Integrated Science Assessment for the Upper Muddy River, Clark County, Nevada

Restored Pederson Spring on the Moapa Valley National Wildlife Refuge. Photo: Louis Provencher, 2003

Final Report to the Clark County Multiple Species Habitat Conservation Plan
March, 2005

by

Louis Provencher[1]
The Nature Conservancy, One East First Street, Suite 1007, Reno, NV 89509
lprovencher@tnc.org

Sue Wainscott
The Nature Conservancy, 3380 West Sahara Avenue, Suite 120, Las Vegas, NV 89102
swainscott@tnc.org

Rob Andress
Otis Bay Riverine Consultants, Inc., 1049 South 475 West, Farmington, UT 84025
rjandress@earthlink.net

Contract #: 2003-TNC-1-A

[1] Citation: Provencher, L., S. Wainscott, and R. Andress. 2005. Integrated Science Assessment for the Upper Muddy River, Clark County, Nevada. Final report to the Clark County Multiple Species Habitat Conservation Plan. The Nature Conservancy, Reno, Nevada.

Table of Contents

1. Executive Summary ... 4
2. Introduction ... 8
  2.1. Study Area and Conservation Significance ... 8
  2.2. Objectives ... 10
  2.3. Content of Final Report ... 10
3. Description of Restoration Actions ... 13
  3.1. Objective ... 13
  3.2. Description of Actions ... 13
    3.2.1. Capacity Building: Alliance Development ... 15
    3.2.2. Land/Water Protection: Publicly-Owned Protected Areas ... 16
    3.2.3. Land/Water/Species Management: Natural Processes Restoration ... 16
    3.2.4. Law & Policy: Policy and Regulations ... 19
    3.2.5. Research, Education & Awareness: Awareness Raising and Communications ... 21
4. Conservation Benefits of Restoration Actions ... 22
  4.1. Objective ... 22
  4.2. Enhanced 5-S Methodology ... 22
    4.2.1. Viability of Focal Conservation Targets ... 23
    4.2.2. Stresses and Sources of Stress ... 25
  4.3. Rank of Restoration Actions ... 26
    4.3.1. Components of the Restoration Rank ... 26
    4.3.2. Restoration Ranks ... 29
5. Description of Restoration Options ... 34
  5.1. Objective ... 34
  5.2. Description of Strategy Options ... 34
6. Effectiveness Monitoring ... 37
  6.1. Objective ... 37
  6.2. Sensitive Species and Communities ... 37
  6.3. Monitoring and Experimental Designs ... 38
    6.3.1. Fish Species Monitoring ... 38
    6.3.2. Breeding Bird Monitoring ... 40
    6.3.3. Threat Abatement Monitoring ... 41
7. Informational Meeting and Questionnaire ... 49
  7.1. Objective ... 49
  7.2. Informational Meeting ... 49
    7.2.1. Questions and Comments from the Informational Meeting ... 49
  7.3. Results of Questionnaire ... 52
8. Acknowledgments ... 57
9. Literature Cited ... 58
Appendix I. Native species of special interest nested within upper Muddy River conservation target systems. ... 60
Appendix II . Assessment of River Channel and Habitat Restoration Recommendations. ... 68
Appendix III. Costs and Supporting Information Associated with Habitat Conservation and Restoration Recommendations ... 159

Appendix IV . Threat Associated with each Conservation Target for all Upper Muddy River Segments 207
Appendix V. Effectiveness Monitoring for Saltcedar and Knapweed Control on the Upper Muddy River Floodplain. 210
Appendix VI . Upper Muddy River Integrated Science Plan Questionnaire 223

1. Executive Summary

The Muddy River is one of the Mojave Desert's most important areas of biodiversity, providing habitat for many species of concern, including 4 fish, 8 invertebrate, and 76 breeding bird species, as well as a unique array of Mojave Desert aquatic and riparian habitats**.** Of particular concern is the endangered Moapa dace (*Moapa coriacea*), which only inhabits the warm spring-fed headwaters of the river system.

The Nature Conservancy was contracted by Clark County to develop a comprehensive upper Muddy River watershed assessment that addresses restoration and land management issues on the Moapa Valley National Wildlife Refuge (NWR) and elsewhere on the upper Muddy River. The watershed assessment has two components—a geomorphic assessment and an integrated science plan. The final outcome of the contract, this final report, proposes a set of restoration strategy alternatives based on scientific and social considerations and a list of research needs that would inform adaptive management of the upper Muddy River. Based on the background results found within the previous year's annual report, the objectives of the final report are to: 1) Describe restoration actions proposed by Otis Bay Riverine Consultants, Inc. for each of nine river segments; 2) Use The Nature Conservancy's methodology to assess the expected contributions of each restoration action to threat abatement and viability enhancement of key ecological systems; 3) Group actions into three restoration options of increasing cost that must always include actions minimally benefiting the Moapa dace; 4) Propose monitoring and experimental designs to measure the effectiveness of actions for desert riparian communities and species listed under the federal Endangered Species Act or addressed by the Clark County Multiple Species Habitat Conservation Plan; and 5) Summarize the results of an informational public meeting held in Moapa during September 2004 that described the preliminary results of the upper Muddy River Integrated Science Plan.

Six ecological systems were previously described for the upper Muddy River and the factors that degrade their viability (species) and functionality (ecological communities). The systems were Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, and Mesquite Bosque. The three main factors responsible for the degradation of the upper Muddy River: a) spring discharge is decreasing steadily because of water withdrawals from the carbonate aquifer; b) the floodplain has been disconnected from its river for at least a century due to deep entrenchment, straightening, and flood and sediment control; and c) non-native invasive plant and animal species occupy most ecological communities. Restoration actions are proposed to abate these threats to the systems of the upper Muddy River.

Otis Bay Riverine Consultants, Inc. proposed nine different sets of restoration actions, which are each applied to a different river segment, designed to abate river degradation. This proposal for restoration recognizes that a) land and water must receive legal protection for restoration to succeed over the long term, b) space must be available for a restored and functional river to meander and overflow its banks, and c) physical actions that enhance functionality of ecological processes and species viability are needed.

We grouped restoration actions into three options based primarily on their anticipated cost. Options are defined as LOW (least expensive), MEDIUM, and HIGH (most expensive). The LOW option included the least expensive strategy that explicitly benefited the Warm Spring Aquatic Assemblage, even if this strategy was not the least expensive overall. In addition, we used The Nature Conservancy's Conservation Project Management tool to calculate an overall rank for each restoration action based on ecological benefit to the six systems, feasibility of successful implementation of the action, and estimated cost of the action. The rank of each action was then used to confirm its placement among the three restoration options.

THE LOW option consists of the minimum actions to benefit the Moapa dace and the cheapest other actions. Total cost is at least $7,652,500.

Prerequisite actions

1) Develop conservation agreements with private land owners;
2) Complete National Environmental Policy Act and other state/federal compliance for public lands and waterways; and
3) Form a conservation partnership with Moapa River Indian Reservation ($30,000).

Restoration actions

1) Construct five fish exclusion barriers and remove blue tilapia (*Oreochromis aurea*) ($1,060,375):
   a) Construct permanent grade control structure and fish barrier at White Narrows ($500,000);
   b) Construct fish exclusion barrier above Warm Springs Road ($500,000);
   c) Construct fish exclusion barrier on Cardy Lamb channel ($20,125);
   d) Construct fish exclusion barrier on Muddy Spring channel ($20,125);
   e) Construct fish exclusion barrier on South Fork channel ($20,125);
2) Conduct targeted removal of fan palms (*Washingtonia filifera*) in critical Moapa dace habitat (warm springs and outflow creeks) ($850,000);
3) Remove saltcedar (*Tamarix ramosissima*) ($1,082,700);
4) Remove Russian knapweed (*Acroptilon repens*), and other non-native plants ($47,000);
5) Revegetate all areas treated for weed removal with native plants ($4,581,425); and
6) Remove flood and sediment control barriers ($1,000).

The MEDIUM option includes all actions within the LOW option, plus channel reconstruction on the Bureau of Land Management (BLM) and TNC properties in segment 3, and actions requiring conservation easements, but no major land acquisitions. Total cost is at least $42,858,600.

Prerequisite actions

1. Complete all LOW option actions;
2. Define ecologically sustainable in-stream flow for Apcar and Moapa Valley NWR spring channels ($200,000);

3. Acquire senior water rights from willing sellers for beneficial wildlife use ($5,000,000); and
4. Acquire conservation easements from willing sellers ($7,000,000).

Restoration actions

1) Reconnect and reconstruct the warm springs complex in historic Moapa dace habitat (blue tilapia removal required) ($2,645,000):
   a) Restore spring channel in Apcar channel within Moapa Valley NWR ($218,750);
   b) Restore spring channel in Muddy Spring channel ($124,250);
   c) Restore spring channel in South Fork channel ($129,500);
   d) Restore spring channel in Plummer channel within Moapa Valley NWR ($175,000);
   e) Restore spring channel within Moapa Valley NWR (Refuge and Apcar channels) ($997,500); and
   f) Restore remaining former recreational structures within Moapa Valley NWR to spring pools and channels ($1,000,000);
2) Conduct a complete channel reconstruction **or** small scale channel reconstruction on BLM and TNC properties in segment 3 (with appropriate permits) ($2,223,600);
3) Pursue legal limitations on future shallow groundwater aquifer withdrawals in the upper Muddy River ($500,000); and
4) Restore or construct wetlands on Warm Spring Ranch ($17,637,500).

The HIGH option consists of all restoration actions described under the LOW and MEDIUM options in addition to major land acquisitions and one additional channel reconstruction. Total cost is at least $52,482,200.

Prerequisite actions

1. Complete all LOW and MEDIUM option actions; and
2. Acquire property from willing sellers (>$7,000,000).

Restoration actions

1. Complete one channel and floodplain reconstruction elsewhere than segment 3 ($2,223,600).
2. Develop public use areas at Moapa Valley NWR ($100,000); and
3. Establish a buffer zone between agricultural fields and river on Moapa River Indian Reservation ($100,000).

Many restoration actions are expensive and their outcomes are sometimes uncertain. Therefore, it is a good business practice to verify whether or not money spent on restoration significantly benefits the ecological systems and species targeted. We describe basic monitoring designs to measure the effectiveness of actions for federally-listed species and species covered under the Section 10 permit for the Clark County Multiple Species Habitat Conservation Plan. In addition, we describe monitoring designs for actions that abate pervasive threats but where the listed or covered species' patchy abundance precludes direct sampling of the targeted species.

Federally-listed and Clark County covered species present on the upper Muddy River are: Moapa dace (listed), Virgin River chub Muddy River population (species of concern), Southwestern Willow Flycatcher (listed and covered), Arizona Bell's Vireo (covered), Blue Grosbeak (covered), Phainopepla (covered), Summer Tanager (covered), Vermilion Flycatcher (covered), and Yellow-billed Cuckoo (covered and candidate for listing). Total population surveys or area searches in the location of restoration projects are the most appropriate monitoring methods for the following species that are uncommon or very restricted to a portion of their historic habitat: Moapa dace, Southwestern Willow Flycatcher, Arizona Bell's Vireo, Summer Tanager, and Yellow-billed Cuckoo. Population size (dace) and nest counts are determined by these methods. Virgin River chub, Blue Grosbeak, Phainopepla, and Vermilion Flycatcher are sufficiently abundant, but sometimes only locally, to have their populations sampled or, in the case of bird species, have the territories mapped. Virgin River chub is only found downstream of White Narrows because of high blue tilapia predation rates. The recommended method for sampling of chub for river-wide or local assessment is the hoop-net method, because the data can be compared to a capture-mark-recapture population estimate from 1995. For the bird species, territory mapping, which is cost intensive, can be applied to small restoration projects (<300 acres), whereas the Nevada Bird Count method (http://www.gbbo.org/nbc.htm) is recommended for sampling over larger areas.

We briefly describe a wide variety of population surveys, sampling designs, or experimental designs that could be implemented on projects where the effects of threat abatement on habitat variables are more easily measured than on the listed or covered species. Monitoring is described for the following possible projects: hydrologic improvements, channel reconstruction, wetland restoration, tilapia removal, fan palm removal, as well as saltcedar and knapweed removal. We use the latter project to develop in greater detail a monitoring proposal that was submitted to Clark County's 2005-2006 Biennium.

A public informational meeting to describe the findings of the upper Muddy River geomorphic assessment and the science workshops was held on September 9, 2004 in Moapa, Nevada. Approximately 23 people attended all or part of the meeting. Lewis Wallenmeyer, Administrator of the Clark County Desert Conservation Program, moderated the meeting and explained the general role of informational meetings in the Clark County Multiple Species Habitat Conservation Plan. Presentations were made by Louis Provencher of The Nature Conservancy and Rob Andress of Otis Bay Riverine Consultants, Inc. In addition, participants were given questionnaires to document their opinions and concerns. Overall, responses were more positive than anticipated and preservation of the rural character of the upper Muddy River floodplain was important to stakeholders. It is clear that concerns about flooding and water quantity and quality will dominate future restoration discussions.

2. INTRODUCTION

2.1. Study Area and Conservation Significance

The upper watershed of the Muddy River is located approximately 60 miles (96.5 km) northeast of Las Vegas in the unincorporated towns of Moapa (282 mi^2 or 730.4 km^2) and Glendale (0.4 mi^2 or 1.04 km^2) in Clark County, Nevada, and upstream of the Interstate 15 Bridge for approximately 14 miles (22.5 km) of the Muddy River (Fig. 1). The Muddy River begins as a series of thermal springs in the upper valley and flows 26 miles (41.8 km) before reaching Lake Mead (which submerges the lowest 7 river miles [11.2 km]). Prior to the construction of Hoover Dam, the Muddy River flowed into the Virgin River just upstream of the confluence of the Virgin and Colorado Rivers.

The Clark County Multiple Species Habitat Conservation Plan (MSHCP; RECON 2000) and The Nature Conservancy's (TNC) Mojave Desert Ecoregional Assessment (TNC 2001) have both identified the Muddy River as one of the region's most ecologically important and threatened riparian landscapes. The Muddy River provides habitat for many species of concern, including 4 fish, 7 invertebrate, and 76 bird species that are known to breed in the upper Muddy River, as well as a unique array of Mojave Desert aquatic and riparian habitats**.** Of particular concern is the endangered Moapa dace (*Moapa coriacea*), an endemic fish species restricted to the warm spring-fed headwaters of this river system. The Conservancy considers its Upper Muddy River (UMR) ecoregional portfolio site as irreplaceable because it contains eight species, belonging to the warm spring/stream aquatic assemblage, found nowhere else in the world (TNC 2001; Appendix I). These species include two fish species, the Moapa dace and Moapa White River springfish (*Crenichthys baileyi moapae*) (Scoppettone et al. 1998), and six invertebrates, the Moapa pebblesnail (*Pyrgulopsis avernalis*), Moapa turban snail (*Pyrgulopsis carinifera*), Moapa Warm Springs riffle beetle (*Stenelmis moapa*), Moapa waterstrider (*Rhagovellia becki*), Pahranagat naucorid bug (*Pelocoris shoshone shoshone*), and Warm Springs naucorid bug (*Usingerina moapensis*) (Sada 2000). Two other fish species, the Moapa speckled dace (*Rhinichthys osculus moapae*) and the Virgin River chub (*Gila seminuda*), are endemics that occupy cooler water downstream from the Warm Springs area (Scoppettone et al. 1998), and also occur in the Virgin River. The Moapa riffle beetle (*Microcylloepus moapus moapus*) is endemic but it is not clear whether or not the subspecies is only found from the Warm Springs area.

TNC described six focal ecological systems to serve as targets for a conservation assessment of the Upper Muddy River portfolio site (TNC 2000): Warm Spring Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodland, Riparian Shrubland, Riparian Marsh, and Mesquite Bosque. These ecological systems each provide habitat for several species of concern (TNC 1999, 2000; Appendix I).

Since Mormon settlement during the mid 1800s the Muddy River has become deeply entrenched and channelized; surface and groundwater is diverted for irrigation, domestic supply, and power generation; land conversion has resulted in loss of habitats and ecological communities; and non-native plant and animal species continue to

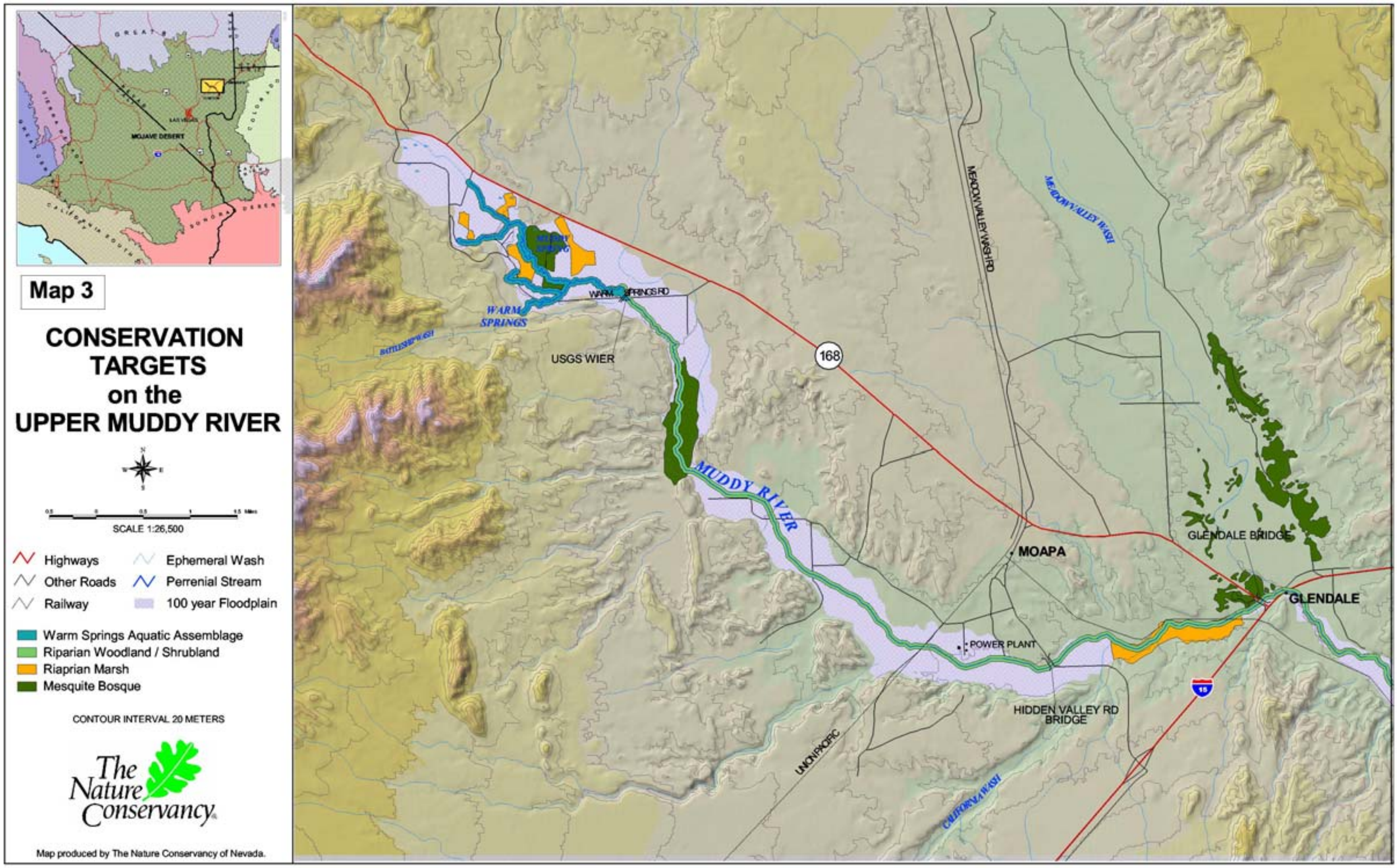

Figure 1. Upper Muddy River watershed, Nevada (TNC 2000).

invade the river and its floodplain. The history of human settlement in the upper Muddy River is further described in Provencher and Andress (2004).

2.2. Objectives

The Nature Conservancy was contracted by Clark County, Nevada to develop a comprehensive upper Muddy River watershed assessment to address restoration and land management issues on the Moapa Valley National Wildlife Refuge and elsewhere in the upper Muddy River floodplain. The watershed assessment has two components—a geomorphic assessment and an integrated science plan.

- The *geomorphic assessment* includes a review of the existing hydrologic, geologic, geomorphic, and groundwater data as they relate to conservation goals on the upper Muddy River. Field work to inform the assessment included characterization of river reaches along the main stem for channel geometry, slope, particle size distribution of streambed, sinuosity, etc. These data were analyzed using a hydrologic model (HEC-RAS) to estimate/predict the flood stage at which the upper Muddy River system would reach its historic floodplain. In conjunction with scientists specializing in adaptive management, the geomorphologists assessed habitat enhancement options for target conservation work and provided preliminary recommendations for habitat and riverine restoration. Experts from Otis Bay Riverine Consultants, Inc., who specialize in Intermountain West desert rivers and springs, were subcontracted to develop the geomorphic assessment.

- The *integrated science plan*: a) integrated existing scientific data and initial direction from the MSHCP adaptive management process as it relates to key conservation targets, b) developed restoration goals for species and communities, and c) defined long-term management practices for the Moapa Valley National Wildlife Refuge and other agency parcels on the upper Muddy River.

From these two reports, TNC has prepared this final watershed assessment report in coordination with agency partners.

2.3. Content of Final Report

This report is focused on restoration actions that were developed by Otis Bay Riverine Consultants, Inc. and analyzed by The Nature Conservancy. The background material used to develop restoration options was presented in our annual report (Provencher and Andress 2004) and is not repeated here. Readers not familiar with the annual report, however, are encouraged to read its main text (obtained from http://www.brrc.unr.edu/, link MSHCP & Project, Contractor TNC & all Years search, Project: MUDDY RIVER WATERSHED ASSESSMENT), as this report will assume baseline knowledge. Appendix II provides an overview of ecological, geomorphological, and logistical factors that support restoration actions. Five core chapters form this report. First, we describe the restoration strategies developed

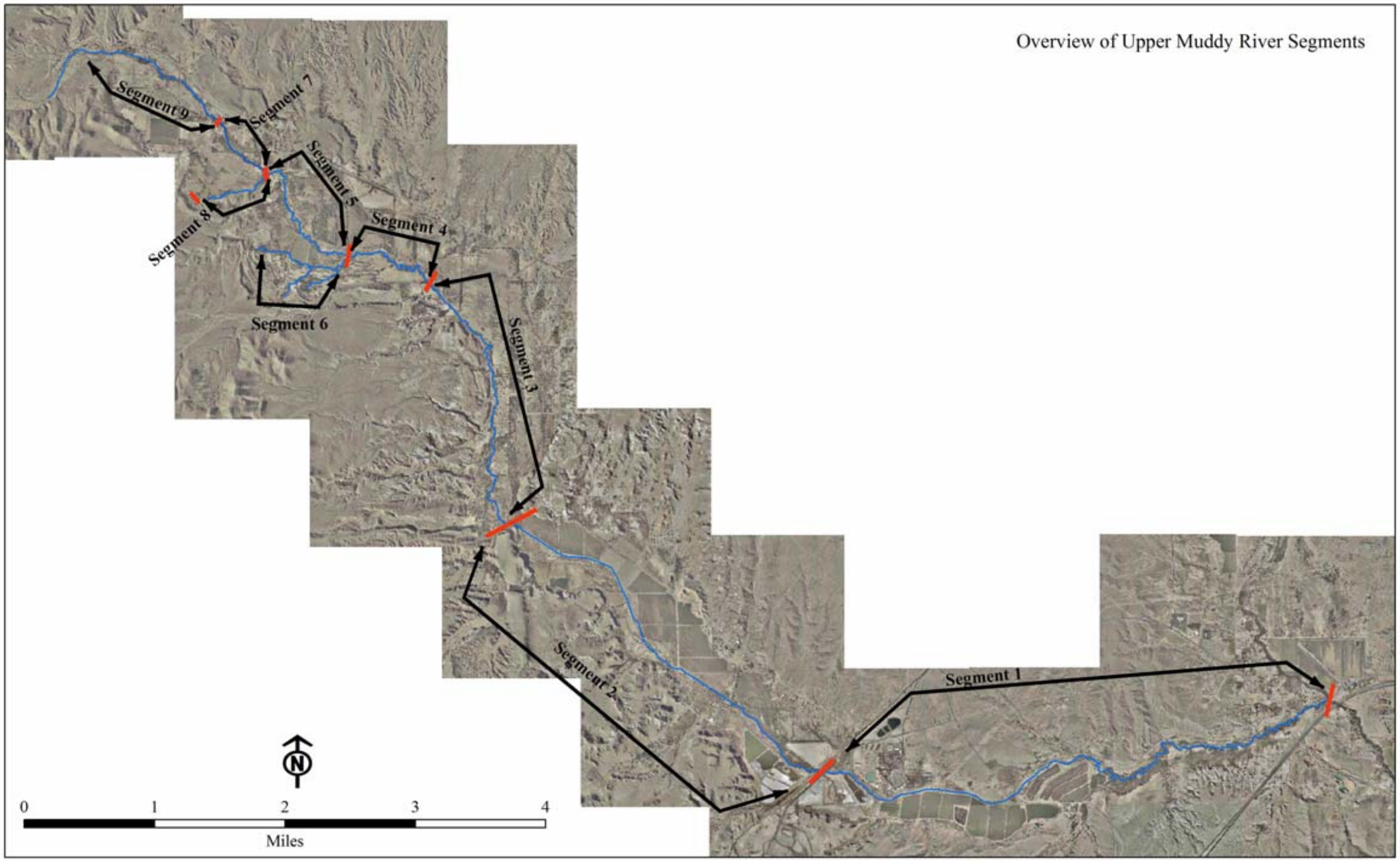

Figure 2. Segment of the upper Muddy River watershed, Nevada.

Table 1. Upper Muddy River segments.

Segment	Start Point Feature	Endpoint Feature
1	Interstate-15 Bridge	Power Station Railroad Bridge
2	Power Station Railroad Bridge	White Narrows
3	White Narrows	Warm Springs Road
4	Warm Springs Road	Warm Springs-Muddy Confluence
5	Warm Springs-Muddy Confluence	North-South Fork Confluence
6	Warm Springs-Muddy Confluence	Warm Springs
7	North-South Fork Confluence	North Fork Headwaters
8	North-South Fork Confluence	South Fork Headwaters
9	North Fork Headwaters	Arrow Canyon

by Otis Bay Riverine Consultants, Inc. for each of the nine segments of the river (Table 1; Fig. 2; Provencher and Andress 2004). Second, we examine the restoration actions' contributions to ecological threat abatement and their benefits to the viability of key ecological systems using The Nature Conservancy's Conservation Project Management tool (TNC 2005). This analysis, which builds on past conservation assessment work by TNC (TNC 2000), was conducted independently for each of the nine river segments, but is presented as an overall result. The goal of the analysis is to determine which restoration actions are expected to have the greatest ecological benefit given their financial and logistical feasibility. Third, we group actions in the context of three restoration options: LOW (least expensive but focuses on actions expected to benefit the warm spring endemics), MEDIUM, and HIGH (most comprehensive and expensive). Fourth, we describe monitoring and experimental designs that may be used to adaptively manage the river's aquatic and riparian habitats and those species listed under the Endangered Species Act or covered by the Clark County MSHCP. These designs are not meant to be comprehensive, but to simply provide guidance on how and where to monitor. The final chapter is a summary of results from a questionnaire distributed during and after an informational public meeting focusing on the conclusions of the upper Muddy River Integrated Science Plan and Geomorphic Assessment held in Moapa in September 2004.

3. Description of Restoration Actions

3.1. Objective

Provenchor and Andress (2004) described six ecological systems for the upper Muddy River and the factors that degrade their viability (species) and functionality (ecological communities). The systems were:

- Warm Springs Aquatic Assemblage;
- Muddy River Aquatic Assemblage;
- Riparian Woodlands;
- Riparian Shrublands;
- Riparian Marshes; and
- Mesquite Bosque.

The major factors responsible for the degradation of the upper Muddy River were:

- spring discharge is decreasing steadily because of water withdrawals from the carbonate aquifer;
- the floodplain has been disconnected from its river for at least a century due to deep entrenchment, straightening, and flood and sediment control; and
- non-native invasive plant and animal species occupy most ecological communities.

Otis Bay Riverine Consultants, Inc. proposed nine different sets of restoration actions designed to abate river degradation, which we describe below. Each set is applied to a different river segment (Appendix III). This proposal for restoration recognizes that a) land and water must receive legal protection for restoration to succeed over the long term, b) space must be available for a restored and functional river to meander and overflow its banks, and c) physical actions that enhance functionality of ecological processes and species viability are needed.

3.2. Description of Actions

For the 9 river segments, 29 unique actions are proposed (Table 3), although some should be viewed as alternatives to the same action (e.g., saltcedar removal with Nevada Division of Forestry Conservation Camp inmate crews or with private contractors). We briefly describe these actions and some logistic aspects below, but refer the reader to Appendix III for a more technical discussion and estimated costs per unit area.

Table 3. Restoration actions by management theme.

THEME	ACTION
CAPACITY BUILDING: ALLIANCE DEVELOPMENT	
	Formation of partnership or agreement and cost sharing of conservation efforts with Moapa River Indian Reservation
LAND/WATER PROTECTION: PUBLICLY-OWNED PROTECTED AREAS	
	Acquisition of fee title for key areas in river segment
	Acquisition of conservation easements or agreements for key areas in river segment
	Acquisition of water rights
LAND/WATER/SPECIES MANAGEMENT: NATURAL PROCESSES RESTORATION	
	Removal of flood and sediment control dams on tributary washes
	Construction of permanent grade control structure and fish barrier at White Narrows
	Construction of permanent grade control structure and rolling drum fish barrier at White Narrows
	Invasive fish exclusion on Cardy Lamb channel
	Invasive fish exclusion on Muddy River above Warm Springs Road
	Invasive fish exclusion on Muddy Spring channel
	Invasive fish exclusion on South Fork channel
	Knapweed control with herbicide and/or goats
	Manual saltcedar removal with inmate crews
	Manual saltcedar removal with standard work crews
	Palm tree removal
	Revegetation following invasive vegetation removal activities
	Complete reconstruction of channel within acquired property

	Construction or enhancement of wetlands within Warm Spring Ranch where wet meadows exist
	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels
	Revegetation following invasive vegetation removal activities
	Spring channel restoration of Apcar channel within Moapa Valley NWR
	Spring channel restoration of Muddy Spring channel
	Spring channel restoration of Plummer channel within Moapa Valley NWR
	Spring channel restoration of South Fork channel
	Spring channel restoration within Warm Spring Ranch (Refuge and Apcar channels)
	Establishment of buffer zone between agricultural fields and river on Moapa River Indian Reservation
LAW & POLICY: POLICY & REGULATIONS	
	Defined ecologically sustainable instream flows for Apcar channel
	Defined ecologically sustainable instream flows for Moapa Valley NWR spring channels
	Limitation of future shallow groundwater aquifer decline
RESEARCH, EDUCATION & AWARENESS: AWARENESS RAISING AND COMMUNICATIONS	
	Development of public use and education areas and trails within Moapa Valley NWR

3.2.1. Capacity Building: Alliance Development

Forming a partnership with The Moapa River Indian Reservation, which has sovereign jurisdiction over its lands, is the only action listed under this theme. A partnership is only necessary to coordinate the following three restoration actions, perhaps even increase their likelihood of their implementation: saltcedar and Russian knapweed removal, installation of a grade control structure at White Narrows, and the creation of a buffer of natural vegetation between the river and agricultural fields. The Tribe is making significant progress on the first two actions while sharing lessons learned with the Muddy River Regional Environmental Impact Alleviation Committee (MRREIAC) on saltcedar and Russian knapweed removal and working collaboratively with the Muddy River Recovery Implementation Team on the design and construction of the White Narrow's grade control structure to maximize its use as a fish barrier. The establishment of a buffer zone between agricultural fields and the river on Moapa River Indian Reservation would reestablish a narrow strip of native riparian vegetation after saltcedar and knapweed removal. This loss of agricultural acreage may reduce farm revenues for the Tribe, which would need to be addressed. Establishing a more formal partnership among the Tribe, the Muddy River Recovery Implementation Team and the Clark County Desert Conservation Program may encourage additional restoration efforts on Reservation lands and waters. We assumed that $30,000 would be needed annually to support this effort (salary, travel, and other expenses).

3.2.2. Land/Water Protection: Publicly-Owned Protected Areas

The three actions listed under this theme are real estate activities: Acquisition of fee title lands, acquisition of conservation easements or agreements for management of priority lands and habitat, and acquisition of water rights. In themselves, these actions do not directly restore habitat, but they may abate threats by preventing further development or loss of habitat. Additionally, many of the actions listed in Table 3 cannot occur on private property if land is not afforded legal conservation protection through acquisition of fee title or conservation easements. Similarly, some actions require more water to ensure their success (restoration of wetlands and complete channel reconstruction), thus acquisition of water rights is necessary. The recommended uses of acquired water rights are discussed below.

Real estate activities are on-going on the upper Muddy River, with interest from private land owners for both fee title and conservation easement acquisitions. Real estate activities should be limited to the 100-year floodplain and to river reaches with permanent flow, wetlands, and a potential to implement restoration or support larger restoration efforts. Acquisitions of any kind are expensive and deals may take years to complete. Another complication is the monitoring of conservation easements to guarantee that land owners respect the terms of their contract and that future owners understand the restrictions placed on their lands without new compensation.

3.2.3. Land/Water/Species Management: Natural Processes Restoration

The majority of restoration actions fit under this theme. Actions can further be grouped by 1) non-native plant species removal and revegetation with native species, 2) non-native animal species removal, 3) channel or wetland enhancement or reconstruction, and 4) removing flood and sediment control structures on a limited number of tributary washes.

Actions are proposed to remove two species of non-native plants: saltcedar and Russian knapweed. Removal is followed by native plant revegetation, although its success has been variable and sometimes natural reestablishment of native plants has achieved better results (*personal communicatio*n, Ann Schreiber, MRREIAC). As mentioned above under *Capacity Building: Alliance Development*, establishment of a buffer zone of riparian vegetation between the Muddy River channel and agricultural fields is recommended. On private properties along the upper Muddy River, MRREIAC has been responsible for a community-based effort to remove saltcedar and Russian knapweed by mechanical and chemical methods following standard protocols using NDF Conservation Camp inmate crews (e.g., chainsaw felling followed by Garlon4® stump painting for saltcedar and Thordon® spraying for knapweed). More recently, there is an increasing emphasis on using domestic goats to browse saltcedar and knapweed alone or prior to mechanical and chemical treatments. Experimental tests of treatment methods combining goats, mechanical felling, herbicide, and native revegetation were proposed by The Nature Conservancy and MRREIAC for the 2005-2007 biennium of the Clark County MSHCP (see Chapter 5).

A third species, fan palm, is native to southern California and thought by many scientists to be non-native to the Muddy River (Provencher and Andress 2004). While the extent of fan palms' historic distribution is in question, it is certain that their alteration of dace spawning habitat and their increase of fire risk in historic dace habitat is incompatible with species recovery efforts (Provencher and Andress 2004). The proposed action is to continue removal in the rest of the historic Moapa dace habitat. On the Moapa Valley NWR, fan palm removal is expensive because whole trees must be hauled away. Chipping trees on site would considerably lower the cost for lands where hauling is not required.

The primary non-native animal species of concern is the blue tilapia, although there is also a threat from non-native crayfish if they continue moving up the Muddy River from Lake Mead. Although tilapia can be stopped with fish exclusion barriers and poisons, no method of control works for non-native crayfish (Hyatt 2004) and special fish barriers are required (*personal communication*, Gary Scoppettone, USGS, 2004).

Proposed actions to control tilapia involve several fish exclusion barriers, taking advantage of the opportunity to coordinate with the Tribe's need for a grade control structure at White Narrows to facilitate irrigation, and application of Rotenone® to small segments of the river above White Narrows. Planning to install fish barriers is currently under way and all structures involve earth excavation and putting solid structures in places. Two important concepts of the multiple fish exclusion strategy are 1) a tradeoff between impeding the dispersal of native aquatic species in the upper river and preventing further invasions of tilapia and 2) the insurance against invasion provided by multiple barriers should any one of them fail, perhaps during flooding. Currently, only one barrier, a rock gabion, prevents tilapia from invading the last dace refuge. Therefore, new fish exclusion barriers are proposed for White Narrows, Cardy Lamb channel, Muddy River above the Warm Springs Road, Muddy Spring channel, and South Fork Channel.

Reconstruction or enhancement of spring channels, the mainstem channel, or wetlands all involve permitting, engineering, earth moving equipment, and hauling material. Therefore, these actions are expensive.

Spring channel reconstruction is necessary to recover the Moapa dace and its habitat, as well as the habitats of other species endemic to thermal spring brooks. Recently, the Pederson Spring on the Moapa Valley NWR was restored by Otis Bay Riverine

Consultants, Inc. This action, which involves five spring channels, is less expensive than wetland restoration or main stem channel reconstruction. Until more tilapia exclusion barriers are established, reconstruction should be limited to the spring channels within the Moapa Valley NWR (Apcar and Plummer). Another reason to initially limit projects to the Refuge is that the Muddy Spring channel, Cardy Lamb channel, South Fork channel, and the lower part of the Apcar and Plummer channels are on private lands for which conservation easements or fee title acquisitions must be negotiated. Therefore, the restoration of most of the historic Moapa dace habitat is a series of actions conditional upon real estate and tilapia control actions.

Main stem river reconstruction is currently only possible for segment 3, where the BLM and TNC own and manage floodplain properties, because the floodplain is: a) sufficiently large to allow river reconstruction and accommodate necessary overbank flow every 5-10 years while protecting current residences from flooding and b) the lands were nominated for or already purchased with funds from the Southern Nevada Public Lands Management Act. Other channel reconstruction projects are possible if legal protection is afforded to sufficiently large river reaches on other segments. River reconstruction would require digging a new meandering river channel away from its deeply entrenchment channel, depositing excavation material into the current channel, elevating the water level, thus the water table, creating wetlands in the filled channel and elsewhere, and planting native plant material. The permitting aspects of complete channel reconstruction should not be underestimated, especially since members of the Moapa River Indian Reservation, which is immediately downstream of segment 3, expressed concerns about water quality and recreational areas on the BLM and TNC properties during the informational meeting held in Moapa in September 2004 (Chapter 7). Moreover, residents of Moapa are generally sensitive about flooding risks and this will likely dominate permit discussions.

An interesting detail about channel reconstruction is the water budget while the raised water table rehydrates the floodplain. A fundamental goal of channel reconstruction is to restore the water table so that desert riparian plant species can again thrive on the floodplain. Because the basin's water is over-appropriated, this implies that water rights will need to be temporarily leased or acquired until the rehydrated floodplain reaches a new equilibrium with the river. It is even possible that the rehydrated floodplain will mete out water to the main channel during the dry summer, thus acting as a stabilizing reservoir in the way wetlands do. Therefore, the acquisition of water rights is a conditional action for complete river channel reconstruction.

Wetlands do not constitute a large area of the upper Muddy River (Figure 1), reaching only 169 acres in extent, however their creation and enhancement is one of our most expensive actions. Proposed wetland restoration would be limited to segments 4, 7, and 8. The larger wetland in segment 1, which is not targeted for direct restoration, would probably be enhanced by on-going saltcedar and knapweed removal and complete channel reconstruction. Wetland restoration is also a well established practice in environmental mitigation. Clark County priority species, such as the Vermilion Flycatcher, depend on the interface of wetlands and riparian shrubland and woodlands.

Wetlands could also support reintroduced populations of relict leopard frogs and other amphibians. The most successful wetland restoration would require the acquisition of water rights, however taking advantage of existing wet meadows and old river oxbows during channel reconstruction would suffice without the acquisition of water rights, provided that no new water withdrawals selectively remove moisture from even those areas.

The removal of flood and silt control structures on tributaries is not generally recommended on the upper Muddy River because of the scattered distribution of residences, human structures, and agriculture needing protection. Therefore, only a handful of areas can be allowed to flood. The southern ephemeral tributaries on the BLM and TNC properties in segment 3 are obvious candidates. The conservation goals of flooding from tributaries is the a) restoration of fisheries by augmenting coarse scale sediment and silt to the riverbed and spawning areas, b) the deposition of sediments on soils supporting riparian plant communities, and c) the beneficial scouring effect of floods on riparian shrub and tree regeneration. Current flood and silt control structures are gradually deteriorating on the BLM and TNC properties and they should not be maintained or repaired. With minimum funding, these structures could be neglected or actively demolished. Resources might be also spent on identifying other river segments where flood and silt control structures could be removed from selected tributaries.

3.2.4. Law & Policy: Policy and Regulations

Clearly, without sufficient water it is not possible to maintain viable riparian and aquatic communities. Two types of policy and regulatory actions may prevent future shallow groundwater declines and maintain enough water to at least sustain the Moapa dace.

The shallow groundwater aquifer will likely decline as more surface wells are created as a result of housing developments, points of diversion for shallow wells are moved upstream, or the regional carbonate aquifer declines due to major water withdrawals in the White River drainage. Acquiring land or conservation easements for undeveloped floodplain real estate can minimize groundwater extraction for domestic use by simply preventing such activity. If users, however, have water rights and propose to divert water upstream of Moapa dace habitat or wetlands, this could lower the water table. One conservation action is to negotiate agreements, even compensation, that would prevent users from moving points of diversion upstream and to provide an incentive to move them as far downstream as possible. Actions to prevent a regional decline of the carbonate aquifer, while being the greatest threat to the Moapa dace, are beyond the scope of this report.

Defining instream flows for the Apcar and Moapa Valley NWR channels is critical to maintain Moapa dace habitat in the Moapa Valley NWR, but potentially complex because of the need for coordination between policy and science actions. Importantly, definitions should include ecologically-sustainable instream flows, also called variable instream flows, for all warm spring endemics, not just the dace. There are two components to this action: a) the legal mechanism by which instream flows are defined and implemented and b) the scientific questions and processes that determine how much and where water is needed (Jowett 1997, Tharme 2003). Both components should be pursued simultaneously as there are inherently beneficial outcomes from managing for increased water flows in sensitive areas even with incomplete scientific data, whereas better data will strengthen more ambitious restoration proposals.

Defining instream flow is challenging because it implies that on most western rivers, which are often fully adjucated, water rights will stay in the waterway, perhaps until a downstream point of diversion. Hence, defining instream flows involves stakeholders that are willing to reach an agreement, a scientific justification for how flows relate to the species ecological requirements, and identification of at least one entity willing to lead and coordinate the process. The result of the process is a group of stakeholders that author a proposal for ecologically-sustainable instream flows that might be submitted to The Court of Jurisdiction for the Muddy River Decree. Realistically, legal challenge to the proposal for ecologically-sustainable instream flow should be expected, especially if the scientific evidence is not solid. This process, however, might not work on the upper Muddy River because water rights were settled long ago, the major water uses are municipal and industrial, and the major stakeholders have no incentive to lose their water rights. There are more viable alternatives for the upper Muddy River.

One option is to buy the most senior water rights and move the point of diversion downstream (ideally to the lower Muddy River) and lease the water rights to downstream users or apply to the Nevada State Engineer to change the manner of use to wildlife. A second option that could be coupled with the acquisition of water rights is to negotiate agreements to, at a minimum, prevent points of diversion from moving upstream into ecologically sensitive habitat and encourage users to change their points of diversion downstream. In addition, operators of shallow groundwater wells that create a cone of depression in the local water table that is detrimental to species recovery and habitat enhancement could be encouraged to relocate their wells to less sensitive areas. Financial incentives could be offered to users to move their points of diversion downstream, especially if expensive infrastructure needs to be moved or rebuilt. Major water users, such as the Southern Nevada Water Authority, could be approached to let water for Las Vegas move down the Muddy River to a point of diversion where water would be pumped to a pipeline, for example. Creative water management has the potential to keep water in the upper Muddy River without the need to purchase additional water rights or with minimal expenditures. The creativity of the management and the quantity of needed water rights will largely depend on how much warm water Moapa dace needs.

The science required to quantify the flows necessary to recover the Moapa dace and other warm spring endemics is in progress but much still needs to be determined. An interesting aspect of the ecology of the upper Muddy River is that the flow of water and its temperature gradient are coupled and both determine the extent of the dace's habitat. The following is a list of questions, by no means exhaustive, that need to be answered to define instream flows:

1. How much water is needed to support the Moapa dace population, their food, and their hydraulic habitat?
2. Do instream flows that support the recovery of the Moapa dace also support the ecological requirements of other warm spring aquatic endemics?
3. How much water is needed to maintain temperature so that the Moapa dace population (and other warm spring aquatic endemics) can grow and utilize the spring area and the river's mainstem?
4. What length of mainstem river is needed to sustain a reproducing population of Moapa dace?
5. How much water is needed to maintain all life stages of the Moapa dace over 20, 50, and 100 years?
6. How much water is needed to maintain its temperature and sustain all life stages of the dace?
7. What level of regional water withdrawal is detrimental to the Moapa dace?

To answer these questions, the following technical information is required:

1. Temperature monitoring from the spring heads down the mainstem of the river;
2. Detailed channel topography;
3. Coupled water and temperature modeling from the spring heads to a point downstream on the mainstem;
4. Detailed habitat and ecological models for the Moapa dace;
5. A model describing the interaction between groundwater and surface water that includes a variable for groundwater extraction; and
6. A study design for instream flow that will have the buy-in of stakeholders.

3.2.5. Research, Education & Awareness: Awareness Raising and Communications

The only action under this theme is the development of public use and education areas/trails within Moapa Valley NWR. Since the Refuge was created, area residents have expressed a strong desire to see it open for public use. Plans for public use on Refuge land include a program of environmental education showcasing the uniqueness of the spring's fauna and ecology. A well-visited Refuge devoted to environmental education will increase citizen awareness about the threat from invasive non-native plant and animal species, the challenges of water management and land development, and the value of desert riparian biodiversity.

4. Conservation Benefits of Restoration Actions

4.1. Objective

Each restoration action, designed to abate threats to at least one of the six ecological systems, was assigned a cost and feasibility rank. We used TNC's Conservation Project Management Workbook software to calculate the overall benefit rank of each action that is calculated from its ecological benefit, feasibility, and cost. These assessments were performed on each river segment and the river-wide rank was obtained by rolling-up the contribution of each segment.

4.2. Enhanced 5-S Methodology

The Conservation Project Management Workbook is a spreadsheet that follows The Nature Conservancy's enhanced 5-S methodology, which encourages experts to identify **systems** (ecological systems and species, called **conservation targets** in Conservancy jargon), **stresses** to the systems, **sources** of those stresses, **strategies** to abate high-ranked sources of stress, and measures of **success**. The Conservation Project Management Workbook is available as public domain software (http://conserveonline.org/;internal&action=dialog.search.action, select "Tools/Software" under "Resource Types" and click "search now").

The 5-S methodology strives to limit the number of ecological systems and species that form focal conservation targets for an area to eight. This number is based on many years of experience and has worked in 99% of cases. In the case of complex rivers or rivers where past research supports segmentation of stresses and actions, the 5-S methodology can be applied to each river segment or reach. We applied the 5-S methodology to each river segment using the six ecological systems identified in Provencher and Andress (2004; Tables 2 and 4). In some river segments, less than six ecological systems were present (Table 4).

Working with a maximum of eight conservation targets forces one to adopt the coarse and fine filter approach, and to be efficient. The coarse filter approach assumes that most species can be managed effectively if the ecological system they live in functions within its normal range of natural variability or is managed to simulate key ecological processes (e.g., prescribed natural flows). Species that do not require special attention and can be managed as part of a larger ecological system are considered nested targets within the ecological system. The fine filter approach addresses the species whose ecological requirements do not match those of the broader ecological systems in which they are found. These species need to be specifically considered so that their special management needs are addressed. We identified no fine filter species for the upper Muddy River, although we believe that future research should test whether or not the ecological requirements of the Moapa dace will satisfy those of other warm spring endemics. In this assessment, we assumed that the recovery of the Moapa dace will benefit all warm spring endemics (*personal communication*, Gary Scoppettone, USGS, July 2002)

Table 4. Ecological systems per Upper Muddy River segment.

River Reach	Warm Springs Aquatic Assemblage	Muddy River Aquatic Assemblage	Desert Riparian Woodland	Desert Riparian Shrubland	Desert Riparian Marsh	Mesquite Bosque
Segment 1	-	X	X	X	X	X
Segment 2	-	X	X	X	-	X
Segment 3	-	X	X	X	X	X
Segment 4	X	X	X	X	-	X
Segment 5	X	X	X	X	X	X
Segment 6	X	X	X	X	X	X
Segment 7	X	X	X	X	X	X
Segment 8	X	X	X	X	X	-
Segment 9	X	X	X	X	-	-

Species (listed and Clark County priority species) nested within each focal conservation target are listed in Appendix I.

The normal output of the Conservation Project Management Tool for segmented rivers, as we chose to do, would be a series of tables for viability, threats (sources of stress across multiple ecological systems), and strategies per segment. Because there are several levels of analysis and detail, the amount of information for all segments becomes bewildering. For restoring the upper Muddy River, TNC designed a “roll-up” software that summarizes the information for all river segments into single tables with overall ranks and, if desired, per segment. The results presented here are rolled-up and thus are more relevant to managers.

4.2.1. Viability of Focal Conservation Targets

Viability is an overall measure of the level of degradation caused by stresses. TNC’s 5-S methodology involves an initial assessment of the **viability** of each conservation target based on the qualitative ranks assigned by experts to its **size**, **condition**, and **landscape context**. These definitions were not available for the majority of systems, however, so we relied upon expert opinion to estimate them. **Size** is the abundance for a species or extent for a community relative to its potential for the area. **Condition** is a combination of the target’s composition, structure, and biotic interactions, which is a reflection of the integrity of reproductive processes and age/size structure, or the biological composition of the community. **Landscape context** combines two processes — ecological processes that maintain or establish the target occurrences and connectivity among occurrences. Overall, **size**, **condition**, and **landscape context** set a benchmark for stress analysis and development of conservation strategies, which allows measures of success over time.

Our current viability assessment is an update of The Nature Conservancy's first assessment for the upper Muddy River (TNC 1999). A brief description of the viability assessment focused on the dominant factors follows. Appendix II from Otis Bay Riverine Consultants, Inc. provides additional background.

Table 5. Viability assessment of ecological systems of the upper Muddy River.

Target	Landscape Context	Condition	Size	Viability Rank
Upper Muddy River-All Segments				
Warm Springs Aquatic Assemblage	Fair	Poor	Poor	Poor
Muddy River Aquatic Assemblage	Fair	Poor	Poor	Poor
Deciduous Riparian Woodland	Good	Poor	Fair	Fair
Riparian Shrubland	Good	Poor	Fair	Fair
Mesquite Bosque	Good	Fair	Poor	Fair
Riparian Marsh	Good	Fair	Poor	Fair
Overall Health Rank				Poor

The **Warm Springs Aquatic Assemblage** and the **Muddy River Aquatic Assemblage** are composed of species of fish and invertebrates that occupy today an area much smaller than they did historically. Also, their population sizes are reduced. Therefore, the sizes of these two systems are poor (Table 5). Water withdrawals, exotic species, and river entrenchment have all contributed to this reduction, thus changing the habitat of these species and introducing non-native predatory and competitive interactions. Some of these factors are completely incompatible with these animal communities, thus condition is poor. The landscape context of these two systems is fair because springs continue to discharge water, water is retained in the mainstem as a result of downstream points of diversion for senior water rights, and flooding periodically occurs and supplies the river with needed coarse sediment. The overall viability ranks for the Warm Springs and the Muddy River Aquatic Assemblages are poor (Table 5).

Riparian Woodlands (*Fraxinus velutina* and *Populus fremontii*) and **Riparian Shrublands** (*Salix gooddingii*, *S. exigua*, *Acacia* spp., and *Pluchea sericea*) do not occupy large areas in today's floodplain. It is not clear that they spanned large areas of the floodplain compared to Mesquite Bosque and riparian marshes, therefore it is assumed that the size of each ecological system is fair (Table 5). Their respective condition, however, is poor because the riparian corridor that they would normally occupy is largely overtaken by saltcedar, fan palms, pastures, and development, and subject to fire particularly where fan palms are present. Landscape context is marginally good because both systems have a high potential for natural recovery due to the abundance of tree and shrub propagules transported by air currents and water. Currently, natural recovery would only be possible after geomorphic restoration of the river channel and water table and removal of competing exotic species. The overall viability ranks for Riparian Woodlands and Riparian Shrublands are fair (Table 5).

Mesquite Bosques and **Riparian Marshes** are estimated to be much smaller today than they were at European settlement. For example, it is believed that most of segments 2 and 3 were thickets of mesquite. Mesquite Bosque and marshes were converted to agriculture and dropping water tables coincident with water withdrawals likely accelerated the decline of these types. Thus size is poor for each (Table 5). Condition is fair because these systems are not the most invaded by saltcedar and fan palms, although Russian knapweed is a growing problem for Mesquite Bosque. On the Warm Springs Ranch, which holds half of the wetlands, wetlands contain pasture species and are grazed by livestock. Landscape context is good because mesquite and wetland species show a tendency to recolonize when livestock is removed and agricultural field left fallow. We expect an even greater response if water tables are elevated, as we are proposing in this report. The overall viability ranks for Mesquite Bosque and Riparian Marshes are fair (Table 5).

4.2.2. Stresses and Sources of Stress

A stress is the impairment that results in reduced viability of a target. Stress analysis is the equivalent of the Evaluation Phase in the BLM's Rangeland Health Standard handbook (Manual 4180). Stresses are evaluated separately from the sources of stress so that we may develop effective conservation strategies to address the causes of degradation in a target's viability. The sources of stress are extraneous factors, such as incompatible human uses, policies, or biological impacts from non-native species. When evaluating the seriousness of a stress, two factors are considered: the severity of damage and the scope of damage to the target over its occurrence. Both factors are based on what can be expected within a 10-year period under current management or circumstances. In this summary, we do not describe stresses (e.g., altered fire regimes) to the conservation targets. However, we uploaded the 5-S spreadsheets for each area to the database of the MSHCP and they are integral to the sources of stress analysis described below.

Each stress affecting a conservation target has at least one or more sources of stress. It is important to identify and rank the sources of stress in order to develop the most effective conservation strategies. A source of stress is the same as a causal factor investigated during the Determination Phase established in the BLM Rangeland Health Standard handbook 4180. Most stresses are caused by incompatible human activities that either occurred in the past (historical stress), or that are occurring now (active stress). Historical sources are no longer active and are no longer adding stress to a target, although they may be responsible for the present state (structure, composition, and function) of the systems. Active sources of stress are those that can be expected to affect the target within a 10-year timeframe. Once sources of stress have been identified they are ranked as to their relative seriousness based on the degree of contribution to the stress and the irreversibility of the stress. For example, a parking lot over a wetland is highly irreversible, whereas drainage ditches have low irreversibility because they can be more easily filled and the wetland restored. The monetary cost of restoration is an important consideration when evaluating irreversibility.

Once the stresses and sources of stress are identified and ranked for each of the conservation targets, the critical and persistent sources of stress are synthesized from the data. Critical sources of stress are those that rank highest and are active. Persistent sources of stress are those with historical sources.

Identifying the critical sources of stress across the system allows managers to focus efforts on source of stress abatement strategies (restoration actions) with the assumption that these will result in higher viability of the conservation targets. Cross-cutting sources of stress that affect more than one conservation target are termed threats. For highly ranked sources of stress with a historical source, managers must focus on restoration actions that improve the ecological condition (viability) of the conservation target. They are shown for the targets in each segment in Appendix IV.

4.3. Rank of Restoration Actions

4.3.1. Components of the Restoration Rank

The main purpose of using the Conservation Management Tool and the "roll-up" software was to rank restoration actions by benefit to ecological systems (i.e., to viability) while considering cost and feasibility. The overall rank is across all river segments. We also provide a rank per river segment to highlight the fact that some ecological systems are absent from some segments. Another important assumption of this ranking is that no priority can be assigned to ecological systems. In Chapter 5, we relax this assumption by assigning a higher priority to the Warm Spring Aquatic Assemblage based on the irreplaceability of its species.

Ranks are based on 9 components, of which the Threat Abatement Benefit and Viability Enhancement Benefit are derived from previous viability and stress assessments. The other components were identified by individuals familiar with the realities of the project.

1) Benefits
    a) Threat Abatement Benefit
    b) Viability Enhancement Benefit
    c) Contribution
    d) Duration
    e) Leverage
2) Feasibility
    a) Lead Individual / Institution
    b) Ease of Implementation
    c) Ability to Motivate
3) Cost
    a) Total Cost ($)

Threat Abatement
Selected action that can reasonably be expected to reduce a threat rank by one or more ranks (i.e., poor to fair, fair to good, and good to very good) for one or more of the targets within the next 10 years if the particular strategic action is successfully implemented.

Viability Enhancement
Estimate of any improvement of key ecological attributes to the targets that might reasonably be expected to occur over 10 years if the strategic action is successfully implemented.

Contribution
The degree to which the proposed strategic action, if successfully implemented, will contribute to the achievement of the objective(s).

☐ Very High: The strategic action, in itself, achieves one or more objectives.

☐ High: The strategic action makes a substantial contribution towards achieving one or more objectives, but is not by itself sufficient.

☐ Medium: The strategic action makes an important contribution towards achieving one or more objectives.

☐ Low: The strategic action makes a relatively small contribution towards achieving one or more objectives.

Leverage
Estimate any leverage towards other high-impact strategies.

☐ Very High: Immediate, visible, tangible results *and* high leverage towards another high impact strategy.

☐ High: Immediate, visible, tangible results *or* high leverage towards another high impact strategy.

☐ Medium: Visible, tangible results *or* moderate leverage towards another high impact strategy.

☐ Low: No apparent leverage.

Duration
The degree to which the proposed strategy, if successfully implemented, is likely to secure a long-lasting outcome.

☐ Very High: The strategy, if successfully implemented, is likely to achieve an enduring, long lasting outcome (e.g., ≥10 years).

- High: The strategy, if successfully implemented, is likely to achieve an outcome with a relatively long duration (e.g., 10 years).

- Medium: The strategy, if successfully implemented, is likely to achieve an outcome of moderate duration (e.g., 3 years).

- Low: The strategy, if successfully implemented, is likely to achieve an outcome with a very short duration (e.g., < 3 years).

Lead individual/institution
Determine whether individuals or institutions can move the strategic action forward towards completion.

- Very High: A lead individual with sufficient time, proven talent, substantial relevant experience and institutional support is reasonably available and committed to lead implementation of the strategy.

- High: An individual with sufficient time, promising talent, some relevant experience and institutional support is reasonably available and committed to lead implementation of the strategy.

- Medium: An individual with promising talent and sufficient time is reasonably available, but lacks relevant experience or institutional support.

- Low: No lead individual currently available.

Ease of implementation
The degree of certainty associated with the implementation of an action.

- Very High: Implementing the strategy is very straightforward; this type of strategy has been done often before.

- High: Implementing the strategy is relatively straightforward, but not certain; this type of strategy has been done before.

- Medium: Implementing the strategy involves a fair number of complexities, hurdles and/or uncertainties; this type of strategy has rarely been done before.

- Low: Implementing the strategy involves many complexities, hurdles and/or uncertainties; this type of strategy has never been done before.

Ability to Motivate
Degree to which the key constituencies (e.g. landowners, public officials, interest groups) whose involvement is critical to implementing the strategic action are well understood, and the strategic action is likely to appeal to their key motives.

- Very High: The key constituencies and their motives are well understood and the strategic action is likely to appeal to their key motives.

- High: The key constituencies are well understood and the strategic action may appeal to their key motives.

- Medium: The key constituencies are somewhat understood and the strategic action may appeal to their key motives.

- Low: The key constituencies are not well understood and it is uncertain whether or not the strategic action will appeal to their key motives.

Cost

Cost can be measured in dollars, number of full-time employees, hours, and volunteer time. Furthermore, total cost can be estimated as a one-time fixed cost or as repeated expenditures. For this project, we multiplied unit costs by the estimated maximum area of treatment. These values were then automatically converted to the categories described below. Where it was not possible to estimate a cost (e.g., future value of real estate), either because the unit cost was unpredictable or the area highly dependent on other factors, we assigned a fixed qualitative cost using the ranking below. For example, we assumed that fee title acquisition was always Very High for the larger properties with significant areas of ecological systems and containing priority species.

- Very High: $1,000,000 or more.

- High: $100,000 or more.

- Medium: $10,000 or more.

- Low: $1,000 or more.

4.3.2. Restoration Ranks

Table 6 shows the overall and per-segment ranks of each restoration action in descending order of value. The order of restoration actions could change as better estimates of cost are developed. For instance, wetland reconstruction, which has a high per-area cost, could move up in rank if only a fraction of the estimated area of wetlands was treated.

A few patterns, which interact, emerge. Actions that affect a greater number of segments and systems generally rank higher. Less expensive actions generally rank higher. Actions that have a weak to moderate effect on a system's viability rank lower. Therefore, KNAPWEED CONTROL WITH HERBICIDE AND/OR GOATS received the highest restoration rank, whereas ESTABLISHMENT OF BUFFER ZONE BETWEEN AGRICULTURAL FIELDS AND RIVER was the lowest.

Table 6. Overall and per segment ranks of restoration actions for the upper Muddy River.

Strategic Action	Overall Rank	Segment 1	Segment 2	Segment 3	Segment 4	Segment 5	Segment 6	Segment 7	Segment 8	Segment 9
Knapweed control with herbicide and/or goats	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Manual saltcedar removal with inmate crews	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Manual saltcedar removal with standard work crews	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Revegetation following invasive vegetation removal activities	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
Acquisition of conservation easements or agreements for key areas in segment	Very High	Very High		Very High	Very High	Very High	Very High	Very High	Very High	
Acquisition of fee title for key areas in segment	Very High	Very High		Very High	Very High	Very High	Very High	Very High	Very High	
Acquisition of water rights	Very High				Very High	Very High	Very High	Very High		Very High
Palm tree removal	Very High				Very High	Very High	Very High	Very High	Very High	
Construction of permanent grade control structure and fish barrier at White Narrows	Very High		Very High							

Construction of permanent grade control structure and rolling drum fish barrier at White Narrows	Very High		Very High						
Invasive fish exclusion on Cardy Lamb channel	Very High								Very High
Invasive fish exclusion on Muddy River above Warm Springs Road	Very High				Very High				
Invasive fish exclusion on Muddy Spring channel	Very High					Very High			
Invasive fish exclusion on South Fork channel	Very High								Very High
Removal of flood and sediment control dams on tributary washes	Very High			Very High					
Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	Very High						Very High		
Spring channel restoration of Apcar channel within Moapa Valley NWR	Very High						Very High		
Spring channel restoration of Muddy Spring channel	Very High					Very High			
Spring channel restoration of Plummer channel within Moapa Valley NWR	Very High						Very High		

Spring channel restoration of South Fork channel	Very High								Very High	
Spring channel restoration within WSR (Refuge and Apcar channels)	Very High						Very High			
Construction/Enhancement of wetlands within WSR where wet meadows exist	High					High		High	High	
Limitation of future shallow groundwater aquifer decline	Medium				Medium	Medium	Low	Medium		Medium
Complete reconstruction of channel within acquired property	Medium			Medium	Medium					
Defined instream flows for Apcar channel	Medium						Medium			
Defined instream flows for Moapa Valley NWR spring channels	Medium						Medium			
Development of public use and education areas/trails within Moapa Valley NWR	Medium						Medium			
Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	Medium		Medium							
Establishment of buffer zone between agricultural fields and river	Low		Low							

All actions consisting of knapweed, saltcedar, fan palm, and tilapia removal, including native plant revegetation after removal, received the highest rank of VERY HIGH. The same rank was given to acquisitions of conservation easement, fee title, and water rights. These real estate actions are often required to implement many other actions. Removal of flood and silt control structures, due to the low cost, also made the highest rank. Finally, restoration of various spring channels also received the VERY HIGH rank. Because some of these channels are on private properties where acquisitions of fee title and conservation easement are pre-requisite actions, their rank would conceivably decrease if we factored in this additional cost for their implementation.

Only construction/restoration of wetlands received the HIGH rank. It is conceivable that without the high cost of this action, it would have reached a rank of VERY HIGH. The rank of this action is misleading, however, because it can only be achieved after acquisition of fee title and conservation easements that allow restoration activities. Thus, the conditional cost of this action would, in reality, lower its rank.

The group of actions that received the MEDIUM rank was the second largest (6 actions). It contained a mix of restoration, policy, and educational actions. These were the limitation of future shallow groundwater aquifer decline, the complete reconstruction of the river channel in segment 3, defining instream flows in the Apcar and Moapa Valley NWR channels, development of public use and education area at the Moapa Valley NWR, and forming a partnership with the Tribe. Channel reconstruction will require the acquisition or leasing of water rights, which could further lower its rank.

The only LOW rank was for the establishment of a native vegetation buffer between the river and agricultural fields on the Moapa River Indian Reservation.

5. DESCRIPTION OF RESTORATION OPTIONS

5.1. Objective

We group restoration actions into three options based primarily on anticipated cost. Options are defined as LOW (least expensive), MEDIUM, and HIGH (most expensive). Options are not only based on cost; indeed, the LOW option has to at least include the least expensive strategy that explicitly benefited the Warm Spring Aquatic Assemblage, even if this strategy was not the least expensive. The rank of each restoration action was further used to place them among the three options. To cite Provencher and Andress (2004);

- Recovery of the Moapa dace is paramount to the conservation efforts because of its irreplaceability, and, therefore, should be considered the highest priority and a fundamental step in improving the integrity of the aquatic ecosystem.
- Conservation needs of Virgin River chub, two other desert fishes, and a suite of endemic species must also be considered a high priority in restoration plan.
- Other conservation activities cannot preclude recovery of federally listed species or the long term viability of endemic species.

5.2. Description of Strategy Options

The three restoration strategy options are packaged actions that help Clark County MSHCP permittees, agencies and other stakeholders to focus their efforts on the recovery of the Moapa dace while having a sense of the approximate cost involved for restoring several segments of the river. Although Clark County and other stakeholders can choose to fund single restoration actions, single actions are less likely to benefit the Moapa dace, especially if applied to river reaches or habitat outside of historic dace habitat. For instance, cost alone may recommend removal of saltcedar and knapweed from segments 1-3, but those actions, although badly needed to restore the riparian systems, will not benefit the Moapa dace.

The LOW option consists of the minimum actions to benefit the Moapa dace and the least expensive other actions specified in Appendix III. The total cost of implementation is at least $7,652,500.

Prerequisite actions

1) Develop conservation agreements with private land owners;
2) Complete National Environmental Policy Act and other state/federal compliance for public lands and waterways; and
3) Form a conservation partnership with Moapa River Indian Reservation ($30,000).

Restoration actions

4) Construct five fish exclusion barriers and remove blue tilapia (*Oreochromis aurea*) ($1,060,375):
    a) Construct permanent grade control structure and fish barrier at White Narrows ($500,000);
    b) Construct fish exclusion barrier above Warm Springs Road ($500,000);

   c) Construct fish exclusion barrier on Cardy Lamb channel ($20,125);
   d) Construct fish exclusion barrier on Muddy Spring channel ($20,125);
   e) Construct fish exclusion barrier on South Fork channel ($20,125);
5) Conduct targeted removal of fan palms (*Washingtonia filifera*) in critical Moapa dace habitat (warm springs and outflow creeks) ($850,000);
6) Remove saltcedar ($1,082,700);
7) Remove Russian knapweed and other non-native plants ($47,000);
8) Revegetate all areas treated for weed removal with native plants ($4,581,425); and
9) Remove flood and sediment control barriers ($1,000).

The MEDIUM option includes all previous actions for the LOW option, complete channel reconstruction on the Bureau of Land Management (BLM) and TNC properties in segment 3, and actions requiring conservation easements, but no major land acquisitions. Total cost is at least $42,858,600.

Prerequisite actions

1) Complete LOW option actions;
2) Define ecologically sustainable in-stream flow for Apcar and Moapa Valley National Wildlife Refuge (Moapa Valley NWR) spring channels ($200,000);
3) Acquire senior water rights from willing sellers for beneficial wildlife use ($5,000,000); and
4) Acquire conservation easements from willing sellers ($7,000,000).

Restoration actions

5) Reconnect and reconstruct the warm springs complex in historic Moapa dace habitat (blue tilapia removal required) ($2,645,000):
   a) Restore spring channel in Apcar channel within Moapa Valley NWR ($218,750);
   b) Restore spring channel in Muddy Spring channel ($124,250);
   c) Restore spring channel in South Fork channel ($129,500);
   d) Restore spring channel in Plummer channel within Moapa Valley NWR ($175,000);
   e) Restore spring channel within Moapa Valley NWR (Refuge and Apcar channels) ($997,500); and
   f) Restore remaining former recreational structures within Moapa Valley NWR to spring pools and channels ($1,000,000);
6) Conduct a complete channel reconstruction **or** small scale channel reconstruction on BLM and TNC properties in segment 3 (with appropriate permits) ($2,223,600);
7) Pursue legal limitations on future shallow groundwater aquifer withdrawals in the upper Muddy River ($500,000); and
8) Restore or construct wetlands on Warm Spring Ranch ($17,637,500).

The HIGH option consists of all restoration actions described under the LOW and MEDIUM options in addition to major land acquisitions and one additional channel reconstruction. Total cost is at least $52,482,200.

Prerequisite actions

1) Complete all LOW and MEDIUM option actions; and
2) Acquire property from willing sellers (>$7,000,000).

Restoration actions

3) Complete one channel/floodplain reconstruction elsewhere than segment 3 ($2,223,600).
4) Develop public use areas at Moapa Valley NWR ($100,000); and
5) Establish a buffer zone between agricultural fields and river on Moapa River Indian Reservation ($100,000).

6. EFFECTIVENESS MONITORING

6.1. Objective

Restoration actions are proposed to abate historic and current threats to species and ecological systems and to improve their ecological viability or functionality. It is not always clear, however, that actions are effective and ecological responses may vary sufficiently to suggest that some actions do not work when, in fact, they just take time. Therefore, it is a good business practice to verify whether or not money spent on restoration actually makes a difference for the ecological systems targeted. In this chapter, we sketch out basic monitoring designs to measure the effectiveness of actions for federally-listed species and Clark County covered species. In addition, we describe monitoring designs for actions that abate pervasive threats but where the listed or covered species' spotty abundance precludes its sampling. In those cases, we are more interested in the response of different features of the habitat type.

6.2. Sensitive Species and Communities

Federally-listed and Clark County covered species for the upper Muddy River are:

Table 7. Listed and Clark County covered species on the upper Muddy River.

LISTED	
	Moapa dace
	Virgin River chub (Muddy River population) [2]
	Southwestern Willow Flycatcher[1]
COVERED	
	Relict leopard frog[3]
	Arizona Bell's Vireo
	Blue Grosbeak
	Phainopepla
	Southwestern Willow Flycatcher
	Summer Tanager
	Vermilion Flycatcher
	Yellow-billed Cuckoo

[1]: During the 2003 breeding season, the Nevada Department of Wildlife detected the first pair of Southwestern Willow Flycatcher nesting in the upper Muddy River on Warm Springs Ranch (NDOW 2003).
[2]: Muddy River population not currently listed, however likely to be designated in future.
[3]: Not currently present on the upper Muddy River, but assumed to historically occur.

Because *Rana anca*, the relict leopard frog, is not currently present on the upper Muddy River, monitoring is limited to the two fish species and seven bird species.

6.3. Monitoring and Experimental Designs

Monitoring is described separately for fish species, bird species, and for threat abatement, although common themes exist among the different groups. In each case, monitoring will be tailored to whether restoration actions are very local (e.g., <300 acres) or dispersed throughout the upper Muddy River.

6.3.1. Fish Species Monitoring

The Moapa dace's population size is so low (<1,500 individuals) and its distribution limited to such a reduced portion of its historic habitat that a total inventory is the best sampling method. Surveys are conducted underwater with snorkels and involve a crew of people moving upstream in the spring channel (Scoppettone et al. 1998). A total inventory takes 1.5 days with a large crew of surveyors. It is pointless to survey Moapa dace in the mainstem and any spring channels not protected from tilapia predation by a fish exclusion barrier. Therefore, it is irrelevant whether restoration projects are large or small for this fish species because the current distribution is small. When more tilapia exclusion barriers are erected and tilapia removed, the area of Moapa dace occupation may become large enough to warrant sampling using the method described for Virgin River chub below. Due to the precarious state of the Moapa dace, on-going fan palm removal, and partial restoration of the Plummer spring and channel, yearly monitoring is required. Unfortunately, only partial yearly winter surveys by the Nevada Department of Wildlife, U.S. Geological Survey, and U.S. Fish and Wildlife Service have been conducted during the last two years because access to the Warm Springs Ranch was denied. In 2005, however, sampling was allowed for months that were never sampled before (e.g., August). Therefore, this new data is difficult to evaluate.

Numbers and habitat size of Virgin River chub are sufficiently large that sampling is required to estimate population size. The chub has been extirpated from the warm springs area. Tilapia feed on the Virgin River chub and predation is more efficient upstream in warmer and more transparent water. Tilapia also prefer warmer water. The chub is currently only found downstream of White Narrows in colder and more turbid waters.

Restoration actions that could benefit the Virgin River chub should occur predominantly on downstream segments, although it is conceivable that tilapia removal above White Narrows could restore the population in segments 3 through 8. The following actions are hypothesized to increase Virgin River chub counts: a) saltcedar removal, b) channel reconstruction in segments 1 and, perhaps, 3, c) removal of flood and silt control structures and, possibly, d) increased instream flow. Removal of saltcedar at river's edge will allow greater light penetration, thus enhance aquatic primary productivity to the benefit of the chub. Sampling results from the Nevada Department of Wildlife provide anecdotal support for this claim (*personal communication*, Jim Heinrich, July 2004). Also, intensive saltcedar removal should reduce evapotranspiration and elevate the water table, which should benefit all aquatic and riparian species. Channel reconstruction will increase the diversity of hydraulic habitats, thus benefiting different life stages of chub. It is not clear, however, whether or not tilapia will be favored by channel reconstruction in the absence of their removal. The removal of flood and silt control structures would improve Virgin River chub spawning habitat by allowing coarse sediment and silt transport (turbidity) in the mainstem. These benefits may be lost, however, after the installation of the White Narrows grade control structure because the proposed control structures are upstream of White Narrows. Increasing instream flow generally benefits aquatic species, but the effect on Virgin River chub is somewhat dependent on the fate of the tilapia. For example, if greater instream flow increases water transparency and temperature, the chub could be pushed further downstream. Again, the proposed White Narrows grade control structure will add its own level of complexity to flows and water quality.

In 1995, the population size of the Virgin River chub was estimated with the mark-and-recapture method from fixed sampling stations at the very beginning of tilapia invasion (Scoppettone et al. 1998). Since that time, population size has decreased. This benchmark from 1995, however, allows index-based population sampling to be correlated to past numbers. The favored method used by the US Geological Survey and the Nevada Department of Wildlife is sampling with hoop nets placed overnight in the river (Scoppettone et al. 1998; Swain et al. 2004). The index measures catch-effort. Resampling Virgin River chub at the same stations established in 1995 would provide the most reliable index of population size, but would not be tailored to particular restoration activities. Therefore, monitoring the effects of upstream tilapia removal, removing flood and silt control structures, increasing (or decreasing) instream flow, and the dispersed removal of saltcedar throughout the mainstem would be better accomplished by sampling yearly using the original methods (hoop nets) and stations proposed by Scoppettone et al. (1998).

Where restoration actions are deployed locally, the hoop net method can be applied on site, preferably before and several years after restoration. A first improvement to the pre- and post-restoration design would be to pair restoration sites with adjacent untreated sites with the goal of comparing fish counts from treated and untreated segments of the river. In the case of channel reconstruction, cost alone prevents the replication of treatment areas (even two projects would not be enough replicates), although several untreated areas can be found upstream and downstream. Also, channel reconstruction would eventually be confounded with tilapia removal effects because both actions would co-occur in segment 3 above White Narrows where Virgin River chub is excluded by tilapia. Untreated areas in segment 3 would provide evidence, albeit weak due to the lack of replication (Hurlbert 1984), to quantify the contribution of channel reconstruction. For sufficiently small treatment areas, such as those employed in saltcedar removal, an experiment could easily be designed by distributing three or more replicates of treated and untreated sites along the mainstem (Steel and Torrie 1980; Scheiner and Gurevitch 2001), with the constraint that each replicate is long enough for valid hoop-net sampling. An experiment would provide stronger support of causal effects between the restoration action and the Virgin River chub. Below, we offer an example of an experiment to measure the effects of saltcedar and knapweed removal and native plant revegetation.

6.3.2. Breeding Bird Monitoring

On the upper Muddy River, Arizona Bell's Vireo, Southwestern Willow Flycatcher, Summer Tanager, and Yellow-billed Cuckoo are too uncommon to lend themselves to any monitoring based on statistical assumptions. Moreover, it is pointless to design experiments around these species because most replicates would yield zero values. Surveys (area searches) where restoration is implemented should be conducted where the goals are 1) to determine that the species is truly absent during 3 years, 2) if present, quantify the number of nests (territories/hectare), and 3) confirm that restoration actions caused a species that was absent to become present, where presence must be demonstrated over a minimum of 3 years for non-listed species and 5 years for listed species. In the case of Yellow-billed Cuckoo, the area search should be conducted later in the summer to coincide with the species' unusual breeding season.

Area searches are time consuming, requiring a minimum of 10 visits per restoration project and one morning per visit (Sutherland 1996, 2000). Also, surveys should be conducted both before and after restoration. Larger sites or increasingly impenetrable vegetation require more visits. Area searches yield valuable data despite their effort and results can be related to regional trends obtained from the Nevada Bird Count (http://www.gbbo.org/nbc.htm). For example, a local increase in nest counts while the species is experiencing a regional decline would probably indicate success. The least desirable outcome would occur when the nest count decreases at the site but the species is increasing in the region. However, if a species is declining regionally and at the restoration site or the species is both increasing at the site and in the region, then one would determine that the relationship between the restoration action and nest counts is inconclusive, although the latter outcome is greatly preferred.

Blue Grosbeak, Phainopepla, and, on the Warm Springs Ranch, Vermilion Flycatcher are sufficiently abundant on the upper Muddy River for quantitative methods, either point counts or territory mapping. Blue Grosbeak is a problematic covered species for Clark County because it is likely to decline with riparian restoration. The Great Basin Bird Observatory (GBBO) determined that Blue Grosbeak is a riparian (anthropogenic) disturbance species seldom found in more pristine habitat (GBBO 2005).

For these more common species, two options are available depending on the extent of restoration. For small restoration projects <120 ha (300 acres) (e.g., wetland restoration and spring channel reconstruction), territory mapping (formerly spot mapping), a special case of area searches, is recommend to detect changes in nest density (Sutherland 1996, 2000). The variable of interest is the number of active nests per hectare that is equated with the number of territories per hectare. Success would be an increase in the number of nests for Phainopepla and Vermilion Flycatcher, but a decrease for Blue Grosbeak from pre- to post-treatment restoration. As described above, 10 visits per site per year before and after restoration during the breeding season are required using one morning per visit. Each visit assumes a full area search. When vegetation becomes sufficiently thick to impede searches in some parts of the project, sighting of active breeders are used to confirm territories.

Territory mapping would be ideally suited to small projects or to experimental designs with small replicates. Each replicate would yield one number for nest counts per species, with no sampling error associated with it. In these cases where the number of replicates and the number of nests are the only determining factors for variability, power analysis should be performed on existing data to calculate required number of replicates following recommendations by Steidl and Thomas (2000). Territory mapping might work best for the following restoration actions: saltcedar removal followed by native plant revegetation, knapweed removal followed by native plant revegetation, fan palm removal, spring channel reconstruction, and wetland restoration. Territory mapping might apply to complete channel reconstruction, however this method of sampling becomes less effective as restoration area exceed 300 acres.

For larger restoration efforts that are not replicated or for actions that are more widely distributed throughout the floodplain (e.g., complete channel reconstruction in segment 3, saltcedar removal throughout the watershed, and increased instream flow in the river's mainstem), the point count method is more feasible and can capture other species as well. Unlike the territory mapping method which gives a nest or territory density, point count methods only estimate an index of bird abundance. We recommend the Nevada Bird Count protocol conceived of by Nevada Partners-in-Flight (NPIF), after publication of the Nevada Bird Conservation Plan (Neel 1999) (http://www.gbbo.org/nbc.htm). The advantage of following this method is to obtain pre- and post-restoration data that could be compared to and integrated into the Nevada state-wide database managed by GBBO. The method is the variable-distance point count plot survey (http://www.gbbo.org/nbc_protocol.htm), which is a habitat-specific, fixed-radius point count survey design. Ten point counts are distributed on one transect, which is approximately 1.5 miles for 250 m between consecutive points. Several transects can be deployed per restoration project. Each point count transect is entirely set within one habitat type and only the bird sightings made within 100 m of the surveyor during 10 minutes are typically used for analyses. The distance of each sighting is recorded by distance class. All 10 points can usually be finished by one person in one morning. Surveys start at sunrise and finish before 10:00 AM. A complete description of the method and field sheets are found at http://www.gbbo.org/nbc_protocol.htm. Again, we recommend pre- and post-restoration sampling and at least 3 visits per site during the breeding season. Post-restoration sampling should be conducted for at least 3 years, preferably 5 years.

6.3.3. Threat Abatement Monitoring

Listed and covered species do not usually lend themselves to direct measurements because uncommon species typically have statistical properties that do not meet the assumptions of sampling designs and statistical tests. Above, we described area searches and total inventories to deal with those cases. Importantly, the more immediate concern is to abate the source of the stress that degrades the ecological community in which these species are or could be found. Therefore, the measures of interest should be descriptors of the habitat that affect species of concern, although these species may be rare or absent from the degraded habitat.

On the upper Muddy River, the most egregious sources of stress are water withdrawals, river entrenchment (and associated hydrological problems), conversion of wetlands, and invasion of tilapia, saltcedar, fan palms, and knapweeds. Looming in the near future is the invasion of non-native crayfish to the upper Muddy River. Several restoration actions are proposed to abate these threats. Below, we discuss general hypotheses, basic data needs, appropriate monitoring methods, and offer one example of a monitoring program addressing the effectiveness of threat abatement.

6.3.3.1. Hydrological improvements

The modification of water withdrawals, implementing ecologically-sustainable instream flows, moving points of water diversion downstream of the historic Moapa dace habitat, and other related activities can have significant beneficial effects on the aquatic species and the plant communities that would respond to an elevated water table. Greater abatement would cause more widespread effects, therefore expectations should be tailored to the size of the action. For example, we would expect primarily local effects if ecologically-sustainable instream flows are only implemented for the Apcar and a few Moapa Valley NWR channels.

For larger abatement efforts (e.g., moving downstream points of diversion for large senior water rights), monitoring would justifiably span a large part of the floodplain and effects would more likely be seen over a longer period of time, especially if the water table mediates the response. An important aspect of large scale monitoring would be to distinguish between upstream and downstream zones from where abatement is implemented and to initiate monitoring prior to restoration actions. Because a large number of aquatic and riparian communities could potentially be affected and thus a large number of variables, it becomes important to narrow monitoring to covered and listed species, to other species that can be measured without extra effort (birds, endemic fishes, and tilapia), and to measure the depth of the water table throughout the floodplain. We strongly recommend that all endemic warm spring aquatic invertebrates be sampled precisely because they receive no protection, they are unique to the Warm Springs Area, and their status is largely unknown since tilapia invasion (Sada 2000). Breeding bird point counts, Moapa dace inventories, hoop net sampling, monitoring wells, and aquatic invertebrate sampling are all important for evaluating the effects of hydrological improvements. Whether or not vegetation and butterflies (Fleishman et al. 2003; MacNally et al. 2004) should be monitored in the effort will depend on budgets. We suggest that a very narrow set of plant species and butterfly species be sampled. For vegetation, we would highly recommend the use of repeat remote-sensing high-resolution imagery analysis to measure the coverage of dense or characteristic vegetation types (for examples; willows thickets, cottonwoods, Mesquite Bosque, and invasive plants) and that field sampling be reserved for less detectable variables that are hypothesized to be important.

6.3.3.2. Channel reconstruction

Channel reconstruction, which is proposed for segment 3, would positively affect a large area containing all conservation targets except the Warm Spring Aquatic Assemblage (the Muddy River Aquatic Assemblage includes adult Moapa dace from the river's mainstem, however). The primarily goal of this action is to reconnect the river to its floodplain by reestablishing hydrological and geomorphic processes: Elevating the river's water level, and thus the water table, engineering river banks to overflow for 5-10 year flood events, and recreating hydraulic habitat diversity with meanders. It is assumed that the restoration of processes will favor the natural reestablishment of riparian and aquatic communities. Active weed and tilapia control, and native plant revegetation will be required, however. Hence, a large number of possible ecological benefits will result from channel reconstruction. The history of, and therefore experience with complete channel reconstruction, however, is limited to a few western rivers, including the Provo and Truckee Rivers. Adaptive management theory would, therefore, suggest that a higher level of monitoring be deployed when uncertainty about outcomes and opportunities for learning are great (Walters and Holling 1990; Hilborn et al. 1995; Hardesty et al. 2000; Wilhere 2002).

The large area potentially affected by complete channel reconstruction precludes both widespread and intensive sampling (e.g., complete territory mapping for breeding birds in all habitat types), and cost and size do not allow for replication of channel reconstruction, thus experimental designs are not applicable (although experiments for other threat abatement actions can be inserted in the project area). As for hydrologic improvements, a large number of variables could be positively impacted by complete channel reconstruction. Although all listed and Clark County covered species, even evaluation species, should be monitored, we recommend that the selection of other variables with better statistical properties follow a decision tree of hypotheses.

Channel reconstruction should increase hydraulic habitat diversity and reduce the depth of the water table. Hence, flow should be measured across river sections and at regular spaced intervals along the construction area, and monitoring wells should be positioned in the floodplain to measure changes in the depth of the water table. From these two concepts, series of relationships can be independently developed for aquatic systems and riparian terrestrial systems.

Aquatic relationships are perhaps the easiest to formulate and measure, because there is a rich history of riverine ecology and water quality methods and protocols. Increased hydraulic habitat diversity and deposition of different particle sizes of sediment should favor aquatic macro-invertebrate and fish species, including the Virgin River chub. Sampling methods for fish species using the hoop nest methods are described above. For macro-invertebrates, we recommend standard methods proposed by the U.S. Environmental Protection Agency.

The effects of the water table on riparian terrestrial plant communities are more complex. At the simplest, recruitment and colonization of riparian and hydrophilic vegetation are predicted to increase. Similarly, animal species that require open water and/or riparian vegetation will be detected more often. We make two general recommendations. The first is to take advantage of the interpretation of remote-sensing imagery for native and non-native vegetation patterns. The second is that monitoring effort be adjusted to the size of the conservation target. The smaller the conservation target, the more feasible intensive sampling can be. For instance, the small area of wetland created as a by-product of channel reconstruction can be monitored with survey methods described in the next section. The largest terrestrial conservation target in segment 3 is Mesquite Bosque. Mesquite is reestablishing in the abandoned agricultural fields of the BLM properties. Phainopepla is, by far, the most common covered species found in this habitat type. However, it is not the only bird species of interest. Therefore, the Nevada Bird Count method described above would be well suited for independent monitoring of Mesquite Bosque and Riparian Shrublands, which are intermingled with Riparian Woodlands long the thin corridor of the river.

Vegetation monitoring can be accomplished in part by remote-sensing imagery (with ground-truthing) to map occurrences and distribution of saltcedar, Russian knapweed, and tall whitetop (*Lepidium latifolium*), and to map the density and presence of clearly defined native cover species, such as willows (*Salix* spp.), adult mesquite, velvet ash (*Fraxinus velutina*), cottonwood (*Populus* spp.), quailbush, and others. This approach is not sufficient to address certain hypotheses. Vegetation sampling to estimate seedling and sapling densities of dominant cover species will be required to demonstrate that recruitment of riparian species is increasing in response to a rising water table. Vegetation sampling is time-consuming, but traditional methods of stratified random sampling (vegetation types are the strata) with either line-intercept, line point-intercept, or plot-based methods can be easily deployed (Elzinga et al. 1998; Herrick et al. 2002). If the goal of sampling is to demonstrate changes in recruitment from pre- to post-restoration, then spatially-nested plot-based methods will more likely detect seedlings and saplings (Elzinga et al. 1998), whereas line or line point-intercept methods will underestimate these variables. Therefore, the objectives of monitoring will dictate sampling methods and these will vary with vegetation types.

Increased soil moisture due to a shallower water table will likely increase flower and nectar production, which are good predictors of butterfly abundance and diversity on the upper Muddy River (MacNally et al. 2004). Past butterfly surveys on the upper Muddy River revealed both common and rare species that merit further monitoring because it is guaranteed that the earth-moving and active plant restoration will temporarily destroy some habitat. Therefore, butterfly counts not too dissimilar to bird point counts could be easily deployed using methods described in MacNally et al. (2004).

6.3.3.3. Wetland restoration

Wetland restoration is a relatively well-established practice in restoration ecology, albeit an expensive one, compared to other actions proposed here. Hence, extensive experimentation and monitoring to demonstrate that the action works may not be needed (Walters and Holling 1990). A lower level of effort should be deployed to monitor 1) listed and Clark County covered species (e.g., Vermilion Flycatcher), 2) non-native plant species, 3) water level in the wetland, and 4) the depth of the water table. For listed and covered birds we recommend area searches in and around the wetlands because the size of any wetland projects is relatively small. Complete area surveys with Global Positioning System (GPS) mapping should be conducted for non-native plant species to direct noxious species eradication crews to appropriate locations. Gauges and monitoring wells, respectively, should be installed in the wetlands and at their periphery.

6.3.3.3. Tilapia removal

The removal of tilapia from spring channels and upstream of White Narrows is the easiest hypothesis to formulate: The population size and distribution of endemic aquatic animal species and many plant species will increase as tilapia is removed. Effectiveness monitoring of tilapia removal itself is important because it would be pointless to reintroduce Moapa dace and Virgin River chub to river reaches and spring channels without first making sure that tilapia are extirpated. Because the hoop net method should be used to monitor tilapia removal success, other fish species will also be collected. Again, we strongly recommend that endemic warm spring invertebrates be sampled for reasons stated above. Sampling should be applied to treated and untreated river reaches (separated by fish exclusion barriers) and spring channels to document success over time, however we do not anticipate that this urgently needed restoration action will lend itself to an experimental design.

6.3.3.4. Fan palm removal

The Moapa Valley NWR obtained hazardous fuels reduction funding from the National Fire Plan to start removing fan palms growing in or adjacent to waterways and around human structures in 2003 and 2004. There are three ecological benefits to removing fan palms. The two most critical are to remove the rapidly growing palm root mass covering Moapa dace spawning habitat and to eliminate the risk of catastrophic fire in proximity of spring heads, spring channels, and the mainstem of the Muddy River in historic dace habitat. The third benefit is to reestablish native species in the riparian shrubland and woodland communities. Because the first two objectives are the most crucial, whereas the third one is controversial, monitoring should be restricted to total inventories of Moapa dace. We hypothesize that a greater number of dace in younger age classes will be recorded as spawning habitat is restored.

A problematic aspect with fan palm removal is that the only yellow bat (*Lasiurus xanthinus*) population in Nevada uses fan palms to roost and requires open water to drink on-the-wing (Bradley et al. 2002). The yellow bat population in Nevada is disjunct from more southern populations. The yellow bat, however, is not restricted to the Warm Springs Area, whereas the dace is, and fan palms are common elsewhere on the river, including around residences. If necessary, surveys of yellow bat could be conducted to insure that they are finding other palms to roost in while fan palms are removed from historic dace habitat.

6.3.3.5. Saltcedar and knapweed removal – an example

Saltcedar and knapweed removal were ranked as the most beneficial restoration actions in Table 6. Here, we provide a more in-depth and technical proposal for monitoring the effects of the actions submitted for funding in for the 2005-2006 Biennium of Clark County by TNC and partners.

Since 1995, the Muddy River Regional Environmental Impact Alleviation Committee (MRREIAC), a not-for-profit corporation dedicated to rural community-based protection and restoration of desert watersheds, riparian areas and wetlands, has operated a demonstration saltcedar and knapweed removal project on sections of approximately 10 km (6 miles) of private lands of the upper Muddy River. MRREIAC has successfully used NDF Conservation Camp inmate crews to fell saltcedar and apply Garlon 4 on fresh stumps, and to apply the herbicide Thordon on knapweeds. Hand-felling is required because the steep and entrenched banks of the upper Muddy River preclude the use of tractors and bulldozers to remove saltcedar.

Artificial native plant restoration following saltcedar and knapweed removal has also been attempted by MRREIAC, but with varying and surprising outcomes. Despite the use of dry water polymers on deeply entrenched river banks, willow and cottonwood cuttings drilled to the water table, hand irrigation, and best advice on desert riparian vegetation restoration, most revegetation attempts have failed. While artificial native vegetation restoration efforts have generally not been successful, native vegetation has naturally established in removal areas even leading to succession from quailbush (*Atriplex lentiformis*)-dominated vegetation to increased presence of mesquite, willows, and cottonwood within 5-10 years. There is a need to understand why artificial native plant revegetation efforts fail and whether the cause of failures is elevated salt content in soils, lack of sufficient soil moisture, or other causes.

Although saltcedar removal by MRREIAC has been successful, efforts have been criticized for three primary reasons: 1) The effectiveness of methods were not monitored either using a comparative sampling design or an experimental design; 2) Widespread removal of saltcedar may result in habitat loss for bird and butterfly species in the absence of remnant native habitat (Fleishman et al. 2003; MacNally et al. 2004), thus the extent and shape of the removal may need to be studied to determine harm caused; 3) Poor success experienced with artificial native plant restoration has created early successional plant communities, that, albeit native, cannot support desirable bird, fish, and butterfly species.

While MRREIAC has implemented several small scale restoration projects, success of removal and native plant restoration from the past 9 years has not been documented quantitatively. Thus, after 9 years of restoration, it is worthwhile to return to areas treated in different years, including current treatment areas, to monitor the effectiveness of past efforts by measuring the change in native plant, fish and bird species. All areas were heavily infested with mature saltcedar prior to treatment and lacked a native understory, although a few remnant willow and mesquite were preserved. The purpose of a retrospective approach acknowledges that the benefits to species addressed by the Clark

County MSHCP from restoration of highly degraded ecosystems may take years to manifest themselves as practitioners can rarely create desirable vegetation structure and composition within a few years. Therefore, one needs to quantify short term benefits to desert riparian animal species, including sensitive species, and the development of vegetation characteristics supporting additional sensitive species.

In addition to evaluating the efficacy of past and current efforts, we recommend that future restoration opportunities be monitored experimentally to verify the effectiveness of traditional and new removal methods, such as using goat herbivory. So far, tree felling and painting fresh stumps with Garlon 4 has proven very effective (Neill 1990 and 1996), however the work is labor intensive and travel within infested areas is hindered by dense saltcedar forests. Moreover, small patches of knapweeds frequently increase after saltcedar removal, thus requiring additional herbicide application. Preliminary trials with goat grazing of saltcedar and knapweed has facilitated human travel within infested areas, changed herbicide application method to wicking of resprouts (larger trees still need to be felled and stumps painted with herbicide), and goat grazing has temporarily removed knapweed patches. It is also important to realize that herbicides applied on knapweed cannot generally be used close to water, whereas goats can access these areas. These experiments will inform future management of riparian habitats in the Muddy River, allow for adaptive management of these unique resources, and inform the development of the Conservation Management Strategy for the Muddy River.

While monitoring the effectiveness of past and near future desert riparian vegetation restoration methods is needed to learn and demonstrate success, there is also a need to detect areas of non-native species invasion (saltcedar, Russian knapweed, and tall whitetop) to identify future restoration. On the upper Muddy River, these areas may be undetected by ground inventories because accesses to private properties are denied, surrounding vegetation is too dense to permit ground detection, patches of invasion may be too small to be easily detected, or not enough staff are available to map weeds. Under these conditions, mapping of non-native invasive species by remote sensing may be the most appropriate and feasible approach.

Remote sensing of non-native species, especially the early detection of small patches, will be a compromise between finer resolution and higher cost. While Landsat imagery offers the cheapest imagery, its 30-m pixel resolution will likely be too small for the detection of small patches of knapweed and whitetop and distribution of saltcedar along narrow linear features such as river fronts and ditches. Alternatively, Ikonos and the newer QuickBird multispectral imageries have pixel resolutions of 4m and 1m, respectively, that will detect small patches, but costs are much higher (up to $31/ sq. km). In any case, ground-truthing of spectral signatures will be required.

This project fits into a larger endeavor of restoring, albeit partially, the function, composition, and structure of the upper Muddy River floodplain (Provencher and Andress 2004). Control of non-native invasive species is paramount because they will doom the unique biota and many Clark County priority species of the upper Muddy River regardless of whether or not hydrology and geomorphology are adequately rehabilitated

(TNC 2000, Provencher and Andress 2004). Interestingly, control of the four most widespread and devastating non-native invasive species (blue tilapia, fan palm, saltcedar, and Russian knapweed) of the upper Muddy River is financially feasible in the long term compared to the cost of actions needed to restore the river's hydrology and geomorphology (Provencher and Andress 2004). Hence, we recommend 1) pursuing non-native species eradication to prevent further loss of natural communities and Clark County priority species, and enhance their habitat over the long term and 2) continuing to inform floodplain landowners and stakeholders about the negative effects of non-native species invasion. The realization of both goals require 1) a retrospective study to determine mechanisms behind past successes and failures, 2) an experiment to compare current and new methods of control and native plant revegetation, and 3) a survey of non-native species using remote sensing imagery and analysis. The details of these approaches, their hypotheses, designs, and sampling methods are explained in-depth in Appendix V.

7. Informational Meeting and Questionnaire

7.1. Objective

Adaptive management is both a science-based process with strong statistical (Wilhere 2002) and modeling (Hilborn et al. 1995; Hardesty et al. 2000) underpinnings and a social process (Walters and Holling 1990; Hardesty et al. 2000). In a more general view, management that is adaptive results in deliberate perturbations to ecological systems (e.g., experiments) and to the social institutions that manage or are affected by them. The Integrated Science Plan for the upper Muddy River was largely designed as a science driven product. The informational meeting and questionnaire, therefore, were added to address, although not fully, the social component of river restoration and increase public participation. The implementation of the upper Muddy River Integrated Science Plan's restoration strategies will fail without support from the stakeholders of the upper Muddy River and from the agencies with responsibilities on the river. As restoration strategies are implemented and successes identified, and public perception and barriers to implementation evaporate, the public values about the role of conservation on the river will likely change.

7.2. Informational Meeting

A public informational meeting to describe the findings of the upper Muddy River geomorphic assessment and the science workshops was held on September 9, 2004 in Moapa, Nevada. The meeting was advertised in the local newspaper. Approximately 23 people attended all or part of the meeting. Lewis Wallenmeyer, Administrator of the Clark County Desert Conservation Program, moderated the meeting and explained the general role of informational meetings in the Clark County Multiple-Species Habitat Conservation Plan. After presentations from Louis Provencher of The Nature Conservancy and Rob Andress of Otis Bay Riverine Consultants, Inc., audience members were allowed to question the presenters (both presentations were posted on Clark County's Website http://www.co.clark.nv.us/comprehensive_planning/Environmental/HabitatConservation.htm ; III. Projects).

In addition, participants were given questionnaires to document their opinions and concerns. A sample of the questionnaire is included in Appendix VI. Participants were given the options of turning in completed questionnaires at the meeting or mailing them in at a later time.

7.2.1. Questions and Comments from the Informational Meeting

The following questions and comments were discussed at the Informational Meeting. Where applicable, answers are provided.

Question #1. Will the reconstruction of the channel/floodplain require more water from the river than is currently available to saturate the new floodplain and elevate the water table?

> **Answer**: Perhaps. There might be a need to acquire water rights to meet restoration demands. However, the question implies something that is not necessarily true because too many compensating variables are involved in floodplain restoration. The water filling a restored floodplain is a temporary reservoir that empties because of a downvalley gradient, therefore a new equilibrium for flows between the floodplain and the river will be reached. Also, the temporary reservoir keeps the water at a cooler temperature, resulting in reduced evapotranspiration compared to the current situation where exposed water heats up and evaporates. Furthermore, restored native vegetation should consume less water than saltcedar. One example is Bear Creek in Oregon where the river became perennial after restoration because the temporary reservoir meted out water year-round, especially during dry periods.

Question #2. Will well drilling in Coyote Springs Valley affect the aquifer and hurt well water supply of Moapa residents?

> **Answer**: Current data shows that water extraction from the White River aquifer has already reduced spring flow for several years. This assessment does not address the question but water withdrawals were identified as a primary source of stress for Moapa dace.

Question #3. Should we be removing flood control structures on the BLM/Perkins property?

> **Answer**: Many flood control structures in this river reach are already broken and not functioning. Regardless, any removal of structures should be coordinated with the Clark County Regional Flood Control District to insure that flood hazard needs are addressed.

Question #4. For this study, was the river segmented in units corresponding to major land ownership, such as Hidden Valley, the Tribe, BLM, and Warm Spring Ranch?

> **Answer**: The river was segmented, but the segments correspond to reasonably homogeneous geomorphic and hydrologic features separated by natural or man-made boundaries, not to land ownership. There is, however, an overlap between these river segments and land ownership.

Question #5. What is the normal flow for the river?

> **Answer**: Currently 30 cfs, which is approximately 10 cfs less than before pre-pumping.

Question #6. Should we be concerned about the increased quantity of mosquitoes with the creation of marshes?

> **Answer**: Mosquitoes are very versatile and use current ditches and man-made ponds and water holes probably as much or more than they would use a marsh. Only a few species of mosquito affect human health and they require stagnant water, which is abundant around ditches, agricultural operations, and residences. This issue should be coordinated with the Clark County Health Department.

Question #7. Do you envision a regional park (especially for BLM lands) that the public can use for recreation? Hopefully the exclusion of the public from the Moapa Valley NWR will not become the standard operating procedure on other restored lands.

> **Answer**: We didn't consider a regional park given the resident's sensitivity about private property, but would encourage more access to the Moapa Valley NWR. The Moapa Valley NWR is currently closed to the public because there is no funding for infrastructure, staff, and liability but plans are being developed (pending funding) to open it to the public after the property is landscaped and facilities are constructed.
>
> **General discussion**: The BLM property (also called BLM/Perkins) would be an ideal place to implement a regional park because the space is sufficient and trails can be designed to minimize impacts. Tribal members expressed concern about presence of more people close to their lands because of problems associated with natural resources degradation as observed in parks elsewhere and possible water pollution concerns. (There was a long discussion about how to control human use of an area by the strategic placement of trails of varying length, restrooms, and camping facilities.) Otis Bay described the Provo River in Utah as an example with similar concerns where different types of activities were controlled and the local community funded a riverkeeper position to police human use. Also, it was pointed out that human visitation may not be desirable during mechanical restoration of the floodplain. The audience was reminded that BLM was developing short- and, eventually, long-term management plans for their properties and that the citizens of Moapa would have the opportunity to comment.

Question #8. What do you want from this audience?

> **Answer**: We want to hear from you about all topics from mosquitoes to a regional park, and your vision of the river. Do you want restoration and to what extent? (It was also explained that the questionnaire provides a more formal way to garner this information.)

Question #9. Will the PowerPoint presentations be available, especially the 1938-2003 aerial photos from Otis Bay?

Answer: We can post the presentation on the Clark County Desert Conservation Program 's Website. (As explained above, they are currently posted.)

Question #10. The previous questionnaire developed by the Moapa Town Board a few years ago showed a wide variety of responses to maintaining a rural life style. Would the responses be different today, years later? (the question was directed to a former Moapa Board member)

Answer: Not really because the community has not changed that much during the last 5 years.

General discussion: Members of the audience talked at length about the expectations of outsiders moving to places like Moapa. Moapa attracted a mixture of people with expectations ranging from a rural lifestyle to amenities found typically in a city (e.g., street lamps and paved roads everywhere).

General Comments. A participant pointed out that despite a 2.5 hour presentation on the ecology of the river, the discussion during the question period was about the need of people. People feel strongly about the use of the land and do not want to be excluded from the river and floodplain.

7.3. Results of Questionnaire

A total of 13 people returned questionnaires to The Nature Conservancy. Not all respondents attended the informational meeting, and not all attendees submitted a completed questionnaire. If a respondent provided two answers for the same question, or if the answer was unclear, it was not counted. Respondents did not always answer all questions, so the total number of answers for each question may be less than 13. Because 13 people do not constitute a representative sample, we refrained from interpretation, however the compiled results are presented. Overall, responses were positive and preservation of the rural character of the upper Muddy River floodplain appeared important to stakeholders. It is clear that concerns about flooding and water quantity and quality will dominate future restoration discussions.

1. How important to you are the following potential benefits of river restoration?

	Very important	Important	Neutral	Not important	Absolutely not important
Less water use by saltcedar	7	4	1	0	0
Reduction of noxious weeds	4	8	0	0	0

Fewer restrictions on private landowners to protect species listed under the Endangered Species Act	7	2	2	0	0
More area for hunting	1	3	1	2	4
More opportunities for bird watching, wildlife viewing	1	4	5	0	1
Higher water table	5	6	1	0	0
Maintain the rural lifestyle of Moapa	6	4	0	1	0
More native vegetation along the river to resemble historic times	4	2	4	1	0

2. Were you aware that the upper Muddy River is an area rich in animal species at risk, including warm-water fishes, and invertebrate (insect and snails) species found nowhere else in the world?

Very aware	6
Somewhat aware	7
Not aware	0

3. Were you aware that the different desert riparian plant communities of the upper Muddy River support a large number of bird species, some uncommon?

Very aware	5
Somewhat aware	7
Not aware	1

4. Were you aware that in the southwestern United States, mesquite woodlands, willow and cottonwood forests, riparian wetlands and marshes found on the upper Muddy River were more common in the past (at European settlement) than they are now?

Very aware	6
Somewhat aware	4
Not aware	2

5. Were you aware that the entrenchment of the upper Muddy River lowers the local water table and changes the plants of the floodplain, making it more desert like?

Very aware	2
Somewhat aware	4
Not aware	6

6. To what degree do you think flooding is necessary to maintain the native animals and plants along the upper Muddy River?

Very necessary	0
Necessary	5
Don't know	5
Unnecessary	3
Flooding is harmful	0

7. How much do you feel current water withdrawals have harmed the native river and floodplain plant and animal species (fishes, aquatic insects, snails, and birds)?

Very negative effect	4
Negative effect	5
No effect	2
Positive effect	0
Very positive effect	0

8. Do you support continued efforts to remove saltcedar?

Greatly support removal	7
Support	6
Neutral	0
Do not support	0
Strongly against removal	0

9. Are there other noxious weed species in the upper Muddy River that you would like Clark County, The Nature Conservancy, and Otis Bay Riverine Consultants to be aware of?

Yes	1
No	4
Species:	*Bassia hyssopifolia* and *Kochia scoparia*

10. Do you support the continued effort to remove the fan palm trees that are invading waterways?

Greatly support limited removal	1
Support limited removal	1
Neutral	6
Do not support limited removal	4
Strongly against limited removal	1

11. To what extent do you support removal of tilapia?

Greatly support removal	1
Support	5
Neutral	3
Do not support	2
Strongly against removal	1

12. Do you support efforts to restore parts of the upper Muddy River and its floodplain on public lands knowing that some or all of these actions could be used?

Greatly support	4
Support	5
Neutral	1
Do not support	2
Strongly against	0

13. Do you support efforts to restore parts of the upper Muddy River and its floodplain on private lands if the landowners are willing to participate, knowing that some or all of these actions could be used?

Greatly support	1
Support	3
Neutral	3
Do not support	3
Strongly against	1

14. How important is it for you to maintain rural character of Moapa, even if it includes protecting land from development?

Very important	5
Important	2
Neutral	2
Not important	0
Want to replace rural with more development	1

15. Do you support actions to maintain minimum flow in the river that will support the Moapa dace, other aquatic species, and riparian vegetation?

Greatly support	6
Support	3
Neutral	3
Do not support	1
Strongly against	0

16. Do you support actions to purchase water rights in the Moapa area from willing sellers and use them to benefit wildlife?

Greatly support	2
Support	4
Neutral	3
Do not support	1
Strongly against	0

17. Would you like to know more about noxious, non-native plants and animals and their control in the upper Muddy River?

Yes	5
No	7

18. Would you like to participate in the restoration effort as a volunteer?

Yes	4
No	9

19. Are there any additional concerns you have with the proposed restoration options that were not addressed in the above questions?

More recreation: parks, picnic areas, hiking trails	1
Concern about loss of private property rights	1
What are the tax ramifications to local citizens	1
Change is natural, man should not meddle	1
Palms provide habitat AND scenic value to valley	1

Nearly every respondent provided written comments to supplement their responses. Comments including those solicited in question 19 are summarized below.

Management actions: Two respondents commented that change is natural, and nature should not be managed by humans. Concerns were expressed by two respondents about the potential impacts of river management changes on flooding of private properties. Another respondent asked whether current saltcedar control efforts would be more efficient if begun in the headwaters and then moved downstream. Two respondents suggested methods which should be used to manage fan palm trees; trim and maintain regularly, and control for fire control and trim the roots out of streams. Another respondent also commented that palms provide habitat for species and add to the scenic value of the area. One respondent questioned what negative impacts fish barriers might have on the spawning habitat of the dace. Another expressed concern about the use of chemicals to eradicate tilapia, and asked if another method was available. One respondent expressed a need for residents to have access to the river area for compatible recreational activities such as parks, picnic areas and hiking trails.

Protection of land and waters: Four respondents expressed concerns about the weakening of private property rights or additional governmental control over land and water uses. Two respondents commented on the need for local residents to have control over local development or land use changes. Two respondents also were concerned about the definition of "willing seller", describing situations where a person may sell land or rights under outside pressures or ignorance of other options. One respondent did not agree that entrenchment of the upper Muddy River caused a drop in the local groundwater table and changes riparian plant communities.

Finally, one respondent commented that several questions were difficult to understand.

20. How would you best describe your relationship to Muddy River?

Own property adjacent to river	1
Own property in the river area	8
Am a resident of river area	1
Frequent visitor to river area	0
Do not live in river area but an interested citizen	3

8. ACKNOWLEDGMENTS

The Nature Conservancy is grateful to the Clark County's Desert Conservation Program and the U. S. Fish and Wildlife Service for funding, on-going advice, and logistic support. We thank Elisabeth Ammon, Janet Bair, Larry Brundy, Jeff Campbell, Lenore Clay, Darren Daboda, Brad Hardenbrook, Jim Haworth, Jim Heinrich, Marci Henson, Hermi Hiatt, Jeri Krueger, Callie Le'au Courtright, Bruce Lund, Gayle Marrs-Smith, Cynthia Martinez, Elise McAllister, David Merritt, Calvin Meyers, Belva Perkins, Ute Leavitt Perkins, Laurel Saito, Rob Scanland, Ann Schreiber, Gary Scoppettone, Amy Sprunger-Allworth, Phil Swain, Cris Tomlinson, Colleen Trujillo, Lewis Wallenmeyer, Grant Webber, Robert Wiggington, and Tim Wood for assistance and/or review of manuscripts. We thank the Moapa Tribal Council, MRREIAC, Nevada Power Company, and Southern Nevada Water Authority for assistance. The Town of Moapa graciously provided a meeting room at its community center.

9. Literature Cited

Bradley, P. V., J. A. Williams, J. S. Altenbach, P. E. Brown, K. Dewberry, D. B. Hall, J. Jeffers, B. Lund, J. E. Newmark, M. J. O'Farrell, M. Rahn, and C. R. Tomlinson. 2002. Nevada Bat Conservation Plan. Nevada Bat Working Group. Austin, Nevada.

Elzinga, C. L., D. W. Salzer, and J. W. Willoughby. 1998. Measuring and monitoring plant populations. Bureau of Land Management Technical Reference 1730-1.

Fleishman, E., N. McDonald, R. MacNally, D. D. Murphy, J Walters, and T. Floyd. 2003. Effects of floristics, physiognomy and non-native vegetation on riparian bird communities in a Mojave Desert watershed. Journal of Applied Ecology 72:484-490.

Great Basin Bird Observatory. 2005. Landbirds of Nevada and the habitats they need: a resource manager's guide to conservation priority species. Great Basin Bird Observatory, Reno, NV. 135 pages.

Hardesty, J., J. Adams, D. Gordon, and L. Provencher. 2000. Simulating management with models: Lessons from ten years of ecosystem management at Eglin Air Force Base. Conservation Biology in Practice 1:26-31.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, and W. G. Whitford. 2002. Monitoring manual for grassland, shrubland and savanna ecosystems. Draft. USDA-Agricultural Research Service-Jornada Experimental Range, Las Cruces, NM.

Hilborn, R., C. J. Walters, and D. Ludwig. 1995. Sustainable exploitation of renewable resources. Annual Review of Ecological Systems 26:45-67.

Hurlbert, S. H. 1984. Pseudoreplication and the design of ecological field experiments. Ecological Monographs 54:187-212.

Hyatt, M. W. 2004. Investigation of crayfish control technology: Final Report. Arizona Game and Fish Department, Phoenix, AZ.

Jowett, I. G. 1997. Instream flow methods: a comparison of approaches. Regulated Rivers: Research & Management 13:115-127.

MacNally, R., E. Fleishman, and D. D. Murphy. 2004. Influence of temporal scale of sampling on detection of relationships between invasive plants and the diversity patterns of plants and butterflies. Conservation Biology 18: 1525-1532.

Neel, L. A. (ed.). 1999. Nevada Partners in Flight Bird Conservation Plan. http://www.blm.gov/wildlife/pifplans.htm

Neill, W. M. 1990. Pp. 91-98, In: M. R. Kunzmann, R. R. Johnson and P. S. Bennett (eds.) Tamarisk control in southwestern United States. Proceedings of Tamarisk Conference, University of Arizona, Tucson, AZ, September 23-3, 1987. Special Report No. 9. National Park Service, Cooperative National Park Resources Studies Unit, School of Renewable Natural Resources, University of Arizona, Tucson, AZ.

Neill, W. M. 1996. Putting it altogether: management strategies and implementation. Presentation at Saltcedar Management and Riparian Restoration Workshop, Las Vegas, NV, September, 1996.

Nevada Department of Wildlife. 2003. Breeding status and surveys for the Southwestern Willow Flycatcher and Yellow-billed Cuckoo at sites in southern Nevada. Southern Region, Diversity Program.

Provencher, L. and R. Andress. 2004. Integrated Science Assessment for the Upper Muddy River, Clark County, Nevada. Annual report to the Clark County MSHCP, Nevada. The Nature Conservancy, Reno, Nevada.

RECON. 2000. Clark County MSHCP/EIS. Multiple Species Habitat Conservation Plan Final 2-1 9/00.

Sada, D. W. 2000. Spatial and Temporal Variation in Aquatic Mollusk Abundance and Habitat as Indicators of Environmental Change, Muddy River Springs, Clark County, Nevada. Unpublished report to Southern Nevada Water Authority, Las Vegas, Nevada.

Scheiner, S. M. and J. Gurevitch, eds. 2001. Design and analysis of ecological experiments. Oxford University Press, New York, New York.

Scoppettone, G. G., P.H. Rissler, M. B. Nielsen, and J. E. Harvey. 1998. The status of *Moapa coriacea* and *Gila seminuda* and status information on other fishes of the Muddy River, Clark County, NV. Southwestern Naturalist 43:115-122.

Steel, R. G. D., and J. H. Torrie. 1980. Principles and procedures of statistics. Second edition. McGraw-Hill, New York, USA.

Steidl, R. J. and L. Thomas. 2000. Using statistical power analysis to improve design of ecological experiments. *In* Design and analysis of ecological experiments, 2nd edition. S. Scheiner and J. Gurevitch, editors. Chapman & Hall, New York, NY.

Sutherland, W. J. 1996. Ecological census techniques: a handbook. Cambridge University Press, Cambridge.

Sutherland, W. J. 2000. The conservation handbook: Research, management, and policy. Blackwell Science, Oxford.

Swain, K. M., R. R. McShane, and G. G. Scoppettone. 2004. Status of Virgin River chub and other fishes of the Muddy River following 1995 invasion of blue tilapia in the Warm Springs Area. United States Geological Survey, Biological Resources Division, Western Fisheries Research Center, Reno Field Station.

Tharme, R. E. 2003. A global perspective on environmental flow assessment: Emerging trends in the development and application of environmental flow methodologies for rivers. River Research and Applications 19:397-441.

The Nature Conservancy. 1999. The Mojave Desert Ecoregion: A working classification of terrestrial ecological communities and descriptions of vegetation alliance. The Nature Conservancy and Association for Biodiversity Information, Western Conservation Science Center, Boulder, CO.

The Nature Conservancy. 2000. Upper Muddy River Site Conservation Plan, Las Vegas, NV.

The Nature Conservancy. 2001. Ecoregion-based Conservation in the Mojave Desert, Las Vegas, NV.

The Nature Conservancy. 2005. Conservation Project Management Workbook. Developing Strategies Group & Conservation Measures Group, The Nature Conservancy, Arlington, VA.

Walters, C. J. and C. S. Holling. 1990. Large-scale management experiments and learning by doing. Ecology 71: 2060-2068.

Wilhere, G. F. 2002. Adaptive management in habitat conservation plans. Conservation Biology 16:20-29.

APPENDIX I. NATIVE SPECIES OF SPECIAL INTEREST NESTED WITHIN UPPER MUDDY RIVER CONSERVATION TARGET SYSTEMS.

Common name	**Latin name**	**TNC target system**	**G rank**	**Legal status**	**Clark County MSHCP status**
Plants					
Honey mesquite	*Prosopis glandulosa*	Mesquite Bosque	G5		
Screwbean mesquite	*Prosopis pubescens*	Mesquite Bosque	G5 S3S4		
Plant species used for traditional purposes by Moapa Band of Paiutes	*Preliminary list received by Sue Wainscott, TNC, August 26, 2004.*	Riparian Woodland, Riparian Shrubland, Riparian Marshes, Mesquite Bosque	Various - common		
Mollusks					
Moapa pebblesnail	*Pyrgulopsis avernalis (syn. Fluminicola avernalis)*	Warm Springs Aquatic Assemblage	G1G2 S1S2		Evaluation-high
Moapa turban snail	*Pyrgulopsis carinifera*	Warm Springs Aquatic Assemblage	G1 S1		Evaluation-high
Grated tryonia	*Tryonia clathrata*	Warm Springs Aquatic Assemblage	G2 S2		Evaluation-high
Insects					
Western great purple hairstreak	*Altides halesus corcorani*	Mesquite Bosque	Not tracked		
Western Palmer's metalmark	*Apodemia palmerii palmerii*	Mesquite Bosque	Not tracked		
Dammer's fatal metalmark	*Calephelis nemesis nemesis*	Riparian Shrublands	Not tracked		

McNiel's desert sooty wing skipper	*Hesperopsis gracielae*	Riparian Shrublands	G2G3 S1	NV BLM sensitive species	
Arizona viceroy	*Limenitis archippus obsoleta*	Riparian Shrublands	T3T4G5 S1		
Southern Melissa blue	*Lycaeides melissa alateres*	Riparian Shrublands	Not tracked		
Moapa riffle beetle	*Microcylloepus moapus moapus*	Warm Springs Aquatic Assemblage	Not tracked		Evaluation-high & medium
Leda hairstreak	*Ministrymon leda*	Mesquite Bosque	Not tracked		
Moapa waterstrider	*Rhagovellia becki*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage	Not tracked		Evaluation-high
Moapa Warm Springs riffle beetle	*Stenelmis moapa (Syn. S. calida moapa)*	Warm Springs Aquatic Assemblage	G1 S1	NV BLM sensitive species	
Pahranagat naucorid bug	*Pelocoris Shoshone shoshone*	Warm Springs Aquatic Assemblage	GIG3 S1		Evaluation-medium
Warm Springs naucorid bug	*Usingerina moapensis (syn. Limnocoris moapensis)*	Warm Springs Aquatic Assemblage	G1 S1		Evaluation-high
Fishes					
Moapa White River springfish	*Crenichthys baileyi moapae*	Warm Springs Aquatic Assemblage	T2G2 S2	NV listed NRS 501	Evaluation-high
Virgin River chub (Muddy River population)	*Gila seminuda*	Muddy River Aquatic Assemblage	T1QG1 S1	Muddy River population not yet listed BLM NV sensitive NV listed NRS 501	Evaluation-high
Moapa dace	*Moapa coriacea*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage	G1 S1	LE - ESA BLM NV special status species NV listed NRS 501	Evaluation-high

Moapa speckled dace	*Rhinichthys osculus moapae*	Muddy River Aquatic Assemblage	T1G5 S1	BLM NV sensitive NV listed NRS 501	Evaluation-medium
Amphibians					
Arizona southwest toad	*Bufo microscaphus*	Riparian Marsh	G3G4 S1S2	NV BLM sensitive species	Evaluation-high
Woodhouse's toad	*Bufo woodhousii*	Riparian Marsh	G5 S5		
Pacific tree frog	*Hyla regilla*	Riparian Marsh	G5 S5		Watch list
Relict leopard frog	*Rana onca*	Riparian Marsh	G1 S1	Candidate – ESA NV listed NRS 501	Covered
Mammals					
Pallid bat	*Antrozous pallidus*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S3B	NV BLM Sensitive	
Desert pocket mouse	*Chaetodipus penicillatus sobrinus*	Riparian Shrublands	G5 S2		Evaluation-high
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G4T4 S4	C. townsendii is a NV BLM Sensitive species	Evaluation-high
Desert kangaroo rat	*Dipodomys deserti*	Riparian Shrublands, Mesquite Bosque	G5 S3S4		Evaluation-high

Spotted bat	*Euderma maculatum*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G4 S1S2	NV listed NRS 501	Watch list
Silver-haired bat	*Lasionycteris noctivagans*	Riparian Woodlands	G5 S3N	NV BLM Sensitive	Covered
Red bat	*Lasiurus blossevillii*	Riparian Woodland	G5 S1S2	NV BLM Sensitive	
Hoary bat	*Lasiurus cinereus*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands	G5 S3?	NV BLM Sensitive	
Western yellow bat	*Lasiurus xanthinus*	Riparian Woodland	G5 S1		
California leaf-nosed bat	*Macrotus californicus*	Riparian Shrublands	G4 S2	NV BLM Sensitive	Watch list
California myotis	*Myotis californicus*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S3B	NV BLM Sensitive	
Fringed myotis	*Myotis thysanodes*	Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G4G5 S2B	NV BLM Sensitive	Evaluation-medium

Yuma myotis	*Myotis yumanensis*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S4B	NV BLM Sensitive	Watch list
Big free-tailed bat	*Nyctinomops macrotis*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S1N	NV BLM sensitive	Watch list
Western pipistrelle	*Pipistrellus hesperus*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S4	NV BLM Sensitive	
Brazilian free-tailed bat	*Tadarida brasiliensis*	Warm Springs Aquatic Assemblage, Muddy River Aquatic Assemblage, Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G5 S4B	NV BLM Sensitive	
Kit fox	*Vulpes macrotis*	Riparian Shrublands	G4 S4	NV fur-bearing animal	Evaluation-high

Birds					
Green Heron	*Butorides virescens*	Riparian Marsh	G5 S4B	NV listed NRS 501 Migratory Bird Treaty Act	
Marsh Wren	*Cistothorus palustris*	Riparian Marsh	G5 S4N	NV listed NRS 501 Migratory Bird Treaty Act	
Yellow-billed Cuckoo	*Coccyzus americanus*	Riparian Woodlands, Riparian Shrublands, Riparian Marsh	G5 S1B	Candidate-ESA BLM special status species NV listed NRS 501 Migratory Bird Treaty Act	Conditionally Covered
Southwestern Willow Flycatcher	*Empidonax trailii extimus*	Riparian Woodlands, Riparian Shrublands, Mesquite Bosque	G5T1T2 S1B	LE - ESA NV BLM special status species NV listed NRS 501 Migratory Bird Treaty Act	Conditionally Covered
Peregrine Falcon	*Falco peregrinus anatum*	Riparian Woodlands, Riparian Shrublands, Riparian Marshes, Mesquite Bosque	G4 S2	LE - ESA NV BLM special status species NV listed NRS 501 Migratory Bird Treaty Act	Covered
Wilson's Snipe	*Gallinago delicata*	Riparian Marsh	G5 S4	NV listed NRS 501 Migratory Bird Treaty Act	
Common Yellowthroat	*Geothlypis trichas*	Riparian Marsh	G5 S3B	Proposed NV BLM Sensitive NV listed NRS 501 Migratory Bird Treaty Act	
Yellow-breasted Chat	*Icteria virens*	Riparian Woodland, Riparian Shrubland, Mesquite Bosque	G5 S3B	NV BLM Sensitive NV listed NRS 501 Migratory Bird Treaty Act	
Western Least Bittern	*Ixobrychus exilis hesperis*	Riparian Marsh	G5 S2N	NV BLM Sensitive NV listed NRS 501 Migratory Bird Treaty Act	
Loggerhead Shrike	*Lanius ludovicianus*	Riparian Shrublands	G4 S3	NV BLM sensitive species NV listed NRS 501 Migratory Bird Treaty Act	
Blue Grosbeak	*Passerina caerulea (syn.Guiraca caerulea)*	Riparian Woodlands, Riparian Shrublands	G5 S3	NV listed NRS 501 Migratory Bird Treaty Act	Conditionally Covered
Phainopepla	*Phainopepla nitens*	Riparian Shrublands, Mesquite Bosque	G5 S2B	NV BLM Sensitive NV listed NRS 501	Covered

				Migratory Bird Treaty Act	
Abert's Towhee	*Pipilo aberti*	Riparian Woodland, Riparian Shrubland, Mesquite Bosque	G3G4 S3	NV listed NRS 501 Migratory Bird Treaty Act	
Western Tanager	*Piranga ludoviciana*	Riparian Woodland	G5 S4B	NV listed NRS 501 Migratory Bird Treaty Act	
Summer Tanager	*Piranga rubra*	Riparian Woodland, Mesquite Bosque	G5 S4?B	NV listed NRS 501 (Migratory Bird Treaty Act)	
Sora	*Porzana carolina*	Riparian Marsh	G5 S3S4B	NV listed NRS 501 (Migratory Bird Treaty Act)	
Vermilion Flycatcher	*Pyrocephalus rubinus*	Riparian Woodlands, Riparian Shrublands, Mesquite Bosque	G5 S3?B	NV listed NRS 501 (Migratory Bird Treaty Act)	Conditionally Covered
Virginia Rail	*Rallus limicola*	Riparian Marsh	G5 S3S4B	NV listed NRS 501 (Migratory Bird Treaty Act)	
Yuma Clapper Rail	*Rallus longirostris yumanensis*	Riparian Marshes	G5T3 S1	LE - ESA NV listed NRS 501 (Migratory Bird Treaty Act)	
Crissal Thrasher	*Toxostoma crissale*	Riparian Shrubland, Mesquite Bosque	G5 S3S4	NV BLM Sensitive NV listed NRS 501 (Migratory Bird Treaty Act)	Evaluation-low
Arizona Bell's Vireo	*Vireo bellii arizonae*	Riparian Woodlands, Riparian Shrublands, Mesquite Bosque	G5T4 S2?B	Proposed NV BLM Sensitive NV listed NRS 501 (Migratory Bird Treaty Act)	Conditionally Covered

Abbreviations: LE – ESA — Listed endangered by the United States Fish and Wildlife Service; NPF — Nevada Partners in Flight; NRS 501 — Nevada Revised Statute 501 which provides for protection of fauna; NNHP — Nevada Natural Heritage Program; G1 — Globally critically imperiled because of extreme rarity, imminent threats, and/or biological factors, generally with 5 or fewer occurrences and/or less than 1,000 individuals, and/or less than 2,000 acres in extent; G2 — Imperiled because of rarity and/or other demonstrable factors, generally with 6-20 occurrences and/or 1,000-3,000 individuals and/or 2,000-10,000 acres in extent; G3 — Rare and local throughout its range, or with very restricted range, or otherwise vulnerable to extinction, generally with 21-100 occurrences and/or 3,000-10,000 individuals, and/or 10,000-50,000 acres in extent; G4 — Apparently secure, though frequently quite rare in parts of its range, especially at its periphery, generally with greater than 100 occurrences, and/or greater than 10,000 individuals, and/or greater than 50,000 acres in extent; G5 — Demonstrably secure, though frequently quite rare in parts of its range, especially at its periphery, with greater than 100 occurrences, and/or greater than 10,000 individuals, and/or greater than 50,000 acres in extent. T1-T5 — Status identical to G status, but applies to trinomial (subspecific) rank. S#S# —A numeric range rank (e.g., S2S3) is used to indicate any range of uncertainty about the status of the species or community. Ranges cannot skip more than one rank (e.g., SU is used rather than S1S4); S1 — Critically imperiled in the nation or state/province because of extreme rarity (often 5 or fewer occurrences) or because of some factor(s) such as very steep declines making it especially vulnerable to extirpation from the state/province; S2 — Imperiled in the nation or state/province because of rarity due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors making it very vulnerable to extirpation from the nation or state/province; S3 —Vulnerable in the nation or state/province due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors making it vulnerable to extirpation; S4 — Uncommon but not rare; some cause for long-term concern due to declines or other factors; S5 — Common, widespread, and abundant in the nation or state/province; B — Conservation status refers to the breeding population of the species in the nation or state/province; N — Conservation status refers to the non-breeding population of the species in the nation or state/province; M — Migrant species occurring regularly on migration at particular staging areas or concentration spots where the species might warrant conservation attention. Conservation status refers to the aggregating transient population of the species in the nation or state/province; Q — Taxonomic status Questionable or uncertain; and ? — Denotes inexact or uncertain numeric rank. (The ? qualifies the character immediately preceding it in the S-rank.)

Appendix II . Assessment of River Channel and Habitat Restoration Recommendations.

Upper Muddy River
Geomorphic Assessment

Assessment of River Channel and Habitat Restoration Recommendations

Prepared by
Otis Bay Inc
9225 Cordoba Boulevard
Sparks, NV 89436

Prepared for
The Nature Conservancy
One East First Street
Reno, NV 89501

Table of Contents

Upper Muddy River Geomorphic Assessment

Assessment of River Channel and Habitat Restoration Recommendations

1.0 Introduction..73

2.0 Restoration Objectives...74

3.0 Assessment of Target Assemblages 76
3.1 Warm Springs and Stream Aquatic Assemblage.....................................77
3.1.1 Introduction...77
3.1.2 Impacts...78
3.1.3 Limitations...79
3.1.4 Recommendations...79

3.2 Muddy River Aquatic Assemblage..82
3.2.1 Introduction...82
3.2.2 Impacts...82
3.2.3 Limitations...83
3.2.4 Recommendations...83

3.3 Riparian Woodland Assemblage 86
3.3.1 Introduction...86
3.3.2 Impacts...86
3.3.3 Limitations...87
3.3.4 Recommendations...87

3.4 Riparian Shrubland Assemblage..88
3.4.1 Introduction...88
3.4.2 Impacts...89
3.4.3 Limitations...89
3.4.4 Recommendations...90

3.5 Riparian Marsh Assemblage...90
3.5.1 Introduction...90
3.5.2 Impacts...91
3.5.3 Limitations...91
3.5.4 Recommendations...91

3.6 Mesquite Bosque Assemblage 92
3.6.1 Introduction 92
3.6.2 Impacts 92
3.6.3 Limitations 93
3.6.4 Recommendations 93

4.0 Assessment of Restoration Potential for Individual River Segments 93
4.1 Methods for the Assessment of Restoration Potential 94
4.1.1 Geomorphic River Segments 94
4.1.2 Aerial Photography Evaluation 94
4.1.3 Restoration Potential Scoring 95

4.2 Definitions for Assessment Criteria 96
4.2.1 Floodplain and River Corridor Attributes 96
4.2.2 Habitat Attributes 98

4.3 Assessment of Restoration Potential 101
4.3.1 Segment 1 101
4.3.2 Segment 2 102
4.3.3 Segment 3 103
4.3.4 Segment 4 104
4.3.5 Segments 5 and 6 104
4.3.6 Segments 7 and 8 105
4.3.7 Segment 9 106

4.4 Restoration Potential Conclusions 107

5.0 Recommendations for Recovery of the Upper Muddy River Riparian Ecosystem 109

5.1 Recommended Conservation Corridor 110

5.2 Determination of Conservation Corridor Width and Hydraulic Modeling 111

5.3 Description of Recommended Conservation Corridor 113
5.3.1 Segment 1...113
5.3.2 Segment 2...113
5.3.3 Segment 3...114
5.3.4 Segment 4...114
5.3.5 Segments 5 and 6...114
5.3.6 Segments 7 and 8...115
5.3.7 Segment 9...115

5.4 Habitat Conservation and Restoration Recommendations
and Alternatives 116

5.5 Example of Restoration Implementation..117

6.0 References...119

Appendix A: Figures
Appendix B: Tables
Appendix C: Upper Muddy River Channel and Habitat Restoration Potential Evaluation Sheets

1.0 Introduction

This document presents an assessment of river channel and habitat restoration recommendations. The priority conservation targets, or assemblages, shown in Table 1, have been accurately delineated and described by TNC (2000). These assemblages were used to complete an assemblage based assessment. The purpose of the assemblage based assessment was to 1) define and describe the impacts that have affected and continue to affect each target assemblage and 2) to define and describe the limitations to the recovery of each assemblage. Next, an assessment of restoration potential within each river segment was completed. Both the assemblage and segment based assessments provide insight to the biological and physical conditions present within the UMR valley and form the basis for habitat conservation and restoration recommendations. High, medium, and low level alternatives for habitat conservation and restoration with the UMR valley are presented following the development of habitat conservation and restoration recommendations.

It is important to note that the term "restoration" and the phrases "river restoration", "habitat restoration", and "ecological restoration" each conjure entirely different images and perceptions to the reader or listener. For example, do we achieve habitat restoration and ecological restoration following the implementation of river restoration activities, or does each type of restoration require separate definitions? Or, is river restoration the return of the river to a dynamic entity that is fully functional in terms of fluvial processes and riparian habitat creation, destruction, and maintenance? To some, restoration is a term that best describes any efforts that we may make to improve river, habitat, and ecological conditions. Furthermore, various interpretations create separate expectations and may lead to differing interpretations and judgments regarding the success of restoration activities. Therefore, an explanation of the term restoration, as it is used within this document, is provided below.

The term "restoration" will be used in this document to describe any activities within the UMR that are intended to lead to an improvement in environmental quality and ecological value. In the future, such as during the planning, design, and implementation stages of efforts intended to improve environmental quality and ecological value, it will be crucial that the intentions of the efforts are made quite clear. For purpose of definition, the intentions may be divided into the following categories; complete restoration, rehabilitation, enhancement, and creation. Complete restoration indicates the complete structural and functional return to a pre-disturbance state, and is an unlikely scenario for the UMR. However, rehabilitation, or partial return of structural and physical function is a likely option within the UMR. In addition, both enhancement and creation are viable restoration methods that may be applied in the UMR. Enhancement is herein defined as any actions completed for the purpose of improving environmental and ecological value. Creation is defined as the development of a resource that did not previously exists at a given location.

2.0 Restoration Objectives

Clearly defined objectives are an integral part of a successful restoration project. Although broad and encompassing, the primary objective of habitat restoration within the UMR valley is to establish, to the maximum extent possible, a self maintaining ecological system. Specific restoration objectives include the maintenance, recovery, and/or reestablishment of the priority conservation targets and associated species. However, physical limitations to the restoration process exist in the form of river channel entrenchment, agriculture, housing, and lowering of the alluvial aquifer water table due to groundwater extraction. Specific restoration objectives are listed below:

- Improve riparian habitat by increasing the riparian corridor width where possible
- Restore the hydraulic connection between river and floodplain where possible
- Increase biological productivity and diversity, with emphasis on target species
- Restore and improve hydraulic habitat for native aquatic species
- Restore a mosaic of riparian, transitional, and wetland aquatic habitat types
- Provide public access to the river and other natural features for low-impact recreational activities

By identifying the restoration objectives and priority conservation targets, restoration results will be measurable. Restoration objectives have been identified in order to restore suitable conditions for the priority conservation targets. The priority conservation targets, or assemblages, are shown in Table 1. These assemblages represent distinct community types that require similar ecological and physical processes for sustainability. Each priority conservation target contains target species and was selected and organized based on 1) viable, vulnerable, rare, and endangered species; 2) species of special concern due to declining numbers, disjunct distribution, or regional endemism; 3) viable ecological communities; and 4) assemblages of ecological communities and species (TNC, 2000). The priority conservation targets describe a specific assemblage of plant and animal species that are adapted to similar ecological and physical factors and will require similar restoration approaches. Therefore, restoration recommendations will focus on the locations where and methods by which these six priority conservation targets can be restored.

Although a self maintaining ecological system is desired, the need for mechanical and human intervention will be likely following future restoration efforts. Because restoration recommendations include human and wildlife needs, continued management of the UMR valley habitat resources will be necessary. Monitoring of the priority conservation targets will allow for the direct measurement of restoration success or failure. Habitat restoration activities present significant potential for the learning process to enhance restoration efforts. Completing the restoration activities in phases will allow the learning experience to increase the value and success rate of restoration efforts. An adaptive management approach following restoration is recommended due to the resource management needs and the likelihood that changes in habitat needs and goals will occur. Post-restoration intervention that would likely be required would include exotic species control, prescribed and selective vegetative thinning, and channel maintenance activities.

Complete restoration of the UMR valley to pre-settlement conditions would most likely meet all restoration objectives, restore balance among the habitat assemblages, and meet specific ecological and physical requirements for both the assemblages and related species. However, physical limitations exist due to historical and present land use and changes in the hydrologic conditions within the UMR valley. Therefore, restoration efforts within the UMR valley will consist of a balance between both human and wildlife needs. Similarly, future restoration planning will require designs based on current physical conditions and limitations rather than the complete reconstruction of historical conditions.

A balance between historical conditions, restoration goals, present conditions, and physical limitations will be required. Both active and passive restoration strategies will be necessary. For example, certain factors, such as a diminished alluvial aquifer, will continue to limit restoration efforts where a shallow depth to groundwater previously supported wetland vegetation. Likewise, the present channel dimensions preclude most of all except the largest flood flows from dispersing onto the floodplain. Therefore, active restoration strategies may be required where physical limitations to restoration must be overcome. However, passive restoration strategies are also suggested where 1) physical limitations are not present; 2) physical limitations are present to a minor degree but are recoverable; or 3) where a minimum amount of active restoration will allow passive restoration to complete the specific restoration goal. Restoration recommendations are provided herein based on the recovery of individual priority conservation targets and the general ecological and physical requirements of species within each priority conservation target.

3.0 Assessment of Target Assemblages

The following sections provide an overview and general information pertinent to the consideration of future restoration efforts within the UMR valley. Specifically, the primary impacts that have affected and continue to affect each assemblage are described. Next, the limitations to the recovery and/or restoration of the individual assemblage are explained. Following the discussion and consideration of impacts and limitations, recommended restoration activities, relative to each target assemblage, are presented.

3.1 Warm Springs and Stream Aquatic Assemblage

3.1.1 Introduction

Perhaps the most unique habitat type within the UMR valley, this assemblage is composed of the plants and animals associated with the headwater springs and tributaries. All of the channels associated with the thermal headwater springs have been altered, channelized, or constructed to various degrees, primarily for water diversion and recreational purposes. The most influential target species within this assemblage is the Moapa dace, which is federally listed as endangered. Additional native and thermal endemic fauna include the White River springfish, Moapa pebblesnail, grated tryonia, Warm Springs riffle beetle, and the Amargosa and Moapa naucorids.

Moapa dace occur throughout the thermal headwater springs in spring pools, spring outflow channels, and the mainstem of the Muddy River and utilize these different habitat types during separate life stages. Larval dace occur most frequently in low velocity backwater and only in the upper reaches of spring channels. Juvenile dace inhabit areas with a wider range of water velocity, but are primarily observed in the spring channels that are tributaries of the Muddy River. Adult dace are found in both the spring channels and mainstem of the Muddy River, but are observed most often in the river. The warm spring channels provide habitat for reproduction and larval and juvenile dace, but larger water volumes (mainstem Muddy River) are necessary for the production of larger dace and a more robust population. Dace commonly feed at drift stations located in reaches of low to moderate water velocity often occurring at pools maintained by channel scour below riffles (Scoppettone et al., 1987, 1992). Adult dace typically inhabit higher velocity water (3.6 to 3.0 ft/s) (Cross, 1976). Successful reproduction is only known to occur in the warmer waters of the spring channels. Redds believed to be those of Moapa Dace have been observed in low velocity (0.125 to 0.25 ft/s) water within the spring channels (Scoppettone et al., 1992).

Five locations, in addition to the Muddy River, containing habitat suitable for Moapa dace were identified in the Moapa dace Recovery Plan (USFWS, 1983) and include springs and associated spring channels of the Apcar, Baldwin, Cardy Lamb, Muddy Spring, and Warm Springs (Refuge) areas. The recovery plan defines three objectives to be accomplished prior to the reclassification of the Moapa dace from endangered to threatened; 1) the protection of existing instream flows and historical habitat in three of the above listed historical habitat locations and the UMR by conservation agreements, easements, or fee title acquisitions; 2) 4,500 adult Moapa dace present among the above-listed five springs; and 3) the Moapa dace population is comprised of three or more age-classes, and reproduction and recruitment is documented from three spring systems. Three additional objectives must be accomplished for delisting and include; 1) 6,000 adult Moapa dace are present among the five spring systems and the UMR for 5 consecutive years; 2) 75 percent of the historical habitat in the five spring systems and the UMR provides dace spawning, nursery, cover, and/or foraging habitat; and 3) nonnative fishes and parasites no longer adversely affect the long-term survival of Moapa dace.

3.1.2 Impacts

This assemblage has been negatively impacted by former recreational development and water diversion activities. All of the headwater springs and channels have been altered in some manner. The springs and channels located within the MVNWR were previously developed into concrete lined pools and channels. The Apcar spring and channel have been modified for water diversion. The Baldwin spring system has been developed for municipal and agricultural uses. Part of the flow from the Apcar system and all of the flow from the Baldwin systems is diverted for use by MVWD. In addition, an unknown amount of discharge from the Apcar system flows overland into former and lightly grazed agricultural fields and returns into the lower Apcar channel at lower temperatures resulting in an increased rate of cooling in the downstream direction within the Apcar channel. The Cardy Lamb spring system was developed for recreational and agricultural uses while the Muddy Spring system is currently used for recreational purposes. Both the Cardy Lamb and Muddy Springs discharge into swimming pools. The Cardy Lamb pool, currently unused, overflows into an irrigation ditch. The Muddy Springs discharge into swimming pools at the LDS recreation area and overflow into the Muddy Springs channel. The introduction of exotic fish, primarily Tilapia, resulted in the greatest impact to the Moapa dace. The alteration of hydraulic habitat by diversion activities, drawdown of the alluvial aquifer, and the introduction of palm and tamarisk represent the remaining most significant impacts to this priority conservation target. A potential decline in flow due to future groundwater extraction from the carbonate aquifer that feeds the headwater springs represents the primary threat to the future preservation of this assemblage. Although the human uses of these spring systems should be maintained, protection and enhancement of this assemblage is necessary.

3.1.3 Limitations

Restoration and enhancement of the Warm Springs and Stream Aquatic Assemblage is limited by the amount of channel available for restoration activities. Legal protection in the form of conservation agreements, conservation easements, or fee title acquisition will be necessary in order to guarantee the protection of this assemblage. Presently, only the portions of the Warm Springs and Apcar channels that are located within the boundaries of the MVNWR are provided legal protection. The primary limitations to recovery of the Moapa dace include the presence of Tilapia within all headwater tributaries other than the Warm Springs and Apcar channels, diminished reproductive and feeding habitat, and altered and destroyed spring channel habitat.

3.1.4 Recommendations

The present Moapa dace population is not sufficiently numerous to warrant reclassification. The expansion and preservation of existing Moapa dace habitat is the most important step in achieving preservation, reclassification, and delisting of the species as well as restoration of the Warm Springs and Stream Aquatic Assemblage. Both the Warm Springs and Apcar channels cross into private land upon exiting the MVNWR and prior to discharging into the Muddy River. Achieving reclassification will require conservation strategies that will include coordination between the USFWS, NDOW, Clark County, SNWA, MVWD, NPC, and other local individuals/groups. The incorporation of these springs and associated channels into a restoration plan will require the consideration of water rights ownership, private land ownership, and local support.

As discussed above, prior to reclassification and delisting, three of the five historical habitat areas must be protected by conservation agreements, easements, or fee title acquisitions. Although the MVNWR provides legal protection to the headwaters of both the Warm Springs and Apcar channels, the entire length of the two channels is not legally protected. A significant potential for Moapa dace habitat expansion and improvement exists within the lower reaches of the Warm Springs and Apcar channels. Currently the Warm Springs and Apcar springs and associated channels are isolated from Tilapia by a gabion structure fish barrier directly upstream from the junction of the combined Warm Springs/Apcar channels and the Muddy River. In addition, plans currently are being completed for the construction of a temporary fish barrier on the Muddy Spring channel (Shawn Goodchild, personal communication, 2003). The potential restoration of the Apcar, Baldwin, Warm Springs, and Cardy Lamb springs and channels hinges on the future management and use of the former Warm Springs Ranch which is currently owned by the South 15 development group.

The Warm Springs, Apcar, and Baldwin springs and associated channels represent the potential for the preservation of three thermal spring channel systems of high habitat quality. The protection of these channels through conservation agreements, easements, or fee title acquisition, could partially fulfill the requirements for the reclassification of the Moapa dace. As explained above, Tilapia are excluded from the Warm Springs and Apcar channels by a fish barrier. The Baldwin channel (South Fork of the Muddy River) joins the mainstem Muddy River in the vicinity of the LDS recreation area. Tilapia could be readily isolated from the Baldwin spring channel with a fish barrier located within the Baldwin channel upstream from its confluence with the Muddy River. The eradication of Tilapia from the thermal tributaries and separation of the individual tributaries from the mainstem of the Muddy River is the first step in preservation of the Moapa dace. Although the establishment of ecological continuity between the thermal tributaries and the mainstem of the Muddy River is preferable, consideration will need to be made for the potential reintroduction of Tilapia to all of the thermal tributaries in the event that Tilapia are initially eradicated from the headwaters and a single fish barrier on the Muddy River is the only obstacle to the reintroduction of Tilapia throughout the headwaters. It may be preferable to maintain fish barriers on the individual spring channels, at the cost of decreased ecological continuity, in order to prevent the reintroduction of Tilapia to all channels.

The restoration of habitat suitable for Moapa dace as well as a restored continuity between the thermal headwater springs and the mainstem of the Muddy River will result in improved conditions for individual species within the Warm Springs and Stream Aquatic Assemblage as well as species in most of the other assemblages. Additional restoration activities within this assemblage should include removal of palm trees and tamarisk. Palm and tamarisk removal in the vicinity of the headwater springs and spring channels should proceed in stages to allow for the recovery of vegetative structure between eradication activities. The opening of the canopy above the spring channels will likely result in an increase in primary production and improved feeding and reproductive conditions for the Moapa dace. Overstory conditions should remain in the vicinity of the spring channels (which may be similar to the Riparian Woodland and Riparian Shrubland assemblages), but should be composed of sedges, rushes, Goodding's willow, velvet ash, Emory's baccharis, arrow weed and wolfberry.

The MVNWR presents a significant potential for public outreach. Although presently closed to public access, the MVNWR presents future opportunities for education, conservation, and the development of local support for restoration activities. Phased restoration of spring and channel habitat is currently underway and plans are presently being developed for the construction of a large spring channel viewing structure. Although future public access is not presently scheduled, public access is a long term goal and is planned to occur following the acquisition of funding and construction of the necessary infrastructure (Amy Sprunger-Allworth, personal communication, 2004).

3.2 Muddy River Aquatic Assemblage

3.2.1 Introduction

The core of all priority conservation targets, the Muddy River Aquatic Assemblage, is comprised of the river from the coalescence of the headwater tributaries to the I-15 Bridge. Therefore, potential for restoration and enhancement of this assemblage exists throughout the entire UMR valley. The target species within this assemblage are all aquatic fish and invertebrates and include the Moapa dace, Moapa speckled dace, Virgin River chub, and Moapa water strider. The presence of Moapa dace within the mainstem of the river below the Warm Springs Bridge is limited due to a preference for warmer temperatures further upstream and the presence of Tilapia within the mainstem.

3.2.2 Impacts

Aside from the introduction of Tilapia, historical changes to the channel and hydraulic habitat present the greatest impacts to this assemblage. Channel incision has resulted in the disconnection of the channel from the floodplain. The combined effects of channel incision and alluvial aquifer drawdown have resulted in vegetative encroachment and crowding adjacent to the channel. Dense stands of palm and tamarisk present throughout the UMR valley limit habitat complexity and diversity and also create the potential for large and destructive fires. The establishment of dense vegetation on the incised channel banks has promoted further channel incision due to the focusing of stream power on the channel bottom rather than distributing the erosive force across a floodplain as would occur in a channel connected with its floodplain. Furthermore, a lack of coarse substrate is evident throughout most of the river. Although fine material has most likely always prevailed within the channel, due to the abundance of fine material throughout the valley and within the Muddy River catchment, the introduction of coarse material from several tributary washes has been altered by the emplacement of flood and silt control dams. These dams are primarily limited to tributaries along the south side of the river within Segments 2 and 3 (the Moapa Indian Reservation and the BLM tract).

3.2.3 Limitations

The primary limitations for recovery and restoration of the Muddy River Aquatic Assemblage are legal protection of the river corridor and instream flows. Without legal protection in the form of conservation easements, conservation agreements, or fee title acquisition, continued degradation or alteration of the UMR conservation targets will likely occur. Due to the appropriation of water within the Muddy River for use in the lower Moapa Valley, there is an indirect guarantee of instream flows for the Muddy River within the UMR valley. However, future changes in water use, distribution, or sale of water rights could potentially result in the diversion of water from the UMR valley thereby decreasing instream flows.

Potential limitations to river channel restoration include the difficulty of reconnecting the river and floodplain due to the high degree of incision and possible re-incision following restoration activities. Re-incision is possible due to the fine-grained nature of the floodplain, and may be unpreventable without the implementation of considerable stabilization efforts or the construction of large grade control structures at strategic locations throughout the UMR valley.

3.2.4 Recommendations

In order to maintain and improve riparian habitat within the UMR valley, and for future restoration efforts to be successful, the long term quantity and quality of water within the river should be legally protected. Protection of the alluvial aquifer and headwater springs from further decline should also be provided. In addition, it may be desirable to obtain water rights for the sole purpose of allowing some rebound of the lowered alluvial aquifer to occur. The recovery of emergent wetland habitat within the UMR valley will require a rise in the level of the alluvial aquifer or the artificial delivery of surface water to former wetland areas. Both protection of river water quality and quantity, as well as protection of the alluvial aquifer will require cooperation and a legal agreement between the USFWS, MVWD, NPC, LVWD, SNWA, private land owners, and other water right owners.

Instream flows should be defined and prescribed for the Muddy River and headwater spring channels. Given the present demands on the water resources within the UMR valley and future developments of current concern, the need for an instream flow regime will likely arise. A definition of instream flow requirements for the UMR valley would aid in the prevention of declining discharge at the headwater springs due to future groundwater extraction from either the alluvial or carbonate aquifers.

Due to the high degree of channel incision, channel reconstruction activities will require large scale construction efforts. An improved connection between the channel and floodplain could be accomplished by either 1) excavating an inset floodplain within the presently incised channel or 2) constructing a large grade control structure in a feasible location (such as the White Narrows) that would maintain the increased channel elevation. Excavating an inset floodplain within the presently incised channel would require the excavation of large quantities of soil. The construction of a large grade control structure would increase the frequency of flooding throughout the UMR valley and would require an analysis of flood prone areas, the protection of structures from increased flood frequency, and the protection of floodplain lands from future development. Depending on funding availability and public consensus, it may be more effective to allocate funding toward legal protection of critical land and water resources or habitat enhancement activities such as invasive species control and enhancement of crucial habitat types. However, channel reconstruction would promote the recovery of geomorphic processes (an improved connection between channel and floodplain and increased frequency of flood, scour, and deposition events) required to maintain native riparian vegetation and a self sustaining riparian ecosystem.

In addition to channel reconstruction efforts, the connection between tributary washes and the mainstem could be improved. Several flood and silt control dams are present in tributary washes along the south side of the UMR valley within Segments 2 and 3. A complete analysis to determine the feasibility of reconnecting tributary washes with the UMR valley and restoring sediment supply to the floodplain should be completed prior to channel restoration activities. In addition, a feasibility study should be completed prior to any significant channel alterations that may result in changes to flood conveyance.

Enhancement of the present channel could be accomplished by the construction of riffles within the present channel. Constructed riffles and drift stations for Moapa dace would raise the elevation of the channel, introduce coarse substrate to the channel, and provide feeding habitat for Moapa dace. However, due to the high degree of channel entrenchment, riffle construction would not improve the connection between the channel and floodplain. Furthermore, the riffles and drift stations could be destroyed or severely altered during a high flow event. The construction of riffles should be seen as a temporary restoration measure.

The eradication of Tilapia from the headwater tributaries and the mainstem of the Muddy River above Warm Springs Road should be implemented. Although Tilapia eradication from the entire mainstem would require a considerable effort, eradication of Tilapia above the Warm Springs Road Bridge and a fish barrier in the vicinity of the bridge would greatly increase habitat for the Moapa dace and other species within the Muddy River Aquatic Assemblage.

Palm and tamarisk removal should be implemented in order to open up the canopy above the channel and promote the development of native overstory vegetation. Current restoration activities being completed by MRREIAC within this assemblage include goat grazing and manual removal of tamarisk and other invasive plant species. At present these activities are primarily limited to the downstream end (Segment 1 and Segment 2) of the UMR valley. In addition, tamarisk removal efforts are currently underway within the Moapa Indian Reservation and plans have been made to implement goat grazing within the Reservation (Ann Schreiber, personal communication 2004). As previously discussed, a fish barrier has been installed by NDOW and the USFWS on the Apcar channel above its confluence with the Muddy River and Tilapia have been eradicated from the Apcar and Warm Springs channels. Additional Tilapia eradication efforts are planned for the Muddy Spring channel (Shawn Goodchild, personal communication, 2003).

3.3 Riparian Woodland

3.3.1 Introduction

This assemblage is most prevalent on the former Warm Springs Ranch property, but other locations exist where enhancement of this assemblage could occur, such as within the MVNWR. Protection of all or portions of the Warm Springs Ranch Property, assuming the willing agreement or sale of all or portions of the property by the current owners, presents the greatest potential opportunity for increasing the coverage of this priority conservation target. Most of the cottonwoods present within the UMR valley are located on this property. Although cottonwoods were likely introduced to the UMR valley during settlement, they are beneficial to neotropical migratory and resident birds (TNC, 2000). Several irrigation ditches in the center of the former Warm Springs Ranch are lined with cottonwood, willow, and tamarisk. The majority of these ditches contain water, and frogs and/or toads were heard along these ditches during field activities (no bullfrogs were heard at the time, although bullfrogs were observed throughout the UMR Valley). The vegetative target species within this assemblage include Fremont cottonwood, Goodding’s willow, and velvet ash. Wildlife target species include the yellow-billed cuckoo, vermillion flycatcher, blue grosbeak, Western tanager, summer tanager, yellow bat, and red bat.

3.3.2 Impacts

The primary impacts to this assemblage are channel incision, a disconnection between channel and floodplain, disconnection from tributary washes due to the emplacement of flood and silt control dams, drawdown of the alluvial aquifer, agricultural activities, and the presence of a palm and tamarisk dominated vegetative community. Channel incision has resulted in a disconnection between the channel and floodplain. The disconnection between the channel and floodplain limits floodplain forest dynamics and nutrient cycling due to limited overbank flows, scour, and deposition throughout the floodplain. In addition, the drawdown of the alluvial aquifer, due to the combined effects of channel incision and groundwater withdrawal, limits suitable moisture conditions for riparian vegetation recruitment. In addition, due to diminished magnitude and frequency of overbank flows and related scour events, there are very few surfaces suitable for the recruitment of cottonwood, willow, and ash. In addition, a palm and tamarisk dominated vegetative community also results in decreased recruitment of cottonwood, willow, and ash woodlands due to the shading by palms and associated thick ground cover of dry fronds and the formation of dense tamarisk thickets with a highly saline ground cover of tamarisk vegetative debris.

3.3.3 Limitations

Space is the primary limitation to the recovery of the Riparian Woodland. Due to the fact that the majority of this assemblage is located within the former Warm Springs Ranch, the potential restoration and enhancement of this assemblage depends on the future use and management status of the property. The drawdown of the alluvial aquifer may limit locations where restoration of this assemblage can occur. In addition, the difficulty of fully restoring the connection between channel and floodplain represents a limitation to the potential restoration of this priority conservation target. However, even partial reconnection of the channel and floodplain will aid in the recovery of the Riparian Woodland. Furthermore, enhancement of the Riparian Woodland assemblage is possible through planting efforts, sufficient irrigation, and invasive species control.

3.3.4 Recommendations

As discussed previously, protection of the alluvial aquifer from further decline is crucial to the maintenance of existing habitat and future recovery efforts and central to the preservation and recovery of the Riparian Woodland. This measure would require cooperation and a formal agreement between USFWS, MVWD, NPC, LVWD, SNWA, private land owners, and other water right owners. Because space is the primary limitation for the recovery of this priority conservation target, conservation easements, agreements, or land acquisition of the former Warm Springs Ranch should be sought, provided mutual and beneficial cooperation with the present property owner. Removal of palms has promoted the recovery of this assemblage throughout the MVNWR where both Riparian Woodland and Shrubland have begun to reestablish. Additional space where this assemblage may be restored is present throughout Segment 1, particularly near the pond and wetland on Hidden Valley Ranch property where sufficient shallow groundwater is present to support cottonwood, ash, and willow. Assuming a mutual and beneficial agreement with the present owners could be accomplished, a conservation agreement, easement, or purchase of the land surrounding the pond and wetland would promote the recovery of the Riparian Woodland, Riparian Shrubland, and Riparian Marsh priority conservation targets.

Although the yellow bat utilizes palm trees for roosting habitat, palms should be removed where restoration activities occur. A series of palm removal activities within the MVNWR has occurred and is scheduled to continue. It is unlikely that palms will be eradicated from the UMR valley due to their desired presence on numerous private properties. Therefore, palm removal within restoration areas will allow for the establishment of woodlands composed of native species while the continued presence on private properties will maintain roosting areas. In addition, roosting and breeding needs of the yellow bat should be further refined. The determination of yellow bat roosting and breeding habitat locations should be completed in order to preserve key palm stands while being able to remove non-utilized stands. Similarly, the establishment of cottonwood galleries should be limited. The establishment of a limited amount of cottonwood will provide additional canopy structure, but should not be the primary vegetative restoration goal. Willow and ash should be the primary vegetative restoration goal for this assemblage.

3.4 Riparian Shrubland

3.4.1 Introduction

The Riparian Shrubland assemblage occurs throughout the UMR valley along the Muddy River, adjacent to springs, and in seasonal and permanent wetlands adjacent to irrigation ditches (TNC, 2000). Vegetative target species within this assemblage include quailbush, arroweed, wolfberry, seep-willow, and narrow-leaved willow. This priority conservation target supports numerous wildlife target species including southwestern willow flycatcher, Bell's vireo, Crissal thrasher, loggerhead shrike, desert pocket mouse, MacNeil's desert sootywing, Southern Melissa blue, Dammer's fatal metalmark, and the Arizona viceroy. Potential for restoration of this priority conservation target exists throughout the UMR valley.

3.4.2 Impacts

Impacts to the Riparian Shrubland are essentially identical to those of the Riparian Woodland and both assemblages require restoration of the primary geomorphic processes necessary (overbank flows, scour, and deposition) to maintain and promote riparian habitat types. The occurrence of overbank flow, scour, and deposition is limited by the degree of channel entrenchment throughout the UMR valley. Drainage of seasonal and permanent wetlands for agricultural purposes has decreased the areal extent of this assemblage throughout the UMR valley. The extent of this assemblage is greater than that of the Riparian Woodland as it exists on steep banks along the length of the river and throughout the valley where sufficient soil moisture is present.

3.4.3 Limitations

Limitations to the Riparian Shrubland are similar to those that affect the recovery of the Riparian Woodland. The primary limitations to restoration of this assemblage are the drawdown of the alluvial aquifer and potential limitations to the restoration of the channel and floodplain connectivity. As previously discussed, channel incision has resulted in vegetative encroachment and the development of a narrow band of both the Riparian Woodland and the Riparian Shrubland (as well as palm and tamarisk) along the steep and incised banks where suitable moisture conditions are present. The development of this assemblage (primarily the willow species) adjacent to seasonal and permanent wetlands as well as irrigation ditches is limited in areas where grazing occurs.

3.4.4 Recommendations

Enhancement of the Riparian Shrubland could be accomplished on presently protected parcels such as the BLM/Perkins tract as well as on private lands. Manual removal and goat grazing of tamarisk and other invasive plants is currently being completed adjacent to the river on private land by MRREIAC. These efforts are primarily focused on the downstream end of the UMR valley between the Hidden Valley Dairy and Highway 168 crossing. Tamarisk removal efforts currently underway on the Moapa Indian Reservation should also promote the recovery of this assemblage. Basic studies should be funded and completed to establish the success and determine the means of greatest impact on the restoration of Riparian Shrubland due to goat grazing and manual removal of invasive plant species.

Restoration of this assemblage at greater distances from the river will only be feasible if suitable soil moisture conditions currently exist or can be improved. The former Warm Springs Ranch contains the largest areas where suitable moisture conditions are present. The establishment of suitable moisture conditions will require raising the elevation of the channel and/or excavation of steep channel banks to provide appropriate depths to water. Further loss of Riparian Shrubland should be prevented by maintaining or improving the current level of the alluvial aquifer. This measure would require cooperation and a legal agreement between USFWS, MVWD, NPC, LVWD, SNWA, private land owners, and other water rights owners. The reconnection of tributary washes with the UMR valley and the subsequent restoration of sediment supply to the floodplain would improve conditions for this assemblage where suitable soil moisture conditions exist or can be improved by irrigation or, on a longer time scale, partial recovery of the alluvial aquifer.

3.5 Riparian Marsh

3.5.1 Introduction

The presence of the Riparian Marsh assemblage primarily is limited to the headwater area of the UMR valley along headwater tributaries and spring channels and within the former Warm Springs Ranch. An additional spring-fed marsh, located on Hidden Valley Dairy property, provides a superb example of how more extensive marshlands were likely to have appeared throughout the UMR valley. The restoration of this assemblage could provide the enhancement and/or recovery of amphibian populations including the Relic Leopard frog, Pacific tree frog, red-spotted toad, southwestern toad, and Woodhouse toad as well as wading and wetland bird populations including the green heron, Virginia rail, sora, marsh wren, common snipe, and common yellow-throat.

3.5.2 Impacts

The primary impact to the Riparian Marsh is the historical decline in the alluvial aquifer. Groundwater extraction from the upper end of the UMR valley has resulted in a gradual drying of the UMR valley. Drainage activities and soil and vegetative mat compaction due to grazing have significantly decreased the amount of area with shallow and discharging groundwater and emergent wetlands. In addition, channel entrenchment promotes increased drainage of shallow groundwater from the floodplain towards the river. Additional impacts to the Riparian Marsh include the disconnection of the channel and floodplain which limits potential scour throughout the floodplain and subsequent revitalization and creation of wetlands.

3.5.3 Limitations

Because the majority of the Riparian Marsh assemblage occurs on the former Warm Springs Ranch, the potential restoration and enhancement of this assemblage depends on the future status of the former ranch. Drawdown of the alluvial aquifer is the most significant limitation to the restoration of this assemblage. Formerly extensive wetlands were supported by groundwater discharging at the surface. Drainage activities, drainage due to channel entrenchment, and drawdown of the alluvial aquifer have decreased the extent of emergent wetland within the UMR valley.

3.5.4 Recommendations

Recovery and enhancement of this assemblage is limited to locations where suitable hydrologic conditions are present. The largest and most promising areas for the recovery and enhancement of this assemblage are located at the pond area on Hidden Valley Dairy property and within the former Warm Springs Ranch. Therefore, conservation agreements, easements, or land acquisition within the former Warm Springs Ranch and Hidden Valley Dairy are essential to the preservation of this priority conservation target. Further declines in the alluvial aquifer should be prevented and will require cooperation and a legal agreement between USFWS, MVWD, NPC, LVWD, SNWA, private land owners, and other water right owners. In addition, the reconnection of tributary washes with the UMR valley and the subsequent restoration of sediment supply and flood waters to the floodplain would improve conditions for this assemblage.

3.6 Mesquite Bosque

3.6.1 Introduction

The Mesquite Bosque assemblage occurs throughout the UMR valley in upland areas, on stream banks, and along ephemeral washes. The primary vegetative components of this assemblage are the honey and screwbean mesquite. Wildlife target species include phainopepla, vermillion flycatcher, Crissal thrasher, Western great purple hairstreak, Leda hairstreak, and Western Palmer’s metalmark. The most extensive example of this assemblage is present on the BLM/Perkins tract where the cessation of agricultural activities has promoted the return of the bosque. Additional bosque is established throughout the drier portions of the former Warm Springs Ranch.

3.6.2 Impacts

The disconnection of the channel and floodplain due to channel incision is the primary impact to this assemblage. Both the disconnection of the channel and floodplain as well as the construction of flood and silt control dams on tributary washes has eliminated the deposition of flood debris essential for the creation of mesquite recruitment sites. Invasive plant species including Russian thistle and Russian knapweed have become established throughout the BLM/Perkins tract. An additional present and future threat to this priority conservation target is imposed by housing development, primarily on the north side of the BLM/Perkins tract and adjacent to the northern end of the former Warm Springs Ranch.

3.6.3 Limitations

Maintenance of existing and future enhancement of bosque within the former Warm Springs Ranch depends on the future use and management status of the property. In addition, the continued development on the north side of the river within Segment 3 may reduce the future extent of the bosque.

3.6.4 Recommendations

The acquisition of the former Perkins Ranch by the BLM represents a crucial step in the preservation of the Mesquite Bosque as well as riparian habitat. Appropriate public use of the BLM/Perkins tract would provide an opportunity for public education regarding the wildlife value of the Mesquite Bosque. Further protection of this priority conservation target could be provided by conservation agreements, easements, or land acquisition within the former Warm Springs Ranch, assuming an agreement, beneficial to the present owners, could be made. Similarly, the acquisition of undeveloped land along the northern side of the BLM/Perkins tract would preserve floodplain lands and space for bosque recovery, and provide space for future floodplain restoration and enhancement activities.

4.0 Assessment of Restoration Potential for Individual River Segments

The methods used to assess the potential for restoration and enhancement activities within each river segment are described in Section 4.1. Assessment criteria were developed in order to assess river channel and floodplain restoration potential as well as habitat restoration potential. The assessment criteria were defined based on conditions specific to both the Muddy River and the target assemblages and provide a framework on which to score each river segment for overall restoration potential. These criteria are defined in Section 4.2. The scoring of the individual river segments, based on the assessment criteria, allows further refinement of the limitations to restoration as well as restoration recommendations. The assessment of restoration potential within each river segment is presented in Section 4.3.

The assessment criteria and scoring system for the assessment of the overall restoration potential of individual river segments is based on nine key management activities or riverine characteristics that are necessary for preservation, maintenance, and recovery of the key conservation targets within the UMR: (1) legal protection of land and water within the 100 year floodplain and/or tracts of critical habitat; (2) implementation of instream flow prescriptions for both spring channels as well as the river that will guarantee future in-channel habitat; (3) protection of river water quality; (4) protection of the 100 year floodplain from urban and industrial development in order to allow the river to establish a new state of equilibrium in response to historical alteration; (5) protection of the Moapa dace population from invasive aquatic species (Tilapia and crayfish); (6) expansion of Moapa dace habitat; (7) restoration or enhancement of the connectivity between the river and floodplain; (8) implementation of land management practices that minimize or eliminate the impacts of grazing on critical habitat; (9) recovery of native vegetation and wildlife species through a combination of activities such as invasive species control/removal and habitat enhancement or restoration.

4.1 Methods for the Assessment of Restoration Potential

4.1.1 Geomorphic River Segments

The nine UMR segments were assessed for river and habitat restoration or enhancement potential. As previously described, the river was divided into geomorphic segments based on such factors as topography, geology, channel planform, channel geometry, and floodplain characteristics. For all segments, historic impacts have permanently altered the hydrologic and morphologic condition of the river. The most significant historic impact is the entrenchment of the river. Therefore, the resulting permanent condition is also considered in the evaluation.

4.1.2 Aerial Photography Evaluation

Georeferenced aerial photography from the years 1938 and 2001 and GIS were used to determine river and floodplain characteristics, existing conditions, associated landscape features in the evaluation area, and restoration potential of each river segment. In addition, the aerial photographs were used to delineate the geomorphic river segments, assess riparian vegetation condition, and define floodplain characteristics. The 2001 series of aerial photography was obtained from Clark County while the 1938 series was obtained through the National Archives and Records Administration (NARA).

4.1.3 Restoration Potential Scoring

Upper Muddy River Channel and Habitat Restoration Potential Evaluation Sheets were designed to include criteria necessary for the determination of riparian habitat restoration potential. In addition, the evaluation sheets were tailored to specific conditions present within the UMR system. For purposes of evaluating restoration potential, the springs and spring channels throughout the UMR have been included in the assessment of the river segment to which each spring or channel is connected. Therefore, the Warm Springs, Apcar, and Muddy Spring are associated with the assessment of Segment 5 while Segment 7 includes the North Fork, South Fork (Baldwin Spring) and Cardy Lamb Spring.

An evaluation sheet was completed for each river segment in order to determine the overall potential for river channel and habitat restoration within each segment. Completed evaluation sheets are provided in Appendix C. Site information at the top of the sheet includes the river segment length, channel length within the segment, and the upstream and downstream ends of the river segment. The bold numbers on the evaluation sheet indicate the individual criteria. The score for each evaluation criteria is highlighted by a box.

Information necessary for the assessment of each river segment was obtained during site visits throughout the completion of tasks associated with each deliverable. Thus, the assessment was completed using an iterative approach allowing for field verification of the assessment and continuous refining of the assessment. Aerial photographs, topographic maps, and GIS were used as aids during field assessment activities.

4.2 Definitions for Assessment Criteria

Criteria were developed in order create a scoring system for the assessment of the overall restoration potential of individual river segments. The scoring system was used to evaluate the potential for **(1) river channel and floodplain restoration** based on river and floodplain attributes and **(2) habitat restoration** based on both physical and biological attributes. The cumulative score of the two components provides an overall assessment of restoration potential within each river segment. Each criterion used in restoration potential ranking is described below. The criteria and respective levels of scoring used during the assessment process are shown in Table 2. The scoring results for each criterion and individual river segment are shown in Table 3. Details of the scoring process completed for each segment as well as considerations unique to each segment are presented in Section 4.3.

4.2.1 Floodplain and River Corridor Attributes

In order to provide a general description of floodplain width, the **(1)** *Width of 100 year floodplain* within each segment is provided. The minimum, maximum, and average measured floodplain width within each segment is presented. In addition, the **(2)** *Relative width of 100 year floodplain* is provided as a qualitative measure of both the potential for flood attenuation and habitat preservation as well as the relative floodplain width compared to other segments. In general, a greater floodplain width will result in increased flood attenuation and habitat preservation potential. Floodplain width was determined using aerial photographs and topographic maps. The specific scoring method used in determining the relative width of 100 year floodplain, measured in feet, is as follows: >3,000 = 5; 2,500 to 3,000 = 4; 1,500 to 2,500 = 3; 500 to 1,500 = 2; and 0 to 500 = 1.

(3) *Entrenchment* is a measure of the extent that the river channel has down cut or incised. All of the segments located on the mainstem of the Muddy River are significantly entrenched to the degree that major earthwork projects would be required to restore a more functional connection between the river and its floodplain. The calculation of a quantitative value of entrenchment is limited to river segments where channel cross section surveys and HEC-RAS modeling was completed. Therefore, actual values of entrenchment are only presented on the evaluation sheets for segments 1, 3, 4, 5, 7, and 9. Entrenchment for these segments was determined by subtracting the difference between the top of bank elevation and the elevation of the water surface observed during channel cross section surveys. The numbers generated from this calculation are presented as entrenchment values. The entrenchment values, measured in feet, were used to determine the following scores: 0 to 5 = 5; 5.1 to 7.5 = 4; 7.6 to 10 = 3; 10.1 to 12.5 = 2; >12.5 = 1. A relative degree of entrenchment is presented for Segment 2 where channel cross section surveys and HEC-RAS modeling was not performed. Relative entrenchment is based on field observations and comparison to other segments.

(4) *Encroachments into the channel* include road and railroad crossings, diversion structures, and water and gas pipelines. Permanent structures act as impediments to river channel and habitat restoration and usually fragment aquatic habitats. Compared to most western rivers, the Muddy River has very few channel encroachments even when the small size of the river is taken into account. In fact, the majority of the channel encroachments are upstream or downstream endpoints of the segments. Therefore, channel encroachments such as the Reid Gardner railroad bridge and the Warm Springs Road Bridge are counted as encroachments in both segments upstream and downstream from the encroachment. Scoring is based on a qualitative assessment of both the type of encroachment and the number of encroachments in an individual segment. For example, Segment 1 has extensive encroachments (score of 1) both because of the number of encroachments as well as the permanency of most of the encroachments such as interstate overpasses, a highway bridge, two railroad crossings, and the Hidden Valley Road crossing. However, Segment 5 has essentially no channel encroachments (score of 5), except for a minor in-channel crossing used for ranching activities that would have no permanency in the event that restoration activities were undertaken.

(5) *Encroachments into the floodplain or riparian corridor* include housing development, roads, railroads, flood control structures, wastewater lagoons, settling ponds, agricultural activities, and irrigation ditches. The degree of encroachment is also a measure of habitat fragmentation as land conversion and agricultural, residential, and industrial development results in the fragmentation of the riparian corridor. Similar to the scoring for channel encroachments, scoring for floodplain encroachments is based on a qualitative assessment of the type, permanency, and number of encroachments into the floodplain. The presence of settling ponds, wastewater lagoons, and heavily utilized agricultural fields and access roads would be considered extensive (score of 1). In comparison, where the presence of floodplain encroachments is limited to irrigation ditches, the degree of encroachment is considered few (score of 4).

(6) *Floodplain reconnection potential* accounts for the amount of infrastructure, residential property, and commercial property on the floodplain, and potential cost to improve the connection between the river and floodplain. While the purpose of the encroachment criteria above is to define the relative quantity and type of obstacles to reconnection present in the channel and floodplain, the purpose of the *Floodplain reconnection potential* criterion is to provide the degree of reconnection difficulty relative to other segments. Due to the high degree of incision, all segments score generally low for this criterion. As previously discussed, an improvement in connection between the river and floodplain would require significant earth moving efforts or large scale construction activities within all segments. However, this criterion allows the consideration of additional factors such as the availability of space in which to complete such channel reconstruction activities and the overall pattern of land ownership within the segment. Therefore, if the degree of incision is high, but the majority of the floodplain is public land, such as Segment 3, the segment would score higher than a segment with an equal degree of incision, but with significant residential or commercial development.

4.2.2 Habitat Attributes

(7) The *Number of assemblages within segment* provides a partial measure of the potential benefit that may be realized following restoration or enhancement activities. However, the remaining habitat attribute criteria account for the physical and biological requirements necessary to improve habitat within the UMR valley. The scores associated with the number of assemblages are as follows: six assemblages = 5; five assemblages = 4; four assemblages = 3; three assemblages = 2; two or less assemblages = 1.

(8) *Connection to landscape features* includes both natural and human made features and habitats such as wetlands, seeps and springs, irrigation ditches, as well as upland habitat types such as hillsides and desert washes. Natural landscape features and the complex arrangement of multiple habitat types often enrich the biodiversity of a given area and were considered in the assessment process because they add to the overall complexity and diversity of the river segment. The connection between the floodplain within each segment and the floodplain upstream and downstream of the segment is an additional component of this criterion. This connection is an important component because of the value added by the presence of a continuous riparian corridor between river segments as well as the increased potential for flood attenuation, nutrient cycling, and wildlife movement throughout the floodplain. Roads, bridges, and railroads that span the entire floodplain (such as the Reid Gardner railroad bridge and associated track) are the greatest influence on upstream and downstream floodplain connection. The scores, based on the number of landscape features with each segment, are as follows: more than eight = 5, seven to eight = 4, five to six = 3, four = 2, three or less = 1.

(9) The criterion *Potential for habitat recovery/expansion by assemblage* allows the scoring of the recovery potential of each target assemblage within an individual river segment. In addition to ranking the potential for recovery and/or expansion of each assemblage within a river segment, this criterion also accounts for the potential recovery and/or expansion of multiple assemblages within a single river segment. The assessment of recovery potential primarily is based on the presence or absence of an individual assemblage within the river segment and the amount of land presently available and suitable for expansion of a given assemblage. In order to assess the potential for habitat recovery and expansion, it has been assumed that the present and future land ownership and use would not preclude the expansion of habitat. In addition, physical conditions and requirements of individual assemblages must be presently existent for the recovery/expansion of an assemblage to occur. Therefore, the purpose of this criterion is to provide the minimum potential recovery and expansion of the individual assemblages.

(10) *Potential to increase relative habitat diversity* is constrained by the physical and biological characteristics of a given river segment. Therefore, this criterion combines features of river and floodplain attributes as well as habitat attributes. The purpose of this criterion is to assess the physical and biological characteristics most central to the UMR system that are necessary in order to increase habitat diversity within individual river segments. For example, important physical aspects that were considered while scoring this criterion include depth to groundwater and the potential for flooding, scour, deposition, and river migration to occur. The assessment of depth to groundwater is based on the presence of standing water or phreatophytic vegetation that was observed during field activities. In general, groundwater is nearest to the ground surface in the upper end of the UMR valley. However, one exception is the presence of the spring and marsh located within Segment 1. As previously discussed, the degree of entrenchment limits the frequency of overbank flooding and river migration in all segments. Therefore, these physical aspects were considered with the recognition that fluvial processes are considerably altered. For purposes of assessment, it is recognized that most scour and deposition occurs within the channel and the creation of fluvial surfaces, necessary for riparian vegetation recruitment, is significantly limited due to entrenchment.

In order to assess the potential to increase relative habitat diversity, it has been assumed that changes in land use and invasive species control are the only habitat enhancement measures required to promote an increase in relative habitat diversity. Although river channel reconstruction is a restoration option, the limitation of enhancement activities to land use changes and invasive species control allows for the assessment of the minimum potential increase in relative habitat diversity. This assumption is required due to the physical constraints on large scale channel reconstruction activities resulting from the high degree of entrenchment in all river segments and the degree to which habitat diversity may increase depending on the level of restoration effort and funds expended.

Biological aspects considered include the previously scored number of assemblages within the segment and connection to landscape features. In addition, the present level (low or high) of apparent habitat diversity within a river segment is included as a component of this criterion. Therefore, a segment presently exhibiting a low degree of apparent habitat diversity that contains the physical components necessary to promote the development of habitat diversity, assuming changes in land management or invasive species control activities were to occur (such as Segment 2), received a higher score for this criterion than a segment that already has a relatively high degree of habitat diversity (such as Segment 9) and subsequently has a lower overall potential to increase habitat diversity. Furthermore, a segment containing multiple assemblages, a complex arrangement of habitat types, areas with groundwater near or at the surface, and available space for flooding and river migration (such as Segment 1), would receive a very high score (score of 5).

4.3 Assessment of Restoration Potential

The purpose of this section is to assess restoration potential within each river segment. The results of river channel and habitat restoration potential scoring for all river segments are presented in Table 3. The scoring ranges utilized to define degrees of restoration potential (very low through very high) are shown in Table 4. The restoration potential in terms of river and floodplain, habitat, and total restoration potential for each mainstem river segment is shown in Table 5. The primary impacts to the floodplain, channel, and habitat within each segment are discussed and restoration and enhancement potential is summarized. Details specific to the scoring of each segment are presented in order to provide a summary of the process used in scoring each segment as well as scoring considerations that are unique to each segment.

4.3.1 Segment 1

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 1 are 9 (low), 36 (high), and 45 (moderate), respectively. Segment 1 contains the narrowest 100 year floodplain, exhibits the greatest degree of entrenchment compared to all other river segments, and has several highly permanent encroachments to the floodplain and channel including the I-15 overpasses, Highway 168 Bridge, two railroad crossings, Hidden Valley Road, Hidden Valley wastewater lagoon, and the NPC settling ponds. In addition, most of the upper half of the segment has been heavily modified and developed. Although the lower half of this segment contains undeveloped floodplain, it is also the narrowest section of floodplain within the UMR valley. The Reid Gardner railroad crossing creates a disconnection between the floodplains within Segment 1 and Segment 2 while the I-15 overpass separates the floodplain within Segment 1 and the floodplain downstream from Segment 1. Overall, Segment 1 scored low for floodplain reconnection potential primarily due to the floodplain encroachments within the upper half of the segment.

However, the channel top width within this segment is greatest resulting in an increased overall cross sectional area, the presence of minor inset floodplain features, and more gently sloping banks. The wider channel, increased cross sectional area, and presence of minor inset floodplain features results in higher potential for the recovery and expansion of both the Riparian Woodland and Riparian Shrubland assemblages within the existing channel assuming that tamarisk removal activities currently underway are continued in the future. Segment 1 received the fourth highest score for habitat restoration potential due to the number of assemblages, connection to landscape features, and high potential for habitat recovery/expansion by assemblage. The presence of the large spring and marsh area at the lower end of this segment increases the ecological value as well as the potential for habitat recovery/expansion within the segment.

4.3.2 Segment 2

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 2 are 13 (moderate), 23 (low), and 36 (low), respectively. Segment 2 exhibits a medium relative floodplain width and exhibits a lower degree of entrenchment than that of other river segments. The Reid Gardner Railroad Bridge creates a disconnection between floodplains within Segment 2 and Segment 1. Extensive floodplain encroachments, primarily agricultural fields, and a low number of assemblages present within the segment result in a low score for total restoration potential. However, due to the low degree of entrenchment, a wide floodplain, and development within the floodplain being limited to agricultural activity, this segment has a moderate potential for the recovery and/or expansion of both Riparian Woodland and Riparian Shrubland assemblages. Furthermore, this potential for recovery and expansion of the two assemblages would require little more than an increase in the width of riparian corridor within the segment.

4.3.3 Segment 3

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 3 are 17 (high), 31 (moderate), and 48 (high), respectively. The relative floodplain width within this segment is rated at medium and few encroachments into the channel or floodplain are present. The primary encroachment to the floodplain is the presence of continuing housing development at the upstream end of the segment at the northern edge of the 100 year floodplain. The floodplain within Segment 3 is partially disconnected from the upstream floodplain by the presence of the Warm Springs Road and Bridge. The floodplain within Segment 3 is connected to the downstream floodplain of Segment 2 through the White Narrows.

HEC-RAS modeling results for Segment 3 indicate that the 10 year flood (1,622 cfs) reaches the present top of bank (due to a lower channel capacity compared to other segments). This calculation can only be confirmed for the section of channel where cross section surveys were completed. However, additional field observations support the assumption that similar channel dimensions are present throughout the remainder of the segment. The presence of more frequent overbank flows, a low number of encroachments to the channel and floodplain, and the large percentage of public land within the segment, results in an increased potential for floodplain reconnection. Regardless, the calculated entrenchment (10 feet) within the segment remains as a significant challenge to the reconnection of channel and floodplain.

The connection of this segment with numerous landscape features including relic channels, upland areas, washes, and hillsides supports the potential benefits of future habitat enhancement activities. Habitat enhancement activities such as invasive plant control could be readily completed within this segment due to the presence of a large percentage of public land. In addition, there is a very high potential for the recovery and expansion of the Riparian Woodland, Riparian Shrubland, and Mesquite Bosque assemblages within Segment 2.

4.3.4 Segment 4

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 4 are 17 (high), 42 (very high), and 59 (very high), respectively. The relative floodplain width is very high and there are relatively few encroachments to the channel and floodplain. The primary encroachments to the channel are the Warm Springs Road Bridge and the NPC diversion structure. Floodplain encroachment is limited to Warm Springs Road and irrigation ditches. The floodplain within Segment 4 is partially disconnected from the downstream floodplain by Warm Springs Road. However, the connection between the floodplain within Segment 4 and the floodplain within all upstream segments is largely uninterrupted.

All assemblages are present within this segment and numerous landscape features including springs, a wide riparian forest, complex topography, upland areas, spring channel tributaries, washes, and hillsides are in connection with the river segment. Furthermore, all assemblages, except Riparian Marsh, were ranked very high based on the potential for habitat recovery/expansion by assemblage.

4.3.5 Segments 5 and 6

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 5 are 19 (high), 43 (very high), and 62 (very high), respectively. Restoration potential for Segments 5 and 6 have been combined in order to assess the Warms Springs, Apcar Spring, and Muddy Spring areas in conjunction with the river mainstem in this vicinity of the UMR valley. Segment 5 and Segment 4 are similar in most river and habitat attributes and therefore received similar scores for total restoration potential. The most significant features of this segment are the tributary springs and associated channels including the Warm Springs, Apcar Spring, and Muddy Spring which increase the restoration potential due to present or potential habitat for Moapa dace and other thermal endemic species. The relative floodplain width is very high and there are essentially no encroachments to either the channel or floodplain. In addition, there is an uninterrupted connection between the floodplain within Segment 5 and the floodplain upstream and downstream from Segment 5.

All target assemblages are present within Segments 5 and 6 and, with the exception of the Riparian Marsh assemblage, received a very high ranking for habitat recovery/expansion potential. The potential for Riparian Marsh habitat recovery/expansion was ranked as high, compared to the medium ranking applied for the same assemblage in Segment 4, due to the observed presence of higher soil moisture contents and the potential for emergent wetland habitat type recovery within Segment 5.

4.3.6 Segments 7 and 8

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 7 are 19 (high), 44 (very high), and 63 (very high), respectively. Restoration potential for Segments 7 and 8 have been combined in order to assess the South Fork (Baldwin Spring), Cardy Lamb Spring, and the North Fork. River channel and floodplain restoration potential, habitat restoration potential, and total restoration potential scoring for the area surrounding Segments 4, 5, 6, 7, and 8 are quite similar due, in part, to their close proximity and location within the upper end of the valley where the overall conditions and potential for restoration are greatest. More importantly, the similar scoring underscores the importance of the relatively large area at the upper end of the Muddy River valley that includes these segments.

Relatively few channel encroachments, a very wide floodplain, and moderate entrenchment results in the highest scoring for river channel and floodplain restoration. The scoring for river channel and floodplain restoration is equivalent in both Segments 5 and 7. The primary floodplain encroachment within Segment 7 is the presence of housing development at the upstream end of the segment along the north edge of the floodplain. However, the majority of this development currently is concentrated adjacent to Highway 168 and creates a relatively small amount of additional fragmentation when compared to encroachments in other river segments.

Habitat attribute scoring within Segments 7 and 8 exhibits the overall importance of this area for habitat preservation and recovery. All target assemblages are located within this area, the presence of numerous landscape features create significant potential for the presence of complex and diverse habitat, and all assemblages received high scorings for habitat recovery/expansion potential. Segment 7 is one of only two segments (the other segment being Segment 1) to receive a scoring of very high potential to increase relative habitat diversity, due to high scoring in all habitat attribute criteria.

4.3.7 Segment 9

The scores for river channel and floodplain restoration potential, habitat restoration potential, and total restoration potential within Segment 9 are 18 (high), 22 (low), and 40 (moderate), respectively. The relatively high scoring for river channel and floodplain restoration potential largely is a result of the lower degree of entrenchment and limited channel and floodplain encroachments. However channel cross section surveys, and therefore measurement of entrenchment, was completed further upstream within the mouth of Arrow Canyon. It is important to note that entrenchment conditions are much greater in the channel just upstream from the headwaters of the North Fork. Collapsing banks eight to ten feet high were observed in this vicinity.

The floodplain width decreases toward the upper end of the valley within this segment. Channel and floodplain encroachments include the two dry channel crossings associated with the upper valley portions of Warm Springs Road, a minor road crossing, and an above ground water pipeline that spans the dry channel. As previously discussed, this segment is an ephemeral channel that begins above the headwater springs on the North Fork and extends upstream into the mouth of Arrow Canyon. Therefore, this segment exhibits conditions unlike any of the other segments and transitions into upland habitat types. Furthermore, habitat becomes less disturbed beyond the furthest upstream Warm Springs Road crossing and toward the mouth of Arrow Canyon. Although the river channel and floodplain restoration potential is high, this segment is not suggested as a priority for such activities due to the ephemeral nature of the channel as well as the lower degree of entrenchment within the upper half of the segment.

The ephemeral nature of the channel within Segment 9 excludes the presence of the majority of the target assemblages. Therefore, Mesquite Bosque is the only assemblage with significant potential for habitat recovery and expansion. Due to the limited number of assemblages and the low relative disturbance of upland habitat types, this segment was scored as low for the potential to increase relative habitat diversity.

4.4 Restoration Potential Conclusions

As shown in Table 3, the river segments that received the highest scores for river channel and habitat restoration potential are located at the upstream end of the UMR valley. Scoring of restoration potential for Segments 4, 5, 6, 7, and 8 resulted in similar results for river and floodplain, habitat, and total restoration potential. These segments received scores of high, very high, and very high for river and floodplain, habitat, and total restoration potential, respectively (Table 5). As shown in Table 3, the high scoring of the river segments within the upstream end of the UMR valley largely is due to the presence of multiple assemblages, a high degree of connection to multiple landscape features (primarily springs and spring channel tributaries), and high potential for the recovery/expansion of multiple assemblages. River and floodplain attributes as well as habitat attributes that resulted in the highest restoration potential within the upstream end of the UMR valley can be ascribed to a lower degree of habitat disturbance and river and floodplain encroachments. Although habitat disturbance and fragmentation is readily apparent within the upstream end of the UMR valley, the presence of shallow groundwater, springs, spring channels, and large parcels of land, results in a high potential for ecosystem recovery. The results of this assessment underscore the importance of the uppermost portion of the UMR valley relative to the preservation of this valuable resource. Indeed, if the ecological integrity of the UMR valley is going to be preserved and improved, legal protection and restoration activities must occur at the headwaters.

The fact that Segments 4, 5, 6, 7, and 8 received the highest scores for restoration potential should not distract from the importance of and need for floodplain and habitat protection in the remaining segments. Segment 1 received scores of low, high, and moderate for river and floodplain, habitat, and total restoration potential, respectively. Although Segment 1 received a low score for river and floodplain restoration, primarily due to a narrow floodplain and numerous encroachments to the channel and floodplain, a high potential for habitat restoration exists within this segment due to the presence of a wider channel with minor inset floodplain surfaces. Continued invasive vegetation removal complimented by revegetation efforts will aid in the realization of the high potential for habitat restoration. In addition, the presence of a spring-fed marsh and pond at the lower end of the segment increases the ecological value within Segment 1.

Although Segment 2 received respective scores of moderate, low, and low for river and floodplain, habitat, and total restoration potential, significant opportunity exists for river channel and habitat improvement within this segment. Continued tamarisk removal and the establishment of an increased buffer width between the agricultural fields and the channel would improve riparian corridor conditions and support mesquite, cottonwood, and willow. Furthermore, the development of a working relationship with the Moapa Indian Reservation and Tribal Council is essential to future implementation of river and habitat restoration activities.

Segment 3 received scores of high, moderate, and high for river and floodplain, habitat, and total restoration potential. High scoring for river and floodplain attributes within Segment 3 primarily is due to the low degree of river and floodplain encroachments. In addition, the large percentage of publicly owned land within the segment increases the potential value of the segment and increases the overall potential for restoration. The percentage of public land within this segment would allow for large scale invasive vegetation removal. In addition, small scale channel reconstruction and restoration demonstration sites could be implemented within this segment.

Segment 9 received respective scores of high, low, and moderate for river and floodplain, habitat, and total restoration potential. The ephemeral nature of this segment presents physical and biological conditions unlike any of the other segments and requires a different interpretation of restoration potential scoring. For example, the high scoring of river and floodplain restoration potential largely is due to a low degree of entrenchment, relatively minor channel and floodplain encroachments, and a subsequently high potential for floodplain reconnection. In fact, entrenchment is sufficiently low throughout most of this segment that large scale channel restoration is not recommended. Although entrenchment is greater in the vicinity of the most downstream Warm Springs Road crossing, large scale channel restoration is not recommended considering the relative importance of restoration needs within other segments throughout the UMR valley. Invasive vegetation species removal and the protection of the alluvial aquifer from further decline are the most important conservation measures that could be implemented within this segment.

5.0 Recommendations for Recovery of the Upper Muddy River Riparian Ecosystem

Following the assessment of restoration potential presented above, it is necessary to determine the actions required to begin the recovery and restoration of the UMR riparian ecosystem. The methods used to determine a recommended conservation corridor are presented in Sections 5.1 and 5.2. A description of the recommended conservation corridor is presented in Section 5.3. The recommended conservation corridor has been provided as a conceptual model for future land use and management within the UMR valley. The purpose of defining the conservation corridor is to exhibit the lands within the UMR valley that should be protected for the purpose of riparian ecosystem recovery and preservation.

Protection of lands within the recommended conservation corridor could be provided through a combination of land acquisition, conservation easements, and conservation agreements. The recommended conservation corridor defines the boundaries within which the implementation of restoration actions should occur and also relates the restoration recommendations (presented in Section 5.4) to the landscape within and surrounding the UMR valley. Habitat conservation and restoration recommendations presented in Section 5.4 are based on the recovery of individual target assemblages that were assessed and presented in Section 3.0. In addition, low, medium, and high level alternatives for UMR habitat conservation and restoration are presented for individual river segments in Section 5.4. A graphical example and conceptual model for the implementation of the habitat conservation and restoration recommendations is presented in Section 5.5.

5.1 Recommended Conservation Corridor

The recommended conservation corridor was created in ArcGIS using aerial photography and GIS coverage of land ownership and the 100 year floodplain. Land ownership, land use, topography, connection of the river corridor with uplands, as well as unique features and areas of critical habitat were evaluated during the development of the recommended conservation corridor. Where possible, the 100 year floodplain was used to define the edge of the conservation corridor as development within the 100 year floodplain will likely lead to property damage or the construction of flood control structures intended to prevent flood damage. The construction of flood control structures for the purpose of facilitating development within the 100 year floodplain is counterproductive to the restoration of the UMR desert riparian ecosystem.

Although a more expansive and preferable corridor for riparian ecosystem recovery could be conceived that would encompass the entire 100 year floodplain and extend further into surrounding public lands, an attempt has been made to define the recommended conservation corridor within the physical constraints that exist presently throughout the UMR valley. Please note that this recommended corridor is intended as a guideline and it is recognized that future changes in land use and ownership status as well as the prioritization of conservation and restoration efforts will determine the mosaic of land status within the UMR valley.

In general, the recommended corridor describes the minimum space necessary for riparian ecosystem preservation and restoration within the UMR valley. However, in many locations, the corridor width is limited by industrial, residential, or agricultural development. The determination of minimum space is based on the need for a dynamic geomorphic setting and available space for the river to flood and migrate throughout the 100 year floodplain. Hydraulic modeling, described below, was used to provide an estimate of the minimum corridor width within each river segment.

5.2 Determination of Conservation Corridor Width and Hydraulic Modeling

The recommended conservation corridor is based primarily on the need to preserve lands adjacent to the channel and connections between the riparian area and uplands. In addition, the corridor is intended to provide sufficient space for the reconnection of the channel and floodplain which is necessary to restore the fluvial processes (flooding, scour, and deposition) required for the recovery and maintenance of the riparian ecosystem. Because the restoration of fluvial processes and the reconnection of the channel and floodplain will result in increased flood elevations, the corridor is also intended to provide space for the increased flood elevations. Hydraulic modeling was performed to estimate the elevation of post restoration flood levels. Please note, that these hydraulic modeling efforts are intended to provide an estimate of flood elevations following restoration, primarily for the purpose of determining a corridor width sufficient for containing the modeled floods and restoring fluvial processes necessary for desert riparian ecosystem recovery.

The HEC-RAS models for Segments 1, 3, 4, 5, and 7 were modified for the purpose of proposing a recommended conservation corridor of sufficient width to accommodate large magnitude flood events (such as the 100 year recurrence interval floods). Due to the fact that the present channel conveys the 100 year recurrence interval flood (based on HEC-RAS modeling), the elevation of the channel within each model was increased in order to reconnect the channel and floodplain. In order to reconnect the channel and floodplain, the channel elevation was increased until the five or ten year recurrence interval floods reached the elevation of the valley floor. Please note that the intent of this exercise is to illustrate the approximate space needed for the restoration of fluvial processes necessary for riparian ecosystem restoration and maintenance. More detailed channel cross section measurements, hydraulic modeling, and channel design/dimensions are required for the accurate determination of flood elevation. Furthermore, accurate channel design for restored conditions will require the determination of lands available for channel and floodplain restoration.

The results of increasing the elevation of the channel for the purpose of restoring the connection between the channel and floodplain are shown in Table 6. The range in widths of the 100 year flood surface for each hydraulic model and river segment prior to and after increasing the channel elevation (and subsequently increasing the 100 year flood elevation) are shown for comparison in Table 6. As expected, the maximum width of the 100 year flood surface within each model increases following an increase in channel elevation and the reconnection of the channel and floodplain. Comparison of the maximum width of the 100 year flood surface following the reconnection of the channel and floodplain with the maximum width of the recommended conservation corridor supports the proposed width of the corridor and underscores the need for sufficient space within the 100 year floodplain to allow for riparian ecosystem recovery.

As shown in Table 6, the results of this exercise indicate that most of the 100 year floodplain would be required for complete restoration of fluvial processes within the UMR. Physical constraints, in the form of present development and land ownership, prevent such a significant change in land use within the UMR valley. However, it would be possible to strike a balance between present use and future recovery of the riparian ecosystem provided sufficient space is set aside in the near future for the purpose of ecosystem preservation and recovery. Therefore, the recommended conservation corridor represents an attempt to define the space necessary for riparian ecosystem recovery as well as the continuation of present land use and ownership. Please note that the boundaries of the recommended corridor are general in nature where privately owned land is present. It is recognized that any future land acquisition, conservation easement, or conservation agreement completed for the purpose of riparian ecosystem recovery will require a mutual agreement between the owner and the purchaser as well as satisfactory compensation for the owner.

5.3 Description of Recommended Conservation Corridor

A description of the recommended conservation corridor is presented in the following sections. An overview of the corridor for the entire UMR valley is presented in Figure 1 and the corridor for individual river segments is presented in Figures 2 through 8.

5.3.1 Segment 1

The conservation corridor includes approximately 860 acres and ranges in width from 200 to 6,600 feet. Due to the narrow nature of the valley within the lower half of Segment 1, the conservation corridor includes most of the 100 year floodplain in the lower half of the segment. However, as shown in Figure 2, the inclusion of the 100 year floodplain is limited in the upper half of the segment by the presence of Hidden Valley Dairy and Reid Gardner Station. The unique spring-fed wetland located within the lower half of the segment is included in the corridor and is considered critical habitat and an especially valuable portion of the corridor. As shown in Figure 2, the width of the recommended corridor is greatest where the corridor has been extended and connected to uplands on both sides near the middle of Segment 1 by an expansion of the corridor toward surrounding BLM lands. In addition, the corridor extends across private land into California Wash where the corridor edge connects with federally owned lands.

5.3.2 Segment 2

The conservation corridor includes approximately 240 acres and ranges in width from 100 to 1,500 feet. As shown in Figure 3, the corridor is connected to uplands on the west side of the corridor by an expansion of the corridor toward surrounding federally owned lands. This extension of the corridor to federally owned lands along the west side of the valley would preserve a connection between the river valley and several ephemeral washes. The corridor width is constrained by agricultural activities within Segment 2. However, the continuation of agricultural activities within the floodplain is a better option than residential or industrial development given the fact that the entire valley floor is within the 100 year floodplain.

5.3.3 Segment 3

The conservation corridor includes approximately 420 acres and ranges in width from 750 to 3,000 feet. As shown in Figure 4, the corridor is largely composed of BLM and TNC property. The presence of BLM property to the west of the corridor provides a connection with the uplands and several ephemeral washes on the west side of the river valley. TNC property is included within the conservation corridor at both the upstream and downstream ends of the segment. The width of the corridor is constrained along the east side of the river valley by numerous parcels of private land. The present land ownership within Segment 3 results in the greatest potential for an uninterrupted conservation corridor and represents the largest, continuous section of the UMR valley that could be included in a conservation corridor. The primary critical habitat within Segment 3 is the Mesquite Bosque that is presently returning to former agricultural fields.

5.3.4 Segment 4

The conservation corridor includes approximately 180 acres and ranges in width from 1,000 to 3,200 feet. A connection to uplands adjacent to the river valley is provided through federally owned lands on the upstream end of the segment near Battleship Wash. The corridor width begins to increase upstream from Segment 3 due to the increasing width of the valley and 100 year floodplain. As shown in Figure 5, the primary critical habitat within this segment is the riparian marsh habitat that occurs throughout the conservation corridor. Additional critical habitat within this segment includes riparian woodland, riparian shrubland, and Mesquite Bosque.

5.3.5 Segments 5 and 6

Segments 5 and 6 have been combined in the recommended conservation corridor for the purpose of maintaining connectivity between the Muddy Spring and mainstem of the river, both of which are located in Segment 5, and the spring channels (Warm Springs and Apcar Spring) which are located in Segment 6. The conservation corridor includes approximately 350 acres and ranges in width from 430 to 4,700 feet. As shown in Figure 6, the conservation corridor in the vicinity of Segments 5 and 6 encompasses both land adjacent to the river as well as land surrounding the Warm Springs, Apcar, and Muddy Spring channels. The corridor is connected to federal lands and federally owned upland areas in the vicinity of the MVNWR. The primary critical habitat within this portion of the conservation corridor are the Warm Springs, Apcar, and Muddy Spring channels, all of which currently support or have historically supported Moapa dace populations. Additional critical habitat includes riparian woodland, riparian shrubland, riparian marsh, and Mesquite Bosque.

5.3.6 Segments 7 and 8

As shown in Figure 7, Segments 7 and 8 have been combined in the recommended conservation corridor in order to maintain connectivity between the North Fork, South Fork, and Cardy Lamb Spring, all of which currently or historically supported Moapa dace. The conservation corridor in the vicinity of Segment 7 includes both the South and North Forks of the UMR and the Cardy Lamb Spring channel, encompasses approximately 200 acres, and ranges in width from 160 to 2,800 feet. Private land and residential development on the northeast edge of the corridor prevents connection of the corridor with federally owned lands to the north side of the valley. As shown in Figure 7, critical habitat within this portion of the corridor includes past and potential Moapa dace habitat within the North and South Forks of the UMR and Cardy Lamb Spring. The conservation corridor is connected to federally owned uplands along the south edge of the corridor in the vicinity of Baldwin Spring.

5.3.7 Segment 9

The conservation corridor includes approximately 350 acres and ranges in width from 160 to 2,700 feet. The primary critical habitat within this portion of the corridor includes upland habitat and ephemeral washes. As shown in Figure 8, this section of the conservation corridor could provide the most extensive connection of the river corridor with federally owned upland areas and ephemeral washes on both the north and south margins of the upstream end of the UMR valley. Connection of the corridor with these federal lands would provide and maintain connectivity of the riparian ecosystem with some of the larger ephemeral tributaries within the UMR valley.

5.4 Habitat Conservation and Restoration Recommendations and Alternatives

Habitat conservation and restoration recommendations, specific to individual characteristics, properties, and restoration needs within individual river segments are shown in Table 7. Restoration recommendations provided in Table 7 are based on the recovery of individual priority conservation targets (assemblages) and the general ecological and physical requirements of species within each priority conservation target. Priority conservation targets, as defined by TNC (2000), were used to evaluate the number of priority conservation targets captured for each recommendation. Restoration recommendations are organized by segment and by the relative level of effort and cost of implementation.

The organization of recommendations by relative effort and cost also provides the basis for the delineation of low, medium, and high level alternatives for UMR habitat conservation and restoration. The recommendations and associated levels of relative cost and effort were used to designate low, medium, and high level alternatives such that 1) the low level alternative (Table 8) includes only those recommendations that entail a low level of effort and cost; 2) the medium level alternative (Table 9) includes recommendations that entail both low and medium levels of effort and cost; and 3) high level alternative (Table 10) includes the recommendations with low, medium, and high levels of effort and cost.

In general, restoration alternatives within the UMR valley can be divided into two categories including 1) legal protection of resources and habitat, and 2) habitat restoration/rehabilitation/enhancement/creation. Legal protection of resources and habitat can range from land acquisition to the purchase of water rights to be used for wetland habitat preservation or creation. Similarly, habitat restoration activities can range from large scale construction activities to invasive species control such as tamarisk removal. Legal protection and large scale habitat restoration activities (construction) are typically the most expensive and effort intensive actions. Therefore, recommendations related to legal protection and large scale habitat restoration (construction) are only included in the high and medium level alternatives while other less expensive recommendations are included in both the medium and low level alternatives.

5.5 Example of Restoration Implementation

The implementation of habitat conservation and restoration recommendations and alternatives could proceed in a variety of ways depending on external factors such as land ownership status, preferences and support by local, municipal, and agency stakeholders, funding availability, and precise habitat restoration needs. Therefore, a graphic example has been created in order to portray one approach of habitat restoration within the UMR valley. The example provided is intended as a conceptual model to exhibit the potential for riparian ecosystem restoration and recovery within the UMR valley. Detailed restoration plans, hydraulic modeling, habitat studies, and permitting activities would be required prior to the implementation of the restoration efforts portrayed in this example.

Pre- and post-restoration conditions are portrayed in Figure 9. The area shown is located within Segment 3 and both federally (BLM) and privately (TNC) owned lands are incorporated. In addition, the restored area exhibited in the example is bordered by a residential area. In general, the example provided represents the implementation of high level recommendations such as channel reconstruction and the construction of a permanent grade control structure and fish barrier. However, both low and medium level recommendations such as invasive vegetation removal and revegetation efforts following invasive vegetation removal and channel reconstruction could be implemented in combination with the overall restoration activities portrayed in Figure 9.

As shown in Figure 9, a permanent grade control structure would be created at the White Narrows for the purposes of establishing and maintaining the elevation of the channel at the downstream end of the restored river segment, preventing channel entrenchment following channel reconstruction activities, and facilitating the exclusion of invasive aquatic species from the headwaters of the UMR valley. Raising the elevation of the channel and improving the connection between the channel and floodplain would promote an increase in riparian corridor width. The creation of surfaces suitable for riparian vegetation recruitment would be facilitated by improving the connection between the channel and floodplain and subsequent scour and deposition that would occur due to more frequent overbank flows. Finally, riparian marsh would be created and maintained following the increased elevation of the channel and subsequent improvement in shallow groundwater and soil moisture conditions.

6.0 References

Cross, J.N. 1976. Status of the native fish fauna of the Moapa River (Clark County, NV). Transactions of the American Fisheries Society 105 (4):503-508.

Goodchild, Shawn. 2003. Personal communication. Conversation between USFWS employee and Rob Andress, October 2003.

The Nature Conservancy. 2000. Upper Muddy River Site Conservation Plan.

Scoppettone, G.G., H.L. Burge, P.L. Tuttle, M. Parker, and N.K. Parker. 1987. Life history and status of the Moapa dace (Moapa coriacea). U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington. 77 pp.

Scoppettone, G.G., H.L. Burge, and P.L. Tuttle. 1992. Life history, abundance, and distribution of Moapa dace (Moapa coriacea). Great Basin Naturalist 52 (3):216-225.

Sprunger-Allworth, Amy. 2004. Personal communication. Conversation between USFWS employee and Rob Andress, February 2004.

United States Fish and Wildlife Service. 1983. Moapa Dace Recovery Plan. Portland, OR.

United States Fish and Wildlife Service. 1999. Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem. Reno, NV.