Arkansas River Water Needs Assessment

A cooperative effort of the:

USDI Bureau of Land Management
USDI Bureau of Reclamation
USDA Forest Service
Colorado Department of Natural Resources

Edited by Roy E. Smith and Linda M. Hill

Though this document was produced through an interagency effort,
the following BLM number has been assigned for tracking and administrative purposes:

BLM/RS/ST-00/002+7200

Arkansas River Water Needs Assessment

A cooperative effort of the:

USDI Bureau of Land Management
USDI Bureau of Reclamation
USDA Forest Service
Colorado Department of Natural Resources

Edited by:

Roy E. Smith and Linda M. Hill

July 2000

Letter to Arkansas River Stakeholders

The agencies that conducted this study and created this report are jointly responsible, subject to existing rights, for managing the Arkansas River corridor and its associated reservoirs between Leadville and Pueblo Reservoir. In 1993, these agencies signed a memorandum of understanding with the goal of creating a scientific foundation for river management processes. The outcome was a 6-year study that resulted in agreement among the agencies on the facts and assumptions that should be used in making river management decisions.

The agencies are pleased to publish and distribute this final report, which contains peer-reviewed results that we believe will stand up to scientific scrutiny. We anticipate that the information in this report will be used for developing flow recommendations and for other river management decisions starting in calendar year 2001 and beyond.

It is important to keep in mind that this report does not contain flow management recommendations, but rather, is only an information base for agency and public deliberations. The agencies recognize that our river management decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. The cooperating agencies have a renewed commitment to work cooperatively with water users to fulfill legal entitlements to water deliveries while managing the river in a way that supports natural resource and recreation values to the greatest extent possible within these constraints.

The cooperating agencies intend that this report will be used in concert with the Storage Needs Assessment currently being spearheaded by the Southeastern Colorado Water Conservancy District, along with the new management plan for the Upper Arkansas Headwaters Recreation Area. We hope that this knowledge foundation will produce improved dialogue and new ideas among all those with a stake in river management.

Greg Walcher
Director
Colorado Department of Natural Resources

Donnie Sparks
Manager, Royal Gorge Field Office
USDI Bureau of Land Management

for Gerald Kelso
Acting Manager, Eastern Colorado Area Office
USDI Bureau of Reclamation

Abigail Kimbell
Supervisor, San Isabel National Forest
USDA Forest Service

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding riverflows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Arkansas River Water Needs Assessment

Section I. Executive Summary

By:

John Gierard, Bureau of Reclamation
Dave Gilbert, Bureau of Land Management
Doug Krieger, Colorado Division of Wildlife
Greg Policky, Colorado Division of Wildlife
Roy Smith, Bureau of Land Management
Steve Swanson, Bureau of Land Management
Dave Taliaferro, Bureau of Land Management

Arkansas River Water Needs Assessment

Section I. Executive Summary

By:

John Gierard, Bureau of Reclamation
Dave Gilbert, Bureau of Land Management
Doug Krieger, Colorado Division of Wildlife
Greg Policky, Colorado Division of Wildlife
Roy Smith, Bureau of Land Management
Steve Swanson, Bureau of Land Management
Dave Taliaferro, Bureau of Land Management

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding riverflows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. This section provides a summary of the entire assessment.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Section I. Executive Summary

The purpose of this section is to summarize all the information and findings associated with the Arkansas River Water Needs Assessment. This section will:

1. Summarize the major legal and institutional elements involved in Arkansas River management, with emphasis on the major facilities and laws that impact flows on the main stem upstream from Pueblo Reservoir.
2. Summarize the extensive hydrologic analysis that was performed. This analysis determined how construction of water management features, such as transbasin import systems and large storage facilities, have affected the magnitude and timing of riverflows.
3. Explain how the Fryingpan-Arkansas Project is operated if the sole objective is to maximize the yield of water from the Project for human uses. An annual hydrograph for this operational approach is presented, using data from the 1982 to 1995 period. The 1982-1995 hydrograph provides a baseline against which natural resource needs can be compared. Since 1990, additional operational goals have been gradually incorporated into Project operations.
4. Incorporate numerous tables that illustrate at a glance the flows and water levels required to support natural resource values on the Arkansas River, at Turquoise and Twin Lakes Reservoirs, and at Pueblo Reservoir. It will also discuss key findings and conclusions reached about the individual resource values in subsequent sections of the report.

Summary of the Arkansas River Institutional and Legal Analysis

In response to the large numbers of demands placed upon it, the Arkansas River is one of the most intensively managed rivers in the western United States (Figure 1-1). The details regarding the laws, institutions, facilities, water rights, and water management operations are discussed in the other sections of this report. Therefore, this summary focuses upon the elements of river management that have the greatest impact on the flows in the study reach between Turquoise and Twin Lakes Reservoirs and Pueblo Reservoir.

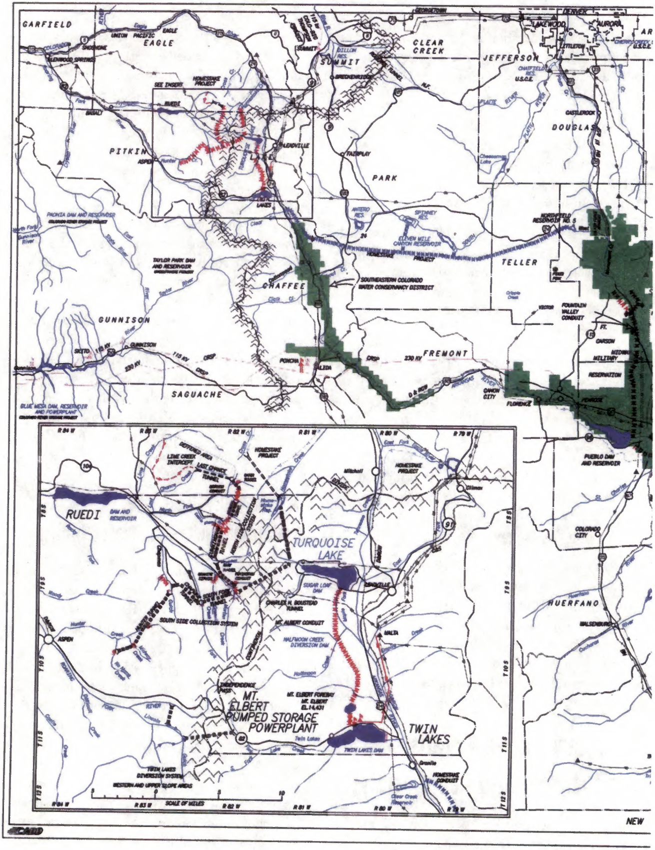
Intensive river management efforts have not dramatically changed the annual hydrograph of the river in the study reach. Rather, river management has had the effect of maintaining peak spring runoff flows at approximately the same level, slightly increasing late summer and early fall flows, and increasing October through March flows by an average of 100 cfs. The magnitude of the river management changes discussed below can be assessed by comparing the number of acre-feet involved to the average annual flow of the river for the 1990 to 1995 period at the Cañon City streamgage, which was 550,000 acre-feet.

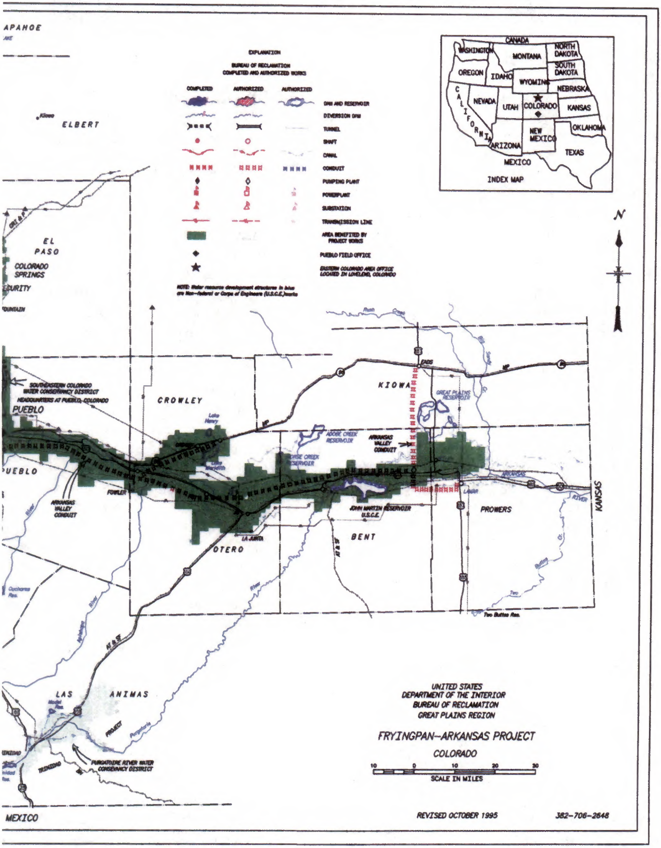
Native Riverflows and Senior Downstream Water Rights

By 1884, all the typical flows of the Arkansas River, exclusive of peak spring runoff and storm events, had been appropriated by agricultural users in the lower Arkansas River Valley. Although some water use was occurring upstream of Cañon City on the main stem and in upper basin tributaries, the large number of downstream water rights ensured that most native flows stayed in the river at least to Pueblo. The potential for these water rights to pull water down to the lower Arkansas Valley was enhanced when ditch companies constructed and obtained decrees for more than 400,000 acre-feet of reservoir space to store diversions. Today, there are 23 major ditch systems diverting water between Pueblo and the Colorado-Kansas border.

FIGURE 1-1

Arkansas River System




UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GREAT PLAINS REGION
FRYINGPAN–ARKANSAS PROJECT
COLORADO
SCALE IN MILES
REVISED OCTOBER 1995
382–706–2648
INDEX MAP
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
OREGON
IDAHO
WYOMING
NEBRASKA
NEVADA
UTAH
COLORADO
KANSAS
CALIFORNIA
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
EXPLANATION
COMPLETED
AUTHORIZED
ELBERT
EL PASO
COLORADO SPRINGS
CROWLEY
KIOWA
PUEBLO
OTERO
BENT
PROWERS
KANSAS
LAS ANIMAS
MEXICO
SOUTHEASTERN COLORADO WATER CONSERVANCY DISTRICT HEADQUARTERS AT PUEBLO, COLORADO
ARKANSAS VALLEY CONDUIT
JOHN MARTIN RESERVOIR U.S.C.E.
PURGATOIRE RIVER WATER CONSERVANCY DISTRICT
N

Early Transmountain Diversions and Upper Basin Storage Facilities

By 1935, 43,000 acre-feet were imported annually from other basins into the Arkansas River Basin. Some of this total was made up from several large, open ditches that crossed the Continental Divide, but the majority was comprised of imports through the Busk-Ivanhoe System and the Twin Lakes Project. Development of the Busk-Ivanhoe System allowed diversion of water from the headwaters of the Fryingpan River to Lake Fork Creek via the Carlton Tunnel. Development of the Twin Lakes Project allowed importation of water from the headwaters of the Roaring Fork River to the North Fork of Lake Creek via the Twin Lakes Tunnel.

At the time of construction, these systems provided water exclusively for agricultural use in the lower Arkansas River Valley. In cases where these diversions were not stored high in the basin, the systems had the effect of increasing flows during spring runoff and early summer in the main stem. These systems continue to operate today, although some of the imported flows are directed to storage before being released to the main stem. Today, the enlarged Twin Lakes system imports an average of 54,500 acre-feet annually, and the Busk-Ivanhoe System imports an average of 6,200 acre-feet annually. The Wertz, Ewing, and Columbine ditches import an average of 4,971 acre-feet annually.

Significant storage facilities were also built in the upper basin to store both native water and imported water. In 1900, the Twin Lakes and Colorado Canal Company constructed Twin Lakes Reservoir on Lake Creek (an enlargement of a natural reservoir), with a capacity of 54,452 acre-feet. CF&I Steel Corporation completed construction of Sugarloaf Reservoir in 1902, with a capacity of 17,416 acre-feet. This reservoir allowed storage of native water from the Lake Fork Creek and storage of water from other Arkansas River tributaries by exchange. Finally, Otero Canal Company constructed Clear Creek Reservoir from 1902 to 1907, with a capacity of 11,486 acre-feet. Construction of these reservoirs slightly reduced spring peak flows by capturing runoff and increased late summer flows by releasing stored water for irrigation purposes.

Municipal Water Supply Systems

Starting in the 1950's, several of the agricultural water supply systems were purchased in whole or in part by municipalities who sought an assured water supply for growing populations. In 1955, Pueblo Board of Water Works purchased Clear Creek Reservoir from the Otero Canal Company. In the early 1970's, the Twin Lakes transmountain diversion system and reservoir were purchased by Colorado Springs, Aurora, Pueblo, and Pueblo West. The change of ownership means that instead of an exclusive pattern of spring storage and summer release for agriculture use, these reservoirs are now managed to provide year-round supplies for the municipalities. Since they are part of a complex municipal supply system, releases of stored water to the main stem may occur at any time of the year. In addition, if part of the yield of these reservoirs is not needed for municipal use, water may be sold to other customers, which results in releases timed to meet the customer's need.

Colorado Springs Utilities has an extensive water supply system that taps multiple watersheds, but only a portion of this system has the capability to affect main stem flows between the headwaters and Pueblo. The Pikes Peak South Slope System and the Penrose Rosemont System divert water out of tributaries that enter the Arkansas River between Cañon City and Pueblo. Water from the Homestake Project, which diverts water from the Eagle River watershed, and the Blue River Project, which diverts water from tributaries to the Blue River in Summit County, is transported directly to Colorado Springs and does not enter the main stem of the Arkansas River. Colorado Springs also obtains water from the Fryingpan-Arkansas Project (discussed in Section 3, Institutional and Legal

Analysis). This water is delivered to Colorado Springs via the Otero Pipeline, which takes water directly from Twin Lakes and transports it over Trout Creek Pass to Colorado Springs Utilities' distribution system. Finally, Colorado Springs obtains water supplies via the Fountain Valley Conduit, a pipeline system that starts at Pueblo Reservoir and runs northward toward Colorado Springs. If Colorado Springs chooses this delivery route for water, rather than the Otero Pipeline from Twin Lakes, then the main stem may see additional flows as the water is delivered to Pueblo Reservoir for placement in the conduit.

Colorado Springs Utilities and the City of Aurora have also purchased water rights from lower Arkansas Valley farms, and have received permission from the water court to transfer those water rights to municipal use. This permission means that the water can be diverted at the Otero Pipeline, high in the basin near Twin Lakes, rather than flowing down the river to be diverted in the lower valley. As of 1997, less than 15,000 acre-feet have been transferred in any one water year, but the total amount available for transfer is approximately 23,400 acre-feet.

Fryingpan-Arkansas Project

Between 1962 and 1980, the Bureau of Reclamation (BOR) constructed or enlarged four storage dams and reservoirs within the basin, creating a total storage capacity of about 630,000 acre-feet: 1) Turquoise Lake 5 miles west of Leadville with a capacity of 120,478 acre-feet, 2) Mount Elbert Forebay Dam and Reservoir at the base of Mt. Elbert, with a capacity of 11,143 acre-feet, 3) Twin Lakes Dam and Twin Lakes at the east end of Independence Pass, with a capacity of 140,855 acre-feet (an enlargement of a natural lake), and 4) Pueblo Dam and Reservoir just west of the City of Pueblo, with a capacity of 357,678 acre-feet. In addition, between 1965 and 1981, BOR constructed and enlarged the west slope collection system, which conveys water to these reservoirs through the Charles H. Boustead Tunnel. The annual amount of water imported to the basin each year has averaged 56,000 acre-feet.

The operating objectives of the Fryingpan-Arkansas Project are to:

- Maximize the storage of Project water from both the west slope and east slope
- Fill Turquoise and Twin Lakes each year during the summer
- Keep Turquoise and Twin Lakes full during the summer and early fall to provide recreational opportunities (this objective has been added since the Project was originally authorized by Federal legislation)
- Minimize the loss of Project water to evaporation
- Maximize electric power generation at the Mt. Elbert Power Plant
- Fulfill contractual obligations for providing storage space and conveyance facilities
- Deliver water at the time and place of needs to customers of the Southeastern Colorado Water Conservancy District

In general, this means that the upper reservoirs, Turquoise Lake and Twin Lakes, are lowered prior to runoff in May to accommodate the predicted water availability from the east slope and west slope diversions. Since 1990, BOR has attempted to accomplish the lowering of upper reservoirs by April, to fulfill flow recommendations from the Colorado Department of Natural Resources (CDNR). Twin Lakes and Turquoise Reservoirs are typically filled by mid-July. From mid-July through September, releases from these reservoirs are roughly equivalent to inflow of native (nonimported) water. Since 1990, BOR's practice has been to gradually deliver water from the upper reservoirs to Pueblo Reservoir between October and March. This water is then delivered to Southeastern customers upon demand. Whenever possible, BOR manages its releases from upper basin reservoirs in accordance with recommendations from the CDNR that are designed to enhance the flow regime of the river to benefit riverine habitat and recreation. This practice has been implemented since 1990 with the support of the Southeastern Colorado Water Conservancy District.

The construction of the Fryingpan-Arkansas Project allowed BOR to sign storage contracts with parties who had a need to store the yield of previously established water rights. These contracts include:

Typically Stored in Turquoise Reservoir
17,416 acre-feet - Colorado Springs Utilities
5,000 acre-feet - City of Aurora (original shares of Busk-Ivanhoe, Inc.)
5,000 acre-feet - Pueblo Board of Water Works (original shares of Busk-Ivanhoe, Inc.)
30,000 acre-feet - Colorado Springs Utilities and City of Aurora

Typically Stored in Twin Lakes Reservoir
54,452 acre-feet - Twin Lakes Reservoir and Canal Company

Frequently, these storage contracts, as well as others signed on a short-term basis, are employed by water users to execute exchanges. These exchanges allow water from lower Arkansas River Valley locations and other upper basin locations to be moved to Turquoise and Twin Lakes Reservoirs. Moving water to these locations allows easy delivery to municipal supply systems via the Otero Pipeline. BOR also stores water for lower basin users at Pueblo Reservoir under a Winter Water Storage Program (WWSP) decreed by the water court. This program allows some water rights holders, primarily agricultural users who historically used water during the winter, to store the yield of those water rights in Pueblo Reservoir from November 15 to March 15 for irrigation at a later time.

Arkansas River Compact of 1948

While the administration of the Arkansas River Compact has major impacts on water use in the lower Arkansas Valley, its impact on streamflows between Twin Lakes and Pueblo Reservoirs is much more limited. The compact ratified irrigation as a legitimate use for John Martin Reservoir, which was previously approved only for flood control. Therefore, John Martin became a major irrigation storage facility with a 1948 priority, which is senior to water rights for the Fryingpan-Arkansas Project. Project facilities cannot store native flows until John Martin Reservoir is full. When this occurs, the main stem of the Arkansas may see a decrease in streamflow as upper basin storage captures a portion of the native flows.

Annual Flow Management Program

In 1990, BOR and the CDNR signed an agreement under which BOR would attempt to provide flows to better support natural resource values. There is no legal obligation upon BOR to provide the flows, and the program must be operated within the context of legally required storage and deliveries for water users. CDNR makes its flow recommendations via an annual letter to BOR each spring. The annual letter has typically included the following six components:

~ Minimum year-round flow of at least 250 cfs to protect the fishery
~ Flows from mid-November through April not less than 5 inches below the height of the river from Oct. 15 - Nov. 15 to protect and incubate brown trout eggs
~ Flows from April 1 - May 15 between 250-400 cfs for egg hatching and fry emergence
~ Augment flows during the July 1 to August 15 period to create flows of at least 700 cfs for recreational purposes
~ Limit daily flow changes to 10-15 percent of flows
~ If possible, reduce flows after Labor Day to levels recommended by Colorado Division of Wildlife (CDOW)

Institutional and Legal Opportunities for Water Management

There are numerous opportunities for improving water management to better meet the needs of water users and the natural environment. However, all of these opportunities involve numerous issues and concerns, affected parties, and legal constraints. These opportunities include:

- Modified management of existing storage and conveyance facilities
- Expanded or new storage capacity
- Construction of a southern delivery system for Colorado Springs Utilities
- Temporary water transfers
- Arrangements with municipal water providers
- Expanded season of exchanges
- Increased water imports
- Agreements regarding upstream irrigation water rights

Most of the water users in the basin have agreed that to better meet water needs, improved storage management should be thoroughly investigated and tried before other options are explored and implemented. To this end, Southeastern Colorado Water Conservancy District is coordinating a study of storage needs and storage management within the basin.

Summary of the Hydrologic Analysis of Changes in Arkansas River Flows Since 1889

The hydrologic analysis of flows was divided into three time periods to reflect major changes in river management. The first designated time period, 1889-1910, reflects the earliest date for which continuous flow records are available, and represents a fairly natural, unregulated system before 1900. Between 1900 and 1910, the system began to experience the effects of limited water imports and the construction of Clear Creek, Twin Lakes, and Sugarloaf Reservoirs in the upper basin. The second designated time period, 1911-1960, reflects a time period when water management was fairly stable, without any major new water management facilities. Transbasin diversions, overall storage capacity, and active storage management increased incrementally, but did not dictate extensive alterations in how the river was managed. The third period, 1982-1995, reflects a period when the Fryingpan-Arkansas Project was coming online, along with associated institutional changes in how water was managed and allocated. The 1961 to 1981 period was not analyzed because the timing and magnitude of flows fluctuated as new water storage and import systems came online.

The overall net effects of water management changes from 1889-1910 are a slight reduction in November-April flows, a reduction in spring runoff flows (May-June), and an increase in August-September flows. These effects are predominantly the result of upper basin storage put into service after 1900. Mean flows for November-April prior to 1901 were approximately 420 cfs, while mean flows for November-April post-1901 were approximately 350 cfs. Mean daily flow before 1901 for the August 1-15 period was 680 cfs, while after 1901, but before 1911, the mean daily flow for the August 1-15 period was 740 cfs.

Flows during the 1911-1960 period were approximately the same as the 1889-1910 period during fall, winter, and spring. However, due to the release of imported water that was stored on the east slope during runoff, July and August flows increased significantly. The mean daily flow for August 1-August 15 for the 1911-1960 period was approximately 1,000 cfs, compared to 740 cfs from 1901-1910. This is an increase of 230 cfs from the 1901-1910 period, and is almost completely attributable to transbasin imported water.

Flow analysis during the 1982-1995 period is complicated by several factors. Completion of the Fryingpan-Arkansas Project created tremendous flexibility in the process of water storage and movement. In addition, the wettest period on record was from 1982-1987, 1989-1992 was extremely dry, and 1995 was the wettest year on record. Finally, an annual flow management program was started in 1990. This program sets target flow ranges for 12 months of the year, and it involved augmentation of late July and early August flows is some water years.

Flow augmentation appears to continue flow levels that have been present since a significant change that occurred in the early 1900's. Even though the flow augmentation program was operated during the 1990-95 period, there were many days in the August 1-15 period in which flows were less than 700 cfs because other factors were at work on the river that reduced flows. The percent of days in which flows exceeded 700 cfs during the August 1 to August 15 period is as follows:

~ Prior to 1900	40 percent
~ 1911-1960	75 percent
~ 1982-1989	80 percent
~ 1990-199	77 percent

In contrast to late summer, the effects of institutional management since 1982 are clearly evident during the November-April period. Since 1982, an average of 40,000 acre-feet of additional water is passed during this period. Mean daily flows have increased approximately 100 cfs during the winter months, in comparison to the 1911-1960 period. This movement can be accounted for by the new movement of water from the upper reservoirs to lower basin storage to allow for spring runoff storage in the upper basin.

Operation of the Fryingpan-Arkansas Project

Water Management Objectives and Actions to Optimize Yield

The purpose of presenting a baseline hydrograph for the Arkansas River is to compare the water needed to support natural resource values with flows designed to optimize water available for consumptive uses.

The baseline Arkansas River hydrograph presented in this section represents Arkansas River flows from 1982 to 1994, incorporating Fryingpan-Arkansas operations during that time period. When utilizing the baseline hydrographs in this section, the following limitations should be kept in mind:

~ The Fryingpan-Arkansas Project regulates only a fraction of total flows in the upper Arkansas River basin, and other legal/institutional factors play a large role in determining flow rates. However, the Fryingpan-Arkansas Project is among the largest of many factors in determining flow rates experienced in the Arkansas River corridor.

~ This baseline does not mimic all of the historic operations of the Project, because significant changes in flows have been implemented as various components of the project have come online, and as BOR has gained more experience in operating the Project.

~ The 1982-1994 period may not be representative of the entire range of hydrologic conditions that could be experienced in the future.

~ This baseline represents an operation that is in variance from the CDNR flow recommendations that have been implemented since 1990.

The baseline developed in this section is a representation of what flows would be expected to occur in the river corridor if the Fryingpan-Arkansas Project were to be operated today to best achieve the following goals:

~ Maximize storage of Project water
~ Minimize unnecessary spilling of non-Project water
~ Minimize loss of Project water to evaporation
~ Maximize energy generation at the Mt. Elbert Power Plant

Full implementation of these goals would entail the following Project operations:

~ Water would be evacuated from Turquoise Lake and Twin Lakes and stored in Pueblo Reservoir, via releases through the Mt. Elbert Conduit and from Twin Lakes Dam, before the spring snowmelt. Releases would be in a quantity sufficient to allow refilling of the two reservoirs with water imported from the west slope by mid-July.

~ Water would not be evacuated from the upper reservoirs before March because an accurate forecast of spring runoff cannot be made until a significant portion of the high elevation snowpack has accumulated.

~ Water would be evacuated from Turquoise Lake before the runoff due to the limited capacity of the Mt. Elbert Conduit. The capacity of the Mt. Elbert Conduit, which carries water from Turquoise Lake to Twin Lakes, is significantly less than the combined spring inflow of the transmountain tunnels and native Lake Fork flows during the runoff. If sufficient space in Turquoise Lake has not been evacuated, then releases from Sugarloaf Dam to Lake Fork would be necessary. Releases in excess of the minimum required releases would be necessary to avoid foregoing west slope imports after the lake fills. Any water released to Lake Fork in excess of the minimum requirement is a loss of energy generation at the Mt. Elbert Power Plant.

~ In a year of normal spring runoff, releases from the upper reservoirs would be made in March and April such that the entire Project storage capacity of Turquoise Lake is evacuated. Releases in May and June, at the height of the spring runoff, would be avoided because the entire safe channel capacity of Lake Creek below Twin Lakes Dam is quite often needed during that time period for the required bypass of the native inflow to Twin Lakes. The native inflow to Twin Lakes includes native flows of Lake Fork and Halfmoon Creek diverted through the Mt. Elbert Conduit, in addition to the native flow of Lake Creek. If the safe channel capacity below Twin Lakes Dam is reached, then diversions of native water from Lake Fork and Halfmoon Creek would be reduced or discontinued and energy generation would be foregone.

~ In a year of heavy spring runoff, releases from upper basin reservoirs would start in March and continue through May in order to evacuate the Project storage capacity of Twin Lakes in addition to that of Turquoise Lake. After all Project storage space is filled in the upper reservoirs, releases from Twin Lakes Dam and, if necessary, Sugarloaf Dam would be made to avoid foregoing imports of Project water from the west slope. An unavoidable bypass of the Mt. Elbert Power Plant would occur in such years.

~ In a year of below average spring runoff, releases from the upper basin reservoirs would be discontinued before the end of April to avoid storing more water in Pueblo Reservoir than is necessary. Any unnecessary storage of water in Pueblo Reservoir represents a risk of foregoing winter water storage in the reservoir in the following winter and spring. Unnecessary storage of Project water in Pueblo Reservoir also causes greater losses of Project water to evaporation. The evaporation from Pueblo Reservoir is greater than from the upper reservoirs.

~ The evacuation of water from the upper reservoirs could be limited, in any kind of runoff year, by the lack of Project storage space in Pueblo Reservoir. The available space in Pueblo Reservoir does not correlate to the runoff in any single year because Pueblo Reservoir is designed to hold multiple years of water supply. Consecutive dry years draw the reservoir down and consecutive wet years fill it up.

~ After the upper reservoirs fill in July, no release of Project water would be made until the following March. The only exceptions would be direct releases of imported water in a heavy runoff year, and releases for Project water demands downstream of Pueblo Reservoir in the event that all Project water is depleted from Pueblo Reservoir. Delaying any further releases until March allows the upper reservoirs to remain as full as possible. This reduces evaporation losses and, as a side benefit, enhances flatwater recreation at the reservoirs.

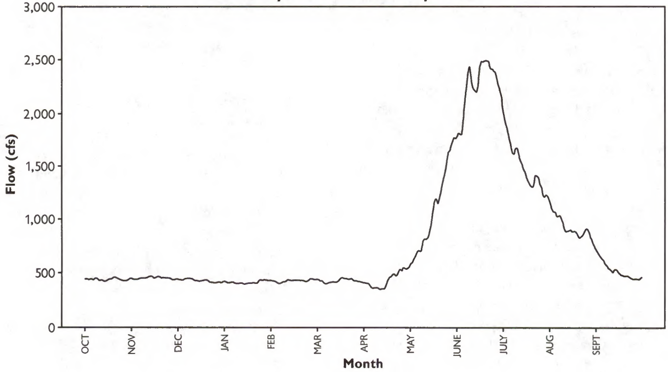
Baseline Arkansas River Hydrograph Incorporating Fryingpan-Arkansas Project Operations

The baseline Arkansas River hydrograph shown in Figure 1-2 was developed by using flows and Project operations that were observed from 1982 through 1994. Project operations that were designed to fulfill flow management recommendations from CDNR have been deleted from the hydrograph whenever a separate accounting of those operations was recorded. The purpose of these adjustments was to create a baseline Arkansas River hydrograph that reflects expected flows when the project is operated to optimize water available for consumptive use and for hydroelectric generation. In the next discussion, this baseline hydrograph will be compared to the flows needed to support natural resource values.

FIGURE 1-2

Arkansas River Baseline Hydrograph (Flows at Wellsville Gage 1982-1994)

Mean Daily Flow: October 1-September 31



Note: Water released from upper basin reservoirs as part of the flow augmentation program between July 1 and August 15 **has been subtracted** from this hydrograph. Water released during other parts of the year as part of the annual flow management program **has not been subtracted** from this hydrograph because those releases are not accounted for separately from other water deliveries.

Water Needed to Protect or Promote Critical Resource Values

Overview of Natural Resource Water Preferences by Location

Arkansas River Flow Preferences

When flow needs for identified resource values along the Arkansas River corridor are compared, there is significant similarity of needs during most of the water year as shown in Table 1-1. Since 1990, BOR has been able to operate the Fryingpan-Arkansas Project to meet many of these resource needs while still meeting the water delivery and storage requirements of water users. Prior to 1990, large releases of water in May-June, combined with lower flows the remainder of the year, created negative impacts to the fishery. This section briefly summarizes flow needs during different time periods, and it provides information about BOR's typical flow management practices during those periods.

November 1 to Start of Spring Runoff (typically around April 15) - The river's fish population and angling opportunities are well-supported by flows

TABLE 1-1

Arkansas River

Summary of Water Needs for Resource Values

Month	Reference Points: 1982-1994 Wellsville average daily flows (cfs)	Fisheries Needs	Boating Needs		Angling Needs			Wildlife and Riparian Needs	Other Needs
			Rafting	Kayaking	Fly	Spin	Float		
November	439	Flow Preference 300-500			Flow Pref 400 - 500	Flow Pref 700 - 1,200		Natural Hydrograph (variability of flows is positive)	
December	452								
January	446								
February	454							Except at high flows, changes in cfs do not have large impact	Dilution of early snow - melt benefits water quality during March and April
March	481						Flow Pref 900 - 1,200		
April	490		Flow Preference 1,500 - 2,000	Flow Preference 1,300 - 1,500					
May	1,189	Spring runoff flow for channel maintenance							
June	2,568								
July	1,727	Flow Preference 300 - 500						Lowest flows impact ground-water levels	
August	956								
September	477								
October	402								

ranging from 300 cfs to 500 cfs. The riparian community is dormant during this time, and very little boating occurs. Since 1990, BOR has typically transferred water from the upper reservoirs to Pueblo Reservoir during this time period. These releases have seldom created a situation in which reservoir releases caused total flows to exceed 500 cfs. Winter releases have also made it possible to meet flow targets for supporting fishery values after April 15 because a significant volume of water has already been transported to Pueblo Reservoir.

Snowmelt Runoff Period (typically April 15-July 15) - Higher flows experienced during this period are not optimal for the fish population or for angling, but spring runoff is an uncontrolled, natural function of rivers. Resource managers recognize that there must be a window to pass significant quantities of water. Conversely, the annual runoff periods usually provide flows that satisfy needs for recreational boating. The variability of the annual high flow events also provides river channel maintenance, habitat maintenance, and habitat creation functions that are critical for riparian and wildlife values. BOR attempts to avoid Project water releases during this time because the channel below Twin Lakes Dam has a limited capacity that is usually already filled with runoff water.

End of Snowmelt Runoff (typically July 15) to Labor Day - During this period, there is a significant difference in flow needs to support fish populations and recreational values. The fish population prefers flows from 300 to 500 cfs. Rafters prefer flows of 1,500 to 2,000 cfs, while kayakers prefer flows of 1,300 to 1,500 cfs. Float fishermen prefer flows of 900 to 1,200 cfs, spin fishermen prefer flows of 700 to 1,200 cfs, and fly fishermen prefer flows of 400 to 500 cfs. If the annual flow management program were not in place, BOR would not release water during this period to avoid unnecessarily storing water in Pueblo Reservoir. Water unnecessarily stored in Pueblo Reservoir increases the risk of spilling winter water, slightly increases the evaporation loss of Project water, and may adversely impact flatwater recreation at the upper reservoirs.

Labor Day-October 31 - Resource needs are similar during this period. Fish population and angling needs are well-supported by flows from 300 to 500 cfs, as is the riparian zone at the end of its growing season. While boating use would be better supported by flows of at least 1,000 cfs, the demand for such use declines sharply after Labor Day weekend. If the annual flow management program were not in place, BOR would not make water releases during this period for the same reasons cited in the discussion for the July 15 to Labor Day period.

Comparison of Natural Resource Flow Preferences to Baseline Arkansas River Flows

When evaluating the effect of various flows on natural resource values, it is important to understand how well baseline Arkansas River flows have supported natural resource values. During some periods of the year, baseline Arkansas River flows are substantially different than the preferred flows for many resource values. To facilitate a comparison between baseline Arkansas River flows and resource needs, the following hydrographs were developed to illustrate flows during the 1982 to 1994 period, when the Fryingpan-Arkansas Project was in full operation. Please note that flows released to fulfill the objectives of the annual flow management program have been subtracted from these hydrographs whenever a separate accounting of these releases was recorded. This means that summer flow augmentation releases have been subtracted out of the hydrographs, while releases during fall, winter, and spring under the annual flow management program have not been subtracted out of the hydrographs.

Two types of hydrographs are presented:

~ Figure 1-3 illustrates baseline Arkansas River flows on a year-round basis, incorporating Fryingpan-Arkansas Project operations. This is the same hydrograph that was presented earlier in this section.

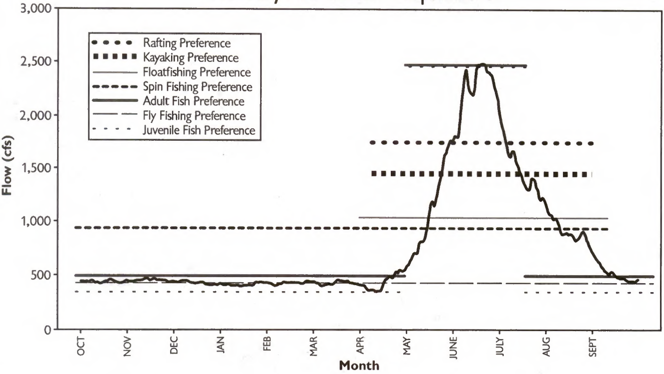
~ Hydrographs are also presented for the annual period between July 24 and September 7, which has been identified by river managers as a period of conflict between competing natural resource values. The additional detail provided in these hydrographs illustrates the difference between typical flows and resource values on a daily basis. Because this period is so critical, hydrographs have been developed for average, wet, and dry years (Figures 1-4 through 1-6). The average hydrograph incorporates all flows from the 1982 through 1994 period. Flows from 1995 were excluded from the average hydrograph because it was one of the wettest water years on record in the basin. The wet year hydrograph incorporates flows during the wet years of 1983, 1984, 1985, and 1995. The dry year hydrograph incorporates the dry years of 1988, 1991, 1992, and 1994.

These hydrographs are overlaid with the preferred flows for various resource values to illustrate how

FIGURE 1-3

Arkansas River Baseline Hydrograph with Flow Preferences (Flows at Wellsville Gage 1982-1994)

Mean Daily Flow: October 1-September 31



Note: Flow preferences that are shown are the median flow in the optimum flow range.

Note: Water released from upper basin reservoirs as part of the flow augmentation program between July 1 and August 15 **has been subtracted** from this hydrograph. Water released during other parts of the year as part of the annual flow management program **has not been subtracted** from this hydrograph because those releases are not accounted for separately from other water deliveries.

FIGURE 1-4

Arkansas River at Wellsville Gage Representative Average Year 1982-1994

July 24—September 7

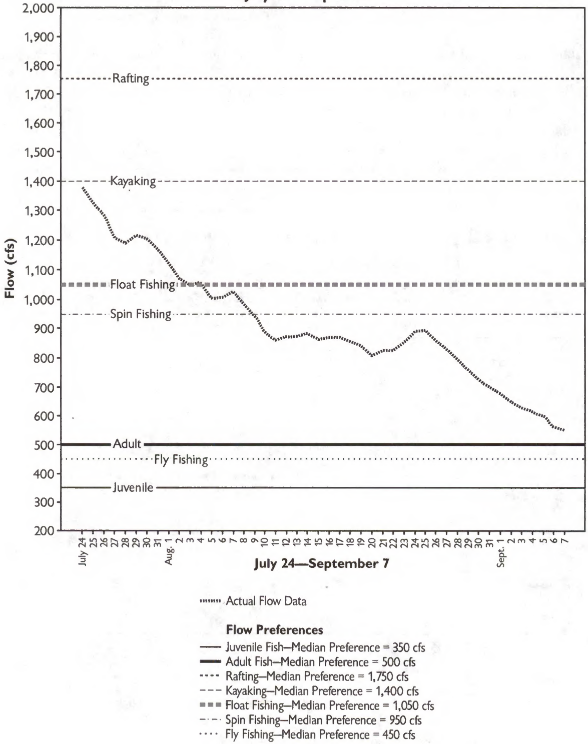
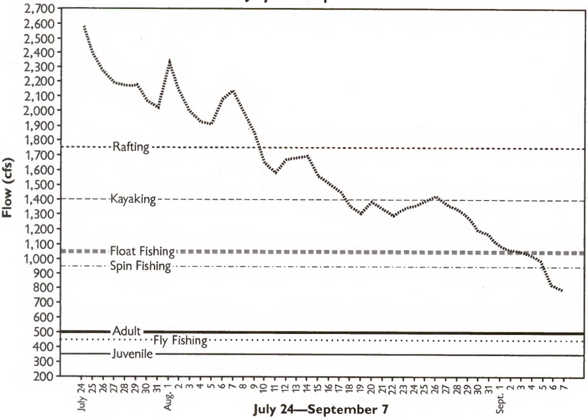


FIGURE 1-5

Arkansas River at Wellsville Gage
Representative Wet Year
(Synthesis of Flows From 1983, 1984, 1985, 1995)
July 24—September 7



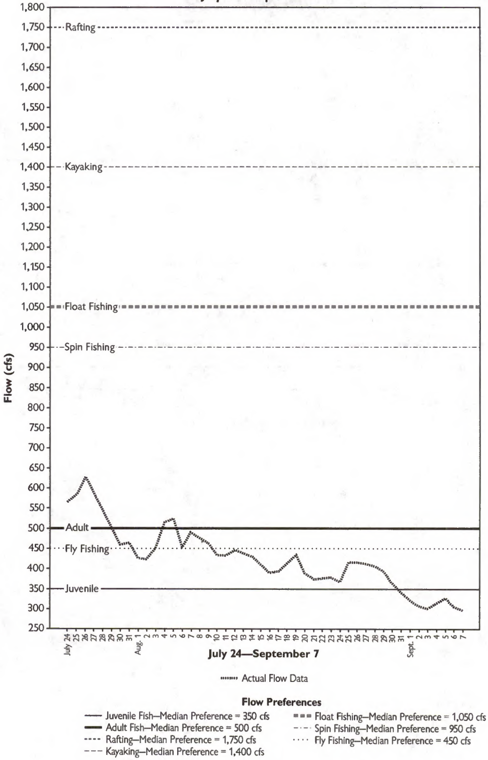
Actual Flow Data

Flow Preferences

- Juvenile Fish–Median Preference = 350 cfs
- Adult Fish–Median Preference = 500 cfs
- Rafting–Median Preference = 1,750 cfs
- Kayaking–Median Preference = 1,400 cfs
- Float Fishing– Median Preference = 1,050 cfs
- Spin Fishing–Median Preference = 950 cfs
- Fly Fishing–Median Preference = 450 cfs

FIGURE 1-6

Arkansas River at Wellsville Gage
Representative Dry Year
(Synthesis of Flows From 1988, 1991, 1992, and 1994)
July 24—September 7



well 1982-1994 flows supported those values. Table 1-2 provides daily flow values for this period so that a typical flow can be determined for any given day during the July 24-September 7 period.

The fact that the historic hydrograph is not neutral in relationship to natural resource values is demonstrated by examining specific flows. For example, in a dry year during the 1982-1994 period, flows recede to 700 cfs on about July 21. A 700 cfs flow represents a significant departure from the preferred flows of 350 cfs for juvenile trout. Similarly, in a dry year during the 1982 to 1994 period, flows reach 500 cfs on about August 12. This flow is significantly below the 1,500 cfs optimum preferred by rafters on the river.

Turquoise Reservoir, Twin Lakes, and Clear Creek Reservoir Water Level Preferences

Various resource values have similar water level needs at both Turquoise and Twin Lakes Reservoirs. All resources are benefitted by maintaining full reservoirs as much of the time as possible, and with as little water level fluctuation as possible. However, resource managers recognize that reservoir operations must continue in order to make water deliveries to water users. With this in mind, resource values are best supported when the reservoirs are kept as full as possible during May, when the vegetation growing season begins and when water temperatures become warm enough to support significant biological activity among fish populations.

Once the reservoirs are full at the end of spring runoff (typically around July 15), resource values are best supported if reservoirs are not drawn down by more than 10 feet between the fill date and October 1. Drawdowns of more than 10 feet reduce the primary productivity (basic food production) of the reservoirs, and reduce the area of feeding habitat for fish. In addition, drawdowns of more than 10 feet affect the scenic quality of the lakes for recreation use, and can make some boat ramps unusable. Gradual drafting

TABLE 1-2

Arkansas River at Wellsville Gage

Actual Measured Data (cfs), Representative Wet, Dry, and Average Years

Date		Wet Year Actual	Dry Year Actual	Avg Year Actual	DateWet Year		Dry Year Actual	Avg Year Actual	Actual
Jul	24	2,580	566	1,380	Aug	16	1,505	390	865
	25	2,373	586	1,323		17	1,455	395	866
	26	2,263	629	1,286		18	1,360	415	852
	27	2,188	590	2,309		19	1,305	436	835
	28	2,173	550	1,189		20	1,395	390	805
	29	2,178	505	1,216		21	1,335	375	820
	30	2,070	459	1,203		22	1,300	377	825
	31	2,018	466	1,166		23	1,340	380	848
Aug	1	2,330	426	1,120		24	1,361	368	886
	2	2,130	424	1,069		25	1,395	418	889
	3	2,005	451	1,049		26	1,431	415	853
	4	1,930	516	1,050		27	1,370	413	822
	5	1,915	525	1,003		28	1,344	407	789
	6	2,075	454	1,002		29	1,283	394	753
	7	2,145	491	1,025		30	1,200	364	722
	8	2,000	478	979		31	1,164	343	693
	9	1,860	464	942	Sep	1	1,096	323	675
	10	1,655	434	886		2	1,059	309	645
	11	1,585	434	859		3	1,053	303	627
	12	1,675	447	868		4	1,032	315	611
	13	1,685	440	871		5	989	329	596
	14	1,695	430	880		6	829	309	561
	15	1,560	412	869		7	801	299	552

Note: The representative wet year incorporates flows during 1983, 1984, 1985, and 1995. The representative dry year incorporates flows during 1988, 1991, 1992, and 1994. The representative average year incorporates flows during 1982-1994.

during the October-March period is preferred over drafting from July-September. Drafting during the July-September period can have negative impacts on fish population productivity, while October-March drafting avoids these impacts.

Clear Creek Reservoir supports a good quality, diverse fish community because reservoir water levels are fairly stable throughout the growing season and the reservoir topography provides an extensive shallow littoral zone. Stable reservoir levels, good access, scenic quality, and a high quality fishery also make Clear Creek Reservoir an attractive location for angling and boating. However, even small variations in reservoir levels can create significant changes in bank exposure because of the shallow areas near the edges of the reservoir. CDOW recently constructed a boat ramp extension to address this problem. All resources at this reservoir are best supported by a continuation of the current operation pattern, which minimizes water level fluctuations during the growing season.

Table 1-3 provides an overview of water level needs at Twin Lakes and Turquoise Reservoirs.

TABLE 1-3

Turquoise Reservoir/Twin Lakes

Summary of Water Level Preferences to Support Resource Values

Month	Reference Points: 1982-1995 Reservoir Operations (mean surface elevation in feet)		Fisheries Needs	Boating Needs	Angling Needs	Wildlife and Riparian Needs	Other Needs
	Turquoise	Twin					
November	9,860	9,189	Full as possible (send no more water down river than absolutely necessary)		Maintain level for ice fishing		Aesthetics-same as fishing and boating prefer-ences
December	9,855	9,189					
January	9,851	9,188					
February	9,845	9,187					
March	9,842	9,186	Maintain water levels; don't drop levels-filling is ok		Maintain water levels; filling is ok		
April	9,837	9,186					
May	9,842	9,186		High as possible minimal fluctuation			
June	9,864	9,193	Don't drop res. elev. by a total of more than 10 feet			Full reservoir by June	
July	9,867	9,193			Don't drop res. elev. by a total of more than 10 feet	Very limited drawdown is permissible, but maintaining full reservoir through August is optimal	
August	9,867	9,190					
September	9,867	9,190	Full as possible				
October	9,863	9,188					

Top of Conservation Pool:

Turquoise Reservoir - 9,869.4 feet

Twin Lakes - 9,200.0 feet

Water level needs for Clear Creek Reservoir are not portrayed because typically there is not a significant fluctuation of water levels at that reservoir.

Pueblo Reservoir Water Level Preferences

Operations to satisfy water storage and water delivery needs are significantly different at Pueblo Reservoir than at Twin Lakes and Turquoise Reservoirs. Instead of reaching its lowest water elevation in late winter and maximum elevation in July, Pueblo Reservoir typically reaches its lowest elevation in early November and its maximum elevation on approximately April 15. From April 15 to late October, the reservoir is gradually drafted. Recognition of these operational parameters, along with a longer growing season and year-round recreational use, produces different water level needs at Pueblo Reservoir. As a result, regardless of what plan of operations is implemented for Pueblo Reservoir, water level needs for various resource values will be in conflict during significant portions of the year as shown in Table 1-4.

TABLE 1-4

Pueblo Reservoir

Summary of Water Level Preferences to Support for Resource Values

Month	Reference Points: 1982-1985 Reservoir Operations (mean surface elevation in feet)		Fisheries Needs	Boating Needs	Angling Needs	Wildlife and Riparian Needs	Other Needs
November	4,850	Filling* ↓	Full as possible ↓				
December	4,857						
January	4,862						
February	4,865						
March	4,868	Gradual drafting* ↓				March and April filling reservoir is preferred ↓	
April	4,865				For safety and shore access, maintain an elevation of at least 4,860 to 4,880.5 feet; however anglers prefer high success rates, so biology needs must be strongly considered. ↓		
May	4,864		Maintain or fill ↓	As full as possible ↓		Reach full reservoir by May 15 ↓	For safety and shore access, maintain an elevation of at least 4,860 to 4,880.5 ↓
June	4,864						
July	4,858		Start rapid drawdown on July 15 to reduce surface area by 10% to 20%; maintain stable water levels from August 15 onward ↓			June, July, August-slight drawdown is permissible ↓	
August	4,854						
September	4,851						
October	4,846						

* driven by water demand and weather

Top of Conservation Pool - 4,880.5 feet

November-Mid-April - Boating and angling use is low during this period and the riparian community is largely dormant. While it is best for the warmwater fishery to have the water level as high as possible during this period, the fishery can survive if there is a sufficient pool of water during the fall and if the reservoir is filled during the winter. The WWSP, as currently operated, benefits the fishery in Pueblo Reservoir.

Mid-April-October (Growing Season) - Water level needs are in conflict during this period. To support boating, optimal water levels would be to have a full reservoir all season, but this conflicts with operational demands on the reservoir. Wildlife and riparian needs are best supported by a full reservoir on May 15, with slight drawdown starting anytime between May 15 and July 15. A slight drawdown allows the rooting zones of riparian plants to remain in contact with groundwater levels, but allows exposure of some reservoir substrate to grow annual vegetation species. The warmwater fish population is best supported by a full reservoir through July 15, followed by a rapid drawdown between July 15 and August 15. The rapid drawdown allows colonization of the exposed substrate by annual species during the growing season, which contributes to reservoir food supplies when reservoir levels rise again. Given these conflicting demands, the overall resource preference is to prevent drawdown as long as possible in the spring, within the confines of operational demands.

Summary of Natural Resource Water Preferences by Individual Resource Values

Water Preferences for Fish Populations

Arkansas River

The Arkansas River is noted for its exceptional brown trout fishery and for its developing rainbow trout fishery. Brown trout were the focus of this study because they are prevalent in the river, the population is self-sustaining, and any given operational program will influence rainbow trout in a similar manner. There are a number of nongame fish species present in the Arkansas River drainage, primarily found between Cañon City and Pueblo Reservoir. This area was not extensively studied, but flows that protect and maintain game species should also protect nongame species. Rare species, such as greenback cutthroat trout, Arkansas River darter, and redbelly dace, are all found in the upper Arkansas River Basin but have not been collected in the main stem river or reservoirs. Habitat needs for brown trout and rainbow trout were analyzed using the Instream Flow Incremental Methodology (IFIM).

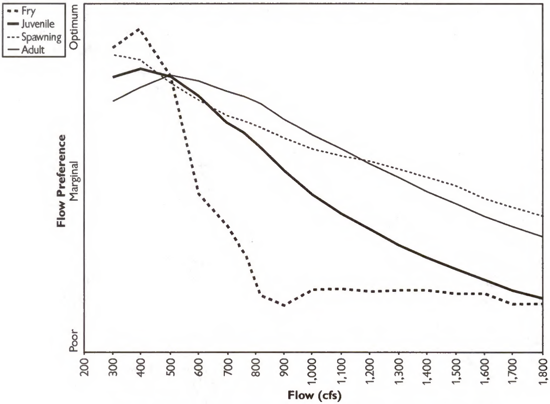
The two most important physical variables affecting fish habitat on the Arkansas River are velocity and depth. The further these variables are from the optimum value, the less likely that position is going to be occupied by a trout, because brown trout occupy positions in a stream that maximize net energy gain during foraging. The carrying capacity of a stream may be determined by available habitat and number of foraging sites. Increasing flows frequently produce unfavorable habitat conditions in the Arkansas River, as illustrated in Figure 1-7 and Appendix D.

Increasing velocity accounts for large drops in suitable habitat, particularly for small fish. For example, adult brown trout prefer a velocity of 1.3 feet per second for spawning, and velocities ranging from 0.9 to 1.3 feet per second for other activities, such as foraging. However, fry and juveniles prefer velocities of 0.3 to 0.7 feet per second. For all life stages, increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects.

As with velocity, increasing depth accounts for drops in suitable habitat, especially for small fish. Depths of 2.0 to 3.0 feet are optimum for adult brown trout spawning, while the suitable range of depth for spawning is 4.8 to 36.0 inches. Redds (spawning locations) are generally found at depths

FIGURE 1-7

Arkansas River Flow Preferences - Fish Population Habitat



Note: Fish population habitat preferences are shown for the Wellsville Stockyard location, which is considered representative of the reach from Turquoise Lake to Pueblo Reservoir. Flows below 300 cfs were not modeled.

of 12.0 to 36.0 inches. Juvenile brown trout have optimum habitat depths ranging from 0.9 to 1.7 feet. Finally, because brown trout are bottom-oriented, visual feeders, greater depth creates conditions that reduce the capture of drifting insects.

In coldwater environments, trout growth is a good indicator of the health of an aquatic ecosystem because it integrates all the biotic and abiotic variables that impact organisms and growth also reflects secondary effects of chronic stress. Pre- and post-runoff periods (April-May and July-September) are critical for brown trout growth and survival because there is a strong correlation between brown trout growth and discharge in the Arkansas River. Warmer water temperatures and poor prey availability make August and September particularly critical months for trout growth. The negative impacts from higher flows are not offset by releases of cooler water from Twin Lakes in August and September because these releases will not decrease water temperature for any appreciable distance downstream.

To optimize the amount of available brown trout and rainbow trout habitat, IFIM analysis showed that a year-round flow of 300 to 500 cfs should be maintained, measured at the Wellsville gage. This flow applies to all life stages on the Arkansas River from near Leadville to Pueblo Reservoir. However, agencies that manage fish populations and fish habitat recognize that the spring runoff must be passed through the system. The most beneficial operation for the fish population would be to ramp down runoff flows as soon as possible. This approach creates a greater period of time when maximum habitat area is available to the fish population during warm temperature periods.

Turquoise Reservoir and Twin Lakes

Turquoise Reservoir and Twin Lakes are primarily managed for lake trout and rainbow trout. Both reservoirs are oligotrophic, meaning that they are low in plant nutrients and oxygen is typically distributed evenly throughout the water body. Lakes of this type are typically suited to salmonids, which are oxygen sensitive. Primary and secondary production is relatively low in both lakes, translating into limited food supplies for fish species. Highest production occurs in the warmer months of July and August in the euphotic zone, where there is sufficient penetration of sunlight into the water column to support plant growth. Thermal stratification at this time, coupled with major adjustments in water levels, increases flushing of nutrients from the reservoir. Maintaining lake levels and controlling flushing rates is critical for successful fishery management, particularly for lake trout. To foster maximum biotic production in these reservoirs and to protect and maximize littoral habitat during the summer months, water surface elevation should be held at some stable level.

Filling and maintaining water levels in Twin Lakes and Turquoise Reservoirs as much as possible prior to October 1 ensures inundation of shorelines, which provide spawning habitat for lake trout adults. Lake trout spawn during October and November in Twin Lakes. Although frequently not possible, maintenance or continued filling during the winter ensures eggs remain inundated until hatching and fry emergence in February or March. Stable water levels from March to June provide habitat for fry and juveniles until they move to deeper water by June. Adjustments to water levels from June to August of more than 10 feet from full pool decrease primary and secondary production. Maintaining stable water levels from August to October lends stability to the reservoir, further enhancing productivity.

Clear Creek Reservoir

Management for kokanee salmon and rainbow trout are emphasized in Clear Creek Reservoir. Clear Creek Reservoir is the most productive of the three upper basin impoundments; however, it is still considered oligotrophic. Clear Creek Reservoir does not experience the daily adjustments to its water level that Twin Lakes and Turquoise Reservoirs do. As a result, Clear Creek Reservoir shows better survival and growth rates, including overwintering, of key species. Fish population needs are best met if Clear Creek Reservoir is maintained as full as possible on a year-round basis.

Pueblo Reservoir

Pueblo Reservoir is managed as a warm-, cool-, and coldwater fishery. The coldwater fishery consists mainly of rainbow trout maintained by annual stocking. The warm- and coolwater fishery is comprised primarily of black basses, crappie, bluegill, walleye, wipers, and channel catfish. Walleye, wipers, and channel catfish are stocked, while bass and crappie are not.

At times, the fluctuation of water levels in Pueblo Reservoir has been very severe. Major drawdowns have dropped the water level up to 49 feet below conservation pool. Depending on when these occur, they can have a major effect on the production of sport and forage fish.

Gradually filling Pueblo Reservoir from November through March allows for the inundation of vegetation and shoreline, which will provide food, cover, and spawning areas in the spring. A full reservoir from March to mid-July allows for good spawning habitat, high plankton levels to feed fry, and cover for adults, juveniles, and fry. Rapidly drawing the reservoir down from mid-July to mid-August exposes shoreline for recolonization of annual (nonriparian) vegetation and concentrates forage species for maximum utilization by sport species for growth. Maintaining stable water levels from mid-August to November lends stability to the reservoir, further enhancing productivity.

Water Preferences for Terrestrial Wildlife

Arkansas River

The wildlife values associated with the Arkansas River corridor and its riparian habitats, wetland habitats, floodplains, and reservoirs are diverse and important in maintaining the ecological stability of this region of Colorado. Riparian and wetland areas have been well-documented as the most productive and attractive of all wildlife habitats. Accordingly, riparian areas often provide the key resources that support biological diversity both in the riparian area and in nearby uplands. Terrestrial wildlife habitat functions provided by the Arkansas River include migration and dispersal routes and a forested connector between habitats for wildlife such as birds, bats, deer, elk, and small mammals.

In general, flow regimes that support a stable riparian community will also support the most stable and diverse assemblage of terrestrial wildlife. The same three factors that are critical in maintaining riparian habitats apply for wildlife as well.

Periodic flooding is required to maintain the species composition of the riparian plant community because this composition is based upon the tolerance of each species to frequency and duration of flooding. Flooding is also required to deposit sediments on which the riparian community can establish, and flooding provides nutrients for established riparian communities. High flows also provide temporary side channel and backwater habitats that are critical to some species. The scouring action provided by flooding also provides the unvegetated soil and substrates needed in the life stages of some bird and small mammal species. On the other hand, severe flooding of several weeks (sustained flows that are larger and last longer than the average annual high flow on the river) temporarily eliminates and may limit resident small mammal populations in the floodplain.

Almost all wildlife species are negatively impacted by unexpected, sustained, and large changes in flows that come at critical points in their life cycles. For example, birds that nest on sand and gravel bars during early spring can be disrupted by unexpected increases in flow that are large enough to inundate these habitats. Fish that spawn in backwater areas can be severely impacted by flows that are not high enough to inundate these areas during spawning periods. While many natural events, such as thunderstorms and rain-on-snow events, can drastically change flows, they are typically of a short duration and provide the type of flood disturbance that can be beneficial for wildlife species. Conversely, reservoir releases that produce flows outside the historic range of flows for extended periods of time can disrupt critical life stages of wildlife species. The species and life stages that are impacted depend upon the exact timing and magnitude of the reservoir releases.

Flow-dependent phenomena that can negatively impact waterfowl include damage to nests from dramatic water level fluctuations, removal or inundation of food sources by severe flooding, and desiccation of water-dependent insects and vegetation that serve as food sources when flow is reduced. Certain species, such as wood ducks, require flooded woodland areas for a portion of the year, and a flow regime that removes the peak flows that create these areas would be detrimental.

For raptors, the continued viability of riverine cottonwood-willow riparian sites is extremely important because they provide roosting and nesting sites. A viable fish population is critical to raptors as a food source, and flow fluctuations that drive small mammal prey species from the riparian corridor would be detrimental.

Similarly, some shorebird species, such as blue herons, rely upon viable riverine cottonwood-willow riparian areas. Shorebird species are even more sensitive to flow variations and flooding of riparian areas because they are dependent on areas such as mud flats, shallows, and gravel bars for feeding purposes. Some shorebird species, such as avocets, also nest in these habitats, so unexpected flood events can severely impact their populations.

The spring and summer breeding period of amphibians and reptiles makes them especially vulnerable to dramatic changes in riverflow that affect sidewaters and backwaters. For examples, reptiles and amphibians can be negatively impacted by reservoir releases of excessively cold water that invade sidewaters and backwaters because they will not feed or breed in water temperatures of less than 50 degrees.

Reservoirs

Wildlife management agencies recognize that reservoirs are not constructed to support optimal wildlife values. However, long-term operations have been somewhat consistent, so certain wildlife species have adapted to and use the habitats surrounding the impoundments. Accordingly, significant modification of reservoir operations away from historic practices that could impact these habitats will, in turn, have an impact on wildlife populations. At Pueblo Reservoir, maintaining a full pool for a longer period of time during the growing season would benefit riparian values, which would, in turn, benefit wildlife populations. However, maintaining a full pool for a longer time during the growing season could be negative for the fish population, and many wildlife species depend on the fish population as a food source. Finally, the basinwide impact of reservoir levels must be considered. If large releases are required from the upper reservoirs to maintain Pueblo Reservoir water levels, the negative effects on the wildlife populations at Turquoise and Twin Lakes Reservoirs may outweigh the gains at Pueblo Reservoir.

Water Preferences for Riparian Habitats

Arkansas River

Riparian and wetland resources in the study reach are largely modified. A century of road and railway construction, dams, irrigation development, conversion of land to agriculture, residential development, and other modifications have influenced the riparian resources present today. Modifications are generally centered around:

~ Vegetation manipulation -- land use activities such as recreation and grazing, introduction and invasion of exotic vegetation, selective harvesting of certain riparian species, etc.

~ Watershed alteration -- land use activities such as roads, logging, agriculture, mining, and urbanization that affect factors such as infiltration, runoff, sediment supply, and water quality.

~ Direct modification -- channelization, draining, filling, conversion to other uses, etc.

~ Hydrology alteration -- water diversions, water importations, storage, etc.

Capability and potential of most riparian and wetland resources within the study area is determined a great deal by the natural shape and form of the river corridor that is created by the geology of the area. Much of the Arkansas River is bounded by rock and is narrow and confined due to the deep canyon landform. Many reaches that were confined naturally are now even more confined because of railway and highway construction. The canyon setting, coupled with high flows, limits soil development and plant rooting abilities. However, some reaches are less confined, and have meander bars and streamside margins with a limited band of riparian vegetation. Downstream of Cañon City, and in the short reach between Leadville and Granite, floodplains with substantial riparian and wetland vegetation have developed. The majority of the riparian and wetland vegetation is composed of grasses-sedge-rush, willows (several species), alders, birch, and cottonwood.

Rather than quantifying the exact changes to be expected from flow alterations, the focus of this water needs assessment was to review the literature related to riparian communities and identify general relationships and effects that should be considered in managing flows. Determining the exact impact of either large- or small-scale flow alterations on Arkansas River riparian communities would require an exhaustive, long-term study that is beyond the scope of this water needs assessment.

The unique setting of each riparian area along the river, in terms of geomorphology, groundwater levels, and gaining/losing stream reaches, also makes it difficult to predict the effects of flow modification without intensive local study. For example, in the Brown's Canyon reach, each 100 cfs increase in flows increases the water surface elevation by 3 to 5 percent, while in the Floodplain reach, the increased water surface elevation is less because of the broader channel. However, the impact from a 100-cfs increase in flows on vegetation will be greater in the Floodplain reach because the vegetation line is closer in elevation to the mean annual water surface elevation.

There are three factors that are critical in maintaining riparian habitats: l) maintaining the historic frequency and duration of floods, 2) maintaining growing season groundwater levels in areas adjacent to the stream, and 3) maintaining the annual and seasonal variation in the hydrograph.

The riparian community is a product of the long-term hydrology of the river, so fairly large variations in flow for 1 year will likely not have a significant effect. Consistently higher or lower flows, however, will likely alter the extent and location of riparian vegetation. The outcome of flow manipulation is more likely to be the evolution of a new riparian area that is a different width and elevation, rather than elimination, enhancement, or large changes in the overall acreage of the riparian community.

For example, a consistent increase in growing season base flows will likely alter the channel width in some reaches by inundating plant communities and eroding fine sediments that provide growing mediums for riparian species. In addition, streambanks may experience catastrophic blowouts as the river attempts to adjust its channel to the new hydrology.

Conversely, consistently lower base flows during growing season will allow the encroachment of vegetation into channel margins. The lower water table associated with lower base flows may place water beyond the reach of the root zone of some established plants. The riparian area may experience a decrease in basal area, density, and width. However, the lower flow may allow colonization of areas that were previously inundated and could not support riparian vegetation.

Finally, alteration of the annual and seasonal variability in flows can eliminate processes that are essential to the survival and evolution of riparian zones. Periodic low flow episodes allow plants to become established in areas where they will later trap and retain sediment. Scouring associated with high flow events creates habitat areas where early successional plants can become established.

Reservoirs

Maintaining the historic pattern of operations at Turquoise and Twin Lakes Reservoirs will maintain the plant communities that evolved under those conditions. Any drawdowns that occur more quickly than the historic pattern will likely limit and/or modify wetland and riparian potential at these reservoirs.

Pueblo Reservoir operations do not currently favor wetland and riparian vegetation because of the timing and magnitude of drawdowns. Accelerating the delivery of water from the upper reservoirs to Pueblo in order to maintain a fuller pool during the growing season would be unlikely to enhance the wetland resource at Pueblo Reservoir. The quantity of water required to enhance Pueblo Reservoir's riparian values is much larger than is available for delivery from upper reservoirs. Similarly, maintenance of a pool level that enhances riparian/wetland values would require operational changes that are presently outside of the reservoir's operating principles.

Water Preferences for Recreation

Arkansas River

The upper Arkansas River is the most intensively used river in the United States for white-water boating, and is heavily used for other recreation activities as well. Based on BLM/USFS/Colorado State Parks records in 1996, an estimated 590,000 visitors used the river for recreation. This represents an increase of 251,000 users, or 74 percent, over the estimated 1990 usage level of 339,000 recreation users. During the summer usage period in July 1996, there was an estimated 176,133 visitors using the river, or approximately 5,680 users per day.

Recent estimates developed by the Colorado Division of Parks and Outdoor Recreation (CDPOR) and CDOW indicate that approximately 50 percent of river use represents boating activity, 30 percent represents sightseeing, between 5 and 16 percent represents fishing, 5 percent represents picnicking, and 3 percent represents camping. The range of river angling use reflects estimates calculated by CDPOR and CDOW using different methodologies.

This report focuses primarily on two recreation activities: fishing and boating use. Of the river angling user days, 54 percent is fly fishing, 28 percent is lure fishing, and 18 percent is bait fishing. Estimated river usage in 1995 by anglers ranges from 23,753 (CDPOR estimate) and 67,973 (CDOW estimate). Boating usage of the river during 1996 was estimated at 251,268 boaters. Of this total, 91 percent was commercial rafting users in rafts carrying an average of seven persons. The remaining 9 percent was private individuals, who were typically kayaking with an average of one person per kayak.

User preferences for water levels were analyzed using various user surveys. Users in both boating and angling recreation activities were asked to judge the acceptability of various flow levels for their respective activities. The optimum flow preferences for each type of recreational user are shown in Table 1-5 and Figure 1-8.

TABLE 1-5

Optimum Flow Preferences for Recreational Activities

Recreation Activity	Optimum Flow Range	Median Optimum Flow
Fly Fishing	400 - 500 cfs	450 cfs
Spin Fishing	700 - 1,200 cfs	950 cfs
Float Fishing	900 - 1,200 cfs	1,050 cfs
Kayaking	1,300 - 1,500 cfs	1,400 cfs
Rafting	1,500 - 2,000 cfs	1,750 cfs

Source: Page 4-1, EDAW Arkansas River Study, October 28, 1997

Turquoise Reservoir and Twin Lakes

Twin Lakes Reservoir and Turquoise Lake Reservoir reported 26,562 user days and 49,610 user days, respectively, in 1996.

Survey results indicate that users prefer higher lake levels. However, changes in reservoir levels do not appear to have a pronounced effect on recreation activities and opportunities.

Regardless of the given reservoir level, a majority of the users indicated that they would return to the site again under identical conditions. These results suggest that while reservoir water levels do influence the overall quality of the recreation experience, they do not play a significant role in determining user behavior patterns for either boating or fishing activities.

Pueblo Reservoir

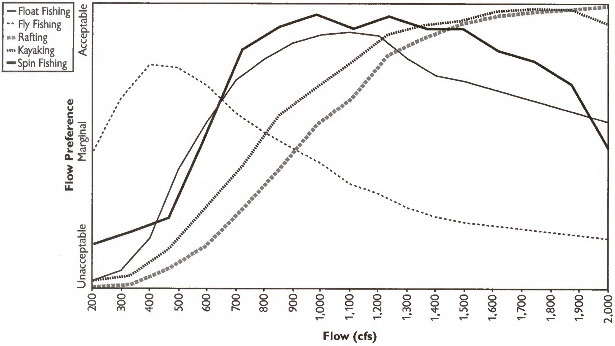
Lake Pueblo State Park, with more than 1,543,000 visitors in 1996, was the fifth most visited recreation area in Colorado. This figure is an increase of 41 percent over 1990 use levels.

Survey results indicate that users prefer higher lake levels. Recreation users at Pueblo Reservoir indicated that they were more strongly affected by water levels than users at Turquoise or Twin Lakes Reservoirs. A majority of users expressed that the quality of their recreation experience, especially the scenic quality, was negatively affected at lower lake levels. However, changes in reservoir levels do not appear to have a pronounced effect on user behavior patterns. This may be in part due to the fact that Pueblo Reservoir users were, and typically are, exposed to much greater drawdowns than users at Turquoise or Twin Lakes Reservoirs. Conditions at Pueblo Reservoir were reported to improve considerably with regard to safety, shoreline access, and visual quality at elevations above 4,850 feet.

The amount of angling use at Pueblo Reservoir is also dependent on the quality, in terms of size and number, of the fish populations being sought.

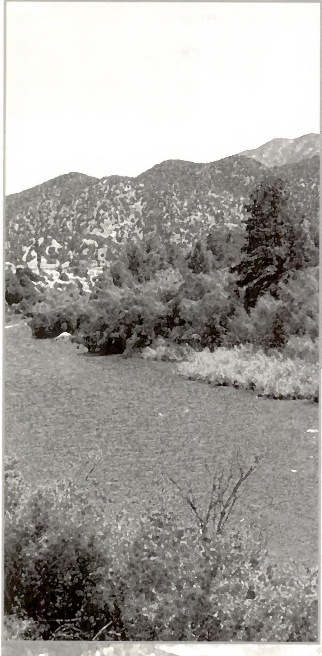
FIGURE 1-8

Arkansas River Flow Preferences - Recreation



Therefore, fishing recreation can also be correlated with water levels that provide preferred water elevations for production of warmwater fish species. However, reservoir elevations that promote productivity within the fish population are typically in conflict with preferred elevations for boating. Given this conflict, it appears that anglers will prefer conditions that provide safety, shoreline access, and visual quality, as long as the fish population provides satisfactory catch results in terms of size and number.

Arkansas River Water Needs Assessment



Section 2. Introduction

By:

Dan Muller, Bureau of Land Management
Roy Smith, Bureau of Land Management

Arkansas River Water Needs Assessment

Section 2. Introduction

By:

Dan Muller, Bureau of Land Management
Roy Smith, Bureau of Land Management

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding river-flows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Appendices

Section 2. Introduction

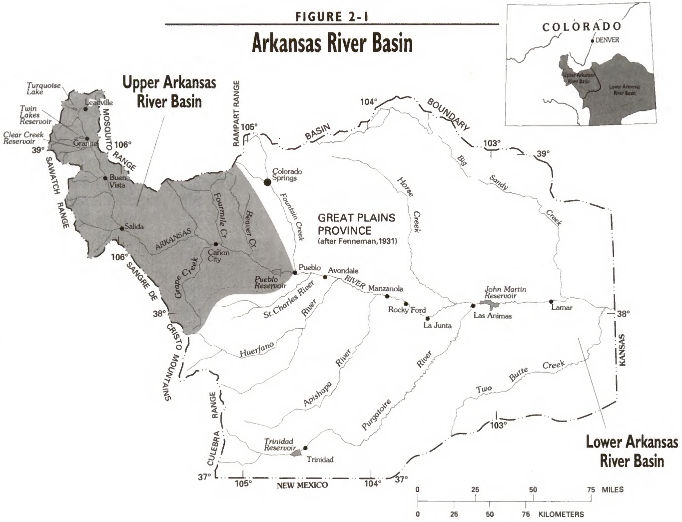
The Upper Arkansas River Basin and its related reservoirs between Leadville and Pueblo are an important hydrological, biological, and recreational resource. Competing demands for water have made it necessary for management agencies to thoroughly understand the effects decisions can have on various resources and to carefully weigh the user preferences, environmental requirements, and legal and administrative constraints associated with decisions that affect water uses, streamflow, and reservoir levels.

Physical Setting

The Arkansas River is the major drainage system in southeastern Colorado (Figure 2-1). The river flows from its headwaters above 12,500 feet in the Mosquito Mountain Range northeast of Leadville through Pueblo into the Great Plains. Other headwater sources to major tributaries are located in the Sawatch Range near Leadville and Sangre de Cristo Mountains between Salida and Cañon City.

FIGURE 2-1

Arkansas River Basin



The change in topography over the river's course is dramatic. From a high-altitude, alpine environment above timberline, it flows through steep confined canyons and broad open valleys until reaching the expansive, flatter Great Plains.

The variation in climate is similarly dramatic. High altitude snowfall and subsequent spring runoff in the Mosquito, Sawatch, and Sangre de Cristo Mountain Ranges predominate the river's flow regime. Over 200 inches of snow fall annually in these mountains, with a mean annual daily temperature of 25 °F. However, the Upper Arkansas River Valley, which comprises the central portion of the basin between 7,000-8,000 feet in elevation, provides a relatively mild climate. A mean annual daily temperature of 46 °F, with mean annual snowfall of 44 inches and annual rainfall of 10 inches, make this an ideal location for recreational opportunities along the river corridor. Conditions change once again as the river approaches the Great Plains. The mean annual daily temperature rises to 55 °F and the climate becomes substantially drier.

The river itself is a single-channel, meandering, and moderately entrenched system. It has achieved a stable channel composed of coarse imbedded material generally larger than 0.1 inch in diameter. The sinuosity is moderate, normally falling between 1.2 and 1.5. Generally the river follows a sequence of low- to moderate-gradient stretches punctuated by short, high-gradient drops with the formation of rapids. The channel is typically 60-100 feet in width, with average water depths usually less than 6 feet and pool depths up to 20 feet. The primary channel adjustment mode is lateral migration associated with meandering. However, adjustments in the geomorphological character are minimal due to the multiple structural controls (e.g., dams, highway) within the basin.

In the upper basin, within Lake County, there are three storage reservoirs operated by the Bureau of Reclamation (BOR) as part of the Fryingpan-Arkansas Project: Turquoise and Twin Lakes Reservoirs and Mount Elbert Forebay. The Pueblo Board of Water Works also operates Clear Creek Reservoir on Clear Creek. From the Leadville area, the Arkansas River flows in a southerly direction through Browns Canyon and turns east as it flows from Salida towards Cañon City. The landscape is rugged as the river flows between narrow canyons and open parks. Below Cañon City, the river enters the eastern plains landscape as it continues its course toward Pueblo Reservoir.

The area included in this assessment comprises the public lands and resources associated with Turquoise, Twin Lakes, and Clear Creek Reservoirs; the main stem of the Arkansas River downstream from those reservoirs to Pueblo Reservoir; and Pueblo Reservoir, for a total of about 150 river miles.

Purpose

The purpose of this assessment is to provide information about the legal and institutional, hydrological, and biological and recreational resource values that are of significance to the instream flows of the upper Arkansas River. The assessment relates riverflows and reservoir levels in the upper basin to these values. This assessment is the direct result of a memorandum of understanding (MOU) signed in 1992 by those Federal and State agencies responsible for managing resources in the Upper Arkansas River Basin, including the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), USDA Forest Service (FS) and Colorado Department of Natural Resources (CDNR). A copy of the MOU can be found in Appendix A. These agencies have been cooperating and collaborating in the development of annual flow recommendations that help guide BOR's operations of Arkansas River reservoirs. A copy of these recommendations can be found in Appendix B.

The MOU states that the primary objective of the assessment is to provide useful information about resource needs, water use constraints, and management opportunities to planners and decisionmakers. Specific objectives outlined in the MOU are to:

1. Develop an understanding of the hydrology and geomorphology of the river and the reservoir operations that affect the river flows.

2. Develop an understanding of the relationships between streamflows, reservoir levels, and the resource values they affect. The resource values to be considered include: fish and wildlife habitat; fishing recreation; boating recreation; water quality; riparian habitat; and aesthetics.

3. Identify and evaluate the management opportunities and strategies to provide water for maintaining and improving the resource values.

4. Determine the physical, legal, and institutional factors that influence the ability to implement the management opportunities and strategies.

This report is not a decision document. However, it may be used to identify opportunities and to support future management decisions and strategies of appropriate agencies and institutions. Any future management actions supported by this report will require compliance with Federal laws (e.g., National Environmental Policy Act) and State laws.

Existing Management and Institutional Framework

The legal and administrative framework governing the Arkansas River is extremely complex (refer to Section 3). Each of the agencies that signed the MOU has specific requirements and legal responsibilities for managing the land and water resources in the Upper Arkansas River Basin. Some of the laws, agreements, and plans that affect the management of these resources are described below.

Colorado Water Law

Interstate compacts, Colorado water law, Federal legislation, and numerous plans and institutional arrangements govern the management of reservoir operations, water allocation, and natural resources in or adjacent to the Arkansas River. The Colorado Division of Water Resources administers allocation of water in accordance with State laws and regulations. The Constitution of the State of Colorado recognizes the doctrine of prior appropriation as the principal means of allocating the usage of the waters of the State. As a result, the State Engineer regulates numerous agricultural, municipal, industrial, and other water rights. Obligations for water deliveries to water rights holders and to holders of water service contracts largely determine how riverflows are managed.

The Arkansas River includes both native water originating within the basin and water imported from the west slope (Colorado River Basin) into the basin by BOR's Fryingpan-Arkansas Project and several other non-Federal diversion projects. Therefore, two river compacts, the Colorado River Compact and the Arkansas River Compact, affect management of flows in the upper Arkansas River. The operation of the transbasin diversion projects and several reservoirs located in the basin directly affects Arkansas River flows.

It is unlikely that any surface water remains available for appropriation in the Arkansas River Basin at this time. Water management in the Upper Arkansas River Basin is complex and highly regulated under the authority of the State Engineer (CRS 37-92-301 and 501 et seq.). There may be opportunities, however, for maintaining and improving resource values within the existing legal, institutional, and management framework. Arrangements have been negotiated in the past to enhance certain water-dependent resource values (i.e., fisheries and float-boating activities on the Arkansas River). Negotiated agreements for reservoir releases, special-use permit stipulations, river exchanges, reservoir release substitutions, or point of-diversion transfers are some of the options that may be available to preserve and enhance the various key resource values.

Fryingpan-Arkansas Project Operating Principles

BOR's Fryingpan-Arkansas Project was authorized by Congress "...for the purposes of supplying water for irrigation, municipal, domestic, and industrial uses, generating and transmitting hydroelectric power and energy, and controlling floods, and for other useful and beneficial purposes incidental thereto, including recreation and the conservation and development of fish and wildlife" (Act of August 16, 1962, P.L. 87-590, 76 Stat. 389). Users of Project water are located in the Southeastern Colorado Water Conservancy District. Project reservoirs located in the Arkansas River Basin are Turquoise Lake and Twin Lakes Reservoirs near Leadville and Pueblo Reservoir near Pueblo. Recreation facilities and activities at the former two reservoirs are administered by the FS and at the latter reservoir by the Colorado Division of Parks and Outdoor Recreation (CDPOR).

Arkansas River Recreation Management Plan

Under a cooperative management agreement, BLM and CDPOR have implemented this plan in the Arkansas Headwaters Recreation Area. This plan recognizes the interrelationship of recreation (e.g., boating, fishing) with the fisheries, aquatic habitats and ecosystems, riparian vegetation, and water quality of the Arkansas River. The agencies direct specific actions to maintain the quality of these resources and the opportunities they present. The plan directs recreation management on the main stem from Leadville to Pueblo Reservoir and it directs coordination with the river corridor communities, local governments, land owners, and water users.

Pike and San Isabel National Forest Plan

This land use plan provides general direction for water resources, including management adjacent to Twin Lakes and Turquoise Reservoirs. Specific management goals are to provide healthy, self-perpetuating plant communities; meet water quality standards; provide habitats for viable populations for wildlife and fish; and provide stable stream channels and still water-body shorelines. An earlier agreement with BOR states that efforts will be made to maintain specified minimum pool elevations for Turquoise Reservoir; however, Project needs could dictate further lowering (1976 Memorandum of Understanding). This agreement also states that the FS is responsible for administration and management of all recreation activities associated with the water surface of Turquoise Reservoir.

Lake Pueblo State Park Management Plan

This plan governs the management of the 4,646-surface-acre reservoir and its adjacent lands by CDPOR. The reservoir is part of the Fryingpan-Arkansas Project, operated by BOR. Goals of the State Park Management Plan are to maintain safe water-based recreation activities, a variety of complementary land-based recreation facilities, the quality of the reservoir fishery, and the viability of reservoir-based concessionaires. The park is managed by agreement with BOR.

Wildlife Management Guidelines for the Upper Arkansas River Basin

The Colorado Division of Wildlife (CDOW), under these guidelines, has set management objectives for the upper Arkansas River, the upper Fryingpan-Arkansas reservoirs, and Pueblo Reservoir. For the main stem, CDOW is to optimize the production of self-reproducing brown trout populations and encourage the development of self-reproducing rainbow trout fisheries. Within the basin, CDOW will maintain healthy populations of bighorn sheep, deer, turkey, and waterfowl, while also protecting and enhancing populations of blue herons, peregrine falcons, and bald eagles. For the upper reservoirs, the objective is to develop and sustain lake trout populations. CDOW's objective for Pueblo Reservoir is to optimize the production of warmwater fish populations.

Assessment Approach

This assessment was a 6-year effort involving a team of Federal and State agency professionals. Early phases of the study focused on collecting and reviewing literature and data (scoping), while latter phases dealt with analyzing legal and institutional, hydrologic, and resource values; evaluating water availability and river-reservoir resource management needs; and reporting the results of the effort (Figure 2-2). Each specific step of the assessment process is described below.

Project Scoping

The scoping process involved a thorough review of literature, discussions with pertinent field personnel and interested parties, and a reconnaissance-level field assessment. Aerial photographs and maps were used to assist with designing specific studies. During this step, interagency cooperative agreements were arranged and specific techniques or methods were selected. This step involved careful coordination between the field personnel of the agencies involved in the MOU and other affected agencies, including offices of the U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and Colorado Department of Public Health and Environment. The scoping resulted in the MOU, documented summaries of literature reviews, and selected methods.

Institutional and Legal Analysis

Both existing and prospective water management were described and analyzed to evaluate both the legal and institutional availability of water; this information may be used to implement alternative management actions. Political considerations were also included in the analysis so that decisionmakers can evaluate water management opportunities that are realistic and feasible. This analysis, which is Section 3 of this report, documents water management options for both the river and reservoirs.

Hydrologic Investigation

The hydrologic investigation included analysis of historic streamflow and reservoir operations data to determine typical and extreme levels of riverflow and reservoir storage contents. This data is relatively abundant in the basin and was analyzed to determine historical trends reflective of water management and use. Reservoir operation and riverflow models were used to simulate various management opportunities. The hydrologic investigation provided the physical resource background for analyzing the water dependency, both river and reservoir, of the resource values identified in the next step. It is Section 4 of this report.

Resource Values Assessment

Significant resource values were evaluated to determine their dependence on reservoir levels, riverflows, or other water-related conditions. This step involved close interaction among project team members with different types of expertise. Results of the hydrologic investigation, including hydraulic, geomorphic, and chemical analyses, were examined in conjunction with evaluations of resource values to develop resource-specific riverflow and reservoir level needs. This assessment documents the need for water to maintain, as well as enhance, fish and wildlife habitat and recreational pursuits, such as rafting and fishing (i.e., fly fishing, spin casting, and float fishing). For the purpose of this assessment, the term "resource values" incorporates a multitude of objective natural resource related requirements (e.g., species like brown trout require specific river conditions to survive) and subjective user preferences (e.g., activities like rafting and fishing require flows to support user experiences). During this step, data was collected to supplement available literature and other information.

Flow requirements for fish habitat and certain recreation values (e.g., boating depths) were analyzed using the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish

FIGURE 2-2

Arkansas River Water Needs Assessment

Values (Scoping)	Analysis	Evaluation	Results
Legal/ institutional	Water rights Reservoir operations	**Water Availability**	
Hydrology/ geomorphology	Streamflow Channel processes Physical setting		
Fisheries	Brown & rainbow trout–Ark. River; lake & rainbow trout–upper reservoirs; black bass & crappie–lower reservoirs	**River Flow and Reservoir Level Needs**	**Assessment Report**
Wildlife	Herons–river and lower reservoir; waterfowl & shorebird–reservoirs; threatened & endangered species, sheep, & raptors–river and reservoirs		
Boating	Boating–river; boating safety–river, navigation & access–reservoirs; boating–lower reservoir		
Fishing	Fishing opportunities–river and reservoirs; shoreline access–reservoirs		
Water Quality	Relationships to river flows & reservoir levels (macroinvertebrates, production, water quality standards)		
Riparian	Woody species–river; habitat–river and reservoirs		
Aesthetics	Desirable shoreline conditions–reservoirs		
1993-95	**1994-96**	**1996-97**	**1997-99**

and Wildlife Service. Fish habitat modeling was accomplished with the Physical Habitat Simulation System (PHABSIM), the computer modeling component of IFIM. The natural resource assessment is Section 5 of this report.

Recreation user surveys were specifically designed and implemented for the purpose of assessing recreation water needs within the study area; one was oriented towards river recreation, and one was oriented towards reservoir recreation. In addition to these user surveys, several other secondary data sources were reviewed and evaluated. The recreation assessment is Section 6 of this report.

Using this approach, reservoir levels and riverflows were evaluated and identified to support the resource values as shown below:

Fisheries

~ Flow requirements to optimize the brown trout fishery and to develop the rainbow trout fishery in the Arkansas River
~ Upper reservoir levels and conditions to sustain and develop lake and rainbow trout populations
~ Pueblo Reservoir levels and conditions for black bass and crappie warmwater fish production

Wildlife

~ Flow and Pueblo Reservoir level requirements to maintain habitat for heron populations
~ Reservoir levels to maintain waterfowl and shorebird populations
~ Flows and reservoir levels to protect bighorn sheep, peregrine falcons, bald eagles, osprey, golden eagles, and other sensitive, threatened, or endangered species and to maintain habitat associated with these animals

Boating

~ Flows for various types of experiences and boats on the river
~ Flows for boating safety on the river
~ Reservoir levels for navigability and accessibility (e.g., shorelines, docks)
~ Pueblo Reservoir levels for various types of craft and experiences
~ Reservoir levels for adequate boater access

Fishing

~ Flows and reservoir levels for various types of fishing opportunities
~ Reservoir levels for access to shorelines

Water Quality

~ Flows and reservoir operations that may indirectly affect resource values (e.g., macroinvertebrates, primary productivity, water quality standards) by substantially changing water quality (water quality is addressed in Appendix E)

Riparian Habitat

~ Flow requirements to maintain significant areas of riparian woody species
~ Pueblo Reservoir levels that may be required to maintain cottonwood trees and other types of woody vegetation

Aesthetics

~ Upper reservoir levels required for desirable shoreline conditions

Additionally, the implications of various flow regimes on these resource values were analyzed using hypothetical scenarios (Appendix F).

Findings and Conclusions

In the final step, the legal and institutional analysis, streamflow and reservoir hydrologic analyses, and resource value assessment were integrated to produce a summary of findings (Section 1 of this report). The findings present water amounts needed to protect or support critical resource values.

Arkansas River Water Needs Assessment

Section 3. Institutional and Legal Analysis

By:

Teresa Rice, University of Colorado
Natural Resource Law Center
Roy Smith, Bureau of Land Management

Arkansas River Water Needs Assessment

Section 3. Institutional and Legal Analysis

By:

Teresa Rice, University of Colorado
Natural Resource Law Center
Roy Smith, Bureau of Land Management

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding river-flows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

This text was developed by the authors in concert with water users and managers throughout the Arkansas River Basin. The text does not represent the official legal opinion or legal position of any of the individuals or organizations who were involved or interviewed, nor does it represent the official legal opinion or legal position of any of the agencies that participated in the *Arkansas River Water Needs Assessment*. The purpose of this document is to present a legal and institutional summary of water management in the basin that can serve as an informational foundation for future water management discussions.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Section 3. Institutional and Legal Analysis

Later sections of this report focus on identifying the flows needed in the Arkansas River to meet public expectations for maintenance of natural systems and for recreation. The purpose of this section is to provide a context for interpreting those needs in light of institutional and legal arrangements for river management. Some of the legal and institutional arrangements have been in place since the 1860's, yet remain dynamic today. It is important that thousands of legally established water rights are not impacted by any modification of flow regimes between the headwaters of the Arkansas River and Pueblo Reservoir to better support natural resource values.

The following legal and institutional analysis does not explicitly recognize the underlying economic and cultural systems on which the water rights, laws, and institutions are based. Therefore, before proceeding to the detailed legal and institutional analysis, the following paragraphs provide a brief overview of the cultural and economic systems associated with the Arkansas River.

The Arkansas River is one of the economic and cultural foundations of southeastern Colorado. Water diversions from the river have supported the development of an extensive and diversified agricultural sector and have supported the development of numerous cities with broadly diversified industrial and commercial economies. Diversions have also supported the transformation of Colorado's arid short-grass prairies into residential areas with lawns, lakes, parks, and gardens. Simultaneously, residents of southeastern Colorado have come to recognize the Arkansas River as a recreational and natural asset of nationwide caliber, and have expectations that cultural and economic water needs can be met while maintaining a healthy and sustainable river environment.

The Arkansas River watershed comprises almost 25 percent of Colorado's land area, and approximately 21 percent of Colorado's population resides in the watershed. Approximately 745,000 persons depend on the Arkansas River and its tributaries for water supplies, including 360,000 residents of Colorado Springs, and 100,000 residents of Pueblo. By the year 2020, the watershed population is projected to grow to 984,000 residents.[1]

Total personal income for the watershed is approximately \$12.271 billion.[2] Much of this income is produced through economic activity directly dependent on water use, such as agricultural and industrial uses. Even businesses not directly dependent on water supplies as a basis for business processes must have reliable supplies to meet the daily needs of their workers for drinking, cleaning, and hygiene.

Total farm income in the watershed is approximately \$203.388 million, or 1.66 percent of the total income for the watershed. However, basinwide statistics can mask the importance of agricultural income in specific counties. For example, the agricultural income as a percentage of total income is very high in some counties: Cheyenne - 44 percent, Crowley - 26 percent, Kiowa - 48 percent, Prowers - 19 percent.[3] The total farm income is produced on approximately 397,000 acres of irrigated lands within the watershed.[4]

[1] U.S. Census Bureau and State of Colorado - Division of Local Government, 1997.

[2] U.S. Bureau of Economic Analysis, 1997.

[3] U.S. Bureau of Economic Analysis, 1997.

[4] Kansas v. Colorado, Special Master's Second Report, June 5, 1997.

The economic and cultural value of Arkansas River water is indicated by both water and land prices. For example, the typical cost to permanently purchase an acre-foot of water native to the basin (not imported) is between $2,000 and $3,000 per acre-foot (agricultural diversions with a firm yield established through a long record of historic diversion).[5] Similarly, urban real property values are dependent upon access to a reliable municipal water supply system.

Diversion and storage from the Arkansas River allow water to be delivered in a convenient and flexible manner to watershed residents, and this flexibility is difficult to quantify in terms of dollar or time values. Only during extreme drought cycles are municipal residents forced to adjust the amount and/or timing of their water demand. In addition, the 300,000 acre-feet of storage that has been developed in the upper basin makes water uses possible during times of the year when natural riverflows alone would not be sufficient to supply these demands.

Overall, a 140-year history of water diversion and storage has created vested water rights, along with expectations that waters users must continue to be able to realize the full yield of their water rights. Therefore, any adjustments to legal and institutional arrangements to better support natural resource values will require consent from these users before such changes are implemented. The purpose of this chapter is to provide a foundation of information and ideas for that dialogue.

History of Water Development and Use in the Arkansas Valley

Development and use of the basin's water supply took hold after the Pike's Peak gold rush of 1858, when farms started to develop in the lower Arkansas Valley. Beginning in the 1860's, several major ditches were constructed and irrigation water rights established. Thirteen major irrigation ditches, all taking water from the river between Pueblo and the Colorado-Kansas border, each received decrees for over 100 cubic feet per second (cfs) of water. Limited development occurred simultaneously in the upper valley as well, but never on the scale of the lower valley. As a result of the early development of water diversion and delivery systems, by 1884, all of the normal flows of the Arkansas River main stem (except for spring runoff and unusually high water supply years) were appropriated.[6]

Since 1884, water users in the valley have responded in several ways to the early and high demands placed on the river's water supply. One response was to construct reservoirs to store water made available under more junior water rights for use during irrigation season. At first carried out by individuals and ditch companies, this effort reached its peak with the development of the Fryingpan-Arkansas Project in the 1960's. (For this section of the document, "project" refers to the Fryingpan-Arkansas Project.) Winter irrigation was another response to more efficiently use the available water supply. Fields were used as a reservoir of sorts under this practice, holding the moisture during winter months for the benefit of the following season's crops. Finally, efforts began early to enhance the basin's native water supply by importing water from the west slope.

After several decades of efforts to better use and expand the available water supply for irrigation use in the valley, water users within and outside the basin began to look to the Arkansas River as a source of supply for urban use. Beginning in the 1950's, land and water rights were purchased for transfer from agricultural to municipal uses. To be

[5] Bud O'Hara, Manager of Water Resources, Pueblo Board of Water Works.

[6] P.O. Abbott, U.S. Geological Survey, Description of Water-Systems Operations in the Arkansas River Basin, Colorado, Water-Resources Investigations Report 85-4092 (1985), at 8. In fact, water rights established later than 1884 are little more than flood rights.

able to use the transferred water rights, water exchanges were established both informally and by court decree. Together, these transfers and exchanges have to some extent modified storage, diversion, and flow patterns in the basin.

After more than 100 years of managing flows and storage to meet human and economic needs, efforts have been made in recent years to accommodate natural resource and recreational values by supplementing flows through voluntary modification of storage releases in the upper basin.

This historical pattern of water development and use in the basin is set out in greater detail in the following sections. The following history starts with the earliest ditches in the lower valley, moves to storage reservoirs and imported water supplies, and finally to more recent practices of exchanging water and supplementing flows.

Early Water Development in the Lower Arkansas Valley

Ditch Development in the Lower Valley

As mentioned above, agricultural and corresponding water use began prior to 1890, downstream from Pueblo. Most of the early ditches in the basin were simple in design, using a headgate at stream level to transfer the water to the fields, which were typically situated on the floodplain of the Arkansas River. Once the irrigable acreage on the floodplain was developed, irrigation extended to the terraces or benchlands above the floodplain. Moving water to these higher lands required greater design skills and more money to construct water conveyance structures. In response, farmers established mutual ditch companies, pooling resources to build these more expensive ditches and to buy water rights associated with the smaller ditches.[7] Large-scale irrigation, carrying water for long distances to serve thousands of acres, began in 1874 in the area of Rocky Ford. Between 1874 and 1884, several ditches from 50 to 100 miles in length were constructed.

Several major irrigation canals were developed during this time between Pueblo and the town of Lamar. The Colorado Canal takes water from the north bank of the Arkansas just upstream from the Huerfano River. Its water rights are more junior than the other major ditches in the valley, with an 1890 priority date. The Highline Canal, which diverts water from the river below the confluence with the Huerfano River, has several water rights dating back before 1886, and is assured of a good water supply in most years. The Rocky Ford Canal, which takes water out of the river between Manzanola and Rocky Ford, has one of the earliest water rights, with an 1875 priority date.[8] Further to the east, the Fort Lyon Canal diverts water between the towns of Swink and La Junta. Fort Lyon Canal also takes water from Horse Creek and Horse Creek Reservoir, as well as Adobe Creek and Adobe Creek Reservoir[9] One of the earliest canals built, Fort Lyon, has one of the oldest and largest water rights in the valley, with over 600 cfs dating back to 1887 or earlier. This right often "sweeps the river" by depleting all of the surface flow available at its headgate. Downstream of Fort Lyon, the flow is replenished by return flows, precipitation, downstream tributary inflow, and releases from downstream storage. This water becomes "the supply for downstream users with more junior priorities."[10]

[7] Abbott at 8.

[8] L. MacDonnell, et al., The Water Transfer Process as a Management Option for Meeting Changing Water Demands, Vol. II (1990), at 26 (Water Transfer Report); priority dates from pp. 11-13 of Bureau of Reclamation Memorandum to Roy Smith dated August 18, 1995 (Reclamation Memorandum).

[9] Water Transfer Report at 26.

[10] Special Master's Report, Kansas v. Colorado, (No. 105 Original) Vol. 1 at 56 (July 1994) (Special Master's Report).

Today, there are 23 canal or ditch systems with rights to take water from the Arkansas River between Pueblo and the Kansas State line. Nine of the canals are located downstream or east of John Martin Reservoir.[11] Because of the pattern of early water development, many of the largest most senior water rights on the Arkansas River divert water between Cañon City and the Kansas State line. Historically, this meant that much of the river's water supply remained in the river above Cañon City and was not diverted upstream in order to satisfy these major downstream water rights.

The diversion systems mentioned above are described in more detail under "Irrigation and Storage Systems Downstream from Pueblo Reservoir that Can Affect Upper Arkansas Streamflows."

Early Reservoir Development in the Lower Valley

Many of the canal companies built offstream reservoirs near their service areas in the late 1800's and early 1900's. The reservoirs were designed to increase and improve the reliability of supplies from the Arkansas River, and in many cases, allowed irrigators more flexibility in timing their irrigation practices. Table 3-1 lists the largest of these reservoirs.

The storage systems mentioned above are described in more detail under "Irrigation and Storage Systems Downstream from Pueblo Reservoir that Can Affect Upper Arkansas Streamflows."

Early Water Development in the Upper Arkansas Valley

Ditch Development in the Upper Arkansas Valley

Several diversion and storage systems were constructed along tributaries to the Arkansas River upstream of Pueblo slightly before irrigation systems were constructed in the lower Arkansas Valley. These systems took advantage of the lower infrastructure costs required to utilize water from a tributary. By building a small diversion dam and using a plow to dig a small ditch, 1 or 2 cfs could easily be diverted from an Arkansas River tributary, whereas main-stem diversions typically required permanent diversion dams and larger canals to be cost effective.

Examples of these early upper valley developments include a diversion from Hayden Creek built in 1870 by trail driver Chauncy Hayden to irrigate hay fields near Coaldale. Similarly, in 1864, the Chuck Nachtrieb family settled on Chalk Creek and established a flour mill powered by falling water. The ditch supplying the mill became known later as Flour Mill Ditch. Although these ditches had the earliest priorities in the basin, they sometimes were not able to divert because of water availability problems on these tributaries during late summer.

Larger ditches were constructed near Cañon City between 1870 and 1885 to irrigate farms that

TABLE 3-1

Largest Off-Stream Reservoirs Built by Canal Companies

Canal Company	Reservoir	Capacity (acre-feet)
Colorado Canal	Lake Henry	10,000
	Lake Meredith	26,000
Fort Lyon Canal	Horse Creek	28,000
	Adobe Creek	85,000
	Thurston (tailwater)	1,515
Amity Canal	Great Plains (three reservoirs)	265,000 (total)

[11] Special Master's Report at 41.

supplied food to the Cripple Creek mining area. They were typically financed by associations of farmers. Examples of these ditches include the Hydraulic Ditch and the Oil Creek Ditch. The DeWeese Ditch was constructed in 1881, and in 1914, DeWeese Dam was constructed at the top of the Grape Creek Canyon. The purpose of the dam was to augment the water supply available from Grape Creek during the summer irrigation period.

Imported Water Supplies

Transmountain diversions into the Upper Arkansas River Basin have been used since the beginning of this century to supplement the more junior water rights associated with many east slope ditches. Unlike native flows, imported water is not subject to the priority system of the Arkansas River. From 1890 to 1910, several tunnels and ditches were built across the Continental Divide, providing an annual average of 11,987 acre-feet of water. By 1935, transmountain diversions began to accelerate rapidly to 43,000 acre-feet per year.

Among the earliest of the direct flow diversions to the Arkansas River Basin are the Medano Ditch and Hudson Ditch, which have a priority date of 1914. These ditches divert water from the headwaters of Medano Creek in the Rio Grande watershed, and convey the water over Medano Pass to the headwaters of Huerfano River. Combined, the two ditches have the capability to divert 15 cfs between May 15 and July 15 each year.

The Larkspur Ditch was constructed by the Catlin Canal Company and has a priority date of 1931. It has the capability to divert up to 10 cfs from the headwaters of Marshall Creek in the Gunnison River watershed. The water is conveyed over Marshall Pass to the headwaters of Poncha Creek.

Some of the early transmountain diversions that supply Arkansas River Basin storage facilities include the Ewing Ditch, Warren E. Wurtz Ditch, Wurtz Ditch Extension, Columbine Ditch, Busk-Ivanhoe Tunnel, and Twin Lakes Project. The least complex of these diversions are the Ewing, Wurtz, and Columbine Ditches in the upper Eagle River watershed. They convey water in open ditches through low points in the Continental Divide into West Tennessee Creek and the East Fork of the Arkansas River north of Leadville. The appropriation dates for these ditches are: Ewing Ditch - 1906, Wurtz Ditch - 1929, Wurtz Extension - 1953, and Columbine Ditch - 1930. These ditches are described in more detail under "Wurtz, Ewing, and Columbine Ditches (Pueblo Board of Water Works)."

The Busk-Ivanhoe System diverts water from Ivanhoe Creek, a tributary of the Fryingpan River, through the Carlton Tunnel near Turquoise Lake. The water is then delivered to Turquoise Lake for storage. (Turquoise Lake development is described under "Development of the Fryingpan-Arkansas Project.") The Fryingpan-Arkansas Project's Charles H. Boustead Tunnel can also be used to transport this Busk-Ivanhoe water during periods of low flow in the tunnel. The Busk-Ivanhoe system was constructed during the early 1920's. This system conveys an average of 6,200 acre-feet annually from the west slope to the east slope.[12] This system is further described under "Busk-Ivanhoe Collection System."

The Twin Lakes transmountain diversion system was constructed in the 1930's to serve land irrigated by the Colorado Canal in Crowley County. The collection system is located in eastern Pitkin County at the headwaters of the Roaring Fork River. Water is diverted from Roaring Fork Creek, Lost Man Creek, New York Creek, Tabor Creek, Brooklyn Creek, and Lincoln Gulch into Grizzly Reservoir. From here, water is transferred through the Twin Lakes (Independence Pass) Tunnel into the North Fork of Lake Creek. The imported water is stored in Twin Lakes for later release. This system conveys an average of 54,500 acre-feet annually. This system is further described under "Twin Lakes Collection System."

[12] Case number 84CW177, Water Division 2, at page 6.

Early Reservoir Development in the Upper Arkansas Valley

Irrigators, individually and through ditch companies, constructed several major reservoirs in the Upper Arkansas Valley to store spring runoff from Arkansas River tributaries. Twin Lakes, completed in 1900 by the Twin Lakes Reservoir and Canal Company, was designed to supplement the 1890 direct flow water rights associated with the company's Colorado Canal. The original capacity of the reservoir was 54,452 acre-feet. The stored water, taken from Lake Creek and other tributaries on the east slope, provided a more stable supply of water to irrigators along the Colorado Canal than could be realized by direct diversion alone.[13] This facility is further described under "Twin Lakes Dam and Twin Lakes."

In 1902, the CF&I Steel Corporation completed construction of Sugarloaf Reservoir, with an original capacity of 17,416 acre-feet. The reservoir was originally constructed to store waters from Arkansas River tributaries, including Lake Fork, Tennessee Fork (by exchange), and East Fork (by exchange). Both Twin Lakes and Sugarloaf Reservoir (now known as Turquoise Lake), were later integrated into the Fryingpan-Arkansas Project,[14] as described under "Development of the Fryingpan-Arkansas Project" and "Sugarloaf Dam and Turquoise Lake."

One of the earliest reservoirs developed in the upper basin was Clear Creek Reservoir, with a capacity of 11,486 acre-feet. It was constructed of native earthen materials from 1902 to 1907 by the Otero Canal Company to store the waters of Clear Creek. In 1955, the Pueblo Board of Water Works purchased the reservoir, dam, and 712 acres of land for $2.7 million. Under the Fryingpan-Arkansas Project, enhancement of Clear Creek Reservoir's storage capabilities was planned but indefinitely deferred.[15] This facility is further described under "Clear Creek Dam and Reservoir.".

Development of Colorado Springs Municipal Supply Systems

As explained in the previous paragraph, many of the water storage and conveyance facilities that provide municipal supplies in the Arkansas River Valley were first developed by canal companies for irrigation purposes. However, Colorado Springs Utilities constructed an extensive supply system between 1880 and 1960 that was designed exclusively for municipal use. This system included the Pikes Peak South Slope System, Penrose Rosemont System, Pikes Peak North Slope System, and the Northfield System (Figure 3-1). Although all of these systems are located within the Arkansas River watershed, the movement of water from the Pikes Peak South Slope System to the Fountain Creek watershed, where Colorado Springs is located, represented some of the earliest transbasin diversions in the State.

The Pikes Peak South Slope System diverts water from the Beaver Creek and Ruxton Creek watersheds and delivers these flows to the Mesa Water Treatment Plant, located on lower Fountain Creek. This system was developed between 1880 and 1920, and includes seven reservoirs, three tunnels, and two pipelines. The Pikes Peak North Slope System diverts water from Catamount Creek, Crystal Creek, Cascade Creek, and French Creek, and delivers the water to the Mesa Water Treatment Plant. This system was developed between 1900 and 1960, and includes three

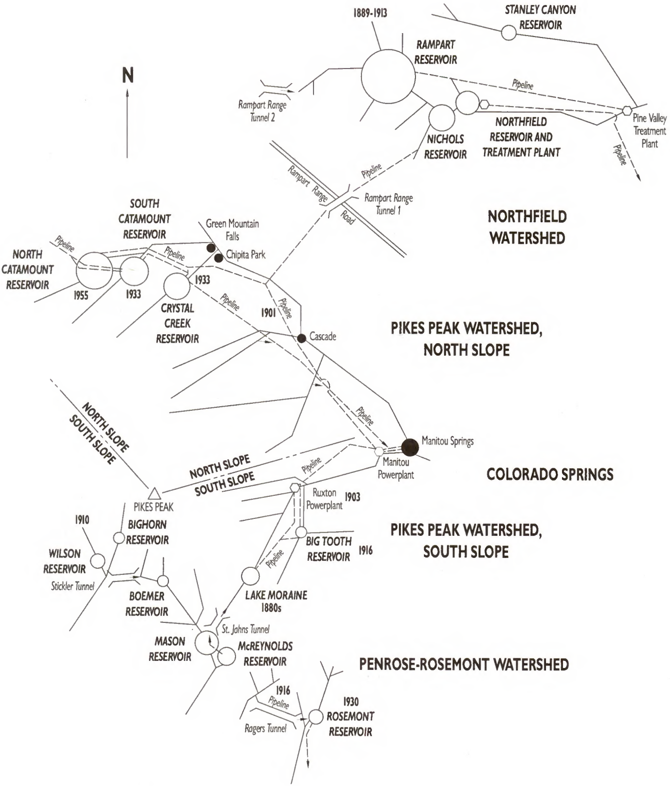
[13] Memorandum prepared for the Twin Lakes Reservoir and Canal Company, Part I, "A Survey of Legal Problems Involved in Any Proposed Reorganization of the Irrigation System of the Twin Lakes Reservoir and Canal Company," prepared by John Carlson of Holland & Hart (dated Jan. 1, 1956).

[14] Abbott at 41.

[15] Environmental Impact Statement, Fryingpan-Arkansas Project, at 11-129.

FIGURE 3-1

Mountain Collection System for the City of Colorado Springs



reservoirs and three pipelines. Together, the Pikes Peak North Slope and South Slope Systems provide Colorado Springs with approximately 28 percent of its water supply.

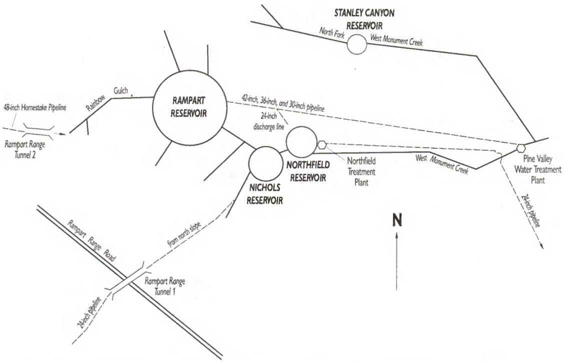
The Penrose-Rosemont System diverts water from Gould Creek and East Beaver Creek and delivers it to the Mesa Water Treatment Plant. This system was developed between 1915 and 1935, and includes one reservoir, two pipelines, and a tunnel. The system provides approximately 1.5 percent of the Colorado Springs water supply.

The Northfield System diverts water from the Monument Creek watershed and delivers it to the Northfield and Pine Valley Water Treatment Plants (Figure 3-2). This system was developed between 1889 and 1915, and includes four reservoirs and two pipelines. The system provides approximately 1.5 percent of the Colorado Springs water supply. In addition, the reservoirs in this system receive water imported into the basin by the Homestake Project, described under "Development of the Homestake Project."

The Blue River Project diverts water from the headwaters of the Blue River in Summit County and conveys that water to Montgomery Reservoir near Fairplay via the Hoosier Tunnel (Figure 3-3). Via the Montgomery Pipeline, water is typically delivered to reservoirs located in the Pikes Peak North Slope System. However, at the Divide Pumping Station, it is possible to divert the water to Rampart Reservoir via the Homestake Project Pipeline. The Blue River Project provides approximately 13 percent of the Colorado Springs water supply.[16]

FIGURE 3-2

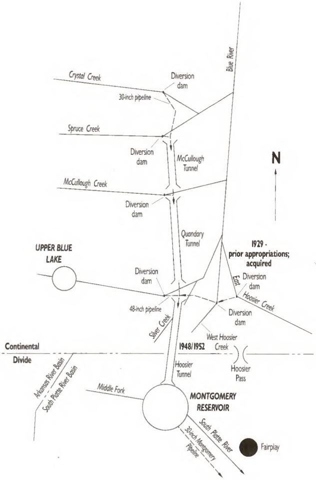
Northfield Watershed, Colorado Springs Mountain Collection System



[16] Material for this section was obtained from three sources: Abbott, P.O., "Description of Water-Systems Operations in the Arkansas River Basin, Colorado;" Colorado Springs Utilities Annual Water Supply Reports, and telephone conversations with Vic Eklund, Colorado Springs Utilities, during September 1996. The percent of Colorado Springs' water supply represented by each of these systems does not add up to 100 percent because the City has come to rely upon additional sources of water outside of the Pikes Peak and Blue River area.

FIGURE 3-3

Blue River Project Collection System



John Martin Reservoir and the Arkansas River Compact

John Martin, the largest reservoir in the Arkansas River Basin, is located 58 miles west of the Kansas State line. The primary purpose of the 605,115 acre-foot reservoir, completed in 1948 by the U.S. Army Corps of Engineers (COE), was flood control. Since the reservoir was constructed exclusively with Federal funds and had no repayment obligations, irrigation and water conservation were deemed secondary purposes. The ability to allocate interstate water under the water conservation purpose was very important politically for obtaining Congressional approval for the project. These secondary purposes were clarified by the 1948 Arkansas River Compact. Subsequent to the compact, a 15,000 acre-foot permanent recreation pool was later added, further modifying reservoir operations.[17] Finally, reservoir operations have been modified due to sedimentation, which has decreased the conservation storage capacity to about 339,000 acre-feet. This facility is further described under "John Martin Reservoir."

One of the primary purposes of the 1948 Arkansas River Compact (referred to as the "compact" throughout the remainder of this document) was to establish criteria for how water would be stored and released from John Martin Reservoir. Prior to construction of John Martin Reservoir in 1948, riverflows fluctuated widely. In addition, Kansas and Colorado hoped the compact would settle Arkansas River water disputes that had existed since 1901.[18] Article IV-C(3) of the compact provides that a conservation pool will operate "for the benefit of water users in Colorado and Kansas, both upstream and downstream from John Martin dam."[19] To implement this compact provision, a common pool concept for allocation was established. This concept guided operations until 1980, when the Arkansas River Compact Administration, the entity which administers the compact, adopted a resolution commonly referred to as the 1980 Operating Plan. Today's operations reflect the general provisions of the compact, with specific administration guided by the 1980 Operating Plan. The specific operational features of the storage program created by the 1980 Operating Plan are discussed under "Compact Provisions Guiding the Operation of John Martin Reservoir."

[17] Abbott at 48.

[18] Bill Howland, "A Short History of the Evolution of the Accounting System," Colo. Streamlines, (Office of the State Engineer, Colorado Division of Water Resources, Denver, Colo.), March 1993 at 7.

[19] Colo. Rev. Stat. § 37-69-101, Article IV(C)(3); Special Master's Report at 45.

Development of the Fryingpan-Arkansas Project

The Fryingpan-Arkansas Project, built by the Bureau of Reclamation (BOR), was developed beginning in the early 1960's as a multipurpose water project "to divert unappropriated water from the western slope of Colorado for use on the more populated and water-short eastern slope."[20] Supplemental irrigation water is delivered to approximately 280,600 acres of irrigated land.[21]

In 1958, prior to construction of the project, the Southeastern Colorado Water Conservancy District was created under Colorado's Water Conservancy District Act. Southeastern's purpose, as well as that of its predecessor organization, the Water Development Association of Southeastern Colorado, was to secure authorization for the project from the U.S. Congress. After the project was authorized in 1962, the purpose of the district evolved into coordination of project development and construction with BOR. Southeastern's allocation of project water and repayment of project construction costs started in 1972. Southeastern signed a final contract with BOR for delivery of project water in 1982.[22] Under the contract, Southeastern holds the water rights for the project.

Between 1962 and 1980, BOR constructed or enlarged five storage dams and reservoirs, creating a total storage capacity of almost 740,000 acre-feet: 1) Ruedi Dam and Reservoir on the western side of the Continental Divide on the Fryingpan River; 2) Turquoise Lake 5 miles west of Leadville; 3) Mount Elbert Forebay Dam and Reservoir at the base of Mount Elbert; 4) Twin Lakes Dam and the enlarged Twin Lakes at the east end of Independence Pass; 5) Pueblo Dam and Reservoir just west of the City of Pueblo.[23] Three of these dams were newly constructed and two were enlargements of existing reservoirs.

Ruedi Reservoir, located on the Fryingpan River about 13 miles east of Basalt, was completed in 1968 as part of the project to provide storage to replace project water diverted out of priority from the west slope and to regulate water supply for other west slope uses. The reservoir also provides water to benefit threatened and endangered fish in the Colorado River. The reservoir has an active storage capacity of 101,278 acre-feet, with about 28,000 acre-feet reserved for west slope replacement water for project diversions to the east slope.[24] This facility is described in greater detail under "Ruedi Dam and Reservoir."

Turquoise Lake is the uppermost storage facility in the project, located about 5 miles west of Leadville on Lake Fork Creek, a tributary to the Arkansas River. BOR purchased Sugarloaf Reservoir from the CF&I Steel Corporation and expanded its storage capacity in 1968 to an active capacity of 120,478 acre-feet.[25] The original water rights owned by CF&I for 17,416 acre-feet have a priority date of 1902, and were preserved with the expansion. This CF&I water may now be stored anywhere in project storage facilities, but must ultimately be delivered at Turquoise Reservoir.[26] After this acquisition, BOR constructed the Charles H. Boustead Tunnel under the Continental Divide to deliver project water collected on the west slope to

[20] Abbott at 43.

[21] Abbott at 46.

[22] Interview with Tom Simpson, Southeastern District, October 2, 1996.

[23] Abbott at 46.

[24] Interview with Tom Gibbens, Bureau of Reclamation, Feb. 21, 1996.

[25] Bureau of Reclamation Water Management Report, at page 2.

[26] Fryingpan-Arkansas Project EIS, at II-32.

Turquoise Lake on the east slope. Turquoise Lake is described in greater detail under "Sugarloaf Dam and Turquoise Lake."

The site of Twin Lakes was purchased from the Twin Lakes Reservoir and Canal Company by BOR. BOR expanded the reservoir to its current storage capacity of 140,855 acre-feet. As a part of the purchase, the Twin Lakes Company retained the use of 54,452 acre-feet of storage capacity in the Fryingpan-Arkansas system.[27] Twin Lakes is described in greater detail under "Twin Lakes Dam and Twin Lakes."

Mt. Elbert Forebay Dam and Reservoir are located on a ridge above Twin Lakes. The reservoir was designed as a regulatory forebay for the Mt. Elbert powerplant, and has a total capacity of 11,143 acre-feet. The forebay receives water from the Mt. Elbert Conduit, which is designed to convey water from Turquoise Lake to Twin Lakes. The dam, reservoir, and conduit were constructed between 1978 and 1981. These facilities are further described under "Mt. Elbert Conduit and Forebay."

Pueblo Reservoir, completed in 1975, is the terminal reservoir of the project. The original total capacity was 357,678 acre-feet. Pueblo Reservoir also has a storage right with an appropriation date of 1939 that allows native flows to be stored when John Martin Reservoir is spilling, subject to terms in its decree .[28][29] This facility is described in greater detail under "Pueblo Reservoir."

In addition to these storage facilities, BOR financed and constructed the Fountain Valley Conduit, which delivers water from Pueblo Reservoir to the Colorado Springs area, between 1980 and 1985. The pipeline is 38 miles long, and its route roughly parallels Interstate 25 between Pueblo and Colorado Springs. The conveyance and pumping capacity of the conduit are 31 cfs.

The west slope water collection systems, which convey water to project reservoirs, were constructed between 1965 and 1981. The North and South Collection Systems were entirely new construction. Water diverted by the project first flowed under the Continental Divide through the Boustead Tunnel in 1972. This collection system is further described under "North and South Collection Systems." Since the project was officially completed in 1981, annual imported water has averaged 56,000 acre-feet per year.[30]

Development of the Homestake Project

The Homestake Project was conceived during the 1950's by John P. Elliot and Edgar Weirs, two entrepreneurs who foresaw dramatically increased demand for municipal water supplies along the Colorado Front Range. Elliot and Weirs appropriated water for the project in 1952 upon completion of surveys to determine the design and location of project components. The primary project features include a collection system in the upper Eagle River watershed, which delivers water to 43,092 acre-foot Homestake Reservoir. Water from the reservoir is routed under the Continental Divide via the Homestake Tunnel, which delivers the imports to Turquoise Lake and Twin Lakes Reservoir. Water rights for the Homestake Project were adjudicated in 1962, after a municipal partnership was formed by Colorado Springs Utilities and the City of Aurora to finance the project.

Construction of tunnels, reservoirs, pipelines, and pumping stations was completed by 1966. To deliver water to Aurora and Colorado Springs, the

[27] Abbott at 50.

[28] Abbott at 46; Special Master's Report at 44.

[29] Special Master's Report at 49.

[30] Special Master's Report at 49.

Otero Pipeline was constructed from Twin Lakes Reservoir to South Park. There the pipeline divides to deliver water to Spinney Mountain Reservoir for Aurora and to the Divide Pumping Plant for Colorado Springs. The original Otero Pipeline intake was located downstream of the confluence of Lake Creek and the Arkansas River near Granite. Water collected by the Homestake Project was first stored in contracted space in Turquoise Lake in 1967, and then released into Lake Fork Creek and the Arkansas River to be subsequently rediverted by the Otero Pipeline. Water from the Homestake Project was first routed from Turquoise Lake to Twin Lakes via the Mt. Elbert Conduit in 1983. Extension of the Otero Pipeline to Twin Lakes was completed in 1986. Since this pipeline extension came into operation, imported water has been transported directly to Colorado Springs and Aurora, rather than using the upper Arkansas River as a conduit to the Otero Pipeline. [31]

The Homestake Project is described in greater detail under "Homestake Project."

Groundwater Development

Groundwater development began in the Arkansas River watershed during the 1930's, when vertical turbine pumps were developed and the electricity needed for operating such pumps became much cheaper and more widely available. Wells that pumped at least 800 gallons per minute were established in both the Arkansas River and Fountain Creek alluviums by 1935. However, by 1940, only 2,000 acre-feet annually was being pumped from the Arkansas River alluvium.

After World War II, well construction increased dramatically. By 1964, there were approximately 1,600 to 1,900 irrigation wells pumping in excess of 100 gallons per minute from the Arkansas River alluvium between Pueblo and the Kansas-Colorado border. Collectively, these wells pumped between 230,000 and 240,000 acre-feet annually. An unknown number of smaller wells existed that also pumped significant volumes.

In 1969, with inexpensive electricity available, it was estimated that the Arkansas River alluvium contained 1.9 million acre-feet of water, and that 1.0 million acre-feet could be extracted economically on an annual basis. At that time, most groundwater uses from the alluvium had not yet been adjudicated by the water courts.[32]

Recognizing that the substantial increase in pumping could be affecting senior appropriators of surface water throughout the Front Range, the Colorado Assembly in 1965 passed the Groundwater Management Act. This act required that all well owners obtain permits from the Division of Water Resources, and it authorized the State Engineer to shut down wells to prevent injury to senior appropriators. The Assembly modified the act in 1969 to create a category of wells that are "exempt" from administration within the priority system, and created criteria that limited the availability of "exempt" well permits. Subsequent to these two acts, the State Engineer's Office issued the "1972 rules," which guided well administration in the Arkansas River Valley until they were amended in 1996.

Recognizing that additional high-capacity wells could further injure senior appropriators, the State Engineer's Office in 1975 placed a moratorium on construction of new high-capacity wells in the Arkansas River Valley. In addition, the State Engineer's Office restricted the use of new "exempt" well permits in the Arkansas River Valley to in-house use only, forbidding the wells to be used for livestock watering or irrigation of property on tracts of less than 35 acres.[33]

[31] Information for this section was obtained from interviews with Vic Eklund, Colorado Springs Utilities, during September 1996.

[32] Material for the proceeding paragraphs in this section was obtained from Bender v. City of Colorado Springs, 291 p. 2nd 684, and Fellhauer vs. Colorado, 447 p. 2nd 986.

[33] Interview with Steve Witte, Colorado Division of Water Resources, Feb. 3, 1997.

In February of 1985, the State of Kansas filed suit against the State of Colorado, alleging that Colorado was failing to make water deliveries to Kansas as specified in the 1948 Arkansas River Compact. A discussion of groundwater developments since the date of the suit is provided under "Colorado Actions in Response to Kansas v. Colorado Decision."

Early Winter Irrigation Practices and Arkansas River Winter Water Storage Program

For many years, Colorado farmers diverted water onto barren fields to take advantage of the flows during the winter. Winter irrigation benefited farmers by increasing the moisture in their fields for future crops. The downside to winter irrigation was that it was often affected by weather—water could evaporate quickly from the soil, resulting in relatively inefficient water use. With the construction of John Martin Reservoir, winter irrigation generally became unnecessary below the reservoir. Under the Arkansas River Compact, all winter flows entering the reservoir are stored. However, this winter storage is subject to demand by the State of Colorado, which may request releases equivalent to the river inflow, not to exceed 100 cfs.

The Arkansas River Winter Water Storage Program (WWSP) began on a trial basis in 1976.[34] The WWSP operates from November 15th to March 15th. The participants include all of the major ditch and reservoir companies between Pueblo and John Martin Reservoirs, except the Otero Ditch Company and the Rocky Ford Canal Company. Each participant stores water during the designated winter months in Pueblo Reservoir, John Martin Reservoir, or other off-channel reservoirs. In the early years of the program, the terms of the storage plan were agreed to each year by a committee of water users in the valley.[35] Allocation formulas are based on long-term average diversions by the participants as well as negotiated agreements among the ditch companies. There is no limit on the amount of water that can be stored except for the capacity limits of Pueblo Reservoir. The program has met with success and, in 1987, the Colorado Water Court officially approved the formula for allocating water.[36] The program is described in greater detail under "Winter Water Storage Program."

Witnessing the success of the program, lower Arkansas River valley agricultural interests have requested more firm storage within Pueblo Reservoir to meet their needs. The Southeastern Colorado Water Conservancy District is considering this need as part of its needs assessment for storage management and construction within the river basin.

Water Transfers and Exchanges

In the 1950's, permanent transfers of water rights began, following a decade of severe drought and duststorms. Several cities initiated efforts to purchase Arkansas Valley water. Eventually two permanent transfers were completed, involving water rights held by irrigation users of the Rocky Ford Ditch and the Colorado Canal.[37]

In 1993, the City of Aurora proposed an exchange of water it owned in the Rocky Ford Ditch. The ditch diverts water for irrigating farmland in the lower Arkansas Valley and its rights are fairly senior. Aurora's plan for the ditch water was to exchange the diversions in the lower valley to a diversion point at Twin Lakes or Turquoise Lakes. From

[34] Note that this program is distinct and separate from the program for storing winter water at John Martin Reservoir.

[35] Abbott at 46.

[36] Special Master's Report at 312.

[37] Water Transfers Report at 28-29.

there, the water would be pumped over Trout Creek pass to Spinney Mountain Reservoir in the South Platte basin to Aurora, using the Otero Pipeline. Aurora's transfer application was granted, subject to the successful implementation of a revegetation plan for the dewatered lands. As of 1997, the revegetation program was 84 percent complete, as determined by an independent panel, so Aurora was able to divert 84 percent of the 8,200 acre-feet that the water court determined could be transferred. This meant that in 1997, 6,888 acre-feet was diverted at the Otero Pipeline rather than at the Rocky Ford Ditch. In water year 1998, Aurora was able to transfer 92.4 percent of the 8,200 acre-feet (7,577 acre-feet), and will be able to transfer almost 100 percent in water year 1999.[38]

The other major water transfers involve the Colorado Canal and Twin Lakes. These two structures were managed under one company until 1970, when the historic Twin Lakes water rights for storage and west slope diversions (water rights established before the Fryingpan-Arkansas Project were built) were separated from the diversion rights for the Colorado Canal in the lower Arkansas River valley. The reason for the separation was that municipalities were interested in purchasing the yield of the Twin Lakes system, and wanted to manage the associated structures to maximize yield for municipal purposes. Therefore, when the Twin Lakes Company was formed, 96 percent interest in the Twin Lakes water rights were purchased by the municipalities of Colorado Springs, Aurora, Pueblo, and Pueblo West. All of the municipal entities take Twin Lakes water for use by direct delivery, so no exchange is needed.

Subsequent to the separation of Twin Lakes and the Colorado Canal, Colorado Springs and Aurora have purchased an 85 percent interest in the Colorado Canal Company. Colorado Canal Company shares include native water rights and storage in the lower basin reservoirs, Lake Henry and Lake Meredith (where the canal company water is typically stored, approximately 50 miles east of Pueblo). Colorado Springs owns 28,000 shares, for which the average annual yield is approximately 16,800 acre-feet (one share typically yields 0.6 acre-feet of historical consumptive use water per year). Aurora owns 14,000 shares, for which the average annual yield is 8,400 acre-feet.[39]

A transfer to municipal use for the shares owned by Colorado Springs and Aurora was approved in by the Colorado Water Division 2 court in a 1984 case.[40] Although the terms of this decree do not require revegetation of the dried up acreage, the municipalities have implemented revegetation. Colorado Springs moves its Colorado Canal Company water to where it is needed through exchanges and water management. For example, to move water from Lake Meredith to Twin Lakes can either be a direct exchange or a two-part exchange. When a two-part exchange is required, one exchange moves the water from Lake Meredith upstream to Pueblo Reservoir, and a second exchange moves the water further upstream to Twin Lakes, where water can be positioned for moving to where it is needed by the City.[41] Aurora's plan for moving Colorado Canal water is similar to the plan for Rocky Ford Ditch, outlined above.[42] These exchanges are possible because of the storage rights held in Lake Meredith.[43]

[38] Conversation with Doug Kemper, City of Aurora, Oct. 15, 1996 and conversation with Gerry Knapp, Arkansas Valley Range Project, December 8, 1997.

[39] Conversation with Alan Ringle, Colorado Canal Company, December 8, 1997.

[40] Case numbers 84 CW 62, 84 CW 63, and 84 CW 64 in Colorado Water Division 2.

[41] Water Transfer Report at 29.

[42] Water Transfer Report at 30.

[43] Telephone conversation with Philip Saletta, Colorado Springs Utilities, Oct. 11, 1996.

Under the Colorado Canal transfer decree, Aurora has transferred a maximum of 3,500 acre-feet in 1 year, and Colorado Springs has transferred a maximum of 5,875 acre-feet in 1 year. It is anticipated that these numbers will steadily increase as the municipal demands increase. During wet years or other times when the transfers are not needed, the water is applied to 4,000 "municipal surplus acres" serviced by the Colorado Canal Company. Colorado Canal Company supplies still irrigate 6,800 other acres that have not been transferred to municipal use. The operation of these exchanges is discussed further under "Annual Sequence of Water Operations" and "Arrangements with Municipal Providers."

Exchanges of water that do not involve a permanent change in the point of diversion for the water right have occurred informally in the Arkansas River system since water use began. Typically, exchanges from downstream locations to upstream locations are designed to accomplish one of two objectives: 1) to allow municipalities to reuse return flows that are a product of water imported from other river basins, or 2) to allow irrigation organizations and municipalities to increase the yield of their water rights by positioning the water in storage structures that are advantageous to their water delivery systems. Exchange arrangements started to become more formalized starting in the 1970's, when multiple water users began to compete for the limited opportunities to exchange water.[44]

In 1988, several of the major exchange operations were decreed, and the participants in the cases signed stipulations, which allocated the exchange opportunities among themselves.[45] These participants included Colorado Springs Utilities; Pueblo Board of Water Works; Colorado Canal Company; Lake Meredith Reservoir Company; Lake Henry Reservoir Company; Resource Investment Group, Ltd.; and City of Aurora. The stipulations allow for a total exchange of up to 377 cfs into Pueblo Reservoir from downstream locations, plus additional amounts subject to terms and conditions in the stipulations. Once the water is exchanged into Pueblo Reservoir, some of the parties exchange the water further upstream into project reservoirs. The overall operation of exchanges is discussed in greater detail under "Protection and Operation of Exchanges."

Efforts to Accommodate Natural Resource Values within the Water Rights System

Anglers and other recreational users of the river sometimes have conflicting views on how the Arkansas River should be managed. The history of responding to these demands began in 1989, when BOR released 44,000 acre-feet of water from Twin Lakes in order to remove a piece of equipment that had remained in the lake since construction of the dam facilities.[46] The timing of the construction release was complementary to the needs of the rafting industry. The following year, BOR agreed to augment the river's natural flows to create a total flow of approximately 700 cfs through August 15th. To provide this flow, BOR released 23,000 acre-feet of water from Twin Lakes.[47] Subsequent analysis demonstrated that only 14,000 acre-feet were needed to maintain the desired flows. Operations to maintain desired flows have been

[44] Interview with Steve Kastner, Colorado Division of Water Resources, Aug. 6, 1996.

[45] Case numbers 84 CW 62, 84 CW 63, 84 CW 64, 84 CW 35, 84 CW 202, 84 CW 203, 84 CW 177, and 84 CW 178, Water Division 2.

[46] Telephone interview with Jack Garner, Area Manager, Bureau of Reclamation (June 8, 1993).

[47] Daniel Reimer, Fryingpan-Arkansas Project Case Study, Reclamation/EPA Environmental Benefits Study, Natural Resources Law Center (1993) at 8 [hereinafter Reimer].

made even more efficient, in terms of water volume required, in subsequent years.

In 1991, the Colorado Department of Natural Resources (DNR), BOR, and Southeastern worked together to establish more structured release guidelines. The resulting plan included: 1) a year-round minimum flow of 250 cfs, as measured at the Wellsville gage, for protection of the fishery; 2) a minimum late-summer flow of 700 cfs, as measured at the Wellsville gage, through August 15th to lengthen the rafting season; 3) a maximum of 10,000 acre-feet to be released by BOR for flow augmentation; and 4) a recommended limit on the changes in flow to the rate of 10 to 15 percent per day.[48]

In 1991, BOR implemented the plan until Trout Unlimited (TU) successfully obtained a preliminary injunction to stop flow augmentation. TU opposed the augmentation program due to concerns that the increased flows would reduce brown trout feeding habitat, cause the trout to expend excessive energy in the feeding process, and impede trout growth.[49] TU's claim was subsequently dismissed, and in 1992, with cooperation from DNR, BOR again informally instituted the augmentation plan. The program is supported by DNR, Arkansas Headwaters Recreation Area members, Bureau of Land Management (BLM), Colorado Division of Parks and Outdoor Recreation, and Southeastern.

In 1992 and continuing through today, DNR modified its flow recommendations to include specified winter flows (depths of no more than 5 inches less than October/November mean flows) from mid-November to the end of April, and if possible, to maintain flows between 250 cfs and 400 cfs from April 1 through May 15 for favorable egg hatching and fry emergence conditions. Intended benefits from the plan include year-round attention to fishery requirements by providing a minimum flow of 250 cfs and winter and spring incubation and hatching flows, as well as enhancing recreational experiences along the upper Arkansas River. Estimates are that, in the long-term, water will be needed to augment August flows.

During 1996, Southeastern passed a resolution which states that the augmentation should be subject to water availability, storage space availability, and the rights of water rights holders to divert and exchange water.[50] The Colorado DNR subsequently incorporated the terms of this resolution into its annual flow recommendations to BOR. Under the terms of the resolution, the augmentation program would be operated to fit within needs to store and release water to meet agricultural and municipal demands. Additionally, BOR has noted that operation of the program is adjusted to react to weather factors, such as above- or below-average water supplies. The augmentation program is described in greater detail under "Memoranda of Agreement and Understanding."

Description of Water Management Facilities Associated with Arkansas River Streamflows

This section provides an overview of the major water management facilities that can have an effect on Arkansas River streamflows. Facilities described in the upper watershed include those managed by BOR as part of the Fryingpan-Arkansas Project, as well as facilities managed by the Pueblo Board of Water Works, Colorado Springs, Aurora, and the

[48] Reimer at 8-9.

[49] Reimer at 10-11.

[50] Resolution of the Board of Directors of the Southeastern Colorado Water Conservancy District, April 18, 1996.

Twin Lakes Reservoir and Canal Company. Facilities described in the lower watershed include canals and reservoirs owned by numerous irrigating companies, as well as John Martin Reservoir, operated by COE.

Fryingpan-Arkansas Project Overview

The project is a transmountain water diversion project located in central and southeastern Colorado (Figure 3-4). The project water collection system is located on the west slope of the Continental Divide in the Hunter Creek and Fryingpan River watersheds. Both of these streams are tributaries of the Roaring Fork River, which is a tributary of the Colorado River. The Charles H. Boustead Tunnel conveys water from the collection system through the Continental Divide to the headwaters of the Lake Fork of the Arkansas River. The project is designed to supplement the water supply that is normally available from native Arkansas River flows and from non-Federal storage projects. (Project water is often referred to as supplemental water throughout this document.)

The project provides supplemental water to numerous municipalities in the Arkansas River Valley, ranging from Buena Vista to Lamar, and in the Fountain Valley, ranging from Colorado Springs to Pueblo. The project also provides supplemental water for irrigation of 280,600 acres of land. Approximately 255,300 acres are located in the Arkansas River Valley between Pueblo and Lamar. Approximately 12,500 acres are located in the Arkansas Valley upstream of Pueblo Reservoir. The remaining 12,800 acres are located in the Fountain Valley upstream of the City of Pueblo. Supplemental water is provided via an extensive west slope collection system and five project dams and reservoirs. One reservoir is located on the west slope. Three reservoirs are located on the east slope in the upper Arkansas River watershed near Leadville. The fifth reservoir is located on the Arkansas River near Pueblo, approximately 150 river miles downstream.

Numerous parties have contract interests in the BOR storage facilities described in the following sections. These storage contracts are described in detail under "Contractual Obligations" and are summarized briefly below:

Typically Stored in Turquoise Reservoir[51]

17,416 acre-feet - Colorado Springs Utilities
10,000 acre-feet - (original CF&I shares)
5,000 acre-feet - City of Aurora, and 5,000 acre-feet - Pueblo Board of Water Works
10,000 acre-feet - (original Busk-Ivanhoe, Inc. shares) City of Aurora [52]
30,000 acre-feet - Colorado Springs Utilities and City of Aurora

Typically Stored in Twin Lakes

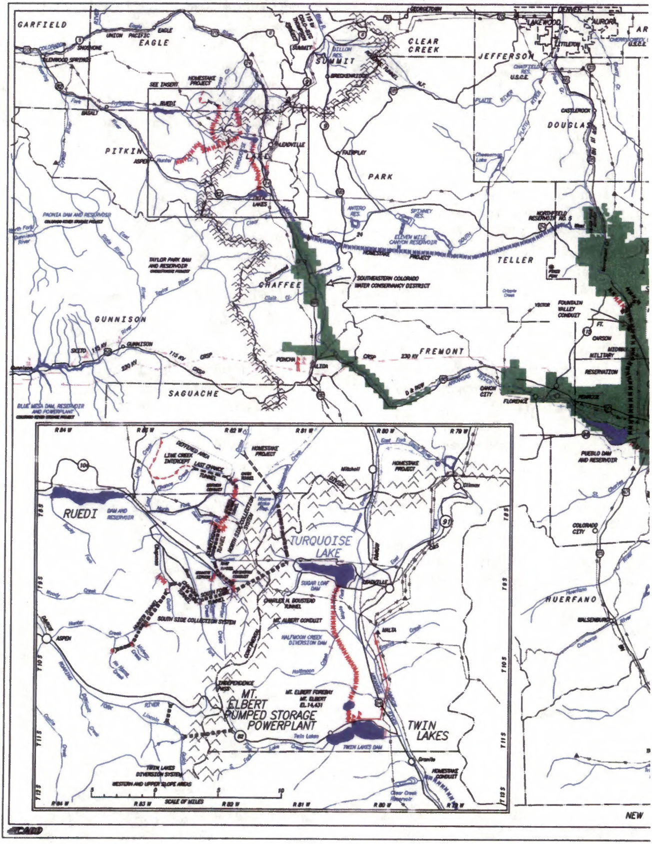
54,452 acre-feet - Twin Lakes Reservoir and Canal Company

[51] These contracts may be stored at any project reservoir at BOR's discretion, as long as the water is delivered at the contracting entity's place of need. For efficiency, these contracts are typically stored at the locations listed on this page.

[52] The 10,000 acre-feet associated with original Busk-Ivanhoe shares may be used for storage of water for irrigation purposes only. When this document was published, the City of Aurora had not negotiated with BOR for storage of domestic water supplies under this contract.

FIGURE 1-1

Fryingpan-Arkansas Project



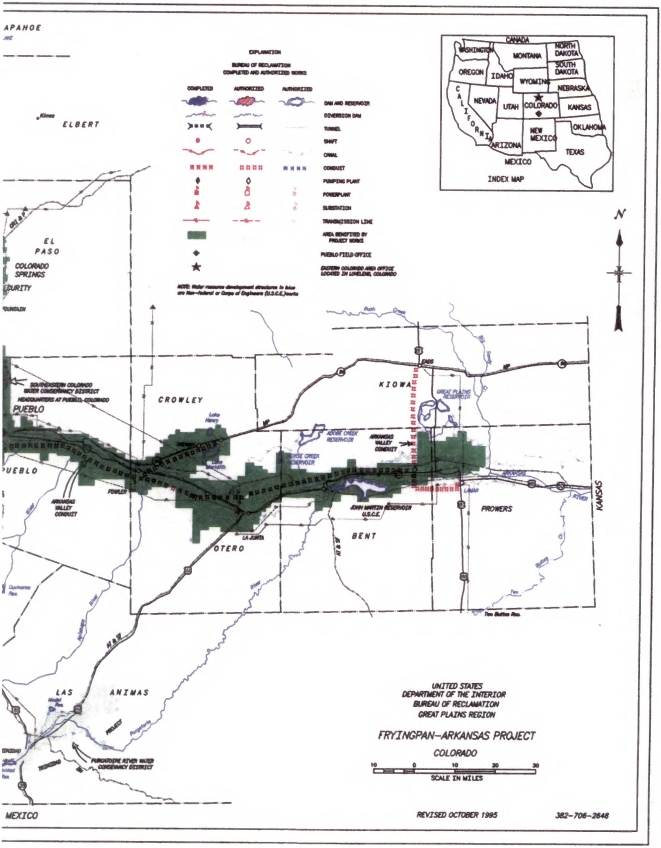
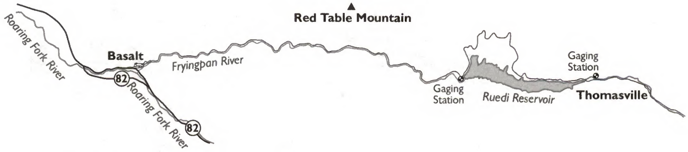

EXPLANATION
BUREAU OF RECLAMATION
COMPLETED AND AUTHORIZED WORKS
COMPLETED
AUTHORIZED
AUTHORIZED
DAM AND RESERVOIR
DIVERSION DAM
TUNNEL
SHAFT
CANAL
CONDUIT
PUMPING PLANT
POWERPLANT
SUBSTATION
TRANSMISSION LINE
AREA BENEFITED BY PROJECT WORKS
PUEBLO FIELD OFFICE
INDEX MAP
CANADA
WASHINGTON
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
OREGON
IDAHO
WYOMING
NEBRASKA
CALIFORNIA
NEVADA
UTAH
COLORADO
KANSAS
ARIZONA
NEW MEXICO
OKLAHOMA
TEXAS
MEXICO
N
ELBERT
EL PASO
COLORADO SPRINGS
CROWLEY
KIOWA
PUEBLO
OTERO
BENT
PROWERS
KANSAS
LAS ANIMAS
SOUTHEASTERN COLORADO WATER CONSERVANCY DISTRICT HEADQUARTERS AT PUEBLO, COLORADO
GREAT PLAINS RESERVOIR
ADOBE CREEK RESERVOIR
ARKANSAS VALLEY CONDUIT
JOHN MARTIN RESERVOIR U.S.C.E.
LA JUNTA
FOWLER
LAMAR
EADS
PURGATOIRE RIVER WATER CONSERVANCY DISTRICT
TRINIDAD
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
GREAT PLAINS REGION
FRYINGPAN–ARKANSAS PROJECT
COLORADO
10 0 10 20 30
SCALE IN MILES
MEXICO
REVISED OCTOBER 1995
382–706–2848

FIGURE 3-5

Location of Ruedi Dam and Reservoir
Fryingpan - Arkansas Project



Ruedi Dam and Reservoir

Ruedi Dam and Reservoir is located on the Fryingpan River upstream and 13 miles east of Basalt (Figure 3-5). Ruedi Reservoir has a total storage capacity of 102,373 acre-feet, allocated as shown in Table 3-2. The water surface area is 998 acres when the reservoir is filled to capacity.

TABLE 3-2

Ruedi Reservoir

Reservoir[53]	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead	63	7,540.0	7
Inactive	1,032	7,566.0	108
Conservation	101,278[54]	7,766.0	998
Total	102,373		

Ruedi Dam has a main outlet works with a maximum release capacity of 1,810 cfs and an auxiliary outlet works with a maximum release capacity of 600 cfs. The Ruedi Water and Power Authority has constructed a hydroelectric powerplant, which has a penstock that intersects the main outlet works. The powerplant penstock has a maximum capacity of 300 cfs. Ruedi Dam has an uncontrolled overflow spillway with a capacity of 5,540 cfs at a maximum water surface elevation of 7,781.8 feet. The nondamaging flow capacity of the Fryingpan River, as measured at the gauging station downstream of Ruedi Dam, is 1,100 cfs.

One of the primary purposes of Ruedi Dam and Reservoir is to permit project diversions to the east slope that could not otherwise be made because of simultaneous demands by senior water rights owners in western Colorado. The other primary purpose of the reservoir is to provide a regulated water supply for the benefit of western Colorado water users. An incidental purpose of the reservoir is to maintain desired flow levels for recreation and fisheries along the Fryingpan River.

Ruedi Dam and Reservoir are operated in accordance with the "Operating Principles - Fryingpan-Arkansas Project - House Document No. 130, 87th Congress, 1st Session" (operating principles). The operating principles require that "For the protection of recreation values, including fishing on the Fryingpan River below Ruedi Reservoir, releases of water from said reservoir, not to exceed the stream inflow, shall be made so that the stream flow immediately below the junction of the

[53] Dead storage means any storage capacity that is below the outlet works of the reservoir and cannot be released downstream. Inactive storage means storage capacity that is above the reservoir outlet works but is typically not released downstream because of reservoir management objectives, such as maintaining a fishery or recreation pool.

[54] The operating principles require that Ruedi Dam and Reservoir be constructed to have an active capacity or conservation capacity of not less than 100,000 acre-feet.

Fryingpan River and Roaring Fork shall not be reduced below 39 cfs from November 1 to April 30, and 110 cfs from May 1 to October 30, or as actual experience or court decree shall hereafter dictate."

Any water left over after replacement water is provided may be sold or leased by the United States for any purpose authorized by the laws of the United States. Since the present demand for the water stored in Ruedi Reservoir is less than 500 acre-feet, the reservoir is operated to benefit recreation, fish and wildlife, flood control, and the endangered fish of the Colorado River.

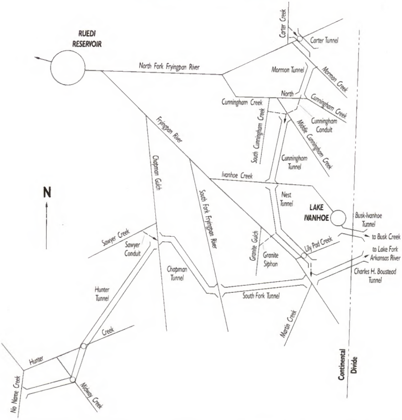
Typical operations result in minimum reservoir levels at the end of April, storage of spring runoff during May and June, with a full reservoir by the end of the first week of July. The reservoir remains full, other than small releases to meet contractual demands from municipal water users, until there is a need for releases for the endangered fishes about August 1. Water for the endangered fishes is released so that the flow in the Fryingpan River below Ruedi Dam does not exceed 250 to 300 cfs. Generally the reservoir capacity is maintained at 85,000 acre-feet or more through the Labor Day weekend, which is considered to be the end of the recreation season. Beginning on October 1, the reservoir is drawn down at a relatively constant release rate to its minimum elevation by the following April 30. Fall and winter water releases represent water that is earmarked for west slope users, rather than for east slope users.

North and South Collection Systems

The North and South Collection Systems on the west slope collect high mountain runoff and convey the diverted waters to the inlet portal of the Charles H. Boustead Tunnel (Figure 3-6).

FIGURE 3-6

North and South Side Collection System
Fryingpan - Arkansas Project



Sixteen diversion structures are used to divert water into the collection system. Three of the diversion structures are located in the Hunter Creek watershed and the remaining 13 are located in the upper Fryingpan River watershed. The system includes eight tunnels with a combined length of approximately 21.5 miles. The 5-mile-long Boustead Tunnel conveys the water from the North and South Collection Systems under the Continental Divide to Turquoise Lake on the east slope.

The diversion capacity, minimum bypass requirement, and conveyance capacity of the North and South collection systems are shown in Table 3-3. All conveyance systems ultimately feed into the Charles Boustead Tunnel, noted on the last line of the table.

TABLE 3-3

Fryingpan-Arkansas Project - North and South Collection Systems

Diversion-Conveyance	Minimum Bypass (cfs)	Diversion Capacity (cfs)	Conveyance Capacity (cfs)
North Collection System			
Fryingpan River Watershed			
Carter - Carter Tunnel	2.0	100	100
North Fork - Carter Tunnel	1.0	30	130
Mormon - Mormon Tunnel	2.0	60	190
N. Cunningham - Cunningham Tunnel	1.0	30	270
M. Cunningham - Cunningham Tunnel	1.0	50 [55]	270
S. Cunningham - Cunningham Tunnel	0.0	20	270
Ivanhoe - Nast Tunnel	2.0	150	360
Granite - Nast Tunnel	0.0	50	360
Lily Pad - Nast Tunnel	0.0	35	360
South Collection System			
Hunter Creek Watershed			
No Name - Hunter Tunnel	4.0	95	270
Midway - Hunter Tunnel	5.0	85	270
Hunter - Hunter Tunnel	12.0	140	270 [56]
Fryingpan River Watershed			
Chapman-Chapman	3.0	300 [57]	300
Sawyer - Chapman Tunnel	0.0	40	300
South Fork - South Fork Tunnel	6.0	250	450
Fryingpan - Fryingpan Feeder	12.0	400	400
Transmountain Diversion			
Charles H. Boustead Tunnel	1,000 cfs water right - 976 absolute, 24 conditional		

[55] The 20 cfs diverted at South Cunningham diversion is discharged into Middle Cunningham Creek and rediverted at Middle Cunningham diversion. This rediversion is included in the 50 cfs diversion capacity of Middle Cunningham diversion.

[56] The Hunter Tunnel is physically larger than 270 cfs, but the conveyance amount is limited by the water rights decree for the tunnel.

[57] The 40 cfs diverted at Sawyer and 270 cfs diverted from the Hunter Creek watershed are discharged into Chapman Creek and rediverted at Chapman diversion. The rediversion is included in the 300 cfs diversion capacity of Chapman diversion.

During the October - March period, bypass requirements are one-half of the amount stated above for each diversion point. Water may be diverted from the Hunter Creek watershed diversion sites any time that the flows at these sites exceed the minimum bypass flows shown in Table 3-3. However, prior to initiating diversions at any of these sites, the flow at the Fryingpan River's Thomasville gaging station must be at least at the levels specified in Table 3-4.

TABLE 3-4

Minimum Fryingpan River Flow Requirements Before Fryingpan-Arkansas Diversions Are Allowed

October 1 - March 31	30 cfs
April 1 - April 30	100 cfs
May 1 - May 31	150 cfs
June 1 - June 30	200 cfs
July 1 - July 31	100 cfs
August 1 - August 31	75 cfs
September 1 - September 30	65 cfs

Average annual diversions by the collection systems to the east slope during any 34-year period are estimated to be 72,200 acre-feet per year. This figure includes 3,000 acre-feet of water for exchange with the Twin Lakes Reservoir and Canal Company.[58] Historical diversions for the period 1982 through 1994 (13 years) have averaged approximately 56,000 acre-feet per year, including 1,600 acre-feet of water for exchange with Twin Lakes Reservoir and Canal Company. This period includes several years (1986, 1987, and 1988) during which diversions were curtailed because east slope reservoirs were full and no storage capacity was available to store project water.

The operating principles limit the transmountain water diversions to 120,000 acre-feet of water in any one year. Exchanges with Twin Lakes Reservoir and Canal Company are not included in this total. The operating principles also limit diversions to an aggregate of 2,352,800 acre-feet in any period of 34 consecutive years, reckoned in continuing progressive series. This equates to an average annual diversion of 69,200 acre-feet. The average annual diversion becomes 72,200 acre-feet if the 3,000 acre-foot Twin Lakes - Roaring Fork exchange is added.

Non-Federal Collector Systems for West Slope Water Imports

Wurtz, Ewing, and Columbine Ditches (Pueblo Board of Water Works)

The Ewing, Wurtz, and Columbine are open ditches, conveying water from the headwaters of the Eagle River in the Colorado River Basin, through saddles in the Continental Divide, into West Tennessee Creek and the East Fork Arkansas River north of Leadville (Figure 3-7). The ditches operate independently, each delivering water to the Arkansas at a distinct point. Water from any of these transmountain diversions is storable in the Arkansas River watershed.

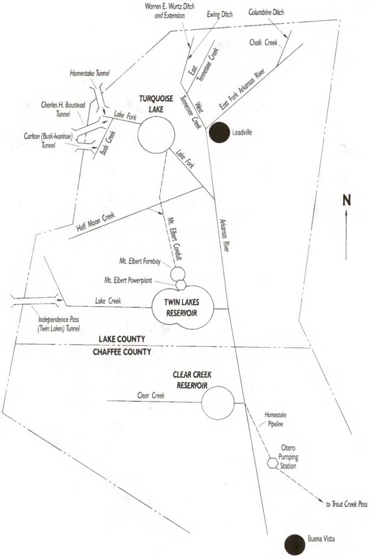
The Ewing Ditch is 3/4-mile long, conveying water from Piney Creek, a tributary of the Eagle River, into a tributary to West Tennessee Creek. It intercepts runoff from a drainage area of 2,400 acres. Ewing Ditch is typically operated April through October, conveying an average of 1,175 acre-feet of water per year.

Similarly, the Wurtz Ditch and Wurtz Ditch Extension convey water from Eagle River tributaries to Tennessee Creek. The Wurtz Ditch is 5 miles long, and the Wurtz Ditch Extension is another 6 miles long. The ditch and the extension together intercept runoff from a drainage area of 5,480 acres. The Wurtz Ditch is typically operated

[58] The purpose of this exchange is to prevent the Upper Roaring Fork and Lincoln Gulch from being dried up by Twin Lakes Canal and Reservoir Company diversions. The right held by the company would allow it to completely dewater these streams if the exchange agreement were not in place.

FIGURE 3-7

Pueblo Board of Water Works System



April through October, and conveys an average of 2,459 acre-feet per year.

The Columbine Ditch intercepts runoff from a drainage area of 1,170 acres in the headwaters of the Eagle River Basin and conveys water to Chalk Creek, a tributary of the East Fork Arkansas River. The Columbine Ditch is typically operated April through October, diverting an average of 1,337 acre-feet per year.[59 60]

Table 3-5 delineates the physical characteristics of these conveyance systems. Conveyance capacities for ditches with multiple headgates are cumulative totals.

[59] P.O. Abbott, "Description of Water-Systems Operations In The Arkansas River Basin, Colorado." Water Resources Investigation Report 85-4092, U.S. Geological Survey.

[60] Rocky Mountain Consultants, Inc. "Report On The Change Of Use Of The Busk-Ivanhoe System, The Columbine Ditch, The Ewing Ditch, And The Wurtz Ditch - Case No. 90CW52 and 90 CW 340." August, 1992.

TABLE 3-5

Wurtz/Ewing/Columbine Ditches - Physical Characteristics

Diversion-Conveyance	Minimum Bypass (cfs)	Diversion Capacity (cfs)	Conveyance Capacity (cfs)
Columbine Headgate No. 1	0	10 cfs	10 cfs
Columbine Headgate No. 2	0	20 cfs	30 cfs
Columbine Headgate No. 3	0	30 cfs	60 cfs
Ewing Ditch	0	18.5 cfs	18.5 cfs
Wurtz Headgate No. 1	0	60 cfs	60 cfs
Wurtz Headgate No. 2	0	15 cfs	75 cfs
Wurtz Headgate No. 3	0	18 cfs	93 cfs
Wurtz Headgate No. 4	0	2 cfs	95 cfs
Wurtz Headgate No. 5	0	5 cfs	100 cfs

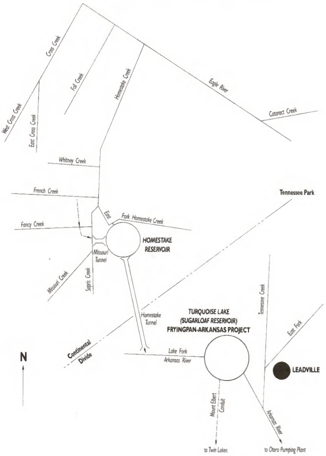
Homestake Project (Colorado Springs Utilities and City of Aurora)

The collection system of the Homestake Project intercepts the headwaters of the Eagle River about 160 miles west of Colorado Springs. The project is a joint venture of Colorado Springs Utilities and the City of Aurora. The purpose of the project is to deliver water to the Arkansas River Basin, for subsequent rediversion to the municipal water supply systems of Aurora and Colorado Springs.

Water is diverted from Fancy Creek, French Creek, Sopris Creek, Missouri Creek, Homestake Creek, and East Fork Homestake Creek (Figure 3-8). The water is collected in Homestake Reservoir and then moved through the Continental Divide via the Homestake Tunnel. Homestake Tunnel discharges into the Lake Fork of the Arkansas

FIGURE 3-8

Blue River Project Collection System



River, which in turn flows into Turquoise Lake. Table 3-6 outlines the capacities and bypass requirements for the components of the Homestake Project.

Diversions are also limited by a minimum bypass flow of 24 cfs at Gold Park gage, located on Homestake Creek downstream of Homestake Reservoir. This requirement often forces curtailment of diversions in advance of calls placed by senior rights in the Colorado River watershed.

The Homestake Tunnel has a capacity of 600 cfs, and holds a water right of 10 cfs for seepage and interception that takes place inside the tunnel. However, conveyance through the Homestake Tunnel is limited by a maximum flow of 300 cfs in the Lake Fork of the Arkansas River, including both native and imported water. All the bypass and maximum flows discussed above were established by the Record of Decision and Environmental Impact Statement for the Homestake II Project, issued by the U.S. Forest Service.

Homestake Project water is stored in Turquoise Lake and routed via the Mt. Elbert Conduit to Twin Lakes, then subsequently released to the Otero Pipeline. The Otero Pipeline delivers water from Twin Lakes to the Otero Pumping Plant, located on the east side of the Arkansas River. The pumping plant supples water to the 66-inch Homestake Pipeline, which conveys it over Trout Creek Pass and across the lower end of South Park. The pipeline then divides to provide water to Aurora at Spinney Mountain Reservoir and to Colorado Springs Utilities at Rampart Reservoir.[61]

To date, the average annual yield of the project is approximately 28,000 acre-feet. The Homestake Project also has additional conditional water rights that have not yet been developed. Only phase one of the project has been completed. Additional decreed conditional rights could be developed and construction is pending, awaiting necessary permit approval. Full development would increase diversions from the Eagle River Basin to the Arkansas River Basin by about 22,000 acre-feet.

TABLE 3-6

Homestake Project

Homestake Reservoir Allocation	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead	211.30		
Conservation	42,881.13		
Total	43,092.43	10,257.0	333.70

Homestake Diversion Structures	Minimum Bypass (cfs)	Decreed Capacity - 1962 (cfs)
French Creek	1.67	180
Fancy Creek	1.00	130
Missouri Creek	3.00	120
Sopris Creek	2.00	160
E. Fk. Homestake Creek	2.67	260
M. Fk. Homestake Creek	6.00	300

[61] Abbott at 22, and interview with Phil Saletta, Colorado Springs Utilities, Nov. 3, 1997.

Busk-Ivanhoe Collection System (Pueblo Board of Water Works and Busk-Ivanhoe, Inc.)

The Busk-Ivanhoe System diverts water from Ivanhoe Creek, Lyle Creek, Pan Creek, and Hidden Lake Creek, all of which are tributaries to the Fryingpan River (Figure 3-9). Water from these diversions is stored in Ivanhoe Reservoir, located on Ivanhoe Creek. Diversions from Lyle Creek are transported to Ivanhoe Reservoir via a ditch from the northwest, while diversions from Pan Creek and Hidden Lake are transported to the reservoir via a ditch from the southwest (Table 3-7). From Ivanhoe Reservoir, water is conveyed through the old Carlton Tunnel to Busk Creek, a Lake Fork tributary, and then directly into Turquoise Lake. The project's Charles H. Boustead Tunnel can also be used to transport this water when space is available in the tunnel, subject to terms of a carriage contract with BOR. This system is typically operated from May through October, conveying an average of 5,081 acre-feet annually from the west slope to the east slope.[62]

FIGURE 3-9

Busk-Ivanhoe Collection System

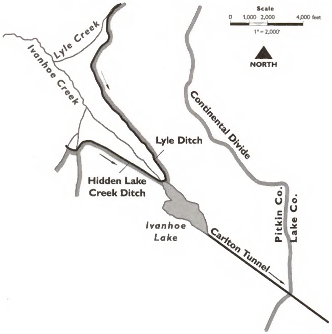


TABLE 3-7

Busk-Ivanhoe Collection System

Diversion-Conveyance	Minimum Bypass (cfs)	Diversion Capacity (cfs)	Conveyance Capacity (cfs)
Lyle Ditch	0	50	50
Ivanhoe Creek	0	35	none-stored immediately in reservoir
Hidden Lake Creek Ditch	0	70	70
Pan Ditch	0	25	25 (+50 conditional)

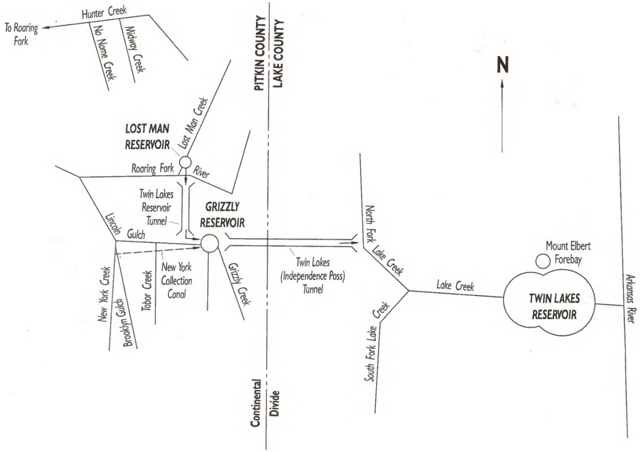
[62] Abbott at 27.

Twin Lakes Collection System (Shares owned by Colorado Canal Irrigators, City of Aurora, Colorado Springs Utilities, Pueblo Board of Water Works, Pueblo West Metropolitan District, Town of Olney Springs, and other parties)

The Twin Lakes Project transmountain diversion system was constructed in the 1930's to serve land irrigated by the Colorado Canal in Crowley County (Figure 3-10). The collection system is located in eastern Pitkin County at the headwaters of the Roaring Fork River. Water is diverted to Grizzly Reservoir from the Roaring Fork River, Lost Man Creek, New York Creek, Tabor Creek, Brooklyn Gulch, and Lincoln Gulch. From here, water is transferred through the Twin Lakes (Independence Pass) Tunnel No. 1 into the North Fork Lake Creek. The imported water is stored in Twin Lakes for later release. This system conveys an average of 54,500 acre-feet of water annually.[63]

FIGURE 3-10

Twin Lakes Project System



[63] Abbott at 49.

Table 3-8 outlines the physical characteristics of the Twin Lakes Collection System.

The Grizzly and Roaring Fork diversions are subject to bypass flows, but the amount of yield lost to the bypass flow is reduced via an exchange with project water at Twin Lakes. Twin Lakes Reservoir and Canal Company receives credit in Twin Lakes for the amount of the bypass flows, subject to the conditions outlined in Table 3-9.

TABLE 3-8

Twin Lakes Collection System

Diversion-Conveyance	Minimum Bypass (cfs)	Diversion Capacity (cfs)	Conveyance Capacity (cfs)
New York Collection Canal (New York Creek, Brooklyn Gulch, and Tabor Creek)			
New York Canal Headgate #1	0	77	77
New York Canal Headgate #2	0	39	116
New York Canal Headgate #3	0	186	302
Roaring Fork River and Lost Man Creek Watersheds			
Twin Lakes Tunnel #2	0	322	322
Transmountain Diversion (diverted from Grizzly Reservoir)			
Twin Lakes Tunnel #1	0	625	625

TABLE 3-9

Twin Lakes Collection System - Grizzly and Roaring Fork Diversions

Month	Grizzly Diversion (cfs)	Roaring Fork Diversion (cfs)
October	3.0	4.0
November	3.0	0.0
December	3.0	0.0
January	3.0	0.0
February	3.0	0.0
March	3.0	0.0
April	3.0	0.0
May	3.0	1.0
June	2.0	1.5
July	2.0	1.5
August	3.0	4.0
September	3.0	4.0

A. Credit will not be granted for any bypass flows in excess of the above amounts.

B. In the event that flows available to be bypassed are less than the above amounts, only the amount actually bypassed will be credited.

C. The total volume of the credit shall not exceed 3,000 acre-feet in any one water year.

D. No credit will be given on days when there is no documentation of bypasses.

E. No credit will be given for water bypassed when diversions are called out by the State Engineer.[64]

[64] U.S. Dept. of the Interior, Bureau of Reclamation. "Annual Operating Plan - Fryingpan Arkansas Project, Water Year 1994-95" at Appendix C.

Grizzly Reservoir stores water from New York Collection Canal and Twin Lakes Tunnel #2 before it is diverted under the Continental Divide by Twin Lakes Tunnel #1 (Table 3-10).

TABLE 3-10

Grizzly Reservoir

Allocation	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead Storage	0		
Conservation	582.0	10,530.0	41.0

Major East Slope Storage Facilities

Sugarloaf Dam and Turquoise Lake (Fryingpan-Arkansas Project)

Sugar Loaf Dam and Turquoise Lake are located on the Lake Fork of the Arkansas River 5 miles west of Leadville. Turquoise Lake is an enlargement of the previous Sugarloaf Reservoir constructed by the CF&I Steel Corporation. The original Sugarloaf Reservoir, with a capacity of 17,416 acre-feet, was purchased by BOR for the project and enlarged to a capacity of 129,398 acre-feet. When the lake is filled to maximum storage level, it has a water surface area of 1,789 acres, at elevation of 9,869.4 feet. Spillway discharge is 2,920 cfs to Lake Fork at maximum water surface elevation 9,872.9 feet. Storage at Turquoise Lake is allocated as shown in Table 3-11.

TABLE 3-11

Turquoise Lake

Reservoir	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead	2,810	9,765.9	542
Inactive	6,110	9,775.4	709
Conservation	120,478	9,869.4	1,789
Total	129,398		

The combined inactive and dead capacity of 8,920 acre-feet is the minimum storage for recreation and fish and wildlife purposes.

Turquoise Lake provides storage for water from four sources:

1. Lake Fork water under the original Turquoise Lake decrees (stored pursuant to contract agreements with the water right owner).
2. Non-project water imported from the west slope by the Homestake and Busk-Ivanhoe projects.
3. Project water imported from the west slope.
4. Lake Fork (native, east slope) water under the project's water right decree.

The water stored in Turquoise Lake is released to the Mt. Elbert Conduit and Lake Fork Creek. Although the outlet works capacity of Sugar Loaf Dam is greater than 1,100 cfs, the maximum release to the Mt. Elbert Conduit is 370 cfs, the capacity of the conduit. The maximum release to the Lake Fork is generally limited to 400 cfs, which is considered to be the maximum nondamaging flow for the Lake Fork stream channel. The required minimum daily release to Lake Fork is 15 cfs or the natural inflow to Turquoise Lake, whichever is less. Water released to the Mt. Elbert Conduit first flows through the Sugar Loaf hydroelectric powerplant, located at the base of Sugar Loaf Dam. This plant was constructed and is operated by private enterprise, under a permit issued by the Federal Energy Regulatory Commission. The most efficient operational range of flow for the powerplant is 250 to 370 cfs.

Mt. Elbert Conduit and Forebay (Fryingpan-Arkansas Project)

The Mt. Elbert Conduit, a 10.7 mile, 90-inch-diameter pipe, with a capacity of 370 cfs, conveys project and nonproject water from Turquoise Lake to the Mt. Elbert Forebay. This 370 cfs total includes 6.7 cfs of project water for the Leadville National Fish Hatchery, located about 2.3 miles southwest of Turquoise Lake. The Halfmoon Diversion Dam, located 4.7 miles south of Turquoise Lake, diverts up to 150 cfs of Halfmoon Creek flow into the Mt. Elbert Conduit. A minimum daily flow of 7.0 cfs, or the inflow to the diversion dam, whichever is less, must be bypassed as a minimum instream flow in Halfmoon Creek.

Water conveyed to the forebay is used to generate hydroelectric power at the Mt. Elbert Pumped-Storage Powerplant. The forebay regulates water only for hydroelectric power generation, and provides no long-term carryover storage for other project purposes. The Forebay water surface elevation may fluctuate as much as 30.7 feet in a 24-hour period. Storage at Mt. Elbert Forebay is allocated as shown in Table 3-12.

TABLE 3-12

Mt. Elbert Forebay

Reservoir	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Inactive	3,825	9615.0	188
Conservation	7,318	9645.7	275
Total	11,143		

The Mt. Elbert Pumped Storage Powerplant is located approximately 13 miles southwest of Leadville, at the northwest corner of the lower lake of Twin Lakes and 0.6 miles south of the forebay. The powerplant has two pump-generator units, each with a nameplate capacity of 100 megawatts (MW). Each of the powerplant penstocks are 15 feet in diameter and have a maximum flow capacity of 3,400 cfs. The tailrace of the power-plant discharges into the lower lake of Twin Lakes. Power produced at this site is fed into the power grid managed by the Western Area Power Administration (WAPA).

Twin Lakes Dam and Twin Lakes (Fryingpan-Arkansas Project)

Twin Lakes Dam and Twin Lakes are located on Lake Creek, a tributary of the Arkansas River about 13 miles south of Leadville. Twin Lakes Dam is an enlargement of the previous Twin Lakes Dam constructed by the Twin Lakes Reservoir and Canal Company. The previous Twin Lakes Dam and Reservoir, with an active capacity of 54,452 acre-feet, was purchased by BOR for the project and enlarged to a total capacity of 140,855 acre-feet.

Twin Lakes has a water surface area of 2,767 acres when filled to capacity. The maximum storage level of Twin Lakes is 9,202.3 feet with a spillway discharge of 1,400 cfs to Lake Creek. The combined inactive and dead storage capacity of 72,938 acre-feet, with a water surface area of 1,702 acres, is used for recreation, fish, and wildlife purposes. Twin Lakes storage is allocated as shown in Table 3-13.

TABLE 3-13

Twin Lakes

Reservoir	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead	63,324	9,162.9	1,599
Inactive	9,614	9,168.7	1,702
Conservation	67,917	9,200.0	2,767
Total	140,855		
Power	7,318	9,197.3-9,200	2,648

(Note: The portion of the conservation pool is generally reserved for power and energy generation.)

Twin Lakes provides up to 54,452 acre-feet of storage for the Twin Lakes Reservoir and Canal Company for water imported from the upper Roaring Fork of the Colorado River on the west slope and/or the native flow of Lake Creek under decrees owned by the company. The remaining

13,465 acre-feet of the conservation capacity are used for project purposes. This total includes 7,318 acre-feet usually reserved for regulation of water for hydroelectric power generation at the Mt. Elbert Pumped-Storage Powerplant.

The water stored in Twin Lakes is released to Lake Creek and/or the Otero Pipeline of the Homestake Project, which is owned by Colorado Springs and Aurora. The outlet works has a maximum release capacity of 3,465 cfs when Twin Lakes is full. The normal maximum release to Lake Creek is about 1,600 cfs, which is generally considered to be the nondamaging flow of Lake Creek. The maximum release to the Otero Pipeline is 150 cfs, the capacity of the pipeline. The required minimum daily release to Lake Creek is 15.0 cfs or native inflow to Twin Lakes, whichever is less. Via the project's operating plan, a minimum flow of 66.0 cfs was established for the Arkansas River at Granite, which is the only legal minimum flow requirement on the main stem of the Arkansas. This flow is assured by releases from Twin Lakes.

The native water of Halfmoon and Lake Creeks released from Twin Lakes to Lake Creek and the Arkansas River is subject to appropriation pursuant to Colorado law. The water is diverted from the Arkansas River at numerous diversion points between Twin Lakes and the Colorado-Kansas State line, but the major diversion points for this water are located east of Pueblo Reservoir.

Project water released from Twin Lakes to Lake Creek and the Arkansas River is delivered to water users located above or below Pueblo Reservoir, or the water is stored in Pueblo Reservoir. Water owned by the City of Aurora and Colorado Springs Utilities is delivered to the Otero Pipeline.

Clear Creek Dam and Reservoir (Pueblo Board of Water Works)

Clear Creek Dam and Reservoir, which is owned, operated, and maintained by the Pueblo Board of Works, is an authorized feature of the Fryingpan-Arkansas Project. However, the acquisition of Clear Creek Dam and Reservoir and construction of the Otero Canal and Otero Powerplant have been indefinitely deferred, and no plans exist for construction. Southeastern is diligent in maintaining the conditional water rights associated with these planned features. Clear Creek Dam is located on Clear Creek at its confluence with the Arkansas River about 11 miles south of Twin Lakes. In 1983 and 1984, the Pueblo Board of Water Works completed a major rebuilding project, including extension of the outlet pipe, addition of a toe berm, and addition of emergency spillways on the north and south portions of the main dam. The physical characteristics of the reservoir are described in Table 3-14.

Clear Creek Reservoir provides storage for native Clear Creek flow during the winter period from November 15 to March 15 and when water rights for native flows come into priority during spring runoff. The reservoir also stores transmountain water from the Columbine, Wurtz, and Ewing Ditches by exchange. The Board may also store water from other sources by exchange. The water stored in Clear Creek Reservoir is released into Clear Creek and the Arkansas River at flow rates and volumes as needed by the Pueblo Board of Water Works customers and the Board's raw water customers.

TABLE 3-14

Clear Creek Reservoir

	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Conservation	11,486	8,880[65]	438.9

Pueblo Reservoir (Fryingpan-Arkansas Project)

Pueblo Reservoir was initially constructed to a capacity of 357,678 acre-feet. The reservoir was

[65] This total includes 800 acre-feet of dead storage.

resurveyed in 1993, and sediment inflow had reduced the water storage capacity to 349,940 acre-feet. The water surface area is 4,611 acres when filled to the top of the conservation capacity. Storage is allocated as shown in Table 3-15.

How the various pools at Pueblo Reservoir may be utilized is outlined in Table 3-16. The primary restrictions revolve around what sources of water may be stored in the pools at various times of the year.

Project water is released from Pueblo Reservoir through multiple conduits. A large percentage of the stored water is released to the Arkansas River and to the Bessemer Ditch for irrigation and municipal use by several entities in the Arkansas Valley east of Pueblo. Water is also released to the Fountain Valley Conduit for municipal use by the members of the Fountain Valley Authority. Members of the authority include the Colorado Springs Utilities and the City of Fountain, Security and Stratmoor Hills Water Districts, and Widefield Homes Water Company. Water is also released to Pueblo West Metropolitan District for municipal use. Native water of about 30 cfs is released through the Pueblo Fish Hatchery to the Arkansas River.

Water can be released from Pueblo Dam to the Arkansas River through seven outlets. This includes three spillway outlets, as well as a river outlet, a south outlet, a fish hatchery outlet, and a Bessemer Ditch outlet. The maximum release to the Arkansas River is in excess of 6,000 cfs at minimum reservoir level, and 10,000 cfs when the reservoir is filled to the spillway crest. Releases above 6,000 cfs are rare because the flood control purpose of the reservoir requires that releases be controlled to limit maximum flows at the Avondale gaging station to 6,000 cfs.

No minimum streamflows have been established for the Arkansas River below Pueblo Dam. However, the requirement to release flows decreed to senior downstream rights usually results in minimum flows in the river below the dam. These

TABLE 3-15

Pueblo Reservoir

Reservoir	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Dead	2,329	4,764.0	420
Inactive	25,792	4,796.7	1,200
Conservation	228,828	4,880.5	4,611
Joint Use	66,000	4,893.8	5,350
Flood Control	26,991	4,898.7	5,671
Total	349,940		

TABLE 3-16

Pueblo Reservoir Pool Allocation

Pool/Allocation	Water Source: Nov. 1 - April 15	Water Source: April 16 - Oct. 31
Conservation	• Native Arkansas water • Project water (both west slope and east slope)	• Project water (both west slope and east slope) • Native Arkansas flows • Native Arkansas water under contract
Flood Control	• Native flood water	• Native flood water
Joint Use (either conservation or flood control)	• Native Arkansas water • Project water (both west slope and east slope) *Must* be used or evacuated by April 15	• Native flood water
Recreation/ Fishery/Wildlife	• Always full - minimum storage level	• Always full - minimum storage level

senior rights include Southern Colorado Power Company's right of 200 cfs, as well as 57.36 cfs of water rights owned by the Pueblo Board of Water Works. All Pueblo water will continue to be released to the river until the City constructs a new water treatment plant immediately below the dam.

The capacity of the south outlet works for municipal purposes is 359 cfs. However, the current maximum release is 50 cfs (31 cfs, the capacity of the Fountain Valley Conduit, and 19 cfs, the capacity of the Pueblo West Pipeline). The remaining 309 cfs capacity is for potential future development of the Arkansas Valley Conduit and the City of Pueblo.

The maximum capacity of the Bessemer Ditch outlet works is 392 cfs. Releases normally do not exceed 300 cfs because the ditch damage may occur at higher flows. The rate of release to the Pueblo Fish Hatchery is about 30 cfs.

Irrigation and Storage Systems Downstream from Pueblo Reservoir that Can Affect Upper Arkansas Streamflows

Irrigation Systems Between Cañon City and John Martin Reservoir

Irrigation is the largest use of water in the Arkansas River watershed. The major water diversions for irrigation are located from Pueblo Dam downstream and east to the Colorado-Kansas border (Figure 3-11). The aggregate of the major direct flow water rights along the Arkansas River is 7,494 cfs, of which 6,371 cfs are located from Pueblo Dam east to the Kansas border. The most senior priority of the major water rights are located from Cañon City east to the State line. Therefore, most of the native flows of the Arkansas River from its headwaters to Cañon City must remain in the river to satisfy these senior rights.

There are several ditches in the Cañon City area that provide water for irrigation of about 4,400 acres. The largest of these ditches are the South Canon Ditch, the Cañon City Hydraulic Ditch, the Cañon City and Oil Creek (Mill) Ditch, and the Union Canal. These ditches have capacities of 55 cfs, 85 cfs, 35 cfs and 50 cfs, respectively. The Minnequa Canal, near Florence, diverts 118 cfs. This includes water for industrial use at CF&I Steel Mills in Pueblo and 50 cfs that is delivered to the Union Canal. The Minnequa Canal also has a junior decree and sufficient capacity to divert an additional 150 cfs, but this right is seldom exercised.

There are several very large diversions downstream of Pueblo Reservoir that typically require water to be left in the river between Turquoise Lake and Pueblo Reservoir in order to satisfy the senior water right. These diversions also acquire supplemental water from the project, so the timing of supplemental water demands can affect flows in the upper Arkansas River. These rights are summarized in the following Table 3-17.

FIGURE 3-11

Major Irrigation Systems Between Cañon City and Colorado - Kansas Border

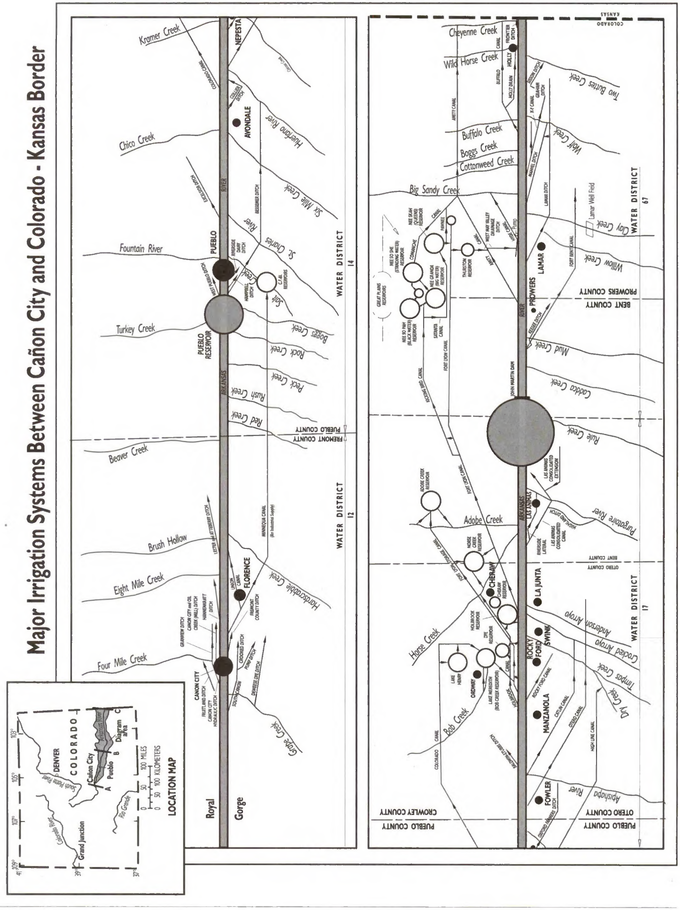


TABLE 3-17

Canals and Ditches Between Pueblo Reservoir and John Martin Reservoir that Receive Supplemental Water from the Fryingpan-Arkansas Project and Other Projects

Ditch Name	Capacity	Water Right Priorities*	Irrigated Acreage (approximate)
Bessemer Ditch	392 cfs	71 cfs - 1882 or earlier 322 cfs - 1887	20,000
Colorado Canal (Majority interest is now owned by Colorado Springs and Aurora.)	800 cfs	756 cfs - 1890	6,800
Highline Canal	600 cfs	120 cfs - 1886 or earlier 378 cfs - 1890	26,000
Oxford Farmers Ditch	130 cfs	13 cfs - 1867 116 cfs - 1887	6,000
Otero Canal Diversion	100 cfs	123 cfs - 1890 335 cfs - 1903	10,000
Catlin Canal	345 cfs	248 cfs - 1884 97 cfs - 1887	19,500
Holbrook Canal	800 cfs	155 cfs - 1889 445 cfs - 1893	19,550
Rocky Ford Canal	150 cfs	112 cfs - 1875 97 cfs - 1890	8,200
(City of Aurora has purchased majority interest. In the future, 8,000 acre-feet will be diverted at Otero Pipeline. By decree, this water must first be exchanged to Pueblo Reservoir, then exchanged to upstream reservoirs or Otero. In addition, it can be exchanged for other water delivered to Otero.)			
Fort Lyon Storage Canal	1,500 cfs	1,500 cfs - 1906	Storage in Horse Ck./ Adobe Reservoirs
Fort Lyon Canal	1,500 cfs	165 cfs - 1884 597 cfs - 1887 171 cfs - 1893	91,300
Las Animas Consolidated Canal	150 cfs	22 cfs - 1875 28 cfs - 1884 80 cfs - 1888	6,950

* Total water rights amounts may exceed capacities because the canals only occasionally use their more junior water rights.

John Martin Reservoir

As described under "John Martin Reservoir and the Arkansas River Compact," the primary purpose of John Martin Reservoir is flood control, while irrigation is a secondary purposes. John Martin Dam, located on the Arkansas River about 58 miles west of the Colorado-Kansas border, was completed by COE in 1948. Water stored in the conservation pool is delivered to Colorado irrigators and to the State of Kansas, using the Arkansas River channel as the conveyance mechanism. The allocation of John Martin Reservoir storage is depicted in Table 3-18.

TABLE 3-18

John Martin Reservoir

	Capacity (acre-feet)	Elevation (feet)	Surface Area (acres)
Inactive	15,000	3,795	1,800
Conservation	335,700	3,851	11,394
Flood Control	269,415	3,870	17,151
Total	605,115*		

* Note: The inactive allocation, which is the same as the recreation pool, may go below 15,000 acre-feet during periods when extremely low water supply is accompanied by high evaporation losses. This 15,000 acre-foot pool is considered to be within, rather than additional to, the conservation pool.

The reservoir may store two types of water for conservation purposes (other than recreation). The first type is current riverflows, which are stored in the reservoir's conservation capacity. In the winter season, November through March, all water entering the reservoir is retained, up to its conservation capacity (flood control gets the top of the reservoir). In the summer season, April through October, current river inflow to the reservoir is passed through the reservoir and supplemented as necessary with previously stored waters to meet the needs of downstream users in Colorado and Kansas. Inflows in excess of the needs of Colorado users are placed in conservation storage and allocated between Colorado and Kansas. Specific allocations of conservation storage among these parties are discussed under "Compact Provisions Guiding the Operation of John Martin Reservoir."

The second type of water that may be stored at John Martin is water typically diverted under the WWSP (this program was previously discussed under "Early Winter Irrigation Practices and Arkansas River Winter Water Storage Program," and is distinct and separate from water that may be stored under Article III of the John Martin Reservoir Operating Plan). Under the WWSP, Las Animas Canal may store 5,000 acre-feet, Fort Lyon Canal may store 20,000 acre-feet, and Amity Canal may store 50,000 acre-feet.[66] Amity Canal has the option of storing the 50,000 acre-feet per year either in John Martin or in the Great Plains Reservoir System.

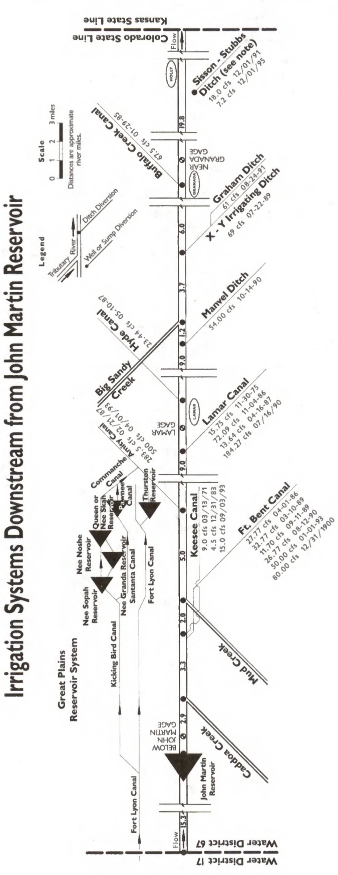
Irrigation Systems Downstream from John Martin Reservoir

All of the ditches downstream and east of John Martin Reservoir are subject to the Arkansas River Compact (Figure 3-12). None are provided water or services from the project, nor are these systems located within the boundaries of the Southeastern District. The amount of water stored in John Martin Reservoir is the primary determining factor as to what impact downstream water right priorities will have on water rights upstream of John Martin Reservoir.

All of the ditch rights below John Martin influence the rights upstream to some degree. The upstream and downstream right owners have entered into an agreement, known as "Agreement B," which, in essence, states that downstream senior rights will

[66] 1980 Operating Plan for John Martin Reservoir at Section III; and case number 80 CW 19, Water Division 2 (change of use case for Great Plains Reservoirs).

FIGURE 3-12



not place a call on upstream junior rights as long as the potentially calling senior has storage in their John Martin account designated as "summer stored water."

The operating principles of "Agreement B" are as follows:

Release into the Accounts-

1. When conservation storage is being released into the accounts according to the provisions of Subsections IIA or IIB, herein, it shall be released at the total rate of 1,000 cfs. However, when conservation storage exceeds 20,000 acre-feet, it shall be released at the total rate of 1,250 cfs.

2. Releases of conservation storage shall be into accounts and said releases shall be apportioned 60 percent for the accounts of the Colorado Water District 67 ditches and 40 percent for the Kansas account.

3. The releases for the Colorado Water District 67 ditches shall be distributed into individual accounts according to the following percentages:

    Fort Bent - 9.9 percent
    Keesee - 2.3 percent
    Amity - 49.5 percent
    Lamar - 19.8 percent
    Hyde - 1.3 percent
    Manvel - 2.4 percent
    X-Y & Graham - 5.1 percent
    Buffalo - 8.5 percent
    Sisson - Stubbs - 1.2 percent

The various ditches in Water District 67 may demand the release of water retained in their respective accounts, at any time or rate they desire, subject to the following provisions:

1. All accruals during the winter storage season shall be "winter stored water." Designated winter water once divided into accounts shall not prevent entities from placing a "call" on the river.

2. Of any remaining water due to Colorado ditches in the "transit loss account" at the end of the year (October 31), one half (1/2) shall be classified "winter" water and transferred November 1 as a block into the individual winter water accounts. (The "transit loss account" is designed to cover evaporation and seepage losses between the reservoir outlet and the Colorado-Kansas border. All entities that have Section III accounts, including Las Animas Canal, Fort Lyon Canal, and Amity Canal, have 35 percent deducted from their accounts to be placed in the "transit loss" account. For further discussion of the "transit loss account," see "Compact Provisions Guiding the Operation of John Martin Reservoir.")

3. All accruals to the Conservation Pool during the remainder of the year shall be "summer stored water" which shall include the remaining one-half of the unused transit loss water due to Colorado ditches.

4. If any entity has designated winter water in its account beyond May 1st of the succeeding year, this water will become summer storage water.

   a. Water stored in the summer storage season from April 1 to October 31 shall be placed into accounts in accordance with subsection IID of the Operating Plan for the John Martin Reservoir. As long as an entity has any summer stored water in its account, it cannot place a "call" above John Martin for its priority on the river.

   b. This agreement shall remain in effect for a period of one year from date hereof and as long thereafter until such time as any party demonstrates material injury. Thereupon, the parties shall renegotiate the agreement to the mutual satisfaction of all parties. Until such negotiations are complete, the call shall operate under Plan "A" for one year.

   c. Both districts agree that in the event winter stored water in Pueblo Reservoir is spilled by BOR, it shall be run to John Martin and regardless of season shall be considered summer water. In the event there is a reasonable prospect John Martin will spill, any spilled water will be declared free and can be picked up by intervening ditches.

The largest of the ditches downstream of John Martin Reservoir which operate under this agreement are listed in Table 3-19.

TABLE 3-19

Selected Ditches Downstream from John Martin Reservoir

Ditch	Water Rights (cfs - date)	Acreage Irrigated
Fort Bent Canal/ Keesee Ditch	27.77 - 1886 32.77 - 1889 26.77 - 1890 50.00 - 1893 80.00 - 1900	8,740
Lamar Canal	15.75 - 1875 72.09 - 1886 13.64 - 1887 11.70 - 1889 184.27 - 1890	8,700
X-Y Canal/ Graham Ditch	69.00 - 1889 61.00 - 1891	6,000
Buffalo Canal	67.5 - 1885	5,000
Amity Canal	283.5 - 1887 500.0 - 1893	37,800

Operating Principles and Water Management Parameters

Because of the large number of demands made on the Arkansas River by water users, the river is one of the most intensively managed in the western U.S. This section describes constraints created by laws and other legal documents that govern this intensive use, specifically constraints that affect streamflows between the headwaters and Pueblo Reservoir. This section proceeds in chronological order, first describing constraints imposed by meeting obligations to holders of senior water rights and satisfying commitments under the Arkansas River Compact between Colorado and Kansas. The section then describes newer constraints imposed by water supply projects, including the Homestake Project built by Colorado Springs and Aurora and BOR's Fryingpan-Arkansas Project.

Protection of Existing Water Rights

Any modification of flow regimes between the headwaters of the Arkansas River and Pueblo Reservoir to better support natural resource values must not injuriously impact the exercise of thousands of legally established water rights. Senior water rights on the Arkansas River ensure some level of flow in the upper river at all times, because the largest and most senior rights are located downstream from Pueblo Reservoir.

Senior Agricultural and Municipal Water Rights

Generally, main stem Arkansas River rights with a priority date of 1884 or earlier are assured a dependable supply of water. The major agricultural and municipal users with the most senior rights divert their water through one of several senior ditches (see Table 3-20). Municipal users with rights in one or more of these senior systems include the Pueblo Board of Water Works, Colorado Springs Utilities, and the City of Aurora. Public Service Company also owns some of these water rights.

TABLE 3-20

Arkansas River Senior Water Rights

Selected Senior Agricultural and Industrial Water Rights
(Greater than 10 cfs; Decreed 1884 or Earlier)

Structure Name	Water District (Div. of Water Resources)	Amount (cfs)
Minnequa and Union	14	118.00
Bessemer	14	70.65
Rocky Ford Highline	14	89.10
Oxford Farmers	14	13.40
Catlin	17	248.00
Rocky Ford	17	111.76
Fort Lyon	17	164.64
Las Animas Consolidated	17	49.80
Keesee	67	13.50
Lamar	67	15.75
TOTAL		894.60

Selected Senior Municipal Water Rights
(Greater than 10 cfs, Decreed 1896 or Earlier)

Structure Name	Water District (Div. of Water Resources)	Amount (cfs)
City of Cañon City	12	19.00
Colorado Light & Power	14	23.00
Pueblo Board of Water Works	14	57.36
West Pueblo (owned by PBWW)	14	18.20
TOTAL		117.56

The water rights listed in the previous tables represent rights to native Arkansas River flows. Many of the senior rights in the Arkansas River Valley also receive supplemental water from the Fryingpan-Arkansas Project in amounts which vary from year to year. This supplemental water is typically released from Pueblo Reservoir and is not subject to the water rights priority system once it is released into the river.

Transit Charges to Protect Senior Water Rights

Water users who take delivery of water stored in reservoirs must pay applicable transit charges to protect senior ditch rights, because water is lost to both evaporation and seepage when the Arkansas River is used as a conduit. For the upper basin between the headwaters and Pueblo Reservoir, the charge is 0.07 percent per river mile. For example, conveyance of water through the 136 river miles between Twin Lakes and Pueblo Reservoir equates to a transit charge of about 10 percent.

Transit charges between Pueblo Reservoir and the Colorado-Kansas border are calculated by a United States Geological Survey (USGS) model, which was developed through water release experiments from Pueblo Reservoir. The model incorporates factors such as antecedent flows, flow durations, specific loss rates for each reach, and the distance the released water is to be transported. For example, transit charges between Pueblo Reservoir and John Martin Reservoir can vary from 25 to 30 percent, depending on the factors previously listed.[67]

Augmentation Plans to Protect Senior Water Rights

Another practice frequently used in the Arkansas River system to protect senior water rights is implementation of augmentation plans. These plans are designed to replace water, in terms of quantity and timing, that junior appropriators divert out of priority. Approximately 90 percent of the augmentation plans that are approved are designed to allow new or continued pumping from wells without injury to surface water rights. The remaining 10 percent of augmentation plans cover depletions caused by operations such as gravel pits, ponds, campgrounds, and commercial operations. Of all types of augmentation plans, approximately 90 percent are submitted for irrigation uses and for domestic uses within subdivisions. The sources of augmentation water typically tapped by these plans include transmountain water, raw water from municipal collection systems, water from ditches where the agricultural land is retired, and excess consumptive use credits accrued by other augmentation plans.[68]

Conditional Water Rights

Conditional water rights are a feature of Colorado water law that allows a potential water user to claim and hold a water right priority date while the user is in the process of developing beneficial uses and water management structures. Conditional water rights can be held indefinitely, as long as the potential users prove at least once every 6 years that they are proceeding diligently with their water development plans. Conditional water rights in the Arkansas River watershed number in the hundreds and cannot be ignored because their development could impact streamflows. Most conditional rights are downstream of Pueblo Reservoir, but some major rights are located between the headwaters and Pueblo Reservoir. Since most of the conditional water rights upstream of Pueblo Reservoir are relatively junior water rights, their eventual development and use would impact streamflow only in high water years when the rights come into priority.

[67] Interviews with Steve Kastner, Colo. Div. of Water Resources, August 1996.

[68] Interview with Steve Kastner, Colo. Div. of Water Resources, Aug. 6, 1996.

The largest of these conditional rights are outlined in Table 3-21. The first 19 rights on the list are associated with features of the Fryingpan-Arkansas Project that have not yet been constructed or enlarged. BOR does not have plans in place to construct these project elements during the next 10 years. Colorado Springs Utilities' claim for a conditional right on Elephant Rock Reservoir, located on the Arkansas River upstream of Buena Vista, does not appear on the list because it is pending in water court and has not been decreed. In case number 90 CW 56 in Water Division 2, Colorado Springs Utilities has claimed a right for 70,000 acre-feet, with an appropriation date of June 16, 1987.

TABLE 3-21

Selected Conditional Water Rights that Have the Potential to Affect Streamflows in the Upper Arkansas River (Greater than 400 acre-feet or 100 cfs)

Name	Stream	Amount	Priority
1. Sugarloaf Enlargement	Lake Fork Creek	10,238 acre-feet	1969
2. Sugarloaf Enlargement	E. Fk. Ark. River	6,338 acre-feet	1969
3. Malta Canal	Arkansas River	350 cfs	1969
Note: Some of the functions of this planned project element have been fulfilled by construction of the Mt. Elbert Conduit.			
4. Twin Lakes-Otero Section	Lake Creek	725 cfs	1969
5. Wapaco Diversion Section	Arkansas River	600 cfs	1969
6. Wapaco-Princeton Section	Arkansas River	600 cfs	1969
7. Princeton Forebay	Arkansas River	500 acre-feet	1969
8. Princeton-Pancho Section	Arkansas River	1,000 cfs	1969
Note: Nonconsumptive water right for a hydroelectric plant.			
9. Chalk Creek Diversion SE	Chalk Creek	375 cfs	1969
Note: Nonconsumptive water right for a hydroelectric plant.			
10. Pancho Forebay	Arkansas River	418 acre-feet	1969
11. Pancho-Salida Section	Arkansas River	1,000 cfs	1969
12. Salida Forebay	Arkansas River	1,425 acre-feet	1969
Note: Nonconsumptive water right for a hydroelectric plant.			
13. Salida Afterbay	Arkansas River	600 acre-feet	1969
Note: Nonconsumptive water right for a hydroelectric plant.			
14. Canal "A" & Tenderfoot	Arkansas River	2,000 cfs	1969
15. Cache Creek Water System	Cache Creek	7,618 acre-feet	1969
16. Grape Creek Dam	Arkansas River	1,620 acre-feet	1968
17. Canal "C"	Arkansas River	2,000 cfs	1968
18. North Fork Res. UAWCD	N. Fk., S. Ark. Riv.	595 acre-feet	1982
19. North Fork Res. 1984 Enlgmt.	N. Fk., S. Ark. Riv.	500 acre-feet	1984
Note: Right for additional uses of existing capacity at North Fork Reservoir, listed above.			
20. Harvey Brothers Reservoir	Currant Creek	19,021 acre-feet	1968
21. Tallahassee Reservoir	Tallahassee Creek	422 acre-feet	1968
22. Florence, Coal Creek, & Williamsburg Reservoir	Arkansas River	2,250 acre-feet & 100 cfs	1980
23. Cotter Reclamation Spillway	Sand Creek	104 cfs	1988
Note: Exchange for maintaining antipollution reservoir at uranium mill.			
24. Potter Turkey Creek Reservoir	Turkey Creek	8238 acre-feet	1916
Note: Right for enlargement of reservoir used by U.S. Army for amphibious military exercise.			

Instream Flow Water Rights

The Colorado Water Conservation Board holds a significant number of instream flow water rights on major tributaries to the Arkansas River (Table 3-22). While these rights are very junior, with priority dates from 1974 to 1995, they are typically assured of water because demands from senior rights force water deliveries to the lower Arkansas Valley. In cases where the Board's rights extend to the tributaries' confluence with the Arkansas River, these rights can help ensure flows in the main stem of the river. In addition, these instream flow water rights can prevent any junior rights or future exchanges from drying up these tributaries.

TABLE 3-22

Instream Flow Rights Held by the Colorado Water Conservation Board on Major Tributaries to the Arkansas River (only summer flows listed)

Creek	Amount	Priority Date
Tennessee Creek	5 cfs	1982
E. Fk. Arkansas River	15 cfs	1977
Big Union Creek	8 cfs	1976
Cottonwood Creek	20 cfs	1979
Trout Creek (headwaters only)	6 cfs	1974
Chalk Creek (headwaters only)	18 cfs	1977
Browns Creek	5 cfs	1979
Squaw Creek (headwaters only)	0.5 cfs	1979
Badger Creek	3 cfs	1974
Bear Creek	10 cfs	1980
Texas Creek	7.75 cfs	1998
Tallahassee Creek	1.00 cfs	1995
Fourmile Creek (in process)	9.5 cfs	2000 (proposed)
Eightmile Creek	2.5 cfs	1999

The number of instream flow rights on tributaries to the Arkansas River could increase significantly during the next 5 years. The State of Colorado and the Forest Service are negotiating a settlement to the Forest Service's claim of reserved water rights in Arkansas River watershed streams that pass through Forest Service lands. According to preliminary terms of the settlement, the Colorado Water Conservation Board would appropriate instream flows on most streams passing through Forest Service lands by the year 2003, with a current-year priority that recognizes existing water uses. Additional flows may be decreed to the Forest Service on some streams with a 1995 priority date. Downstream of Forest Service boundaries, the BLM has submitted instream flow recommendations on several Arkansas River tributaries.

Protection and Operation of Exchanges

An exchange is an operation whereby a water right or water user may take water from a stream system at one point out of priority and then replace a like amount at another point on the stream system, so long as the operation does not cause injury to water rights between the diversion and replacement points or to downstream water rights. The typical objectives for executing exchanges are to exercise water rights in locations that would otherwise be called out by the priority system, and to maximize the use of storage space within the Arkansas River Basin. Proposed exchanges are evaluated on a case-by-case basis by the Colorado Division of Water Resources. Some exchanges are decreed, although this is not required under Colorado water law.

Factors Limiting Exchange Opportunities

Summarizing the actions taken by water administrators to protect and operate exchanges is very complex, because there are a number of factors that determine whether or not an exchange may be executed.

Water Supply

Many water rights are reliant upon return flows from upstream water rights. Without sufficient streamflow, an exchange may deprive a downstream right of its full diversion amount. This is especially true if there is a significant distance between the diversion location and the replacement flow location.

Storage Conditions

Frequently, the destination for exchanged water is a storage facility that will allow the user to hold the water until needed. If the storage facility is full, an exchange may not be possible. Frequently, the availability of storage space does not coincide with streamflow conditions that are favorable to exchanges. The same factors arise when a user attempts to exchange "previously stored" water. The destination for the "previously stored" water may be a pump, ditch, or another storage facility. Again, storage availability and streamflow conditions dictate whether previously stored water may be exchanged to these locations.

Demand for Water Deliveries and Exchanges

Agricultural and municipal demand for water does not correspond neatly with typically available flows, so many water users are interested in exchanges that allow water to be moved into storage for later use. In addition, flow and storage conditions favorable to exchanges may occur in short, concentrated periods of time. The combination of water demand and limited exchange opportunities means that all parties interested in exchanging at one time may not be able to simultaneously do so. Finally, demands for exchanges are often market-driven, where a water user is seeking to move water from a location where the storage charge is high to a location where the storage charge is lower.

General Characteristics of Exchange Operations

Although exchange operations are highly variable because of these factors, exchange practices do exhibit some general characteristics. Exchanges can be operated at any time of the year, but most exchanges are executed between March 15 and November 15, which avoids conflicts with the WWSP. Within this 8-month window, the magnitude of spring runoff often controls exchange activity. Typically, the first priority for water users is to divert as much spring runoff water as possible under water rights that allow diversion into upstream storage facilities or contracted storage space. If large riverflows in the spring exceed the amount necessary to satisfy these water rights, then significant exchange activity can occur. Other events, such as large spring rains or summer thunderstorms, can create favorable exchange conditions by decreasing agricultural and municipal water demand and by increasing streamflows beyond the amount needed to satisfy water rights.

Many water exchanges on the Arkansas River involve two steps. First, the water is exchanged to Pueblo Reservoir from some downstream diversion or return flow point; then it is exchanged later from Pueblo Reservoir to an upstream storage location. The reason this occurs is because flow conditions may be favorable for exchanges in one reach of the river but may not be favorable in another reach. For example, project reservoir operations often create flow conditions between Twin Lakes and Pueblo Reservoir that are very different than flow conditions downstream from Pueblo Reservoir.

Since these variable flow conditions create constantly varying flow amounts that can be exchanged, most water users request a specific volume, rather than a flow rate, when making an exchange request to the Division of Water Resources. The Division then notifies the users if conditions will permit the exchange. Volumes typically requested range from 1,000 to 5,000 acre-feet, resulting in a typical exchange rate of 10 to 200 cfs.[69]

[69] Interview with Steve Kastner, Colorado Division of Water Resources, Aug. 7, 1996.

Paper Exchanges

Many of the exchanges that occur on the Arkansas River are "paper" exchanges executed for accounting purposes and they do not result in any physical changes to riverflows. For example, several municipalities hold contracts for storage space in project reservoirs, and exchanges are commonly used to get water into this storage space. The municipality may be interested in transferring stored water from Pueblo Reservoir to either Turquoise Reservoir or Twin Lakes so that the stored water can be efficiently delivered to the municipality's distribution system. In this scenario, BOR would simply designate some of the project water already stored at Twin Lakes or Turquoise Reservoir as now belonging to the municipality, and the municipality water stored at Pueblo would become project water. This type of paper exchange is possible because the delivery point for most of BOR's customers in the Southeastern District is at or below Pueblo Reservoir. Another type of paper exchange may occur between different types of storage contracts in a given reservoir. For example, a municipality may be interested in transferring water stored under an "if and when" contract storage space (subject to spill under certain conditions) to firm contract storage space (not subject to spill) in order to increase reliability of supply. If firm contract storage space is available, BOR will simply make a note in the reservoir accounting records to execute the exchange.

Several municipalities hold water rights located downstream of project reservoirs, and these water rights may come into priority only during high flow conditions. When the water rights are in priority, these municipalities may ask BOR to "exchange" the yield of the water rights into contract storage space that the municipalities hold in project reservoirs. During the exchange, the municipality will not increase its downstream diversion, and BOR will not increase its diversions into project reservoirs. Rather, BOR will simply allocate some of the current diversion rate at project reservoirs into the municipalities accounts via an accounting procedure.[70]

Decreed Exchanges

More than 99 percent of the exchanges that affect the upper Arkansas River are executed by six water user organizations. In 1988, these organizations obtained decrees confirming their exchange practices. The exchanges included practices that move water from downstream points to Pueblo Reservoir and also through Pueblo Reservoir to upstream structures including Clear Creek Reservoir, Twin Lakes, and Turquoise Reservoir. These organizations include Colorado Springs Utilities, Pueblo Board of Water Works, Colorado Canal Company, Lake Meredith Reservoir Company, Lake Henry Reservoir Company, and City of Aurora. In a stipulation that was part of each of these cases, the six entities allocated the limited exchange opportunities to move water from below Pueblo Reservoir back up into storage at Pueblo as shown in Table 3-23.

These decreed exchanges may involve the water stored under very senior water rights, but the exchange operation can never cause injury to another senior water right on the river. The exchange operations are typically implemented when the river experiences high flows. This allocation of exchange opportunities applies only to exchanges made below Pueblo Reservoir. Moving water above Pueblo Reservoir is usually dependent upon the volume of inflow into the reservoir, which is the ultimate destination for the water, and the date of individual exchange decrees. In addition, all the exchange decrees have stipulations regarding limitations on exchanges into Pueblo Reservoir during the WWSP.

[70] Much of the information for this section was obtained through interviews with Steve Witte, Colorado Division of Water Resources, during May 1998.

TABLE 3-23

Allocation of Arkansas River Exchange Opportunities Below Pueblo Reservoir[71] (in cfs)

Priority	Pueblo	Colorado Springs	Colo. Canal Companies	Aurora	Total
1	27				27
2		100			127
3	50	50			227
4		50			277
5				Max. Flow Rate Allowed in 83 CW 18[72]	
6		100			377
7[73]		1/2 remaining exchange opportunity minus Aurora under this priority	1/2 remaining exchange opportunity	Up to 40 cfs of 1/2, but not to exceed 500 acre-feet annually; thereafter 25 percent of not to exceed 500 acre-feet annually	

[71] This stipulation is incorporated in cases with the following case numbers in Water Division 2: 84 CW 62, 84 CW 63, 84 CW 64, 84 CW 35, 84 CW 202, 84 CW 203, 84 CW 177, 84 CW 178, and 83 CW 18. Language in this table is taken directly from the decree, but for the purposes of this document, some parts of the table have been omitted.

[72] Case number 83 CW 18 allows variable flow rates, determined by several terms and conditions. See decree for further details.

[73] Priority seven for exchanges is divided between Colorado Springs, Colorado Canal Companies, and Aurora. No flow rate is specified because exchange opportunities are variable, depending upon water supply and demand conditions. Priority seven exchanges cannot be implemented unless there is an exchange opportunity remaining after the first six priorities are fulfilled. Under the number seven priority, Colorado Canal Companies may take half the opportunity. The other half of the seventh priority is divided between Aurora and Colorado Springs. The two entities may simultaneously exchange up to 40 cfs, but Aurora is limited to a total volume of 500 acre-feet while diverting its 40 cfs. After Aurora reaches 500 acre-feet, it may only divert 25 percent of the existing exchange opportunities, up to a total of another 500 acre-feet. After Aurora has exhausted its 1,000 acre-feet of exchange opportunity under priority seven, Colorado Springs shares all of the remaining priority seven exchange opportunity with Colorado Canal Companies.

Exchange Volumes

It is extremely difficult to forecast typical exchange volumes under this decree and their effect on upper Arkansas River flows, because variable supply, demand, and storage conditions create unique exchange patterns each year. However, it is possible to observe aggregate amounts of water exchanged upstream. Table 3-24 portrays the monthly volumes exchanged from Pueblo Reservoir to upstream destinations such as Turquoise Lake and Twin Lakes, the facilities that are used in the overwhelming majority of exchanges. The percentages at the bottom of the page provide a context for interpreting the exchanged amounts. These numbers represent flows for the indicated year as a percentage of mean annual flow at the Wellsville gage for the 1990-1995 period, when the Fryingpan-Arkansas Project was in full operation. From this limited set of data, it does not appear that exchange volumes are strongly correlated with annual water supply patterns.

USGS worked with water users in the basin to study the amounts of water exchanges involving Colorado

TABLE 3-24

Acre-Feet Exchanged from Pueblo Reservoir to Upstream Locations During Irrigation Season[74]

	1990	1991	1992	1993	1994
March	37	93	0	0	113
April	48	60	0	6,859	543
May	73	1,255	0	0	1,980
June	1,811	2,406	0	4,769	15,746
July	4,481	4,572	1,955	196	1,194
Aug	6,244	2,593	0	267	495
Sept	331	712	0	471	186
Oct	166	161	0	2,561	190
Total	13,191	11,852	1,955	15,123	20,447
Total annual Arkansas River flow volume as a percent of 1990-95 mean Arkansas River flow[75]	83%	95%	90%	128%	103%

[74] This chart was created from Pueblo Reservoir accounting maintained by Bureau of Reclamation, Pueblo Field Office, and verified by Linda Hopkins, Bureau of Reclamation, on January 8, 1998.

[75] Percentages below 100 percent indicate a lower water supply year, while percentages above 100 percent indicate a higher water supply year.

Springs Utilities and the City of Aurora for the purpose of determining potential impacts of the exchanges on water quality.[76] This study concluded that Colorado Springs Utilities presently has an exchange demand of approximately 60 acre-feet per day, and that the exchange demand could increase to 360 acre-feet per day. This demand occurs because Colorado Springs Utilities exchanges its return flows from transmountain diversions upstream. These return flows enter Fountain Creek from the city's wastewater treatment facilities, and then are exchanged upstream to Pueblo Reservoir and Twin Lakes. In addition, the study determined the exchange of Aurora's Rocky Ford Canal water to upstream points will result in an exchange rate that varies seasonally from 22 acre-feet per day in March to 63 acre-feet per day in June and July.

The USGS study simulated implementation of the exchanges, using hydrologic data from 1986 to 1993, and using several constraints, including exercise of senior water rights and limitations on storage space. Simulated daily mean streamflow decreased by an average of 16.1 percent at the Portland gage (located downstream from Cañon City) in response to a simulated increase in the exchange demand of 298 acre-feet per day. In addition, the study simulated exchanges with an additional constraint—that streamflows would not be reduced below 700 cfs during the July 1 to August 15 rafting period. In July, this additional constraint reduced exchange potential by about 35 percent, from 843 acre-feet to 548 acre-feet. In August, this additional constraint reduced exchange potential by about 60 percent, from 368 acre-feet to 147 acre-feet.

BOR and Southeastern Involvement in Exchanges

During the last 10 years, BOR has received an increasing number of requests from water users to utilize storage space in project facilities for executing exchanges. Because the aggregate volume of exchanges involving project reservoirs has the potential to become a major Federal Government action with significant impacts on the Arkansas River natural environment, BOR has notified water users in the basin that it intends to conduct a National Environmental Policy Act (NEPA) analysis on the aggregate amount of exchanges. The results of the analysis will help BOR determine the extent to which project reservoirs will be available to implement exchanges. BOR has not yet set a timetable for the NEPA analysis. Until BOR determines how much reservoir space will be available to execute exchanges, opportunities to execute or decree new exchanges using project facilities will be very limited.

As holder of the water rights for the Fryingpan-Arkansas Project, Southeastern has very broad exchange capabilities under decrees for the project reservoirs. Specifically Southeastern has:

> "the right under priority of February 10, 1939, to take and store water of the Arkansas River so located as to be physically controllable by said reservoirs (Turquoise Reservoir, Twin Lakes, and Pueblo Reservoir) in substitution for the waters from the Colorado River Tributaries decreed for storage in said reservoirs and introduced into said Arkansas River."[77]

Southeastern has not implemented these exchanges, because operational situations where execution of these exchanges would benefit project yield have not occurred.

Arkansas River Compact Parameters

This section describes how certain compact requirements may affect flows in the upper Arkansas River. It also describes what actions the

[76] "Simulated Effects of Water Exchanges on Streamflow and Specific Conductance in the Arkansas River, Colorado" U.S. Geological Survey Water Resources Investigation Report 98-4140.

[77] Colorado Water Division 2, Civil Action 5141, and case numbers B-42135, W-0028-76, and W-3994.

State of Colorado is taking to come into compliance with the Kansas v. Colorado decision by the U.S. Supreme Court.

Compact Provisions Guiding the Operation of John Martin Reservoir

In 1948, Colorado and Kansas entered the Arkansas River Compact (compact) for the primary purpose of equitably apportioning the waters of the Arkansas River.[78] The compact was created in response to long-running conflicts over allocation of Arkansas River flows, and in response to the opportunity created by completion of John Martin Reservoir in 1948. The primary effect of the compact on upper basin flows is that it ratified use of John Martin storage for irrigation purposes, in addition to the original flood control purpose.

By ratifying additional uses for John Martin Reservoir, the compact created a major irrigation storage facility on the Arkansas River with a 1948 priority date. This date is earlier than all of the priorities associated with project storage facilities. This means that project water rights for storing native flows do not come into priority until the John Martin conservation storage is full. Since John Martin's 1948 priority date is junior to other storage rights in the upper basin, such as Pueblo Board of Water Works and Twin Lakes Canal Company, these upper basin rights for storage of native flows have not been affected by John Martin operations or compact provisions.[79]

The 1980 Operating Plan for John Martin Reservoir, created by compact administrators, allocates 40 percent of the stored water to Kansas and divides the remaining 60 percent among the nine canal companies located in Colorado Water District 67, located downstream of John Martin.[80] The river channel is used to make deliveries of this stored water. Transit losses associated with this delivery were taken into consideration when Colorado and Kansas agreed to apportionment of streamflows in the 1948 compact.

The 1980 plan additionally allows three canal companies (Las Animas Consolidated, Fort Lyon, and Amity) to store water in John Martin, a usage that was not contemplated by the 1948 compact between Colorado and Kansas. The companies typically use this storage space to store water available to them under the WWSP. In return for these storage rights, the three companies agreed to relinquish 35 percent of this stored water into various accounts, including a Kansas transit loss account. This account compensates Kansas for transit losses between John Martin and the State line, since the riverbed is used to convey water to the Kansas State line, and the compact requires that Kansas be satisfied by "an equivalent stateline flow."[81]

The 1980 Operating Plan also contains provisions that determine when certain water rights located below John Martin Reservoir are integrated into the Arkansas River priority system. This, in turn, can have an affect on upper basin flows. To understand when these priorities are integrated, provisions for releasing water from John Martin Reservoir must be understood. These provisions are explained in the following paragraphs.

[78] Colo. Rev. Stat. § 37-69-101, Art. 1.

[79] Under Section 4(d) of the Arkansas River Compact, there is a potential for operation of John Martin Reservoir to affect water rights for storage of native flows. However, this situation has not occurred since construction of the reservoir.

[80] Special Master's Report at 173-74.

[81] Special Master's Report at 174; Colo. Rev. Stat. § 37-69-101, Art. V(E)(3).

As explained previously under "Description of Water Management Facilities Associated with Arkansas River Streamflows," John Martin can store water from two sources: current riverflows and water typically diverted under WWSP. Once water reaches John Martin Reservoir, releases from John Martin are based exclusively upon allocations of water into accounts established for Colorado canals and the State of Kansas. This allocation works as follows:

(1) During the winter, November through March, all inflow is directed into storage. On or before April 7, this water is divided into accounts based on preestablished percentages to each canal company. Under this process, 40 percent of the stored water is allocated to Kansas, and 60 percent is allocated to Colorado irrigators.

(2) During the summer, April through November, all inflow to the reservoir is passed through the reservoir, unless the inflow exceeds the demand of Colorado users by at least 1,000 acre-feet per day. Any excess to the demand of Colorado users is placed in the conservation pool, and is then allocated in the same ratio as winter flows: 40 percent to Kansas and 60 percent to Colorado.

Colorado irrigators and Kansas can call for reservoir releases at any time and at any rate, as long as these releases do not exceed the amount of water in that user's account. However, there are limitations on the rate at which water can be allocated into these accounts from general conservation storage. This is a paper allocation, rather than physical delivery of water. Normally, water is transferred at the rate of 1,000 cfs (or approximately 2,000 acre-feet per day) and this is divided among the accounts according to their entitlements for water. This paper allocation can start no earlier than March 31 and no later than April 7. If total conservation storage exceeds 20,000 acre-feet, then the "paper" water is transferred at the rate of 1,250 cfs and then placed into accounts.

Only after "conservation storage" has been allocated to accounts (exhausted) and a Colorado user's "summer stored" water account has been emptied can that user place a call upstream. Exhaustion of conservation storage can happen very quickly after the current year's winter storage has started to be allocated to user accounts. For example, Amity generally places a call on the river by early May. Conservation storage is empty, yet water remains in the "winter storage" account from the previous winter. When Amity is integrated back into the priority system, the additional demand is met calling out junior water rights located upstream. Depending upon where these junior rights are located, a call to satisfy the Amity priority may occasionally increase flows above Pueblo Reservoir.

Other effects of the compact on upper basin flows are very limited because there is no storage of project water in John Martin and there are no project lands below John Martin Reservoir. The only potential limitation concerns the operation of current and future water development activities above John Martin. This limitation provides that such activity shall not materially deplete, in usable quantity or availability for use of the waters in Colorado or Kansas, the native flows of the Arkansas River.

Colorado Actions in Response to *Kansas v. Colorado* Decision

Rules and Regulations Governing Water Use

In *Kansas v. Colorado*, 1995 WL 283477 (U.S.), the U.S. Supreme Court upheld the ruling of the Special Master that well pumping in Colorado has caused material depletion to the usable flow of the Arkansas River and that well pumping in Colorado must be further regulated. This ruling was the first part of a two-part proceeding and addressed the issue of liability. The Special Master in 1996 conducted further proceedings on the next part of the case to determine the amount of damages and remedies. During the second phase, Kansas and Colorado have stipulated that the amount of depletions to the useable flow at the Colorado-Kansas State line caused by Colorado between 1950 and 1985 total 328,505 acre-feet. The number of acre-feet for which Colorado is liable from 1986 through 1994 has been determined to be 91,565 acre-feet.[82] An important issue for the second phase was Colorado's recent efforts to comply with the Arkansas River Compact. Toward this end, the Colorado State Engineer has promulgated rules and regulations governing well pumping.[83]

Development of the rules followed several months of meeting with representatives of Arkansas River Valley water users and local government entities. The rules replace old rules that allowed pumping for 3 days out of 7, and address both the impact on surface water rights in Colorado and depletions to the usable flow at the Colorado-Kansas State line. The rules impose full-time augmentation requirements on all nonexempt wells diverting tributary ground water in the Arkansas River Basin in Colorado. The rules took effect June 1, 1996, following a court case in which the rules were challenged by certain groups representing well owners. These new rules are enforceable by fines, recovery of State court costs, and authorized entry of private property by the Division of Water Resources to shut off wells that operate outside of the rules.[84]

The rules use the following approaches to control depletions to useable State line flows:

~ Well users will submit annual well augmentation plans individually or in concert with other well owners.
~ The regulations recognize that there is an abundant, economical supply of replacement water available in the foreseeable future.
~ For wells that tap tributary ground water from the Valley Fill Aquifer and surficial aquifers along the Arkansas River between Pueblo and the Colorado-Kansas border, the following provisions apply:
  - The regulations set presumptive depletion rates (outlined below) that may be reviewed and adjusted annually. However, well owners are not precluded from submitting evidence that their depletion is less.
    - Presumed depletion rate for groundwater used as supplemental supply for flood/furrow irrigation - 30 percent of the amount diverted.
    - Presumed depletion rate for groundwater used as sole source of supply for flood and furrow irrigation - 50 percent of the amount diverted.
    - Presumed depletion rate for groundwater used as sole source of supply for sprinkler irrigation systems - 75 percent of the amount diverted.
  - For wells that tap tributary groundwater but that are located upstream from Pueblo, depletions will be determined by a site-specific analysis.
  - For the 700 wells established prior to the Arkansas River Compact (December 14, 1948), depletions are collectively limited to 15,000 acre-feet of pumping, unless depletions to State line flow caused by pumping in excess of 15,000 acre-feet are replaced in accordance with an augmentation plan approved by the Division Engineer. The rules establish a formula for allocating the 15,000 acre-feet among the 700 wells.
  - To the extent that replacement of out-of-priority depletions to senior surface rights does not sufficiently reduce depletions to useable State line flow, the regulations allocate such unreplaced depletions among

[82] Special Master's Second Report, *Kansas v. Colorado*, (No. 105 Original) at 46 (Sept. 1997).

[83] Colorado State Engineer, Amended Rules and Regulations Governing The Diversion and Use of Tributary Groundwater in the Arkansas River Basin, Colorado. September 27, 1995.

[84] Colorado Water Division 2, Case No. 95 CW 211.

> various well owners in the area covered. The regulations require total discontinuance of "post-compact groundwater diversions until each user has an approved plan for replacing his/her allocated share."

In addition to the amended rules, the State has been working with Southeastern to establish a role for Southeastern in providing augmentation water for the well owners. The Board of Southeastern has approved the formation of the Southeastern Colorado Water Activity Enterprise, which will operate separately from Southeastern's governmental responsibilities. The Enterprise will assist well owners with developing augmentation plans as required under the regulations, and will sell water that may be used in augmentation plans.

Primary sources of augmentation water to be sold by the Enterprise will include return flows from water delivered to municipalities. Before offering these return flows for augmentation use, the Enterprise shall give first right of refusal to project water recipients. The first right of refusal will be limited to return flow created by project water deliveries to that entity's water delivery system. In addition, the right of refusal for irrigation return flows will be limited to irrigation entities, rather than individual irrigators who are members of the entities. As of February 15, 1996, Southeastern set the price for return flow water at $8 per acre-foot.[85]

Offset Account in John Martin Reservoir for Colorado Pumping

Via a resolution dated March 31, 1997, the Arkansas River Compact Administration created an "Offset Account in John Martin Reservoir for Colorado Pumping." Establishment of the account was requested by the State of Colorado to facilitate the replacement of depletions to usable State line flows caused by pumping in excess of the precompact pumping entitlement of 15,000 acre-feet.[85]

The resolution created a 20,000 acre-foot account that resides below the flood control pool at John Martin Reservoir. Only the Colorado Division of Water Resources may approve deliveries into the account, and applicable transit charges must be paid on any river losses that occur while the water makes its way to John Martin Reservoir. The typical parties who place water in the account are augmentation associations. These organizations have been created to purchase replacement water for members whose pumping causes depletions to senior surface water rights in Colorado and depletions to usable State line flows to Kansas.

The account provides benefits to the State of Colorado because it replaces cumbersome water management actions that were designed to deliver replacement for depletions to usable State line flows to Kansas. For example, delivering water directly to Kansas from upstream reservoirs often created large transit losses, created conflicts with storage objectives in upstream reservoirs, and was difficult to track and account. The State of Kansas benefits from the account because it can call for water from the account in timing and amounts that are the most beneficial for water users in Kansas. Kansas receives a monthly accounting of pumping in excess of Colorado's entitlement, a monthly estimate of compact compliance, and a monthly accounting of deliveries to the account, all of which allow Kansas to better forecast water availability for water users.

Once a delivery to the account arrives at John Martin Reservoir, Colorado and Kansas have determined a procedure for allocating the applicable evaporation charges for water in the offset account and for transit losses that occur as water deliveries travel between John Martin Reservoir and the Kansas-Colorado border. In general, Colorado users of the account pay evaporation for water in

[85] "Resolution Establishing The Southeastern Colorado Water Activity Enterprise" approved and adopted September 21, 1995; and "Southeastern Colorado Water Activity Enterprise Policy Concerning Sale of Return Flows from Fryingpan-Arkansas Project Water" approved and adopted February 15, 1996.

the offset account until it is made available to Kansas to replace estimated depletions to usable State line flows. If Kansas chooses to hold this water at John Martin for later delivery, then Kansas pays for evaporation charges.

The account has been established as an annually renewable arrangement, which may be canceled by sufficient notice from either Kansas or Colorado. Between April 1 and October 31, 1997, 6,454 acre-feet of consumable State line flows had been placed in the account. During this period, Kansas requested two deliveries, which totaled 1,935 acre-feet in credit.

Formation of Groundwater Augmentation Associations

Most well owners are now represented by one of three large associations. These associations have undertaken the responsibility for the preparation of augmentation plans, including the acquisition of replacement water. These associations include Colorado Water Protective and Development Association (CWPDA), the Arkansas Groundwater Users Association (AGUA), and the Lower Arkansas Water Management Association (LAWMA). LAWMA includes wells between John Martin Reservoir and the Colorado-Kansas border, while the other two represent owners primarily between Pueblo Reservoir and John Martin Reservoir. In addition to the three large associations, the Upper Arkansas Water Conservancy District has started an augmentation program. This program provides approximately 100 acre-feet of water to offset depletions by well owners in the upper basin, and this amount is expected to increase as more well owners join the program.

It appears in the near term that sufficient replacement water is available to offset pumping depletions to usable State line flows. Some organizations are purchasing agricultural water rights, while between 33,000 and 43,000 acre-feet of excess transmountain water is expected to be available from the Colorado Springs Utilities and the City of Pueblo for approximately the next 20 years. The current price of replacement water appears to be $8 to $10 per acre-foot.[86]

Homestake Project Operating Principles and Parameters

Operation of the Homestake Project has very limited impact on Arkansas River main stem flows. Imported flows of up to 300 cfs are stored at Turquoise Lake after the water passes through the Homestake Tunnel. Homestake water is then conveyed from Turquoise Lake to Twin Lakes via the Mt. Elbert Conduit. From Twin Lakes, Homestake water is released into the Otero Pipeline and is not conveyed via the Arkansas River.

Homestake Project diversions are most frequently limited by minimum flow requirements on west slope streams and by west slope senior water rights as discussed under "Homestake Project." In dry water years, senior water rights located downstream may call out Homestake Project water rights before minimum flow requirements on west slope streams become a controlling factor. On the east slope, flows from the Homestake Tunnel may not exceed 300 cfs, but this limit typically does not come into play during normal project operation. After the water reaches the east slope, it may be stored in Twin Lakes, Turquoise Lake, or Pueblo Reservoir, pursuant to contracts with the Bureau. Other than the limits described above, there are no other legal constraints on collection or storage of Homestake water.[87]

[86] Kansas v. Colorado, Special Master's Second Report, June 5, 1997, page 66.

[87] Telephone interview with Gary Bostrom, Colorado Springs Utilities (Nov. 10, 1995) and personal interview with BOR, Loveland Area Office (Aug. 5, 1995).

Fryingpan-Arkansas Project Operating Principles and Parameters

Legislative Parameters

The Fryingpan-Arkansas Project was authorized for construction, operation, and maintenance by Public Law 87-590, approved August 16, 1962. Public Law 87-590 was amended by Public Law 93-493, Sections 1101 and 1102, approved October 27, 1974, and Public Law 95-586, Sections 901, 902, and 903, approved November 3, 1978. The legislation specifies that the project was authorized for the purpose of supplying water for irrigation, municipal, domestic, and industrial uses; generating and transmitting hydroelectric power; and controlling floods. The project was also authorized for other useful and beneficial purposes incidental to the purposes listed above, including recreation and the conservation/development of fish and wildlife.

The project was authorized to be constructed, operated, and maintained substantially in accordance with House Document No. 187, 83rd Congress, 1st Session, as modified by BOR's September 1959 report entitled "Ruedi Dam and Reservoir Colorado." Public Law 93-493 authorized an increase in the cost ceiling for construction of the project, and it also authorized the installation of a second 100-megawatt unit at the Mt. Elbert Pumped Storage Powerplant. Public Law 95-586 further modified the construction of the project, so that it would be in accordance with the project plan described in the final environmental impact statement, dated April 16, 1975.

The authorizing act provides for the project to be operated in accordance with the "Operating Principles - Fryingpan Arkansas Project" adopted by the State of Colorado on April 30, 1959. This document was amended on December 30, 1959, and December 9, 1960, and was ordered to be printed on March 15, 1961, as House Document No. 130, 87th Congress, 1st Session. Public Law 95-586 amended Public Law 87-590, and created supplemental operating principles. These operating principles: 1) require compliance with the laws of the State of Colorado for establishing minimum streamflows for the reasonable protection of the natural environment, provided such laws are not inconsistent with Section 3(a) of the authorizing act; and 2) establish limits on diversions from the Hunter Creek watershed and minimum streamflows at the points of diversion on No Name, Midway, and Hunter Creeks.

Public Law 87-590 authorized BOR to construct, operate, and maintain public recreational facilities on lands withdrawn or acquired for project development. It also directed BOR to conserve the scenery, the national historic and archaeological objects, and the wildlife on these lands; provide public use of lands and water areas created by the project that are consistent with project purposes; and construct, operate, and maintain facilities for conservation and development of fish and wildlife resources. BOR is authorized to dispose of the lands for the purposes described above to Federal, State, and local governmental agencies. These disposals may be executed by lease, transfer, exchange, or conveyance, using terms and conditions that protect the best interest of the public. All lands for these purposes that are within the exterior boundaries of a national forest, and that are not needed for uses connected to the project, must become national forest lands.

The use of water diverted from the Colorado River watershed to the Arkansas River watershed is subject to and controlled by the Colorado River Compact, the Upper Colorado River Basin Compact, the Boulder Canyon Project Act, the Boulder Canyon Project Adjustment Act, the Colorado River Storage Project, and the Mexican Water Treaty. The water is included in the quantity of water Colorado is entitled to use under the above compacts, statutes, and treaty. None of the water imported from the Colorado River watershed by the project may be made available for consumptive use outside the State of Colorado or outside of Southeastern's district boundaries. It may also not be made available for consumptive use by exchange or substitution to any State not a party to the Colorado River Compact. The operations of the project may not alter or interfere with the obligations of the State of Colorado under the provision of the Arkansas River Compact.

General Project Operations

Project Diversions and Deliveries

The North and South Collection Systems and east slope facilities are operated to divert and store as much west slope and native Arkansas River water as is available to the project pursuant to its water rights. Such water is delivered to the eligible agricultural, domestic, municipal, and industrial water users located within the Southeastern District. In addition, the conveyance and storage of nonproject water is accommodated pursuant to contractual arrangements. The origin and nature of these agreements is described under "Contractual Obligations."

Diversion of project water from the west slope through the Boustead Tunnel generally occurs during the months of May, June, and July. In some years it may begin as early as late April and extend into late August or early September. This water is stored in Turquoise Lake and Twin Lakes if storage capacity is available. If capacity is not available, any additional water diverted from the west slope is conveyed down the Arkansas River to be stored in Pueblo Reservoir or delivered directly to project water users. If there is no storage capacity available in the project's east slope reservoirs and there is no demand for the direct delivery of project water, diversions from the west slope are curtailed.

The greatest use of project water is by agricultural and municipal users who take delivery at Pueblo Dam. These users are located in the Fountain Creek watershed or the Arkansas River Valley east of the dam. Because of this delivery point, most project water diverted from the west slope and stored in either Turquoise Lake or Twin Lakes is conveyed down the Arkansas River to Pueblo Reservoir at some time during the year.

The storage of native Arkansas River water in the project's east slope reservoirs occurs when the project water rights for these reservoirs come into priority. This occurs when John Martin Reservoir has filled to capacity, a total of approximately 350,000 acre-feet. Historically, the project has stored native water under these rights only in 1985, 1987, 1995, and 1997.

Winter Water Storage Program

Nonproject water is stored in project facilities (and in John Martin Reservoir as well) as a result of the WWSP developed by the following entities:

- Southeastern Colorado Water Conservancy District
- Amity Mutual Irrigation Company
- Bessemer Irrigating Ditch Company
- Catlin Canal Company
- Colorado Canal Company
- Fort Lyon Canal Company
- Highline Canal Company
- Holbrook Mutual Irrigating Company
- Lake Henry Reservoir Company
- Lake Meredith Reservoir Company
- Las Animas Consolidated Canal Company
- Oxford Farmers Ditch Company
- Riverside Dairy Ditch
- West Pueblo Ditch

Streamflows in excess of the amount necessary to supply senior priorities not participating in the program may be stored in Pueblo Reservoir, John Martin Reservoir, or off-stream storage facilities of participants from November 15 through March 15. The amount that can be stored in John Martin is limited by terms of the 1980 Operating Plan developed by compact administrators. This plan allows Amity Canal company to store 50,000 acre-feet, Fort Lyon Canal Company to store 20,000 acre-feet, and Las Animas Consolidated Canal Company to store 5,000 acre-feet. It also set up an account system for water users located in Water District 67 and in Kansas.

The interlocutory decree for the WWSP entered by consent of all parties, was approved by the water court judge for Water Division No. 2 on November 10, 1987. After 3 successful years of operation, the decree for the program became final on November 10, 1990. The WWSP is operated under the direction of a board of trustees, composed of one member from each entity. However, the Colorado Canal, Lake Henry, and Lake Meredith Reservoir Companies together have one vote.

The WWSP water in Pueblo Reservoir is subject to be spilled under two conditions: 1) if the storage space it occupies within the conservation pool is required for the storage of project water, or 2) if the storage space it occupies is within the joint-use pool, it must be evacuated pursuant to the project flood control criteria by April 15 of each year. Also, if not furnished to a user within 18 months from commencement of the winter storage period, all winter water must be released from storage as promptly as possible at a time and rate determined by the Colorado State Engineer. This release may not occur any later than May 1 of the year following the completion of the winter storage season. The participants who store winter water in Pueblo Reservoir must pay a storage charge for the maximum amount of winter water storage provided, including any releases during the storage period.

The WWSP decree also incorporates a stipulation designed to protect the winter storage options of upstream parties who were not applicants for a decree for permanent winter storage in Pueblo Reservoir. These include Colorado Springs Utilities, Pueblo Board of Water Works, Twin Lakes Reservoir and Canal Company, Mt. Pisgah Reservoir and Ditch Company, Fountain Mutual Irrigation Company, Deweese Dye Reservoir Company, Beaver Park Water Company, and the Upper Arkansas Water Conservancy District. The primary provisions of the stipulation are:

- During the winter storage period, the parties listed above may store natural inflows available to their storage locations without being called out by WWSP applicants. These reservoirs include Turquoise Lake, South Slope Storage System of Colorado Springs, Fountain Mutual Irrigation Company Reservoirs, Deweese Dye Reservoir, Mt. Pisgah Reservoir, Clear Creek Reservoir, Twin Lakes Reservoir, and Brush Hollow Reservoirs.
- During the winter storage period, Southeastern, Colorado Springs Utilities, and Pueblo may exchange transmountain return flows[88] upriver, subject to administration and conditions imposed by the Division Engineer.
- Colorado Springs agrees to limit its winter exchange into Pueblo Reservoir to not more than 17,000 acre-feet. When native inflows present exchange opportunities into Pueblo Reservoir, these opportunities will be shared by Colorado Springs and the participants in the WWSP.
- Pueblo agrees that any upstream exchanges of transmountain return flows into Pueblo Reservoir that it seeks to have decreed will not operate during the winter storage season.

Reservoir Operations

The concept for operating the east slope reservoirs originated in the initial modeling and in the Congressional report authorizing the project. This concept evolved over time into the current framework:

1. Create adequate vacant space in Turquoise Lake and Twin Lakes by the end of April, in anticipation of the current year diversions of project and nonproject water from the west slope. This is accomplished through the release of project water from the upper two reservoirs and conveyance of such water down the Arkansas River to Pueblo Reservoir during the previous months of October, November, December, January, February, March, and April.

[88] Transmountain return flows are return flows accruing from the usage of any water that has been imported to the Arkansas River watershed.

2. Divert all west slope water available to the project to the east slope, subject to the operating principles, limits of reservoir storage capacity, contractual arrangements, and demand for direct delivery of project water.

3. Store as much of the newly diverted west slope project water as possible in the upper reservoirs, subject to the limits of reservoir storage capacity and contractual arrangements.

4. Convey newly diverted west slope project water that cannot be stored in the upper reservoirs down the Arkansas River to Pueblo Reservoir, subject to the limits of reservoir storage capacity and contractual arrangements.

5. Release project water from the upper reservoirs to meet the demands of project water users who are located in the Southeastern District upstream of Pueblo Reservoir. These releases may occur in any month throughout the year.

6. Release project water from Pueblo Reservoir to the Arkansas River, the Fountain Valley Conduit, and Bessemer Ditch to meet the demands of project water users that may be served from Pueblo Reservoir. Releases to the Arkansas River and Fountain Valley Conduit may occur in any month throughout the year. Releases to the Bessemer Ditch occur during the irrigation season.

Flow Augmentation for Fish and Recreation

The timing and rates at which project water is moved from the upper reservoirs to Pueblo Reservoir is at the discretion of BOR. It was recognized during the investigation and planning of the project that the introduction of project water to the Arkansas River above Pueblo Reservoir could both positively and negatively affect the fishery resources, depending upon the rates and timing of the releases. The U.S. Fish and Wildlife Service, in cooperation with the Colorado Division of Wildlife (CDOW), Colorado State Parks, and BLM, recommended that year-round flows of the Arkansas River at Wellsville, Colorado, be maintained at no less than 250 cfs if project water is available for release. It was also emphasized that highly fluctuating flows could adversely affect the survival of eggs and newly hatched fry during the fall and winter. Therefore, BOR attempts to release project water at rates that minimize the fluctuation of flows. It is important to recognize that the flows maintained by BOR releases are not instream flows legally protected by the Colorado Water Conservation Board, and the flows are subject to annual review by the Colorado DNR. In addition, there is no legal obligation to provide these flows, but rather they are provided under an agreement between BOR and the Colorado DNR.

During the 1980's, the popularity of whitewater rafting and boating increased dramatically. The reach of the Arkansas River from Granite, Colorado, through the Royal Gorge has become one of the most attractive and heavily used rafting areas in the nation, both commercially and privately.

In 1990 and subsequent years, BOR has been requested by commercial rafting interests, Colorado DNR, and BLM to release project water during July and early August from upper project reservoirs to augment flows for enhanced white-water rafting and boating. BOR, with the cooperation of Southeastern, has made such releases. The objective in 1991, 1992, 1993, and 1994 was to release project water as necessary to maintain a minimum daily flow of 700 cfs in the Arkansas River at Wellsville through August 15. Releases of project water totaling 5,731, 6,154, 443, and 10,000 acre-feet were made from Twin Lakes in 1991, 1992, 1993, and 1994, respectively, to maintain the desired flow. In 1995, the augmentation program was not operated because of very high native flows in the Arkansas River.

DNR makes its flow recommendations via an annual letter to BOR each spring. DNR states in its annual letter that "flow management must be subordinate to the rights of water right owners and water users, and not impair their associated diversions or exchanges of water." In addition, it states that "while these recommendations are for one year only, we anticipate that they will remain valid until new information suggests otherwise."

In a resolution passed April 18, 1996, Southeastern concurred with the DNR recommendations, but suggested additional terms and conditions:

- Releases should be limited to 10,000 acre-feet, unless Southeastern approves additional amounts.
- Releases should be subject to water availability and storage space limitations.
- Southeastern should be identified as a management partner because it has legal responsibility as the official project contracting agency and as owner of the water rights.

The DNR current flow management goals for the Arkansas River at Wellsville are outlined below. BOR considers these requests when developing its annual operating plan for the movement of project water from Turquoise Lake and Twin Lakes to Pueblo Reservoir. BOR has been able to implement the recommendations of this letter under river conditions that have occurred to date. The following are key excerpts from the current recommendation letter:

- The highest priority is the maintenance of a minimum year-round flow of at least 250 cfs to protect the fishery.

- Winter incubation flows (mid-November through April) should be maintained at a level of not more than 5 inches below river height during the spawning period (October 15 to November 15). The optimum flow range is from 250 to 400 cfs, depending on spawning flows:

Minimum Incubation Flow November 16 - April 30		**Spawning Flow** October 15 - November 15
250 cfs	if	300 - 500 cfs
325 cfs	if	500 - 600 cfs
400 cfs	if	600 - 700 cfs

- To the extent possible, between April 1 and May 15, the Bureau of Reclamation (BOR) should maintain flows within the range of 250 to 400 cfs in order to provide conditions favorable to egg hatching and fry emergence.

- Deliveries in excess of 10,000 acre-feet should be subject to review and consideration, prior to such deliveries, by BOR and the Southeastern Colorado Water Conservancy District (SECWCD).

- Subject to water availability, BOR should augment flows during the July 1 to August 15 period at 700 cfs through releases from the Fryingpan-Arkansas River Project. The 700 cfs level is a target; when augmentation occurs, every effort should be made to ensure that flows are as little above, or as little below, 700 cfs as possible. The Colorado Division of Parks and Outdoor Recreation (CDPOR), using funds collected from commercial outfitters, shall be responsible for replacing evaporative losses caused by summer augmentation.

- BOR should avoid dramatic fluctuations on the river as much as possible throughout the year. When it is necessary to alter flow rates, BOR should limit the daily change to 10-15 percent.

- It may be possible to improve feeding conditions for brown trout by reducing flows between Labor Day and October 15 in years when flows would otherwise be higher than those recommended by CDOW. If potential benefits warrant the effort, Arkansas Headwaters Recreation Area (AHRA) managers, CDOW, BOR and the Division II Engineer should work with the water users to seek opportunities for reducing flows after Labor Day.

Contractual Obligations

Although BOR may enter into a broad range of contracts with water users, it typically executes five primary types of contracts, each imposing different types of constraints on BOR operations.

Acquisition Contracts

BOR acquired existing storage facilities where project reservoirs were constructed. In return for acquiring these storage facilities, BOR signed contracts with the owners guaranteeing them storage and water delivery from the project reservoirs, which replaced the original facilities. These storage contracts take priority over storing project water when storage space and water supplies are limited. The total amount of storage space obligated is 81,868 acre-feet, but BOR may use the space for project water when the contracting entities are not using the space. These contracts are as follows:

~ Contract Number 6-07-70-W0089, executed on November 1, 1965, with the Colorado Fuel and Iron Corporation (CF&I Steel Corporation) and now assigned to the City of Aurora, Colorado Springs Utilities, and the Board of Water Works of Pueblo (Board), permits the storage of up to 27,416 acre-feet (17,416 acre-feet - Colorado Springs; 5,000 acre-feet - Aurora; and 5,000 acre-feet - Pueblo Board of Water Works) of water in Turquoise Lake. (Note that the 5,000 acre-feet assigned to Aurora and the 5,000 acre-feet assigned to the Board of Water Works of Pueblo are long-term contracts rather than acquisition contracts.) Water stored pursuant to this contract is normally conveyed through the Mt. Elbert Conduit to Twin Lakes for power generation purposes, and to protect the stream channel below Turquoise Lake from excessively high releases. Water owned by the City of Aurora and Colorado Springs Utilities is delivered to the Otero Pipeline at Twin Lakes Dam. Water owned by the Board is released to Lake Creek and the Arkansas River for subsequent diversion from the Arkansas River downstream of Pueblo Dam.

~ Contract Number 7-07-70-L0056, executed on January 19, 1977, and amended on June 14, 1977, with the Twin Lakes Reservoir and Canal Company, permits the storage of up to 54,452 acre-feet of water in project reservoirs. Water stored pursuant to this contract is obtained from two sources: 1) diverted from the upper Roaring Fork River watershed through the Independence Pass Tunnel to Lake Creek, and 2) stored native Lake Creek water pursuant to company water rights.

Long-Term Contracts

Long-term contracts are generally effective for periods of 10 to 40 years, and permit use of project storage and conveyance facilities. Many, but not all, of these contracts were signed with parties who held significant storage capability before the project was built. Therefore, the provisions of these contracts were built into modeling and engineering efforts, which led to project construction.

Long-term contracts have priority over the project water contract with Southeastern, unless the long term contract has some "if and when" provisions. In addition, BOR may store water in the space obligated to the contracts, if the contracting entity is not using the space. BOR has the flexibility to store this contracted water in any of the project reservoirs, as long as it can deliver the water at the time and place of need. Long-term contracts are as follows:

~ The Homestake Project, owned jointly by the City of Aurora and Colorado Springs Utilities, stores up to 30,000 acre-feet of water in Turquoise Lake, Twin Lakes, and Pueblo Reservoir pursuant to Contract Number 6-07-70-W0090, executed on December 14, 1965. The Homestake Project water is diverted from the upper Eagle River watershed through the Homestake Tunnel to Turquoise Lake. The water is conveyed through the Mt. Elbert Conduit to Twin Lakes and is delivered to the Otero Pipeline at Twin Lakes Dam. Homestake Project water is generally held in Turquoise Lake and Twin Lakes. Occasionally it is stored in Pueblo Reservoir. The amount is variable and is subject to BOR's discretion as long as BOR can deliver the water to users at their place and time of need.

- Contract Number 9-07-70-W0099, executed on April 25, 1969, and amended on February 1, 1972, with the Highline Canal Company and now assigned to Busk- Ivanhoe, Inc., permits an alternative means to convey Busk-Ivanhoe water through the Nast and Boustead Tunnel system from the upper Fryingpan River watershed when capacity is available. The primary means of conveying the company water to the east slope is through the Busk-Ivanhoe Tunnel (Carlton Tunnel), an abandoned railroad tunnel. The contract also permits the storage of up to 10,000 acre-feet of company water for irrigation purposes in Turquoise Lake, Twin Lakes, and Pueblo Reservoir if and when vacant space is available. The Busk-Ivanhoe water is also generally held in Turquoise Lake and Twin Lakes. Occasionally it is stored in Pueblo Reservoir. The amount is variable and is subject to BOR's discretion as long as BOR can deliver the water to users at their place and time of need.

Project Water Contract with Southeastern Colorado Water Conservancy District

The Southeastern Colorado Water Conservancy District is the official repayment entity for the project. Therefore, all transmountain diversions made possible by the project are obligated to the district, except for water used to satisfy other legislated project purposes.

Southeastern annually allocates the available supply of project water to the various water users within the District, guided by its allocation principles and water allocation policy. BOR notifies Southeastern in early May of the amount of project water available. Southeastern then solicits requests from the various water users and makes its allocation. Subsequently, the water users arrange for delivery of their respective amounts of project water in collaboration with Southeastern, BOR, and the Division Engineer.

BOR determines the annual allotment available to Southeastern by using four factors: 1) forecast of spring/summer runoff, 2) amount of water in storage at project reservoirs, 3) transit losses and evaporation incurred as part of water delivery to Southeastern, and 4) incidental environmental needs, as directed by authorizing legislation for the project.

West slope diversions of project water are typically controlled only by the magnitude of runoff and size of conveyance facilities, because Ruedi Reservoir protects these diversions from downstream calls. The amount of storage in project reservoirs at the time the allotment is made is dependent on two factors: 1) whether the project's east slope storage water rights are in priority, and 2) water carried over from the previous water year. The water rights that allow BOR to store native, east slope water are very junior. Therefore, they are "feast or famine" water rights, typically allowing storage only once every 10 or 11 years. The amount of carryover storage is a function of the seniority of the water rights held by Southeastern's customers. During an above average water year, customers with senior water rights may not require supplemental water from Southeastern, leaving allocated water in project reservoirs. This storage may be reallocated the following spring.

Transit and evaporation losses are deducted before BOR makes an allotment to Southeastern. Many of Southeastern's customers have delivery points located downstream of Pueblo Reservoir, so transit losses incurred by using the Arkansas River as a conduit must be deducted. Evaporation losses are deducted only when water is carried over in project reservoirs from one water year to the next.

The volume of water subtracted from Southeastern's allotment to meet the project's environmental requirements is at BOR's discretion, and is guided by needs specified in the project's authorizing legislation. Historically, these needs have included water for wildlife food plots managed by CDOW, augmentation water to cover evaporation losses at the CDOW hatchery near Pueblo Reservoir, and augmentation water for operation of recreational wells located at Turquoise Lake and Twin Lakes. BOR and Southeastern do not have a written agreement on the extent to which BOR may subtract water from Southeastern's allotment for incidental environmental purposes.

Historical allocations made by Southeastern to its customers are outlined in Table 3-25.

TABLE 3-25

Historical Allocations Made by Southeastern Colorado Water Conservancy District

Year(s)	Project Water (acre-feet)	Allocation of Project Water Return Flows (acre-feet)
1972 - 1984	366,694	28,080
1985	24,285	845
1986	23,645	1,308
1987	12,542	712
1988	79,494	1,410
1989	108,728	2,520
1990	46,082	2,745
1991	56,004	2,730
1992	32,901	2,563
1993	68,190	2,595
1994	55,577	3,880
1995	59,261	4,417

The history of contracts between BOR and Southeastern is as follows:

~ BOR executed Contract Number 5-07-70-W0086 for water service from the project with Southeastern on January 21, 1965. This contract has been amended six times as follows:

Amendment No. 1	August 31, 1976
Amendment No. 2	October 23, 1981
Amendment No. 3	August 8, 1984
Amendment No. 4	January 23, 1986
Amendment No. 5	February 26, 1988
Amendment No. 6	July 17, 1996

Amendment No. 2 established the initial delivery for project water as January 1, 1982, and initiated the 50-year period for repayment of the District's financial obligations to the United States. The cost of project water delivered to the District was set at $8 per acre-foot, subject to review and revision beginning January 1, 1987, and every 4 years thereafter.

~ In addition to the repayment contract with Southeastern, BOR executed Contract Number 9-07-70 W0315 with the District for conveyance service from the Fountain Valley Conduit on July 10, 1979. On the same date, the District executed a contract with the Fountain Valley Authority for conveyance service from the conduit. Payments pursuant to the contract were initiated in 1986. The contract contains a conveyance service schedule, revised on November 8, 1984, that calls for delivery of a firm water supply of 20,100 acre-feet of project water annually.

Use of Facilities Contracts

Use of facilities contracts are signed by BOR to make more efficient use of project facilities in conjunction with other water supply and delivery systems. These contracts typically do not place operating constraints on BOR, because they encourage full use of the project facilities that BOR is underutilizing.

~ The Pueblo Board of Water Works acquired an interest in certain west slope water rights of the Highline Canal Company (now Busk-Ivanhoe, Inc.). On February 1, 1972, Pueblo executed Contract Number 2-07-70-W0104 that permits an alternative means to convey its share of Busk Ivanhoe water through the Nast and Boustead Tunnel system from the upper Fryingpan River watershed when capacity is available. The primary means of conveying this water is through the Busk-Ivanhoe Tunnel. No storage of Pueblo water is permitted by this contract.

~ Contract 4-07-40-W0692, executed on August 3, 1984, with Pueblo West Metropolitan

District, permits the conveyance of District owned water through the manifold of the south outlet works of Pueblo Dam resulting in a savings in energy and pumping costs to the District. A pipeline conveys the water from the manifold to the District pumping plant and water treatment plant.

If and When (Temporary) Contracts

Temporary contracts are signed on a year-to-year basis, allowing the contracting party to use project storage space or conveyance facilities. These types of contracts were not anticipated within the authorizing legislation for the Fryingpan-Arkansas Project. BOR has offered these contracts on a discretionary basis, with the goal of improving the utilization of reservoir space. Execution of the contracts is contingent upon whether storage patterns and flow regimes make facilities available for the contracted use.

The number and amount of these contracts is highly variable from year to year, driven by needs identified by water users and physical constraints of project facilities. Typically, BOR examines reservoir storage levels in the fall, and determines whether any storage space would be available in the spring, assuming an average runoff year. If runoff and storage turn out to be greater than average, these contracts are the first to spill water. Temporary contracts are also limited by the ability of contractors to obtain water for storage. Contractors must either have control of native water that can be stored, or be able to purchase transmountain water from parties holding transmountain water decrees.

Other factors driving the level of temporary contracts include environmental analysis and BOR contract policies. If BOR determines that execution of a proposed contract will create significant adverse effects, it will decline to sign the contract. Policy considerations driving when and if contracts include current regulations limiting the length of contracts, maximum amounts of storage that can be contracted, rates charged for storage, and supervisory approvals required within the agency. Because of the large number of factors influencing temporary contracts, it is misleading to suggest a number and amount of contracts in an average water year.

Order of Spill for BOR Contracts

As part of the contract between Southeastern and BOR, the order of spill for the various types of project contracts has been specified. The following language is taken directly from Contract Number 5-07-70-W0086, Amendment 4, January 23, 1986:

> Article 13
> (a) Whenever water is evacuated from Pueblo, Twin Lakes, and Turquoise Reservoirs to meet the necessities of project flood control, power generation purposes, storage of transmountain project water, storage of native project water, and project operational requirements; except as provided in subarticle (b), the water evacuated shall be charged in the following order:
>
> 1. Against water stored under contracts for if-and-when storage space for entities which will use the water outside District boundaries.
>
> 2. Against water stored under contracts for if-and-when storage space for entities which will use the water within the District boundaries. This water will be charged pro rata against water stored under all such like contracts at the time of evacuation.
>
> 3. Against any winter storage in excess of 70,000 acre-feet.
>
> 4. Against water stored under contracts with municipal entities within the boundaries of the District, which water is neither project water nor return flow from project water, and which water is limited to 163,100 acre-feet, less any project water purchased and stored by the municipal users. This

evacuation will be charged pro rata against the water stored under all such like contracts at the time of evacuation.

5. Against winter storage water not in excess of 70,000 acre-feet.

6. Against project water accumulated from the Arkansas River and its tributaries.

(b) Evacuation of water from storage pursuant to existing firm storage contracts, the Highline storage contract, and future Pueblo Board of Water Works, and Twin Lakes Reservoir and Canal Company contracts to satisfy prior commitments will be made pursuant to the terms of such storage contracts.

All temporary contracts have a lower priority than the project water contract with Southeastern, and they also have a lower priority than "use of facilities" contracts. If spills of temporary contract storage are required, the first group of contracts to spill are those held by parties outside of the Southeastern District. The second group of contracts to be spilled are those held by parties located within the Southeastern District. If spills are required, they are prorated among the parties in each group, rather than assigning priorities within the group.

Memoranda of Agreement and Understanding

The following agreements affect project operations:

1. Memorandum of Understanding (MOU) was executed with the U.S. Forest Service on July 1, 1976, concerning the transfer of lands acquired by BOR to the Forest Service at Sugar Loaf Dam and Turquoise Lake. A provision of the MOU states that BOR "...recognizes recreation values on Turquoise Lake and will minimize draw-down during the June 15th through September 15th period. Efforts will be made to maintain a minimum pool elevation of 9,835 feet during this period; however, project needs could dictate further lowering. A minimum pool at elevation 9,776 feet will be maintained for fish habitat and aesthetic purposes." An elevation of 9,835 feet is a target level and equals reservoir contents of 72,505 acre-feet, and an elevation of 9,776 feet equals contents of 9,348 acre-feet. The Forest Service is responsible for administration and management of all recreation activities associated with the water surface of Turquoise Lake and the funding, design, construction, operation, and maintenance of the associated recreation facilities.

2. Memorandum of Agreement (MOA) was executed with the U.S. Forest Service on April 12, 1984, concerning the transfer of lands acquired by BOR to the Forest Service at Twin Lakes. A provision of the MOA states that BOR "...recognizes public recreation values of Twin Lakes and will attempt to optimize reservoir surface elevations for all reclamation project purposes including public recreation. A minimum pool at elevation 9,168.7 feet will be maintained for power purposes which should enhance the fish habitat and visual resources." An elevation of 9,168.7 feet equals reservoir contents of 72,938 acre-feet. The Forest Service is responsible for administration and management of all recreation activities associated with the reservoir's water surface and the funding, design, construction, operation, and maintenance of recreation, historic, and other public resource facilities.

3. A lease (Contract Number 14-06-700-8018) between the United States and the State of Colorado, acting by and through the DNR, Division of Parks and Outdoor Recreation, and Division of Wildlife, was executed on January 15, 1975. The lease provides the State access to selected Pueblo Reservoir lands, including the reservoir water surface, for administration of recreation, management of fish and wildlife resources, and related purposes and uses. The State has concession, licensing, and subleasing rights within the area of the leased premises for the purposes of recreation, fish and wildlife, and

related purposes subject to review and approval of BOR prior to issuance. The Division of Parks and Outdoor Recreation manages recreation lands, including the water surface, and is responsible for operation, maintenance, and replacement of the recreation facilities. The Division of Wildlife manages other lands for fish and wildlife. All lands, including the water surface, are included in Pueblo Lake State Park. The lease was amended in 1988, extending the term to 50 years.

4. The Pueblo Reservoir Fish Hatchery was constructed by BOR and is now operated via an MOU between BOR and CDOW. The facilities include a warm-water fish hatchery and a cold-water rearing unit located below Pueblo Dam. CDOW is responsible for funding, operation, maintenance, and replacement of the hatchery features. BOR retained ownership of the land, hatchery, and related facilities.

5. The project has no facilities in the 143-mile reach between Twin Lakes and Pueblo Reservoir other than acquired conservation easements for fishing and recreation access along the Arkansas River. These conservation easements are located in Chaffee County northwest of Salida and in Fremont County southeast of Salida, and provide access to a total of 5 river miles for fishing and recreation. The easements have been transferred to the Colorado DNR for management, administration, operation, and maintenance by a Memorandum of Understanding with a term of 25 years. BOR retained ownership of the conservation easements.

Typical Annual Scenario of Water Operations

Water operations occur throughout the year, but change with the different seasons according to patterns of supply and use. Snowpack conditions, weather conditions in irrigated areas, storage carryover, and numerous other factors combine to create a river management situation in which there is no "normal year." However, it is possible to generalize the annual sequence of operations, always keeping in mind that there are frequent exceptions to these generalizations.

Releases from lower basin reservoirs reach their lowest level in the winter as most users save their water until spring and attempt to position water in anticipation of the following year's water supply. A large percentage of these winter flows are stored at Pueblo Reservoir, as part of the WWSP. Because evaporation losses are high at low elevations and increase as the growing season proceeds, most ditch companies use this carryover winter water after March 15, but generally no later than May 1. Most of the water associated with the WWSP is also used during this period. Therefore, in April and early May, releases from upper basin storage are relatively small, except during dry years when rain and snowfall on the plains is negligible.

By May 1, runoff typically has begun. Essentially no releases of stored water are executed between May 1 and mid-July. During this period, water users attempt to fill storage facilities, and irrigation users can rely on the typically high riverflows.

Following the runoff season, stored water is released from storage as needed. Peak releases from stored water are made during this time, generally about mid-July through September. From November 1 onward, there is a decrease in releases. Water users generally call for some of the previous winter's water during the fall, while reserving some to be used the following spring, should the coming winter produce limited water supplies.[89]

In addition to climate, snowpack, and storage conditions, economics play a major role in the annual sequence of operations. Typically, water users seek the lowest cost method for obtaining the water required to meet their demands, and then consult

[89] Telephone conversations with Steve Witte, Colorado Division of Water Resources (July 1995), Tom Simpson, Southeastern Colorado Water Conservancy District (July 1995), and Tom Gibbens, Bureau of Reclamation (July 1995).

with the Division of Water Resources to determine if that method can be used without injuring other water users or violating water rights decrees. For example, water users consider the cost of project water, the cost of augmentation or exchange water available from other water rights holders, and the cost of storage at various locations in making water use decisions. Sometimes water is not moved in response to demand, but rather in an attempt to store water in the least expensive location. Similarly, water users may use their lowest cost water first, regardless of its storage location, in the hope that weather patterns or yield from spring runoff will reduce their need later in the year for more expensive water from other sources.

The following section describes the major surface water operation events that occur at various times throughout a typical year provides more detail about the general sequence of operations described above.

Annual Sequence of Water Operations

In the first part of the calendar year, there is little use by irrigators, and generally, the entire basin is in a storage mode. Under the Arkansas River Compact, winter storage in John Martin is to commence on November 1 and to continue until March 31 of the succeeding year. Conservation storage also begins on November 1 at John Martin Reservoir. Another of the storage programs operating during this time is the WWSP, which includes Pueblo Reservoir and other smaller reservoirs downstream. This program extends from November 15th to March 15th of the succeeding year. Storage begins on November 15 at Clear Creek Reservoir, Mt. Pisgah Reservoir, Deweese Reservoir, and in Colorado Springs' Pikes Peak System.

By March 15th of each year, storage practices return to the usual priority system, and there is an accounting distribution of the water accumulated under the WWSP from the previous winter season. Participants in the WWSP may divert water stored by the program before March 15, but these diversions are charged against the user's entitlement under the program. Deliveries of WWSP water prior to March 15 are not an unusual occurrence, because if the participant diverts water during the program season, the user is not assessed a storage charge. Typically, deliveries prior to March 15 are routed to storage reservoirs owned by the participants. March 15 also marks the beginning of direct-flow diversions by surface water rights, according to the availability of the water supply at that time and the priority of the respective water rights.

No earlier than April 1 and no later than April 7 of each year, water administrators begin to distribute all conservation storage from John Martin Reservoir. The rate of distribution is limited by the allowable release rate under the John Martin operating guidelines.[90] For water rights upstream of John Martin, this event is significant because, until the distribution takes place, water rights for ditches below John Martin are precluded from exerting a call upstream of John Martin Reservoir. This limitation has the effect of increasing the water supply available to direct-flow appropriators upstream from John Martin. However, exchange opportunities may also be limited before April 7 because additional water is being diverted at upstream points rather than being routed downstream to John Martin Reservoir. Storage appropriators upstream of John Martin Reservoir do not usually receive an increased water supply before April 7 because those rights are not typically in priority. It is also important to note that the John Martin Reservoir always exercises a 1948 call, unless the reservoir is spilling. This reservoir call may be in operation even when ditches below the reservoir with more senior priority dates are precluded from exercising a call by the John Martin operating guidelines.

Water stored in Pueblo Reservoir under the WWSP from the winter storage period previous to the one most recently concluded (two winters ago) must be released to the river by May 1 of each year. Up until this date, water users may supplement their water

[90] Resolution Concerning an Operating Plan for John Martin Reservoir, April 24, 1980, at sections I(D), I(E), and III.

supply with any water in their storage accounts, including any remaining allocation of project water, the previous year's winter water, and the current year's winter water. In fact, users with water in their account from any source may call for releases at any time. On May 1, any project water allocations of agricultural water from the previous year that have not been used are subject to cancellation and reallocation under Southeastern's water allocation policy.

After May 1, BOR makes a forecast of the amount of project water that will be available for allotment to Southeastern, based on snow surveys conducted by the Natural Resources Conservation Service.[91] At Southeastern, a committee uses this forecast to recommend a plan for allocation to Southeastern's board at its May meeting. Southeastern's allocation policy requires that the district make the allocation at its regular May meeting, held on the third Thursday of the month.

According to Southeastern's allocation principles and its operating principles, 51 percent of the allocatable supply is reserved for municipal use. If municipalities do not request 51 percent of the anticipated supply, then the remaining water is subject to allocation for irrigation use. Historically municipalities have requested an average of 26 percent of the supply (Table 3-26).

TABLE 3-26

Southeastern Colorado Water Conservancy District Fryingpan-Arkansas Project Water Allocations

Year	Agriculture (thousands of acre-feet)	Municipal (thousands of acre-feet)	Total (thousands of acre-feet)	Agriculture (% of Allocation)	Municipal (% of Allocation)
1972	13.6	6.4	20.0	68	32
1973	13.8	0.2	14.0	99	1
1974	15.7	2.9	18.6	84	16
1975	21.8	3.2	25.0	87	13
1976	8.0	1.8	9.8	82	18
1977	No Allocation in 1977				
1978	20.0	4.3	24.3	82	18
1979	21.1	3.9	25.0	84	16
1980	40.7	15.9	56.6	72	28
1981	16.4	7.5	23.9	69	31
1982	47.2	18.9	66.1	71	29
1983	0.6	18.5	19.1	3	97
1984	0.1	29.2	29.3	0	100
1985	4.1	20.2	24.3	17	83
1986	15.8	7.8	23.6	67	33
1987	6.3	6.3	12.6	50	50
1988	71.1	8.3	79.4	90	10
1989	95.7	13.1	108.8	88	12
1990	30.7	15.4	46.1	67	33
1991	45.8	10.2	56.0	82	18
1992	22.6	10.3	32.9	69	31
1993	56.1	12.1	68.2	82	18
1994	37.9	13.8	51.7	73	27
1995	59.2	16.4	75.6	78	22
1996	77.9	14.5	92.4	84	16
1997	60.5	15.7	76.2	79	21

[91] Forecasting is a continuous process. It officially begins October 1 but is continually revised, sometimes within a single day, in order to be responsive to changes in conditions. The final decision is made on the most recent information, which is after May 1. Telephone interview with Tom Gibbens (July 1995), and comments of Steve Witte (July 21, 1995).

Allocation is typically based on the number of irrigated acres. The total amount of water available is divided by the total number of irrigated acres and allocated on an acre-foot per irrigated acre basis. In addition, transmountain return flows (return flows attributable to the use of water imported into the basin) are allocated first to any entity receiving project water. If they do not exercise this preference, return flows are made available to other users in accordance with Southeastern's return flow policy.[92]

In most years, by mid-June the basin experiences peak snowmelt runoff. This is the time when relatively junior water rights are most likely to be entitled to receive water. The native supply in the Arkansas River Basin is distributed to the most senior rights first in order to ensure that they are satisfied in accordance with their priority. Since storage rights are generally relatively junior, the best opportunity to divert is early June or the peak runoff period. These storage rights are regulated on the basis of priority, just as direct-flow rights that take the water and apply it to an immediate use.

Mid-June is also the time when imports of water from the Colorado River Basin are generally at their maximum. Peak inflows through the Boustead Tunnel normally occur on or about June 10. The peak can vary, however, with weather conditions. For example, in 1995, with its wet, cool spring, the peak did not occur until July. Climatic conditions can also affect the duration of imported flows. Imports through the tunnel usually begin in May and continue through June and July. Depending on the snowpack and other conditions, water may be imported as early as April and as late as October.[93]

Exchange opportunities can occur at any time, but conditions are particularly favorable during months such as June. If storage space is available in upper reservoirs, the high flows that typically occur during June allow diversions into upper basin reservoirs, with sufficient flows remaining to satisfy downstream water rights.[94] Space is needed in the upper reservoirs because, under an exchange, water is released from Pueblo Reservoir in exchange for inflows into the upper reservoirs. If there is no space in the upper reservoirs, inflows cannot be stored and the exchange cannot occur.

Using this exchange approach, Colorado Springs and Aurora can position water for the most efficient operation of their municipal systems. Generally, Colorado Springs stores water in Pueblo Reservoir from Fountain Creek by exchange all year long. During the winter water storage period, Colorado Springs is unable to effectuate exchanges into upper Arkansas reservoir accounts, although it is able to store winter water from Lake Fork and Lake Creek in its Turquoise Lake CF&I accounts and its Twin Lakes Canal Company account. Storage of main stem flows during the winter water program occurs at Lake Meredith and Lake Henry as a result of Colorado Springs' majority ownership in the Colorado Canal System.

During spring, Colorado Springs and Aurora store as much water as they are entitled to in Twin Lakes from the Twin Lakes Tunnel and native Lake Creek water. From there, it can be released to the Otero Pipeline, where it is delivered to the cities' service areas. Since Arkansas River exchanges from Pueblo Reservoir and the Colorado Canal System upstream to Twin Lakes and Turquoise Lake

[92] Policy Concerning Sale of Return Flows from Fryingpan-Arkansas Project Water (April 21, 1994). Entities receiving project water allocations are given a first right of refusal. Telephone interview with Tom Simpson, Southeastern Colorado Water Conservancy District (July 24, 1995).

[93] Interview with Tom Gibbens, Bureau of Reclamation, Feb. 21, 1996.

[94] Telephone interview with Steve Witte, Colorado Division of Water Resources, April 14, 1995. An exchange is an operation whereby a water right or water user may take water from a stream system at one point and then replace the amount consumptively used at another point on the stream system, so long as the operation does not cause injury to water rights between the exchange and replacement points or to downstream water rights. Proposed exchanges are evaluated on a case-by-case basis. Some exchanges are decreed, although this is not required under Colorado water law.

require the storage of native inflows, such exchanges can occur only when there is exchange potential and the storage rights for the Twin Lakes Canal Company and the Turquoise Lake CF&I accounts are not in priority. Exchange potential is greatest during the months of May and June during spring runoff, when native inflows to Twin Lakes can be in excess of 1,000 cfs. Later in the year, exchange potential decreases. Exchanges made during the later summer and fall months are usually much smaller in volume and do not create noticeable changes in streamflow.

Colorado Springs has been very successful in moving water upstream using "contract" exchanges. Contract exchanges are effectuated by trading water stored by Colorado Springs in either Pueblo Reservoir or the Colorado Canal System for water stored by other municipalities, irrigators, and/or BOR. These exchanges can occur at any time during the year because they do not require the storage of native inflows to either Twin Lakes or Turquoise Lake. In addition, contract exchanges do not result in any variation in daily Arkansas River native flows, although they do decrease the total annual volume of water that flows from the upper reservoirs to Pueblo Reservoir.[95]

The Pueblo Board of Water Works (Board) also uses exchanges frequently to store transmountain diversions in Clear Creek Reservoir. Transmountain diversions are released by Pueblo to satisfy downstream water rights, and in turn, Pueblo can divert the same amount of water from Clear Creek. These exchanges typically occur during the spring runoff, but cannot occur during the winter storage period, November 15 through March 15. Spring runoff is also the time when the Board can store the maximum amount of water from its transmountain ditches (Wurtz, Ewing, and Columbine Ditches) by exchange. Water imported into the basin from these ditches is measured as it enters the basin. The imported water then flows down the Arkansas River, past Clear Creek. An amount of water equal to the imported quantity may be diverted by the Board from Clear Creek and stored in Clear Creek Reservoir.[96]

Water supply in late June and continuing through the end of August may fluctuate dramatically due to sporadic precipitation events during this time. These events may supply sufficient water to satisfy junior water rights, including storage rights, according to their priority. But between these events, the supply may drop. As a result, the river call can shift both in terms of the priority date and in terms of the location on the river where those rights exist. This condition during midsummer complicates the problem of distributing water strictly in accordance with priorities at any given time.

Later in the summer, water users, particularly irrigators, tend to rely on their senior rights. They may, however, find it necessary to supplement their water supply from senior rights with releases from storage or with ground water. As a consequence of this pattern, water levels in the reservoirs are lowered, especially in Pueblo and John Martin Reservoirs, often to the disappointment of flat-water recreational interests.

Reservoir releases of previously stored native or imported water, or transmountain water that is released to the stream system, are not subject to distribution on the basis of priority.[97] That water is generally targeted for specific delivery to its owners. This water may be taken out high in the system, at a point such as the Otero Pipeline near Buena Vista, or it may stay in the river until it is diverted further downstream. However, any such water conveyed along a natural watercourse is

[95] Telephone interviews with Jim McGrady, Senior Analyst, Water Resources and Planning, Water Resources Department, Colorado Springs Utilities (Feb. 27-29, 1996).

[96] Information provided by Bud O'Hara, Pueblo Board of Water Works (Nov. 17, 1995).

[97] Previously stored native water refers to current year storage or storage from previous water years.

subject to an administrative assessment for transit losses.[98] Transit losses can amount to 10 to 20 percent of the release volume.[99]

In early fall, BOR generally begins to transfer to Pueblo Reservoir water imported to the upper basin during the summer months. This is done to create storage capacity for the year to come and to position the water for later delivery. BOR tries to maintain sustained flow releases, to avoid dramatic highs and lows in flow levels that can have a negative effect on fish spawning and feeding.[100] Deliveries of project water may also provide for some limited irrigation use in the upper and lower basin that continues into October.

Winter storage at John Martin begins November 1 and at Pueblo Reservoir on November 15.[101] [102] BOR stores water in Pueblo Reservoir from direct flow winter water rights. This amounts to about 30,000 to 50,000 acre-feet of water stored in Pueblo Reservoir, and up to 75,000 acre-feet stored in John Martin Reservoir. Larger canal companies have their own storage for their winter water, and so avoid having to pay BOR for storage in Pueblo Reservoir. These companies also generally begin to store their winter water in November.

Storage Patterns During Times of Average, Low, and High Water Supplies

When there is an unusually low water supply year, some changes to the typical patterns may be adopted. Rather than a change in operations, these may more accurately be defined as changes in the volume of water that is stored and released. For example, in a dry year, reservoirs will be low, so less water may be released from the upper reservoirs down to Pueblo Reservoir. For the purpose of maintaining stream conditions in dry years, project reservoirs are required only to pass through inflow; previously stored water is not released to meet minimum flows.[103]

In high water supply years, there may also be an adjustment in the volume of water released from storage. If Pueblo Reservoir is full, no water except the minimum flow may be released from upstream reservoirs. Flows could not be passed through Pueblo Reservoir if it would increase flows at Avondale (15 miles below Pueblo Reservoir) above 6,000 cfs. Moreover, when Pueblo Reservoir has limited storage capacity, as it did in the fall of

[98] Telephone interview with Steve Witte, Colorado Division of Water Resources (July 18, 1995); see also 1994 Annual Report, Southeastern Colorado Water Conservancy District.

[99] Telephone interview with Doug Cain, U.S. Geological Survey (July 1995).

[100] A 1991 plan agreed to by BOR, Southeastern, BLM, and the Colorado calls for, in addition to minimum flow levels, staging flow changes at the rate of 10 to 15 percent per day. See letter from Steve Reese (Colorado Division of Parks and Outdoor Recreation) and Pete Zwaneveld (Bureau of Land Management) to Citizen Task Force Members (April 17, 1991).

[101] At John Martin Reservoir, storage begins under the 1948 Arkansas River Compact on November 1. The winter water storage program was begun at Pueblo Reservoir to allow farmers an option to store their winter water. Storage under this program begins November 15. Subsequently, some of the farmers asked to store their water at John Martin Reservoir. This was approved, with the condition that storage begin on the same date as it would have at Pueblo. Therefore, although John Martin begins storing water on November 1, it does not store winter water under the Winter Water Storage Program until November 15. Telephone interview with Steve Witte (July 18, 1995).

[102] Normal winter storage at John Martin consists of inflow of Arkansas River tributaries downstream of Pueblo Reservoir, as well as return flows that accrue to the river downstream from Pueblo Reservoir from water uses that occur during the winter, such as municipal use. Water stored under the Winter Water Storage Program at John Martin is received via specific deliveries from Pueblo Reservoir. All participants in the Winter Water Storage Program receive set percentages of winter inflows to Pueblo Reservoir, as specified by decree. Under the percentage allocation, water that accrues to entities with storage space in John Martin is then delivered to John Martin via the Arkansas River channel.

[103] Telephone interview with Tom Gibbens, Bureau of Reclamation (Nov. 7, 1995).

1995, the only remaining space is the joint use pool. Those storing water under the WWSP must store the water in this pool. Unlike other space, this pool must be evacuated by April 15, which may be earlier than the water is needed. Similarly, in high volume years, any water carried over under "if and when" contracts may be spilled along with the winter water. This occurred in 1995.[104]

Another characteristic of wet years is that there are restrictions on imports due to the upstream channel and reservoir capacity. For example, if snowmelt causes Lake Creek to have high flows, it will not be available as a conduit for imported water. In fact, during 1995, Pitkin County requested that additional water be imported into Twin Lakes from the Roaring Fork to alleviate a flooding problem in the town of Aspen. However, cabins on Lake Creek might have been flooded if imports had been increased as requested. Additionally, the water decree for Twin Lakes requires a reduction in the storage of imported water when native supplies are in priority.[105]

Analysis of Legal and Institutional Opportunities for Water Management

The first four parts of this section describe the history, infrastructure, legal constraints, and operational requirements that create a typical annual pattern of streamflows in the Upper Arkansas River basin. In this part, the potential opportunities for modifying river management in the upper basin in order to accommodate natural resource values and to better provide for other water uses are examined. These opportunities are based upon information provided from parties who were interviewed as a part of this study. Municipalities, the Colorado Division of Water Resources, and other water users and managers have supplied much of the background provided. Some of these opportunities for change are based, at least in part, on changes already planned or underway in the basin.

Specific opportunities are offered here as a vehicle for understanding existing legal and institutional parameters within which water is currently managed. Accordingly, each opportunity that is discussed identifies which of these parameters might be triggered if the opportunity were to be implemented. With this in mind, water users and managers would have the basic foundation for further examination and discussion. Implementation will only happen, of course, where factors are present that support such change. These factors are complex, and might include water supply and demand, other market conditions, public values, existing legal rules, and new court decisions or other legal developments.

For each opportunity explored, the report considers how it might be implemented, identifies the parties involved or affected, and describes the benefits (to resources, water users, and water management) that might be realized from implementation. Issues and concerns, such as cost or legal constraints, are also considered. Although the authors intended this material to be as comprehensive as possible, there no doubt are other parties, benefits, issues, and concerns that will emerge as these opportunities are discussed.

How might this analysis be used? Where economic, physical, and social factors support it, these opportunities, in some form, might be implemented proactively, to offset likely changes to riverflows as a result of the exercise of existing legal rights. For example, some of the water historically delivered to ditches below Pueblo Reservoir is now stored in upstream reservoirs and/or diverted at

[104] Telephone interview with Steve Witte, Colorado Division of Water Resources (Nov. 11, 1995).

[105] Telephone interview with Steve Witte, Colorado Division of Water Resources (Nov. 11, 1995).

Otero Pipeline, modifying the historic pattern of flows between the Otero Pipeline and Pueblo Reservoir. Some of this change is due to the transfer of water from agricultural to municipal use. As these transfers are fully implemented, additional flow modifications can be anticipated. Water managers, including the Division Engineer, BOR, and Southeastern, under some conditions, may be able to offset existing and future changes to riverflows by making other adjustments, for example, in the timing of storage releases.

Similarly, when water managers have knowledge of proposed water development projects in the basin, they can collectively look for mechanisms to improve water management in light of such projects. This might include consideration of alternatives to the proposed development that would achieve the proponent's objectives while not negatively impacting overall water management. The opportunities described here will hopefully become springboards for further discussion of ways to improve river management to meet current and future needs. Through such dialogue, other issues and opportunities may emerge that have not been considered in this report.

Some of the opportunities may appear less feasible than others in light of the issues or obstacles they raise. For example, importing additional water to the upper Arkansas River, though probably legally plausible, raises concerns for west slope water users and raises concerns about physical limitations of existing storage and conveyance facilities. Nevertheless, the objective of this part of the report is to identify ideas and to promote broad thinking, while recognizing the legal and institutional limits of a specific tool. The opportunities discussed in this report include:

~ Modified Management (Reoperation) of Existing Storage and Conveyance Facilities
~ Expanded or New Storage
~ Second Southern Delivery System
~ Temporary Water Use Transfers
~ Arrangements with Municipal Providers
~ Expanded Season of Exchanges
~ Increased Water Imports
~ Agreements Regarding Upstream Irrigation Water Rights

Modified Management (Reoperation) of Existing Storage and Conveyance Facilities[106]

Reservoirs and lakes in the upper basin above Pueblo Reservoir have a combined capacity of over 300,000 acre-feet.[107] BOR regulates most of this storage under both long-term and year-to-year contract arrangements. BOR has much discretion regarding these upstream operations, as long as water rights are not affected, contractual obligations are met, compact provisions are followed, and operations fall within the parameters of the broad project operating principles. These principles include many directives on water allocation and operations, including a preference for domestic use over any other type of use.[108] The

[106] A storage needs assessment study for the basin is underway, initiated by the Southeastern Colorado Water Conservancy District.

[107] Water Resources Appraisal of the Upper Arkansas River Basin from Leadville to Pueblo, Colorado, USGS Water Resources Investigation Report 82-4114 (1984), at p. 28.

[108] Operating Principles, Fryingpan-Arkansas Project, House Doc. No. 130, 87th Cong., 1st Sess.(1961), para. 13 [hereinafter operating principles]. The language parallels the Colorado Constitution, art. XVI, sec. 6, which states that, "when the waters of any natural stream are not sufficient for the service of all those desiring the use of the same, those using the water for domestic purposes shall have the preference over those claiming for any other purpose." The operating principles do not include a second preference in this constitutional provision, for agricultural use over manufacturing. Early Colorado court cases have established that the constitutional language amounts only to a right to condemn inferior uses if compensation is paid. See George Vranesh, Colorado Water Law (1987), at Section 6.8, page 732.

principles also state that the project is to be operated "in such a manner as to secure the greatest benefit from the use and reuse of imported project waters within project boundaries in the State of Colorado.[109]

BOR's potential opportunities to manage storage for the benefit of other resources while protecting existing water uses is best understood by examining the types of releases that BOR makes from storage. Project water is released from the upper reservoirs for one or more of the following reasons: 1) to meet project water deliveries (above, at, or below Pueblo Reservoir); 2) to make space for additional trans-mountain storage by contract holders or by the project; 3) to make space in anticipation of native spring flows; 4) to augment flows for rafting and fish habitat (by agreement) or other purposes within the project authorization; and 5) to meet minimum flow requirements in the upper basin.

Releases to Meet Project Water Delivery Requirements

The amount of water released from the upper reservoirs for project water deliveries varies depending on the water supply year. Each year, BOR notifies Southeastern in early May as to how much water will be available. Southeastern, in turn, allocates water based upon the available supply and the requests it receives from users. In 1989, a low water supply year, over 100,000 acre-feet of project water was allocated by Southeastern, and there were numerous operating requirements for BOR to deliver water when and where project water recipients needed it. In contrast, in 1983, a much higher water supply year, only about 12,500 acre-feet of project water was allocated, creating much fewer delivery requirements for BOR. If any portion of project yield is not demanded by project water recipients, BOR has the flexibility to keep the water higher in the basin. Of course, other project operating principles, such as flood control, may negate this flexibility.

When releases are needed to meet project delivery requirements, BOR has some discretion in deciding where to make the release. For example, if a project water recipient below Pueblo Reservoir requires a delivery, BOR may make a release for this purpose from Turquoise Lake, Twin Lakes, or Pueblo Reservoir. Physically, the releases must be made from Pueblo Reservoir because it captures all inflow from the upper basin, but BOR has flexibility to determine when this water arrives at Pueblo Reservoir and which upstream reservoir will make the delivery to Pueblo Reservoir. The movement of water to Pueblo Reservoir can be timed so that it is simultaneous with the delivery need, or it may come earlier or later. The quantity of project water in Pueblo Reservoir serves as a cushion, allowing BOR to meet delivery demands while retaining flexibility in when and how water is moved to Pueblo Reservoir to meet the demands.

Other storage management techniques might be considered by BOR to add flexibility in how demands are met for the delivery of project water. For example, BOR could consider earlier than usual water deliveries to project water recipients who have available storage space downstream. While spring and early summer often finds these recipients with limited ability to store water locally, their ability to do so generally increases beginning later in the summer. This might enable BOR to avoid additional releases at times that could be damaging to fishery and recreation values. Although BOR would probably be required to offset evaporation losses due to early water delivery, which goes against the operating concept of retaining water high in the basin to avoid evaporation losses, the benefits may be significant enough that benefitting parties may be willing to cover the evaporation losses. There may also be a higher storage charge for lower basin storage sites.

Similar to making early deliveries to downstream storage, allowing exchanges with owners of lower basin storage facilities could also be considered by BOR. For example, BOR could ask a party with

[109] Operating principles, at para. 14.

lower basin storage to make a water delivery instead of releasing that water delivery from upper basin storage. In return, BOR could agree to provide the lower basin party with temporary storage of an equivalent amount of water in an upper basin reservoir. This temporary, high-elevation storage could result in evaporation savings for the party who would normally store water in their own facility in the lower basin.

When considering BOR's discretion in storage management, it is important to remember that project water is not always moved out of storage in the year it is purchased.[110] For example, if Fountain Valley Authority has not yet taken the full 25 percent of supply that Southeastern allocates to municipal uses, the balance can be carried over.[111] Even agricultural project water users may carry over water if they are unable to use it all in the year allocated.[112] While carryover storage is necessary, it somewhat decreases BOR's flexibility to store current year flows because additional storage space is being used. On the other hand, it increases delivery flexibility. Generally, BOR has the flexibility to maintain this carryover storage anywhere in its system. To free up storage space, BOR may be able to negotiate dates for delivering the carryover storage with parties who have their own storage facilities or who rely upon multiple sources of water to satisfy their needs.

Storage management is affected by Southeastern's water allocations. Although existing allocations are based on project operating principles, opportunities exist to modify allocations based on demonstrated need. This could be accomplished, for example, through some type of short-term agreement among Southeastern's water users that would not require an amendment of project operating principles.

Project Releases to Create Space for Imported and Native Runoff

As mentioned previously, BOR stores both project water and water imported by holders of storage contracts. Between October and April, BOR typically moves about 50,000 to 75,000 acre-feet of previously stored water from the upper reservoirs to Pueblo Reservoir to make room for runoff. This equates to a typical release of 200 to 500 cfs. By the end of April, BOR wants to have the upper basin reservoirs drawn down as far as possible, generally to the level of the combined dead and inactive storage pools. This means that Turquoise Lake is drawn down to about 9,000 acre-feet and Twin Lakes is drawn down to about 67,000 acre-feet.[113] However, historic storage levels have been significantly higher than this amount due to water stored under various storage contracts. Total storage has never fallen below 60,000 acre-feet at Turquoise Reservoir or below 73,000 acre-feet at Twin Lakes.

This 7-month time period to vacate the upper reservoirs creates flexibility in the magnitude and

[110] Southeastern may carry over water, which is credited to a "paid for" account. In some years, BOR and the District may do a second allocation later in the season. Telephone interview with Tom Gibbens, Bureau of Reclamation, April 20, 1995.

[111] U.S. Dept. of the Interior, Bureau of Reclamation, 1990 Review of Operations, at 35, Table 8. Southeastern's municipal allocations accounted for 14,000 acre-feet in 1989 (about 14 percent of Southeastern's total allocations) and about 6,000 acre-feet in 1987 (about 50 percent of Southeastern's total allocations). Southeastern's total annual allocations vary, depending on the water supply each year. Telephone interview with Tom Gibbens, Bureau of Reclamation, April 20, 1995.

[112] This carryover is not expressly allowed under Southeastern's Water Allocation Policy, paragraph 8, but has occurred in the past with Southeastern's consent. BOR is not a party to Southeastern's allocation principles and policies. The space designated by Southeastern for municipal carryover is not a BOR rule. BOR must follow Colorado Compact requirements for all imported water; it cannot release water downstream unless it can be used within Colorado. Therefore, if downstream reservoirs are full and there is no demand downstream, then BOR may not import water, which happened in the mid-1980's. Telephone interview with Tom Gibbens, Bureau of Reclamation, April 20, 1995.

[113] Gibbens interview, Feb. 21, 1996.

timing of releases, especially since many project water recipients are not taking water deliveries at this time. BOR's ability to make additional winter releases is limited because all inflows to upper reservoirs go to parties who hold contracts with BOR for upstream storage. BOR could offer temporary storage to these water rights in Pueblo Reservoir, allowing this water to be sent downstream during the winter months. However, the implications for storage at Pueblo Reservoir would have to examined very carefully, because the additional water placed in Pueblo Reservoir storage could result in unwanted spills.

BOR has further discretion in storage because contract storage holders do not use their storage space year-round. For example, BOR uses some storage space in Turquoise Lake that is held by municipalities. This space may need to be vacated if the cities need their storage space. For example, a provision in the CF&I contract gives the successors to CF&I (Aurora and the Pueblo Board of Water Works) a right to store 27,416 acre-feet. BOR may use this space to store project water early in the season, for example, but may later need to move water down to Pueblo Reservoir if the cities need their allocated space. In practice, BOR has not had a problem being able to move the water down to Pueblo Reservoir as necessary for this purpose.

Project Releases to Support Natural Resource Values

As described earlier, BOR tries to follow flow and ramping recommendations made by the Colorado DNR,[114] and has not experienced significant storage management problems in providing these flows. In general, the guidelines require gradual releases with no dramatic change in volume. These flow volume and change guidelines are for the benefit of fish and wildlife in the upper basin. Winter flow releases from the upper reservoirs generally range from 200 to 500 cfs. During this time, native flows into Turquoise Lake are at about 3 to 4 cfs, and flows into Twin Lakes are a bit higher at about 15-20 cfs. Therefore, BOR releases to the Arkansas River have a significant impact on flows during this time of year.

Even if the Department's flow recommendations were to change based on new research or management goals, BOR could theoretically accommodate those recommendations if it did not require aggregate releases in excess of the typical 50,000 to 75,000 acre-feet released during the winter, or more than 10,000 acre-feet of augmentation water during the summer months. Recommendations to reduce or limit releases might also be implemented. Of course, BOR would not be able to implement any change in the Department's recommendations if doing so would force BOR to violate project operating principles, contract agreements, or State water law.

A minimum flow of 66.0 cfs has been established for the Arkansas River at Granite, which is assured by releases from Twin Lakes. In addition, BOR maintains, in both Lake Fork below Turquoise Lake and Lake Creek below Twin Lakes, minimum flows of at least 15.0 cfs during the summer and 3.0 cfs or the natural inflow during the winter. If inflow to either of these lakes is less than 15 cfs, BOR is required only to bypass inflow. Since these minimum flows are relatively small amounts, they are typically met by project releases for other purposes, and typically do not become a major factor in storage management.

Parties Involved

Altering the times of storage and release to benefit flows in the upper basin would require the involvement of Federal and State agencies and water users.

[114] This is called the "Cooperative Flow Management Program." See letter to Jack Garner, Area Manager, Bureau of Reclamation from James S. Lochhead, Executive Director, Colorado Department of Natural Resources, dated March 9, 1995, Re: 1995-96 Flow Recommendations for the Upper Arkansas; these recommendations set flow targets for moving most of the water down from the upper reservoirs in the spring. These recommendations and flow change criteria are not mandatory for BOR, but BOR operates as closely as it can to these levels. Gibbens interview, April 20, 1995.

Thus, these parties would need to be involved in decisions to make such changes. BOR operates the three major reservoirs. If some type of river exchange was involved, the Division Engineer would also need to be involved to approve the exchange, along with the parties to the exchange. Finally, if flow patterns were changed during the winter, certain municipalities would want assurances that minimum flows would be maintained below their wastewater treatment facilities. These municipalities would include Salida, Florence, and Cañon City. In addition, wildlife interests would want assurances that flow conditions for fisheries would not be impacted.

Potential Benefits

Several benefits might result from changes in storage and release of water in the upper basin. Managers would have more flexibility in deciding when water should be released down to Pueblo Reservoir. Upper basin flows could be increased or decreased at times beneficial to fish, water quality, recreation, and other resources. Changes in release and storage might improve water quality and reduce treatment costs for municipalities with raw water treatment facilities taking water out of the upper basin.

Municipalities may be able to make exchanges if, for example, BOR needed to get water down to Pueblo Reservoir for use at or below the reservoir at a time when it was not desirable to increase flows in the upper basin, possibly due to fisheries concerns. The municipality could take advantage of the situation by moving some of its water upstream, so that it could be taken out at Otero, in exchange for providing water to BOR at Pueblo Reservoir. This type of exchange would avoid problems for the fish habitat in the upper basin while meeting the water demands at or below Pueblo Reservoir. BOR currently charges a per acre-foot fee for these types of contract exchanges.

Issues and Concerns

Modification of storage and release patterns requires consideration of all of the factors that go into BOR's decision on where to store water within the basin. These factors include:

- ~ The ability to meet project water deliveries;
- ~ The need to vacate storage space in the upper reservoirs in the spring to maximize import opportunities;
- ~ The desire to avoid moving water downstream to Pueblo Reservoir if doing so would cause winter water to spill and "if and when" contracts to spill (winter and spring months);
- ~ Minimization of evaporation losses associated with Pueblo Reservoir (summer months); and
- ~ Recreational demands at Pueblo and upstream reservoirs and in the river itself (generally summer months).

Another concern is in the area of State law, Southeastern's Allocation Principles and policies, and Federal reclamation law (including project operating principles). State water law requires that water be used for a beneficial purpose. Instream flow use of water is permitted only by the Colorado Water Conservation Board, although recent cases suggest that private parties or public entities may hold similar rights if "control" of the water is adequately demonstrated.[115] However, if the water released is recaptured at Pueblo Reservoir, then this issue of diversion or control should not present a problem, so long as water is eventually applied to beneficial use below Pueblo Reservoir. Under the Colorado River Compact, also a part of State law, all imported water released from the upper reservoirs must be stored in Pueblo

[115] See, e.g., City of Thornton v. City of Fort Collins, 830 P.2d 915 (Colo. 1992), in which the Colorado Supreme Court held that water need not be removed from its source if appropriator shows sufficient control of the water within its natural course or location.

[116] Colorado River Compact, 43 U.S.C. § 617(l); Colo. Rev. Stat. § 37-61-101 to -104.

Reservoir or used within the State of Colorado.[116] Furthermore, under Southeastern's policy and its contract with BOR, project water must be used within the District.[117]

Changes in storage and release patterns would likely have little impact on the ability to generate power below Turquoise Lakes. The Mt. Elbert Conduit can handle flows of up to 370 cfs. As a result, only large releases exceeding this amount would cause water to bypass the powerplant.[118] If storage space is available in Turquoise Lake, BOR may be able to mitigate the loss of power by releasing water instead at Twin Lakes. The operational flexibility would allow water to remain in Turquoise Lake that would later be released and, in the process, would be run through the Mt. Elbert powerplant.

Any potential change would need to be reviewed by BOR, the Division Engineer, and Southeastern to determine the possible impact on established operations, and legal obligations or rights. BOR generally notifies the Division Engineer's office of the flow releases so that office can administer water rights. Releases should not conflict with Southeastern's Allocation Principles and Water Allocation Policies, and the allocation of project water should not be changed.[119] There may be some concern that any change in release patterns benefiting an entity outside Southeastern's boundaries should require compensation to Southeastern that can then be applied toward Southeastern's repayment obligation.[120]

Expanded or New Storage

Increased storage upstream or at Pueblo Reservoir would allow water managers to control or regulate a larger volume of water in many water supply years. In addition to generally increasing the volume of stored water, increased storage might provide an opportunity to enter agreements with entities in need of additional storage space. These agreements may provide benefits to natural resource values and other water users in the basin.[121]

Under the direction of Southeastern, a water and storage needs assessment is underway. The broad goal of the study is to develop alternative strategies for meeting future water supply and storage needs of Southeastern's constituents while protecting existing interests in the Fryingpan-Arkansas Project. One of the specific objectives of the study is to identify and rank opportunities for developing additional water supplies, including "reoperation" of existing reservoirs and conveyance facilities and implementation of new storage projects. Other objectives include assessing future water needs within the District and evaluating the ability of existing facilities to meet future needs.[122]

Municipal providers, such as Colorado Springs Utilities, may benefit from additional storage and may be able to modify their patterns of water use to help other water-dependent resources in the basin. For example, assuming there is an interest in maintaining waterflows in the river between the

[117] Water Allocation Policy, Southeastern Colorado Water Conservancy District, Policy No. 1 (amended Jan. 1993).

[118] There is also a smaller hydroelectric facility located below Turquoise Lake. BOR has no obligation to provide a specific flow to this facility. Gibbens Interview, April 20, 1995.

[119] These District policies and principles may or may not be binding on BOR. Gibbens interview, April 20, 1995.

[120] Gibbens interview, April 20, 1995; interview with Tom Simpson, Southeastern Colorado Water Conservancy District, April 21, 1995.

[121] Transcript of presentation by Gary Bostrom, Colorado Springs Utilities, at Arkansas River Forum, Pueblo (Jan. 1995).

[122] Fax to Roy Smith, Bureau of Land Management, from Tom Simpson, Southeastern Colorado Water Conservancy District, at Section 5.2, Goals and Objectives (faxed Nov. 7, 1997).

Otero Pipeline and Pueblo Reservoir, an agreement might be worked out under which Colorado Springs would get additional storage in Pueblo Reservoir and, in exchange, would agree to take a set volume or percentage of its annual water entitlement at or below Pueblo Reservoir, thus ensuring that this amount of water would be in the river between Otero and Pueblo Reservoir.

Increased storage would have different impacts depending on where in the system the expansion occurred. Expanding the active storage capacity of Pueblo Reservoir might ensure that more water will flow from the upper reservoirs down to Pueblo in order to fill this space and create more room in upper reservoirs. Expanding the active capacity at Turquoise Lake or Twin Lakes would in general increase the volume of water controlled in the upper basin, and would create opportunities to hold back flows when it would benefit water users and/or natural resource values.

Parties Involved

If one of the existing project reservoirs were to be expanded, BOR would be a necessary party. In addition, Congressional approval might be needed, for example, if the expansion were not within the original authorizing legislation, as amended. If Federal funding, either as a loan or a grant, was being sought, Congress might need to approve the funding. Alternatively, funding could be sought from a nongovernmental lending institution.

Other natural resources, including fish and wildlife, might be impacted by any storage development or expansion. If BOR facilities were involved, the National Environmental Policy Act (NEPA) would apply, which would require the involvement of several other State and Federal agencies, including the Colorado DNR and the U.S. Fish and Wildlife Service.

Any storage expansion may involve new or modified water rights in order to fill the expanded capacity. In Colorado, this would mean an application to the water court for a new or modified water rights decree. This action would bring in the Division Engineer and any water users with concerns about the impacts of additional storage on their existing water rights.

Potential Benefits

Additional storage space high in the basin would correspondingly increase the volume of water that may be stored. Not only can this help entities with a need for additional storage, such as Colorado Springs, it may help to ensure that some of that additional volume of stored water will supplement upper basin flows at critical times for other resource needs. Additional storage might also increase exchange opportunities for municipalities wanting to move water out of the basin at Otero Pipeline.

Issues and Concerns

One of the major concerns with storage expansion would be environmental compliance. If a full environmental impact statement was required under NEPA, the process could be time-consuming and the costs could be high. Who would bear these costs is another issue. Presumably the party or parties benefitting from the additional storage would pay both construction and compliance costs. There are a number of actions that can trigger the requirement for NEPA compliance, including the involvement of Federal agencies or money and the modification of contracts between the Federal Government and other entities. For example, a change in storage allocation may require a change in Southeastern's operating principles. This, in turn, may trigger a full NEPA review of those Principles.

Some options for expanding storage present unique issues. The expansion of Turquoise Lake, for example, is not likely because there is a limited water supply even if the capacity were increased. In addition, raising the level of Twin Lakes Dam might flood the Mt. Elbert pumping plant and the sewage system of the Town of Twin Lakes.[123]

[123] Gibbens interview, Feb. 21, 1996.

Second Southern Delivery System

Another possible water management change within the basin might be to add an additional southern delivery system below Pueblo Reservoir for delivering water to municipal users in the lower basin. The existing southern delivery system is operated by the Fountain Valley Authority but, as described in the next few paragraphs, is expected to reach capacity by the year 2012. The construction of a new southern delivery system may enhance upper basin flows by allowing a larger volume of water to remain in the river between Otero Pipeline and Pueblo Reservoir.

Under current operating practices, Colorado Springs Utilities, one member of the Fountain Valley Authority, delivers about 1,200 acre-feet of water from Pueblo Reservoir through the existing Fountain Valley Conduit. This amount is expected to increase to 14,000 acre-feet, the full entitlement under Colorado Springs Utilities' contract with Southeastern. Most of the water currently needed by Colorado Springs Utilities (about 48,000 acre-feet out of a total of 75,000 acre-feet) is diverted out of the basin (by exchange, direct diversion, or release of transmountain water) at Otero Pipeline.[124] This amount of water does not flow in the river between the upper reservoirs and Pueblo Reservoir.

Colorado Springs Utilities' plans for future projects include the development of a southern delivery system and the expansion of Otero Pipeline. Relying upon a recently completed study, Colorado Springs Utilities has projected an increase in water demand through the year 2040. By the year 2012, Colorado Springs Utilities will be fully utilizing both the Otero Pipeline (along with the City of Aurora) and the existing Fountain Valley Conduit, but will need to deliver approximately 74,500 acre-feet of additional water. This could be accomplished in part by increasing diversions higher in the basin through, for example, an expanded Otero Pipeline. However, future expansion at Otero is planned at only 14,500 acre-feet, which leaves about 60,000 acre-feet that cannot be diverted at Otero, even if expanded. An additional southern delivery system would provide flexibility for Colorado Springs Utilities to move increased volumes of water from Pueblo Reservoir to where the water is needed in its service area.

Additional firm storage in Pueblo Reservoir may be needed in order for Colorado Springs Utilities to be able to effectively deliver water through a second southern delivery system. In fact, Colorado Springs Utilities, which currently holds about 230,000 acre-feet in storage in the Arkansas River Basin, has estimated a need for an additional 42,000 acre-feet. Colorado Springs Utilities would need to contract for the storage, and could, through this contract, agree to take a minimum or set amount of its water supply at Pueblo Reservoir rather than divert the water out of the basin at Otero Pipeline.[125]

Regardless of which of Colorado Springs Utilities' proposals is implemented, forecasts predict that by the year 2040, Colorado Springs Utilities will divert an additional 74,500 acre-feet of imported and native flows from reservoirs within the Arkansas River Basin. By building a second southern delivery system, in lieu of other options for distribution and delivery, up to 60,000 acre-feet of this additional 74,500 acre-feet annually might remain in the river between the upper basin reservoirs and Pueblo Reservoir, water that otherwise would be diverted out of the upper basin.[126]

[124] Currently, Otero Pipeline's capacity is 60,000 acre-feet.

[125] Interview with Gary Bostrom and Philip Saletta, Colorado Springs Utilities, Water Resources Department (Oct. 13, 1994) [hereinafter Colorado Springs interview, Oct. 13, 1994].

[126] Interview with Philip Saletta, Colorado Springs Utilities, March 3, 1998.

Parties Involved

BOR and Southeastern would need to be involved in any effort to provide additional storage in the project for Colorado Springs Utilities. Any changes to existing water rights would require the approval of the State Engineer. Colorado Springs Utilities would, of course, be a party to any activity affecting its water delivery system. In addition, other existing storage rights holders and numerous other entities that might be affected by the reallocation of storage would have to be consulted.

Potential Benefits

A larger volume of stored water upstream, which could then be delivered to a southern delivery system, could greatly increase flexibility in managing flows. Potentially, about 60,000 acre-feet of water would flow through the upper basin to benefit natural resource values dependent on streamflows rather than being diverted for the upper basin. This volume of water may also aid in river administration by enhancing the flexibility to move water down from the upper reservoirs to Pueblo Reservoir, and to position water in Pueblo Reservoir to meet downstream water needs.

The tool might also provide advantages to Colorado Springs Utilities, which would receive the additional storage needed to manage its water supply and delivery system, and may be able to better manage its exchange program. Colorado Springs Utilities may also be better able to manage its native water rights, such as those of the Colorado Canal, that are located downstream from Twin Lakes.

Other entities in the basin would also benefit from this approach. With this option, Colorado Springs Utilities may no longer pursue its proposal to construct a new storage facility in the upper basin, a proposal that has raised concerns among some interests in the basin.

Issues and Concerns

One significant issue for any construction project is the cost. An evaluation would be needed of how much it would cost to build a new southern delivery system, and how this cost compares with other options for increasing the volume of water that can be delivered. Construction of the existing conduit at Fountain Valley would cost in excess of $45 million.[127] The construction expense of a new delivery system would probably be assessed at least in part to water users receiving water through the new system. In addition to construction costs, pumping and treatment expenses may be higher for a system taking water at Pueblo Reservoir. Water diverted higher in the system, for example at Otero, is not significantly affected by agricultural return flows and other factors that contribute to quality degradation, although potential contamination from old mining operations begins in the headwaters. Water quality degradation translates to higher treatment costs for Colorado Springs Utilities if the intended use is domestic.

If Federal funds were sought to finance part of the construction costs, authorizing federal legislation would be needed. Contracts with BOR, however, might provide rights-of-way and technical assistance without the need for legislation. Federal agency involvement with the project may trigger the requirement for NEPA compliance, adding to the cost.[128]

Another issue is the effect of selling firm storage space at Pueblo Reservoir for the storage of

[127] See subcontract between the Southeastern Colorado Water Conservancy District and Fountain Valley Authority, Colorado Springs Utilities, City of Fountain, Security Water District, Stratmoor Hills Water District, and Widefield Homes Water Company for Conveyance Service from the Fountain Valley Conduit, dated July 10, 1979; and Contract Between the United States and the Southeastern Colorado Water Conservancy District for Conveyance Service from the Fountain Valley Conduit, No. 9-07-70-W0315, dated July 10, 1979, at para. 7.

[128] Gibbens interview, Feb. 21, 1996. See also 42 U.S.C. 4331.

nonproject water. Any agreement for providing additional firm storage to entities other than Southeastern would need to protect Southeastern's ability to divert and store project water rights, which include both east slope and west slope water rights, and rights under the WWSP. There should be no impact on existing project water users in the Southeastern District. Nevertheless, Southeastern would want any new allocation of storage space to be subject to the need to store project water, which could be handled by requiring that the firm storage be spilled under certain conditions or through terms for mitigation for any loss of project storage.[129]

Once the issue of BOR providing additional firm storage in Pueblo Reservoir is raised, other water users might also want the opportunity to obtain additional firm storage in Pueblo Reservoir under terms like those offered to Colorado Spring Utilities. Agricultural water users participating in the WWSP, for example, whose water is now subject to spill, may be opposed to any new storage allocation that would be perceived as favoring other stored water over their own. They too would like the opportunity to purchase firm storage space in Pueblo Reservoir.

Temporary Water Use Transfers

Entitlements to the use of native and developed water in the Arkansas, as in most river basins in the West, are governed by an elaborate and complex legal structure, based primarily on the date on which water uses were established, beginning in the 1800's. Also similar to other basins, irrigation use in the Arkansas River Basin historically accounted for the most senior priorities to the use of water and for the largest percentage of entitlements, and this is still the case. This proportion is shifting, however, as more water rights are transferred from irrigation to municipal use, and as opportunities for the development of new supplies diminish.

In the Arkansas River Basin, reallocation from irrigation to municipal and other uses has most often occurred when water is permanently removed from formerly irrigated lands in the lower valley. But there are significant costs in effecting these types of transfers. The transfer process is expensive and long, often taking several years to complete. Moreover, there may be significant adverse local economic effects associated with large-scale transfers. Yet water transfers have been successful in serving at least a portion of the need for more flexibility in the allocation and use of water resources.

Short-term transfers are, in general, tools for transferring water use rather than water rights, and they are used in several locations in the West. They offer a potential solution for meeting some types of water supply needs with fewer negative impacts than permanent transfers. Harm to local communities and to the land can be reduced because the lands are kept productive in most years. These transfers are structured to provide water to the purchaser under specified conditions, such as a low water supply year, for a set period of time. The contract may be for several years, while conditions triggering a right or obligation to buy water are usually evaluated annually. Because only water use is transferred, costs generally are lower than the transfer of water rights. Compared to water rights transfers, the approval process for short-term transfers is streamlined in many States. Water laws have been modified in several States to include provisions governing proof of no injury and the loss of a water right for nonuse. In some cases, there may be an intermediary or broker, such as a water district, matching willing sellers and buyers. However, in several States, there are short-term transfers occurring between private parties.

An example of this latter type of temporary transfer is the dry-year option contract, under which the parties agree that, under certain water supply conditions, water will be transferred for that season or year. This approach is being used in some areas of the West to obtain a water supply for

[129] Interview with Tom Simpson, Southeastern Colorado Water Conservancy District, April 21, 1995.

nonagricultural users in times of water shortage. Under these types of contracts, the holder of the option has the right to buy water from the seller (an irrigation user) and the seller agrees to make water available in the future under specified conditions for a preestablished price. When the conditions are triggered, water is transferred from the irrigation use to a higher valued use where it is needed temporarily. The irrigator receives compensation from the buyer for the temporary use of water, yet remains the holder of the underlying water right, with the right to receive water during normal water supply years.[130]

The structure of the dry-year option agreement is open to negotiation. The contract establishes the conditions under which the option would be triggered, for example, when the water supply in the basin falls below a specified amount of acre-feet of native or imported flows (or some combination). In those years, the irrigator agrees to forgo diversions and allow the buyer, generally a municipal water provider, to take the water at the same or an alternate point of diversion. The irrigator is compensated for entering the contract, possibly with some amount up front, but at least with some amount in those years the option is triggered.

An example of a dry-year option contract is the 1992 agreement between the Metropolitan Water District of Southern California and the Dudley Ridge Water District in King County, California. Dudley Ridge agreed to facilitate the sale, at an agreed-to price of $125 an acre-foot, of a portion of its 57,700-acre-foot annual allocation of California State Water Project water supply, if not requested by district water users. Dudley Ridge users had no obligation to sell, but the Metropolitan Water District had an obligation to buy water under specific conditions.[131]

Where there is a brokering entity matching willing buyers and sellers year to year (sometimes called water banks), the transfer process is often institutionalized, with known procedures and some kind of public regulation and recognition. Once again, the process is streamlined compared to the permanent water rights transfer process. A water entitlement may be deposited with the broker and may be purchased and withdrawn for use by others, subject to conditions, including the payment of a fee. The depositor hopes to be compensated for the use by another, but may later withdraw the water if there has not been a buyer. The buyer uses the broker to find water more quickly, perhaps, and at a lower cost than is available from other sources.[132]

The upper Snake River in Idaho provides a good example of a temporary water transfer program. The rental of water on a temporary basis has been occurring in the upper Snake River Basin since the 1930's, but it was only in 1979, with the adoption of a statute, that a formal, Statewide program for year-to-year transfers began. Only water available under storage water rights can be sold through local water districts in Idaho, including the upper Snake River Basin.[133] This limitation avoids some of the injury questions that otherwise would arise.

[130] See Rice and MacDonnell, Agricultural to Urban Water Transfers in Colorado, CWRRI Completion Report No. 177 (1993), at pp. 66-67.

[131] See L. MacDonnell and T. Rice, "Moving Agricultural Water to Cities," 2 West-Northwest 50 (Fall 1994) {hereinafter Moving Water}.

[132] See L. MacDonnell, et al., Water Banks in the West, Natural Resources Law Center, Research Report No. 12 (1994), at pp. 1-4 (hereinafter Water Banks in the West).

[133] Idaho law recognizes storage water rights and natural flow rights. A storage right is the right to store water, when it is available under a specified priority date, for a later, specified beneficial use. If water is stored under a storage right and not needed, it can be carried over. Natural flow rights, in contrast, must be diverted and used as they come into priority or, if not used, passed to the next appropriator in line.

State water administrators appointed a local committee in the upper Snake River Basin to manage the transfers. Operating procedures were adopted by the committee and approved by the State. Among other matters, these procedures address: 1) determining priorities among competing applicants for the purchase or lease of water, 2) pricing water and administrative fees, 3) establishing conditions for preventing injury to other water rights and to the local public interest, and 4) accounting for transfer funds. For example, rules provide for a preference for irrigation uses during the first few months of irrigation season.[134]

The concept of temporary or year-to-year water transfers is not new. Water districts and ditch companies have practiced "rotation" of water among users within their systems in many locations in the West. This idea of rotating water is taken one step further by facilitating transfers to a broader range of uses in a wider geographic area.

Temporary water transfers, as stated earlier, will not meet all future needs of, for example, a municipal water provider needing an assured water supply. However, they can provide a mechanism for bringing greater flexibility into a water rights and water storage system in a manner that may avoid some of the costs and effects of permanent transfers.[135]

Opportunities for Temporary Transfers in the Arkansas Basin

Water needs in the Arkansas River Basin vary from year to year, depending on precipitation and other factors affecting water supply and demand. Water rights adequate in one year may not be in another, more limited water supply year. Temporary water transfers may take care of some of these fluctuating water supply needs without the cost and impacts associated with permanent transfers.

Two mechanisms used in the management of project reservoirs are a type of short-term transfer system: carryover of project water allocations and "if and when" storage contracts for the storage of nonproject water. The amount of carryover of Southeastern's allocation of project water varies from year to year and differs from the permanent allocation set out in Southeastern's policies. In addition, temporary "if and when" storage contracts between water users and BOR allow water users to store nonproject water on a temporary or short-term basis. Users are permitted to carry over water stored in the reservoirs under these contracts as long as the contracts are renewed annually and space is available. These methods for enhancing flexibility in how storage space and water supply is used from year to year share traits with some short-term water transfer programs already operating in other river systems in the West.[136]

BOR might, at some future time, consider dedicating a portion of project reservoir storage space to a more institutionalized temporary transfer program. A recent study by Colorado Springs Utilities indicates that there may be a significant amount of storage available in most years in the upper basin.[137] Some of this storage is currently leased on an annual basis under "if and when" contracts, as mentioned earlier.[138] Since the upper reservoirs are already

[134] Upper Snake River Basin, District 1 Rules, at 7.1.

[135] Water Banks in the West, at 1-2 to 1-3.

[136] Gibbens interview, February 21, 1996.

[137] Transcript of presentation by Gary Bostrom, Colorado Springs Utilities, at Arkansas River Forum, Pueblo (Jan. 1995). The figure of 80,000 acre-feet was suggested. This amount of storage may not be available, however, in wetter years when Southeastern's Front Range storage rights come into priority. It is possible that, if this were to occur, the water that could not be taken could be stored in Ruedi Reservoir. However, there may be no unused space in Ruedi in those years when the Front Range storage rights would come into priority. Interview with Tom Simpson, Southeastern Colorado Water Conservancy District, April 21, 1995.

operating under a sort of short-term transfer system, this would not present a major change to current operations. A specific amount of space could be identified for these types of transfers.

Any type of short-term transfer system would have to be carried out carefully and thoughtfully, in a manner that protects existing water users while providing enough of an incentive for participation. Rules can be designed with protective mechanisms. For example, some of the storage space could be targeted for irrigation uses, with a lower cost and shorter term contracts. Some space could be targeted for municipal uses, carrying a higher cost and allowing for longer term contracts. Regardless of the length of the irrigation and municipal uses contracts, there should be some space available on a year-to-year basis to take care of short-term needs. Existing holders of "if and when" contracts could be given some initial preference if the new transfer system were to replace the "if and when" contracts. While BOR need not be the manager of these short-term transfers, it would need to maintain overall responsibility for storage management in the upper basin.

Parties Involved

Any transfer or lease of water or water rights would require the involvement of the selling and buying entities. Other water users might also be involved, under a brokered type of transfer program. Moreover, under current law, the State Engineer would need to approve these types of temporary changes unless they fell within the parameters of the very narrow short-term transfer statute[139] or another provision of State water law that grants an exception to the usual change of water rights proceedings. Under usual transfer procedures, transfers in the Arkansas River Basin would require that an application be filed with the Division 2 water court. BOR would be involved in any change that affected how water rights are administered in the upper basin, if storage and release patterns may be modified. Potential purchasers of irrigation water would include municipal water providers, well owners seeking augmentation water, and other interests wanting to supplement streamflows or increase their consumptive use on a temporary or short-term basis.

Brokered short-term transfer programs require some type of managing entity to match willing sellers and willing buyers. This could be an existing organization, such as Southeastern or another existing water district, or it could be a new organization formed specifically for the purpose of managing the transfers. If it is a new organization, it might include representatives from the full range of water managers in the basin, including Southeastern, BOR, and the Colorado State Engineer's Office. This authority should also be representative of the water-based interests in the Arkansas River Basin. Borrowing from transfer programs in other States, this entity could be the decisionmaking body, with day-to-day management delegated to one or two people. An administering entity for short-term transfers can be established through administrative or gubernatorial appointment or formation under legislatively adopted standards. These standards might set out, for example, requisite categories of membership, such as Federal representative, agricultural and municipal water users in the basin, a State representative, and other categories appropriate for the basin.

For the brokered type of transfer program, water users and other interests in the basin would want to participate in establishing program rules, policies, and procedures. The rules could address many management parameters, including establishing who would be eligible to transfer water through the brokering entity. Presumably, existing water users in the basin would be among those able to lease and rent water, although there might be preferences for certain uses during certain times of the year. Parties who are not existing users may also be eligible to lease and rent water under certain conditions that ensure the protection of basin water users.

[139] Colo. Rev. Stat. 3783-105.

Potential Benefits

With proper consideration of the potential impacts on other water users, temporary water transfers, including brokered transactions, hold much promise for improved water management in the basin. For example, access to water and storage might be easier or less expensive for irrigation users than is currently available through "if and when" contracts or temporary leasing from municipal providers. Cities may be able to acquire long-term storage and eliminate or delay a need to acquire additional agricultural water rights or build or expand storage facilities. Finally, other types of water users, such as rafting interests, might secure water as needed on an annual basis to increase flows during the rafting season. Under the Colorado Compact and current Colorado water law, this water would need to be recaptured at Pueblo Reservoir for subsequent consumptive use.

A temporary transfer system might also provide a vehicle for entities needing to fill excess storage space in any given year. Some entities purchasing "if and when" storage space may have a sufficient water rights allocation to fill the storage. Others, however, may be looking for year-to-year water leases to fill their space. In a wet year, for example, an irrigation water user in the lower part of the basin may be able to sell a portion of his annual water supply to a municipality holding space, but without water to fill that space. The municipality may be able to store that water for use in another year. Similarly, an irrigation water user could purchase water to be held over until another year.

Issues and Concerns

One concern of a temporary water transfer operation would be potential injury to water rights and water users. Under a brokered system, procedures and conditions would need to be established to ensure that transactions would not cause injury to other water rights. They could establish, for example, how the amount of water that can be transferred is to be measured in a manner that considers consumptive use and return flows. In addition, there might have to be rules for "order of spill" for water, as there are under the "if and when" contracts and as set out in Southeastern's repayment contract and policies.

Brokered or not, formal or not, one of the advantages of short-term transfers where they are occurring is that they can provide water quickly, when it is needed. Therefore, to encourage the use of this opportunity, State transfer review should be limited, and many States have done this.[140] This could be accomplished through the State Engineer approval of a substitute supply plan, as authorized by statute, or through a court decree authorizing the operation of a temporary transfer program. Alternatively, the legislature could specifically authorize the program and protect such water from abandonment or forfeiture of the underlying water right. Administrative rules could create a presumption of no injury, for example, if the amount of water transferred were limited to the amount of water that has been consumptively used by the transferor. This kind of objective standard would substitute for case-by-case determinations governing permanent change-of-water-rights proceedings.

At present, Colorado water law provides a judicial review process only for the permanent transfer of water rights.[141] The 1899 provision allowing transfers for a "limited time" for the purpose of "saving crops or using the water in a more economical manner" requires no administrative review or approval.[142] This law could be updated to recognize that today other purposes could benefit by such transfers and to provide for some form of limited review.

[140] See Moving Water, at 46.

[141] Colo. Rev. Stat. 37-92-304

[142] Colo. Rev. Stat. 37-83-105

If there is a year-to-year transfer program with a brokering entity, there may be some impacts on storage management. As mentioned above, in water-short years, there may be space available that, in higher water supply years, would have been filled with more junior water rights. One way to avoid impacts is to use mitigation mechanisms that offset any loss of water yield in those years where the use of this space for temporary transfer water would affect yield.

As is true with permanent water transfers, it may be difficult to anticipate possible adverse economic and environmental damages associated with temporary transfers. One way to address these types of concerns is to charge a "mitigation fee" on each transaction, perhaps as a percentage of the price paid for the water. Funds from the mitigation account could be allocated according to some objective formula of likely impact, rather than attempting to measure and address specific impacts.

The character of the water temporarily transferred may be another issue. For example, if project water is transferred on a temporary basis, the purpose of the new use (just like the original use) would need to comply with project authorizing legislation. However, the purposes set out in the authorizing language are broadly worded, including irrigation, municipal, domestic, and industrial uses, generating and transmitting hydroelectric power, controlling floods, recreation, fish and wildlife, and other incidental useful and beneficial purposes.[143] In addition, the use of project water would need to comply with the project operating principles' preference for domestic purposes.[144] Third, storage of nonproject water in the upper reservoirs may trigger the requirement of the Reclamation Reform Act, since the use is "benefitted" by the project.[145] Finally, the Colorado River Compact may restrict the leasing of imported water for any use outside of Colorado. For example, the use of such water for augmentation by well owners for replacement of depletions to usable State line flows may be limited. The leasing of project water or storage space for a use outside of the Southeastern District may require that some extra fee be imposed to compensate Southeastern since the user would not be subject to the Southeastern's ad valorem tax.[146] In addition, under the current repayment contract, project water and project storage space cannot be used for purposes outside of the District.

The layout of irrigated lands in the upper basin may make it difficult to obtain sufficient water for use on a short-term basis. The 60,000 irrigated acres are spread out over 150 miles of river and tributaries. Securing a measurable yield from land fallowing at any given point on the river may be a challenge. While an objective standard for measuring saved water saves time during the transfer process, such a standard may be difficult to apply under these conditions. This fact may be offset, however, by leaving a portion of the estimated savings in the stream to mitigate potential injury to other users.

Arrangements with Municipal Providers

Several municipal water providers hold storage and direct flow water rights in the basin. Most municipalities necessarily plan for future growth and drought years, and therefore acquire rights to more storage and water than is currently needed in average water supply years. The additional storage

[143] Act of Congress approved August 16, 1962, 76 Stat. 389, as amended by the Act of October 27, 1974, 88 Stat. 1486.

[144] The project repayment contract between Southeastern and the United States, No. 5-07-70- W0086, requires Southeastern to allocate the project water supply in accordance with the project operating principles adopted by the State of Colorado on Dec. 9, 1960, and reprinted in House Document 130, 87th Congress. See operating principles, at p. 13.

[145] Gibbens interview, April 20, 1995.

[146] Gibbens interview, April 20, 1995.

and water supplies could be managed to increase or decrease riverflows to benefit natural resource values, while still providing traditional water user benefits to the entity holding the rights. Special or short-term arrangements regarding agricultural water rights are addressed under "Temporary Water Use Transfers."

Water held by the Pueblo Board of Water Works provides one example. In addition to having storage and water rights in Turquoise Lake, the Board owns and operates Clear Creek Reservoir.[147] Pueblo currently markets excess storage and water on a year-to-year basis. For example, most of Pueblo's Twin Lakes shares (which include storage and water) of about 11,500 acre-feet is leased to agricultural water users in the lower valley. Pueblo has also entered into contracts with the Colorado Division of Parks and Outdoor Recreation and with CDOW to supply water to Trinidad Reservoir by exchange.

In addition to short-term leases, a municipal provider might also enter into exchange contracts with entities needing upstream storage releases in order to make an exchange. For example, under an existing agreement between the Pueblo Board of Water Works and the City of Aurora, Aurora exchanges Rocky Ford (a.k.a. "RIG") water with Pueblo water to move it up and out of the basin.

Another opportunity might be provided by arrangements between basin well owners and municipal water providers to provide augmentation water for the well owners. As mentioned above, augmentation water is required under basinwide groundwater rules.[148] An agreement to purchase water on a temporary basis (though maybe for longer than one year) could be entered with one or more of the basin's well owners' organizations. If the well owners were able to purchase consumable native flows rather than transmountain water, they might be able to use this water to replace pumped water if this type of use is consistent with other legal and compact requirements.

Parties Involved

Any arrangements for the use of water or storage owned by municipalities would necessarily involve the municipality. If the water involved in the arrangement is project water or the storage involves a project facility, BOR would need to be involved and may need to approve any storage and delivery modifications under existing contracts. Southeastern would be involved if the water made available is allocated project water. If the arrangement changed the pattern of storage and release, there might be an impact on riverflows that benefits or detracts from in-place uses of the river, such as fishing and rafting, thus affecting interests concerned with these uses.

Potential Benefits

As discussed in the previous section on short-term transfers of agricultural water rights, temporary arrangements with municipal water providers offer several advantages over permanent purchases of water rights or storage. They are less costly and risky to the purchasing entity. They can be implemented more quickly to address immediate supply or storage problems. They may avoid some of the negative impacts associated with permanent transfers of water rights, discussed above. Finally, a municipality selling water or storage on a short-term basis should benefit by being able to maintain its water and storage rights while earning some compensation in water and/or money for the temporary use of the water or storage.

Arrangements with a municipal provider like Pueblo may be possible with other types of water users. For example, the rafting industry might lease some of the City's water for release at times to

[147] Interview with Bud O'Hara, Pueblo Board of Water Works (Oct. 13, 1994).

[148] Amended Rules and Regulations Governing the Diversion and Use of Tributary Groundwater in the Arkansas River Basin, Colorado. State Engineer's Office, State of Colorado, September 27, 1995.

supplement rafting flows. Rafters or other water users could also enter agreements with the City for the right to use excess water in years the water is available. Under many conditions, water released to supplement flows for rafting are recaptured in Pueblo Reservoir and subsequently beneficially used. In this case, the cost related to the release to supplement flows may be the amount of water lost to evaporation as a result of an early release downstream and storage costs for "if and when" contract space at Pueblo Reservoir.

Issues and Concerns

Although these arrangements can provide the seller with additional revenue and serve other resource needs in the basin, they also raise some concerns. As with any change of water right, there would be concern that the transfer, whether temporary or permanent, not affect other water rights in the basin. At the same time, temporary or short-term transfers require some type of expedited review process in order to be of most value to the seller and buyer.

Creating expectations of available supplies is another concern, particularly for the municipalities. Over time, the seller may no longer want to sell, yet expectations have been established among buyers. For example, Pueblo anticipates that, eventually, the City will reduce the amount of water it leases as the City's water demands increase. There is some concern about buyers expecting this supply to be perpetually available to them.

There may be additional costs to the seller not necessarily reflected in the selling price. Water moved down to Pueblo Reservoir may be more costly to store, particularly for entities who hold firm storage space upstream. Storage fees are assessed for Pueblo Reservoir storage under contracts with BOR. Entities such as the Pueblo Board of Water Works, which holds firm storage upstream, would not have to pay this expense if its water remained upstream.

Depending on when water is released from the upper reservoirs under these contracts, there may be concerns about undesirable changes in the flow volume or ramping rates in the upper basin. For example, if the release requirement from Turquoise Lake exceeded the capacity of the Mt. Elbert pumping plant, the result may be a loss in power revenues. An exchange with Twin Lakes might be possible in order to mitigate such a loss. In addition, any added wintertime releases would need to be tailored to avoid ramping in a manner adverse to fisheries and recreational needs, such as for the Salida Caddis Fly Festival.[149]

State water law also raises some issues. As described above, some of Pueblo's nonproject municipal water stored in Clear Creek Reservoir might be leased on a temporary basis by recreation or fisheries interests to supplement flows in the upper basin. To avoid any problem with changes in water use, or questions about the use of water for instream flows, this water could be recaptured at Pueblo Reservoir. Storage of the released water in Pueblo Reservoir would require Pueblo or the lessee to pay for an "if and when" storage contract with BOR. Since "if and when" storage contracts are the first to be spilled from Pueblo Reservoir when storage is required for other project objectives, such a practice also creates the risk that this stored water may be lost before the Board can make use of it. The other cost attributable to the upstream flow supplementation would be the additional evaporation losses caused by early release downstream.

Other municipalities have similar capabilities to lease water for upstream uses because they also own storage in upstream reservoirs. If a lease is not available from the Pueblo Board of Water

[149] This latter situation wold not be a violation of law or regulation, but may be contrary to agreed-to operating guidelines between the Colorado Department of Natural Resources and the Bureau of Reclamation. See letter to Jack Garner, Area Manager, Bureau of Reclamation from James S. Lochhead, Executive Director, Colorado Department of Natural Resources, dated March 9, 1995, Re: 1995-96 Flow Recommendations for the Upper Arkansas.

Works, then potential lessees could work with these other municipalities.

Expanded Season of Exchanges

As described earlier in this report, since the 1950's Front Range cities have been purchasing and transferring agricultural water rights that at one time supplied water to canals in the lower basin. In order to move this water to the cities' service areas, cities first exchange (most of) the water upstream to Pueblo Reservoir and second, from Pueblo Reservoir to an upstream reservoir. Once exchanged upstream, the water can be diverted into the Otero Pipeline and delivered to the cities.

Outside of exchanges, there are limited options for moving this acquired water to where it is needed. Colorado Springs, located within the basin, has the option of moving up to 14,000 acre-feet through the Fountain Valley Conduit, as described above, but because of the cost associated with using the conduit, Colorado Springs Utilities currently moves as much water as possible through Otero Pipeline. Aurora's service area, in contrast, is outside of the Arkansas River Basin. Therefore, Aurora's only option at this time is to move the water out of the basin through the Otero Pipeline.

There are two general types of exchanges implemented by water users. Noncontract exchanges are typically variable from year to year. They occur when a water user has a demand for water that emerges at a specific location, and when it appears that river conditions will allow movement of water to that location. The water user must obtain permission from the Division Engineer to implement the noncontract exchange so that other water users will be protected from injury. The other type of exchange, a "contract exchange," typically occurs between water users who own diversion and storage facilities. The users enter a contract exchange because they find it beneficial to exchange ownership of water that is diverted and controlled by those facilities during a specific water year. These contracts are typically arranged to avoid any injury to other water users, so no permission from the Division Engineer is required to implement the exchange.

Expanding the times during which noncontract and contract exchanges may be made might provide an opportunity to lessen the impact of moving water out of the basin and, at the same time, assist the cities in moving their water supply to their distribution system.

Noncontract Exchanges

As explained in detail under "Protection and Operation of Exchanges" above, several factors affect the ability to execute a noncontract exchange. These include storage space, water supply, and the downstream demand for water. Market forces also influence exchange decisions, since storage costs vary significantly from reservoir to reservoir. Of these factors, the one that appears to be the most readily leveraged to expand the season of exchanges is the availability of storage. A thorough examination of how all reservoirs in the basin could be reoperated may uncover opportunities to provide more storage for exchange operations. Similarly, construction of additional storage in the basin may expand exchange opportunities.

Some examples clearly illustrate how limited availability of storage space in the upper and lower basin restricts when exchanges can occur. For example, both Colorado Springs and Aurora are constrained by their storage rights in when they can make river or noncontractual exchanges. Colorado Springs has some storage in the upper basin that facilitates exchange opportunities. Aurora, in contrast, holds little storage in the upper basin and is more limited in its ability to make exchanges. Aurora has, so far, been able to move all of its acquired Rocky Ford water.[150] All of this water is conveyed over to Spinney Mountain

[150] Under the stipulations in case 83 CW 18, Water Division 2, the full 8,200 acre-feet is not yet available for Aurora's non-Rocky Ford ditch uses.

Reservoir and into the South Platte River. In the spring, however, Spinney may be full as a result of spring runoff, limiting the amount of water that can be moved from the Arkansas River Basin.

Storage availability changes throughout the year, affecting when exchanges can occur. From November 16 through March 14, as noted earlier, all the inflow into the upper reservoirs goes to satisfy winter water rights of Colorado Springs, Twin Lakes Company, and Pueblo. These rights are not part of the WWSP discussed earlier, although these entities are signatories to the 1984 stipulation.[151] They would not gain anything if they used available inflow for exchanges that otherwise would be filling with their winter storage water.[152] Therefore, the cities must often wait until later in the water year to make exchanges since they are dependent on natural flows or releases made by other entities to create river conditions that allow an exchange.[153]

Contract Exchanges

Increasing the number of "contracted-for" exchanges might also help to expand the season during which the cities may move water to where it is needed. Aurora, for example, has entered a contract arrangement with Pueblo that allows it to exchange about 4,000 acre-feet upstream. This exchange sometimes occurs at times when river conditions would otherwise not allow an exchange. Other contract exchanges could be structured to allow cities to make exchanges during the winter months. The arrangement might, for example, involve three parties: the entity wishing to make the exchange, BOR, and Southeastern. Compensation could be paid to Southeastern, to be credited toward the repayment of project facilities. This would be a volume-for-volume exchange. The character of some fixed volume of water in Pueblo Reservoir would become project water, while the same volume of project water in an upper basin reservoir would become the water of the entity wishing to make the exchange.

There may also be some limited opportunity prior to November 16, for example, for a contract exchange with the Pueblo Board of Water Works, under which another city might be able to exchange water upstream to Clear Creek Reservoir. However, Pueblo is usually trying to move its water up to Clear Creek Reservoir by this date.[154]

Parties Involved

Under contract exchanges, the parties involved would include the parties to the contract. The contract exchange might also involve BOR and Southeastern if project facilities or project water were necessary to implement the exchange. For contract and noncontract exchanges, the Division Engineer would need to be advised in order to approve or administer the arrangement and determine any evaporation charges associated with moving the water downstream, as discussed above.

Potential Benefits

As the cities complete their revegetation requirements under water transfer decrees and more water

[151] Stipulation between Colorado Springs Utilities, et al., Case Nos. 84 CW 62, 84 CW 63, and 84 CW 64, District Court, Water Division 2, March 19, 1984.

[152] Gibbens interview, April 20; interview with Bill Paddock, Attorney for Colorado Springs (April 21, 1995).

[153] Interview with Doug Kemper, City of Aurora (March 9, 1995). Exchange decrees may place other limitations on when exchanges may occur. For example, the Pueblo Board of Water Works is prevented from doing wintertime exchanges under the terms of its exchange stipulation.

[154] Pueblo operates this way to avoid the cost of storing water in Pueblo Reservoir during the winter months. Paddock interview, April 21, 1995.

become available for transfer, existing exchange opportunities may not be sufficient.[155] For example, as Aurora's Rocky Ford Ditch water comes on-line, it will eventually add 8,000 acre-feet (on average) of water that must be exchanged upstream. To further complicate the issue, some of Aurora's yield from the Arkansas River Basin is not realized until October, so it cannot be exchanged before this time. Expanding the time for exchange opportunities would assist Aurora in delivering its water supply to its distribution system.

Southeastern could benefit both monetarily and in water credits. Since the Division Engineer generally requires that exchanges be volume-for-volume, Southeastern could make about 10 percent in water volume on any exchange. This is because, generally, there is about a 10 percent loss of volume for water traveling from the upper reservoirs down to Pueblo Reservoir due to evaporation and transit losses.[156] In addition, as discussed below, Southeastern might be compensated monetarily for the exchange.

Expanding the season of exchange opportunities can give water managers more flexibility in moving water around in the basin. It might allow managers, for example, to move water down to Pueblo Reservoir in late summer and move water back up in the basin before the following spring. In the summer of 1994, Colorado Springs Utilities agreed to release water from Twin Lakes to supplement flows for rafting. About 5,000 acre-feet of water was moved down between August 1 and 15. The costs of doing this are the additional expense for transit and evaporation losses and Pueblo Reservoir storage costs. In this example, Colorado Springs Utilities was paid about $10,000 by the Arkansas River Headwaters Recreation Fund to cover these costs. However, as long as the water remains in Pueblo Reservoir, storage costs to Colorado Springs Utilities continue to accrue. Expanding opportunities for fall and winter exchanges may reduce the economic risks associated with these types of exchange arrangements, particularly late summer exchanges, and may reduce the overall transaction costs accrued with such exchanges.

Issues and Concerns

If project water was used in the exchange, some specific concerns arise. First, BOR would likely require the entity benefitting from the exchange to pay some amount that would be credited towards the project repayment obligation.[157] Second, all exchanged water would have to be vacated by the end of April to make space for storing spring runoff.

Regardless of whether project water or project storage is used, Colorado water administrators would likely require that the exchanges be volume-for-volume exchanges, as noted above. This condition addresses the potential risk of adverse impacts on other water users in the basin. Moreover, administrators and users would want to avoid impacts exchanges might have on the WWSP.

Maintenance of flows is another concern. A flow of a least 190 cfs is required below the discharge for the City of Florence's wastewater treatment facility, and would need to be maintained if exchanges against native flows were involved (contract exchanges are not affected by the minimum flow requirements). Similarly, the following flows would

[155] Under the transfer decrees described in an earlier section of this report, the water court required that lands taken out of production be successfully revegetated before the water may be transferred to municipal use.

[156] The general 10 percent transit loss charged for exchanges may be increased or decreased, depending on the distance the water must travel. The general rule is that the transaction, including the transit charge, must result in a one-for-one exchange, whether the water is exchanged up or down the river. The transit surcharge is not charged for project water, only for exchanges involving native flows. Conversation with Steve Kastner, Colorado Division of Water Resources, December 20, 1995.

[157] Gibbens interview, April 21, 1995.

have to be maintained below Salida: 189 cfs November-January, 180 cfs February-April, 239 cfs May-July, and 229 cfs August-October.[158]

Aurora's exchange decrees would need to be examined to determine if they allow exchanges during different times of the year, and if they do, to establish what conditions would need to be met. Earlier decrees limit Aurora to moving water upstream under "approved" exchange decrees. In addition, case 87 CW 63 contains instream flow conditions that must be maintained and prohibits exchanges during the winter period.

As mentioned under "Protection and Operation of Exchanges," BOR plans to undertake a NEPA analysis on the aggregate amount of exchanges that may be executed using project reservoirs. The study will also look at seasonal exchange patterns and opportunities. The results of the analysis may result in opportunities or constraints in executing exchanges using project storage space.

Increased Water Imports

The volume of water that may be imported under project water rights is limited by decree conditions, including minimum flow requirements in west slope streams and the priority date of the water rights. Even though Ruedi Reservoir helps protect the project against west slope calls, this pool of water cannot protect project diversions in every conceivable climatic and water demand situation. In addition, due to a lack of storage on the east slope, BOR has not diverted all water available under its priority. Not enough time has passed to assess whether the multiyear volume allowed by the decree can be realized while meeting decree conditions. This is true because the decree is based on a 34-year period of operations, and not enough years have passed to produce the full range of hydrologic variability that is possible in a 34-year period.[159] BOR also has conditional water rights on the west slope that will not be developed until it is determined whether BOR is able to import the volume of water permitted under the decree.

There may be an opportunity to increase the volume of imports by taking advantage of the replacement water available in Ruedi Reservoir. The project decrees and operating principles give BOR the rights to replacement water in Ruedi Reservoir that allows BOR to continue diverting west slope water when downstream water rights are placing a call on the river. However, because its diversion rights are usually first called out by minimum flow requirements above Ruedi (most commonly at the Thomasville gage), BOR has not been able to fully utilize its Ruedi replacement water. This water could be utilized if BOR or some other water user organization were able to make a large investment in pumping facilities to convey replacement water to the east slope. A pumping facility would allow BOR to divert water below Ruedi Reservoir during high runoff periods in May and June. This water could then be pumped to the east slope later in the water year when there is storage space available in east slope project reservoirs. BOR estimates that approximately 20,000 acre-feet could be available for pumping to the east slope using this approach. However, the project authorizing legislation specifies that the Colorado River Water Conservation District must provide consent for this type of project. In addition, there are numerous legal questions that would have to be resolved before construction commenced.[160]

Federal legislation would be needed for BOR to be involved with building a pumping station at Ruedi. If BOR were the constructing entity, it is likely that repayment would be required from

[158] See Colorado Springs Utilities, Arkansas River Exchange Plan, Decree and Stipulations, Case No. 84 CW 203, Water Division No. 2, June 16, 1987. Also see cases 84 CW 178 and 87 CW 63, Water Division 2.

[159] Gibbens interviews, April 20, 1995 and Feb. 21, 1996.

[160] Gibbens interview, Feb. 21, 1996.

entities that benefit from additional water imports. It is also possible that the pumping facility could be financed by non-Federal interests with technical assistance from BOR. Front Range municipalities may be interested in financing such a pumping project if incentives for their involvement were sufficient. For example, a Front Range municipality may be interested in transferring its west slope water rights to west slope consumptive uses and/or to benefit Colorado River endangered fishes if the municipality were able to obtain equal or lower cost water from the pumping project. If BOR involvement was limited to technical assistance on system design, system operation, and rights-of-way for construction, then it is not likely that special legislation would be required.[161]

There is also the possibility that a pumping plant at Ruedi could serve as an alternative to undeveloped portions of the project. Southeastern holds plans for a collection system located on Last Chance Creek and Lime Creek in the Holy Cross Wilderness Area. Southeastern could finance the pump station independently or become a co-investor with interested Front Range municipalities.[162]

Another opportunity to increase imports could be created if BOR were to enter an agreement with certain holders of west slope water rights. BOR could release Ruedi replacement water to meet west slope needs, and in return, be compensated with water to enhance BOR imports into the Arkansas River Basin. One of the very limited opportunities to implement this type of agreement is when Twin Lakes diversion rights are called out on the Roaring Fork. In some cases, BOR may be able to release Ruedi replacement water to meet the downstream call, if the call were below the confluence of the Roaring Fork and Fryingpan Rivers. In this way, Twin Lakes may continue to divert water out of the Roaring Fork and import that water to the Arkansas River Basin. As with other proposals to increase imports, numerous legal issues would have to be resolved before this proposal could be implemented.[163]

Finally, if the minimum flow requirements on the west slope were in some manner reduced, the total annual volume of water diverted from the west slope and imported into the Arkansas River Basin would be increased.[164] This is particularly true at the Thomasville gage, which typically is the first to curtail project diversions.

Parties Involved

These arrangements would require the cooperation and consent of the Water Division 5 Engineer and the State Engineer. The Colorado River Water Conservation District would be involved because of Ruedi Reservoir water rights and because of language in the project authorizing legislation and operating principles. Any investors and beneficiaries of pumping plant construction would also be involved, possibly including Southeastern and municipalities. Southeastern would be involved because it holds the underlying water rights that would make the construction possible. BOR would be involved in coordinating construction and operation with other project features. Other Federal and State agencies would be involved in permitting processes. Depending on the change, there may be a need to apply for a change of water right to obtain a new point of diversion for the water rights involved in the transaction.

Any new contract arrangement with BOR would likely trigger the need for NEPA compliance, requiring at a minimum the preparation of an

[161] Gibbens interview, Feb. 21, 1996.

[162] Gibbens interview, Feb. 21, 1996.

[163] Colorado Springs Utilities interview, April 21, 1995; Southeastern interview, April 21, 1995.

[164] See decree and operating principles establishing the minimum flows for west slope streams above Reudi Reservoir, including Operating Principles, Fryingpan-Arkansas Project, House Document No. 130, 87th Cong., 1st Sess. (1961).

Environmental Assessment. Under its repayment contract with BOR, Southeastern would also need to be a party to any arrangement that affected project water imports.

Potential Benefits

Increasing flows into the Arkansas River Basin from the west slope may improve water management in the basin, although it presents challenges of what arrangements can be worked out on the west slope. There may be ways to structure an exchange or expansion to include a benefit for west slope water users, for example, by releasing replacement flows at times most beneficial to downstream users.

Issues and Concerns

Any changes in the use of Ruedi Reservoir storage, including pumping out of Ruedi, may require changes in legislation and face challenges with the language in court documents. For example, if BOR were to be involved in the financing of a pumping facility, authorizing legislation would be required. It may also be necessary to request a modification of BOR's State water rights decrees. Third, project operating principles might present additional obstacles. Paragraph 6(b) of the operating principles provides that the regulatory capacity in Ruedi Reservoir (portion of the total reservoir capacity not needed for west slope replacement purposes) may be sold or leased for use outside of the Colorado River Basin only with the consent of the Colorado River Water Conservation District. Finally, if at some point in the future, imported water were considered for use outside of Colorado, project authorizing legislation would present an obstacle. The language in the legislation states: "no such waters shall be made available for consumptive use in any State not a party to the Colorado River Compact by exchange or substitution."[165]

BOR efforts to augment flows for the benefit of threatened and endangered species habitat on the west slope does not affect the quantity of imports. Present releases to benefit threatened and endangered species amount to more than 10,000 acre-feet annually under average streamflow conditions, but this allocation is subtracted from the volume of Ruedi Reservoir water available to west slope users. BOR has made a commitment to provide 5,000 acre-feet of water withheld from sales to west slope users, and another 5,000 acre-feet will be made available in 4 out of 5 years by releasing stored water during the summer months rather than during the winter months. The Colorado River Recovery Implementation Program has requested that BOR commit 21,650 acre-feet of the Ruedi yield to threatened and endangered species purposes for at least 15 years, with a review at the end of the period to determine if a longer term commitment to threatened and endangered species should be made.

If an exchange with Twin Lakes were possible, it is not clear how much additional water might be imported. The minimum flow requirement in the Fryingpan River above Ruedi Reservoir may limit diversions even while replacement water is released from Ruedi. The additional yield would probably be minimal, occurring only when Twin Lakes is full and BOR has other storage space available. Situations such as this occur when the City of Aspen requests that more water be diverted to Twin Lakes to prevent floods on the Roaring Fork.

Agreements Regarding Upstream Irrigation Water Rights

Another opportunity for adding flexibility in upper basin river management is through the purchase, lease, or transfer of upstream (nonproject) irrigation water rights. About 60,000 acres are irrigated above Pueblo Reservoir, consuming an average of

[165] PL 87-590 at Sec. 5(c)

111,325 acre-feet of water.[166][167] The City of Aurora, for example, is considering the purchase of irrigation water rights associated with the Hayden Ranch in Lake County.[168] The yield of these water rights is approximately 1,000 acre-feet of historical consumptive use. In addition, Aurora is considering the purchase of the Spurlin-Shaw Ranch, which crosses the Lake Fork of the Arkansas River, and its associated 250 acre-feet of water rights. While Aurora may be considering permanent transfers of these water rights, these examples are offered only to indicate there may be a market for other types of transfer arrangements.

In addition to permanent transfers, temporary transfers are possible that would provide water under certain conditions, such as during a low water supply year, while maintaining the traditional water use. For example, cities, fisheries interests, or the rafting industry could enter agreements for dry-year options or land fallowing agreements. Before implementation, these interests would need to consider how much water is actually consumed by these upstream uses and what sections of the river are depleted as a result of upstream diversions.

One example of a temporary transfer is the dry-year option. This tool is discussed in detail under "Temporary Water Use Transfers." In the upper Arkansas River Basin, one of the municipal water providers could enter a dry-year option contract with one or more irrigators.

Parties Involved

Any transfer or lease of water or water rights would require the involvement of the irrigation water rights holder who is a party to the transaction. Other users would also be involved if the transaction required a change in point of diversion or place of use, or both. This would be true under Colorado water law whether the change is temporary or permanent. Moreover, the State Engineer may need to approve these types of temporary changes. Any permanent transfer of an agricultural right would require that an application be filed with the Division 2 water court.

BOR may be involved in any change that affected how water rights are administered in the upper basin. For example, if the yield of a water right is temporarily transferred from the upper Arkansas Valley to the lower Arkansas Valley, then BOR may have to change its storage and release patterns as necessary to meet flow targets on the Arkansas River below BOR reservoirs.

Potential purchasers of irrigation water who may be involved would include municipal water providers, well owners seeking mitigation water, and other interests wanting to supplement streamflows or increase their consumptive use.

Potential Benefits

Temporary water transfers offer several advantages over outright purchases of agricultural water rights. First, harm to local communities and to the land can be reduced because the lands are kept productive in most years. In addition, dry-year options and similar types of short-term water transfer arrangements may be a less costly method for meeting some water supply needs.

Resources could be benefitted by the addition of water to the river in dryer years, assuming the purchaser of the water would run the water down to Pueblo Reservoir rather than divert or use the water higher up in the basin. If the water was diverted out of the basin, for example at Otero, there would likely be no benefit to the resources in the upper Arkansas River Basin.

[166] Transcript of presentation by Doug Cain at Arkansas River Forum, Pueblo (Jan. 1995).

[167] USGS web site: ftpdcolka.cr.usgs.gov (Jan. 2000).

[168] Interview With Doug Kemper, City of Aurora, (February 5, 1998)

Issues and Concerns

As with any change of water right, there would be concern that the transfer, whether temporary or permanent, not affect other water rights in the basin.

At present, Colorado water law provides only for the permanent transfer of water rights. It does not contain provisions recognizing and protecting the short-term transfer of water use. It may be difficult to implement this option because of the layout of irrigated lands in the upper basin. The 60,000 irrigated acres are spread out over 150 miles of river and tributaries. It would be difficult to obtain a measurable yield from land fallowing at any given point on the river. An objective standard of measuring saved water may be difficult to apply under these conditions. This fact may be offset by leaving a portion of the estimated savings in the stream to mitigate potential injury to other users.

Glossary [169]

Water-resource terms associated with this report are italicized and defined below. Additional terms used by irrigators, water commissioners, water managers, hydrologists, and others with water-related occupations in the Arkansas River Basin in Colorado are also included.

Absolute Decree (Absolute Water Right) - A decree is "conditional," as long as the facility used to store, divert, or otherwise exercise the right is under construction, and until the time the full quantity of the decreed water has been stored or diverted. Any time after the full decree has been stored or diverted and placed to beneficial use, the holder of the decree can go to court and have the decree made absolute, in total or in increments. For example, if after the first year of storage a reservoir had been filled to some part of the capacity of its conditional decree, an absolute decree for that quantity of storage can be obtained.

Active Pool - See Reservoir Space Allocation.

Adjudication Date - The date of the court action on which the right to use of the water is legally acknowledged. Three dates are important in the determination of the basin priority of a water right: 1) the appropriation date when the initial work toward utilizing the water was begun; 2) the adjudication date, when the decree was granted by the court; and 3) the date of the previous adjudication. Consideration of the last date is necessary, as all rights must have an equal opportunity to adjudicate; in the past, courts in some areas of the Arkansas River Basin adjudicated at different times from those in other areas of the basin. This is no longer a problem, as water rights are now adjudicated in one water court.

Alternate Point of Diversion - A change in decree must be obtained to divert from a point other than that described in the decree. In recent years, wells located in the alluvial aquifer commonly have been made alternate points of diversion for surface-water rights.

Appropriation - "...the application of a specified part of the waters of the State to a beneficial use pursuant to the procedures described by law...." [170] The term fully appropriated means that there are enough adjudicated water rights along the particular reach of stream to divert all water in the stream under normal conditions.

Called Out - The demand that a junior right cease diversion in order that sufficient water be available to the senior right.

Canal - An artificial waterway for the delivery of water; synonymous with "ditch" in the Arkansas River Basin.

Change in Water Right - "...a change in the type, place, or time of use; a change in the point of diversion; a change from a fixed point of diversion to alternate or supplemental point of diversion; a change in means of diversion; a change in the place of storage; a change from direct application to storage and subsequent application; a change from storage and subsequent application to direct application; a change from a fixed place of storage to alternate places of storage; a change from alternate places of storage to a fixed place of storage; or any combination of such changes. The term 'change of water right' includes changes of 'conditional' water rights as well as changes of 'absolute' water rights...."[171]

[169] This glossary is an adapted version of the glossary found in P.O. Abbott, "Description of Water-Systems Operations in the Arkansas River Basin," Colorado, U.S. Geological Survey Report 83-4092.

[170] Radosevich, G.E., D.H. Hamburg, L.L. Swick (compiler). 1975. Colorado water laws: a compilation of statutes, regulations, compacts and selected cases. 3d ed. Fort Collins, CO.

[171] Radosevich et al. 1975.

Conditional Decree (Conditional Water Right) - "...a right to perfect a water right with a certain priority upon the completion, with reasonable diligence, of the appropriation upon which such water right is to be based...."[172] See Absolute Decree.

Conduit - As used in this report, a closed duct or pipe for transporting water, a pipeline, or an aqueduct.

Conservation Pool - See Reservoir Space Allocation.

Dead-Storage Pool - See Reservoir Space Allocation.

Direct-Flow Water Right - See Water Right. A direct-flow water right requires that the water be put to immediate beneficial use, as opposed to a storage right, which allows storage of a set volume of water for later use. Direct-flow water rights are described by a rate of diversion, such as cubic feet per second, gallons per minute, or (rarely) miners' inches. (The latter two have been converted to cubic feet per second in recent tabulations.)

Ditch - Used here synonymously with Canal.

Diversion or Divert - "removing water from its natural course or location, or controlling water in its natural course or location, by means of a ditch, canal, flume, reservoir, bypass, pipeline, conduit, well, pump, or other structure device...."[173]

Division Engineer - The State of Colorado is divided into seven water divisions under the State Engineer, roughly based on major river basins within the State. Each water division is administered by a Division Engineer, who is responsible for administering the water rights in the division. The division is further divided into water districts, which are administered by water commissioners directly responsible to the Division Engineer. The Arkansas River Basin constitutes Division 2.

Due Diligence - The holder of a conditional water right must prove to the water court once every 6 years that he or she is working with reasonable diligence toward the appropriation of that right; for example, he or she is working toward the construction of the system, reservoir, or canal, required to regulate the water.

Evaporation Charge - If evaporation from the water surface of an on-channel reservoir was not accounted for, it would constitute a loss to the stream on which the reservoir is built. To offset this loss of public waters, the daily rate of evaporation is measured (usually by a class A pan). A pan factor is applied to convert pan evaporation to lake-surface evaporation, and this rate is applied to that day's lake-surface area to compute the day's evaporation. Allowance is made for the evaporation that would have taken place had the lake not been present, and the resulting volume is released to the river from the storage account occupying the lake. The evaporation charge is administered in the Arkansas River Basin by the Division Engineer, Colorado Water Division 2.

Exchange - A water exchange is possible by diverting water at one point in the river system, and replacing a like quantity of water from storage or transmountain diversions at another point in the system. To be legal, no party can be injured by the diversion. For example, an exchange is made to enable use of Lake Meredith water by irrigators who have rights to water diverted by the Colorado Canal. As Lake Meredith is downgrade from most land irrigated by water diverted by the canal, water is diverted from the river at the Colorado Canal headgate, and replaced, made whole, from storage through the Meredith Outlet Canal, which enters the river a few miles downstream from the

172 Radosevich et al. 1975.

173 Radosevich et al. 1975.

174 Radosevich et al. 1975.

headgate. Sufficient flow must be left in the river downstream from the Colorado Canal headgate to satisfy any senior rights between the headgate and the outlet canal. Exchanges can be made upstream or downstream from the point of use. River-transit losses are accounted for in the exchange.

Flood-Control Pool - See Reservoir Space Allocation.

Flood Right - Said of a very junior right, one that is in priority only during flooding or during a free river.

Irrigation Pool - See Reservoir Space Allocation.

Joint-Use Pool - See Reservoir Space Allocation.

Junior Right - A relative term describing a water right with a priority less than that of a "senior right." In general use in the Arkansas River Basin, junior rights refer to those water rights seldom in priority; senior rights refer to those water rights usually in priority.

Minimum Pool - A volume of water retained in a reservoir for accomplishing specific objectives. Frequently, these objectives are not related to water deliveries, such as providing water for recreational boating or fishing.

Native Water - As used in this report, water naturally occurring in the basin in which it is found, not imported from outside the basin.

Off-Stream Reservoir (Off-Channel Reservoir) - A surface-water storage reservoir located outside the channel of the stream that constitutes the principal source of the water stored in the reservoir. Off-stream storage is supplied by a ditch or conduit, with the headgate located on a stream other than that in which the reservoir is situated. Those off-stream reservoirs located in the channel of a tributary might store minor quantities of the waters of that tributary as well. Like other reservoirs in Colorado, a storage right is required that describes the source, quantity, use, and priority of all water stored.

Penstock - The conduit that conveys water under pressure to the turbines of a hydroelectric power-plant.

Plan for Augmentation - "...a detailed program to increase the supply of water available for beneficial use in a division or part thereof by the development of new or alternate means or points of diversion; by pooling of water resources; by water-exchange projects, by providing substitute supplies of water; by the development of new sources of water; or by any other appropriate means. 'Plan for Augmentation' does not include the salvage of tributary waters by the eradication of phreatophytes, nor does it include the use of tributary water collected from land surfaces that have been made impermeable, thereby increasing the runoff, but not adding to the supply of tributary water...."[175]

Priority System - In the United States, two major types of water-law doctrines occur. The riparian doctrine holds that waters are appurtenant to the land through which they flow. The appropriation doctrine holds that the waters within a State are the property of the public, with a vested right to the use of the appropriation: the first in time to use the water is first in right. It is the establishment of the order of the first in time being first in right that has been designated "priority," and the system under which these water rights are administered has been referred to as the "priority system."

Raw Water - In this report, raw water refers to untreated municipal or industrial water supplies.

Recreation Pool - See Reservoir Space Allocation.

Replacement Storage - A feature of transmountain diversions in Colorado. The purpose of replacement storage is to store water during that part of the year when runoff is at a peak and all rights are being satisfied downstream in the basin, and to hold these waters for later release. Later release comes during that part of the year when the

[175] Radosevich et al. 1975.

snowmelt peak has ended and runoff in the basin is at a much slower rate. Water upstream from the transmountain-diversion system in excess of minimum fish-flow requirements might still be diverted, regardless of the date of the call on the river from which the diversions are made, provided a quantity equal to that diverted from the basin be released from replacement storage to meet the demands of senior rights downstream.

Reservoir Space Allocation - Federally constructed reservoirs serve multiple purposes. Space in these reservoirs is allocated to the various purposes. These spaces, called pools, usually are defined by their bottom and top elevation. Sediment accumulation necessitates periodic redefinition of these top and bottom elevations. Terminology will vary slightly with the agency operating the reservoir and with the chief purpose for which the reservoir was constructed. Space allocation terms used in reservoirs located in the Arkansas River Basin in Colorado include: The *minimum pool* or permanent pool is the pool below which water is not withdrawn. It can include a *dead-storage pool* below the elevation of the outlet works, or a *recreation pool* that is held at a certain level to provide scenic, fishing, boating, or other recreational opportunities. The minimum pool might be held at a certain level to enable delivery of water to a given required elevation. Above the permanent pool is the *active pool*, where water can be regulated. The *conservation pool* is used to store water for later use. If the use is for irrigation, the conservation pool can be considered the *irrigation pool*; under other uses, it might be the *power pool* or the *municipal pool*. The *flood-control pool* (flood pool) is considered inviolate space, and it cannot be decreased during the *economic life of the reservoir* by sedimentation. *Surcharge* is water temporarily stored above the lip of the uncontrolled spillway, which helps decrease the peak of very large floods. The *sediment pool* is the space reserved for accumulation of sediment throughout the economic life of the reservoir, (usually 75 to 100 years). Because water surfaces of most on-stream reservoirs are constantly changing, the sediment is not deposited below a specific elevation; therefore, the top and bottom of the sediment pool are not defined by elevation. The *joint-use pool* is a pool used for more than one purpose.

Sediment Pool - See Reservoir Space Allocation.

Senior Right - A relative term referring to a right with an earlier priority. See Junior Right.

Storage - "...the impoundment, possession, and control of water by means of a dam...."[175] To retain possession of stored waters requires a storage right (storage decree).

Storage Right - See Water Right. A storage right allows the holder to store a given volume of water each year for beneficial use later in the season or in following seasons.

Water Right - The right to use the waters of a State in a specified quantity, at a specified time, and for specified types of uses. A critical element of the right is its priority relative to other rights, which is established by the historic date on which water was first used (first in time, first in priority). A water right is established by diverting water and applying it to a beneficial use recognized by the State in which the diversion occurs (known as an "appropriation").

Arkansas River Water Needs Assessment

Section 4. Hydrologic Analysis

By:

Steve Swanson, Bureau of Land Management

Arkansas River Water Needs Assessment

Section 4. Hydrologic Analysis

By:

Steve Swanson, Bureau of Land Management

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding river-flows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Section 4. Hydrologic Analysis

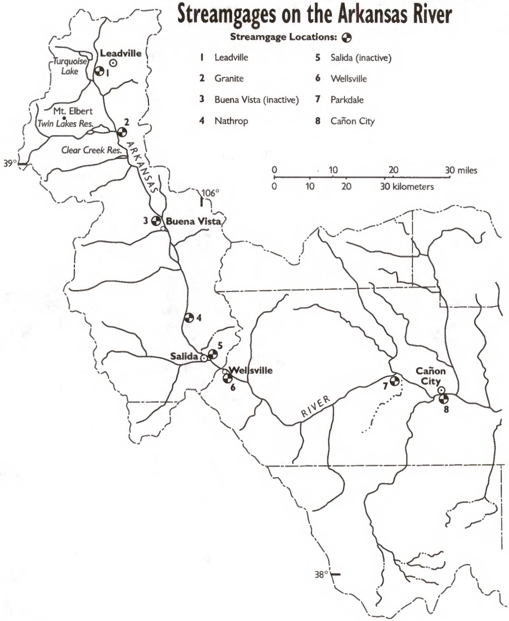
Historical Streamflow

Approximately 745,000 people both within and outside of the watershed depend on the Arkansas River and its tributaries for water supplies. This demand results in one of the most intensively managed river systems in the United States. A multitude of water rights, five major reservoirs, and extensive transbasin diversions complicate the management of the system.

The purpose of this section is to analyze historical and current flows. Fortunately, there are streamgages, two inactive and six active (Figure 4-1), maintained by the United States Geological Survey

FIGURE 4-1

Streamgages on the Arkansas River



(USGS) or the Colorado Department of Water Resources that supply up to 105 years of record. In addition, there are comprehensive reservoir operations records and accurate transbasin diversion data, all of which provide a reasonably complete picture of historical streamflows.

The analysis of streamflow was broken into several distinct time periods for several reasons. The Cañon City stream gage, located at the lower end of the study area, provided the longest period of record (1889-1995) available for analysis. This long period of record, along with the gage location, framed the overall time period analyzed. The development of various management systems in the watershed also dictated the selection of significant time periods. For streamflow study purposes, the watershed was evaluated solely as a high altitude, snowmelt-driven system, which requires analysis of specific annual (monthly) time periods as well as long-term historical periods.

The first designated time period is from 1889-1910. The starting year, 1889, is the earliest flow record available for the Upper Arkansas Basin and is compiled from the Cañon City gage. Based on the flow record, this period was chosen to best represent a natural, undisturbed, unregulated system. However, there were some minor alterations to streamflow, which will be discussed in the next section.

The period from 1911-1960 represents the second time period. This period was chosen because of its relatively stable institutional situation regarding water management. Although there are some variations (e.g., transbasin diversions, reservoir management, additional storage), these changes did not dictate extensive alterations in how the overall system was operated.

Not included in the analysis was the period from 1961-1981. This is a period of significant changes in the institutional status of the system. Major transbasin water projects such as the Fryingpan-Arkansas and the Homestake Projects were coming on line during this period, making streamflow analysis difficult.

The final time period analyzed is from 1982-1995. This period was selected due to the completion of the projects occurring from 1961-1981 and the full implementation of the associated institutional changes. Also, although the system was extensively managed during this timeframe, the flow records, reservoir operations records, and transbasin diversion volumes are readily available and accurate. This period will also require a further subdivision due to some unusual controls placed on the system after 1990.

1889-1910 Period

As previously indicated, the period from 1889-1910 is the best available representation of a natural hydrograph with some limitations. There were minor off-channel diversions and transbasin imports occurring during this time, but they resulted in minimal changes in flow. The most significant modifications occur from 1901-1910 when three upper basin reservoirs, Clear Creek, Twin Lakes, and Sugarloaf, were constructed with a combined storage capacity of approximately 85,000 acre feet. Therefore, the best representation of unaltered flow in the system is prior to 1900. Also limiting the analysis of this time period is the Cañon City gage data. Much of the winter daily flow data from 1889-1910 is recorded as average monthly data, which limits the use of medians, flow frequency analysis, and flow duration analysis.

With these limitations taken into consideration, Figure 4-2 illustrates the mean daily flows by month at Cañon City for the period 1889-1910. Figure 4-3 provides a view of the storage effects after 1901. Flows through the winter are slightly lower after 1901. Mean winter (November-April) flows prior to 1901 are approximately 420 cfs and after 1901 are 350 cfs, indicating some upper basin winter storage effects. Starting in May and continuing through June, spring runoff flows drop significantly after 1901 due to the upper basin storage. This stored water is released in late July

FIGURE 4-2

Mean Daily Flow (cfs) by Month
1889-1910
Cañon City Gage

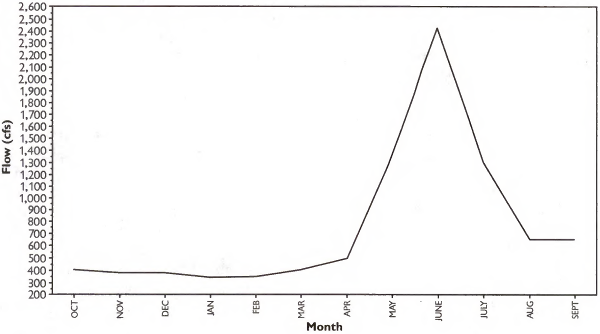
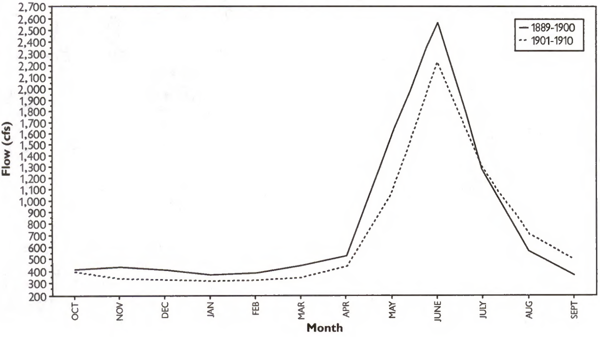


FIGURE 4-3

Mean Daily Flow (cfs) by Month
1889-1900; 1901-1910
Cañon City Gage



through September when natural runoff flows begin to diminish. From 1889-1901, the mean daily flow for the period from August 1-August 15 is approximately 650 cfs. From 1901-1910, the mean daily flow for the same period is approximately 770 cfs, which is indicative of upper basin storage releases for late season irrigation requirements. This augmented flow continues through August and September, finally diminishing in early October. There were some transbasin diversions in place prior to 1910, but the volume of water transferred is small compared to the reservoir storage effects.

The overall net effects of the period from 1889-1910 are a slight reduction in winter flows (October-April) accompanied by a large reduction in spring runoff flows (May-June) and a subsequent increase in late summer and early fall (August-September) flows. These effects are predominantly the result of upper basin storage put into service after 1900.

1911-1960 Period

The period defined from 1911-1960 is characterized by relatively stable water management within the basin. There is a continuing trend of increasing import water, mostly in the Twin Lakes system, but there are no significant new projects completed in the upper basin. By 1961, transbasin imports had reached almost 50,000 acre-feet/year, most of which supplemented low natural flows occurring after peak runoff in June. Figure 4-4 provides the mean monthly hydrograph for the period 1911 1960. Figure 4-5 provides a comparison between the 1901-1910 period and the 1911-1960 period. The figure indicates similar fall, winter, and spring flows, with obvious increases in July and August from 1911-1960. This additional flow represents the additional transbasin diversions brought into the watershed to augment mid- to late summer natural flows. For example, the mean daily flow for August 1-August 15 for this time period is approximately 1,000 cfs. This is an increase of 230 cfs from the 1901-1910 period and is almost completely attributable to transbasin imported water.

1982-1995 Period

The 1982-1995 period marks an era of significant institutional changes in the watershed. Two large transbasin diversion projects were completed between 1961 and 1981, one of which created significant changes in streamflow. The Fryingpan-Arkansas Project involved the construction of three new reservoirs, a trans-Continental Divide tunnel, and the expansion of two of the existing reservoirs to transport unappropriated west slope water into the Arkansas River Basin. This project created tremendous flexibility in the process of storage and water movement in the Upper Arkansas Basin and has significant impacts on flows (a comprehensive discussion of upper basin imports and diversions is included in the Institutional and Legal Analysis section). The Homestake Project moved water from the Eagle River watershed, approximately 160 miles west of Colorado Springs, into Homestake Reservoir and then through the Continental Divide via the Homestake Tunnel into Arkansas River Basin reservoirs. However, after 1986, most of the Homestake water did not reach the main stem but was diverted directly out of the basin, thus having little impact on streamflow. In addition to new water projects coming online, there are several other factors that complicate the evaluation of this time period. The wettest period on record is from 1982-1987, 1989-1992 is extremely dry, and 1995 is the wettest single year on record. After 1989, an informal plan to artificially augment late summer flows to support the commercial rafting industry was implemented, and in 1995, annual flow recommendations to protect and enhance the fisheries were presented. These modifications after 1989 dictate subdividing this period into 1982-1989 and 1990-1995. A comparison of historical records was also completed using the current time periods, 1982-1989 and 1990-1995, with the period 1911-1960. The time period from 1911-1960 was chosen for comparative purposes because it provides the longest history of relatively stable management of the system. This 50 years of data better represent a long-term base condition of streamflow than the short-term "natural" record prior to 1900.

FIGURE 4-4

Mean Daily Flow (cfs) by Month
1911-1960
Cañon City Gage

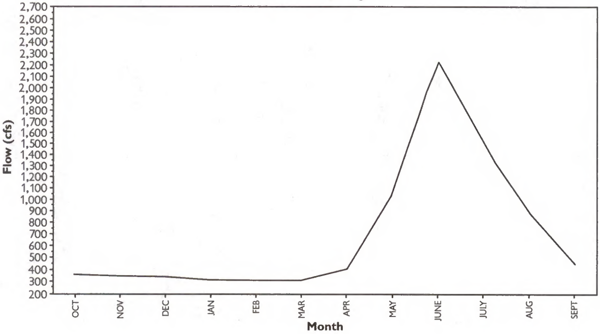
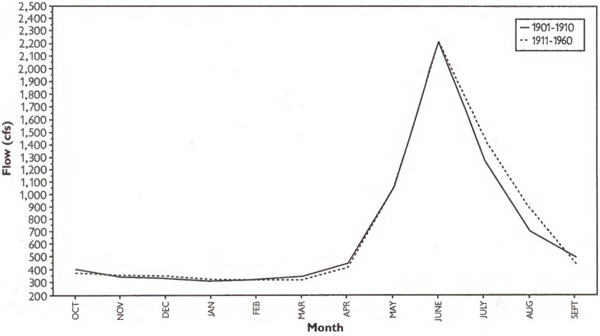


FIGURE 4-5

Mean Daily Flow (cfs) by Month
1901-1910; 1911-1960
Cañon City Gage



Comparison of Seasonal Flows for Each Time Period

Comparison of these time periods is best illustrated by a further annual breakdown to winter flows (October-April), spring or runoff flows (May-July), and late summer flows (August-September).

Figure 4-6 and Table 4-1 provide a comparison of annual mean monthly hydrographs and mean monthly flows, respectively, for the periods 1911-1960, 1982-1989, and 1990-1995.

FIGURE 4-6

Mean Daily Flow (cfs) by Month 1911-1960, 1982-1989, 1990-1995
Cañon City Gage

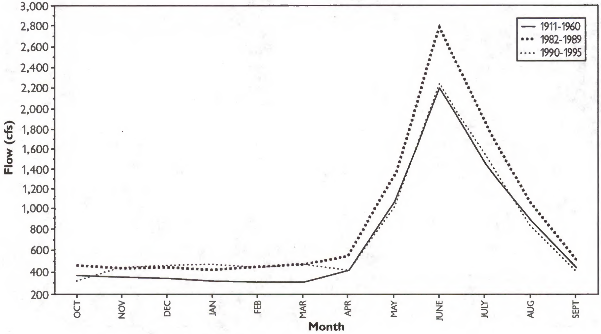


TABLE 4-1

Annual Mean Monthly Flow (cfs)
Cañon City Gage

Month	1911-1960	1982-1989	1990-1995
October	370	464	320
November	361	464	433
December	352	444	463
January	327	424	475
February	318	456	451
March	318	479	483
April	417	550	408
May	1,062	1,330	1,001
June	2,218	2,802	2,256
July	1,464	1,862	1,546
August	885	1,055	823
September	447	520	418

Table 4-2 provides the mean annual flow (acre-feet) for each timeframe. The high annual flow from 1982-1989 is reflective of the wettest time period on record, 1982-1987. Although more water appears to pass annually during the 1990-1995 period than the 1911-1960 period, the flow is heavily weighted by 1995, the wettest year on record. The exclusion of 1995 adjusts the mean annual flow down to 470,000 acre-feet, which more accurately reflects this unusually dry period.

TABLE 4-2

Mean Annual Flow (acre-feet)

1911-1960	1982-1989	1990-1995
516,000	655,000	550,000

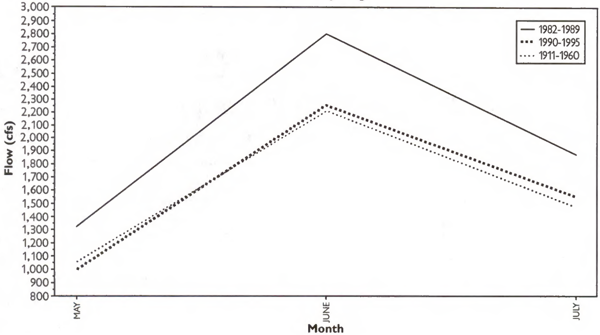
For each of the time periods, approximately 53 percent of the annual flow is passed during the 3 month snowmelt runoff (May-July). Figure 4-7 illustrates a comparison of mean daily monthly flows for the runoff period (May-July). Although the values are obviously higher from 1982-1989, this reflects an unusually wet time period. Overall, the difference in flows will only reflect differences in snowpack and summer temperatures and not significant changes in institutional controls.

Winter flows (October-April) should reflect changes in institutional controls within the system. These flows are predominantly independent of weather considerations, so any variations between time periods are probably artificial. Mean winter flows for the three time periods, 1911-1960, 1982-1989, and 1990-1995, are 148,000, 196,000, and 182,000 acre-feet, respectively. Winter flows from 1911-1960 can be considered reasonably consistent because of a stable institutional environment. Therefore, these values indicate over 40,000 acre-feet of additional water being passed in the winter months after 1982. This movement can be accounted for by the new movement of water from

FIGURE 4-7

Mean Daily Flow (cfs) May, June, July 1911-1960, 1982-1989, 1990-1995

Cañon City Gage



upper reservoirs to lower basin storage during the winter months to allow for spring runoff storage in the upper basin. This transfer is attributable to the Fryingpan-Arkansas Project and the construction of Pueblo Reservoir. Figure 4-8 and Table 4-3 illustrate the changes in mean daily flows by month from October-April for each of the three periods of record.

Table 4-3 also highlights the percentage variation in the flows by time period. After 1982, mean daily winter flows increased approximately 100 cfs.

FIGURE 4-8

Mean Daily Flow (cfs) October - April
1911-1960, 1982-1989, 1990-1995
Cañon City Gage

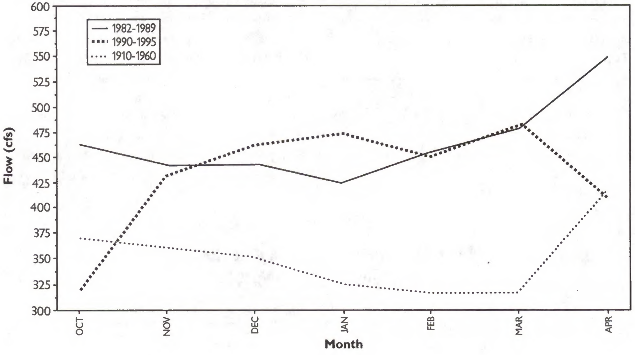


TABLE 4-3

Mean Daily Flow (cfs) October-April
1911-1969, 1982-89, 1990-95

Month	1911-60	1982-89	1990-95	% Change 1911-60 to 1982-89	% Change 1911-60 to 1990-95
Oct	370	464	320	25.4	-13.4
Nov	361	442	433	22.6	20.0
Dec	352	444	463	26.17	31.6
Jan	327	424	475	29.9	45.4
Feb	318	456	451	43.5	41.9
Mar	318	479	483	50.6	52.1
Apr	417	550	408	31.98	-1.96

This equates to a mean increase of approximately 30 percent over the 1911-1960 period. Flow duration analysis also supports this increase in winter flows. Table 4-4 compares the 180-day low flow prior to implementation of the Fryingpan-Arkansas Project (1911-1960) with postimplementation flow (1982-1995).

The 180-day flow was chosen because it predominantly reflects the winter flow period. Once again the flows exhibit a marked increase after completion of the Fryingpan-Arkansas Project. The corresponding flow frequency analysis highlights the same trend. Figures 4-9 to 4-15 illustrate the winter flow frequencies for the same time periods. There is a consistent increase in higher flows after 1982. One overall effect of project development between 1960-1982 has been a marked increase in winter flows in the system.

Late summer (August-September) flows can be difficult to interpret. There are institutional agreements to move water late in the season, such as the flow augmentation for the commercial rafting industry, but large winter snowpacks coupled with cold summer temperatures can also extend runoff into early August. The mean annual August-September flow for 1911-1960 was 79,000 acre-feet, for 1982-1989 was 95,000, and for 1990-1995 was 75,000 acre-feet. The significantly higher flows from 1982-1989 are undoubtedly due to the extremely high water during this time extending the runoff season into August.

Concern over August-September flows originates after 1989, when the annual flow management program was proposed and initiated. The critical period appears to be August 1-15, when the annual flow management program provides a minimum flow of 700 cfs at the Wellsville gage. In order to compare August 1-15 flows among the different periods in this hydrologic analysis, it was necessary to adjust historical readings at the Cañon City gage to show the corresponding flow that would have occurred at the Wellsville gage. This was accomplished by developing a linear regression equation that shows the relationships between the two gages. Using this relationship, the mean daily flow for August 1-15 at the Wellsville gage was:

- 1911-1960 period - 1,080 cfs
- 1982-1989 period - 1,271 cfs
- 1990-1995 period - 973 cfs

The 1911-1960 period of record is long enough to be adequate for statistical purposes. Analysis of the August 1-15 data indicates a normal distribution of values, so 1,080 cfs is an appropriate flow

TABLE 4-4

180-Day Low Flow Recurrence (cfs)

Recurrence Interval (yr)	1911-1960 Flow	1982-1995 Flow	% Change
100	208	264	26
50	218	277	27
20	235	298	27
10	252	319	27
5	275	347	26
2	327	410	25
1.25	393	491	25
1.11	434	541	25
1.04	485	602	24
1.02	523	646	24
1.01	559	689	23

FIGURE 4-9

Arkansas River Flow Duration, October, Cañon City Gage

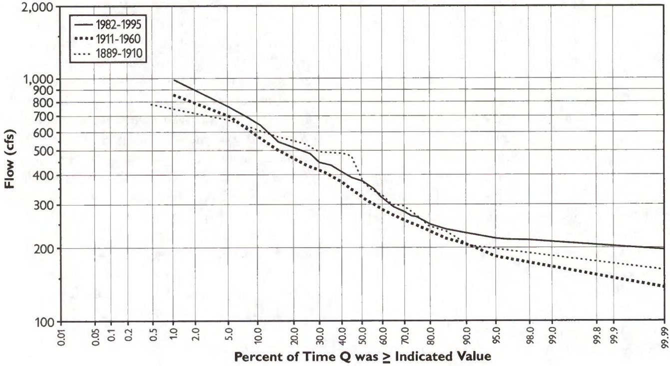


FIGURE 4-10

Arkansas River Flow Duration, November, Cañon City Gage

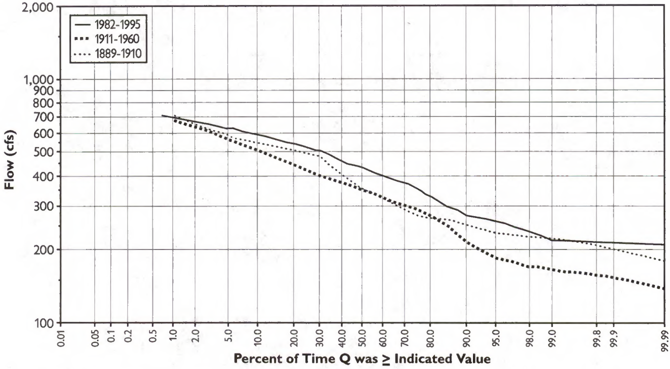


FIGURE 4-11

Arkansas River Flow Duration, December, Cañon City Gage

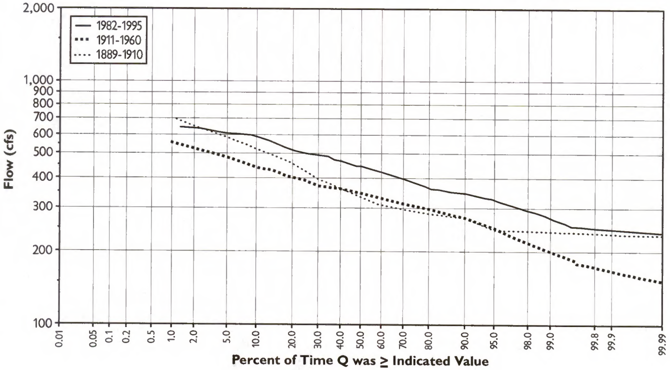


FIGURE 4-12

Arkansas River Flow Duration, January, Cañon City Gage

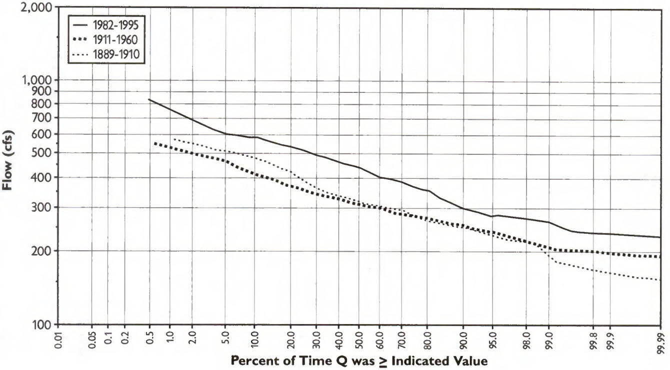


FIGURE 4-13

Arkansas River Flow Duration, February, Cañon City Gage

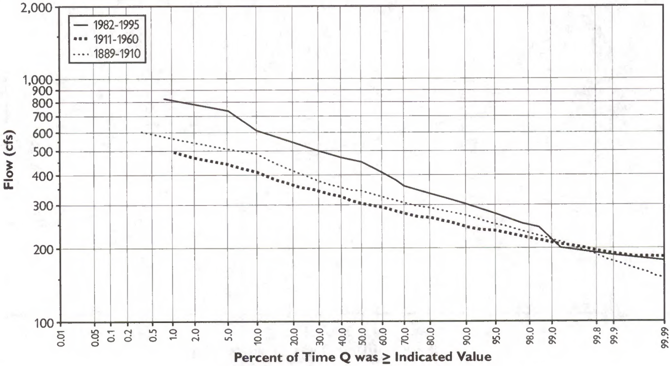


FIGURE 4-14

Arkansas River Flow Duration, March, Cañon City Gage

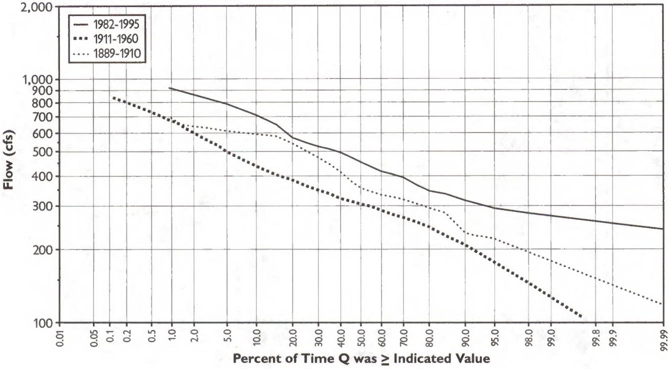
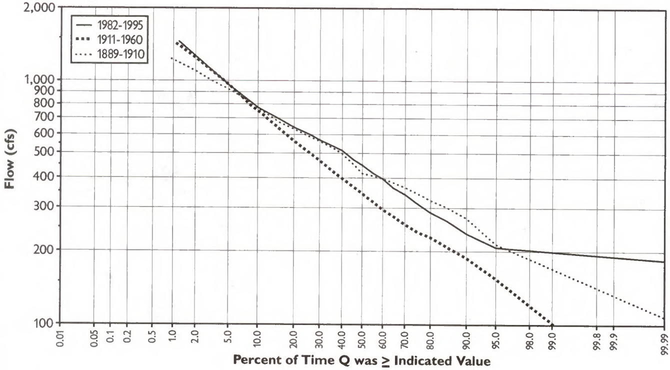


FIGURE 4-15

Arkansas River Flow Duration, April, Cañon City Gage

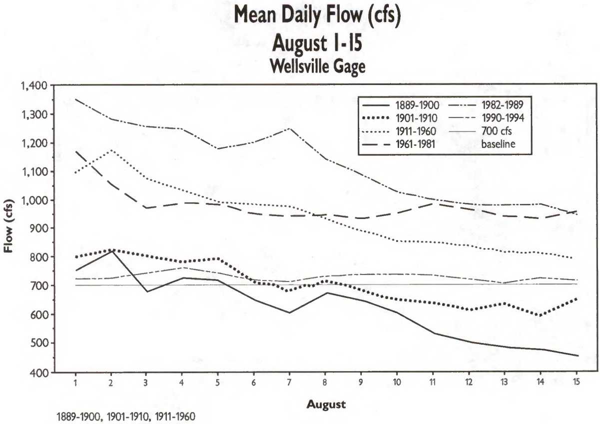


estimate over this period of record. Data from earlier than 1911 is comprised of short periods of record and sampling that is too infrequent for reliable interpretation of medians or flow frequency analysis, but mean flows can be determined. For the period from 1898-1900, before any upper basin storage was available, mean August 1-15 flows at Wellsville were approximately 680 cfs. After 1900, but before 1911, when three storage facilities were constructed in the upper basin, mean August 1-15 flows rose to 740 cfs. The proportion of days exceeding 700 cfs for each time period provides an indicator of August 1-15 flow changes:

- 1889-1900 period - 40 percent (limited data set, but only data available)
- 1911-1960 period - 75 percent
- 1982-1989 period - 80 percent
- 1990-1995 period - 77 percent

Figure 4-16 provides mean daily flows for August 1-15 for all time periods, including during Fryingpan-Arkansas Project construction from 1960-1982. The figure includes a baseline flow of 700 cfs. Even with the annual flow management program, the system does not appear to exhibit any radical change from its long-term history. The current 700 cfs augmentation target flow is significantly lower than mean flows from the previous 87 years. In addition, the augmentation target flow does not differ dramatically from mean flows from 1889 to 1900. Higher flows during the 1982-1989 period are undoubtedly due to the extremely high precipitation during this time, which extended the runoff period into August. Flows during the 1990-95 period declined to the lowest of any period since 1910, but this could be attributed to the dry years associated with this period.

FIGURE 4-16



1889-1900, 1901-1910, 1911-1960
1961-1981, 1982-1989, 1990-1994

Post Fryingpan-Arkansas Project Streamflow

The construction of upper basin reservoirs after 1900, development of transbasin imports after 1910, the Homestake project, and the Fryingpan-Arkansas Project have all permanently altered the flow regime of the Upper Arkansas River Basin. Because comprehensive records of imported water volumes, reservoir operations, and streamflow are available after 1982, the impact of the largest of these projects, the Fryingpan-Arkansas, can be assessed. The following analysis and discussion are correlated with the Wellsville USGS streamflow gage.

Table 4-5 provides the annual flows by month (acre-feet x 1,000) from 1982-1995 for the Wellsville gage(Q_{act}). These values can be adjusted based on the following equation to estimate natural flows without the effects of transbasin imports and water projects(Q_{adj}):

Q_{adj} = Q_{act} - total imports + total change in reservoir content + total losses out of the system

The total imports (acre-feet x 1,000) to the system are represented by the following:

1. Columbine Ditch
2. Ewing Ditch
3. Wurtz Ditch
4. Homestake Tunnel import
5. Boustead Tunnel import (Fryingpan-Arkansas Project)
6. Busk-Ivanhoe Tunnel import
7. Twin Lakes Tunnel import

Figures 4-17 to 4-20 illustrate the mean annual imports by month from 1982-1995 for each of the ditches and tunnels above. The majority of imported water occurs from May-July with the exception of Homestake Tunnel imports.

TABLE 4-5

Q_{act}, Monthly Flow (acre-feet x 1,000), Wellsville Gage by Year

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1982	23.6	19.7	22.5	25.2	25.4	24.9	20.2	41.5	124.0	93.4	73.3	43.2	536.9
1983	37.9	34.6	39.1	35.4	31.6	25.1	15.7	25.1	170.7	188.5	88.1	34.1	725.8
1984	26.3	22.0	24.2	20.8	16.6	18.8	30.6	144.1	200.0	152.7	116.2	51.8	824.0
1985	46.1	32.2	27.1	29.2	40.5	37.2	37.5	93.5	189.8	112.4	45.9	28.4	719.9
1986	32.3	29.4	26.2	20.1	16.7	17.6	24.3	85.5	188.9	134.7	51.6	36.1	663.3
1987	32.4	33.6	25.1	21.2	18.6	22.6	34.3	92.5	135.6	60.0	40.4	24.7	541.0
1988	22.0	23.8	22.4	19.1	16.8	18.5	20.0	48.2	90.1	44.5	32.5	22.3	380.1
1989	18.8	20.8	21.8	18.2	14.8	35.1	41.2	48.7	73.2	74.5	57.5	20.5	444.8
1990	19.9	24.1	20.3	17.6	15.1	15.4	13.4	30.6	1,16.5	64.0	38.8	19.5	395.2
1991	25.6	27.6	23.3	31.3	27.3	23.0	26.5	58.4	99.3	51.8	34.0	18.7	446.8
1992	17.2	28.4	29.5	30.2	26.7	27.7	19.9	58.1	69.0	50.6	42.9	25.2	425.3
1993	21.1	24.1	27.2	27.0	28.0	39.8	22.7	85.8	148.6	107.1	41.6	31.8	604.7
1994	29.1	28.1	30.2	31.0	27.0	28.3	24.1	58.5	128.6	45.7	34.4	20.1	485.3
1995	26.5	29.6	33.8	30.7	23.1	28.9	30.5	65.2	178.4	216.5	109.4	48.9	821.5
Mean	27.1	27.0	26.6	25.5	23.4	25.9	25.8	66.8	136.6	99.7	57.6	30.4	572.5

FIGURE 4-17

Mean Annual Imports by Month
1982-1995
Twin Lakes System

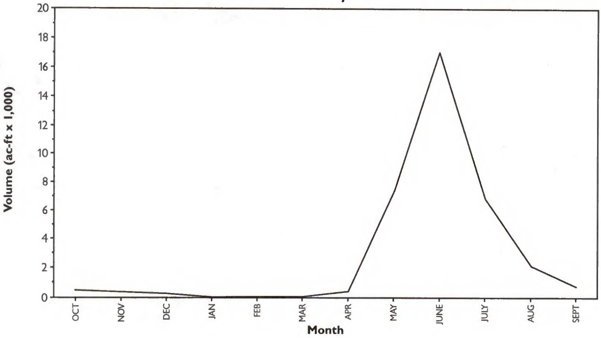


FIGURE 4-18

Mean Annual Imports by Month 1982-1995 Boustead Tunnel

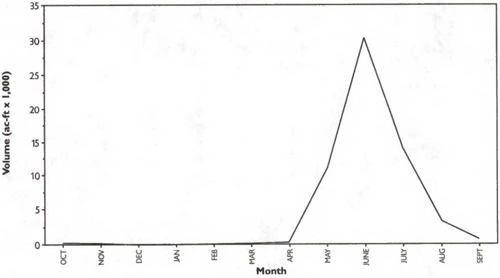


FIGURE 4-19

Mean Annual Imports by Month 1982-1995 Homestake Project

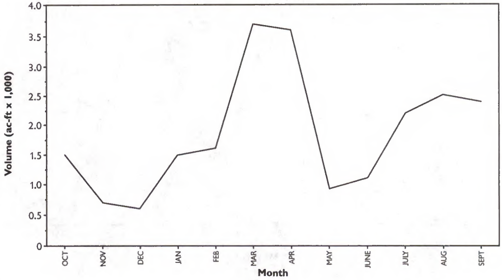
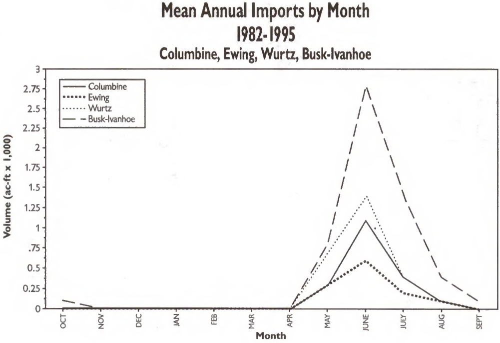


FIGURE 4-20



The net losses (acre-feet x 1,000) to the system are represented by the following:

1. Evaporative losses from Turquoise Reservoir
2. Evaporative losses from Clear Creek Reservoir
3. Evaporative losses from Twin Lakes and Mt. Elbert Forebay
4. Otero Pipeline: Otero Pipeline moves Homestake water directly out of the reservoir system via the Otero pump station to the Cities of Aurora and Colorado Springs. This water never enters the main stem of the Arkansas even though it is imported.

Figure 4-21 illustrates the mean annual reservoir evaporation (acre-feet x 1,000) during the period 1982-1995. These volumes are small and occur only in the summer months.

The Otero Pipeline losses (Figure 4-22) are relatively consistent year-round during this period, with slightly lower values in the winter and slightly higher values in the spring and summer. Most of this water is earmarked for municipal and industrial use, so it is not subject to the large seasonal fluctuations associated with irrigation.

Changes in reservoir content (acre-feet x 1,000) are represented by the three reservoirs in the Upper Basin:

1. Turquoise Reservoir
2. Clear Creek Reservoir
3. Twin Lakes Reservoir and Mt. Elbert Forebay

Figure 4-23 provides mean annual monthly reservoir level changes (acre-feet x 1,000) from 1982-1995 for each of the upper basin reservoirs. A negative value denotes reservoir drawdown/ release and a positive value denotes an increase in reservoir level (storage). The majority of reservoir drawdown occurs during the winter months and storage occurs during runoff (May-July). The August release from Twin Lakes can be attributed to the post-1990 flow augmentation program.

Table 4-6 provides a summary of the mean monthly changes in the system at Wellsville from 1982-1995 based on the variables discussed

FIGURE 4-21

Mean Reservoir Evaporation 1982-1995

Twin Lakes, Clear Creek, Turquoise

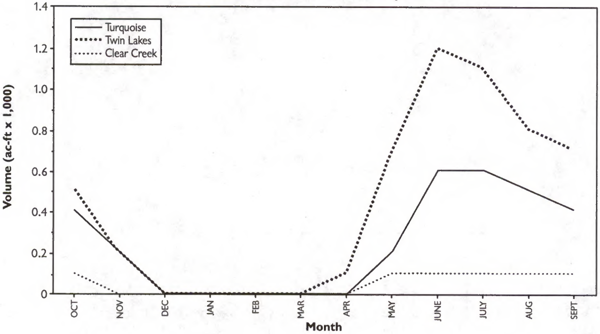


FIGURE 4-22

Mean Monthly Otero Exports 1982-1995

Exports out of the Upper Arkansas Basin

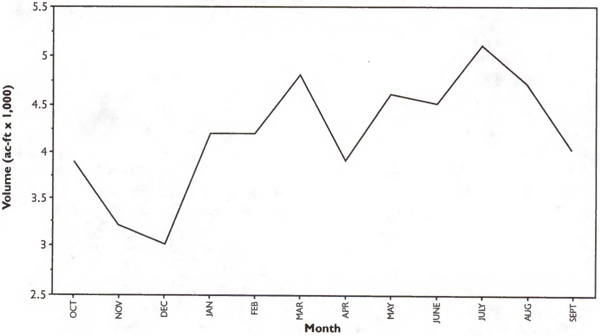
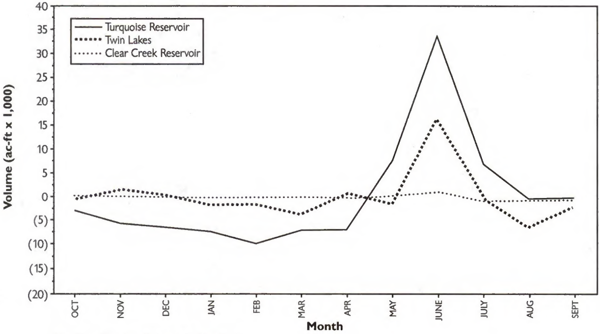


FIGURE 4-23

Mean Monthly Reservoir Changes 1982-1995



Negative values denote reservoir drawdown
Positive values denote reservoir gains

TABLE 4-6

Estimated Mean Monthly Changes (acre-feet x 1,000), Wellsville Gage by Year

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1982	1.9	-0.4	3.8	9.2	13.8	11.0	2.8	3.4	-2.7	0.7	15.1	-0.2	58.4
1983	2.6	7.9	17.1	17.5	15.9	8.5	1.2	-8.3	-13.0	59.3	4.8	6.7	1,20.2
1984	-3.7	-11.1	-15.6	-4.2	16.2	17.9	19.3	38.1	9.8	-0.2	27.3	6.7	100.5
1985	0.2	0.0	0.2	8.0	20.8	16.6	8.1	3.7	-9.4	18.5	4.8	1.1	72.6
1986	0.2	-0.1	1.0	-0.3	-0.5	0.7	1.8	35.8	18.1	16.6	3.1	0.0	76.4
1987	-1.8	0.3	-1.2	-1.3	-0.7	0.2	-2.3	-2.2	3.1	1.2	4.1	0.8	0.2
1988	0.6	0.3	-0.2	-1.4	-1.0	-0.7	3.0	11.4	-2.5	0.3	0.2	-1.3	8.7
1989	-0.8	0.7	0.5	0.7	0.0	16.4	21.1	-3.1	-3.8	25.7	20.7	-0.6	77.5
1990	-0.6	0.3	0.6	0.4	0.9	0.7	-0.5	-3.5	0.2	11.7	10.9	-1.8	19.3
1991	-1.2	-0.1	2.9	12.9	12.5	6.9	13.0	6.3	1.0	2.5	5.1	-1.2	60.6
1992	-0.1	4.9	10.0	13.1	12.8	11.2	2.8	2.9	1.2	4.8	9.0	-0.3	72.3
1993	-0.5	0.1	6.3	8.2	12.5	22.4	7.5	21.7	2.1	25.3	6.8	6.5	118.9
1994	5.8	4.2	10.2	13.0	12.5	11.1	2.6	-12.1	-3.2	13.4	10.3	-1.0	66.8
1995	1.5	7.8	13.3	12.2	6.3	10.5	10.4	29.4	-50.6	-6.2	19.7	1.7	56.0
Mean	0.3	1.1	3.5	6.3	8.7	9.5	6.5	8.8	-3.6	12.4	10.1	1.2	64.9

above. Positive values denote additional water in the system and negative values denote less water, both of which are due to institutional controls. Based on this table, approximately 64,000 acre-feet of additional water annually has been introduced to the system since 1982. However, approximately 43,000 acre-feet of this water was already in place by 1935. The majority of this water was moved from mid-July through September. So the net impact of the water projects brought online between 1960-1982 is approximately 20,000 acre-feet of additional flow annually in the main stem of the Arkansas. Probably the largest effect of the Fryingpan-Arkansas Project is the timing of additional flows in the system and not the additional volume. Prior to 1960, winter flows were reduced to fill upper basin reservoirs. After 1982, with the construction of Pueblo Reservoir, winter flows were markedly increased as water was moved lower in the system to make room for spring runoff storage in the upper reservoirs. Based on the values in Table 4-6, of the 64,000 acre-feet of additional water, approximately 42,000 acre-feet is passed during the winter months. Approximately two-thirds of the additional water passed through the system is moved from October-April.

Resource Considerations

Resource analysis was completed at various locations from near Leadville to Parkdale. This extensive range of locations presents a problem for determining how flow rates in various locations are related to each other. What would a recommended flow rate in the lower portion of the basin correspond to in the upper portion of the basin?

To mitigate this problem, the flow analysis associated with the biological work is indexed to the Wellsville USGS gage. The three other gages that represent flows corresponding to areas of biological analysis, Granite, Nathrop, and Parkdale, were regressed on the measured flows at the Wellsville gage. This allows all flows to be indexed to a single location and then adjusted to each individual point of interest. Table 4-7 provides the regression equation results and flows over the range of interest.

TABLE 4-7

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

$$\text{estimate} = e^{|a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 + 2)|}$$

$$\text{95 percent confidence interval} = e^{|(\ln \text{estimate} - |d^2 + 2]) \pm (d \times 1.98)|}$$

Granite regression based on daily mean discharge values from water years 1982 to 1987, $a = -3.376913$, $b = 1.624432$, $c = -0.321887$, $d = 0.342872$
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, $a = -3.363741$, $b = 1.8927$, $c = -0.0595647$, $d = 0.1577784$
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, $a = 2.648973$, $b = 0.2921178$, $c = 0.0495163$, $d = 0.1132864$

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
100	17.0	35.6	66.1	43.7	60.4	81.6	124	156	194	100
105	18.2	38.0	70.5	46.6	64.5	87.1	129	162	201	105
110	19.4	40.4	75.1	49.6	68.7	92.7	133	168	209	110
115	20.5	42.9	79.7	52.6	72.8	98.3	138	174	216	115
120	21.8	45.4	84.4	55.7	77.1	104	142	179	223	120
125	23.0	48.0	89.1	58.8	81.3	110	147	185	230	125
130	24.2	50.5	93.9	61.9	85.6	116	151	191	237	130
135	25.4	53.1	98.7	65.0	90.0	121	156	196	244	135
140	26.7	55.8	104	68.2	94.4	127	160	202	251	140
145	28.0	58.4	109	71.4	98.8	133	165	208	258	145
150	29.3	61.1	113	74.6	103	139	169	213	265	150
155	30.6	63.8	119	77.8	108	145	174	219	272	155
160	31.9	66.5	124	81.1	112	151	178	224	279	160
165	33.2	69.3	129	84.4	117	158	183	230	286	165
170	34.5	72.2	134	87.6	121	164	187	235	293	170
175	35.8	74.9	139	91.0	126	170	191	241	300	175
180	37.2	77.7	144	94.3	130	176	196	247	307	180
185	38.6	80.5	150	97.6	135	182	200	252	313	185
190	39.9	83.4	155	101	140	189	205	258	320	190
195	41.3	86.2	160	104	144	195	209	263	327	195
200	42.7	89.1	166	108	149	201	213	269	334	200
205	44.1	92.1	171	111	154	208	218	274	341	205
210	45.5	95.0	176	115	159	214	222	280	348	210
215	46.9	97.9	182	118	163	220	226	285	354	215
220	48.3	101	187	121	168	227	231	290	361	220
225	49.7	104	193	125	173	233	235	296	368	225
230	51.2	107	199	128	178	240	239	301	375	230
235	52.6	110	204	132	182	246	244	307	381	235
240	54.1	113	210	135	187	253	248	312	388	240
245	55.5	116	215	139	192	259	252	318	395	245
250	57.0	119	221	142	197	266	257	323	402	250
255	58.5	122	227	146	202	273	261	328	408	255
260	60.0	125	233	149	207	279	265	334	415	260
265	61.4	128	238	153	212	286	269	339	422	265
270	62.9	131	244	157	217	292	274	345	429	270
275	64.4	135	250	160	221	299	278	350	435	275
280	65.9	138	256	164	226	306	282	356	442	280
285	67.5	141	262	167	231	312	287	361	449	285
290	69.0	144	268	171	236	319	291	366	455	290
295	70.5	147	273	174	241	326	295	372	462	295
300	72.0	150	279	178	246	332	299	377	469	300
305	73.6	154	285	182	251	339	304	382	476	305
310	75.1	157	291	185	256	346	308	388	482	310
315	76.6	160	297	189	261	353	312	393	489	315
320	78.2	163	303	192	266	359	316	399	496	320
325	79.8	167	309	196	271	366	321	404	502	325
330	81.3	170	315	200	276	373	325	409	509	330
335	82.9	173	321	203	281	380	329	415	516	335
340	84.5	176	328	207	286	387	334	420	522	340
345	86.0	180	334	211	291	393	338	425	529	345

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

estimate = $e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 + 2)]}$

95 percent confidence interval = $e^{[(\ln \text{estimate} - [d^2 + 2]) \pm (d \times 1.98)]}$

Granite regression based on daily mean discharge values from water years 1982 to 1987, a = -3.376913, b = 1.624432, c = -0.321887, d = 0.342872
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, a = -3.363741, b = 1.8927, c = -0.0595647, d = 0.1577784
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, a = 2.648973, b = 0.2921178, c = 0.0495163, d = 0.1132864

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
350	87.6	183	340	214	296	400	342	431	536	350
355	89.2	186	346	218	302	407	346	436	542	355
360	90.8	190	352	222	307	414	351	442	549	360
365	92.4	193	358	225	312	421	355	447	556	365
370	94.0	196	365	229	317	428	359	452	562	370
375	95.6	200	371	233	322	434	363	458	569	375
380	97.2	203	377	236	327	441	368	463	576	380
385	98.8	206	383	240	332	448	372	468	582	385
390	100	210	390	244	337	455	376	474	589	390
395	102	213	396	247	342	462	380	479	596	395
400	104	217	402	251	347	469	385	485	602	400
410	107	223	415	258	358	483	393	495	616	410
420	110	230	428	266	368	497	402	506	629	420
430	114	237	441	273	378	511	410	517	642	430
440	117	244	453	281	389	524	419	527	656	440
450	120	251	466	288	399	538	427	538	669	450
460	124	258	479	296	409	552	436	549	682	460
470	127	265	492	303	420	566	444	560	696	470
480	130	272	506	311	430	580	453	570	709	480
490	134	279	519	318	440	594	461	581	723	490
500	137	286	532	326	451	608	470	592	736	500
510	141	294	545	333	461	622	478	603	749	510
520	144	301	558	341	471	636	487	613	763	520
530	147	308	572	348	482	650	495	624	776	530
540	151	315	585	356	492	664	504	635	789	540
550	154	322	599	363	503	678	513	646	803	550
560	158	330	612	371	513	693	521	656	816	560
570	161	337	626	378	524	707	530	667	830	570
580	165	344	639	386	534	721	538	678	843	580
590	168	352	653	393	544	735	547	689	856	590
600	172	359	667	401	555	749	555	699	870	600
610	175	366	680	409	565	763	564	710	883	610
620	179	374	694	416	576	777	572	721	897	620
630	183	381	708	424	586	791	581	732	910	630
640	186	389	722	431	597	805	590	743	923	640
650	190	396	736	439	607	820	598	753	937	650
660	193	404	750	446	618	834	607	764	950	660
670	197	411	763	454	628	848	615	775	964	670
680	200	419	777	461	639	862	624	786	977	680
690	204	426	791	469	649	876	633	797	991	690
700	208	434	805	477	660	890	641	808	1,000	700
710	211	441	820	484	670	904	650	819	1,020	710
720	215	449	834	492	681	919	659	829	1,030	720
730	219	456	848	499	691	933	667	840	1,040	730
740	222	464	862	507	702	947	676	851	1,060	740
750	226	472	876	515	712	961	684	862	1,070	750
760	230	479	890	522	722	975	693	873	1,090	760
770	233	487	905	530	733	989	702	884	1,100	770
780	237	495	919	537	743	1,000	710	895	1,110	780
790	241	503	933	545	754	1,020	719	906	1,130	790

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

$$\text{estimate} = e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 \div 2)]}$$

$$95 \text{ percent confidence interval} = e^{[(\ln \text{estimate} - [d^2 \div 2]) \pm (d \times 1.98)]}$$

Granite regression based on daily mean discharge values from water years 1982 to 1987, a = -3.376913, b = 1.624432, c = -0.321887, d = 0.342872
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, a = -3.363741, b = 1.8927, c = -0.0595647, d = 0.1577784
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, a = 2.648973, b = 0.2921178, c = 0.0495163, d = 0.1132864

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
800	244	510	948	552	764	1,030	728	917	1,140	800
810	248	518	962	560	775	1,050	736	928	1,150	810
820	252	526	977	568	785	1,060	745	938	1,170	820
830	256	534	991	575	796	1,070	754	949	1,180	830
840	259	541	1,010	583	806	1,090	763	960	1,190	840
850	263	549	1,020	590	817	1,100	771	971	1,210	850
860	267	557	1,030	598	827	1,120	780	982	1,220	860
870	271	565	1,050	605	838	1,130	789	993	1,240	870
880	274	573	1,060	613	848	1,140	797	1,000	1,250	880
890	278	581	1,080	620	859	1,160	806	1,020	1,260	890
900	282	588	1,090	628	869	1,170	815	1,030	1,280	900
910	286	596	1,110	636	879	1,190	824	1,040	1,290	910
920	289	604	1,120	643	890	1,200	832	1,050	1,300	920
930	293	612	1,140	651	900	1,220	841	1,060	1,320	930
940	297	620	1,150	658	911	1,230	850	1,070	1,330	940
950	301	628	1,170	666	921	1,240	859	1,080	1,340	950
960	305	636	1,180	673	932	1,260	867	1,090	1,360	960
970	308	644	1,200	681	942	1,270	876	1,100	1,370	970
980	312	652	1,210	688	953	1,290	885	1,110	1,390	980
990	316	660	1,230	696	963	1,300	894	1,130	1,400	990
1,000	320	668	1,240	703	973	1,310	903	1,140	1,410	1,000
1,010	324	676	1,260	711	984	1,330	911	1,150	1,430	1,010
1,020	328	684	1,270	718	994	1,340	920	1,160	1,440	1,020
1,030	331	692	1,290	726	1,000	1,360	929	1,170	1,460	1,030
1,040	335	700	1,300	733	1,010	1,370	938	1,180	1,470	1,040
1,050	339	708	1,320	741	1,030	1,380	947	1,190	1,480	1,050
1,060	343	716	1,330	748	1,040	1,400	956	1,200	1,500	1,060
1,070	347	724	1,350	756	1,050	1,410	964	1,210	1,510	1,070
1,080	351	732	1,360	763	1,060	1,430	973	1,230	1,520	1,080
1,090	355	741	1,380	771	1,070	1,440	982	1,240	1,540	1,090
1,100	359	749	1,390	778	1,080	1,450	991	1,250	1,550	1,100
1,110	362	757	1,410	786	1,090	1,470	1,000	1,260	1,570	1,110
1,120	366	765	1,420	793	1,100	1,480	1,010	1,270	1,580	1,120
1,130	370	773	1,440	801	1,110	1,500	1,020	1,280	1,590	1,130
1,140	374	781	1,450	808	1,120	1,510	1,030	1,290	1,610	1,140
1,150	378	789	1,470	816	1,130	1,520	1,040	1,300	1,620	1,150
1,160	382	798	1,480	823	1,140	1,540	1,040	1,320	1,640	1,160
1,170	386	806	1,500	831	1,150	1,550	1,050	1,330	1,650	1,170
1,180	390	814	1,510	838	1,160	1,570	1,060	1,340	1,660	1,180
1,190	394	822	1,530	846	1,170	1,580	1,070	1,350	1,680	1,190
1,200	398	830	1,540	853	1,180	1,590	1,080	1,360	1,690	1,200
1,210	402	839	1,560	861	1,190	1,610	1,090	1,370	1,710	1,210
1,220	406	847	1,570	868	1,200	1,620	1,100	1,380	1,720	1,220
1,230	409	855	1,590	876	1,210	1,640	1,110	1,390	1,730	1,230
1,240	413	863	1,600	883	1,220	1,650	1,120	1,410	1,750	1,240
1,250	417	872	1,620	890	1,230	1,660	1,130	1,420	1,760	1,250
1,260	421	880	1,630	898	1,240	1,680	1,130	1,430	1,780	1,260
1,270	425	888	1,650	905	1,250	1,690	1,140	1,440	1,790	1,270
1,280	429	896	1,670	913	1,260	1,700	1,150	1,450	1,800	1,280
1,290	433	905	1,680	920	1,270	1,720	1,160	1,460	1,820	1,290

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

$$\text{estimate} = e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 \div 2)]}$$

$$\text{95 percent confidence interval} = e^{[(\ln \text{estimate} - [d^2 \div 2]) \pm (d \times 1.98)]}$$

Granite regression based on daily mean discharge values from water years 1982 to 1987, a = -3.376913, b = 1.624432, c = -0.321887, d = 0.342872
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, a = -3.363741, b = 1.8927, c = -0.0595647, d = 0.1577784
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, a = 2.648973, b = 0.2921178, c = 0.0495163, d = 0.1132864

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
1,300	437	913	1,700	927	1,280	1,730	1,170	1,470	1,830	1,300
1,310	441	921	1,710	935	1,290	1,750	1,180	1,490	1,850	1,310
1,320	445	930	1,730	942	1,300	1,760	1,190	1,500	1,860	1,320
1,330	449	938	1,740	950	1,310	1,770	1,200	1,510	1,870	1,330
1,340	453	946	1,760	957	1,320	1,790	1,210	1,520	1,890	1,340
1,350	457	955	1,770	964	1,330	1,800	1,220	1,530	1,900	1,350
1,360	461	963	1,790	972	1,340	1,820	1,220	1,540	1,920	1,360
1,370	465	971	1,800	979	1,360	1,830	1,230	1,550	1,930	1,370
1,380	469	980	1,820	987	1,370	1,840	1,240	1,560	1,950	1,380
1,390	473	988	1,840	994	1,380	1,860	1,250	1,580	1,960	1,390
1,400	477	977	1,850	1,000	1,390	1,870	1,260	1,590	1,970	1,400
1,410	481	1,000	1,870	1,010	1,400	1,880	1,270	1,600	1,990	1,410
1,420	485	1,010	1,880	1,020	1,410	1,900	1,280	1,610	2,000	1,420
1,430	489	1,020	1,900	1,020	1,420	1,910	1,290	1,620	2,020	1,430
1,440	493	1,030	1,910	1,030	1,430	1,930	1,300	1,630	2,030	1,440
1,450	497	1,040	1,930	1,040	1,440	1,940	1,310	1,650	2,050	1,450
1,460	501	1,050	1,940	1,050	1,450	1,950	1,320	1,660	2,060	1,460
1,470	505	1,060	1,960	1,050	1,460	1,970	1,320	1,670	2,070	1,470
1,480	509	1,060	1,980	1,060	1,470	1,980	1,330	1,680	2,090	1,480
1,490	513	1,070	1,990	1,070	1,480	1,990	1,340	1,690	2,100	1,490
1,500	518	1,080	2,010	1,070	1,490	2,010	1,350	1,700	2,120	1,500
1,510	522	1,090	2,020	1,080	1,500	2,020	1,360	1,710	2,130	1,510
1,520	526	1,100	2,040	1,090	1,510	2,030	1,370	1,730	2,150	1,520
1,530	530	1,110	2,050	1,100	1,520	2,050	1,380	1,740	2,160	1,530
1,540	534	1,110	2,070	1,100	1,530	2,060	1,390	1,750	2,170	1,540
1,550	538	1,120	2,090	1,110	1,540	2,080	1,400	1,760	2,190	1,550
1,560	542	1,130	2,100	1,120	1,550	2,090	1,410	1,770	2,200	1,560
1,570	546	1,140	2,120	1,130	1,560	2,100	1,420	1,780	2,220	1,570
1,580	550	1,150	2,130	1,130	1,570	2,120	1,430	1,800	2,230	1,580
1,590	554	1,160	2,150	1,140	1,580	2,130	1,430	1,810	2,250	1,590
1,600	558	1,170	2,160	1,150	1,590	2,140	1,440	1,820	2,260	1,600
1,610	562	1,170	2,180	1,160	1,600	2,160	1,450	1,830	2,280	1,610
1,620	566	1,180	2,200	1,160	1,610	2,170	1,460	1,840	2,290	1,620
1,630	570	1,190	2,210	1,170	1,620	2,180	1,470	1,850	2,300	1,630
1,640	575	1,200	2,230	1,180	1,630	2,200	1,480	1,870	2,320	1,640
1,650	579	1,210	2,240	1,180	1,640	2,210	1,490	1,880	2,330	1,650
1,660	583	1,220	2,260	1,190	1,650	2,230	1,500	1,890	2,350	1,660
1,670	587	1,230	2,280	1,200	1,660	2,240	1,510	1,900	2,360	1,670
1,680	591	1,230	2,290	1,210	1,670	2,250	1,520	1,910	2,380	1,680
1,690	595	1,240	2,310	1,210	1,680	2,270	1,530	1,920	2,390	1,690
1,700	599	1,250	2,320	1,220	1,690	2,280	1,540	1,940	2,410	1,700
1,710	603	1,260	2,340	1,230	1,700	2,290	1,550	1,950	2,420	1,710
1,720	607	1,270	2,360	1,230	1,710	2,310	1,560	1,960	2,440	1,720
1,730	611	1,280	2,370	1,240	1,720	2,320	1,560	1,970	2,450	1,730
1,740	616	1,290	2,390	1,250	1,730	2,330	1,570	1,980	2,460	1,740
1,750	620	1,290	2,400	1,260	1,740	2,350	1,580	1,990	2,480	1,750
1,760	624	1,300	2,420	1,260	1,750	2,360	1,590	2,010	2,490	1,760
1,770	628	1,310	2,440	1,270	1,760	2,370	1,600	2,020	2,510	1,770
1,780	632	1,320	2,450	1,280	1,770	2,390	1,610	2,030	2,520	1,780
1,790	636	1,330	2,470	1,290	1,780	2,400	1,620	2,040	2,540	1,790

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

estimate = $e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 + 2)]}$

95 percent confidence interval = $e^{[(\ln \text{estimate} - [d^2 + 2]) \pm (d \times 1.98)]}$

Granite regression based on daily mean discharge values from water years 1982 to 1987, a = -3.376913, b = 1.624432, c = -0.321887, d = 0.342872
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, a = -3.363741, b = 1.8927, c = -0.0595647, d = 0.1577784
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, a = 2.648973, b = 0.2921178, c = 0.0495163, d = 0.1132864

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
1,800	640	1,340	2,480	1,290	1,790	2,410	1,630	2,050	2,550	1,800
1,810	644	1,350	2,500	1,300	1,800	2,430	1,640	2,060	2,570	1,810
1,820	649	1,350	2,520	1,310	1,810	2,440	1,650	2,080	2,580	1,820
1,830	653	1,360	2,530	1,310	1,820	2,450	1,660	2,090	2,600	1,830
1,840	657	1,370	2,550	1,320	1,830	2,470	1,670	2,100	2,610	1,840
1,850	661	1,380	2,560	1,330	1,840	2,480	1,680	2,110	2,630	1,850
1,860	665	1,390	2,580	1,340	1,850	2,490	1,690	2,120	2,640	1,860
1,870	669	1,400	2,600	1,340	1,860	2,510	1,700	2,140	2,660	1,870
1,880	673	1,410	2,610	1,350	1,870	2,520	1,700	2,150	2,670	1,880
1,890	678	1,410	2,630	1,360	1,880	2,530	1,710	2,160	2,680	1,890
1,900	682	1,420	2,640	1,360	1,890	2,550	1,720	2,170	2,700	1,900
1,910	686	1,430	2,660	1,370	1,900	2,560	1,730	2,180	2,710	1,910
1,920	690	1,440	2,680	1,380	1,910	2,570	1,740	2,190	2,730	1,920
1,930	694	1,450	2,690	1,390	1,920	2,590	1,750	2,210	2,740	1,930
1,940	698	1,460	2,710	1,390	1,930	2,600	1,760	2,220	2,760	1,940
1,950	703	1,470	2,720	1,400	1,940	2,610	1,770	2,230	2,770	1,950
1,960	707	1,480	2,740	1,410	1,950	2,630	1,780	2,240	2,790	1,960
1,970	711	1,480	2,760	1,410	1,960	2,640	1,790	2,250	2,800	1,970
1,980	715	1,490	2,770	1,420	1,970	2,650	1,800	2,270	2,820	1,980
1,990	719	1,500	2,790	1,430	1,980	2,670	1,810	2,280	2,830	1,990
2,000	723	1,510	2,810	1,430	1,990	2,680	1,820	2,290	2,850	2,000
2,050	744	1,550	2,890	1,470	2,030	2,750	1,870	2,350	2,920	2,050
2,100	765	1,600	2,970	1,510	2,080	2,810	1,910	2,410	3,000	2,100
2,150	786	1,640	3,050	1,540	2,130	2,880	1,960	2,470	3,070	2,150
2,200	807	1,690	3,130	1,580	2,180	2,940	2,010	2,530	3,150	2,200
2,250	828	1,730	3,120	1,610	2,230	3,010	2,060	2,590	3,220	2,250
2,300	850	1,770	3,300	1,650	2,280	3,070	2,110	2,650	3,300	2,300
2,350	871	1,820	3,380	1,680	2,320	3,140	2,160	2,710	3,380	2,350
2,400	892	1,860	3,460	1,710	2,370	3,200	2,200	2,780	3,450	2,400
2,450	913	1,910	3,540	1,750	2,420	3,270	2,250	2,840	3,530	2,450
2,500	935	1,950	3,620	1,780	2,470	3,330	2,300	2,900	3,600	2,500
2,550	956	2,000	3,710	1,820	2,510	3,390	2,350	2,960	3,680	2,550
2,600	977	2,040	3,790	1,850	2,560	3,460	2,400	3,020	3,760	2,600
2,650	999	2,090	3,870	1,890	2,610	3,520	2,450	3,090	3,840	2,650
2,700	1,020	2,130	3,960	1,920	2,660	3,590	2,500	3,150	3,910	2,700
2,750	1,040	2,180	4,040	1,950	2,700	3,650	2,550	3,210	3,990	2,750
2,800	1,060	2,220	4,120	1,990	2,750	3,710	2,600	3,270	4,070	2,800
2,850	1,080	2,270	4,210	2,020	2,800	3,770	2,650	3,340	4,150	2,850
2,900	1,110	2,310	4,290	2,050	2,840	3,840	2,700	3,400	4,230	2,900
2,950	1,130	2,360	4,370	2,090	2,890	3,900	2,750	3,460	4,310	2,950
3,000	1,150	2,400	4,460	2,120	2,930	3,960	2,800	3,530	4,390	3,000
3,050	1,170	2,450	4,540	2,150	2,980	4,020	2,850	3,590	4,470	3,050
3,100	1,190	2,490	4,630	2,190	3,030	4,080	3,900	3,660	4,550	3,100
3,150	1,210	2,540	4,710	2,220	3,070	4,150	2,950	3,720	4,620	3,150
3,200	1,240	2,580	4,790	2,250	3,120	4,210	3,000	3,780	4,710	3,200
3,250	1,260	2,630	4,880	2,280	3,160	4,270	3,060	3,850	4,790	3,250
3,300	1,280	2,670	4,960	2,320	3,210	4,330	3,110	3,910	4,870	3,300
3,350	1,300	2,720	5,050	2,350	3,250	4,390	3,160	3,980	4,950	3,350
3,400	1,320	2,760	5,130	2,380	3,300	4,450	3,210	4,040	5,030	3,400
3,450	1,350	2,810	5,220	2,410	3,340	4,510	3,260	4,110	5,110	3,450

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

estimate = $e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 \div 2)]}$

95 percent confidence interval = $e^{[(\ln \text{estimate} - [d^2 \div 2]) \pm (d \times 1.98)]}$

Granite regression based on daily mean discharge values from water years 1982 to 1987, a = -3.376913, b = 1.624432, c = -0.321887, d = 0.342872
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, a = -3.363741, b = 1.8927, c = -0.0595647, d = 0.1577784
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, a = 2.648973, b = 0.2921178, c = 0.0495163, d = 0.1132864

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
3,500	1,370	2,850	5,300	2,450	3,390	4,570	3,310	4,170	5,190	3,500
3,550	1,390	2,900	5,390	2,480	3,430	4,630	3,370	4,240	5,270	3,550
3,600	1,410	2,950	5,470	2,510	3,470	4,690	3,420	4,310	5,350	3,600
3,650	1,430	2,990	5,560	2,540	3,520	4,750	3,470	4,370	5,440	3,650
3,700	1,450	3,040	5,640	2,570	3,560	4,810	3,520	4,440	5,520	3,700
3,750	1,480	3,080	5,730	2,610	3,610	4,870	3,580	4,500	5,600	3,750
3,800	1,500	3,130	5,810	2,640	3,650	4,930	3,630	4,570	5,680	3,800
3,850	1,520	3,170	5,900	2,670	3,690	4,990	3,680	4,640	5,770	3,850
3,900	1,540	3,220	5,980	2,700	3,740	5,050	3,740	4,700	5,850	3,900
3,950	1,560	3,270	6,070	2,730	3,780	5,100	3,790	4,770	5,930	3,950
4,000	1,590	3,310	6,150	2,760	3,830	5,160	3,840	4,840	6,020	4,000
4,050	1,610	3,360	6,240	2,800	3,870	5,220	3,900	4,910	6,100	4,050
4,100	1,630	3,400	6,320	2,830	3,910	5,280	3,950	4,970	6,190	4,100
4,150	1,650	3,450	6,410	2,860	3,950	5,340	4,000	5,040	6,270	4,150
4,200	1,670	3,500	6,490	2,890	4,000	5,400	4,060	5,110	6,350	4,200
4,250	1,700	3,540	6,580	2,920	4,040	5,450	4,110	5,180	6,440	4,250
4,300	1,720	3,590	6,670	2,950	4,080	5,510	4,170	5,250	6,520	4,300
4,350	1,740	3,630	6,750	2,980	4,120	5,570	4,220	5,310	6,610	4,350
4,400	1,760	3,680	6,840	3,010	4,170	5,620	4,270	5,380	6,690	4,400
4,450	1,780	3,730	6,920	3,040	4,210	5,680	4,330	5,450	6,780	4,450
4,500	1,810	3,770	7,010	3,070	4,250	5,740	4,380	5,520	6,870	4,500
4,550	1,830	3,820	7,090	3,100	4,290	5,800	4,440	5,590	6,950	4,550
4,600	1,850	3,870	7,180	3,130	4,340	5,850	4,490	5,660	7,040	4,600
4,650	1,870	3,910	7,270	3,160	4,380	5,910	4,550	5,730	7,120	4,650
4,700	1,900	3,960	7,350	3,190	4,420	5,960	4,600	5,800	7,210	4,700
4,750	1,920	4,010	7,440	3,220	4,460	6,020	4,660	5,870	7,300	4,750
4,800	1,940	4,050	7,520	3,250	4,500	6,080	4,710	5,940	7,380	4,800
4,850	1,960	4,100	7,610	3,280	4,540	6,130	4,770	6,010	7,470	4,850
4,900	1,980	4,140	7,700	3,310	4,580	6,190	4,830	6,080	7,560	4,900
4,950	2,010	4,190	7,780	3,340	4,630	6,240	4,880	6,150	7,650	4,950
5,000	2,030	4,240	7,870	3,370	4,670	6,300	4,940	6,220	7,730	5,000
5,050	2,050	4,280	7,960	3,400	4,710	6,350	4,990	6,290	7,820	5,050
5,100	2,070	4,330	8,040	3,430	4,750	6,410	5,050	6,360	7,910	5,100
5,150	2,100	4,380	8,130	3,460	4,790	6,460	5,110	6,430	8,000	5,150
5,200	2,120	4,420	8,210	3,490	4,830	6,520	5,160	6,500	8,090	5,200
5,250	2,140	4,470	8,300	3,520	4,870	6,570	5,220	6,570	8,180	5,250
5,300	2,160	4,520	8,390	3,550	4,910	6,630	5,280	6,650	8,260	5,300
5,350	2,180	4,560	8,470	3,580	4,950	6,680	5,330	6,720	8,350	5,350
5,400	2,210	4,610	8,560	3,610	4,990	6,740	5,390	6,790	8,440	5,400
5,450	2,230	4,660	8,650	3,640	5,030	6,790	5,450	6,860	8,530	5,450
5,500	2,250	4,700	8,730	3,660	5,070	6,850	5,510	6,930	8,620	5,500
5,550	2,270	4,750	8,820	3,690	5,110	6,900	5,560	7,010	8,710	5,550
5,600	2,300	4,800	8,910	3,720	5,150	6,950	5,620	7,080	8,800	5,600
5,650	2,320	4,840	8,990	3,750	5,190	7,010	5,680	7,150	8,890	5,650
5,700	2,340	4,890	9,080	3,780	5,230	7,060	5,740	7,220	8,980	5,700
5,750	2,360	4,940	9,170	3,810	5,270	7,110	5,790	7,300	9,070	5,750
5,800	2,390	4,980	9,250	3,840	5,310	7,170	5,850	7,370	9,160	5,800
5,850	2,410	5,030	9,340	3,870	5,350	7,220	5,910	7,440	9,250	5,850
5,900	2,430	5,080	9,430	3,890	5,390	7,270	5,970	7,520	9,350	5,900
5,950	2,450	5,120	9,510	3,920	5,430	7,330	6,030	7,590	9,440	5,950

TABLE 4-7 (continued)

Ordinary Least Squares Regression Estimates of Daily Mean Discharge on Arkansas River

$$\text{estimate} = e^{[a + (b \times \ln q) + [c \times (\ln q)^2] + (d^2 + 2)]}$$

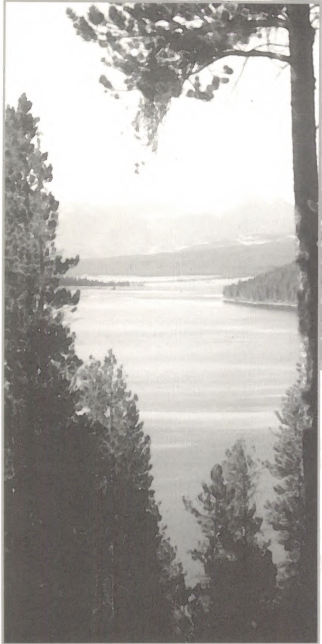
$$\text{95 percent confidence interval} = e^{[(\ln \text{estimate} - [d^2 + 2]) \pm (d \times 1.98)]}$$

Granite regression based on daily mean discharge values from water years 1982 to 1987, $a = -3.376913$, $b = 1.624432$, $c = -0.321887$, $d = 0.342872$
Nathrop regression based on daily mean discharge values from water years 1978 to 1982, $a = -3.363741$, $b = 1.8927$, $c = -0.0595647$, $d = 0.1577784$
Parkdale regression based on daily mean discharge values from water years 1983 to 1987, $a = 2.648973$, $b = 0.2921178$, $c = 0.0495163$, $d = 0.1132864$

Note: all units in cubic feet per second.

Wellsville	Granite			Nathrop			Parkdale			Wellsville
Measured discharge	Lower 95% confidence interval	Estimated discharge at Granite	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Nathrop	Upper 95% confidence interval	Lower 95% confidence interval	Estimated discharge at Parkdale	Upper 95% confidence interval	Measured discharge
6,000	2,480	5,170	9,600	3,950	5,470	7,380	6,080	7,660	9,530	6,000
6,050	2,500	5,220	9,690	3,980	5,510	7,430	6,140	7,740	9,620	6,050
6,100	2,520	5,260	9,770	4,010	5,540	7,480	6,200	7,810	9,710	6,100
6,150	2,540	5,310	9,860	4,030	5,580	7,540	6,260	7,880	9,800	6,150
6,200	2,560	5,360	9,950	4,060	5,620	7,590	6,320	7,960	9,900	6,200
6,250	2,590	5,400	10,000	4,090	5,660	7,640	6,380	8,030	9,990	6,250
6,300	2,610	5,450	10,100	4,120	5,700	7,690	6,440	8,110	10,100	6,300
6,350	2,630	5,500	10,200	4,150	5,740	7,740	6,500	8,180	10,200	6,350
6,400	2,650	5,540	10,300	4,170	5,780	7,800	6,560	8,260	10,300	6,400
6,450	2,680	5,590	10,400	4,200	5,810	7,850	6,620	8,330	10,400	6,450
6,500	2,700	5,640	10,500	4,230	5,850	7,900	6,670	8,410	10,500	6,500
6,550	2,720	5,680	10,600	4,260	5,890	7,950	6,730	8,480	10,500	6,550
6,600	2,740	5,730	10,600	4,280	5,930	8,000	6,790	8,560	10,600	6,600
6,650	2,770	5,780	10,700	4,310	5,970	8,050	6,850	8,630	10,700	6,650
6,700	2,790	5,820	10,800	4,340	6,000	8,100	6,910	8,710	10,800	6,700
6,750	2,810	5,870	10,900	4,370	6,040	8,150	6,970	8,780	10,900	6,750
6,800	2,830	5,920	11,000	4,390	6,080	8,210	7,030	8,860	11,000	6,800
6,850	2,860	5,960	11,100	4,420	6,120	8,260	7,090	8,940	11,100	6,850
6,900	2,880	6,010	11,200	4,450	6,150	8,310	7,160	9,010	11,200	6,900
6,950	2,900	6,060	11,300	4,470	6,190	8,360	7,220	9,090	11,300	6,950
7,000	2,920	6,100	11,300	4,500	6,230	8,410	7,280	9,170	11,400	7,000
7,050	2,950	6,150	11,400	4,530	6,270	8,460	7,340	9,240	11,500	7,050
7,100	2,970	6,200	11,500	4,550	6,300	8,510	7,400	9,320	11,600	7,100
7,150	2,990	6,240	11,600	4,580	6,340	8,560	7,460	9,400	11,700	7,150
7,200	3,010	6,290	11,700	4,610	6,380	8,610	7,520	9,470	11,800	7,200
7,250	3,040	6,340	11,800	4,640	6,410	8,660	7,580	9,550	11,900	7,250
7,300	3,060	6,390	11,900	4,660	6,450	8,710	7,640	9,630	12,000	7,300
7,350	3,080	6,430	11,900	4,690	6,490	8,760	7,700	9,700	12,100	7,350
7,400	3,100	6,480	12,000	4,710	6,520	8,810	7,770	9,780	12,200	7,400
7,450	3,130	6,530	12,100	4,740	6,560	8,860	7,830	9,860	12,300	7,450
7,500	3,150	6,570	12,200	4,770	6,600	8,910	7,890	9,940	12,400	7,500
7,550	3,170	6,620	12,300	4,790	6,630	8,950	7,950	10,000	12,500	7,550
7,600	3,190	6,670	12,400	4,820	6,670	9,000	8,010	10,100	12,600	7,600
7,650	3,210	6,710	12,500	4,850	6,710	9,050	8,080	10,200	12,600	7,650
7,700	3,240	6,760	12,600	4,807	6,740	9,100	8,140	10,200	12,700	7,700
7,750	3,260	6,810	12,600	4,900	6,780	9,150	8,200	10,300	12,800	7,750
7,800	3,280	6,850	12,700	4,920	6,820	9,200	8,260	10,400	12,900	7,800
7,850	3,300	6,900	12,800	4,950	6,850	9,250	8,330	10,500	13,000	7,850
7,900	3,330	6,950	12,900	4,980	6,890	9,300	8,390	10,600	13,100	7,900
7,950	3,350	6,990	13,000	5,000	6,920	9,340	8,450	10,600	13,200	7,950
8,000	3,370	7,040	13,100	5,030	6,960	9,390	8,510	10,700	13,300	8,000
8,050	3,390	7,090	13,200	5,050	6,990	9,440	8,580	10,800	13,400	8,050
8,100	3,420	7,140	13,300	5,080	7,030	9,490	8,640	10,900	13,500	8,100
8,150	3,440	7,180	13,300	5,110	7,070	9,540	8,700	11,000	13,600	8,150
8,200	3,460	7,230	13,400	5,130	7,100	9,590	8,770	11,000	13,700	8,200
8,250	3,480	7,280	13,500	5,160	7,140	9,630	8,830	11,100	13,800	8,250
8,300	3,510	7,320	13,600	5,180	7,170	9,680	8,890	11,200	13,900	8,300
8,350	3,530	7,370	13,700	5,210	7,210	9,730	8,960	11,300	14,000	8,350
8,400	3,550	7,420	13,800	5,230	7,240	9,780	9,020	11,400	14,100	8,400
8,450	3,570	7,460	13,900	5,260	7,280	9,820	9,080	11,400	14,200	8,450

Arkansas River Water Needs Assessment



Section 5. Natural Resource Assessment

By:

Clay Bridges, Bureau of Land Management
Mark Elkins, Colorado Division of Wildlife
Dave Gilbert, Bureau of Land Management
Greg Policky, Colorado Division of Wildlife

Arkansas River Water Needs Assessment

Section 5. Natural Resource Assessment

By:

Clay Bridges, Bureau of Land Management
Mark Elkins, Colorado Division of Wildlife
Dave Gilbert, Bureau of Land Management
Greg Policky, Colorado Division of Wildlife

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding river-flows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Section 5. Natural Resource Assessment

Resource Values

The purpose of this section is to describe the aquatic and terrestrial biota found in and associated with the Upper Arkansas River Basin and its associated reservoirs, and to highlight those species and their life stages that are either dependent on flow (river) or water elevation (reservoirs). The resource values are considered by habitat type: the Arkansas River corridor, the coldwater upper reservoir systems (Twin, Turquoise, and Clear Creek), and the warmwater lower reservoir system (Pueblo). The relationship of specific resource values to water is evaluated using data from a number of reports and studies that are listed in the references at the end of this chapter. Some of the relevant information used in this section is general in nature and was obtained from published reports on species life histories, habitat, freshwater ecology, limnology, and hydrology. Other data is specific to actual data collections and studies completed within the Upper Arkansas River Basin by the U.S. Bureau of Land Management (BLM), U.S. Bureau of Reclamation (BOR), U.S. Forest Service (USFS), Colorado Division of Wildlife (CDOW), and Colorado State University (CSU).

Aquatic and terrestrial habitat varies considerably within the study area. Elevations range from almost 10,000 feet above sea level at Turquoise Reservoir to less than 5,000 feet at Pueblo Reservoir. The terrain consists of mountainous topography in the upper basin, canyon reaches along the upper river corridor, and a rolling valley plains ecosystem below Cañon City. Dominant vegetation consists of conifers in the mountains, riparian vegetation such as cottonwoods and willows within the river corridor, and pinon/juniper on the river uplands. The river is characterized by six distinct aquatic habitat types that are defined by river geomorphology. These habitat types are intermixed within the study area.

The complexity of river habitat and landforms provides a rich diversity of wildlife within the basin. Approximately 25 fish species have been identified by the Colorado Division of Wildlife (CDOW) as inhabiting the study area. These include members of the trout, minnow, catfish, bass, and perch families. Terrestrial wildlife species range from amphibians and reptiles, to a variety of mammals and birds. There are a number of species within the study area that are Federally listed as threatened or endangered, including the greenback cutthroat trout, bald eagle, peregrine falcon, and Mexican spotted owl. The only State listed wildlife species occurring in the study area are the southern redbelly dace and possibly the boreal toad.

The resource values evaluated were selected based on their importance to the ecology of the Arkansas River Valley and to users of those resources, and on their perceived dependence on riverflows or reservoir water elevations/fluctuations. The resource values considered were:

Fisheries

~ Lake trout, rainbow trout, and primary/secondary production (Twin, Turquoise, and Clear Creek Reservoirs)
~ Black bass and crappie (Pueblo Reservoir)
~ Brown and rainbow trout (Arkansas River)

Wildlife

~ Waterfowl (all reservoirs)
~ Raptors, including bald eagles, golden eagles, osprey, and peregrine falcons (river and reservoirs)
~ Wading birds and shore birds (river and reservoirs)
~ Bighorn sheep (river and reservoirs)
~ Amphibians and reptiles (river and reservoirs)

Riparian Wetlands

~ Riparian woody species (Arkansas River)
~ Shoreline vegetation (reservoirs)

Fisheries

Coldwater Reservoir Habitat and Biota

Twin Lakes Reservoir and Turquoise Reservoir were constructed and are operated as part of the Fryingpan-Arkansas Project administered by the BOR. Both reservoirs are situated on public lands controlled by the USFS and have recreational amenities including campgrounds, day-use parking and picnic areas, and boat ramps. Twin Lakes Reservoir was formed from two natural mountain lakes on Lake Creek that were enlarged to a single reservoir with two subbasins. The combined reservoir is at an elevation of 9,202 feet and has a surface area of 2,767 acres at capacity. Turquoise Reservoir is a 1,789-surface-acre impoundment located on the Lake Fork of the Arkansas River at an elevation of 9,869 feet. Both reservoirs are considered to be oligotrophic to ultraoligotrophic (low biotic productivity) due to their water source, location within granitic basins, high elevation, and high flushing rates.

Clear Creek Reservoir is located on Clear Creek, north of Buena Vista, Colorado, at an elevation of approximately 8,880 feet. The 439-surface-acre impoundment is operated by the Pueblo Board of Water Works, and is managed as a State Wildlife Area through a lease agreement with the CDOW. This reservoir is not part of the Fryingpan-Arkansas Project, but is an important component of water management within the study area.

Lake Trout

This species is found only in Twin and Turquoise Reservoirs and the populations are supported by natural reproduction and some supplemental stocking. Lake trout are sensitive to reservoir water surface elevations and fluctuations at several stages during their life. Their dependence on water depth is particularly important during spawning, incubation of eggs, and development of young fry, but water fluctuation is also a critical aspect for feeding and for the prey base. This species has been studied extensively in Twin Lakes, but life history attributes are likely similar for lake trout in Turquoise Reservoir (Griest 1976).

Lake trout, or mackinaw trout as they are sometimes called, are highly prized by sport anglers because they are a long-lived fish and can reach substantial sizes. The record lake trout in Colorado is 38.4 pounds. Lake trout older than 25 years are common. Growth rates for lake trout vary due to many factors (e.g., age, strain, location, food, etc.). Carlander (1969) found that the weight of lake trout increases at a rate greater than the cube of the length. He also found that the age of lake trout at first spawn is related to growth rates. Where the growth rate is slow, maturity may not be reached until age 17. With rapid growth rates, males may reach maturity by age 5 and females at age 6. Griest (1977) found lake trout in Twin Lakes to mature over a period of years. In other words, 20.9 percent of age 4 males are mature and 100 percent of males reach maturity by age 7. Comparatively, 8.1 percent of age 4 females are mature and 100 percent of females reach maturity by age 9.

Lake trout select spawning areas in shoreline habitat. Therefore, the success of reproduction and egg incubation is susceptible to water level decreases from October to June. Historically, Fryingpan-Arkansas Project operations during this period are characterized by reservoir drawdown at Twin Lakes and Turquoise Reservoirs. Lake trout are considered lacustrine spawners and spawn during October and November in Twin Lakes (Nolting 1968; Walch 1979). Frequently, this spawn seems to occur with fall turnover. Lake trout broadcast eggs and milt over a spawning bed. The prefer substrate that is cobble, rubble, or boulders with good interstitial spacing, but they have been known to use sand and silt bottoms. Spawning depths in lakes have been reported to range from 5.9 inches to over 180.5 feet (Carlander 1969). Nolting (1968) reported lake trout spawn at 6.6- to 32.8-foot depths and prefer temperatures near 47.3 °F in Twin Lakes. Walch (1979) located spawning lake trout at similar depths, 4.9-39.4 feet, in Twin Lakes. The key to a successful spawn in lakes or reservoirs is that the spawn depths remain below natural or human-caused drawdown levels to prevent exposure of eggs (Bergerson and Maiolie 1981). Successful incubation and hatching of eggs deposited in spawning areas (5- to 35-foot water strata) will be increased by restricting drawdowns from October to March to no more than 10 feet (from October 1 water elevations) at Twin Lakes and Turquoise Reservoirs. Most spawning activity takes place between dusk and 11 p.m. (Carlander 1969). Lake trout do not spawn every year, but may spawn once every 2 or 3 years (Burr 1987). Nolting (1968) reported spawning success in Twin Lakes, primarily on the south shore and in the north Bay. Walch (1979) found spawning lake trout in the eastern two-thirds of the lower lake and found that they did not use the powerplant area. Hatching likely occurs in February or March in Twin Lakes, with fry migrating to deeper water by June (DeRouche 1969).

Between June and October, lake trout are less likely to be directly affected by water fluctuations (however, their food base may be). Lake trout are highly mobile and usually occur wherever water temperatures are favorable. Overall, Walch (1979) determined that, in the summer, lake trout preferred deeper areas of lower Twin Lakes, where the water temperature is cool, and most fish were found within 9.8 feet of the bottom. They were found at depths where temperatures averaged 47.3 50.9 °F in late summer and fall. Few fish moved into water warmer than 53.6 °F, except to forage. Shoreward movements occurred year-round, usually during the day and just prior to sunset in the winter. Most fish exhibiting shoreward movement during the ice-free season were large (over 21.7 inches), while all fish, regardless of size, moved inshore in the winter.

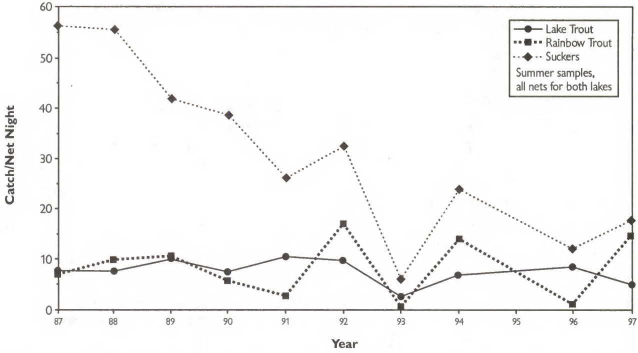
Fish prey for lake trout is limited in both Twin Lakes and Turquoise Reservoirs. This means that primary and secondary productivity is a much more important component for their food base. Literature suggests that lake trout feed on the most abundant food available. As juveniles, they feed primarily on small crustaceans, macroinvertebrates, or small fish, switching to primarily a fish diet as they mature. Griest (1977) reported that lake trout growth rate slowed between ages 5 and 8 at Twin Lakes. This corresponds to a shift in preferred forage. Lake trout less than age 5 utilize zooplankton and macroinvertebrates, and those over age 8 prefer fish for forage. Few lake trout over 16.9 inches (approximately age 6) are present in either Twin Lakes or Turquoise Reservoir. Large forage is not available in sufficient quantity to recruit many lake trout over age 6. This is directly related to the poor productive capacity of these reservoirs, beginning at the lowest trophic levels of the food chain. Water level variability impacts on base production is discussed in more detail below.

A population assessment of lake trout at Twin Lakes indicates that their numbers have declined with water management changes related to operations of the Mt. Elbert pumped storage project. Annual standardized gill net surveys conducted by the CDOW reveal that lake trout numbers have stabilized at low levels, but only with supplemental stocking since 1985 (Figure 5-1). Approximately 20,000, 3.9-inch lake trout were planted annually from 1985 to 1993, with the exception of 1989 and 1991. The number of fingerlings stocked was reduced to 12,000 annually from 1994 to 1996 in response to the lake's decreasing carrying capacity. Hydroacoustic studies conducted by BOR in 1980, 1993, and 1994 also show a decline in the lake trout fishery in Twin Lakes Reservoir after the Mt. Elbert plant began operation (Mueller and Hiebert 1996). Restrictive harvest fishing regulations, regardless of type, have not influenced lake trout size structure, providing further evidence of the impact of environmental/water factors controlling the fish community.

Lake trout numbers have fluctuated considerably at Turquoise Reservoir since 1987 despite steady annual stocking of 16,000, 3- to 5-inch fish, although no fish were planted between 1988 and 1990 (Figure 5-2). There is no lake trout fishery at Clear Creek Reservoir.

FIGURE 5-1

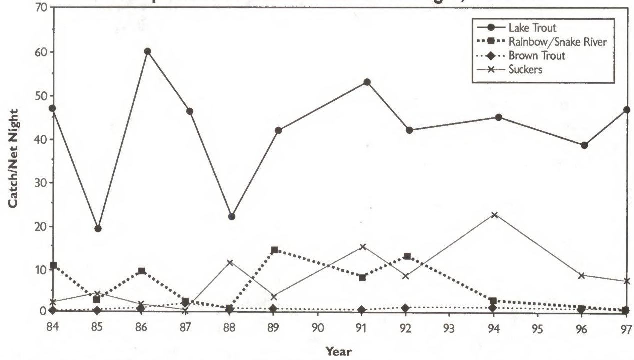
Twin Lakes Reservoirs Catch/Gill Net Night, 1987-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

FIGURE 5-2

Turquoise Reservoir Catch/Gill Net Night, 1984-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

Rainbow Trout

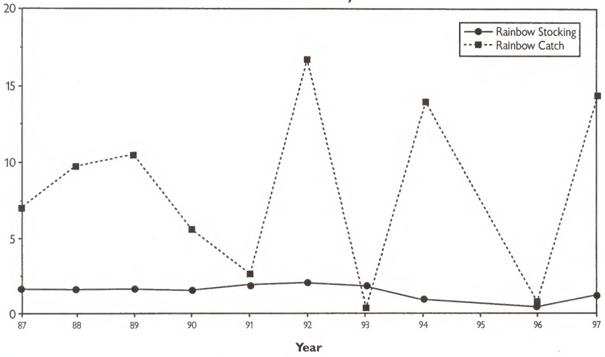
This species is found in all three coldwater reservoirs and is the dominant sport fish. Very little natural reproduction occurs and populations are supported by stocking of catchable (10-inch) and subcatchable (7-inch) fish. These fish are typically stocked regularly during the fishing season from after ice-out (mid- to late May) to September. They are sought by anglers during both the regular fishing season and ice fishing season at Twin Lakes Reservoir and Clear Creek Reservoir.

Rainbow trout feed on zooplankton and invertebrates that are typically associated with the littoral areas of the reservoirs. Water elevation and fluctuation determine the amount of available littoral area and also have some impact on the productivity of those areas for food for rainbow trout. In some instances, the depth of the reservoir outlet is important to the potential loss of fish from the reservoirs.

At Twin Lakes, rainbow trout numbers fluctuated considerably from 1984-1993 based on CDOW gill net surveys (Figure 5-3) in spite of relatively consistent annual stocking of 160,000, 7- to 10 inch fish during this time period. Predation of rainbow trout by lake trout, particularly by older fish, has been documented (Nolting 1968; Griest 1977) and might influence the number of rainbow trout present in any year. Variation in gill net catch of rainbow trout might also be explained by fish escapement from the reservoir (Nesler 1981). Data suggest that fish left the reservoir during high releases and possibly during winter releases when environmental conditions were unfavorable. The low production capacity of the lakes may also contribute to poor overwinter survival. The limited number of fish caught that were larger than the size stocked (longer than 12 inches) is indicative of this condition. Approximately 38,000, 7- to 9-inch rainbow have been stocked annually at Turquoise Reservoir since 1989, but again gill net surveys show considerable variation in catches since that time.

FIGURE 5-3

Twin Lakes Reservoirs Rainbow Trout Stocking (x100,000) Versus Gill Net Catch, 1987-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets when they are retrieved from the lake.

The abundance and size of rainbow trout at Clear Creek, on the other hand, represent a productive fishery with rainbows and a diverse fish community (Figure 5-4). Fish survival and growth is good and trout overwinter well in the reservoir. However, trout are susceptible to flushing out of the reservoir as evidenced by the sampling of reservoir fish downstream in the Arkansas River. Typically trout use the entire water column and can be flushed through the outlet regardless of the surface elevation.

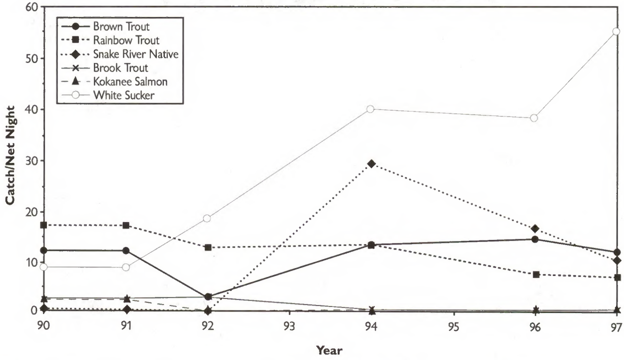
Primary and Secondary Production

The production of phytoplankton (primary) and zooplankton or invertebrates (secondary) is considered the base of the food chain in aquatic ecosystems. Generally, the greater the potential for production of these food sources, the greater the standing crop of fish that can be supported. A simple analogy is the production of cattle, where the lushness of the grazing lands determines the number and weight of livestock produced from a given area of land. Because of the physical, chemical, and geomorphological characteristics of the upper basin reservoirs, they are considered oligotrophic and have a low capacity for base fish food production in terms of phytoplankton and zooplankton. One of the primary determinants of the physical and chemical characteristics of the upper basin reservoirs (and therefore the food production capacity as well) is the water regime. Because the productivity of the reservoirs is already at a low baseline level, factors such as water elevations, timing and magnitude of fluctuation, water temperature, and flushing rate play a particularly critical role in the productivity potential at any point in time.

Primary productivity can be approximated by measuring the amount of chlorophyll biomass (contained in phytoplankton) present in a given volume of water. Chlorophyll biomass has been quantified during 1993-1996 in all three reservoirs from a variety of depths and locations (BOR-unpublished report). The values for chlorophyll biomass are similar for the three reservoirs, ranging

FIGURE 5-4

Clear Creek Reservoir Catch/Gill Net Night, 1990-1997



Note: For sampling purposes, a number of gill nets are set in the lake on the same night each year. The left axis represents the average number of fish from each species found in each of the gill nets, when they are retrieved from the lake.

from 0.6-3.5 µg/m³, and are representative of oligotrophic waters. Secondary productivity is characterized by the species and densities of zooplankton. Larger species, typically represented by cladocerans, are preferred food for planktivorous fish like small rainbow and lake trout. On the other hand, small zooplankters like rotifers can be used as forage, but are not as valuable as a food item.

An indication that primary productivity is affected by water management operations is evident from data at Twin Lakes. Primary productivity, as indicated by chlorophyll biomass, has declined in Twin Lakes with changes in water movement, volume, and fluctuation related to powerplant operation. Chlorophyll biomass for Twin Lakes from 1993-1996 is significantly lower than values determined for the 1977-1985 period, when values ranged from 2.0-7.6 µg/m³ in the lower basin and from 1.4-6.0 µg/m³ in the upper basin. In fact, the recent (1993-1996) August value in Twin Lakes was at, or just above, the minimum value measured during the 1977-1985 period. The euphotic zone in Twin Lakes is subjected to daily mixing by operations of the pumped-storage powerplant. Daily operations can cause the water surface elevation to fluctuate up to 9 feet vertically. Hydraulic retention times in the lakes are significantly less than prior to pumped-storage powerplant operations, even with the overall increase in storage in the reservoir of approximately 15-28 percent behind the new Twin Lakes Dam constructed in 1984. The mean annual storage volume of the lakes from 1977-83 was about 99,000 acre-feet. The mean annual storage from 1984-85 was 129,000 acre-feet, and from 1993-96 was 114,500 acre-feet. A greater storage volume and a decreased hydraulic retention time inevitably mean that flushing of the euphotic zone is occurring at a proportionately higher level than just the computed retention time may indicate. Prior to pumped-storage powerplant operations, the average hydraulic residence time was about 1 year. During the postoperational phase of the previous studies at Twin Lakes and the current studies, the average hydraulic residence time is less than 0.5 year.

During peak runoff in late spring and early summer, both lake basins approach or go below the 30 day residence time that seems necessary for planktonic biomass accumulation to occur at the water temperatures usually prevailing at that time of year (Campbell and LaBounty 1985). Prior to pumped-storage powerplant operations, phytoplankton generally reached maxima in summer, and typically within the euphotic zone, the strata at the top of the reservoir that is characterized by light penetration levels conducive to plant growth. However, after powerplant operations (1993-1996 study period), strong vertical biomass maxima were not commonly seen. Induced mixing of the euphotic zone due to powerplant operations tends to prevent accumulation of biomass along an underwater density gradient, such as a thermocline, particularly in the lower basin.

Currently at Twin Lakes Reservoir, drawdown precedes spring runoff in late winter and early spring, and then water surface elevations are held at higher levels in the summer and fall months, with maximum storage levels generally coinciding with the summer growing season. Production in the lakes may continue to be adversely affected as long as pumped storage powerplant operations continue to cause the water surface elevation to fluctuate daily. The effect of pumped storage operations on productivity is compounded when these operations coincide with large volumes of water passing back and forth between the lower lake basin and the forebay. The effect is also compounded when the pumped storage operations coincide with maximum releases from Twin Lakes to Lake Creek and the Otero Pipeline. The daily fluctuation in water surface elevation also adversely affects the littoral areas around the lakes, providing little vegetation or other habitat in the fluctuation zone and only intermittent feeding habitat for terrestrial insects to some fish species.

Unstable water column conditions favor diatoms and other quick-growing, small-bodied algal species (Reynolds 1984). At Twin Lakes, diatoms dominated each August phytoplankton assemblage in both lake basins throughout the study period, ranging from 42-99 percent of total phytoplankton density in the lower basin and from 52-100 percent in the upper basin. Chrysophycean species, i.e., *Dinobryon bavaricum* or *D. cylindricium*, never comprised more than 26 percent of total phytoplankton densities in the upper basin or more than 19 percent in the lower basin. These levels represent a significant departure from algal dominance patterns observed in Twin Lakes during previous studies (1977-85) in the upper basin, which continued to be dominated by chrysophycean species in mid- to late summer. The upper basin still exhibits strong thermal stratification in midsummer, but diatom-dominated phytoplankton densities prevail, perhaps indicating unstable conditions in the euphotic zone or some other circumstance favoring diatoms over chrysophycean algae.

At Twin Lakes Reservoir, secondary productivity, particularly forage for small trout, is similarly limited as the phytoplankton on which it is dependent. This is an ecological feature where physical and chemical attributes (including water management) influence the entire biotic food chain in the reservoirs. Zooplankton group dominance indicates a very low percentage of cladocerans and a relatively high percentage of rotifers, which are particulate feeders on detritus or small-bodied phytoplankton cells (LeCren and Lowe-McConnell 1980). Cladocerans never comprised more than 22 percent of total zooplankton densities in either basin. In addition, the typical cladoceran species was the small-bodied *Bosmina longirostris* rather than the larger cladoceran *Daphnia* sp. Low densities of cladocerans have been typical of Twin Lakes zooplankton studies. Zooplankton grazing pressure on phtyoplanktonic algae may be partially responsible for the overall low chlorophyll biomass in the lakes, but the overall zooplankton densities for groups other than rotifers and copepodids (immature copepods) were also low, translating into a limited food resource for planktivorous fish in both lake basins. Of concern is the fact that zooplankton densities were highest in the littoral areas between 0-32 feet during daylight hours, and are therefore subject to impact by water level fluctuations and releases.

Primary production in Turquoise Reservoir, like that in Twin Lakes Reservoir, is relatively low. Nesler (1981) reported a range of chlorophyll from 2.2-3.5 $\mu g/m^3$ from June-September 1980. During the study period (summer months of 1994-96), chlorophyll values ranged from 0.8-2.6 $\mu g/m^3$ at the sampling site near the dam, and from 1.5-3.5 $\mu g/m^3$ at the sampling site in midreservoir. This still places Turquoise Reservoir in the oligotrophic category (Likens 1975). The greatest production observed in the study period was in July and August (midsummer). The distribution of chlorophyll biomass, like that in Twin Lakes, is greatest in the euphotic zone. Although Turquoise Reservoir thermally stratifies in the summer, usually between 23-29.5 feet deep, no chlorophyll biomass vertical maxima were ever noted either using the transmissometer, which measures light passing through a 1.6-foot path, nor in chlorophyll samples collected at the 29.5-foot depth interval. Phytoplankton populations were dominated by diatoms or green algae and were comparable in densities to those observed in Twin Lakes. Zooplankton populations were also similar or slightly greater than those observed in Twin Lakes. During midsummer, there are sometimes abundant cladocerans (*Daphnia* sp.) in the 0-32-foot intervals, making them susceptible to water fluctuation at that time.

Clear Creek Reservoir is shallower and has more littoral habitat than Twin or Turquoise Reservoirs, and it is common for the euphotic zone to encompass the entire vertical depth of the reservoir. Although shallow, the reservoir does thermally stratify in midsummer and water temperatures are warmer throughout the water column than in either Twin Lakes or Turquoise Reservoirs, and consequently, it produces more food. For example, phytoplankton populations are usually dominated by diatoms and green planktonic algae; however, chrysophycean and blue-green algae can sometimes form a significant percentage of the total population, which is evidence of increased productivity. Zooplankton populations were generally numerically more abundant in Clear Creek Reservoir than in Twin Lakes or Turquoise Reservoirs. Cladoceran species such as *Bosmina* sp. and *Daphnia* sp. form a small percentage of total zooplankton densities throughout the year (3-13 percent), but since overall densities are greater, these may provide valuable fish food resources.

Other Coldwater Fishery Considerations

Although white suckers were not identified as a resource value (primarily because of their limited value as a sport fish), they are a good indicator species of ecological integrity. Suckers of all ages are omnivores that feed indiscriminately on forage items found in and on bottom substrates in littoral areas. Chironomid larvae, zooplankton, invertebrates, and other organic debris comprise much of their diet (USDI 1993). The dependence of suckers on primary and secondary productivity as forage means that decreases in this food resource negatively impact their survival and growth. In turn, lake trout have some dependency on suckers for food. Since 1987, the number of white suckers in Twin Lakes has steadily declined, based on gill net surveys. Predation by lake trout alone cannot explain the decline, and changes in water management and the resulting impacts to primary and secondary productivity are likely contributors to the decline.

Warmwater Reservoir Habitat and Biota

Pueblo Reservoir is located on the Arkansas River just west of the city of Pueblo, Colorado. This main lower reservoir basin encompasses 4,611 acres and is generally characterized as steep-sided and rocky, and when filled to capacity, has a water depth in excess of 118 feet. Shallow littoral zones are found in the backs of the coves and in the upper end of this reservoir. Soils along most shorelines are shallow, very rocky, and do not provide a quality plant source medium. However, since initial filling of the reservoir, multiyear drawdowns and wind/wave erosion activities have increased shoreline soils in some areas. This improved plant source medium has allowed herbaceous and woody vegetation to vegetate these sites. These areas provide excellent habitat and are primary spawning and nursery areas for black bass, crappie, and gizzard shad (primary forage fish) when inundated.

Water levels at Pueblo Reservoir influence the amount and quality of the shoreline habitat that is critical for the development of black bass (largemouth and smallmouth bass) and crappie, the resource values of interest for the reservoir. Drawdowns of 15-25 feet are most commonly seen from April to October, but major drawdowns have dropped the water level 49 feet below the conservation pool. Depending on the timing and magnitude of these drawdowns, the production of sport fish and forage fish can be affected.

With the development of the Winter Water Storage Program (WWSP), water levels have been beneficial to the development of an excellent warmwater fishery. This annual cycle begins with maximum storage in late March, gradual drawdown to early summer (mid-June), with an accelerated drawdown due to irrigation demands during summer and fall. By mid-November, the WWSP begins and the reservoir fills throughout the winter. This water management scheme coincides with requirements for warmwater fish species that inhabit the inshore areas of Pueblo Reservoir. The biological needs of these species for spawning, fry development, and feeding are dependent on water depth and temperature, water chemistry, primary and secondary production, shoreline plant growth, and prey base development, all of which are influenced by water levels and water movement.

Pueblo Reservoir is managed as a warm-, cool-, and coldwater fishery. The coldwater fishery consists mainly of rainbow trout maintained by annual stocking, with some large rainbows available as older, overwintered fish. The warm- and coolwater fishery is primarily composed of black bass, crappie, bluegill, walleye, wiper, and channel catfish. These species comprise the bulk of the fishery at Pueblo Reservoir. The walleye, wiper, and channel catfish populations are supported by stocking and are least affected by the severe fluctuation, while bass and crappie are not stocked and are dependent on reservoir conditions that allow successful reproduction and growth.

Black Bass

Black bass is a grouping of four species of bass, of which three species, largemouth, smallmouth, and spotted bass, are common in Pueblo Reservoir. Black bass are found in riverine habitats, but prefer and reach maximum potential in a lake environment. Stuber et al. (1982) identify optimal habitat as being warmwater lakes containing large areas of shallow water (≤19.7 feet) that supports submergent vegetation and deep enough (9.8-49.2 foot mean depth) to provide sufficient overwintering habitat. This typical bass habitat in Pueblo Reservoir occurs in the coves and the upper end of the reservoir and most likely comprises less than 10 percent of the surface acres in the reservoir.

Ideal temperatures for growth of adult black bass range from 75-86 °F with very little growth occurring below 59 or above 97 °F (Carlander 1977). Preferred temperatures for fry growth are 81-86 °F. Little fry growth occurs below 59 or above 89 °F (Strawn 1961). Summer temperatures in Pueblo Reservoir tend to run in the 59-77 °F range, although the shallow water habitat in the coves and upper end of the reservoir will commonly reach temperatures approaching 86 °F. Pueblo Reservoir water temperatures are higher and occur earlier in the growing season in years when drawdowns are more drastic. Growth of bass in Pueblo Reservoir is slower than the national average (mean length of 11.8 inches by 4 to 5 years of age), due to the relatively cooler water temperatures and adverse environmental conditions.

Stuber et al. (1982) identified gravel as preferred spawning substrate, usually associated with vegetation, rocks, and trees. However, bass have been found to successfully spawn on vegetation, roots, sand, and/or mud. Successful spawning and incubation takes place between 55 and 79 °F. Stable water levels are important during spawning activities and severe drawdowns typically result in poor survival. Spawning in Pueblo Reservoir takes place in the shallow littoral zones at depths of 3-16 feet from late April to early June. This is generally a period of gradual water-level reduction.

Adult black bass feed primarily upon fish and crayfish, while juveniles consume insects and small fish, and bass fry feed upon microcrustaceans and small insects. The primary forage in Pueblo Reservoir for the bass is various life stages of gizzard shad, crayfish, yellow perch, and numerous macroinvertebrates. Young bass are restricted to shallow water habitat after hatching in early summer and are dependent on the availability of suitable food items within these shoreline nursery areas. At Pueblo Reservoir, these food items (primarily shad fry) reach maximum densities in shallow waters when water temperatures exceed 65 °F and primary/secondary productivity is high.

Crappie

White crappie and black crappie are both found in Pueblo Reservoir, with white crappie being more abundant. Preferred habitat for crappie is medium- to large-sized lakes and reservoirs with moderately turbid to clear waters. Cover, especially aquatic vegetation, is important for quality growth and reproduction (Sigler and Miller 1963). Preferred daytime habitat is dense vegetation around submerged trees, brush, or other objects in shallow water (Edwards et al. 1982a). In Pueblo Reservoir, crappie tend to prefer the areas of flooded timber and brush in the coves and upper end of the reservoir.

Spawning usually begins when water temperatures reach 55-57 °F. With these environmental cues, males move into littoral areas to establish territories and construct nests. Nests are shallow bowl shaped depressions (<23.6 inches) in beds of vegetation located on soft mud, sand, or gravel substrate (Edwards et al. 1982a). Crappie spawning in Pueblo Reservoir usually occurs in flooded vegetation and brush in the backs of coves and in the upper reaches of the reservoir during the months of May and June. Drastic drawdowns during this time have contributed to poor spawning success for crappie in some years.

Edwards et al. (1982b) state that the abundance and quality of food is a limiting factor for crappie.

Adults feed predominantly on fish and planktonic insects. Fry and juveniles feed on microcrustaceans and planktonic insects. Adults and juveniles usually feed over open water. Crappie in Pueblo Reservoir are primarily dependent on gizzard shad for forage once they reach a juvenile life stage. At a young life stage, crappie are dependent on shallow water and vegetation for protection from predation and cannot venture to deeper waters for feeding. Stable water management at this time of year (May and June) encourages warming of surface waters and allows productivity to reach acceptable levels, which in turn attracts forage and benefits crappie fry survival and growth.

Crappie growth and survival is influenced by water temperatures. Water temperature at Pueblo Reservoir, although largely determined by ambient air temperatures, can also be affected by water elevation (amount of shallow water habitat) and water management (flushing rate). Edwards et al. (1982a) state that adult crappie have been found to exist in summer habitat of temperatures of 63-86 °F with a preferred mean around 75 °F. Optimal growth of juveniles was found between 72 and 77 °F. Little information was available on temperature ranges for fry. Edwards et al. (1982a) found optimal embryo survival between 66 and |67 °F, which is within the range of summer temperatures found at Pueblo Reservoir. Growth of crappie in Pueblo Reservoir is slower than the national average (with the average crappie reaching 9.8 inches in approximately 4 to 6 years) because of the relatively cooler water regime.

Other Warmwater Fishery Considerations

Forage fish important to the survival of black bass and crappie in Pueblo Reservoir are bluegill and gizzard shad. Habitat requirements for bluegill are very similar to the requirements of the black bass. Gizzard shad are a pelagic species for most of the year and feed on plankton. Adult shad in Pueblo Reservoir will reach sizes of 11.8-15.7 inches. Adult shad move into littoral zones when water temperatures approach 68 °F (mid-May to mid-June) and spawn on virtually any flooded substrate including brush, vegetation, wood, rock, and gravel. Newly emerged shad fry provide suitable forage for bass and crappie fry in late spring and early summer. Although young shad in Pueblo Reservoir reach 1.2-3.1 inches by July and August, their small size makes them the major forage species through the growing season.

Arkansas River Habitat and Biota

The Arkansas River is noted for its exceptional brown trout fishery and its developing rainbow trout fishery. Surveys conducted by the CDOW document that brown trout are present throughout the Arkansas River study area. Brown trout numbers average about 2,000 fish/mile throughout much of the river, while rainbow trout average about 100 fish/mile. Brown trout are sustained through natural reproduction, while rainbow trout are supported by stocking of fingerling-sized fish.

For the purpose of this study, these two trout species will be emphasized in the river because of their sportfishing value and the amount of information available. Even though the emphasis of this study is towards managing game species, there are a number of nongame species present in the Arkansas River drainage. For example, white suckers, fathead minnows, and longnose dace are found throughout the study area. Most of the nongame fish species (killifish, dace, shiners, etc.) are found in the lower portions of the Arkansas River and/or Pueblo Reservoir (Woodling 1985). Rare species have not been collected in the studied reservoirs or in the main stem of the Arkansas River. It is assumed that flows that protect and maintain game species should be sufficient to protect nongame species.

To analyze the relationship between Arkansas riverflows and available habitat for brown and rainbow trout, the Instream Flow Incremental Methodology (IFIM) developed by the U.S. Fish and Wildlife Service (Bovee 1982 and Stalnaker et al. 1995) was used. This biological model is used to quantify aquatic habitat as a function of stream discharge by measuring actual stream and hydraulic attributes of depth, velocity, and substrate. The results from IFIM can be found in Appendix C. The amount of habitat for each species for each of their four life stages can then be calculated for different flows using the Physical Habitat Simulation System (PHABSIM). The results from PHABSIM can be found in Appendix D. These techniques have been widely used throughout the United States to evaluate the effects of incremental changes in the streamflow on aquatic life, and have been accepted as an appropriate methodology for resolution of many controversial water related issues (Stalnaker et al. 1995).

For the purpose of this study, habitat in the Arkansas River was characterized within six habitat types, which are interspersed throughout the entire study reach (Figure 5-5):

1. Low gradient, moderate widths, cobble substrate with an unconfined channel: This type of habitat can be found between Leadville and Granite and is represented by the Leadville station.

2. Areas of steep gradient, fast water, medium boulder substrate, and a confined channel: The river between Buena Vista and Granite typifies this habitat type. The Numbers IFIM station is within this section.

3. Deep pools, moderate gradient, narrow widths, and large boulder substrate: Browns Canyon is typical of this habitat type and is characterized by the Browns Canyon station.

4. Low gradient, wide, moderate depth riffles, cobble substrate, and islands: The river between Coaldale and Howard is typical of this habitat type and is characterized by the Independent Whitewater station.

5. Moderate gradient, medium boulder and cobble substrate, moderate widths, and pocket water: The river between Texas Creek and Cotopaxi typifies this habitat type and is represented by the Stockyard Bridge station.

6. Stair-stepped, fast water flowing into deep runs, substrate small to medium boulders, with moderate widths: This type of habitat is found between Parkdale and Texas Creek and is represented by the Floodplain site.

Each IFIM site contains a cluster of dependent transects used to characterize the habitat type.

Although IFIM is a well-recognized and widely accepted model to quantify fish habitat and standing crop, historical field data on brown trout collected at the Wellsville site on the Arkansas River from 1981-1996 was also used to establish the relationship between available habitat and fish growth (Anderson and Krieger 1994; Policky - CDOW unpublished reports). Growth of brown trout collected during electrofishing surveys was evaluated in relation to flow levels and water temperatures that the trout had experienced during their lives. The relationships were statistically analyzed to quantify the strength of the correlations.

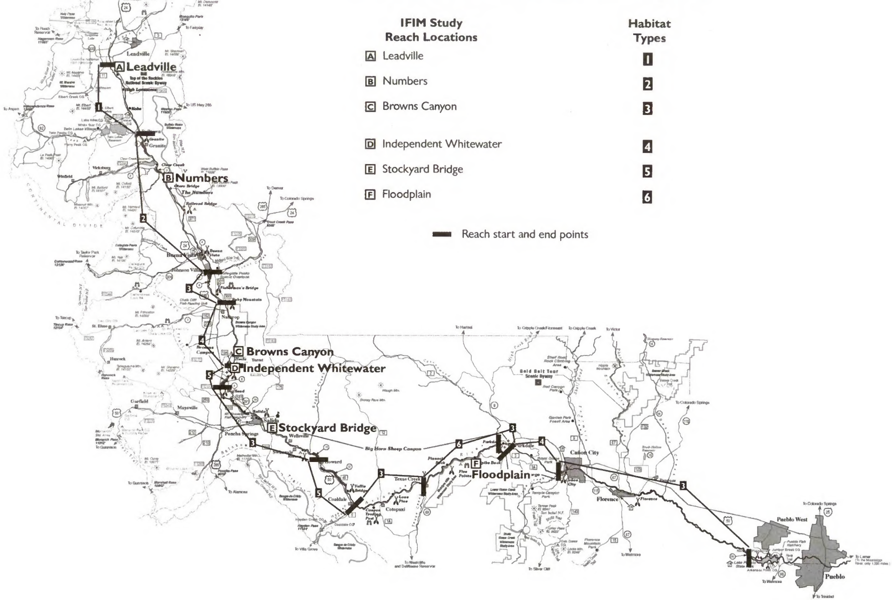
Brown Trout

The quantity and quality of brown trout habitat varies considerably in the Arkansas River depending on water discharge, based on IFIM analysis. Raleigh et al. (1986) identified optimal brown trout habitat as "clear, cool to cold water; a relatively silt-free rocky substrate in riffle-run areas; a 50-70 percent pool to 30-50 percent riffle-run habitat combination with areas of slow, deep water; well vegetated, stable stream banks; abundant instream cover; and relatively stable annual water flow and temperature regimes." Basically, brown trout occupy reaches of low to moderate gradient (<1 percent) in suitable, high-gradient river systems. A base flow ≥50 percent of the average annual daily flow is considered excellent for brown trout production (Binns and Eiserman 1979).

Frost and Brown (1967) established that migration to locate suitable spawning sites begins when water

FIGURE 5-5

Characterization of Habitat in the Study Area



temperatures reach 42.8-44.6 °F. Mansell (1966) found that spawning occurs at 44.6-48.2 °F. Spawning sites are generally located at the head of a riffle or at the tail of a pool and have well defined redds. Reiser and Wesche (1977) observed that brown trout prefer gravel 0.4-2.8 inches in diameter for spawning, with the maximum size related to the size of the spawning female. Allen (1951) found the size of redds varied in width from <11.8 to >42.1 inches. Hooper (1973) constituted a range of velocities from 0.5-3.0 ft/s to be suitable for brown trout spawning. Shrivell and Dungey (1983) established that velocity was more important than depth as a selection criterion for spawning, with a mean velocity of 1.3 ft/s the preferred velocity. Waters (1976) observed optimal water depths for brown trout at redd sites to be 9.6-18.0 inches, with a suitable range of 4.8-36.0 inches.

Brown trout spawn in the Arkansas River from mid-October to mid-November. The amount of suitable spawning habitat (depth, velocity, substrate, and water temperature) is dictated by water discharge existing at the time of spawning. Redds were observed in the upper Arkansas River in late October 1992 during an extensive CDOW survey. Redds were most abundant behind boulders or woody debris, in the tail of pools where the stream bottom is rising, or in glides. These areas correspond to appropriate substrate conditions, water velocity, and depth—all necessary for successful spawning. The lower velocities in these areas encourages deposition of appropriate sized gravel. Side channels and ditch diversions are also being utilized by spawning trout. Most redds were found at velocities above 0.5 ft/s. Redds were generally found at depths between 12.0 and 36.0 inches, but some at depths up to 72.0 inches. Areas with the above characteristics and high redd count include the area around State Highway 291 in Salida and just upstream of Badger Creek. For higher gradient, more confined areas, such as Brown's Canyon and Floodplain, redds were often associated with instream cover or were toward the river's edge. Redds were found where gravel was present and depth and velocity were suitable, but were less numerous in these areas. IFIM analysis at the six sampling locations resulted in quantification of available spawning habitat under a range of water discharge.

Tributary streams can be important spawning areas when favorable spawning habitat conditions exist. These sites may be selected if conditions are unsatisfactory in the Arkansas; however, the majority of spawning occurs in the main stem of the Arkansas River. Cottonwood, Chalk, and Texas Creeks are examples of tributary streams where brown trout spawning is known to occur.

Brown trout eggs incubate from mid-October through March in the Arkansas River. During this period, flows have to be high enough to meet the needs of developing embryos (prevent winter freezing), but not so high that they allow destructive movement of the substrate.

Brown trout hatch and emerge in the Arkansas River from April 1 to May 15. Flows and resulting fry habitat from April through June (snowmelt runoff period) influences fry survival, recruitment success, and resulting year class strength on the Arkansas River (Nehring and Anderson 1986). Nehring and Anderson (1993) reported similar results for 12 other Colorado streams.

Like any salmonid, dispersal of fry takes place immediately after emergence. Mills (1971) found that brown trout fry were aggressive and territorial, and that they distributed themselves to suitable habitat within a week. Wesche (1980) found that both fry and juvenile brown trout prefer shallower depths and velocities <0.5 ft/s, while adults prefer depths $\geq$5.9 inches and a focal point velocity of <0.5 ft/s for resting and feeding. Shuler (1992) and Shuler et al. (1994) reported depths ranging from 2.0-3.0 feet and velocities from 0.9-1.3 ft/s as being optimum for adult brown trout, while juvenile brown trout have optimum depths ranging from 0.9-1.7 feet and velocities from 0.3-0.7 ft/s. Shuler's study was conducted on the Rio Grande River, Colorado, which has a gradient, channel width, elevation, and brown trout population similar to the Arkansas River. Fry habitat for brown trout was one of the life stages quantified by IFIM and PHABSIM analysis.

Cover, which is essential to adult and juvenile brown trout for survival and growth, is dependent on flow. Quantification of habitat for these two life stages within the Arkansas River was part of the output of the IFIM modeling. In general, cover important to brown trout includes such items as instream and streambank vegetation, undercut banks, woody debris, substrate, pool depth, and surface turbulence. Raleigh et al. (1986), based on numerous studies throughout the U.S., found that a cover area of ≥35 percent of the total stream area provides adequate cover for adults, while ≥15 percent of the total stream area is adequate for fry and juveniles. During winter months, substrate particle size of 3.9-15.7 inches provides excellent cover for fry and small juveniles (Everest 1969). Typically adults tend to move into deeper, slower moving water during the winter.

Many researchers have reported on the foraging strategy of brown trout and flow-related impacts on feeding efficiency. They are bottom-oriented (Shrivell and Dungey 1983), visual feeders (Bachman 1984; Ringler 1979; Bannon and Ringler 1986) that use a sit and wait foraging strategy (Ringler 1979). Brown trout are categorized as size-selective feeders, preferring larger prey (Ringler 1979). Generally they feed on terrestrial and aquatic insects until they exceed 10.0 inches in length and then they switch to fish and crustaceans (Hannukula 1969). Winters (1988) suggested the absence of forage fish or large invertebrates may be limiting the size potential of brown trout on the Arkansas River. He found that collector-gatherers dominated the benthos community, while shredding invertebrates were almost nonexistent. Trout fry in the Arkansas River feed predominantly on drifting aquatic and terrestrial macroinvertebrates, while older fish feed predominantly on *Brachycentrus occidentalis* larvae, and all age classes of trout feed on adult chironomids and ephemeropterans when available. Winters (1988) also noted that mean monthly densities of benthic macroinvertebrates were lowest during runoff and highest during autumn. Mean biomass values were also lowest during snowmelt runoff, but were highest in the spring (prerunoff) when large mature nymphs were abundant. Accordingly, brown trout body condition was lowest following snowmelt runoff and was highest before runoff in the spring. Winters' study demonstrates the importance of pre- and postrunoff periods on macroinvertebrate populations and the resulting brown trout foraging efficiency and growth.

Fausch (1984) suggest salmonids select feeding positions on the basis of water velocity characteristics and their food supply in order to maximize net energy gain, and therefore, growth is predictably related to flow. Greater depths and increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects.

Rainbow Trout

The quantity and quality of rainbow trout habitat varies considerably in the Arkansas River depending on water discharge, as determined by IFIM and PHABSIM analysis. Generally, optimal rainbow trout riverine habitat is characterized by clear, cold water; a silt-free rocky substrate in riffle-run areas; an approximately 1:1 pool-to-riffle ratio, with areas of slow, deep water; well vegetated streambanks; abundant instream cover; and relatively stable waterflow, temperature regimes, and streambanks (Raleigh et al. 1984).

Rainbow trout females normally select a redd site in gravel substrate at the head of a riffle or the downstream edge of a pool (Orcutt et al. 1968). Raleigh et al. (1984) found optimal spawning gravel conditions to include ≤5 percent fines; ≥30 percent fines are assumed to result in low survival of embryos and emerging sac fry. Optimal spawning substrate size averages 0.6-2.4 inches for rainbows ≤20 inches long and 0.6-3.9 inches for spawners ≥20 inches long (Orcutt et al. 1968). Raleigh et al. (1984) state that optimal water velocity above rainbow trout redds is between

1.0-2.3 ft/s. Velocities <0.3 ft/s or greater than 3.0 ft/s are unsuitable.

Rainbow trout spawn in the Arkansas River from March to early April. They generally select spawning sites with similar substrate, depth, and velocity characteristics to brown trout (see Brown Trout section above). Typically, they tend to select sites closer to the edge of the river because of higher midchannel velocities during spawning.

Rainbow trout eggs incubate from March to late May in the Arkansas River. Incubation time varies inversely with temperature. Eggs usually hatch within 28-40 days after they were deposited (Cope 1957).

Rainbow trout hatch by the end of May and emerge from the gravel in June in the Arkansas River. This emergence period corresponds to high flows and limited fry habitat, which was supported by IFIM modeling outputs. Fry require shallower water and lower velocities than at other stages of the trout life cycle (Horner and Bjornn 1976). They utilize velocities <1 ft/s, but velocities <0.3 ft/s are preferred (Griffith 1972). Rainbow trout fry overwinter in shallow areas of low velocity, with rubble being the principal cover (Bustard and Narver 1975). Optimal size substrate ranges from 3.9-15.7 inches in diameter (Hartman 1965). Due to limited fry production, rainbow trout populations are supported by fingerling stocking of wild stock from the Colorado River. IFIM analysis at the six sampling locations resulted in quantification of available spawning habitat under a range of water discharge.

Cover is an essential component in rainbow trout streams, and to a large extent determines the stream's carrying capacity. It can be found in two forms: 1) bank cover (vegetation) and 2) instream cover (substrate, turbulence, etc.). Wesche (1980) reports that areas of obscured stream bottom with water ≥5.9 inches deep and velocities of ≤0.5 ft/s will provide important cover. A cover area of ≥25 percent of the total stream area provides adequate cover for adult trout (Raleigh et al. 1984).

Adult and juvenile rainbow trout are opportunistic feeders. Their diet consists mainly of aquatic insects (Allen 1969), but foods such as zooplankton (McAfee 1966), terrestrial insects, and fish are locally or seasonally important (Carlander 1969). The relative importance of aquatic and terrestrial insects to resident stream rainbow trout varies greatly among different environments, seasonally and daily, and with the age of the trout (Bission 1978). Rainbow trout feeding efficiency is affected by water discharge (like brown trout) in the Arkansas River with pre- and postrunoff periods being the most critical times.

As for brown trout, flow regime influences the amount of quality rainbow trout habitat. A base flow of ≥50 percent of the average annual daily flow is considered excellent for maintaining quality habitat, 25-50 percent is considered fair, and <25 percent is considered poor (Binns and Eiserman 1979).

Wildlife

Wildlife values associated with the Arkansas River corridor riparian and wetland habitats, floodplains, and reservoirs are diverse and important in maintaining the ecological stability of this part of Colorado. Species range from amphibians and reptiles to a variety of mammals and birds.

Riparian and wetland areas have been well-documented as the most productive and attractive of all wildlife habitats (USDA 1979). Riparian communities have an importance to fish, wildlife, and recreation which is greatly disproportionate to the acreage of these areas (Brown et al. 1977). Although less than 1 percent of the landscape is riparian vegetation, greater than 80 percent of breeding bird species occur in this vegetation type in the central Rocky Mountains (Knopf 1988). Riparian areas often provide the key resources that support biological diversity both in the riparian area and nearby uplands (USDA 1990).

Riparian and wetland areas (see also Riparian Habitats discussion) are critical for water-dependent terrestrial wildlife species and provide important corridors for movement of wildlife (Bacon 1990). The linear nature of riparian ecosystems provides distinct corridors important as migration and dispersal routes and as forested connectors between habitats for wildlife such as birds, bats, deer, elk, and small mammals (Brinson et al. 1981).

Periodic flooding is one of the most significant phenomena affecting use of riparian ecosystems by fish and wildlife (Brinson et al. 1981). Runoff has been consistently correlated with the kind and amount of vegetation (Miller et al. 1989). Short-term floods (several days) often have little detrimental effect on wildlife; deer mice, tree squirrels, and box turtles apparently take refuge in unflooded sites or trees (Brinson et al. 1981). In contrast, severe flooding (several weeks) temporarily eliminates and may limit resident small mammal populations in a floodplain (Brinson et al. 1981).

Floodflows are not always considered detrimental to wildlife and their habitats; they are needed to improve and maintain the quality of various wildlife species' habitats. While floods cause some destruction of nests and other loss to wildlife and may at times temporally destroy wildlife habitat, the possibility of more serious and irreversible damage to the riparian ecosystem, and thus to wildlife, lies in floodflow reduction and reduced instream flows (Bayha 1983).

Species addressed in this document are those potentially at risk for significant direct or indirect impacts from variations in flow levels of the Arkansas River and water fluctuations in the associated reservoirs described. Some species potentially are subject to human disturbance and the amount and timing of human disturbance is related to flow levels. Disturbance usually involves interactions with humans; however, automobile strikes, vegetation trampling, and other direct effects increase with increased human use.

There are numerous ways in which wildlife express disturbance. These expressions vary seasonally and by species. For waterfowl and many other birds, for instance, spring disturbance may cause abandonment of nest sites prior to, or after initiation of, incubation. Disturbance can flush young of the year, causing them to expend metabolic resources to flee. Ground nests may also be trampled. Mammals such as bighorn sheep are vulnerable to disturbance. Mammals stressed by disturbance can be weakened, and animals of any age are subject to increasing mortality if weakened. The scenarios for potential wildlife harm are difficult to predict without intense, local, species-by-species study.

Unless otherwise noted and referenced, all information in this wildlife discussion has been taken from the Colorado Division of Wildlife's "1983 Colorado Species Data Base - Quick Test Program."

Waterfowl

Canada geese were evaluated because they winter and nest along the Arkansas corridor. This species is most commonly found associated with large reservoirs, meadows, and "small grain" fields. Limited use is made of the river itself. The greatest direct impacts are from hunting and predation on the geese, as well as on their eggs, by predators such as foxes. Indirect impacts result from water fluctuation damage to nests and impacts on food sources.

Canada geese feed on the surface of the water, on aquatic vegetation, and on terrestrial grasses, forbs, grains, stems, leaves, fruits, flowers, and insects. The quality of winter forage has a significant effect on spring reproductive success.

Important periods for geese along the Arkansas River include the breeding and molting period of March through July. Peak nesting occurs around the first of April. Most nests are located within 30 feet of open water, but some may be found up to 300 feet from water. An incubation period of 25-30 days is typical. Paired adults normally reach sexual maturity after 3 years and return to the area where they were fledged. It is important that water levels are not raised quickly during April.

Wood ducks are specialized breeders within the corridor. They nest in cavities from April to July; their preferred nesting habitat is large cottonwood trees. Nests are usually located 30 feet or higher in large trees. Incubation takes 30 days. Hens return to the same breeding area year after year. Periodic high floodflows are needed to maintain nesting habitat, i.e., tree regeneration, as availability of suitable nest sites can be a limiting factor.

The common merganser feeds at various depths below the surface. Food consists of fish, invertebrates, crayfish, and other aquatic life. Mergansers are also primarily tree cavity nesters. Nests are used year after year and may be located up to 200 yards from water. Aquatic, wetland, and cottonwood/willow riparian areas are important habitats for these birds and impacts to these ecosystems would impact merganser populations. The amount, velocity, and quality of water that affects prey species and the ability of mergansers to forage would affect their use of the river and reservoirs.

Raptors

The goshawk is addressed in this document because of its "special concern" status in Colorado. This species is generally considered a bird of the coniferous forests but is actually a habitat generalist and will hunt along rivers and streams, preying on a wide range of 50 or more birds and mammals (Graham et al. 1993).

Goshawk nest from April to July and exhibit a high nest site tenacity (Graham et al. 1993). Nests are located in trees. Limiting factors are prey abundance and availability of suitable nest sites (Graham et al. 1993). Water levels in the Arkansas River are expected to have a minimal impact on goshawk populations unless drastic changes are made.

There is one known bald eagle nest site in the Arkansas River drainage (offsite main stem). There is also considerable winter use along the river and on several of the associated lakes and reservoirs. Bald eagles feed primarily on fish and waterfowl in the aquatic, riparian, and wetland habitats. Trees more than 30 feet from the shoreline are seldom used by eagles on the lookout for fish (Bayha 1983).

Dense cottonwood-willow sites are extremely important to wintering bald eagles for resting, and perching, and roosting (Bayha 1983). Wintering eagles normally arrive in Colorado in late October, and most birds leave by mid-April.

Limiting factors for wintering bald eagles in Colorado include availability of fish, wounded or sick waterfowl, and illegal killing. Bald eagles are highly intolerant of human disturbance within about 800 feet of their roost tree. A buffer of dense riparian vegetative cover extending a 250-foot or more radius around a roost tree helps reduce the negative effects of nearby human activity (Bayha 1983).

Golden eagles are found in many habitats throughout south-central Colorado, but some of the most important habitats are in the riparian and wetland areas. These areas are used for nesting, migration, wintering, and hunting zones. The primary prey species are squirrels, rabbits, and hares with some waterfowl taken in winter, especially on frozen lakes and reservoir. Breeding takes place from March to July; nests are located on cliffs and in large trees.

Important factors that limit the region's golden eagle populations include nest desertion resulting from human harassment, scarcity of prey, and illegal killing of birds. Water-related factors that affect riparian habitats, wetland habitats, or prey species habitats would impact use of the area by golden eagles.

Osprey are closely associated with water and fish. Osprey migrate as far as South America, then return to North America to nest and fledge their young. Breeding takes place between April and July. These birds roost and nest in large coniferous and cottonwood trees, often with their nests overhanging water.

Several factors that adversely affect osprey populations include limited nest sites, low fish numbers, pesticides, and illegal shootings. Any changes in flows that would impact tall conifers and cottonwood trees could affect nesting sites. Abormal water quality or quantity changes could affect the osprey's food sources.

Another predatory bird that breeds in the Arkansas River area from April to July is the peregrine falcon. This bird is listed as "endangered" by the Federal Government. Several "hack sites" have been constructed in the vicinity of the Arkansas River in an effort to establish viable populations within their historic range. This hacking effort has been successful and currently there are nesting birds along the river corridor.

Peregrine falcons feed primarily on birds and find the most rewarding hunting areas in riparian and wetland habitats. Waterbirds, passerines, and other small- to medium-sized birds are preferred. Nest sites are located on small ledges on the sides of steep cliffs. Impacts to riparian and wetland vegetation, as well as water conditions that would affect prey species, would have an affect on peregrine falcon use within this area.

The spotted owl that inhabits the Arkansas River watershed is the southern or Mexican subspecies. This subspecies has been declared a "threatened species" by the Federal Government. This species is not directly tied to the Arkansas River but does use the watershed and canyons of the river's side drainages. Mexican spotted owls feed on rodents, squirrels, reptiles, amphibians, insects, small birds, and spiders. Nest sites are located in canyons, often near the base of steep canyon walls. All known Colorado nest sites have been located on rock ledges or in small crevices.

Shorebirds

Great blue heron use along the Arkansas River corridor is high, but usage locations are dispersed for much of the year. Rookeries (nest colonies) are located on Pueblo Reservoir and near Salida in groves of large cottonwood trees. These areas are considered crucial to maintaining viable populations in this area.

Colonies require a minimum one-half-mile buffer zone that is free of disruptive human activity during the nesting period of mid-March to late July (Bayha 1983). These birds feed on a variety of insects and small fish in the shallow waters and associated mud flats. Frogs, lizards, snakes, and small mammals are also sometimes taken.

Herons are most likely to be affected by changes in flows that destroy large cottonwood trees, reduce habitat of prey species, and reduce the extent of shallow areas for foraging.

American avocets use mud flats and shallow water habitats along the Arkansas River and associated reservoirs. These birds feed on seeds, fruits, and other aquatic vegetation parts, as well as on a variety of insects. Avocets nest on mud flats, sand bars, gravel, and in marshes. Nests are bare ground scrapes and usually contain four eggs, which are incubated over a 24-day period from April through July.

Any action that would seasonally flood nesting habitats, especially after the avocets have begun nesting, or that would disrupt feeding would adversely affect these birds.

Killdeer are closely associated with the Arkansas River's wetland and shoreline habitats for most of their life cycle; some birds inhabit the area yearlong, while others migrate. Killdeer use sand bars and mud flats for feeding and nesting. These birds feed primarily on invertebrates. Killdeer breeding habitat is usually bare sandy ground. Breeding takes place from April to July.

Any activities that limit potential nest sites, destroy existing nests, or adversely affect prey populations would impact killdeer populations.

Spotted sandpipers use wetlands, water surfaces, and riparian areas during the spring, summer, and fall before they migrate south for the winter.

These birds feed on a variety of insects, snails, mollusks, spiders, and other invertebrates.

Spotted sandpipers breed in June and July in many different habitats: on bare soil, sand, rubble, marshes, grass, and woody sites. The birds reach sexual maturity in 2 years. A female mates with two or more males and the males care for the brood.

Activities that make prey and their habitats unavailable to spotted sandpipers and those actions that destroy or make nest sites unsuitable should be avoided.

Dipper

The American dipper is a species with a wide distribution across western North America, but its habitat preferences are flowing rivers and streams. The dipper is totally dependent upon clean riverine ecosystems. Nests are located on logs, bridges, midstream rocks, and streamside gravel beds. The birds breed from late February into July, with most birds bringing off two clutches per year.

The dependence of the dipper on quality water that has predictable flows, especially during nesting season, makes water management crucial for this species' survival along the Arkansas River and many of its tributaries.

Mammals

Bighorn sheep are yearlong residents of the drainage, though they sometimes move seasonally within the overall area. Sheep are primarily grazers, but do utilize shrubs at some times of the year. Bighorns require freestanding water and come to the Arkansas River daily during most of the year to drink and feed on succulent vegetation associated with the riparian zone.

Bighorns breed from November through December and lambs are born in May or June. Lambing grounds are usually the roughest and steepest areas of the bighorn's ranges. Home ranges extend from .25 mile to 2 miles (occasionally more), depending on availability of food, water, living space, and the level of disturbance. Predators, disease, human disturbance, and low quality/quantity of food and water adversely impact this species.

Actions that increase human disturbance, change water quality (or significantly change water quantity), or impact riparian vegetation will affect bighorn sheep.

Amphibians and Reptiles

In contrast to the bighorn sheep, amphibians like the Woodhouse's toad receive little attention or recognition from the general public; they are, however, an integral and important part of the properly functioning riparian ecosystem and are now being recognized as valuable indicators of environmental quality (Brinson et al. 1981). The Woodhouse's toad occupies riparian and wetland habitats along the Arkansas River up to about 7,900 feet. This toad species breeds in the aquatic habitats and spends the rest of its life in a riparian or wetland area. Woodhouse's toads eat a variety of insects, spiders, and centipedes. They breed in May and June and tadpoles hatch within a few days.

Because of their dependence upon aquatic, riparian, and wetland habitats, all actions that affect these habitats will affect Woodhouse's toads. Water temperature and water quality are important habitat elements to manage, as are flows that impact breeding.

Painted turtles are found in lacustrine, littoral, palustrine, and riverine aquatic habitats and adjacent riparian and wetland areas of the Arkansas River drainage (most often found in ponds near rivers and streams). They feed on snails, mollusks, insects, worms, carrion, and vegetation. Feeding occurs in waters with temperatures of 59 °F or warmer. Painted turtles are active from March through November and overwinter in muddy bottoms of ponds that have mud up to 18 inches deep.

These turtles breed in water that is less than 2 feet deep after reaching sexual maturity at about 3 years of age. Painted turtles breed from March to mid-June and may use waters that have temperatures of 50-82 °F. They build nests that can be up to 200 feet from water. Management practices that protect and sustain aquatic habitats, primarily a water table to maintain lowland standing water, will be beneficial to painted turtles.

Riparian Habitats

Riparian and wetland resources receive significant attention from land management agencies (USDI 1991, USDA 1992) and the public because of their limited relative abundance, functions associated with improving water quality and quantity, importance to wildlife, and numerous other critical functions that collectively lead to healthier watersheds. These important features, coupled with the potential for management to alter and disrupt riparian function, dictate careful evaluation prior to undertaking management actions that may affect riparian habitat.

Riparian and wetland resources in the region addressed by this water needs assessment have been greatly modified. A century of road, railway, and dam construction, irrigation, conversion of land to agriculture, urban development, and other modifications have transformed riparian resources. Riparian and wetland resources have been altered as a result of:

1. Vegetation Manipulation - land use activities such as recreational vehicle use, grazing, and introduction/invasion of exotic vegetation.

2. Watershed Alteration - land use activities such as road construction, logging, and grazing affect infiltration, runoff, sediment supply, and water quality.

3. Direct Modification - channelization of streams, draining or filling of wetlands, and conversion to other uses.

4. Hydrologic Alteration - water diversions, water importations, and dam construction.

The Arkansas River's riparian and wetland areas have been altered by all the modifications listed above. Understanding these changes is essential when evaluating recommended flow management scenarios. It is important to realize that all future modifications will be acting upon a system that has already been greatly modified.

Because this study deals with potential modification of the existing hydrologic regime, it is crucial to link hydrology to the ecology of the riverine environment. Changes to riparian areas and wetlands will affect other resources that depend upon properly functioning riparian and wetland areas.

Description of Riparian and Wetland Resources

The extent of riparian and wetland resources within the study area is determined to a large degree by natural geomorphology. Much of the Arkansas River is bounded by rock, narrow, and confined due to its landform. Many reaches that were confined naturally are now even more confined as a result of highway and railroad construction. The rocky, narrow canyon topography, coupled with high spring flows, limits soil development and plant establishment. In less confined reaches, meander bars and streamside floodplains have a limited band of riparian vegetation. For example, downstream of Cañon City, and for a short reach between Leadville and Granite, the river features a well-developed floodplain with substantial acres of riparian vegetation.

The majority of the riparian and wetland vegetation along the Arkansas River is composed of grasses, sedges, rushes, willows (several species), alders, birch, and cottonwood. There are limited amounts of emergent or submergent shoreline vegetation. The combination of cool temperatures, lack of nutrients, and high flows limits aquatic macrophytes. Kittel et al. (1996) provide an excellent description of community-based riparian and wetland resources in the Arkansas River Basin.

Based on the channel classification system of Rosgen and Silvey (1996), most of the Arkansas River is classified as either a "B" or "F" channel type. There are small areas that are classified as "C" channel types. The predominant channel types (B and F) are not well-suited for the development of extensive riparian and wetland vegetation. From a geologic standpoint the river is incised in pre-Cambrian rock, except for downstream of Cañon City and the reach between Leadville and Granite. Below Cañon City, and just below Leadville, the river flows through sedimentary/alluvial outwash materials that allow floodplain development.

General River Hydrology, Riparian and Wetland Resources

Because of the constricted nature of the channel, the annual flow regime greatly affects riparian and wetland resources. Flows at bankfull and higher increase depth much faster than width compared to unconfined river systems. Bankfull flow (1.5-year high-flow frequency) and higher, less frequent peak flows scour the channel of fine sediment deposits and vegetation. Discharges at bankfull flow (i.e., the riparian vegetation line in many reaches) are 2,000-2,200, 2,300, 2,500, and 3,000 cfs for the Numbers, Browns Canyon at Hecla Junction, Wellsville, and Floodplain cross sections, respectively. There is a large separation between bankfull stage and lower base flows, which leaves a large expanse of rock between base flow levels and the riparian and wetland vegetation line. Late summer water surface elevations, for example, are substantially below the riparian and wetland vegetation line for much of the study area. The growing season water table, however, is linked to established riparian and wetland communities.

Reservoir Riparian and Wetland Resources

Reservoir operations largely dictate the composition of the reservoir riparian and wetland communities. Operation procedures differ substantially from reservoir to reservoir. The upper reservoirs, Turquoise, Twin Lakes, and Clear Creek, tend to be near full pool early in the growing season. This operation schedule supports a narrow band of wetland vegetation along the reservoir shoreline, except where bedrock is the dominant substrate. Wetland vegetation is also found at inlet areas in response to the delta effect and sediment deposits. Shoreline areas at the mouths of tributaries, and areas with substantial hillside toe-slope moisture, also support wetland communities. The upper reservoirs are usually full and spilling through runoff. Drawdown begins in late summer. Drawdown occurs prior to plant dormancy; however, the water needs of plants are reduced late in the growing season, when drawdown leads to lowering of the water table. The wetland vegetation communities at these high elevation reservoirs have evolved to survive the water management timetable.

Operation procedures for Pueblo Reservoir are very different. Timing of annual full pool is variable, depending on snowpack, and is rarely at maximum. During dry periods, existing wetland vegetation dies because of separation from the water table. When the dry period ends, filling to a higher level inundates recently established low lake level shoreline vegetation. Unlike the upper reservoirs, drawdown at Pueblo Reservoir coincides with the growing season, so even in relatively stable years, the water table separates from the vegetation before plants become dormant. Even though there is substantial wetland vegetation at Pueblo Reservoir, the community is not stable. The reservoir supports substantial riparian vegetation around the inlet due to a large delta effect. Standing dead cottonwood trees in the shallow inlet area, which are important for bird populations, are remnants of trees living prior to reservoir construction. These trees are not regenerating and will topple over time. Younger trees are establishing at the upper inlet margin.

Hydrologic Concepts Related to Riparian and Wetland Resources

Numerous site-specific variables determine the composition of a riparian or wetland community

(Nilsson 1982). The geomorphic setting, soils, land use, climate, discharge, and a host of other factors are important. The timing, duration, and magnitude of discharge are of major importance to the riparian community. Risser and Harris (1989) discuss riparian studies and point to the difficulties, inconsistencies, and inherent problems related to transferability of results from one location to another. The unique setting of each riparian area makes transferability of results unreliable. Risser and Harris (1989) note, however, that common ecological principles apply almost everywhere. Without intensive local study, it is difficult to predict how flow modification in the Arkansas River will affect riparian community composition. However, established ecological principles and existing studies can be used to predict how the riparian community will respond to different flow regimes.

There has been considerable research on the effects of flow reduction on riparian and wetland resources (Szaro and DeBano 1985; Smith et al. 1991; Kondolf et al. 1987). The results of these studies document the effects of diverted water or reduced flow on riparian communities. Other studies discuss altered hydrograph scenarios, common in this region of the country, whereby peak flows are reduced and annual low flow is raised (Risser and Harris 1989; Petts et al. 1995). Response to reduced peak flows and higher annual flows below reservoirs is well-documented, typically resulting in encroachment of riparian vegetation.

Research on flow reduction shows that reduction in annual or growing season discharge affects foliage basal area, foliage density, water table, and width of the riparian area (Reily and Johnson 1982; Stromberg and Patten 1990, 1991). Other variables that change in response to alteration of the hydrograph are sediment characteristics (e.g., sediment size), water temperature, and inundation/saturation regimes. Each of these variables directly influences riparian vegetation. Winter flow changes alter icing patterns, which change (by physical actions) riparian and wetland disturbance patterns. Reduction of peak flows causes riparian and wetland vegetation encroachment into the channel, thereby reducing stream width (Risser and Harris 1989, Petts et al. 1995). Many of the past investigations document effects when flows are reduced during partial or extreme dewatering situations; fluctuating flow scenarios are less studied.

There have been few studies of riparian and wetland response to increased late summer flow. Stabler (1985) reports increased summer flows resulted in beneficial effects to riparian vegetation when grazing practices were modified and flows increased. Similar beneficial effects related to beaver dams and increased flows have also been documented (Wilen et al. 1975). In these increased flow studies, stream size has been relatively small, certainly much smaller than that of the Arkansas River.

Inference to the Arkansas River

Studies show that reduced flow, particularly during the growing season, has a negative effect on riparian and wetland vegetation. Conversely, a likely assumption is that extended high flows during the growing season would benefit plant basal area, foliage density, and other factors, which collectively determine a riparian area's extent and functioning condition. However, it is difficult to transfer results of actions from one riparian area to another. Soil moisture, bank erosion rates, and water table levels are just some of the variables to consider when flows are modified. Flow manipulations will likely cause an evolution to a new riparian community, with a different width and composition. An action perceived to enhance vegetation could erode streambanks and ultimately limit the vegetation extent.

The Arkansas River is rocky and subject to high scouring flows. Since most of the study area does not have well-developed floodplains, riparian community composition and extent are governed by channel geomorphology and high flows. Extended high base flows in the upper Arkansas River will likely further erode sediment deposition areas, and may **slightly** raise the water table in areas that are not solid rock.

Channel profiles for the sampling sites in this study yielded "grassline" elevations that match flows of 2,000 cfs and higher for upstream reaches, and 3,000 cfs for the floodplain reach. Although there is a clear separation between bankfull vegetation and late summer flows, elevated summer flows do have the potential to inundate plant roots in some areas.

Flow Effects on Riparian Vegetation

The upper Arkansas River has relatively little riparian or wetland vegetation as a result of its channel type and geomorphology. The scarcity of riparian and wetland vegetation in the Arkansas River basin increases the importance of properly maintaining or enhancing existing riparian and wetland areas. Riparian vegetation is controlled by high flow events and the elevation of riparian vegetation is generally separated from lower base flows. Riparian and wetland communities have adapted to the historic hydrograph, which incorporates natural flow variability. Fluctuations in late summer flows within this natural variability are unlikely to cause obvious changes to the riparian or wetland communities, unless they are consistently higher or lower than average. Extended high flows will serve to erode banks and widen the channel in areas with depositional features. In areas that are largely rock or confined, increased flow will raise water surface elevations slightly, but water levels will still remain below the streambank grassline. In other less confined reaches, riparian areas will widen in response to the increased flows. However, these gains will likely be offset by loss of riparian vegetation in areas where banks have eroded.

Reservoir operations play a key role in determining the structure of adjacent riparian and wetland communities. Different reservoir operating plans result in different vegetation communities. Significant changes in reservoir operations will alter the corresponding vegetation community. Composition of future reservoir riparian communities are tied to water levels and timing of drawdown.

Analysis of Water Preferences

Fisheries

Coldwater Reservoirs

Twin, Turquoise, Clear Creek, and Pueblo Reservoirs have been studied extensively by the Bureau of Reclamation Research Section, the Division of Wildlife, and graduate students from Colorado State University. Numerous studies are cited in the Resource Values - Fisheries discussion that provide a basis to examine fish populations, and the base production on which they are dependent, in relation to water levels. Using this information, some conclusions have been formulated that present water level requirements for maintaining aquatic biota.

To provide optimal habitat for lake trout, rainbow trout, and primary/secondary productivity, which supports the food chain, an ideal water level management plan for the upper coldwater reservoirs would be to maintain full reservoirs (top of the conservation pool) year-round and stabilize water levels, particularly from July to October, with no daily fluctuation.

Water operations that entail significant changes in water elevations or flushing rates do not present conditions that allow establishment of a sustained fishery. For example, current operation of Twin Lakes during the summer induces mixing of the euphotic zone (top 30 feet of water), particularly in the lower lake, on a daily basis. This daily mixing disrupts physical and chemical conditions that limit plankton reproduction, prevents vegetation from establishing in the littoral areas around the lake, and thus decreases primary and secondary food production. Thermocline development occurs at the lower level of this euphotic zone and is an important feature for holding warmed water near the surface during the summer months. Disruption of this water stratum by drawdown or by increasing flushing rates directly limits biotic food production and fish feeding. It follows that the greater the disruption (in vertical feet drawdown or volume of flushing), the greater the decrease in overall biotic production and fishery potential. Lake and rainbow trout are dependent upon primary and secondary producers for a food base, and decreases in this food base will negatively impact the survival and growth rates of trout. Where these conditions continue, the establishment, development, and management of reservoir trout fisheries will be limited. If water evacuation is necessary, particularly during the critical summer period (July to October), incremental invasion of the littoral zone within the top 30 feet will result in proportionally greater impacts to sustaining aquatic life.

If water releases are necessary during the fall and winter, restricting drawdowns from October to March to no more than 10 feet (from October 1 water elevations) at Twin Lakes and Turquoise Reservoirs will increase the successful incubation and hatching of lake trout eggs deposited in spawning areas.

Shoreline habitat for fry and juvenile lake trout at Twin and Turquoise Reservoirs increases with higher water levels in the spring. Stabilizing or increasing water levels from March to June allows these littoral areas to provide food and cover for fry and juveniles until they are ready to move to deeper water.

Of the three reservoirs, Clear Creek is the most productive due to its shallow basin and warmer water. Clear Creek Reservoir also does not experience the continuous water level fluctuations seen at Turquoise Reservoir, and more notably at Twin Lakes, and this benefits productivity as well. As a result, Clear Creek Reservoir shows better year-round trout survival and growth. Nonetheless, with incremental drawdown from full pool, the loss of production within the euphotic zone (basically the entire water column) and the physical loss of rainbow trout due to emigration increases. This loss is likely to increase as the water surface elevation drops due to the proximity of the outlet to the warmer and more nutrient-laden surface waters. Flushing rates also will increase with proportionally greater drawdown and less reservoir volume.

Warmwater Reservoir

Pueblo Reservoir, located in the lower reaches of the Arkansas River study area, provides habitat for several warmwater species of fish that may be affected either positively or negatively by water fluctuation. Two groups of these species (black bass and crappie) were selected as resource values for assessment because of their dependency on water level and fluctuation. Based on information summarized in the Resource Values discussion, the following water management plan optimizes fishery values in Pueblo Reservoir:

1. Fill the reservoir to the top of the conservation pool (4880 feet) from November through March.

2. Maintain a full reservoir pool from March to July 15.

3. Draw down approximately 10-20 percent of surface acreage of the reservoir from July 15 to August 15.

4. Maintain stable water levels from August 15 to November 1.

This water level fluctuation plan holds a variety of benefits to the fishery in Pueblo Reservoir. Filling the reservoir in the late fall and winter allows for the inundation of vegetation and the shoreline, which will provide food, cover, and spawning areas in the spring. The stable water level during the spring and early summer allows for good spawning habitat, high plankton levels to feed fry, and cover for adults, juveniles, and fry during this period. A drawdown in mid-July to mid-August exposes the shoreline for recolonization of vegetation and concentrates forage species for maximum utilization by sport species for growth.

The fluctuation plan presented for Pueblo Reservoir is a fairly standard warmwater fluctuation plan for reservoirs across the United States. Hall and Van Den Avyle (1986) stated that because plants support bacteria, zooplankton, benthos, and fish, effects of water level changes on primary production can greatly influence responses at higher trophic levels. Additions to the plan could include seeding of exposed shoreline with ryegrass or wheat to enhance vegetation growth. Groen and Schroeder (1978) showed an increase in walleye, white crappie, white bass, and gizzard shad as a result of this type of water level management plan.

Conversely, a water level management plan that includes rising water levels in late summer and downward fluctuations in spring and early summer has been shown to have adverse effects on sport fish populations. The dewatering of spawning areas can result in abandonment of nests by adult crappie, which can result in increased predation of eggs. Spring drawdowns can dewater black bass redds and eggs and result in weakened or failed year class survival. High water levels in late summer could reduce foraging efficiency and growth of sport fish, as well as preventing establishment of habitat conditions necessary for optimum spawning activities during the following spring spawning season.

Arkansas River

Each life stage of a fish (spawning, fry, fingerling, adult) has specific habitat requirements that can be defined by three values: depth, velocity, and substrate. By physically measuring these three attributes and using IFIM to analyze the data and essentially "map" a cross-section of a stream, the amount of habitat suitable for various life stages of trout can be predicted.

The discharge of a stream, of course, alters all three of these attributes. As discharge changes, so does the water depth, water velocity, and possibly the type of substrate inundated. Therefore, the defined habitat for trout also changes with flow. The amount of habitat for each trout species and each life stage can be quantified for any stream discharge using PHABSIM and compared with habitat suitability curves for each species. These two model components link the physical habitat to the biological habitat requirements of the fish, and result in a model output that quanitifies fish habitat in units called "weighted usable area" (WUA).

Habitat modeling was accomplished during the fall of 1996 using PHABSIM (Milhous et al. 1989) for each of the six study reaches. Water surface elevations and velocities were simulated for flows ranging from 350-2000 cfs. The habitat suitability information used for the Arkansas River was originally developed from the South Platte River. The spawning and fry data were developed in 1987 (Nehring and Anderson 1993). The juvenile and adult data utilize substrate codes instead of cover codes because habitat utilization was not verified on the Arkansas River. Also, velocities and depths were adjusted for juveniles and adults to reflect habitat verification studies on the South Platte River in 1988 (Nehring personal communication 1997; Shuler 1992; Shuler and Nehring 1994; Shuler et al. 1994). These curves have been widely applied in Colorado and transferability has been proven to be reliable (Nehring personal communication 1997; Thomas and Bovee 1993). Table 5-1 is an example of output from this modeling process.

The data in Table 5-1 shows that habitat is optimized for adult brown trout at the Floodplain site at 350 cfs, when 49 percent of the total habitat is available. When flows increase to 900 cfs, almost half of the available adult habitat at the Floodplain site is lost (reduced to 29 percent).

Table 5-2 lists the optimum flows for brown trout and rainbow trout life stages of spawning, fry, juvenile, and adult for the six IFIM sites. Modeled data was then reviewed relative to the percent of habitat present with varying discharge to determine flows where habitat is limited for a life stage. These instances are marked with the symbol ¿ in Table 5-2. For example, the optimum flow for brown trout spawning at the Floodplain site is

TABLE 5-1

Weighted Usable Area (WUA) for Adult Brown Trout at the Floodplain Site

Discharge (cfs)	WUA (square feet) by Cross Section				Total WUA	% WUA	WUA/1,000 ft River Length
	2	3	4	5			
350	7,350	4,344	1,241	4,496	17,431	.49	27,890
450	6,845	4,143	1,143	5,040	17,171	.46	27,474
540	6,302	3,682	1,095	5,056	16,135	.41	25,816
630	5,788	3,410	1,057	4,625	14,880	.37	23,808
730	5,279	3,103	987	4,158	13,527	.34	22,352
900	4,665	2,580	795	4,158	12,198	.29	19,517
1,200	3,573	2,025	585	3,553	9,736	.21	15,558
1,630	2,634	1,586	611	3,375	8,206	.17	13,130
1,850	2,362	1,406	623	3,092	7,483	.15	11,973
2,000	2,156	1,316	628	3,149	7,249	.15	11,598

TABLE 5-2

Arkansas River Optimum Water Discharge for Fisheries

IFIM Station/ Species	Trout Life Stage/Discharge (cfs)			
	Spawning	Fry	Juvenile	Adult
Floodplain:				
brown trout	1850⇦	540⇦	350	350
rainbow trout	1850⇦	540⇦	350	450
estimated flow	377	377	377	377
Stockyard Bridge:				
brown trout	300	356	356	500
rainbow trout	356	300	300	600
gaged flow	300	300	300	300
Independent Whitewater:				
brown trout	250	400⇦	250	327
rainbow trout	250	400⇦	250	400
estimated flow	246	246	246	246
Browns Canyon:				
brown trout	250	250	250	357
rainbow trout	250	250	250	357
estimated flow	246	246	246	246
Numbers:				
brown trout	210	500⇦	210	350
rainbow trout	210	500⇦	210	500
estimated flow	131	131	131	131
Leadville:				
brown trout	100	500⇦	100	100
rainbow trout	100	300⇦	70	100
estimated flow	28	28	28	28

⇦ denotes flows where limited habitat is available for a life stage

Note: "Estimated flow" means the estimated flow at that site when the gaged flow at Stockyard is 300 cfs. This relationship between flows at various sites is described in the Hydrologic Analysis section of this report.

1,850 cfs, but only 0.14 percent of the total habitat is spawning habitat. Accordingly, Arkansas River flows should not be managed to gain this small amount of spawning habitat at Floodplain while sacrificing habitat for other life stages and species in the rest of the river.

Modeling a river with a variety of habitat types typically results in major conflicts between key species and their life stages. This was not the case for the Arkansas River. Optimum flows for both brown trout and rainbow trout at various life stages were similar (Table 5-2). Optimum flows also matched well within the entire study area. For example, habitat at the other IFIM stations is near optimum when gauged flows at the Stockyard Bridge site are 300 cfs (Table 5-2).

Managing the Arkansas River fisheries requires more than identifying optimum flows. It requires balancing flows for key species and their life stages during certain times of the year while accounting for natural flows like runoff. When comparing the modeled data (relative to percent of habitat present) with optimum discharge, a secondary inflection point, where habitat significantly drops, was observed in most cases. For example, in Table 5-1, a significant decline in percent WUA occurs from 450-540 cfs (5 percent). From this, a range of optimum flows was established from 350-450 cfs for brown trout adults at the Floodplain site, which is also illustrated in the habitat versus discharge relationship figures in Appendix C. This exercise was accomplished for all life stages of both brown trout and rainbow trout at all IFIM sites. When optimum flow ranges at the Stockyard site are extrapolated to the other sites, the resulting discharges consistently protect all life stages and species at that site (Table 5-2). From this, the following ideal range of flows was established for the Arkansas River, measured at the Wellsville gauge. Brown trout are the focus of this water needs analysis because they are more prevalent than rainbow trout and they are self-sustained. Rainbow trout habitat will also be optimized as follows, except for fry during runoff, a period where little flow management exists (see the Resource Values discussion).

Period: October 15-November 15
Flows: 250-450 cfs (optimum)

This is the spawning period for brown trout. All efforts should be directed at maintaining steady flows within the range indicated. Best survival will occur if spawning, incubation, hatching, and fry emergence flows are similar.

Period: November 16-March 31
Flows: 250-450 cfs (optimum)

This is the egg incubation period. At least 60 percent of the spawning flow should be maintained to prevent egg desiccation from dewatering of spawning redds.

Period: April 1-May 15
Flows: 250-450 cfs (optimum)

This is the egg hatching and fry emergence period, and is the most critical period concerning fry survival. All efforts should be directed at maintaining steady flows within the range indicated. Fry are especially vulnerable to flows above this range due to their inability to withstand high velocities.

Period: May 16-May 31
Flows: 250-450 cfs (optimum)

This is the period of fry development and their continued protection from flows above this range is important for survival and growth prior to runoff.

Period: June 1-July 15
Flows: 250-450 cfs (optimum)

This is the runoff period where little flow control exists. The fishery could tolerate additional flows above runoff for a short period. This is preferred rather than releasing extra water earlier (April 1-June 1).

Period: July 16-October 14

This is the most critical period concerning trout growth. It is preferred that flows return naturally to base flow or 250 cfs, whichever is greater.

Managing the Arkansas River for brown trout and rainbow trout also requires following some general guidelines:

1. Dramatic fluctuation should be avoided as much as possible (limit the daily change to 25 percent).

2. Every effort should be made to avoid violating the April 1-May 15 flow period recommendation.

3. The following priority ranking should be considered in case of unexpected high snowpack and possible violation of the April 1-May 15 flow recommendation:

   a. Increase flows November 16-March 31 up to 500 cfs.
   b. Increase flows May 16-May 31 up to 500 cfs.
   c. Increase flows June 1-July 15 up to the channel maintenance flow.

4. The following priority ranking should be considered in case of unexpected low snowpack:

   a. Decrease flows June 1-July 15 to the channel maintenance flow.
   b. Decrease flows May 16-May 31 to base flow or the 60 percent rule, whichever is greater.
   c. Decrease flows November 16-March 31 to base flow or the 60 percent rule, whichever is greater.

Fish habitat has an optimum value at a certain velocity and depth, the most important habitat variables on the Arkansas River. As velocity and depth values move further from the optimum, it becomes less likely that a trout will occupy that location in the river. Currently, high flows frequently produce unfavorable habitat conditions in the Arkansas River. As flow increases above 400 cfs at Wellsville, depth and velocity increase disproportionately compared to width. Velocity accounts for large drops in suitable habitat, particularly for small fish. This phenomenon is even more pronounced in more confined river reaches. High velocity is generally recognized as the most critical variable in microhabitat selection by lotic trout (Jenkins 1969; Bachman 1984; Fausch 1984; Shrivell and Dungey 1983). Fausch (1984) and Bachman (1984) point out that brown trout occupy positions in a stream that maximize net energy gain during foraging. The potential profitability of a specific position should be predictably related to growth of a fish (Fausch 1984), and therefore, profitability is also a function of flow. Many authors have suggested the carrying capacity of a stream may be determined by available habitat and number of foraging sites (Chapman 1966; Hunt 1969; Bachman 1984).

Although IFIM is a well-recognized and acceptable model, historical field data on brown trout collected at the Wellsville site on the Arkansas River from 1981-1996 was also used to establish the relationship between available habitat and fish growth (Anderson and Krieger 1994; Policky - CDOW unpublished reports). Growth of brown trout collected during electrofishing surveys was evaluated in relation to flow levels and water temperatures that the trout had experienced during their lives. A strong correlation between brown trout growth and discharge, particularly in August (Anderson and Krieger 1994), was discovered. R-squared values of age 1 and age 2 brown trout growth versus the number of days discharge was <700 cfs in August and September were 0.76 and 0.55, respectively. It is important to stress that 700 cfs does not represent favorable habitat, but simply illustrates the relationship between brown trout growth and discharge. Indeed, trout habitat is optimized at a much lower discharge level, as stated above. Trout growth is a good indicator of the health of an aquatic ecosystem because it integrates all the biotic and abiotic variables impacting organisms and reflects secondary effects of chronic stress (Geode and Barton 1990).

Greater depths and increased velocities not only increase the metabolic cost associated with foraging, but also create conditions that reduce the capture of drifting insects. These conditions, combined with warm water temperatures and poor prey availability (Winters 1988), make August a critical month for trout growth. Higher releases from Twin Lakes in August and September will not decrease water temperature for any appreciable distance downstream. Figures 5-6 and 5-7 demonstrate the poor relationship between flow and water temperature. And, as stated previously, augmented flows at this time cause decreased growth of young fish. The only way to maximize trout growth at this time is to keep flows within the optimum range after runoff.

There is a negative correlation between water temperature and discharge in March and April. However, Figures 5-8 and 5-9 show that this correlation is poor, particularly in March. Anderson and Krieger (1994) felt releases during this period in 1989 and 1993 accounted for some of the variability in growth of age 1 and 2 brown trout captured the following spring. They theorized egg development and subsequent hatching could be delayed by cold water releases in March and April. Subsequently, prerunoff growth could be affected and smaller fish would be less able to withstand the rigors of runoff.

Wildlife

The flows of the Arkansas River affect various wildlife species in a variety of ways including: food availability and variety, quality and quantity of escape cover, habitat for breeding and rearing young, alteration of migration and movement routes, and creation of barriers and hazards resulting in drowning and other forms of accidental death.

Wildlife species living along the river corridor have survived and adapted to fluctuations in water levels. Although a few individuals may die as a result of rising water levels, populations are not normally directly impacted to a significant degree. Vegetation habitat components, however, may and have historically been altered as a result of changes in the water flow regimes of the Arkansas River. These changes in vegetation are then reflected in changes in the associated wildlife populations' use of the riverside habitats and the movements of individuals and groups of animals through and along these riparian zones. Because of this interrelationship between riparian vegetation and wildlife use, flows that protect aquatic, riparian, and wetland habitats will be adequate in fostering suitable wildlife use along the Arkansas River.

Additionally, flows that result in greater human use in the Arkansas corridor and associated reservoirs should be considered in the evaluation of future flow management. Wildlife/human interactions have varying degrees of direct and indirect effects on wildlife populations.

Riparian Habitats

Riverine Riparian Resources

The optimal hydrograph for riparian and wetland resources that exist through most of the study area would be one which closely mimics the natural hydrograph (see the Hydrologic Analysis section of this report). Given the storage and water rights constraints, exact natural flows are unobtainable; however, the natural pattern of flows should be obtainable. High spring flows are needed to move and deposit sediment. Low flows during a large portion of the growing season are needed to allow vegetation to colonize new banks. Riparian vegetation catches sediments at high flow and maintains healthy banks.

Variation in high and low flows is also important. Consistently high growing season flows will result in a wider channel in locations where vegetated banks line the stream (resulting in shallower water). These effects will be less noticeable where the channel is confined and rocky.

Reservoir Wetlands

The optimal water level for reservoir riparian and wetland resource management is difficult to

FIGURE 5-6

Arkansas River August Mean Temperature/Flow Relationship 1982-1995

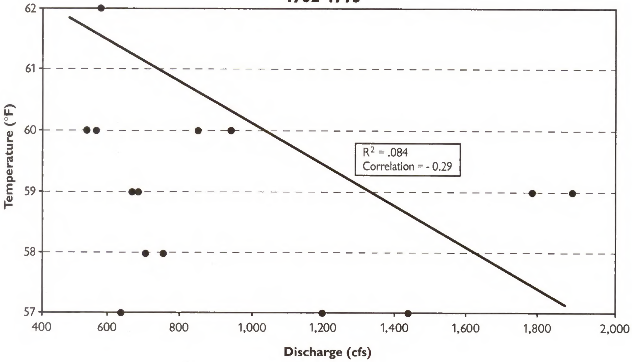


FIGURE 5-7

Arkansas River September Mean Temperature/Flow Relationship 1982-1995

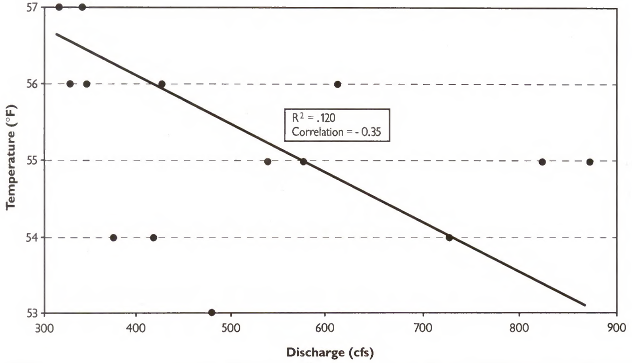


FIGURE 5-8

Arkansas River March Mean Temperature/Flow Relationship 1982-1995

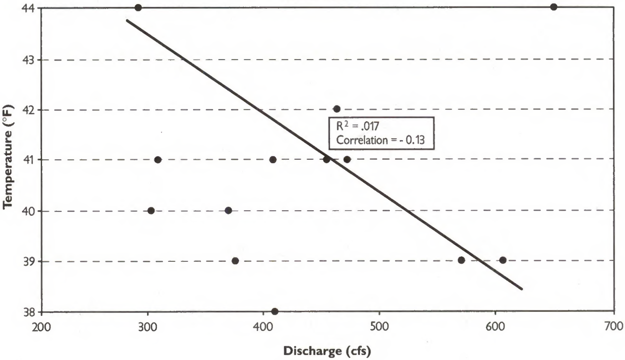
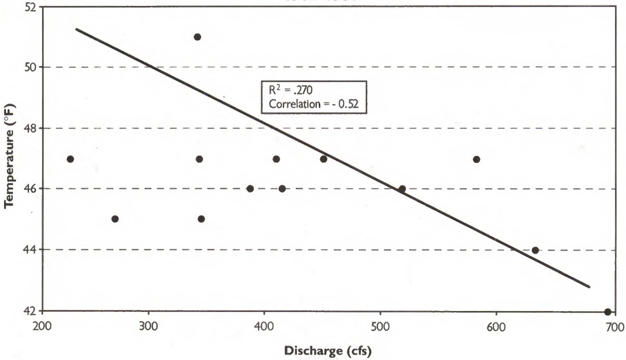


FIGURE 5-9

Arkansas River April Mean Temperature/Flow Relationship 1982-1995



recommend. Reservoirs are constructed for other purposes and operate to meet water demands that counter optimal riparian/wetland management. An operation plan where full pools are obtained as closely as possible to the beginning of the growing season is beneficial. A near stable full pool with a very slight drawdown through the growing season would also be optimal to maintain maximum riparian and wetland resource values (this does not speak to all wildlife species). Drawdown after dormancy has less impact on riparian vegetation. Because late drawdown can conflict with water delivery for agriculture needs, it may not be a workable option. The greatest benefits for reservoir wetlands can be achieved by working toward stabilizing reservoir levels at full pool for as much of the year as possible; coordinating the operation of upper basin and lower reservoirs so that optimal water levels occur at critical periods during the growing season; and modifying drawdown practices to meet both human and riparian/wetland needs.

References

Allen, K.R. 1951. The Horokiwi Stream, A Study of a Trout Population. New Zealand Marine Dept. Fish. Bull. 10. 231 pp.

Allen, K.R. 1969. Limitations on Production in Salmonid Populations in Streams. Symposium on Salmon and Trout Instreams. H.R. MacMillan Lecture Series in Fisheries, Univ. Br. Columbia, Vancouver. pp. 3-18.

Anderson, R.M. and D.A. Krieger. 1994. Impact Analysis of a Flow Augmentation Program on the Brown Trout Fishery of the Arkansas River, Colorado. Special Report Number 70. Colo. Div. Wildl. 24 pp.

Bachman, R.A. 1984. Foraging Behavior on Free-Ranging Wild and Hatchery Brown Trout in a Stream. Trans. Am. Fish. Soc. 113:1-32.

Bacon, C.G. 1990. Riparian Silviculture - Active Riparian Management for Multiple Resources. Society of Foresters National Convention, Spokane, Washington. pp 99-102.

Bannon E. and N.H. Ringler. 1986. Optimal Prey Size for Stream Resident Brown Trout (Salmo trutta): Tests of Predictive Models. Cn. J. Zool. 64:704-713.

Bayha, K.D. 1983. Management of Cottonwood-Willow Riparian Associations in Colorado. The Colorado Chapter-The Wildlife Society. 53 pp.

Bergerson, E.P. and M. Maiolie. 1981. Colorado Cooperative Fishery Research Unit Studies at Twin Lakes, Colorado: 1980 Report of Findings. Bur. Rec. Rep. REC-ERC-828:1-66.

Binns, N.A. and F.M. Eiserman. 1979. Quantification of Fluvial Trout Habitat in Wyoming. Trans. Am. Fish. Soc. 108:215-228.

Bission, P.A. 1978. Diel Food Selection by Two Sizes of Rainbow Trout (Salmo gairdneri) in an Experimental Stream. J. Fish. Board Can. 35:971-975.

Bovee, K.D. 1982. A Guide to Stream Habitat Analysis Using the Instream Flow Incremental Methodology. FWS Instream Flow Information Paper No. 12. FWS/OBS-82/26. pp. 248.

Brinson, M.M., B.L. Swift, R.C. Plantico, and J.S. Barclay. 1981. Riparian Ecosystems: Their Ecology and Status. FWS/OBS-81/17. Eastern Energy and Land Use Team, September 1981, Washington, DC. 155 pp.

Brown, D.E., H.L. Lowe, and J.F. Hausler. 1977. Southwestern Riparian Communities: Their Biotic Importance and Management in Arizona. Forest Service Gen. Tech. Rep. RM-43. pp 210-211.

Burr, J.M. 1987. Synopsis and Bibliography of Lake Trout (Salvelinus namaycush) in Alaska. Alaska Dept. of Fish and Game, Juneau, Alaska. 50 pp.

Bustard, D.R. and D.W. Narver. 1975. Aspects of the Winter Ecology of Juvenile Coho Salmon (Oncorhyncus skisutch) and Steelhead Trout (Salmo gairdneri). J. Fish. Res. Board Can. 32:667-680.

Campbell, S.G. and J.F. LaBounty. 1985. Chlorophyll a Concentration and Distribution in Twin Lakes, Colorado, Prior to Operation of Mt. Elbert Pumped-Storage Powerplant, 1977-81. Bureau of Reclamation Report No. REC-ERC-85-6. Denver, Colorado. 41 pp.

Carlander, K.D. 1969. Handbook of Freshwater Fishery Biology. Vol. I. Iowa State Univ. Press, Ames. 752 pp.

Carlander, K.D. 1977. Largemouth Bass. Handbook of Freshwater Fishery Biology, Iowa State University. Press, Ames, Iowa. Vol. 2. pp. 200-275.

Chapman, D.W. 1966. Food and Space as Regulators of Salmonid Populations in Streams. Am. Naturalists. 100:345-357.

Cope, O.B. 1957. The Choice of Spawning Sites of Cutthroat Trout. Proc. Utah Acad. Sci., Arts, and Letters 34:73-79.

DeRouche, S.E. 1969. Observations on the Spawning Habits and Early Life History of Lake Trout. Progress. Fish. Cult. 31:109-113.

Edwards, E.A., D.A. Krieger, G. Gebhart, and O.E. Maughan. 1982a. Habitat Suitability Index Models: White Crappie. FWS Western Energy and Land Use Team, February 1982, Washington, DC. 22 pp.

Edwards, E.A., D.A. Krieger, M. Bacteller, and O.E. Maughan. 1982b. Habitat Suitability Index Models: Black Crappie. FWS Western Energy and Land Use Team, February 1982, Washington, DC. 25 pp.

Everest, F.H. 1969. Habitat Selection and Spatial Interactions of Juvenile Chinook Salmon and Steelhead Trout in Two Idaho Streams. Ph.D. Dissertation. Univ. of Idaho, Moscow. 77 pp.

Fausch, K.D. 1984. Profitable Stream Positions For Salmonids: Relating Specific Growth Rate To Net Energy Gain. Can. J. Zool. 62:441-451.

Frost, W.E. and M.E. Brown. 1967. The Trout. Collins, St. James' Place, London. 286 pp.

Goede R.W. and B.A. Barton. 1990. Organismic Indices and an Autopsy-Based Assessment as Indicators of Health and Condition of Fish. Am. Fish. Soc. Symp. 8:93-108.

Graham, R.T., T.B. Jain, R.T. Reynolds, and D.A. Boyce. 1993. From Single Species Management to Ecosystem Management, The Goshawk. Forest Service NC Gen. Tech. Rep. SE-88. pp. 113-123.

Griest, J.R. 1976. The Lake Trout of Twin Lakes, Colorado. M.S. Thesis. Colorado State Univ. Fort Collins, CO. 68 pp.

Griest, J.R. 1977. The Lake Trout of Twin Lakes, Colorado. Bureau of Reclamation Report No. REC-ERC-77-4. Denver, CO. 29 pp.

Griffith, J.S. 1972. Comparative Behavior and Habitat Utilization of Brook Trout (Salvelinus fontinalis) and Cutthroat Trout (Salmo clarki) in Small Streams in Northern Idaho. J. Fish. Res. Board Can. 29(3):265-273.

Groen, C.L. and T.A. Schroeder. 1978. Effects of water level management on walleye and other coolwater fishes in Kansas reservoirs. American Fisheries Society Special Publication 11:278-283.

Hall, G.E. and M.J. Van Den Avyle, ed. 1986. Reservoir Fisheries Management Strategies for the 80's. Reservoir Committee, Southern Division American Fisheries Society, Bethesda, Maryland. pp. 86-97.

Hannukula, P.R. 1969. Food Habits of Brown Trout in Anna River, Alger County, Michigan. Michigan Dept. Nat. Resour., Res. and Develop. Rep. 186. 12 pp.

Hartman, G.F. 1965. The Role of Behavior in the Ecology and Interaction of Underyearling Coho Salmon (Oncorhynchus kisutch) and Steelhead Trout (Salmo gairdneri). J. Fish. Res. Board Can. 22:1035-1081.

Hooper, D.R. 1973. Evaluation of the Effects of Flows on Trout Stream Ecology. Dept. of Eng. Res., Pacific Gas and Electric Co., Emeryville, CA. 97 pp.

Horner, N. and T.C. Bjornn. 1976. Survival, Behavior, and Density of Trout and Salmon Fry in Streams. Dept. of Eng. Res., Pacific Gas and Electric Co., Emeryville, CA. 97 pp.

Hunt R.L. 1969. Overwinter Survival of Wild Fingerling Brook Trout in Lawrence Creek, Wisconsin. J. Fish. Res. Bd. Canada. 26:1473-1483.

Jenkins, T.M. 1969. Social Structure, Position Choice and Microdistribution of Two Trout Species (Salmo trutta and Salmo gairdneri) Resident in Mountain Streams. Animal Behavior Monographs 2:57-123.

Kittel, G., R. Rondeau, and A. McMullen. 1996. A Classification of the Riparian Vegetation of the Lower South Platte and Parts of the Upper Arkansas River Basins, Colorado. 234 pp.

Knopf, F.L. 1988. Riparian Wildlife Habitats: More, Worth Less, and Under Invasion. A Symposium of the Rocky Mountain Chapter of the Society of Wetland Scientists, November 14-16 1988. pp 20-22.

Kondolf, M.G., W.J. Webb, M.J. Sale, and T. Felando. 1987. Basic Hydrologic Studies for Assessing Impacts of Flow Diversions Riparian Vegetation: Examples from Streams of the Eastern Sierra Nevada, California, USA Environmental Management, Vol. 11. pp. 757-769.

LeCren, E.D. and R.H. Lowe-McConnell, eds. 1980. The functioning of freshwater ecosystems. Cambridge University Press, New York. 588 pp.

Likens, G.E. 1975. Primary Productivity of Inland Aquatic Ecosystems. In Leith, H. and T.H. Whittaker, eds. Primary Productivity of the Biosphere. Springer-Verlag. New York. pp. 185-202.

Mansell, W.O. 1966. Brown Trout in Southwest Ontario. Ontario Fish Wildl. Rev. 5(2):3-8.

McAfee, W.B. 1966. Rainbow Trout. Inland Fisheries Manage. CA. Dept. Fish and Game. 546 pp.

Milhous, R.T., M.A. Updike, and D.M. Schneider. 1989. Physical Habitat Simulation System Reference Manual - Version II. FWS Instream Flow Information Paper No. 26. U.S. Fish Wild. Serv. Biol. Rep. 89(16).

Miller, R.F., L.E. Eddleman, and R.F. Angell. 1989. Effects of Plant Structure and Composition on Upland Hydrologic Cycles: Juniper Woodlands. Practical Approaches to Riparian Resource Management-An Educational Workshop. pp 171-172.

Mills, D. 1971. Salmon and Trout: A Resource, Its Ecology, Conservation and Management. St. Martin's Press, New York. 352 pp.

Mueller, G. and S. Hiebert. 1996. A Pelagic Fish Survey of Turquoise and Twin Lakes, Colorado, From 1993 Through 1995. U.S. Bureau of Reclamation Technical Memorandum No. 8220-96-7. 10 pp.

Nehring, R.B. and R.M. Anderson. 1993. Determination of Population-Limiting Critical Salmonids Habitats in Colorado Streams Using the Physical Habitat Simulation System. Rivers 4(1):1-19.

Nehring, R.B. and R.M. Anderson. 1986. Stream Fisheries Investigations. Colo. Div. Wildl. Job Prog. Rep., Fed. Aid Proj. F-51. 124 pp.

Nesler, T.P. 1981. Studies of the Limnology, Fish Populations, and Fishery of Turquoise Lake, Colorado-1979-80. Bureau of Reclamation Report No. REC-ERC-82-5. Denver, CO. 31 pp.

Nilsson, C. 1982. Effects of Stream Regulation on Riparian Vegetation. In Lillehammer, A. and S.J. Saltveit, editors. Regulated Rivers. Columbia University Press, New York. pp. 93-106.

Nolting, D.H. 1968. The Lake Trout in Colorado. Fish. Res. Div., Colorado Div. of Wildlife. Unpublished. Denver, CO.

Orcutt, D.R., B.R. Pulliam, and A. Arp. 1968. Characteristics of Steelhead Trout Redds on Idaho Streams. Trans. Am. Fish. Soc. 97:42-45.

Petts, G., I. Maddock, M. Bickerton, and A.J. Ferguson. 1995. Linking Hydrology and Ecology: The Scientific Basis for River Management. In Harper, D.M. and A. J. Ferguson, editors. The Ecological Basis for River Management. John Wiley & Sons Ltd, West Sussex England.

Raleigh, R.F., L.D. Zuckerman, and P.C. Nelson. 1986. Habitat Suitability Index Models and Instream Flow Suitability Curves: Brown Trout. National Ecology Center, Washington, DC. 65 pp.

Raleigh, R.F., T. Hickman, R.C. Solomon, and P.C. Nelson. 1984. Habitat Suitability Information: Rainbow Trout. FWS Western Energy and Land Use Team, January 1984, Washington, DC. 64 pp.

Reily, P.W. and W.C. Johnson. 1982. The Effects of Altered Hydrological Regime on Tree Growth Along the Missouri Riverine North Dakota, Canadian Journal of Bot., 60 2410-2423.

Reiser, D.W. and T.A. Wesche. 1977. Determination of Physical and Hydraulic Preferences of Brown and Brook Trout in the Selection of Spawning Locations. Water Resour. Re. Inst., Water Resour. Res. Ser. 64. 100 pp.

Reynolds, C.S. 1984. The Ecology of Freshwater Phytoplankton. Cambridge University Press, New York. 384 pp.

Ringler, N.H. 1979. Selective Predation by Drift Feeding Brown Trout (Salmo trutta). J. Fish. Res. Board Can. 36(4):392-403.

Risser, R.J. and R.R. Harris. 1989. Mitigation for Impacts to Riparian Vegetation on Western Montane Streams. In Gore, J.A. and G.E. Petts, editors. Alternatives in Regulated River Management., CRC Press. Boca Raton, FL.

Rosgen, D. and H.L. Silvey. 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado. 388 pp.

Shrivell, C.S. and R.G. Dungey. 1983. Microhabitats Chosen by Brown Trout for Feeding and Spawning in Rivers. Trans. Am. Fish. Soc. 112(2):355-367.

Shuler, S.W. 1992. An Evaluation of Boulder Structures Placed in the Rio Grande River, Colorado, Using the Physical Habitat Simulation Model. M.S. Thesis, Colo. State Univ., Fort Collins, Colorado.

Shuler, S.W. and R.B. Nehring. 1994. Using the Physical Habitat Simulation Model to Evaluate a Stream Habitat Enhancement Project. Rivers. 4(3):175-193.

Shuler, S.W., R.B. Nehring, and K.D. Fausch. 1994. Diel Habitat Selection by Brown Trout in the Rio Grande River, Colorado, after Placement of Boulder Structures. North American Journal of Fisheries Management. 14:99-111.

Sigler, W.J. and R.R. Miller. 1963. Fishes of Utah. Utah Department of Fish and Game, Salt Lake City, UT. 203 pp.

Smith, S.D., B.A. Wellington, J.L. Nachlinger, and C.A. Fox. 1991. Functional Responses of Riparian Vegetation to Streamflow Diversion in the Eastern Sierra Nevada. Ecological Application Vol.1. pp.89-97.

Stabler, F.D. 1985. Increasing Summer Flow in Small Streams Through Management of Riparian Areas and Adjacent Vegetation: A Synthesis. Paper presented at the North American Riparian Conference, Tucson, Arizona.

Stalnaker, C., B.L. Lamb, L. Henriksen, K. Bovee, and L. Bartholow. 1995. The Instream Flow Incremental Methodology: A Primer for IFIM. U.S. Fish and Wildlife Service Biological Report 29. 45 pp.

Strawn, K. 1961. Growth of Largemouth Bass Fry at Various Temperatures. Trans. American Fisheries Society, Vol. 90. Maryland. pp. 334-335.

Stromberg, J.C. and D.T. Patten. 1990. Riparian Vegetation Instream Flow Requirements: A Case Study from a Diverted Stream in the Eastern Sierra Nevada, California, USA Environmental Management, Vol. 14, No.2. pp. 185-194.

Stromberg, J.C. and D.T. Patten. 1991. Instream Flow Requirements for Cottonwoods at Bishop Creek, Inyo County, California, Rivers 2. pp. 1-11.

Stuber, R.J., G. Gebhart, and O.E. Maughan. 1982. Habitat Suitability Index Models: Largemouth Bass. FWS Western Energy and Land Use Team, July 1982, Washington, DC. 32 pp.

Szaro, R.C. and L.F. DeBano. 1985. The Effects of Streamflow Modification on the Development of a Riparian Ecosystem.

Thomas, J.A. and K.D. Bovee. 1993. Application and Testing of a Procedure to Evaluate Transferability of Habitat Suitability Criteria. Regulated Rivers - Research and Management. 8:285-294.

U.S. Department of Agriculture. 1979. Riparian Wildlife Resume. Forest Service, Intermountain Region. 28 pp.

U.S. Department of the Interior. 1993. Aquatic Ecology Studies of Twin Lakes, Colorado 1971-86: Effects of a Pumped-Storage Hydroelectric Project on a Pair of Montane Lakes. Bureau of Reclamation. Colorado State University. Engineering and Science Monograph No. 43. 200 pp.

U.S. Department of Agriculture. 1990. Healthy Riparian Areas. Forest Service FS-445.

U.S. Department of Agriculture. 1992. Riparian Management; A Leadership Challenge. Forest Service. 4 pp.

U.S. Department of the Interior. 1991. Riparian-Wetland Initiative for the 1990's. Bureau of Land Management, BLM/WO/GI-91/001+4340, Washington, DC. 50 pp.

Walch, L.A. 1979. Movements of Lake Trout in Twin Lakes, Colorado, in Relation to a Pumped-Storage Powerplant. M.S. Thesis, Colo. State Univ. Fort Collins. 129 pp.

Waters, B.F. 1976. A Methodology for Evaluating the Effects of Different Streamflows on Salmonid Habitat. West. Div. Am. Fish. Soc. and Power Div. Am. Soc. Civil Eng., Boise, ID, May 3-6, 1976, Proceedings Volume II:254-277.

Wesche, T.A. 1980. The WRRI Trout Cover Rating Method: Development and Application. Water Res. Res. Inst., Laramie, WY. Water Resour. Ser. 78. 46 pp.

Wilen, B.O., B.P. Macconnell, and D.L. Mader. 1975. The Effects of Beaver Activity on Water Quality and Water Quantity. Proc. Soc. Am. For. pp. 235-240.

Winters, D.S. 1988. Seasonal Relationships Between the Benthos, Invertebrate Drift and Brown Trout Predation. M.S. Thesis, Colo. State Univ. Fort Collins. 106 pp.

Woodling, J. 1985. Colorado's Little Fish: A Guide to the Minnows and Other Lesser Known Fishes in the State of Colorado. CDOW, Dept. Nat. Resour., Denver, CO. 77 pp.

Glossary

Bankfull Flow - The maximum stream flow without overflowing in the bank which effectively maintains the channel while discharging sediment, forming bars and bends to generally retain characteristic channels.

Benthos Community - Bottom dwelling organisms including plants, invertebrates, and vertebrate animals that inhabit the benthic zone of a water body.

Biomass - The amount of living matter in a given area or volume of habitat at a given time.

Channel Types - They are defined by evolutionary variables and sequences which result in different width/depth ratios, slope and adjustments over time. They may be wide and shallow, narrow and deep or both.

Channelization - The mechanical alteration of a stream usually by deepening and straightening an existing stream channel to facilitate the movement of water.

Chironomids - Large family of very small, non-biting mosquito-like insects; often found in large swarms, usually in the evening.

Chlorophyll - Green photosynthetic coloring matter of plants made chiefly of esters.

Chrysophycean - A type of segmentation, brightly colored, often living in burrows on mud bottoms created by seasonal shift of phytoplankton.

Cladocerans - An order of crustaceans including water fleas; a part of zooplankton densities.

Confined - The river channel is limited in its lateral movement by valley walls or relic terraces.

Coniferous - Any of an order of evergreen trees or shrubs.

Copepods - Any large subclass of minute fresh-water and marine crustaceans.

Diatom - Microscopic algae with a silaceous skeleton that occurs as plankton or attaches to substrate.

Emergent - Reference here is to a plant rooted in shallow water and having most of the vegetative growth above water.

Endangered and Threatened - Plant or animal life whose innate ability to survive is susceptible to extinction. The endangered are those species that are practically extinct while threatened species are disappearing from our environment at a more rapid, alarming rate than their biological cycle would dictate and are becoming extinct. In both cases the problem is exacerbated because the species habitat is nearly destroyed, drastically modified or has disappeared altogether.

Ephemeropterans - Soft bodied order of insects which includes the mayfly.

Euphotic Zone - Lighted region in a body of water that extends vertically from the surface to the depth at which light is insufficient to enable photosynthesis to exceed respiration of phytoplankton.

Geomorphology - Study of the origin of landforms, the processes that form them, and their material composition.

Gill Net - A flat net suspended vertically in the water. It is a mesh that allows the head of a fish to pass through, but the fish is entangled as it seeks to withdraw.

Glides - A calm stretch of shallow water flowing smoothly.

Hydraulic Retention - Holding back the flow of water - may be caused by a mechanical device or a restrictive occurrence in nature.

IFIM - Abbreviation for instream flow incremental methodology. A method for relating changes in the physical characteristics of a stream to changes in flows.

Inundation - To cover with water or flood.

Lacustrine - Pertaining to lakes, reservoirs, wetlands, or any standing water body with a total surface area exceeding 20 acres.

Limnology - The study of the functional relationships and productivity of freshwater biotic communities as they are affected by the dynamics of physical, chemical, and biotic environmental parameters.

Littoral - Shallow shore area (less than 20 ft. deep) of a water body where light can usually penetrate to the bottom and that is often occupied by rooted macrophytes.

Mackinaw - A large trout usually found in deep cold lakes-a member of the Salmonidae Family.

Macroinvertebrates - Invertebrate animals (without backbone) large enough to be seen without magnification.

Metabolic Cost - The sum of the chemical changes in living cells in a particular environment.

Oligotrophic - Water body characterized by low dissolved nutrients and organic matter, dissolved oxygen near saturation, and chlorophyll levels typically at less than 4 mg/m3 during the growing season.

Palustrine - Nontidal wetland that is dominated by trees, shrubs, persistent emergents, mosses, or lichens.

Phytoplankton - Unattached microscopic plants of plankton, subject to movement by wave or current action.

Planktivorous - Mostly small fish who feed principally on the minute and plant life in an aquatic habitat.

Planktonic - The floating or weakly swimming microscopic animal and plant life in an aquatic habitat.

Raptors - Predatory birds that prey upon other animals.

Recruitment - To secure the services of; to get new members; to restore or increase the health, vigor or intensity.

Redd - Nest excavated in the substrate by fish for spawning where fertilized eggs are deposited and develop until the eggs hatch and larvae emerge from the substrate.

Riffle - A small wave or succession of small waves; an unevenness or disturbance of the surface of a body of water.

Riverine - Relating to, formed by or resembling a river.

Rookeries - The nests, breeding grounds or haunt of gregarious birds or mammals; can also be home for a colony of rooks.

Rotifers - Any of various minute, multicellular aquatic organisms having at the anterior end a wheel-like ring of cilia.

Salmonid - Any of elongated soft-finned fish that have the last vertebrae upturned - Family Salmonidae.

Secondary Producer - The flow of energy through the ecosystem produces various levels of nutrients for feeding (larvae, plankton, etc.) and green plants (photosynthesis). The trophic level is next in the food chain-the secondary producer, a part of the nutrient cycle in the food chain of the ecosystem.

Thermocline - A layer of thermally stratified body of water that separates an upper, warmer, lighter oxygen rich zone from a lower, colder, heavier oxygen poor zone.

Trophic Level - One of several successive levels of nourishment in a food chain, i.e. plant producers constitute the first and lowest trophic level; carnivores the last and highest trophic level.

Turnover - When the thermal stratification found in lakes during the summer ends as water temperatures equalize throughout the water column due to wind action and less solar energy input.

Zooplankton - Microscopic animals of plankton suspended in water of an aquatic habitat - depends on currents and water movement due to limited capability for locomotion.

Arkansas River Water Needs Assessment

Section 6. Recreation Assessment

By:

Bruce DiGennaro, EDAW*
Dave Taliaferro, Bureau of Land Management

* Under contract to the Colorado Division of Parks and Outdoor Recreation and the U.S. Department of the Interior, Bureau of Land Management

Arkansas River Water Needs Assessment

Section 6. Recreation Assessment

By:

Bruce DiGennaro, EDAW*
Dave Taliaferro, Bureau of Land Management

* Under contract to the Colorado Division of Parks and Outdoor Recreation and the U.S. Department of the Interior, Bureau of Land Management

July 2000

Preface

Each section of the *Arkansas River Water Needs Assessment* contains information that may be useful for a variety of purposes. However, each section is just a part of the overall *Arkansas River Water Needs Assessment* and the information contained therein should not be taken out of context or considered in isolation. Decisions regarding river-flows and reservoir levels should consider the findings of the assessment as a whole, while also recognizing that such decisions are limited by the necessity to supply water for domestic, agricultural, and other uses in the basin consistent with existing water rights held by water users. A summary of the entire assessment can be found in Section 1 of this report.

Acknowledgments

This assessment could not have been completed without an extensive amount of coordination and cooperation among the participating agencies. The following individuals participated in interagency workgroups throughout the assessment and are recognized for the significant amount of time and resources they invested in conducting various studies and documenting the findings in this report:

Water Workgroup: Bill Carey (Bureau of Land Management), John Gierard (formerly Bureau of Reclamation, now Western Area Power Administration), Dan Muller (Bureau of Land Management), Roy Smith (Bureau of Land Management), Steve Swanson (Bureau of Land Management), and Steve Witte (Colorado Division of Water Resources).

Biological Workgroup: Clay Bridges (Bureau of Land Management, retired), Mark Elkins (Colorado Division of Wildlife), Dave Gilbert (Bureau of Land Management), Doug Krieger (Colorado Division of Wildlife), Greg Policky (Colorado Division of Wildlife), and Rich Roline (Bureau of Reclamation).

Recreation Workgroup: Mike French (Colorado Division of Parks and Outdoor Recreation), Steve Reese (Colorado Division of Parks and Outdoor Recreation, retired), Mike Sugaski (U.S. Forest Service), and Dave Taliaferro (Bureau of Land Management).

Editorial and Graphics Workgroup: Linda Hill (Bureau of Land Management) and Jennifer Kapus (Bureau of Land Management).

The assessment team was guided throughout the process by a management advisory group, which was established through a formal memorandum of understanding. The members of this group are recognized for being responsive to the study team's needs and providing helpful advice, on numerous occasions, regarding controversial issues that arose during the study: Levi Deike (Bureau of Land Management), Dave Giger (Colorado Division of Parks and Outdoor Recreation), Alice Johns (Bureau of Reclamation), Dan McAuliffe (Colorado Department of Natural Resources), and Donnie Sparks (Bureau of Land Management).

During the assessment process, the services of several individuals were acquired through contracts and an interagency agreement. The timely deliverables, extraordinary assistance, and dedication to the assessment of these individuals under these formal arrangements were extremely appreciated. Kip Bossong (U.S. Geological Survey) compiled and analyzed a large amount of historic data, which significantly aided the streamflow analyses in this report. Bruce DiGennaro (formerly EDAW) provided a wealth of insight and strategy towards completing the recreation user surveys and assessment. Teresa Rice (formerly University of Colorado Natural Resource Law Center) completed an enormous amount of research on water uses and institutions. Both Bruce and Teresa wrote reports that are of such quality they could stand alone as exhaustive treatments of their respective assignments.

Certain individuals who were responsible for initiating preliminary discussions and studies leading to this assessment deserve special thanks for their vision and support. They include: Mac Berta (Bureau of Land Management, retired), Jim Fogg (Bureau of Land Management), Jack Garner (Bureau of Reclamation), Larry MacDonnell (formerly University of Colorado Natural Resource Law Center), Steve Norris (Colorado Division of Wildlife), Don Prichard (Bureau of Land Management), Donnie Sparks (Bureau of Land Management), Steve Vandas (U.S. Geological Survey), and Pete Zwaneveld (Bureau of Land Management).

Several individuals provided the team with helpful insight and reviews of documents. In particular, we acknowledge the following individuals for their commitment to participating in meetings and providing review comments:

Legal and Institutional Analysis Advisory Group: Carl Genova (Southeastern Colorado Water Conservancy District), Denzel Goodwin (Upper Arkansas River Water Conservation District), Alan Hamel (Pueblo Board of Water Works), Steven Kastner (Colorado Division of Water Resources), Phil Saletta (Colorado Springs Utilities), and Tom Simpson (Southeastern Colorado Water Conservancy District).

Biology, Hydrology, and Recreation Peer Reviewers: Mark Butler (U.S. Fish and Wildlife Service), Paul Flack (Colorado Division of Parks and Outdoor Recreation), Bill Hagdorn (Bureau of Land Management), Mike Lewis (U.S. Geological Survey), Rich Niemeyer (National Park Service), Scott Schuler (U.S. Forest Service), and Jay Thompson (Bureau of Land Management).

Advisor on Reservoir Operations: Tom Gibbens (Bureau of Reclamation, retired).

Table of Contents

Section 6. Recreation Assessment

In 1993, the U.S. Bureau of Land Management, in cooperation with Colorado's Department of Natural Resources (Division of Water Resources, Division of Wildlife, and Division of Parks and Outdoor Recreation), the U.S. Forest Service, and the U.S. Bureau of Reclamation (BOR) initiated a Water Needs Assessment for the Upper Arkansas River and its associated reservoirs. The following report describes studies and analyses conducted as a part of this assessment to determine water needs for recreation.

The study area includes the Arkansas River from Leadville to Pueblo and four associated storage reservoirs; Turquoise Lake, Twin Lakes, Clear Creek Reservoir, and Pueblo Reservoir (Figure 6-1). This area supports a wide variety of water-based recreation activities. Many of these activities, particularly fishing, white-water boating, and reservoir boating are directly affected by water management in the basin, which determines riverflows and lake levels.

The purpose of this section of the report is to document water needs for fishing and boating activities on the Arkansas River and its associated storage reservoirs. The report provides an evaluation of both river- and lake-oriented recreation, focusing primarily on evaluating water needs for fishing and boating activities. Other recreation activities that occur in the study area, such as sightseeing and camping, are less directly influenced by water levels and therefore were not evaluated. For the purposes of this section, water needs are defined primarily through the development of user preference curves. Rather than providing absolute binary functions, these curves indicate degrees of acceptability associated with various water conditions. Threshold values have also been developed to indicate acceptable and optimal conditions for each major activity.

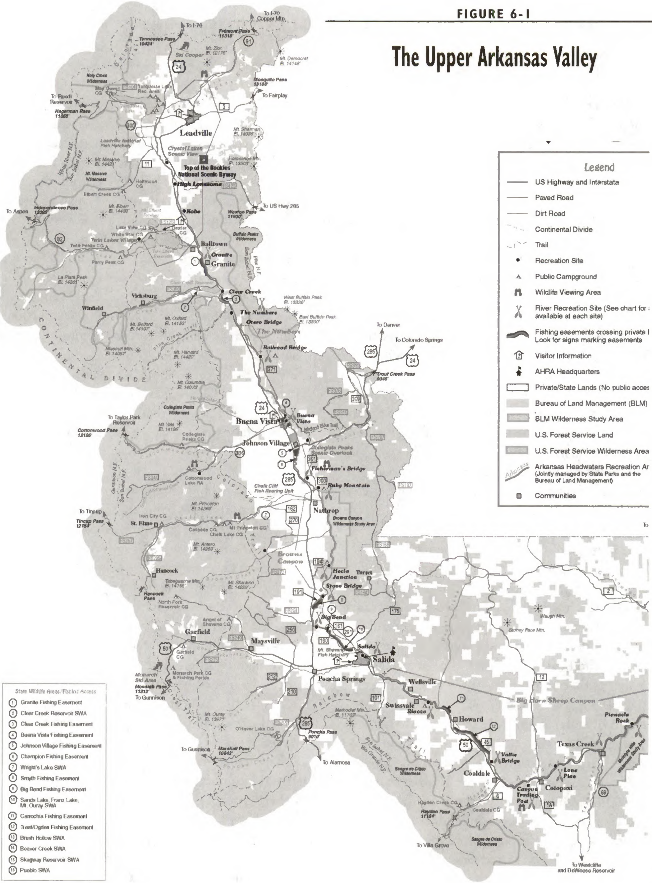
The recreation water needs presented herein are based on: 1) an analysis of the physical characteristics of the river and reservoirs in relation to water levels; 2) an assessment of use patterns in relation to various flow conditions (based upon the Wellsville gage) and reservoir levels; and 3) results from several user surveys conducted between 1991 and 1995. Each of these data sources are compared and contrasted to develop the most accurate depiction of flow needs possible. The data includes responses from experienced users, casual users, private boaters, commercial boaters, and anglers of all types for six sections of the river, as well as for Twin Lakes, Turquoise Lake, and Pueblo Reservoirs. Some limited data were also collected for Clear Creek Reservoir because, even though it is not a Fryingpan-Arkansas Project reservoir, its operations are included within this study.

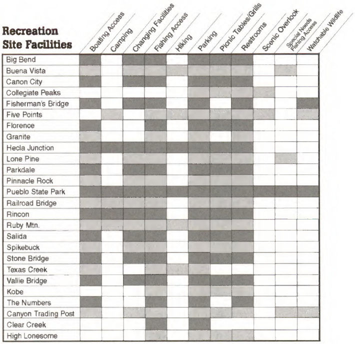
The relationship between water levels and recreation opportunities is highly complex, particularly when there is a diversity of users such as in the upper Arkansas Basin. Water levels can influence a variety of factors important to recreation, including, shoreline access, navigability, safety, fishing success, white-water dynamics, and ultimately, the overall quality of the recreation experience. In addition, each recreation activity may have slightly different needs. What is good for one user may be bad for another. In some cases, water levels (particularly at the extremes) may influence actual recreation decisions. However, recreation decisions are also typically influenced by numerous other factors, including weather, the time of year, family summer vacations, and the availability of other substitute opportunities.

Preferences for specific water levels are generally derived from experience. Users who recreate in the area frequently, and thus are exposed to a variety of

FIGURE 6-1

The Upper Arkansas Valley





N

1" = 5 miles

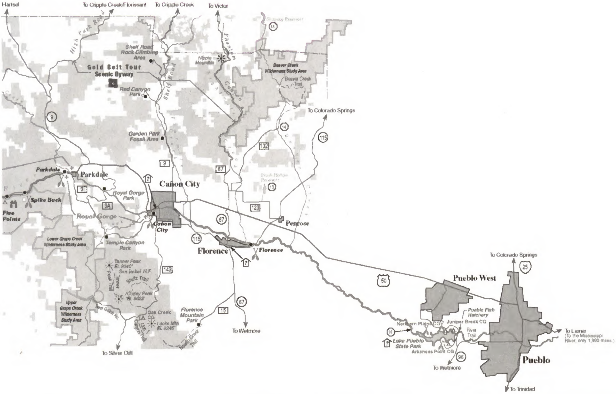
activities

ands.

ss)

Public Land

ee



different water levels, will tend to have stronger and more well-defined preferences. Users who have only experienced one or two flow levels have less information from which to derive a preference (i.e., little to compare the experience to). Skill level, which is typically related to experience, also tends to play a strong role in defining tolerance levels and preferences. For example, highly skilled boaters often desire difficult, challenging conditions, while less skilled boaters prefer calmer, safer, less threatening conditions.

Recreation Setting

The Arkansas River Basin in Colorado is one of the nation's outstanding recreation areas. The area's natural resources attract millions of recreation visitors each year and offer abundant and outstanding opportunities for fishing, rafting, kayaking, picnicking, hiking, camping, mountain biking, and sightseeing. In addition to river-oriented opportunities, Clear Creek, Turquoise, Twin, and Pueblo Reservoirs provide a wide variety of flat-water recreation opportunities, including fishing, power boating, sailing, water skiing, and sailboarding.

Recreation use within the study area is considerable and has increased significantly over the past 7 years (see Table 6-1). In 1990, the Arkansas River supported an estimated 339,000 recreation users. In 1996, an estimated 590,000 visitors used the river for recreation, an increase of 251,000 users or 74 percent over 1990 use levels. The Arkansas River is the most popular river in the U.S. for white-water boating. Demand for lake recreation opportunities has also increased, but at a slower rate. In 1990, Lake Pueblo State Park supported an estimated 1,096,000 visitors. By 1996, this had increased to over 1,543,000 visitors, an increase of approximately 447,000 visitors or 41 percent over 1990 use levels. These use estimates are based on user counts conducted by the Colorado Division of Parks and Outdoor Recreation. According to the USDA Forest Service, in 1996, there were 50,000 visitors for camping at Turquoise Reservoir and 27,000 visitors for camping at Twin Lakes Reservoir.

Recreation activities within the study area contribute significantly to the region's economy. Survey data regarding recreational spending within the area suggest that in 1996 direct expenditures associated with recreation activities on the Arkansas River contributed over $23 million to the region's economy. Using a standard accepted economic multiplier of 2.56 (source: Colorado Visitor Expenditures Study), these expenditures equate to a total economic impact of nearly $60 million for river-oriented activities. Fees associated with just the 76,000 camping visitors at Turquoise and Twin Lakes Reservoirs contributed $235,133 to the region's economy. Using the economic multiplier, these partial expenditures equate to an economic impact of over $600,000. Economic contributions to the region from Pueblo Reservoir are estimated, using the same economic multiplier, at $34 million. In total, those recreation activities

TABLE 6-1

Trends in Annual Visitor Use (in thousands)

	1990	1991	1992	1993	1994	1995	1996
Arkansas River Recreation Area	339	402	472	518	557	545	590
Lake Pueblo State Park	1,096	1,092	1,337	1,378	1,522	1,621	1,543*

Source: Colorado Division of Parks and Outdoor Recreation

* After 1996, there is an upward trend at Lake Pueblo State Park, with annual vistor use estimates ranging from 1.7 to over 2 million from 1997-1999.

associated with the river and the reservoirs contributed nearly $95 million to the region's economy.

Generally, recreation activity within the study area is greatest between the months of April and September, with peak use occurring in June, July, and August. Table 6-2 provides the monthly use estimates for the Arkansas River and the reservoirs in the study area for 1996. Of the 590,000 users visiting the Arkansas River in 1996, about 69 percent visited the river during the months of June, July, and August. Of the 1,543,000 visitors to Lake Pueblo State Park in 1996, about 57 percent visited the lake during the months of June, July, and August. Of the 76,000 visitors to Turquoise and Twin Lakes Reservoirs during 1996, 94 percent visited the lakes during the months of June, July, and August. The visitor numbers for Clear Creek Reservoir are for anglers only. Substantial ice fishing use occurs at the upper reservoirs during the winter months (see Table 6-2).

Recreation Management

In recognition of the river corridor's outstanding recreation values, the Arkansas Headwaters Recreation Area (AHRA) was established in October 1989. Recreation management activities and resource management activities within the AHRA are directed through a cooperative effort between the U.S. Bureau of Land Management (BLM), USDA Forest Service (USFS), Colorado Division of Parks and Outdoor Recreation (CDPOR), and Colorado Division of Wildlife (CDOW). Portions of the "Pine Creek" and "Numbers" sections of the AHRA also involve cooperative management between the USFS, BLM, and CDPOR. Recreation facilities at

TABLE 6-2

1996 Monthly Visitor Use

	Arkansas River	Clear Creek Reservoir*	Turquoise Lake Reservoir*	Twin Lakes Reservoir*	Pueblo Lake Reservoir
January	7,965	796	191	138	48,174
February	7,247	796	191	138	50,428
March	14,379	796	191	138	72,541
April	19,145	796	191	138	97,499
May	54,833	1,114	631	1,066	241,062
June	115,854	2,304	8,896	3,727	361,472
July	176,133	3,134	19,198	10,737	283,385
August	112,699	2,676	18,823	9,917	238,465
September	34,572	1,920	725	149	36,087
October	27,271	796	191	138	40,975
November	9,451	796	191	138	27,453
December	10,643	796	191	138	45,291
Total	590,192	16,720	49,610	26,562	1,542,832

* Numbers for October through April are estimates only; they are not from actual counts.

Sources: Arkansas Headwaters Recreation Area, USDA Forest Service, Lake Pueblo State Park, and Colorado Division of Wildlife

Turquoise and Twin Lakes are managed by the USFS. The CDOW manages recreation access at Clear Creek Reservoir and the CDPOR manages recreation at Lake Pueblo. The CDOW also has acquired and manages several easements across private lands within the river corridor for the primary purpose of providing for improved angler access. The CDOW is responsible for all facets of wildlife management within the study area, including special regulations on two sections of the river and fish stocking programs.

Approximately 60 percent of the river corridor is in private ownership, while the remaining forty percent is on Federal and State public lands. Almost all of the properties surrounding Turquoise and Twin Lakes are national forest land managed by the USFS. Lake Pueblo is surrounded primarily by State lands managed by CDPOR as Lake Pueblo State Park.

Commercial recreation activities within the AHRA are regulated through special 5-year concession agreements. As of May 1996, a total of 94 permits were in place, covering white-water boating, float fishing, walk and wade fishing, shuttles, and video and still photography. A total of 63 white-water boating outfitters are permitted to operate on the river. Permit revenues in fiscal year 95 totaled more than $410,000, and in fiscal year 96 totaled over $499,000.

Management of the Arkansas Headwaters Recreation Area is guided by the Arkansas River Recreation Management Plan developed by the BLM and CDPOR with input from a 22-member advisory committee representing a wide array of varying user groups, agencies, and other concerns. Implementation of this plan involves a continuing effort by those that developed the plan through a designated Citizen Task Force. This Citizen Task Force represents anglers, private boaters, environmental concerns, commercial boaters, landowners/cattlemen, the Upper Arkansas Area Council of Governments, and water users.

Key management issues dealt with in the plan include development of additional public access and facilities, public safety (including work with the Colorado Department of Transportation to develop better and safer highway access to recreation facilities), natural resource monitoring and management, carrying capacities for white-water boating, rationing plans for commercial outfitting uses, education and interpretation, and law enforcement. Recreation management costs are funded almost entirely through user fees, including both access/parking fees and commercial permit fees.

Management of Turquoise and Twin Lake recreation areas is guided by the San Isabel National Forest Land Management Plan. These two reservoirs are managed mainly for fishing, camping, picnicking, and boating. Clear Creek Reservoir is managed by the City of Pueblo's Board of Public Water Works in partnership with the CDOW. The reservoir is managed mainly for fishing and boating, as well as for some limited camping. Pueblo Reservoir is operated by the Bureau of Reclamation (BOR) in partnership with the CDPOR and CDOW. Recreation use of Pueblo Lake State Park is guided by the Lake Pueblo State Park Management Plan.

River Recreation

The physical characteristics of the Arkansas River vary considerably from Leadville to Pueblo (about 150 miles). These different physical settings provide for different recreation opportunities in terms of access, activities, and experiences. Table 6-3 briefly describes each of the primary river segments and lists the identified management focus for each segment, as defined in the Arkansas River Recreation Management Plan. Table 6-4 briefly illustrates the established carrying capacities by river segment, season, and launch window, as defined in the Arkansas River Recreation Management Plan.

Recreation activity on the Arkansas River varies from year to year. Recent use estimates developed by the CDPOR and CDOW indicate that approximately 50 percent of river use is for boating

TABLE 6-3

River Segment Descriptions and Water-Based Recreation Values

Segment	Description	Recreation Values
1. Leadville to Buena Vista	The upper reaches of this segment provide fairly quiet, calm waters. Below Granite, the river changes dramatically as it flows into a narrow canyon culminating at Pine Creek rapids (Class V-VI). Below Pine Creek, the river offers kayakers and rafters technically challenging waters (Class III-V) all the way to Buena Vista, especially in the popular "Numbers" section. Fishing is very good in this upper segment, especially between Kobe Access Site down to the Granite Gorge. Recreational gold panning is popular in this segment.	~ Angling ~ Boating (technical white-water kayaking; no commercial boating above Granite)
2. Buena Vista to Salida	This segment of the river receives the most intense recreation use focused especially on the popular "Browns Canyon" section. Browns Canyon offers outstanding fishing, camping, and picnicking, as well as challenging white-water boating opportunities (Class II-IV). Below Browns Canyon, the valley widens as the river passes through the Big Bend section. This area offers prime trout fishing opportunities and includes numerous access easements across private lands to access points on public lands.	~ Wildlife observing ~ Angling ~ Boating (white water rafting/kayaking, quiet-water boating, float fishing)
3. Salida to Vallie Bridge	Deep pools, rock banks, and gravel bars are common in this segment of the river, making it particularly attractive and enjoyable for anglers. The segment also contains a number of intermediate white-water rapids. Angling access in this area is provided by many access easements across private lands and numerous public recreation sites.	~ Wildlife observing ~ Angling ~ Boating (some sections offer white-water rafting, quiet water boating, float fishing)
4. Vallie Bridge to Parkdale	The river drops sharply in this segment with numerous white-water sections of the river. This segment is intensively used by anglers and white-water boaters (Class III-IV). Viewing bighorn sheep is very popular at many locations in this segment. Recreational gold panning is popular in this segment as well. Numerous public recreation access points and sites are in this segment.	~ Wildlife observing ~ Angling ~ Boating (white water rafting/kayaking with some quiet water boating and float fishing)
5. Parkdale to Cañon City	This segment of the river is dominated by the more than 1000-foot-deep Royal Gorge. The river is used extensively for white-water boating. Sightseeing is very popular, especially from the Royal Gorge City Park.	~ Angling ~ Boating (technical white-water rafting/kayaking) ~ Sightseeing
6. Cañon City to Pueblo Reservoir	Below Cañon City, the river changes into a quiet, meandering, Great Plains-type river. A wide ribbon of cottonwood and willow trees creates an important riparian/wetland zone for wildlife. Some angling and canoeing occur in this segment, but it receives much less recreation use than the other river segments. The river offers excellent wildlife viewing and quiet-water float fishing opportunities.	~ Wildlife observing ~ Angling ~ Boating (mostly canoeing and float fishing)

Source: Arkansas Headwaters Recreation Area

TABLE 6-4

Carrying Capacities by Season and Segment

Segment	Primary Use	Location: From-To	Capacities (Boats Per Day)		Seasons	Windows
			Private	Commercial		
1A	Fisheries rehabilitation	Leadville-Granite	10	0	Year-round	None
1B	Private boating	Granite-RR Bridge	350	30	5/15 - Labor Day	Rafts launch 8:30 a.m.-11:00 a.m.
			[200]	[10]	[Labor Day - 5/14]	[same]
1C	Mixed boating	RR Bridge-Buena Vista	150	150	5/15 - 8/14	None
			[100]	[50]	[8/15 - 5/14]	
2A	Commercial boating	Buena Vista-Big Bend	150	450	5/15 - Labor Day	None
			[100]	[50]	[Labor Day - 5/14]	
2B	Multiple use recreation	Big Bend-Salida	150	150	5/15 - 8/14	Comm. off river by 5:00 p.m.
			[30]	[10]	[8/15 - 5/14]	[same]
3	Fishing	Salida-Vallie Bridge	150	150	5/15 - 7/14	Comm. off river by 5:00 p.m.
			[30]	[10]	[7/15 - 5/14]	[same]
4A	Multiple use recreation	Vallie Bridge-Texas Creek	100	150	5/15 - 8/14	Comm. off river by 5:00 p.m.
			[30]	[10]	[8/15 - 5/14]	[same]
4B	Multiple use recreation	Texas Creek-Parkdale	150	300	5/15 - Labor Day	Comm. off river by 5:00 p.m.
			[30]	[30]	[Labor Day - 5/14]	[same]
5	Technical white-water boating and fishing	Parkdale-Cañon City	150	150	5/15 - Labor Day	None
			[75]	[30]	[Labor Day - 5/14]	[same]
6	Specialty quiet-water w/fishing	Cañon City-Pueblo Reservoir	35	35	Year-round	None

Notes: Riverwide commercial launch window is 8:30 a.m. to 3:30 p.m.; [ ] designates off-season;
Float fishing trips must occur within carrying capacity trips.
Source: Arkansas Headwaters Recreation Area

activity, 30 percent is for sightseeing, between 5 and 16 percent is for fishing, 5 percent is for picnicking, and 3 percent is for camping. Of these uses, the two primary activities that are most directly affected by changes in riverflow are angling and boating. The range of river angling use presented above represents different estimates calculated by CDPOR and CDOW (as described under "Angling").

Angling

The Arkansas River offers excellent angling opportunities along its entire length and is well-known for its outstanding brown trout fishery. Opportunities for wade fly angling are particularly good in segments 1, 2, and 3, due to a predominance of shallow water habitat and easy public access. Float fishing is popular in segments 2, 3, 4, and 6. Bait and lure angling are particularly popular in segment 4. Both brown and rainbow trout catches in the river average 10 to 12 inches, but there is the possibility of an occasional trophy catch.

The majority of the anglers on the river are fly fishing anglers. Results from a 1995 CDOW creel census indicate that 54 percent of the anglers were fly fishing, 28 percent were lure fishing, and 18 percent were bait fishing. While the vast majority of the angling is "walk and wade," a number of users also "float fish" on the river. Both commercial walk and wade and commercial float fishing outfitters operate on the river. Statistics maintained by CDPOR indicate that a total of 3,109 commercial clients engaged in float fishing on the river in 1996. Throughout the remainder of this report, the lure and bait fishing narratives, tables, and charts will be combined.

Total annual angling use of the river is difficult to estimate due to the length of the river, multiple access points, and different counting techniques employed by CDOW and CDPOR. Statistics compiled by the Arkansas Headwaters Recreation Area and CDOW indicate that somewhere between 23,753 and 67,973 anglers visited the upper Arkansas River in 1995. Table 6-5 presents monthly angling use estimates developed by the Arkansas Headwaters Recreation Area for 1995. Table 6-6 presents angling use estimates prepared by CDOW for that same year (by geographic river reach).

Angler use estimates presented in Table 6-5 are based on year-round daily counts conducted during routine field patrols for approximately 125 miles of the river from the Cañon City area up to the Kobe Access Site. Daily counts have been extrapolated to account for areas and times not observed.

TABLE 6-5

Arkansas Headwaters Recreation Area River Angling Use Estimates - 1995

Month of Field Count	Anglers Counted
January	439
February	630
March	1,595
April	1,478
May	2,433
June	979
July	2,859
August	3,984
September	3,294
October	4,547
November	863
December	652
Annual Total	23,753

Source: Arkansas Headwaters Recreation Area

Use estimates presented in Table 6-6 are based on creel survey data collected by CDOW from April through September 1995. Angling use on private property was assumed to be 25 percent of that on public lands. Use within individual river segments was also expanded by 25 percent to estimate annual angler use. Table 6-6 displays those areas where surveys were conducted; the river reach where that creel area data was extrapolated to; what part of the reach is publicly or privately owned; and the estimated anglers in those reaches. Figure 6-2 displays the location of the 1995 creel surveys. This data represents approximately 100 river miles from Parkdale upriver to the Kobe Bridge.

Differences between the estimates shown in Tables 6-5 and 6-6 are due to the different sampling methodologies employed by the Arkansas Headwaters Recreation Area and CDOW, including different sampling locations and sampling times and different extrapolation techniques. While no attempt has been made to calculate the error functions associated with these two estimates, it is likely that the margin of error for both estimates is

TABLE 6-6

Colorado Division of Wildlife Arkansas River Angling Use Estimates - 1995

		Public			Private (Note: private anglers/mile are 25 percent of public anglers/mile)			
Creel census area name and miles	Extrapolated river reach and miles	Anglers per mile	Miles	Total anglers	Anglers per mile	Miles	Total anglers	Total anglers
Floodplain to Pinnacle Rock (3.0 miles)	Parkdale - Texas Creek (13.3 miles)	786	13.3	10,454	0	0	0	10,454
Lone Pine to Big Cottonwood Crk (3.0 miles)	Texas Crk - Lazy J (12.0 miles)	1,550	4.8	7,440	388	7.2	2,794	10,234
	Lazy J - Upper Howard Brdg (8.3 miles)	1,550	3.1	4,805	388	5.2	2,018	6,823
Badger Crk to Stockyard Bridge (6.4 miles)	Howard Brdg - Stockyard Brdg (11.4 miles)	792	5.2	4,118	198	6.2	1,228	5,346
County Road 166 to Big Bend (2.0 miles)	Stockyard Brdg - Stone Brdg (10.9 miles)	702	7.8	5,476	175	3.1	543	6,019
	Stone Brdg - Ruby Mtn (11.2 miles)	702	10.2	7,160	175	1.0	175	7,335
	Ruby Mtn - Hwy 285 Brdg (6.0 miles)	702	1.8	1,264	175	4.2	735	1,999
Railroad Bridge to Otero Bridge (3.1 miles)	Hwy 285 Brdg - Otero Brdg (9.0 miles)	256	6.2	1,587	64	2.8	179	1,766
Granite Gorge to Chaffee/Lake County Line (1.0 mile)	Otero Brdg - Granite Brdg (7.8 miles)	256	5.0	1,280	64	2.8	179	1,459
	Granite Brdg - Kobe Brdg (6.0 miles)	1,343	2.0	2,686	336	4.0	1,344	4,030
	Totals	–	59.4	46,270	–	36.5	9,195	55,465
	Total Annual Anglers							67,973*

Source: Colorado Division of Wildlife
* Extrapolated by 25 percent to include the remaining river miles not covered by the creel census.

FIGURE 6-2

Creel Census Areas on Arkansas River

relatively large. This is common for extrapolations that attempt to estimate annual recreation use over a large geographic area that is influenced by many uncontrolled variables such as weather. Combined, the two estimates provide a general range of estimated angling use on the river.

White-Water Boating

The upper Arkansas River is one of the most popular white-water boating rivers in the United States. The river offers a broad variety of boating experiences from easy Class I (beginner) to challenging Class V-VI (experts only), and boasts several nationally recognized white-water boating sections including the Numbers, Browns Canyon, and Royal Gorge. Few other rivers in the country offer the combination of diversity and accessibility available along the Arkansas River.

White-water boating use on the river includes both private and commercial users. Commercial rafting activities are focused in three segments of the river: Browns Canyon (segment 2); Pinnacle Rock (segment 4); and Royal Gorge (segment 5). Over 60 commercial outfitters are permitted to operate on the river. Private boating (rafting and kayaking) is also concentrated in these three segments, but is common in other areas, particularly Numbers (segment 1). White-water boating opportunities (particularly commercial opportunities) attract large numbers of visitors to the Arkansas River. Figures 6-3, 6-4, and 6-5 provide maps of the river corridor.

Boating use of the river has increased significantly (approximately 34 percent) over the past 5 years with over 287,000 boaters estimated for all of 1996. The river is heavily used by commercial white-water companies that offer full-day and half-day trips on various sections of the river. This commercial use dominates the white-water boating activity, accounting for over 90 percent of the total boating activities on the river (see Table 6-7).

Reservoir Recreation

At the upper end of the Arkansas River Basin, Turquoise Reservoir, Twin Lakes, and Clear Creek Reservoirs provide shoreline and boat angling opportunities in a scenic, high-altitude mountain setting. Total recreation use at these upper reservoirs is shown in Tables 6-1 and 6-2. Maps of Turquoise and Twin Lakes and their existing

TABLE 6-7

River Boating Use 1991-1997 (May through September)

Year	Commercial Clients	Private Individuals	Total Boaters
1991	157,862	18,569	176,431
1992	181,716	15,948	197,664
1993	185,123	22,871	207,994
1994	201,040	22,890	223,930
1995	199,109	22,487	221,596
1996	228,153	23,115	251,268
1997	235,931	21,287	257,218

Source: Arkansas Headwaters Recreation Area

FIGURE 6-3

Upper Section-Upper Arkansas River Basin

FIGURE 6-4

Middle Section-Upper Arkansas River Basin

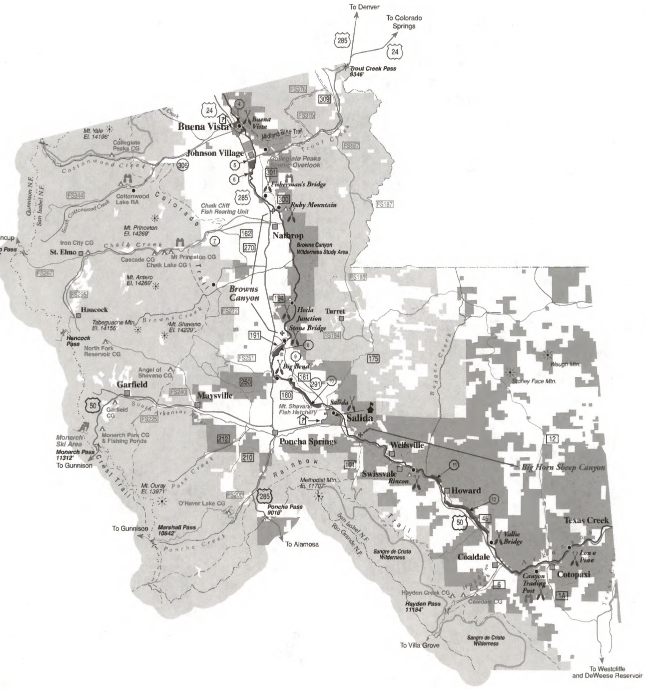
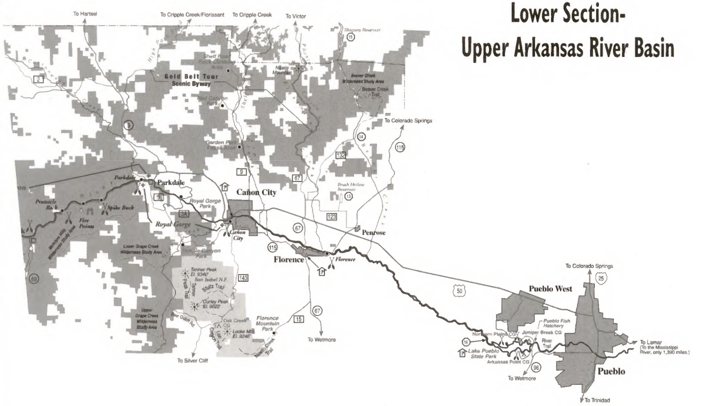


FIGURE 6-5

Lower Section-
Upper Arkansas River Basin



recreation facilities are shown in Figures 6-6 and 6-7. Table 6-8 describes the recreation values that exist at the basin reservoirs.

At the downstream end of the study area, Pueblo Reservoir offers opportunities for more intensive water sports and a wide range of boating activities. Pueblo Reservoir also offers opportunities for warm- and cold-water fishing. A map of Lake Pueblo State Park and its associated recreation areas is shown in Figure 6-8. Lake Pueblo State Park is one of the heaviest used State Parks in Colorado, accommodating 1.7 million visitors a year. Total recreation use at Lake Pueblo State Park for 1990-1996 is shown in Table 6-1.

Angling

The four upper basin reservoirs offer excellent angling opportunities. They are known for the variety of fish species that reside there. Lake trout and rainbow trout are the most caught species at Turquoise and Twin Lakes Reservoirs, while rainbow trout comprise the majority of the anglers' catches at Clear Creek Reservoir. Eighty percent of angling is from shore, while 20 percent occurs from a boat. At Pueblo Reservoir, smallmouth bass and walleye are the most caught species. Approximately 30 percent of Pueblo Reservoir visitors are anglers, the majority fishing from boats (57 percent). CDOW and CDPOR angling use estimates are shown in Table 6-9. The majority of angling use occurs in June, July, and August at these waters; however, use does take place the remainder of the year as well (e.g., ice fishing at the upper reservoirs and open-water fishing throughout the year at Pueblo Reservoir).

Boating

Boating takes place on all four reservoirs. Boating on the upper three reservoirs is mainly tied to boat angling, sailing, and pleasure power boating. Boating on Pueblo Reservoir includes power boating, boating for water skiing, personal watercraft operation, sailboating, sailboarding, and general pleasure boating.

FIGURE 6-6

Turquoise Lake

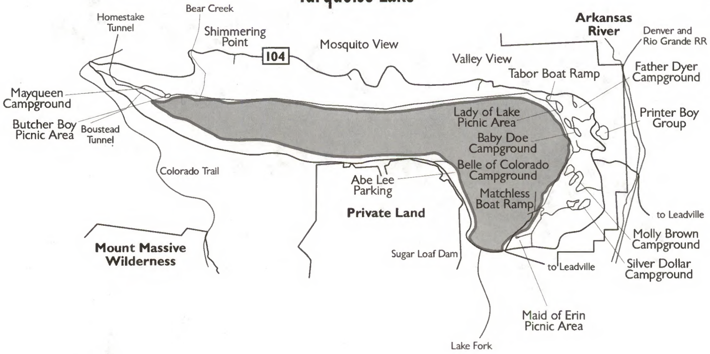


FIGURE 6-7

Twin Lakes

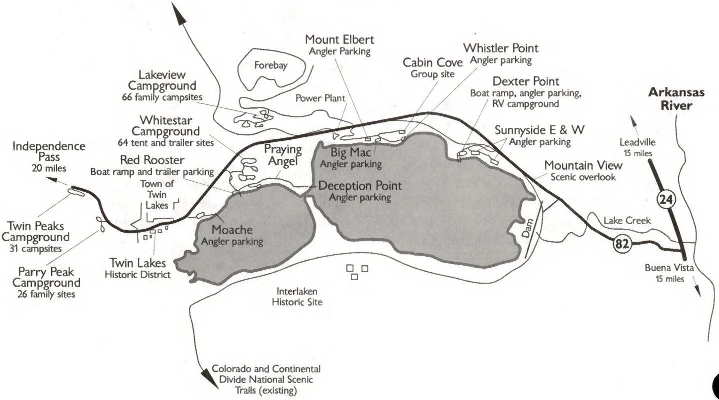


TABLE 6-8

Reservoir Recreation Values

Reservoir(s)	Description	Reservoir Values
Upper Reservoirs (Turquoise, Twin Lakes, and Clear Creek)	These reservoirs are located near the upper end of the study area, offering high-elevation recreation opportunities including fishing, boating, camping, and picnicking. Most of the recreation activities at these reservoirs occur during June, July, and August, except for winter ice fishing.	~ Fishing (shore, ice, and boat fishing) ~ Boating
Pueblo Reservoir	Lake Pueblo State Park, located at Pueblo Reservoir, offers opportunities for swimming, boating, water skiing, wind surfing, camping, and both warm- and coldwater fishing. The reservoir is one of the most intensively used State Parks in Colorado. Most of the recreation use occurs in April, May, June, July, August, and September, except for winter fishing. There are significant recreational opportunities at this reservoir throughout the year as well.	~ Fishing (shore, ice fishing, and boat) ~ Water skiing ~ Power boating ~ Personal watercrafts ~ Sailboarding ~ Sailboating

FIGURE 6-8

Pueblo State Park

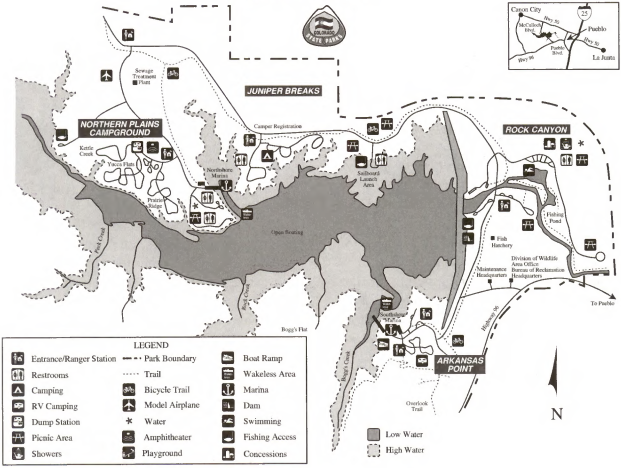


TABLE 6-9

Reservoir Angling Estimates 1994-1998

	Twin Lakes (1995) [1]	Turquoise (1997) [1]	Clear Creek (1995) [1]	Pueblo (1998) [2]
January	138	191	796	9,500
February	138	191	796	15,210
March	138	191	796	35,560
April	138	191	796	52,800
May	141	191	1,114	55,800
June	543	2,522	2,304	66,880
July	579	2,638	3,134	60,440
August	519	1,766	2,676	56,500
September	149	725	1,920	38,400
October	138	191	796	20,100
November	138	191	796	15,500
December	138	191	796	13,200
Total	2,897	9,179	16,720	439,890

[1] **Source:** Colorado Division of Wildlife and USDA Forest Service (Angler use in the winter was estimated, not surveyed, to be 50 percent of the summer use at Twin Lakes and Clear Creek Reservoirs, 20 percent at Turquoise Reservoir, and 10 percent at Pueblo Reservoir.)

[2] **Source:** Colorado Division of Parks and Outdoor Recreation

Hydrology and Water Augmentation

Riverflows within the upper Arkansas River vary considerably from month to month and year to year depending on precipitation, weather, natural runoff patterns, and operation of the BOR's Fryingpan-Arkansas Project. Figure 6-9 displays the mean daily base flows for three periods of time. Figure 6-10 displays an average hydrograph for the upper Arkansas River. The solid black line represents the average of the mean monthly flow as measured at the Wellsville gaging station for water years 1991 to 1995. Mean monthly flows for water years 1995 and 1996 are shown as dashed lines in Figure 6-10 as an indication of the variability that can occur from one year to the next. Riverflows are particularly variable during spring runoff, which generally occurs from May through June. In wet years, such as 1995, relatively high riverflows are common in the river well into August and September. In dry and average years, the spring runoff is generally shorter in duration and smaller in magnitude.

Riverflows within the study area are regulated to some degree by the operation of the Fryingpan-Arkansas Project and releases from Turquoise and Twin Lakes. The Fryingpan-Arkansas Project was designed and built to capture, store, and regulate "nonnative" water (i.e., waters diverted from the western slope) primarily for the purpose of providing irrigation water for agricultural use downstream. Overall, project operations increase the total amount of water that flows through the system by an average of 69,500 acre-feet annually, relative to preproject conditions. Nonnative, project water is generally stored in Turquoise and Twin Lakes Reservoirs during the spring and released in late fall and winter. These releases augment native flows and increase the total flow of the river. Timing of releases, riverflows, and reservoir levels are also affected by the needs and calls of water rights owners in coordination with the State Engineer's Office.

FIGURE 6-9

Mean Daily Base Flows by Month for Three Periods
Measured at the Wellsville Gage

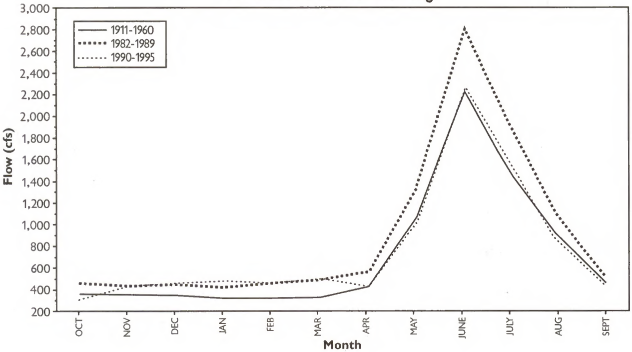
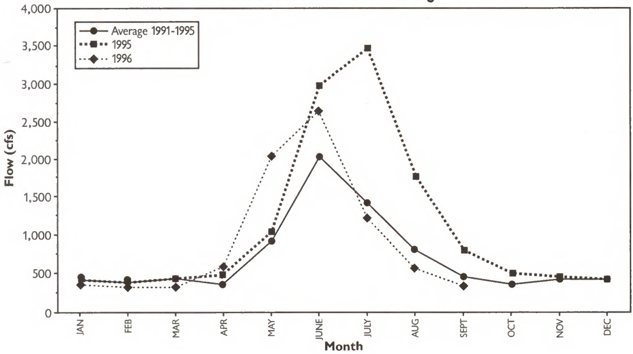


FIGURE 6-10

Arkansas River Mean Monthly Flows 1991-1996
Measured at the Wellsville Gage



In 1990, an annual flow program was initiated to enhance white-water boating, river angling opportunities, and the fishery resource. Under this program, Fryingpan-Arkansas project operating procedures have been modified when feasible and used to maintain minimum acceptable flows on a year-round basis. This has been accomplished by changing Fryingpan-Arkansas releases and municipal flow releases from fall periods to mid- to late summer periods. When native flows in the river have dropped below specified levels, project water has been released to augment that low flow. The distribution of the augmentation water differs from year to year depending on native flow conditions.

Following are the key elements of this annual flow program (as paraphrased from the 1998-1999 annual flow letter to BOR):

~ The highest priority is the maintenance of a minimum year-round flow of at least 250 cfs to protect the fishery.

~ Winter incubation flows (mid November through April) should be maintained at a level of not more than 5 inches below river height during the spawning period (October 15 to November 15). The optimum flow range is from 250 to 400 cfs, depending on spawning flows:

Minimum Incubation Flow November 16 - April 30		**Spawning Flow** October 15 - November 15
250 cfs	if	300 - 500 cfs
325 cfs	if	500 - 600 cfs
400 cfs	if	600 - 700 cfs

~ To the extent possible, between April 1 and May 15, the Bureau of Reclamation (BOR) should maintain flows within the range of 250 to 400 cfs in order to provide conditions favorable to egg hatching and fry emergence.

~ Deliveries in excess of 10,000 acre-feet should be subject to review and consideration, prior to such deliveries, by the BOR and the Southeastern Colorado Water Conservancy District.

~ Subject to water availability, BOR should augment flows during the July 1 to August 15 period at 700 cfs through releases from the Fryingpan-Arkansas River Project. The 700 cfs level is a target; when augmentation occurs, every effort should be made to ensure that flows are as little above, or as little below, 700 cfs as possible. The Colorado Division of Parks and Outdoor Recreation (CDPOR), using funds collected from commercial outfitters, shall be responsible for replacing evaporative losses caused by summer augmentation.

~ BOR should avoid dramatic fluctuations on the river as much as possible throughout the year. When it is necessary to alter flow rates, BOR should limit the daily change to 10-15 percent.

~ It may be possible to improve feeding conditions for brown trout by reducing flows between Labor Day and October 15 in years when flows would otherwise be higher than those recommended by the Colorado Division of Wildlife (CDOW). If potential benefits warrant the effort, Arkansas Headwaters Recreation Area (AHRA) managers, the CDOW, BOR and the Division II Engineer should work with the water users to seek opportunities for reducing flows after Labor Day.

Water lost to evapotranspiration due to the summer augmentation program (and the fact that waters are being released during the hot summer months as opposed to the cooler winter months) is paid for by commercial boater fees and released to water users by AHRA. A provision within the flow program maintaining flows of 700 cfs from July 1 through August 15 has caused concerns regarding potential impacts on the river fishery associated with flow conditions during the late summer. These concerns prompted implementation of a detailed water needs assessment for the river, of which this report is a component.

Water levels at Turquoise, Twin Lakes, and Pueblo Reservoirs are determined primarily by natural runoff conditions and project operations. Typically, the upper reservoirs (Turquoise and Twin Lakes) are lowered during the late fall and winter months to make storage space available for the following spring runoff. The reservoirs are generally filled in June and July and remain relatively full until they are drafted again in the fall. Lake Pueblo is operated somewhat differently. Rather than maximizing spring storage, the reservoir fills during the winter months (as the upper reservoirs are drafted). Lake levels typically peak in May or June, then decline steadily over the summer months in response to downstream irrigation demands. Figures 6-11 through 6-13 display monthly lake levels at the three reservoirs during the calendar year 1996.

Assessment Methodology

Two recreation user surveys were specifically designed and implemented for the purpose of assessing recreation water needs within the study area; one was oriented towards river recreation, and one was oriented towards reservoir recreation. In addition to these two user surveys, several other secondary data sources were reviewed and evaluated. Information from these secondary sources was used to test the accuracy and validity of the primary survey data. Where appropriate, results were compared, contrasted, and combined to provide the most accurate and comprehensive analysis possible. The overall goal of this approach was to obtain multiple viewpoints using multiple evaluation techniques as a means of corroborating findings and

FIGURE 6-11

Twin Lakes Reservoir Monthly Water Surface Elevations for 1996

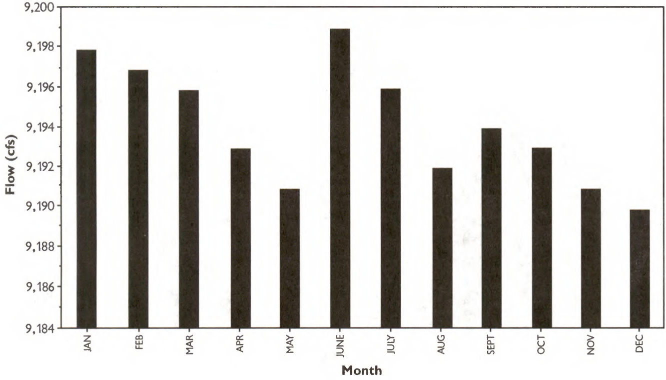


FIGURE 6-12

Turquoise Reservoir Monthly Water Surface Elevations for 1996

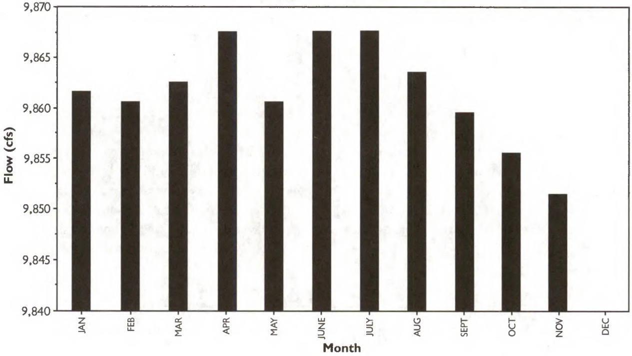
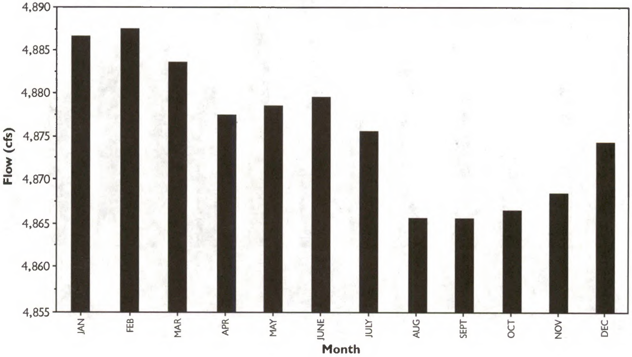


FIGURE 6-13

Pueblo Reservoir Monthly Water Surface Elevations for 1996



minimizing potential bias that could be associated with reliance on only one assessment technique. In total, information from over 4,000 different users was used in determining water needs for river and reservoir recreation.

The two primary data sources (1994 reservoir user survey and 1995 river user survey) were specifically designed with the intent of evaluating river and reservoir water level needs. Both surveys relied on widely accepted social survey techniques that have been applied elsewhere to evaluate similar relationships. The methods were selected to provide the best available information given the particular circumstances for the Arkansas River. In the case of the reservoir surveys, because little existing information regarding users and user preferences was available, user contact surveys were designed and employed specifically to gather data on user opinions at discretely different lake levels. Considerable time was spent by the CDPOR and CDOW at each of the reservoirs to maximize the sample sizes of the data sets for each lake level. Rigorous statistical tests were applied to this data by staff at Colorado State University to evaluate relationships between lake levels and a variety of measures of user satisfaction. The data set was sufficiently robust to accommodate these analyses.

With regard to the river data and the 1995 river user survey (as described below), off-site surveys of knowledgeable, experienced users (often referred to as flow comparison surveys) are recognized as one of the best methods for establishing flow preference curves. This technique provides a series of individual preference curves (based on actual, past experiences) that can be aggregated to develop overall curves for specific recreation activities. The technique allows the researcher to control both the flow being evaluated and the user conducting the evaluation. In the case of the Arkansas River, the presence and relative accessibility of so many frequent, experienced river users makes this assessment technique an ideal choice. In designing and implementing the survey, a focus group was assembled to pretest the survey instrument and a comprehensive mailing list was compiled to ensure that a range of different users were sampled. Ultimately, the survey yielded responses from over 400 users.

The statistical reliability of this data and its conclusions were strengthened by comparing and contrasting the results with several other surveys, as described in detail under "Results." This technique allows for cross referencing and provides additional protection against bias that could be associated with one particular study or assessment technique. This technique also allows for further examination of the variability in the data, not only within a given data set, but from one data set to another, which has tremendous value in evaluating the overall congruency of the data. Specific statistical analyses employed are described in more detail below and under "Results." Ultimately, the results from all the various data sources examined are remarkably similar, particularly given the inherent variability associated with recreation analyses that attempt to identify preferences for large populations representing a broad diversity of activities and interests (see "Results").

Data Sources

The data sources that were reviewed, evaluated, and analyzed to determine water needs for recreation on the Arkansas River and its associated storage reservoirs included:

Primary Data
1994 reservoir user survey
1995 river user survey

Secondary Data
1991 river user survey
Creel census data
1994 focus group meeting
Arkansas Headwaters Recreation Area visitor use data
Physical habitat modeling data
Reservoir surface area/elevation curves

These data sources include surveys of experienced users, casual users, private boaters, commercial boaters, and anglers of all types for all six segments of the river from Leadville to Pueblo Reservoir and all four of the basin reservoirs. Of the users surveyed regarding river conditions, approximately 70 percent were anglers and 30 percent were boaters. Activities surveyed at the reservoirs differed according to the individual reservoir.

Tables 6-10 and 6-11 summarize survey data used for the river analysis. Table 6-12 summarizes activities surveyed at each reservoir. The specific reservoir elevations sampled and the number of users interviewed are shown in Table 6-13. Each of the data sources evaluated is described briefly below.

TABLE 6-10

Data Sources and Sample Sizes Used for River Recreation Analysis

	No. Boaters	No. Anglers	Total
1995 river user survey	288	131	419
1994 focus group meeting	14	5	19
1992 CDOW creel census	-	1,514	1,514
1991 river user survey	524	305	829
Total Sample Size	**826**	**1,955**	**2,781**

Source: EDAW, Inc.

TABLE 6-11

Representation of Private and Commercial River Boating Use

	Private	Commercial	Total
1995 river user survey	162	126	288
1991 river user survey	88	436	524
Total Sample Size	**250**	**562**	**812**

Source: EDAW, Inc

TABLE 6-12

Reservoir Sample Sizes and Activity Percentages*

Reservoir	No. of People Surveyed	% Boating	% Fishing
Turquoise	477	23	71
Twin	429	23	72
Pueblo	394	67	42
Total Sample Size	**1,300**		

* Percentages may not add up to 100 because some respondents were neither boating nor fishing and percentages may add to more than 100 because users were both boating and fishing.
Source: EDAW, Inc.

TABLE 6-13

Reservoir Survey Sample

Reservoir	Survey Dates	Elevation (ft)	Drawdown (ft)	No. Users Sampled (n)
Turquoise				
(Top of conservation pool = 9,869 feet)	May 28-29, 1994	9,845	24	69
	June 11-12, 1994	9,861	8	110
	June 25-26, 1994	9,869	0	143
	July 16-17, 1994	9,867	2	39
	August 13-14, 1994	9,867	2	116
Twin Lakes				
(Top of conservation pool = 9,200 feet)	June 11-12, 1994	9,194	6	96
	June 25-26, 1994	9,196	4	100
	July 25-29, 1994	9,193	7	26
	July 30-31, 1994	9,191	9	16
	August 13-14, 1994	9,186	14	88
Pueblo				
(Top of conservation pool = 4,880 feet)	June 25-26, 1994	4,860	20	84
	July 23-24, 1994	4,848	32	127
	August 20-21, 1994	4,842	38	70
	Sept. 10-11, 1994	4,839	41	40
	July 1-29, 1995, 19944,881	4,881	0	33

Source: EDAW, Inc.

1994 Reservoir User Surveys

- Primary source of data for reservoir recreation analysis.
- On-site user surveys.
- Conducted at Turquoise, Twin Lakes, and Pueblo Reservoirs in 1994.
- Designed by EDAW, Inc., specifically for this water needs assessment.
- Focused on the relationship between lake levels and recreation opportunities/experiences.
- Implemented by BLM and the CDPOR
- User interviews conducted during several weekends throughout the summer season representing different reservoir levels.
- Surveys focused primarily on weekend days to maximize user encounters and increase the overall sample size.
- Total of 1,300 users contacted (477 at Turquoise, 429 at Twin Lakes, and 394 at Pueblo).

- Sampled reservoir elevations at Turquoise Lake: 9,869 to 9,845 feet, a difference of 24 feet.
- Sampled reservoir elevations at Twin Lakes: 9,189 to 9,196 feet, a difference of 7 feet.
- Sampled reservoir elevations at Pueblo Reservoir: 4,839 to 4,881 feet, a difference of 42 feet.
- Sample size for each reservoir water level ranged from a low of 16 people to a high of 127 people.

1995 River User Survey

- Primary source of data for river recreation analysis.
- Off-site mail survey designed by EDAW, Inc., specifically for this water needs assessment
- Implemented by BLM and CDPOR
- Focused on experienced users with existing knowledge of different flows.
- Mailing list compiled from outfitters, clubs and organizations, and local users.
- Notices soliciting input were also posted at local bait and tackle stores and in local newspapers.
- Total of 419 respondents. Many respondents provided information for more than one activity and/or more than one river segment.
- Two-thirds of the respondents provided information regarding boating activities, while one-third provided information regarding fishing opportunities.
- Two-thirds of the respondents represented private interests, while the remaining one-third represented commercial interests.
- Respondents were specifically asked to rate flow levels for different recreation activities from 200 cfs to 2,500 cfs in 100-cfs increments. Responses were based on an individuals prior experiences and knowledge of river conditions at specific flow levels.

1991 River User Survey

- Designed and conducted by Virginia Polytechnical Institute (VPI).
- On-site contacts followed by detailed mail surveys.
- Focused on boaters and anglers.
- Conducted from Leadville to Cañon City. However, angling contacts were concentrated in river Segments 3 (Stockyard Bridge to Badger Creek) and 4 (Coaldale to Pinnacle Rock).
- Anglers were sampled from June 14 to September 30.
- Boaters were contacted between Memorial Day and August 16.
- Both commercial and private boaters were surveyed.
- Encompassed flows from 300 cfs to >2,400 cfs.
- 829 river users were asked about flows (524 boaters - 63 percent and 305 anglers - 37 percent).
- 83 percent of boaters surveyed were commercial users, primarily customers.

Creel Census Data

- Creel census conducted by CDOW in 1989, 1992, and 1995.
- Focused on Arkansas River anglers, including bait anglers, lure anglers, and fly anglers.
- Included monthly angling use estimates for censussed river segments.
- 1992 census was conducted in spring (April and May) and fall (September).
- 1995 census was conducted from April through September.
- Creel data includes information regarding flow preferences provided by 1,514 anglers.
- Riverflows ranged from 266 to 1,229 cfs during the 1989 census, 270 to 1,500 cfs during the 1992 census, and 385 to 3,520 cfs during the 1995 census.

1994 Focus Group Meeting

- Small group of local users convened in November 1994 to discuss flow needs for river recreation.
- Used to pretest draft mail survey.
- Group included boaters and anglers.
- Participants were asked to each individually complete a brief questionnaire regarding flow preferences.
- The group also participated in an open discussion regarding flow preferences for specific recreation activities.

- A total of 19 individuals participated in the meeting.

Arkansas Headwaters Recreation Area Visitor Use Data

- Monthly visitor use estimates by activity type from 1991-1996.
- Commercial and private boater counts compiled by 2-week increments for April-September for 1991-1996.
- Commercial counts compiled by daily use and flow increments for August 16-31, between 1991 and 1996.

Physical Modeling

- Transect results for Wellsville station.
- Indicate how the wetted perimeter, depth, and velocity of the river change with changing streamflows.
- Reservoir surface area/elevation curves calculated based on area capacity curves

Data Analyses

Analysis of the two primary data sources focused on identifying observed relationships between reported experiences and river and lake water levels (relative frequency analysis). Typical analyses included evaluating how average responses to specific questions varied with changing water levels, as well as how the percentage of individuals providing a particular response to a given question changed as water levels changed. Where appropriate, various statistical techniques, including T-tests and analysis of variance, were applied to determine if observed differences in responses between various water levels were statistically significant at a 95 percent confidence interval. Specific key analyses and a discussion of their statistical significance are described briefly below.

User Survey Analyses

The 1995 river user survey was specifically designed to facilitate the development of flow preference curves. Responses to question A5, which asked respondents to evaluate specific riverflows based on their past experience on a scale from totally unacceptable to totally acceptable, were averaged for each identified flow level and plotted to derive flow preference curves for different activities, different river segments, and different skill levels. Standard deviations were calculated about the means to assess the variability in the data. Regression analyses were also performed to develop lines of best fit to the data.

The 1991 river survey also asked users to rate the quality of the riverflow for their given activity. However, instead of evaluating several flows based on past experience, respondents were asked via a mail survey to recall and rate the flow level they experienced on the day they were contacted. Responses for this question were aggregated according to discrete flow ranges and average responses were calculated and plotted. These curves were then compared with the curves generated from the 1995 user survey. For comparison purposes, the 1991 data was rescaled to represent a five-point rating scheme (rather than the existing six-point scheme) that would be consistent with the 1995 data. In rescaling the 1991 data, the existing perfect and superior responses were combined to create one response that would be similar to a rating of totally acceptable on the 1995 survey. The net effect of this rescaling was relatively small because few of the 1991 survey respondents used the perfect rating. For the purpose of comparison between the two surveys, responses of "good" were equated with "somewhat acceptable," responses of "acceptable" were equated with "marginal," responses of "substandard" were equated with "somewhat unacceptable," and responses of "terrible" were equated with "totally unacceptable."

The 1992 CDOW creel census also specifically asked anglers contacted on the river to indicate whether they felt the flow they had experienced on that day was good, too high, or too low. Responses from this question were aggregated according to three discrete flow ranges (250-500 cfs, 500-900 cfs, and 900-1,500 cfs) and the relative frequency for each response category was calculated. Relative frequencies were than plotted to generate a flow preference curve for anglers. This curve was compared to the other flow preference curves described above. Flow preference curves were also created from the data obtained during the 1994 focus group meeting and compared to those developed from the 1991 and 1995 survey data.

Using the various flow preference curves described above, thresholds for acceptable and optimal conditions for angling and white-water boating were identified. Thresholds for acceptability were selected based on the point at which the flow preference curve crossed the neutral, or marginal, line. Thresholds for optimal conditions were selected based on the identified peak of the curve. As a sensitivity analysis, optimum thresholds were also selected based on clear inflection points rather than the peak of the graph. The results of this analysis for each flow preference curve were aggregated by selecting the highest and lowest values represented from all the curves to generate thresholds that represented all of the data combined. This process is presented in detail under "Results." As an additional validity check, responses to questions A2, A4, and A5 on the 1995 user survey (which specifically asked users to identify what they considered to be the optimum range, as well as the highest and lowest flow acceptable) were averaged by activity and the results compared with the results of the procedure described above. Relative frequency analyses of these questions were also performed to examine the congruency of the data.

Historical Use Analyses

Visitor use estimates for angling and boating on the river were examined relative to different historic flow conditions in the river to see if flows had a detectable effect on the amount and/or type of use on the river. Where available, bimonthly use estimates were examined specifically to evaluate the potential incremental impact of the water augmentation program on angling and boating use. Use during the months of April-September were specifically examined, with particular attention paid to April and August. Reservoir use levels for 1996 were also examined relative to measured lake level elevations.

Physical Modeling

In addition to evaluating the results of the various user contact surveys, two physical analyses were conducted to assess the impact of altered riverflows and lake levels on shoreline conditions and wadability. For the river, output from the IFIM Physical Habitat Modeling program for a transect location near Wellsville was examined to see how changes in riverflow influence the wetted perimeter of the river, water depths, and water velocities. This output provides some indication of how access and wadability opportunities may change as riverflows change. With regard to the reservoirs, existing area/capacity data were used to assess how the acres of exposed shoreline change with changing lake levels. These data provide an indication of potential threshold levels above or below which there may be significant differences in terms of shoreline access and/or boating safety.

Results

Results are presented below according to the key analyses conducted (as described "Assessment Methodology"). For each analysis, summary results are presented, followed by results from each of the data sources examined. Where data exists, results are presented by primary activity.

River Recreation Survey Results

As described under "Assessment Methodology," flow preference curves were calculated from the various surveys for each of the primary river recreation activities. Threshold flows were then derived from these flow preference curves and combined to determine the range of acceptable and optimal flow for each major activity type. Table 6-14 presents the combined acceptable flow results and the acceptable flow ranges from all of the survey data examined.

Study results indicate that, in general, the majority of anglers using the river prefer lower flows. Fly anglers, or about 54 percent of all anglers, have a threshold acceptable low flow preference of 250 cfs and an acceptable high flow preference of 800 cfs. Of course, preferences vary for anglers. Spin and bait anglers, or about 46 percent of all anglers, have a threshold acceptable low flow preference of 500 cfs and an acceptable high flow preference of 2,000 cfs. Flow preferences for float fishing anglers have a threshold acceptable low flow preference of 550 cfs and an acceptable high flow preference of 2,500 cfs. Float fishing activities (which involve a combination of angling and boating activities) are presented in the discussion on river boating. See Tables 6-14, 6-15, and 6-16, and Table 6-17 (later in this section).

However, optimum conditions vary considerably depending on the type of angling and individual skills and experience. Study results show that fly anglers have expressed an optimum threshold flow preference range between 400 and 500 cfs. Spin and bait anglers appear to be more tolerant of higher flows than fly anglers (see river angling discussion under "River Recreation Survey Results"). Spin and bait anglers have expressed in study results an optimum threshold flow preference range between 700 to 1,200 cfs. Flow preferences for float fishing are also higher with optimum conditions ranging from 900 to 1,200 cfs (see the river boating discussion under "River Recreation Survey Results").

Study results indicated that, in general, the majority of boaters using the river prefer higher flows. Kayakers, or about 10 percent of all boaters, have a threshold acceptable low flow preference of 650 cfs and an acceptable high flow preference of 2,500 cfs. Rafters, or about 90 percent of all boaters, have a threshold acceptable low flow preference of 750 cfs and an acceptable high flow preference of 2,500 cfs. See Table 6-14 and Tables 6-17 and 6-18 (later in this section).

However, optimum conditions vary for boaters depending upon type of boating and individual skills and experience. Study results show that kayakers have expressed an optimum threshold flow preference range between 1,300 and 1,500 cfs. Rafters have expressed in study results an optimum threshold flow preference range between 1,500 and 2,000 cfs.

TABLE 6-14

Overall Combined Threshold Flow Values (cfs) and Range of Acceptable Flows for Recreation

Activity	Acceptable Low Flow [Range of Acceptable Low Flows]	Optimum Low Flow [Range of Acceptable Optimum Flows]	Optimum High Flow [Range of Acceptable Optimum High Flows]	Acceptable High Flow [Range of Acceptable High Flows]
Fishing	250	250	500	1,200
	[250 - 500]	[250 - 700]	[300 - 1,200]	[800 - 2,000]
Boating	550	1,000	2,000	2,500
	[550 - 750]	[900 - 1,500]	[1,200 - 2,400]	[1,500 - 2,500]

Source: EDAW, Inc.

River Angling

Tables 6-15 and 6-16 display the calculated threshold values for acceptable and optimum conditions for river angling from each of the four river user surveys examined. The bottom row of Table 6-15 displays a combined set of values, which encompasses all of the data sets by selecting the lowest and highest values displayed in the table after eliminating the most extreme values. Tables 6-15 and 6-16 also provide an indication of the overall congruency of the results.

TABLE 6-15

Summary of Threshold Levels for Angling

Data Source	Acceptable Low Flow [cfs]	Optimum Low Flow [cfs]	Optimum High Flow [cfs]	Acceptable High Flow [cfs]
1995 River Survey - Fly Fishing	250	400	500	800
1991 River Survey - Spin Fishing	500	700	1,200	2,000
1991 River Survey	250	n/a	n/a	1,200
Creel Census	250	250	500	900
Focus Group	200	200	300	800
Combined *	250	250	500	1,200

* Determined by selecting lowest and highest represented value after eliminating the most extreme value.

Source: EDAW, Inc.

TABLE 6-16

Relative Frequency Distribution of Responses to Questions Regarding the Acceptable and Optimum Flows for Angling

Flow [cfs]	Lowest Acceptable Ave. = 324	Low Optimum Ave. = 386	High Optimum Ave. = 863	Highest Acceptable Ave. = 1,118
200	**38%**	**21%**	0%	0%
300	**41%**	**35%**	3%	2%
400	5%	**25%**	**15%**	4%
500	3%	7%	**26%**	**10%**
600	2%	1%	**9%**	**15%**
700	1%	1%	6%	**14%**
800	3%	4%	8%	**11%**
900	2%	2%	3%	1%
1,000	0%	1%	9%	6%
1,200	1%	1%	6%	6%
1,500	1%	1%	3%	6%
2,000	0%	0%	3%	9%

Sources: EDAW, Inc. & 1995 River Use Survey

Results from each of the individual data sources are described below.

1995 User Survey Results

Figure 6-14 displays the flow preference curve generated from all anglers surveyed during the 1995 river user survey (131 individuals). The bars shown in Figure 6-14 represent the average rating calculated for each flow. The line shown indicates the percentage of respondents that rated each flow as somewhat acceptable. These two displays simply represent two different techniques for assessing the preference for a given flow. In both cases, results show increasing acceptability as flows increase from 200 to 500 cfs, followed by a steady decline in acceptability as flows increase above 500 cfs. Figure 6-15 displays the calculated standard deviation about the mean response, as well as a fitted regression line to the average response for each flow. While the variability about the calculated preference curve appears relatively large, the regression analysis shows a very good fit with an r^2 of 0.79.

Figures 6-16 and 6-17 show calculated preference curves for respondents representing two different types of angling: spin fishing and fly fishing. Again the bars indicate the average rating for each flow, while the lines indicate the percent of respondents that indicated they would be somewhat satisfied with a given flow. A comparison of Figures 6-16 and 6-17 suggests that spin anglers and fly anglers have fairly different flow preferences. While fly anglers appear to consider flows of 400 to 500 cfs to be optimum and flows greater than 800 cfs to be unacceptable, spin anglers appear to consider flows of <400 cfs to be unacceptable or marginal and flows around 1,000 cfs to be optimum. The significance of this apparent difference should be considered with caution given the relatively low number of spin anglers sampled (28 individuals). However, the difference is a reasonable expectation given the difference in fishing style employed by the two user groups. Fly anglers typically fish relatively shallow riffle areas and commonly wade while fishing. Spin and bait anglers, on the other hand, tend to fish from shore and prefer areas where there are deeper pools. Consequently, fly anglers would be expected to be more sensitive to increasing flows than spin anglers.

FIGURE 6-14

Calculated Flow Preference Curve for River Angling

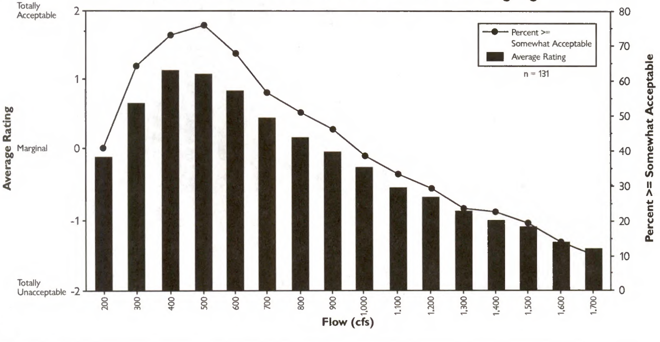


FIGURE 6-15

Standard Deviation and Regression Fit for River Angler Flow Preference Curve

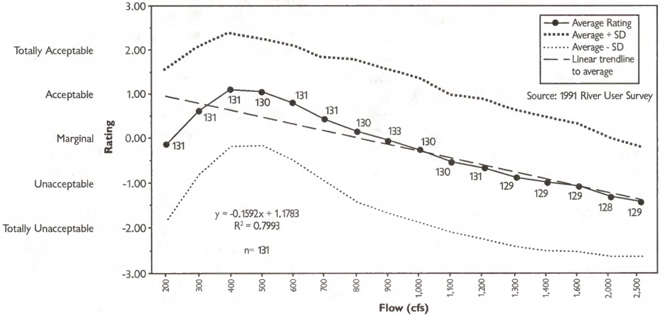


FIGURE 6-16

Spin Fishing Flow Preference

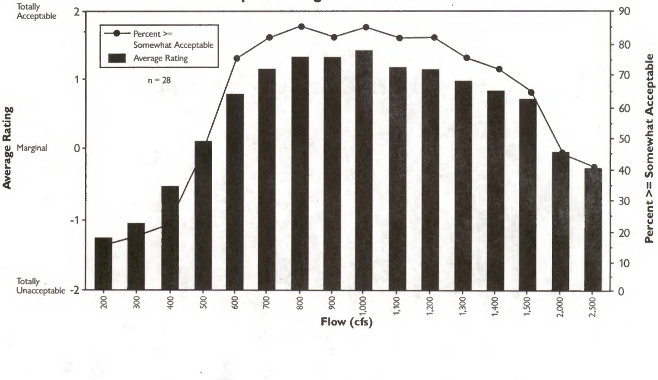
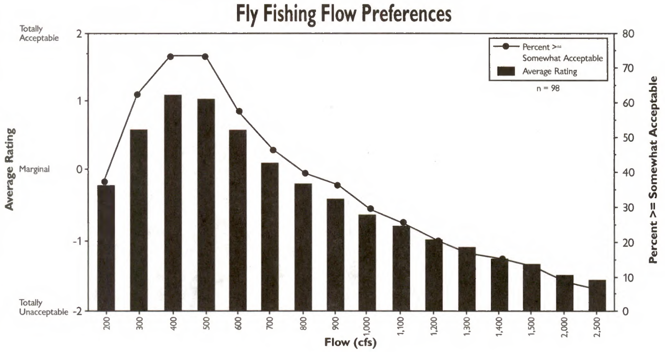


FIGURE 6-17



Figures 6-18 and 6-19 display calculated angler flow preferences by skill level and river segment. Figure 6-18 suggests that expert anglers are somewhat more tolerant of high flows than intermediate or advanced anglers, with flows as high as 1,200 cfs considered somewhat acceptable. This result may suggest that expert anglers are more adept at fishing in less than ideal conditions and/or are more knowledgeable of specific locations that are acceptable for fishing at higher flows, and therefore, they are less affected by increasing flow levels. Again it should be noted that at this level of stratification, the sample sizes are relatively low. Figure 6-18 suggests that the relationship between flow and angling opportunity does not differ significantly from reach to reach. Interestingly, it does suggest that the uppermost segment of the river is considered better at the lowest flows and worst at the highest flows. Similarly, the lower gradient segments of the river, such as segment 4 and segment 7, are more acceptable at the highest flows. This is generally consistent with what would be expected given the physical characteristics of the river channel and gradient.

Assuming that the point at which the average curve crosses the marginal level is a reasonable estimate of the range of acceptable flow, and that the peak of the curve is a reasonable estimate of the range of optimal conditions, the results shown in Figures 6-16 and 6-17 suggest the following thresholds for river angling:

	Spin Angling	Fly Angling
Acceptable Range:		
	500 - 2,000 cfs	250 - 800 cfs
Optimum Range:		
	700 - 1,200 cfs	400 - 500 cfs

In addition to asking users to rate specific flow levels, the 1995 survey also specifically asked respondents to indicate what they considered to be the lowest acceptable flow, the highest acceptable flow, and the optimum flow range (survey questions A2-A4). Results from these three questions are summarized in Table 6-16, which displays the relative frequency distribution of the respondent choices across the

FIGURE 6-18

Flow Preference by Angler Skill Level

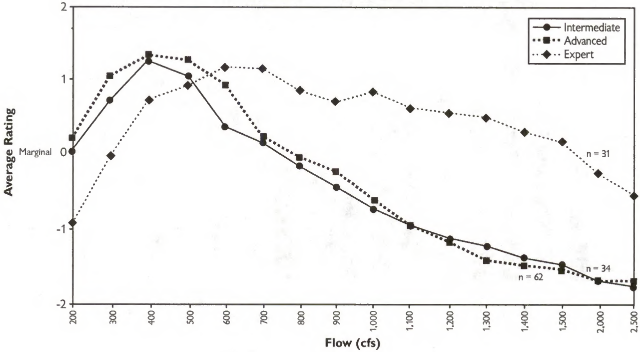
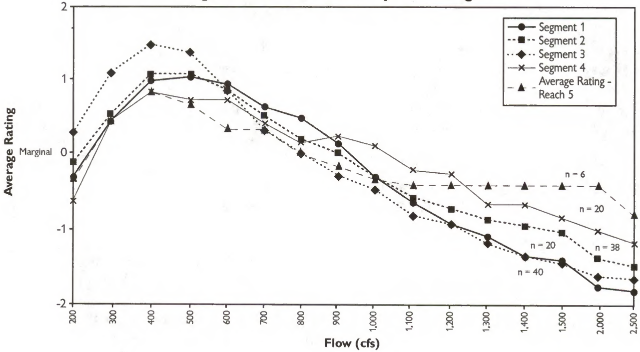


FIGURE 6-19

Angler Flow Preference by River Segment *



* Segments are defined in Table 6-3.

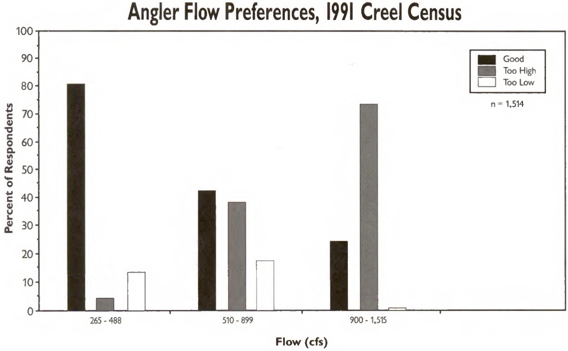
range of flows identified for all anglers. Table 6-16 also provides the average of all the responses. The average response for lowest acceptable flow was 324 cfs and almost 80 percent of the respondents indicated either 200 or 300 cfs. This result is in general agreement with the threshold values identified above. The average response for highest acceptable flow was 1,118 cfs. The distribution of responses regarding the highest acceptable flow indicates that there is not strong agreement on the exact flow, but that 51 percent of the respondents placed it between 500 and 800 cfs.

It should be noted that the results presented above were derived from a survey specifically targeted towards knowledgeable, experienced users of the river. It is assumed that these users are a reasonable surrogate for other, less experienced users and that what these users consider to be acceptable and optimum would also be considered acceptable to a less frequent user or a first-time angler visiting the river.

Creel Census Data

During CDOW's 1992 creel census of the Arkansas River, 1,514 anglers were contacted on the river and asked to indicate whether they felt flows were good, too high, or too low. Anglers did not know the flow at the time they were interviewed. Figure 6-20 displays a relative frequency distribution of the responses to this question aggregated by three flow ranges: 265-488 cfs; 510-899 cfs; and 900-1,515 cfs. These flow ranges represent a natural break in preference values as flow changed through the season. In other words, the majority of anglers thought the flow was good when it was actually in the 265-488 cfs range. The dark black bars in Figure 6-20 indicate the percentage of anglers that indicated flows were good for each flow category. Similarly, the gray bars indicate the percentage of anglers that felt the flow was too high. The results displayed in Figure 6-20 suggest that flows between 265 and 488 cfs are clearly considered superior (with 80 percent of the anglers encountered satisfied), flows between 510 and 899 cfs are marginal (about half of the anglers satisfied and half unsatisfied), and flows between 900 and 1,515 cfs are unacceptable to the vast majority of anglers encountered (approximately 25 percent of the anglers satisfied and 75 percent unsatisfied). The inverse relationship between angling quality and flows greater than 488

FIGURE 6-20



cfs displayed in Figure 6-20 is very consistent with the results from the 1995 user survey. In terms of thresholds, results from the 1992 creel census suggest the following:

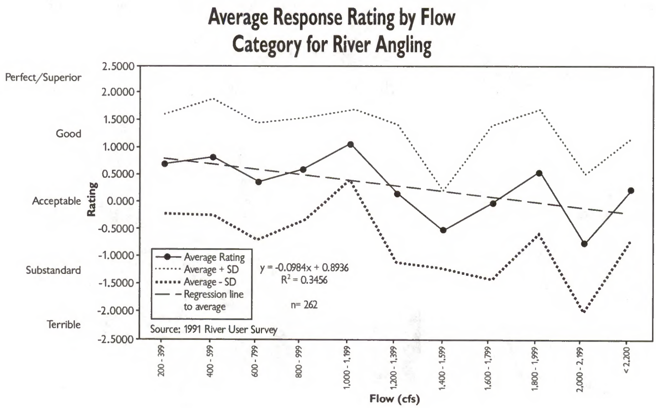
Acceptable Range: 265 - 899 cfs
Optimum Range: 265 - 488 cfs

Data from the 1992 CDOW creel census also suggest that angler water needs may differ by season. The creel census was conducted in the spring (April and May) and the fall (September). Flows below 500 cfs occurred and were sampled in both cases. However, angler reactions to these lower flows were somewhat different in the spring than they were in the fall. During the spring, almost 90 percent of the anglers contacted at flows below 500 cfs indicated that the flows were good, and very few (5 percent) indicated that they were too low. By contrast, the percentage of anglers that indicted flows below 500 cfs were good during the fall survey was smaller (approximately 70 percent), while the percentage that indicated flows below 500 cfs were too low was much larger (approximately 30 percent). These results suggest that either there is a very different user group fishing the river during these two seasons, or there are some other environmental conditions, such as water quality, that influenced user responses in the fall.

1991 River User Survey

During 1991, 305 anglers completed surveys that included a question regarding the quality of the riverflow for fishing. These users were asked to indicate whether the flow was perfect, superior, good, acceptable, substandard, or terrible. Figure 6-21 displays the average scores calculated from this data for a range of flow categories. The flow categories displayed were chosen based on the distribution of the samples across the full range of flows and is intended to create bin sizes that are of sufficient size and that are relatively even across all the categories. Figure 6-21 also displays the calculated standard deviation about the mean and a

FIGURE 6-21



fitted regression line. This display is intended to be directly comparable to Figure 6-15 which show results from the 1995 user survey. As noted under "Assessment Methodology," the perfect and superior categories were combined to convert the existing six-point rating scale to a five-point rating scale that would be consistent with the data from the 1995 user survey. Generally, this conversion has little effect on the interpretation of the 1991 survey results because the number of individuals selecting the perfect category was very small.

As shown in Figure 6-21, the calculated relationship between flow and angling opportunity is inversely proportional, with quality decreasing as flows increase. This result is very similar to the results from both the 1995 survey data and the 1992 creel census data (see Figures 6-15 and 6-20), namely that there is an inversely proportional relationship with flow.

In terms of threshold values, assuming all data points above the acceptable line on the Y-axis are acceptable and that the peak of the graph represents optimum conditions, the 1991 data suggests the following:

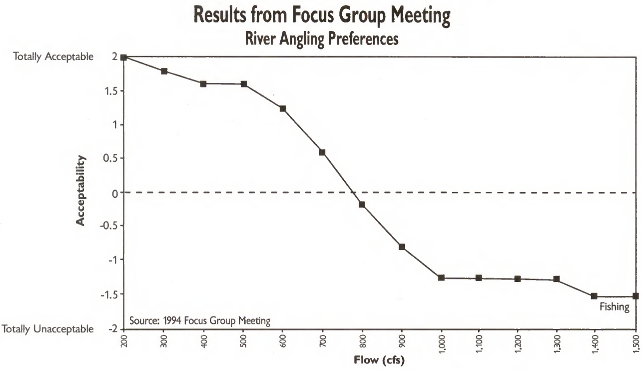
Acceptable Range: 250 - 1200 cfs
Optimum Range: No distinct peak in graph

1994 Focus Group Meeting

Participants in the 1994 focus group meeting were asked to rate specific flow conditions for angling based on their past experiences. The question provided to participants was identical to the question ultimately used for the 1995 user survey. Figure 6-22 displays the average ratings for the five anglers that participated in the focus group meeting. As with the other analyses presented above, results show declining quality with increasing flows. With regard to threshold values, Figure 6-22 suggests the following:

Acceptable Range: 200 - 800 cfs
Optimum Range: 200 - 300 cfs

FIGURE 6-22



River Boating

Table 6-17 shows threshold values for acceptable and optimum conditions for river boating from each of the three data sources examined. The bottom row of the table displays a combined set of values, which encompasses all of the data sets by selecting the lowest and highest values displayed in the table after eliminating the most extreme values. Table 6-17 also provides an indication of the overall congruency of the results. Results from each of the survey data sources examined are presented below. Results are presented for both white-water boating and float fishing.

1995 User Survey Results

Figure 6-23 displays a flow preference curve generated from all boaters surveyed during the 1995 river user survey (288 individuals). The bars in Figure 6-23 represent the average rating calculated for each flow. The line indicates the percentage of respondents that rated each flow as somewhat acceptable. In both cases, results show a steeply increasing level of acceptability as flows increase from 200 cfs to 1,000 cfs followed by a flattening of the curve, with little difference in acceptability ratings from 1,000 cfs to 2,500 cfs. Figure 6-24 displays, for the same data set, the calculated standard deviation about the mean response, as well as a fitted regression line to the average response for each flow. While the variability about the calculated preference curve appears relatively large, the regression analysis shows a very good fit with an r^2 of 0.89.

Figure 6-25 shows calculated preference curves for respondents representing three different types of boating: white-water rafting, white-water kayaking, and float fishing. These results show that the river is generally unacceptable for all forms of boating at flows less than 500 cfs and that the acceptability of the river for all forms of boating increases at a relatively steep rate as flows increase from 400 cfs to 1,000 cfs. These results also show some distinct differences in flow preferences for each of the three boating activities. At flows greater than 1,000 cfs, the acceptability of the river for white-water rafting and kayaking continues to increase, though at a relatively small incremental rate. The acceptability of the river for float fishing at flows greater than 1,000 cfs declines at a relatively steep rate. Another interesting difference between the three types of river boating is the spread in the magnitude of the acceptability ratings for flows between 400 cfs and 1,000 cfs. The acceptability of the river for float fishing was consistently rated higher for flows in this range indicating a higher tolerance for lower flows.

TABLE 6-17

Summary of Threshold Levels for Boating

Data Source	Acceptable Low Flow (cfs)	Optimum Low Flow (cfs)	Optimum High Flow (cfs)	Acceptable High Flow (cfs)
1995 River Survey Float Fishing	550	900	1,200	2,500
1995 River Survey Kayaking	650	1,300	1,500	>2,500
1995 River Survey Rafting	750	1,500	2,000	>2,500
1991 River Survey	500	1,500	>2,400	>2,400
1994 Focus Group	550	1,000	1,500	>1,500
Combined *	550	1,000	2,000	>2,500

> Means greater than value shown

* Determined by selecting lowest and highest represented value after eliminating the most extreme value

Source: EDAW, Inc.

FIGURE 6-23

Calculated Flow Preference Curve for River Boating - 1995

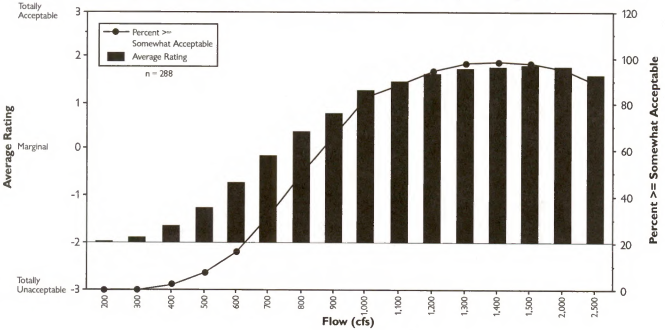


FIGURE 6-24

Standard Deviations and Regression Line for River Boating

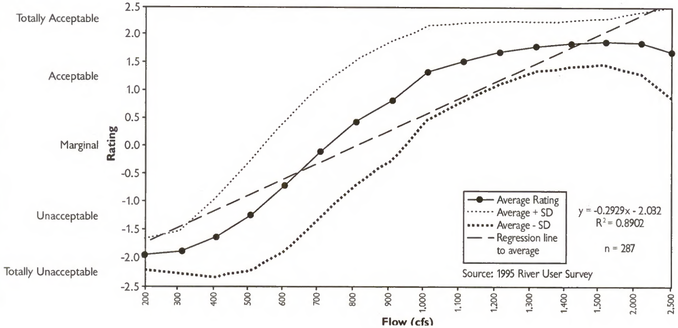
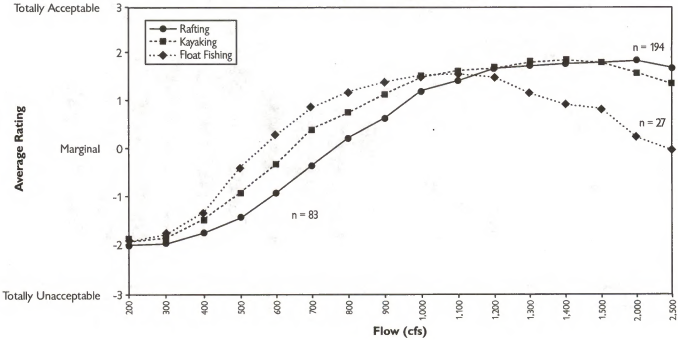


FIGURE 6-25

Flow Preferences by Boating Activity



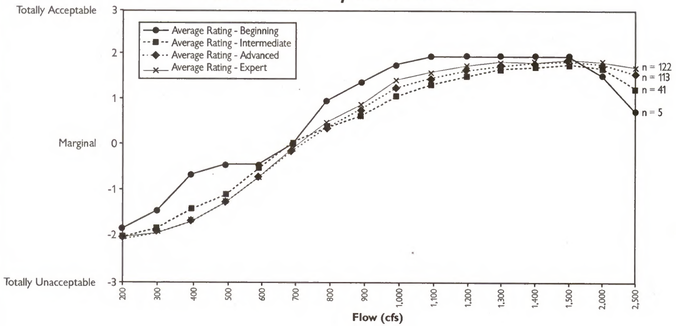
Similarly, the acceptability of the river for white-water kayaking was consistently rated higher in this flow range than it was for white-water rafting, again indicating a slightly higher tolerance for lower flows. Intuitively, these results make sense and are generally what would be expected. Float anglers are generally more concerned with the overall navigability, or floatability, of the river and the ability to fish, which is typically easier at slower velocities. Float anglers are generally not looking for a white-water experience and therefore do not require the higher flow levels that cause more challenging river hydraulics, which are attractive to white-water boaters. In fact, flows that are too high will detract from the angling experience, which is what is shown in Figure 6-25. The observed difference between white-water kayakers and white-water rafters is also predictable. Kayaks are considerably smaller and more maneuverable crafts requiring less in the way of channel widths and river depths. The white-water hydraulics required for a challenging kayaking experience are also often less than they are to provide an exciting white-water rafting experience.

Figure 6-26 displays the calculated flow preferences for different boating skill levels. These results show very little difference between intermediate, advanced, and expert boaters. However, they do show that beginning boaters consider the acceptability of the river to be greater at low flows, particularly at flows between 400 cfs and 1,100 cfs. At flows greater than 1,500 cfs, there is a relatively steep decline in acceptability for these beginning boaters, particularly as compared with the more skilled boaters. Both of these results are consistent with what would be expected.

Assuming that the points at which the average curve crosses the marginal level is a reasonable estimate of the range of acceptable flow, and that the peak of the curve is a reasonable estimate of

FIGURE 6-26

Flow Preferences by Boater Skill Level



the range of optimal conditions, the results shown in Figure 6-25 suggest the following thresholds for river boating:

	Float Fishing	Kayaking	Rafting
Acceptable Range:	**550 - 2,500 cfs**	**650 - >2,500**	**750 - >2,500**
Optimum Range:	**900 - 1,200 cfs**	**1,300 - 1,500**	**1,500 - 2,000**

In addition to asking users to rate specific flow levels, the 1995 survey also specifically asked respondents to indicate what they considered to be the lowest acceptable flow, the highest acceptable flow, and the optimum flow range (survey questions A2-A4). Results from these three questions are summarized in Table 6-18, which displays the relative frequency distribution of the respondents' choices across the range of flows identified for all boating. Table 6-18 also displays the average of all the responses in the top row.

As with the 1995 user survey data for anglers, it should be noted that the results presented above for river boating were derived from a survey instrument specifically targeted towards knowledgeable, experienced users of the river. It is assumed that these users are a reasonable surrogate for other, less experienced users and that what these users consider to be acceptable and optimum would also be considered acceptable to a less frequent user or a first-time boater visiting the river.

1991 River User Survey

During 1991, 524 boaters completed surveys that included a question regarding the quality of the riverflow for boating. These users were asked to indicate whether the flow was perfect, superior, good, acceptable, substandard, or terrible. Figure 6-27 displays the average scores calculated from this data for a range of flow categories. The flow categories displayed were chosen based on the distribution of the samples across the full range of

TABLE 6-18

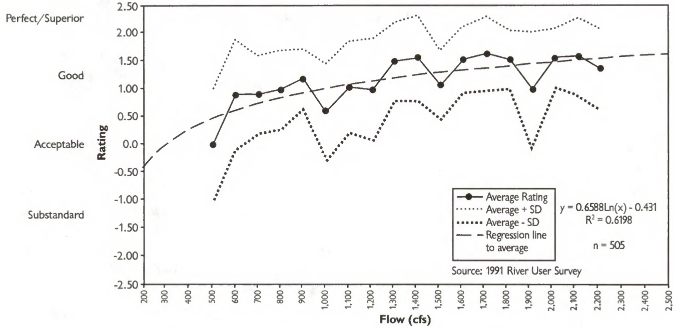
Relative Frequency Distribution for Responses to Questions Regarding the Acceptable and Optimum Flows for Boating

Flow	Lowest Acceptable	Low Optimum	High Optimum	Highest Acceptable
	Ave. = 764 cfs	Ave. = 1,144 cfs	Ave. = 2,922 cfs	Ave. = 3,762 cfs
300	3 %	0 %	0 %	0 %
400	9 %	3 %	0 %	0 %
500	**14 %**	4 %	0 %	0 %
600	**12 %**	4 %	0 %	1 %
700	**17 %**	7 %	0 %	0 %
800	**16 %**	**11 %**	0 %	0 %
900	8 %	**7 %**	0 %	0 %
1,000	16 %	**23 %**	1 %	0 %
1,200	2 %	**9 %**	1 %	0 %
1,500	0 %	**17 %**	5 %	2 %
2,000	0 %	8 %	**15 %**	5 %
2,500	0 %	2 %	**14 %**	**10 %**
3,000	0 %	1 %	**23 %**	**20 %**
4,000	0 %	0 %	**13 %**	**13 %**
5,000	0 %	0 %	2 %	**15 %**

Source: EDAW, Inc.

FIGURE 6-27

Average Response by Flow Category for River Boating - 1991



flows and is intended to create bin sizes that are of sufficient size and that are relatively even across all of the categories. Figure 6-27 also displays the calculated standard deviation about the mean and a fitted regression line. This display is intended to be directly comparable to Figure 6-24 which show results from the 1995 user survey. As noted under "Assessment Methodology," the perfect and superior categories were combined to convert the existing six-point rating scale to a five-point rating scale that would be consistent with the data from the 1995 user survey. Generally, this conversion has little effect on the interpretation of the 1991 survey results because the number of individuals selecting the perfect category was very small.

The results from the 1991 survey (as shown in Figure 6-27), show a much flatter flow preference curve for boating than that derived from the 1995 survey data (see Figure 6-24). While the acceptability or quality of the experience appears to increase with increased flow, the incremental benefit is much less per cfs than displayed in Figure 6-24. In addition, Figure 6-27 suggests that all the flows sampled were considered to be acceptable, even flows in the 500-700 cfs range. No flows below 500 cfs were sampled. Consequently, it is difficult to project the preference curve below this water level. However, the data show a very steep slope between the 500-599 cfs category and the 600-699 cfs category with a fairly strong inflection point at 600 cfs. This suggests a high degree of sensitivity to changes in flow in this range and the likelihood that samples below 500 cfs would have been rated unacceptable.

The relatively flat slope of the preference curve shown in Figure 6-27 and the fact that virtually all the users sampled were satisfied is somewhat predictable given the methodology used to collect this data. On-site user surveys are generally biased towards the sampling of satisfied users. Users that consider certain flow conditions to be unacceptable, and therefore choose not to use the river at those flows, are far less likely to be encountered on the river at those flow conditions, and therefore are not represented in the sample. Similarly, users that consider certain flow conditions to be acceptable, or do not know or care about specific flows, are the users that will likely be encountered at those flow conditions. In addition to this fact, over 80 percent of the boaters surveyed during the 1991 user survey (whose responses are displayed in Figure 6-27) were commercial rafting customers. Most of these users are boating the Arkansas River for the first time and therefore have no point of reference against which to evaluate the flow experienced. This is not to say that the results displayed in Figure 6-27 are not representative of the general experiences of the commercial customer population, but that these data are not particularly suitable for the development of preference curves, which by nature require an individual to compare and contrast multiple experiences at different flow conditions.

In terms of threshold values, assuming all data points above the acceptable line on the Y axis are acceptable and that the peak of the graph represents optimum conditions, the 1991 data suggests the following for white-water boating, particularly commercial rafting:

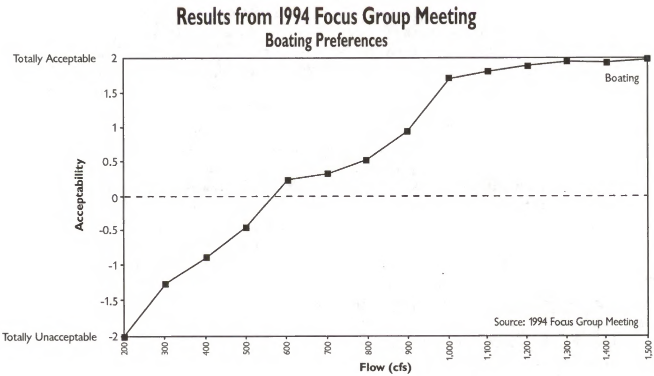
Acceptable Range: 500 - >2,400 cfs
Optimum Range: 1,500 - >2,400 cfs

1994 Focus Group Meeting

Participants in the 1994 focus group meeting were asked to rate specific flow conditions for boating based on their past experiences. The question provided to participants was identical to the question ultimately used for the 1995 user survey, except that the upper limit of the flows evaluated was 1,500 cfs rather than 2,500 cfs as in the 1995 survey. Figure 6-28 displays the average ratings for the 14 boaters that participated in the focus group meeting. As with the other analyses presented above, results show increasing quality with increasing flows in a fashion similar to that shown in Figure 6-24. With regard to threshold values, Figure 6-28 suggests the following:

Acceptable Range: 550 - >1,500 cfs
Optimum Range: 1,000 - 1,500 cfs

FIGURE 6-28



Historical Use Analysis Results

In 1995, the Arkansas River Basin had one of the wettest years on record, and riverflows were correspondingly high. This unusual event provided an opportunity to analyze how river usage corresponds with increased flows. However, other factors affecting river usage, such as summer vacation schedules and weather, were not considered in the analysis.

The analysis of 1995 usage patterns on the Arkansas River indicated increased recreation and boating use during periods of high flow (see Figures 6-29 and 6-30, respectively). Specifically, in the months of June, July, and August, when riverflows were between 1,800 and 3,500 cfs, river recreation use increased significantly. In May and September, there were approximately 20,000 and 16,000 river recreation users, respectively, while in June, July, and August, there were 60,000, 70,000, and 35,000 users, respectively. For boating, there were 32,000 users in May and 23,000 users in September, while during June, July, and August, there were approximately 90,000, 105,000, and 55,000 users respectively. Conversely, 1995 angling use produced an inverse curve, meaning that when riverflow was the highest, angling usage was the lowest (see Figure 6-31). During the months of June and July, which were periods of high riverflow, angling use decreased from approximately 4,200 users in May to 850 users in June (CDOW creel survey 1995), an 80 percent decline. The AHRA estimates show about a 60 percent reduction for the same period.

River Angling

Existing data on angling use of the river over time under different flow conditions is limited. However, data from 1995 (as shown in Figure 6-31) suggests that angling use is adversely affected by very high flows (>3,000 cfs). Peak use occurred in May when average monthly flows were 1,061 cfs. Use was also relatively high in August when flows in the river averaged 1,779 cfs. These findings suggest that while anglers may not prefer flows greater than

FIGURE 6-29

Monthly Arkansas River Recreation Use vs. Flow for 1995

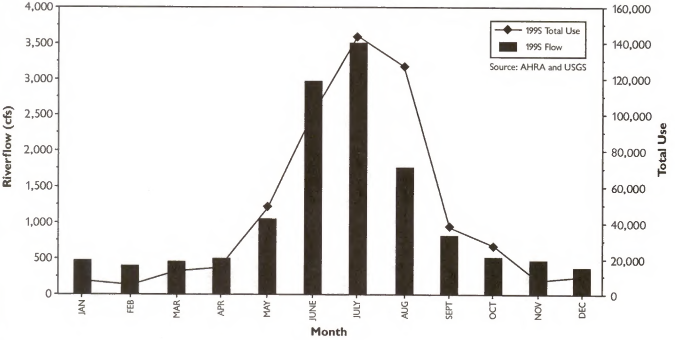


FIGURE 6-30

Monthly Arkansas River Boating Use vs. Flow for 1995

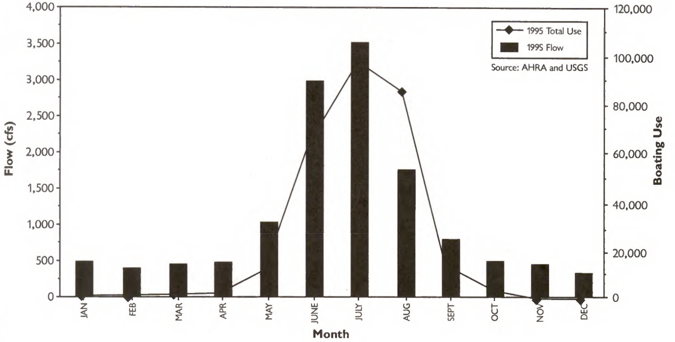
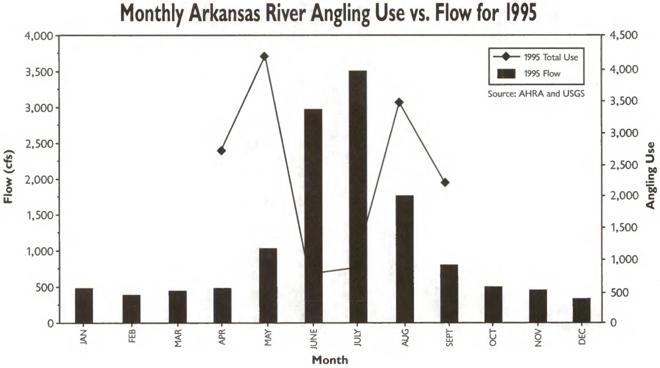


FIGURE 6-31



1,000 cfs they will tolerate such flows and do use the river at these flows. Numerous factors influence angling use, including events such as the occurrence of insect hatches that influence the quality of fishing. These factors may often be more important to the angler than flows and may tend to override the influence of flow on their decision to fish the river.

Combining what data is available from historic creel surveys on the river, it is possible to compare use patterns in relation to flow for the Big Bend to County Road 166 section of the river (2 miles) for certain months. This area was surveyed in 1989, 1991, 1992, and 1995, but was not surveyed during the same time periods each year. These data are shown in Table 6-19 for CDOW.

The data in Table 6-19 suggest that flows may influence angling use, particularly flows above 1,000 cfs, but that other factors likely also play a strong role. The highest monthly angling use observed in this section of the river occurred in August 1995 when the average flow was 1,779 cfs. The lowest use observed was in June 1995 when no anglers were seen and average flows were just under 3,000 cfs.

For the month of April, the data shows that use levels were approximately equal in 1992 and 1995 (277 and 242 anglers, respectively), while average flows were 334 cfs and 512 cfs, respectively. This suggests that flow changes in this range may not have a large influence on use. For the month of May, the data shows decreasing levels of use with increasing flows. Monthly use decreased from 600 anglers in 1989 when the average flow was 791 cfs, to 275 anglers in 1995 when the average flow was 1,061 cfs. Historical use patterns for September indicate a similar trend with use levels declining as flows increase. Monthly use in September 1989 was 404 anglers when flows averaged 344 cfs. In September 1995, use was 188 anglers with an average flow of 821 cfs. This pattern is similar in June, July, and August, with the exception of August 1995 when use levels were significantly higher than in 1989 or 1991 despite that fact that average flows were 1,779 cfs.

Angler monthly use as recorded by the AHRA was also compared to average monthly flows as shown in Table 6-20. In all of these cases, it should be noted that the potential influence of other factors has not

TABLE 6-19

CDOW Monthly Angler Use and Average Monthly Flows for the Big Bend to County Road 166 Section of the Arkansas River

Monthly	1989 [flows]	1991 [flows]	1992 [flows]	1995 [flows]
April			277 [334]	242 [512]
May	600 [791]		583 [944]	275 [1,061]
June	322 [1,229]	227 [1,669]		0 [2,998]
July	213 [1,211]	216 [842]		59 [3,521]
August	131 [934]	321 [554]		639 [1,779]
September	404 [344]		451 [423]	188 [821]

Source: CDOW Creel Data

TABLE 6-20

AHRA Estimates for Monthly Angler Use and Average Monthly Flows [measured in cfs at Wellsville Gage] for 1990 through 1995

Month	1990 [flows]	1991 [flows]	1992 [flows]	1993 [flows]	1994 [flows]	1995 [flows]
April	[225]	870 [445]	1,475 [334]	1,700 [382]	1,498 [404]	1,573 [512]
May	2,565 [498]	1,980 [949]	1,960 [944]	2,210 [1,396]	2,785 [952]	3,115 [1,061]
June	1,394 [1,957]	1,825 [1,669]	1,925 [1,160]	1,282 [2,498]	1,091 [2,161]	1,014 [2,998]
July	2,236 [1,041]	3,035 [842]	3,490 [822]	3,110 [1,741]	3,895 [743]	2,904 [3,521]
August	3,381 [632]	3,453 [554]	3,757 [697]	4,762 [676]	4,932 [560]	4,404 [1,779]
September	2,572 [327]	2,628 [314]	2,822 [423]	3,386 [534]	3,503 [338]	3,539 [821]

Source = AHRA & USGS

been accounted for. Observed differences in use from year to year may have been related to factors other than flow.

River Boating

Boating use patterns and riverflows over time are displayed in Table 6-21, which compares 1992-1995 data for the month of August, and in Figure 6-32, which shows average bimonthly commercial rafting use and river flow data from 1991 to 1995. Data are displayed for 2-week increments to better account for the variability that occurs within a month. Rafting use patterns are relatively similar from year to year despite considerably different magnitudes of flow. This is particularly evident when comparing 1992 with 1993 or 1995. Peak use always occurs in June, July, and August, consistent with the peak summer recreation season and summer vacations, and is generally of a similar magnitude. This suggests a level of demand that is largely driven by factors other than flow. However, it should be noted that

TABLE 6-21

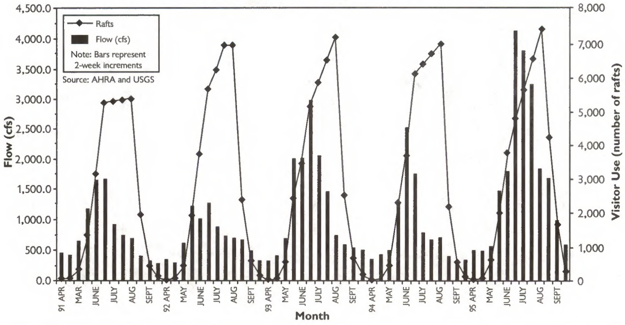
Comparison of August Commercial Rafting Use with Average August Riverflows

Year	Period	Average August Flow (cfs)	Total Commercial Rafts
1992	August 1-15	750	6,967
	August 16-31	724	2,389
1993	August 1-15	770	7,184
	August 16-31	646	2,503
1994	August 1-15	750	6,998
	August 16-31	433	2,175
1995	August 1-15	1,900	7,444
	August 16-31	1,806	4,235

Source = AHRA

FIGURE 6-32

Bimonthly Arkansas River Rafting Use vs. Flow, 1991-1995



the flow augmentation program was in place in all these years.

The greatest 2-week increment of use always appears to occur during the first 2 weeks in August as shown in Figure 6-33. From 1992 to 1994, the number of commercial rafts using the river was fairly consistent, averaging 7,050. Average flows during this period were also fairly consistent at 760 cfs, with the exception of 1995 when the river averaged 1,900 cfs during the first 2 weeks of August.

Rafting use typically declines considerably during the second 2 weeks of August as shown in Figure 6-34.

FIGURE 6-33

Early August Commercial Rafting with Average Early August Riverflows

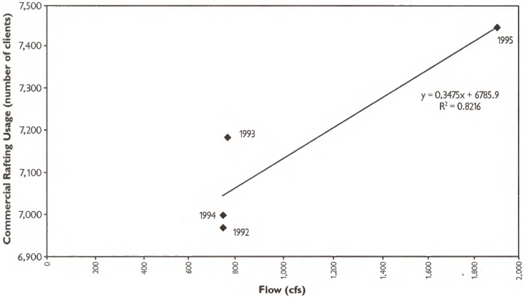
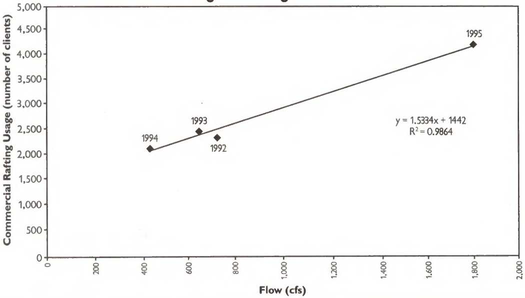


FIGURE 6-34

Late August Commercial Rafting with Average Late August Riverflows



However in 1995 use levels were higher than in previous years, corresponding to much higher flow conditions. The total number of rafts using the river during the second 2 weeks in August was fairly consistent from 1992 to 1994, ranging between 2,100 and 2,500. Average flows during this time were 724 cfs, 646 cfs, and 433 cfs for 1992, 1993, and 1994, respectively. In contrast, rafting use levels during this same time period in 1995 were considerably higher (4,235) corresponding to an average flow of 1,806 cfs.

The data from Table 6-21 for 1992-1995, as well as the data from 1991, are shown graphically in Figures 6-35 through 6-41. This data illustrates the relationship between daily riverflows and daily commercial use figures during the period August 16-31. On this daily level, the data shows that, in general, as flows drop after August 15, after the 700 cfs augmentation ends, there is a corresponding drop in commercial use. Table 6-22 shows this relationship clearly even when the 1995 late August data is excluded.

Overall, the data presented in Table 6-21 and in Figures 6-32 and 6-33 through 6-41 provides a general indication of how rafters have responded to different flow conditions in the past. During the months of June and July, and the first 2 weeks of August, there is not a significant correlation of flows and commercial use. It is not until flows drop below 700 cfs that clear correlation becomes apparent. In all of these cases, it should be noted that the potential influence of other factors has not been accounted for. Observed differences in use from year to year may have been related to factors other than flow.

Reservoir Recreation Survey Results

Survey results indicate that while users clearly prefer higher lake levels, water surface elevations play only a minor role in determining the overall quality of their recreation experience. This was particularly true for Turquoise and Twin Lakes Reservoirs, where the majority of users (>75 percent) indicated that lake

FIGURE 6-35

August Flows and Total Commercial Use - 1991

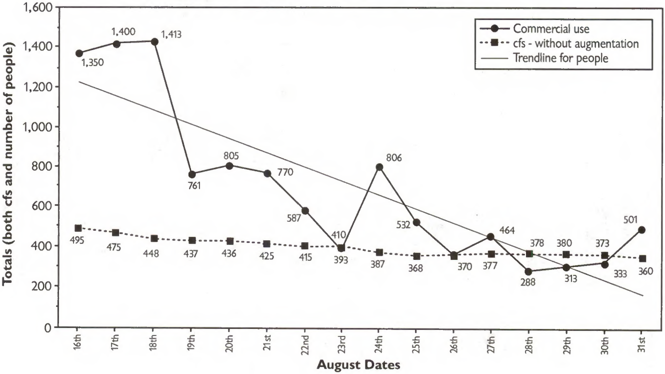


FIGURE 6-36

August Flows and Total Commercial Use - 1992

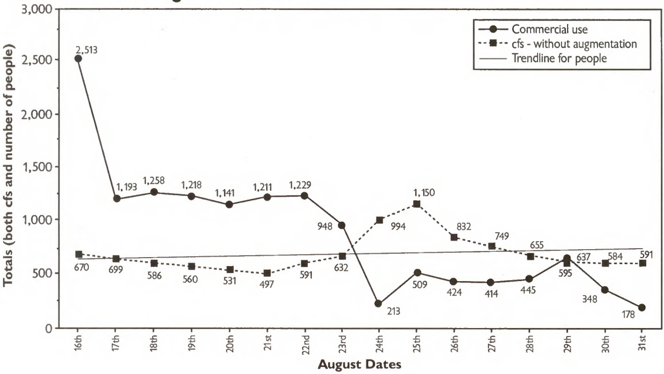


FIGURE 6-37

August Flows and Total Commercial Use - 1993

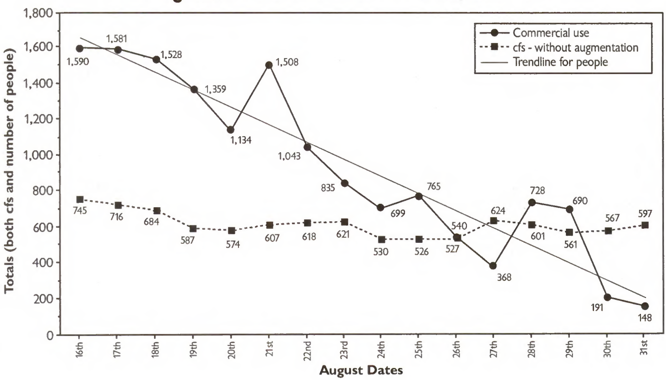


FIGURE 6-38

August Flows and Total Commercial Use - 1994

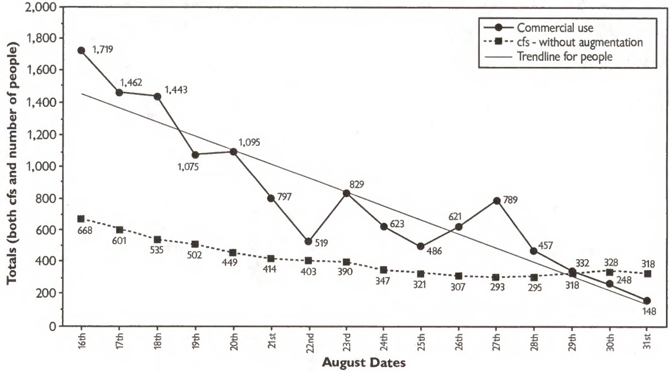


FIGURE 6-39

August Flows and Total Commercial Use - 1995

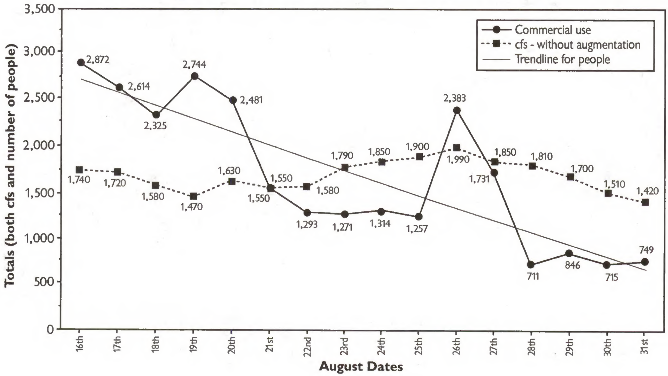


FIGURE 6-40

August Flows and Total Commercial Use - 1996

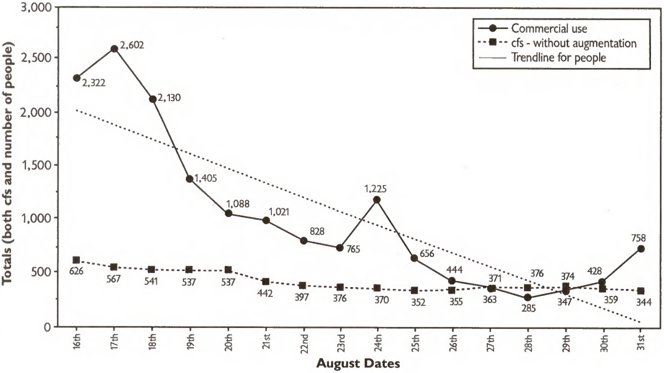


FIGURE 6-41

Averages of Commercial Use - 1991-1996
(Excluding 1995)

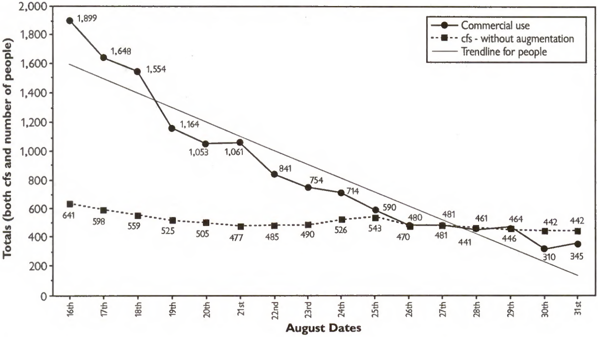


TABLE 6-22

Averages of 1991-1996 Late August Commercial Use (Excluding 1995)

Late August Date	Flows at Wellsville Gage (cfs)	Total Commercial Boats	Total People (clients & guides)
16	641	322	1,899
17	598	283	1,648
18	559	274	1,554
19	525	208	1,164
20	505	194	1,053
21	477	200	1,061
22	485	161	841
23	490	147	754
24	526	130	714
25	543	113	590
26	478	99	480
27	481	97	481
28	461	90	441
29	446	96	464
30	442	63	310
31	442	71	345

Source: AHRA

levels did not affect the quality of their experience and users consistently rated their overall experience as good to excellent, regardless of the lake level. Recreation users at Pueblo Reservoir appear to be more strongly affected by lake levels. At the lowest lake level surveyed (4,839 feet - 41 feet below full conservation pool), as many as 70 percent of the users surveyed indicated that their experience was affected by water level. At a higher water level (4,865 feet - 15 feet below full conservation pool), this percentage was reduced to slightly more than 10 percent, with almost 90 percent of the users indicating that they were not affected by water levels.

In all cases, at all three reservoirs, the majority of users surveyed (>87 percent) indicated that, regardless of water levels, they would choose to return under identical conditions. This suggests that while water levels have an influence on the recreation experience, water levels themselves (at least not across the range surveyed for this study) do not generally influence people's behavior patterns. Users have become accustomed to fluctuating water levels, particularly at Pueblo Reservoir.

Turquoise and Twin Lakes Reservoirs

Turquoise and Twin Lakes Reservoirs are similar in both their setting characteristics and the recreation activities that they support. Both reservoirs are situated at the upper end of the study area and both provide a relatively high elevation mountain experience. Both reservoirs are located entirely within the San Isabel National Forest and support developed day use and overnight facilities managed by the USFS. Most of the recreation use at the reservoirs is oriented towards camping, boating, fishing, and sightseeing. Approximately 60 percent of the users surveyed at Turquoise and Twin Lakes were camping, 70 percent were fishing, and 20 percent were boating. Almost all of the boating activity was oriented towards fishing.

The majority of users at Turquoise Reservoir came from the Front Range area of Colorado (70 percent). Approximately 8 percent of the users were from out-of-state. About a third of the users were first-time visitors while approximately 25 percent were frequent repeat users (had visited more than 10 times). Users at Twin Lakes were similar except that only 58 percent of the users came from the Front Range. Almost 20 percent of the users came from southeastern Colorado (as opposed to 9 percent at Turquoise), and 16 percent of the users were from out of state. As with Turquoise, about one-third of the users were first-time visitors and one-fourth were frequent visitors.

With regard to the effect of water levels on recreation, survey results indicate that users prefer higher water levels. Overall, the quality of the recreation experience was rated high at both lakes regardless of water level. The type and distribution of activities at the two reservoirs did not change with changing water levels.

Typically, reservoir water levels influence the overall appearance or aesthetics of the landscape. However, survey results for Turquoise and Twin Lakes suggest that while the appearance of the lakes is important, water levels (at least those sampled) do not play a strong role. While only 1 year was sampled, the lake level conditions experienced in 1994 were typical of the normal operation of the two reservoirs (see the "Recreation Setting" discussion for more details regarding reservoir operations). Users at both Turquoise and Twin Lakes indicated that their recreation experience was either somewhat or strongly affected by the appearance of the lakes. However, when asked if water levels themselves affected the quality of their experience, most users said no (75 percent at Turquoise and 81 percent at Twin Lakes).

Figures 6-42 and 6-43 show responses regarding the scenic beauty of the lakes versus water level. Each of the black bars shown represents a different weekend period that corresponds to a given lake level as shown with the overlaid line graph. The height of each bar graph depicts the percentage of users that consider the scenic beauty of the lake to be excellent. Results show that while this percentage generally increased as water levels increased, the change was

FIGURE 6-42

Turquoise Reservoir Scenic Beauty vs Water Level

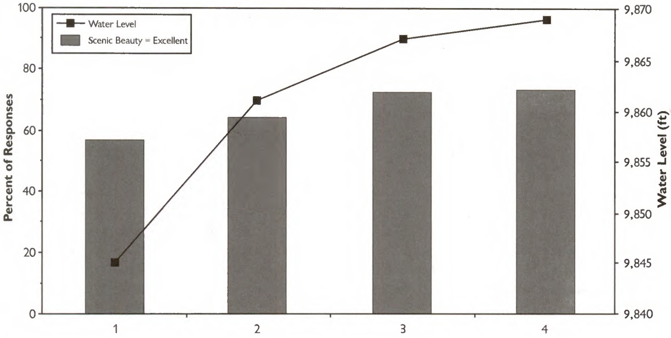
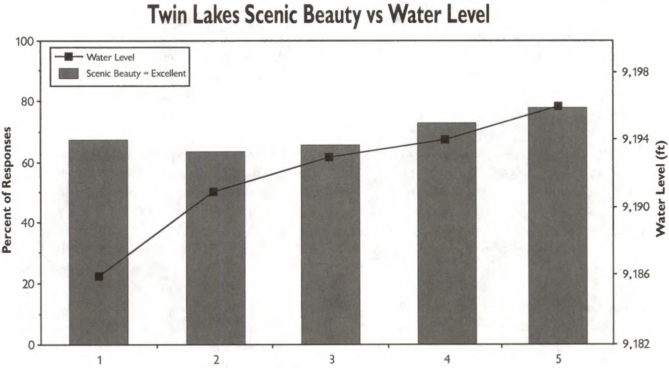


FIGURE 6-43



extremely small and the percentage of respondents rating scenic beauty as excellent was high (>60 percent), even at low water levels.

When asked if they would prefer water levels that were higher, lower, or the same, users generally indicated a preference for higher levels when the lakes were at their lowest and the same levels when the lakes were at their highest. These results are displayed in Figures 6-44 and 6-45, which show the percentage of respondents choosing either the same or higher/much higher at each of the surveyed water elevations for Turquoise and Twin Lakes. Again, each cluster of bar graphs represents a different sampling time, which corresponds to a different lake level as shown with the line graph. These results are generally consistent with the theory that users, when given a choice, prefer a full reservoir. However, they also suggest that users may not differentiate between a full reservoir and a minimal drawdown of only a few feet.
Finally, Figures 6-46 and 6-47 show how the percentage of respondents rating the overall recreation experience as excellent changed according to changing water levels at Turquoise and Twin Lakes Reservoirs. Again, there is a slight trend towards higher average scores as water levels increase, but the change is generally insignificant and the overall ratings are high even at low water levels.

Pueblo Reservoir

Located at the lower end of the study area, Pueblo Reservoir provides very different recreation opportunities from Turquoise and Twin Lakes Reservoirs. Pueblo Reservoir offers a high desert type setting and is used extensively for water-based activities including water skiing, sailboarding, and other personal watercrafts. Pueblo Reservoir is much larger than Turquoise or Twin Lakes Reservoirs and supports much higher use levels. Survey results indicate the predominant recreation activities at Pueblo Reservoir are boating (67 percent), fishing (42 percent), camping (31 percent), and water skiing (27 percent).

FIGURE 6-44

Turquoise Reservoir Water Level Preference

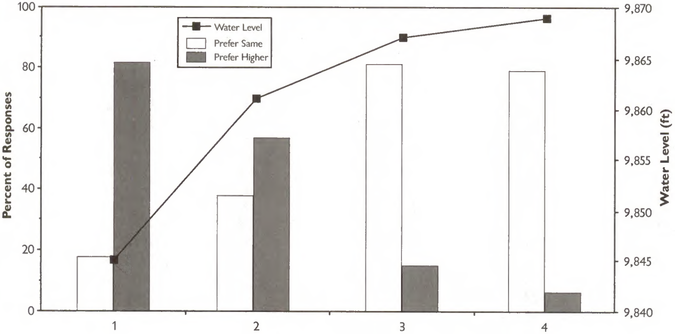


FIGURE 6-45

Twin Lakes Water Level Preference

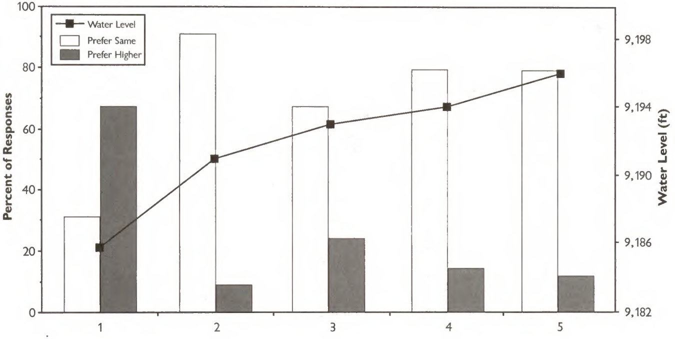


FIGURE 6-46

Turquoise Reservoir Overall Experience vs Water Level

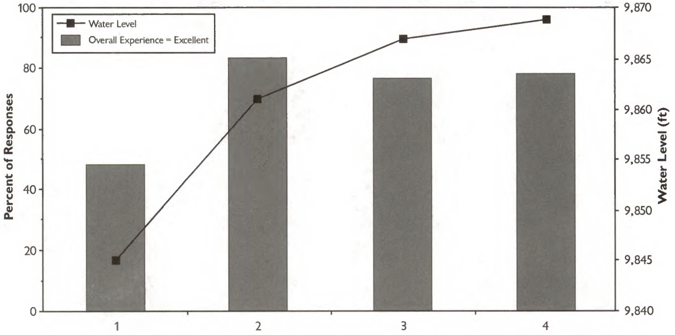
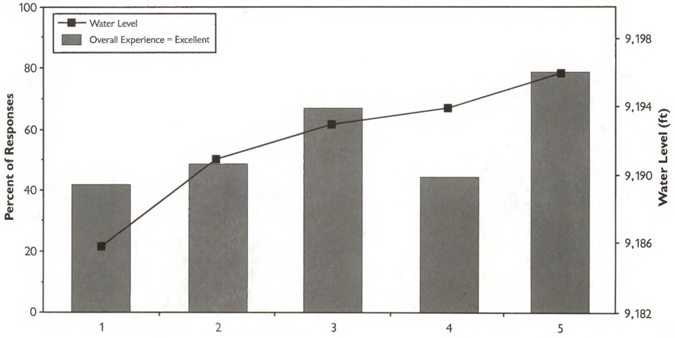


FIGURE 6-47

Twin Lakes Overall Experience vs Water Level



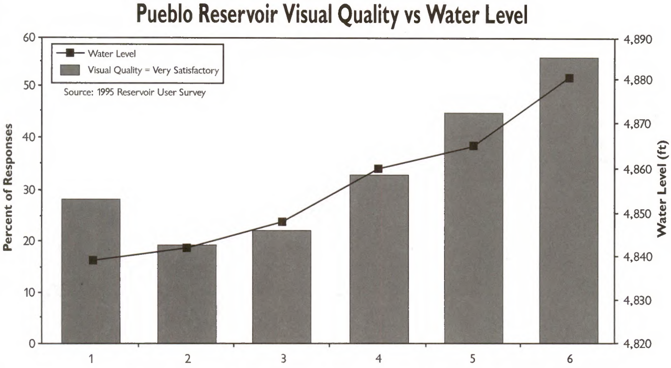
Almost two-thirds of the users surveyed at Pueblo Reservoir came from southeastern Colorado. Approximately one-third came from the Front Range, and 4 percent were from out of state. The majority of the users (54 percent) were frequent repeat users (had visited more than 10 times). About 20 percent of the users had been to the reservoir 2-5 times before, and just under 15 percent were first-time visitors.

With regard to the effect of water levels on recreation, survey results indicate a clear preference for higher water levels and concerns regarding safety, aesthetics, and the overall quality of the experience at low water levels. Unlike Turquoise and Twin Lakes Reservoirs, where the majority of users indicated that water levels did not affect the quality of their experience, 70 percent of the users surveyed at Pueblo Reservoir indicated that the quality of their experience was affected by water level at the lowest water level conditions (4,839 feet). This percentage decreased as water levels increased, but remained relatively high (>50 percent) for most of the water levels sampled. The type and distribution of activities at the reservoir, however, did not change with changing water levels.

The more pronounced influence of water level at Pueblo Reservoir compared to Turquoise or Twin Lakes Reservoirs is partly explained by the more severe drawdown at Pueblo (41 feet below full conservation pool versus 24 feet and 14 feet at Turquoise and Twin Lakes, respectively); the generally shallower nature of the reservoir shoreline; and the more water-oriented, body-contact recreation activities pursued at Pueblo.

When asked about the visual quality of the reservoir, users tended to provide higher ratings at higher water levels, as shown in Figure 6-48. Overall, 63 percent of the users surveyed indicated that the appearance of the lake had a somewhat strong to strong effect on their recreation experience.
When asked about safety, a higher percentage of the respondents tended to indicate that conditions were unsatisfactory or very unsatisfactory at lower

FIGURE 6-48



water levels. This trend is displayed in Figure 6-49. These results suggest that there is somewhat of a threshold water level between 4,850 feet and 4,860 feet at which safety concerns are significantly reduced. A similar threshold is shown in Figure 6-50, which displays user perceptions regarding shoreline access. These results indicate that a significantly higher percentage of the users are satisfied with shoreline access between water levels of 4,860 feet and 4,880 feet.

When asked if they would prefer water levels that were higher, lower, or the same, users generally indicated a preference for higher levels when the lakes were at their lowest and the same levels when the lakes were at their highest. These results are displayed in Figure 6-51, which shows the percentage of respondents choosing either the same or higher/much higher at each of the surveyed water elevations at Pueblo Reservoir. These results indicate that users, when given a choice, prefer more water in the reservoir.

Finally, Figure 6-52 shows how the overall recreation experiences of respondents changed according to changing water levels at Pueblo Reservoir. These results indicate a definite preference for water levels greater than 4,848 feet. Surprisingly, they also show that an increase in water level from 4,860 feet to 4,880 feet, a difference of 20 feet, did not make a significant difference in the overall quality of the experience. In fact, the higher water levels were rated, on average, slightly lower than the 4,860-foot level. This suggests that the recreation experiences available at Lake Pueblo when water levels are at 4,860 feet are similar to those that are available at higher elevations, such as 4,880 feet.

FIGURE 6-49

Pueblo Reservoir Safety vs Water Level

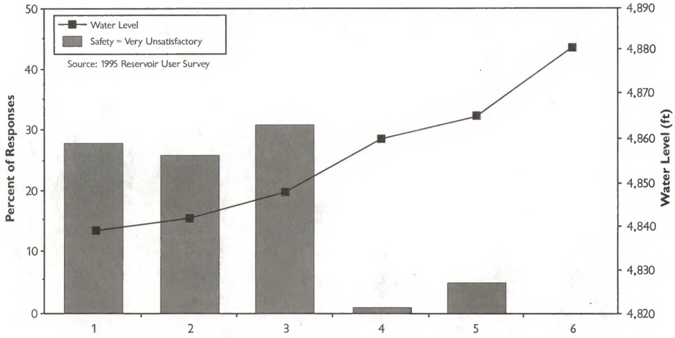


FIGURE 6-50

Pueblo Reservoir Shore Access vs Water Level

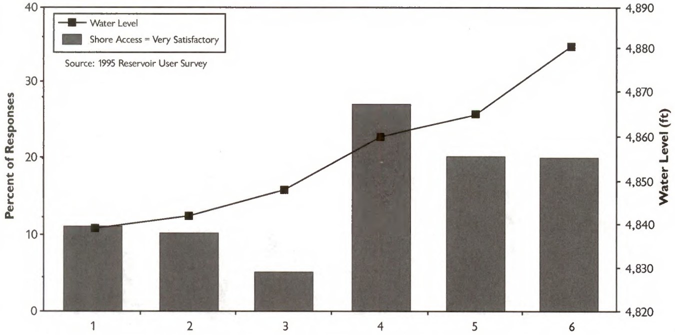


FIGURE 6-51

Pueblo Reservoir Water Level Preference

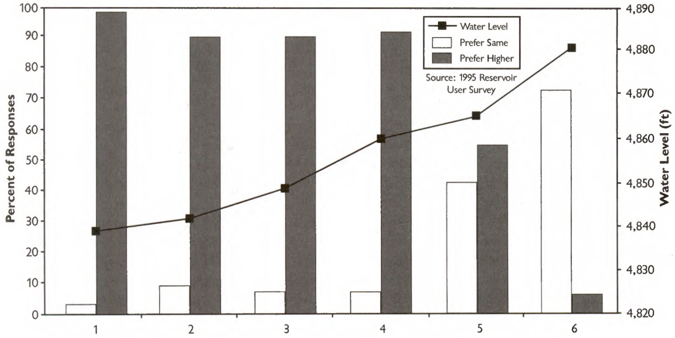
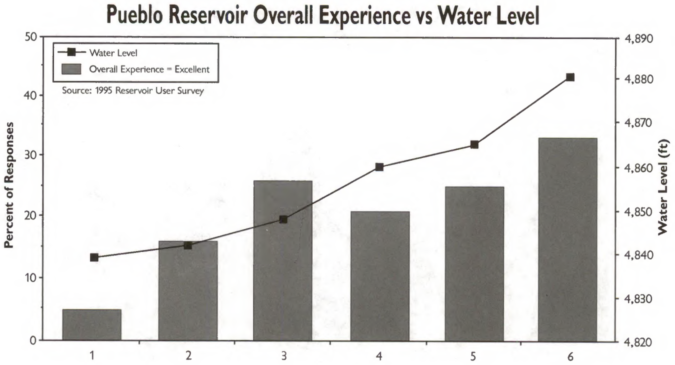


FIGURE 6-52



Physical Modeling Results

The relationship between reservoir water elevation and exposed shoreline acreage is linear at the three reservoirs, based upon physical modeling results (see Figures 6-53, 6-54, and 6-55). Twin Lakes Reservoir, at its highest surface elevation of 9,200 feet, has zero acreage of exposed shoreline. At the lowest modeled water elevation of 9,186 feet, a difference of 14 feet, there was an increase of 595 acres of exposed shoreline. The largest increase occurs with the surface elevation change from 9,199 to 9,198 feet, in which exposed shoreline increases 50 percent, from 44 to 88 acres. Surface elevation subsidence from 9,198 to 9,197 feet produces a 34 percent increase of exposed shoreline. The remaining elevation changes produce increases in exposed shoreline ranging from 25 percent to 6 percent. The relationship between draw-down and exposed shoreline has implications for both recreation and biological values. Figure 6-45 shows that a drawdown of 10 feet does not affect user preference. However, 70 percent of users prefer a higher water level when the lake is drawn down 14 feet. Biological impacts also occur with drawdowns of more than 10 feet (i.e., loss of littoral habitat - see Section 5 of the report for more details.)

The Turquoise Lake Reservoir model used decreasing water elevation changes of 5 feet. Exposed shoreline acreage ranged from 45 to 265 acres. Increases in exposed shoreline ranged between 38 percent and 22 percent for each 5-foot change in elevation. The most significant increase in exposed shoreline occurred with the water elevation drop from 9,870 to 9,865 feet, equaling 38 percent. The lowest percentage increase occurred with the water elevation decrease from 9,855 to 9,850 feet, equaling 22 percent. Again, the relationship between drawdown and exposed shoreline has implications for both recreation and biological values. User preferences are similar to those at Twin Lakes. A 5-foot drawdown does not affect user preferences (i.e., 80 percent are satisfied with the water level). However, 60 percent of users preferred a higher water level when

FIGURE 6-53

Calculated Relationship Between Twin Lakes Elevation and Exposed Shoreline

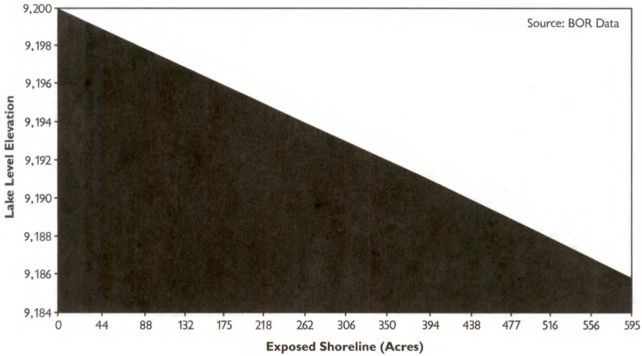


FIGURE 6-54

Calculated Relationship Between Turquoise Lake Elevation and Exposed Shoreline

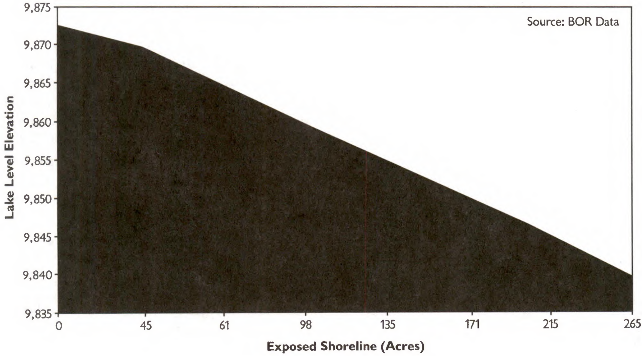
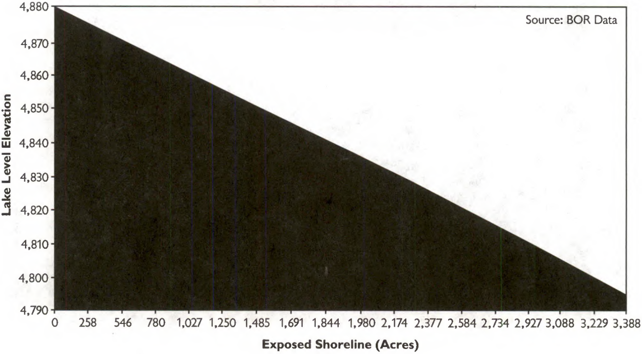


FIGURE 6-55

Calculated Relationship Between Pueblo Lake Elevation and Exposed Shoreline



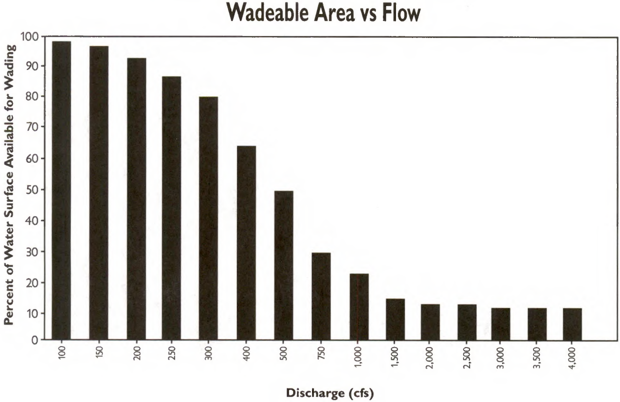
drawdown was 12 feet (Figure 6-44). Drawdowns of more than 10 feet affect user preferences and have similar biological implications to those at Twin Lakes.

The Pueblo Reservoir model presented a similar result. Exposed shoreline increases significantly with initial decreases in water elevation; for example, 53 percent more shoreline acreage is exposed when the water level drops from 4,875 to 4,870 feet as shown in Figure 6-55. However, the percent change in exposed shoreline decreases systematically and then levels off in the model's final elevation level changes. The last 10 of a total 17 elevation changes modeled show an increase of exposed shoreline ranging from only 5 to 10 percent. Figure 6-51 shows the majority of users prefer water levels higher than 4,860 feet, which is 20 feet below the top of the conservation pool.

Figure 6-56 illustrates the percentage of Arkansas River area available for wading at different riverflows. Wading area means the flow level at which the average person is capable of wading comfortably. Wading area was calculated by using wadability curves[1] and plugging those into the Physical Habitat Simulation Model used for the fisheries analysis. This produced an amount of wadable area for each fisheries site analyzed on the river, including sites such as the Floodplain reach and the Wellsville reach. When the discharge

[1] Hyra, Ronald. 1978. Methods of Assessing Instream Flows for Recreation. U.S. Fish and Wildlife Service. Publication Number FWS-OVS-78-34. 16 pp.

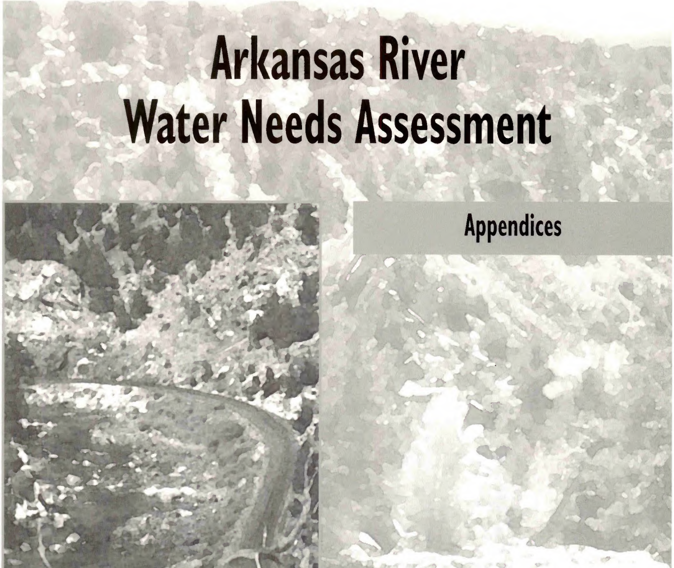
FIGURE 6-56



amounts are between 100 and 300 cfs at the Wellsville gage, river availability for wading ranges between 99 percent and 80 percent. Additional increases in flow alter availability significantly, with a flow rate of 400 cfs resulting in 69 percent availability. Wade area availability drops below 50 percent when flows increase above 500 cfs. Flow rates of 1,500 to 4,000 cfs all produce wading area availability below 15 percent.

Arkansas River Water Needs Assessment

Appendices



Arkansas River Water Needs Assessment

Appendices

July 2000

Table of Contents

Appendix A.
Memorandum of Understanding

U.S.D.I. BUREAU OF LAND MANAGEMENT
U.S.D.I. BUREAU OF RECLAMATION
U.S.D.A. FOREST SERVICE
COLORADO DEPARTMENT OF NATURAL RESOURCES

CO-050-138-8350

BACKGROUND AND PURPOSE

The Arkansas River and its related reservoirs between Leadville and Pueblo are an important hydrological, biological, and recreational resource. Competing demands for water have made it necessary for management agencies to thoroughly understand and carefully weigh the tradeoffs associated with decisions that affect water uses, stream flows, and reservoir levels. Current and comprehensive information is essential to support sound decision making.

The study area for the Arkansas River Water Needs Assessment comprises Twin Lakes, Turquoise and Clear Creek Reservoirs; the mainstem of the Arkansas River downstream from Leadville to the dam at Pueblo Reservoir; and Pueblo Reservoir.

The Parties to this Memorandum of Understanding (MOU) affirm the need for cooperation and collaboration in developing an understanding of the water resource values, as identified herein, and related management objectives within the study area. The Parties, acknowledging their various authorities and management responsibilities, agree to design and conduct cooperative evaluations of water-dependent resource values within the study area.

The Parties affirm that the Colorado Constitution recognizes the doctrine of prior appropriation as the principle means of allocating the usage of the waters of the State. Around this doctrine a body of law has been developed to protect property rights in water usage, including the right to determine management practices that are in the best interests of water right holders. The Parties recognize that numerous water rights exist and are held by various entities whose interests lie within the study area and who rely upon these protections. The Parties agree that the Water Needs Assessment should not be used to justify actions that result in injury to water right owners.

PROJECT OBJECTIVES

The primary objective of the Water Needs Assessment is to provide useful information (a data base) about resource needs, water use constraints, and management opportunities to planners and decision makers. Specific objectives of the Assessment are:

1. Develop an understanding of the hydrology and geomorphology of the river, and the reservoir operations that affect the river flows.

2. Develop an understanding of the relationships between streamflows, reservoir levels, and the resource values they affect. The resource values to be considered include: fish and wildlife habitat; fishing recreation; boating recreation; water quality; riparian habitat; and aesthetics.

3. Identify and evaluate the management opportunities and strategies to provide water for maintaining and improving the resource values.

4. Determine the physical, legal, and institutional factors that influence the ability to implement the management opportunities and strategies.

RESPONSIBILITIES

1. In order to meet these objectives, the Parties agree to develop an Arkansas River Water Needs Assessment Project Statement of Work. The Statement will be a plan of study that includes the following investigations:

(a) preliminary assessment and detailed study design;

(b) hydrologic investigation of streamflow and reservoir levels;

(c) evaluation of flow- and reservoir level- dependent resource values and the flows and levels required to support those values;

(d) analysis of the legal and institutional framework for providing stream flows and maintaining reservoir levels; and

(e) presentation of opportunities for providing and maintaining desired flows and water levels, including scenarios that describe tradeoffs associated with a range of management options.

2. The Parties are to meet as necessary to develop the study design, coordinate work on the study, and evaluate progress. Each signer of this MOU will designate a person to act in their behalf. Exhibit 1 lists the persons responsible for coordinating the study activities included in this MOU.

3. The Parties will discuss and concur on specific work tasks to be performed under this MOU. The Parties will address other study-related matters, such as administration, subcontracting, and publications, in the Project Statement of Work.

4. The Parties agree to cooperate in supporting this project through funding, personnel, and other means; however, this MOU does not commit any Party to any specific commitment of funds, personnel, or other assistance. Participation by the Parties in the Water Needs Assessment will reflect their expertise and their ability to participate given the resources available to them through normal budget processes.

5. The Parties agree to consult with and keep informed the water users, recreational interests, local governments, and others during the development and implementation of the Water Needs Assessment.

GENERAL PROVISIONS

1. This memorandum shall be effective from the date of latest signature and shall continue in force for a period of five years unless mutually or unilaterally terminated.

2. Any party may withdraw from this MOU upon thirty (30) days notice to the other signatory agencies. Any separate Purchase Order or Contract entered into relating to this memorandum shall not affect this memorandum.

3. Changes or modifications of this memorandum may be initiated by any party. The changes or modification shall not be incorporated until all Parties agree, they are specified in an amendment to the memorandum, and signed by all Parties.

4. No member of or delegate to Congress, or resident commissioner, shall be admitted to any share or part of the MOU, or to any benefit that may arise therefrom; but this provision shall not be construed to extend to this MOU if made with a corporation for its general benefit.

5. During the performance of activities and projects initiated pursuant to this MOU, or any separate agreement entered into pursuant to this MOU, the Parties agree to abide by the terms of Executive Order 11246 on non-discrimination and will not discriminate against any person because of race, color, religion, sex, or national origin. The Parties will take affirmative action to ensure that applicants are employed without regard to their race, color, religion, sex, or national origin.

SIGNATURES

Bob Moore
U.S.D.I. Bureau of Land Management
State Director, Colorado

Date 7/17/92

Neil Stessman
U.S.D.I. Bureau of Reclamation
Regional Director, Great Plains Region

Date July 22, 1992

John Marman Jr.
U.S.D.A. Forest Service
Regional Forester, Rocky Mountain Region

Date 8/13/92

Ken Salazar
Colorado Department of Natural Resources
Executive Director

Date 7/17/92

Appendix B.
Annual Flow Recommendation Letter to BOR

STATE OF COLORADO

OFFICE OF THE EXECUTIVE DIRECTOR
Department of Natural Resources
1313 Sherman Street, Room 718
Denver, Colorado 80203
Phone: (303) 866-3311
TDD: (303) 866-3543
Fax: (303) 866-2115

DEPARTMENT OF NATURAL RESOURCES

Bill Owens
Governor

Greg E. Walcher
Executive Director

April 7, 2000

Gerald Kelso
Eastern Colorado Area Office
U.S. Bureau of Reclamation
11056 West County Road 18E
Loveland, CO 80537-9711

Re: 2000-2001 Flow Recommendation for the Upper Arkansas

Dear Mr. Kelso:

The Colorado Department of Natural Resources (DNR) appreciates the Bureau of Reclamation's and the Southeastern Colorado Water Conservancy District's continued cooperation with the implementation of an annual flow program for fisheries and rafting in the Upper Arkansas River Basin, consistent with the operation of the Frying Pan-Arkansas Project. We are once again submitting this year's recommendations for the annual flow management program for the Upper Arkansas River. This request covers the period from May 2000 to May 2001. This request is supported by the managers of the Arkansas Headwaters Recreation Area.

These recommendations are intended to provide an annual flow regime that helps the state maintain the brown trout fishery, meet the demand for boating recreation, support the region's tourism industry, and allow the managers of the Arkansas Headwaters Recreation Area to meet their obligation to manage recreation and natural resources within the area's boundaries.

As always, the DNR recognizes that the implementation of these flow management recommendations will be subordinate to the rights of water owners and water users, and must not impair their associated diversions, storage, or exchanges of water. All flows recommended here should be measured at the Wellsville gauge.

The DNR is also aware that an Arkansas River Water Needs Assessment is being completed by the Bureau of Land Management and may be released later this year. Once this document is finished we may review our recommendations in light of its information. However, we do not believe that its completion alone will alleviate the need for the DNR to request continuation of the voluntary flow program.

Board of Land Commissioners • Division of Minerals & Geology/Geological Survey
Oil & Gas Conservation Commission • Colorado State Parks • Soil Conservation Board
Water Conservation Board • Division of Water Resources • Division of Wildlife

Gerald Kelso
April 7, 2000
Page 2

Specifically, with respect to the 2000-2001 flow program, we recommend that:

1. The highest priority is the maintenance of a minimum year-round flow of at least 250 cfs to protect the fishery. (This priority remains unchanged from those of previous years.)

2. Winter incubation flows (mid November through April) should be maintained at a level of not more than 5 inches below river height during the spawning period (October 15 to November 15). The optimum flow range is from 250 to 400 cfs, depending on spawning flows (this priority remains unchanged from those of previous years):

Minimum Incubation Flow		*Spawning Flow*
Nov. 16 - Apr. 30		*Oct. 15 - Nov. 15*
250 cfs	*IF*	*300 - 500 cfs*
325 cfs	*IF*	*500 - 600 cfs*
400 cfs	*IF*	*600 - 700 cfs*

3. To the extent possible, between April 1 and May 15, Reclamation should maintain flows within the range of 250 to 400 cfs in order to provide conditions favorable to egg hatching and fry emergence. (This priority remains unchanged from those of previous years.)

4. Deliveries in excess of 10,000 acre-feet should be subject to review and consideration, prior to such deliveries, by the Bureau and the District.

5. Subject to water and storage availability, Reclamation should augment flows during the July 1 to August 15 period at 700 cfs through releases from the Fry-Ark Project. The 700 cfs level is a target; when augmentation occurs, every effort should be made to ensure that flows are as little above, or as little below, 700 cfs as possible. The Division of Parks and Outdoor Recreation, using funds collected from commercial outfitters, shall be responsible for replacing evaporative losses caused by summer augmentation. (This priority remains unchanged from those of previous years.)

6. Reclamation should avoid dramatic fluctuations on the river as much as possible throughout the year. When it is necessary to alter flow rates, Reclamation should limit the daily change to 10-15 percent. (This priority remains unchanged from those of previous years.)

Gerald Kelso
April 7, 2000
Page 3

7. It may be possible to improve feeding conditions for brown trout by reducing flows between Labor Day and October 15 in years when flows would otherwise be higher than those recommended by the Division of Wildlife. If potential benefits warrant the effort, AHRA managers, the Division of Wildlife, Reclamation and the Division II Engineer should work with water users to seek opportunities for reducing flows after Labor Day. (This priority remains unchanged from those of previous years.)

Without the commitment and cooperation among the DNR, the Bureau of Reclamation, the SECWCD, local governments, water users, and the Bureau of Land Management, flow management for recreation and wildlife purposes in the Upper Arkansas River would not occur. We look forward to working with you, the District, and others to address issues related to resource management and recreation in this region.

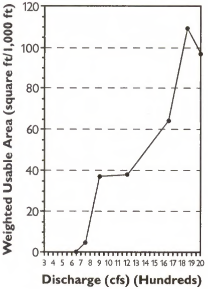
Very truly yours,

Greg Walcher
Executive Director

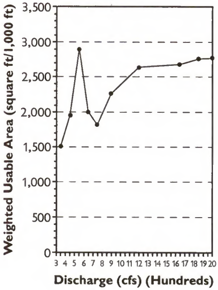
cc: Steve Arveschoug, Director, SECWCD
Laurie Mathews, Director, Colorado State Parks
John Mumma, Director, Division of Wildlife
Hal Simpson, Director, Water Resources
Peter Evans, Director, Water Conservation Board
Donnie Sparks, Field Office Manager, Bureau of Land Management
Tony Kay, Executive Director, Colorado Trout Unlimited
Bob Hamel, President, Arkansas River Outfitter Association

Appendix C. Arkansas River Habitat Versus Discharge Relationships

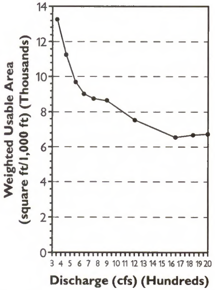
Floodplain - Brown Trout Spawning



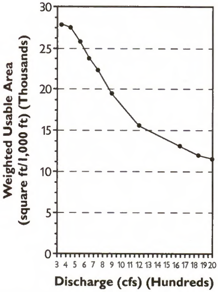
Floodplain - Brown Trout Fry

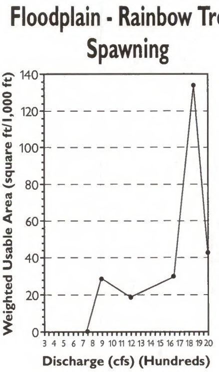


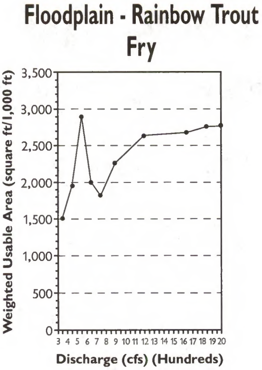
Floodplain - Brown Trout Juvenile

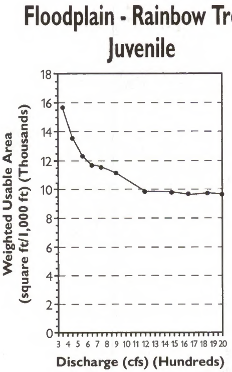


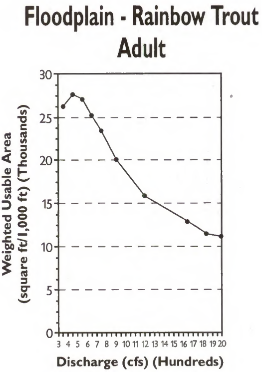
Floodplain - Brown Trout Adult



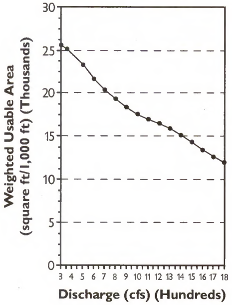

Floodplain - Rainbow Trout
Spawning
Weighted Usable Area (square ft/1,000 ft)
0
20
40
60
80
100
120
140
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Discharge (cfs) (Hundreds)


Floodplain - Rainbow Trout
Fry
Weighted Usable Area (square ft/1,000 ft)
0
500
1,000
1,500
2,000
2,500
3,000
3,500
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Discharge (cfs) (Hundreds)

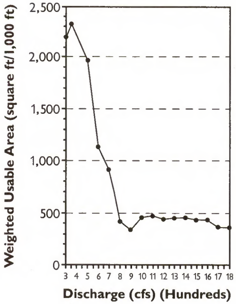

Floodplain - Rainbow Trout
Juvenile
Weighted Usable Area
(square ft/1,000 ft) (Thousands)
0
2
4
6
8
10
12
14
16
18
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Discharge (cfs) (Hundreds)


Floodplain - Rainbow Trout
Adult
Weighted Usable Area
(square ft/1,000 ft) (Thousands)
0
5
10
15
20
25
30
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Discharge (cfs) (Hundreds)

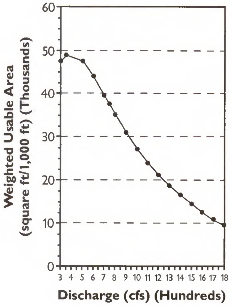
Stockyard - Brown Trout Spawning



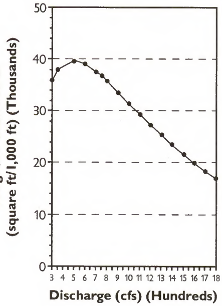
Stockyard - Brown Trout Fry

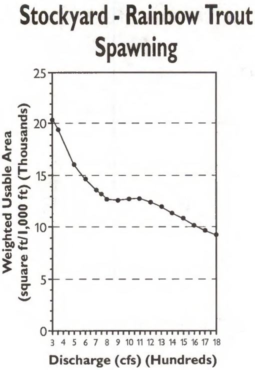


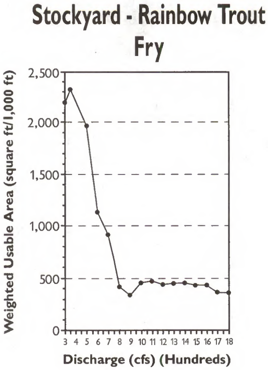
Stockyard - Brown Trout Juvenile

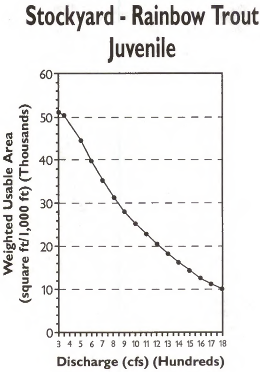


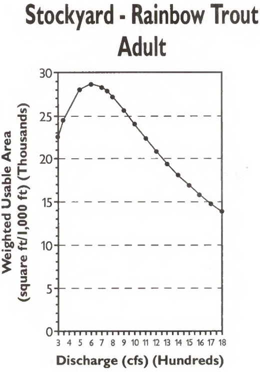
Stockyard - Brown Trout Adult



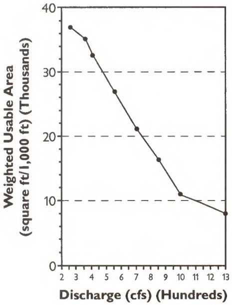

Stockyard - Rainbow Trout
Spawning
Weighted Usable Area
(square ft/1,000 ft) (Thousands)
0
5
10
15
20
25
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Discharge (cfs) (Hundreds)


Stockyard - Rainbow Trout
Fry
Weighted Usable Area (square ft/1,000 ft)
0
500
1,000
1,500
2,000
2,500
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Discharge (cfs) (Hundreds)

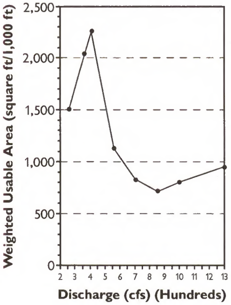

Stockyard - Rainbow Trout
Juvenile
Weighted Usable Area
(square ft/1,000 ft) (Thousands)
0
10
20
30
40
50
60
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Discharge (cfs) (Hundreds)


Stockyard - Rainbow Trout
Adult
Weighted Usable Area
(square ft/1,000 ft) (Thousands)
0
5
10
15
20
25
30
3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18
Discharge (cfs) (Hundreds)

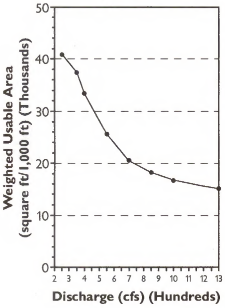
Independent WW - Brown Trout Spawning



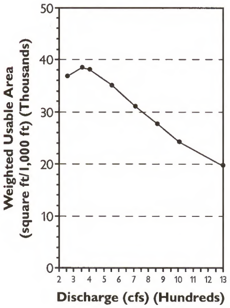
Independent WW - Brown Trout Fry



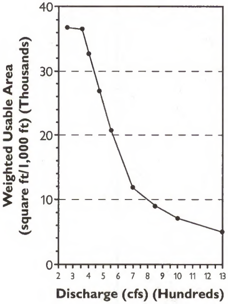
Independent WW - Brown Trout Juvenile



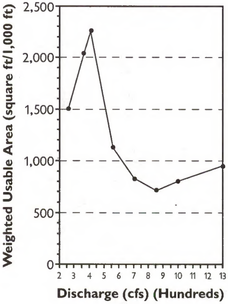
Independent WW - Brown Trout Adult



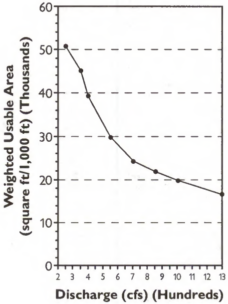
Independent WW - Rainbow Trout Spawning



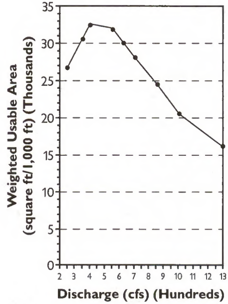
Independent WW - Rainbow Trout Fry



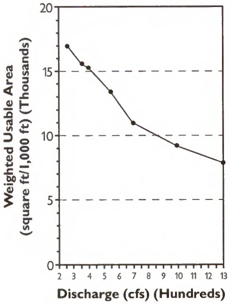
Independent WW - Rainbow Trout Juvenile



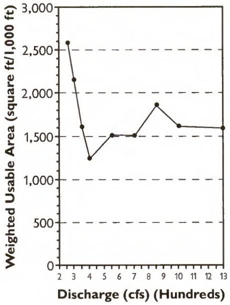
Independent WW - Rainbow Trout Adult



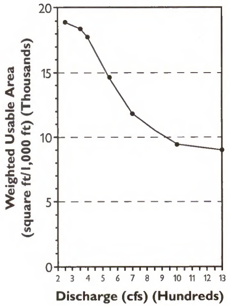
Browns Canyon - Brown Trout Spawning



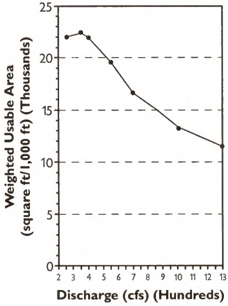
Browns Canyon - Brown Trout Fry



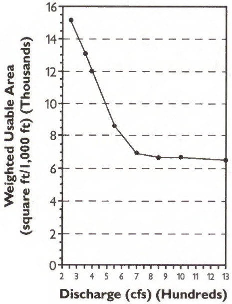
Browns Canyon - Brown Trout Juvenile



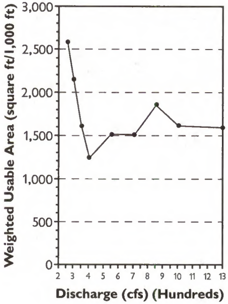
Browns Canyon - Brown Trout Adult



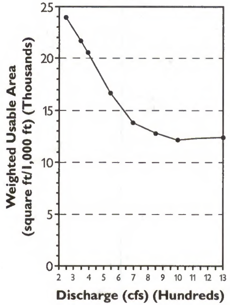
Browns Canyon - Rainbow Trout Spawning



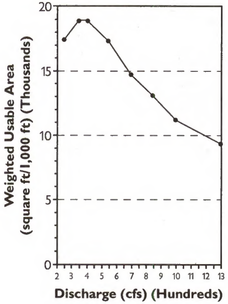
Browns Canyon - Rainbow Trout Fry



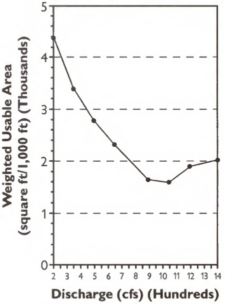
Browns Canyon - Rainbow Trout Juvenile



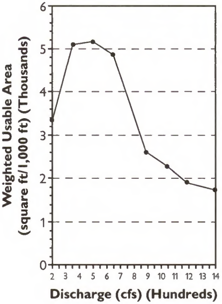
Browns Canyon - Rainbow Trout Adult



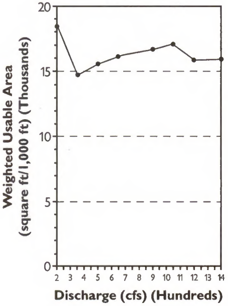
Numbers - Brown Trout Spawning



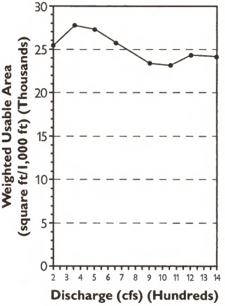
Numbers - Brown Trout Fry



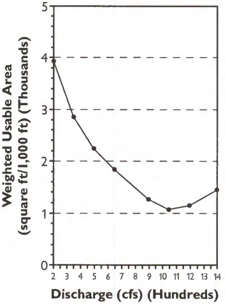
Numbers - Brown Trout Juvenile



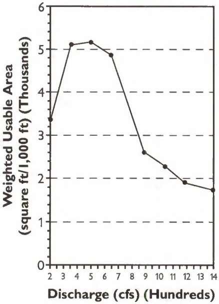
Numbers - Brown Trout Adult



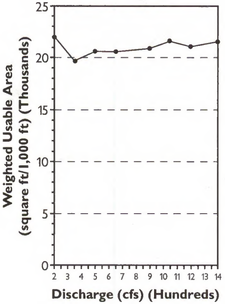
Numbers - Rainbow Trout Spawning



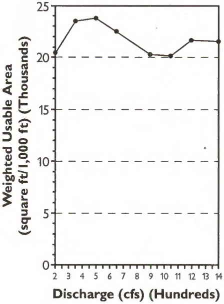
Numbers - Rainbow Trout Fry

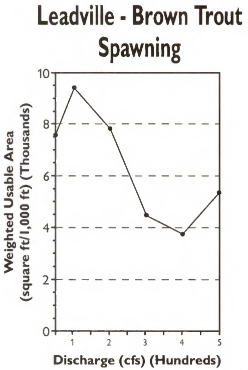


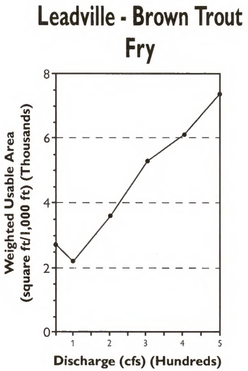
Numbers - Rainbow Trout Juvenile

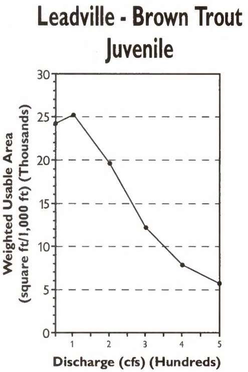


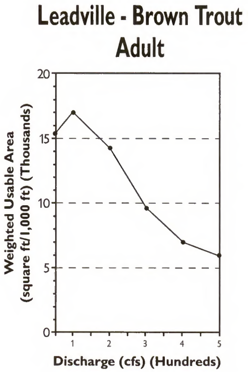
Numbers - Rainbow Trout Adult

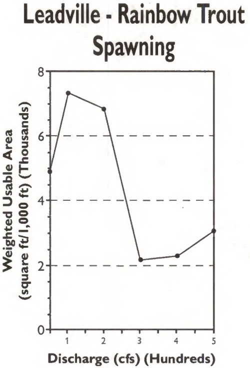


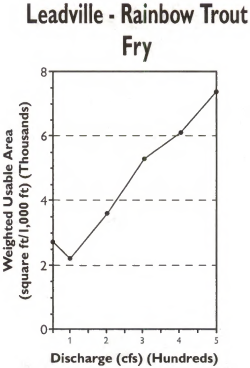

Leadville - Brown Trout
Spawning
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)
0
2
4
6
8
10
1
2
3
4
5

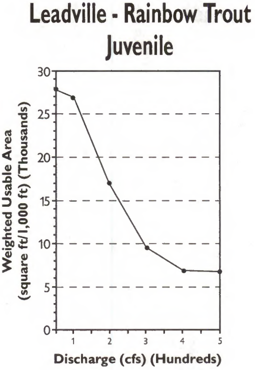

Leadville - Brown Trout
Fry
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)
0
2
4
6
8
1
2
3
4
5

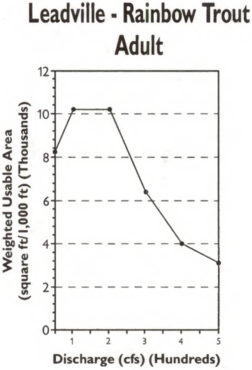

Leadville - Brown Trout
Juvenile
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)
0
5
10
15
20
25
30
1
2
3
4
5


Leadville - Brown Trout
Adult
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)
0
5
10
15
20
1
2
3
4
5


Leadville - Rainbow Trout
Spawning
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)


Leadville - Rainbow Trout
Fry
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)


Leadville - Rainbow Trout
Juvenile
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)


Leadville - Rainbow Trout
Adult
Weighted Usable Area (square ft/1,000 ft) (Thousands)
Discharge (cfs) (Hundreds)

Appendix D.
Summary of Weighted Usable Area at the Six Cross Section Locations

Floodplain
Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
350	0	1,517	13,251	27,890
450	0	1,954	11,254	27,474
540	0	2,909	9,677	25,816
630	0	1,995	8,981	23,808
730	5	1,808	8,728	22,352
900	37	2,251	8,613	19,517
1,200	38	2,621	7,496	15,578
1,630	64	2,670	6,512	13,130
1,850	109	2,744	6,621	11,973
2,000	96	2,760	6,690	11,598

Rainbow Trout

350	0	1,517	15,670	26,254
450	0	1,954	13,571	27,694
540	0	2,909	12,286	27,074
630	0	1,995	11,678	25,165
730	0	1,808	11,571	23,419
900	29	2,251	11,114	20,083
1,200	19	2,621	9,843	15,821
1,630	30	2,670	9,667	12,842
1,850	134	2,744	9,706	11,414
2,000	43	2,760	9,581	11,096

Stockyard

Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
300	25,621	2,190	47,533	36,049
356	25,218	2,326	48,923	37,915
500	23,318	1,968	47,558	39,678
600	21,683	1,135	44,099	39,031
700	20,421	918	39,677	37,518
744	19,915	689	37,722	36,733
800	19,384	414	35,270	35,646
900	18,388	334	31,094	33,497
1,000	17,605	449	27,292	31,368
1,100	16,992	468	24,015	29,305
1,200	16,501	438	21,219	27,276
1,300	15,928	448	18,737	25,299
1,400	15,157	447	16,484	23,385
1,500	14,336	427	14,422	21,514
1,600	13,406	423	12,512	19,802
1,700	12,602	356	10,826	18,180
1,797	11,924	352	9,417	16,730

Rainbow Trout

300	20,476	2,190	50,932	22,058
356	19,526	2,326	50,248	24,467
500	16,086	1,968	44,574	28,026
600	14,711	1,135	39,782	28,590
700	13,625	918	35,258	28,250
744	13,214	689	33,427	27,844
800	12,721	414	31,375	27,115
900	12,607	334	28,005	25,585
1,000	12,747	449	25,241	23,955
1,100	12,756	468	22,810	22,334
1,200	12,395	438	20,490	20,783
1,300	11,979	448	18,346	19,401
1,400	11,345	447	16,283	18,108
1,500	10,843	427	14,400	16,895
1,600	10,160	423	12,692	15,772
1,700	9,695	356	11,294	14,730
1,797	9,274	352	10,194	13,823

Independent Whitewater
Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
250	36,979	1,505	40,880	36,970
327	35,182	2,034	37,422	38,520
400	32,660	2,260	33,350	38,241
550	26,892	1,132	25,587	35,244
700	21,217	824	20,444	31,320
830	16,404	711	18,127	27,979
1,000	11,062	808	16,661	24,425
1,300	8,007	954	15,028	19,734

Rainbow Trout

250	36,695	1,505	50,690	26,581
327	36,474	2,034	44,988	30,602
400	32,573	2,260	39,277	32,502
550	20,793	1,132	29,679	31,865
700	11,744	824	24,172	28,093
830	8,945	711	21,796	24,437
1,000	6,995	808	19,779	20,452
1,300	4,938	954	16,353	15,928

Brown's Canyon

Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
250	16,930	2,590	18,845	22,069
357	15,560	1,604	18,375	22,438
400	15,229	1,241	17,717	22,012
550	13,409	1,500	14,629	19,583
715	10,959	1,506	11,838	16,692
830	10,055	1,855	10,547	15,101
1,000	9,195	1,608	9,449	13,344
1,325	7,839	1,584	9,026	11,505

Rainbow Trout

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
250	15,163	2,590	23,873	17,409
357	13,140	1,604	21,635	18,825
400	11,998	1,241	20,475	18,805
550	8,644	1,500	16,622	17,191
715	6,969	1,506	13,746	14,664
830	6,672	1,855	12,744	13,029
1,000	6,686	1,608	12,111	11,156
1,325	6,514	1,584	12,290	9,333

Numbers

Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
210	4,396	3,206	18,383	25,295
350	3,390	5,108	14,726	27,640
500	2,781	5,147	15,566	27,159
650	2,320	4,839	16,128	25,642
890	1,646	2,594	16,675	23,362
1,050	1,594	2,275	17,078	23,143
1,200	1,914	1,904	15,877	24,287
1,420	2,024	1,739	15,925	24,048

Rainbow Trout

210	3,928	3,206	21,994	20,438
350	2,849	5,108	19,634	23,542
500	2,240	5,147	20,555	23,806
650	1,823	4,839	20,573	22,556
890	1,250	2,594	20,864	20,341
1,050	1,064	2,275	21,548	20,209
1,200	1,145	1,904	21,047	21,691
1,420	1,437	1,739	21,517	21,486

Leadville

Brown Trout

WUA (square ft/1,000 ft)

Discharge (cfs)	Spawning	Fry	Juvenile	Adult
70	7,588	2,739	24,140	15,334
86	8,611	2,452	24,968	16,434
97	9,285	2,272	25,172	16,868
100	9,444	2,195	25,190	16,944
200	7,843	3,613	19,642	14,212
300	4,488	5,280	12,227	9,587
400	3,747	6,089	7,875	6,968
500	5,360	7,406	5,695	5,951

Rainbow Trout

70	4,909	2,739	27,820	8,288
86	6,202	2,452	27,624	9,432
97	7,086	2,272	27,149	10,048
100	7,336	2,195	26,963	10,192
200	6,847	3,613	16,996	10,176
300	2,150	5,280	9,496	6,410
400	2,265	6,089	6,814	4,003
500	3,041	7,406	6,635	3,106

Appendix E.
Summary of Arkansas River Water Quality Issues

Introduction

The purpose of this appendix is to present an overview of water quality in the upper Arkansas River from its headwaters to Pueblo Reservoir. Water quality in the upper Arkansas River has been heavily impacted by hard-rock mining that has occurred in the basin for over 100 years. Water flowing through abandoned mines and tailings piles has contributed high concentrations of cadmium, copper, lead, zinc, and other metals to the upper Arkansas River (Lewis and Clark 1996). Therefore, this discussion of water quality is primarily concerned with the occurrence and concentration of metals in the upper Arkansas Basin and their effects on designated uses.

The upper Arkansas River supports a number of designated uses, including recreation, aquatic life, domestic water supply, and agriculture (Colorado Department of Public Health and Environment, Water Quality Control Commission 1996). Recreation and aquatic life are most sensitive to water quality, because water in the upper Arkansas is rarely unsuitable for agriculture, and waters classified for domestic water supply must be treated prior to use (Colorado Department of Public Health and Environment, Water Quality Control Commission 1996). The Arkansas River between Buena Vista and Pueblo Reservoir is the most extensively used recreational river in Colorado (Colorado Department of Public Health and Environment, Water Quality Control Commission 1996). Recreational activities include, but are not limited to, fishing, swimming, rafting, and kayaking (Colorado Department of Public Health and Environment, Water Quality Control Commission 1996). Aquatic life is directly related to recreation activities such as fishing because a healthy aquatic food chain is necessary to support healthy fish populations.

Most of the information contained in this appendix was taken directly from existing publications. No new water quality data collection or analysis was done as a result of this project. In particular, this appendix relies heavily on a comprehensive water quality study performed by the U.S. Geological Survey from 1990 to 1993 (Ortiz et al. 1998; Clark and Lewis 1997; Lewis and Clark 1996; Dash and Ortiz 1996). The primary reason for emphasizing this study is that two water treatment plants, one at the Leadville Mine Drainage Tunnel on the East Fork of the Arkansas River above Leadville and the other at the Yak Tunnel on California Gulch, began operation in 1992. The purpose of both of these plants is to remove heavy metals from tunnel discharge water. Because these two tunnels have been identified as major contributors of metals to the Arkansas River, any assessment of current water quality conditions must be made using data collected after the plants began operations. The USGS study is the most comprehensive published study that contains data collected after the plants began operating.

General Water Quality Characteristics

Water quality samples were collected and analyzed for dissolved and total recoverable metals, major ions, and nutrients at eight sites on the Arkansas River between Leadville and Portland from April 1990 through March 1993 (Ortiz et al. 1998). For these eight sites, pH generally ranged from 7.5 to 8.5 and tended to increase downstream (Clark and

Lewis 1997). This range of pH is within the range of 6.5 to 9.0 contained in the water quality standards for the upper Arkansas River (Colorado Department of Public Health and Environment, Water Quality Control Commission 1995). Alkalinity ranged from as low as 20 to 30 mg/L as $CaCO_3$ at Granite to about 170 mg/L near Portland (Clark and Lewis 1997). The lowest alkalinity values at Granite were the result of low alkalinity inflow from Lake Creek (Clark and Lewis 1997). Dissolved oxygen concentrations generally were near saturation throughout the basin (Clark and Lewis 1997). Ammonia, nitrate, and total-phosphorus concentrations were low in comparison to State and Federal criteria (Ortiz et al. 1998).

Major solutes in the upper Arkansas River reflect the weathering of various rock types in the basin. Inflows affected by acid mine drainage in the Leadville area reflect the oxidation of metal-sulfide deposits, producing acidic, sulfate-rich water (Kimball et al. 1995). The igneous and metamorphic rocks of the Leadville area also contribute calcium, sodium, and bicarbonate to the river (Kimball et al. 1995). The proportion of sedimentary rock increases downstream of Granite (Clark and Lewis 1997). The chemistry of inflows downstream of Salida is strongly influenced by the weathering of shale that contributes calcium, sodium, and sulfate (Kimball et al. 1995). Dissolved solids concentrations are lowest at Granite due to dilution by inflow from Lake Creek, and increase downstream as the less resistant sedimentary rocks contribute more solutes to the river. Dissolved metals are discussed in detail in the following sections.

Metals Toxicity in the Aquatic Environment

Although some metals, in trace amounts, are essential for life, most metals become toxic in high concentrations (Lewis and Clark 1996). Cadmium, copper, lead, and zinc are the metals of particular concern in the upper Arkansas River because of their toxicity to aquatic life (Lewis and Clark 1997). Metals in the aquatic environment can occur in the dissolved or particulate phase, or they can become sorbed to particulates (Lewis and Clark 1996). The toxicity of metals is related not only to their concentration, but also to their phase (Lewis and Clark 1996). The uptake of metals from the dissolved phase generally is the pathway that is most toxic to aquatic life (Lewis and Clark 1996).

The dissolved phase of a water sample is traditionally defined by passing the sample through a 0.45 µm filter (Kimball et al. 1995). For metal-rich streams affected by mining, 0.45 µm is not an effective breakpoint for measurement of dissolved and particulate concentrations (Kimball et al. 1995). This is because metals coming out of solution form a continuum of particulate sizes from about 0.001 to about 1.0 µm (Kimball et al. 1995). Particles in this size range are called colloids. Aggregation of individual colloids is primarily responsible for the larger particulate sizes in this continuum (Kimball et al. 1995). Metals that are toxic to aquatic life, such as cadmium, copper, lead, and zinc, may form colloids or they may be sorbed to other colloids such as iron colloids (Kimball et al. 1995). The actual mechanism of colloid formation was shown by Witters et al. (1996) to be toxic. Witters et al. (1996) found that the toxicity to brown trout was greater during the formation of aluminum colloids than the toxicity when mature, developed aluminum colloids were present. The direct implication of the Witters et al. (1996) study is that any change in chemistry that induces colloid formation in a metal-rich stream could create an area of increased toxicity to fish. Changes in chemistry can result from any inflow with sufficiently different chemistry than the receiving stream. In addition to the toxic effects of colloids, metal toxicity varies depending on what chemical association the dissolved metal is in.

Dissolved metals can exist by themselves as free-metal ions, or they can form complexes with other constituents in the water, such as carbonates, chlorides, and sulfates (Lewis and Clark 1996). These different complexes, including the free, uncomplexed metal ion, are referred to as different "species" of the dissolved metal. Most studies of metal toxicity have indicated that the free-metal ion is the more toxic dissolved metal species (Lewis and Clark 1996). Low alkalinity and pH are more conducive to the existence of free-metal ions in solution (Lewis and Clark 1996). In the upper Arkansas River, the high streamflow during snowmelt runoff typically has a lower alkalinity and pH than the flows that occur throughout the remainder of the year.

Another factor affecting alkalinity and pH is that water imported from the Colorado River Basin generally has lower alkalinity and pH than native water (Lewis and Clark 1996). Since most of the imported water is routed through Twin Lakes Reservoir and Lake Creek, the reach immediately downstream from the confluence of Lake Creek is most susceptible to being affected by the chemistry of the imported water (Lewis and Clark 1996).

Water Quality Criteria for Metals

Water quality criteria for metals in the upper Arkansas consist of acute and chronic numerical values. A violation of an acute criterion can be established based on one sample, whereas a violation of a chronic criterion is usually based on an average of several samples taken within a specified time period (Colorado Department of Public Health and Environment, Water Quality Control Commission 1996). Metals concentrations for the 1992-1993 samples can only be compared to acute standards because sampling occurred too infrequently for them to be compared with chronic standards.

Water quality criteria for metals are based on a computation that involves hardness because the toxicity of metals to aquatic life is affected by the hardness of the water. Most metals are less toxic in water with hardness exceeding 100mg/L as calcium carbonate (Gerhardt 1993).

Impairment from Dissolved Metals Before and After 1992

The impairment of beneficial uses due to dissolved metals concentrations prior to 1992 is described in the 1989 Colorado Nonpoint Source Assessment Report (Colorado Department of Public Health and Environment, Water Quality Control Division, 1989) for the upper Arkansas River:

> "One of the most impacted segments of the Arkansas River lies immediately below California Gulch near Leadville, and upstream of the confluence with the Lake Fork. Concentrations of zinc, cadmium, copper, lead, manganese, and iron are the metals of concern in this segment. Concentrations of metals appear to decrease in the segment of the Arkansas below the Lake Fork and above Lake Creek. Basic standards for aquatic life are exceeded for cadmium, copper, zinc, iron, and lead, though at somewhat reduced levels from those immediately upstream. Chronic toxicity is evident by the greatly reduced trout populations in this reach of the river. The reach of the Arkansas River between Browns Canyon (about six miles north of Salida) and Cañon City exceeds basic standards for aquatic life for cadmium, zinc, nickel, lead, and copper. The source of the metals appears to be drainage from the many mining districts upstream. In this reach of river few trout are found over three years of age."

Table E-1 compares the use-support status of the upper Arkansas River as reported in the 1992 and 1996 305(b) reports (Colorado Department of Public Health and Environment, Water Quality Control Division, 1992, 1996). This comparison shows a distinct improvement in water-quality conditions in the 4-year period after the two treatment plants began operation. The remaining sources of metals upstream of Lake Creek are St. Kevin Gulch and nonpoint sources, including placer deposits along the river alluvium (Clark and Lewis 1997).

TABLE E-1

Use-Support Status for the Upper Arkansas River as Reported in the 1992 and 1996 305(b) Reports

Segment	1992 Status	Cause	1996 Status	Cause
Leadville Drain to California Gulch	Not Supporting	Metals	Fully Supporting	
California Gulch to Lake Fork	Not Supporting	Metals	Partially Supporting	Cadmium & Zinc
Lake Fork to Lake Creek	Partially Supporting	Metals	Partially Supporting	Zinc
Lake Creek to Cañon City	Not Supporting	Metals	Fully Supporting	
Cañon City to Pueblo Reservoir	Water Quality Limited	Metals	Fully Supporting	

According to Table E-1, cadmium and zinc continue to cause some use impairment in the California Gulch to Lake Creek reach. For data collected after the treatment plants began operating, Ortiz et al. (1998) found no exceedances of the acute criterion for cadmium and one exceedance of the acute criterion for zinc. Sufficient data were not collected to determine exceedances of the chronic criteria.

Cadmium and Zinc

Lewis and Clark (1996) reported that dissolved cadmium and zinc exhibited similar spatial patterns even though their concentrations were different. The highest concentrations of dissolved cadmium and zinc were found at the Empire Gulch site, which is the only sampling station in the California Gulch to Lake Creek reach (Lewis and Clark 1996). Concentrations decreased more than 50 percent between Empire Gulch and Granite, largely because of dilution by Lake Creek (Lewis and Clark 1996).

The free-metal ions (Cd^{+2} and Zn^{+2}) dominated the speciation from Leadville to Nathrop, whereas cadmium and zinc complexes dominated the speciation from Wellsville to Portland (Lewis and Clark 1996). More than 60 percent of the dissolved species occurred as free-metal ions at Granite and Buena Vista (Lewis and Clark 1996). The low alkalinity and low dissolved solids concentration of the inflow from Lake Creek results in low metal-complexing potential and, compared to upstream sites, a higher percentage of free-metal ions at Granite and Buena Vista (Lewis and Clark 1996).

The highest concentrations of dissolved cadmium and zinc occurred during early snowmelt runoff (Lewis and Clark 1996). During early snowmelt runoff, streamflow begins to increase as snow at lower elevations melts and flushes the abandoned mines, mine dumps, and tailings piles of metal enriched water (Lewis and Clark 1996). The volume of water that actually flows into the river during this time is relatively small, but because the flow of the river is low, the effect on metal concentrations can be substantial (Lewis and Clark 1996). Dissolved metal concentrations become diluted by large volumes of snowmelt during peak snowmelt runoff in May and June (Lewis and Clark 1996). Although dissolved cadmium and zinc concentrations decreased during peak snowmelt runoff, the percentage of free-metal ions increased to about 70 percent (Lewis and Clark 1996). The lower alkalinity and lower pH of snowmelt water tend to favor the speciation of free metal ions compared to metal complexes (Lewis and Clark 1996). In contrast, less than 50 percent of the dissolved cadmium and zinc exists as free-metal ions during the post snowmelt and low-flow periods, when alkalinity and pH generally are higher (Lewis and Clark 1996).

For the 1990-1993 study, the dissolved phase was defined by filtering water samples through a 0.45µm filter (Lewis and Clark 1996; Clark and Lewis 1997; Dash and Ortiz 1996). However, Kimball et al. (1995) found that iron concentrations were consistently higher in the colloidal fraction (>0.001 µm) than in the truly dissolved phase as defined by ultrafiltration (<0.001 µm). Partitioning of ferric iron (Fe^{3+}) to the colloidal fraction between pH 7 and 8 is by precipitation of amorphous ferrihydrite ($Fe(OH)_{3(s)}$) (Kimball et al. 1995). The amorphous structure of ferrihydrite creates a large surface area that strongly influences the partitioning of toxic metals through sorption and coprecipitation (Clark and Lewis 1997; Kimball et al. 1995). To determine the effect of adsorption on concentrations calculated for species of cadmium and zinc, Clark and Lewis (1997) used an adsorption model for reactions involving colloidal ferrihydrite.

A range of dissolved iron concentrations from 25-700 µg/L was modeled to determine the adsorption effects on concentrations calculated for species of cadmium and zinc (Clark and Lewis 1997). For high concentrations of dissolved iron (700 µg/L), the model indicated that about 12 percent of available zinc and about 2 percent of available cadmium became bound to the ferrihydrite surfaces (Clark and Lewis 1997). About 5 percent of the zinc was contributed from the Zn^{+2} species and about 7 percent was contributed from complexed species (Clark and Lewis 1997). About 1 percent of the cadmium was contributed from the Cd^{+2} species and about 1 percent was contributed from complexed species (Clark and Lewis 1997). For low concentrations of dissolved iron (25 µg/L), the adsorption effect was negligible (Clark and Lewis 1997).

Summary and Flow Options

Water quality in the upper Arkansas River Basin is dominated by high concentrations of metals that result from historic mining activity. Water treatment plants on two major mine drainage tunnels have significantly decreased metals concentrations since the plants began operating in 1992. The remaining sources of metals upstream of Lake Creek are St. Kevin Gulch and nonpoint sources, including placer deposits along the river alluvium (Clark and Lewis 1997). Contributions of these metals to the Arkansas occur mostly during snowmelt runoff, with highest concentrations occurring during the early snowmelt period (Clark and Lewis 1997).

Although metals concentrations have decreased since the treatment plants began operating, cadmium and zinc continue to cause some use impairment in the California Gulch to Lake Creek reach (Colorado Department of Public Health and Environment, Water Quality Control Division 1996). The free-metal ions (Cd^{+2} and Zn^{+2}) dominate the speciation in this reach (Clark and Lewis 1997). Most studies of metal toxicity have indicated that the free-metal ion is the more toxic dissolved metal species (Lewis and Clark 1996). The inflow from Lake Creek dilutes metals concentrations, but the lower alkalinity, pH, and dissolved solids concentrations of Lake Creek water tend to increase the percentage of free-metal ions in solution (Clark and Lewis 1997). The highest concentrations of dissolved cadmium and zinc occurred during early snowmelt runoff.

An adsorption model indicated that adsorption to ferrihydrite colloids had a small to negligible effect on dissolved concentrations of Cd^{+2} and Zn^{+2} (Clark and Lewis 1997). For high concentrations of dissolved iron (700 µg/L), the model indicated that about 12 percent of available zinc and about 2 percent of available cadmium became bound to the ferrihydrite surfaces (Clark and Lewis 1997). About 5 percent of the zinc was contributed from the Zn^{+2} species and about 1 percent of the cadmium was contributed from the Cd^{+2} species (Clark and Lewis 1997). For low concentrations of dissolved iron (25 µg/L), the adsorption effect was negligible (Clark and Lewis 1997).

Little can be done with respect to flow scenarios that would benefit water quality in the California Gulch to Lake Fork reach, because there are no storage facilities upstream of Lake Fork. The most beneficial flow scenario for water quality would be to provide dilution flows from Turquoise Reservoir during early snowmelt. Although the Turquoise Lake water would probably increase the percentage of free-metal ions in solution, it would also reduce concentrations of dissolved metals in the Lake Fork to Lake Creek reach.

References

Clark, M.L., and Lewis, M.E., 1997, Metal speciation in the upper Arkansas River, Colorado, 1990 93: U.S. Geological Survey Water-Resources Investigations Report 96-4282, 24 p.

Colorado Department of Public Health and Environment, Water Quality Control Commission, 1996, The Basic Standards and Methodologies for Surface Water 3.1.0: 5 CCR 1002-8, 141 p.

Colorado Department of Public Health and Environment, Water Quality Control Commission, 1995, Classifications and numeric standards for the Arkansas River Basin 3.2.0: 37 p.

Colorado Department of Public Health and Environment, Water Quality Control Division, 1989, Colorado nonpoint source assessment report: 189 p.

Colorado Department of Public Health and Environment, Water Quality Control Division, 1992, Colorado water quality: 103 p.

Colorado Department of Public Health and Environment, Water Quality Control Division, 1996, Status of water quality in Colorado: 178 p.

Dash, R.G., and Ortiz, R.F., 1996, Water-quality data for the Arkansas River Basin, Southeastern Colorado, 1990-1993: U.S. Geological Survey Open-File Report 95-464, 137 p.

Gerhardt, A., 1993, Review of impact of heavy metals on stream invertebrates with special emphasis on acid conditions: Water, Air, and Soil Pollution, v. 66, pp. 289-314.

Kimball, B.A., Callender, E., and Axtmann, E.V., 1995, Effects of colloids on metal transport in a river receiving acid mine drainage, upper Arkansas River, Colorado, U.S.A.: Applied geochemistry, v. 10, pp. 285-306.

Lewis, M.E., and Clark, M.L., 1996, How does streamflow affect metals in the upper Arkansas River?: U.S. Geological Survey Fact Sheet, FS-226-96.

Ortiz, R.F., Lewis, M.E., and Radell, M.J., 1998, Water-quality assessment of the Arkansas River Basin, Southeastern Colorado, 1990-1993: U.S. Geological Survey Water-Resources Investigations Report 97-4111, 69 p.

Witters, H.E., Van Puymbroeck, S., Stouthart, A.J.H.X., and Bonga, S.E.W., 1996, Physiochemical changes of aluminum in mixing zones: mortality and physiological disturbances in brown trout (*Salmo Trutta* L.): Environmental Toxicology and Chemistry, v. 15, n. 6, pp. 986-996.

Appendix F. Analysis of Natural Resource Tradeoffs Associated with Arkansas River Flows

Arkansas River Water Management Scenarios

Assumptions Used in Scenarios

The water management scenarios outlined in this section incorporate one critical assumption. The scenarios were established for analysis purposes only to help resource managers see the natural resource implications of various flow regimes. They are designed to provide objective information that may be later utilized in a variety of circumstances by river managers and the public. As such, the scenarios do not constitute any sort of recommendation by the study group that flows be managed in the manner outlined in the scenario. In addition, the scenarios were not developed to serve as a preset number of alternatives for any future decisionmaking process that will involve public participation.

To focus on these natural resource tradeoffs, the study group made a hypothetical assumption that each of the scenarios could be implemented without injury to established water rights, water storage/delivery contracts, and other legal obligations. When river managers use the information contained in the scenarios to make decisions about specific flow management practices, a specific analysis would have to be conducted to test the above assumption. Any flow management practices that are considered during a public decisionmaking process will have to be altered and tailored to fit legal, storage, and operational requirements. None of the scenarios have been put through a modeling process to determine if these requirements can be met.

Rationale for Using Water Management Scenarios for Natural Resource Analysis

As noted in the previous section, flow preferences for biological and recreational values on the Arkansas River are very similar and mutually reinforcing during 10 months of the year. However, during the period from July 24 through September 7, these preferences diverge. This divergence occurs for two reasons:

~ This period has warmer stream water temperatures, presenting an opportunity for good growth among all trout life stages if suitable habitat is present. Higher flows during this period reduce the amount of usable habitat for the trout and can decrease the carrying capacity of the river for trout populations. Reduced growth and weight loss in fish is indicative of this reduction in habitat.

~ Demand for recreational boating increases during this period. This period presents an opportunity for satisfying the public's demand for boating opportunities and for recreation oriented businesses to attract customers. Lower flows during this period equate to river conditions that may present marginal riverflows for rafting.

~ Demand for recreational angling is high during this period. This period presents an opportunity for satisfying public demand for float fishing, spin fishing, and fly fishing. However, the three different types of angling activities all have different flow preferences.

When river managers make decisions about what flow conditions to provide during this period, it is not sufficient to know just the generalities outlined above and what the preferred flows are for each resource value. It is essential to know exactly how well the preferences for each resource value are met under different flow regimes. For that reason, this analysis will utilize flow scenarios to illustrate the tradeoffs between various resource values.

The Relationship of Water Management Scenarios to the Arkansas River Baseline Hydrograph

Flow scenarios are simply different combinations of flow rates and timing during the July 24 to September 7 timeframe. Each scenario is only a point along a spectrum. The spectrum ranges from flows that strongly favor biological values in the river to flows that strongly favor recreational values on the river. As such, the study group does not recommend that any of the scenarios be directly adopted by river managers as a river management plan.

To facilitate the process of identifying how different flow regimes might fit into legal water delivery requirements, the analysis of tradeoffs began by using the baseline hydrograph for the Arkansas River.

~ First, the volume of flow releases and/or storage space required to implement each scenario was calculated. Then the baseline flow rate that is typically seen in the Arkansas River during each day of the July 24 to September 7 period was identified, as was the amount of water that would either need to be stored or released to meet the target flow rate in the scenario. The hydrologic analysis that was conducted in cooperation with the U.S. Geological Survey and that is part of this volume was used to calculate volumes of flow releases and storage space required.

~ Second, the required storage volumes and flow rates to implement each scenario were then either added to or subtracted from the typical flow rates and storage volumes seen in the Arkansas River baseline hydrograph. The increase/decrease in storage and flow levels is noted in the description of each scenario.

It should be noted that the predictions of increase/decrease in flow and storage levels assumes that all other water management factors on the river are held constant. In reality, implementation of these scenarios would not automatically produce the predicted results because there are so many other factors that influence river and storage levels. Again, the scenarios have not been run through a modeling effort that incorporates these other factors.

Descriptions of Water Management Scenarios

Scenario 1 - 1,000 cfs from July 24 to September 7

This scenario represents flows that most strongly favor recreational boating values. Because surveys indicated that experienced boating users preferred a flow of at least 1,000 cfs for their river experiences, this scenario analyzes a flow maintained at 1,000 cfs through Labor Day, a date after which boating use falls off sharply. After September 7, the Frypingan-Arkansas Project baseline flow patterns would resume. Slightly lower flows from October to March would be required to offset the additional water released from upper basin reservoirs.

Implementation of this scenario would require the following water management considerations.

Average Water Supply Year

Augmentation of baseline hydrograph would need to begin: August 7
Required augmentation volume: 12,600 acre-feet
Decrease in October through March riverflows: 35 cfs/day

Effects of this scenario:

1. Maximum decrease in upper basin reservoir elevation during augmentation period (assumes needed water releases are evenly divided between the two reservoirs):

   Turquoise: - 3.7 feet
   Twin: - 2.5 feet

2. Historical mean water surface elevation at Pueblo Reservoir on July 24: 4,858.0 feet
3. Increase in Pueblo Reservoir elevation by September 7 due to augmentation: +2.5 feet

Wet Water Supply Year

Augmentation of baseline hydrograph would need to begin: September 5
Required augmentation volume: 500 acre-feet
Decrease in October through March riverflows: insignificant

Effects of this scenario:

1. Maximum decrease in upper basin reservoir elevation during augmentation period (assumes needed water releases are evenly divided between the two reservoirs):

   Turquoise: less than 0.5 foot
   Twin: less than 0.5 foot

2. Historical mean water surface elevation at Pueblo Reservoir on July 24: 4,880.0 feet
3. Increase in Pueblo Reservoir elevation by September 7 due to augmentation: less than 0.5 feet

Dry Water Supply Year

Augmentation of baseline hydrograph would need to begin: July 24
Required augmentation volume: 53,000 acre-feet
Decrease in October through March riverflows: 150 cfs/day

Effects of this scenario:

1. Maximum decrease in upper basin reservoir elevation during augmentation period (assumes needed water releases are evenly divided between the two reservoirs):

   Turquoise: - 16.0 feet
   Twin: - 12.25 feet

2. Historical mean water surface elevation at Pueblo Reservoir on July 24: 4,845.0 feet
3. Increase in Pueblo Reservoir elevation by September 7 due to augmentation: +14.0 feet

Scenario 2 - 700 cfs from July 24 to September 7

This scenario represents flows that are designed to support boating throughout the high usage season, while using the minimum amount of augmentation water possible. Even though the river may be technically navigable at lower flows, user surveys indicated that the minimum acceptable flow for rafting users is approximately 750 cfs. Therefore, under this scenario, flows are provided at 700 cfs through September 7. After September 7, the baseline flow patterns would resume. Slightly lower flows from October to March would be required to offset the additional water released from upper basin reservoirs.

Implementation of this scenario would require the following water management considerations:

Average Water Supply Year

Augmentation of baseline hydrograph would need to begin: August 29
Required augmentation volume: 1,000 acre-feet
Decrease in October through March riverflows: insignificant

Effects of this scenario:

1. Maximum decrease in upper basin reservoir elevation during augmentation period (assumes needed water releases are evenly divided between the two reservoirs):

   Turquoise: less than 0.5 foot
   Twin: less than 0.5 foot

2. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,858.0 feet

3. Increase in Pueblo Reservoir elevation by September 7 due to augmentation: less than 1.0 foot

Wet Water Supply Year

Augmentation of baseline hydrograph would need to begin: not required
Required augmentation volume: not required
Decrease in October through March riverflows: not applicable

Effects of this scenario:

None.

Dry Water Supply Year

Augmentation of baseline hydrograph would need to begin: July 24
Required augmentation volume: 25,000 acre-feet
Decrease in October through March riverflows: 70 cfs/day

Effects of this scenario:

1. Maximum decrease in upper basin reservoir elevation during augmentation period (assumes needed water releases are evenly divided between the two reservoirs):

   Turquoise: - 7.5 feet
   Twin: - 5.25 feet

2. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,845.0 feet

3. Increase in Pueblo Reservoir elevation due to augmentation: + 5.0 feet

Scenario 3 - 550 cfs from July 24 to September 7

Fisheries studies indicate that usable habitat starts to be lost most rapidly as riverflows exceed 550 cfs. Therefore, this scenario provides a flow of 550 cfs from July 24 to September 7. After September 7, flows would return to baseline levels. Under this scenario, BOR would have to ensure that it had adequate storage space for supplemental storage during the July 24 to September 7 period. Creating this storage space may require higher releases during runoff prior to July 24 in some water years, a practice that might not be possible if the channel below Twin Lakes is already at capacity. The required supplemental storage would result in full reservoirs being maintained through September 7 in many water years.

Higher flow releases during the **following** October to March would be required to offset the additional water held at upper basin reservoirs during the July 24 to September 7 period. These higher releases would be required to make sure that the reservoirs are drawn down sufficiently to accommodate the following year's spring runoff.

Higher flow releases during the **preceding** October to March period may be required to offset the additional water held at upper basin reservoirs during the July 24 to September 7 period. These higher releases may be required to ensure that BOR has sufficient water available for delivery to water users from Pueblo Reservoir during the late summer period. Because there are so many factors that go into water delivery decisions, it is impossible to predict the frequency or magnitude of this possible event.

In addition to the flow management considerations outlined above, BOR would have to work with the Colorado Division of Water Resources to address multiple institutional and legal concerns that would be created by increased storage in late summer. For example, downstream water rights that rely upon flows from the upper basin during the July 24 to September 7 time period would have to be protected. If BOR had to store water out of priority to implement this scenario, those flows would have to be replaced by releases from another storage structure.

Implementation of this scenario would require the following water management considerations:

Average Water Supply Year

Supplemental storage would need to occur from July 24 to: September 7
Required storage volume: 33,000 acre-feet

Effects of this scenario:

1. Approximate increase in May 15 to July 15 flows to create storage space for July 24 to September 7 period = 300 cfs

2. Upper reservoir drawdown required by July 24 to accommodate storage during July 24 to September 7 period:

   Turquoise: 9.5 feet
   Twin: 7.0 feet

3. Increase in October through March riverflows: 100 cfs/day

4. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,858.0 feet

5. Foregone storage elevation at Pueblo Reservoir by September 7 due to upper basin storage and reduced releases July 24 to September 7: - 11.0 feet

Wet Water Supply Year

Supplemental storage would need to occur from July 24 to: September 7
Required storage volume: 98,000 acre-feet

Effects of this scenario:

1. Approximate increase in May 15 to July 15

flows to create storage space for July 24 to September 7 period = 825 cfs

2. Upper Reservoir drawdown required by July 24 to accommodate storage for July 24 to September 7 period:

   Turquoise: 33.0 feet
   Twin: 27.0 feet

3. Increase in October through March riverflows: 275 cfs/day

4. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,880.0 feet

5. Foregone storage elevation at Pueblo Reservoir by September 7 due to upper basin storage and reduced releases July 24 to September: - 34.0 feet

Dry Water Supply Year

Supplemental storage would need to occur from July 24 to: not required
Required storage volume: not required
Increase in October through March river flows: not applicable

Effects of this scenario:

None.

Scenario 4 - 400 cfs from July 24 to September 7

This scenario represents flows that most strongly favor biological values during the July 24 to September 7 period. Studies indicate that the maximization of usable fishery habitat occurs between flows of 300 cfs and 400 cfs. Therefore, this scenario provides flows at 400 cfs from July 24 to September 7. After that point, flows would return to baseline levels. Under this scenario, BOR would have to ensure that it had adequate storage space for supplemental storage during the July 24 to September 7 period. Creating this storage space may require higher releases during runoff prior to July 24 in some water years, a practice that might not be possible if the channel below Twin Lakes is already at capacity. The required supplemental storage would result in full reservoirs being maintained through September 7 in many water years.

Higher flow releases during the **following** October to March would be required to offset the additional water held at upper basin reservoirs during the July 24 to September 7 period. These higher releases would be required to make sure that the reservoirs are drawn down sufficiently to accommodate the following year's spring runoff.

Higher flow releases during the **preceding** October to March period may be required to offset the additional water held at upper basin reservoirs during the July 24 to September 7 period. These higher releases may be required to ensure that BOR has sufficient water available for delivery to water users from Pueblo Reservoir during the late summer period. Because there are so many factors that go into water delivery decisions, it impossible to predict the frequency or magnitude of this possible event.

In addition to the flow management considerations outlined above, BOR would have to work with the Colorado Division of Water Resources to address multiple institutional and legal concerns that would be created by increased storage in late summer. For example, downstream water rights that rely upon flows from the upper basin during the July 24 to September 7 time period would have to be protected. If BOR had to store water out of priority to implement this scenario, those flows would have to be replaced by releases from another storage structure.

Implementation of this scenario would require the following water management considerations:

Average Water Supply Year

Supplemental storage would need to occur from July 24 to: September 7
Required storage volume: 47,000 acre-feet

Effects of this scenario:

1. Approximate increase in May 15 to July 15 flows to create storage space for July 24 to September 7 period = 390 cfs
2. Upper reservoir drawdown required by July 24 to accommodate supplemental storage during July 24 to September 7 period:

   Turquoise: 14.0 feet
   Twin: 11.75 feet
3. Increase in October through March riverflows: 130 cfs/day
4. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,858.0 feet
5. Foregone storage elevation at Pueblo Reservoir by September 7 due to upper basin storage and reduced releases July 24 to September 7: -16.0 feet

Wet Water Supply Year

Supplemental storage would need to occur from July 24 to: September 7
Required storage volume: 112,000 acre-feet

Effects of this scenario:

1. Approximate increase in May 15 to July 15 flows to create storage space for July 24 to September 7 period = 930 cfs

2. Upper reservoir drawdown required by July 24 to accommodate supplemental storage during July 24 to September 7 period:

   Turquoise: 35.0 feet
   Twin: 33.0 feet

3. Increase in October through March riverflows: 310 cfs/day

4. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,880.0 feet

5. Foregone storage elevation at Pueblo Reservoir by September 7 due to upper basin storage and reduced releases July 24 to September 7: - 42.0 feet

Dry Water Supply Year

Supplemental storage would need to occur from July 24 to: August 20
Required storage volume: 4,000 acre-feet

Effects of this scenario:

1. Approximate increase in May 15 to July 15 flows to create storage space for July 24 to September 7 period = 30 cfs

2. Upper Reservoir drawdown required by July 24 to accommodate storage during July 24 to September 7 period:

   Turquoise: 1.5 feet
   Twin: 2.0 feet

3. Increase in October through March riverflows: 10 cfs/day

4. Historic mean water surface elevation at Pueblo Reservoir on July 24: 4,845.0 feet

5. Foregone storage elevation at Pueblo Reservoir by September due to supplemental storage and reduced releases July 24 to September 7: 1.0 feet

Discussion of Natural Resource Tradeoffs for Water Management Scenarios

Procedures and Assumptions Used in Analyzing Tradeoffs Between Resource Values

In the previous sections of this study, a relationship has been identified between flow levels (or reservoir levels) and how well a resource value is supported. For each resource value, a given flow or reservoir level will lie somewhere in a spectrum ranging from "does not support this resource value" to "optimally supports this resource value." Tradeoffs simply illustrate how resource values are affected by various flows. To derive the full picture of all the tradeoffs associated with a given scenario, a resource manager would look at each resource value (rafting, angling, fish habitat, etc.) at each water management location (Arkansas River, Turquoise Reservoir, Twin Lakes, and Pueblo Reservoir.) When taking this overall view, it becomes readily apparent that flows which are excellent for supporting some resource values are very negative for other resource values.

For this analysis, it is helpful to review the flow preferences and baseline Arkansas River hydrograph presented in the Executive Summary (Section 1).

Resource Tradeoffs - Arkansas River

Table F-1 indicates how each water management scenario affects various resource values. The type of analysis used in this section is a "departure" analysis, which simply means that the flow provided under each scenario has been compared with the preferred flow for each resource value. Specifically, the preferred flow is subtracted from the flow provided in the scenario to determine how much change there is, in terms of cubic feet per second, from the preferred flow. The amount of change from the preferred flow is expressed in terms of a percentage difference.

Table F-1 shows the departure ratings for each resource value under each of the flow scenarios. It is followed by text that summarizes and highlights the resource tradeoffs.

Key to Table of Arkansas River Tradeoffs

Rating of the Streamflow Provided in Scenario	Percentage Departure from Preferred Flow
extremely negative	71 or more
very negative	61 - 70
somewhat negative	51 - 60
slightly negative	41 - 50
slightly positive	31 - 40
somewhat positive	21 - 30
very positive	11 - 20
extremely positive	0 - 10

Departure Analysis Example: The juvenile fish population prefers a flow of 350 cfs. Under Scenario 1, the flow rate of 1,000 cfs would be a difference of 650 cfs from the preferred flow rate of 350 cfs. The 650 cfs change divided by 350 cfs preference reveals that the 1,000 cfs flow rate would be departure (change) of 185 percent from the preferred flow rate. A change of 185 percent would receive a rating of "extremely negative."

When using Table F-1, the following important limitations and background information should be considered:

1. Even though all resource values are given equal space on the table, there are dramatically different levels of river usage during the July 24 to September 7 timeframe:

   ~ Juveniles of the fish population are more affected by flow manipulations than adults during the July 24 to September 7 period. Fry have recruited to the juvenile life stage by this date, and spawning does not occur during this time. The row in the table that illustrates effects on juveniles has been shaded to indicate their susceptibility to changes in flow during this time period.

TABLE F-1

Arkansas River Tradeoffs.
(Shading indicates the recreational activities and biological life stages that have the highest river usage rates during the July 24 to September 7 period.)

Resource Value	Scenario 1 - 1,000 cfs	Scenario 2 - 700 cfs	Scenario 3 - 550 cfs	Scenario 4 - 400 cfs
Fish population - juvenile (median preference = 350 cfs)	Extremely negative (185% departure)	Extremely negative (100% departure)	Somewhat negative (57% departure)	Somewhat positive (30% departure)
Fish population - adult (median preference = 500 cfs)	Extremely negative (185% departure)	Slightly positive (40% departure)	Extremely positive (10% departure)	Very positive (20% departure)
Rafting (median preference = 1,750 cfs)	Slightly negative (42% departure)	Somewhat negative (60% departure)	Very negative (69% departure)	Extremely negative (71% departure)
Kayaking (median preference = 1,400 cfs)	Somewhat positive (29% departure)	Slightly negative (50% departure)	Very negative (61% departure)	Extremely negative (71% departure)
Fly fishing (median preference = 450 cfs)	Extremely negative (122% departure)	Somewhat negative (56% departure)	Somewhat positive (22% departure)	Very positive (11% departure)
Spin fishing (median preference = 950 cfs)	Extremely positive (5% departure)	Somewhat positive (26% departure)	Slightly negative (42% departure)	Somewhat negative (58% departure)
Float fishing (median preference = 1,050 cfs)	Extremely positive (5% departure)	Slightly positive (33% departure)	Slightly negative (48% departure)	Very negative (62% departure)

- ~ Of total boating use, 90 percent is use by rafters, while the other 10 percent is use by kayakers. The row in the table that illustrates effects on rafting has been shaded to indicate the large overall effect.

- ~ Of total angling use, 54 percent is fly fishing, 41 percent is spin fishing, and 5 percent is float fishing. The row in the table that illustrates effects on fly fishing has been shaded to indicate the higher level of use.

2. Fish population preferences were calculated by using brown trout as an indicator species. This does not mean that other fish species, such as rainbow trout, were ignored. Rather, rainbow trout preferences are close to brown trout preferences, and one species had to be selected in order to avoid an overly complicated analysis and presentation of data.

3. All preferences are expressed as flow preferences at the Wellsville streamflow gage. Because inflow from tributaries upstream and downstream from the gage, a given flow at Wellsville will translate to a lower flow upstream and a higher flow downstream. For a discussion of how to calculate the typical flow differences between different reaches of the river, please see the Hydrologic Analysis (Section 4) in this report.

4. By using scenarios that provide a constant flow rate over the 45-day period from July 24 to September 7, the resource implications of changes in flows that naturally occur during this period are not illustrated. For example, the current flow augmentation program to support rafting uses typically starts operation when natural flows come down to 700 cfs, rather than automatically providing an exact flow rate of 700 cfs starting on July 24. Natural riverflows may not recede to 700 cfs until well into the July 24 to September 7 period. Therefore, the analysis of the scenarios does not take into account any flows that might have been much higher than 700 cfs before the augmentation program begins.

Discussion of Arkansas River Tradeoffs

In this section, flow preferences for each resource value are discussed. The flow preferences in relation to the four river management scenarios presented previously are also discussed.

Fish Habitat Tradeoffs

Fish habitat tradeoffs in relation to discharge at the Wellsville gage can be easily discerned by referring to the flow preference curves from the Executive Summary (Section 1, Figure 1-7). Flow preference for brown trout was the focus of this analysis because they are prevalent in the river, the population is self sustaining, and any given operational program will influence rainbow trout in a similar manner. Figure 1-7 displays all life stages of brown trout so tradeoffs can be determined year-round. However, the focus of this analysis is from July 24 to September 7, when juveniles and adults are prevalent in the river. Growth of juvenile fish (fish that are approximately 2 to 8 inches in length) is the primary lifestage of concern during this period. This is because fish growth can be particularly affected by flows above 550 cfs, as demonstrated by the sharp loss in usable habitat in the juvenile trout flow preference curve.

The Stockyard station was selected to illustrate flow preferences for fish populations because fish populations throughout the remainder of the river are generally protected when a preferred flow is delivered at the Wellsville gage, which is close to the Stockyard study site. However, caution should be exercised when extrapolating flows to other reaches. The Stockyard reach has a wider channel than much of the river, and therefore, a flow that provides preferred habitat at Stockyard may produce depths and velocities that are either above or below the preferred range at other sites.

Habitat consistently improves with lower discharge down to 300 cfs (flows were not modeled below 300 cfs). The amount of habitat available at various flow levels can be determined by referring to the Instream Flow Incremental Methodology (IFIM) data in Appendices C and D. Preferred flows are obtained most often in dry water years, as illustrated by the hydrographs in the Executive Summary (Section 1).

In addition, Figures 1-4, 1-5, and 1-6 from Section 1 provide an idea of typical flow rates for average, wet, and dry water years. From this, frequency of preferred flows can be determined. The following discussion describes tradeoffs for brown trout juveniles under the various flow scenarios outlined previously. It should be noted that the water levels needed for reservoir fisheries are discussed later, and that water needs for river fisheries do not always produce reservoir conditions that are favorable to reservoir fisheries.

Scenario 1 (1,000 cfs) provides the least amount of habitat and is furthest from the flow preference for fish populations. Although Scenario 2 (700 cfs) provides more habitat than Scenario 1, it is still almost double the preferred flows for fish habitat.

IFIM research demonstrated that the amount of usable habitat rapidly declines as flows exceed 550 cfs, so Scenario 3 (550 cfs) delivers significantly more available habitat than Scenario 2. However, it is still more than 50 percent higher than the preferred flow for juvenile fish populations. Scenario 4 delivers a flow that is within the optimum range for habitat preference.

Under many of the flow scenarios, Arkansas River flows may need to be manipulated at other times of the year outside of the July 24 to September 7 period. In general, when the winter flows remain inside the 300 to 500 cfs range, there would be no major impact on the fishery. In two cases, winter flows would fall outside this range. Scenarios 3 and 4 would require a mean discharge of 770 cfs and 805 cfs respectively from October through March in wet years, and would require a mean discharge of 595 cfs and 625 cfs during an average year. This would result in a reduction of available habitat, but it occurs during a period that is much less critical to fish growth and recruitment than summer months.

Winter flow adjustments (December through March) have the least impact on fish populations. Reservoir releases could be ramped up during this period to minimize impacts during October and November. Alternatively, if the total volume that needs to be sent downstream is small enough, the least impact on habitat occurs if releases are evenly spread out from October through March to attempt to keep flows at 500 cfs or below. As mentioned previously, spawning (mid-October to mid-November) and hatching/emergence flows (April to mid-May) that are similar tend to maximize survival rates.

Riparian Tradeoffs

The exact magnitude, extent, and acreage of riparian change under the four scenarios is impossible to calculate because there is continuous change along the river corridor in terms of channel type, soil parent materials, streambank porosity, and local water table depths. However, principles from the scientific literature are well-established. The present-day riparian community is a direct result of the baseline hydrograph presented previously. Any effects to the riparian communities along the river due to a different flow regime during the growing season will occur slowly and can only be quantified via long-term studies.

Consistently lower growing season flows could cause encroachment on the channel by riparian vegetation, while higher elevation riparian plants could be lost if lower groundwater tables occur as a result of lower growing season flows. The overall result may be approximately the same amount of riparian acreage, but at different locations relative to the river channel.

Consistently higher growing season flows could cause long-term flooding and extermination of some riparian sites. In some locations, higher flows could also cause erosion of soils and substrates that support riparian resources. However, higher groundwater levels and newly deposited soils could create riparian communities in locations that were either previously unvegetated or vegetated by upland species. The overall result may be approximately the same amount of riparian acreage, but at different locations relative to the channel.

Scenario 1 would not increase flows over those typically experienced during wet water years. However, flows would increase during average and dry water years. Under Scenario 1, the river would experience flows of 1,000 cfs much more frequently after August 8 than under present management, so the increase in water level would be likely to prolong inundation of some riparian communities and raise water table levels. Although there is no certainty that change would occur, principles of riparian ecology would suggest that the composition and placement of riparian vegetation could change based on the tolerance individual species have for duration of flooding and groundwater levels. Similarly, longer periods of shear stress on unvegetated banks at higher flows could erode streambanks. Because of the solid rock substrate underlying much of the river corridor, it is difficult to determine if elevated flows would create wetland/riparian potential in new locations.

Scenario 2 would not increase flows over those typically experienced during wet and average water years, but there would be an increase over typical dry year flows. Implementation of Scenario 2 would not be expected to significantly change the riparian community, since flows are increased over baseline flows only during dry years.

Scenarios 3 and 4 could significantly decrease flows for a 6-week period of the growing season. Consistent implementation of these scenarios could cause wetland species encroachment into the channel during the growing season. This encroaching vegetation may be successful in establishing itself, or it could then subsequently be removed by the sheer stress associated with spring runoff. In addition, vegetation at the upper margin of the band of riparian vegetation could experience dieback. Loss of this vegetation may make these soil surfaces more prone to erosion during high flow events. October through March flows in Scenarios 3 and 4 increase a maximum of 310 cfs, which translates to a mean October through March flow of 805 cfs. These flow levels would not be expected to significantly affect the riparian community because they are still significantly below the rooting zone of most riparian communities along the river.

Wildlife Tradeoffs

As stated previously, flow regimes that support a stable and diverse riparian community will also support the most stable and diverse assemblage of terrestrial wildlife. The negative and positive effects of the scenarios outlined in the riparian section above would also translate into negative and positive indirect effects for wildlife. However, the effects of the scenarios on wildlife are even more difficult to predict than the effects on riparian vegetation because many of the wildlife species of concern are mobile and have some ability to adapt to gradual changes in the riparian community that would occur as the result of a changed growing season flow regime. As noted in the riparian discussion, it is also difficult to predict whether suitable replacement habitat would emerge after a new flow regime is implemented.

Under Scenario 1, the river would experience flows of 1,000 cfs much more frequently and for a longer duration than under present management. This increase in water level would be likely to create a situation where some breeding, nesting, feeding, and prey areas are inundated for longer periods than under the baseline flow. Backwater and side channel areas could remain connected to the main channel for a longer period, possibly producing depths and water temperatures that are not usable by some wildlife species. Implementation of Scenario 2 would not be expected to significantly impact wildlife species since flows are increased over baseline flows only during dry years.

Consistently lower flows occur during 6 weeks of the growing season in Scenarios 3 and 4. Some breeding, nesting, feeding, and prey areas would not be inundated for a sufficient period of time to produce usable substrate conditions, plant composition, cover, and prey populations. Backwater and side channels may not flood or may not remain connected to the main channel. Therefore, water depth, inundated area, and water quality may not be sufficient for terrestrial wildlife use. The increase in October through March flows in Scenarios 3 and 4, which is a maximum of 310 cfs, would not be a large enough increase to significantly impact the amount and quality of habitat available to terrestrial wildlife.

If the flows provided in Scenarios 1 and 2 result in higher numbers of recreational users floating the river, then additional impacts related to disturbance of wildlife would be expected. Presence of humans can flush wildlife out of breeding, feeding, resting, and cover areas. The additional disturbance can cause wildlife to utilize metabolic reserves that would normally be used for completing important life stages. In addition, the disturbance can result in the loss of usable habitat, creating greater competition for wildlife resources in undisturbed areas.

Recreation Tradeoffs

Scenarios 1 and 2 illustrate that augmentation of baseline flows is most beneficial to spin fishing, float fishing, kayaking, and rafting in dry water years. During dry water years, augmentation of flows in Scenario 1 (up to the 1,000 cfs level) creates significant additional periods of time when flows are within the preferred ranges for float fishing and spin fishing. In addition, augmentation to 1,000 cfs brings flows to within the acceptable range for kayaking and rafting.

Scenario 2 (700 cfs) provides similar benefits to these activities, with two exceptions. At 700 cfs, flows for float fishing are within the acceptable range rather than the preferred range. At 700 cfs, flows are 50 cfs outside of the acceptable range for kayaking. However, reducing the augmentation target to the 700 cfs level in Scenario 2 brings flows to within the range of preferred flows for fly fishing.

In average to wet water years, implementation of Scenarios 1 and 2 would not dramatically improve recreation managers' ability to provide the ranges of preferred flows because in wet years the baseline flows are typically above 700 cfs and frequently above 1,000 cfs.

Implementation of Scenario 3 (550 cfs) and Scenario 4 (400 cfs) would reduce flows that rafters, kayakers, spin fishers, and float fishers have enjoyed from 1982 to 1995 in average and wet years. Under Scenario 3, flows would be outside of the preferred range of flows for spin fishing and float fishing, significantly diminishing the quality of the experience that is available to those users. However, fly fishing users would be expected to have a higher quality experience, as flows are brought to within the range of preferred flows for that activity. During a wet year, implementation of Scenarios 3 and 4 would be positive for spin fishing and fly fishing because the baseline flows in wet years were above the range of acceptable flows for those activities.

Under Scenario 4 (400 cfs), the quality of all recreation activities, except for fly fishing, would suffer significant negative impacts in average and wet water years. This flow is outside of the preferred flow range for all activities except fly fishing. The constant flow of 400 cfs in Scenario 4 is similar to what already occurs in dry water years. During dry years, baseline flows are low enough to be outside of the range of preferred flows for most recreational activities.

Resource Tradeoffs - Reservoirs

Resource tradeoffs for reservoirs were also evaluated by using preferences that were identified in the biological and recreational studies. Ratings of each scenario are based upon how much water levels would increase or decrease relative to the preferred reservoir level. Under Scenarios 1 and 2, an assumption is made that the reservoirs would be full on July 24. Under Scenarios 3 and 4, an assumption is made that reservoirs would have to be drawn down by July 24 to accommodate additional storage during the July 24 to September 7 period.

Key to Table of Turquoise Reservoir and Twin Lakes Tradeoffs

Biological studies revealed that fish populations at Turquoise and Twin Lakes Reservoirs prefer full reservoirs in which the water level does not fluctuate dramatically during critical growth periods. Recreational studies revealed that users also prefer full reservoirs in which the water level does not fluctuate dramatically. Implementation of the scenarios occurs between July 24 to September 7, which is a period critical for both fish growth and recreation usage.

The ratings used in Table F-2 can be interpreted as follows:

Rating of Reservoir Level in Scenario	Change in Reservoir Elevation
very negative	8-foot or more loss
somewhat negative	4- to 8-foot loss
no change	changes between -4 feet and +4 feet
somewhat positive	4- to 8-foot gain
very positive	8-foot or more gain

Key to Table of Pueblo Reservoir Tradeoffs

Biological studies revealed that fish populations at Pueblo Reservoir prefer stable to gradually dropping water levels during the July 24 to September 7 period. Some warmwater species benefit from a quick drop in reservoirs levels between July 15 and August 15. Recreational studies revealed that the user preference for boating during this period is for stable or gradually increasing water levels. Anglers prefer stable to increasing water levels for access and safety reasons, but satisfactory angling success rates are also critical, so the fish population needs must be strongly considered.

Ratings are based upon how much water levels would change under each of the scenarios during the July 24 to September 7 period. The table assumes the following historic mean surface elevations at Pueblo Reservoir on July 24:

Average year - 4,858.0 feet
Wet year - 4,880 0 feet
Dry year - 4,845.0 feet

TABLE F-2

Turquoise Reservoir and Twin Lakes Tradeoffs

During Implementation of Scenarios July 24-September 7

	Scenario 1 - 1,000 cfs			Scenario 2 - 700 cfs			Scenario 3 - 550 cfs			Scenario 4 - 400 cfs		
	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating
Average Year	no change	no change	no change	no change	no change	no change	7- to 9.5-foot drawdown as of 7/24	somewhat negative to very negative	somewhat negative to very negative	12- to 14-foot drawdown as of 7/24	very negative	very negative
Wet Year	no change	no change	no change	no change	no change	no change	27- to 33-foot drawdown as of 7/24	very negative	very negative	33- to 35-foot drawdown as of 7/24	very negative	very negative
Dry Year	12- to 16-foot drawdown 7/24-9/7	very negative	very negative	5- to 7-foot drawdown 7/24-9/7	somewhat negative	somewhat negative	no change	no change	no change	no change	no change	no change

Given that *fisheries* prefer stable to declining water levels, the ratings used in Table F-3 can be interpreted as follows:

Rating of Reservoir Level in Scenario	Change in Reservoir Elevation
very negative	8-foot or more gain
somewhat negative	4- to 8-foot gain
no change	changes between -4 feet and +4 feet
somewhat positive	4- to 8-foot loss
very positive	8-foot or more loss

Given that *recreationists* prefer stable to increasing water levels, the ratings used in Table F-3 can be interpreted as follows:

Rating of Reservoir Level in Scenario	Change in Reservoir Elevation
very negative	8-foot or more loss
somewhat negative	4- to 8-foot loss
no change	changes between -4 feet and +4feet
somewhat positive	4- to 8-foot gain
very positive	8-foot or more gain

TABLE F-3

Pueblo Reservoir Tradeoffs

During Implementation of Scenarios July 24-September 7

	Scenario 1 - 1,000 cfs			Scenario 2 - 700 cfs			Scenario 3 - 550 cfs			Scenario 4 - 400 cfs		
	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating	Water Level	Fish Habitat Rating	Recreation Rating
Average Year	no change	no change	Boating - no change Angling*	no change	no change	Boating - no change Angling*	11-foot foregone elevation 7/24-9/7	very positive	Boating - very negative Angling*	16-foot foregone elevation 7/24-9/7	very positive	Boating - very negative Angling*
Wet Year	no change	no change	Boating - no change Angling*	no change	no change	Boating - no change Angling*	34-foot foregone elevation 7/24-9/7	very positive	Boating - very negative Angling*	42-foot foregone elevation 7/24-9/7	very positive	Boating - very negative Angling*
Dry Year	14-foot gain 7/24-9/7	very negative	Boating - very positive Angling*	5-foot gain 7/24-9/7	somewhat negative	Boating - somewhat positive Angling*	no change	no change	Boating - no change Angling*	no change	no change	Boating - no change Angling*

* Angling preference parallels boating preference, but angling use is also affected by fish habitat preference

Discussion of Tradeoffs - Reservoirs

Fish Habitat Tradeoffs

The first part of this discussion focuses on primary and secondary production impacts related to water level manipulations at Twin Lakes and Turquoise Reservoirs. July 24 to September 7 manipulations that result in drafts of more than 10 feet from the top of the conservation pool, the elevation where the greatest impacts on primary productivity occur, are of highest concern. Impacts on the fishery at other times of the year are also briefly discussed.

Typical reservoir elevations and the corresponding drawdown with typical Fryingpan-Arkansas operations from 1982 to 1995 were used to create a baseline to begin tradeoff analysis. Typical 1982-1995 drawdowns were used to calculate reservoir level increases and decreases for each of the scenarios. Mean elevation with Fryingpan-Arkansas operations at Twin Lakes in July, August, and September is 9,193, 9,190, and 9,190 feet, respectively, representing drawdowns of 7, 10, and 10 feet. Turquoise Reservoir is typically at 2 feet below the top of the conservation pool for all 3 months. In the scenarios, it is assumed that one-half of the total acre-feet of water needed to accommodate a scenario would come from each reservoir. However, the drawdowns in the scenarios could be adjusted to optimize levels within each reservoir.

Clear Creek Reservoir is not part of the Fryingpan-Arkansas Project and, therefore, is not discussed. However, natural resource values are best maintained when the reservoir is maintained as close to full pool as possible year-round.

Scenario 1 - Impacts to primary productivity would occur at Twin Lakes and Turquoise Reservoirs for all 3 months in dry and average years. This is of particular concern in dry water years where the surface elevation in this scenario could be 22 feet below the top of the conservation pool at Twin Lakes and 18 feet below at Turquoise Reservoir. Drawdowns of 12.5 feet could occur in average water years at Twin Lakes in this scenario. However, this drawdown could possibly be kept to less than 10 feet by drafting more water from Turquoise Reservoir. Drafts of over 10 feet would not occur in either impoundment during wet years. Drawdowns to achieve this scenario would take place from July 24 to September 7, the most critical time of year concerning productivity.

Scenario 2 - Impacts to productivity would occur at Twin Lakes and Turquoise Reservoirs for all 3 months in a dry water year. The resulting surface elevation in this scenario could be 15 feet below the top of the conservation pool at Twin Lakes and 10 feet below at Turquoise Reservoir. Drafts of over 10 feet would not occur in either impoundment in wet or average years in this scenario. Drawdowns to achieve this scenario would take place from July 24 to September 7, the most critical time of year concerning productivity.

Scenario 3 - Impacts to productivity at Twin Lakes and Turquoise Reservoirs would occur for all 3 months in wet and average years in this scenario. This scenario is of particular concern in wet water years where the surface elevation could be 31 feet below the top of the conservation pool at both Twin Lakes and Turquoise Reservoirs. In an average water year, this scenario could produce a surface elevation 16 feet below the top of the conservation pool at Twin Lakes and 11 feet below at Turquoise Reservoir. Drafts of over 10 feet would not occur in either impoundment in dry years in this scenario. Although these drawdowns are undesirable, any winter or spring drawdown effects on productivity are of less concern compared to late summer. However, during a wet year, possible reduction of spawning habitat in October and dewatering of redds in the winter could impact lake trout reproduction.

Scenario 4 - Impacts to productivity at Twin Lakes and Turquoise Reservoirs would occur for all 3 months in wet and average years in this scenario. This scenario is of particular concern in wet water years where the surface elevation could be 34 feet below the top of the conservation pool at Twin Lakes and 36 feet below at Turquoise Reservoir. In an average water year, this scenario could produce a surface elevation 20 feet below the top of the conservation pool at Twin Lakes and 16 feet below at Turquoise Reservoir. Drafts of over 10 feet would not occur in either impoundment in dry years. Although these drawdowns are undesirable, any winter or spring drawdown effects on productivity are of less concern compared to late summer. However, during a wet year, possible reduction of spawning habitat in October and dewatering of redds in the winter could impact lake trout reproduction.

The following tradeoffs would be expected at Pueblo Reservoir:

Scenario 1 - In a dry year, Pueblo Reservoir water levels would be expected to increase by approximately 14 feet. This increase would occur at a time when declining water levels are preferred for revitalization of shorelines and increasing predation of forage fish.

Scenario 2 - In wet or average years, there would be minimal or no increases to water levels in Pueblo Reservoir. Although the historic, baseline water levels are not preferred levels, they would not be significantly detrimental to fish populations. In dry years, the 5-foot increase in water levels would be a negative factor for increasing the productivity of the warmwater fishery.

Scenario 3 - In wet or average years, this scenario would result in foregone elevations of 11 and 34 feet, respectively, at Pueblo Reservoir. This would provide excellent benefits to the primary productivity of the reservoir and to prey foraging by bass and crappie.

Scenario 4 - At Pueblo Reservoir, the fishery would only be marginally affected in a dry year. In wet and average years, this scenario creates foregone elevations of 16 and 42 feet, respectively. This would provide midseason benefits to the warmwater fishery by allowing shoreline areas to rejuvenate and by providing maximum efficiency of prey foraging by sport fish.

Riparian/Wildlife Tradeoffs

All five scenarios require reservoir operational changes that could affect riparian and wetland resources. Scenario 1 would require the release of more water from upper reservoirs than has historically occurred during average and dry years. Scenario 2 would require the release of more water from upper reservoirs than historically occurred during dry years. The amount released varies greatly depending on the water supply situation, but it is the most significant in dry water years. Any accelerated lowering of reservoir levels beyond the long-term elevation trends will separate groundwater from the rooting zones of some riparian/wetland plants.

At Pueblo Reservoir, the historic water elevation during late summer is typically far removed from the rooting zone of riparian/wetland plants. The water elevations gained under implementation of Scenarios 1 and 2 would be insufficient to bring the water level back up to the rooting zone of riparian/wetland plants.

Implementation of Scenarios 3 and 4 would mean that Turquoise and Twin Lakes Reservoirs would be filling or remain full during the July 24 to September 7 period in most water years. An increasing water level during the late growing season would mean that many plants that established themselves earlier in the growing season (when reservoirs had to be kept at lower elevations to accommodate July 24 to September 7 storage) could be flooded out late in the growing season. In turn, flooded riparian areas may mean less available habitat for wildlife species. During wet water years, the supplemental storage in upper basin reservoirs during this period would mean that between 34 and 42 feet of storage would be foregone at Pueblo Reservoir during the July 24 to September 7 period. Although Pueblo Reservoir water levels are typically below the rooting zone during this period, a significant and infrequent opportunity to increase the vigor and extent of the riparian/wetland community would be foregone.

Recreation Tradeoffs

Although recreation users express a preference for full reservoirs with a stable water level, actual recreation use at reservoirs is not extremely sensitive to water levels. Decreases in water elevation of 10 feet or less at Turquoise Reservoir, 10 feet or less at Twin Lakes, and 15 feet or less at Pueblo Reservoir would not be expected to dramatically change recreation use patterns. Fishing usage under all scenarios would be expected to track with the impact of water on fish populations, which is discussed in the previous section.

Under Scenario 1 during a *dry* water year, water levels would drop 16.0 feet at Turquoise Reservoir and 12.25 feet at Twin Lakes. The quality of user experiences would be diminished significantly, and it would be anticipated that some unquantified drop in usage would occur. During *average* and *wet* years, no significant changes to water levels would be expected to occur at Turquoise and Twin Lakes Reservoirs. At Pueblo Reservoir, water levels would increase by 14 feet during the July 24 to September 7 period, assuming that other operational variables remain constant. Accordingly, unquantified increases in recreational boating use would be expected, along with enhanced shoreline access, visual quality, and safety.

Under Scenario 2, changes in reservoir levels would be modest. Turquoise Reservoir would lose 7.5 feet during a *dry* year, while Twin Lakes would lose 5.25 feet. This would be expected to slightly decrease the quality of the recreational experience for users, but the change may not be of sufficient magnitude to discourage users from visiting.

Under Scenario 3 during a *wet* water year, approximately 34 feet of water elevation would be foregone at Pueblo Reservoir during the July 24 to September 7 period, assuming all other operational variables remain constant. Pueblo Reservoir is typically filled to the top of the conservation pool on July 24 of a *wet* year, and would likely remain full if water were not held back in upper basin storage. Therefore, under this scenario, water levels would likely decline because there would be less inflow to replace deliveries of water made to water users. If the reservoir forgoes the entire 34 feet of storage and large water demands significantly lower the reservoir, boating uses could be almost entirely eliminated. Shoreline access, visual quality, and safety would be very seriously affected.

Under Scenario 3, Turquoise and Twin Lakes Reservoirs would have to be drawn down significantly by July 24 to provide the storage space needed to hold back flows during the July 24 to September 7 period. In an *average* year, Turquoise Reservoir would be drawn down 9.5 feet, while Twin Lakes would be drawn down 7.0 feet. In a *wet* year, these effects would be even more pronounced, requiring Turquoise Reservoir to be draw down by 33.0 feet, and Twin Lakes to be drawn down by 27.0 feet to accommodate the supplement storage required to implement the scenario. At the peak season of recreational use, reservoir levels could be more than 30 feet below capacity, severely affecting the quality of recreation use. While reservoir levels would be rising during the July 24 to September 7 period, the reservoir may not fill until early September, just when recreational demand is starting to taper off.

If Scenario 4 were implemented, the effects at Pueblo Reservoir, Turquoise Reservoir, and Twin Lakes would be similar to Scenario 3, but more pronounced. During a *wet* water supply year, 42 feet of water elevation would be foregone at Pueblo Reservoir during the July 24 to September 7 period. In a *wet* year, up to 35 feet of drawdown may be required at the upper reservoir by July 24 to provide the storage space needed to implement the scenario. An *average* year would see 16.0 feet of foregone storage at Pueblo Reservoir during the July 24 to September 7 period, while the upper reservoirs would need to be lowered from 11.75 to 14.0 feet by July 24 to provide the storage space needed to implement the scenario. The *dry* year effects of implementing this scenario would be minimal because only 4,000 acre-feet of additional storage would be required in upper basin reservoirs to keep riverflows at 400 cfs from July 24 to September 7.

☆ U.S. GOVERNMENT PRINTING OFFICE: 2000 — 673-075 / 39000 Region No. 8

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE July 2000

3. REPORT TYPE AND DATES COVERED Final

4. TITLE AND SUBTITLE
Arkansas River Water Needs Assessment

5. FUNDING NUMBERS

6. AUTHOR(S)
Roy E. Smith and Linda M. Hill (Editors)

8. PERFORMING ORGANIZATION REPORT NUMBER
BLM/RS/ST-00/002+7200

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Department of the Interior
Bureau of Land Management
National Applied Resource Sciences Center
P.O. Box 25047
Denver, CO 80225-0047

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

The upper Arkansas River Basin and its associated reservoirs are important hydrological, biological, and recreational resources. The Arkansas River is also one of the most intensively managed river systems in the United States. Competing demands for water have made it necessary for management agencies to thoroughly understand the effects decisions can have on various resources and to carefully weigh the user preferences, environmental requirements, and legal and administrative constraints associated with decisions that affect water uses, streamflow, and reservoir levels. The Bureau of Land Management, Bureau of Reclamation, Forest Service, Colorado Department of Natural Resources conducted a cooperative assessment, which included an institutional and legal analysis, a hydrologic analysis, and an examination of natural resource and recreation values, to provide a common set of data on which water management decisions could be based.

14. SUBJECT TERMS
- Arkansas River
- Instream flow
- Hydrology
- Natural resources
- Fryingpan Arkansas Project
- River management
- Water rights

15. NUMBER OF PAGES 416 including covers

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
296-102