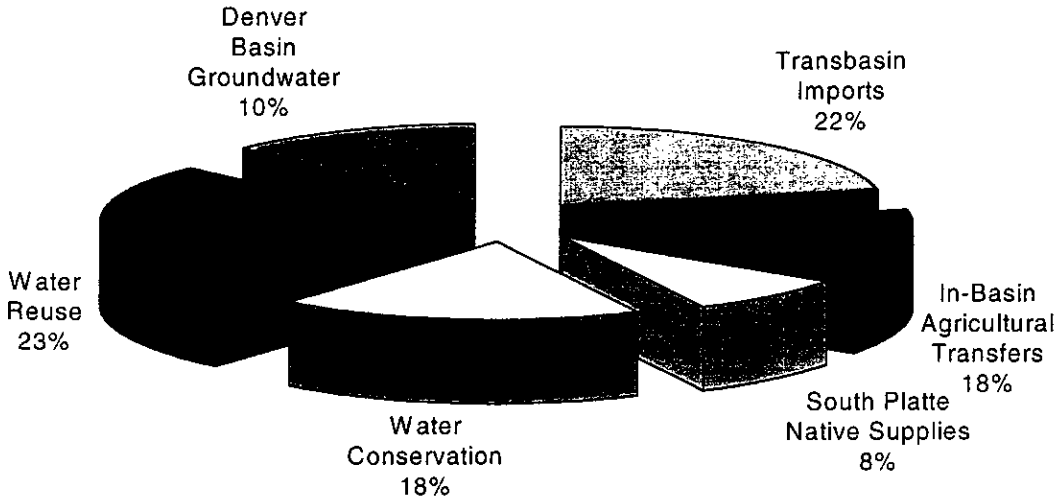
Figure 16: Future Mix of Water Management Strategies, Metro Denver Area



Planning strategies for meeting projected future demands primarily involve the use of existing water rights and projects already in hand. While permitting, water rights changes, enlargement of existing reservoirs, and construction of new storage and conveyance facilities will be involved; large capital-intensive projects with major environmental impact issues will probably not be required.

4.4. REGIONAL IMPACTS AND TRENDS

As a result of existing water supply plans of South Platte basin water providers, the following regional impacts and trends can be reasonably discerned.

- Future unmet needs in the major regions of the metropolitan Denver area can be met effectively through a variety of cooperative water supply management actions. These actions do not require construction of significant new transbasin diversion systems, though some additional transbasin diversions using existing facilities and water rights may be necessary if growth in the metropolitan area, particularly in Douglas and Arapahoe Counties, is to be served without increased reliance upon non-renewable groundwater supplies.

- South Platte flows out of Colorado are likely to increase. This is simply a result of the mix of water supply sources being developed. Much of the basin's future water demands will be met with additional transbasin diversions, transfers from agriculture, and non-tributary groundwater development. These supplies increase the return-flow

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supply to the region. Much of that increase will come in the fall, winter and early spring months, due to relatively higher municipal return flows during this period; hence, the utility of a Tamarack recharge project to re-regulate those flows to help meet endangered species' needs downstream.

- Current plans of water providers envision conversion of about 76,000 acre-feet of water from irrigation to municipal and industrial uses from a total of over 2.5 million acre-feet of existing irrigation use.

- The use of Denver Basin groundwater will remain at relatively low levels, even without conjunctive use. Future municipal water supply plans for Douglas County currently anticipate an aggregate use of about 84,000 acre-feet per year. Under conjunctive use discussions currently underway between Denver and Douglas County, this 84,000 acre-foot projection could be significantly reduced through a conjunctive use arrangement with Denver to store South Platte and Colorado River surface flows.

- Under current plans, transmountain diversions from the Colorado River Basin to the South Platte from existing facilities and water rights would increase from the current levels of about 450,000 acre-feet per year to about 550,000 acre-feet per year.

4.5. PROCESS-RELATED OBSERVATIONS AND RECOMMENDATIONS

1. It is recommended that a continuing state-sponsored cooperative supply planning forum be established.

The MWSI has improved communication, mutual understanding and cooperation between metro Denver area water providers, West Slope interests and environmental interests. Is has resulted in several ongoing collaborative studies which are designed to increase water supplies in mutually acceptable ways. It has also had a major effect upon other ongoing planning efforts addressing issues of critical importance to the metro Denver area's water supplies. These include:

- Quadrant investigations of various cooperative water supply opportunities
- The Platte River Cooperative Agreement and EIS process
- The Upper Colorado River Basin Study
- The Colorado River Endangered Fish Species Water Availability Study
- The Chatfield Reservoir Reallocation Feasibility Study
- The USFS's South Platte Wild & Scenic Study and associated negotiations.
- The Northern Regional Water Coalition's investigation of long-term future M&I water needs of the Northern Front Range
- Development of a South Platte Decision Support System

These studies and planning efforts are proceeding independently, but are highly interrelated and deal with complex issues that affect numerous parties. It is therefore recommended that a continuing state-sponsored forum be established to serve the following functions:

- Coordination and integration among interested parties regarding these interrelated studies and planning efforts.
- Provide an opportunity for parity to be maintained between large and small providers and other interest groups; facilitate open discussion and resolution of issues and concerns, thereby reducing the potential for litigation
- A forum for addressing State policy issues and access to state agency technical expertise
- An opportunity for regular and periodic updating of the MWSI database
- A sounding board for future studies and development of decision support systems.

This may be best accomplished by regular periodic meetings convened by an appropriate state agency such as the Colorado Water Conservation Board.

2. It is recommended that the MWSI database be periodically updated through a state-coordinated effort as part of the continuing state-sponsored forum.

The MWSI has resulted in development of a relatively comprehensive and detailed database base on metro Denver water supply providers and their water supply systems. This database has improved the understanding of the overall operation and interplay between metro area water supply systems and the status of individual providers' planning efforts. For example, information from this database was used to formulate Colorado's Plan for Future Depletions pursuant to the Platte River Cooperative Agreement. This database should be maintained and periodically updated so that it continues to be useful for cooperative municipal water supply planning and assessment of regional and basin-wide issues. Ultimately this database should be incorporated into the South Platte Decision Support System.

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APPENDIX 1

Executive Order

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Denver, Colorado 80203-1792
Phone (303) 866-2471

Roy Romer
Governor

B. 016 93

EXECUTIVE ORDER
FRONT RANGE WATER FORUM

WHEREAS, the need for water supply planning and management for the Denver metropolitan area has been heightened by the veto of the Two Forks Project by the Environmental Protection Agency, by the increasingly stringent requirements of the federal Safe Drinking Water Act, and by the existence of continued growth throughout the area;

WHEREAS, the State of Colorado is concerned about water supply for cities in the Denver metropolitan area because their demands have created: (1) a situation in which many communities in the Denver metropolitan area lack a reliable water supply while others have more than enough water for the foreseeable future; (2) conflicts with agricultural, rural, and environmental interests when water is transferred to municipal users; and (3) litigation costing millions of public and private dollars in engineering and legal fees;

WHEREAS, participants at the 1993 State Water Convention indicated: (1) a priority for enhanced cooperation in pursuing water supplies for cities; and (2) the need for the state of Colorado to provide a forum for the discussion and resolution of these issues, providing data and information, and exploring mutually beneficial arrangements between agricultural and municipal water users;

WHEREAS, the General Assembly authorized the Colorado Water Conservation Board to expend up to $450,000 to investigate opportunities for enhanced coordination in meeting the water supply needs of metropolitan Denver;

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WHEREAS, the State of Colorado can: (1) provide state agency support to pursue cooperative solutions; (2) use the expertise of personnel within state agencies to address these issues; (3) use state resources as incentives to foster cooperation; and (4) help develop data and information systems to help make informed decisions on water supply;

NOW THEREFORE, I, Roy Romer, Governor of the State of Colorado, under the authority vested in me under the laws and Constitution of the State of Colorado, **DO HEREBY ORDER THE FOLLOWING:**

1. A Front Range Water Forum is hereby created and shall be comprised of (the following): the Governor of the State of Colorado; the Mayors of Denver, Aurora, Thornton, Arvada, Westminster, Commerce City, Parker, Castle Rock, Northglenn, Broomfield, Littleton, and Lakewood; one representative each from the Denver Water Board, the Colorado River Water Conservation District, the Northern Colorado Water Conservancy District, the Colorado River Headwaters Forum, Club 20, the Southeastern Colorado Water Conservancy District, the Central Colorado Water Conservancy District, the Denver Metro Wastewater Reclamation District, the entities consisting of the Barr Lake Group, the Arapahoe County Utility Advisory Board, the Douglas County Water Resource Authority, the Board of Waterworks of Pueblo, the Colorado Springs Utilities Department, Centennial Water and Sanitation District, and the Willows Water District; up to four members of the General Assembly, two from each political party, designated by the Chairs of the Senate and House Agriculture and Natural Resources Committees; and the Executive Directors of the Departments of Natural Resources, Health, Agriculture, and Local Affairs, and the director of the Colorado Water Conservation Board, and the Colorado State Engineer.

   The Governor may appoint additional representatives to the Forum as necessary.

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2. Each member of the Forum representing an entity with technical expertise on water supply is invited to nominate one person to be a part of a Technical Advisory Committee. It is understood that it will not be necessary for all members of the Forum to nominate a person to serve on the Technical Advisory Committee. The Technical Advisory Committee will meet regularly during the course of the investigation and will provide technical oversight and guidance in the investigation of water supply solutions that may enhance the Denver metropolitan, municipal, and industrial water supplies in efficient, practical and environmentally sound ways. These targeted opportunities may include:

(a) the potential integration of the Burlington, Henrylyn, and the Farmers Reservoir and Irrigation Systems into municipal and industrial water supply systems, (a part of which may involve the reallocation of storage in Chatfield and Bear Creek Reservoirs);

(b) the potential for voluntary and cooperative integration of water supply systems in the Denver Metropolitan area and the Northern Colorado Water Conservancy District and Municipal Subdistrict, in order to provide for existing and future water municipal, industrial, agricultural, and recreational demands throughout these areas;

(c) conjunctive use of surface and groundwater, including the use of tributary sources of water in groundwater recharge projects, the use of nontributary sources of groundwater available for use in the Front Range, and the use of nontributary groundwater available and under the control of the State Board of Land Commissioners; and

(d) other opportunities decided upon by the Technical Advisory Committee.

3. The State of Colorado shall designate a management team with staff from the Colorado State Engineer, the Water Conservation Board, and the Water Quality Control Commission. The Executive Director of the Department of Natural Resources will designate a team leader for the management team. The State of Colorado will also hire a

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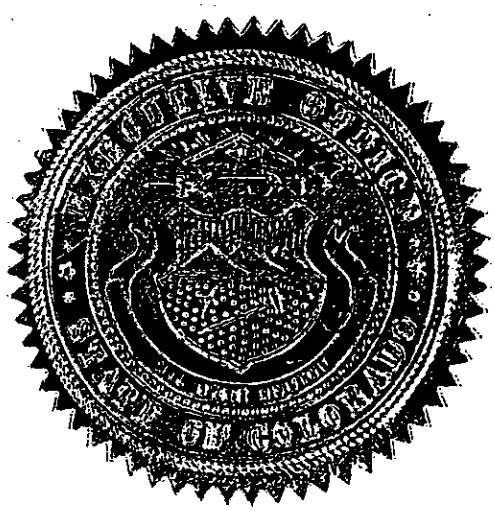
management consultant to coordinate and manage the investigation. The management consultant may conduct parts of the study or investigation and may use subcontractors to conduct parts of the investigation. The members of the Technical Advisory Committee will provide technical oversight and guidance in the conduct of the investigation.

4. The role of the Forum will be to consider any policy issues which emerge from the investigation. The intent for the creation of the Forum is to provide an open and technically sound atmosphere to support the investigation. Further, it is not intended that this investigation comprehensively review all possible options for water supply development and management to meet existing and future demands for water for the Denver metropolitan area. Other proposed projects are being planned by various entities. The principal focus of this investigation will be on certain options that involve integration of elements of previously disparate existing systems, in which the Forum may have a unique coordinating role.

5. It is anticipated that the members of the Forum shall meet at the beginning of the investigation, and then again only as needed as the investigation proceeds. At the conclusion of the investigation, the Governor and the members of the Forum will decide whether to continue the Forum.

6. The scoping and selection of targeted water supply opportunities will be completed within three months from the date of this executive order. Unless otherwise extended by executive order, the investigation will be completed within two years from the date of this executive order.



GIVEN under my hand and the Executive seal of the State of Colorado, this sixth day of October, 1993.

Roy Romer
Governor

APPENDIX 2

List of Forum Members

FRONT RANGE WATER FORUM
As of September, 1994

The Honorable Roy Romer
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The Honorable Jeannie Reeser
State Representative

The Honorable Joan Johnson
State Senator

The Honorable Don Ament
State Senator

The Honorable Lew Entz
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The Honorable Tilman Bishop
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The Honorable Wellington Webb
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The Honorable Margaret Carpenter
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APPENDIX 6

PACSM Description

MEMORANDUM

TO: MWSI Project Files
FROM: Lee Rozaklis, Hydrosphere
SUBJECT: Denver Water's PACSM Model
DATE: April 2, 1998

The analyses of surface water resource issues conducted in the MWSI relied in part on output data from Denver Water's recently developed Platte and Colorado Simulation Model (PACSM). The MWSI relied on PACSM because of several factors:

- The MWSI consultants were familiar with Denver's modeling approach.
- Denver Water agreed to provide the consultants with all necessary access to PACSM data and assumptions for purposes of validation and review.
- It was the MWSI consultants' opinion that PACSM was the most comprehensive and detailed model of metro Denver area water rights and water supply systems currently in existence.
- PACSM is an application of the Boyle Engineering Stream Simulation Model (BESTSM), which has been widely applied and accepted in other river basin studies.
- Use of PACSM was a cost effective and superior alternative to developing a new model or relying exclusively on historical data.

PACSM simulates the surface water hydrology, water rights and operations of water supply systems in the South Platte River tributary to the Henderson gage and in the Colorado River Basin down to and including the Grand Valley diversions. PACSM was designed to help Denver make comparative analyses for the assessment of various historic and proposed river basin management policies. The model is capable of simulating very complex physical systems operating under the water rights provisions of the Prior Appropriations Doctrine. PACSM operates on a daily time covering the 1947-1991 period of hydrologic record and incorporates routing of stream flows between different locations.

In PACSM, a river basin is represented as a system of "linked nodes". Each node or measurement point represents a diversion, a stream gage a reservoir a point requiring a minimum stream flow, or any other location where information is known or needed. The nodes in the system are "linked" by river channels canals, pipeines, ditches or aqueducts. PACSM performs all basin accounting and flow routing between river nodes. The model represents complex networks consisting of multiple stream branches with complex cross linkages and off-channel facilities.

The simulation function of PACSM is primarily controlled by the water rights input to the model. Using water allocation priorities the model simulates the following types of water rights:

- Direct flow rights;
- Reservoir storage rights;
- Instream flow rights;
- Operational rights (rights pertaining to reservoir releases); and
- Exchange rights.

Each water right is given a basin priority and location. PACSM then sorts the water rights by input rank and simulates the water rights in order of priority. PACSM allocates water to a diversion or reservoir based on available flow (including both natural flows and allocable return flows), water rights, diversion or storage capacity, and demand.

In developing PACSM, Denver has provided the most detail for those portions of the South Platte and Colorado basins which have the most direct effect on Denver's raw water system. For example, PACSM contains a very detailed representation of natural flows, water rights, transmountain imports, reservoirs and project operations for the South Platte above Strontia Springs because Denver has extensive water rights and facilities in this sub-basin. In comparison, PACSM currently represents the Plum Creek, Cherry Creek and Clear Creek basins simply as historical inflows to the South Platte based on gage data. It should be noted that Denver Water is continually refining its PACSM model. Generally speaking, PACSM currently represents the following aspects of the South Platte Basin in a highly detailed manner:

- Natural flow hydrology, water rights, transmountain imports and project operations in the South Platte and its tributaries above Strontia Springs including Denver's and Aurora's raw water systems and Thornton's South Park water rights.
- Hydrology, return flows, water rights and project operations for the South Platte main stem between Strontia Springs and the Henderson gage including Centennial's and Englewood's surface water systems, PSCO's Arapahoe, Zuni and Cherokee power plants, and the Burlington System.
- Metro, Bi-Cities and Marcy Gulch wastewater treatment plant flows consistent with modeled water demands levels.
- Stream gains due to stormwater runoff from urban areas.
- Hydrology and water rights on Bear Creek below the Morrison gage.
- Denver's and Aurora's exchange rights between Metro and Strontia Springs, Cheesman and Spinney Mountain reservoirs.
- South Platte water rights calls from below the Henderson gage. These are modeled based on the historical relationship between Henderson flows and downstream calls.

The following aspects of the South Platte Basin are currently represented in PACSM in a relatively less detailed manner or are not explicitly included in the model:

- Cherry Creek and Plum Creek inflows to the South Platte are simply represented as the historical gage flows for Cherry Creek below Cherry Creek Reservoir and Plum Creek at Titan/Louviers, respectively. As such, they do not reflect changes in flows that may occur due to urban stormwater runoff, municipal wastewater discharges, augmentation and reuse activities, storage projects, or changes in discharges to surface drainages from increased pumping of the Denver Basin aquifers.
- Clear Creek inflows to the South Platte are simply represented as the historical gage flows for Clear Creek at its mouth.

APPENDIX 7

Work Plans for Cooperative Action Studies

Douglas County Water Authority/Denver Water Cooperative Action Proposal - Phase 1

Work Plan
January 20, 1997

PURPOSE

The Douglas County Water Authority is interested in a cooperative venture with Denver Water for the purpose of increasing the water supply of both entities. This study will seek to define the potential additional yield that could be cooperatively developed using Denver's existing water supply system and some of its water rights in conjunction with water rights, storage, conveyance and delivery facilities currently or potentially available to Authority members. The results of this study will be used by Denver in its "Phase 1" evaluation of potential cooperative actions.

APPROACH

This study will build upon the conjunctive use concepts previously developed in the MWSI project, but with an increased emphasis on the potential benefits of new off-stream surface storage capacity in one or more locations in Douglas County.

A series of operational scenarios progressing from simple to complex will be examined. These scenarios will focus on the increased yield resulting from new off-stream storage, conjunctive use of surface water and ground water supplies, aquifer recharge, and borrowing/payback arrangements with Denver. Various combinations of these options will be explored.

A range of water rights availability assumptions will be tested, including Blue River water only, Blue plus South Platte water from Denver's existing rights, and Blue plus South Platte "new decree" water. Storage decree limits and augmentation implications of each scenario will be tracked to the degree feasible. The basis for these water rights assumptions will be developed in cooperation with Denver and the Authority

Analyses will be done using an Excel-based model to allow for easy illustration of concepts and sensitivity analyses. The model will be developed incrementally, with input from the Authority and Denver on data, assumptions, operational logic and presentation. Analyses will be done on a daily or monthly basis depending on initial examination of the significance of using daily versus monthly time steps.

This study will rely on a variety of data from Denver Water. PACSM model output data to be provided by Denver Water will reflect completion of 45,000 AF of Denver's near-term supply elements. Data will reflect Denver's "baseline plus near term" scenario

and will be provided in both daily and monthly forms. Data to be provided by Denver will include the following (to be provided in stages consistent with the study's development):

- potential divertible at Dillon
- Dillon contents
- Roberts Tunnel flows
- North Fork South Platte at Grant
- South Platte potential divertible at 11-Mile
- South Platte potential divertible increment at Cheesman
- South Platte potential divertible increment at Strontia
- South Platte potential divertible increment at Chatfield
- Cheesman Contents
- 11-Mile Contents
- Chatfield Contents
- Conduit 27 flows
- South Platte below Englewood
- Burlington diversions
- South Platte below Burlington
- South Platte at Henderson Gage

The following sequence of operational scenarios will be initially explored:

1. New raw water pipelines from Strontia Springs and/or Chatfield to one or more off-stream surface storage facilities in Douglas County. Diversion of Denver's unused Blue River supplies and excess South Platte flows as available. Delivery as an exclusive supply to serve Authority members and Denver via new delivery pipelines.

2. Same as #1, but with deliveries to serve Denver only during dry periods based on Denver system storage triggers.

3. Same as #2, but with Denver Basin groundwater available to Authority members as a conjunctive use supply based on surface water availability triggers.

This sequence of scenarios will then be re-examined with the addition of 1) supplemental "borrowed" deliveries from Denver storage to increase effectiveness of Denver system spill capture, and 2) "payback" to Denver from Authority members' off-stream surface storage and/or groundwater if Denver's reservoirs do not subsequently refill based upon storage triggers.

This sequence of six scenarios would form the initial basis for modeling analysis. Each scenario will incorporate the ability to vary Authority and Denver demand levels,

off-stream reservoir and conveyance pipeline sizes, well pumping and recharge capacities and basic operational trigger criteria.

Once the scenarios have been developed, it is anticipated that adjustments to scenarios may be required based upon review by Authority members and Denver's Phase 1 internal analysis of the interactions of cooperative proposals with Denver's system.

PRODUCT

The product of this work effort will consist of a Phase 1 memorandum report documenting each scenario as well as an Excel-based model or models capable of representing the scenarios. Each scenario will be reported on in term of input assumptions and rules, operational data, and yield results in a manner that will facilitate evaluation by Authority members and by Denver.

It is anticipated that Hydrosphere would work with Authority members and Denver staff to refine scenarios as part of Denver's Phase 1 analysis following completion of the initial study product.

SCHEDULE

- Initial input data is expected from Denver Water by January 20, 1997.
- Development of water rights/operating assumptions by February 20, 1997
- Initial model development by March 30, 1997
- Daily/monthly data trade-off analysis by April 15, 1997
- Refined model runs by May 15, 1997
- Phase 1 Report and deliverable model by June 15, 1997
- Discussions with Authority members and Denver as needed.

BUDGET

It is anticipated that this Phase 1 effort will require the full $35,000 currently available for this effort. Work will be scoped to require that no more than $30,000 is used for development of the Phase 1 report and the deliverable model. This will allow $5,000 to support iterative review with Denver and Authority members following June 15, 1997.

Exhibit A

WORK PLAN FOR NORTHEAST COOPERATIVE WATER SUPPLY INVESTIGATIONS

September 18, 1997

The purpose of this work plan is to assist interested water providers with service areas in western Adams County (the Northeast Provider Group) with preliminary cooperative regional water supply planning efforts. The Northeast Provider Group includes Aurora, Brighton, FRICO, South Adams County Water & Sanitation District and Thornton.

Specifically, the Northeast Provider Group, in cooperation with Denver Water and the State of Colorado, will engage in preliminary quantitative studies to define the potential additional yield that could be cooperatively developed using water rights, storage, conveyance and delivery facilities currently or potentially available to the Northeast Provider Group in conjunction with Denver's existing water supply system and some of Denver's water rights.

This study will build upon effluent management and systems integration concepts previously identified in the MWSI project. Specifically, this study will focus on the hydrology, water rights, operations, water quality and raw water storage aspects of contemplated actions. Three areas are of particular interest:

1) Developing the remaining substitution opportunities using downstream reusable return flows and the participants' upstream diversion points, subject to water rights, water quality and instream flow concerns. The utility of additional storage below Metro and the water quality impacts on water users located below points of substitution are items of particular mutual interest.

2) Enhancing the size, reliability and water quality of potable municipal supplies diverted from the South Platte River at or below the Burlington Ditch. Alternate sources of supply could include the Barr Lake/Beebe Draw area or the South Platte River near the Burlington Ditch. These sources could be regulated by local downstream storage.

3) Optimizing the delivery of nonpotable water from the Metro plant for appropriate uses. The utility of additional storage below Metro and the "trade potential" of participating in a nonpotable reuse plan in trade for additional potable water supplies from Denver Water are areas of particular mutual interest.

This Study will rely upon information provided by individual study participants including output data from Denver Water's PACSM model, previous operational models developed by South Adams County Water & Sanitation District, water rights and recent historical operations data provided by Thornton, FRICO, Aurora and Brighton.

The results of this study will be used to by the Northeast Provider Group and by Denver Water to evaluate potential cooperative water supply actions.

Tasks

1. Initial Data Development. For the purpose of improving the participants' mutual understanding of cooperative action potentials and constraints, a variety of descriptive and operational data will be developed and shared along with a map of the Northeast water supply systems.

   Descriptive data will include descriptions of individual water supply system facilities, relevant water rights and system operations illustrating typical seasonal and annual variations.

   Operational data will include tabular and graphical presentations of selected data for two scenarios: existing conditions and future conditions. Existing conditions will be portrayed using historical 1987-1996 data. Future conditions will be portrayed using output from Denver's PACSM model for its Baseline NT scenario, adjusted to reflect the "reasonably certain" future operations of other providers not explicitly represented in Denver's model. These primarily include portions of Thornton's, Aurora's and SACWSD's systems. For each scenario the following data will be developed:

   - South Platte flow at Burlington below the Burlington Ditch, at the Henderson gage, and at State Highway 7.
   - South Platte River minimum flow between Spinney Mountain Reservoir and the Burlington Ditch
   - Metro discharges
   - Metro pumping into the Burlington, by entity
   - Exchanges to the Burlington Ditch, to Chatfield and to Strontia, by entity
   - Thornton's South Park deliveries out of Chatfield
   - periods and amounts of free river water at Burlington and at Henderson
   - remaining reusable water in the stream at Burlington and at Metro, by entity
   - Burlington and O'Brian canal diversions
   - Thornton municipal diversions from Burlington
   - SACWSD recharge facility diversions from Burlington
   - seasonal water quality data for South Platte at Burlington (existing conditions only)
   - estimates of Denver's releases for South Platte urban instream flow

   The descriptive and operational data will help to identify planning constraints and opportunities and to drive various modeling studies.

The map will be a large format schematic illustration of the major streams and system facilities including diversion points, canals, pipelines, reservoirs, treatment plants, principal treated water distribution lines and interconnections. The map will help to identify critical linkages, capacities and bottlenecks and will serve as a guide to operational analyses.

It is anticipated that all of this information is readily available from participants. This information will be developed to a level of detail sufficient for the purposes of this study and will expand upon the information presented at the Northeast systems integration meeting on February 10, 1997. This will involve information sharing and work meetings among participants.

2. Downstream Storage Analysis - Exchanges and Augmentation. Using data from Task 1, an operational model will be developed. The model will represent the South Platte River between Spinney Mountain Reservoir and the South Platte at State Highway 7, including a simplified representation of the Burlington Ditch system.

   The model will be used to examine the utility of additional storage capacity located below Metro for the purposes of making exchanges to points upstream, augmenting nonpotable reuse deliveries and regulating reusable supplies for delivery to downstream points of substitution. The utility of additional storage will be examined from both an individual and cooperative perspective.

   Model results will also be used to examine how exchanges alter the relative contributions of Chatfield outflows, wastewater discharges, metro area gains, and substitute supply water to the overall supply available to water users below the exchange reaches.

   The amount of storage will be quantified based on exchange and augmentation opportunities and supplies as defined by task 1 data and input from participants. The use of storage and the resulting changes in river flows will be determined.

   It is anticipated that this model would be implemented on a daily or monthly time step using an Excel application or a simple network tool with an Excel interface. The model will be developed incrementally, with input from the Northeast participants on data, assumptions, operational logic and presentation.

3. Downstream Storage Analysis - Regional WTP. The model will be used to simulate the operation of a regional water treatment plant supplied by a combination of free river water and reuse credits available to the participants. The required amounts of downstream storage (for regulation of effluent supplies) and upstream storage (for regulation of water to supply the treatment plant) will be examined and quantified. Diversion will be controlled by various flow-based water quality thresholds. These storage requirements will be integrated with those identified in Task 2.

4. FRICO/Burlington System Analysis - Regional WTP & Substitution Opportunities. The model will be used to simulate the operation of a regional water treatment plant supplied by water pumped from the Beebe Draw aquifer in the vicinity of Barr Lake. The required amounts of replacement effluent supply to be returned to Barr Lake will be quantified based on a variety of assumptions with respect to timing of return supply.

   The model will also be used to explore the utility of various substitution arrangements canal lining proposals involving the FRICO/Henrylin system, as directed by the participant group and subject to budget limitations.

Deliverables

The products of this work effort will consist of a Task 1 descriptive and operational data, a regional schematic map, a series of memorandum reports documenting the modeling analyses listed above as well as an Excel-based model or models capable of representing the operational scenarios. Each scenario will be reported on in term of input assumptions and rules, operational data, and yield results in a manner that will facilitate evaluation by Northeast Provider Group members and by Denver Water.

It is anticipated that Hydrosphere would work with Northeast Provider Group members and Denver Water staff to refine scenarios of interest as part of follow-up analyses by Denver Water following completion of the study product.

Schedule

- Initiation of study by September 18, 1997
- Schematic regional facilities map by October 10, 1997
- Description of system operations/water rights by October 31, 1997
- Downstream storage analysis of exchanges and augmentation by December 1, 1997
- Downstream storage analysis for a regional WTP by January 9, 1997.
- FRICO/Burlington system opportunities analysis by January 30, 1997
- Study Report and deliverable model by February 17, 1998
- Discussions with Northeast Provider Group members and Denver as needed.

Budget and Funding

This work plan is based upon a $35,000 budget. It is assumed that funding for this work will be jointly provided by the State of Colorado and the participating water providers at the following levels: State of Colorado ($10,000), City of Aurora ($5,000), City of Brighton ($5,000), Farmers Reservoir and Irrigation Company ($5,000), South Adams County Water & Sanitation District ($5,000) and City of Thornton ($5,000). It is further assumed that most of the input data needed for this study is available and will be provided by the participating water providers and by Denver Water (from their PACSM model). The scope of work and budget contemplated in this Work Plan are contingent on such financial participation and cooperation in terms of information sharing.

It is anticipated that this study will require the full $35,000 currently contemplated for this effort. Work will be scoped to require that no more than $30,000 is used for the Study report and the deliverable model. This will allow $5,000 to support iterative review with Denver and Northeast Providers following February 17, 1998.

MEMORANDUM

TO: Northwest Quadrant Members
FROM: Lee Rozaklis, Hydrosphere
SUBJECT: Work Plan for Northwest Cooperative Investigations
DATE: October 8, 1997

Purpose

The purpose of this work plan is to assist interested water providers in the Clear Creek/Big Dry Creek basins (the Northwest Provider Group) with regional water supply planning efforts. The Northwest Provider Group includes the cities of Arvada, Broomfield, Westminster and the Consolidated Mutual Water Company.

Specifically, the Northwest Provider Group, in cooperation with Denver Water and the State of Colorado, will engage in a study to define the potential additional yield that could be cooperatively developed using water rights, storage, conveyance and delivery facilities currently or potentially available to the Northwest Provider Group in conjunction with Denver's existing water supply system and some of its water rights. This study will build upon system integration concepts previously identified in the MWSI project, with emphasis on the potential benefits of system interconnections and cooperative use of storage facilities at one or more locations in the Northwest area.

The results of this study will be used to by the Northwest Provider Group and by Denver Water to evaluate potential cooperative water supply actions.

Tasks

1. Mutual Education. For the purpose of establishing a mutual understanding of cooperative development potentials and constraints, a schematic facilities map of the Northwest water supply systems, a description of system operations on a seasonal basis for wet/average/dry years, and a listing of participants' relevant water rights will be developed. The map will depict the major system facilities including diversion points, canals, pipelines, reservoirs, treatment plants, principal treated water distribution lines and interconnections. The map will help to identify critical linkages, capacities and bottlenecks and will serve as a guide to operational analyses. The descriptions of systems operations and water rights will similarly help to identify constraints and opportunities. It is anticipated that all of this information is readily available from participants. This information will be developed to a level of detail sufficient for the purposes of this study and will expand upon the information presented at the Northwest systems integration meeting on December 3, 1996. This will involve information sharing and a series of work meetings among participants.

2. Future Baseline Representation. Using historical data and output from existing system models, a simplified regional model of "future baseline" operations of Northwest water supply systems will be developed for a representative period of record. The "future baseline" would include full utilization of water rights, supply sources, and permitted facilities that are currently available to the participating entities. This would include existing contracts and cooperative agreements between the participating entities. Attention would be focused on identifying storage levels in major reservoirs and levels of use of major conveyance facilities. Periods of unused storage and conveyance capacity within individual systems would be identified. For the sake of flexibility and ease of use, it is anticipated that this analysis would be done on a monthly time step using an Excel application or a simple network model with an Excel interface. The regional model will be developed incrementally, with input from the Northwest participants on data, assumptions, operational logic and presentation.
3. Estimate Future Unused Supplies. Monthly time series estimates would be made of unused supplies available under the parties' water rights under "future baseline" conditions. These would include estimates of supplies from the Moffat and Gumlick Tunnels, South Boulder Creek, Coal Creek, Ralston Creek and Clear Creek. Reusable supplies and unused Clear Creek exchange potential (which may exist due to insufficient storage or individual exchange supplies) would also be estimated. The water rights assumptions associated with these estimates would be defined.
4. Operational Analyses. A series of operational analyses progressing from simple to complex will be conducted. These analyses would look at how unused supplies could be "firmed" from a regional perspective by delivery to demand locations or to available storage capacity using existing and assumed future interconnections. Initial analyses would focus on the regional opportunities associated with existing systems. In subsequent efforts, the benefits of additional storage capacity at Standley, Gross, Leyden Gulch and other locations would be examined.

This study will rely on a variety of data from the Northwest Provider Group and Denver Water. Data will generally reflect a "baseline future" condition to be mutually defined with respect to individual systems.

Data needed for each individual water supply system from the Northwest Provider Group (including the Marshall and Standley divisions of FRICO) will include:

- raw water reservoir contents,
- flows in major raw water conveyance facilities
- unused divertible supplies
- remaining Clear Creek exchange potential
- reusable return flows in Big Dry Creek
- reusable return flows at Metro

In the case of Denver Water, PACSM model output data will reflect Denver's "baseline near-term" scenario which assumes completion of 45,000 AF of Denver's near-term supply elements. Data to be provided by Denver will include the following:

- potential divertible at Gumlick Tunnel
- Gumlick Tunnel deliveries
- potential divertible at Moffat Tunnel
- Moffat Tunnel deliveries
- Gross Reservoir contents
- South Boulder Diversion Canal flows
- Ralston Reservoir contents
- potential divertible at South Boulder Creek
- remaining reusable return flows (after DW exchanges) at Metro

Deliverables

The product of this work effort will consist of a Phase 1 memorandum report documenting the four tasks listed above as well as an Excel-based model or models capable of representing the operational scenarios. Each scenario will be reported on in term of input assumptions and rules, operational data, and yield results in a manner that will facilitate evaluation by Northwest Provider Group members and by Denver Water.

It is anticipated that Hydrosphere would work with Northwest Provider Group members and Denver Water staff to refine scenarios of interest as part of follow-up analyses by Denver Water following completion of the study product.

Schedule

It is currently anticipated that this study will proceed according to the following schedule.

- Initiation of study by October 8, 1997.
- Schematic regional facilities map by November 8, 1997.
- Description of system operations/water rights by December 1, 1997.
- Estimates of future unused supplies by December 31, 1997.
- Future baseline representation by January 23, 1998.
- Initial operational analyses by March 1, 1998
- Refined operational analyses by April 1, 1998
- Study Report and deliverable model by April 15, 1998

- Discussions with the Northwest Provider Group and Denver as needed.

Budget

It is anticipated that this study will require the full $35,000 currently contemplated for this effort. Work will be scoped to require that no more than $30,000 is used for development of the Study report and the deliverable model. This will allow $5,000 to support iterative review with Denver and Northwest Provider Group following April 15, 1998.

APPENDIX 8

Denver Board of Water Commissioners, Resource Statement