STUDY PLAN

To Evaluate Effects of Aspinall Unit Operations to Benefit Habitat and Recovery of Endangered Fishes in the Gunnison and Colorado Rivers

Photo by Lee Gelatt

Final May 3, 2011

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Prepared by

Aspinall Unit Study Plan *ad hoc* Committee

Coordinated by

Upper Colorado River Endangered Fish Recovery Program

Final
May 3, 2011

Preface

The Upper Colorado River Endangered Fish Recovery Program (Recovery Program) has completed this Aspinall Study Plan in fulfillment of its commitment identified in the U.S. Fish and Wildlife Service's Gunnison River Programmatic Biological Opinion. However, significant uncertainty remains regarding the U.S. Bureau of Reclamation's related and ongoing NEPA compliance of their Aspinall Unit Operations. Recovery Program partners have a vested interest in that NEPA process, therefore, the Recovery Program will revisit and revise as needed this Study Plan upon issuance of Reclamation's Aspinall Unit Operations Record of Decision.

ACKNOWLEDGEMENTS

Aspinall Study Plan *ad hoc* Committee

Brandon Albrecht	Environmental Groups
Shane Capron	Western Area Power Administration
Patty Gelatt	U.S. Fish and Wildlife Service
Sherman Hebein	Colorado Division of Wildlife
Kirk LaGory	Argonne National Laboratory
Steve McCall	Bureau of Reclamation
Barb Osmundson	U.S. Fish and Wildlife Service
Doug Osmundson	U.S. Fish and Wildlife Service
Tom Pitts	Upper Basin Water Users Representative
Michelle Shaughnessy	U.S. Fish and Wildlife Service
Dave Speas	Bureau of Reclamation
Melissa Trammell	National Park Service

Support Staff

Tom Chart	Upper Colorado River Endangered Fish Recovery Program
Angela Kantola	Upper Colorado River Endangered Fish Recovery Program

Reviewers of Draft Study Plan

Leslie James	Colorado River Energy Distributors Association
Bart Miller	Western Resource Advocates
Tom Pitts	Upper Basin Water Users
Mike Roberts	The Nature Conservancy

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EXECUTIVE SUMMARY

The 2009 *Final Gunnison River Basin Programmatic Biological Opinion* (PBO) identified this Study Plan as one component of nondiscretionary terms and conditions associated with reasonable and prudent measures to avoid and minimize the impacts of incidental take of the four listed Colorado River fishes: Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*). This Study Plan was developed by an *ad hoc* Committee, which included representatives from the Bureau of Reclamation, Western Area Power Administration, U.S. Fish and Wildlife Service, National Park Service, environmental groups, Upper Basin Water Users, and the Colorado Division of Wildlife. Development of the Study Plan was coordinated by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program), and benefited greatly from input by members of the Biology and Water Acquisition committees and principal investigators conducting studies in the Colorado River Sub-basin.

The purpose of this Study Plan is to identify and recommend to the Recovery Program those monitoring and/or research projects necessary to evaluate effects of the proposed operations of the Aspinall Unit described in the biological opinion, to determine how those operations improve habitat and contribute to recovery of the endangered fishes, and to evaluate effects on critical habitat in the Gunnison River and in the Colorado River from the Gunnison River confluence to Lake Powell. Those projects include studies to evaluate the anticipated effects of implementing the proposed operations, including potential adverse effects identified in the Biological Assessment and Biological Opinion on Aspinall Unit operations, and studies to examine recognized uncertainties regarding impacts and effects that are inherent in the recommendations. Objectives of this Study Plan are to: (1) demonstrate how results of ongoing Recovery Program studies contribute to evaluating the Aspinall Unit operations; (2) identify deficiencies in monitoring or research, and prioritize and recommend to the Recovery Program revised ongoing or new studies to fill important information needs; (3) develop and recommend a timeline and approach for periodically assessing implementation and evaluation of the Aspinall Unit operations; and (4) recommend to the Recovery Program modifications to the Recovery Implementation Program Recovery Action Plan (RIPRAP) to implement Study Plan recommendations in order to assure compliance with the PBO.

The methodology used to develop the Study Plan was as follows. Anticipated effects and uncertainties associated with a change in operations at the Aspinall Unit were gleaned from a variety of authority or guidance documents. With input from principal investigators, ongoing or pending studies were reviewed to determine how well the anticipated effects or uncertainties have been (or were being) addressed. Information needs were then identified and categorized into focus areas. New studies (with suggested revisions to the RIPRAP) were identified.

The Study Plan identifies 58 anticipated effects or uncertainties associated with implementation of the Aspinall Unit operations. Unfortunately, none of these is fully addressed via recently completed, ongoing, or pending Recovery Program studies. Seventeen (11 on the Gunnison River; 6 on the Colorado River) of the 58 uncertainties were ranked as highest priority for evaluating the Aspinall Unit operations. These 17 uncertainties were grouped into the following "focus areas": (1) sediment transport; (2) main channel fish habitat; (3) floodplain

inundation in the (a) Gunnison and (b) Colorado rivers; and (4) fish community monitoring in the (a) Gunnison and (b) Colorado rivers. The remaining 41 uncertainties ranked medium or low, and some fell into two additional focus areas: (1) temperature and hydrology tradeoffs in the Gunnison River; and (2) related policy issues throughout both river basins.

An integrated approach is implicit to the implementation of this Study Plan. Many anticipated effects and uncertainties are interrelated, and specific study designs and results will need to be integrated to gain a better understanding of the effects of the Aspinall Unit operations. This integrated approach is necessary to better understand dynamics of physical and biological resources. Consideration will be given to tradeoffs among potential effects. For example, peak- and base-flow magnitudes and temperatures that maximize benefits to endangered fish may also benefit nonnative species that in turn prey upon and compete with endangered forms.

Study results would be used to evaluate and, if deemed appropriate, potentially revise the Aspinall Unit operations in a manner consistent with an adaptive-management approach and Reclamation's Final EIS and Record of Decision. Any refinements in Aspinall operation are expected to be within the scope of the current proposed action. If refinements outside the limits of the proposed action were proposed, additional NEPA and ESA compliance would be required before they could be implemented.

1.0 INTRODUCTION

1.1 Purpose and Objectives

The 2009 *Final Gunnison River Basin Programmatic Biological Opinion* (PBO) identified this Study Plan as one component of nondiscretionary terms and conditions associated with reasonable and prudent measures to avoid and minimize the impacts of incidental take of the four listed Colorado River fishes: Colorado pikeminnow (*Ptychocheilus lucius*), humpback chub (*Gila cypha*), razorback sucker (*Xyrauchen texanus*), and bonytail (*Gila elegans*). The purpose of this Study Plan is to identify and recommend to the Upper Colorado River Endangered Fish Recovery Program (Recovery Program) those monitoring or research projects necessary to evaluate effects of the proposed operations of the Aspinall Unit (Gunnison River, Colorado) described in the PBO, to determine how those operations improve habitat and contribute to recovery of the endangered fishes, and to evaluate effects on critical habitat in the Gunnison River and in the Colorado River from the Gunnison River confluence to Lake Powell. Those projects include studies to evaluate the anticipated effects of implementing the proposed operations, including potential adverse effects identified in the Biological Assessment and Biological Opinion on Aspinall Unit operations, and studies to examine recognized uncertainties regarding impacts and effects that are inherent in the recommendations. Objectives of this Study Plan are to:

1. demonstrate how results of recently completed, ongoing, or pending Recovery Program monitoring or research projects (studies) are being or will be used to evaluate the Aspinall Unit operations;

2. identify deficiencies in monitoring or research studies, and prioritize and recommend to the Recovery Program revised ongoing or new studies to satisfy important information needs[1];

3. develop and recommend a timeline and approach for periodically assessing implementation and evaluation of the Aspinall Unit operations; and

4. recommend to the Recovery Program modifications to the Recovery Implementation Program Recovery Action Plan (RIPRAP) to implement Study Plan recommendations in order to assure compliance with the PBO.

The Study Plan was developed under the principles of adaptive management in which monitoring and research results are used to revise ongoing studies and guide new studies. The Study Plan was developed by an *ad hoc* Committee of representatives from the Bureau of Reclamation, Western Area Power Administration, U.S. Fish and Wildlife Service (Service), National Park Service, environmental groups, Upper Basin water users, and the Colorado Division of Wildlife. Development of the Study Plan was coordinated by the Upper Colorado River Endangered Fish Recovery Program (Recovery Program), and benefited greatly from input

[1] Information needs were defined as those topics considered relevant to anticipated effects or uncertainties that had not been addressed in previous or ongoing studies.

by members of the Biology and Water Acquisition committees and principal investigators conducting studies in the Colorado River Sub-basin.

This Study Plan identifies information needs to implement and evaluate the Aspinall Unit operations (Figure 1). Those operations are described in the *Programmatic Biological Assessment: Gunnison River Basin, Colorado: Operations of the Wayne N. Aspinall unit, operations and depletions of existing Reclamation projects, and operations and depletions of non-Federal water development* (PBA; Reclamation 2008) and the PBO. The Study Plan is not intended to evaluate if operation of the Aspinall Unit is meeting the proposed action, nor does it identify specific annual dam operations. Those determinations will be conducted through other interagency processes (e.g. the Service's annual Sufficient Progress Review, Aspinall Working Group meetings).

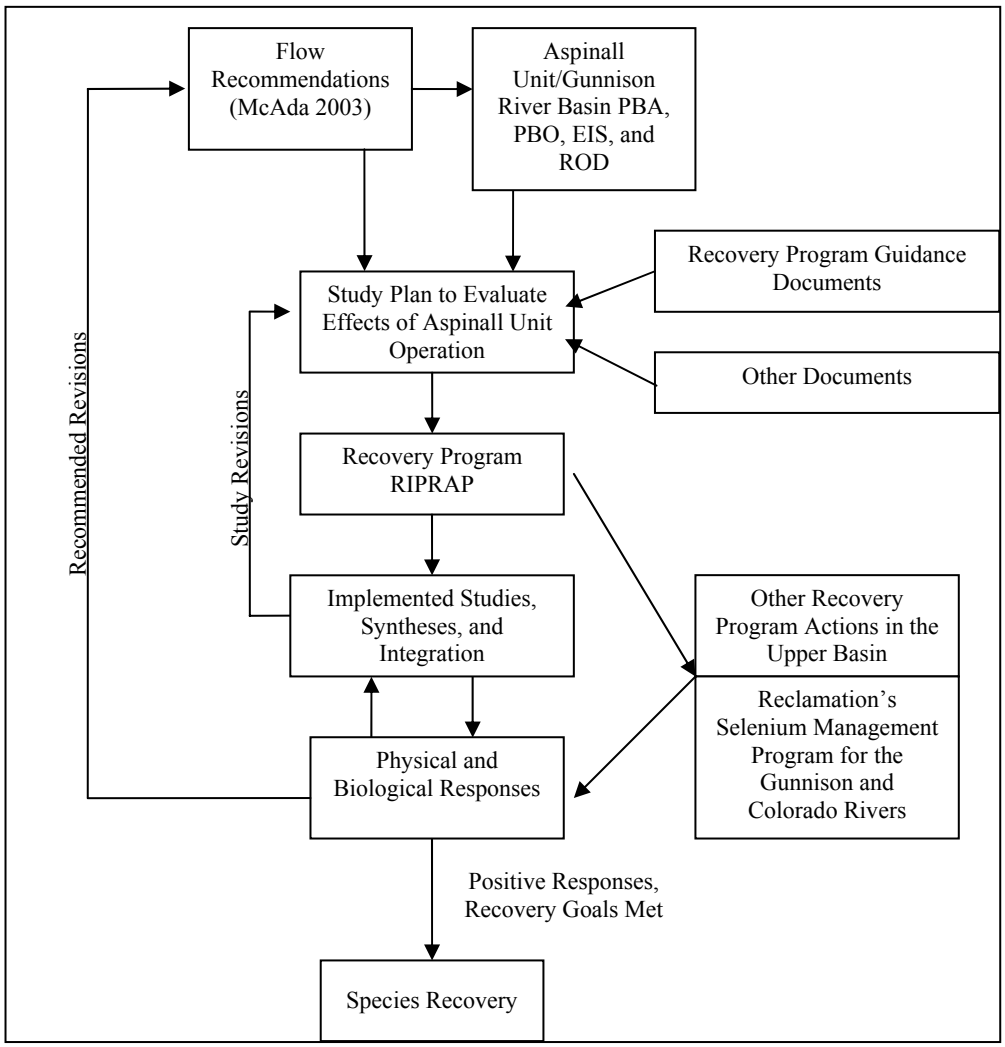

Figure 1. Process for evaluating the effects of the proposed operations of the Aspinall Unit.

Information feedback into the revision process occurs both at the project level, in which individual projects are revised to address information needs identified from information

syntheses, and at the flow recommendation level, in which response of fish populations guides the revision process.

The Study Plan and Aspinall Unit operations are parts of the efforts to achieve species recovery in the Upper Colorado River Basin. Results from studies recommended in this Study Plan will be used to evaluate and, if deemed appropriate, potentially revise the Aspinall Unit operations in a manner consistent with adaptive-management approach as discussed in the EIS and Record of Decision. Such revisions approved by the Service and the Recovery Program could be implemented directly into the annual operating plan. It is expected that any refinements in operation of the Aspinall Unit would be within the scope of the current proposed action. In the event that revisions are proposed that are outside the limits of the proposed action, additional NEPA and ESA compliance would be required before such revisions could be implemented.

Implicit in the Aspinall Unit operations is the need for research and monitoring as part of the adaptive management approach. In addition to the need to collect real-time biological and physical data each year to refine how the recommendations are implemented, there is a need to conduct additional research and long-term monitoring of fish responses to address the identified uncertainties (Figure 1). The flow recommendations suggested that the collection of additional data on endangered fishes and their habitats should focus on the evaluation and possible modification of those recommendations by following an adaptive management process. Research should test well-defined hypotheses.

Evaluation of Aspinall Unit operations in the Gunnison and Colorado rivers should include an assessment of overall responses by the endangered fish populations. These responses include many aspects of the life histories of these species (e.g., reproduction, survival of young, recruitment to adults, etc.), with establishment and maintenance of self-sustaining populations as the goal of recovery (U.S. Fish and Wildlife Service 2002a, 2002b, 2002c, 2002d). Responses by various life-history aspects to Aspinall Unit operations may be observable over a short time span, but because the endangered fishes are long-lived, population responses (i.e., self-sustainability) may be observable only over longer time spans. Short-term monitoring should focus on responses of specific life history aspects, but long-term monitoring must detect differences in population sizes and sustainability. Any proposed revisions to Aspinall Unit operations should be based on sound scientific information regarding the current status of populations, sediment resources, and other relevant ecological factors.

1.2 Authority and Guidance Documents

1.2.1 Authority Documents

The following describes each of the "authority" documents that led to the development of this Study Plan, and the principal anticipated effects or uncertainties associated with implementation of the Aspinall Unit operations identified by each document.

Flow Recommendations for the Colorado and Gunnison Rivers

In 2003, the Recovery Program issued *Flow Recommendations to Benefit Endangered Fishes in the Colorado and Gunnison Rivers* (McAda 2003). Based on results from studies conducted as part of the Aspinall Unit investigations primarily in the 1990's, the report developed recommendations to provide annual and seasonal patterns of flow in the Gunnison River and the Colorado River (downstream from their confluence) to enhance populations of the four endangered fish (Figure 2).

Flow recommendations for the Colorado and Gunnison rivers were developed using a lines-of-evidence approach similar to that used to develop flow recommendations for the Green River (Muth et al. 2000). Recommendations presented in that report were intended to address recovery elements identified by the Recovery Program. Information on each endangered fish species was used to develop integrated Aspinall Unit operations for the Gunnison River and Colorado River downstream of the Gunnison River confluence.

The goal of these recommendations is to provide the annual and seasonal patterns of flow in the Gunnison River and in the Colorado River downstream from their confluence to enhance populations of the four endangered fishes. The specific objectives were developed to create and maintain the variety of habitats used by all life stages of the four endangered fishes:

- Provide habitats and conditions that enhance gonad maturation and provide environmental cues for spawning movements and reproduction;

- Form low-velocity habitats for adult staging, feeding, and resting areas during snowmelt runoff;

- 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;

- Restore and maintain in-channel habitats used by all life stages: (1) spawning areas for adults, (2) spring, summer, autumn and winter habitats used by subadults and adults, and (3) nursery areas used by larvae, YOY, and juveniles; and

- Provide base flows that promote growth and survival of young fish during summer, autumn, and winter.

Because historical river flows were dependent on water availability, flow recommendations were developed for six hydrologic categories that correspond to unregulated April–July inflow based on the 1937–1997 period of record: Dry (90–100% exceedance); Moderately Dry (70–90% exceedance); Average Dry (50–70% exceedance); Average Wet (30–50% exceedance); Moderately Wet (10–30% exceedance); and Wet (0–10% exceedance). Flow recommendations are for the Gunnison River at the USGS river gage near Grand Junction, Colorado (09152500) and for the Colorado River at the USGS river gage near the Colorado-Utah

state line (09163500). Spring peak-flow recommendations for both rivers correspond to specific recommendations by Pitlick et al. (1999) to maintain and improve in-channel habitat in both rivers. Peak-flow recommendations include two components: (1) threshold levels corresponding to ½ bankfull discharge and bankfull discharge and (2) the number of days (duration) that flows should equal or exceed these levels. In addition, recommended durations are presented as a range of days to provide flexibility to river managers.

Anticipated effects of the flow recommendations are listed in Tables 1 and 2. In general, spring flows recommended for the dry categories provide small peaks used as spawning cues by endangered fish, but contribute little to habitat maintenance; spring flows recommended for average categories promote scouring of cobble and gravel bars and provide localized flooding of short duration; and spring flows for the wet categories promote wide-spread scouring of cobble and gravel bars, flushing of side channels, removal of encroaching vegetation, and inundation of floodplain habitats. Base-flow recommendations also vary with hydrologic category and are designed to allow fish movement among river segments and to provide maximum amounts of warm, quiet-water habitats to enhance growth and survival of young endangered fish.

The flow recommendations identified uncertainties associated with their implementation and recognized the importance of managing for unanticipated effects. McAda (2003; pages 4-32 and 4-33) identified the following overarching uncertainties that would need to be addressed during implementation of the flow recommendations:

1. Determination of the amount and location of floodplain habitat necessary for the recovery of the endangered fishes. Development of management plans for those habitats.

2. Determination of the frequency (recurrence interval) and duration (number of days) that flows need to exceed ½ bankfull and bankfull discharge to maintain the suite of habitats required by the endangered fishes.

3. Determination of water availability in the Gunnison River basin, with specific volumes identified for the endangered fishes.

4. Determination of the amount and quality of habitat necessary to maintain populations at levels identified in the recently developed recovery goals for the four species.

McAda (2003; in narrative format beginning on page 4-28) also described a host of related uncertainties and information needs which can be grouped into the following categories:

Biological

1. Restoration of floodplain function to the Gunnison and Colorado rivers is inferred to benefit recruitment of razorback sucker based on information from the Green River. However, adult populations must be reestablished before that hypothesis can be tested in the upper Colorado River sub-basin.

2. The positive relationships between reproductive success of Colorado pikeminnow and humpback chub and peak river flows are based on limited data. The response of these species to the modified flow regime should be assessed.

3. Nonnative fishes that compete with or prey on young Colorado pikeminnow and humpback chub are temporarily reduced following high spring flows, but populations rebound quickly when low-water years occur. Management actions to reduce population size of nonnative fishes through mechanical means have been initiated, but detrimental effects of nonnative fishes must be reduced before full benefits of the recommended flow regime can be realized.

4. Although partial restoration of floodplain function through mimicking a natural hydrograph is hypothesized to benefit the endangered fishes, it may also benefit some nonnative fishes. Studies are underway to evaluate nonnative fish response to floodplain restoration. Results of these studies will guide the Recovery Program as it continues the floodplain restoration program.

5. The relationship between fine sediments and primary and secondary production in the two rivers needs to be further assessed. Long-term studies need to be conducted to evaluate response of periphyton, macroinvertebrates, and other small organisms to a flow regime with a higher frequency of flushing flows. These organisms form the basis of the riverine food web and it remains to be determined whether food availability is limiting abundance of endangered fishes in any or all of the upper Colorado River system.

6. Studies suggest that periodic, channel wide flushing of cobble bars is necessary to maintain habitat; however, the frequency required is unknown.

7. All four endangered fish are long lived therefore to gage population response will require long term monitoring of all their life stages.

8. The recommended flow regime may need to be modified as more information is accumulated and response of the endangered fish is assessed.

Physical / Policy

1. The ability of the Aspinall Unit and the rest of the Gunnison River basin to contribute to the recommended flow regime is uncertain and an analysis of such needs to be completed.

2. Current ramping rates (developed around the coldwater fishery) should be examined to determine if modifications could be made to benefit the endangered fishes.

3. It is uncertain if mimicry of a natural hydrograph will restore riverine habitats sufficiently to recover the four endangered fishes. The flow regime has changed substantially over the last century, and recommendations for level and duration of spring peaks are considerably less than occurred historically. Monitoring of the physical environment should occur to ensure that important habitats continue to be created and maintained.

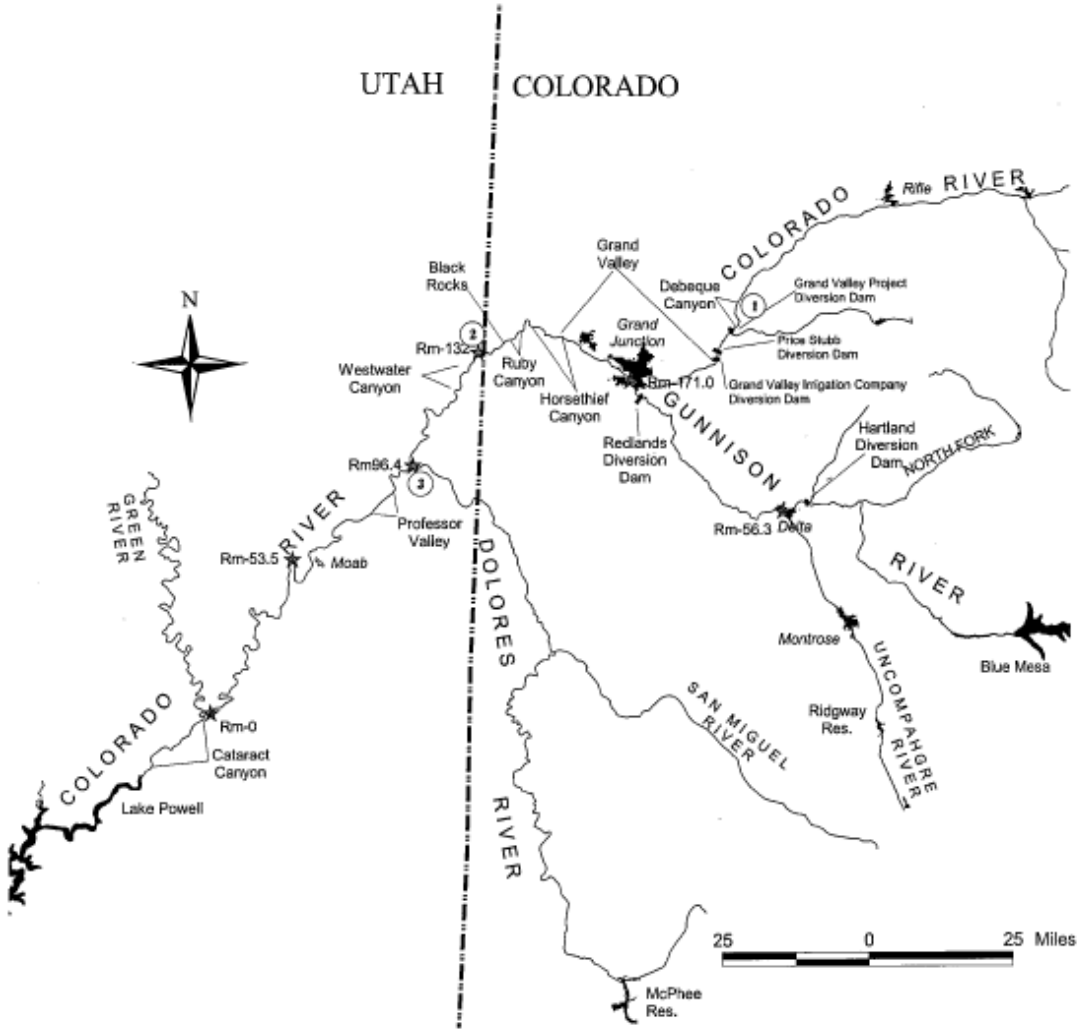

Figure 2. Overview of the upper Colorado and Gunnison rivers. River mile 0 for the Colorado River is the mouth of the Green River and RM 0 for the Gunnison River is its mouth. The Grand Valley portion of the Colorado River is often divided into two reaches because of influences of diversion dams and the Gunnison River: (1) 15-mile reach (Grand Valley Irrigation Company Dam to mouth of Gunnison River, RM 185–171) and (2) 18-mile reach (Gunnison River downstream, RM 171–153).

4. Because of timing and other differences in runoff patterns of the two rivers, it is difficult to predict the effects of flow changes in the Gunnison River on flow patterns of the Colorado River at the Utah-Colorado state line and whether those changes are sufficient to attain recovery.

5. Spring flows may affect private property and may not mesh with the Black Canyon water right

The flow recommendations contained in this report should be implemented using adaptive management. As used here, adaptive management refers to an integrated method for addressing uncertainty in natural resource management. It is an interactive process that not only reduces, but also benefits from uncertainty (Holling 1978). In Uncertainties Section 4.5 of McAda (2003) the author recognized that further investigation and monitoring, or related activities would be needed and cautioned that careful consideration be given to resolving these uncertainties as the flow recommendations are implemented. Effective use of adaptive management will allow for adjustment of these flow recommendations as more information is gained through monitoring.

Biological Assessment and Biological Opinion on Reoperation of the Aspinall Unit

As part of ESA compliance, Reclamation developed the Programmatic Biological Assessment (PBA) for the proposed action of modifying the operation of the Aspinall Unit to achieve the flow recommendations (Reclamation 2008). The PBA determined that the proposed action may adversely affect the four endangered fish species. Included as part of the proposed action was a list of conservation measures developed to offset adverse affects, which were later incorporated into the PBO.

Reclamation's Proposed Action did not adopt verbatim the recommendations described in McAda (2003). This Study Plan has been designed to evaluate the Proposed Action (excerpted from the Service PBO below – please refer to pgs 5-20 in the Service PBO, dated December 4, 2009 [USFWS 2009], for a full description of the Proposed Action and Conservation Measures)

The Proposed Action with respect to Aspinall Unit operations is excerpted from the PBO as follows:

Proposed Action

Aspinall Unit Operations

Reclamation proposes to modify operation of the Aspinall Unit to address flow needs for the endangered fish in the Gunnison and Colorado rivers, while continuing to maintain authorized Unit purposes. The new operation is designed to increase downstream spring peak flows while maintaining moderate base flows. Pursuant to the proposed operating regime, Reclamation will attempt to meet the desired spring peak, minimum duration, and base flow targets at Whitewater and below the Redlands Diversion. The new operation plan has four basic goals:

- *Meet or attempt to meet spring peak targets on the Gunnison River and in concert benefit Colorado River mainstem habitat as outlined in the Flow Recommendations (McAda 2003) (Summary Appendix A);*

- *Meet or attempt to meet minimum duration targets for half bankfull discharge and bankfull discharges pursuant to the Flow Recommendations;*
- *Meet or attempt to meet targets for base flows as outlined in the Flow Recommendations; and*
- *Meet or attempt to meet fish ladder, fish screen, and migration flows at and below the Redlands Water and Power Diversion Dam (Redlands Diversion).*

The new operation plan makes releases that meet or attempt to meet a spring peak target at the Whitewater gage at the time the North Fork of Gunnison River is near its peak (generally May 15 to May 31). Peak targets at Whitewater are based on the May 1 or May 15 "April through July forecast" of Blue Mesa unregulated inflow. The forecast is provided by the National Weather Service through the Colorado Basin River Forecast Center starting in January and is updated twice per month until the end of July. In order to maximize peaks targeted at Whitewater, the proposed action attempts to combine peak Aspinall Unit releases with peak North Fork flows, subject to flood control responsibilities. Therefore, it is not feasible for the proposed operations to specifically attempt to match Gunnison River and Colorado River peaks.

[The length and duration of flows is dependent on the "Year Type" as summarized in PBO Table 1]

Spring peak and duration targets for range of forecasted inflow.

Blue Mesa Forecasted Inflow	*Peak Target @Whitewater*	*Duration of Half Bank (8,070 cfs)*	*Duration of Bankfull (14,350 cfs)*
Acre-feet	*cfs*	*Days*	*Days*
< 381,000	*900*	*0*	*0*
381,000 to 516,000	*2,600 to 8,070*	*0*	*0*
516,001 to 709,000	*8,070*	*10*	*0*
709,001 to 831,000	*8,070 to 14,350*	*20*	*2*
831,001 to 1,123,000	*14,350*	*40*	*10*
> 1,123,001	*14,350*	*60*	*15*

Uncertainties related to the proposed action as presented in the PBO, which reiterated many listed in McAda (2003) include:

- *While relationships among initial motion, significant motion and streamflow are well defined, duration of flows necessary to accomplish habitat work is not completely known. Because flow duration recommendations were developed based on a wet period, the recommended durations require a large volume of water that may not always be available.*

- *Water availability may limit the ability of the Gunnison River to meet the Flow Recommendations under certain conditions.*

- *"…the duration of flows necessary to accomplish in-channel and out-of-channel habitat maintenance objectives is not known."*

- *Because of timing and other differences in runoff patterns of the Colorado and Gunnison rivers, it is difficult to predict the effect of Gunnison River flow changes on the Colorado River.*

- *The trade-off facing Colorado pikeminnow between stream bed maintenance and temperature regime in the Gunnison River is an uncertainty that may need to be evaluated by the Recovery Program.*

- *The Recovery Program may need to evaluate the trade-off between high spring flows and base flows needed during the mid- to late summer to operate Redlands (and, to a lesser extent perhaps, maintain movement of sediment through the system).*

In light of these uncertainties (as well as potential impacts of climate change), the proposed action calls for using adaptive management to respond to new knowledge and using monitoring to evaluate the physical response of the habitat and biological response of the fish to the flow regimes. Adaptive management is a systematic approach for improving resource management by learning from management outcomes. Adaptive management promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become understood. Essentially, the long-term responses of endangered fish to new operations and other Recovery Program actions are uncertain and future monitoring will be needed to make adjustments in implementing operations and the overall Recovery Program.

Although the Aspinall operations were predicted to adversely affect all four fish species and critical habitat, the Service (2009) concluded in their PBO that the proposed action is not likely to jeopardize the continued existence of the four endangered fishes and will not result in the destruction or adverse modification of their critical habitat if reasonable and prudent measures are implemented. Additionally, the PBO identified conservation measures which the action agency agreed to implement to further the recovery of the species under review. The beneficial effects of conservation measures were taken into consideration for determining jeopardy, adverse modification of critical habitat and incidental take analyses. Implementation of the proposed action and reasonable and prudent measures is expected to result in overall beneficial effects to the endangered fishes and their critical habitat in the Gunnison and Colorado rivers.

The implementation of the Recovery Program and the proposed operations of the Aspinall Unit are intended to recover the listed species and minimize impacts of water depletions, therefore, the proposed operations and other recovery action items will also serve as reasonable and prudent measures for minimizing the take that results from the water depletions addressed in the biological opinion. To reduce the level of incidental take associated with water depletions and water quality, the following reasonable and prudent measures (excerpted from the PBO) were developed to minimize take:

1. *Implementation of the proposed action will include an adaptive management process. Reclamation will work through the Recovery Program to implement appropriate monitoring and research studies to test the result of implementing the proposed action. The purpose of adaptive management is to improve the condition of critical habitat for endangered fish and thereby contribute to their recovery. The Service considers the Recovery Program the appropriate science body to develop and implement monitoring and research studies that would address uncertainties associated with the proposed action. In accordance with the Section 7 agreement, Reclamation and the Service will work with the Recovery Program to revise the RIPRAP as necessary to incorporate the approved studies deemed necessary to evaluate the proposed action.*

2. *Reclamation will produce a summary report each year to document annual operations and the information used to develop those operations.*

3. *Reclamation will implement a mechanism (Memorandum of Agreement or similar process) between all appropriate parties to facilitate the development of the Selenium Management Program. This agreement would commit the parties to actively participate in implementation of the program.*

4. *Reclamation will keep the Service apprised of the progress of the Selenium Management Program.*

5. *Water quality in the Gunnison and Colorado Rivers will be monitored under various programs and Reclamation will compile data and report to the Service.*

6. *Biological monitoring developed in coordination with the Recovery Program will be conducted to determine effects to aquatic resources in the Gunnison River and Colorado Rivers.*

7. *Reclamation shall ensure that proposed conservation measures (outlined in the project description), as further refined by these terms and conditions, are formally adopted and implemented.*

To implement RPM (1), the PBO directs Reclamation to work through the Recovery Program technical committees to ***develop a Study Plan to evaluate the effects of the proposed operations of the Aspinall Unit and how it improves habitat and thereby contributes to recovery***. The Study Plan should also include an evaluation of the effects of reoperation on critical habitat in the Colorado River from the Gunnison River confluence to Lake Powell. This document is that Study Plan and it focuses on previously identified anticipated effects or uncertainties related to floodplain inundation, geomorphic processes, response of endangered fish populations, water temperature, and selenium remediation as it relates to recovery.

Environmental Impact Statement and Record of Decision

The Environmental Impact Statement for reoperation of the Aspinall Unit is in the process of being completed, and thus no Record of Decision is available at this time. This Study Plan will be revised or supplemented as warranted by the Record of Decision. Draft environmental commitments (January 2009) include:

> **Fish and Wildlife**: Ramping rate guidelines will be used in planning reservoir operations, including ramping rates of 25 percent on ascending limb and at 15 percent or 400 cfs per day whichever is greater on descending limb. The downstream of Crystal Dam minimum flow of 300 cfs will continue to be followed with the exception of emergencies and extended droughts when it may be reduced to 200 cfs as in the past.
>
> **Endangered Species:** The preferred alternative will be followed to provide flows for downstream endangered fish. An adaptive management process will be developed with the Fish and Wildlife Service and the Recovery Program to address new information and existing uncertainties.

1.2.2 Guidance Documents

In addition to the authority documents (Section 1.2.1), certain Recovery Program "guidance" documents were used to clarify, confirm, and expand, as necessary, the anticipated effects or uncertainties or to identify opportunities to address those uncertainties. Following are descriptions of each of the Recovery Program guidance documents.

Recovery Action Plan (RIPRAP)

The *Recovery Implementation Program Recovery Action Plan* (RIPRAP) was developed by Recovery Program participants in support of the Section 7 Agreement using the best and most current scientific information available. The RIPRAP identifies specific actions and time frames currently believed to be required to recover the endangered fishes in the Upper Colorado River Basin, consistent with species recovery goals.

The RIPRAP is the Recovery Program's long-range operational plan that is reviewed and revised annually. It contains dates for accomplishing specific actions over the next 5 years and beyond. The RIPRAP tracks accomplishments to ensure that the Recovery Program can continue to serve as a reasonable and prudent alternative for water projects undergoing Section 7 consultation to avoid the likelihood of jeopardizing the continued existence of the endangered fishes as well as to avoid the likely destruction or adverse modification of their critical habitat.

Species Recovery Goals

Recovery goals for each of the four endangered fish species were approved by the Region 6 Director of the Service in 2002 (U.S. Fish and Wildlife Service 2002a, 2002b, 2002c, 2002d).

These recovery goals amend and supplement the respective species recovery plans and identify site-specific management actions and objective, measurable criteria for recovery.

Recommended Priorities for Geomorphology Research

In 2003, the Recovery Program convened two workshops attended by researchers from various agencies, universities, and consulting firms, and produced *Recommended Priorities for Geomorphology Research in Endangered Fish Habitats of the Upper Colorado River Basin* (LaGory et al. 2003). The goal of this project was to identify priorities for geomorphology research in endangered fish habitats of the Upper Colorado River Basin. Recommended priorities were provided to the Recovery Program to help develop a comprehensive research and monitoring program for endangered fish habitats in the Upper Basin.

The geomorphology report focused on reaches and habitats used by life stages (larvae, juveniles, subadults, adults, and spawning) of Colorado pikeminnow, humpback chub, and razorback sucker, and identified the following primary information needs in the Gunnison and Colorado river sub-basins for overall reach-habitat priorities and for species-specific reach-habitat priorities.

Unless otherwise noted, the following habitat information needs are based on existing, observed levels of habitat use by endangered fish.

Primary Information Needs to Address Overall Reach-Habitat Priorities

1. Connected backwaters and side channels (Moab Bridge to Green River):

    - Role of peak flow (magnitude, duration, and frequency) and sediment on formation and maintenance of habitats
    - Effects of antecedent conditions (flow and sediment) and base-flow magnitude on habitat availability
    - Effects of base-flow variability on inter-annual availability, intra-annual stability, and within-day stability

2. Flooded bottomlands (Palisade to Gunnison River and Gunnison River to Loma):

    - The relationship of habitat availability to peak-flow and base-flow magnitude
    - Effects of peak flow (magnitude, duration, and frequency), sediment, and configuration of connection to main channel on maintenance of connection and sediment deposition effects

3. Flooded bottomlands (Gunnison River—Hartland Dam to Roubideau Creek)

    - Effects of peak flow (magnitude, duration, and frequency), sediment, and configuration of connection to main channel on maintenance of connection and sediment deposition effects

4. Spawning bar complexes in the Colorado River (Palisade to Gunnison River, Gunnison River to Loma, and Loma to Westwater Canyon) and Gunnison River (Hartland Dam to Roubideau Creek, Roubideau Creek to Colorado River):

    - Location and characteristics of spawning habitats
    - Effects of peak flow (magnitude, duration, frequency, and timing), base flow (magnitude and duration), and sediment on habitat conditions during the spawning period.

<u>Primary Information Needs to Address Species-Specific Reach-Habitat Priorities</u>

1. Colorado Pikeminnow
    a) Connected backwaters and side channels (Cottonwood Wash to Dewey Bridge, Jackass Canyon to Moab Bridge, Moab Bridge to Green River)

        - Role of peak flow (magnitude, duration, and frequency) and sediment on formation and maintenance of habitats
        - Effects of antecedent conditions (flow and sediment) and base-flow magnitude on habitat availability
        - Effects of base-flow variability on inter-annual availability, intra-annual stability, and within-day stability

    b) Spawning bar complexes in the Colorado River (Palisade to Gunnison River, Gunnison River to Loma, Loma to Westwater, Cottonwood Wash to Dewey Bridge) and Gunnison River (Hartland Dam to Roubideau Creek, Roubideau Creek to Colorado River)

        - Location and characteristics of spawning habitats
        - Effects of peak flow (magnitude, duration, frequency, and timing), base flow (magnitude and duration), and sediment on habitat conditions during the spawning period.

2. Humpback Chub
    a) Spawning bar complexes (Loma to Westwater Canyon—Black Rocks portion, Westwater Canyon)

        - Location and characteristics of spawning habitats
        - Effects of peak flow (magnitude, duration, frequency, and timing), base flow (magnitude and duration), and sediment on habitat conditions during the spawning period.

3. Razorback Sucker
    a) Flooded bottomlands (Palisade to Gunnison River, Gunnison River to Loma, Gunnison River—Hartland Dam to Roubideau Creek)

        - The relationship of habitat availability to peak-flow and base-flow magnitude

- Effects of peak flow (magnitude, duration, and frequency), sediment, and configuration of connection to main channel on maintenance of connection and sediment deposition effects

b) Spawning bar complexes in the Colorado River (Palisade to Gunnison River, Gunnison River to Loma, Moab Bridge to Green River-) and Gunnison River (Hartland Dam to Roubideau Creek)

- Location and characteristics of spawning habitats
- Effects of peak flow (magnitude, duration, frequency, and timing), base flow (magnitude and duration), and sediment on habitat conditions during the spawning period.

c) Connected backwaters and side channels (Moab Bridge to Green River)

- Role of peak flow (magnitude, duration, and frequency) and sediment on formation and maintenance of habitats
- Effects of antecedent conditions (flow and sediment) and base-flow magnitude on habitat availability
- Effects of base-flow variability on inter-annual availability, intra-annual stability, and within-day stability

Colorado River Sub-basin Floodplain Management Plan

In 2006, the Recovery Program issued *Colorado River Sub-basin Floodplain Management Plan* (Valdez and Nelson 2006). This plan was developed in order for the Recovery Program to establish goals, identify management actions, and to gage progress on habitat restoration and protection. Implementation of this management plan is one means by which the Recovery Program achieves floodplain-related recovery criteria and management actions. The goal of this plan was to provide adequate floodplain habitats for all life stages of razorback sucker, particularly to serve as nursery areas for larvae and juveniles, for establishment and maintenance of self-sustaining populations.

The floodplain management plan identified the following uncertainties, research needs, and recommendations (summarized).

Uncertainties and Research Needs

1. **Effectiveness and alternatives for "reset theory".**

A research need identified in Valdez and Nelson (2006) was evaluation of 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:

1) early departure by fish;
2) desiccation of the floodplain;
3) failure of the floodplain to reconnect because of extended low river flows
4) disease outbreaks in floodplains
5) loss of native fish from periodic desiccation
6) predation and competition from nonnative fish.

Key floodplains should be evaluated for effectiveness of restoration. Evaluation should include connection with the river, levee erosion, larval entrainment (uncertainty 3, below), growth and survival of fish (uncertainty 4, below), 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.

Also, 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 highly managed system 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 Sub-basin 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 radio-tagged adults to better define areas or sites used for spawning. This information will help to characterize larval (uncertainty 3, below) drift and ultimately focus floodplain management on sites most likely to serve as nurseries and benefit the razorback sucker.

Osmundson and Seal (2009) found that razorback sucker spawning sites in the Colorado River were widely distributed between Loma, CO and Moab, UT and suggested that the river reach downstream of the CO/UT state line deserves consideration for nursery habitat management. Spawning locations in the Gunnison River were less clearly identified, although the authors suggested that the river reach downstream of Whitewater, CO could be managed as nursery habitat in the future. However, they recommended use of radio-telemetry to more clearly identify important razorback sucker spawning habitats in both rivers. Proximity of major spawning areas to sites heretofore considered "high priority" nursery habitats remains a major uncertainty.

3. Drift and entrainment of wild razorback sucker larvae.

Drift characteristics and entrainment of larval razorback sucker are currently not well understood. Characteristics of downstream drift and larval entrainment during implementation of the Aspinall Unit operations should be described to assess the effectiveness of key floodplain sites, and to guide best strategies for levee modification and construction. 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. 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 Aspinall Unit operations in order to maximize entrainment.

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. Existing fish growth and survival studies should be integrated, synthesized, and interpreted to identify essential information gaps, guide additional research, and recommend best strategies for managing floodplain habitats and releasing hatchery-reared fish.

5. Value 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 flow recommendations 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 Sub-basin.

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 Sub-basin 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. The floodplain management plan (Valdez and Nelson) was 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. 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.

1.2.3 Other Documents

In addition to the authority and guidance documents (Sections 1.2.1 and 1.2.2), the following are examples of other documents that were used to further evaluate studies and how well those studies address the Aspinall Unit operations.

- *Geomorphology and Hydrology of the Colorado and Gunnison Rivers (Pitlick et al. 1999).* Most of the uncertainties identified in this document were discussed in McAda (2003) as they pertain to development and implementation of the flow recommendations. Chief among these are uncertainties surrounding frequency, duration and magnitude of peak flows in maintaining channel geometry and fish habitat, and ability of flows to move sediment throughout critical reaches and prevent channel simplification and narrowing.

- *Procedures for Stocking Nonnative Fish Species in the Upper Colorado River Basin* (Upper Colorado River Endangered Fish Recovery Program 2009).

- Nonnative fish management and control workshops held annually since 2002.

- *Protocols for Colorado Pikeminnow and Humpback Chub Population Estimates* (Upper Colorado River Endangered Fish Recovery Program. 2002b).

- *Evaluation of Population Estimates for Colorado Pikeminnow and Humpback Chub in the Upper Colorado River Basin* (Upper Colorado River Endangered Fish Recovery Program 2005b).

- *Gunnison River and Aspinall Unit Temperature Study* (Boyer and Cutler 2004).

- *Sediment Characteristics and Transport in Selected Mainstem Reaches of the Upper Colorado River (Williams et al.; in draft)*

2.0 METHODS

2.1 Steps in Study Plan Development

The following steps were taken to develop this plan (Figure 3).

1. Anticipated effects or uncertainties were identified from the authority or guidance documents described in Sections 1.2.1 and 1.2.2.

2. Ongoing or pending studies were identified that were related to each anticipated effect or uncertainty.

3. With input from the principal investigators, goals and objectives of each ongoing study were examined to determine how well the studies address an anticipated effect or uncertainty.

4. Anticipated effects and uncertainties were categorized into focus areas to identify important information needs. Revised ongoing or new studies were recommended to fill those needs.

5. Authority, guidance, and other documents were used to screen information needs and to prioritize studies.

6. Recommendations were formulated for the Recovery Program to incorporate into the RIPRAP.

2.2 Linkage of Studies to Anticipated Effects and Uncertainties

This Study Plan identifies primary and supporting monitoring or research studies that evaluate to varying degrees the anticipated effects or uncertainties related to the Aspinall Unit operations. The anticipated effects and uncertainties are identified in Tables 1 and 2 the Gunnison and Colorado rivers and for spring peak and base flow periods in each system. The language regarding the flow recommendations and anticipated effects was taken directly from McAda (2003). The *ad hoc* Committee realized that the Proposed Action differs slightly from McAda (2003); however, the Committee agreed that all of McAda's anticipated effects still applied. Many of the original anticipated effects and uncertainties were not specific to the Gunnison or Colorado rivers; however, if the *ad hoc* Committee thought they were universal they were accounted for under both river basins. Uncertainties were taken from the flow recommendations, PBA, PBO, floodplain management plan, geomorphic priorities document and other documents.

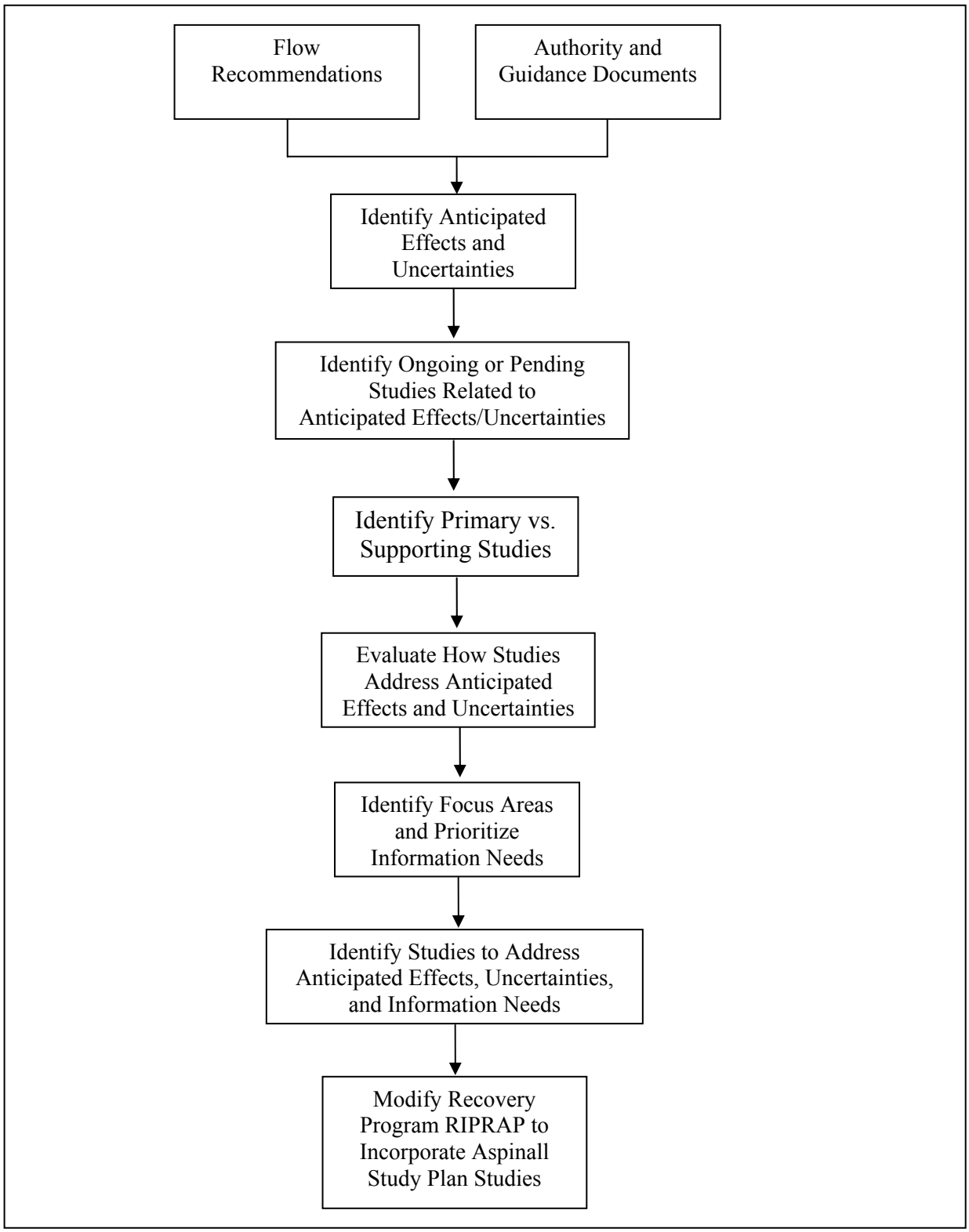

Figure 3. Process for developing the Aspinall Study Plan.

Table 1. Anticipated effects and uncertainties associated with Aspinall Unit operations for the Gunnison River. "Priority" is the prioritization of the importance of evaluating the hypothesis; L=low, M=medium, H=high (discussed in Section 2.4)

Anticipated Effects and Uncertainties	
Spring Peak	**Priority**
Anticipated Effect Gunnison #1 (AEG1). Spring Flows Are Necessary to Maintain Channel under Various Hydrologic Conditions (McAda 2003) Wet and Moderately Wet: 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 critical wintering habitat for both species. Widespread areas with clean substrates should provide habitat needed for maximum reproductive success of Colorado pikeminnow and increased primary and secondary production. Avg Wet: The median level for significant motion is reached or exceeded 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. Avg: 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. Moderately Dry: 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. Dry: 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.	H
Uncertainties associated with AEG1 UG1. The relationship between fine sediments and primary and secondary production in the two rivers needs to be further assessed. Long-term studies need to be conducted to evaluate response of periphyton, macroinvertebrates, and other small organisms to a flow regime with a higher frequency of flushing flows. These organisms form the basis of the riverine food web and it remains to be determined whether food availability is limiting abundance of endangered fishes in any or all of the upper Colorado River system. (McAda 2003; Rees et al.2008).	H
UG2. Periodic, channel wide flushing of cobble bars is necessary to maintain habitat; however, the frequency required is unknown (McAda 2003)	H
UG3. SEVERAL: Determine the frequency (recurrence interval) and duration (number of days) that flows need to exceed ½ bankfull and bankfull discharge to maintain the suite of habitats required by the endangered fishes. (McAda 2003). "While relationships among initial motion, significant motion and streamflow are well defined, duration of flows necessary to accomplish habitat work is not completely known" (USFWS 2009) (USBR 2008). LaGory et al 2003 identified a similar concern with regard to the effect of both spring and base flows on condition of spawning bars. "…the duration of flows necessary to accomplish in-channel and out-of-channel habitat maintenance objectives is not known. (McAda 2003; PBO)"	H
UG4. Determine the amount and quality of habitat necessary to maintain populations at levels identified in recovery goals for the four species. (McAda 2003)	H
UG5. The positive relationships between reproductive success of Colorado pikeminnow [and humpback chub] and peak river flows are based on limited data. The response of these species to the modified flow regime should be assessed. (McAda 2003)	M
UG6. A complete analysis of the Aspinall Unit and the rest of the Gunnison River's water availability may limit the ability of the Gunnison River to meet the flow recommendations under certain conditions. (McAda 2003) (USFWS 2009) (USBR 2008) "Because flow duration	Policy[2]

[2] Refer to *Policy* discussion in Section 2.4

recommendations were developed based on a wet period, the recommended durations require a large volume of water that may not always be available (USFWS 2009; USBR 2008)". NOTE – Since these foundational documents were written, Reclamation has addressed issues of water availability through the hydrology modeling conducted to support NEPA compliance.	
UG7. Current ramping rates (developed to protect the coldwater fishery) should be examined to determine if modifications could be made to benefit the endangered fishes. (McAda 2003)	Policy[2]
UG8. Spring flows may affect private property and may not mesh with the Black Canyon water right. (McAda 2003)	Policy[2]
UG9. Because of timing and other differences in runoff patterns of the Colorado and Gunnison rivers, it is difficult to predict the effect of Gunnison River flow changes on the Colorado River. (McAda 2003) (USFWS 2009) (USBR 2008)	M
UG10. Mimicry of a natural hydrograph may not sufficiently restore riverine habitats to recover the four endangered fishes. The flow regime has changed substantially over the last century, and recommendations for levels and duration of spring peaks are considerably less than occurred historically. Monitoring of the physical environment should occur to ensure that important habitats continue to be created and maintained. (McAda 2003)	M
Anticipated Effect Gunnison #2 (AEG2). Spring Flows Provide Floodplain Habitat Under Various Hydrologic Conditions – Wet Years: Floodplains are extensive for two weeks (about 200 ac at Escalante SWA at14,000 cfs); river flows exceeding 8,000 cfs will provide floodplain habitat at Escalante SWA Moderately wet: Floodplains are extensive for a brief period (about 200 ac at Escalante SWA at 14,000 cfs); river flows exceeding 8,000 cfs will provide floodplain habitat at Escalante SWA Avg wet: 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. Avg: Floodplain inundation will begin, but habitat will be limited Moderately dry and dry years. No flooded bottomland habitat will be provided.	H
Uncertainties Associated with AEG2. UG11. Restoration of floodplain function to the Gunnison and Colorado rivers is inferred to benefit recruitment of razorback sucker based on information from the Green River. However, adult populations must be reestablished before that hypothesis can be tested in the upper Colorado River sub-basin. (McAda 2003)	H
UG12. Partial restoration of floodplain function through mimicry of a natural hydrograph is hypothesized to benefit the endangered fishes, it may also benefit some nonnative fishes. (McAda 2003) (Valdez and Nelson 2006)	H
UG13. Spawning sites for razorback sucker are not definitively known. Further investigations are needed to focus floodplain management. (Valdez and Nelson 2006; LaGory et al. 2003)	H
UG14. The amount and location of floodplain habitat necessary for the recovery of the endangered fishes needs to be determined. (McAda 2003)	M
UG15. Drift characteristics of wild razorback sucker larvae are not well understood. This may be a function of river flow and timing and may be necessary information to evaluate flow recommendations. (Valdez and Nelson 2006)	L
UG16. Effectiveness of the "reset theory, which calls for inundation of floodplains for 12-24 months followed by draining could release nonnative fish into the river to the detriment of the desired purpose. (Valdez and Nelson 2006)	M
UG17. Can sufficient numbers of razorback sucker or bonytail survive in floodplains to recruit at sufficient numbers to equal or exceed adult mortality? It may be necessary to install inlet and outlet gates to control floodplain water levels. (Valdez and Nelson 2006)	M
UG18. Value of gravel pits, depressions, and short-term floodplains	M
UG19. "The floodplain management plan was 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 [reference here to the Floodplain Management Plan] should focus on this fundamental strategy" (Valdez and Nelson 2006).	H
UG20. Effects of peak flow (magnitude, duration and frequency), sediment and configuration of connection to main channel on maintenance of connection and sediment deposition effects	M

(LaGory et al 2003)	
UG21. The relationship of habitat availability to peak-flow and base-flow magnitude (LaGory et al. 2003)	M
Anticipated Effect Gunnison #3 (AEG3). Spring Peaks Provide Spawning Cues – All years: The spring peak will provide spawning cues for Colorado pikeminnow and razorback sucker.	L
Anticipated Effect Gunnison #4 (AEG4). Spring Flows Provide Staging Habitat for Adult – All years: Some inundation of tributary mouths (and floodplains in the wetter years) will occur, providing some warm, quiet water habitats for growth and gonad maturation of endangered fish.	L
Base Flows	
Anticipated Effect Gunnison #5 (AEG5). Flow Management Could Affect the Thermal Regime in the Gunnison River – Flows needed to maintain stream bed could negatively affect the thermal regime in the Gunnison River.	L
Uncertainties Associated with AEG5. UG22. The trade-off facing Colorado pikeminnow between stream bed maintenance and temperature regime in the Gunnison River is an uncertainty that may need to be evaluated by the Recovery Program. (USFWS 2009) (USBR 2008)	L
UG23. Nonnative fishes that compete with or prey on young Colorado pikeminnow and humpback chub are temporarily reduced following high spring flows, but populations rebound quickly when low-water years occur. Management actions to reduce population size of nonnative fishes through mechanical means have been initiated. However, full benefits of the recommended flow regime will remain uncertain until nonnative fish have been reduced. (McAda 2003; paraphrased slightly to define the uncertainty).	M
Anticipated Effect Gunnison #6 (AEG6). Flow Management Provides Low Flow Habitats – All years: The recommended flow provides pool and slow-run habitats throughout the Gunnison River. Avg Dry – Wet: A wide range of habitats are available in the entire Gunnison River when flows fall within the target ranges. Stable flows provide warm, quiet-water habitats along the shorelines of the river	H
Uncertainties associated with AEG6. UG24. Determination of the amount and quality of habitat necessary to maintain populations at levels identified in the recovery goals for the four species (McAda 2003)	H
UG1 (repeated). The relationship between fine sediments and primary and secondary production in the two rivers needs to be further assessed.	H
Anticipated Effect Gunnison #7(AEG7). Flow Management Provides Fish Passage Below Redlands – All years: This (what?) flow provides access to and from the fish passage at Redlands Diversion Dam. Gradually reducing flows will allow endangered fish to leave the 2.5-mi reach and prevent stranding.	L
UG25. The Recovery Program may need to evaluate the trade-off between high spring flows and base flows needed during the mid- to late summer to operate the Redlands fish passage and to maintain movement of sediment through the system.	L

Table 2. Anticipated effects and uncertainties associated with Aspinall Unit operations for the Colorado River. "Priority" is the prioritization of the importance of evaluating the hypothesis; L=low, M=medium, H=high.

Anticipated Effects and Uncertainties	
Spring Peak	**Priority**
Anticipated Effect Colorado River #1 (AEC1). Spring Flows Necessary to Maintain Channel Under Various Hydrologic Conditions (McAda 2003) Avg Wet: Median significant motion 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. Mod Wet and Avg Wet: 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. Avg Dry: Initial motion is reached so some in-channel scouring of gravel and cobble bars will occur. Areas with clean substrates for 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, Moderately Dry and Dry: 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).	M
Uncertainties associated with AEC1 UC1. The relationship between fine sediments and primary and secondary production in the two rivers needs to be further assessed. Long-term studies need to be conducted to evaluate response of periphyton, macroinvertebrates, and other small organisms to a flow regime with a higher frequency of flushing flows. These organisms form the basis of the riverine food web and it remains to be determined whether food availability is limiting abundance of endangered fishes in any or all of the upper Colorado River system. (McAda 2003).	M
UC2. Periodic, channel-wide flushing of cobble bars is necessary to maintain habitat; however, the frequency required is unknown (McAda 2003)	M
UC3. Determine the frequency (recurrence interval) and duration (number of days) that flows need to exceed ½ bankfull and bankfull discharge to maintain the suite of habitats required by the endangered fishes. (McAda 2003) (USFWS 2009) (USBR 2008). LaGory et al 2003 identified a similar concern with regard to the effect of both spring and base flows on condition of spawning bars.	M
UC4. Determine the amount and quality of habitat necessary to maintain populations at levels identified in the recently developed recovery goals for the four species. (McAda 2003)	H
UC5. The positive relationships between reproductive success of Colorado pikeminnow [and humpback chub] and peak river flows are based on limited data. The response of these species to the modified flow regime should be assessed. (McAda 2003)	M
UC6. Determine the role of peak flow (magnitude, duration, and frequency) and sediment on formation and maintenance of connected backwaters and side channels (Moab to Green River reach) (LaGory et al. 2003)	M
UC7. Spawning Bar Complexes (Gunnison River to Loma, and Loma to Westwater, Cottonwood Wash to Dewey Bridge): 1. Locate and characterize spawning habitats, and 2. Determine the effects of peak flow (magnitude, duration, frequency, and timing) and base flow (magnitude and duration) and sediment on habitat conditions during the spawning period. (LaGory et al. 2003)	M
UC8. Because of timing and other differences in runoff patterns of the Colorado and Gunnison rivers, it is difficult to predict the effect of Gunnison River flow changes on the	M

Colorado River. (USFWS 2009) (USBR 2008)	
UC9. Mimicry of a natural hydrograph may not sufficiently restore riverine habitats to recover the four endangered fishes. The flow regime has changed substantially over the last century, and recommendations for levels and duration of spring peaks are considerably less than occurred historically. Monitoring of the physical environment should occur to ensure that important habitats continue to be created and maintained. (McAda 2003)	M
Anticipated Effect Colorado River #2 (AEC2). Spring Flows Provide Floodplain Habitat Under Various Hydrologic Conditions – Wet and Mod Wet. Floodplain 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 floodplain area is available to improve growth and survival of YOY razorback suckers. 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. Avg wet: Flooding in and around 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. Avg Dry and Mod Dry: Some warm quiet-water habitats will be provided for growth and gonad maturation of endangered fish. The backwater at Walker SWA will provide some of this quiet habitat. Dry: No flooded bottomland habitat will be provided, but some inundation of tributary mouths may occur.	H
Uncertainties Associated with AEC2. UC10. Restoration of floodplain function to the Gunnison and Colorado rivers should benefit recruitment of razorback sucker based on information from the Green River. However, adult populations must be reestablished before this hypothesis can be tested in the upper Colorado River sub-basin. (McAda 2003)	M
UC11. Partial restoration of floodplain function through mimicry of a natural hydrograph will benefit the endangered fishes and may also benefit some nonnative fishes. (McAda 2003) (Valdez and Nelson 2006)	H
UC12. Spawning sites for razorback sucker are not definitively known. Further investigations are needed to focus floodplain management. (Valdez and Nelson 2006) (LaGory et al. 2003)	H
UC13. Drift characteristics of wild razorback sucker larvae are not well understood. This may be a function of river flow, timing, and availability of floodplain habitat and may be necessary information to evaluate flow recommendations. (Valdez and Nelson 2006)	L
UC14. The amount and location of floodplain habitat necessary for the recovery of the endangered fishes needs to be determined. (McAda 2003)	M
UC15. Effectiveness of the "reset theory, which calls for inundation of floodplains for 12-24 months followed by draining could release nonnative fish into the river to the detriment of the desired purpose. (Valdez and Nelson 2006)	M
UC16. Can sufficient numbers of razorback sucker or bonytail survive in floodplains to recruit at sufficient numbers to equal or exceed adult mortality? It may be necessary to install inlet and outlet gates to control floodplain water levels. (Valdez and Nelson 2006)	M
UC17. Value of gravel pits, depressions, and short-term floodplains	M
UC18. "The floodplain management plan was 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" (Valdez and Nelson 2006).	H
UC19. Palisade to Gunnison River and Gunnison River to Loma: The relationship of habitat availability to peak-flow and base-flow magnitude (LaGory et al 2003)	H

UC20. Palisade to Gunnison River and Gunnison River to Loma: Effects of peak flow (magnitude, duration, and frequency), sediment, and configuration of connection to main channel on maintenance of connection and sediment deposition effects (LaGory et al 2003)	M
Anticipated Effect Colorado River #3 (AEC3). Spring Peaks Provide Spawning Cues – All years: The spring peak will provide spawning cues for Colorado pikeminnow and razorback sucker.	L
Anticipated Effect Colorado River #4 (AEC4). Spring Flows Provide Staging Habitat for Adult Endangered Fish – All years: Some inundation of tributary mouths (and floodplains in the wetter years) will occur, providing some warm, quiet water habitats for growth and gonad maturation of endangered fish.	L
Base Flows	
Anticipated Effect Colorado River #5 (AEC5). Base Flows Provide Nursery Habitat for Age 0 CPM Under Various Hydrologic Conditions – Wet years Backwaters will be fewer and smaller than at lower flows, but they will still be available for YOY Colorado pikeminnow to use. Mod Dry – Mod Wet: Backwaters in nursery areas should be maximized in both quantity and surface area. Dry: Backwaters for YOY Colorado pikeminnow will be available, but not at maximum number or surface area.	M
Anticipated Effect Colorado River #1 (AEC6). Base Flows Provide Suitable Habitat for Optimal Growth of a variety of life stages for all endangered fish– Mod Dry – Mod Wet: 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.	H

Each anticipated effect or uncertainty is fundamentally a statement about the expected or unknown outcome of a given flow recommendation. Relevant and recently completed, ongoing, or pending monitoring or research Recovery Program studies (Table A1), as well as non-program studies whose results are being or will be used to implement and evaluate the Aspinall Unit operations are linked to these expected or unknown outcomes in Tables A2–A3.

2.3 Evaluation of Studies

The body of available information collected in the Gunnison River by the Recovery Program and others is relatively scarce compared to the information needs for evaluating Aspinall operations. The lower occurrence of endangered fish in the Gunnison River and the large number of Section 7 consultations in the Green River and Colorado River resulted in prioritizing data collection on the Green and Colorado rivers. More information has been collected in the Colorado River both immediately upstream of the Gunnison River confluence as well as downstream to the Green River confluence where stronger a population of Colorado

pikeminnow, a population of humpback chub, and a greater accumulation of stocked razorback sucker are found.

As part of the development of this Study Plan, the *ad hoc* Committee broadened the evaluation of available information beyond ongoing and pending studies to consider earlier work that could serve as a basis for future evaluation of the proposed action. Primary studies that most directly address the anticipated effects or associated uncertainties were distinguished from the supporting studies. The goals and objectives for each study are provided in Table A1. Details of each Recovery Program study identified in this Study Plan can be found on the Recovery Program web site at: http://www.coloradoriverrecovery.org/index.html.

Objectives described for each study were used to determine how well a particular study or several studies taken together address uncertainties. Tables A4 through A6 were constructed to compare study objectives to uncertainties for each river and flow recommendation combination. How well a particular study or group of studies addressed a given hypothesis was determined from the aggregate of objectives.

Preliminary assessments of how well each study addresses specific uncertainties were made and each evaluation was classified as follows:

- N/A = study not designed to address hypothesis;
- P = study partially addresses hypothesis; or
- Y = study addresses hypothesis.

A "P" was used to indicate that a study or group of studies only partially addresses a given uncertainty. A "Y" indicates that a study or group of studies collectively addresses a given hypothesis, and an "N" indicates that they do not. However, those ongoing studies that addressed an anticipated effect or uncertainty (i.e., denoted as "Y") would have to be completed before it could be determined that a particular uncertainty had been appropriately addressed, or if additional uncertainties remained.

A summary evaluation for each anticipated effect and uncertainty was determined and indicated as either "P", "Y" or "N". These summary evaluations were used to identify information needs or deficiencies in existing scopes of work.

2.4 Information Needs, Revised or New Studies, and Prioritization

Information needs were identified from the above evaluation, and new studies or modifications of existing studies were recommended (Tables A2 and A3). This evaluation was done for all uncertainties to ensure that studies designed to address information needs are providing a comprehensive assessment.

Each uncertainty was prioritized categorically as High (H), Medium (M), or Low (L) based on the following criteria:

- Concurrence with environmental commitments identified in the PBO and ROD.
- Closeness to the point of control - Although there are stronger populations of endangered fish in the Colorado River, the effects of Aspinall reoperations below the confluence with the Colorado River are moderated and blended with effects of flow management and recovery actions on the Colorado River. Greater importance was generally assigned to Gunnison River uncertainties.
- Because the McAda (2003) recommendations were based primarily on sediment transport as related to maintenance and improvement of physical habitat, uncertainties regarding sediment transport, i.e. tradeoffs between spring peak magnitude and duration, were scored high.
- McAda (2003) assigned high importance to floodplain habitats. Uncertainties associated with flow and floodplain inundation also received a high priority.
- Uncertainties that address fish community response, either direct or indirect, were also rated high with greater emphasis on the Gunnison River and the reach of the Colorado River closest to their confluence.

McAda (2003) identified several uncertainties that the *ad hoc* Committee determined to be policy related (water availability to meet the flow recommendations, ramping rates, potential flooding at Delta, Colorado). These important issues will be addressed in other Recovery Program forums, but were considered outside the scope of this science-based evaluation of the proposed action.

Many of the Aspinall uncertainties are interrelated. Therefore, the Aspinall *ad hoc* Committee grouped the uncertainties into six ”focus areas” (Tables A4 and A5) common to both rivers. These focus areas were prioritized and further categorized by study discipline (physical vs. biological). One focus area (Temperature and Flow tradeoffs) was specific to the Gunnison River. A final focus area addressed primarily policy-type issues (ramping rates, availability of the water to meet the proposed action, flooding in Delta, CO). Although there was considerable overlap between the study disciplines, these groupings provided the framework to identify information needs, to suggest areas of new study, and to place those studies in a timeline based on priorities.

3.0 RECOMMENDATIONS

This section describes: (1) adequacy of studies to address uncertainties, (2) grouping uncertainties into categories (physical and biological) and "focus areas" to identify information needed and a recommended approach, (3) prioritization of focus areas, (4) timeline for recommended studies and integration of information, and (5) recommended RIPRAP revisions.

3.1 Adequacy of Studies to Address Uncertainties

A total of 7 anticipated effects and 24 uncertainties are associated with implementation of the Aspinall Unit operations in the Gunnison River. Many of those, 6 anticipated effects and 20 uncertainties, apply to expected physical and biological responses in the Colorado River. Each of those was compared to past and ongoing investigations (Tables 1 and 2; see also Tables A2 and A3) to determine if the current level of information was adequate. While this proved a useful exercise to inventory where the Recovery Program has been, where it is currently, and how we can build on existing work, there were no uncertainties being fully addressed with ongoing work. Therefore, the *ad hoc* Committee identified several new areas of research and monitoring.

3.2 Consolidation of Anticipated Effects and Uncertainties into Focus Areas, Identify Important Information Needs, Suggested New Areas of Research

Some anticipated effects and uncertainties are more testable than others. The *ad hoc* Committee grouped these into six major focus areas that fall into two general categories: Physical and Biological. Five of the six focus areas apply to both the Gunnison and Colorado rivers, although the specific information needs are not always the same for each river. One focus area is specific to the Gunnison River. In addition, several uncertainties address more long term, operational issues and were categorized under Policy.

Categories and Focus Areas

PHYSICAL:

Focus areas:

1) sediment transport (i.e., the basic assumptions of Pitlick et al. 1999);
2) main channel fish habitat, including complexity, condition and accumulation of fine sediments;
3) floodplains, including area of inundation and connection flow; and
4) tradeoffs among meeting flow targets and potential negative effects on the thermal regime (applies only to the Gunnison River).

BIOLOGICAL:

Focus Areas:

1) floodplain fish community response to the proposed action (native and non-native); and

2) mainstem fish community response to the proposed action (native and non-native);

POLICY: a single category that attempts to encompass uncertainties that could influence policy decisions, including availability of water to meet the proposed action, effects of ramping rates, adequacy of the proposed action in combination with Colorado River operations (CROS and HUP) to meet flow targets in the Colorado River below the Gunnison River confluence.

A matrix relating each anticipated effect (AE) and uncertainty (U) to these categories and focus areas is presented in Tables A4 and A5. The categories and focus areas are discussed below with a summary of available information; high priority anticipated effects and uncertainties; and suggested new areas of research or monitoring. Where possible, this discussion applies to both rivers.

CATEGORY: PHYSICAL QUESTIONS

FOCUS AREAS:

1. **Sediment Transport During Spring Flows** (applies to Gunnison and Colorado Rivers) –

The spring peak flow recommendations for both the Gunnison and Colorado rivers are strongly founded on the Pitlick et al 1999 contention:

> *"The single most important thing that can be done to maintain habitats used by the endangered fishes is to assure that the sediment supplied to the critical reaches continues to be carried downstream. Sediment that is not carried through will accumulate preferentially in low velocity areas, resulting in further channel simplification and narrowing." – Pitlick et al. 1999*

McAda (2003) summarized historical hydrology, historical water development and all available information on Gunnison River sediment transport / geomorphology (Milhous 1995; Milhous 1998; Pitlick et al.1999) to develop sediment-transport based recommendations.

More specifically, McAda (2003) developed peak and duration targets for each hydrologic category as related to initial and significant motion thresholds defined by Pitlick et al. 1999. Perhaps the most pressing uncertainty associated with these flow recommendations is whether the durations identified in McAda 2003 are necessary to accomplish the sediment transport necessary to maintain channel width and complexity. This uncertainty applies to Reclamation's Proposed Action (see Section 1.2.1)

This group of related uncertainties (see below) can be addressed on two fronts: 1) an intensive validation of the sediment transport equations; and 2) an extensive assessment of expected changes in channel morphology - manifest in channel width and complexity.

This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

- AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)
- UG1. Fine sediment and productivity
- UG3. Frequency/duration to maintain habitat (1/2 and bankfull)
- UG4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question)
- AEG6. Low water habitat (pools/runs, sediment management)
- UG24. Habitat to achieve recovery
- UC4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question)
- AEC6. Base flows and habitat for growth (all life stages)

Overall Focus Area Priorities: **Gunnison River = H**; **Colorado River = M** (due to distance removed from point of control [Aspinall Unit] and additional variability induced by flow management for the 15-Mile reach)

Suggested Approach / New Areas of Research –

a. Intensive validation of sediment transport – Build on recommendations from Project 85f (Williams et al. 2011; in draft). The purpose of this sediment monitoring study is to characterize the changes in the magnitude, timing, and size distribution of sediment transport to the Gunnison, Colorado and Green rivers in order to aid the Recovery Program in the evaluation of the effects of streamflow and sediment transport on critical habitat for the endangered fish. Williams et al. (2011; in draft) report that peak flow conditions of up to 14,000 cfs failed to sufficiently mobilize most, if not all, areas within their surveyed cross sections on the Gunnison River. This new information suggests the initial and significant motion flow values identified by Pitlick et al. (1999) may be too low, but this new information has not been adequately interpreted in light of Pitlick et al (1999) and other related studies (Milhous 1998; Lisle et al. 2000; Pitlick and Wilcock 2001). Suggested New Area of Research – Until recently, the Recovery Program thought the key physical uncertainty was whether the flow durations identified in McAda (2003) were necessary to accomplish the intended sediment transport. It now appears the larger issue may be the spring flow magnitudes. Therefore the Recovery Program should finish its review / interpretation of Williams et al. (2011; in draft) in light of previous geomorphology and consider additional field studies in the Gunnison River to validate initial and significant motion flow thresholds (e.g. add sediment facies mapping, buried chains, painted rock, or other

monitoring protocols). Note: J. Pitlick (personal communication; March 9, 2011) recommended the painted rock approach as this can be done relatively inexpensively, but more importantly at a variety of locations. In addition, a preliminary recommendation from Williams et al. (2011; in draft) calls for a continuation of daily sediment monitoring in the Gunnison River. **Priority** for this specific new area of research: Gunnison River = **H**; Colorado River = **M**

b. Extensive assessment of peak flow effects on channel morphology (channel width and complexity) – Pitlick et al (1999) documented large scale morphological changes that have occurred in parts of the Gunnison (lower 60 miles) and 18-mile reach by comparing aerial photography taken at five times between 1937 and 1995. Use Reclamation's 2008 photo series (available at http://www.fineimagegraphics.com/) and/or subsequent images to extend the Pitlick et al (1999) analysis. Frequency of sampling – Pitlick and VanSteeter (1998) recommended gathering aerial images on 10-yr intervals. Also review and update as needed McAda and Fenton's (1998) channel transects in the upper Gunnison River to evaluate sedimentation in pools. **Priority** for this specific new area of research: Gunnison River = **H**; Colorado River = **M**

Related question – Will the proposed action adequately cleanse riffles and runs of fine sediments to promote growth of primary and secondary producers (i.e. during the base flow period)? Osmundson et al. 2002 described productivity as a function of spring peaks. Rees et al. 2008 (never approved by the Recovery Program) described the limiting factor as a mud drape delivered during summer thunderstorms. Suggested New Area of Research - Revisit the Depth to Embeddedness (DTE) measurement in riffles and runs near the Escalante Bridge on the Gunnison River; and Lamarra's (1999) synoptic sites in the 18-Mile Reach. Both Lamarra (1999) and Osmundson et al. 2002 found relatively strong predictive capabilities between DTE (Depth of Free Space), and productivity. Therefore, DTE is a logical starting point but sampling invertebrates and perhaps periphyton may be necessary to more adequately characterize habitat quality. **Priority** for this specific new area of research: Both rivers = **M**

2. **Main Channel Fish Habitat** – Will the proposed action maintain or improve a proper mix of slow runs and pools in the main channel and backwaters during the base flow period? (Applies to Gunnison and Colorado Rivers, but the questions are not completely universal, (e.g. maintenance of backwater as nursery areas for young Colorado pikeminnow is unique to the Colorado River)).

   Habitats were mapped and channel cross sections were established in five reaches of the Gunnison River during development of base flow recommendation McAda and Fenton (1998). Similar raw data are available to serve as a habitat mapping baseline for the 18-Mile reach (data collected during Osmundson 1995).

A related uncertainty questions whether the proposed action will properly maintain spawning bars once they have been identified. The DTE evaluation of fine sediment accumulation in riffles and runs, mentioned above, could also serve to evaluate condition of spawning bars.

This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

- AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)
- UG1. Fine sediment and productivity
- UG3. Frequency/duration to maintain habitat (1/2 and bankfull)
- UG4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question)
- AEG6. Low water habitat (pools/runs, sediment management)
- UG24. Habitat to achieve recovery
- UC4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question)
- AEC6. Base flows and habitat for growth (all life stages)

Overall Focus Area Priorities: **Gunnison River = H**; **Colorado River = M** (due to distance removed from point of control [Aspinall Unit] and additional variability induces by flow management for the 15-Mile reach)

Suggested Approach / New Areas of Research –

a. Availability of pools and runs in the Gunnison River – Periodically repeat McAda and Fenton's (1998) Gunnison River habitat mapping. Use the same base flow aerial photography mentioned above as base maps to determine if McAda's (2003) assumptions of the availability of pool and slow run habitats at base flows persist. Consider repeating McAda and Fenton's (1998) transects at five locations in the upper Gunnison River to evaluate sedimentation in the same habitats. More quantifiable approaches may be available (e.g. USU's current work on the San Rafael River; 2D modeling), but a new baseline would need to be established.

    i. Suggested baseline data sets – McAda and Fenton (1998) in the Gunnison River. Osmundson et al (1995) conducted similar habitat mapping surveys in the Colorado River, but the focus was in the 15-Mile reach.

    ii. Frequency of sampling should be linked to the assessment of channel width and complexity mentioned above.

    Priority for this specific new area of research: Gunnison River = **H**; Colorado River = **NA**

b. Backwaters in the lower Colorado River – assume that we are gathering adequate information via Project 138 and the pending synthesis of that data, or repeat the nursery habitat design (Trammell and Chart 1999b), or establish a sand bar topography program (LaGory et al. 2009 – specific to middle Green River) if more detailed information on configuration of nursery habitats is needed. **Priority** for this specific new area of research: Colorado River -= **M**

3. **Floodplain Habitat (Gunnison)** – Will the proposed action continue to provide the expected acreage of floodplain habitat on the Gunnison River (Escalante Wildlife Area located approximately 7 miles downstream of Delta, CO) identified in McAda (2003) and Valdez and Nelson (2006).

   This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

   - AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)
   - AEG2. Spring flows and floodplain habitat
   - UG19. Recover fish in presence of nonnatives

   Overall Focus Area Priority: Gunnison River = H

   Suggested Approach / New Areas of Research –

   a. Repeat Tetra Tech (2000), which focused on floodplain inundation at the Escalante site. McAda and Fenton (1998) also provide a set of baseline inundation values in their assessment of all habitat types. Periodically gather aerial photography (spring peak) to quantify and compare with previous flights to determine area of inundation. **Priority** for this specific new area of research: Gunnison River = **H**

   b. Continue Project C6Hydro to monitor/evaluate floodplain connections **Priority** for this specific new area of research: Gunnison River = **H**

   Floodplain Habitat (Colorado) – Will the proposed action continue to provide the expected acreage of floodplain habitat on the Colorado River (referenced in Irving and Burdick (1995); and Valdez and Nelson 2006)

   This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

   - AEC2. Peak flows and floodplain habitat
   - UC18. Recover fish in presence of nonnatives
   - UC19. Habitat availability in relation to peak flows, Palisade to Loma

   Overall Focus Area Priority: Colorado River = H

Suggested Approach / New Areas of Research –

c. Periodically gather aerial photography (spring peak) to quantify and compare with previous flights - use Irving and Burdick (1995) connecting flow and areas of inundation as the baseline.

d. Continue Project C6Hydro to monitor / evaluate floodplain connections **Priority** for this specific new area of research: Colorado River = **H**

4. **Temperature vs. Hydrology (Gunnison)** – Will the proposed action negatively affect the thermal regime in the Gunnison River?

Subsequent to finalizing McAda 2003, the Recovery Program completed the second phase of the Gunnison River temperature investigations (Boyer and Cutler 2004). Boyer and Cutler (2004) concluded that large releases from Crystal Dam combined with increased release temperatures from Blue Mesa Reservoir (via a multi-level control) could result in as much as 5°C warming in the river at Delta, Colorado. They cautioned however, that the warming affect could be lost, if North Fork inputs were of similar magnitude and cooler than the mainstem. Boyer and Cutler (2004) recommended that more temperature monitoring locations be added below the Aspinall Unit on the mainstem, on the North Fork, and in the Uncompahgre River. They did not conduct a full analysis of operations needed to accomplish the annual thermal units (ATU's) estimated necessary to promote year-round occupation of the upper Gunnison River by Colorado pikeminnow (Osmundson 1999). Osmundson (1999) recommended an increase of 1° – 2°C from late May to mid-October would result in the desired ATU's.

More recently, Osmundson (2010) took a more comprehensive perspective to characterize occupied range of Colorado pikeminnow in many Upper Colorado River basin rivers as a function of mean daily temperature converted into annual thermal units. Osmundson (2010) reiterates his 1999 recommendations with respect to the Gunnison River and cautioned fishery managers to consider biophysical ramifications of providing flows based purely on geomorphic objectives.

This focus area and the suggested new areas of research discussed do not address any high priority AE and U.

Overall Focus Area Priority: Gunnison River = L

Suggested Approach / New Areas of Research –

a. In Recovery Program Project 19b, the number of temperature monitoring sites in the Gunnison River and its tributaries has been increased in accordance with Boyer and Cutler's (2004) recommendation. Now that additional temperature information is available, determine if additional modeling is necessary.

i. Baseline data sets – Boyer and Cutler model; Osmundson (1999); Osmundson 2010 (Annual Thermal Unit analysis revisited)

Priority for additional modeling: Gunnison River = **L**

CATEGORY: BIOLOGICAL QUESTONS

FOCUS AREAS:

5. **Fish Community Response - Floodplain (Gunnison)** – Will the proposed action provide adequate floodplain habitat to assist in the recovery of the endangered fish and benefit the native fish community of the Gunnison River?

   Valdez and Nelson (2006) identified one priority floodplain reach in the Gunnison River (RM 60-50). McAda 2003 recognized the same geographic area by drawing attention to a floodplain complex at the Escalante State Wildlife Area. Osmundson and Seal (2009) reported the collection of positively identified razorback sucker larvae as far upstream as RM 52.7 (collection date - June 2003). The authors directed future attention to the Whitewater area as a potential razorback sucker spawning area.

   The Recovery Program has breached a levee to connect a gravel pit in the lower portion of the Gunnison River; the Butch Craig site located 13 miles upstream of the Colorado River confluence. The intent there was to provide nursery habitat for larval razorback sucker produced in the Gunnison River as well as staging / resting habitat for juvenile and adult endangered species.

   Currently the Recovery Program is not sampling the fish community in any floodplain habitats in the Gunnison River. Some evaluation of the role of these important habitats needs to be addressed in a Gunnison River fish community (native and nonnative species) monitoring program or as part of a larger programmatic razorback sucker monitoring program.

   This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

   - AEG2. Spring flows and floodplain habitat
   - UG11. Razorback sucker larvae in floodplain/lack of adults
   - UG12. Nonnative fish benefit from floodplains
   - UG19. Recover fish in presence of nonnatives

   Overall Focus Area Priority: Gunnison River = H

   Suggested Approach / New Areas of Research –

   a. Specific sampling in floodplain habitats should be a component of the Gunnison River fish community monitoring effort. Review Burdick's (1995) approach of

sampling these habitats and consider this as a baseline data set and a basic study basis. **Priority** for this specific new area of research: Gunnison River = **H**

b. Take direction from the pending Razorback Sucker Monitoring Program, which likely will require sampling for early life stages in the aforementioned floodplain habitats and ephemeral tributary mouths. **Priority** for this specific new area of research: Gunnison River = **H**

Fish Community Response - Floodplain (Colorado) – Will the proposed action provide adequate floodplain habitat to assist in the recovery of the endangered fish and benefit the native fish community of the Colorado River?

Valdez and Nelson (2006) identified two priority floodplain reaches in the Colorado River downstream of the Gunnison River confluence: the 18-mile reach (CO RM 171-153) and from Moab, Utah downstream to the Green River confluence (CO RM 60-0). They identified 19 sites, which included their highest ranked site for the entire Colorado River sub-basin – Walter Walker State Wildlife Area (near CO RM 165). Osmundson and Seal (2009) reported the collection of positively identified razorback sucker larvae from the Colorado River. In recent years, researchers with the Grand Junction, CO CRFP have reported aggregations of stocked razorback sucker in spawning condition in the 18-Mile reach.

The Recovery Program has breached levees to connect gravel pits at several locations throughout the Grand Valley downstream of the Gunnison River confluence. The intent was to provide nursery habitat for larval razorback sucker produced in the Gunnison River as well as staging / resting habitat for juvenile and adult endangered species.

Currently the Recovery Program is not conducting a directed effort to sample the fish community in any floodplain habitats in the Colorado River. The Recovery Program should consider evaluation of reoperation of the Aspinall Unit as they develop the Colorado River component of the pending Razorback Sucker Monitoring.

This focus area and the suggested new areas of research discussed below are specifically intended to address (directly or indirectly) the following high priority AE and U:

- AEC2. Peak flows and floodplain habitat.
- UC11. Nonnative fish benefit from floodplains
- UC12. Spawning sites for razorback sucker not definitively known. Need further investigations to focus floodplain management
- UC18. Recover fish in presence of nonnatives
- UC19. Habitat availability in relation to peak flows, Palisade to Loma

Overall Focus Area Priority: Colorado River = M

Suggested Approach / New Areas of Research –

c. Take direction from the pending Razorback Sucker Monitoring Program, which likely will require sampling for both juveniles/adults and early life stages. **Priority** for this specific new area of research: Colorado River = **M**

d. We strongly encourage some fish community component (all species) in floodplain habitats in the 18-Mile reach to assist in evaluation of the Aspinall Unit reoperation. **Priority** for this specific new area of research: Colorado River = **M**

6. **Fish Community Response – Main Channel (Gunnison)** Will the proposed action assist in the recovery of the endangered species and benefit the native fish community in the Gunnison River?

The only ongoing fish community monitoring effort in the Gunnison River is being conducted by the CDOW via commitment to the 3 Species Conservation program. CDOW's effort consists of electrofishing main channel habitats during base flow periods.

Burdick (1995) sampled large-bodied fish (primarily with electrofishing), small-bodied fish (with beach seines), and larval fish with one-man dipnets. Burdick also did some sampling in floodplain habitats. As Burdick's (1995) study built on sampling conducted throughout the Gunnison River conducted in the early 1980's by CRFP (Valdez et al. 1982) and CDOW (Wick et al. 1985) we strongly recommend that Burdick's design be considered as a template for future actions.

It is critically important to reinitiate a fish community monitoring program on the Gunnison River. We have to assume that the outcome of many of the physical and biological uncertainties associated with this proposed action will ultimately be manifest as some response in the fish community.

We also strongly recommend that particular emphasis be given to a small-bodied fish component of the fish community monitoring program as they are the species or life stages of species that will respond most quickly to implementation of the proposed action.

This focus area and the suggested new areas of research discussed below are intended to address (directly or indirectly) the following high priority AE and U:

- AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)
- UG1. Fine sediment and productivity
- UG3. Frequency/duration to maintain habitat (1/2 and bankfull)
- UG4. Amount and quality of habitat necessary to maintain populations at recovery goals levels (physical habitat question)
- UG13. Spawning sites for razorback sucker are not definitively known. Further investigations are needed to focus floodplain management.
- AEG6. Low water habitat (pools/runs, sediment mgmt)

- UG24. Habitat to achieve recovery

Overall Focus Area Priority: Gunnison River = H

Suggested Approach / New Areas of Research –

a. Use Burdick (1995) as the baseline study design and dataset. Structure a monitoring program after that approach.

b. Incorporate CDOW's ongoing main channel electrofishing efforts – catch-per-effort (CPE)-based throughout Critical Habitat; 50% of CH sampled each year
NOTE - On Green River, researchers tasked with evaluating flow recommendations (as well as controlling nonnative fish) have determined that two electrofishing passes (one mid-summer and one in the fall) are needed to monitor the large bodied fishes in Reach 1 and upper portions of Reach 2 (Project 115). Also as part of those Project 115 sampling trips, researchers monitor the small bodied fish, and a Colorado pikeminnow larval drift component has been incorporated.
Priority for the development and implementation of Gunnison River fish community monitoring program = **H**

c. Immediate changes / additions needed:

   i. Incorporate a small bodied fish component (minimally, an autumn seine sampling effort in low velocity habitats).

   ii. Let a CPE-based monitoring program determine when/if a more robust (e.g., mark/recapture) methodology is necessary.

   iii. Endangered species specific – Grand Junction CRFP recommends some level of electrofishing in the spring when endangered fish (juveniles and adults) are most susceptible to capture (Burdick 1995 sampled prior to, during and after spring runoff).

   iv. Consider incorporating larval sampling for both Colorado pikeminnow and razorback sucker to determine: a) where spawning is occurring, and b) how spawning is influenced by hydrology.

Fish Community Response – Main Channel (Colorado) – Will the proposed action assist in the recovery of the endangered species and benefit the native fish community in the Colorado River?

Considerable monitoring is ongoing for Colorado pikeminnow and humpback chub in the Colorado River downstream of the Gunnison River confluence (CPM= Projects 127 and 138; HBC = Projects 131 and 132). With the exception of Project 138 (backwater

sampling for Age-0 CPM, there is no formal, ongoing effort to monitor the fish community downstream of Westwater Canyon.

This focus area and the suggested new areas of research discussed below are intended to address (directly or indirectly) the following high priority AE and U:

- UC4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question)
- UC12. Spawning sites for RZ not definitively known. Need further investigations to focus floodplain management.
- UC18. Recover fish in presence of nonnatives
- AEC6. Base flows and habitat for growth (all life stages)

Overall Focus Area Priority: Colorado River = H

Suggested Approach / New Areas of Research –

d. Continue all ongoing efforts.

e. Immediate changes needed:

i. Incorporate a fish community monitoring effort upstream of Westwater Canyon preferably in the 18-Mile Reach. The *ad hoc* Committee strongly recommends that a small-bodied fish component be part of this effort (e.g. reinstate the ISMP YOY reach in the Upper River). **Priority** for this specific new area of research: Colorado River = **H**

ii. Take direction from the pending Razorback Sucker Monitoring Program, which likely will require sampling for both juveniles/adults and early life stages in the same area (and others). Use this information to either identify razorback sucker spawning areas, or identify more specific studies to gather that information. **Priority** for this specific new area of research: Colorado River = **H**

The areas of new research identified above are necessary for evaluating the Aspinall Unit operations, but are not necessarily inclusive of all of the most important issues and studies necessary for recovery of the four endangered fish species in the Upper Basin. In Table A6, the suggested new areas of research were compared to the focus areas to reiterate our approach and to demonstrate the interrelatedness of the uncertainties. However, other Recovery Program actions are addressing issues not related to the Aspinall Unit operations (Figure 1). The ultimate goal of all of the Recovery Program actions, including these Aspinall Unit operations, is to elicit a positive response by the endangered fishes.

An integrated approach is necessary when implementing this Study Plan. Anticipated effects or uncertainties are interrelated and must be considered together to gain a better understanding of the effects of the Aspinall Unit operations. It is also noted that information

needs and recommended studies ally closely with priorities identified in the Recovery Program guidance documents (Section 1.2.2).

3.3 Summary of Suggested Approaches and New Areas of Research with associated Priorities.

A summary of the Suggested Approaches and New Areas of Research and their priority from Section 3.2 is presented in Table 3.

Table 3. Summary of Suggested Approaches and New Areas of Research (from Section 3.2) with relative priority.

Suggested Approaches / New Areas New of Research	Priority of New Approach / Research	
	Gunnison River	Colorado River
1. Focus Area: Physical - Sediment Transport: Gunnison and Colorado rivers		
Complete the review / interpretation of Williams et al. (2011; in draft) in light of previous geomorphological studies.	**H**	**M**
Field studies in the Gunnison River to validate initial and significant motion flow thresholds (e.g. add sediment facies mapping, buried chains, painted rock, or other monitoring protocols)H	**H**	**M**
Reinstate daily sediment monitoring as directed by USGS / Program through Project 85f (Gunnison and Colorado (?) rivers)	**M**	**M**
Aerial photography base flow to determine channel width and complexity – both rivers are considered high priority. Apply methodology of Pitlick et al. 1999.	**H**	**M**
Repeat Depth to Embeddedness (DTE) in the Gunnison River near Escalante Bridge and the synoptic sites on the Colorado River. If DTE does not prove to be a good predictor of productivity more research could be needed to strengthen that relationship.	**M**	**M**
2. Focus Area: Physical - Fish Habitat		
Repeat McAda and Fenton (1998): habitat mapping (using aerial photography collected during base flows as base maps) and channel transects. (Gunnison)	**H**	**-**
Repeat DTE – referenced above in Sediment Transport section	**M**	**M**
Continue backwater monitoring in the lower Colorado River (ongoing Project 138)	**-**	**M**
3. Focus Area; Physical - Floodplain inundation—Gunnison and Colorado Rivers		
Aerial Photography (spring peaks) (both rivers).	**H**	**H**
Repeat Tetra Tech (2000); McAda and Fenton (1998) also determined inundation flows in Escalante area.	**M**	**-**
Continue C6-Hydro - to monitor physical condition and connection flows at levee breach sites (split efforts between Green and Colorado sub-basins)	**H**	**H**

4. Focus Area: Physical – Temperature vs. Hydrology		
Revisit available modeling (Boyer and Cutler 2004), or initiate a new effort as needed, to take advantage of new temperature monitoring sites.	**L**	**-**
5. Focus Area: Biological – Fish Community Monitoring (floodplain) —Gunnison and Colorado Rivers		
Pattern a monitoring program after the Burdick (1995) design including large and small bodied fish in floodplains. These efforts will need to coordinate with the Program's Razorback Sucker Monitoring Program.	**H**	**M**
6. Focus Area: Biological – Fish Community Monitoring (Main Channel)—Gunnison and Colorado Rivers		
Pattern a monitoring program after the Burdick (1995) design including large and small bodied fish in the main channel. Build on CDOW's main channel sampling efforts.	**H**	**-**
Influence the Recovery Program Razorback Sucker monitoring effort to sample for larval fish to assess reproduction and assist in identifying spawning areas.	**M**	**H**
Continue all ongoing population monitoring efforts for CPM and HBC.	**-**	**H**
Initiate fish community monitoring (priority on small bodied fish) in the 18-mile reach.	**-**	**H**

3.4 Integration of Information

The Recovery Program's evaluation of the Proposed Action will occur at several levels:

1st level - The Recovery Program evaluates accomplishments and shortcomings of all ongoing efforts under all recovery elements via its annual RIPRAP review and through coordination with the Service as they complete their Sufficient Progress review. That evaluation feeds back, and results in needed changes to ongoing studies, the RIPRAP, or the Recovery Goals themselves as needed to better address uncertainty, i.e. adaptive management (Figure 4).

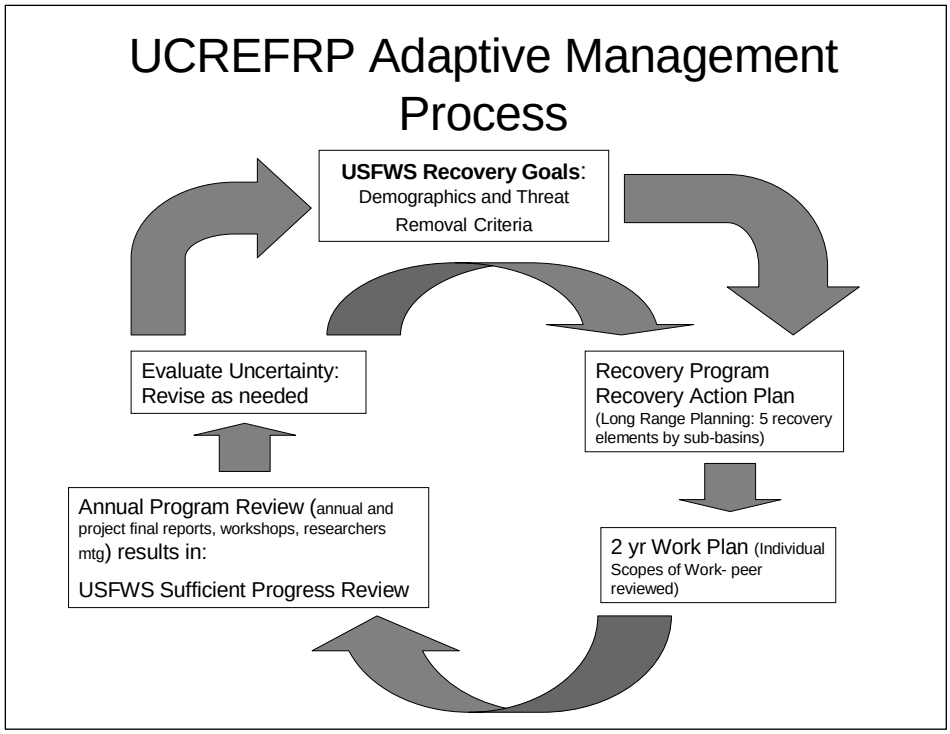

Figure 4. Conceptual diagram of the Upper Colorado River Endangered Fish Recovery Program's adaptive management process. This represents the first level of information integration needed to evaluate the Proposed Action.

2nd level: There are several ongoing, long term synthesis efforts on the Colorado River (e.g. Colorado pikeminnow population estimation; humpback chub population estimation in Black Rocks and Westwater Canyons; Age-0 pikeminnow monitoring in the lower Colorado River; nonnative fish management upstream of Black Rocks), which will contribute to an evaluation of the Proposed Action. However, with the exception of CDOW's recent efforts into fish community efforts and the Redlands Fish ladder operations, there are few ongoing efforts that will contribute directly to an evaluation of the Proposed Action on the Gunnison River. Nevertheless, all of these efforts need to continue as they will be an important component of the integration in the long term.

3rd level: We recommend a specific integration of all ongoing and related monitoring efforts (see 2nd level) as well as new areas of research recommended above to occur on five year intervals. This larger integration effort will rely on Reclamation's Annual Operations Reports to describe the treatment. Again, the Recovery Program continually monitors progress of all recovery action on annual basis (see Figure 4), but a more directed integration of all available information to evaluate the Proposed Action needs to incorporate data collected during a variety of hydrologies (hence the five year timeframe). Therefore, the first formal evaluation of the Proposed Action is scheduled to occur after the 2015 field season.

3.5 Recommended RIPRAP Revisions

Study Plan recommendations (from Table 3) for the *Gunnison and Colorado River Action Plan: Mainstem* sections of the RIPRAP will be considered for incorporation when the RIPRAP is reviewed in spring 2011. The following Tables 4 and 5 should serve as the basis for those discussions.

Table 4. Recommended changes to the *Gunnison River Action Plan* section of the RIPRAP.

RIPRAP line	ACTIVITY	WHO	STATUS	11	12	13	14	15	16	OUT-YEARS
I.D.	Evaluate and revise as needed flow regimes to benefit endangered fish populations.	Program	Ongoing	X	X	X	X	X	X	X
I.D.1.	Develop study plan to evaluate flow recommendations	Program	Pending	X						
I.D.1.a	Monitor Physical Response in the Gunnison River to the Proposed Action									
I.D.1.a(1)	Complete the review / interpretation of Williams et al. (2011; in draft) in light of previous geomorphological studies.	Program		X						
I.D.1.a(2)	Reinstate sediment monitoring in the Gunnison River as directed by project 85f	Program	New Start		X	X	X			
I.D.1.a(3)	Conduct aerial photography during the peak flows to determine area of floodplain inundation at Escalante SWA and other sites	BOR				X				
I.D.1.a(4)	Conduct aerial photography during base flows to monitor channel width and complexity and to serve as base maps for habitat mapping.	BOR				X				
I.D.1.a(5)	Repeat Depth to Embeddedness (DTE) surveys in the Escalante area.	??	New Start					X		
I.D.1.a(6)	Evaluate the effect of operations to meet the Proposed Action on the Gunnison River thermal regime.	BOR	New Start						X	
I.D.1.b	Monitor Biological Responses in the Gunnison River to the									

	Proposed Action									
I.D.1.b(1)	Initiate a fish community monitoring study in Gunnison River main channel and floodplain habitats	CDOW / FWS	New Start	X	X	X	X	X	X	X
I.D.1.b(2)	Assess primary and secondary productivity in cobble bars (runs and riffles)	??						X		
I.D.1.c	Support Reclamation's Selenium Management Program									
I.D.1.c(1)	Collect tissues from endangered fish (or surrogate species) as directed by FWS (coordinated with fish community monitoring)	CDOW / FWS	New Start	X	X	X	X	X	X	
I.D.1.c(2)	Identify allowable levels of selenium to support recovery of razorback sucker and Colorado pikeminnow.	Program	New Start		X	X	X	X	X	
I.D.2.	Integrate and synthesize information to evaluate and recommend necessary revision of the proposed action	Program	New Start						X	

Table 5. Recommended changes to the *Colorado River Action Plan* section of the RIPRAP

RIPRAP line	ACTIVITY	WHO	STATUS	11	12	13	14	15	16	OUT-YEARS
I.B.5.	Evaluate and revise as needed flow regimes to benefit endangered fish populations.	Program	Ongoing	X	X	X	X	X	X	X
I.B.5.a	Develop study plan to evaluate flow recommendations (Aspinall Study Plan)	Program	Pending	X						
I.B.5.a(1)	Monitor Physical Response in the Colorado River to the Proposed Action									
I.B.5.a(1)i	Conduct aerial photography during the peak flows to determine area of floodplain inundation at floodplain sites (Valdez and Nelson 2006)	BOR				X				
I.B.5.a(1)ii	Conduct aerial photography during base flows to monitor channel width and complexity and to serve as base maps for habitat mapping.	BOR				X				
I.B.5.a(1)iii	Repeat Depth to Embeddedness (DTE) surveys in the 18-mile reach.	??	??					X		
I.B.5.a(2)	Monitor Biological Responses in the Gunnison River to the Proposed Action									
I.B.5.a(2)i	Initiate a fish community monitoring study in Colorado River main channel and floodplain habitats (focus on 18-mile reach)	CDOW / FWS	New Start	X	X	X	X	X	X	X
I.B.5.a(2)ii	Assess primary and secondary productivity in cobble bars (runs and riffles)	??						X		
I.B.5.a(2)iii	Continue ongoing fish community monitoring (CPM and HBC pop estimation; CPM Age-0 monitoring)	FWS / UDWR	Ongoing	X	X	X	X	X	X	X
I.B.5.b	Integrate and synthesize information to evaluate and recommend necessary revision of the proposed action	Program	New Start					X	X	

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Table A1. Goals, objectives, and status for studies (primary studies in bold text) **relevant to evaluation of the Aspinall Unit operations. See Tables A2–A3 for links of studies to Aspinall Unit operations, and anticipated effects or uncertainties.**

Studies	River	Study Goal and Objectives	Comment
85f, sediment transport	**GUN, COR**	A. Goals: The goal of the sediment monitoring program is to provide information with which to evaluate changes in the magnitude, timing, and size distribution of sediment delivery to the Gunnison and Green River systems and their potential effects on the riverine ecosystem, specifically as they relate to recovery of the endangered fishes. B. Objectives: The primary objective of this sediment-monitoring project is to address key uncertainties in priority reaches of the Colorado, Gunnison and Green Rivers relevant to the role of streamflow and sediment transport on the formation and maintenance of backwater habitats and spawning bars. A secondary objective is to collect necessary sediment data to aid in the evaluation of Service flow recommendations for the Aspinall Unit and Flaming Gorge Reservoir. Also: 1. A retrospective analysis of historic sediment data will be done to determine the availability of historic sediment data for the key sites on the Colorado, Gunnison, and Green Rivers. 2. To support the evaluation of the effects of streamflow and sediment movement on the morphometric and bed material characteristics of Gunnison and Green Rivers. 3. Determine if there is any distinction between sediment load estimates computed from daily sediment data, sediment transport equations, and empirical bedload transport equations. 4. Evaluate the dynamics of sediment movement in the study reaches by collecting and analyzing data to compute sediment load, including suspended sediment using daily samples and sediment transport equations. 5. Collect necessary topology data near the Jensen site for use in a Surface Water Modeling System (SWMS) Demonstration Project to determine the suitability of this type of modeling of sediment transport as it relates to current and future efforts to monitor habitat for the endangered fishes. 6. Collect water-surface elevation, channel cross-section, and streambed sediment-size data from the Gunnison River at Delta to evaluate incipient motion conditions at which the discharge is sufficient to begin transport of the streambed sediment.	
Aerial photography	**COR, GUN**	1. Collect aerial imagery during high run-off conditions in the Colorado, Yampa, Green and Gunnison rivers; Collect aerial imagery at base flow conditions of the Gunnison (Delta to confluence) and Green rivers.	

Aerial photography	**COR, GUN**	2. Compile/backup collected imagery. 3. Create mosaics (stitch together frames) of digital high resolution imagery with imagery scale attached and organized by river mile into a 'map book format', and also provide a digital version.	
121a, razorback sucker spawning (Osmundson and Seal 2009)	GUN	Study Goals 1. Provide continuity of verification of spawning by razorback sucker in the Gunnison River. 2. Provide continuity of verification of spawning by razorback sucker in the Upper Colorado River. Objective: Collect samples of larvae from the Gunnison River and Upper Colorado River during and immediately after the suspected spawning season and determine if razorback sucker larvae are present among samples.	
127, Colorado pikeminnow estimate (Osmundson and White 2009)	COR	Goal Our goal is to provide three annual whole-river estimates for abundance of Colorado pikeminnow > 250 mm TL and for Colorado pikeminnow >450 mm TL in the Colorado River mainstem, with coefficients of variation of 20% or less. Objectives 1. Capture and mark subadult and adult Colorado pikeminnow from throughout the river for a three-year period making four complete passes through the upper reach (upstream of Westwater Canyon) and four through the lower reach (downstream of Westwater Canyon) each year. 2. Develop a population estimate from mark-recapture data. 3. Assess recruitment trends by analyzing length-frequency histograms. 4. Also, reduce centrarchid abundance in the study area by removing those encountered during field sampling so as to help meet objectives of Project 126 (bass removal). 5. Capture stocked razorback sucker and bonytail opportunistically for late assessment of their populations.	
128, Green R. pikeminnow estimate (Bestgen et al 2010)	GR	Goals: Obtain accurate (unbiased) and reliable (precise) estimates of adult population abundance and survival of Colorado pikeminnow that occupy the Green River study area. Objectives: 1. Complete a minimum of three sampling passes through the five Green River Basin reaches listed to capture sub-adult and adult Colorado pikeminnow: a) Green River between the confluence of the White River upstream to the lower end of Whirlpool Canyon (i.e., upper Rainbow Park); b) White River between the confluence of the Green River upstream to Taylor Draw Dam; c) Yampa River between Deerlodge Park and Craig, excluding Cross Mountain Canyon; d) Green River from the White River confluence downstream to near Green River, Utah; and	Green river study; to be used as guidance in development of GUN/COR studies, if necessary

128, Green R. pikeminnow estimate	GR	e) Green River from downstream of Green River, Utah, to the confluence with the Colorado River. 2. Obtain highest possible rates of capture of Colorado pikeminnow within concentration habitats and maximize number of individuals marked and captured on each sampling occasion. 3. Obtain estimates of probability of capture and abundance for Colorado Pikeminnow in each of the five reach and for the entire study area. Razorback sucker data gathered concurrently will also be analyzed, mostly related to survival rate estimation. We will also assist with analysis of Colorado pikeminnow data in the Colorado River.	
138, ISMP Age-0 pikeminnow monitoring	**GR, COR**	1. Determine size and relative abundance of YOY Colorado pikeminnow at the end of their first growing season to complement larval and juvenile sampling data. 2. Estimate the response of small-bodied and YOY native fish to removal of northern pike and smallmouth bass. 3. Determine relationships between YOY Colorado pikeminnow CPE abundance estimates with respect to flow and temperature. 4. Using new and existing data, develop predictive model that relates larval and YOY Colorado pikeminnow abundance 5. Using new and existing data, develop predictive model that relates YOY and juvenile Colorado pikeminnow abundance	Colorado River sites disbanded in recent years
C-6 hydrology	**GUN, COR**	Goal: To restore floodplain nursery habitats to assist in recovery of the endangered fishes, and to ensure that the habitats function as designed and constructed, and to take remedial measures as necessary. Objectives: 1. To determine, as a function of main-stem flows, how well selected floodplain nursery habitats connect with the river and are likely to entrain drifting larvae (Audubon, Unaweep, Walter Walker); 2. To characterize post-runoff habitat and levee-breach morphology at selected sites (Audubon, Unaweep, Walter Walker) and compare to as-built morphology (Audubon, Unaweep); 3. To identify potential problems and make recommendations (Audubon, Unaweep, Walter Walker); 4. To estimate when the downstream levee will breach at GJ Pipe.	Objectives will change from year to year depending on study locations
C6-RZ-ENTR, razorback larvae entrainment	GR	Study Goal Evaluate larval razorback sucker drift characteristics and use the data to revise management for middle Green River floodplains based on potential larval razorback sucker entrainment. Study Objectives 1. Evaluate larval drift and entrainment patterns downstream from Razorback bar.	Green river study; to be used as guidance in development of GUN/COR studies, if necessary

C6-RZ-ENTR	GR	2. Evaluate larval drift and entrainment into floodplains from other potential spawning sites. 3. Continue to evaluate the effectiveness of breach connections for entraining drift at various points on the hydrograph. 4. Use data to refine the Floodplain Drift Model and for testing floodplain management scenarios.	
22f, larval drift	GR	Goal The goal of this project is to detect timing of reproduction by razorback sucker and Colorado pikeminnow, and determine patterns of presence of larvae and their relative abundance downstream of potential Spawning sites in the middle Green River system. A second goal is to monitor temperature regimes of the Green and Yampa rivers in order to comply with Flaming Gorge flow recommendations. The data gathering for this aspect will be accomplished by personnel from the U.S. Fish and Wildlife Service. Objectives 1). To determine timing and duration of spawning by razorback suckers and presence and abundance of larvae in the system as measured by capture of larvae in light traps. 2). To determine timing and duration of spawning by Colorado pikeminnow and presence and abundance of larvae in the system as measured by capture of larvae downstream of spawning areas in the lower Yampa River.	Green river study; to be used as guidance in development of GUN/COR studies, if necessary
FR-FP Synth, larval drift/entrainment synthesis (Bestgen and Haines, in draft)	GR	Synthesize existing information on floodplain inundation and larval drift and entrainment to meet the following information needs: 1. Flow and stage at which floodplains with levee breaches become sufficiently inundated to provide nursery habitat for razorback suckers. 2. Frequency of floodplain inundation relative to the hydrologic cycle. 3. Area, depth, volume, and persistence of floodplain depression habitat after peak flows recede and relationship with peak flow magnitude. 4. Rates of sediment deposition and erosion in breaches and floodplains. 5. Entrainment and retention of larvae in floodplain nursery habitats as a function of physical characteristics and timing of drift. 6. Temporal relationships between drifting larvae and hydrology during the runoff period with a focus on the peak flow characteristics needed to entrain larvae. 7. The area of terrace and depression floodplains inundated at different flows. 8. What is the optimal combination of flow magnitude and duration to maximize entrainment of razorback sucker larvae?	Green river study; to be used as guidance in development of GUN/COR studies, if necessary
FR-115, fish community monitoring	GR	**Goal:** Remove non-native fishes and determine if changes in Green River flow and thermal regimes are associated with changes in distribution and abundance patterns of native and nonnative fishes in Browns Park, Lodore and Whirlpool canyons, and Island-Rainbow Park. Objective 1. Remove non-native fishes and determine if shifts in distribution and	Green river study; to be used as guidance in development of GUN/COR studies, if necessary

FR-115	GR	abundance of large-bodied fishes have occurred in Lodore Canyon and Whirlpool Canyon by comparing the results of shoreline electrofishing and trammel net surveys with the results of previous studies, particularly Bestgen and Crist (2000) and results of the 2002-2008 sampling. Objective 2. Remove non-native fishes and determine if shifts in the distribution and abundance of small-bodied fishes have occurred in Brown's Park, Lodore and Whirlpool canyons, and Island-Rainbow Park by comparing results of low-velocity, nearshore seining with the results of previous studies, particularly Bestgen and Crist (2000) and results of the 2002 to 2008 sampling. Objective 3. Determine if Colorado pikeminnow spawn in the Green River upstream from the Yampa River confluence by sampling with drift nets in lower Lodore Canyon, and by summer sampling to determine presence of ripe adults. Drift net sampling will be done only occasionally when Green River flows are low and warm (conditions when pikeminnow spawning might be expected) and will be done in conjunction with drift-net sampling in the Yampa River (project 22f). Objective 4. Analyze hydrological records as recorded by the USGS at their gaging station (09234500) near Greendale, Utah, to compare differences in current and historical operations. Objective 5. Analyze temperature records of the Green River through Browns Park, Lodore Canyon, and Whirlpool Canyon to compare differences in current and historical operations. Objective 6. Continue to analyze past otolith samples and those collected in 2007-2009 to understand smallmouth bass spawning periodicity to assist with flow-related management of that species. Objective 7. Based on results of objectives 1–6, determine physical effects of new operations and subsequent effects on the fish community of the Green River downstream of Flaming Gorge Dam.	
FR-BW Synthesis	GR	The motivation for this project is to understand reasons for the decline in abundance of age-0 Colorado pikeminnow in backwaters in the Green River. This study will investigate anticipated effects and uncertainties of the flow recommendations as identified in the Green River Study plan, including: • Effect of base flow variability (within-day, within-season, within-year, between years) on backwater quality in reaches 2 and 3, • The effect of base flows on nonnative fish populations in Reach 2, • Base flows in summer and autumn scaled to hydrologic condition favor formation of backwaters in Reach 2, and • Maintenance of mean base flow within recommended levels of season and daily flow variability will promote favorable backwater conditions in Reach 2.	Green river study; to be used as guidance in development of GUN/COR studies, if necessary
Backwater topography	GR	Couldn't find concise objective statement in RIP SOW's	Green river study; to be used as guidance in

(LaGory et al 2009)			development of GUN/COR studies, if necessary
C-4b, Redlands fish passage	**GUN**	Continue to collect data on the number of large-bodied fish, different fish species, and seasonal distribution of fish that use the Redlands passageway. Summarize the annual results of passageway fish use in the annual RIP report.	Longer-term synthesis would be nice
C-6 RZ larvae, Middle Green (growth and survival)	GR	There were several studies conducted in Green river floodplains that investigated larval razorback survival and growth in semi-controlled environments culminating in the ongoing management of the Baeser Bend floodplain site.	Green river study; to be used as guidance in development of GUN/COR studies, if necessary
C-6 RZ RECR, razorback recruitment	GR	Goal: Characterize age of emigration of razorback sucker from floodplain wetlands to the Green River. Objectives: 1. Maintain multiple year-classes of razorback sucker in the Stirrup floodplain throughout the study (stock razorback sucker and maintain sufficient water quality). 2. Determine the average length of time (via age class and size) that razorback sucker stay within the floodplain before migrating to the river by installing and maintaining appropriate technology within the breach of the floodplain during the spring peak.	Green river study; to be used as guidance in development of GUN/COR studies, if necessary
126, smallmouth bass control	**COR**	Study Goals The purpose of this proposed study is to remove as many smallmouth bass of all sizes in main channel riverine habitats in a 61-mile reach of the Upper Colorado River between Price-Stubb Dam and Westwater boat landing in eastern Utah. The goal is to reduce the abundance of smallmouth bass as quickly as possible in this reach, which will ultimately benefit native listed fishes, and possibly contribute to their recovery. Objectives: 1. remove all sizes of smallmouth bass in the Upper Colorado River by boat and raft based electrofishing, and 2. obtain an abundance estimate for smallmouth bass juvenile (100-199 mm) and adults (≥ 200 mm) by mark and recapture methods for the Upper Colorado River between GVIC Dam and Loma Boat Landing and the Lower Gunnison River between Redlands Dam and the Colorado/Gunnison river confluence.	
C18/19, chemical fingerprinting	COR, GUN	**Goals:** a) determine how configuration of outlet structures, dam operations, and hydro-climatic variability affect the likelihood of nonnative fish emigration from reservoirs, b) determine chemical "fingerprints" of nonnative fishes in reservoirs that are potential sources of nonnative fishes to critical habitat. **Objectives:** Primary objectives of the investigation will be to: 1. identify species/water-years/locations with the highest risk of emigration from	

C18/19	COR, GUN	reservoirs, 2. quantify chemical "fingerprints" of fishes within study reservoirs and evaluate the degree of inter-annual variation in those fingerprints. 3. determine if fish sampled in rivers in the vicinity of study reservoir possess otolith core signatures that identify them as having originated from one of the study reservoirs. 4. improve our understanding of the degree to which immigration or transfers from reservoirs contributes to the load of nonnative fishes in critical habitat of the Upper Colorado River basin. 5. provide recommendations to guide management efforts to reduce the influx of nonnative fishes from reservoirs.	
131, HBC in Black Rocks	**COR**	A. Goal: Estimate size and recruitment of the humpback chub population in Black Rocks B. Objectives: 1. Use mark-recapture to estimate the population size (including adults >200 mm TL) and recruitment (i.e., juveniles 150B199 mm TL) of humpback chub in Black Rocks. 2. Describe population structure of humpback chub in Black Rocks by analyzing length frequency distributions.	
132, HBC in Westwater	**COR**	Goal: To estimate the population size of humpback chub in Westwater Canyon with the most precise confidence intervals possible. Objectives: 1) Obtain a population estimate of adult humpback chub (> 200 mm) in Westwater Canyon 2) Determine mean estimated recruitment of naturally produced subadult humpback chub (150-199 mm) in Westwater Canyon	
159, razorback sucker monitoring plan	**All**	Goals: Obtain accurate (unbiased) and reliable (precise) demographic parameter estimates for razorback suckers stocked in the Green and Colorado River basins, 2004-2007 via analysis of capture-recapture records and develop a monitoring plan for razorback suckers in the Upper Colorado River Basin. Objectives: 1. Analyze additional razorback sucker data collected from 2004 through 2008 to obtain more robust estimates of survival and other demographic parameters of interest. Specific elements include: a. compile and proof stocking and capture data for stocked razorback suckers, b. identify possible covariates for data analysis including evaluation of effects of hatchery source and rearing (pond vs. tank) techniques, c. analyze data with appropriate parameter estimation software to obtain the most unbiased and precise survival rate estimates possible, d. compare survival rate estimates to those available in other parts of the range of razorback sucker and those assumed in stocking plans,	**Need to ensure that COR/GUN plans are consistent with this document**

		e. recommend revisions to stocking plans, based on results of analyses. 2. Develop a razorback sucker monitoring plan. Specific elements include: a. compile literature and sampling data relevant to understanding early life and adult razorback sucker distribution and ecology, b. conduct analyses appropriate to understanding sampling intensity, c. make recommendations for sampling.	
Osmundson 2010	**GUN**	Objective: Determine if thermal regimes were similar at the distributional boundaries of Colorado pikeminnow in the [historical range of the Colorado and Gunnison Rivers]; if so, a minimum thermal suitability threshold could be inferred. The identification of such a threshold could then be used to address two management objectives: -Predict the extent of range expansion in the Colorado River where passage facilities will allow access to an upstream reach; and -Estimate how much summer temperatures in the Gunnison River would have to be raised to restore thermal suitability to historically used habitat	Boyer and Cutler (2004) could also be used as background
Rees et al. 2008 (never approved by Recovery Program)		The initial focus of this study within the 15-Mile reach was to address the hypothesis that the current peak flow regime is limiting to the recovery of the listed native fish species and the aquatic community on which they depend.	Could be important to evaluate summer/fall sediment loading
Hartland Fish Passage??	**GUN**	Maintain Hartland Irrigation Company's senior decree while reducing liability and decreasing maintenance costs • Increasing habitat connectivity and total numbers of the target species upstream of the current dam – potential improved aquatic habitat extends throughout the Black Canyon of the Gunnison National Park, and the Gunnison Gorge National Conservation Area to the dam downstream of the Crystal Reservoir, and throughout the North Fork of the Gunnison to the Paonia Reservoir encompassing approximately 230 river miles • Increased river system stability by returning the river morphology to a more natural state and stabilization of the downstream river banks • Reduce trespassing and protect adjacent landowner from liability • Reducing danger to boaters	Not a program project, but may need to assess status of project and role (if any) in conducting RIP studies, especially pikeminnow thermal requirements

Table A2. Evaluation of how well primary studies address AE's and U's associated with Aspinall Unit reoperations in the Gunnison River. Y= AE or U being addressed by study; P=study partially addresses AE or U; NA=study not designed to address A or U; N=AE or U not addressed by this study. Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

	Proj. 85f	Photography (2008)	CDOW's	Larval RBS	C-6	C-4b	Thermal Units	Rees et al. 2008	BOR's Annual Operations Report	Temperature	Primary & Secondary Productivity	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
GUNNISON RIVER																
Peak Flows / In-Channel Habitat Formation and Maintenance																
AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)	P	P	P	P	NA	NA	NA	P	NA	NA	P	P	Too broad - topics are addressed below as they relate to more specific uncertainties. Whereas there is a strictly physical aspect to many of the associated uncertainties, ultimately the Program will need to establish a fish community monitoring program with specific components directed toward endangered fish response to evaluate.	Too broad - topics addressed below as they relate to more specific uncertainties. Develop necessary fish community monitoring program.		
UG1. Fine sediment and productivity	P	NA	P	NA	NA	NA	NA	P	NA	NA	P	P	Pick up where CRWCD (Miller and Mussetter) and Lamarra et al left off with their investigations into ecosystem productivity. Can Depth to Embeddedness serve as a surrogate? If not, additional work (primary and secondary productivity measurements) may be needed to strengthen these linkages.	Need periodic assessment of fine sediment accumulation (also under base flows). Take direction from USGS (Project 85f) and their daily sediment grab sampling component. Pick up where CRWCD (Miller and Mussetter) and Lamarra et al left off with their investigations into ecosystem productivity. If relationships between Depth to Embeddedness are not strong enough additional work to strengthen these linkages may be necessary, i.e. a fairly involved project. This is a base flow issue as well (see AEG 6 and UG25 below) Assess usefulness of ongoing USGS sediment monitoring in the Gunnison - augment as directed by USGS via Project 85f. Track channel width & complexity over time via aerial photography.		
UG2. Frequency of fine sediment flush	P	P	P	P	NA	NA	NA	P	NA	NA	P	N				
UG3. Frequency/duration to maintain habitat (1/2 and bankfull)	P	P	NA	NA	NA	NA	NA	NA	P	NA	NA	P	Key question raised by McAda. Project 85f designed specifically to answer - take guidance from USGS to determine next steps.			
UG4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question).	P	P	P	NA	NA	NA	NA	NA	NA	NA	NA	N	Although habitats are created and maintained during peak flows, would likely need to be monitored during base flows. There are expectations in McAda (% of macro habitat types) that are not being tracked.	During base flows, either map habitats or conduct more involved 2D modeling. Develop a fish community monitoring program to evaluate.		
UG5. Do peak flows provide spawning habitat?	P	P	NA	P	P	NA	NA	NA	NA	NA	NA	N	Peak flows affect CPM spawning bars most directly; RBS spawning bars less directly.	Currently, Program assesses CPM spawning success via Age-0 monitoring in the lower Colorado river in the autumn. A more direct measured would be to reinstate CPM larval drift in Gunnison River and secondarily to assess RBS larval production.		

	Proj. 85f	Photography (2008)	CDOW's	Larval RBS	C-6	C-4b	Thermal Units	Rees et al. 2008	BOR's Annual Operations Report	Temperature	Primary & Secondary Productivity	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
UG6. Water availability for flow recs (policy?)	P	P	NA	NA	P	P	NA	NA	P	NA	NA	N	These uncertainties go beyond the scope of the Recovery Program.	Policy issues – BOR will need to track via their annual operations reporting.		
UG7. Ramping rates (policy?)	NA	NA	NA	NA	NA	NA	P	NA	P	NA	NA	N				
UG8. Property (Delta flooding issue)	NA	P	NA	NA	NA	NA	NA	NA	P	NA	NA	N				
UG8a. Black Canyon. Water right	NA	NA	NA	NA	NA	NA	NA	NA	P	NA	NA	N				
UG9. Effects of Aspinall releases on Co. R. (just an evaluation of how we're operating to meet the Colorado River flow recs)	P	P	NA	P	P	NA	NA	NA	Y	NA	NA	N				
UG10. Mimicry of natural hydrograph	P	P	P	NA	NA	P	P	P	P	NA	P	N		Broad question that would be addressed on a variety of fronts. Would be cumulatively assessed though a periodic evaluation of the flow recommendations.		
Peak Flows and Floodplain Habitat																
AEG2. Spring flows and floodplain habitat *(Note: review analysis in BA for other sites)*	NA	P	P	NA	Y	NA	NA	NA	P	NA	NA	P	C6 Hydro monitors connections flows and condition of levee breaches. No ongoing assessment of availability of floodplain habitat.	Aerial photos during peak flows to determine if floodplain inundation (e.g. Escalante Wildlife Area) is occurring as planned.		
UG11. RZB larvae in floodplain/lack of adults	NA	P	NA	P	P	NA	NA	NA	NA	NA	NA	N	Osmundson and Seal provide general direction as to where RBS spawning may occur. However, these uncertainties are focused on native and nonnative species life history and interactions in the floodplain habitat - not currently being addressed.	First step - develop a floodplain component to a Gunnison River fish community monitoring program. Consider telemetry of stocked fish to discover wild congregations of spawning fish? Draw on available information collected in the Green River system to help identify information needs.		
UG12. NNF benefit from floodplains	NA	NA	P	NA	P	NA	NA	NA	NA	NA	NA	N				
UG13. Spawning sites for RZ not definitively known. Need further investigations to focus floodplain management.	NA	P	NA	P	NA	NA	NA	NA	NA	NA	NA	N				
UG14. Amount/location of floodplains for recovery	NA	P	NA	P	P	NA	NA	NA	NA	NA	NA	N				
UG15. Drift of RZ larvae	NA	NA	NA	P	P	NA	NA	NA	P	NA	NA	P				
UG16. Effectiveness of "reset theory"	NA	P	NA	P	P	NA	NA	NA	NA	NA	NA	N				
UG17. RZ BT survival in floodplains	NA	NA	P	NA	P	NA	NA	NA	NA	NA	NA	N				
UG18. Value of gravel pits, depressions, etc	NA	P	P	P	P	NA	NA	NA	NA	NA	NA	N				
UG19. Recover fish in presence of nonnatives	NA	P	P	P	P	NA	NA	NA	NA	NA	NA	N				

	Proj. 85f	2008 Photography	CDOW's	Larval RBS	C-6	C-4b	Thermal Units	Rees et al. 2008	BOR's Annual Operations Report	Temperature	Primary & Secondary Productivity	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
UG20. Flow effects on breach configuration	P	P	NA	NA	P	NA	NA	NA	P	NA	NA	N		Continue C6-Hydro		
UG21. Habitat availability at peak/base flows to flood and maintain depression or gravel pit floodplain habitats	NA	P	NA	P	P	NA	NA	NA	P	NA	NA		This is a quality (persistence) of floodplain habitat issue. Unlike natural floodplain depressions gravel pits seem to consistently provide year round habitat, which is good for early life stages of natives, but perhaps to the detriment (as refuge for nonnatives) of the fish community.	Consider with UG 11-19 above		
Peak Flows and Spawning Cues																
AEG3. Spring peaks provide spawning cues	NA	NA	NA	P	NA	NA	P	NA	NA	NA	NA	N	CPM and RBS spawning success is not currently being monitored in the Gunnison River.	see UG5 above		
Peak Flows and Staging Habitat																
AEG4. Spring peaks provide staging habitat	NA	NA	NA	P	NA	NA	NA	NA	NA	NA	NA	N	There is no fish community monitoring occurring during peak flows in the Gunnison River	Develop a fish community monitoring program (both small and large bodied fish) for the Gunnison River. Determine if spring sampling for adults is a high priority component of this program.		
Base Flows (not changing much under proposed action) - thermal regime													.	.		
AEG5 Flow effects on temperature	NA	NA	P	P	NA	P	Y	NA	Y	Y	NA	P	Program completed a dual Phase analysis of the effect of Aspinall releases and Gunnison River thermal regime including potential benefits of a thermal control device (Boyer and Cutler).	If determined a high priority, there may be utility in either revisiting Boyer and Cutler's model with greater amount of temperature data now available or develop another temperature model.		
UG22. Peak duration/base flow temperature	NA	NA	P	P	NA	P	P	NA	Y	Y	NA	N				
UG23. Response of nonnative fish *(probably low priority on Gunn)*	NA	NA	P	NA	NA	P	P	NA	NA	P	NA	P				
Base Flows and Habitat Availability / Productivity																
AEG6. Low water habitat (pools/runs, sediment mgmt)	NA	P	P	NA	NA	Y	NA	P	NA	NA	P	P	Fenton and McAda developed the expectations for habitat availability presented in McAda 2003 - no current monitoring in place to assess.	Develop a habitat monitoring component that either builds on Fenton and McAda or explores a more intensive 2D modeling approach. This AE and U, and many others ultimately need to be assessed via a fish community monitoring program.		
UG24. Habitat to achieve recovery	P	P	P	NA	P	NA	NA	P	NA	NA	P	P				
UG1 (repeated). Fine sediment and productivity	P	NA	P	NA	NA	NA	NA	P	NA	NA	P	P		see above		

	Proj. 85f	Photography (2008)	CDOW's	Larval RBS	C-6	C-4b	Thermal Units	Rees et al. 2008	BOR's Annual Operations Report	Temperature	Primary & Secondary Productivity	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
Base Flows - Fish Passage in Lower Gunnison River																
AEG7. Passage and minimum flow mgmt below Redlands	NA	NA	NA	NA	NA	P	NA	NA	P	NA	NA	P	Flow tradeoffs should be addressed in BOR's annual ops report. FWS will continue to monitor fish passage at Redland's ladder.	Current monitoring at the ladder coupled with BOR's assessment of flows should suffice.		
UG25. Peak duration/ Redlands operation	NA	NA	NA	NA	NA	P	NA	NA	P	NA	NA	P				

Table A3. Evaluation of how well primary studies address AE's and U's associated with Aspinall Unit reoperations in the Colorado River. Y= AE or U being addressed by study; P=study partially addresses AE or U; NA=study not designed to address A or U; N=AE or U not addressed by this study. Summary shows how the studies cumulatively satisfy the anticipated effect or uncertainty.

	Proj. 85f	Photography (2008)	Osmundson and White 2009	C-6 Hydrology	NNF Removal	Proj. 131 & 132	Proj. 138	Larval RBS	Larval Drift	Primary & Secondary Productivity	Rees et al. 2008	BOR's Annual Operations Report	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
COLORADO RIVER																	
Peak Flows / In-Channel Habitat Formation and Maintenance																	
AEC1. Flow effects on habitat (channel width, complexity, fine sediment on bars)	P	P	P	P	P	NA	P	NA	P	P	P	NA	P	Too broad - topics addressed below as they relate to more specific uncertainties. Whereas there is a strictly physical aspect to many of the associated uncertainties, ultimately the Program will need to augment existing fish community monitoring efforts to evaluate AE's and U's.	Too broad - topics addressed below as they relate to more specific uncertainties. Develop necessary fish community monitoring program.		
UC1. Fine sediment and productivity	P		P			P	P	NA	P	Y	Y	NA	P	Review the recent Project 85f study to determine next steps.	Need periodic assessment of fine sediment accumulation (also under base flows). Take direction from USGS (Project 85f) and their daily sediment grab sampling component. Pick up where CRWCD (Miller and Mussetter) and Lamarra et al left off with their investigations into ecosystem productivity. If relationships between Depth to Embeddedness are not strong enough additional work to strengthen these linkages may be necessary, i.e. a fairly involved project. This is a base flow issue as well (see AEC 6)		
UC2. Frequency of fine sediment flush	P	NA	NA	NA	NA	NA	P	NA	P	P	P	P	P				
UC3. Frequency/duration to maintain habitat (1/2 and bankfull)	P	P	P	P	NA	P	P	P	NA	P	P	P	P	Key question raised by McAda. Project 85f designed specifically to answer - take guidance from USGS to determine next steps.	Assess usefulness of ongoing USGS sediment monitoring in the Colorado River - augment as directed by USGS via Project 85f. Track channel width & complexity over time via aerial photography.		
UC4. Amount and quality of habitat necessary to maintain populations at recovery goals levels (physical habitat question).	P	P	NA	P	NA	NA	NA	P	NA	P	P	NA	P	Although habitats are created and maintained during peak flows, would likely need to be monitored during base flows. There are expectations in McAda (% of macro habitat types) that are not being tracked.	During base flows, either map habitats or conduct more involved 2D modeling. Develop a fish community monitoring program to evaluate.		

	Proj. 85f	Photography (2008)	Osmundson and White 2009	C-6 Hydrology	NNF Removal	Proj. 131 & 132	Proj. 138	Larval RBS	Larval Drift	Primary & Secondary Productivity	Rees et al. 2008	BOR's Annual Operations Report	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
UC5. Do peak flows provide spawning habitat?	P	NA	Y	NA	NA	Y	Y	NA	Y	P	P	NA	P	Peak flows affect CPM spawning bars most directly; RBS spawning bars less directly.	Currently, Program assesses CPM spawning success via Age-0 monitoring in the lower Colorado River in the autumn. A more direct measure would be to reinstate CPM larval drift in Colorado River and secondarily assess RBS larval production.		
UC6. Peak flow effects on backwaters (Moab to Green R.) *What about upstream of Westwater?*	P	P	P	NA	NA	NA	Y	NA	NA	NA	NA	NA	P	UDWR is reviewing information from the lower Colorado River. A similar synthesis is occurring for the Green River nursery habitats. These effort should direct future work if necessary.	There may be a need to reinstate nursery habitat sampling upstream of Westwater Canyon with an emphasis on entire fish community sampling.		
UC7. Location of, and peak flow effects, on spawning bars (physical habitat question).	P	P	Y	NA	NA	P	P	P	Y	P	NA	NA	P	Spawning areas are generally known for CPM; not known for RBS.	Currently, Program assesses CPM spawning success via Age-0 monitoring in the lower Colorado River in the autumn. A more direct measure would be to reinstate CPM larval drift. RBS spawning sites need to be determined through larval studies or radio telemetry. The physical condition of spawning cobbles could be evaluated with DTE.		
UC8. Effects of Aspinall releases on Co. R. (just an evaluation of how we're operating to meet the Colorado R. flow recommendations)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	Y	Y	USGS gages provide necessary information. BOR's pending annual operation report should adequately synthesize information to address this from a purely 'flow target' perspective.	BOR's annual operations report.		
UC9. Mimicry of natural hydrograph	P	P	P	P	P	P	P	P	P	P	P	P	P		Broad question that would be addressed on a variety of fronts. Would be cumulatively assessed though a periodic evaluation of the flow recommendations.		
Peak Flows and Floodplain Habitat																	
AEC2. Peak flows and floodplain habitat.	NA	Y	P	Y	P	NA	NA	NA	NA	NA	NA	P	P	C6 Hydro monitors connections flows and condition of levee breaches. No ongoing assessment of availability of floodplain habitat.	Aerial photos during peak flows to determine if floodplain inundation is occurring as planned. Reference Burdick, Irving, Valdez, and Nelson for expected connection flows and areas of inundation.		

	Proj. 85f	Photography (2008)	Osmundson and White 2009	C-6 Hydrology	NNF Removal	Proj. 131 & 132	Proj. 138	Larval RBS	Larval Drift	Primary & Secondary Productivity	Rees et al. 2008	BOR's Annual Operations Report	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
UC10. RZB larvae in floodplain/lack of adults	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA	P	Osmundson and Seal provide general direction as to where RBS spawning may occur. However, these uncertainties are focused on native and nonnative species life history and interactions in the floodplain habitat - not currently being addressed.	First step - develop a floodplain component to a Colorado River fish community monitoring program. Consider telemetry of stocked fish to discover wild congregations of spawning fish? Draw on available information collected in the Green River system to help identify information needs.		Need RBS Monitoring Program
UC11. NNF benefit from floodplains	NA	NA	NA	NA	P	NA	NA	NA	NA	NA	NA	NA	P				
UC12. Spawning sites for RZ not definitively known. Need further investigations to focus floodplain management.	NA	NA	NA	NA	NA	NA	NA	Y	NA	NA	NA	NA	N				
UC13. Drift of larval RZB	NA	NA	NA	NA	NA	NA	NA	P	NA	NA	NA	P	P				Rely on Green River Studies
UC14. Amount/location of floodplains for recovery	NA	Y	NA	Y	NA	NA	NA	Y	NA	NA	NA	NA	P				
UC15. Effectiveness of “reset theory”	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N				
UC16. RZ BT survival in floodplains	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N				Need RBS Monitoring Program
UC17. Value of gravel pits	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N				Look to old Burdick and Osmundson Gravel Pit studies
UC18. Recover fish in presence of nonnatives	NA	NA	Y	NA	P	Y	P	NA	NA	NA	NA	NA	P				
UC19. Habitat availability in relation to peak flows, Palisade to Loma.	P	P	Y	NA	NA	Y	Y	NA	Y	P	P	NA	P				
UC20. Peak flows/ sediment/connectivity, Palisade to Loma.	P	P	NA	P	NA	NA	NA	NA	NA	NA	NA	P	P				

	Proj. 85f	Photography (2008)	Osmundson and White 2009	C-6 Hydrology	NNF Removal	Proj. 131 & 132	Proj. 138	Larval RBS	Larval Drift	Primary & Secondary Productivity	Rees et al. 2008	BOR's Annual Operations Report	Cumulative	Topic Not Addressed by Studies (information needs)	Recommended Studies		Comments
Peak Flows and Spawning Cues																	
AEC3. Spring peak spawning cues.	NA	NA	Y	NA	NA	Y	Y	P	P	NA	NA	NA	P	CPM and RBS spawning success is not currently being monitored in the Colorado River	see UC5 above		
Peak Flows and Staging Habitat																	
AEC4. Spring peak staging habitats	NA	NA	Y	NA	N	NA	Y	P	P	NA	NA	NA	P	There is no fish community monitoring occurring during peak flows in the Colorado River	Develop a fish community monitoring program (both small and large bodied fish) for the Colorado River. Determine if spring sampling for adults is a high priority component of this program.		
Base Flows and Habitat Availability / Productivity																	
AEC5. Base flows and CPM nursery habitat	P	P	Y	NA	NA	NA	Y	NA	P	NA	NA	NA	Y?	see discussion for UC6 above			
AEC6. Base flows and habitat for growth (all life stages)	NA	NA	Y	NA	NA	Y	Y	P	P	P	P	NA	P	The only fish community monitoring that is occurring in the Colorado River comes in the ongoing Project 138 (backwater sampling in the lower Colorado River)	Implement a fish community monitoring program (both large and small bodied fish) that gages response to Aspinall Re-ops. Focus efforts in the 18-Mile reach as the area most directly affected by the proposed action.		

Table A4. Gunnison River anticipated effects and uncertainties as identified in foundational documents as related to future research focus areas. One Focus Area omitted - Flow vs. Temperature relates to AEG 5; UG22 and UG23.

	Focus Areas					
	Physical Questions			*Biological Questions*		
	Sediment Transport	**Mainstem Fish Habitat**	**Physical Floodplain Habitat**	**Floodplain Fish Community response**	**Mainstem Fish Community response**	**Other**
Peak Flows / In-Channel Habitat Formation and Maintenance						
AEG1. Flow effects on habitat (channel width, complexity, fine sediment on bars)	Yes	Yes	Yes	No	In part	
UG1. Fine sediment and productivity	Yes	Yes	No	No	In part	
UG2. Frequency of fine sediment flush	Yes	Yes	No	No	In part	
UG3. Frequency/duration to maintain habitat (1/2 and bankfull)	Yes	Yes	No	No	In part	
UG4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question).	Yes	Yes	No	In part	Yes	
UG5. Do peak flows provide spawning habitat?	Yes	Yes	No	Yes (RBS have been found spawning in Co Riv gravel pits, etc. -- floodplains w cobble)	Yes	
UG6. Water availability for flow recs (policy?)	Yes	Yes	Yes	No	Yes (future question if endangered fish don't respond)	
UG7. Ramping rates (policy?)	No	No	No	No	Yes (future question if endangered fish	

					don't respond)	
UG8. Property (Delta flooding issue)	No	No	No	No	No	Yes
UG8a. Black Canyon water right	No	No	No	No	No	Yes
UG9. Effects of Aspinall releases on Co. R. (just an evaluation of how we're operating to meet the Colorado R. flow recs)	No	No	No	No	No	
UG10. Mimicry of Natural hydrograph	Yes	Yes	Yes	Yes	Yes	
Peak Flows and Floodplain Habitat						
AEG2. Spring flows and floodplain habitat (Note: review analysis in BA for other sites)	No	No	Yes	Yes	No	
UG11. RZB larvae in floodplain/lack of adults	No	No	No	Yes	No	
UG12. NNF benefit from floodplains	No	No	No	Yes	No	
UG13. Spawning sites for RZ not definitively known. Need further investigations to focus floodplain management.	No	No	No	Yes	Yes	
UG14. Amount/location of floodplains for recovery	No	No	Yes	Yes	No	
UG15. Drift of RZ larvae	No	No	No	Yes	Yes	
UG16. Effectiveness of “reset theory”	Yes	No	Yes	Yes	No	
UG17. RZ BT survival in floodplains	No	No	No	Yes	No	
UG18. Value of gravel pits, depressions, etc	No	No	Yes	Yes	No	
UG19. Recover fish in presence of nonnatives	No	No	Yes	Yes	No	
UG20. Flow effects on breach configuration	Yes	No	Yes	No	No	

UG21. Habitat availability at peak/base flows to flood and maintain depression or gravel pit floodplain habitats	No	No	Yes	Yes	No	
Peak Flows and Spawning Cues						
AEG3. Spring peaks provide spawning cues	No	No	Yes	Yes	Yes	
Peak Flows and Staging Habitat						
AEG4. Spring peaks provide staging habitat	No	No	Yes	Yes	Yes	
Base Flows (not changing much under proposed action) - thermal regime						
AEG5 Flow effects on temperature	No	No	No	No	Yes	
UG22. Peak duration/base flow temperature	No	No	No	No	Yes	
UG23. Response of nonnative fish (probably low priority on Gunnison)	No	No	No	No	Yes	
Base Flows and Habitat Availability / Productivity						
AEG6. Low water habitat (pools/runs, sediment mgmt)	Yes	Yes	No	No	Yes	
UG24. Habitat to achieve recovery	Yes	Yes	No	No	Yes	
UG1. Fine sediment and productivity	Yes	Yes	No	No	Yes	
Base Flows - Fish Passage in Lower Gunnison River						
AEG7. Passage and minimum flow mgmt below Redlands	No	Yes	No	No	Yes	Yes (primarily look at USBR's annual operation report)
UG24. Peak duration/Redlands operation	No	Yes	No	No	Yes	Yes (primarily look at USBR's annual operation report)

Table A5. Colorado River anticipated effects and uncertainties as identified in foundational documents as related to future research focus areas.

	Focus Areas					
	Physical Questions			***Biological Questions***		
	Sediment Transport	**Mainstem Fish Habitat**	**Physical Floodplain Habitat**	**Floodplain Fish Community response**	**Mainstem Fish Community response**	**Other**
Peak Flows / In-Channel Habitat Formation and Maintenance						
AEC1. Flow effects on habitat (channel width, complexity, fine sediment on bars)	Yes	Yes	Yes	No	In Part	
UC1. Fine sediment and productivity	Yes	Yes	No	No	In Part	
UC2. Frequency of fine sediment flush	Yes	Yes	No	No	In Part	
UC3. Frequency/duration to maintain habitat (1/2 and bankfull)	Yes	Yes	No	No	In Part	
UC4. Amount and quality of habitat necessary to maintain pops at recovery goals levels (physical habitat question).	Yes	Yes	No	In Part	Yes	
UC5. Do peak flows provide spawning habitat?	Yes	Yes	No	Yes (RBS have been found spawning in Co R gravel pits, etc. -- floodplains w cobble)	Yes	
UC6. Peak flow effects on backwaters (Moab to Green R.) *What about upstream of Westwater?*	Yes	Yes	No	No	Yes	

UC7. Location of, and peak flow effects on, spawning bars (physical habitat question).	Yes	Yes	No	No	Yes	
UC8. Effects of Aspinall releases on Co. R. (just an evaluation of how we're operating to meet the Colorado R. flow recommendations)	No	No	No	No	No	Yes (primarily look at USBR's annual operation report)
UC9. Mimicry of natural hydrograph	Yes	Yes	Yes	Yes	Yes	
Peak Flows and Floodplain Habitat						
AEC2. Peak flows and floodplain habitat.	No	No	Yes	Yes	No	
UC10. RZB larvae in floodplain/lack of adults	No	No	No	Yes	No	
UC11. NNF benefit from floodplains	No	No	No	Yes	No	
UC12. Spawning sites for RZ not definitively known. Need further investigations to focus floodplain management.	No	No	No	Yes	Yes	
UC13. Drift of larval RZB	No	No	No	Yes	Yes	
UC14. Amount/location of floodplains for recovery	No	No	Yes	Yes	No	
UC15. Effectiveness of “reset theory”	Yes	No	Yes	Yes	No	
UC16. RZ BT survival in floodplains	No	No	No	Yes	No	
UC17. Value of gravel pits	No	No	Yes	Yes	No	
UC18. Recover fish in presence of nonnatives	No	No	Yes	Yes	Yes	
UC19. Habitat availability in relation to peak flows, Palisade to Loma.	No	No	Yes	Yes	No	

UC20. Peak flows/ sediment/connectivity, Palisade to Loma.	Yes	No	Yes	No		
Peak Flows and Spawning Cues						
AEC3. Spring peak spawning cues.	No	No	Yes	Yes	Yes	
Peak Flows and Staging Habitat						
AEC4. Spring peak staging habitats	No	No	Yes	Yes	Yes	
Base Flows and Habitat Availability / Productivity						
AEC5. Base flows and CPM nursery habitat	Yes	Yes	No	No	Yes	
AEC6. Base flows and habitat for growth (all life stages)	Yes	Yes	No	No	Yes	

Table A6. A comparison of suggested new areas of research under the Aspinall Study Plan and the hypothesis focus areas.

Focus Areas										
	Physical						Biological			
	Sediment Transport		*Fish Habitat*	*Floodplain*		*Temp vs. Hydro*	*Floodplain Fish Comm.*		*Main Channel Fish Comm.*	
Suggested New Areas of Research	**Sediment Transport / Spring Flows**	**Sediment Transport/ Base Flows**	**Fish Habitat Main Channel**	**Floodplain Quantity Gunnison River**	**Floodplain Quantity Colorado River**	**Temperature vs. Hydrology**	**Fish Community Response - Floodplain (Gunnison)**	**Fish Community Response - Floodplain (Colo.)**	**Fish Community Response - Main Channel (Gunnison)**	**Fish Community Response - Main Channel (Colorado)**
Aerial Photography -										
Spring Flows (Colorado and Gunnison Rivers) to track floodplain inundation	N/A	N/A	N/A	Direct	Direct	N/A	Indirect	Indirect	Indirect	Indirect
Base Flows (Colorado and Gunnison Rivers) to track channel width and complexity	Direct	N/A	Indirect	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Habitat Mapping										
Track expected percentages of pools and runs in Gunnison River (McAda 2003) - use base flow aerials as base maps for mapping or conduct more intensive 2D modeling	N/A	N/A	Direct	N/A	N/A	N/A	N/A	N/A	Indirect	Indirect
Sediment Monitoring -										
Gunnison River spring flow focus - to validate Pitlick's work as referenced in McAda (2003) - take direction from USGS' Project 85f.	Direct	Indirect	N/A	N/A	N/A	N/A	N/A	N/A	Indirect	N/A
Gunnison and Colorado River base flow focus - to evaluate the effects of summer storm input. Continue the automated sediment grab samples - take direction from USGS' Project 85f.	N/A	N/A	Direct	N/A	N/A	N/A	N/A	N/A	Indirect	Indirect

Suggested New Areas of Research	Sediment Transport / Spring Flows	Sediment Transport/ Base Flows	Fish Habitat Main Channel	Floodplain Quantity Gunnison River	Floodplain Quantity Colorado River	Temperature vs. Hydrology	Fish Community Response - Floodplain (Gunnison)	Fish Community Response - Floodplain (Colo.)	Fish Community Response - Main Channel (Gunnison)	Fish Community Response - Main Channel (Colorado)
Gunnison and Colorado River base flow focus - to evaluate the effects of summer storm input. Monitor DTE as indicator of system health relying on existing relationships b'twn DTE and primary and secondary productivity.	N/A	N/A	Direct	N/A	N/A	N/A	N/A	N/A	Indirect	Indirect
Gunnison and Colorado River base flow focus - to evaluate the effects of summer storm input - Biology Support - Augment existing information on primary and secondary productivity to improve relationships with DTE	N/A	N/A	Direct	N/A	N/A	N/A	N/A	N/A	Indirect	Indirect
Fish Community Monitoring Gunnison River										
Spring Flows										
Larval Razorback sampling in floodplain / flooded trib mouth habitats	N/A	N/A	N/A	Indirect	N/A	N/A	Direct	N/A	Indirect	N/A
Drift sampling for CPM larvae	Indirect	N/A	Indirect	N/A	N/A	Indirect	N/A	N/A	Direct	N/A
Base Flows										
Main Channel sampling to determine distribution and relative abundance of large bodied fish (all spp.)	Indirect	Indirect	Indirect	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Indirect	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Direct	N/A
Main Channel sampling to determine distribution and relative abundance of small bodied fish (all spp.)	Indirect	Indirect	Indirect	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Indirect	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Direct	N/A

Suggested New Areas of Research	Sediment Transport / Spring Flows	Sediment Transport/ Base Flows	Fish Habitat Main Channel	Floodplain Quantity Gunnison River	Floodplain Quantity Colorado River	Temperature vs. Hydrology	Fish Community Response - Floodplain (Gunnison)	Fish Community Response - Floodplain (Colo.)	Fish Community Response - Main Channel (Gunnison)	Fish Community Response - Main Channel (Colorado)
Main Channel sampling to estimate abundance (pop estimates) of juvenile and adult RBS	Indirect	N/A	Indirect	Indirect	N/A	Indirect	Direct	N/A	Direct	N/A
Main Channel sampling to estimate abundance (pop estimates) of juvenile and adult CPM	N/A	Indirect	Indirect	N/A	N/A	Indirect	N/A	N/A	Direct	N/A
Fish Community Monitoring Colorado River										
Spring Flows										
Larval Razorback sampling in floodplain / flooded tributary mouth habitats	N/A	N/A	N/A	N/A	Indirect	N/A	N/A	Direct	N/A	N/A
Re-instate drift sampling for CPM larvae	Indirect	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Indirect
Base Flows										
Main Channel sampling to determine distribution and relative abundance of large bodied fish (all spp.) Focus on 18-mile reach as area most affected by Aspinall re-ops.	Indirect	Indirect	Indirect	N/A	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	N/A	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Direct
Main Channel sampling to determine distribution and relative abundance of small bodied fish (all spp.). Focus on 18-mile reach as area most affected by Aspinall re-ops. Consider the existing ISMP (proj 138) protocols in the lower river as a model.	Indirect	Indirect	Indirect	N/A	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	N/A	Indirect (relative abundance of native and nonnatives in the main channel could be a function of floodplain habitat availability)	N/A	Direct

Suggested New Areas of Research	Sediment Transport / Spring Flows	Sediment Transport/ Base Flows	Fish Habitat Main Channel	Floodplain Quantity Gunnison River	Floodplain Quantity Colorado River	Temperature vs. Hydrology	Fish Community Response - Floodplain (Gunnison)	Fish Community Response - Floodplain (Colo.)	Fish Community Response - Main Channel (Gunnison)	Fish Community Response - Main Channel (Colorado)
Main Channel sampling to estimate abundance (pop estimates) of juvenile and adult RBS	Indirect	Indirect	Indirect	Indirect	Indirect	N/A	N/A	Indirect	N/A	Direct
Continue main channel sampling to estimate abundance of juvenile and adult CPM	Indirect	Indirect	Indirect	N/A	N/A	N/A	N/A	N/A	N/A	Direct
Temp vs. Flow										
Augment existing modeling efforts, or write a new model - incorporate new thermograph data	N/A	N/A	Indirect	N/A	N/A	Direct	N/A	N/A	Indirect	Indirect