# Arkansas River Water Needs Assessment

## Section 1. Executive Summary


By:

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Doug Krieger, Colorado Division of Wildlife
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# 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 1. 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.

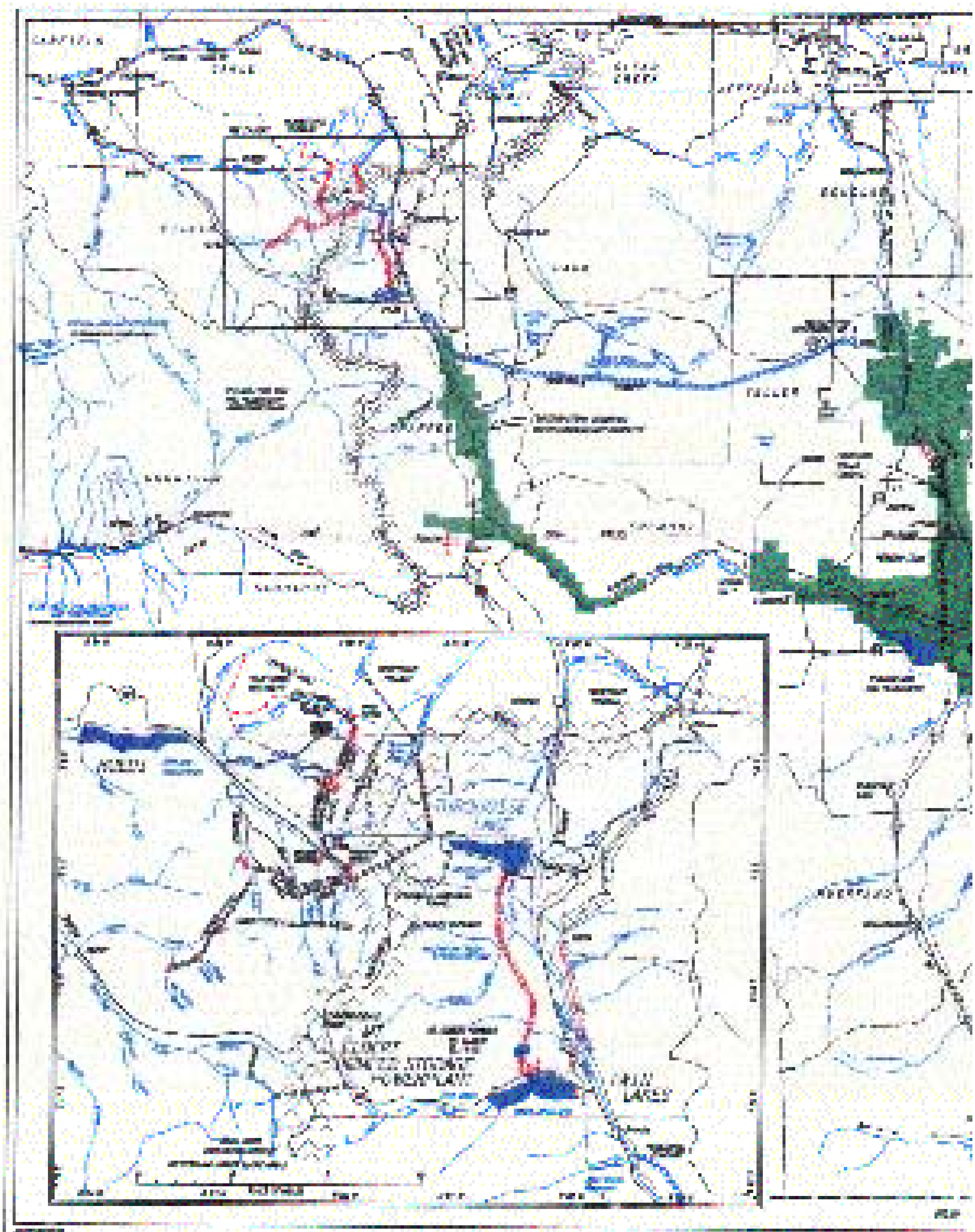
Intensive river management efforts have not dramatically changed the annual hydrograph of the river in the study reach. Rather, river management has had the effect of maintaining peak spring runoff flows at approximately the same level, slightly increasing late summer and early fall flows, and increasing 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.

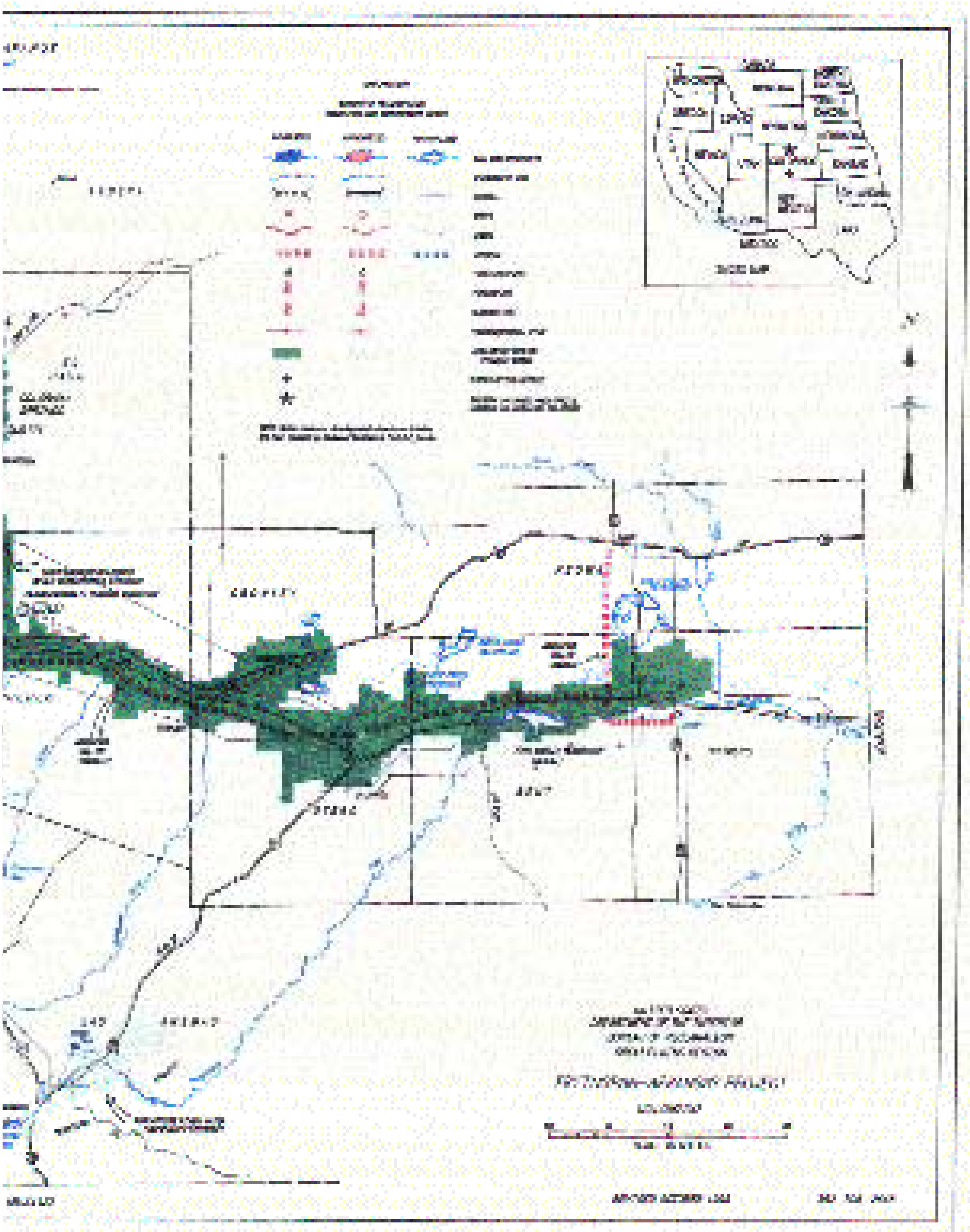
### Native Riverflows and Senior Downstream Water Rights

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





## 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.

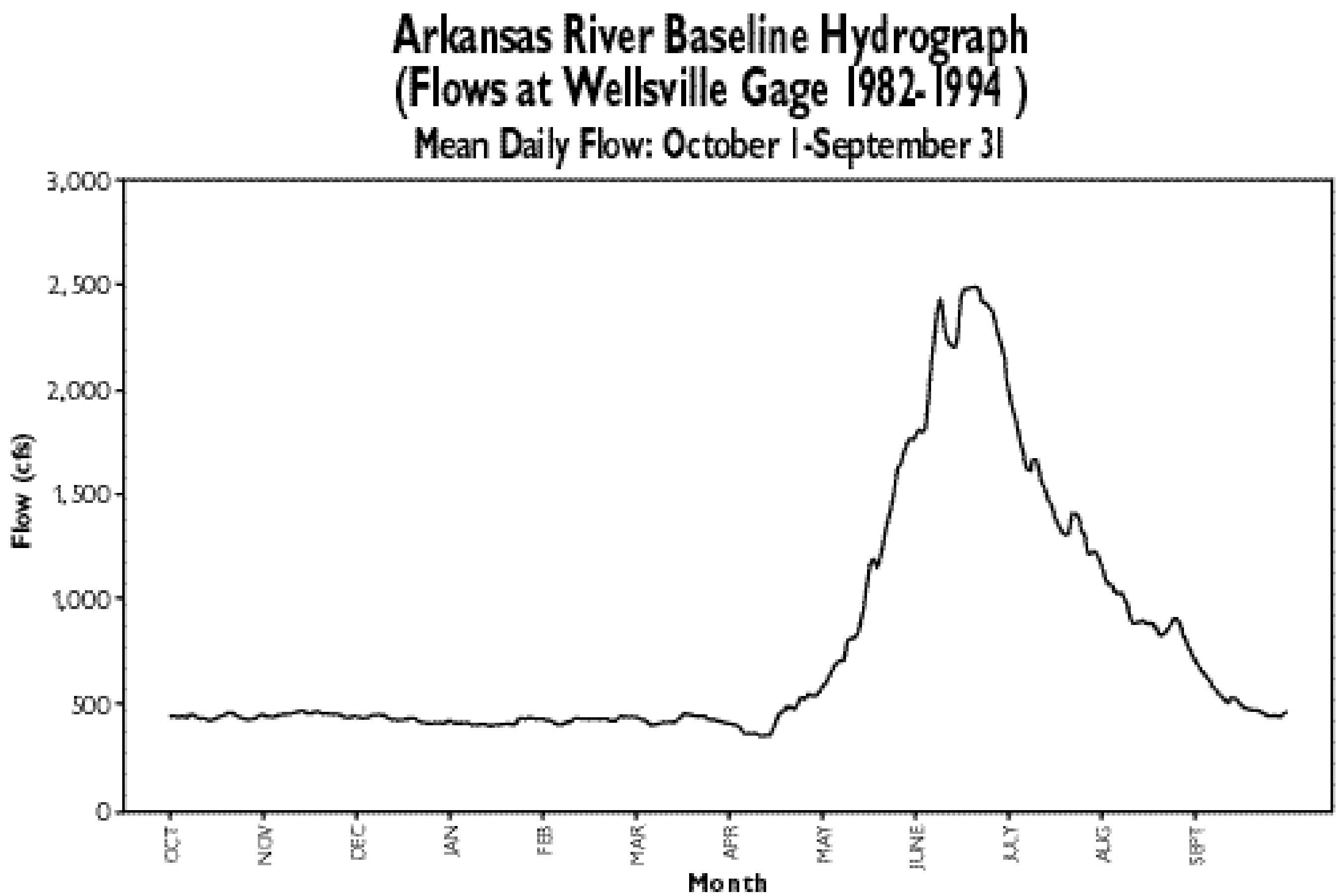
~ The evacuation of water from the upper reservoirs could be limited, in any kind of runoff year, by the lack of Project storage space in Pueblo Reservoir. The available space in Pueblo Reservoir does not correlate to the runoff in any single year because Pueblo Reservoir is designed to hold multiple 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




**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 l to Start of Spring Runoff (typically around April 15)** - The river's fish population and angling opportunities are well-supported by flows ranging from 300 cfs to 500 cfs. The riparian

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 | | | | | | | Lowest flows impact ground-water levels | |
| July | 1,727 | Flow Preference 300 - 500 | | | | | | | |
| August | 956 | | | | | | | | |
| September | 477 | | | | | | | | |
| October | 402 | | | | | | | | |

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:

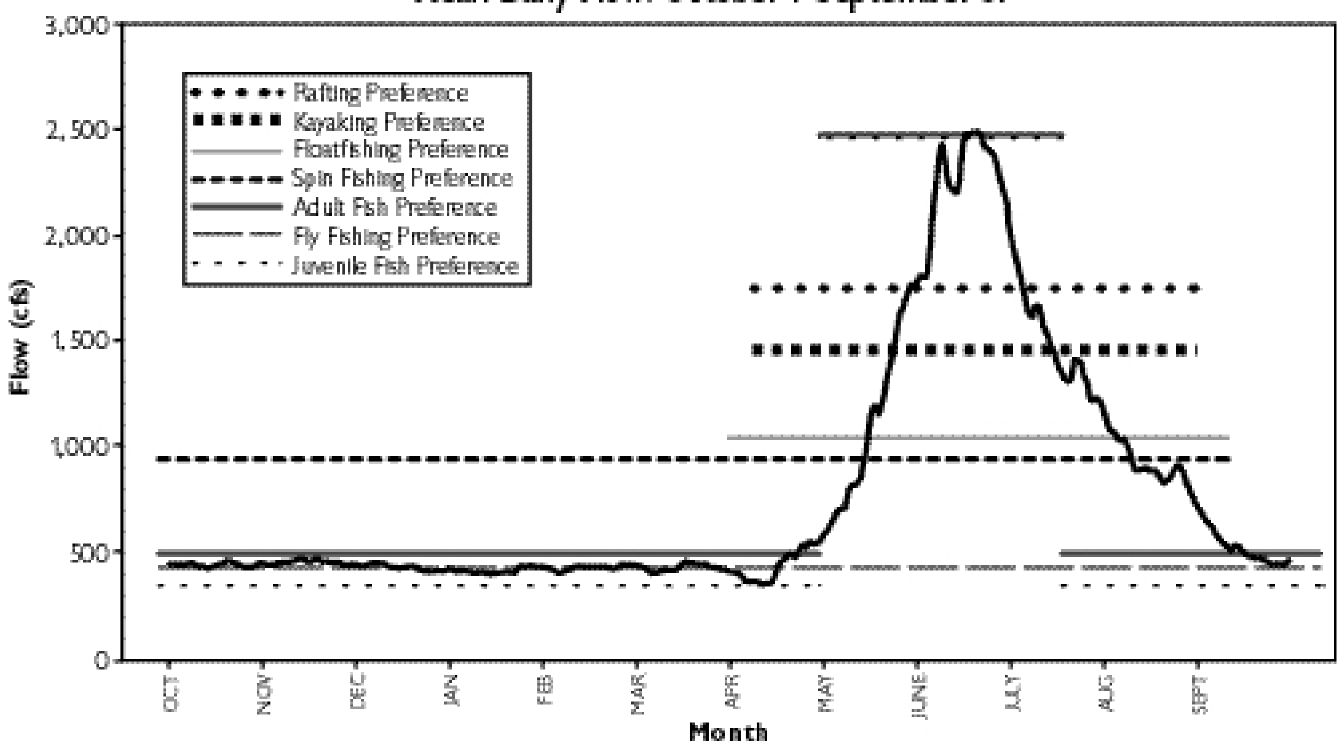
~ Figure 1-3 illustrates baseline Arkansas River flows on a year-round basis, incorporating Fryingpan-Arkansas Project operations. This is the same hydrograph that was presented earlier in this section.

~ 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

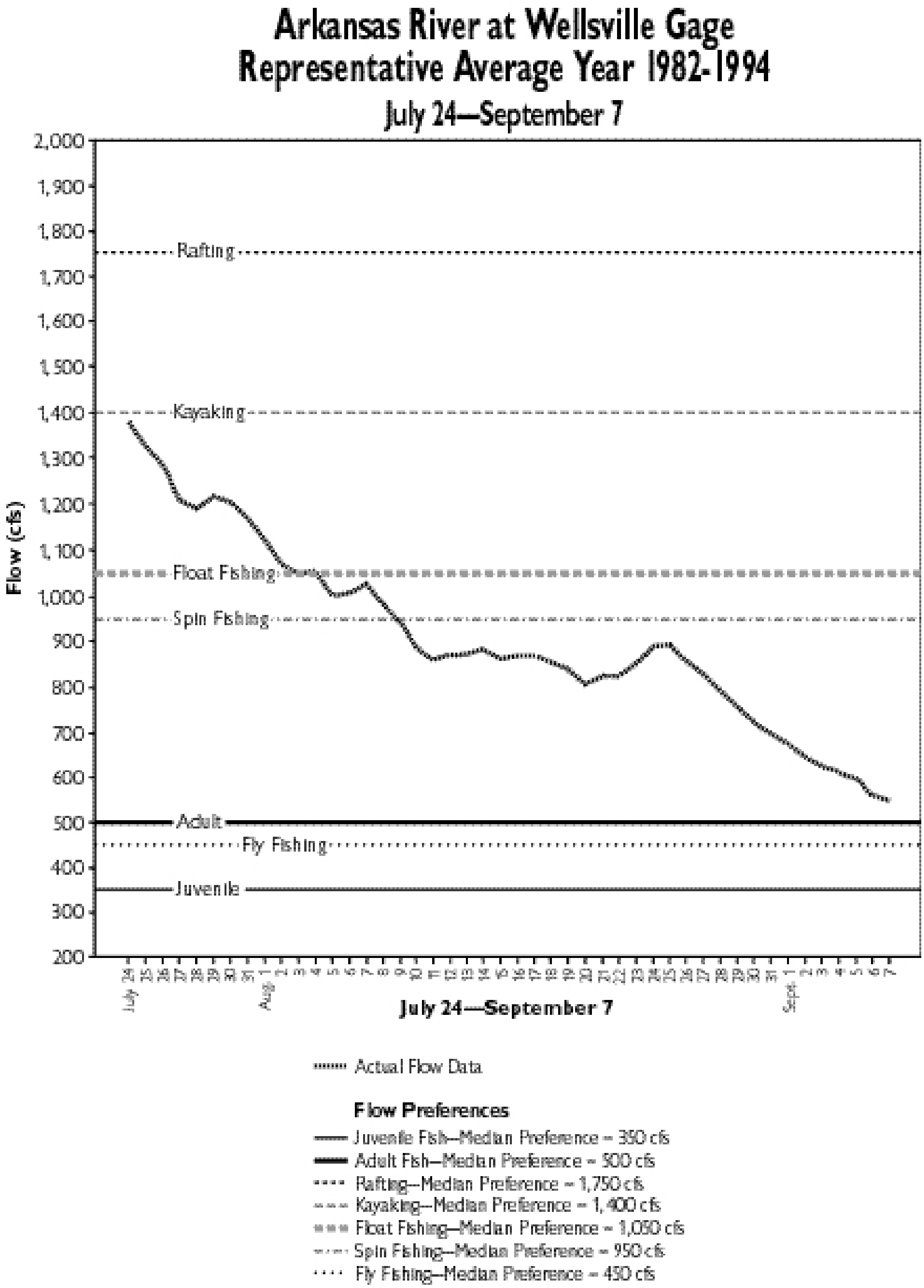

Arkansas River at Wellsville Gage
Representative Average Year 1982-1994
July 24—September 7
Flow (cfs)
2,000
1,900
1,800
1,700
1,600
1,500
1,400
1,300
1,200
1,100
1,000
900
800
700
600
500
400
300
200
Rafting
Kayaking
Float Fishing
Spin Fishing
Adult
Fly Fishing
Juvenile
July
Aug.
Sept.
July 24—September 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 1-5

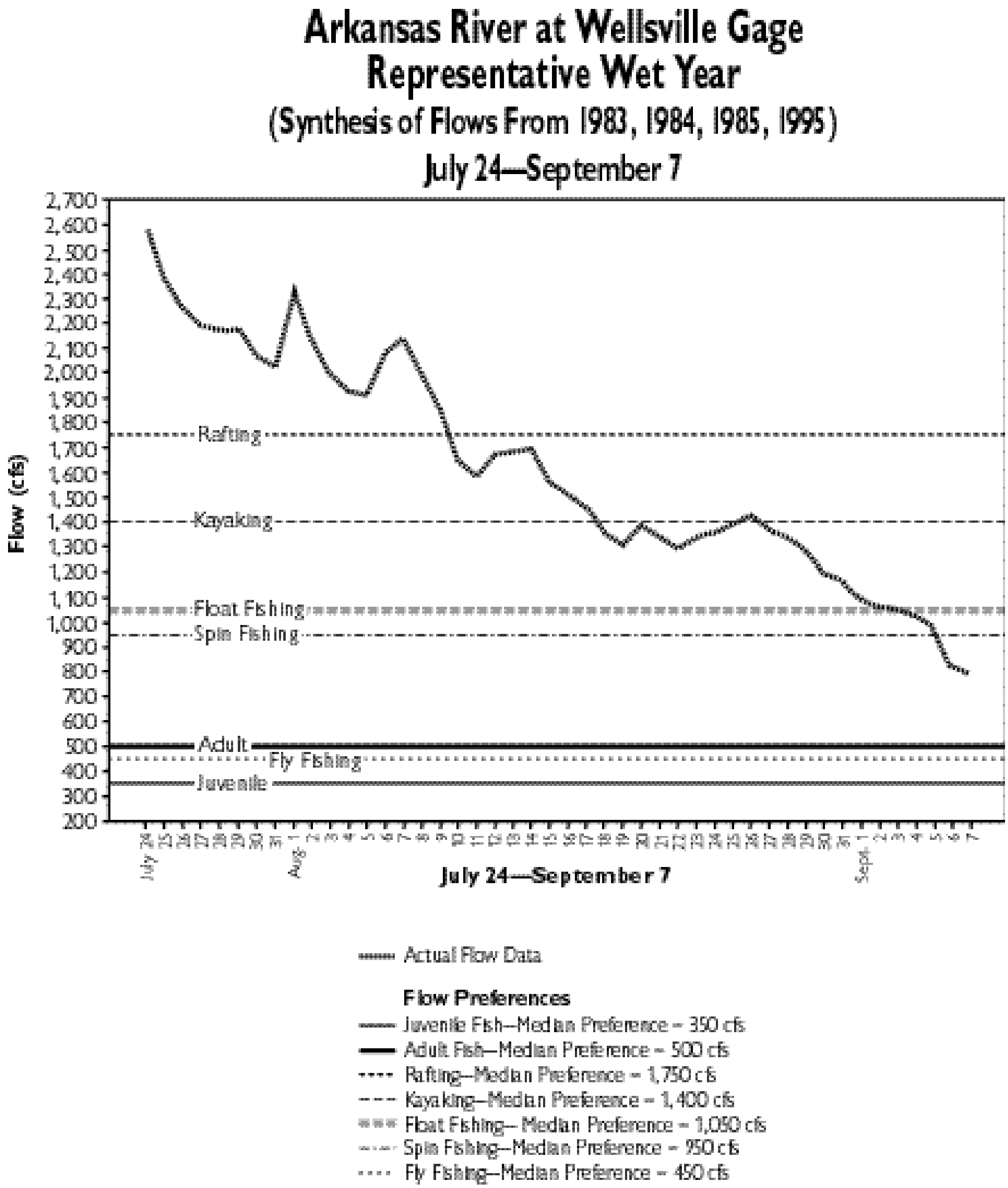
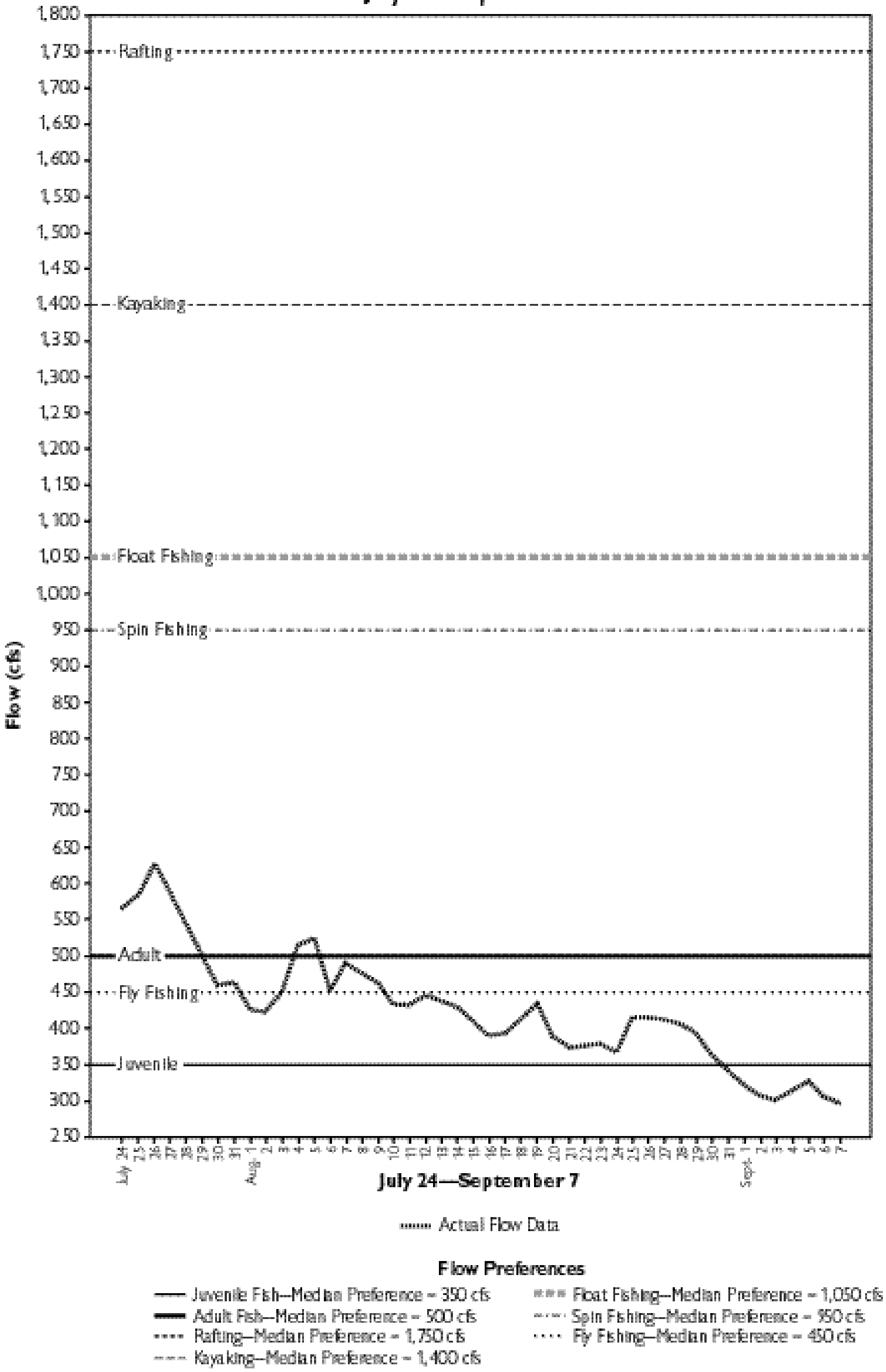

Arkansas River at Wellsville Gage
Representative Wet Year
(Synthesis of Flows From 1983, 1984, 1985, 1995)
July 24—September 7
Flow (cfs)
Rafting
Kayaking
Float Fishing
Spin Fishing
Adult
Fly Fishing
Juvenile
July 24—September 7
Actual Flow Data
Flow Preferences
Juvenile Fish—Median Preference = 350 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

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 |
|---|---|---|---|---|
| Jul | 24 | 2,580 | 566 | 1,380 |
| | 25 | 2,373 | 586 | 1,323 |
| | 26 | 2,263 | 629 | 1,286 |
| | 27 | 2,188 | 590 | 2,309 |
| | 28 | 2,173 | 550 | 1,189 |
| | 29 | 2,178 | 505 | 1,216 |
| | 30 | 2,070 | 459 | 1,203 |
| | 31 | 2,018 | 466 | 1,166 |
| Aug | 1 | 2,330 | 426 | 1,120 |
| | 2 | 2,130 | 424 | 1,069 |
| | 3 | 2,005 | 451 | 1,049 |
| | 4 | 1,930 | 516 | 1,050 |
| | 5 | 1,915 | 525 | 1,003 |
| | 6 | 2,075 | 454 | 1,002 |
| | 7 | 2,145 | 491 | 1,025 |
| | 8 | 2,000 | 478 | 979 |
| | 9 | 1,860 | 464 | 942 |
| | 10 | 1,655 | 434 | 886 |
| | 11 | 1,585 | 434 | 859 |
| | 12 | 1,675 | 447 | 868 |
| | 13 | 1,685 | 440 | 871 |
| | 14 | 1,695 | 430 | 880 |
| | 15 | 1,560 | 412 | 869 |

| Date | Wet Year | Dry Year Actual | Avg Year Actual | Actual |
|---|---|---|---|---|
| Aug | 16 | 1,505 | 390 | 865 |
| | 17 | 1,455 | 395 | 866 |
| | 18 | 1,360 | 415 | 852 |
| | 19 | 1,305 | 436 | 835 |
| | 20 | 1,395 | 390 | 805 |
| | 21 | 1,335 | 375 | 820 |
| | 22 | 1,300 | 377 | 825 |
| | 23 | 1,340 | 380 | 848 |
| | 24 | 1,361 | 368 | 886 |
| | 25 | 1,395 | 418 | 889 |
| | 26 | 1,431 | 415 | 853 |
| | 27 | 1,370 | 413 | 822 |
| | 28 | 1,344 | 407 | 789 |
| | 29 | 1,283 | 394 | 753 |
| | 30 | 1,200 | 364 | 722 |
| | 31 | 1,164 | 343 | 693 |
| Sep | 1 | 1,096 | 323 | 675 |
| | 2 | 1,059 | 309 | 645 |
| | 3 | 1,053 | 303 | 627 |
| | 4 | 1,032 | 315 | 611 |
| | 5 | 989 | 329 | 596 |
| | 6 | 829 | 309 | 561 |
| | 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.

boat ramps unusable. Gradual drafting 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 | | | | | |
| June | 9,864 | 9,193 | Don't drop res. elev. by a total of more than 10 feet | High as possible minimal fluctuation | | 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 ground-water 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*

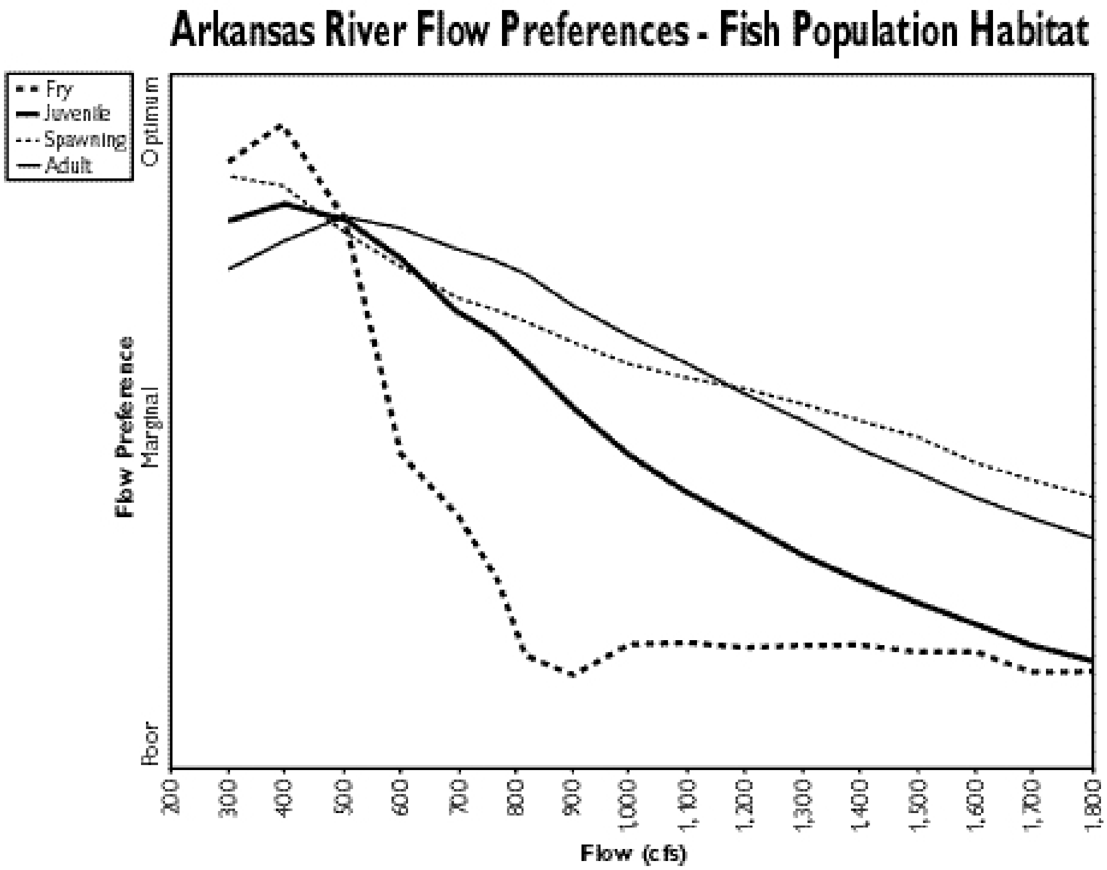
The Arkansas River is noted for its exceptional brown trout fishery and for its developing rainbow trout fishery. Brown trout were the focus of this study because they are prevalent in the river, the population is self-sustaining, and any given operational program will influence rainbow trout in a similar 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

FIGURE 1-7




**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.

spawning is 4.8 to 36.0 inches. Redds (spawning locations) are generally found at depths 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, ground-water 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 | Optimum | Median |
|---|---|---|
| Activity | Flow Range | 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.

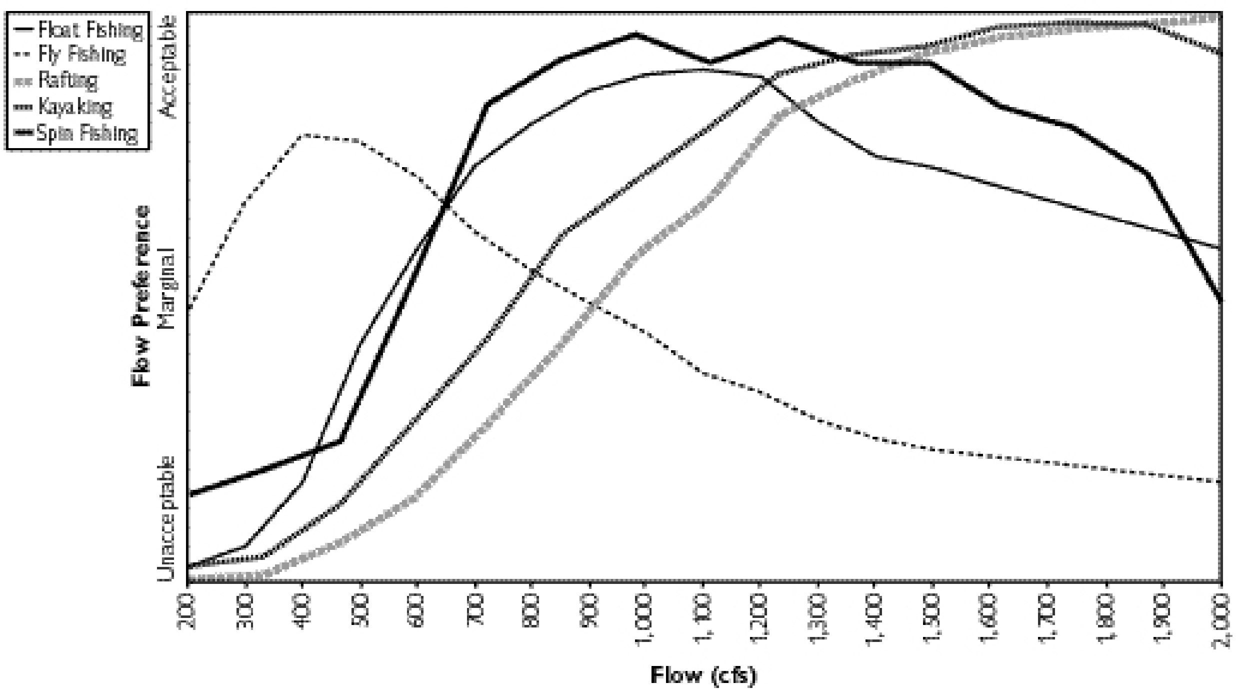
### *Pueblo Reservoir*

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

FIGURE 1-8

## Arkansas River Flow Preferences - Recreation




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. Therefore, fishing recreation can also be correlated with water levels that provide preferred water eleva-