Upper Colorado River Endangered Fish Recovery Program

UPPER COLORADO RIVER SUBBASIN

Floodplain Management Plan

FINAL **February 2006**

Cover Photo: Aerial photo of the confluence of the Colorado River (from top) and the Gunnison River (from right) at Grand Junction, Colorado. The Jarvis Restoration Site is on the left bank, immediately downstream of the bridges of State Highway 50 and a spur of the Denver and Rio Grande Western Railroad. Bureau of Reclamation photo.

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UPPER COLORADO RIVER SUBBASIN FLOODPLAIN MANAGEMENT PLAN

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Final Report

Upper Colorado River Endangered Fish Recovery Program
Project No. C-6

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

EXECUTIVE SUMMARY

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) developed this Floodplain Management Plan (Plan) to provide restoration and management strategies for existing floodplain sites in the Upper Colorado River Subbasin that have been acquired and/or are managed by the Recovery Program for the benefit of the endangered razorback sucker (*Xyrauchen texanus*). The goal of this Plan is to provide adequate floodplain habitats for all life stages of razorback sucker for the establishment and maintenance of self-sustaining populations, particularly to serve as nursery areas for larvae and juveniles in the Upper Colorado and Gunnison rivers. The objectives of this Plan are to: (1) Inventory floodplain habitats; (2) Identify floodplains necessary for life stages of razorback sucker; (3) Restore and manage strategic floodplains to benefit razorback sucker; and (4) Evaluate effectiveness of floodplain restoration. It is hypothesized from scientific studies and hatchery culture that two other endangered fish species, bonytail (*Gila elegans*) and Colorado pikeminnow (*Ptychocheilus lucius*), will also benefit from a greater availability of floodplain habitat.

An inventory of floodplains in the Upper Colorado and Gunnison rivers identified 58 floodplains in five reaches as either priority sites or of interest to the Recovery Program because of their location to likely, but unconfirmed, spawning sites and their apparent suitable ecological characteristics. These include four reaches on the Upper Colorado River: (1) Palisade to the Gunnison River; (2) Gunnison River to Loma; (3) Rulison to Palisade; and (4) Moab Bridge to Green River confluence; and one reach on the Gunnison River: (1) Hartland Dam to Roubideau. Totals of 16, 19, 14, 1, and 8 floodplain sites are located in each of the five reaches, respectively. Of the 57 sites, 35% are gravel pit ponds, 42% are terraces that fill and drain with river stage, and 23% are side channels and oxbows. Structural modifications and investigations have already been conducted, or are ongoing, on some of these floodplains, and information being gathered is valuable to better understand best management strategies. Bathymetric profiles of these sites have not been developed and the total floodable area of these floodplains is unknown. Inundation of these floodplains occurs in wet, moderately wet, and average wet years, and there is little inundation in average dry, moderately dry, and dry years because of existing flow regulation.

Strategies for this Plan are designed to consider a regulated flow regime, no known spawning areas, and a determination of strategic floodplain sites. Wild razorback sucker occur in very low numbers in the Upper Colorado River Subbasin, and hatchery fish are being released to augment the population. Small numbers of drifting larvae have been found recently, but specific spawning sites have not been located. Razorback sucker are known to spawn on mainstem cobble bars during spring runoff. Their larvae emerge in about 3 weeks as passive drift in river currents, and entrainment in productive, sheltered floodplains is critical to their survival. The five strategies of this Plan are to: (1) Identify spawning sites of razorback sucker through release and monitoring of hatchery-reared fish; (2) Mechanically reconfigure strategic floodplain sites downstream of identified spawning sites to provide suitable flooding and entrainment for nursery and rearing of larval razorback sucker; (3) Assist establishment of wild populations of razorback sucker and bonytail through release of hatchery-reared fish; (4) Investigate and implement best management strategies to reduce detrimental effects of nonnative fishes in floodplain habitats; and (5) Insure suitable instream flows to inundate key floodplain sites on a timely basis.

The first strategy, to identify spawning sites of razorback sucker, should be implemented and achieved in the first 5 years of the plan, by the end of the year 2010. This 5-year period should be sufficient time for stocked fish to mature, recruit to adults, and reproduce naturally. Much of the investigation to identify best stocking strategies has already been conducted. Radiotelemetry studies should be initiated to track the fish to spawning areas. The second strategy, to mechanically reconfigure strategic floodplain sites, has already been done at some sites and additional work should not be implemented until spawning sites of razorback sucker are identified and confirmed with presence of eggs and/or newly-hatched larvae. The third strategy, to assist establishment of wild populations with hatchery-reared fish, is fundamental to recovery of the razorback sucker and bonytail in the Upper Colorado River Basin.

The Recovery Goals for razorback sucker and bonytail estimate that self-sustaining populations will become established by about the year 2015. This time schedule should allow sufficient time for hatchery-reared fish and their progeny to mature and reproduce in the wild. The fourth strategy, to reduce detrimental effects of nonnative fishes in floodplains, is part of ongoing investigations in the Upper Colorado River Basin. These investigations should continue, but new and innovative ideas are needed to cope with this persistent threat. The need for nonnative fish management may extend beyond establishment of self-sustaining populations and may remain a long-term management action necessary to maintain recovered populations. The fifth strategy, to insure suitable instream flows, is also an ongoing upper basin activity. This strategy is based on implementation, evaluation, and revision of current flow recommendations for the Upper Colorado and Gunnison rivers.

ACKNOWLEDGMENTS

This Floodplain Management Plan was developed with funding from the Upper Colorado River Endangered Fish Recovery Program (Recovery Program). The Recovery Program is a cooperative partnership of the U.S. Fish and Wildlife Service; Colorado River Energy Distributors Association, Colorado Water Congress, Land and Water Fund of the Rockies, National Park Service, State of Colorado, State of Utah, State of Wyoming, The Nature Conservancy, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Utah Water Users Association, Western Area Power Administration, and Wyoming Water Association.

We thank Dr. Robert Muth, Recovery Program Director, as well as the Biology Committee, for their input into development of this Plan. Tom Pitts, Dave Speas, Melissa Trammell, and Tom Chart reviewed this plan and provided valuable comments and guidance on the final document. We also thank the Upper Colorado River Team, including Chuck McAda, Bob Burdick, Doug Osmundson, and Patty Schraeder.

1.0 INTRODUCTION

1.1 Background

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) is a cooperative partnership involving public and private interests dedicated to recovering endangered fishes in the Upper Colorado River Basin, while water development proceeds in compliance with Federal and State laws (U.S. Department of the Interior 1987). The Recovery Program is coordinated by the U.S. Fish and Wildlife Service (Service) with seven major program elements to recover the endangered Colorado pikeminnow (*Ptychocheilus lucius*), razorback sucker (*Xyrauchen texanus*), humpback chub (*Gila cypha*), and bonytail (*Gila elegans*). One of seven major program elements is Habitat Restoration. A principal aspect of this element is floodplain restoration with the goal *"...to improve and maintain sufficient habitat to support the endangered fish species; and to apply habitat development and enhancement techniques experimentally to determine if the rare fishes will use developed habitat and if such techniques contribute to recovery"* (Nelson and Soker 2002).

Floodplains are important nursery and rearing habitats for razorback sucker (Bestgen 1990; Minckley 1983; Minckley et al. 1991; Muth et al. 1998) and possibly bonytail (Mueller 2003). Colorado pikeminnow also use warmed floodplains during high spring flows for feeding and gonadal maturation (Modde and Irving 1998; Modde 1996), but there is no known link between floodplains and life history needs of humpback chub. Availability of floodplains in the upper basin has been reduced by flow regulation and geomorphic river channel changes. The need to restore these floodplains has been identified as important to recovery of these endangered fishes (Tyus and Karp 1990; Modde et al. 1996). Habitat restoration in the upper basin includes acquisition, restoration, and maintenance of floodplain sites. A Draft Floodplain Habitat Synthesis Report (Nelson and Soker 2002) provides an assimilation of acquisition and restoration efforts, and related studies.

1.2 Goals and Objectives

The goal of this Floodplain Management Plan (Plan) is to provide adequate floodplain habitats for all life stages of razorback sucker in the Upper Colorado and Gunnison rivers (Figure 1-1) for establishment and maintenance of a self-sustaining population, particularly to serve as nursery areas for larvae and juveniles. It is hypothesized from scientific studies and hatchery culture that bonytail will also benefit from a greater availability of floodplain habitat. The objectives of this Plan are to:

1. Inventory floodplain habitats;
2. Identify floodplains necessary for life stages of razorback sucker;
3. Restore and manage strategic floodplains to benefit razorback sucker; and
4. Evaluate effectiveness of floodplain restoration.

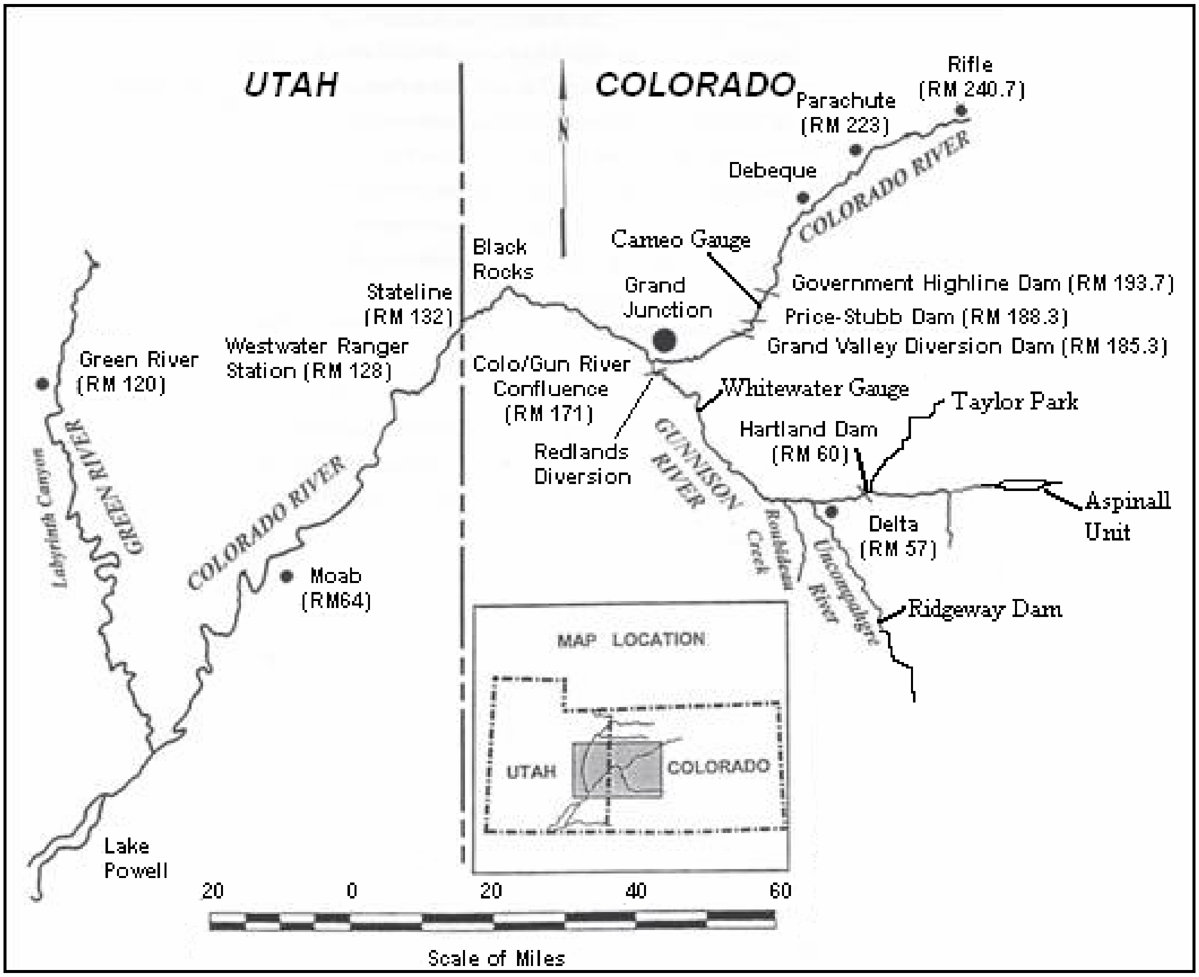


Figure 1-1. The Upper Colorado River Subbasin and key locations referenced in this report.

Floodplain management plans were developed concurrently for the Upper Colorado River Subbasin and the Green River Subbasin (Valdez and Nelson 2004) to provide restoration and management strategies for existing floodplain sites that have been acquired and/or are managed by the Recovery Program for the benefit of endangered fishes. These plans are necessary for the Recovery Program to establish goals, identify management actions, and to gauge progress on habitat restoration and protection. Implementation of these management plans will be the means by which the Recovery Program achieves floodplain-related recovery criteria and management actions identified in the Razorback Sucker Recovery Goals (U.S. Fish and Wildlife Service 2002a) and Bonytail Recovery Goals (U.S. Fish and Wildlife Service 2002b).

1.3 Relationship to Recovery

Final recovery goals for the razorback sucker and bonytail were approved and signed on August 1, 2002 (U.S. Fish and Wildlife Service 2002a, 2002b), and issued as a Notice of Availability on August 28, 2002 (67 FR 55270–55271). These recovery goals are consistent with requirements of the Endangered Species Act of 1973, as amended (ESA; 16 U.S.C. 1531 *et seq.*), and contain site-specific management actions; objective, measurable criteria; and estimates of time and costs for conservation of the species. The following site-specific management actions and tasks were identified in the Razorback Sucker Recovery Goals with respect to floodplain habitats:

"Management Action A-5.—Provide floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles.

> *Task A-5.1.—Identify appropriate bottomland sites and assess opportunities for land acquisition or easements.*
>
> *Task A-5.2.—Acquire or procure easements (as determined under Task A-5.1) for bottomland sites where determined necessary and feasible."*

Objective, measurable criteria were also identified in the recovery goals to address threats under each of the five listing factors (Section 4(a)(1) of ESA), and were stated as the following recovery factor criteria for downlisting and delisting with respect to floodplain habitats for razorback sucker:

> *"Factor A.—Adequate habitat and range for recovered populations provided."*
>
> For Downlisting: *"7. Appropriate bottomland sites identified and opportunities for land acquisition or easements assessed (Task A-5.1)."*
>
> For Delisting: *"7. Bottomland sites acquired or easements procured (Task A-5.2)."*

2.0 PLANNING AND DEVELOPMENT

2.1 Planning

The Recovery Program was initiated under a 15-year Cooperative Agreement dated September 29, 1987 (U.S. Department of the Interior 1987; Wydoski and Hamill 1991; Evans 1993). The program functions under the general principles of adaptive management and consists of seven program elements (Box 1). In 1992, the Recovery Program initiated an inventory of upper basin bottomlands (i.e., floodplains; Irving and Burdick 1995) to guide acquisition and restoration activities under the Habitat Restoration element. Capital funds became available through Bureau of Reclamation (Reclamation) beginning in 1993 for floodplain restoration. A Fiscal Year (FY) 1993 proposal for a Habitat Enhancement Implementation Program was submitted by Reclamation for $230,000 (Johnston 1992). The proposal was revised and renamed for FY94 as the Habitat Enhancement Project – Flooded Bottomlands, and was submitted for $1,046,000 (Nelson and Soker 2002). Total out-of-year costs in that proposal were projected at $9,920,000 through 2003, the year the Recovery Program was scheduled to end. Project activities included acquisition of property easements for management by the Recovery Program and redesign and construction of floodplains to enhance fish habitat. On October 30, 2000, Public Law 106–392 was signed by Congress authorizing up to $46 million of congressional appropriations for the Upper Colorado River Endangered Fish Recovery Program and the San Juan River Basin Recovery Implementation Program. This legislation extended the Recovery Program through 2011, but did not specifically allocate capital construction funds for the Habitat Enhancement Project.

Box 1. Recovery Program Elements

1. Instream Flow Protection;
2. Habitat Restoration;
3. Reduction of Nonnative Fish and Sportfishing Impacts;
4. Propagation and Genetics Management;
5. Research, Monitoring, and Data Management;
6. Information and Education; and
7. Program Management.

From 1992 through 2002, the Recovery Program inventoried floodplains in the Upper Colorado River Basin (Irving and Burdick 1995; Irving and Day 1996; Bell [undated]; Bell et al. 1998; Cluer and Hammack 1999). Floodplain sites available to the Recovery Program were identified in the Green River Subbasin and the Upper Colorado River Subbasin, and by September, 2003, easements for access and restoration were acquired on 19 private property sites totaling 1,600 acres of land. The Recovery Program also identified and negotiated access to numerous sites on lands administered by State and Federal agencies, as well as municipalities.

In February, 2003, the Biology Committee of the Recovery Program identified the need for comprehensive floodplain management plans for the Green River Subbasin and the Upper Colorado River Subbasin. The purpose for these plans was to assimilate and synthesize information from past floodplain restoration activities and to identify objectives and management actions for reaches of each subbasin, as well as for specific floodplain sites. These management plans will be used as guidance for recovery of the razorback sucker and possibly for the bonytail. The Green River Subbasin Floodplain Management Plan (Valdez and Nelson 2004) was completed and approved in April 2004 and applies primarily to the Green River. This Upper Colorado River Subbasin Floodplain Management Plan (Plan) applies principally to the Upper Colorado and Gunnison rivers.

2.2 Plan Development

This Plan was developed with two fundamental considerations: (1) spawning sites of razorback sucker in the Upper Colorado and Gunnison rivers are not known; and (2) restoration and management of floodplain sites is contingent on identifying and locating spawning sites. Numbers of wild and hatchery-reared adult razorback sucker in these rivers are so low that either spawning sites are scattered or numbers of fish spawning are small. Congregations of spawning fish have not been detected and numbers of larvae are so small that natal areas cannot be pinpointed. Radiotelemetry with hatchery-reared fish is recommended to help identify and locate these spawning sites. Once spawning sites are located, floodplain sites immediately downstream should be prioritized for acquisition, restoration, and management to enhance entrainment of larvae and for rearing.

Five priority reaches have been identified by integrating information from the Draft Floodplain Habitat Synthesis Report (Nelson and Soker 2002), Research Priorities For Geomorphology Research (LaGory et al. 2003), and a Floodplain Model (Valdez 2004). These reaches encompass most of the Upper Colorado River Subbasin and include floodplains that have preliminarily been identified as important for species conservation. This Plan calls for continued research on best management strategies for these floodplain sites, but with a greater emphasis and prioritization on identifying and locating spawning sites.

2.3 Role of Propagation and Augmentation Programs

The success of this Plan depends heavily on implementation of the razorback sucker and bonytail propagation and augmentation programs (Nesler et al. 2003) and the genetics management plan (Czapla 1999). These programs and plan are vital to establishment of sufficient numbers of fish in the wild in order to identify patterns of habitat use, spawning sites, drift and entrainment of wild-produced larvae, and appropriate flow and floodplain management strategies to enhance survival and recruitment. Hatchery fish should also be used for radiotelemetry studies to locate and identify spawning sites used by razorback sucker and possibly bonytail. Monitoring drift and habitat use by larval razorback sucker will provide a better understanding of the role of floodplain habitat in the life cycle of the species, as well as differences between floodplain sites with respect to entrainment of larvae and growth and survival. Initial management of selected Recovery Program sites will include stocking and evaluation of hatchery fish (excess to meeting the State stocking plans) to guide research and to supplement population augmentation efforts. Hatchery bonytail will also be released in and near floodplains to assess habitat use, growth, and survival.

Hatchery culture and holding facilities for razorback sucker have been established at the Ouray National Fish Hatchery, Ouray, Utah; and at the Service's Endangered Fish Facility, Grand Junction, Colorado. Hatchery bonytail are available from Dexter National Fish Hatchery, Roswell, New Mexico; Wahweap State Fish Hatchery, Big Water, Utah; and Mumma Native Aquatic Species Restoration Facility, Alamosa, Colorado.

2.4 Role of Floodplain Model

A Floodplain Model (Valdez 2004) was developed for the Recovery Program to estimate the amount of floodplain habitat necessary to recover the razorback sucker and to support recovered self-sustaining populations. This mathematical model is user interactive and consists of 31 numbered steps, including 11 user-specified input variables (Box 2) and 20 automated output variables (Box 3). Input variables include initial population size, sex ratio, average fish length, and survival and growth rates of life stages. A subroutine in the model computes larval entrainment, growth, and survival in any user-specified floodplain site at mile intervals. Output variables include total acres and hectares of floodplains necessary to support specified densities of fish, number of fish recruiting to maturity at 400 mm TL, and recruitment rate as a percentage of the initial adult population.

Box 2. Model Input Variables

1. Initial population size,
2. Sex ratio,
3. Average total length (TL) of females,
4. Percent hatching success,
5. Percent larval emergence,
6. Survival rate of larvae per mile,
7. Time in floodplains,
8. Survival in floodplains,
9. Fish growth rate,
10. Fish density, and
11. Annual survival in mainstem.

Box 3. Model Output Variables

1. Number of females from adults, sex ratio,
2. Average female fish weight,
3. Number of eggs produced,
4. Number of larvae emerging,
5. Percent of larvae entrained,
6. Number of larvae entrained,
7. Number of fish surviving in floodplains,
8. Average total length,
9. Average weight,
10. Biomass of fish surviving,
11. Computed area of floodplains in acres,
12. Computed area of floodplains in hectares,
13. Number of fish escaping to the mainstem,
14. Total length of fish escaping,
15. Number recruited as adults (400 mm TL),
16. Growth in mm to reach 400 mm TL,
17. Months required to reach 400 mm TL,
18. Total months for fish to recruit,
19. Number recruited, and
20. Percent recruitment.

The principles of the Floodplain Model were used in development of this management plan to help assess the importance of river reaches. However, because established spawning sites of razorback sucker are not known in the Upper Colorado and Gunnison rivers, the Floodplain Model could not be used to assess the importance and role of specific floodplain sites. When spawning sites are located, the model may be used to evaluate the importance of specific floodplain sites, identify floodplain area needed for recovery, and better gauge the magnitude of restoration efforts.

The Floodplain Model estimates that for the Green River about 2,000 acres (810 ha) of floodplain depressions are needed to support a self-sustaining population of 5,800 adult razorback sucker (recovery goals target). The Programmatic Biological Opinion (Opinion) for the Bureau of Reclamation's Operations and Depletions in the Upper Colorado River includes plans to acquire interest in up to 3,500 acres of bottomland habitat along the Upper Colorado River in the Grand Valley and along the Gunnison River (U.S. Fish and Wildlife Service 1999). Neither the estimated 2,000 acres from the floodplain model or the 3,500 acres from the Opinion have been tested or evaluated to confirm that these acreages are needed for razorback sucker recovery. However, these figures provide a range of floodplain acreage that the Recovery Program can use to gauge floodplain requirement in the Upper Colorado River Subbasin. Floodplain acreage actually required for the Upper Colorado and Gunnison rivers will need to be estimated and refined as more is learned about razorback sucker spawning sites, larval drift patterns, and strategic locations of floodplains.

2.5 Coordination

This Plan was developed under the authority and support of the Upper Colorado River Endangered Fish Recovery Program. Recovery Program partners include: Colorado River Energy Distributors Association, Colorado Water Congress, Land and Water Fund of the Rockies, National Park Service, State of Colorado, State of Utah, State of Wyoming, The Nature Conservancy, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, Utah Water Users Association, Western Area Power Administration, and Wyoming Water Association.

An interdisciplinary team was established for the Upper Colorado River Subbasin to provide input for development of this Plan. The team was comprised of core principal investigators, biologists, and managers involved in floodplain habitat activities in the Upper Colorado River Subbasin representing the Service and Colorado Division of Wildlife (CDOW). This team was established to work with the Principal Investigator for this Plan, the Habitat Restoration Coordinator, and the Recovery Program Director's office to: (a) identify important river reaches, (b) identify important floodplain sites, (c) describe past and ongoing floodplain investigations, and (d) identify successful and unsuccessful management strategies. A workshop with the Upper Colorado River Team was held July 15, 2003.

3.0 SCIENTIFIC BASIS AND UNDERLYING PRINCIPLES

3.1 Scientific Basis for This Plan

This Plan is based on scientific principles derived from research on floodplains throughout the Colorado River Basin, as well as from other systems. The fundamental basis of this Plan is that floodplains provide nursery habitat for razorback sucker, and restoration and appropriate management of these floodplains will assist the recovery of this and other endangered and native fish species. Floodplains develop along rivers with valley floors that are extensively covered with alluvium and/or sand. The river flowing through this substrate carves an active channel that is flanked by low relief bottomlands that may have groundwater connection with the river and/or become inundated during high-flow periods. High-flow periods of most western rivers are usually associated with snow-melt runoff in spring (Poff et al. 1997; Stanford and Ward 1986a). The timing and frequency of flooding, magnitude of flows, and duration of peak flows determine the degree of floodplain connection to the river. Considerable scientific research has been conducted to better understand the complex inter-relationships associated with formation, inundation, maintenance, and desiccation of riverine floodplains (Ward 1989; Stanford and Ward 1986b).

Flow regulation can disrupt hydrological and ecological connectivity between the river channel and alluvial floodplains (Ward and Stanford 1995). Reduction in spring peaks can reduce connectivity and lead to geomorphic channel changes and vegetative encroachment that may exacerbate this disconnection (Andrews 1986; Graf 1978). Floodplain reconnection is vital to restoring some of the structure and function of floodplains disrupted by flow regulation (Stanford et al. 1996). This reconnection can be achieved through hydrologic re-regulation and/or mechanical modification of floodplain geomorphology and/or the berms that separate floodplains from the main channel.

Floodplains in the Upper Colorado River Subbasin are principally in the Upper Colorado and the Gunnison rivers. Flow of the Upper Colorado River is regulated and depleted by various diversions, primarily in tributaries; and flow of the Gunnison River is largely regulated by the Aspinall Unit (i.e., Morrow Point, Blue Mesa, and Crystal dams), Taylor Park Dam, and Ridgeway Dam. This flow regulation has reduced the frequency of connectivity of the river to floodplains, as well as the duration of connection (Stanford 1994), and is believed to be a major factor in the endangerment of the razorback sucker in the Upper Colorado River Subbasin (Osmundson and Kaeding 1989; Osmundson et al. 1995; Osmundson 2000; McAda 2003). Various tributary inflows can periodically affect mainstem flows during spring snow-melt runoff or late-summer monsoonal rain storms. The relationship of flow regulation and floodplain connection and inundation in the Upper Colorado River is not sufficiently understood to predict numbers, acreage, and types of floodplains at all river stages. Individual floodplain dynamics are also not well understood (e.g., flow and particle entrainment rates, sedimentation, water retention) and are often confounded by physical, chemical, and biological attributes and linkages that are unique to each floodplain site (Burdick 2002). Given this complexity and dynamic nature of floodplains and river flows, predictions in floodplain formation and maintenance—as well as management plans for these floodplains—must be considered provisional and subject to ongoing modification with new information from scientific findings. A detailed description of flow recommendations for the Upper Colorado and Gunnison rivers (McAda 2003) is provided in section 4.0 of this plan.

3.2 Underlying Principles of This Plan

This Plan is based on six underlying principles:

1. Structure and function of the Upper Colorado River ecosystem are sufficiently intact to support wild self-sustaining populations of razorback sucker and bonytail;

2. Floodplain restoration (e.g., protection, mechanical modification, river reconnection) and flow re-regulation will enhance endangered fish habitats;

3. Flow recommendations for the Upper Colorado River and Gunnison River will be implemented, evaluated, and modified under principles of adaptive management, in accordance with the Recovery Action Plan (RIPRAP);

4. Wild populations of razorback sucker and bonytail must be initiated from hatchery stocks and through habitat restoration to better understand specific life history needs in the wild, including nursery and rearing habitats;

5. Young razorback sucker and bonytail remaining in floodplain depressions for at least 2 years exhibit the best growth, survival, and predator avoidance before recruiting to mainstem populations; and

6. Best management strategy is based on the "reset theory" of inundating floodplains for 2–3 years to enhance growth and survival of razorback sucker and bonytail, and allowing floodplains to become desiccated to periodically kill nonnative fish.

The first and second principles state that the Upper Colorado River Subbasin retains many of its natural ecological aspects and that floodplain restoration, combined with flow re-regulation, can maintain and enhance the structure and function of these habitats to assist recovery of razorback sucker and possibly bonytail. Although much of the Upper Colorado River Basin is flow-regulated and nonnative fishes are common, much of the original structure and function of the ecosystem are intact. The Upper Colorado and Gunnison rivers support a wild self-sustaining population of Colorado pikeminnow and two of the six known wild self-sustaining populations of humpback chub. The Upper Colorado River Subbasin also supports viable self-sustaining populations of the four other native, non-endangered fish species: flannelmouth sucker (*Catostomus latipinnis*), bluehead sucker (*Catostomus discobolus*), roundtail chub (*Gila robusta*), and speckled dace (*Rhinichthys osculus*). This naturalized system provides the opportunity for recovery of razorback sucker and possibly bonytail through habitat restoration and flow re-regulation. Estimated time to achieve recovery of these species is 22 years (U.S. Fish and Wildlife Service 2002a), based on the assumption that habitat restoration and self-sustaining populations can be achieved and established in the first 14 years.

The third principle assumes that flow recommendations for the Upper Colorado River and Gunnison River (McAda 2003) will be implemented, evaluated, and modified under principles of adaptive management, in accordance with the RIPRAP, and that flows to support recovered self-sustaining populations will be maintained in perpetuity (U.S. Fish and Wildlife Service 2002a, 2002b). Flows provided through this compliance process are expected to provide inundation of floodplains on a regular basis.

The fourth principle is that wild populations of razorback sucker and bonytail must be initiated from hatchery stocks and habitat restoration to better understand specific life history needs, including habitat requirements. Floodplain restoration activities will be conducted simultaneous to releases of hatchery fish in order to better understand life history needs based on fish habitat use and response. Larval entrainment, growth, and survival in floodplains will be confirmed from wild, free-roaming fish.

The fifth and sixth principles are based on the "reset theory" of floodplain management, which allows floodplains to inundate and remain flooded for at least 2 years, then desiccate. This "reset theory" serves the fundamental ecological functions of providing connectivity for fish entrainment and movement, stimulated floodplain production, and periodic desiccation to reduce effects of nonnative fishes (Box 4). This "reset theory" has not been thoroughly tested, but research on various components of the strategy indicate a high probability of success (Modde 1996, 1997; Modde et al. 1998; Christopherson and Burchell 2002; Christopherson et al. 1999).

Box 4. Ecological Functions of "Reset Theory"

1. Periodic inundation allows access to drifting larval razorback sucker and escapement of adults,
2. Periodic inundation/desiccation stimulates food production and freshens water quality, and
3. Periodic desiccation strands and kills nonnative fishes

3.3 Types of Floodplains

Floodplains in the Upper Colorado River Basin are classified as depressions, terraces, and gravel pits. Gravel pits are mechanical excavations that often function as depressions (Figure 3-1; Irving and Burdick 1995). A fundamental understanding of the hydrological and biological chronology of these floodplains is important to correlate management of these floodplains with appearance and development of the larval fish. All three features may become inundated during high spring runoff and may dry and reset in summer. The degree of inundation varies among floodplain sites, depending on the magnitude of runoff and the ground elevation that separates the feature from the main river channel. Depressions and gravel pit ponds are typically separated from the main channel by an elevated levee that is either natural or manmade. An undesirable feature of gravel pits is that they are often excavated below the river bed elevation and retain water permanently, serving as long-term refuges and continuous sources of nonnative fishes. Terraces are sloping features that fill and drain with changes in river stage. The current management strategy for depressions and gravel pit ponds is habitat restoration through either partial removal of levees or one or more breaches in a levee to allow flooding at lower river stages (Burdick 2002; Lentsch et al. 1996a; Utah Division of Wildlife Resources 1996; FLO Engineering 1996, 1997; Nelson and Soker 2002).

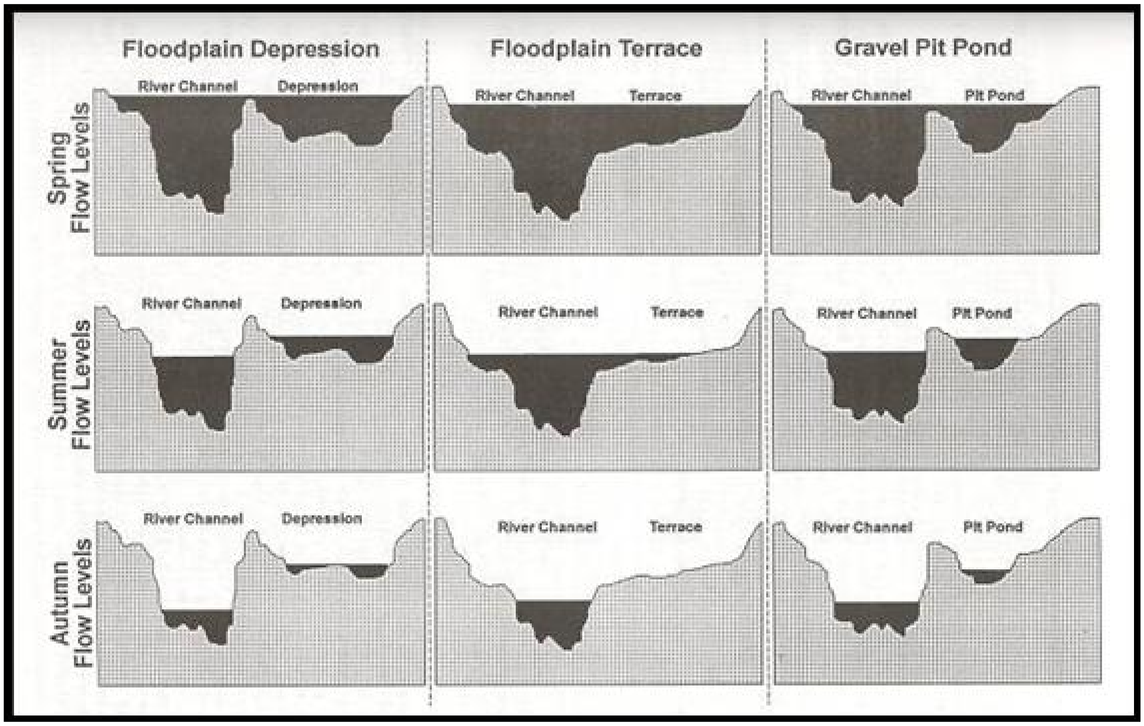


Figure 3-1. Schematic of the bed profile of the three major floodplain classifications at various flow regimes in the Upper Colorado River Basin (excerpted from Irving and Burdick 1995).

3.4 Role of Floodplains

Floodplains are low lying areas that adjoin the active river channel and become inundated during periods of over-bank flooding (Armantrout 1998), primarily during spring floods. The reproductive biology of the razorback sucker is linked to these spring flood events (Tyus 1987; Tyus and Karp 1990; Modde et al. 1995). Adults deposit and fertilize eggs over main channel cobble bars near the peak of spring runoff (Tyus 1987; Tyus and Karp 1990; Modde and Irving 1998). Spawning occurs at 16–19°C, hatching occurs in 6–7 days at 18–20°C, and larvae swim up in 12–13 days (Snyder and Muth 1990). Larvae become transported downstream by river currents at swim-up phase and are entrained in riverside floodplains when the river is still at flood stage (Osmundson and Kaeding 1989). These floodplain habitats are highly productive (Mabey and Shiozawa 1993; Modde 1997) and provide an important and timely food source for the young fish during a “critical period” when nutritional needs shift from endogenous (yolk sac absorption) to exogenous (active feeding) sources at between 8 and 19 days of age (Papoulias and Minckley 1990, 1992). Hence, it is critical for razorback sucker larvae to reach productive and sheltered habitats within 1–2 days of swim-up (Figure 3-2; Hamman 1987). Several factors determine benefits of these floodplains to razorback sucker, including timing of inundation, duration of intra-annual connection with the river, inter-annual frequency of connection, and inter- and intra-annual persistence of water quantity and quality to sustain fish.

Days																									
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
<Eggs hatch in 6–7 days->							**<-----------Larvae swim up in 12–13 days----------->**													**<----Larvae drift---->**					
														<-------------Larvae shift from endogenous to exogenous food source in 8–19 days------------>											
														<Larvae may starve without nursery habitat->											

Figure 3-2. Chronology of egg incubation, swim-up phase, and shift to exogenous food sources for razorback sucker larvae. Larvae need a food source or may begin to starve at 8-19 days of age.

3.5 Nonnative Fish in Floodplains

Over 40 species of nonnative fish have become established in the Upper Colorado River Basin (Tyus et al. 1982). Many are predators and competitors of native fish and are considered a principal cause of species endangerment (Tyus and Saunders 1996). One of seven Recovery Program elements is Reduction of Nonnative Fish and Sportfishing Impacts, and activities in the upper basin are ongoing to reduce the detrimental effects of these nonnatives. Floodplains attract large numbers of nonnative fishes and some reproduce in these habitats (Modde 1997; Birchell and Christopherson 2002; Burdick 2002, 2003; Mueller 2003). The principal and most common floodplain species include cyprinids, centrarchids, and ictalurids (Box 5). Control efforts in the upper basin have yielded variable results, and show that certain large predators (i.e., northern pike [*Esox lucius*], smallmouth bass [*Micropterus dolomieui*], channel catfish [*Ictalurus punctatus*]) can be reduced in numbers, but small forms (e.g., red shiner, fathead minnow, green sunfish, bullheads) are less affected (Lentsch et al. 1996b; Upper Colorado River Endangered Fish Recovery Program 2002). The large numbers of nonnative fishes in floodplains are logistically difficult to control without intensive long-term management and ongoing financial investment, which are not consistent with the concept of population self-sustainability for recovered species. This highly-

Box 5. Principal Nonnative Fish in Floodplains

1. Common carp (*Cyprinus carpio*),
2. Fathead minnow (*Pimephales promelas*),
3. Green sunfish (*Lepomis cyanellus*),
4. Black bullhead (*Ameiurus melas*),
5. Red shiner (*Cyprinella lutrensis*), and
6. Largemouth bass (*Micropterus salmoides*)

managed approach of isolating floodplains from the river channel and mechanical or chemical removal of nonnatives (i.e., "floodplain repatriation") is being used in the Lower Colorado River Basin where flows are highly regulated and habitat is fragmented (Minckley et al. 2003; Mueller and Marsh 2003).

The recommended strategy of floodplain management for the upper basin is based on the "reset theory", and is different from the "floodplain repatriation" approach. Resetting floodplains allows periodic inundation and desiccation that provide timely productive habitats for native fishes and reduce numbers of nonnative forms. Spring flooding allows entrainment of drifting razorback sucker larvae, escapement of older fish, and periodic desiccation serves to reset the floodplain and kill all remaining fish. Nonnative fish can also access the floodplains during connection with the river, but initially in low numbers and primarily as adults which generally feed on prey larger than larvae. Reproduction by nonnatives occurs in late spring and summer when size of young razorback sucker exceeds that of newly-produced nonnatives, hence reducing predation effects.

Studies of Green River floodplains indicate that razorback sucker can survive in the presence of large numbers of nonnative fish following a year of desiccation. In October, 1995, Modde (1997) reported 28 age-0 razorback sucker (3.7 inches TL, 94 mm TL) in Old Charlie Wash in the presence of large numbers of nonnative fish and after a dry period in 1994. In August, 1996, Modde (1997) also reported 45 age-0 razorback sucker (2.6 inches TL, 66 mm TL). Assuming that these fish entered Old Charlie Wash as larvae during runoff in the previous June, the fish captured in October, 1995, were about 4 months old, and those captured in August, 1996, were about 2 months old. The Floodplain Model uses existing literature and predicts highest growth rate of razorback sucker at 94 mm TL in 3.3 months, and growth to 66 mm TL in 2.3 months. Hence, growth exhibited by these wild fish in the presence of large numbers of nonnatives was higher than or equal to highest growth rates for the species. Survival rate of these fish was not determined because the initial numbers of entrained young was not known.

A separate study tested the hypothesis that larval razorback sucker can survive in floodplain depressions following a reset year (Birchell and Christopherson 2002). Larval razorback sucker and bonytail stocked into the Stirrup floodplain in May 2002 in the presence of adult fathead minnow, red shiner, black bullhead, green sunfish, and common carp survived at rates of 1.7–1.9% for bonytail (17.1% in control) and 0.4–0.7% for razorback sucker (12.0% in control). A study to evaluate the Leota floodplain as a grow-out site assessed survival of 66,110 stocked larvae and 900 razorback sucker of various sizes during March through May 2001. A total of 84 razorback sucker were recaptured, including 35 age-0 fish in the presence of large numbers of nonnative fishes. Specific survival rate could not be determined because fish could have escaped during draining of the floodplain.

Effective long-term reduction and control of nonnative fish in the Upper Colorado River Basin may require perpetual mechanical removal on a river reach scale (Burdick 2002). It is uncertain if mechanical removal, by itself, can be an effective method to control and reduce nonnative fish in off-channel habitats or in the mainstem. Screening to prevent escapement of nonnative fish into the mainstem river and chemical rehabilitation (i.e., rotenone) of many gravel-pit ponds within the 50-year floodplain in the Upper Colorado and Gunnison rivers were conducted over a 4-year period from 1997 to 2001 (Martinez 2001). Altogether, 54 ponds were reclaimed with rotenone, but 31 (57%) were rapidly reinvaded and colonized by nonnative fishes. Green sunfish was the most numerous species and was collected in 22 of the 31 ponds (71%). Other reinvading nonnative fish included fathead minnow (11 of 31 ponds [35%]) and black bullhead (4 of 31 ponds). Since 1996, the abundance of some nonnative fish (largemouth bass, green sunfish, white sucker, black bullhead) has increased in riverine habitats in the 15- and 18-Mile reaches (Osmundson 2000).

3.6 Floodplain Management Strategy

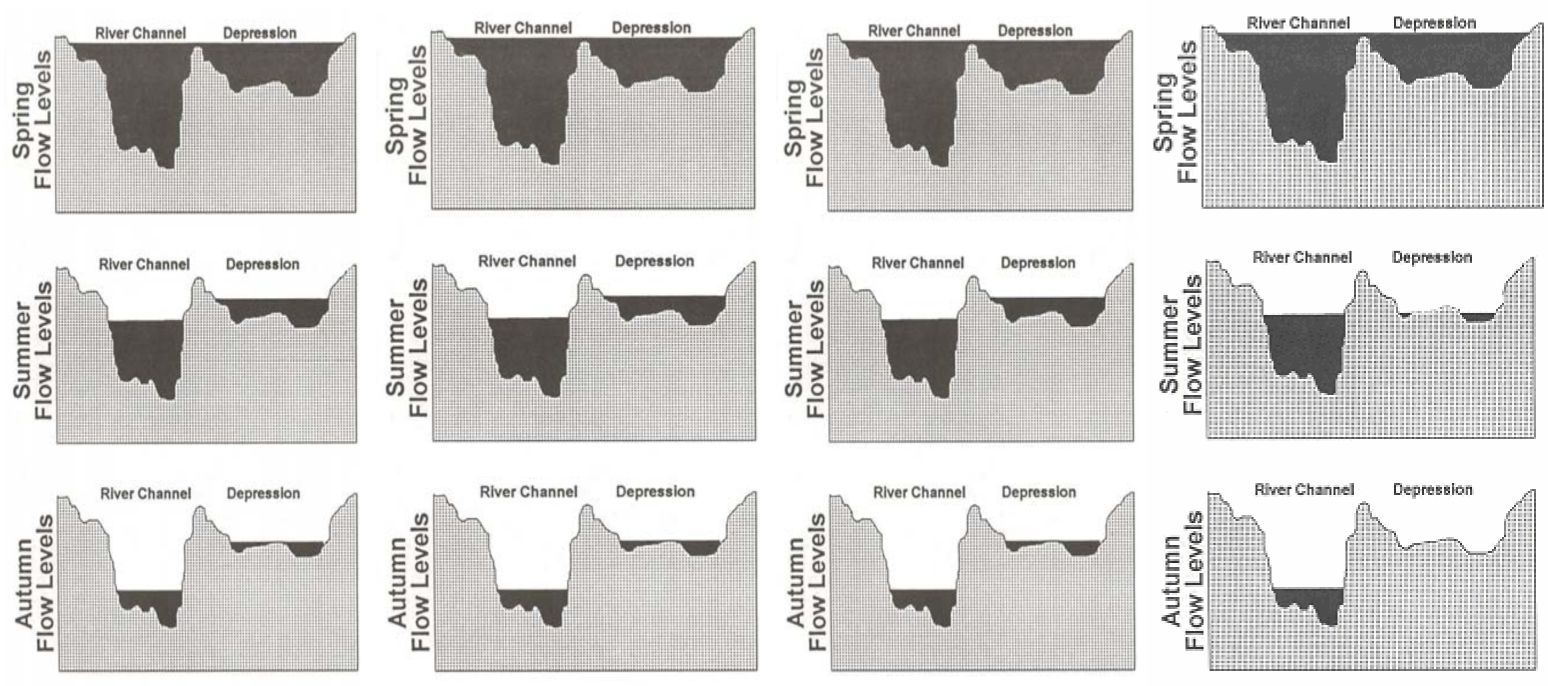
The recommended management strategy for floodplains of the upper basin is based on the "reset theory" of inundation and desiccation of depressions on a 12 or 24–month cycle (Figures 3-3 and 3-4). The "reset theory" of floodplain management has not been implemented and tested in its entirety. Components of the strategy have been successful, and uncertainties, risks, contingencies are presented in section 6.6. The success of this floodplain management strategy depends on six factors:

1. Connection of the floodplain with the river channel in year 1;
2. Entrainment of drifting larvae in year 1;
3. Sufficient food production chronology timed to arrival of larvae;
4. Suitable quantity and quality of water to support fish for 12 or 24 months;
5. Reconnection in year 2 or 3 for fish escapement and fresh water quality; and
6. Periodic desiccation to reset floodplain.

3.6.1 Floodplain Connection

Connection of the floodplain to the river channel is critical to this management strategy. Historically, the river flooded in spring and the area of connected floodplain habitat depended on the magnitude of runoff. Flow regulation and concomitant geomorphic changes in the river channel have altered the magnitude, frequency, duration, and timing of floodplain connection and inundation. The foundation of this strategy is to enhance floodplain connection and inundation through mechanical modification (e.g., levee removal or breaches) and flow re-regulation (e.g., flow recommendations; see section 4.0). Despite modification and flow re-regulation, floodplain connection is not possible for most floodplains in dry years (90–100% peak exceedance) and moderately dry years (70–90% peak exceedance). Key floodplains should connect in most average dry years (50–70% peak exceedance), average wet years (30–50% peak exceedance); and most should connect in moderately wet (10–30% peak exceedance) and wet years (0–10% peak exceedance).

The goal of this Plan—to provide adequate floodplain habitats for all life stages of razorback sucker—must eventually be accomplished by modifying floodplains to inundate with flows identified in the flow recommendations. It is recognized that not all floodplains will connect to the main channel in given years, or if connected may not function as desired. Nevertheless, the greatest number of connected floodplain habitats possible will increase the likelihood of success for this strategy.



YEAR 1	YEAR 2	YEAR 3	YEAR 4
• First Connection	• Reconnect in Spring	• Reconnect in Spring	• Reconnect in Spring
• Larval Entrainment	• Fish Remain	• Some Fish Escape	• Fish Escape
• River Inundation	• Water Refresh	• Water Refresh	• Desiccate – Reset
• High Production	• Renewed Production	• Renewed Production	• No Production
• Fish Length: 20–150 mm	• Fish Length: 150–300 mm	• Fish Length: 300–400 mm	• Fish Length: 400+ mm

Figure 3-3 Schematic of idealized “reset theory” of floodplain management strategy for the Upper Colorado River Subbasin.

Management Action or Event	YEAR 1												YEAR 2												YEAR 3											
	Year-->				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Floodplain connected; larvae become entrained					<>																															
Fish remain in floodplain through summer and over winter year 1						<------------------------------>																														
Floodplain connected; fish remain entrained																	<>																			
ESCAPE SCENARIO 1: Floodplain is drained forcing fish to leave after 16 m																			<--->																	
Fish remain in floodplain through summer and over winter year 2																			<-------------------------->																	
ESCAPE SCENARIO 2: Floodplain connected; some fish leave voluntarily																													<>							
ESCAPE SCENARIO 3: Floodplain is drained forcing fish to leave after 28 m																															<--->					
Fish size at growth rate: LOW					20												100			210									312			363				
MODERATE					20												150			300									512			530				
HIGH					20												200			400									536			560				

Figure 3-4. Floodplain management strategy with three escape scenarios that assume the fish will return to the main river. Size of fish in millimeters at the end of indicated number of months is presented for low, moderate, and high growth rates.

3.6.2 Larval Entrainment

The proportion of drifting razorback sucker larvae entrained at floodplain sites downstream of a spawning bar has not been determined. Given that the razorback sucker is a highly fecund fish species, with average production of about 188,600 eggs per female at 550 mm TL and 1,757 g body weight, the number of larvae produced by a population of 5,800 adults with a 3:1 male to female effective sex ratio (i.e., 1,450 females) is expected to be about 5.5 million (Floodplain Model, Valdez 2004). It is hypothesized that drifting larvae follow a pattern of downstream reduction in numbers of drifting particles described as a negative exponential decay function, which assumes ongoing mainstem mortality and periodic entrainment at floodplain sites. Eventually, numbers of drifting larvae become extinguished with distance downstream from a spawning bar. The Floodplain Model predicts that only about 1% of drifting larvae remain in the main channel 36 miles downstream of a spawning bar at a 90% mile-to-mile survival rate and 10% entrainment at five sites. Hence, it is believed that downstream floodplain sites closest to a spawning bar are likely to entrain the greatest numbers of drifting larvae and provide earliest refuge for maximum growth and survival of young fish. This theory of downstream transport and retention of larvae in floodplains of the Upper Colorado River Basin has not been tested and is being evaluated in the Green River with simultaneous drift studies of artificial beads and live razorback sucker larvae.

The geomorphic and hydrologic characteristics of given floodplains that maximize larval entrainment are not well understood. It is assumed that drifting larvae are randomly mixed in the river water column and that those floodplains that receive the greatest water volume entrain the greatest numbers of larvae. Studies of drifting surrogate species and artificial beads indicate that these assumptions may not be correct. Numbers of drifting larvae of flannelmouth sucker and bluehead sucker in the Upper Colorado River were greater along shorelines than in the central channel (Valdez et al. 1985). Preliminary studies with artificial beads also indicate that particle distribution may not be random (Personal communication, Kevin Christopherson, Utah Division of Wildlife Resources), and that larval entrainment at a given floodplain may be a function of local geomorphic features (e.g., sand bars, position of floodplain in river bend, number and position of levee openings) and river hydraulics (e.g., local currents, diel river surges). Studies are necessary to better understand drift and entrainment characteristics of larvae in order to better design floodplain sites.

3.6.3 Sufficient Food Production

Most floodplains produce an abundance of food for fish in the first few months of inundation, although the amount of food produced may vary with floodplain site (Crowl et al. 1998a, 1998b, 2002; Gourley and Crowl 2002). Timing of inundation and chronology of food production is critical to growth and survival of entrained larvae. Production in floodplains occurs as a chronology of communities that begins with inundation of dry floodplains and the appearance of rich detrital loads, diatoms, and algae. This is followed by emergence of various zooplankton, such as rotifers and copepods, that transition into larger forms including cladocerans and various insect larvae (Mabey and Shiozawa 1993; Modde 1997; Crowl et al. 2002; Gourley and Crowl 2002). Rich detritus and invertebrates are important food sources for young fish (Papoulias and Minckley 1990, 1992), and the timing of their appearance with the entrainment of larvae in these floodplains is critical to larval survival (Wydoski and Wick 1998). Larval razorback sucker pass through a “critical period” when nutrition shifts from endogenous (yolk sac absorption) to exogenous (active feeding) sources at between 8 and 19 days of age, and they require immediate sources of moderate to high food densities to avoid starvation (Papoulias and Minckley 1990, 1992; see section 3.3).

The importance of low velocity habitats to the production of zooplankton for fish in the Upper Colorado River Basin has been described (Burdick 1995). Mabey and Shiozawa (1993) reported zooplankton densities in the middle Green River as 0.3 to 1.3 organisms per liter, 1.5 to 7.1 in the Ouray backwater, 63.4 at Intersection Wash (another backwater), and 206 to 690 in Old Charlie Wash (Woods Bottom) on the Ouray National Wildlife Refuge, located downstream from Vernal, Utah. Grabowski and Hiebert (1989) reported 0 to 20 planktonic crustaceans (cladocerans and copepods) per liter in the middle Green River channel and 0.02 to 17 organisms per liter in backwaters during 1987 and 1988. In an open water bottomland habitat of the Moab Slough on the Colorado River near Moab, Utah, the density of planktonic crustaceans (cladocerans and copepods) averaged about 36 organisms per liter in the summer of 1993 (Cooper and Severn 1994a). Cooper and Severn reported a mean of only 2 organisms per liter for backwater sites. Samples of planktonic crustaceans (cladocerans and copepods) from the Escalante Ranch site on the middle Green River, upstream from Jensen, Utah, contained 0 organisms per liter for the main channel, a mean of 41 organisms per liter for backwaters, and a mean of 71 organisms per liter for an open water wetland (Cooper and Severn 1994b). The mean number of cladocerans and copepods from a backwater of the Gunnison River at the Escalante SWA, about 5 miles downstream from Delta was 11 organisms per liter of water and the mean number from an open water wetland was 25 organisms per liter (Cooper and Severn 1994c). Zooplankton (cladocerans and copepods) samples from a bottomland (Old Charlie Wash) on the Ouray National Wildlife Refuge contained a mean of 31 organisms per liter of water (Cooper and Severn 1994d). Samples taken from the middle Green River and a backwater on the refuge did not contain any cladocerans or copepods.

3.6.4 Suitable Quantity and Quality of Water

Depression floodplains must have sufficient depth to maintain suitable water quantity and quality for fish to survive during hot summer days and cold winters for at least 1 year. Some depression floodplains may be perched (i.e., elevation higher than the river bed) and maintaining water in these will require excavation to offset evaporative losses, high water temperatures, low oxygen, and complete ice formation in winter. Other depression floodplains may receive surface inflow or seepage that will help to freshen water quality, moderate temperatures, and prevent total freezing. Suitable water quality in these floodplains is critical to insure maximum fish growth and survival.

3.6.5 Reconnection of Floodplain To Main Channel

Reconnection of a floodplain to the main river channel is critical to completion of the "reset theory" cycle of inundation and desiccation. Reconnection allows the 1 or 2–year old razorback sucker to escape to the river where they can mature and reproduce. Observations of hatchery razorback sucker indicate that age-1 fish will not leave a floodplain during reconnection (Personal communication, Tim Modde, U.S. Fish and Wildlife Service; Kevin Christopherson, Utah Division of Wildlife Resources). Similar observations have been made for fish 1 to 2 years of age, although these conclusions are preliminary. These observations indicate that young razorback sucker will remain in sheltered floodplains through their first 1–2 years of life, which is consistent with the floodplain management strategy fundamental to this Plan.

Recent studies of hatchery razorback sucker released in floodplains show that survival in floodplains in the first month is low (<5%), but little or no survival is presumed in the main river channel (Christopherson and Birchell 2002; Birchell and Christopherson 2002). Survival in floodplains after the first month is greatly increased, but it is believed that razorback sucker must be over about 90 mm TL (about 6 months old at low growth rate) and preferably over 230 mm TL (about 17 months old at low growth rate) to survive in the main channel. Fish entrained in a floodplain depression that do not escape to the main channel during a flow connection will become stranded until the following runoff cycle. Given that floodplain connections during spring runoff are typically less than 1 week, the best survival strategy for razorback sucker is believed to be a 24-month residence in a productive floodplain that allows the fish to reach sufficient size for mainstem survival and to escape predators. Until self-sustaining populations become established and multiple spawning sites and floodplains are used by wild fish, it may be necessary to manually transfer fish from floodplains to the main channel when river flows are insufficient to connect floodplains and fish are old enough for mainstem survival.

Levee breaches at key floodplains will increase the frequency of connection with the mainstem and inundation in all but dry and moderately dry years. The hydrologic cycle of the Upper Colorado River Subbasin typically consists of periods of 3–5 years of wet and moderately wet years followed by periods of dry and moderately dry years (Muth et al. 2000). The "reset theory" is based on this hydrologic cycle in which connection of most floodplains occurs annually in wet years and desiccation (i.e., reset) occurs in intervening dry years. This cycle will also occur in average years with fewer floodplain sites expected to be connected annually. This strategy also recognizes that magnitude, duration, and possibly frequency of inundation will vary among floodplain sites with river stage, and emphasizes the importance of all sites for overall recovery of the endangered fish species.

3.6.6 Desiccation to Reset Floodplain

The key to the "reset theory" is periodic desiccation of the floodplain to reset or kill all remaining fish and reset productivity. Ideally, floodplains should desiccate every fourth year to allow razorback sucker sufficient time to grow and escape to the main river, to limit the numbers of nonnative fish produced in the floodplain, and to insure 100% kill of nonnative fish remaining in the floodplain. Razorback sucker or other native fish may die as well from the desiccation event, but studies and observations show that most native fish species evacuate drying floodplains. This aspect of escapement from floodplains will be a part of the evaluation described in this Plan.

4.0 FLOW RECOMMENDATIONS

Flow recommendations to benefit endangered fish in the Upper Colorado and Gunnison rivers were developed by the U.S. Fish and Wildlife Service (McAda 2003) with the goal of providing annual and seasonal patterns of flow downstream of the confluence of these rivers. These flow recommendations were designed to create and maintain a variety of habitats used by all life stages of the four endangered fishes. The Colorado River immediately upstream of the confluence with the Gunnison River (15-Mile Reach) is currently operating under a programmatic biological opinion (PBO; U.S. Fish and Wildlife Service 1999) that allows for additional water development in the Upper Colorado River provided that progress is made toward recovery of the four endangered fishes. The PBO provides for coordinated operation of upstream reservoirs to assist in meeting flow recommendations for the 15-Mile Reach (Osmundson et al. 1995). These flow recommendations have not been fully implemented and evaluated, and will continue to be revised and refined, as necessary, under the principles of adaptive management.

One of five objectives of the 2003 flow recommendations (McAda 2003) is to:

> *"Inundate floodplains and other off-channel habitats at the appropriate time and for an adequate duration to provide warm, food-rich environments for fish growth and conditioning, and to provide river-floodplain connections for restoration of ecosystem processes."*

This objective is intended to benefit all endangered and native fish, but particularly razorback sucker and Colorado pikeminnow. Adults of both species move into warm, food-rich floodplains in spring to feed and coincidentally, warm-water temperatures in these riverside habitats promote gonadal maturation in advance of spawning. These floodplains are also important sheltered habitats for young and juveniles of all native species, but are vitally important nurseries for recently-hatched larvae of razorback sucker during runoff in spring.

4.1 Hydrology of the Upper Colorado River

Regulation of water in the Upper Colorado River has altered the annual hydrograph and affected the frequency, magnitude, and timing of floodplain inundation. Formation of floodplain habitat is dependent on high spring flows. The magnitude of annual peak flows, which usually occurs in late May or early June, has declined significantly since the 1950s (Figure 4-1). The greatest decline, as a proportion of the annual peak, is generally greatest in low water years or "dry years".

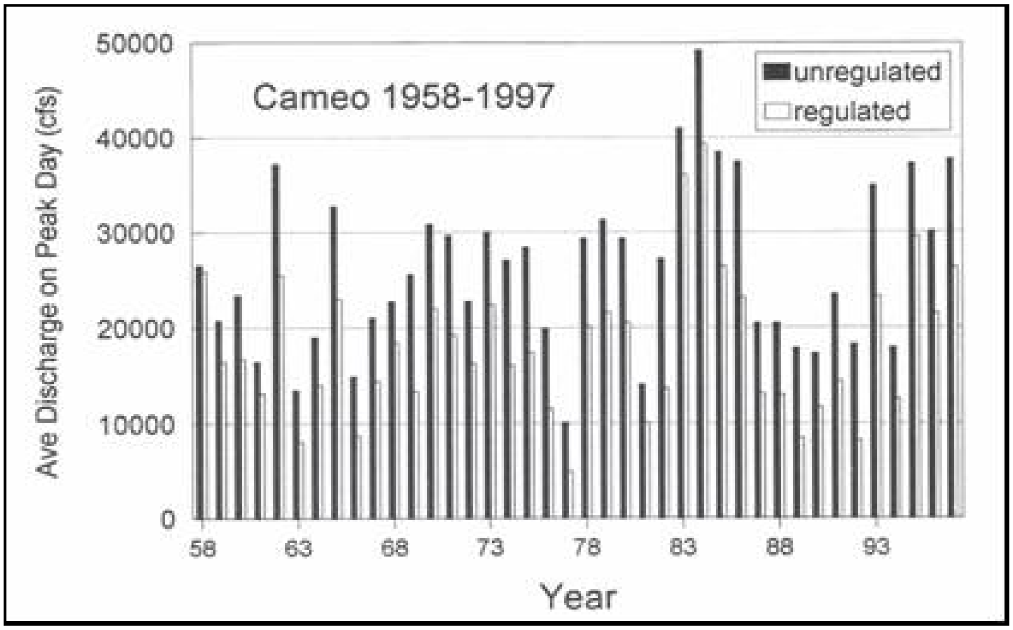


Figure 4-1. Unregulated (predicted) and regulated (actual) annual peak discharge (mean flow of the highest day of the year) at the USGS gauge near Cameo during 1958-1997. Figure 8 from Osmundson (2001).

Of four hydrology categories, the largest mean percent decrease (41%) for the Upper Colorado River near Cameo was for the dry years (Figure 4-2). Mean peak-day flow also decreased for below-average (27%), above-average (36%), and wet (27%) years. The median peak flow for the 1958-1997 period (16,550 cfs) was only 54% of the 1902-1942 median peak flow (30,500 cfs), reflecting a 46% reduction attributable to the combined effects of climate change and river regulation. The median peak flow for the 1958-1997 period would have been an estimated 26,000 cfs in the absence of river regulation, reflecting a decline of 15% due to climate change. The difference between the estimated median peak flow of 26,000 cfs and the actual median peak flow of 16,550 cfs reflects a decline of 36% attributable to river regulation alone (Osmundson 2001).

This decrease in mean peak flows of the Upper Colorado River from Rifle to Grand Junction affects the formation, amount, and duration of floodplains that are vital nurseries to drifting razorback sucker larvae. This regulation has effectively reduced spring peaks in all years while base flows have remained relatively unchanged or slightly increased. Timing of spring peaks has not shifted significantly, but the duration of high flows (i.e., width of peak) has been reduced concomitantly as a result of reduced spring peaks.

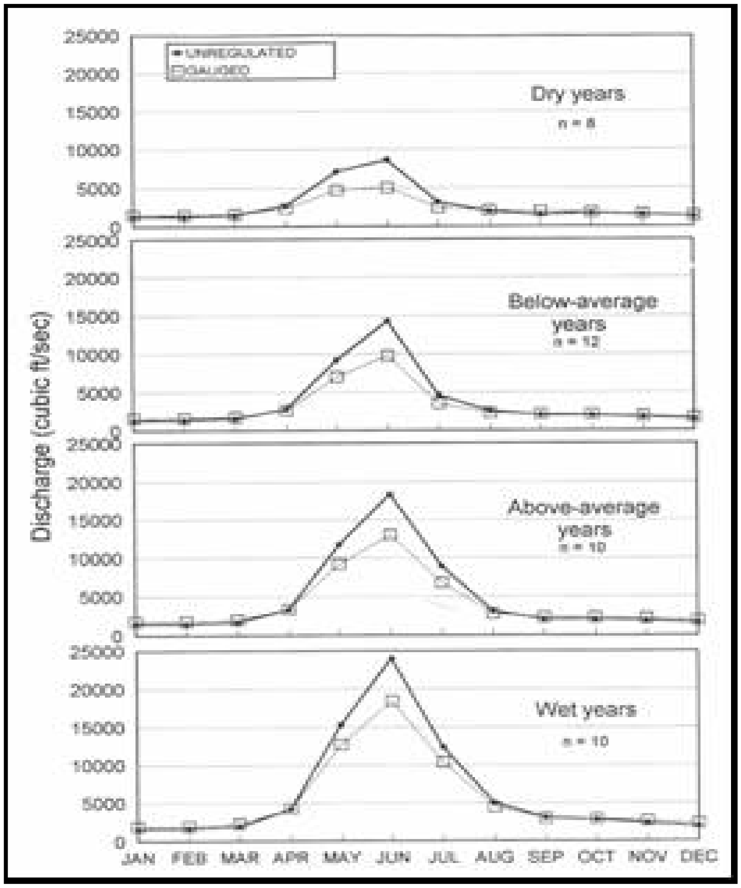


Figure 4-2. Unregulated (predicted) and regulated (actual) mean monthly flows at the USGS gauge near Cameo averaged over several years within each of four precipitation categories during 1958-1997. Figure 7 from Osmundson (2001).

4.2 Hydrology of the Gunnison River

Flow of the Gunnison River is regulated by the Aspinall Unit (Morrow Point, Crystal, Blue Mesa dams), Taylor Park Dam, and Ridgeway Dam. The largest effect of regulation comes from Blue Mesa Reservoir (Figure 4-3). After construction of Blue Mesa Dam in 1966, peak flows decreased by 38% from a mean of 15,925 cfs in pre-dam years to 9,887 cfs in post-dam years. Mean monthly flows during spring runoff in May and June have been reduced by about 65% by the Aspinall Units and Taylor Park Dam (Figure 4-4). Mean monthly flows during April and July (transition months before and after runoff) have remained about the same. However, mean monthly flows from December through March have increased by 131-174%. This regulation has altered the flow regime to lower spring peaks and higher base flows.

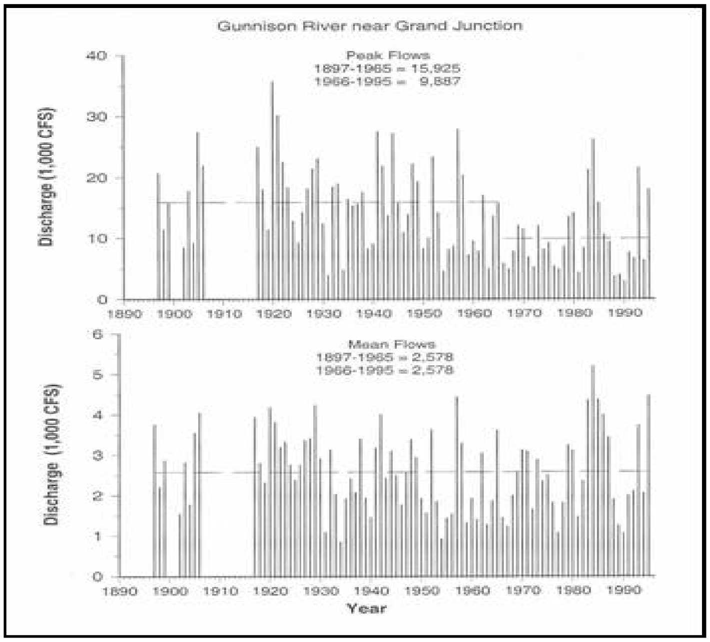


Figure 4-3. Change in peak flow (highest mean-daily flow of the year; upper) and annual mean flow (lower) in the Gunnison River near Grand Junction (09152500) after construction of the Aspinall Unit. Figure 2.4 from McAda (2003).

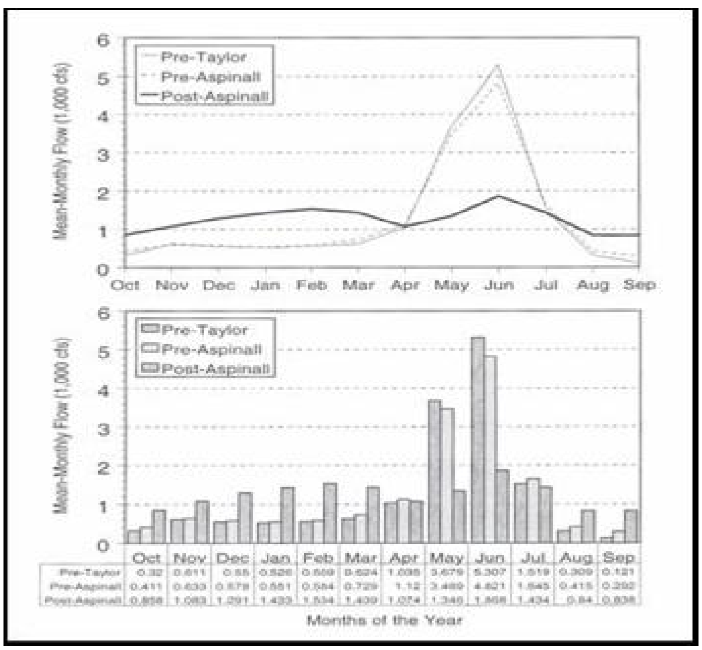


Figure 4-4. Effect of the Aspinall Unit on mean monthly flows of the Gunnison River below the Gunnison Tunnel (09128000). Post-Aspinall Unit flows were developed from gauge readings during 1971-1991. Pre-Taylor Park and pre-Aspinall Unit flows were estimated by removing the influence of Taylor Park Reservoir and the Aspinall Unit to represent flows without these developments. Figure 2.5 from McAda (2003).

4.3 Relationship of Floodplains to Upper Colorado River Flows

Floodplain inventories of the Upper Colorado and Gunnison rivers (Irving and Burdick 1995) identified 46 floodable bottomlands of various sizes along the Upper Colorado River between Rifle, Colorado, and the mouth of the Gunnison River; and 64 floodable bottomlands downstream of the Gunnison River to the confluence of the Green River (Appendix Table A-1). Total floodable sites along the Upper Colorado River were 110 for 241 miles from Rifle, Colorado to the Green River confluence. Forty-eight sites were also identified along 75 miles of the Gunnison River from the North Fork of the Gunnison River to the Upper Colorado River confluence.

In 1993, Irving and Burdick (1995) installed staff gauges at nine bottomland sites during mid-May and monitored these for approximately 45 days to obtain stage vs. discharge information during the high-flow period. Estimated over-bank flooding and frequency of flooding at the nine bottomland sites are shown in Table 4-1. Spring runoff in the Colorado and Gunnison rivers was moderately low in 1994 compared to 1993 which was considered a moderately high year. Respective maximum mean daily flows for 1993 and 1994 for the Colorado River at the USGS Stateline gauge was 44,000 and 13,700 cfs, and 20,500 and 6,040 cfs for the Gunnison River at the Whitewater gauge. Results of this staff gauge work showed the variable flows at which different floodplain sites first become connected (i.e., over-bank) to the river; some as low as about 8,000 cfs, while others require nearly 20,000 cfs. A clear stage:discharge relationship has not been established for key floodplain sites along the Upper Colorado and Gunnison rivers.

Table 4-1. Estimated over-bank flooding and frequency of flooding at the nine bottomland habitat sites in the Colorado (CO) and Gunnison (GU) rivers. Over-bank flooding was determined from staff vs. discharge relationships and river profiles conducted for each site in 1994. Flow percentile data for the post-water development period were taken from USGS stream gauging stations nearest the site. Table 8 from Irving and Burdick (1995).

Site River Mile	Estimated Over-bank/Side Channel Floodinq (cfs)	Percent Time Flood Flows Available	USGS Stream Gauge/ Time Period Evaluated
Johnson Boy's Slough–GU 53. 7	No Estimate	---	---
Confluence Park–GU 57.1	8,000- 9,000	15-20%	GU @ Delta/1967-93
Adobe Creek–CO 159.9	19,000-20,000	20-25%	CO @ Stateline/1952-93
30-29 Road–CO 174.4	16,000-19,000	10%	15-mi1e reach staff gauges
Griffith's–CO 176.0	9,000-10,000	50%	15-mile reach staff gauges
Clifton Sanitation No. 1–CO 178.5	Reduce dike elevation to 9,600 cfs	50%	15-mile reach staff gauges
Pike's–CO 179.1	No Estimate	---	---
EXXON–CO 220.0	No Estimate	---	---
Battlement Mesa–CO 221.3	10,500-12,000	44-54%	CO @ Cameo/1952-93

Surface area habitat mapping of the Upper Colorado River near Parachute in 1983 (Carter et al. 1985) showed a clear relationship for total surface area of four habitat types during record high flows (Figure 4-5). Habitat areas measured at 12 flows showed a gradual increase in floodplains from about 10,000 to 21,000 cfs, followed by a rapid increase in area from 21,000 to 24,000 cfs, and a decreased rate of increase at flows higher than 24,000 cfs.

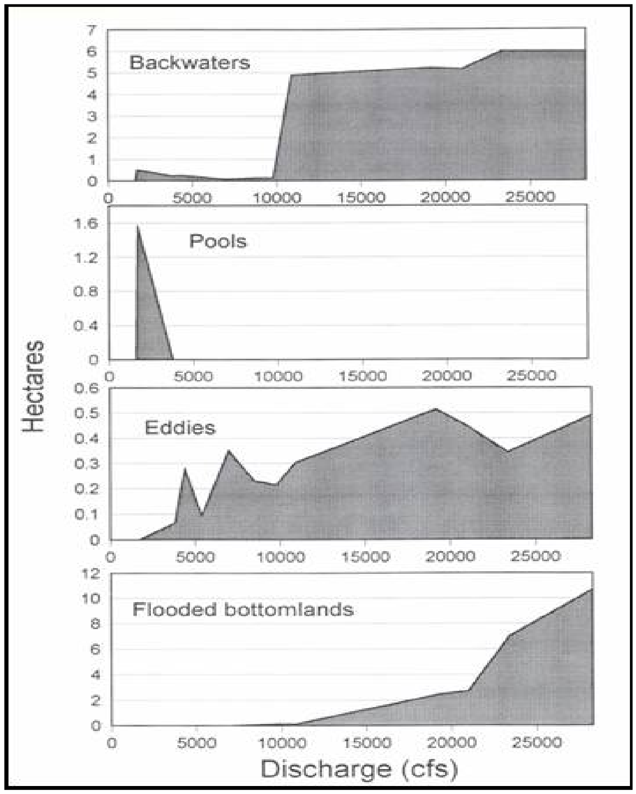


Figure 4-5. Cumulative area of four preferred mesohabitat types at 12 discharge levels in a 3.2-km reach of the Upper Colorado River near Parachute, Colorado, 1983. Figure 5 from Osmundson (2001) who utilized data from Carter et al. (1985).

4.4 Relationship of Floodplains to Gunnison River Flows

Most of the floodplains along the Gunnison River occur in the vicinity of Delta between the mouths of the North Fork and Roubideau Creek (Irving and Burdick 1995). Limited floodplains occur at scattered locations downstream, but these are small and generally require relatively high flows for inundation (Irving and Burdick 1995; McAda and Fenton 1998). Irving and Burdick (1995) identified 48 sites along the Gunnison River with some potential as bottomland habitat. These sites contained a total of about 830 acres of flooded area at 14,800 cfs (range, 0-48 acres). This analysis did not distinguish between quiet-water habitat and areas with fast water velocities and it was estimated that about 3,200 acres of floodable habitat were available prior to flow regulation and dike construction.

Irving and Burdick (1995) identified three important bottomlands near Delta: (1) opposite Confluence Park (RM 57.1), (2) Johnson Slough (RM 53.6), and (3) Escalante State Wildlife Area (SWA; RM 50.7-52.3). Staff gauges were placed at Confluence Park and Johnson Slough to estimate flows required for river connection with the following results:

1. Confluence Park - flooding began at about 9,000 cfs at the upper end of the site, but substantial flooding did not occur until about 10,000 cfs; limited flooding began at the lower end of the site at 5,000-6,000 cfs (Irving and Burdick 1995; McAda and Fenton 1998);

2. Johnson Slough - flooding began at 5,000-6,000 cfs in an old river oxbow, but substantial flooding did not occur until flows reached 8,000-10,000 cfs (McAda and Fenton 1998). Irving and Burdick (1995) estimated that there were about 99 acres of flooded habitat at Confluence Park, 156 acres at Johnson Slough, and 191 acres at Escalante SWA when the Gunnison River reached 14,800 cfs (at the USGS gauge near Grand Junction); and

3. Escalante SWA - Additional work at this site determined that floodability had been substantially reduced by river regulation (Cooper and Severn 1994c). Several options were identified for dike removal that could increase flooded habitat under the current flow regime. Surveys of the relationship between discharge and flooded habitat (Figure 4-6; Tetra Tech 2000) determined that flooded area was about 63 acres at 8,750 cfs and increased to 368 acres at a 29,700 cfs (USGS gauge near Grand Junction). Flooded area could be increased at most flows by removing or breaching dikes at key locations along the river. The greatest relative gain in flooded habitat occurs as flows increase to 10,000 cfs, and levels off between 10,000 and 13,700 cfs, then increases again up to 17,300 cfs. Dike removal at key locations could keep habitat gain at a relatively high level as river flows increase to 17,000 cfs.

McAda and Fenton (1998) also related available habitat to discharge at Escalante SWA, but included all available habitats rather than just floodplain habitat (Figure 4-7). McAda and Fenton (1998) surmised that floodplain habitat at Escalante SWA increased relatively little as flow increased from 13,300 to 15,800 cfs (the highest flows measured).

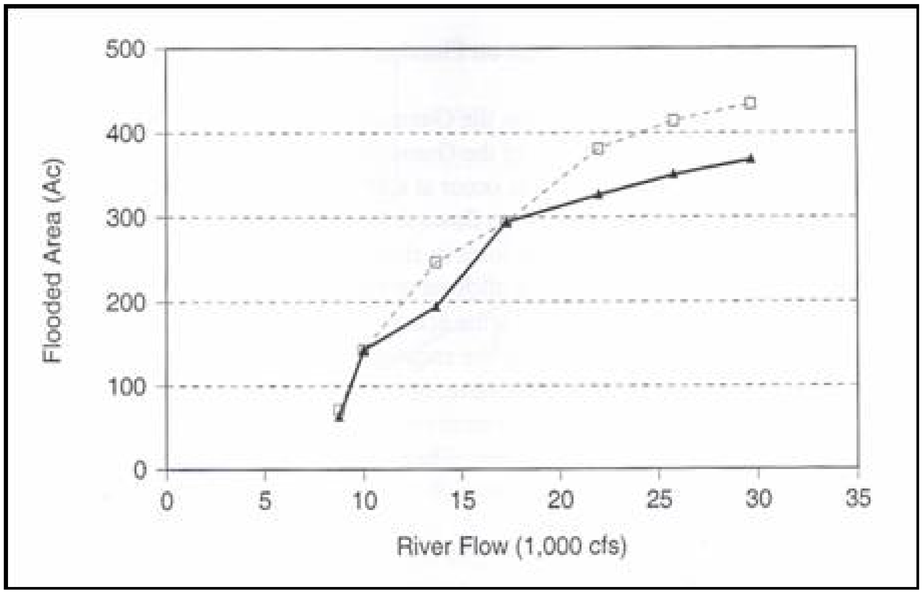


Figure 4-6. Relationship of floodable area to river flow at Escalante SWA near Delta. Dashed line indicates additional acreage that could be flooded by removing dikes or lowering banks. River flow was measured at the USGS gauge near Grand Junction. Figure 2.28 from McAda (2003) who utilized data from Tetra Tech (2000).

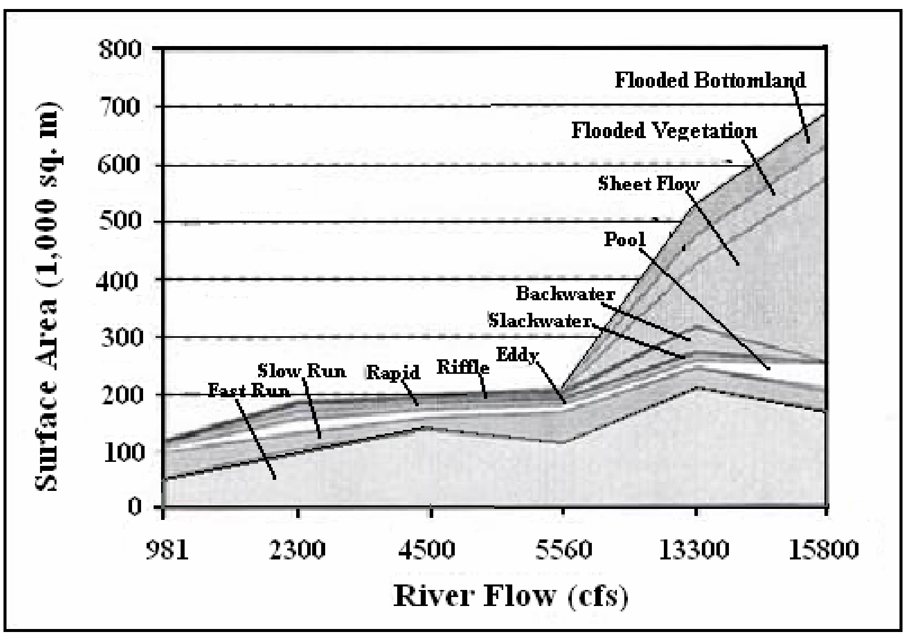


Figure 4-7. Relationship of surface area of different habitat types to river flow at a study site within Escalante SWA. River flow was measured at the USGS gauge near Grand Junction. Figure from McAda (2003).

Water development has significantly reduced the frequency and duration of flows sufficient to connect floodplain habitats in both the Upper Colorado and Gunnison rivers. Flood-frequency curves for the Gunnison River near Grand Junction, Colorado (USGS gauge 09152500) and the Colorado River at Cisco, Utah (USGS gauge 09180500), partitioned into three water-development periods (Figure 4-8) illustrate the low probability of floodplain connection at many sites in dry and moderately dry years. This means that although floodplain connections likely occur in wet and moderately wet years, the overall frequency of inter-annual connection is reduced. This reduced flood frequency has a number of repercussions, including: (1) reduced floodplain dynamics resulting in fewer backwaters and oxbows being created and maintained, (2) fewer sites suitable for cottonwood regeneration, (3) reduced frequency of connection with existing backwaters and oxbows, (4) reduced flushing of floodplain soils to remove salts (Cooper and Severn 1994b), and (5) reduced inter-annual availability of floodplain nursery habitats for razorback sucker.

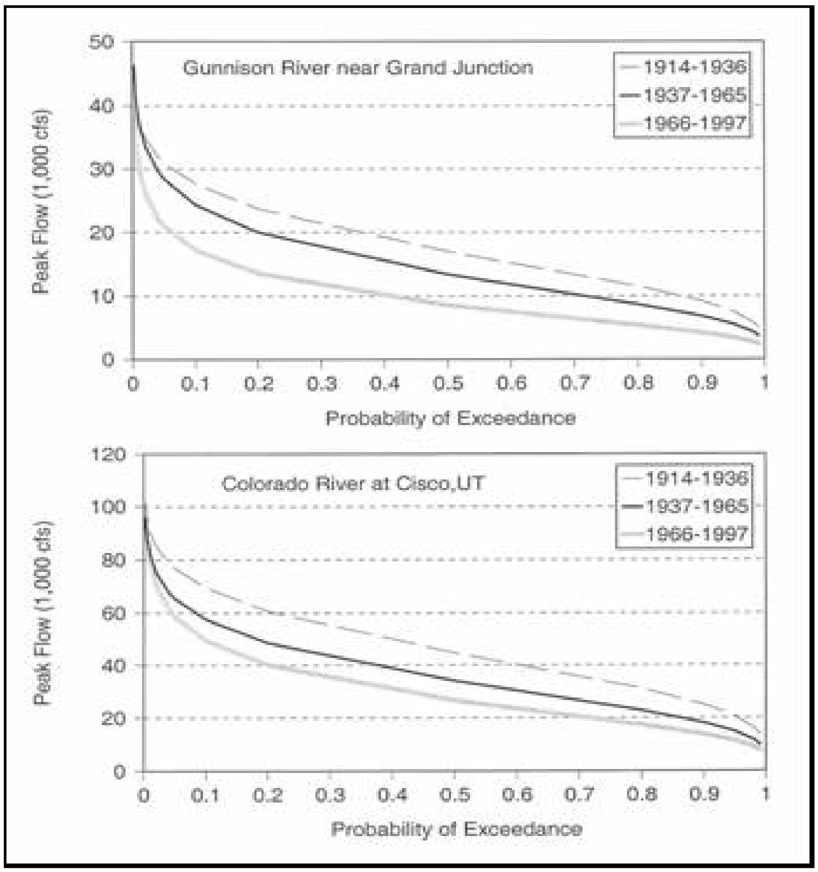


Figure 4-8. Flood-frequency curves for the Gunnison River near Grand Junction, Colorado (USGS gauge 09152500) and the Colorado River at Cisco, Utah (USGS gauge 09180500), partitioned into three water-development periods. Probabilities were calculated using a Log-Pearson Type III analysis. Figure A-1 from McAda (2003).

4.5 Flow Recommendations for the Upper Colorado River

The following flow recommendations were developed for the Upper Colorado and Gunnison rivers by the U.S. Fish and Wildlife Service (McAda 2003). These flow recommendations are being implemented and evaluated, and may be modified and/or refined before being implemented as part of systems operations. Specific flow recommendations for each hydrologic category for the Upper Colorado River are summarized in Table 4-2. Detailed flow recommendations are provided in Appendix B. A description of the recommendations that apply to floodplains is provided below.

Table 4-2. Spring peak-flow recommendations for the Colorado River near the Colorado-Utah state line (USGS 09163500), number of days per year the flows should exceed ½ bankfull discharge (Qc = 18,500 cfs), and bankfull discharge (Qb = 35,000 cfs). Table 4.8 from McAda (2003).

Hydrologic Category	Expected Occurrence	Flow Target and Duration[b]		Instantaneous Peak Flow (cfs)
		Days/Year ≥18,500 cfs	Days/Year ≥35,000 cfs	
Wet	10%	80-100	30-35	39,300-69,800[d]
Moderately Wet	20%	50-65	15-18	35,000-37,500[e]
Average Wet	20%	30-40	6-10	35,000[f]
Average Dry	20%	20-30	0	18,500-26,600[e]
Moderately Dry	20%	0-10	0	9,970-27,300[g]
Dry	10%	0	0	5,000-12,100[g]
Long-Term Weighted Average[c]		28-39	7.2-9.1	

[a]This table represents one possible way of achieving the long-term weighted average for sediment transport.
[b]Lower value in each range is for maintenance, higher (bold) value in each range is for improvement.
[c]Weighted values equal days/year x expected occurrence (the sum of all weighted average values equals the long-term weighted average in days/year).
[d]Instantaneous peak flows within this range have occurred in these hydrological categories since Blue Mesa Reservoir was closed. These observed instantaneous peaks are desired in the future in conjunction with meeting the flow targets. No specific peak flow is recommended to ensure continued variability among years.
[e]Lower number reflects the expected minimum peak flow when recommendations are met and the upper number reflects peak flows that have occurred since Blue Mesa Reservoir was closed. Peak flow is expected to occur within this range, but no specific value is provided to ensure variability among years.
[f]Expected peak flow when flow recommendations are met. Actual peak may exceed this level ensuring variability among years.
[g]Range of peak flows that have occurred since Blue Mesa Reservoir was closed. Peak flows are expected to continue to fall within this range when Qc is not reached. No specific recommendation within this range is made to ensure variability among years.

The Upper Colorado River immediately upstream from the confluence with the Gunnison River (15-Mile Reach) is currently operating under a programmatic biological opinion (PBO) that allows for additional water development in the Upper Colorado River Subbasin provided that progress is made toward recovery of the four endangered fishes. The PBO provides for coordinated operation of upstream reservoirs to assist in meeting flow recommendations made for the 15-Mile Reach. Ultimately, flows in the lower reaches of the Upper Colorado River will depend on the combination of modified flows in the Gunnison River and flows currently provided for under the PBO. Until there is more definitive evidence for the volume and timing of water needed for recovery, flow recommendations at the Colorado-Utah state line will be consistent with all agreements and mandates.

Spring Peaks.—Peak flows for the Upper Colorado River are measured at the USGS stream gauge near the Colorado-Utah state line. Flows from the Gunnison River will contribute a substantial volume of water to peak flows in the Upper Colorado River, but it is unlikely that peak flows from both the Gunnison and Colorado rivers will match exactly. Aspinall Unit releases should occur between May 15 and June 15 and be timed to match peak flows of the North Fork to contribute maximum volume to the Upper Colorado River. These flows correspond to recommendations for channel maintenance (Pitlick et al. 1999); there are no specific flow recommendations for floodplain habitat, but estimates of flooded habitat are provided for different flow levels.

Dry.—Instantaneous peak flows ranging from 5,000 cfs to 12,100 cfs have occurred in this category since Blue Mesa Reservoir was closed, but no flooded bottomland habitat will be provided anywhere in the river under this hydrologic category.

Moderately Dry.—Flows equal to or greater than 18,500 cfs are recommended for 0-10 days in years falling into this category. Peak flows have ranged from 9,970 to 27,300 cfs since Blue Mesa Reservoir was completed and should continue to fall within this range for at least 1 day when water availability is sufficient. No flooded bottomland habitat is provided anywhere in the river, but some quiet-water habitats will be provided in flooded tributary mouths to provide warmer water for gonad maturation of endangered fish. The backwater area at Walter Walker SWA will provide a limited amount of flooded habitat.

Average Dry.—River flows should reach or exceed 18,500 cfs for 20 to 30 days in this category. To ensure variability among years within this category, the highest 1-day peak flow should fall within the 18,500 to 26,600 cfs range when sufficient water is available. Floodplain inundation will increase, but will be limited in duration. However, warm, quiet-water habitats will be available early in the year for growth and gonad maturation of razorback sucker and Colorado pikeminnow.

Average Wet.—River flows should reach or exceed 18,500 cfs for 30 to 40 days and should exceed 35,000 cfs for 6 to 10 days. Flooding in and around Walter Walker SWA will provide important floodplain habitats, but the extent of available habitat is not known.

Duration of flooding will be short, but should promote growth of larval razorback sucker before they leave the floodplain and enter the main channel.

Moderately Wet.—River flows should exceed 18,500 cfs for a total of 50 to 65 days and should exceed 35,000 cfs for 15 to 18 days. To ensure variability among years, the 1-day peak flow should be between 35,000 and 37,500 cfs when water availability is sufficient. Floodplain habitats will be extensive, but the surface area of those habitats is not quantified. However, quiet, warm-water habitats should be available in sufficient area and duration to improve growth and survival of larval razorback sucker.

Wet.—River flows should exceed 18,500 cfs for 80 to 100 days and should exceed 35,000 cfs for 30 to 35 days. Instantaneous peak flows should be between 39,300 and 69,800 cfs, which is the range of peak flows that have occurred since Blue Mesa Reservoir was closed. To ensure variability among years, the 1-day peak flow should be within that range when water availability is sufficient. Floodplain habitats will be extensive (although unquantified) and will be available for sufficient duration to benefit growth and survival of larval razorback suckers.

Base Flows.—The base-flow period begins after spring runoff is completed and continues through initiation of spring runoff the following year, depending on inflow to the upper Colorado River subbasin. Base flows do not directly impact floodplains because they are generally too low to connect any bottomland site with the river.

4.6 Flow Recommendations for the Gunnison River

The following flow recommendations were developed for the Upper Colorado and Gunnison rivers by the U.S. Fish and Wildlife Service (McAda 2003). These flow recommendations are being implemented and evaluated, and may be modified and/or refined before being implemented as part of systems operations. An EIS is currently underway to identify re-operation of the Aspinall Unit. Specific flow recommendations for each hydrologic category for the Gunnison River are summarized in Table 4-3. Detailed flow recommendations are provided in Appendix B. A description of the recommendations that apply to floodplains is provided below.

Spring Peaks.—Spring peak flows are the defining flows of a river system and do most of the work to maintain habitat for the endangered fish. Releases from the Aspinall Unit to assist in meeting these target flows should gradually increase and decrease according to established ramping rates (300-500 cfs/day at releases <5,000 cfs and 10% per day at releases >5,000 cfs). To the extent possible, maximum Aspinall Unit releases should be timed to correspond with maximum flows of the North Fork to provide maximum benefit to the Gunnison River within critical habitat. Although timing of peak flows in the North Fork (measured at the USGS gauge near Somerset, 09132500) and the Gunnison River did not always coincide before the Aspinall Unit was constructed, highest mean-daily flows for the year for both rivers fell within 2 days of each other 75% of the time during 1937-1965. To correspond with the historical hydrograph, peak flows in the Gunnison River should occur between May 15 and June 15 each spring.

Table 4-3. Spring peak-flow recommendations for the Gunnison River near Grand Junction (USGS 09152500), number of days per year the flows should exceed ½ bankfull discharge (Qc = 8,070 cfs), and bankfull discharge (Qb = 14,350 cfs). Table 4.8 from McAda (2003).

Hydrologic Category	Expected Occurrence	Flow Target and Duration[b]		Instantaneous Peak Flow (cfs)
		Days/Year ≥8,070 cfs	Days/Year ≥14,350 cfs	
Wet	10%	60-100	15 - 25	15,000-23,000[d]
Moderately Wet	20%	40-60	10 - 20	14,350-16,000[d]
Average Wet	20%	20-25	2-3	14,350[e]
Average Dry	20%	10-15	0-0	8,070[e]
Moderately Dry	20%	0-10	0-0	2,600[f]
Dry	10%	0-0	0-0	~900-4,000[g]
Long-Term Weighted Average[c]		20 - 32	4-7	

[a]This table represents one possible way of achieving the long-term weighted average for sediment transport.
[b]Lower value in each range is for maintenance, higher (bold) value in each range is for improvement.
[c]Weighted values equal days/year x expected occurrence (the sum of all weighted average values equals the long-term weighted average in days/year).
[d]Instantaneous peak flows within this range have occurred in these hydrological categories since Blue Mesa Reservoir was closed. These observed instantaneous peaks are desired in the future in conjunction with meeting the flow targets. No specific peak flow within this range is recommended to ensure continued variability among years.
[e]Expected minimum peak flow when recommendations are met; actual peak may exceed this value, ensuring continued variability among years.
[f]Instantaneous peak flow that has occurred since Blue Mesa Reservoir was closed. Peak flows are expected to equal or exceed this level in years when Qc is not reached.
[g]Range of peak flows within this category that have occurred since Blue Mesa Reservoir was closed. Lowest number reflects base flow. Peak flows are expected to continue to occur within this range; no specific flow within this range is recommended, ensuring variability among years.

Dry.—Instantaneous peak flows ranging between about 900 cfs (base flow) and 4,000 cfs have occurred in this category since Blue Mesa Reservoir was closed. Instantaneous peak flows should be in that range when water availability is sufficient, but no flooded bottomland habitat is provided at this flow.

Moderately Dry.—Flows equal to, or greater than, 2,600 cfs are recommended to occur between 0 and 10 days in this category. Over the long term, flows exceeding 2,600 cfs should occur in at least some years that fall into this category in order to improve conditions (Pitlick et al.1999). No floodplain habitat is provided in this category, but the rising and falling river associated with even a small peak will provide environmental cues that the endangered fish use for spawning.

Average Dry.—Flows should reach 8,070 cfs for 10 to 15 days. Most of the flooded habitat at this level is upstream from Escalante SWA, but about 80 acres of flooded habitat will occur at the Escalante SWA as well, although these will be of short duration.

Average Wet.—River flows should equal or exceed 8,070 cfs for 20 to 25 days and should equal or exceed 14,350 cfs for 2 to 3 days. Flooded bottomlands become important at this level, with flooded habitats developing at several locations between Delta and Escalante SWA. About 200 acres of flooded bottomland is available in Escalante SWA at 14,000 cfs. Total flooded acreage there could be increased to about 240 acres by removing a dike that prevents water from entering some low-lying areas. Other flooded habitats will exist at this flow, but the total surface area of habitat is not quantified at sites other than Escalante SWA. Duration of large areas of floodplain habitat will be short, but will provide opportunity for adult Colorado pikeminnow and razorback sucker to utilize the quiet water habitat to feed and rest away from the main river channel. Floodplain duration will probably not be sufficient to benefit larval razorback suckers except in flooded tributary mouths or other smaller habitats along the river margins.

Moderately Wet.—Flows should equal or exceed 8,070 cfs for 40 to 60 days and should equal or exceed 14,350 cfs for 10 to 20 days in this category. To ensure natural variability among years within this category, a 1-day peak flow should be between 14,350 and 16,000 cfs (reached within this category since Blue Mesa Reservoir was closed) when sufficient water is available. Flooded bottomland habitat increases to about 260 acres in Escalante SWA at a river flow of 16,000 cfs. With a peak flow of this magnitude, duration of floodplain habitats should be sufficient to provide productive habitats for YOY razorback sucker long enough for them to get a good start on growth before reentering the river when flows subside. Exceeding 8,070 cfs for 40 days should provide flooded habitat long enough to benefit larval razorback sucker at Escalante SWA. Flooded bottomlands will also occur at other sites along the Gunnison River, but total surface area at these sites is not quantified.

Wet.—River flows should exceed 8,070 cfs for 60 to 100 days and should exceed 14,350 cfs for 15 to 25 days. To ensure natural variability among years, the 1-day peak flow should fall between 15,000 and 23,000 cfs when sufficient water is available; peak flows have fallen within this range since Blue Mesa Reservoir was closed. Flooded bottomland habitat should be widely available at Escalante SWA and at other locations near Delta. The duration of flows greater than 8,070 cfs should provide quiet, warm-water long enough to provide considerable benefits to support growth of larval razorback sucker.

Base Flows.—The base-flow period begins after spring runoff is completed and continues through initiation of spring runoff the following year, depending on inflow to the Upper Colorado River. Base flows do not directly impact floodplains because they are generally too low to connect any bottomland site with the river.

5.0 PRIORITIZATION OF REACHES AND SITES

5.1 Priority River Reaches

Priority river reaches and floodplain sites were identified for this Plan to focus management actions on those areas most likely to benefit razorback sucker and to assist species recovery. Prioritization of river reaches by life stages of razorback sucker was determined for the Upper Colorado River Subbasin for geomorphology research (LaGory et al. 2003) and was used as the basis for prioritization in this Plan. Of 13 reaches identified for research, three were designated as important to razorback sucker. Reach-habitat scores for all life stages of razorback sucker were highest for Palisade to Gunnison River (15-Mile Reach), Gunnison River to Loma (18-Mile Reach), and Gunnison River—Hartland Dam to Roubideau Creek (Figure 5-1). Of eight habitat types identified for actual and potential use by larval razorback sucker, flooded bottomlands (i.e., floodplains) in restricted meander reaches received the highest scores.

Members of the Upper Colorado River Team also identified Rulison to Palisade and Moab to Green River as important reaches for razorback sucker in the Upper Colorado River Subbasin. Prioritization of reaches for the Upper Colorado River Subbasin (CO = Upper Colorado River; GU = Gunnison River) was determined for razorback sucker as follows:

1. Palisade to Gunnison River (15-Mile Reach; CO RM 185-171);
2. Gunnison River to Loma (18-Mile Reach; CO RM 171-153);
3. Gunnison River—Hartland Dam to Roubideau Creek (GU RM 60-50);
4. Rulison to Palisade (CO RM 232-185); and
5. Moab Bridge to Green River (CO RM 64-0).

Other reaches of the Upper Colorado River identified by LaGory et al. (2003), included Loma to Westwater Canyon, Westwater Canyon, Cottonwood Wash to Dewey Bridge, Dewey Bridge to Hittle Bottom, Hittle Bottom to White Rapid, White Rapid to Jackass Canyon, Jackass Canyon to Moab Bridge, and Green River to Lake Powell.

Locations of each of the five reaches are shown in Figure 5-1. These reaches encompass most of the established floodplain sites along the Upper Colorado and Gunnison rivers. These floodplains are generally located in alluvial river reaches that are broadly canyon-confined and not in reaches confined by steep, narrow canyon walls. The locations of these floodplains may be important to razorback sucker that tend to spawn in gravel/cobble riffles in or near canyon-confined reaches upstream of alluvial reaches with floodplains (Modde and Wick 1997). An important consideration for these reaches is connectivity, which is not currently the case for the Rulison to Palisade Reach, where fish passage ways are being designed for construction at the Price-Stubb Dam and the Government Highline Dam.

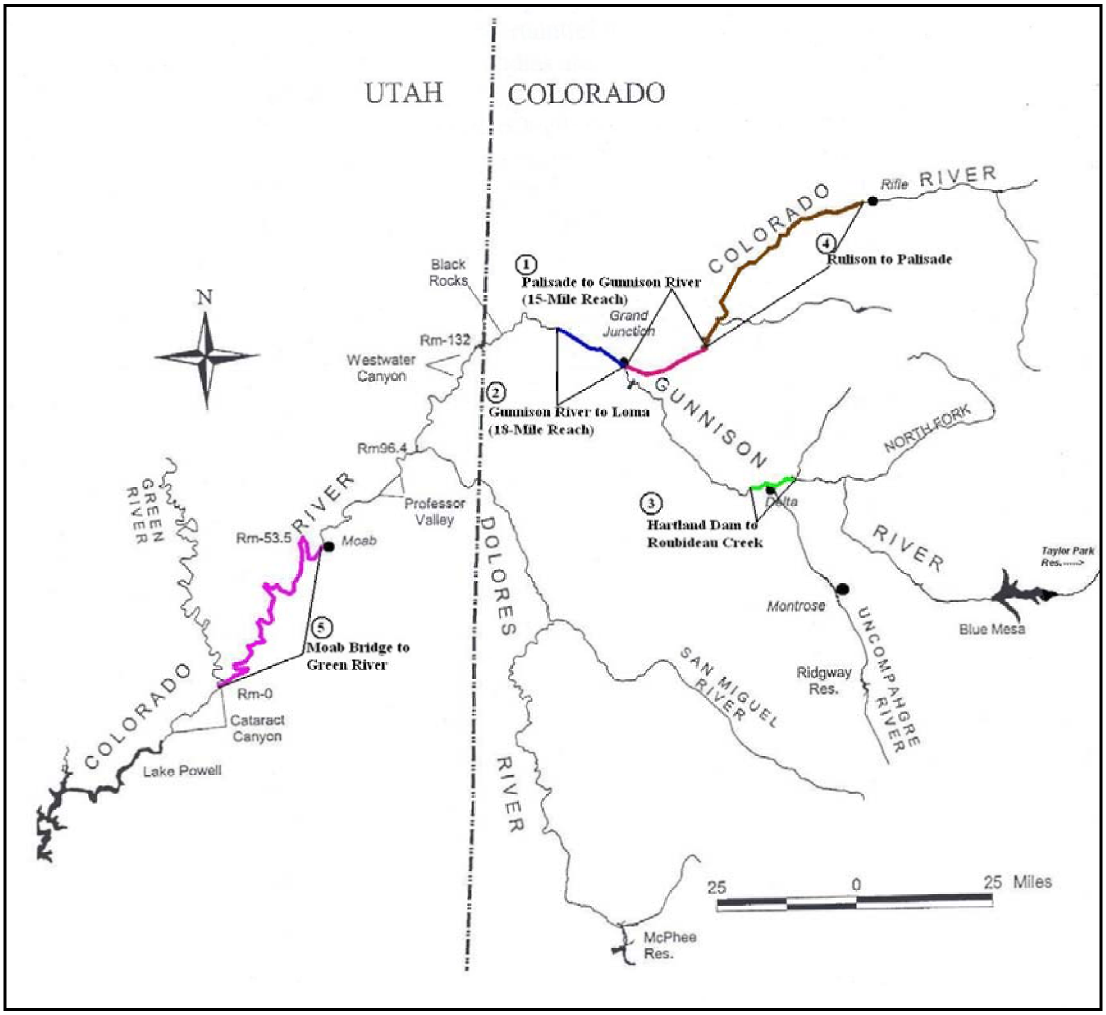


Figure 5-1. The Upper Colorado River Subbasin and location of the five priority reaches of floodplain habitats. River Miles (RM) are given as distance from the confluence of Green and Colorado rivers.

5.2 Priority Floodplain Sites

Priority floodplain sites are preliminarily identified in this Plan, but extensive restoration and management of these sites for larval entrainment and nurseries should await identification and location of spawning sites. Irving and Burdick (1995) identified and inventoried 110 floodplain sites in the Upper Colorado River and 48 sites in the Gunnison River (Table A-1). Areas of inundation during high water (May and June) and low water (September) in 1993 are compared with areas that historically flooded in 240 miles of the Upper Colorado River from the Green River confluence to Rifle, Colorado, and 75 miles of the Gunnison River from the Colorado River confluence to the North Fork (Figure 5-2).

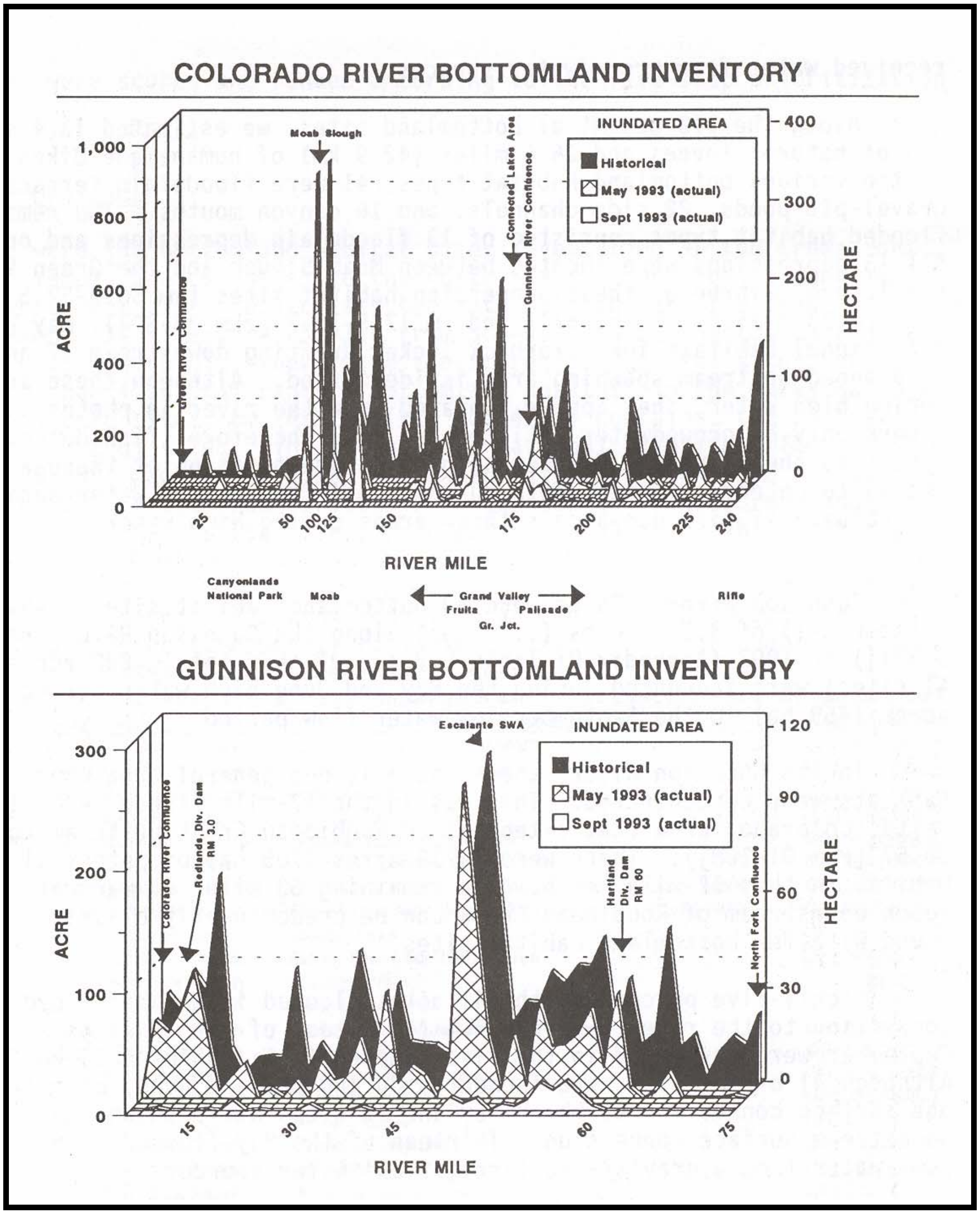


Figure 5-2. Areas inundated during high water (May and June) and low water (September) in 1993 compared to areas that historically flooded in 240 miles of the Upper Colorado River from the Green River confluence upstream to Rifle, Colorado, and 75 miles of the Gunnison River from the Upper Colorado River confluence upstream to the North Fork confluence. Inundated areas include floodplain depressions and terraces, side channels, canyon mouths, and artificial habitats such as gravel-pit ponds. There are 110 sites inventoried on the Upper Colorado River and 48 sites on the Gunnison River. Figure 5 from Irving and Burdick (1995).

Irving and Burdick (1995) identified 26 sites as high priority areas for floodplain restoration on the basis of a ranking system that included various considerations of location, size, connectivity, land ownership, proximity to a suspected spawning bar (no definitive spawning site(s) were identified), June connection to the river, and potential network of sites (Table 5-1). These 26 sites were scattered among four priority reaches, including 10 sites within the Rulison to Palisade Reach (RM 202.3-221.7), 8 sites within the 15-Mile Reach (RM 173.9-184.2), 5 sites within the 18-Mile Reach (RM 161.0-169.6), and 3 sites within Hartland Dam to Roubideau Creek Reach of the Gunnison River (RM 50.2-54.2). The top ranked site was the Walter Walker State Wildlife Area in the 18-Mile Reach, and four other sites ranked 6^{th} and 10^{th}. Johnson Boy's Slough along the Gunnison River ranked 2^{nd}; the Clifton Pond area ranked 3^{rd}; and the Debeque I-70 Slough ranked 4^{th}. Six other sites immediately downstream of the Debeque I-70 Slough ranked 9^{th} and 11^{th}.

Relatively little work has been done on these sites to determine their floodability. Pitlick and Cress (2000) estimated that bankfull discharge at or near these sites ranged from 32,000 to 48,000 cfs. No relationships between river stage and flooded habitat are available. These high priority sites include Walter Walker State Wildlife Area, which is regularly used by Colorado pikeminnow in spring and was one of the last places where wild razorback sucker were found in the Upper Colorado River. Staff gauge data indicate that usable quiet-water habitat occurs at the mouth of a large backwater at the Walter Walker SWA at 16,000 cfs, although most of the backwater remains shallow and unavailable to large fish at that stage (Scheer 1998; McAda 2003).

Irving and Burdick (1995) also identified an important floodplain site near Moab at the Scott Matheson Wildlife Preserve, currently managed by The Nature Conservancy (TNC). Cooper and Severn (1994b) assessed the floodability of this site and determined that flows of about 40,000 cfs (as measured at the USGS gauge near Cisco) or greater are required for substantial flooding. As with other sites in the subbasin, the frequency and duration of river flows that provide critical floodplain habitat at all floodplain sites have declined. Cooper and Severn (1994b) concluded that flows of 40,000 cfs or greater occurred for 5 days or more in 1 of 2 years during 1914-1958, but the frequency declined to 1 in 9 years during 1959-1993. Flow duration of 10 days or more occurred 1 of 3 years during the early period, but only 1 of 11 years during the latter period. As with other floodplains in the Upper Colorado River Subbasin, the contribution of the Scott Matheson Wildlife Preserve to river productivity has been substantially reduced because it is infrequently connected to the river under current conditions. Dike removal would increase floodplain habitat, but specific relationships between river flow and area of inundation have not been described, and the site is not currently drainable. Flooding could damage nature trails, walkways, and interpretive kiosks constructed by TNC, and contaminants have not been fully evaluated. These issues may be resolvable if it is determined that this site is suitable nursery habitat and contributes towards recovery of the razorback sucker. The only juvenile razorback suckers collected from the Upper Colorado River were in the vicinity of Scott Matheson Wildlife Preserve.

Table 5-1. Twenty-six top-ranked floodplain sites (Irving and Burdick 1995) and 32 sites evaluated by the Recovery Program in each of five priority reaches of the Upper Colorado and Gunnison rivers. CDOW=Colorado Division of Wildlife; RP-Recovery Program.

Site Description	Rank	River Miles	Floodable Area (acres)	Form Type (manmade levy or natural berm)	Ownership and Status
Upper Colorado River: 15-Mile Reach					
"No-name"	12	183.3-184.2		Terrace	Unknown
Labor Camp	5	182.9-183.6		Side Channel	Owned by Elam Construction; no access by RP
"No-name"	11	181.7-182.2		Terrace	Unknown
Clifton Sanitation	13	179.1-181.1		Oxbow (levy)	Owned by City of Clifton; no access by RP
Bounds		180.6	25	Terrace/Pond	Perpetual easement from landowner by RP
McGuire's		180.6	3.4	Terrace	Perpetual easement from landowner by RP
Pike's		179.1		Terrace	Unknown
Clifton Pond Area	3	177.7-178.2		Gravel Pit (levy)	Owned by Mesa County; accessible to RP
Corn Lake State Park		177.0		Gravel Pit (levy)	Isolated; owned by CDPOR; used as a recreational fishery; no access by RP
Humphrey's	9	175.3-176.6		Gravel Pit (levy)	Unknown
Griffith's	9	174.1-176.5	154	Terrace	Acquired in fee from landowner by RP & BR
MC Pickup		175.0		Gravel Pit (levy)	Owned by Mesa County; being considered for acquisition by RP; accessible to RP
Beswick's Pond		174.6	23.4	Gravel Pit (levy)	Perpetual easement from landowner by RP; owner R. Tipping (new owner CDPOR) ; accessible to RP
Gardner Pond--29 5/8 Rd		174.4		Gravel Pit (levy)	Owned by Colorado Division of Parks and Outdoor Recreation; accessible to RP
"Hotspot Junction"	12	173.9-175.1		Side Channels (berm)	Accessible to RP
Upper Colorado River: 18-Mile Reach					
Peterson Pond		170.8		Gravel Pit (levy)	Constructed and owned by Bureau of Reclamation
Jarvis Pond		170.8		Landfill (levy)	Agreement with RP; Old gravel pit, sanitary land fill owned by Grand Jct.; accessible to RP
Broadway Bridge Pond		170.0		Gravel Pit (levy)	No access to RP

Site Description	Rank	River Miles	Floodable Area (acres)	Form Type (manmade levy or natural berm)	Ownership and Status
"No-name"	10	169.4-169.6		Terrace	Unknown
Audubon Pond		167.8		Gravel Pit (levy)	Perpetual easement from landowner Audubon Society by RP
Connected Lakes State Park		167.0-167.7		Gravel Pit (levy)	Owned by Colorado State Parks; no access to RP
Mesa County		168.2	12.9	Side Channel	Perpetual easement from landowner by RP (Mesa Co)
G.J. Pipe		165.5	17.6	Gravel Pit (levy)	Acquired in fee from landowner by RP
Pennington/Bird		165.2	21	Terrace	Perpetual easement from landowner by RP
Walter Walker South	10	164.4-166.0		Terrace	Owned by CDOW; accessible to RP
Panorama	6	163.1-163.6		Side Channels	Unknown
Walter Walker SWA	1	162.7-165.1		Gravel Pit (levy)	Owned by CDOW; accessible to RP
"No-name"	10	161.0-162.0		Terrace	Unknown
Ellen Madden Property		161.7		Terrace	Gravel pit being mined by G.J. Pipe; accessible to RP
Mesa County		161.6	20.1	Terrace	Perpetual easement from landowner by RP (Mesa Co)
Dupont Island Complex		160.0-161.5		Gravel Pit (levy)	No access to RP
Adobe Creek		159.9		Side Channels	Several owners; agreement by RP to use a portion
Paul Smith's		158.7		Backwater	Blown out gravel pit
Snook's Bottom		156.0		Gravel Pit	New gravel pit owned by Fruita; no access to RP
Gunnison River: Hartland to Roubideau					
Confluence Park		57.1		Terrace	Various owners
Morgan		55.0	45	Terrace	Perpetual easement from landowner by RP
Fedler		54.5	54.5	Terrace	Perpetual easement from landowner by RP
Johnson Boy's Slough	2	53.2- 54.2		Oxbow (levy)	
Escalante SWA (North)	8	50.8- 52.9	53	Oxbow (levy)	Owned by CDOW; accessible to RP
Escalante SWA (South)	8	50.2- 52.4		Side Channel	Owned by CDOW; accessible to RP
Whitewater Gravel Pit		13.5-14.5		Gravel Pit (levy)	Owned by gravel company; still being mined

Site Description	Rank	River Miles	Floodable Area (acres)	Form Type (manmade levy or natural berm)	Ownership and Status
Unaweep CR (Butch Craig)		13.0	98.7	Gravel Pit (levy)	Acquired in fee from landowner by RP
Upper Colorado River: Rulison to Palisade					
Hoagland Property		227.3	90	Terrace	Perpetual easement from landowner by RP
Battlement Mesa	10	220.7-221.7		Terrace	Unknown
EXXON	11	218.9-220.1		Terrace	Unknown
Wallace Creek Island	11	215.9-216.5		Terrace	Unknown
Debeque 1-70 Slough	4	209.6-211.4		Side Channel (levy)	Unknown
Stoddard Property	7	209.4-210.1		Gravel Pit (levy)	Unknown
Latham's	9	207.9-208.8		Terrace/Ponds (levy)	Unknown
"No-name"	9	206.2-207.5		Terrace	Unknown
Etter's	9	204.7-206.6		Gravel Pit (levy)	Unknown
CDOW Property		205		Gravel Pit (levy)	Owned by CDOW
"No-name"	11	202.3-204.2		Terrace	Unknown
"No-name"	11	201.9-202.4		Terrace	Unknown
Island Acres State Park		192.5		Gravel Pit (levy)	Owned by Colorado State Parks; popular recreation area; no access to RP
Coal Mine Area		190.6		Terrace	Privately owned; offer for access by RP on hold
Moab Bridge To Green River Confluence					
Scott Matheson WP		61.0-64.0		Oxbow (berm)	No access to RP

5.2.1 Palisade to Gunnison River (15-mile Reach)

This reach is 15 miles long (RM 185-171) and is the reach of the Upper Colorado River from Palisade, Colorado, to the mouth of the Gunnison River. A total of 16 sites are identified in this reach, including 8 sites ranked by Irving and Burdick (1995) and 8 additional sites evaluated by the Recovery Program (Table 5-1; Figure 5-3). The Recovery Program currently has a perpetual easement on Bounds (25.5 acres), McGuire's (3.4 acres), and Tipping's (23.4 acres), and has acquired in fee Griffith's (154 acres) for a total of 206.3 acres (83.5 ha) of floodplains.

Specific stage-discharge relationships for most of the floodplains in this reach are not known and the total area that can be flooded at various river flows is undetermined. Irving and Burdick estimated potential floodable area by using bottomland elevations (Figure 5-2), but could not account for berms and dikes separating the floodplain from the main river channel. The occurrence of potentially floodable lands in the 15-Mile Reach is evident from this figure, but the specific river flows at which levees or berms are topped are generally not known. Furthermore, the majority of floodplains in this reach are abandoned gravel pits with a bed elevation generally lower than the river bed, which results in long-term retention of water and an inability to drain and reset these habitats.

5.2.2 Gunnison River to Loma (18-Mile Reach)

This reach is 18 miles long (RM 171-153) and is the reach of the Upper Colorado River from the mouth of the Gunnison River to Loma. A total of 19 sites are identified in this reach, including 5 sites ranked by Irving and Burdick (1995) and 14 additional sites evaluated by the Recovery Program (Table 5-1; Figure 5-3). The Recovery Program currently has a perpetual easement on four properties, including two Mesa County sites, Audubon Pond, and Pennington/Bird for a total of 79.6 acres of floodplains, plus G.J. Pipe in fee (17.6 acres).

Specific stage-discharge relationships for most of the floodplains in this reach are not known and the total area that can be flooded at various river flows is undetermined. Irving and Burdick estimated potential floodable area by using bottomland elevations, but could not account for berms and dikes separating the floodplain from the main river channel. The occurrence of potentially floodable lands in the 18-Mile Reach is evident from this figure, but the specific river flows at which levees or berms are topped are generally not known. The majority of floodplains in this reach are terraces or abandoned gravel pits with a bed elevation generally lower than the river bed, which results in long-term retention of water and an inability to drain and reset these habitats.

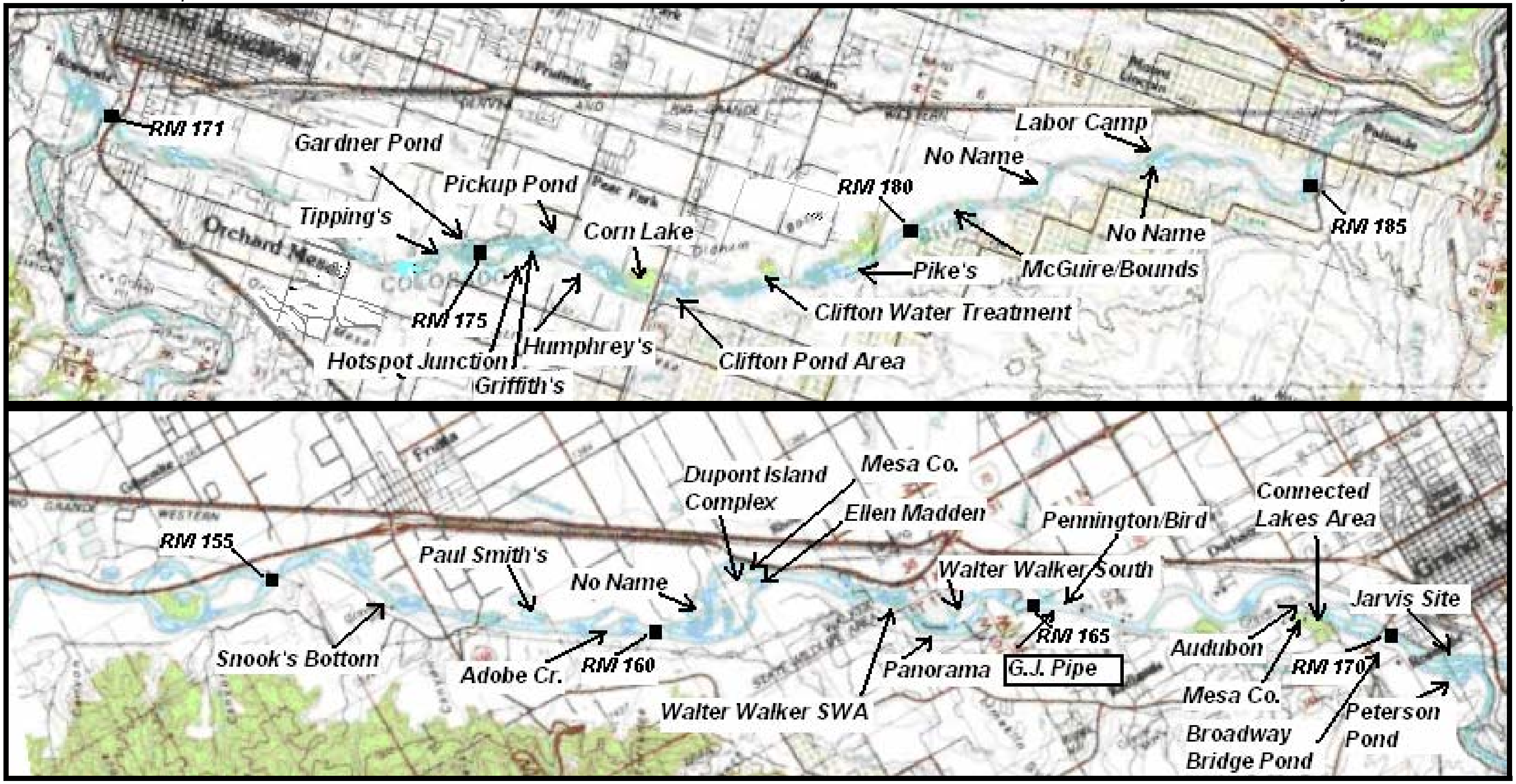


Figure 5-3. The 15-Mile Reach (top) and the 18-Mile Reach (bottom) of the Upper Colorado River with priority floodplain sites identified by Irving and Burdick (1995), as well as sites evaluated by the Recovery Program. River Mile (RM) is distance upstream from the confluence of the Upper Colorado and Green rivers.

5.2.3 Gunnison River—Hartland Dam to Roubideau Creek

This reach is 10 miles long (RM 60-50) and is the reach of the Gunnison River from Hartland Dam downstream to Roubideau Creek. A total of 8 sites are identified in this reach, including 3 sites ranked by Irving and Burdick (1995) and 5 additional sites evaluated by the Recovery Program (Table 5-1; Figure 5-4). The Recovery Program currently has access to a portion of the Escalante State Wildlife Area, and also has a perpetual easement on Morgan (45 acres), and Fedler (54.5 acres). Unaweep (Butch Craig), located downstream at RM 13, was acquired in fee (98.7 acres), all for a total of about 198.2 acres (80.3 ha) of floodplains in this reach.

Specific stage-discharge relationships for most of the floodplains in this reach are not known and the total area that can be flooded at various river flows is undetermined. Irving and Burdick estimated potential floodable area by using bottomland elevations (Figure 5-2), but could not account for berms and dikes separating the floodplain from the main river channel. The occurrence of potentially floodable lands in the Hartland Dam to Roubideau Creek Reach is evident from this figure, but the specific river flows at which levees or berms are topped are generally not known.

5.2.4 Rulison to Palisade

This reach is 47 miles long (RM 232-185) and is the reach of the Upper Colorado River from Rulison to Palisade, Colorado. A total of 14 sites are identified in this reach, including 10 sites ranked by Irving and Burdick (1995) and 4 additional sites evaluated by the Recovery Program (Table 5-1; Figure 5-5). The Recovery Program has a perpetual easement on 90 acres at one property, Hoagland.

Specific stage-discharge relationships for most of the floodplains in this reach are not known and the total area that can be flooded at various river flows is undetermined. Irving and Burdick estimated potential floodable area by using bottomland elevations (Figure 5-2), but could not account for berms and dikes separating the floodplain from the main river channel. The regular and frequent occurrence of potentially floodable lands in the Rulison to Palisade Reach is evident from this figure, but the specific river flows at which levees or berms are topped are generally not known.

5.2.5 Moab Bridge to Green River (CO RM 64-0)

This reach is 64 miles long (RM 64-0) and is the reach of the Upper Colorado River from the Moab Bridge to the Green River confluence, Utah. Only one site is identified in this reach—the Scott Matheson Wildlife Preserve (Table 5-1; Figure 5-6). The site is owned and managed by The Nature Conservancy and Utah Division of Wildlife Resources.

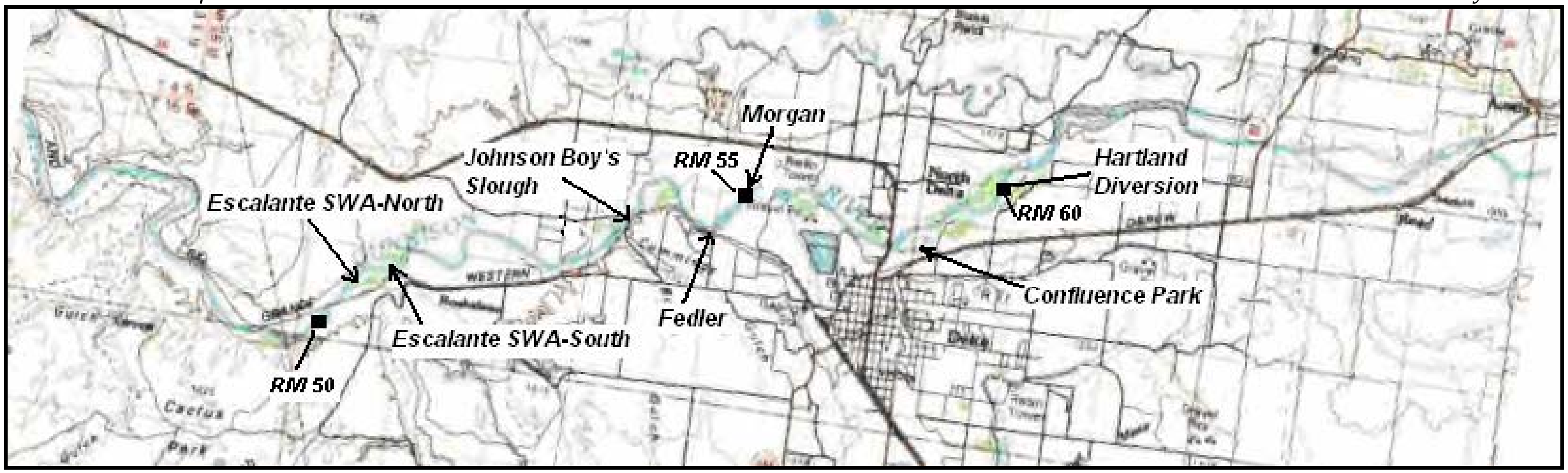


Figure 5-4. The Hartland Dam to Roubideau Creek Reach of the Gunnison River with priority floodplain sites identified by Irving and Burdick (1995), as well as sites evaluated by the Recovery Program. River Mile (RM) is distance upstream from the confluence of the Upper Colorado and Gunnison rivers.

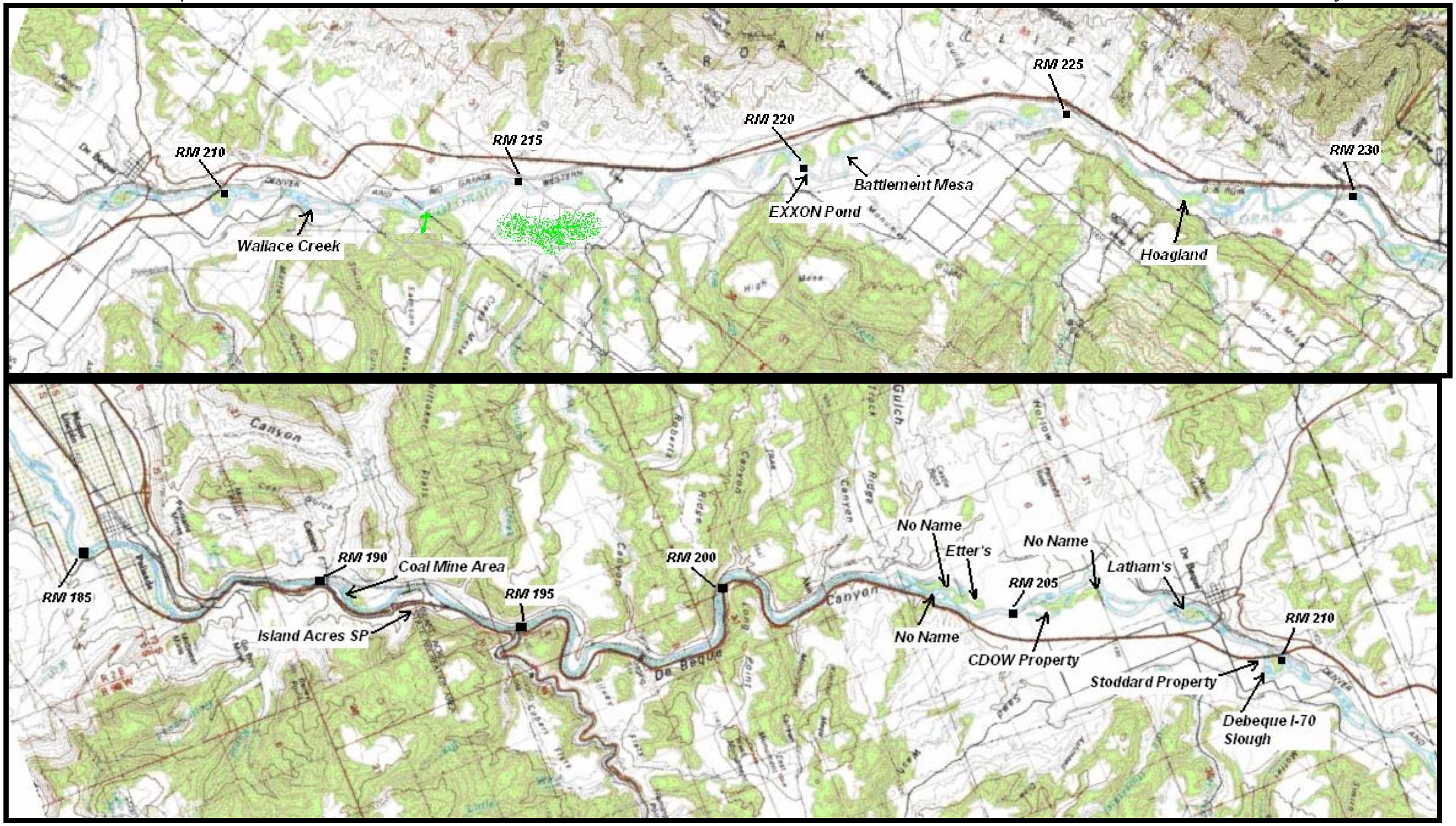


Figure 5-5. The Rulison to Palisade Reach of the Upper Colorado River with priority floodplain sites identified by Irving and Burdick (1995), as well as sites evaluated by the Recovery Program. River Mile (RM) is distance upstream from the confluence of the Upper Colorado and Green rivers.

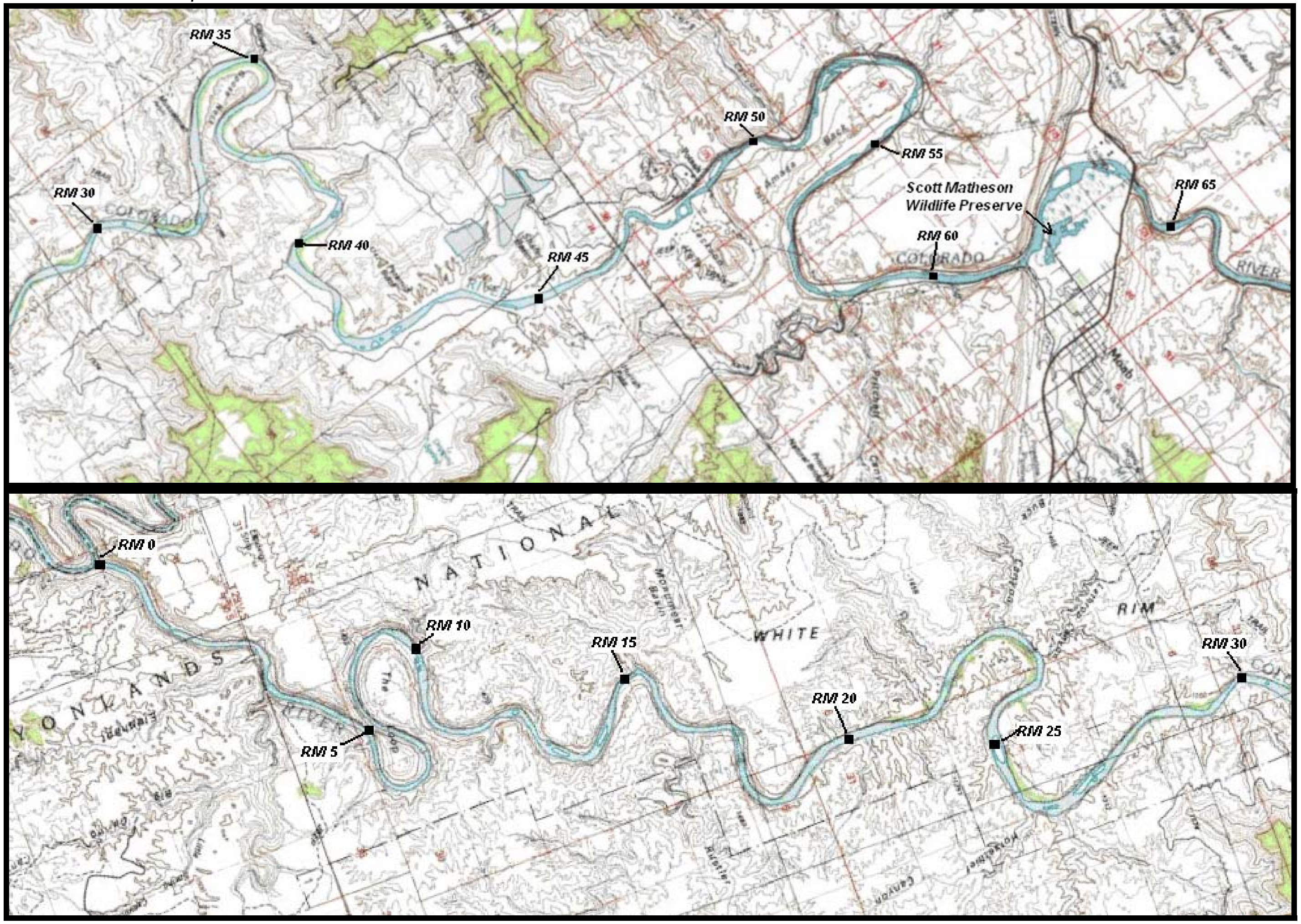


Figure 5-6. The Moab Bridge to Green River Confluence Reach of the Upper Colorado River. River Mile (RM) is distance upstream from the confluence of the Upper Colorado and Green rivers.

6.0 MANAGEMENT OF FLOODPLAIN SITES

6.1 Summary of Past Management Plans and Actions

6.1.1 Upper Colorado River

There has been considerable study of the role and management of floodplains in conservation of endangered fish in the Upper Colorado River Basin. Investigators recognize the value of floodplains to native fish from their persistent occurrence in these warm, productive, sheltered habitats (McAda 1977; Valdez et al. 1982; Valdez and Wick 1983). The relationship of flow to floodplain formation is acknowledged as an essential element to the proper ecological function of these habitats (Ward 1989; Ward and Stanford 1995), and appropriate flow recommendations have been developed (Kaeding and Osmundson 1989; Osmundson and Kaeding 1991; Burdick 1997). Historic flows are no longer available and it is evident that existing flow regimes limit the amount and duration of floodplain formation. Flow recommendations issued by the U.S. Fish and Wildlife Service (McAda 2003) are based on existing availability of water for dry, wet, and average water years, and acknowledge that the frequency and magnitude of flooding no longer reflects historic levels, except perhaps in wet years. The absence of a natural flow regime necessitates floodplain management designed to offset these effects.

Studies of connected and isolated floodplains in the Upper Colorado River Subbasin have examined and evaluated ecological functions and productivity (Cooper and Severn 1994a, 1994b, 1994c, 1994d); geomorphic features of floodplains (Burdick 2002); effects and removal of nonnative fish (Osmundson 1987; Burdick 2002; Burdick et al. 1997; Martinez 2001, 2002); and growth and survival of stocked razorback sucker (Burdick 1992, 2002a, 2003; Burdick and Bonar 1997; Burdick et al. 1995). Management plans have been conceptualized, developed, and/or proposed for some floodplains in the Upper Colorado River (Valdez and Wick 1983; Burdick 1994a; Collins 1994) and the Gunnison River (Burdick 1994b). Three important considerations are identified in these management plans: (1) frequency, magnitude, and duration of connection is limited by flow re-regulation and floodplain geomorphology; (2) an abundance of predaceous and competing nonnative fish may limit survival of young native fish in floodplains; and (3) razorback sucker are not currently reproducing in sufficient numbers in the Upper Colorado River Subbasin to enable researchers to identify reaches and floodplains of greatest importance to the species.

Management plans have been developed and actions have been implemented on several riverside floodplain ponds along the Upper Colorado River. Various survey activities and studies have been conducted on the following sites, and habitat enhancement activities have taken place to improve river connection, duration of flooding, and periodic draining: Butch Craig's, Audubon, Walter Walker SWA, Adobe Creek, Tipping's/Hot Spot, Gardner Pond, Jarvis Pond, and the Escalante SWA. Examples of the types of actions implemented on these sites include a 50-foot levee notch excavated in 2004 to connect the Audubon Ponds to the river; and excavation of the upstream levee at Walter Walker SWA to lower flood elevation.

Plans are underway to enhance “Hot Spot Complex” starting in 2005 for razorback sucker nursery habitat. This complex has been one of the more consistent sites in terms of production or contributing to the stocking goals. At present, the plan for the Hot Spot Complex is to finalize NEPA and Section 7, and have all issues resolved in preparation for enhancing the site as a razorback sucker nursery habitat. However, construction will be deferred until options have been identified and implemented to replace production at that complex.

Other sites have been surveyed and studied with the intent of establishing a river connection, but no further action has been taken on these sites for various reasons (e.g., lack of funding, problems with easement acquisition, flood damage risk to adjacent landowners, estimated costs of acquisition/restoration too high). These sites include G.J. Pipe, TF/Rigg, Bounds, Snooks Bottom, CDOT Pond, Clifton Pond/Slough, Moab Slough, and Pickup Pond. Details of activities are provided below for Jarvis Pond, Gardner Pond, and Pickup Pond. The following describes each site and summarizes management plans and actions implemented by the Recovery Program.

Jarvis Pond

Jarvis Pond is located on the east bank of the Upper Colorado River immediately downstream of the confluence with the Gunnison River (RM 170.8). It is located about 5 mi1es downstream from Gardner and Pickup ponds and is technically within the "18-mile Reach" (Figures 5-2, 6-1) of the Upper Colorado River. The pond has a potential wetted surface area of about 4 ha during wet water years and peak runoff. The Recovery Program’s 2000 RIPRAP refers to Jarvis Pond and Gardner Pond along with two other sites in the 15- and 18-Mile reaches as bottomland areas that "have been restored" (U.S. Fish and Wildlife Service 2000). Jarvis and Gardner ponds were designed and configured for use by juvenile, sub-adult, and adult fish; and not specifically for use by earlier life stages (i.e., larvae).

Jarvis Pond is located on property owned by the City of Grand Junction (City), and is managed as part of the Jarvis Endangered Fish Habitat Project to provide habitat that will benefit the endangered fish. Management of Jarvis Pond is part of a cooperative agreement between the City, Colorado Soil Conservation Service, Mesa County Soil Conservation Service, Bureau of Reclamation, and the Service. The project entailed breaching a 12-m section of an existing dike to form a channel that connects the former isolated pond with the mainstem. The pond was reshaped and recontoured to allow complete drainage during low flow (Burdick 2002). Observation of the Jarvis Pond after 2002 indicated that this pond was not draining, and a substantial amount of additional work may be needed to make the pond drain. Prior to construction, the duration of surface connection with the river was approximately 51 days in 1999 (May 21 to July 10) and only 38 days in 2000 (May 4 to July 11). The duration of connection has increased following construction and the suitability of this site continues to be evaluated. This project was intended to satisfy any and all required mitigation for the Orchard Mesa Footbridge that was constructed upstream at RM 172.3 in 1997. This project was meant to serve as a reasonable and prudent alternative for future federally approved or funded projects proposed by the City in the 100-year floodplain. This habitat rehabilitation project complied with Section 404 of the Clean Water Act (Corps of Engineers, Regional General Permit Number 057).

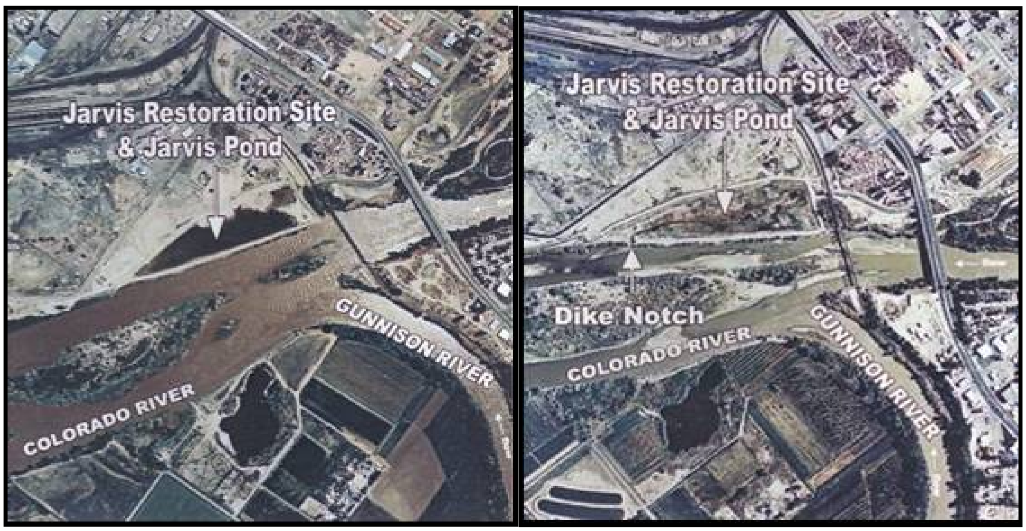


Figure 6-1. Aerial photos of the Jarvis Restoration Site adjacent to the Upper Colorado River (RM 170.8) on June 3, 1997 (left) and September 7, 2000 (right), at flows of 24,800 cfs and 1,090 cfs, respectively (USGS gauge near Palisade). Photos from Burdick (2002).

Gardner Pond

Gardner Pond (RM 174.4) is located on property owned by the Colorado Department of Natural Resources, Division of Parks and Outdoor Recreation (CDPOR). It is an abandoned gravel-pit pond (depression) with a surface area of approximately 3 ha, an average depth of about 1.7 m, and a maximum depth of 4.6 m. For many years, this pond was isolated from the mainstem Colorado River, and in December 1995, it was connected to the mainstem with an excavated channel. However, the pond did not drain naturally and held water year-around, serving as a refuge for nonnative fish. A report discussing seasonal fish use of Gardner Pond and adjacent Hotspot Pond was prepared by Burdick et al. (1997) and showed that nonnative species (e.g., green sunfish and black bullhead) recolonized Gardner Pond at a faster rate than other nonnative species. Following this 1-year evaluation, an earthen berm was placed in the connecting channel in September 1996 to prevent nonnative fish in Gardner Pond from escaping to the river and the pond was mostly drained and most nonnative fish removed in mid-March and fall, 1997. The pond was back-filled and sloped toward the river and in March 1998 successfully connected and filled during runoff, and drained during post-runoff.

Pickup Pond

Pickup Pond (RM 175.0) is owned by Mesa County and is located upstream and east of Gardner Pond. It has a total surface area of 1.6 ha and an average depth of about 1.5 m. Pickup Pond is a former gravel-pit that was a depression connected to the river, but had not been back-filled or sloped toward the river to drain. Pickup Pond was selected as a replacement for Jarvis Pond in 1998 when reconfiguration of the latter was not completed in time for a floodplain study (Burdick 2002). Like Gardner and Jarvis ponds, large numbers of nonnative fish were found in Pickup Pond.

Of the sites evaluated in the Upper Colorado River Subbasin (i.e., Jarvis, Gardner, Pickup), none is ideally suited as nursery habitat for drifting larval razorback sucker because of their inability to completely drain and the large resident nonnative fish populations. However, these floodplains provide habitat for native fish species during spring runoff and they provide a nutrient source to the mainstem.

6.1.2 Gunnison River

Several floodplain sites along the Gunnison River have management potential to benefit razorback sucker and other native fish. The following is a description of the Escalante SWA and the Butch Craig property.

Escalante State Wildlife Area (SWA)

In January 2001, construction was completed at the Escalante SWA on the Gunnison River 5 miles downstream from Delta, Colorado. A levee was removed and relocated, and two Texas crossings were excavated to restore river connection to a 200-acre oxbow when river flows exceed 13,700 cfs, a 1 in 5-year event. The goal was to provide floodplain habitat for adult Colorado pikeminnow and razorback sucker during spring runoff. The Escalante SWA, owned by the Colorado Division of Wildlife, includes 5 core tracts that comprise 4,044 acres, and encompasses the largest remaining floodplain bottomland habitat along the Gunnison River.

Razorback sucker have not been reported recently in the immediate area of the Escalante SWA. However, a small remnant population of Colorado pikeminnow resides in the Gunnison River downstream of the proposed site. One radiotagged Colorado pikeminnow was located at river mile 48.4 in the Gunnison River in 1993 (Unpublished data, USFWS), and relocated at river mile 59.1 in May 1994, indicating that it had passed by the Escalante SWA sometime between October 1993 and May 1994. This movement suggests that fish move past the SWA and may use available floodplain sites.

The last known capture of a wild adult razorback sucker in 1981 was immediately upstream of the Escalante SWA at river mile 54.0 (Holden et al. 1981). The stocking of adult razorback sucker in 1994 provided researchers with information regarding use of present and newly reconnected habitats, such as at Site 2. The Recovery Program approved a plan (Burdick 1992) for the stocking of about 20 adult razorback sucker in the Gunnison River to gain biological information on survival, dispersal, and general movements, in addition to habitat use of riverine and off-channel areas. These 20 fish were surgically implanted with long-term (4-+ years) radiotransmitters and were released April 6-7, 1994, between Roubideau Creek (RM 50.5) and Hartland Diversion (RM 59.9). Seven of these razorback sucker were stocked in backwater areas in the vicinity of the Escalante SWA. Release of hatchery fish in the vicinity of repatriated floodplains helps researchers understand fish use of these areas and helps to imprint endangered fish to these rehabilitated sites.

Butch Craig's

Habitat restoration was completed at the Unaweep Charolais Ranch (i.e., Butch Craig's) near Whitewater, Colorado, in October 2003. The 55-acre gravel pit, 13 miles upstream from the confluence with the Colorado River, was designed as a razorback sucker nursery habitat for the lower Gunnison River. The Butch Craig site was acquired in October 2000. The 98.7-acre site includes a 55-acre gravel pit pond. The levee separating the pond from the Gunnison River was breached in two locations, upstream and downstream, to allow flow through when flows at the Whitewater gage (Gunnison River near Grand Junction USGS gage #09152000) equal or exceed 4,160 cfs (1.11-year return flow). The 50-foot-wide levee notches were designed to entrain drifting razorback sucker larvae from the mainstem and into the pond during spring runoff in most years.

At the time of acquisition and restoration of the Butch Craig site, it was not known where razorback sucker spawning populations would become reestablished within the Gunnison River sub-basin. It was assumed that spawning would likely occur somewhere upstream in the system because Butch Craig is located in the lower part of the river, approximately 13 miles upstream from the confluence with the Colorado River. The most likely spawning habitats were thought to be in the vicinity of the Escalante State Wildlife Area at approximately river mile 52. Also at the time, the "larval decay rate theory" (Valdez 2004) had not been put forth. It was believed that sites lower in the system would entrain adequate numbers of drifting larvae, and avoid accidentally restoring a sites upstream from what could become the major spawning areas. Since construction at Butch Craig's, captures of larval razorback sucker have verified that spawning has occurred in the Gunnison River. Specific spawning locations have yet to be identified but, between 2002 and 2004, 7 larvae were captured downstream from Butch Craig and 10 were captured upstream. The larvae, captured between river miles 4.8 and 54.1, could have been produced anywhere upstream from river mile 4.8. Efforts are underway to identify specific spawning locations within the Gunnison River.

Capture of Razorback Sucker Larvae

Wild razorback suckers were last captured in the Gunnison River in the late 1970s (Holden et al. 1981) and in the upper Colorado River in the late 1990s (from the Walter Walker Wildlife Area in 1998). Wild razorback sucker are virtually extirpated in these two river systems. Restoration stocking of razorback sucker began in April 1994 in the Gunnison River and continued annually through 2004 (Burdick 2003). About 19,800 juvenile, sub-adult, and adult razorback sucker were stocked between 1994 and 2004. Restoration stocking began in the upper Colorado River in 1999 and is ongoing. Through 2004, about 47,500 juvenile, sub-adult, and adult razorback sucker have been stocked in the Colorado River. Larval fish sampling conducted in the Gunnison River during 2002-2004 (Osmundson and McAda 2005) show no particular pattern of frequency or occurrence (Table 6-1) and spawning sites have not been located.

Table 6-1. Numbers of larval razorback sucker captured in the Gunnison River during 2002-2004. Data from Osmundson and McAda (2005).

2002		2003		2004	
No. Caught	River Mile	No. Caught	River Mile	No. Caught	River Mile
4	4.8	1	15.1	1	33.6
3	5.9-9.1	1	17.5	1	33.4
1	50.2	1	30.4		
		1	37.0		
		1	47.8		
		1	52.7		
		1	54.1		

6.2 Management Plan Strategies

Reach and site-specific management objectives and actions are not described in this plan, as for the Green River Subbasin Floodplain Management Plan (Valdez and Nelson 2004), because of the large number of potential floodplain sites, lack of adequate stage/inundation relationships for many sites, and lack of known and documented razorback sucker spawning sites. Instead, the following five fundamental strategies are provided, followed by implementation, monitoring, risks and uncertainties, research needs, and recommendations.

1. Identify spawning sites of razorback sucker through release and monitoring of hatchery-reared fish and larval sampling.

2. Mechanically reconfigure floodplain sites downstream of identified spawning sites to provide suitable flooding and entrainment of larval razorback sucker.

3. Assist establishment of wild populations of razorback sucker and bonytail through release of hatchery-reared fish.

4. Continue to investigate and implement best management strategies to reduce detrimental effects of nonnative fish in floodplain habitats.

5. Insure suitable instream flows to inundate key floodplain sites on a timely basis.

6.2.1 Identify Spawning Sites of Razorback Sucker

Identification of spawning sites for razorback sucker is vital to development of effective floodplain management strategies. Immediate entrainment by drifting larvae in proximate functional floodplains is important to maximize survival and recruitment. Studies of particle drift in the Rio Grande (Platania 1995; Dudley and Platania 1999, 2000) and the Pecos River (Kehmeier et al. 2004), show that about 90% of drifting artificial particles (i.e., gelatinous beads to simulate eggs) are entrained within 75 miles of origin at a 6-7%/mile entrainment rate. A simulation model (Valdez 2004) supports this entrainment rate phenomenon and shows that nearly 99% of drifting larvae are retained in the first 35 miles of river drift at a 10%/mile entrainment rate (see section 2.4). Hence, the first strategy of this plan is to identify spawning sites and insure that functional floodplains are accessible during spring runoff within about 35 miles downstream. Those floodplain sites closest to a spawning site will have the greatest importance. This theory of larval drift and entrainment has not been tested and is being evaluated with field experiments.

The number of wild razorback sucker in the Upper Colorado and Gunnison rivers is extremely low, but apparently some natural reproduction occurs. Small numbers of larvae have been reported in the Gunnison River, including eight in 2002 and seven in 2003. Approximately 50,000 juvenile, sub-adult, and adult razorback sucker were stocked in the Upper Colorado River (31,531) and the Gunnison River (18,423) from April 1994 through October 2001. Studies of these hatchery-reared fish indicate that survival is highest for fish larger than 200 mm TL and that dispersal of about 50-70 miles downstream may be ameliorated through site-acclimation by stocking the fish directly into floodplains or holding them in cages (Burdick 2003).

Hatchery-reared fish should be released in or immediately upstream of suitable cobble/gravel substrate reaches and in upstream proximity to known floodplain sites. Geomorphic and hydraulic characteristics of a known spawning site of razorback sucker in the middle Green River (Wick 1997) can be used as a model for likely spawning sites. Fish should be released in the 15-Mile Reach, 18-Mile Reach, Gunnison River, and the Rulison to Palisade Reach. Fish passage is expected to be completed by about 2005 over the Price-Stubb Diversion Dam and the Government Highline Dam to allow movement of fish into and from the Upper Colorado River upstream of Palisade. This will connect about 50 miles of suitable habitat to the existing habitat of razorback sucker in the Upper Colorado River in a similar manner as the Redlands Fish Passage has provided access to the Gunnison River. Floodplains in the Rulison to Palisade Reach, although not in great amount, occur regularly and should provide suitable nursery and rearing habitat.

Release of hatchery-reared razorback sucker should be supplemented with companion studies of movement, habitat use, and suspected spawning site using radiotagged adults. Radiotelemetry has proven an effective tool in identifying and evaluating spawning sites of Colorado pikeminnow in the Green River (Tyus 1990) and the San Juan River (Ryden 2003; Ryden and McAda 2004), as well as movement and suspected spawning sites of humpback chub and roundtail chub (Valdez and Clemmer 1982; Kaeding et al. 1990). Colorado pikeminnow and razorback sucker were responsive in laboratory tests to chemical attractants (e.g., morpholene; Scholz et al. 1992, 1993) and these imprinting chemicals may be useful if radiotelemetry is unsuccessful. Synoptic larval drift sampling should also be continued and augmented to confirm suspected spawning sites with capture of drifting razorback sucker larvae. Identification of spawning sites will enable a more focused effort for floodplain management.

6.2.2 Mechanically Reconfigure Strategic Floodplain Sites

Mechanical reconfiguration of most targeted floodplains in the Upper Colorado and Gunnison rivers appears likely and necessary, given the geomorphic nature of most sites and the reduction of spring runoff from flow regulation. However, extensive reconfiguration should await identification and location of spawning sites. Twenty of 57 (35%) floodplain sites in the Upper Colorado and Gunnison rivers are gravel pits (Table 5-1). This is a potentially large resource of floodplain habitat, but most of these features will likely require some form of mechanical reconfiguration. Twenty-four of 57 (42%) sites are terraces that fill and drain with river stage, and may not be suitable for holding water for extended periods, regardless of mechanical reconfiguration. The remainder of sites (13 of 57, 23%) are side channels and oxbows for which reconfiguration may or may not be necessary. Mechanical reconfiguration, in the form of levee removal, has been implemented in the middle Green River with some success, but evaluation studies continue. Mechanical reconfiguration can be challenging and costly, and requires careful consideration and design of strategically located sites for maximum benefit.

6.2.3 Assist Establishment of Wild Populations With Hatchery Fish

The Recovery Program has determined that numbers of wild razorback sucker in the Upper Colorado River Basin are sufficiently depleted to require release of hatchery-reared fish to assist establishment of populations. Stocking plans for the States of Colorado (Nesler 2001) and Utah (Hudson 2001) have been integrated into a single plan (Nesler et al. 2003) that outlines the numbers of razorback sucker to be released annually. Releases of these hatchery-reared fish should continue with appropriate evaluation to assist establishment of wild populations. Highest survival has been found for stocked fish greater than 200 mm TL. These fish will mature and provide information on location of suitable spawning sites.

6.2.4 Reduce Detrimental Effects of Nonnative Fish in Floodplains

Studies of nonnative fish in backwaters and floodplains of the Upper Colorado and Gunnison rivers have acknowledged the difficulty of controlling numbers of problematic species (Osmundson 1987; Burdick 2002; Burdick et al. 1997; Martinez 2001, 2002). Some investigators have concluded that nonnative fish may limit recovery of native fish and that floodplain sites must be isolated from the river and nonnative fish mechanically or chemically removed (Minckley et al. 2003). The "reset theory" of floodplain management is being implemented and tested in floodplains of the middle Green River (Christopherson and Birchell 2002, 2004). A recent series of low water years has delayed full evaluation of this theory (Valdez and Nelson 2004).

The problem with nonnative fish in the Upper Colorado River may be exacerbated by the predominance of gravel pit ponds that fail to drain because of a bottom elevation below river elevation (see section 3.3). These gravel pits are productive refuges for nonnative fish and, if connected to the river, can be a constant source of these species to the main channel. The hypothesis to reconfigure these gravel pits into sloped ponds that will fill and drain with river stage (Valdez and Wick 1983) has been tested with inconclusive results because of the inability to fully drain these sites (Burdick 2002).

Nonnative fish, particularly in undrainable gravel pit ponds will continue to be a potential limiting factor to razorback sucker recovery in the Upper Colorado River Subbasin, and must be addressed in order to better define site-specific management actions for specific floodplain sites. New and innovative ideas are needed to cope with this problem. Strategies for reducing detrimental effects of nonnative fish in gravel pit ponds need to be developed in the interim of identifying spawning sites with the aid of radiotagged adults.

One option that may play a role in management of these gravel pits is the repatriation strategy of the Lower Colorado River Basin (Minckley et al. 2003). Nonnative fish are removed from isolated riverside ponds and razorback sucker and bonytail are allowed to reproduce naturally. A similar strategy is currently being implemented in the upper basin in which hatchery fish are held in predator-free "grow-out ponds" for growth and acclimation before being released to the nearby river. The Recovery Program has leased nearly 15 ponds on private property as grow-out ponds and researchers continue to evaluate the most suitable ponds based on geomorphic, hydrologic, chemical, and biological attributes.

6.2.5 Insure Suitable Instream Flows

Flow recommendations have been developed for the Upper Colorado and Gunnison rivers (McAda 2003). Implementation and evaluation of these recommendations with respect to floodplain formation is vital to conservation of razorback sucker and possibly bonytail. Under the current regulated flow regime, an abundance of floodplains are inundated in wet and moderately wet years, but less inundation occurs in average wet years, and little or no floodplain formation occurs in average dry, moderately dry, and dry years (section 4.0; Appendix B). In all likelihood, this inter-annual frequency of floodplain formation is inadequate for survival of young razorback sucker and recruitment. We conclude that mechanical reconfiguration will be necessary to offset the effect of flow regulation.

6.3 Implementation

The five strategies described above may be partially or entirely implemented and span from calendar year 2005 to 2015 (Fiscal Year 2006-2016; Table 6-2). This is an approximate time line because of the uncertainty regarding effectiveness of management actions (e.g., levee breaches, nonnative fish control, etc.), annual variation in river stage (i.e., low spring runoff precludes evaluation of breaches and water entrainment), and availability of construction, research, and evaluation funds. The time line for the three phases corresponds to 12 of 14 years estimated to establish self-sustaining populations of razorback sucker and bonytail in the Upper Colorado River and Green River subbasins (U.S. Fish and Wildlife Service 2002a, 2002b).

The following are specific activities by fiscal year for implementation of this plan:

1. Identify spawning sites of razorback sucker

   1a. FY ‘06: Assess fish species composition and relative abundance in the Gunnison River to identify/detect spawning aggregations of razorback sucker and Colorado pikeminnow, and to evaluate status and potential trends in problematic nonnative fish species. If spawning aggregations are not detected via sampling surveys, consider using and continuing radio telemetry for FY 07-08.

   1b. FY ‘06-‘08: 1b. Use radiotelemetry to locate spawning sites of razorback sucker. Hatchery fish and wild-caught fish should be equipped with radiotags to track and help locate aggregations of fish and spawning sites.

   1c. FY ‘06-‘10: During other studies and monitoring response, identify/detect spawning aggregations of razorback sucker in the Colorado River. If spawning aggregations are not detected during surveys, consider using and continuing radio telemetry.

2. Mechanically reconfigure strategic floodplain sites

   2a. FY ‘06: Monitor habitats that have been enhanced (i.e., Butch Craig’s, Audubon, Walter Walker) to ensure they continue to function as designed and constructed. Identify any potential problems.

   2b. FY ‘07-‘08: Construct flow-through connection at the Hot Spot Complex to entrain drifting razorback sucker larvae (if grow-out pond production at Tipping Pond B has been replaced with suitable alternatives).

   2c. FY ’06-’12: Floodplain sites that have been enhanced in the past and those that are being enhanced should be monitored to ensure that activities are effectiveness for nursery habitats of razorback sucker.

3. Assist establishment of wild populations

   3a. FY ‘06-‘12: Continue to stock hatchery razorback sucker. It is highest priority to get more fish, more spawning, and more drifting larvae in the rivers to determine where the best nursery habitats may be located.

   3b. FY ‘06-‘08: Identify/evaluate options (including additional grow-out ponds) for increasing razorback sucker production to meet or exceed annual stocking goals for the Colorado and Gunnison rivers. It is highest priority to get more fish, more spawning, and more drifting larvae in the rivers to determine where the best nursery habitats may be located.

   3c. FY ‘06-‘10: Stock any excess hatchery-produced razorback sucker (all sizes) into Butch Craig’s or other suitable floodplain ponds that are known to connect to the river during spring runoff.

4. Reduce detrimental effects of nonnative fish

   4a. FY ‘06-‘12: Ongoing nonnative fish removal programs should be continued and evaluation of the reset strategy should be continued.

   4b. FY ‘13-‘16: The Recovery Program should reassess the reset strategy and, if deemed necessary, readjust the approach to reducing detrimental effects of nonnative fish in floodplains.

5. Insure suitable instream flows

   5a. FY ’06-’24: Suitable instream flows should be insured to provide nursery habitat for razorback sucker.

Table 6-2. Estimated time line for the three phases of the floodplain management plan compared to the recovery time line in years for razorback sucker and bonytail.

Fiscal Years (2003-2024):	‘03	‘04	‘05	‘06	‘07	‘08	‘09	‘10	‘11	‘12	‘13	‘14	‘15	‘16	‘17	‘18	‘19	‘20	‘21	‘22	‘23	‘24
Approximate Species Recovery Time Line:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Primary Species Recovery Elements:	Establish Self-Sustaining Populations of Razorback Sucker/Bonytail->														Downlist/Delist Monitoring---------->							

Strategy and Specific Action	Approximate Time Period																		
1. Identify spawning sites of razorback sucker	<-------------------------->																		
1a. Assess species composition; identify spawning sites	<->																		
1b. Use radiotelemetry to locate spawning sites	<-------------->																		
1c. Monitor response, identify/detect spawning sites	<-------------------------->																		
2. Mechanically reconfigure strategic floodplain sites																			
2a. Monitor habitats that have been enhanced	<->																		
2b. Construct flow-through connection at the Hot Spot		<-------->																	
2c. Continue to monitor past and future enhanced sites	<--------------------------------------->																		
3. Assist establishment of wild populations	<-->																		
3a. Continue to stock hatchery razorback sucker	<--------------------------------------->																		
3b. Identify/evaluate options for increased fish production	<-------------->																		
3c. Stock excess hatchery fish (Butch Craig’s, others)	<--------------------------->																		
4. Reduce detrimental effects of nonnative fish	<-->											<--->							
4a. Continue fish removal and evaluation of reset strategy	<-------------------------------------->																		
4b. Reassess reset strategy and readjust as necessary								<---------------------->											
5. Insure suitable instream flows	<--->																		

The first strategy, to identify spawning sites of razorback sucker, should be implemented and achieved in the first 5 years of the plan, by the end of the FY 2010. This 5-year period should be sufficient time for stocked fish to mature, recruit to adults, and reproduce naturally. Much of the investigation to identify best stocking strategies has already been conducted. Radiotelemetry studies should be initiated to track the fish to spawning areas. The second strategy, to mechanically reconfigure strategic floodplain sites, has been implemented at some sites and should continue with a focus to spawning sites of razorback sucker identified and confirmed with presence of eggs and/or newly-hatched larvae. The third strategy, to assist establishment of wild populations with domestic fish, is fundamental to recovery of the razorback sucker and bonytail in the Upper Colorado River Basin. The Recovery Goals estimate that self-sustaining populations will become established by about the year 2015. This time schedule should allow sufficient time for domestic fish and their progeny to mature and reproduce in the wild.

The fourth strategy, to reduce detrimental effects of nonnative fish in floodplains, is part of ongoing investigations in the upper basin. These investigations should continue, but new and innovative ideas are needed to cope with this persistent threat. The need for nonnative fish management may extend beyond establishment of self-sustaining populations and may remain a long-term management action necessary for maintenance of recovered populations. The fifth strategy, to insure suitable instream flows, is also an ongoing upper basin activity. This strategy is based on implementation, evaluation, and revision of flow recommendations for the Upper Colorado and Gunnison rivers.

6.4 Monitoring

A formal fish population monitoring program is not currently recommended to evaluate response to floodplain management actions. Numbers of razorback sucker and bonytail in the upper basin are currently too low to effectively monitor for population response. Increased numbers and distribution of razorback sucker and bonytail should be detectable through other ongoing Recovery Program activities, such as Colorado pikeminnow and humpback chub population estimates, nonnative fish control programs, and larval drift studies. These program activities are ongoing in the Upper Colorado River, but not in the Gunnison River, and a monitoring program is needed in the Gunnison to evaluate success of hatchery-fish stockings, reproduction, and use of floodplains. All information on captured razorback sucker and bonytail should be centralized into the Recovery Program database. The Service may decide to implement population monitoring consistent with species recovery goals. Effectiveness of levee breaches, floodplain inundation, larval entrainment, fish growth and survival, and selenium remediation should be evaluated, as appropriate for this Plan.

Four elements of this Plan should be monitored:

1. When sufficient adult fish are in system to produce larvae, presence/absence of YOY/juveniles in floodplains should be monitored.

2. Long-term survival of stocked fish should be evaluated.

3. When implemented, floodplains that are mechanically reconfigured should be monitored for effectiveness of reconfiguration.

4. Recruitment of juveniles/adults back to mainstem rivers should be monitored.

6.5 Success Criteria

Success criteria provide measures of achievement for actions recommended in this Plan. The Recovery Program should monitor these actions to track the Plan's progress and success.

6.5.1 Track Radiotagged Adult Razorback Sucker

There is a great deal of experience with radiotelemetry of razorback sucker, Colorado pikeminnow, humpback chub, and bonytail, and chances of success for use of this tool to identify spawning sites of razorback sucker is high. This component of the Plan should initially be implemented for 3 years to provide sufficient time and opportunity for these fish to either spawn or aggregate with other spawning fish. An additional 2 years is programmed for this strategy to investigate and develop alternative means of identifying spawning sites, which may include use of chemical attractants (e.g., morpholene).

6.5.2 Evaluate Long-Term Survival of Stocked Fish

Various studies have been conducted on growth and survival of hatchery-reared razorback sucker and bonytail at several floodplain sites (Valdez and Nelson 2004). These studies have involved primarily caged fish introduced at different sizes and under different densities of nonnative fish (e.g., Christopherson and Birchell 2002; Birchell and Christopherson 2002; Modde et al. 1998). This information is being assimilated and evaluated to determine further need for these studies and to identify a specific strategy for use of hatchery fish to augment the wild populations. Growth and survival of hatchery razorback sucker and bonytail should be evaluated at various floodplains following reconfiguration (e.g., levee breaches). Also, effects of selenium on endangered fish should continue to be evaluated (Hamilton 1998; Hamilton et al. 2001a, 2001b; Beyers and Sodergren 2002). The success of this action should be gauged by development of a strategy for releasing hatchery-reared fish into the wild that will result in recruitment to the wild population. Information from this assessment will bear directly on growth and survival of wild larvae entrained in floodplains.

6.5.3 Evaluate Floodplain Reconfiguration

Mechanical reconfiguration of floodplains needs to be carefully designed and implemented for greatest likelihood of success. Success can be based on a variety of achievements, including, but not limited to, proper connection to the river, minimization of nonnative fish effects, and suitable water quality. Levee breaches, if necessary, should maximize flooding, larval entrainment, and retention of quality water for over-wintering fish. Topographic surveys and levee designs will likely be necessary and evaluations should report successful entrainment, growth, and survival of razorback sucker larvae. An assessment of the floodplain should be performed to determine the success of management actions, and to identify additional activities, as necessary. It may be necessary, for example, to investigate the need for water control gates for better flooding, fish entrainment, and water quantity and quality. Control gates would also allow timed escape of fish from the floodplain to the main channel. Ultimately success criteria will be entrainment, growth, survival, and recruitment by razorback sucker, bonytail, and other native species.

6.6 Risks, Uncertainties, and Contingencies

There are inherent risks and uncertainties associated with any plan of action. It is prudent to understand these risks and uncertainties and to establish research needs to fill information gaps, as well as contingencies to accommodate errors in predicted outcomes. The following are risks and uncertainties associated with this Plan, and possible contingencies. A research need is identified in Section 6.7 for each uncertainty listed below. The level of risk and uncertainty should be reduced as knowledge is gained from implementation and evaluation of management actions in this Plan. Properly designed studies, structural features, and management strategies will inevitably increase the probability of success and minimize the need for contingencies.

1. Effectiveness and alternatives for "reset theory".

The fundamental principle behind this Plan is the "reset theory" in which floodplains are allowed to inundate and desiccate on a 12 or 24-month cycle to provide productive habitats for maximum growth of razorback sucker. This strategy also allows escapement of fish to the river, and reduction of nonnative fish through periodic desiccation. This floodplain management strategy has not been fully tested and evaluated. Elements of this strategy have shown to be effective (e.g., enhanced floodplain connection with levee modification, high fish growth in floodplains, survival in high densities of nonnative fish), but others continue to be evaluated (e.g., larval entrainment, best survival, minimization of nonnative effects from periodic desiccation, winterkill/freezing). There are a number of uncertainties and inherent risks in managing floodplains to hold fish for 12 or 24 months, including early departure by fish, desiccation of the floodplain, failure of the floodplain to reconnect because of extended low river flows, disease outbreaks in floodplains, loss of native fish from periodic desiccation, and predation and competition from nonnative fish. The

Recovery Program has gained considerable understanding of floodplain functions and values and continues to develop best management strategies from applied experience.

Levee breaches and possibly inlet and outlet control gates are identified as potential structural components of some floodplains to control inundation, desiccation, and escapement of fish. These breaches and control gates are susceptible to erosion and damage by high river flows, and should be engineered and evaluated to account for this risk. Such features as gated canal inlets/outlets (instead of structures on the exposed face of levees), and lowered portions of levees (e.g., "Texas crossings") to relieve pressure of high flows should be considered. Breaches and gates should not include fish screens or kettles that may impede water flow and are more likely to erode. Water control gates are a contingency in case natural inundation and draining is ineffective.

If evidence from monitoring indicates that this approach will not achieve a self-sustaining population of razorback sucker or bonytail, as judged by the Recovery Program, an alternative or modification of the strategy may need to be implemented as a contingency. Some aspects of the "floodplain repatriation" strategy being used in the Lower Colorado River Basin may apply. Floodplains in the lower basin are isolated from the river and desiccated or chemically treated to completely eliminate nonnative fish. Razorback sucker or bonytail are stocked and held for 24 months, then manually released to the river. This is a highly managed system that requires ongoing investment in resources and is not consistent with the concepts of long-term species recovery and population self-sustainability. However, it may be possible to combine this strategy of contained rearing of fish to initiate the population, then allow the "reset theory" to function within the framework of floodplain restoration and flow regulation.

2. Location of razorback sucker spawning sites.

Spawning sites of razorback sucker in the Upper Colorado River Subbasin are not definitively known. The distribution of captured larvae in the Upper Colorado River and the Gunnison River is scattered with no distinct pattern of origin. Further investigation is needed with the aid of radiotagged adults to better define areas or sites used for spawning. This information will help to focus floodplain management on those sites that are most likely to serve as nurseries and benefit the razorback sucker.

3. Drift and entrainment of wild razorback sucker larvae.

Understanding drift and entrainment of wild razorback sucker larvae at key floodplain sites is critical to the success of this plan and to species recovery. Drift characteristics and entrainment of larval razorback sucker are not well understood. Larvae may not become entrained in sufficient numbers at key managed floodplains, and reconfiguration of floodplain levees, inlets, and outlets may be necessary, including installation of water control structures. Entrainment is also a function of river flow timing, and it may be necessary to evaluate and possibly revise flow recommendations in order to maximize entrainment. Entrainment is expected to be a resolvable issue.

4. Growth and survival over a 12 to 24-month period.

High rates of growth are consistently demonstrated in floodplains by most fish species. Of greatest concern is whether young razorback sucker can quickly reach sufficient size in an available floodplain to minimize the risk of predation. The greater uncertainty is whether sufficient numbers of razorback sucker or bonytail can survive in floodplains to recruit at a rate that equals or exceeds adult mortality. It may be necessary to install inlet and outlet gates at floodplain sites to regulate inflow and outflow, water level in the floodplain, and fish escapement. Water control will also allow for a periodic influx of fresh water into floodplains to minimize disease outbreaks and insure water quality. Growth and survival studies in Green River floodplains have produced much valuable information.

5. Value of gravel pits, depressions, and short-term floodplains.

Some floodplains are small and/or shallow and do not hold water year-around. Fish that become stranded in these floodplains will die from poor water quality or desiccation, and so, fish that use these short-term floodplains must escape to the river as flows recede. However, fish that escape the floodplain at a small size (i.e., <90 mm TL) will likely have low survival in the mainstem (Personal communication, Tim Modde, U.S. Fish and Wildlife Service; Kevin Christopherson, Utah Division of Wildlife Resources). Short-term floodplains may have little value as nurseries, but isolating these from the river is not recommended at this time because these sites may remain flooded during wet years and successfully produce fish. These sites may also be used transiently by large juvenile and adult razorback sucker, bonytail, and Colorado pikeminnow during spring runoff.

6. Reduction in nonnative fish effect.

Nonnative fish from the Upper Colorado River Subbasin can gain access to floodplains during inundation, and some produce young that escape back to the river and bolster overall nonnative fish populations. The strategy of cyclic inundation/desiccation of these floodplains should reduce this effect. Also, benefits gained from possible razorback sucker survival and from providing habitat for transient adult Colorado pikeminnow and possibly razorback sucker and bonytail during runoff outweigh the risk of enhanced nonnative fish production. Currently, it is believed that benefits gained from possible razorback sucker survival in wet years and from providing access to transient juveniles and adults during runoff outweigh the risk of enhanced nonnative fish production. If it is determined that this floodplain management strategy is serving to bolster nonnative fish populations, elements of the “floodplain repatriation” strategy may need to be implemented as a contingency.

6.7 Research Needs

The following research needs are identified to address uncertainties and to fill information gaps necessary for achievement of this Plan. These research needs are listed in order of priority, but the need to allow flexibility for implementation is recognized, depending on success of previous actions and available funding.

1. Evaluate effectiveness of "reset theory".

Key floodplains should be evaluated for effectiveness of restoration. Evaluation should include connection with the river, levee erosion, larval entrainment, growth and survival of fish, escapement to the river, and recruitment to the wild adult population, as documented by increased numbers of adults and marked fish returning to spawning areas. This ongoing evaluation should be part of an adaptive management approach to make changes or adjustments in floodplain management strategy. This research need will likely require several studies to evaluate the various components of the "reset theory" as identified above.

2. Locate razorback sucker spawning sites with radiotelemetry.

Radiotagged adult razorback suckers should be tracked for locating and identifying spawning sites. This technique has worked for locating spawning sites and aggregations of Colorado pikeminnow, and preliminary tracking of fish in the Upper Colorado and Gunnison rivers indicates that it can be a successful strategy. Once spawning sites are identified, this will help to characterize larval drift and to focus on restoration of key floodplain sites.

3. Describe larval drift and entrainment.

Characteristics of downstream drift and larval entrainment should be described to assess the effectiveness of key floodplain sites, and to guide best strategies for levee modification and construction. This evaluation should be part of the Comprehensive Larval Drift Report. Existing information should be assimilated to assess geomorphic and hydrologic characteristics of the river channel and key floodplains in order to determine the best strategy for breaching levees separating the main channel from the floodplain to achieve maximum flooding and larval entrainment. This report should be done collaboratively with a similar reporting requirement identified for floodplains of the Green River Subbasin (Valdez and Nelson 2004).

4. Assess growth and survival.

A Comprehensive Growth/Survival Report should be assembled to integrate, synthesize, and interpret prior fish growth and survival studies. This report should assess the state of knowledge, identify essential information gaps, guide additional research, and recommend best strategies for managing floodplain habitats and releasing hatchery-reared fish. This report should be done collaboratively with a similar reporting requirement identified for floodplains of the Green River Subbasin (Valdez and Nelson 2004).

5. Evaluate importance of gravel pits, depressions, and short-term floodplains.

Since 35% of the floodplains identified in this plan are artificial (i.e., gravel pits with limited ability to drain, or "reset") and another 42% are terraces (i.e., thought to be less vital as nursery areas than depressions), the importance of floodplains in maintaining populations of endangered fish in the upper Colorado River sub-basin should be further evaluated in order to better identify priority sites. This evaluation should be done in the context of available flows for the Upper Colorado and Gunnison rivers and how successful floodplain inundation will be in recovery of the razorback sucker in the Upper Colorado River Subbasin.

6. Evaluate effects of nonnative fish.

It is known that nonnative fish generally have a negative effect on native species recovery. It is also known that removal strategies for small-bodied nonnative fish in the Colorado River ecosystem have had limited success, short of total isolation and chemical treatment of confined habitats. This floodplain management plan is based on the fundamental hypothesis that razorback sucker recovery can be assisted with restoration of floodplain habitats and flow regulation in the presence of nonnative fish species. Future research and evaluation of the management actions identified in this Plan should focus on this fundamental strategy; i.e., like Colorado pikeminnow and humpback chub, recovery of razorback sucker and possibly bonytail can be achieved in the presence of nonnative species, given suitable habitat conditions and flows.

7.0 RECOMMENDATIONS

The following recommendations identify actions that should either be implemented immediately or prioritized for implementation. These recommendations are prioritized and are intended to provide direct and immediate guidance for initiating implementation of this floodplain management plan. These recommendations should be incorporated into the RIPRAP and implemented in accordance with other recovery program actions and activities.

1. Continue stocking of hatchery razorback sucker and bonytail.

Release of hatchery razorback sucker and bonytail is vital to species recovery. These fish augment sparse wild populations, provide the foundation for a self-sustaining population, and provide wild larvae for locating spawning areas and necessary nursery sites. Stocking provides fish in the wild to better assess best management strategies for floodplains. Biologists should continue to monitor distribution and behavior of razorback sucker to evaluate and identify additional and potential spawning sites. An evaluation of stocked razorback sucker in the Upper Colorado River Subbasin integrates, synthesizes, and interprets past fish growth and survival studies (Burdick 2003). This report should be used as guidance for refining stocking strategies for razorback sucker and bonytail in the Upper Colorado River Subbasin.

2. Identify and locate razorback sucker spawning sites.

Radiotelemetry of adult hatchery-reared fish and larval sampling should be implemented and continued to help identify spawning sites in the Upper Colorado and Gunnison rivers. This, coupled with the best available information on larval entrainment, should be a priority action in order to first identify the most strategic floodplain sites before making large capital investments in easements or floodplain site construction.

3. Describe larval drift and entrainment.

Understanding patterns of razorback sucker larval drift and entrainment is vital to better managing key floodplain sites and relationship of flow patterns. Larval sampling should continue in the Upper Colorado and Gunnison rivers with a focus downstream of identified spawning sites.

4. Assess growth and survival of razorback sucker and bonytail in floodplains.

Growth and survival of razorback sucker and bonytail in floodplains should be evaluated in a manner similar to studies of the Green River. These studies should further the understanding of best stocking strategies for fish in floodplains, as well as survival by wild fish naturally entrained in floodplains.

5. Identify and reconfigure, as necessary, key floodplain sites to benefit razorback sucker and bonytail.

Identification of spawning areas as sources of drifting larvae is vital to focusing initial management efforts that provide the greatest benefit to the species for the investment of resources. Floodplain management should focus on key floodplains most likely to maximize entrainment and survival of drifting larvae. This strategy does not discount the importance of other floodplain sites as the population expands or as sources of nutrient enrichment to the river. Floodplain sites nearest downstream of spawning sites (when spawning sites are confirmed) may be the most important sites, depending on results of larval drift and entrainment studies. Geomorphic and hydrologic characteristics of selected sites should be evaluated for floodability and larval entrainment potential. Limnological characteristics and biological productivity should be evaluated where necessary. Existing information should be assimilated to determine the best strategy for breaching levees to achieve maximum flooding and larval entrainment.

6. Acquire property easements in the Upper Colorado River Subbasin, as necessary, and coordinate floodplain restoration and management with various stakeholders.

It has not been determined if floodplain areas in the Upper Colorado and Gunnison rivers, that are currently accessible to the Recovery Program through negotiated easements and coordination with State, Federal, and local agencies, are sufficient habitat for recovery of razorback sucker. Further acquisition of easements may be necessary if spawning sites of razorback sucker are identified with no access to key floodplain sites. Before additional sites are acquired, these need to be investigated and evaluated for geomorphic, hydrologic, limnological, and biological characteristics to insure that selected sites will benefit the razorback sucker.

Many floodplain sites in the Upper Colorado and Gunnison rivers are under ownership and management of State or Federal agencies, counties, or municipalities. The Recovery Program should initiate and continue coordination and partnerships, as necessary, to manage key floodplains to benefit the endangered fish and not negatively impact the goals and objectives of properties associated with these floodplain sites.

7. Develop, test, and evaluate strategies for reducing effects of nonnative fish in floodplain habitats.

Nonnative fish have been identified as one of the most significant threats to native fish in floodplain habitats. Strategies should be developed, tested, and evaluated to reduce the negative effects of nonnative fish in floodplains.

8. Centralize data from existing programs to monitor response by razorback sucker and bonytail.

The Recovery Program should use existing programs, as much as possible, to monitor population response of razorback sucker and bonytail to floodplain management actions. Continued release of hatchery fish and restoration of floodplains should lead to successful reproduction and recruitment that should be detected by ongoing sampling programs. Various sizes of razorback sucker and bonytail should be captured during electrofishing and netting operations as part of population estimates of Colorado pikeminnow and humpback chub, as well as nonnative fish control programs. This sampling is being conducted through most of the upper basin and should provide sufficient geographic coverage and sampling intensity for detecting increased numbers of razorback sucker and bonytail. Segmented monitoring duplicates sampling that can lead to stress and mortality of endangered fish from over-handling. Various population estimation programs are ongoing in the Upper Colorado River, but not in the Gunnison River, and a monitoring program is needed in the Gunnison to evaluate success of hatchery-fish stockings, reproduction, and use of floodplains. The Recovery Program may choose to implement a more detailed sampling program in the future. Monitoring for downlisting and delisting will be implemented after self-sustained populations are established, as specified in species recovery goals.

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APPENDIX A: Table of Floodplain Sites in the Upper Colorado River Subbasin

Table A-1. Bottomland habitat sites, river mile, actual (May [runoff] and September [post-runoff] 1993) inundated area (hectares), and historical inundated area (hectares), Colorado and Gunnison rivers, Colorado and Utah, May and September 1993. Table E-7 from Irving and Burdick (1995).

Site Description	River Mile	Actual Inundated Area /ha)		Historical Inundated Area (ha)
		Runoff (May 1993)	Post-Runoff (September 1993)	
Colorado River				
Rifle West	238.0-241.1	12.2	12.1	150.7
Rifle 1-70 West Interchange	236.5-238.0	5.3	5.3	126.4
COCNI /Gentry Property	234.2-235.8	10.4	10.2	66.8
"Trash-can Pond"	230.2-230.8	5.3	1.8	5.8
Mahaffey/Lemon	228.2-229.8	6.5	2.3	54.4
Mahaffey's	228.5-229.5	2.5	2.2	30.5
Hoaglund's	227.1-227.7	1.2	< 0.1	16.4
Dere/Ortiz	227.5-228.5	6.1	6.0	39.3
Parachute East	223.0-223.4	2.1	0.7	13.7
Knight's	224.5-225.4	4.4	0	28.2
Parachute Bridge	223.0-223.4	2.1	0.7	13.7
"No Name"	222.7-223.1	0.4	0.6	8.6
"No Name"	221.1-222.9	11.5	11.3	23.4
Battlement Mesa	220.7-221.7	10.2	3.9	34.4
EXXON	218.9-220.1	3.1	0	34.9
Doyle Property	218.4-219.5	0	0	8.7
"No-name"	217.2-218.0	1.4	0	22.3
Una North	216.4-217.4	6.4	6.3	40.7
Wallace Creek Island	215.9-216.5	3.4	0	13.3
Stoddard Property	209.4-210.1	8.1	8.1	23.2
Debeque 1-70 Slough	209.6-211.4	6.7	3.6	40.4
Latham's	207.9-208.8	6.2	1.6	26.1
"No Name"	206.2-207.5	2.1	0	22.9
Etter's	204.7-206.6	22.8	22.8	65.1
"No Name"	202.3-204.2	6.9	3.3	86.4
"No Name"	201.9-202.4	0.2	0	6.1
Long Point Bottom	198.0-198.9	2.3	0.2	10.6
Beavertail	194.3-195.6	2.0	1.8	12.6
Island Acres	191.1-192.1	11.4	11.4	28.1
Cameo	190.0-191.0	1.2	1.2	24.6
Palisade	184.2-185.0	2.5	2.1	22.0
"No Name"	183.3-184.3	3.8	1.3	17.2
Labor Camp	182.9-183.6	8.3	2.7	19.6
"No Name"	181.6-182.6	0.6	0	43.3
"No Name"	181.7-182.2	2.8	2.2	6.9
"No Name"	180.4-181.5	4.2	1.4	21.2
Clifton Water Treatment	179.1-181.1	20.7	17.8	122.5
Clifton Pond	177.7-178.2	21.7	15.6	81.7
Corn Lake	176.6-177.7	14.5	8.3	38.6
Humphrey's	175.3-176.7	47.9	25.0	86.2
Griffith's	174.1-176.5	24.2	2.6	52.7
"Hotspot Junction" (30-29 Rd)	173.9-175.1	11.3	9.4	97.9
"No-name"	173.4-173.8	1.4	0.6	10.6
"No-name"	173.0-173.6	0	0	7.8
Mill Tailing Site	172.5-173.4	1.9	< 0.1	40.6
Watson Island	171.0-172.1	9.3	4.6	20.6

Site Description	River Mile	Actual Inundated Area /ha)		Historical Inundated Area (ha)
		Runoff (May 1993)	Post-Runoff (September 1993)	
"No-Name"	171.3-171.8	3.0	0.4	5.9
"No-name"	170.4-171.0	11.2	0	16.4
Connected Lakes Area	168.7-170.3	77.2	59.3	220.6
Walter Walker South	164.4-166.0	28.7	3.0	60.3
"No-name"	166.4-169.7	30.7	20.3	117.0
Appleton Drain East	165.1-166.4	19.5	17.0	61.1
Walter Walker SWA	162.7-165.1	17.6	4.7	144.5
Panorama	163.1-163.6	3.1	2.8	20.6
"No-name"	161.0-162.7	2.5	0.9	20.6
DuPont Island	161.0-162.0	16.8	3.6	73.9
DuPont's	159.1-161.9	37.5	25.2	86.6
Paul Smith's	158.0-159.1	13.8	2.4	53.4
Fruita Sewage Ponds	156.6-158.0	16.6	16.5	40.9
Fruita 340 Bridge	157.5-158.3	0.8	0.4	17.0
Snook's Bottom	155.9-157.1	1.4	0.6	38.0
Horsethief SWA	151.9-154.7	4.9	1.5	180.9
Spann's	151.4-152.4	5.2	4.7	34.0
"No-name"	150.8-151.5	0	0	27.5
Crow Bottom	143.9-146.5	0	0	96.0
"No-name"	145.5-146.6	0	0	39.7
Vulture Bottom	139.7-142.1	0	0	61.5
"No-name" Island	137.2-138.0	0	0	23.2
Black Rocks	136.7-137.1	0.6	0	17.8
Knowles Canyon	133.6-135.0	1.0	0	52.0
Jouflas Bottom	129.8-133.9	0	0	99.6
Wildass Canyon Ranch	127.3-131.3	14.6	1.9	189.0
"No-name"	125.8-126.8	0.8	0	54.0
Elizondo Ranches	126.5-127.8	4.0	1.7	87.1
Westwater Wash	124.8-126.0	16.8	0.2	84.0
Cisco Landing Area	107.6-111.6	4.0	0	267.0
Ash Ford Area	103.0-105.9	10.6	0	100.5
McGraw/Hotel Bottom	98.1-101.0	24.7	?	123.7
White Ranch	77.5-78.4	0	0	26.1
Courthouse Wash	63.8	1.6	0	2.8
Moab Slough	61.5-64.0	212.0	81.0	354.0
Kane Spring	58.2	1.6	0	2.8
Billboard (Lake Bottom)	50.9-52.5	9.9	0	36.0
Jackson Bottom	47.4-49.0	13.8	0	34.0
"No-name"	44.0-44.7	11.4	0	23.0
"No-name"	42.8-43.7	4.8	0	22.0
"No-name"	41.1-42.1	10.7	0	22.3
"No-name"	40.2-41.3	0.4	0	21.0
"No-name"	39.5-40.6	1.2	0	17.4
"No-name" Canyon Mouth	38.8	0.4	0	1.2
"No-name"	38.6-39.2	0.6	0	10.5
Goose Neck	33.2-35.6	10.1	0	57.5
Shafer Canyon Mouth	34.8	1.2	0	5.8
"No-name" Canyon Mouth	32.1	0.4	0	1.6
"No-name" Canyon Mouth	31.6	0.2	0	1.6
"No-name"	30.8-31.9	1.9	0	27.9
Little Bridge Canyon	30.0	0.8	0	1.8

Site Description	River Mile	Actual Inundated Area /ha)		Historical Inundated Area (ha)
		Runoff (May 1993)	Post-Runoff (September 1993)	
Lockhart Canyon	26.5	0.6	0	5.8
"No-name"	25.3-26.5	7.7	0	31.0
Lathrop Canyon	23.5	0.4	0	4.5
Buck Canyon	22.7	0.6	0	4.5
Gooseberry Canyon	21.7	0.4	0	2.8
Dogleg Canyon	21.2	0.4	0	3.2
Sheep Bottom	17.5-18.7	0.8	0	27.3
Indian Creek Canyon Mouth	16.5	0.6	0	4.5
Monument Creek Mouth	15.3	0.2	0	5.3
"No-name" Canyon Mouth	11.9	< 0.1	0	3.2
"No-name" Canyon Mouth	10.1	0.2	0	0.4
Salt Creek Canyon Mouth	3.4	< 0.1	0	2.9
Elephant Creek Canyon Mouth	3.0	< 0.1	0	1.7
Gunnison River				
"No-name"	74.3-74.7	0	0	24.0
Lawhead Gulch Bottom	70.1-71.6	0.4	0	13.8
Ferganchick's	69.5-70.5	0	0	16.7
"No-name"	68.3-69.4	0	0	12.1
"No-name"	67.5-68.2	0	0	3.8
Austin County Bridge	65.7-66.4	0	0	17.2
Austin Hwy 92 Bridge	65.0-05.5	4.1	0	13.5
"No-name"	63.3-65.3	0.8	0	52.2
"No-name"	63.0-64.6	0	0	17.7
Colorado Hwy 65 Bridge	62.6-63.2	9.9	0	14.4
Tongue Creek	61.5-62.5	16.2	0	35.6
Hutchin's	60. 1-60.8	4.8	1.6	17.3
North Delta	57.6-59.5	14.0	0	49.3
South Delta	57.6-58.8	10.0	9.9	39.9
Confluence Park	56.7-57.7	8.4	6.7	40.1
Uncompahgre R Confluence	56.3-57.0	8.1	9.3	34.4
Delta City Sewage Plant	55.6-56.5	14.7	3.6	38.0
"No-name"	54.6-55.5	1.9	1.5	27.9
"No-name"	54.2-55.1	9.8	2.2	28.2
"No-name"	53.1-54.1	1.3	0	21.7
Johnson Boy's Slough	53.2-54.2	9.9	4.1	63.1
Escalante SWA North	50.8-52.9	28.7	6.0	110.5
Escalante SWA South	50.2-52.4	48.6	4.5	82.6
"Blue Duck" Bottom	49.5-50.4	6.2	0	21.7
"No-name"	49.4-49.7	3.5	0	11.2
"No-name"	48.6-49.3	3.5	0	14.1
"No-name"	46.6-47.5	4.9	0	14.2
Escalante Ranches	41.7-42.8	2.5	0	15.1
"No-name"	39.9-41.0	16.4	0	33.8
Dominguez	36.4-36.9	2.8	1.3	11.0

APPENDIX B – Flow Recommendations (McAda 2003)

B-1.0 Flow Recommendations for the Gunnison River

The following are flow recommendations from McAda (2003). The following information reiterates the spring peak-flow recommendations described in Table B-1 and places them in context with the amount of in-channel habitat maintenance that is expected to occur. Recommended base-flow conditions for the summer, autumn, and winter periods are also described to provide habitat for the endangered fishes throughout the year.

B-1.1 Spring Peaks

Spring peak flows are the defining flows of a river system and do most of the work to maintain habitat for the endangered fishes. Releases from the Aspinall Unit to assist in meeting these target flows should gradually increase and decrease according to established ramping rates (300-500 cfs/d at releases <5,000 cfs and 10% per day at releases >5,000 cfs). To the extent possible, maximum Aspinall Unit releases should be timed to correspond with maximum river flows in the North Fork of the Gunnison River to provide maximum benefit to the Gunnison River within critical habitat. Although timing of peak flows in the North Fork (measured at the USGS gauge near Somerset, 09132500) and the Gunnison River did not always coincide before the Aspinall Unit was constructed, highest mean-daily flows of the year for both rivers fell within 2 d of each other 75% of the time during 1937-1965. To correspond with the historical hydrograph, peak flows in the Gunnison River should occur between May 15 and June 15 each spring.

Specific flow recommendations for six hydrologic categories are presented below and summarized in Table B-1. These flows correspond to the Pitlick et al. (1999) recommendations for channel maintenance. There are no specific flow recommendations for floodplain habitat; however, the benefits are described when floodplain habitat is expected to be created.

Dry.—Flows equal to ½ bankfull or bankfull discharge are not required in this category. However, instantaneous peak flows ranging between about 900 cfs (base flow) and 4,000 cfs have occurred in this category since Blue Mesa Reservoir was closed. Instantaneous peak flows should be in that range when water availability is sufficient. There will be no channel maintenance occurring in this category. However, the rising and falling river associated with even a small peak will provide environmental cues that the endangered fishes use for spawning. Because considerable extra water would be required to reach river levels associated with initial motion, it is not warranted to provide that extra water during dry years. Releases from the Aspinall Unit should correspond to historical spring release patterns with no extra water released for the endangered fishes. Water for the endangered fishes should be stored for release during the summer migration period to provide access to the Redlands Fishway. No flooded bottomland habitat is provided at this flow.

Table B-1. Flow recommendations for the Gunnison River measured at the USGS gauge near Grand Junction (09152500). (McAda 2003).

Hydrologic Category	Magnitude and Duration	Discussion! Anticipated Effect
Spring Peak Flow		
Dry: 90-100% exceedance	1-d peak of 900-4000 cfs	No in-channel scouring of gravel or cobble bars is anticipated at this flow; however, fine material on the surface will be moved and further deposition will be slowed. No flooded bottomland habitats will be provided, but some inundation of tributary mouths will occur. The small peak will provide spawning cues for Colorado pikeminnow and razorback sucker.
Moderately Dry: 70-90% exceedance	≥8,070 cfs (Q_c) 0-10 d 1-d peak when Q_c not reached, ≥2,600 cfs	In-channel maintenance will not occur unless initial motion is reached for at least one day; however, fine material on the surface will be moved and further deposition will be slowed. The limited peak will provide spawning cues for Colorado pikeminnow and razorback sucker. No flooded bottomland habitat will be provided, but some inundation of tributary mouths will occur, providing some warm, quiet water habitats for growth and gonad maturation of endangered fish.
Average Dry; 50-70% exceedance	≥8,070 cfs (Q_c) 10-15 d Peak flow should at least equal Q_c	The median level for initial motion will be reached, providing some cleansing of gravel and cobble bars. This will prepare spawning habitat for Colorado pikeminnow and increase primary and secondary production. Floodplain inundation will begin, but habitat will be limited; however, some warm, quiet-water habitats will be available for growth and gonad maturation of razorback sucker and Colorado pikeminnow.
Average Wet; 30-50% exceedance	≥8,070 cfs (Q_c) 20-25 d ≥14,350 cfs (Q_b) 2-3 d Peak flow should at least equal Q_b	The median level for significant motion is reached or exceeded in in the river. Widespread cleansing of gravel and cobble bars is accomplished. In-channel habitats used by endangered fish will be maintained in important river reaches; channel narrowing will be slowed or prevented. Floodplain habitats will be widespread (about 80 ac will be available at Escalante SWA at flows greater than 8,000 cfs), but duration of widespread flooding will be brief. Quiet water habitats will be available for use by adult endangered fish. Wide-spread areas with clean substrates should provide habitat needed for maximum reproductive success of Colorado pikeminnow and increased primary and secondary production.
Moderately Wet: 10-30% exceedance	≥8,070 cfs (Q_c) 40-60 d ≥14,350 cfs (Q_b) 10-20 d 1-d peak of 14,350-16,000 cfs	The median level for significant motion is reached or exceeded in the river, creating and maintaining important habitats for Colorado pikeminnow and razorback sucker in large areas of the river. Gravel is flushed from pools, creating important wintering habitat for both s8ecies. Floodplains are extensive for a brief period (about 20 ac at Escalante SW A at 14,000 cfs); river flows exceeding 8,000 cfs will provide floodplain habitat at Escalante SWA and surrounding areas to provide quiet, warm-water habitat for growth and survival of larval razorback sucker. Wide-spread areas with clean substrates should provide habitat needed or maximum reproductive success of Colorado pikeminnow and increased primary and secondary production.

Hydrologic Category	Magnitude and Duration	Discussion! Anticipated Effect
Spring Peak Flow		
Wet: 0-10% exceedance	≥8,070 cfs (Q_c) 60-100 d ≥14,350 cfs (Q_b) 15-25 d 1-deakof 15,000-23,000 cfs	The median level for significant motion is reached or exceeded in the river, creating and maintaining important habitats for Colorado pikeminnow and razorback sucker in large areas of the river. Braided channels are maintained, creating complex areas with a variety of habitats. Gravel is flushed from pools, creating critical wintering habitat for both species. Floodplains are extensive for two weeks (about 20 ac at Escalante SWA at 14,000 cfs); river flows exceeding 8,000 cfs will provide floodplain habitat at Escalante SWA and surrounding areas for an extended period to provide quiet, warm-water habitat for growth and survival of larval razorback sucker.
Summer Through Winter Base Flow		
Dry: 90-100% exceedance	≥750- ≥1,050 cfs	Flows should gradually decline from peak runoff, but a minimum of 1,050 cfs should be provided during the adult migration and larval drift periods from about June through July (Dry) or August (Moderately Dry). This flow provides access to and from the fish passage at Redlands Diversion Dam and provides pool and slow-run habitats through out the Gunnison River. During periods of drought, river flows may decrease below 1,050 cfs after spawning migrations and larval drift are completed, but only after careful analysis of water availability an consultation with Service biologists. Flows downstream from Redlands
Moderately Dry: 70-90% exceedance	≥750- ≥1,050 cfs	Diversion Dam should decline by no more than 100 cfs/d during the transition between 1,050 cfs and the target flow. Movement to and from the Redlands Diversion Dam will be significantly restricted, and pool and slow run habitats will be limited below the dam. However, endangered fish restrict movements in autumn and winter, and adequate pool and slow run habitat (preferred winter habitat for Colorado pikeminnow and razorback sucker) is available in other reaches. Gradually reducing flows will allow endangered fish to leave the 2.5-mi reach and prevent stranding. Base flows should be maintained as a minimum until initiation of runoff the following year.
Average Dry: 50-70% exceedance Average Wet: 30-50% exceedance	>1,050-2,000 cfs	Flows should gradually decline from peak runoff to the target flows by about August (Average Dry and Average Wet) or September (Moderately Wet and Wet). Access to fish passage at Redlands Diversion Dam is provided during migration periods. Further, adequate flows are available to provide year-round habitat in the 2.5 mi of the Gunnison River downstream from the Dam. A wide range of habitats are available in the entire
Moderately Wet; 10-30% exceedance Wet: 0-10% exceedance	1,500-2,500 cfs	Gunnison River when flows fall within the target ranges. Stable flows provide warm, quiet-water habitats along the shorelines of the river. Base flows should be maintained as a minimum until initiation of runoff the following year.

Moderately Dry.—Flows equal to, or greater than, 8,070 cfs are recommended to occur between 0 and 10 d in this category. Over the long term, flows exceeding 8,070 cfs should occur in at least some years that fall into this category in order to improve conditions according to Pitlick et al. (1999) guidelines. Flows should reach at least 2,600 cfs in years when ½ bankfull discharge is not reached and sufficient water is available. Very little in-channel habitat maintenance will occur unless flows exceed 8,070 cfs. No floodplain habitat will be provided in this category. However, the rising and falling river associated with even a small peak will provide environmental cues that the endangered fishes use for spawning.

Average Dry.—Flows should reach 8,070 cfs for 10 to 15 d. Median initial motion is reached that will provide some cleaning of cobble and gravel bars in the majority of the river. Productive bottomlands downstream from Delta begin to flood at this level, but habitat is still limited. Most of the flooded habitat at this level is upstream from Escalante SW A, but about 80 ac of flooded habitat will occur there as well. However, duration of these productive habitats will be short at this flow.

Average Wet.—River flows should equal or exceed 8,070 cfs for 20 to 25 d and should equal or exceed 14,350 cfs for 2 to 3 d. Median significant motion for the Gunnison River is reached at 14,350 cfs. Removing fine sediments from pools and runs will provide appropriate substrates for maximization of primary and secondary production in these dominant habitats. It also ensures that adequate pool habitat is available for adult Colorado pikeminnow and razorback sucker during the rest of the year. Milhous (1998) recommended that river-wide flushing should occur 50% of the time, which corresponds to this hydrologic category.

Flooded bottomlands become important at this level, with flooded habitats developing at severallocatiol1s between Delta and Escalante SW A. About 200 ac of flooded bottomland is available in Escalante SW A at 14,000 cfs. Total flooded acreage there could be increased to about 240 ac by removing a dike that prevents water from entering some low-lying areas. Other flooded habitats will exist at this flow, but the total surface area of habitat is not quantified at sites other than Escalante SWA. Duration of large areas of floodplain habitat will be short, but will provide opportunity for adult Colorado pikeminnow and razorback suckers to utilize the quiet water habitat to feed and rest out of the main river channel. Floodplain duration will probably not be sufficient to benefit larval razorback suckers except in flooded tributary mouths or other smaller habitats along the river margins.

Moderately Wet.—Flows should equal or exceed 8,070 cfs for 40 to 60 d and should equal or exceed 14,350 cfs for 10 to 20 d in this category. Widespread channel maintenance should occur at these levels, maintaining pool and side channel habitats and cleansing cobble and gravel bars throughout the river. To ensure natural variability among years, a 1-d peak flow should be between 14,350 and 16,000 cfs (reached within this category since Blue. Mesa Reservoir was closed) when sufficient water is available to do so.

Flooded bottomland habitat increases to about 260 ac in Escalante SW A at a river flow of 16,000 cfs. With a peak flow of this magnitude, duration of floodplain habitats will be sufficient to provide productive habitats for YOY razorback suckers long enough for them to get a good start on growth before reentering the river when flows subside. Exceeding 8,070 cfs for 40 d should provide flooded habitat long enough to benefit larval razorback sucker at Escalante SW A. Flooded bottomlands will also occur at other sites along the Gunnison River, but total surface area at these sites is not quantified.

Wet.—River flows should exceed 8,070 cfs for 60 to 100 d and should exceed 14,350 cfs for 15 to 25 d. This will provide widespread channel maintenance in the Gunnison River. To ensure natural variability among years, the 1-d peak flow should fall between 15,000 and 23,000 cfs when sufficient water is available to do so; peak flows have fallen within this range since Blue Mesa Reservoir was closed. Flooded bottomland habitat should be widely available at Escalante SW A and at other locations near Delta. The duration of flows greater than 8,070 cfs should provide quiet, warm-water long enough to provide considerable benefits to support growth of larval razorback suckers.

B-1.2 Base Flows

Base-flow recommendations for the different hydrologic conditions are presented in TableB-1 as ranges of flows over the summer, autumn, and winter. The base-flow period begins after spring runoff is completed and continues through initiation of spring runoff the following year, depending on inflow to the Gunnison River basin. Flows should remain within the ranges specified, but the upper and lower limits are not intended to be targets. Natural variation occurred within the base-flow period and should be used to direct flows based on water availability. The range of allowable flows is not intended to restrict natural variation. Further, the onset of the base-flow period varied considerably - beginning as early as late June in dry years or as late as September or October in wet years. Therefore, base flow recommendations are presented for different time periods depending on hydrological category. No specific recommendations are presented for the transition between recommended peak flows and the recommended base flows. Flows during the transition period will be largely dependent on declining flows in the tributaries to the Gunnison River. Any modifications in releases from Crystal Reservoir should conform to currently accepted ramping rates (300-500 cfs/d at flows >5,000 cfs and 10% per day at flows >5,000 cfs).

Although base flows may vary among years and hydrologic conditions, a minimum flow of at least 1,050 cfs should be maintained at the USGS gauge near Grand Junction during summer, autumn, and winter in all but dry and moderately dry years. This flow approximates the lowest flow measured by McAda and Fenton (1998) - 981 cfs - and maximizes the amount of pool habitat in the Gunnison River. Pools are preferred habitat for adult Colorado pikeminnow and razorback sucker. Also, flows exceeding 950 cfs prevent fine sediments from settling in riffles which might smother eggs and larvae of endangered fishes. A flow of 1,050 cfs also roughly corresponds to providing a minimum of 300 cfs downstream from Redlands Diversion Dam (based on a senior water right of 750 cfs) and provides access for migrating fish to the fishway that was recently built there.

During dry and moderately dry years, flows may decrease below 1,050 cfs after the Colorado pikeminnow migration period when doing so would enhance the chances of supplementing peak flows in the upcoming spring and/or providing minimum flows of 300 cfs below Redlands Diversion Dam during the following migration period. However, this reduction should only occur after careful analysis of available water supplies and consultation with Service biologists. Based on estimates extrapolated from McAda and Fenton (1998), pools and slow runs will still be adequate to provide some habitat for Colorado pikeminnow and razorback sucker in the Gunnison River upstream from Redlands Diversion Dam. However, the 2.5-mi reach downstream from Redlands Diversion Dam would experience severe dewatering at this level and endangered fish would be forced to leave this short reach of critical habitat. When possible, flows should decline by ~100 cfs/d during this transition period to prevent stranding endangered fish in the reach. Endangered fish will be able to find adequate wintering habitat downstream in the Colorado River during these extreme conditions. Duration of flows <1,050 cfs should be kept to an absolute minimum, and monitoring should be done to evaluate the effects of these extremely low flows.

The base-flow recommendations are based on the same hydrological categories as the recommendations for peak flows. However, it is recognized that water availability may change as the seasons progress depending on precipitation. Adjustments may be necessary if water availability changes dramatically during the base-flow period based on input from a technical team to be formed to implement these recommendations. During dry and moderately dry years, base flows may persist through late winter and early spring. Recommendations allow for increasing flows during that period, but the target for base flows should continue to be met. During extremely dry years (as occurred in 2002), the technical team should consider water availability and make decisions on when flows downstream from Redlands fishway are most important; water may need to be conserved for critical migration periods. Downstream flows may be reduced, or even stopped briefly, to ensure that at least some water is available when needed. Specific recommendations for the different hydrologic categories appear in Table B-1.

B-2.0 Flow Recommendations for the Colorado River Downstream from the Gunnison River

The following information reiterates the spring peak-flow recommendations described in Table B-2 in context with the amount of in-channel habitat maintenance expected. Recommended base-flow conditions for summer, autumn, and winter are also described to provide habitat for the endangered fishes throughout the year.

Table B-2. Flow recommendations for the Colorado River; measured at the USGS gauge near the Colorado Utah state line (09163500).

Hydrologic Category	Magnitude and Duration	Discussion/Anticipated Effect
Spring Peak.Flow		
Dry: 90-100% exceedance	1-d peak of 5,000-12,100 cfs	No channel maintenance will occur in this category. No flooded bottomlands will be provided, but some inundation of tributary mouths may occur. However, a small peak will provide spawning cues for Colorado pikeminnow, razorback sucker, and humpback chub.
Moderately Dry: 70-90% exceedance	1-d peak of 9,970-27,300 cfs ≥18,500 cfs (Q_c) 0-10 d	No channel maintenance will occur unless the threshold flow of 18,500 cfs is reached. However, the threshold flow should be reached during at least some years within this category in order to improve main channel habitats (Pitlick et al. 1999). Some warm quiet-water habitats will be provided for growth and gonad maturation of endangered fish. The backwater at Walter Walker SWA will provide some of this quiet habitat
Average Dry: 50-70% exceedance	≥18,500 cfs (Q_c) 20-30 d 1-d peak of 18,500-26,600 cfs	Initial motion is reached so some in-channel scouring of gravel and cobble bars will occur. Areas with clean substrates or egg deposition and incubation should provide habitat needed for reproduction of Colorado pikeminnow, razorback sucker, and humpback chub, and increased primary and secondary production. Significant motion is not reached, so maintenance of major habitat features within the channel (e.g. pools, runs) will be limited. Some floodplain inundation will occur; therefore, some warm, quiet-water habitats will be available early in the year for growth and gonad maturation of razorback sucker and Colorado pikeminnow.
Average Wet: 30-50% exceedance	≥18,500 cfs (Q_c) 30-40 d ≥35,000 cfs (Q_b) 6-10 d 1-d peak of ≥35,000 cfs	Significant motion is reached, therefore, in-channel habitats used by endangered fish will be maintained in important river reaches; channel narrowing will be slowed or prevented. Flooding in and around Walter Walker SWA will provide important floodplain habitats, but the extent of available habitat is not known. Widespread areas with clean substrate should provide habitat needed for maximum reproductive success of Colorado pikeminnow, razorback sucker and humpback chub, and increased primary and secondary production.
Moderately Wet: 10-30% exceedance	≥18,500 cfs (Q_c) 50-65 d ≥35,000 cfs (Q_b) 15-18 d 1-d peak of 35,000 -37,000 cfs	Significant motion is reached, creating and maintaining important habitats for Colorado pikeminnow and razorback sucker in wide areas of the river. Floodlain habitats will be extensive, but the surface area of those habitats is not quantified. The duration of flows greater than 35,000 cfs will ensure that floodplains are available to improve growth and survival of yoy razorback suckers.
Wet: 10% exceedance	≥18,500 cfs (Q_c) 80-100 d ≥35,000 cfs (Q_b) 30-35 d 1-d peak of 39,300-69,800 cfs	Median significant motions is exceeded in the Colorado River for an extensive time period, creating and maintaining important habitats for Colorado pikeminnow and razorback sucker in wide areas of the river. Vegetation encroachment will be halted and reversed in wide areas of the river. Floodplain habitats will be extensive, but surface area of those habitats is not quantified. The duration of flows exceeding significant motion will ensure that yoy razorback sucker will be able to utilize floodplain habitats for sufficient time to increase their growth and survival.

Hydrologic Category	Magnitude and Duration	Discussion/Anticipated Effect
Summer Through Winter Base Flow		
Dry: 90-100% exceedance	≥1,800 cfs	Backwaters for yoy Colorado pikeminnow will be available, but not at maximum number or surface area. Low stable flows will provide for maximum growth of yoy Colorado pikeminnow.
Moderately Dry: 70-90% exceedance	2,500-4,000 cfs	Backwaters in nursery areas should be maximized in both quantity and surface area. Stable flows will provide for constant habitats and maximum warming of water for growth of Colorado pikeminnow. Stable flows will also provide a variety of in-channel habitats for use by juveniles and adults of all endangered species. Pools and slow run habitats will be maximized for winter use of Colorado pikeminnow and razorback sucker. Pools and eddy habitats will be maximized in canyon reaches for humpback chub.
Average Dry: 50-70% exceedance		
Average Wet: 30-50% exceedance	3,000-4,800 cfs	
Moderately Wet: 10-30% exceedance		
Wet: 10% exceedance	3,000-6,000 cfs	Backwaters will be fewer and smaller than at lower flows, but they will still be available for yoy Colorado pikeminnow to use.

B-2.1 Spring Peaks

As described in section 4.2, peak flows for the Colorado River are measured at the USGS river gauge near the Colorado-Utah state line. Flows from the Gunnison River will contribute a substantial volume of water to peak flows in the Colorado River, but it is unlikely that peak flows from both the Gunnison and Colorado rivers will match exactly. Aspinall Unit releases should occur between May 15 and June 15 and timed to match peak flows in the North Fork of the Gunnison River to contribute the maximum volume possible to the Colorado River. Specific flow recommendations for each hydrologic category are presented below and summarized in Table B-2. These flows correspond to prior recommendations for channel maintenance (Pitlick et al. 1999). There are no specific flow recommendations for floodplains; however, benefits are expected when floodplain habitat is created.

The Colorado River immediately upstream from the confluence with the Gunnison River (15-Mile Reach) is currently operating under a programmatic biological opinion (PBO) that allows for additional water development in the upper subbasin provided that progress is made toward recovery of the four endangered fishes. The PBO provides for coordinated operation of upstream reservoirs to assist in meeting flow recommendations made for the 15-Mile Reach. Ultimately, flows in the lower reaches of the upper Colorado River will depend on the combination of modified flows in the Gunnison River and flows currently provided for under the PBO. Until there is more definitive evidence as to where and how much water is needed for recovery, recommendations at the Colorado-Utah state line should not be used to override agreements already in place for the upper Colorado River.

Dry.—Flows equal to ½ bankfull or bankfull discharge are not required in this category. However, instantaneous peak flows ranging between 5,000 cfs and 12,100 cfs have occurred in this category since Blue Mesa Reservoir was closed. Instantaneous peak flows should be in that range when water availability is sufficient. This 1-d peak will ensure natural variation among years. Flows of this level will do very little to maintain in-channel habitats; however, the rising and falling river associated with even a small peak will provide some of the environmental cues that endangered fish use to prepare for spawning. No flooded bottomland habitat will be provided anywhere in the river.

Moderately Dry.—Flows equal to or greater than 18,500 cfs (Q_{50}; ½ median bankfull discharge) are recommended to occur between 0-10 d in years falling into this category. Peak flows should exceed this level during at least some years to ensure that habitat is improved according to recommendations by Pitlick et al (I999). Peak flows have ranged 9,970-27,300 cfs since Blue Mesa Reservoir was completed and should continue to fall within this range for at least 1 d when water availability is sufficient to do so. Peak flow should be at least 9,970 cfs when median ½ bankfull flow can not be reached. No channel maintenance will be accomplished unless ½ bankfull flow is reached. No flooded bottomland habitat is provided anywhere in the river, but some quiet-water habitats will be provided in flooded tributary mouths to provide warmer water for gonad maturation of endangered fish. The backwater area at Walter Walker SWA will provide a limited amount of flooded habitat.

Average Dry.—River flows should reach or exceed 18,500 cfs for 20 to 30 d in this category. To ensure variability among years within this category, the highest 1-d peak flow should fall within the 18,500 to 26,600 cfs range when sufficient water is available. In--channel scouring of gravel and cobble bars will begin in much of the river. If flows approach 26,600 cfs, scouring will be widespread and large areas of clean substrates for egg deposition and incubation should provide for maximum reproductive success of Colorado pikeminnow and increased primary and secondary production. Floodplain inundation will increase, but will be limited in duration. However, warm, quiet-water habitats will be available early in the year for growth and gonad maturation of razorback suckers and Colorado pikeminnow.

Average Wet.—River flows should reach or exceed 18,500 cfs for 30 to 40 d and should exceed 35,000 cfs for 6 to 10 d. At these flows, the median level for significant motion will be exceeded and scouring of cobble and gravel bars will be widespread. Scouring of pools, runs, and side channels will occur, maintaining in channel habitats for adult Colorado pikeminnow and razorback sucker. Clean cobble and gravel substrates should provide for maximum reproduction of Colorado pikeminnow and increased primary and secondary productivity. Flooding in and around Walter Walker SWA will provide important floodplain habitats, but the extent of available habitat is not known. Duration of flooding will be short, but should give larval razorback sucker a spurt of growth before they leave the floodplain and enter the main channel.

Moderately Wet.—River flows should exceed 18,500 cfs for a total of 50 to 65 d and should exceed 35,000 cfs for 15 to 18 d. To ensure variability among years, the 1-d peak flow should be between 35,000 and 37,500 cfs when water availability is sufficient. The median level for significant motion will be exceeded throughout the river, creating and maintaining important habitats for Colorado pikeminnow and razorback sucker in wide areas of the river. Floodplain habitats will be extensive, but the surface area of those habitats is not quantified. However, quiet, warm-water habitats should be available in sufficient area and duration to improve growth and survival of larval razorback sucker.

Wet.—River flows should exceed 18,500 cfs for 80 to 100 d and should exceed 35,000 cfs for 30 to35 d. Instantaneous peak flows should be between 39,300 and 69,800 cfs, which is the range of peak flows that have occurred since Blue Mesa Reservoir was closed. To ensure variability among years, the 1-d peak flow should be within that range when water availability is sufficient. The long duration at flows exceeding significant motion will ensure that extensive channel maintenance occurs throughout the Colorado River. Vegetation encroachment will be reduced and pools, runs, and side channels will be reworked. Complex river-channel segments that provide important habitats for Colorado pikeminnow and razorback sucker will be created and maintained. Floodplain habitats will be extensive (although unquantified) and will be available for sufficient duration to benefit growth and survival of larval razorback suckers.

4.4.2 Base Flows

Base-flow recommendations for the different hydrologic conditions are presented in Table B-2 as ranges of flows over the summer, autumn, and winter. The base-flow period begins after spring runoff is completed and continues through initiation of spring runoff the following year, depending on inflow to the upper Colorado River subbasin. Flows should remain within the bounds specified, but the upper and lower limits are not intended to be targets. Natural variation occurred within the base-flow period, and the range of allowable flows is not intended to restrict that variation. Further, the onset of the base-flow period varied considerably—beginning as early as late June in dry years or as late as September or October in wet years. Therefore, base-flow recommendations are presented for different time periods depending on hydrological category. No specific recommendations are presented for the transition between recommended peak flows and the recommended base flows. Flows during the transition period will be largely dependent on declining flows in the many tributaries to the Colorado River.