Appendix B

Tables

Table 1. Upper Muddy River priority conservation targets.

Warm Spring/Stream Aquatic Assemblage	
Moapa dace	*Moapa coriacea*
Moapa White River springfish	*Crenichthys baileyi moapae*
Moapa pebblesnail	*Pyrgulopsis avernalis*
	*(Fluminicola avernalis)**
Grated tryonia	*Tryonia clathrata*
Moapa water strider	*Rhagovelia becki*
Moapa Warm Springs riffle beetle	*Stenelmis moapa*
Pahranagat naucorid	*Pelocoris shoshone shoshone*
Moapa naucorid	*Usingerina moapensis*
Muddy River Aquatic Assemblage	
Virgin River chub	*Gila seminuda*
Moapa speckled dace	*Rhinichthys osculus moapae*
Moapa dace	*Moapa coriacea*
Moapa water strider	*Rhagovelia becki*
Riparian Woodland	
Fremont cottonwood	*Populus fremontii*
Goodding's willow	*Salix gooddingii*
Velvet ash	*Fraxinus velutina*
Yellow-billed cuckoo	*Coccyzus americanus*
Vermillion flycathcer	*Pyrocephalus rubinus*
Blue grosbeak	*Passerina caerula*
	*(Guiraca caerula)**
Western tanager	*Piranga ludoviciana*
Summer tanager	*Piranga rubra*
Yellow bat	*Lasiurus xanthinus*
Red bat	*Lasiurus blossevillii*
Riparian Shrubland	
Quailbush	*Atriplex lentiformis*
Arrow weed	*Pluchea sericea*
Seep-willow	*Baccharis* spp.
Narrow-leaved willow (coyote willow)	*Salix exigua*
Southwestern willow flycatcher	*Empidonax trailii extimus*
Bell's vireo	*Vireo bellii arizonae*
Crissal thrasher	*Toxostoma dorsale*
Loggerhead shrike	*Lanius ludocianus*
Desert pocket mouse	*Chaetodipus pencillatus*
MacNiel's desert sootywing	*Hesperopsis gracielae*
Southern melissa blue	*Lycaeides melissa alateres*

Dammer's fatal metalmark	*Calephelis nemesis nemesis*
Arizona viceroy	*Limenitis archippus obsoleta*
Riparian Marsh	
Cattail	*Typha* spp.
Sedge	*Carex* spp.
Rush	*Juncus* spp.
Green heron	*Butorides virescens*
Virginia rail	*Rallus limicola*
Sora	*Porzana carolina*
Marsh wren	*Cistothorus palustris*
Common snipe	*Gallinago gallinago*
Common yellowthroat	*Geothlypis trichas*
Pacific tree frog	*Hyla regilla*
Red-spotted toad	*Bufo punctatus*
Southwestern toad	*Bufo microscaphus microscaphus*
Woodhouse toad	*Bufo woodhousii*
Mesquite Bosque	
Honey mesquite	*Prosopis glandulosa*
Screwbean mesquite	*Prosopis pubescens*
Phainopepla	*Phainopepla nitens*
Vermillion flycatcher	*Pyrocephalus rubinus*
Crissal thrasher	*Toxostoma crissale*
Western great purple hairstreak	*Altides halesus corcorani*
Leda hairstreak	*Ministrymon leda*
Western Palmer's metalmark	*Apodemia palmerii palmerii*

* Scientific names in parentheses are previously used names that have recently been changed.
Modified from (TNC, 2000)

Table 2. Summary of Upper Muddy River restoration potential criteria and scoring levels.

Criteria		Scoring 5	4	3	2	1
	River and Floodplain Attributes					
1	*Width of 100 year floodplain (not a scored criteria)*	--	--	--	--	--
2	*Relative width of 100 year floodplain*	very wide (>3,000 ft)	wide (2,500 to 3,000 ft)	medium (1,500 to 2,500 ft)	narrow (500 to 1,500 ft)	very narrow (0 to 1,500 ft)
3	*Entrenchment*	none (<0 to 5 ft)	little (5.1 to 7.5 ft)	moderate (7.6 to 10 ft)	great (10.1 to 12.5 ft)	very great (>12.5 ft)
4	*Encroachments into the channel*	none	few	some	many	extensive
5	*Encroachments into the floodplain or corridor*	none	few	some	many	extensive
6	*Floodplain reconnection potential*	very high	high	medium	low	very low
	Habitat Attributes					
7	*Number of assemblages within segment*	six	five	four	three	two or less
8	*Connection to landscape features*	more than eight	seven to eight	five to six	four	three or less
9	*Potential for habitat recovery/expansion by assemblage*	very high	high	medium	low	very low
10	*Potential to increase relative habitat diversity*	very high	high	medium	low	very low

Table 3. Summary of Upper Muddy River restoration potential criteria and scoring results.
Minimum and maximum scoring scale provided at right for comparison.

		Segment							Minimum	Maximum
		1	2	3	4	5,6	7,8	9	Scoring	Scoring
Criteria	**River and Floodplain Attributes**									
1	*Width of 100 year floodplain (not a scored criteria)*	--	--	--	--	--	--	--	--	--
2	*Relative width of 100 year floodplain*	2	3	3	5	5	5	3	1	5
3	*Entrenchment*	1	3	3	2	1	3	5	1	5
4	*Encroachments into the channel*	2	3	4	3	5	5	3	1	5
5	*Encroachments into the floodplain or corridor*	2	1	4	4	5	3	3	1	5
6	*Floodplain reconnection potential*	2	3	3	3	3	3	4	1	5
	Habitat Attributes									
7	*Number of assemblages within segment*	4	2	3	5	5	5	2	1	5
8	*Connection to landscape features*	4	3	4	5	5	5	4	1	5
9	*Potential for habitat recovery/expansion by assemblage*									
	Warm Springs/Stream Aquatic	2	1	1	5	5	5	1	1	5
	Muddy River Aquatic	3	3	3	5	5	5	1	1	5
	Riparian Woodland	5	4	5	5	5	5	3	1	5
	Riparian Shrubland	5	4	5	5	5	5	3	1	5
	Riparian Marsh	4	1	2	3	4	4	1	1	5
	Mesquite Bosque	4	2	5	5	5	5	5	1	5
10	*Potential to increase relative habitat diversity*	5	3	3	4	4	5	2	1	5
									Lowest possible score	Highest possible score
River and floodplain restoration potential score (add 2 through 6)		9	13	17	17	19	19	18	5	25
Habitat restoration potential score (add 7 through 10)		36	23	31	42	43	44	22	9	45
Total Score		45	36	48	59	62	63	40	14	70

Table 4. Scoring ranges and associated degrees of river and floodplain, habitat, and total restoration potential.

	Degree of Restoration Potential						
	Very Low	Low	Moderate	High	Very High	Lowest Possible Score	Highest Possible Score
River and floodplain restoration potential	5-8	9-12	13-16	17-20	21-25	5	25
Habitat restoration potential	9-16	17-24	25-32	33-40	41-45	9	45
Total restoration potential	14-24	25-35	36-46	47-57	58-70	14	70

Table 5. Summary of river and floodplain, habitat, and total restoration potential for each mainstem river segment.

	Segment						
	1	2	3	4	5,6	7,8	9
River and floodplain restoration potential	Low	Moderate	High	High	High	High	High
Habitat restoration potential	High	Low	Moderate	Very High	Very High	Very High	Low
Total restoration potential	Moderate	Low	High	Very High	Very High	Very High	Moderate

Table 6. Modeled 100 year flood surface width prior to and after reconnection of channel and floodplain compared to the width of the recommended conservation corridor.

	Prior to Reconnection 100 Year Flood Surface Width (ft)		After Reconnection 100 Year Flood Surface Width (ft)		Recommended Conservation Corridor Width (ft)	
Segment	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
1	213	678	680	1,226	200	6,600*
3	1,574	2,515	1,484	2,546	750	3,000
4	180	754	2,171	3,380	1,000	3,200
5	165	3,407	1,443	4,327	430	4,700
7	734	1,956	1,499	2,076	160	2,800

* Recommended width significantly greater than 100 year flood surface width after reconnection due to corridor expansion toward federally owned upland areas on both sides of corridor.

Table 7. Upper Muddy River habitat conservation and restoration recommendations.

Segment	Relative Level of Effort and Cost	Recommendation	Priority Conservation Targets Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	3, 4, and 5
	Medium	Conservation easement for floodplain real estate	3, 4, 5, and 6
	High	Acquisition of Hidden Valley Dairy pond and surrounding wetland	3, 4, and 5
	High	Acquisition of floodplain real estate	3, 4, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Medium	Revegetation following tamarisk removal activities	variable
	Medium	Revegetation following invasive vegetation removal activities	3 and 4
	High	Construction of permanent grade control structure and rolling drum fish barrier at White Narrows	1 and 2
	High	Construction of permanent grade control structure and fish barrier at White Narrows	1 and 2
	High	Establishment of buffer zone between agricultural fields and river	3 and 4
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements for remaining floodplain real estate	3, 4, 5, and 6
	Medium	Acquisition of remaining floodplain real estate	3, 4, 5, and 6
	High	Complete reconstruction of channel within BLM property	2, 3, 4, 5, and 6
	High	Removal of flood/silt control dams on tributary washes	2, 3, and 4
4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1 and 2

	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	1, 2, 3, 4, 5, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on South Fork channel	1 and 2
	Medium	Invasive fish exclusion on Cardy Lamb channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
9 - North Fork Headwaters to Arrow Canyon			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	4 and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6

* Individual conservation targets shown below
1 - Warm Spring/Stream Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Interior Riparian Woodland
4 - Interior Riparian Shrubland
5 - Interior Riparian Marsh
6 - Mesquite Bosque

Table 8. Low level altermative for Upper Muddy River habitat conservation and restoration.

Segment	Relative Level of Effort and Cost	Recommendation	Priority Conservation Targets Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	variable
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 2, 3, 4, and 5
7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6

	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy Spring channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 2, 3, 4, 5, and 6
	Medium	Conservation easements within Muddy Spring area/LDS recreation area	1, 2, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Spring channel restoration of Muddy Spring channel	1, 2, 3, 4, and 5
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 2, 3, 4, and 5
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Defined instream flows for Moapa Valley NWR spring channels	1 and 2
	Medium	Defined instream flows for Apcar channel	1 and 2
	High	Spring channel restoration of Plummer channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration of Apcar channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration within Warm Springs Ranch (Refuge and Apcar channels)	1, 2, 3, 4, and 5
	High	Conservation easements along spring channels on Warm Springs Ranch	1, 2, 3, 4, and 5
	High	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	1, 2, 3, 4, and 5
	High	Development of public use and education areas/trails within Moapa Valley NWR	non-habitat benefits, public outreach
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	1, 3, 4, and 6

9 - North Fork Headwaters to Arrow Canyon	Low Low	Knapweed control with goats Manual tamarisk removal	1, 2, 3, 4, and 5 4 and 6

* Individual conservation targets shown below
1 - Warm Spring/Stream Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Interior Riparian Woodland
4 - Interior Riparian Shrubland
5 - Interior Riparian Marsh
6 - Mesquite Bosque

Table 9. Medium level alternative for Upper Muddy River habitat conservation and restoration.

Segment	Relative Level of Effort and Cost	Recommendation	Priority Conservation Targets Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	3, 4, and 5
	Medium	Conservation easement for floodplain real estate	3, 4, 5, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	variable
	Medium	Revegetation following tamarisk removal activities	variable
	Medium	Revegetation following invasive vegetation removal activities	3 and 4
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements for remaining floodplain real estate	3, 4, 5, and 6
	Medium	Acquisition of remaining floodplain real estate	3, 4, 5, and 6
4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1 and 2
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5

	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy Spring channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 2, 3, 4, 5, and 6
	Medium	Conservation easements within Muddy Spring area/LDS recreation area	1, 2, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 2, 3, 4, and 5
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Defined instream flows for Moapa Valley NWR spring channels	1 and 2
	Medium	Defined instream flows for Apcar channel	1 and 2

7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	1, 3, 4, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	1, 2, 3, 4, 5, and 6
8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on South Fork channel	1 and 2
	Medium	Invasive fish exclusion on Cardy Lamb channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
9 - North Fork Headwaters to Arrow Canyon			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	4 and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6

* Individual conservation targets shown below
1 - Warm Spring/Stream Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Interior Riparian Woodland

4 - Interior Riparian Shrubland
5 - Interior Riparian Marsh
6 - Mesquite Bosque

Table 10. High level alternative for Upper Muddy River habitat conservation and restoration.

Segment	Relative Level of Effort and Cost	Recommendation	Priority Conservation Targets Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	3, 4, and 5
	Medium	Conservation easement for floodplain real estate	3, 4, 5, and 6
	High	Acquisition of Hidden Valley Dairy pond and surrounding wetland	3, 4, and 5
	High	Acquisition of floodplain real estate	3, 4, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	variable
	Medium	Revegetation following tamarisk removal activities	variable
	Medium	Revegetation following invasive vegetation removal activities	3 and 4
	High	Construction of permanent grade control structure and rolling drum fish barrier at White Narrows	1 and 2
	High	Construction of permanent grade control structure and fish barrier at White Narrows	1 and 2
	High	Establishment of buffer zone between agricultural fields and river	3 and 4
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements for remaining floodplain real estate	3, 4, 5, and 6
	Medium	Acquisition of remaining floodplain real estate	3, 4, 5, and 6
	High	Complete reconstruction of channel within BLM property	2, 3, 4, 5, and 6
	High	Removal of flood/silt control dams on tributary washes	2, 3, and 4
4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6

	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1 and 2
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy Spring channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 2, 3, 4, 5, and 6
	Medium	Conservation easements within Muddy Spring area/LDS recreation area	1, 2, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Spring channel restoration of Muddy Spring channel	1, 2, 3, 4, and 5
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 2, 3, 4, and 5
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Defined instream flows for Moapa Valley NWR spring channels	1 and 2
	Medium	Defined instream flows for Apcar channel	1 and 2
	High	Spring channel restoration of Plummer channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration of Apcar channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration within Warm Springs Ranch (Refuge and Apcar channels)	1, 2, 3, 4, and 5
	High	Conservation easements along spring channels on Warm Springs Ranch	1, 2, 3, 4, and 5
	High	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	1, 2, 3, 4, and 5
	High	Development of public use and education areas/trails within Moapa Valley NWR	non-habitat benefits, public outreach
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6

	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	1, 3, 4, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	1, 2, 3, 4, 5, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on South Fork channel	1 and 2
	Medium	Invasive fish exclusion on Cardy Lamb channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
9 - North Fork Headwaters to Arrow Canyon			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	4 and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6

* Individual conservation targets shown below
1 - Warm Spring/Stream Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Interior Riparian Woodland
4 - Interior Riparian Shrubland
5 - Interior Riparian Marsh
6 - Mesquite Bosque

Appendix C

Upper Muddy River Channel and Habitat Restoration Potential Evaluation Sheets

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

Segment: 1
Location Description: I-15 Bridge to Reid Gardner Railroad Bridge
Segment Length: 21, 321 feet (4.04 miles)
Channel Length: 27,564 feet (5.22 miles)

River and Floodplain Attributes

(1) ***Width of 100 year floodplain***
Minimum 390 ft Maximum 2,918 ft Average 1,564 ft

(2) ***Relative width of 100 year floodplain*** Score: 5 (v wide), 4 (wide), 3 (med), [2] (narrow), 1 (v narrow)

(3) ***Entrenchment*****:** 17.3 ft Score: [1] (v great), 2 (great), 3 (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: 5 (none), 4 (few), 3 (some), [2] (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), 4 (few), 3 (some), [2] (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), 3 (medium), [2] (low), 1 (v low)
Explain:

Habitat Attributes

(7) N***umber of assemblages within segment*** Score: 5 (six), [4] (five), 3 (four), 2 (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** 5 (>8), [4] (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: 5 (v high), 4 (high), 3 (med), [2] (low), 1 (v low)
Muddy River Aquatic Score: 5 (v high), 4 (high), [3] (med), 2 (low), 1 (v low)
Riparian Woodland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)
Mesquite Bosque Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: [5] (v high), 4 (high), 3 (medium), 2 (low), 1 (v low)

Scoring:
River channel and floodplain restoration potential score (add 2 through 6): 9
Habitat restoration potential score (add 7 through 12): 36
Total Score: 45

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

Segment: 2
Location: Reid Gardner Railroad Bridge to White Narrows
Segment Length: 16,048 feet (3.04 miles)
Channel Length: 18,072 feet (3.42 miles)

River and Floodplain Attributes

(1) ***Width range of 100 year floodplain***
Minimum 1,613 ft Maximum 3,191 ft Average 2,344 ft

(2) ***Relative width of 100 year floodplain*** Score: 5 (v wide), 4 (wide), [3] (med), 2 (narrow), 1 (v narrow)

(3) Relative e*ntrenchment*: Score: 1 (v great), 2 (great), [3] (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: 5 (none), 4 (few), [3] (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), 4 (few), 3 (some), 2 (many), [1] (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes

(7) N*umber of assemblages within segment* Score: 5 (six), 4 (five), 3 (four), [2] (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** 5 (>8), 4 (8- 7), [3] (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Muddy River Aquatic Score: 5 (v high), 4 (high), [3] (med), 2 (low), 1 (v low)
Riparian Woodland Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Mesquite Bosque Score: 5 (v high), 4 (high), 3 (med), [2] (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)

Scoring:

River channel and floodplain restoration potential score (add 2 through 6): 13
Habitat restoration potential score add (7 through 12): 23
Total Score: 36

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

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Segment: 3
Location: White Narrows to Warm Springs Road Bridge
Segment Length: 10,784 feet (2.04 miles)
Channel Length: 12,944 feet (2.45 miles)

River and Floodplain Attributes
(1) ***Width range of 100 year floodplain***
Minimum 1,783 ft Maximum 2,780 ft Average 2,253 ft

(2) ***Relative width of 100 year floodplain*** Score: 5 (v wide), 4 (wide), [3] (med), 2 (narrow), 1 (v narrow)

(3) E*ntrenchment* 10.0 ft**:** Score: 1 (v great), 2 (great), [3] (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: 5 (none), [4] (few), 3 (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), [4] (few), 3 (some), 2 (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes
(7) N*umber of assemblages within segment* Score: 5 (six), 4 (five), [3] (four), 2 (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** 5 (>8), [4] (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Muddy River Aquatic Score: 5 (v high), 4 (high), [3] (med), 2 (low), 1 (v low)
Riparian Woodland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), 4 (high), 3 (med), [2] (low), 1 (v low)
Mesquite Bosque Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)

Scoring:
River channel and floodplain restoration potential score (add 2 through 6): 17
Habitat restoration potential score (add 7 through 12): 31
Total Score: 48

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

Segment: 4
Location: Warm Springs Road Bridge to Warm Springs – Muddy Confluence
Segment Length: 3,671 feet (0.70 miles)
Channel Length: 5,171 feet (0.98 miles)

River and Floodplain Attributes

(1) ***Width range of 100 year floodplain***
Minimum 2,656 ft Maximum 3,845 ft Average 3,335 ft

(2) ***Relative width of 100 year floodplain*** Score: 5 (v wide), 4 (wide), 3 (med), 2 (narrow), 1 (v narrow)

(3) E*ntrenchment* 12.3 ft**:** Score: 1 (v great), 2 (great), 3 (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: 5 (none), 4 (few), 3 (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), 4 (few), 3 (some), 2 (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), 3 (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes

(7) N*umber of assemblages within segment* Score: 5 (six), 4 (five), 3 (four), 2 (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** 5 (>8), 4 (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Muddy River Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Woodland Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Mesquite Bosque Score: 5 (v high), 4 (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: 5 (v high), 4 (high), 3 (medium), 2 (low), 1 (v low)

Scoring:
River channel and floodplain restoration potential score (add 2 through 6): 17
Habitat restoration potential score (add 7 through 10): 42
Total Score: 59

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

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Segment: 5
Location: Warm Springs-Muddy Confluence to North-South Fork Confluence including Muddy Spring
Segment Length: 5,289 feet (1.0 miles)
Channel Length: 6,985 feet (1.32 miles)

Segment: 6
Location Description: Warm Springs-Muddy Confluence to Warm Springs and Apcar Spring
Segment Length: 1,928 feet (0.37 miles)
Channel Length: 2,359 feet (0.45 miles)

River and Floodplain Attributes

(1) ***Width range of 100 year floodplain***
Minimum 1,853 ft Maximum 4,776 ft Average 3,508 ft

(2) ***Relative width of 100 year floodplain*** Score: [5] (v wide), 4 (wide), 3 (med), 2 (narrow), 1 (v narrow)

(3) E*ntrenchment* 15.4 ft**:** Score: [1] (v great), 2 (great), 3 (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: [5] (none), 4 (few), 3 (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: [5] (none), 4 (few), 3 (some), 2 (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes

(7) N*umber of assemblages within segment* Score: [5] (six), 4 (five), 3 (four), 2 (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** [5] (>8), 4 (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Muddy River Aquatic Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Woodland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)
Mesquite Bosque Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: 5 (v high), [4] (high), 3 (medium), 2 (low), 1 (v low)

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet
Segments 5 and 6 continued

Scoring:
River channel and floodplain restoration potential score (add 2 through 6): 19
Habitat restoration potential score (add 7 through 10): 43
Total Score: 62

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

Segment: 7
Location: North-South Fork Confluence to North Fork Headwaters
Segment Length: 2,963 feet (0.56 miles)
Channel Length: 3,268 feet (0.62 miles)

Segment: 8
Location Description: North-South Fork Confluence to South Fork Headwaters and Cardy Lamb Spring
Segment Length: 2,632 feet (0.50 miles)
Channel Length: 3,209 feet (0.61 miles)

River and Floodplain Attributes
(1) ***Width range of 100 year floodplain***
Minimum 2,401 ft Maximum 3,912 ft Average 3,353 ft

(2) ***Relative width of 100 year floodplain*** Score: [5] (v wide), 4 (wide), 3 (med), 2 (narrow), 1 (v narrow)

(3) E*ntrenchment* 9.2 ft**:** Score: 1 (v great), 2 (great), [3] (mod), 4 (little), 5 (none)

(4) ***Encroachments into the channel*** Score: [5] (none), 4 (few), 3 (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), 4 (few), [3] (some), 2 (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), 4 (high), [3] (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes
(7) N*umber of assemblages within segment* Score: [5] (six), 4 (five), 3 (four), 2 (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** [5] (>8), 4 (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Muddy River Aquatic Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Woodland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Shrubland Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), [4] (high), 3 (med), 2 (low), 1 (v low)
Mesquite Bosque Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: [5] (v high), 4 (high), 3 (medium), 2 (low), 1 (v low)

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet
Segments 7 and 8 continued

<u>Scoring:</u>
River channel and floodplain restoration potential score (add 2 through 6): 19
Habitat restoration potential score (add 7 through 10): 44
Total Score: 63

Upper Muddy River Channel and Habitat Restoration Potential - Evaluation Sheet

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Segment: 9
Location: North Fork Headwaters to Arrow Canyon
Segment Length: 8,865 feet (1.68 miles)
Channel Length: 9,305 feet (1.76 miles)

River and Floodplain Attributes
(1) ***Width range of 100 year floodplain***
Minimum 470 ft Maximum 3,187 ft Average 2,293 ft

(2) ***Relative width of 100 year floodplain*** Score: 5 (v wide), 4 (wide), [3] (med), 2 (narrow), 1 (v narrow)

(3) E*ntrenchment* 4.8 ft**:** Score: 1 (v great), 2 (great), 3 (mod), 4 (little), [5] (none)

(4) ***Encroachments into the channel*** Score: 5 (none), 4 (few), [3] (some), 2 (many), 1 (extensive)

(5) ***Encroachments into the floodplain or corridor*** Score: 5 (none), 4 (few), [3] (some), 2 (many), 1 (extensive)

(6) ***Floodplain reconnection potential*** Score: 5 (v high), [4] (high), 3 (medium), 2 (low), 1 (v low)
Explain:

Habitat Attributes
(7) N*umber of assemblages within segment* Score: 5 (six), 4 (five), 3 (four), [2] (three), 1 (two or less)

(8) ***Connection to landscape features – shade all that apply*** 5 (>8), [4] (8- 7), 3 (6 - 5), 2 (4), 1(#3)
Wetlands, Seeps\Springs, Irrigation ditches, Relic channel\Side channel, Wide riparian forest, Complex riparian forest, Complex topography, Upland areas, Tributaries, Washes, Hill Side, Upstream Floodplain, Downstream Floodplain

(9) ***Potential for habitat recovery/expansion by assemblage***
Warm Springs/Stream Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Muddy River Aquatic Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Riparian Woodland Score: 5 (v high), 4 (high), [3] (med), 2 (low), 1 (v low)
Riparian Shrubland Score: 5 (v high), 4 (high), [3] (med), 2 (low), 1 (v low)
Riparian Marsh Score: 5 (v high), 4 (high), 3 (med), 2 (low), [1] (v low)
Mesquite Bosque Score: [5] (v high), 4 (high), 3 (med), 2 (low), 1 (v low)

(10) ***Potential to increase relative habitat diversity*** Score: 5 (v high), 4 (high), 3 (medium), [2] (low), 1 (v low)

Scoring:
River channel and floodplain restoration potential score (add 2 through 6): 18
Habitat restoration potential score (add 7 through 10): 22
Total Score: 40

Appendix III. Costs and Supporting Information Associated with Habitat Conservation and Restoration Recommendations.

Otis Bay Riverine Consultants Inc. proposed a group of restoration actions for each of nine river segments. This Appendix contains Otis Bay's deliverable. An important element of this deliverable is Table 1, which was slightly modified from Otis Bay's original table and used in The Nature Conservancy's assessment (Chapters 3-5). The main differences between Table 1 and the original table are that 1) the list of benefiting conservation targets is reduced (for example, the Warm Spring Aquatic Assemblage is not found in or benefiting from actions in segment 1, thus is not listed in Table 1 for segment 1, but it is listed in Otis Bay's original product) and 2) the name of actions is standardized between segments (required for TNC's Conservation management Tool).

Table 1. Recommended restoration actions for the nine segments of the upper Muddy River. Cost and target ecological systems are identified for each action.

Segment	Relative Level of Effort and Cost	Recommendation Action	Priority Ecological System Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with herbicide and goats	2, 3, 4, and 5
	Low	Manual saltcedar removal	3, 4, and 6
	Medium	Revegetation following saltcedar removal activities	3, 4, and 6
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	3, 4, and 5
	Medium	Conservation easement for floodplain real estate	3, 4, 5, and 6
	High	Acquisition of Hidden Valley Dairy pond and surrounding wetland	3, 4, and 5
	High	Acquisition of floodplain real estate	3, 4, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with herbicide and goats	2, 3, and 4
	Low	Manual saltcedar removal	3 and 4
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	variable
	Medium	Revegetation following saltcedar removal activities	variable
	Medium	Revegetation following invasive vegetation removal activities	3 and 4
	High	Construction of permanent grade control structure and rolling drum fish barrier at White Narrows	1 and 2
	High	Construction of permanent grade control structure and fish barrier at White Narrows	1 and 2
	High	Establishment of buffer zone between agricultural fields and river	3 and 4
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with herbicide and goats	2, 3, 4, and 5

	Low	Manual saltcedar removal	3, 4, and 6
	Medium	Revegetation following saltcedar removal activities	3, 4, and 6
	Medium	Conservation easements for remaining floodplain real estate	3, 4, 5, and 6
	Medium	Acquisition of remaining floodplain real estate	3, 4, 5, and 6
	High	Complete reconstruction of channel within Bureau of Land Management property	2, 3, 4, 5, and 6
	High	Removal of flood and sediment control dams on tributary washes	2, 3, and 4
4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with herbicide and goats	1, 2, 3, and 4
	Low	Manual saltcedar removal	3 and 4
	Medium	Palm tree removal	1, 2, 3, and 4
	Medium	Revegetation following saltcedar removal activities	3, 4, and 6
	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1 and 2
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, and 6
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with herbicide and goats	1, 2, 3, 4, and 5
	Low	Manual saltcedar removal	3, 4, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following saltcedar removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy Spring channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 2, 3, 4, 5, and 6
	Medium	Conservation easements within Muddy Spring area/church recreation area	1, 2, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Spring channel restoration of Muddy Spring channel	1, 2, 3, 4, and 5
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with herbicide and goats	1, 2, 3, 4, and 5
	Low	Manual saltcedar removal	1, 2, 3, 4, and 5
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following saltcedar removal activities	3, 4, 5, and 6
	Medium	Defined instream flows for Moapa Valley National Wildlife Refuge (NWR) spring channels	1 and 2
	Medium	Defined instream flows for Apcar channel	1 and 2

	High	Spring channel restoration of Plummer channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration of Apcar channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration within Warm Springs Ranch (Refuge and Apcar channels)	1, 2, 3, 4, and 5
	High	Conservation easements along spring channels on Warm Springs Ranch	1, 2, 3, 4, and 5
	High	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	1, 2, 3, 4, and 5
	High	Development of public use and education areas/trails within Moapa Valley NWR	non-habitat benefits, public outreach
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with herbicide and goats	1, 2, 3, 4, and 5
	Low	Manual saltcedar removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following saltcedar removal activities	3, 4, and 6
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	1, 3, 4, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	1, 2, 3, 4, 5, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with herbicide and goats	1, 2, 3, 4, and 5
	Low	Manual saltcedar removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following saltcedar removal activities	3, 4, and 5
	Medium	Invasive fish exclusion on South Fork channel	1 and 2
	Medium	Invasive fish exclusion on Cardy Lamb channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, and 5
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	Medium	Spring channel restoration within of South Fork	1, 2, 3, 4, and 5

	High	channel Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, and 5
9 - North Fork Headwaters to Arrow Canyon			
	Low	Knapweed control with herbicide and goats	3, and 4
	Low	Manual saltcedar removal	4
	Medium	Revegetation following saltcedar removal activities	3 and 4
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, and 4

* Individual conservation targets shown below
1 - Warm Spring Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Riparian Woodland
4 - Riparian Shrubland
5 - Riparian Marsh
6 - Mesquite Bosque

Upper Muddy River
Geomorphic Assessment

Costs and Supporting Information Associated with Habitat Conservation and Restoration Recommendations

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Upper Muddy River Geomorphic Assessment

Costs and Supporting Information Associated with Habitat Conservation and Restoration Recommendations

1.0 Introduction

The primary goals of the UMR geomorphic assessment were to characterize key features of the river and its floodplain, assess the present geomorphic condition of the river, and to provide habitat restoration recommendations for the UMR valley. This document is intended to synthesize information presented in previously submitted deliverables and to distill the most relevant supporting information with regard to the recommendations for habitat conservation and restoration. This document presents recommendations for habitat conservation and restoration, costs associated with those recommendations, and information to support the recommendations for habitat conservation and restoration activities within the UMR valley. Habitat conservation efforts within the UMR should be prioritized as follows:

1) Protect the remaining and most important areas of habitat
2) Enhance the remaining habitat
3) Restore lost habitat

Obviously, opportunities to accomplish any one of the three above efforts should not be forgone in order to focus only on the priority of a higher level. In fact, these three effort levels are actually occurring simultaneously within the UMR. For example, legal protection of habitat has been accomplished through the acquisition of land on and in the vicinity of the former Perkins Ranch. Habitat enhancement is being completed by the removal of tamarisk and knapweed along the mainstem of the Muddy River and the removal/thinning of palm trees within the MVNWR. Finally, restoration of spring and spring channel habitat is underway and planned to continue within the MVNWR.

Habitat conservation and restoration recommendations, specific to individual characteristics, properties, and restoration needs within individual river segments are shown in Table 1. Restoration recommendations provided in Table 1 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. In addition, the recommendations provided for each river segment are limited to actions that are physically possible within each individual river segment. For example, the construction or enhancement of wetlands is limited to the river segments upstream from Warm Springs Road bridge where, although hydrologic conditions have been altered, areas of shallow groundwater and some standing water persists that would support enhanced or constructed wetlands.

In general, habitat conservation and restoration recommendations specific to 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 include efforts such as land acquisition, conservation easements, conservation agreements, the purchase of water rights to be used for wetland habitat preservation or creation, and the determination of flows required for the preservation of aquatic species within and riparian vegetation adjacent to both the spring channel tributaries and the mainstem of the Muddy River. Habitat restoration activities include the removal or control of invasive plant and fish species, revegetation, wetland enhancement and construction, and large scale channel reconstruction. Legal protection and large scale habitat restoration activities (construction) are typically the most expensive and effort intensive actions.

2.0 Habitat Conservation and Restoration Costs

The purpose of this document is to present a suite of approximate costs for habitat conservation and restoration recommendations that could be implemented within the UMR valley. The purpose of developing costs for habitat conservation and restoration recommendations is to define the approximate costs associated with implementation of the recommendations within distinct segments of the river.

2.1 Development of Habitat Conservation and Restoration Costs

Where possible, unit costs have been developed for individual habitat conservation and restoration recommendations. The preparation of each unit cost required certain assumptions regarding project size, design, duration, efficiency, work rate, equipment and crew size, and site conditions. Unit costs have been developed for the following categories of habitat conservation and restoration activities.

- Invasive vegetation removal
- Revegetation
- Invasive fish barriers on spring channel tributaries
- Spring pool and channel reconstruction
- Wetland construction
- Fish barriers on the mainstem river channel
- River channel reconstruction

The approximate unit costs and assumptions associated with the above habitat conservation and restoration activities are shown in Tables 2 through 7. Invasive vegetation control/removal, revegetation, and wetland construction are calculated on a per acre basis. Similarly, the costs associated with the categories of spring channel restoration and river channel reconstruction are provided on a per foot and per mile basis, respectively. The cost for construction and emplacement of invasive fish barriers on spring channels and the river channel is based on the cost per individual structure. These approximate costs are intended to be used for planning purposes. Projects and efforts of varying degrees of complexity and size are likely within the UMR valley. Therefore, preparation of individual restoration plans associated with each project, or a group of projects is required in order to specify project scale and objectives. In addition, a more detailed analysis of cost would be required prior to funding acquisition and project implementation due to the potential for a wide range of project sizes and complexities.

The development of costs in this manner is intended to provide approximate costs for specific habitat conservation and restoration activities. Therefore, the costs associated with specific restoration recommendations can be used individually or as components of a larger project that may include several habitat conservation and restoration activities. As noted above, these approximate costs are intended to be used for general planning purposes and the determination of relative level of cost for habitat conservation and restoration activities shown in Table 1. The implementation of habitat conservation and restoration activities at any single location within the UMR valley will require the consideration of specific details such as the physical setting and constraints, habitat conservation and restoration objectives, land and water rights ownership, and the temporal and spatial scale of the project to be implemented.

2.2 Explanation of Unit and Total Costs

A general explanation of the methods and logic used to determine approximate unit costs and total costs per river segment for habitat conservation and restoration recommendations is presented in the following sections. A general description of the assumptions associated with each recommendation is also provided. As stated previously, the preparation of each unit cost required certain assumptions regarding project size, design, duration, efficiency, work rate, equipment and crew size, and site conditions. Permitting costs, which may be required for certain activities, are not included due to the uncertainty in determining the scope and quantity of permitting efforts that could arise.

Total costs associated with implementation of individual habitat conservation and restoration recommendations for which unit costs were prepared are shown in Table 8. Detailed assumptions associated with the development of individual unit costs are provided in Tables 2 through 7. The presentation of tables within this document is intended to allow the reader to view the habitat conservation and restoration recommendations along with unit and total costs in Table 8. In addition, Tables 2 through 7 are provided in order to allow the reader access to the methods used and assumptions required for the development of the unit costs.

2.2.1 Knapweed Control with Goats

A unit cost has been provided (Table 2) for knapweed control implemented with goat grazing. Assumptions associated with knapweed control are provided in Table 2c. Due to the uncertainty regarding the density of knapweed, location of knapweed infestations, and total knapweed acreage, a total cost has not been determined. The daily knapweed removal rate and daily cost per goat is based on work completed by MRREIAC in 2004. Although the daily knapweed removal rate is relatively accurate, the annual removal rate may vary due to the fact that additional passes on approximately two to three week cycles may be required in order for successful knapweed control in heavily infested areas (Ann Schreiber, personal communication, 2004).

2.2.2 Manual Tamarisk Removal with Prison Crews

Both a unit and total cost for the manual removal of tamarisk throughout the UMR valley is provided. The daily work crew costs, tamarisk removal rate (based on 100 days per year at 0.3 acres/day), and average annual herbicide use shown in Table 2a are based on work completed by MRREIAC using prison work crews during 2004. In order to estimate a total cost for tamarisk removal adjacent to the river, tamarisk acreage was calculated using aerial photography and GIS. In order to simplify acreage quantification, the measurement of tamarisk acreage was limited to the area within 100 to 200 feet from the river channel. However, where a continuous thicket of tamarisk was evident, the area measured occasionally extended beyond this distance. Although the areas measured contain plant species in addition to tamarisk, field observation indicates that a large proportion of the plant community adjacent to the channel is composed of tamarisk. Therefore, this approach is suitable for the purpose of determining an approximate acreage within which crews would be working to remove tamarisk. In addition, it should be recognized that numerous, disperse patches of tamarisk are present throughout the UMR valley that are not located adjacent to the river channel. Therefore, this measurement is not intended to provide a quantification or approximate cost of removal for tamarisk in those areas.

2.2.3 Manual Tamarisk Removal with Standard Work Crews

Unit costs developed for manual tamarisk removal using standard work crews (Table 2b) are based on approximate labor rates ($16/hr for crew members and $30 for crew the boss) and an average tamarisk removal rate of 0.3 acres/day. For consistency and ease of comparison to prison work crews, the annual number of days worked by standard work crews was assumed to be 100 days. As would be expected, tamarisk removal by standard work crews is more expensive when compared to prison crew labor. The difference in cost between prison and standard work crews primarily is due to increased equipment and labor expenses.

2.2.4 Palm Tree Removal

The unit cost for palm tree removal is based on the approximate cost per tree removed during recent (Summer 2003) efforts completed within MVNWR. The $1,000 unit cost includes removal labor and off-site disposal by a professional landscaping or tree trimming contractor. This cost could be reduced if palm trees did not have to be hauled off-site or if removal was part of a larger habitat restoration project such as stream or spring channel reconstruction. A total cost has not been provided for palm tree removal due to the uncertainty regarding the number of palm trees that could be removed.

2.2.5 Revegetation Following Tamarisk Removal Activities

The unit costs and primary assumptions associated with revegetation are shown in Tables 3 and 3a. The cost associated with planning and design is for one acre of revegetation. Although planning, design, and implementation costs vary depending on project size, the per acre cost provided is similar to revegetation costs on other projects with which Otis Bay Inc. has been associated. Post project maintenance and weed control is not included in the cost provided. The approximate irrigation cost is based on one year of irrigation efforts. Maintenance and irrigation for up to 3 years is often required to increase the success rate of planting efforts and to allow planted material to become established without being impacted by the return of invasive plants. In addition, the assessment of soil conditions is not included in the unit costs. The assessment of soil conditions may be necessary in order to minimize planting mortality due to elevated soil salinity levels often common following site inhabitation by tamarisk for numerous years. The selection of plants suitable for highly saline soils may be necessary.

2.2.6 Invasive Fish Exclusion on Tributary Channels

The unit cost for fish barrier installation on tributary channels, shown in Table 4, is based on the cost of installation of gabion type fish barriers. The primary assumptions associated with the installation of fish barriers are provided in Table 4a. The cost associated with fish barriers for tributary channels has been limited to the gabion type barriers. Based on the size of barrier required for the tributary channels, it is reasonable to assume that a similar cost would be associated with other types of non-electric fish barriers, such as rolling drum barriers, if a different type of fish barrier was desired. Due to the uncertainty of power availability and logistics regarding land ownership, costs for electric fish barriers on the tributary channels are not provided. One gabion type fish barrier is present near the confluence of the Apcar channel and the mainstem of the Muddy River. The construction of gabion type fish barriers is only appropriate for installation on spring channel tributaries. Much larger, flood proof fish barriers would be required for installation on the river mainstem due to the potential for large magnitude floods. The description of fish barriers suitable for installation on the river mainstem is provided below in Section 2.2.9.

2.2.7 Spring Pool and Channel Restoration

Unit costs for spring pool and spring channel construction are shown in Tables 5 and 5a, respectively. The unit cost for spring channel construction was developed based on the amount of equipment and labor required to construct/restore 500 linear feet of spring channel. This is similar to the level of effort and project scale that has been completed to date within the MVNWR. In general, spring pool and spring channel restoration and construction projects are of a much smaller scale when compared to channel construction, wetland construction, or revegetation projects. Therefore, the cost unit must be decreased to square feet of spring pool surface and linear feet of spring channel. Differences in project scale could vary significantly depending on the number of spring sources or pools and the total length of spring channel to be restored or constructed. Due to the small project scale of spring pool and spring channel restoration compared to channel construction, wetland construction, or revegetation, costs associated with spring pool and spring channel restoration and construction largely are based on past experience of spring and spring channel restoration within the MVNWR.

Total costs for spring channel restoration within the UMR valley were obtained by measuring the channel lengths of the Apcar channel, the Refuge spring channel system that flows into the Apcar channel, the Muddy Spring channel, and the South Fork channel. The channel length is approximate and was obtained from aerial photography and GIS. Detailed surveys would be required to determine more accurate channel lengths. Due to the degree of modification, uncertainty regarding the present channel configuration, and uncertainty regarding the potential restored location, a length was not determined for the Cardy Lamb channel. The total cost for spring channel restoration, presented in Table 8, is based on the assumption that complete excavation and reconstruction would be required at all locations. This assumption is necessary due to the uncertainty regarding the degree of alteration and habitat quality decline at each location.

It is possible that certain spring channels or sections of individual spring channels would require less restoration or construction effort than that required elsewhere. In addition, it should be recognized that spring channel restoration has been completed within the Pederson unit of the MVNWR. Channel restoration within this section is largely complete with the possible exception of a portion of the channel system that remains as a concrete lined channel and future, minor enhancement of in-channel habitat. The approach and methods used for spring channel restoration will be unique at individual locations. Therefore, the costs provided are limited to actual excavation and construction of the spring channel. Costs for removing old recreational structures, palm trees, and tamarisk would be in addition to the construction costs provided.

2.2.8 Wetland Construction

Unit costs and assumptions associated with wetland construction are provided in Tables 6 and 6a. For calculation purposes, the unit cost is based on the equipment and labor required for the construction of a one acre wetland with an average depth of 5 feet. It is recognized that land ownership, site characteristics, and restoration objectives will dictate the size, location, and arrangement of restored wetlands. Furthermore, wetland construction will only be successful where hydrologic conditions are suitable for the maintenance of wetland habitat. A total cost for wetland construction within the UMR valley is not provided due to the uncertainty of total acreage that would be restored. Costs associated with permitting, land and water rights acquisition, and revegetation should be considered as additional to the unit cost for wetland construction.

2.2.9 Invasive Fish Exclusion on the Mainstem River Channel

In order to prevent invasive fish species from being reintroduced and to prevent the fish barrier from being destroyed or compromised during flood events, fish barrier construction on the river mainstem would be much larger than those that would be installed on the spring channel tributaries. A fish barrier constructed on the mainstem of the Muddy River would need to be a permanent structure. In addition, if channel construction were to occur, the design and planning phase of fish barrier installation should consider how the structure would be incorporated into large scale channel construction activities.

Two types of barriers that could be suitable for the mainstem are rolling drum barriers or a much larger structure such as a roller compacted concrete dam. A rolling drum barrier would be suitable in the vicinity of Warm Springs Road bridge while a rolling drum or a roller compacted concrete dam would be suitable at White Narrows. Approximate costs for rolling drum barrier installation at Warm Springs Road and White Narrows is provided in Table 8. Although a structure such as a roller compacted concrete dam is expensive and may not be desired in the UMR valley, the structure could be designed to allow floods to pass through the valley with limited impoundment and could also serve as a grade control structure as part of a large scale channel reconstruction effort. An estimated cost, based on typical, large scale, earthen structures of the approximate size that would be required at White Narrows has been provided in Table 8. This cost is approximate and a detailed cost estimate has not been provided with the recommendation.

2.2.10 River Channel Construction

The unit cost and assumptions for channel reconstruction are presented in Tables 7 and 7a. In order to calculate the amount of earthwork required for channel construction, the assumption of a channel cross sectional area was required. This channel cross section is based on a general approximation of the present width of the water surface within the channel (35-40 feet) and an approximation of the depth of channel from the top of bank to bottom of channel (8 feet) that would be required to result in more frequent overbank flooding (approximately every 5-10 years). This combination of width and depth resulted in the assumption that the average cross sectional area of the constructed channel would be 295 ft^2. The channel design implemented could differ due to site constraints, hydrologic characteristics, and detailed design parameters obtained from future design studies that would be necessary prior to the implementation of such a large scale project.

Due to the entrenched nature of the present channel, the potential for channel construction exists within all of the mainstem river segments. However, the estimation and presentation of a total cost for channel construction provided in Table 8 is limited to Segment 3 where sufficient, federally owned land is present for consideration of such a large scale restoration effort. It should be recognized that channel reconstruction is a significant endeavor and extensive planning would be required in order to successfully implement channel construction in disconnected portions of the UMR valley and to formulate a channel construction design for all of the locations that would be suitable such that the constructed channel would be sustainable and appropriate relative to the current hydrologic and sediment supply regimes, site constraints, and restoration objectives.

2.2.11 Land and Water Rights Acquisition

It is recognized that land acquisition and conservation easements or agreements will be required in order for certain restoration efforts to occur on private lands, such as large scale channel reconstruction, spring channel restoration, and wetland construction or enhancement. In addition, water rights may be required for many of the above activities. However, due to the potentially wide range of costs for land and water within the UMR valley, a unit cost for these items is not presented. Based on recent land sales within the valley, land costs range from $5,000 to $15,000 per acre for 40 acre parcels. Recent groundwater rights were purchased for $3,000 per acre foot (Rob Scanland, personal communication, 2004). Land costs for parcels purchased within the UMR valley through the Southern Nevada Public Lands Management Act also reflect a similar average cost per acre as provided above. Parcel size is a significant factor influencing the cost per acre for land. Furthermore, the acquisition of lands for the purpose of creating a conservation corridor, or the purchasing of multiple parcels within the 100-year floodplain could result in a higher than average cost per acre due to the large amount of land and additional costs associated with acquiring land from numerous land owners.

If land acquisition is completed for the purpose of protecting habitat within the UMR, the process of direct acquisition, conservation easements, or conservation agreements will occur on a case by case basis and over a long period of time. The price of each parcel has the potential to vary widely due primarily to the following two reasons; 1) the differences in market value per acre of individual parcels resulting from parcel qualities such as location and desirability and 2) the changes in market value of individual parcels over the long time frame within which acquisition throughout the UMR valley would occur.

In addition, the primary question that arises when considering land and water rights acquisition for the purpose of habitat protection is “how much land and how much water is required?”. Because this question is beyond the scope of this project, and due to the complexity of calculating costs for land and water acquisition, costs are not calculated for legal protection of habitat through the purchase of land and water rights. Therefore, land and water costs should be considered as additional costs to habitat conservation and restoration efforts that may require the acquisition of land and water.

3.0 Supporting Information Associated with Habitat Conservation and Restoration Recommendations

The Muddy River creates and supports a desert riparian area. Riparian areas are the most rich and diverse habitats in the arid west due primarily to the presence of water. Riparian areas comprise only 1% of the landscape throughout the west and have been reduced by as much as 80% since European settlement (Smith et al., 1991) while numerous vertebrate species in the west use riparian areas during at least one stage of their lifecycle. In addition, the UMR valley contains open space and the potential for the preservation of that open space if so desired by the local community. Furthermore, preservation of open space would promote the continued existence of a rural character and lifestyle.

The following sections provide supporting information and justification for costs associated with the implementation of habitat restoration and conservation recommendations. Supporting information is provided for the following categories of habitat conservation and restoration activities.

- Invasive vegetation removal and revegetation
- Spring pool and channel restoration
- Wetland construction
- Invasive fish exclusion from tributary channels and mainstem river channel
- River channel construction
- Land and water rights acquisition

3.1 Invasive Vegetation Removal and Revegetation

Tamarisk, Russian knapweed, and palm trees pose a significant threat to the sustainability of the desert riparian ecosystem within the UMR valley. Both Russian knapweed and tamarisk are designated noxious weeds in the state of Nevada. The long tap root of tamarisk allows the plant to intercept shallow groundwater at greater depths than most native plants and thus interferes with natural aquatic systems by utilizing large quantities of a limited resource. Tamarisk infestation often results in the complete displacement of native riparian and wetland vegetation due to the ability of tamarisk to spread rapidly, high rates of water consumption, and the tendency of tamarisk to increase the salinity of the soil.

Russian knapweed also disrupts the desert riparian ecosystem. Russian knapweed spreads rapidly through a combination of adventitious shoots and allelopathic compounds that inhibit the growth of native plants. These compounds, contained in the roots, have been shown to persist in the soil for several years. The rapid spread of knapweed can largely be attributed to its ability to reproduce vegetatively. The depth of the Russian knapweed root system can exceed 2.5 meters while horizontal roots can extend greater than seven meters. The plants grow radially in all directions and are capable of covering an area of 12 m^2 within two years (Watson, 1980). The growth pattern and presence of allelopathic compounds can result in the rapid formation of a Russian knapweed monoculture.

The presence of dense stands of palm trees adjacent to the spring channels prevents the recruitment of native vegetation and results in an increased rate of water consumption. The loss of suitable habitat for the Moapa dace and native aquatic species occurs as palm roots and fronds fill the spring channels. The accumulation of large amounts of vegetative debris from the palm trees as well as the filling of the spring channels with palm roots results in overland sheeting of water. The spreading of water overland, rather than maintaining the water in the original channel, results in a loss of habitat and thermal load. Loss of thermal load results in an increased rate of cooling in the downstream direction and the subsequent loss of suitable habitat for the native and thermal endemic species within the UMR valley.

The invasion of native plant communities by non-native species can affect native ecosystems by altering fire regimes (intensity and frequency of fires) and soil nutrient availability such that native species can no longer adapt (Brooks et al., 2004). Dense growth of tamarisk and palm trees, as well as the accumulation of large amounts of vegetative debris, creates the potential for large and destructive fires resulting in an unnatural fire regime within the UMR valley. Furthermore, dense stands of palm and tamarisk and large areas of Russian knapweed reduce habitat complexity and diversity.

Tamarisk removal would improve riparian corridor conditions and promote the recruitment of mesquite, cottonwood, and willow. The removal or thinning of palms in the vicinity of the spring channels will result in a more open canopy above the channels and likely result in an increase in primary production and improved feeding and reproductive conditions for the Moapa dace. Finally, invasive plant species removal and control would improve habitat availability for species within all of the priority conservation targets or assemblages.

3.2 Spring Pool and Channel Restoration

The preservation and restoration of spring pool and channel habitat is essential for the recovery of the Moapa dace. 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. Successful reproduction is only known to occur in the warmer waters of the spring channels. 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 (Scoppettone et al., 1987, 1992). The thermal 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. Therefore, suitable habitat within the headwater springs, tributaries, and mainstem of the river is necessary for the recovery and sustainability of the Moapa dace population.

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. All of the headwater springs and channels that represent the historic range of the Moapa dace 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 and 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 while 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. However, 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 the headwater springs and associated spring channels. 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 the headwater springs and associated spring channels. Although the human uses of these spring systems should be maintained, protection and enhancement of this unique resource is necessary. Presently, only the portions of the Warm Springs and Apcar channels that are located within the boundaries of the MVNWR are provided legal protection.

3.3 Wetland Construction

Historical decline in the alluvial aquifer due to 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. The disconnection of the channel and floodplain, due to channel incision, limits potential scour throughout the floodplain and subsequent revitalization and creation of wetlands. Wetland construction would promote an increase in habitat for the species within the Riparian Woodland, Riparian Shrubland and Riparian Marsh Assemblages.

3.4 Invasive Fish Exclusion from Tributary Channels and Mainstem River Channel

The presence of Tilapia is the primary threat to the recovery of the Moapa dace. The presence of Tilapia within the mainstem limits the size of the Moapa dace population and reduces the amount of suitable habitat for the Moapa dace. Therefore, 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. In addition, eradication of Tilapia from the headwater tributaries and the mainstem of the Muddy River above Warm Springs Road should also 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.

3.5 River Channel Construction

Historic changes to the channel and hydraulic habitat represent the greatest impacts to the river channel and floodplain. Channel incision has resulted in the disconnection of the channel from 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 resulting in vegetative encroachment and crowding adjacent to the channel. 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.

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. 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.

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 watershed, 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).

River channel construction would result in more frequent overbank flow events and the associated processes of scour and deposition that create surfaces necessary for the recruitment of native riparian vegetation. Restoring geomorphic process and function would result in a wider riparian zone. The increase in channel elevation associated with river channel construction would improve shallow groundwater conditions and promote the establishment of native riparian vegetation. It should be recognized that river channel construction may also require the acquisition of land and water rights and the implementation of invasive species control efforts. River channel construction would promote the recovery of the Muddy River Aquatic, Riparian Woodland, Riparian Shrubland, Riparian Marsh, and Mesquite Bosque Assemblages.

3.6 Land and Water Rights Acquisition

Legal protection of land and water for the purpose of habitat preservation is a necessary step to maintaining and restoring the desert riparian ecosystem within the UMR valley. Without legal protection of crucial lands and habitat in the form of conservation easements, conservation agreements, or fee title acquisition, continued degradation or alteration of the UMR conservation targets will likely occur. The acquisition of additional areas for the purpose of preserving and recovering the Moapa dace will support the preservation and restoration of the desert riparian ecosystem within the UMR valley.

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. 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 a defined instream flow 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.

4.0 Conclusions

The overall purpose of the Upper Muddy River Geomorphic Assessment was to characterize key features of the river and its floodplain, asses the present geomorphic condition of the river, and to provide habitat restoration recommendations for the UMR valley. Thus, the human aspect of the area, or how humans fit into the need for desert riparian ecosystem preservation was not a direct task in the assessment. However, to complete the assessment and not recognize the presence of the local population as well as their input and needs would result in an incomplete assessment of the area. It should be recognized that prior to the implementation of any of the recommendations provided as part of the assessment, community input and public involvement will occur.

The preservation and restoration of the desert riparian ecosystem within the UMR valley has the potential to create significant benefits for individuals that live in the valley as well as individuals that live elsewhere. The preservation and restoration of habitat can prevent endangered species listings which make private land use decisions problematic and often costly. The establishment of conservation easements and agreements can lead to the recovery of threatened, endangered, and sensitive species which has both economic and ecologic ramifications. Finally, the preservation and restoration of habitat can enhance the local quality of life by creating a recreation corridor for compatible uses and wildlife dependent activities.

The protection and restoration of habitat within the UMR valley will result in the preservation of the rural lifestyle that presently exists. If a rural lifestyle is desired by the majority of individuals in the community, then the preservation of open space and the riparian corridor is necessary. Preventing development within the floodplain, and the subsequent need for flood control structures, will provide the space needed to accommodate floods, promote the recovery of the riparian ecosystem, and preserve the rural lifestyle. Often, the value of living in a place such as the UMR valley is an unquantifiable feature often referred to as a sense of place. Part of that sense of place is related to the surrounding landscape, how one interacts and views the landscape, the plant and animal communities that occur within the landscape, the human, regional, and biological heritage of the area, and the value that an individual places on their surroundings. Riparian ecosystem restoration promotes the preservation of the surrounding landscape as well as the regional and biological heritage.

5.0 References

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Appendix II.A

Tables

Table 1. Upper Muddy River habitat conservation and restoration recommendations.

Segment	Relative Level of Effort and Cost	Recommendation	Priority Conservation Targets Captured*
1 - I-15 Bridge to Reid Gardner RR Bridge			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	3, 4, and 5
	Medium	Conservation easement for floodplain real estate	3, 4, 5, and 6
	High	Acquisition of Hidden Valley Dairy pond and surrounding wetland	3, 4, and 5
	High	Acquisition of floodplain real estate	3, 4, and 6
2 - Reid Gardner RR Bridge to White Narrows			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	variable
	Medium	Revegetation following tamarisk removal activities	variable
	Medium	Revegetation following invasive vegetation removal activities	3 and 4
	High	Construction of permanent grade control structure and rolling drum fish barrier at White Narrows	1 and 2
	High	Construction of permanent grade control structure and fish barrier at White Narrows	1 and 2
	High	Establishment of buffer zone between agricultural fields and river	3 and 4
3 - White Narrows to Warm Springs Road			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements for remaining floodplain real estate	3, 4, 5, and 6
	Medium	Acquisition of remaining floodplain real estate	3, 4, 5, and 6
	High	Complete reconstruction of channel within BLM property	2, 3, 4, 5, and 6
	High	Removal of flood/silt control dams on tributary washes	2, 3, and 4

Table 1 continued. Upper Muddy River habitat conservation and restoration recommendations.

4 - Warm Springs Road to Warm Springs-Muddy River Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3 and 4
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1 and 2
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	3, 4, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on Muddy Spring channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 2, 3, 4, 5, and 6
	Medium	Conservation easements within Muddy Spring area/LDS recreation area	1, 2, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Spring channel restoration of Muddy Spring channel	1, 2, 3, 4, and 5
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6

Table 1 continued. Upper Muddy River habitat conservation and restoration recommendations.

6 - Warm Springs-Muddy River Confluence to Warm Springs			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 2, 3, 4, and 5
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Defined instream flows for Moapa Valley NWR spring channels	1 and 2
	Medium	Defined instream flows for Apcar channel	1 and 2
	High	Spring channel restoration of Plummer channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration of Apcar channel within Moapa Valley NWR	1, 2, 3, 4, and 5
	High	Spring channel restoration within Warm Springs Ranch (Refuge and Apcar channels)	1, 2, 3, 4, and 5
	High	Conservation easements along spring channels on Warm Springs Ranch	1, 2, 3, 4, and 5
	High	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	1, 2, 3, 4, and 5
	High	Development of public use and education areas/trails within Moapa Valley NWR	non-habitat benefits, public outreach
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
7 - North-South Fork Confluence to North Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	1, 3, 4, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	1, 2, 3, 4, 5, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6

Table 1 continued. Upper Muddy River habitat conservation and restoration recommendations.

8 - North-South Fork Confluence to South Fork Headwaters			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	1, 3, 4, 5, and 6
	Medium	Palm tree removal	1, 2, 3, 4, and 5
	Medium	Revegetation following tamarisk removal activities	3, 4, 5, and 6
	Medium	Invasive fish exclusion on South Fork channel	1 and 2
	Medium	Invasive fish exclusion on Cardy Lamb channel	1 and 2
	Medium	Conservation easements throughout Warm Springs Ranch	1, 3, 4, 5, and 6
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	3, 4, and 5
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	1, 2, 3, 4, 5, and 6
9 - North Fork Headwaters to Arrow Canyon			
	Low	Knapweed control with goats	1, 2, 3, 4, and 5
	Low	Manual tamarisk removal	4 and 6
	Medium	Revegetation following tamarisk removal activities	3, 4, and 6
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	1, 2, 3, 4, 5, and 6

* Individual conservation targets shown below
1 - Warm Spring/Stream Aquatic Assemblage
2 - Muddy River Aquatic Assemblage
3 - Interior Riparian Woodland
4 - Interior Riparian Shrubland
5 - Interior Riparian Marsh
6 - Mesquite Bosque

Table 2. Upper Muddy River invasive vegetation removal cost estimate.

Purpose: develop approximate cost per acre for knapweed removal performed by goat grazing

Implementation	**Quantity**	**Cost/Unit**	**Daily Total**	**Annual Total**
Goats (100 days for herd of 200 goats)	200	$2.50	$500.00	$50,000.00
Subtotal				$50,000.00
Annual Knapweed Removal Rate	**Days/Year**	**Acres/Day**	**Acres/Year**	
	100	0.5	50	
Total per acre cost			**$1,000.00**	

Table 2a. Upper Muddy River invasive vegetation removal cost estimate.

Purpose: develop approximate cost per acre for tamarisk removal performed by prison work crews

Implementation	**Quantity**	**Cost/Unit**	**Annual Total**
Labor (100 days for 12 person crew)	100	$800.00	$80,000.00
Garlon 4 (gallons)	125	$80.00	$10,000.00
Subtotal			$90,000.00
Annual Tamarisk Removal Rate	**Crew Days/Year**	**Acres/Day**	**Acres/Year**
	100	0.3	33
Total per acre cost			**$2,700.00**

Table 2b. Upper Muddy River invasive vegetation removal cost estimate.

Purpose: develop approximate cost per acre for tamarisk removal performed by standard work crews

Equipment and Maintenance	**Quantity**	**Cost/Unit**	**Annual Total**
Chainsaws, fuel, oil, and assorted tools (L.S.)	1	$5,000.00	$5,000.00
Personal protection equipment (L.S.)	1	$2,000.00	$2,000.00
Subtotal			$7,000.00
Implementation	**Quantity**	**Cost/Unit**	**Annual Total**
Labor (100 days for 12 person crew)	100	$1,536.00	$153,600.00
Labor (100 days for crew boss)	100	$240.00	$24,000.00
Garlon 4	125	$80.00	$10,000.00
Subtotal			$187,600.00
Annual Tamarisk Removal Rate	**Crew Days/Year**	**Acres/Day**	**Acres/Year**
	100	0.3	33
Total per acre cost			**$5,838.00**

Table 2c. Assumptions associated with invasive vegetation removal.

Assumptions	
General Assumptions	Costs not included for permitting or NEPA requirements if activities completed on federally owned lands. Prison work crew rates based on work completed by MRREIAC. Standard work crew rates based on $16/hr crew member hourly wage and $30/hr crew boss hourly wage. Annual work days for both prison crews and standard work crews based on 100 annual work days completed by MRREIAC. 100 day work unit selected in order to compare per acre cost of both prison and standard work crews. Annual tamarisk removal rate for both prison and standard work crews based on average acres cleared per day during MRREIAC activities. Annual tamarisk removal rate may vary depending on days worked, crew size, site conditions, and tamarisk density.
Manual tamarisk removal - Prison Work Crews	
Implementation	Daily crew rate based on current rate paid by MRREIAC for 12 person prison crew. Equipment costs included in hourly crew rate. Garlon 4 price based on 2004 prices and average annual usage during MRREIAC activities. Annual tamarisk removal rate based on 100 crew days per year.
Manual tamarisk removal - Standard Work Crews	
Equipment and Maintenance	Equipment costs based on approximate cost associated with equipment for 12 person crew.
Implementation	Daily crew rates based on $16/hr crew member hourly wage and $30/hr crew boss hourly wage for an 8 hour day. Garlon 4 price based on 2004 prices and average annual usage during MRREIAC activities. Annual tamarisk removal rate based on 100 crew days per year.
Knapweed Removal	
Implementation	100 day work unit selected in order to maintain similarity in cost estimate between manual tamarisk control and control of knapweed by goat grazing. Herd size and daily rate per goat based on knapweed control efforts completed by MRREIAC. Knapweed removal rate based on average acres controlled per day during MRREIAC efforts.

Table 3. Upper Muddy River revegetation cost estimate.

Purpose: develop approximate cost per acre for revegetation on the UMR

Revegetation	**Unit/Acre**	**Cost/Unit**	**Total**
Revegetation planning and design (hours)	40	$75.00	$3,000.00
Planting materials (individual plants)	500	$4.00	$2,000.00
Installation labor (hours)	50	$12.00	$600.00
Planting crew direction and oversight (hours)	15	$75.00	$1,125.00
Subtotal			$6,725.00
Irrigation	**Unit/Acre**	**Cost/Unit**	**Total**
Installation labor (hours)	80	$15.00	$1,200.00
Sprinkler and drip irrigation supplies (L.S.)	1	$500.00	$500.00
Operation and maintenance (hours)	200	$15.00	$3,000.00
Subtotal			$4,700.00
Total per acre cost			**$11,425.00**

Table 3a. Assumptions associated with revegetation.

Assumptions	
Re-vegetation	Cost not included for soil assessment that may be necessary to determine suitable plants for specific project location. Assumes both soil and hydrologic conditions are suitable for desired type of revegetation. Assumes planting densities at 500 plants per acre on all suitable sites. Cost not included for post-planting weed control and maintenance.
Irrigation	Assumes water/water rights available for irrigation. Assumes sprinkler and drip irrigation systems of planted sites. Continued operation and maintenance of irrigation program often required for 2-3 years following the completion of construction and planting. Per acre cost for operation and maintenance based on salaried individual employed for one year and maintaining 10 acres of irrigation works.

Table 4. Upper Muddy River tributary fish barrier construction cost estimate.

Purpose: develop approximate cost for gabion type fish barrier construction on tributaries of the UMR

Construction Activities	**Days**			
Construct and install gabion type fish barrier	5			
Equipment	**Quantity**	**Hrly Cst w\Oprtr**	**Weekly Cost**	**Total**
Cat 320 Excavator	1	$130.00	$6,500.00	$6,500.00
Service Truck\Forman	1	$95.00	$2,375.00	$2,375.00
Subtotal			$8,875.00	$8,875.00
Implementation	**Quantity**	**Cost/Unit**		**Total**
Mobilization (Transported Equipment)	1	$600.00		$600.00
Construction Oversight (Weeks) (1 senior staff)	1	$7,500.00		$7,500.00
Planning and Design (L.S.)	1	$2,500.00		$2,500.00
Surveying (L.S.)	1	$500.00		$500.00
Rock material (tons)	10	$15.00		$150.00
Subtotal				$11,250.00
Total cost				**$20,125.00**

Table 4a. Assumptions associated with fish barrier construction.

Assumptions	
Construction Activities	Costs not included for site preparation which could include palm removal, demolition of former structures, and offsite disposal of debris.
	Assumes approximately 1 week required for construction of gabion type fish barrier.
	Actual barrier design may differ due to site constraints or agency needs/requirements.
	Costs associated with the offsite hauling and disposal of soils not included.
Equipment	
Equipment hourly rates	Equipment rates include machine and operator
Weekly cost	Assumes 10 hr days, 50 hrs per week
Cat 320 Excavator	1 machine full time, 50 hrs per week
Service Truck\Forman	1 machine, one operator, half time, 25 hrs per week
Implementation	
Mobilization (Transported Equipment)	Assumes local supplier.
Construction Oversight (1 person)	Ensures that designs are accurately constructed, includes full time at 50 hrs per week.
Planning and Design (L.S.)	Does not include engineered/stamped drawings.
	Costs not included for permitting requirements.
Surveying (L.S.)	Includes minimum surveying required for planning and design.
Rock material	Quantity may vary based on site conditions and design requirements.

Table 5. Upper Muddy River spring pool construction cost estimate.

Purpose: develop approximate cost per square foot of spring pool construction on the UMR

Construction Activities	**Area (ft^2)**	**Depth (ft)**	**Cubic Yards (yds^3)**	**Days**
Cut	100	3	11	2
Pool shaping/construction				2
Equipment	**Quantity**	**Hrly Cst w\Oprtr**	**Weekly Cost**	**Total**
Cat 320 Excavator	1	$130.00	$6,500.00	$6,500.00
973 Loader	1	$150.00	$7,500.00	$7,500.00
4000 gal Water Truck	1	$76.00	$3,800.00	$3,800.00
Service Truck\Forman	1	$95.00	$2,375.00	$2,375.00
Subtotal			$20,175.00	$20,175.00
Implementation	**Quantity**	**Cost/Unit**		**Total**
Mobilization (Transported Equipment)	3	$600.00		$1,800.00
Construction Oversight (Weeks) (1 person)	1	$7,500.00		$7,500.00
Construction Oversight (Weeks) (1 field technician)	1	$3,750.00		$3,750.00
Planning and Design (L.S.)	1	$3,500.00		$3,500.00
Surveying (L.S.)	1	$1,000.00		$1,000.00
Subtotal				$17,550.00
Total cost per 100 square feet of constructed spring				**$37,725.00**
Approximate cost per square foot of constructed spring				**$377.25**

Table 5a. Upper Muddy River spring channel construction cost estimate.

Purpose: develop approximate cost per foot for spring channel construction on the UMR

Construction Activities	**Area (ft^2)**	**Length (ft)**	**Cubic Yards (yds^3)**	**Days**
Cut	12	500	222	4
Channel shaping/construction				6
Equipment	**Quantity**	**Hrly Cst w\Oprtr**	**Weekly Cost**	**Total**
Cat 320 Excavator	1	$130.00	$13,000.00	$26,000.00
973 Loader	1	$150.00	$7,500.00	$15,000.00
4000 gal Water Truck	1	$76.00	$3,800.00	$7,600.00
Service Truck\Forman	1	$95.00	$2,375.00	$4,750.00
Subtotal			$26,675.00	$53,350.00
Implementation	**Quantity**	**Cost/Unit**		**Total**
Mobilization (Transported Equipment)	3	$600.00		$1,800.00
Construction Oversight (Weeks) (1 senior staff)	2	$7,500.00		$15,000.00
Construction Oversight (Weeks) (1 field technician)	2	$3,750.00		$7,500.00
Planning and Design (L.S.)	1	$7,500.00		$7,500.00
Surveying (L.S.)	1	$2,000.00		$2,000.00
Boulders/Gravel (tons)	25	$15.00		$375.00
Subtotal				$34,175.00
Total cost per 500 feet of constructed channel				**$87,525.00**
Approximate cost per foot of constructed channel				**$175.05**

Table 5b. Assumptions associated with spring pool construction.

Assumptions	
Construction Activities	Costs not included for site preparation which could include palm removal, demolition of former structures, and offsite disposal of debris. Assumes approximately 1 week required for construction of 100 square foot spring pool, average depth 3 feet. Actual spring pool design may differ due to site constraints, hydrologic characteristics, restoration objectives, and more detailed design studies. Costs associated with the offsite hauling and disposal of soils not included. Costs not included for revegetation design/planning, revegetation efforts, or weed control. Costs not included for purchase of water rights or water delivery system/structure.
Equipment	
Equipment hourly rates	Equipment rates include machine and operator
Weekly cost	Assumes 10 hr days, 50 hrs per week
Cat 320 Excavator	1 machine full time, 50 hrs per week
973 Loader	1 machine full time, 50 hrs per week
4000 gal Water Truck	1 machine full time, 50 hrs per week
Service Truck\Forman	1 machine, one operator, half time, 25 hrs per week
Implementation	
Mobilization (Transported Equipment)	Assumes local supplier
Construction Oversight (2 persons)	Ensures that designs are accurately constructed, includes full time at 50 hrs per week
Planning and Design (L.S.)	Includes restoration design plan. Does not include engineered/stamped drawings. Does not include revegetation planning/design. Costs not included for permitting requirements.
Surveying (L.S.)	Includes minimum surveying required for planning and design.

Table 5c. Assumptions associated with spring channel construction.

Assumptions	
Construction Activities	Costs not included for site preparation which could include palm removal, demolition of former structures, and offsite disposal of debris.
	Assumes approximately 2 weeks required for construction of 500 linear feet of channel, average width 4 feet, average depth of 3 feet.
	Actual channel design may differ due to site constraints, hydrologic characteristics, restoration objectives, and more detailed design studies.
	Costs associated with the offsite hauling and disposal of soils not included.
	Costs not included for revegetation design/planning, revegetation efforts, or weed control.
	Costs not included for purchase of water rights or water delivery system/structure if required.
Equipment	
Equipment hourly rates	Equipment rates include machine and operator
Weekly cost	Assumes 10 hr days, 50 hrs per week
Cat 320 Excavator	1 machine full time, 50 hrs per week
973 Loader	1 machine full time, 50 hrs per week
4000 gal Water Truck	1 machine full time, 50 hrs per week
Service Truck\Forman	1 machine, one operator, half time, 25 hrs per week
Implementation	
Mobilization (Transported Equipment)	Assumes local supplier.
Construction Oversight (2 persons)	Ensures that designs are accurately constructed, includes full time at 50 hrs per week.
Planning and Design (L.S.)	Includes restoration design plan. Does not include engineered/stamped drawings.
	Does not include revegetation planning/design.
	Costs not included for permitting requirements.
Surveying (L.S.)	Includes minimum surveying required for planning and design.
Boulders/Gravel	Quantity may vary based on site conditions and design requirements.

Table 6. Upper Muddy River wetland construction cost estimate.

Purpose: develop approximate cost per acre for wetland construction.

Construction Activities	**Area (ft^2)**	**Depth (ft)**	**Cubic Yards (yds^3)**	**Days**	**Months**
Cut	43,560	5	8,067	13	0
Fill			8,067	13	0
Equipment	**Quantity**	**Hrly Cst w\Oprtr**	**Monthly Cost**	**Total**	
Cat 320 Excavator	1	$130.00	$26,000.00	$26,000.00	
973 Loader	1	$150.00	$7,500.00	$7,500.00	
D400 Articulating Dump Truck	1	$145.00	$29,000.00	$29,000.00	
Dozer	1	$130.00	$6,500.00	$6,500.00	
4000 gal Water Truck	1	$76.00	$7,600.00	$7,600.00	
Service Truck\Forman	1	$95.00	$9,500.00	$9,500.00	
Subtotal			$86,100.00	$86,100.00	
Implementation	**Quantity**	**Cost/Unit**		**Total**	
Mobilization (Transported Equipment)	5	$600.00		$3,000.00	
Construction Oversight (Month) (1 senior staff)	1	$30,000.00		$30,000.00	
Planning and Design (L.S.)	1	$20,000.00		$20,000.00	
Surveying (L.S.)	1	$2,000.00		$2,000.00	
Subtotal				$55,000.00	
Total per acre cost				**$141,100.00**	

Table 6a. Assumptions associated with wetland construction.

Assumptions	
Construction Activities	Assumes approximately 1 month required for construction of 1 acre wetland, average depth of 5 feet. Costs not included for revegetation design/planning, revegetation efforts, or weed control. Costs not included for permitting requirements. Wetland design based on average depth of 5 feet. Actual wetland design may differ due to site constraints, hydrologic characteristics, restoration objectives, and more detailed design studies. Costs associated with the offsite hauling and disposal of soils that cannot be disposed of on site or used to create topography are not provided in this estimate. Costs not included for purchase of water rights or water delivery system/structure.
Equipment	
Equipment hourly rates	Equipment rates include machine and operator
Monthly cost	Assumes 10 hr days, 200 hrs per month
Cat 320 Excavator	1 machine full time, 200 hrs per month
973 Loader	1 machine quarter time, 50 hrs per month
D400 Articulating Dump Truck	1 machine full time, 200 hrs per month
Dozer	1 machine quarter time, 50 hrs per month
4000 gal Water Truck	1 machine half time, 100 hrs per month
Service Truck\Forman	1 machine, one operator, half time, 100 hrs per month
Implementation	
Mobilization (Transported Equipment)	Assumes local supplier.
Construction Oversight (1 person)	Ensures that designs are accurately constructed, includes full time at 200 hrs per month.
Planning and Design (L.S.)	Includes restoration design plan. Does not include engineered/stamped drawings. Does not include revegetation planning/design.
Surveying (L.S.)	Includes minimum surveying required for planning and design.

Table 7. Upper Muddy River channel construction cost estimate.

Purpose: develop approximate cost per mile for channel construction on the UMR

Construction Activities	**Area (ft^2)**	**Length (ft)**	**Cubic Yards (yds^3)**	**Days**	**Months**
Cut	295	5,280	57,689	90	3
Fill			57,689	90	3

Equipment	**Quantity**	**Hrly Cst w\Oprtr**	**Monthly Cost**	**Total**
Cat 320 Excavator	2	$130.00	$52,000.00	$312,000.00
973 Loader	1	$150.00	$15,000.00	$90,000.00
D400 Articulating Dump Truck	2	$145.00	$58,000.00	$348,000.00
Dozer	1	$130.00	$13,000.00	$78,000.00
4000 gal Water Truck	1	$76.00	$15,200.00	$91,200.00
Service Truck\Forman	1	$95.00	$19,000.00	$114,000.00
Additional Operators	1	$42.00	$8,400.00	$50,400.00
Service Truck	1	$90.00	$9,000.00	$54,000.00
Subtotal			$189,600.00	$1,137,600.00

Implementation	**Quantity**	**Cost/Unit**		**Total**
Mobilization (Transported Equipment)	8	$600.00		$4,800.00
Construction Oversight (Month) (1 senior staff)	6	$30,000.00		$180,000.00
Planning and Design (L.S.)	1	$150,000.00		$150,000.00
Surveying (L.S.)	1	$10,000.00		$10,000.00
Subtotal				$344,800.00
Total per mile cost				**$1,482,400.00**

Table 7a. Assumptions associated with channel construction.

Assumptions	
Construction Activities	Cut quantities based on channel design of average cross sectional area of 295 ft^2. Actual channel design may differ due to site constraints, hydrologic characteristics, and more detailed design studies and resultant design parameters. Cut and fill quantities indicate approximately 6 months will be required to complete one mile of channel construction. Time required to cut and fill estimated based on 15 min. round trip haul time. Costs estimated for planning, design, and channel construction. Costs not included for channel materials such as cobbles or gravels. Costs not included for revegetation efforts. Costs not included for permitting requirements. Costs associated with the offsite hauling and disposal of soils that cannot be disposed of in the former channel or used to create topography are not provided in this estimate.
Equipment	
Equipment hourly rates	Equipment rates include machine and operator
Monthly cost	Assumes 10 hr days, 200 hrs per month
Cat 320 Excavator	2 machines full time, 200 hrs per month
973 Loader	1 machine half time, 100 hrs per month
D400 Articulating Dump Truck	2 machines full time, 200 hrs per month
Dozer	1 machine half time, 100 hrs per month
4000 gal Water Truck	1 machine full time, 200 hrs per month
Service Truck\Forman	1 machine, one operator, full time, 200 hrs per month
Additional Operators	1 additional operator, full time, 200 hrs per month
Service Truck	1 machine, half time, 100 hours per month
Implementation	
Mobilization (Transported Equipment)	Assumes local supplier
Construction Oversight (1 person)	Ensures that designs are accurately constructed, includes full time at 200 hrs per month
Planning and Design (L.S.)	Includes restoration design plan. Does not include engineered/stamped drawings. Costs for land and water acquisition, if required, should be considered as an additional cost. Does not include development of CCRFCD approved hydraulic model.
Surveying (L.S.)	Includes minimum surveying required for planning and design

Table 8. Costs associated with Upper Muddy River habitat conservation and restoration recommendations.

Segment	Relative Level of Effort and Cost	Recommendation	Quantity	Unit	Unit Cost	Total
1 - I-15 Bridge to Reid Gardner RR Bridge						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	160	Acre	$2,700	$432,000
	Low	Manual tamarisk removal with standard work crews	160	Acre	$5,838	$934,080
	Medium	Revegetation following tamarisk removal activities	160	Acre	$11,425	$1,828,000
	Medium	Conservation easement for Hidden Valley Dairy Pond and surrounding wetland	ND	ND	ND	ND
	Medium	Conservation easement for floodplain real estate	ND	ND	ND	ND
	High	Acquisition of Hidden Valley Dairy pond and surrounding wetland	ND	ND	ND	ND
	High	Acquisition of floodplain real estate	ND	ND	ND	ND
2 - Reid Gardner RR Bridge to White Narrows						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	80	Acre	$2,700	$216,000
	Low	Manual tamarisk removal with standard work crews	80	Acre	$5,838	$467,040
	Low	Formation of partnership/agreement and cost sharing of conservation efforts with Tribe	ND	ND	ND	ND
	Medium	Revegetation following tamarisk removal activities	80	Acre	$11,425	$914,000
	High	Installation of rolling drum fish barrier at White Narrows	1	Structure	Estimated	0.25 to 0.5 million
	High	Construction of roller compacted concrete structure and fish barrier at White Narrows	1	Structure	Estimated	0.5 to 1 million
	High	Establishment of buffer zone between agricultural fields and river	ND	ND	ND	ND
3 - White Narrows to Warm Springs Road						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	36	Acre	$2,700	$97,200
	Low	Manual tamarisk removal with standard work crews	36	Acre	$5,838	$210,168
	Medium	Revegetation following tamarisk removal activities	36	Acre	$11,425	$411,300
	Medium	Conservation easements for remaining floodplain real estate	ND	ND	ND	ND
	Medium	Acquisition of remaining floodplain real estate	ND	ND	ND	ND
	High	Complete reconstruction of channel within BLM property	1.5	Mile	$1,482,400	$2,223,600
	High	Removal of flood/silt control dams on tributary washes	ND	ND	ND	ND

Table 8 continued. Costs associated with Upper Muddy River habitat conservation and restoration recommendations.

4 - Warm Springs Road to Warm Springs-Muddy River Confluence						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	21	Acre	$2,700	$56,700
	Low	Manual tamarisk removal with standard work crews	21	Acre	$5,838	$122,598
	Medium	Palm tree removal	ND	Tree	$1,000	ND
	Medium	Revegetation following tamarisk removal activities	21	Acre	$11,425	$239,925
	Medium	Invasive fish exclusion on Muddy River above Warm Springs Road	1	Structure	Estimated	0.25 to 0.5 million
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	ND	ND	ND	ND
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	ND	ND	ND	ND
5 - Warm Springs-Muddy River Confluence to North-South Fork Confluence						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	36	Acre	$2,700	$97,200
	Low	Manual tamarisk removal with standard work crews	36	Acre	$5,838	$210,168
	Medium	Palm tree removal	ND	Tree	$1,000	ND
	Medium	Revegetation following tamarisk removal activities	36	Acre	$11,425	$411,300
	Medium	Invasive fish exclusion on Muddy Spring channel	1	Structure	$20,125	$20,125
	Medium	Conservation easements throughout Warm Springs Ranch	ND	ND	ND	ND
	Medium	Conservation easements within Muddy Spring area/LDS recreation area	ND	ND	ND	ND
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	ND	Acre	$141,100	ND
	High	Spring channel restoration of Muddy Spring channel	710	Feet	$175	$124,250
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	ND	ND	ND	ND
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	ND	ND	ND	ND

Table 8 continued. Costs associated with Upper Muddy River habitat conservation and restoration recommendations.

6 - Warm Springs-Muddy River Confluence to Warm Springs						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	10	Acre	$2,700	$27,000
	Low	Manual tamarisk removal with standard work crews	10	Acre	$5,838	$58,380
	Medium	Palm tree removal	ND	Tree	$1,000	ND
	Medium	Revegetation following tamarisk removal activities	10	Acre	$11,425	$114,250
	Medium	Defined instream flows for Moapa Valley NWR spring channels	ND	ND	ND	ND
	Medium	Defined instream flows for Apcar channel	ND	ND	ND	ND
	High	Spring channel restoration of Plummer channel within Moapa Valley NWR	740	Feet	$175	$129,500
	High	Spring channel restoration of Apcar channel within Moapa Valley NWR	1,250	Feet	$175	$218,750
	High	Spring channel restoration within Warm Springs Ranch (Refuge and Apcar channels)	5,700	Feet	$175	$997,500
	High	Conservation easements along spring channels on Warm Springs Ranch	ND	ND	ND	ND
	High	Restoration of remaining former recreational structures within Moapa Valley NWR to spring pools and channels	ND	ND	ND	ND
	High	Development of public use and education areas/trails within Moapa Valley NWR	ND	ND	ND	ND
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	ND	ND	ND	ND
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	ND	ND	ND	ND
7 - North-South Fork Confluence to North Fork Headwaters						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	23	Acre	$2,700	$62,100
	Low	Manual tamarisk removal with standard work crews	23	Acre	$5,838	$134,274
	Medium	Palm tree removal	ND	Tree	$1,000	ND
	Medium	Revegetation following tamarisk removal activities	23	Acre	$11,425	$262,775
	Medium	Conservation easements throughout Warm Springs Ranch	ND	ND	ND	ND
	Medium	Conservation easements on private property within headwater area for Moapa dace habitat preservation	ND	ND	ND	ND
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	ND	Acre	$141,100	ND
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	ND	ND	ND	ND
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	ND	ND	ND	ND

Table 8 continued. Costs associated with Upper Muddy River habitat conservation and restoration recommendations.

8 - North-South Fork Confluence to South Fork Headwaters						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	10	Acre	$2,700	$27,000
	Low	Manual tamarisk removal with standard work crews	10	Acre	$5,838	$58,380
	Medium	Palm tree removal	ND	Tree	$1,000	ND
	Medium	Revegetation following tamarisk removal activities	10	Acre	$11,425	$114,250
	Medium	Invasive fish exclusion on South Fork Channel	1	Structure	$20,125	$20,125
	Medium	Invasive fish exclusion on Cardy Lamb channel	1	Structure	$20,125	$20,125
	Medium	Conservation easements throughout Warm Springs Ranch	ND	ND	ND	ND
	Medium	Construction/Enhancement of wetlands within Warm Springs Ranch where wet meadows exist	ND	Acre	$141,100	ND
	High	Spring channel restoration of South Fork	1,000	Feet	$175	$175,000
	High	Preservation of critical areas on former Warm Springs Ranch (conservation easements, agreements, or acquisition)	ND	ND	ND	ND
9 - North Fork Headwaters to Arrow Canyon						
	Low	Knapweed control with goats	ND	Acre	$1,000	ND
	Low	Manual tamarisk removal with prison crews	25	Acre	$2,700	$67,500
	Low	Manual tamarisk removal with standard work crews	25	Acre	$5,838	$145,950
	Medium	Revegetation following tamarisk removal activities	25	Acre	$11,425	$285,625
	High	Acquisition of water rights and/or limitation of future shallow groundwater aquifer decline	ND	ND	ND	ND

ND indicates quantity or cost not determined

APPENDIX IV . THREAT ASSOCIATED WITH EACH CONSERVATION TARGET FOR ALL UPPER MUDDY RIVER SEGMENTS

The following six tables summarize the information obtained from nine spreadsheets (one per river segment) of TNC's Conservation Management Tool. Each row represents a threat, which is a source of stress that degrades the viability or functionality of at least one conservation target. Columns are the different river segments where the conservation target is found. The contribution of a threat to the degradation of a conservation target is ranked from Very High, High, Medium, to Low. A Very High rank indicates that the threat can cause the destruction or serious impairment of the conservation target. Restoration actions that abate a Very High threat should always have the highest priority for implementation. A Low rank indicates a low contribution of the threat to the conservation target's viability or functionality and does not warrant urgent action. "Tamarix" was used in TNC's software and in the following spreadsheets, whereas "saltcedar" is used in the main text of the report to discuss the same species.

Warm Springs Aquatic Assemblage

Threats Across Systems		Project	Upper Muddy River-Segment 4	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7	Upper Muddy River-Segment 8	Upper Muddy River-Segment 9
		Target	Warm Springs Aquatic Assemblage	Warm Springs Aquatic Assemblage	Warm Springs Aquatic Assemblage	Warm Springs Aquatic Assemblage	Warm Springs Aquatic Assemblage	Warm Springs Aquatic Assemblage
1	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High
2	Recreational use		Very High	Very High	Very High	Very High	Very High	-
3	Invasive species (tilapia)		Very High	Very High	Very High	Very High	Very High	-
4	Incompatible land development		Very High	Very High	Very High	Very High	Very High	-
5	Local aquifer withdrawal		High	High	High	High	High	High
6	Irrigation ditches for pasture		Medium	Medium	Medium	Medium	Medium	-
7	Invasive species (fan palms)		Medium	Medium	Medium	Medium	Medium	-

Muddy River Aquatic Assemblage

Threats Across Systems		Project	Upper Muddy River-Segment 1	Upper Muddy River-Segment 2	Upper Muddy River-Segment 3	Upper Muddy River-Segment 4	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7	Upper Muddy River-Segment 8	Upper Muddy River-Segment 9
		Target	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage	Muddy River Aquatic Assemblage
1	Invasive species (tilapia)		High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	-
2	Local aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
3	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
4	Invasive species (tamarix and knapweeds)		High	High	High	High	High	High	High	High	High
5	Entrenchment of River Channel		High	High	High	High	High	High	High	High	High
6	Invasive species (fan palms)		-	-	Medium	Medium	Medium	Medium	Medium	Medium	-
7	Flood control dams and sediment traps		Medium	Medium	Medium	-	-	-	-	-	-
8	Incompatible land development		Low	Low	Low	Low	Low	Low	Low	Low	-

Riparian Woodland

Threats Across Systems		Project	Upper Muddy River-Segment 1	Upper Muddy River-Segment 2	Upper Muddy River-Segment 3	Upper Muddy River-Segment 4	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7	Upper Muddy River-Segment 8	Upper Muddy River-Segment 9
		Target	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland	Deciduous Riparian Woodland
1	Invasive species (fan palms)		-	-	Very High	Very High	Very High	Very High	Very High	Very High	-
2	Incompatible land development		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Medium
3	Entrenchment of River Channel		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
4	Local aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
5	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
6	Invasive species (tamarix and knapweeds)		High	High	High	High	High	High	High	High	High
7	Flood control dams and sediment traps		High	High	High	-	-	-	-	-	-
8	Incompatible grazing practices		Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

Riparian Shrubland

Threats Across Systems		Project	Upper Muddy River-Segment 1	Upper Muddy River-Segment 2	Upper Muddy River-Segment 3	Upper Muddy River-Segment 4	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7	Upper Muddy River-Segment 8	Upper Muddy River-Segment 9
		Target	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland	Riparian Shrubland
1	Incompatible land development		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Medium
2	Invasive species (tamarix and knapweeds)		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
3	Entrenchment of River Channel		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
4	Local aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
5	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High	Very High
6	Flood control dams and sediment traps		High	High	High	-	-	-	-	-	-
7	Incompatible grazing practices		Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

Riparian Marsh

Threats Across Systems		Project	Upper Muddy River-Segment 1	Upper Muddy River-Segment 3	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7	Upper Muddy River-Segment 8
		Target	Riparian Marsh	Riparian Marsh	Riparian Marsh	Riparian Marsh	Riparian Marsh	Riparian Marsh
1	Local aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High
2	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High
3	Entrenchment of River Channel		High	High	High	High	High	High
4	Conversion to agriculture		Medium	Medium	Medium	Medium	Medium	Medium
5	Incompatible grazing practices		Medium	Medium	Medium	Medium	Medium	Medium
6	Incompatible land development		Medium	Medium	Medium	Medium	Medium	Medium
7	Invasive species (tamarix and knapweeds)		Medium	Medium	Medium	Medium	Medium	Medium

Mesquite Bosque

Threats Across Systems		Project	Upper Muddy River-Segment 1	Upper Muddy River-Segment 2	Upper Muddy River-Segment 3	Upper Muddy River-Segment 4	Upper Muddy River-Segment 5	Upper Muddy River-Segment 6	Upper Muddy River-Segment 7
		Target	Mesquite Bosque	Mesquite Bosque	Mesquite Bosque	Mesquite Bosque	Mesquite Bosque	Mesquite Bosque	Mesquite Bosque
1	Local aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High
2	Regional aquifer withdrawal		Very High	Very High	Very High	Very High	Very High	Very High	Very High
3	Entrenchment of River Channel		High	High	High	High	High	High	High
4	Incompatible land development		Medium	High	Medium	Medium	Medium	Medium	Medium
5	Incompatible grazing practices		Medium	Medium	Medium	Medium	Medium	Medium	Medium
6	Flood control dams and sediment traps		Medium	Medium	Medium	-	-	-	-
7	Conversion to agriculture		Low	Medium	Low	Low	Low	Low	Low
8	Invasive species (tamarix and knapweeds)		Low	Low	Low	Low	Low	Low	Low

APPENDIX V. EFFECTIVENESS MONITORING FOR SALTCEDAR AND KNAPWEED CONTROL ON THE UPPER MUDDY RIVER FLOODPLAIN.

Hypotheses

A. Retrospective effectiveness monitoring

The retrospective effectiveness monitoring is designed to document the responses of plant, fish, and bird species, and soil chemistry in areas where saltcedar was removed in different years (same method in different years) and where artificial native plant restoration was attempted with varying success. Hence, this component of the proposal is not experimental.

We do not propose a hypothesis for saltcedar mortality because past saltcedar removal by MRREIAC was highly successful (greater than 99% mortality) and new saltcedar occurrences are monitored and killed on formerly treated river reaches. Hypotheses (null = H_o and alternative = H_i , where i = 1, 2, 3, 4) are formulated for the success of native plant restoration, succession pattern, and ultimate effects to bird and fish species, which may include species addressed by the Clark County MSHCP.

<u>Native plant restoration</u>

H_o: Native riparian plants will naturally reestablish after removal of saltcedar and knapweeds. Natural revegetation will require that treated areas be fallow for one year to leach salts from the soil.

H_1: Artificial native plant restoration will be more successful in the lower riparian zone than in the upper riparian zone because greater water availability will increase planting success (conversely less successful in the upper riparian zone due to less water availability).

H_2: In the lower riparian zone, willow and cottonwood cuttings drilled to the water table will be more successful than plantings because surface soil salt content is higher closer to the water surface and harms rooting.

H_3: Restoration of the upper riparian zone will benefit less from artificial native planting than the lower riparian because salt content decreases away from the water surface and salt resistant plants from the upper riparian zone have naturally higher resistance to salt.

H_4: Artificial native plant restoration is more successful one year than immediately after saltcedar removal because surface soil salt content decreases with time since removal.

<u>Succession</u>

H_o: Early successional desert riparian plants (e.g., quailbush) will dominate cover after saltcedar removal, reaching >75% cover within the first 5 years.

H_1: Later successional plant species (e.g., mesquite and wolfberry) from the upper riparian zone will reach at least 10% cover after 10 years.

H_2: Willow, cottonwood, and other riparian species will naturally reestablish in the lower riparian zone after 10 years reaching at least 10% cover.

H_3: The cover of later successional species is negatively correlated to surface soil salt content and the depth of river entrenchment.

Species of Concern

H_o: Removal of saltcedar will have no effect on bird and fish species abundance compared to similar untreated areas.

H_1: Removal of saltcedar will cause bird and fish species abundance to increase with time since removal compared to untreated areas. Fish species will benefit from increased light penetration that stimulates aquatic primary and secondary productivity, whereas birds will benefit from increased vegetation cover and height.

H_2: Removal of saltcedar will reduce bird and fish species abundance during the first 6 months compared to untreated areas, however abundance will increase as vegetation recovers thereafter exceeding levels observed in untreated areas.

H_3: Removal of saltcedar will only decrease bird and fish species abundance with time since removal compared to untreated areas.

H_4: Native trees that were saved during removal of saltcedar will increase the abundance of birds compared to plots with fewer remnant native trees.

B. Experimental effectiveness monitoring

The purpose of this component of the proposal is to design non-native invasive species control and native plant restoration by MRREIAC as an experiment, therefore allowing 1) replication of methods, 2) a statistically valid comparison among a no-removal control and different removal methods, and 3) a statistically valid comparison test between native plant restoration and natural revegetation. The experiment will be a 4 x 2 randomized complete block factorial design with four saltcedar treatments and two native plant restoration methods. The saltcedar treatments will be: no removal control (hereafter control), chainsaw felling followed by painting stumps with Garlon 4 (Arsenal closer to water) and spraying knapweeds with Thordon [hereafter traditional], goat grazing only (trees remain standing), and goat grazing followed by wicking of resprouts with Garlon 4 and use of the traditional method for larger trees not girdled by goats (no Thordon on knapweeds). Each saltcedar treatments will be crossed with two forms of native plant restoration: natural regeneration (do-nothing control) and artificial native plant restoration using different species and methods for the lower and upper riparian zones as accomplished by Nevada Division of Forestry (NDF) in the past.

Saltcedar mortality

H_o: There will be no differences in saltcedar mortality among the four saltcedar treatments.

H_1: Saltcedar mortality will increase in the following order of treatments: control, goat only, traditional, goat+traditional.

Knapweed mortality

H_o: Knapweed mortality will not vary among removal treatments.

H_1: Knapweed mortality will increase in the following order of treatments: control, traditional, goat only, and goat+traditional.

Upper and lower riparian native plant restoration (not attempted in control)

H_o: There will be no difference in plant species composition and richness between natural regeneration and artificial regeneration of native riparian species (i.e., artificial native plant restoration failed).

H_1: Plant species used for artificial native plant restoration will dominate plant species composition 2 years after saltcedar removal.

H_2: Surface soil salt content is lower with increased saltcedar mortality (including control) and decreases since time of saltcedar removal.

H_3: In the lower riparian zone, cottonwood and willow cuttings drilled to the water table is more successful than plantings because of greater surface soil salt content nearer to the water surface.

H_4: Cover of native plant species will be higher where goats were used due to the fertilizing effect of goat activity and manure.

H_5: Cover of native plant species used in artificial revegetation will be higher where goats were used due to the fertilizing effect of goat activity and manure.

Locations of the Project

All private properties, and those BLM managed public lands within the Disposal Area in the upper Muddy River are considered to be Unmanaged Areas (UMA) under the MSHCP, but the restoration of both mesquite/catclaw ecosystems and desert riparian/aquatic ecosystems are high priorities for Phase 2 of the Clark County MSHCP. In the upper Muddy River the majority of both of these ecosystems are located on private lands. In fact, the MSHCP describes 35.5 percent of all desert riparian/aquatic habitat in Clark County as having UMA status due to it's ownership by private entities or Native American reservations.

A. Retrospective Study

The retrospective effectiveness monitoring will be conducted on the following four different private properties:

1. Three river reaches of the Southern Nevada Power Company property treated in 1995-1996, 1996-1997, and 1997-1998 (respectively, Fig. 1 sections D, A&B, and C);

2. Three river reaches of the Hidden Valley Dairy property treated in 1996-1998, 1998-2000, and 2003 (respectively, Fig. 1 sections E, F, and G). In addition, a fourth river reach will serve as an untreated control (Fig. 1 Section H);

3. One untreated (control) river reach on the Omer property (Fig. 1 Section J); and

4. One river reach treated in 2002-2003 on the Hester property immediately upstream of the 168 Highway bridge (Fig. 1 Section K).

In all cases saltcedars were felled with chainsaws and fresh stump painted with Garlon 4, except the river reach of the Southern Nevada Power Company treated in 1995 whose resprouts were wicked with Garlon 4 in 1996. All treated properties in the upper Muddy River are considered UMA, but the restoration of both mesquite/catclaw ecosystems and desert riparian/aquatic ecosystems are high priorities for Phase 2 of the Clark County MSHCP. In the upper Muddy River the majority of both of these ecosystems are located on private lands. The Hidden Valley Dairy property has been identified as critical to the maintenance of the biodiversity of the upper Muddy River because it harbors a high quality, remnant marsh encroached by saltcedar and knapweed and experiences natural flooding from California Wash (Provencher and Andress 2004).

B. Experimental Study

The experimental effectiveness monitoring will be conducted on untreated sections of the following properties:

Alamo property recently acquired by The Nature Conservancy (Fig. 2);

Shirley Perkins property recently acquired by The Nature Conservancy (Fig. 2);

Henrie property recently acquired by The Nature Conservancy;

Perkins-BLM property (Fig. 2);

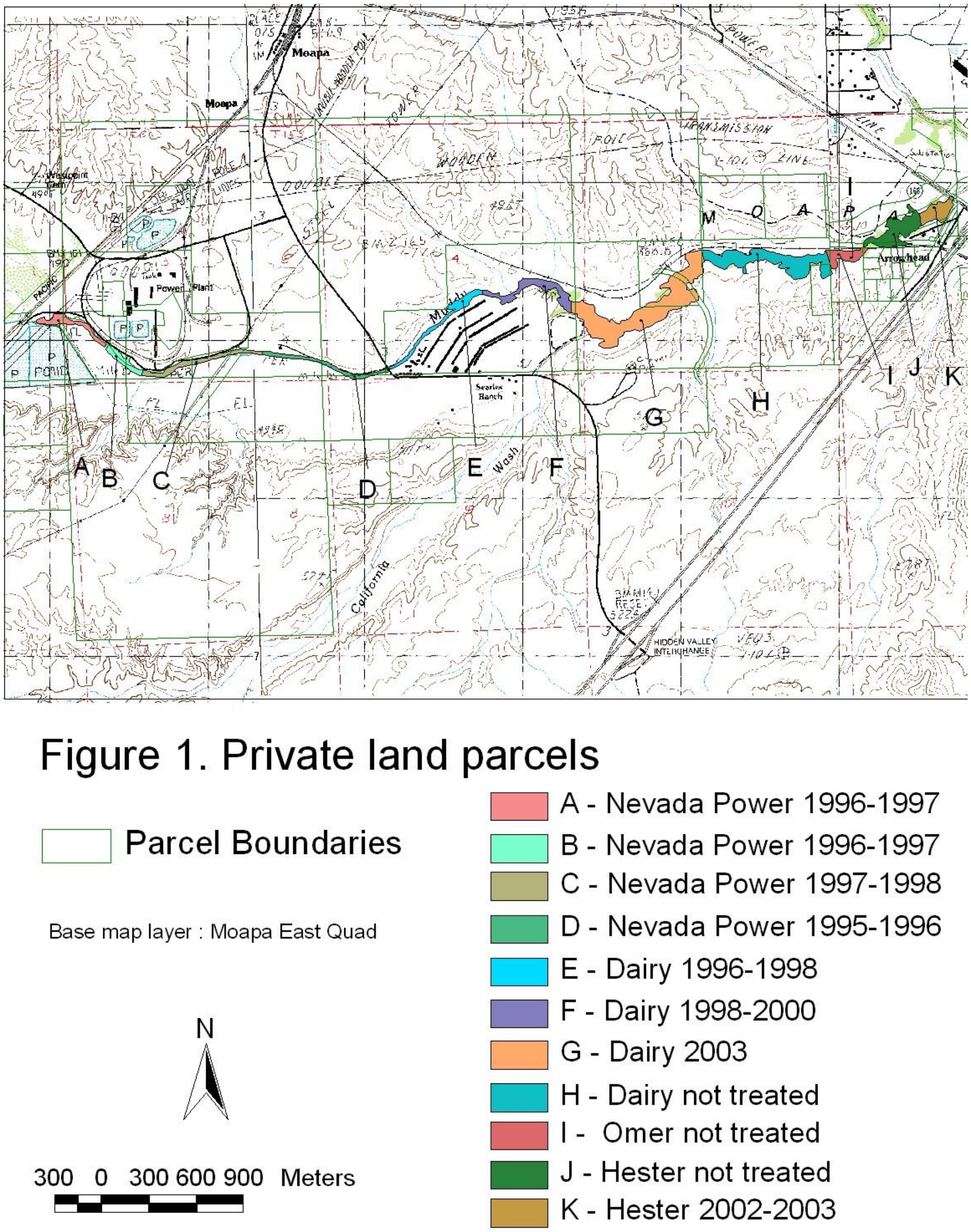

Figure 1. Private land parcels

Hidden Valley Dairy property (Fig. 1 Section H); and

Omer property situated immediately downstream and on the eastern bank of the Hidden Valley Dairy property (Fig. 1 Section J).

The Alamo and Shirley Perkins properties have the smallest length of desert riparian habitat. Each property has approximately 200m of river frontage. The Henrie property is not on the river but in a part of the 100-year floodplain that would naturally support a mesquite Bosque. Together these properties offer the opportunity for >10 replicates of each of eight treatment combinations (see later). The Nature Conservancy has the support of, and will cooperate with the BLM to implement the experiment and effectiveness

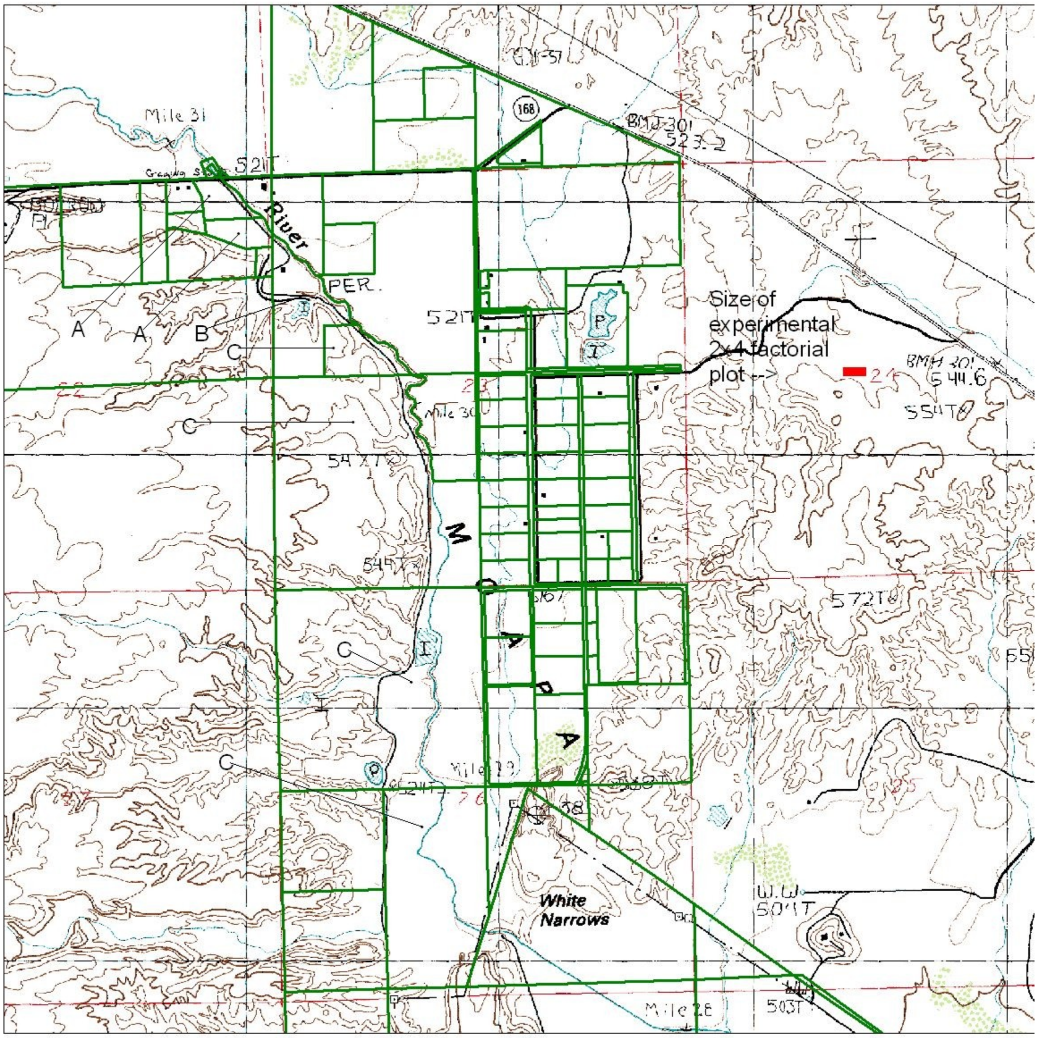

Figure 2. Private and BLM parcels

Parcel Boundaries

Base map layer : Moapa West Quad

N

200 0 200 400 Meters

A - TNC Alamo

B - TNC Shirley Perkins

C - BLM

monitoring if the Alamo, Shirley Perkins, and Henrie properties are transferred to the BLM before and after this study is initiated, pending necessary NEPA and other analyses. In addition, the BLM has given us similar support to implement replicates of the experiment on the Perkins-BLM property. In all cases, BLM has agreed to assist with all required NEPA analyses and pesticide use permit documentation. All of the above mentioned properties are designated UMA by the MSHCP, but the restoration of both mesquite/catclaw ecosystems and desert riparian/aquatic ecosystems are high priorities for Phase 2 of the Clark County MSHCP.

Design

Because sampling methods for soil chemistry, plant species cover, and bird and fish species abundance (where applicable) will be identical between the retrospective and experimental analyses, these are explained later after the description of the sampling design for the retrospective study and experimental design for future saltcedar and knapweed removal.

A. Retrospective effectiveness monitoring sampling design

Nine private property river reaches were retained for sampling the past removal activities of MRREIAC, including two no-treatment controls on the Hidden Valley Dairy property and the Omer property. These segments offer unique combinations of treatment years and property locations (Southern Nevada Power 1995-1996 & 1996-1998; Hidden Valley Dairy property 1998-2000, 2000-2002, 2002-2003; and Hester property 2003) between the Moapa River Indian Reservation and Highway 168. These properties are contiguous along the river. Because some control plots will be shared between the retrospective and experimental studies on the Hidden Valley Dairy and Omer properties, the complete length of the control plots of the retrospective will be sampled prior to saltcedar control, with some control plots then retained for the experiment.

To increase the consistency between the two components of this proposal, the unit of vegetation and soil sampling will be tailored to the size of the smallest experimental sampling unit (discussed later), which is 10m long. Note that we may increase this length to up to 20m pending further surveys of newly acquired properties. The total sampling area will be segmented in 10m linear units of river front and a minimum of 10 10-m units per year × property combination will be randomly selected for sampling. This approach is essentially a systematic random (also misleadingly called stratified random) sampling design (Elzinga et al. 1998). The width of each unit is generally narrow and largely irrelevant. Power analyses to determine acceptable sample sizes (minimum 80% power; Elzinga et al. 1998) will be performed after at least five sampling stations are completed per year × property combination to determine whether there is a need for a greater sample size.

B. Experimental effectiveness monitoring design

We will use a complete randomized block 4 × 2 factorial design to test the joint effects of saltcedar/knapweed treatments and native plant species restoration (Steel and Torrie 1980). Replication will be achieved through spatial blocking by property and different portions within larger properties (e.g., Hidden Valley Dairy and Perkins-BLM properties). At least 10 blocks will be used, obtained from the following properties: Alamo, Shirley Perkins, other, Perkins-BLM (>3 blocks), Omer, and Hidden Valley

Dairy (>3 blocks). Each block will be 90m long containing 8 10-m long plots (width will vary with the size of the distance between the water and the upper bank) aligned along the river front, or other linear feature for inland plots, and separated by 1m boundaries. The unique combinations of treatments (see later) will be randomized by block (Table 1, Figure 3). Sampling will be conducted pre-treatment and 1-3 years post-treatment depending on funding renewal. Due to the limited availability of NDF inmate crews, not all plots will be treated during the first year. However, a sufficient number of replicates will be completed during the first year and we will budget for saltcedar/knapweed removal by a private contractor in the emergency event that more replicates need to be added during the first year.

Saltcedar treatments will be: no removal control (hereafter control), chainsaw felling followed by painting stumps with Garlon 4 and spraying knapweeds with Thordon [hereafter traditional], goat grazing only (trees remain standing), and goat grazing followed by wicking of resprouts with Garlon 4 and use of the traditional method for larger trees not girdled by goats (no Thordon on knapweeds). Each saltcedar treatments will be crossed with two forms of native plant restoration: natural regeneration (no-planting control) and artificial native plant restoration using different species and methods for the lower and upper riparian zones as accomplished by NDF in the past. Treatment combination codes are shown in Table 1.

Table.1. Treatment combination codes.

NON-NATIVE SPECIES REMOVAL	NATIVE PLANT RESTORATION	
	natural	artificial
control	C+N	C+A
traditional	T+N	T+A
goat only	G+N	G+A
goat and traditional	GT+N	GT+A

River

10m	10m						
GT+A	C+A	C+N	T+A	GT+N	G+N	G+A	T+N

Upland

Fig. 3. Example of treatment combination randomization for one block (in reality, several blocks will be used with a different randomization per block)

Common sampling methods
In each unit for both the retrospective and experimental studies, we will establish five 10-m parallel line transects (also parallel to the river) separated by 1m in the upper riparian zone and similarly 5 parallel transects in the lower riparian zone with one transect close to the river's edge (Fig. 4). In the future, we may decide that the lower riparian transects need to be closer than 1m to avoid upland vegetation. Hence, vegetation will be stratified by the upper and lower riparian zone to account for natural differences in species composition with distance to the water table (Elzinga et al. 1998). Only five parallel transects will be sampled in the upper riparian zone for plots situated away from the river. Vegetation cover of understory and midstory herbaceous and woody species will be measured on these transects using the line-intercept method (Elzinga et al. 1998, Herrick et al. 2002), which is efficient and logistically feasible for low diversity shrublands (e.g., Muddy River) where movement is difficult (e.g., dense quailbush). Cover per plant species will be calculated from the total number of centimeters from the five 10-m transects. If different species overlap vertically, the cover of each will be measured and the relative vertical layer occupied by the species will be noted. Bare ground and litter will also be measured if no vegetation is present.

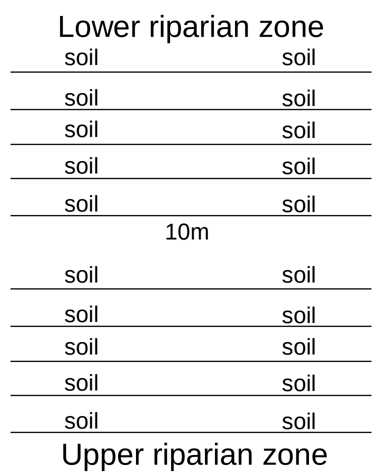

Fig. 4. Ten 10-meter line intercept for vegetation sampling and location of soil samples in the upper and lower riparian zones. Vegetation height will be measured every 5m (0m, 5m, and 10m).

Understory and midstory vegetation height along each 10-m transect will be measured at every 5m regardless of species. The height of each native tree species in a plot will be visually estimated to the closest 1m interval (Haglof electronic clinometer) and the species noted. We expect a low density of native trees per plot. For saltcedar, we will visually estimate the average height of the stand. This last measurement should only apply to the dense control plots of the retrospective study and the control and pre-treatment phase of the experimental plots.

Canopy cover will be measured with a spherical densitometer (manufactured by Dr. Paul E. Lemmon; Lemmon 1956 and 1957) by taking one reading from a random location per each 10-m tape. We have considerable experience with the spherical densitometer (Provencher et al. 2001a &b), which is efficient, cheap, reliable, usable in all weather conditions, and provides consistent measurements (Gainey and Block 1994). Except for the control properties, canopy cover is expected to be low.

Soil samples will be taken at 2m and 8m on each transect with a 7cm diameter soil auger pressed to a depth of 10cm (locations on Fig AIV.4). For each riparian strata (lower and upper), the 10 soil samples will be combined in one paper bag and mixed for soil analysis. Soil samples will be sent to a professional laboratory for analysis of pH, B, Cl, Mg, Na, and SO4 (Dr. David Merritt, USFS RMRS, pers. comm.). Due to the high cost of soil chemistry analysis ($98/sample), we will need to subsample properties of the retrospective effectiveness monitoring. We will not subsample the experimental effectiveness monitoring study. Ten replicates per property segments are proposed for vegetation sampling, whereas we will only collect soil samples in 5 randomly chosen replicates among each group of 10.

Bird and fish species abundance will be sampled in the retrospective study only. The experimental plots are too small to be sampled for bird and fish species and the short duration of the experiment does not make it realistic to expect suitable habitat to be created fast enough to support species addressed by the Clark County MSHCP. Also, sampling bird and fish species in small plots would probably violate the assumption of independence among treatments because individual animals could forage in different treatments during the same breeding season.

Bird sampling will be conducted by NDOW as part of their normal operations using a method closely following the state-wide method established by the Great Basin Bird Observatory (www.gbbo.org/nbc_protocol.htm). Bird and vegetation sampling stations will not be match in space as the whole river reach between the Moapa River Indian Reservation and Highway 168 will be required for bird sampling. Instead, bird point counts will be distributed according to established methods within each treated and control river reaches. Birds will be sampled using limited distance point counts with stations spaced 60-75m apart (GPS locations noted). As many as 10 point count stations will be established per river reach within a certain treatment condition. Point counts surveys will be conducted weekly from mid-May through mid-July. A single observer can be used for the whole effort. The duration of each count will be 6 minutes per station. During that time, all individual birds heard or seen within a 30-m radius of each station will be counted.

Fish species will also be sampled by NDOW following standard protocols (see above letter from NDOW). Sampling at each site consisted of three passes with a Dirigo Model 750 backpack shocker unit. Transect length varies from 30.5 to 61 m (100 to 200 feet) depending on available habitats and velocity barriers such as falls and chutes. At each pass fish are netted, placed in buckets, identified to species and measured. If sample size is adequate, a population estimate is calculated to species number, per 30.5 m (100 feet) of stream reach. This electrofishing technique does provide a sample bias, favoring native species while the shortfin molly and blue tilapia are taken only occasionally.

The GPS location of all sampling plots will be noted for the beginning and end of each of the four transects (UTM coordinates, Zone 11, NAD 27 CONUS). All sampling plots will also be photo-monitored. A digital photograph will be taken from each end of the third 10-m transects looking inside the transect (i.e., two photographs per riparian zone). A 1.5m high photo-board placed 2m inside the transect pair will be used to identify the plot/transect and provide a sense of proportion.

<u>Non-native invasive species mapping with remote sensing</u>

Quickbird imagery will be captured during the mid-late spring to coincide with the flowering of knapweed, saltcedar, and tall whitetop. Should this be required, it is also possible to time the date of capture to coincide with saltcedar flowering later in the summer when other desert species are not flowering. We will purchase 64 sq. km of non-orthorectified QuickBird's imagery that covers all of the 500-yr floodplain of the upper Muddy River and parts of the floodplain of the lower Meadow Valley Wash (the upper Muddy River is only 22.5 km or 14 mi long). Orthorectification will be completed by Spatial Solutions, Inc., which is also the reseller of QuickBird imagery. Spatial Solutions will analyze the imagery, which will require up to three field visits for ground-truthing. Aerial photography already in TNC's possession may be analyzed to complete the work.

Data analysis

A. Retrospective effectiveness monitoring

Robust ordination techniques, such as the non-parametric ordination method "non-metric multi-dimensional scaling" (NMDS; Kruskall 1964, Kenkel and Orlóci 1986), and linear regressions will be used on the more common variables with better statistical properties to determine whether multivariate plant species cover, soil chemistry, and animal species abundance change with time since saltcedar removal. Control plots will not be included in the ordination to avoid causing data disjunctions, which happen when a variable is completely absent from some condition (e.g., saltcedar only in control plots and quailbush absent from control plots). Control plots will be used for simple comparisons to treated plots, although we will refrain from performing t-tests because of pseudoreplication (Hurlbert 1984). Regressions will be performed for specific hypotheses, such as the cover of certain species (e.g., saltcedar) and bird detection rates.

B. Experimental effectiveness monitoring

Because the experiment is a block factorial design with pre-treatment sampling, we will use a three-way analysis of covariance with random block effects (df = no. of blocks-1) and fixed effects for removal (df = 4-1 = 3) and native plant restoration (df = 2-1 = 1) treatments (Steel and Torrie 1980). To control for the correlation among multiple response variables (plant species cover and soil chemistry), we will perform a multivariate analysis of covariance (Scheiner and Gurevitch 2001). The covariates will be the value of each variable during the pre-treatment sampling (df = 1 for each covariate) (Steel and Torrie 1980, Sokal and Rohlf 1981). However, pre-treatment values may be zero for many variables found during the post-treatment phase, such as some plant species. In these cases, we will not specify covariates for these variables. Finally, each variable will be checked for heterogeneous variances among treatments (more important than departure from normality), transformed using different formulas (square-root, logarithm, inverse, and arc-sin square-root), and then checked again to verify that the transformations worked and then select the best one. The error term for the test of removal and native plant restoration effects will be the residual mean square after accounting for all main and interaction effects (Steel and Torrie 1980: 348-352). Pre-planned contrasts will be used to test the various hypotheses (e.g., control vs. rest, among removal without the control, and so on).

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APPENDIX VI . UPPER MUDDY RIVER INTEGRATED SCIENCE PLAN QUESTIONNAIRE

Upper Muddy River Integrated Science Plan
Questionnaire

Goal

The upper Muddy River (above Interstate 15) is an important area in Clark County and the Mojave Desert. It is also a major source of water for wildlife and humans. As a result, the Muddy River receives a lot of attention. The Nature Conservancy and Otis Bay Ecological Consultants studied the geology, hydrology, and ecology of the upper Muddy River and its floodplain (the area likely to flood during a 100-year flood event) to identify options for restoration. The local community and landowners in this area play a key role in the success of restoring the Upper Muddy River. We value your input and hope that together we can create a vision for the future of this unique area.

Please read the summary of our findings below and fill out our questionnaire. Your comments are important to us and will help us understand your vision and identify your concerns. Please return by October 30, 2004.

A. Summary of findings to date

The Muddy River is an important area for humans, as well as plants and animals in the Mojave Desert. It provides habitat for 4 aquatic and endemic—found nowhere else in the world—fish species, 7 species of aquatic insects and snails, 76 breeding bird species, and a unique assemblage of Mojave Desert riparian (riverside) vegetation. Of particular concern is the Moapa dace (*Moapa coriacea*), an endangered species of fish. The dace can only be found in the water that feeds the Muddy River.

The scientific literature review revealed many interesting facts, but the following have more immediate and practical implications:

- Spring output is decreasing steadily because of water withdrawals from the (regional) carbonate aquifer. The Moapa dace and other species dependent upon the warm springs are predicted to be directly affected by this reduced output;
- The floodplain has been disconnected from the upper Muddy River for at least a century due to deep entrenchment and channel straightening;
- Non-native invasive plant and animal species are present throughout the river and floodplain;
- River management and restoration options for public land managers are greatly limited because most of the floodplain is privately owned;
- On the more hopeful side, many native animal species of concern are supported in areas that still have native plant communities;
- The relatively short length of river and small acreage of floodplain in the upper Muddy River limits the areas of non-native invasive species invasion, and makes long-term control of these species a reasonable possibility;
- Non-native species removal and land acquisition for conservation are on-going and laying down the foundation for future restoration activities;

- Many native species of concern have common ecological needs that could be met with the same restoration and management activities; and,
- Local stakeholders have demonstrated success and interest in the conservation of the upper Muddy River.

The scientific literature review also identified issues where native species of concern depend on human-caused habitat features that might be affected by river restoration activities:

- Vermilion Flycatchers require open water and, as a result, utilize the irrigation ditches next to mesquite bosques, riparian shrublands, and open riparian forests;
- Although saltcedar (tamarisk) removal is desirable, its wholesale removal may result in the temporary loss of all habitat structure for bird species unless some thought is given to the rate and shape of removal (the current rate of removal is small) and native plant revegetation; and,
- The only population of yellow bat (*Lasiurus xanthinus*) in Nevada is found roosting in fan palms of the upper Muddy River, including at the Moapa Valley National Wildlife Refuge. While this species is more common in Arizona and California, some stakeholders value the presence of this disjunct occurrence of the species and wish to protect it.

This preliminary technical analysis proposes several possible restoration actions for each river segment, along with cost estimates and potential benefits to native species of interest. We are now seeking public input because we need to refine these options, keeping in mind that a) our highest priority for restoration activities is the recovery of the Moapa dace and conservation of other endemic species because of their irreplaceability, and b) by law (Endangered Species Act) conservation activities cannot preclude recovery of the Moapa dace. The technical information and the information we gather from stakeholders and local community members will be used within the context of Clark County's Multiple Species Habitat Conservation Plan to develop a conservation management strategy to shape the funding decisions that will be used to implement restoration of the upper Muddy River.

(Please keep this page for your information, you do not need to return it to us with your survey answers.)

B. Questions

For each question, you will be asked to select a choice and then you will have space to provide written comments.

1. It is anticipated that restoration of the upper Muddy River and its floodplain will benefit the local human community. Possible benefits are listed below. **Please indicate how important each of these anticipated benefits is to you.**

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					
Reduction of noxious weeds					
Fewer restrictions on private landowners to protect species listed under Endangered Species Act					
More area for hunting					
More opportunities for bird watching, wildlife viewing					
Higher water table					
Maintain the rural lifestyle of Moapa					
More native vegetation along the river to resemble historic times.					

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

Comments:

Very aware___
Somewhat aware ___
Not aware ___

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___ Comments:
Somewhat aware ___
Not aware ___

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___ Comments:
Somewhat aware ___
Not aware ___

5. The Muddy River in the Moapa area is deeply down-cut, with steep banks sometimes reaching 15 feet below the floodplain. This is called entrenchment, a condition that has affected the river for the last 100+ years and that was probably started by channel straightening and made worse by water diversions, field drainage activities, and bank slumping caused by heavy livestock use. **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___ Comments:
Somewhat aware ___
Not aware ___

6. Although the upper Muddy River is spring fed, it still is prone to flash flooding. Deep river channel entrenchment, however, prevents the river from overflowing its banks during flood events. The nutrients, sediments and water that used to reach the floodplain regularly now only reach the floodplain during 50 to 100 year flood events. **To what degree do you think that flooding is necessary to maintain the native animal and plants along the upper Muddy River?**

Very necessary___ Comments:
Necessary___
Don't know ___
Unnecessary___
Flooding is harmful___

7. Groundwater and surface water withdrawals cause less water to flow in the Muddy River and has lowered the water table (groundwater level) in the Moapa area. **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 ___ Comments:
Negative effect ___
No effect ___
Positive effect___
Very positive effect___

8. A very visible tree along the Muddy River is saltcedar (tamarisk). Saltcedar is a non-native invasive plant that has spread along the waterways of the southwestern United States. During the past 10 years, you may have noticed properties where saltcedar was removed by local landowners or by MRREIAC (Muddy River Regional Environmental Impact Alleviation Committee) in Moapa. Saltcedar is being removed because these trees crowd out native plants, facilitates the invasion of other noxious weeds such as Russian knapweed, increases the chances of intense wildfires, and generally provides poorer habitat for wildlife than native plants. **Do you support continued efforts to remove saltcedar?**

Greatly support removal___ Comments:
Support ___
Neutral ___
Do not support___
Strongly against removal___

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___ **If so, what species and where are they located?**
No ___

Comments:

10. Another very visible tree in Moapa is the fan palm that grows along the banks of the river and ditches in the upper parts of the river. There is debate about whether the fan palm is native to the Muddy River or was introduced by European settlers. Fan palm trees are being removed from the waterways of the Moapa Valley National Wildlife Refuge because the roots of the palm trees grow into the waterways and clog the spawning habitat of the Moapa dace. Also, the dry foliage of palm trees have spread intense and dangerous wildfires that killed Moapa dace and other animals, and destroyed buildings. However, several native bird species use the palms, and the yellow bat roosts in the fan palms of Moapa. **Do you support the continued effort to remove the fan palm trees that are invading waterways?**

Greatly support limited removal___ Comments:
Support limited removal ___
Neutral ___
Do not support limited removal___
Strongly against limited removal___

11. The list of non-native species that harm the native species of the Muddy River includes tilapia, bullfrogs, and crayfish. These species are less visible than the non-native plants, but may be more harmful to the at-risk native species. Tilapia is common in the river and is a predator of the Moapa dace. Tilapia can be prevented from moving into new areas with fish barriers (dams and gabions), however infested river segments must be treated with rotenone to remove tilapia. (Rotenone is a chemical that interferes with fishes' ability to breathe underwater, but used carefully, according to label instructions, is not harmful to humans or other non-fish species). These treatments have been successful in the past but more control structures and tilapia removal projects are needed. **To what extent do you support removal of tilapia?**

Greatly support removal___ Comments:
Support ___
Neutral ___
Do not support___
Strongly against removal___

12. Many options to partially restore the floodplain of the upper Muddy River are being developed. These options will have different costs and could be funded by the Clarck County Desert Conservation Program or the Southern Nevada Public Lands Management Act (SNPLMA). Restoration could involve a wide variety of actions that may include but are not limited to: removing non-native plant and animal species, building fish barriers, removing some flood control structures to improve fish spawning, reconnecting the river to the floodplain by reconstructing parts of the river channel, creation of wetlands, restoring spring heads and warm spring channels, and protection of important lands needed for wildlife habitat and restoration using conservation easements and land purchases. All these restoration actions would be conducted within the constraints of current laws and land use regulations and flood control requirements. **Do you support efforts to restore parts of the upper Muddy River and its floodplain on <u>public lands</u> knowing that some or all of these actions could be used?**

Greatly support restoration on public lands___
Support restoration on public lands ___
Neutral ___
Do not support restoration on public lands___
Strongly against restoration on public lands___

Comments:

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 restoration on private lands___
Support restoration on private lands ___
Neutral ___
Do not support restoration on private lands___
Strongly against restoration on private lands___

Comments:

14. Land development in the floodplain results in loss of habitat for the fishes, aquatic insects, snails, and birds. Land development could also change the rural character of Moapa, through increased housing, resorts, traffic, water use, and commercial activity. **How important is it for you to maintain the rural character of Moapa, even if it includes protecting land from development?**

Very important to maintain___
Important___
Neutral___
Not important to maintain___
Want to replace rural lifestyle with more development___

Comments:

15. A key element of river restoration is the availability of in-stream flow. Although water is fully appropriated in the upper Muddy River, pressure to increase water withdrawal from the valley and from Coyote Springs Valley is probably inevitable and could affect the river's potential to support its group of unique species. One strategy to maintain water in the river is to define a minimum in-stream flow (i.e., define the amount of water that must remain in the river) and, based on this amount, to buy senior water rights and use them to benefit wildlife. **Do you support actions to maintain a minimum flow in the river that will support the Moapa dace, other aquatic species, and riparian vegetation?**

Greatly support ___
Support ___
Neutral ___
Do not support___
Strongly against ___

Comments:

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

Greatly support ___ Comments:
Support ___
Neutral ___
Do not support___
Strongly against ___

17. **Would you like to know more about noxious, non-native plants and animals and their control in the upper Muddy River?**
Yes___ If yes, please contact the Clark County Desert Conservation Program to receive more information. (702)-383-8678
No___

18. **Would you like to participate in the restoration effort as a volunteer?**
Yes ___ If yes, please contact the Clark County Desert Conservation Program to receive more information. (702)-383-8678
No____

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

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

_____ I own property adjacent to the Muddy River

_____ I own property in the Muddy River area

_____ I am a resident of the Muddy River area

_____ I am a frequent visitor to the Muddy River area

_____ I do not live in the Muddy River area, but am an interested citizen.

Thank you for your assistance in completing this questionnaire.

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To return this survey (only section B) to us by US Postal Mail, please fold so that address below shows, apply a first-class stamp if printed double-sided or two stamps if printed one-sided, and place in any mailbox. Alternatively, return this copy to Ann Schreiber in person or by leaving it at Calamity's. Ann will forward the questionnaire to The Nature Conservancy.

Thank you very much for you time and response!

The Nature Conservancy of Nevada
One East First Street, #1007
Reno, NV 89501

stamp

Louis Provencher
The Nature Conservancy of Nevada
One East First Street, Suite # 1007
Reno,   NV 89501