THE ALBUQUERQUE REACH
HABITAT ANALYSIS AND RECOMMENDATIONS STUDY,
MIDDLE RIO GRANDE ENDANGERED SPECIES COLLABORATIVE PROGRAM

Prepared for:

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1.0 INTRODUCTION

1.1 REPORT GOALS AND OBJECTIVES

The objective of the Albuquerque Reach Habitat Analysis and Recommendations Study (hereafter referred to as the Study) is to assess the condition of the habitat for the Rio Grande silvery minnow (silvery minnow; *Hybognathus amarus*) and the southwestern willow flycatcher (flycatcher; *Empidonax traillii extimus*) and to make recommendations to the Middle Rio Grande Endangered Species Collaborative Program (Collaborative Program) for additional habitat restoration within the Albuquerque Reach of the Middle Rio Grande (MRG). For the purposes of the Study, the Albuquerque Reach is defined as the portion of the MRG from Angostura Diversion Dam to the southern Isleta Pueblo border, excluding Santa Ana, Sandia, and Isleta Pueblo lands. Completion of the Study will assist the Collaborative Program in meeting its requirements and responsibilities as defined in the March 2003 *Biological Opinion on the Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operations, and Non-Federal Actions* (U.S. Fish and Wildlife Service [USFWS] 2003).

The Study has been based on a review of existing information provided by the Collaborative Program's Habitat Restoration Workgroup (HRW) and other information obtained from key agencies involved with endangered species issues in the MRG. The *Habitat Restoration Plan for the Middle Rio Grande* (Habitat Restoration Plan) (Tetra Tech 2004), the *Final Restoration Analysis and Recommendations for the Isleta Reach of the Middle Rio Grande* (Parametrix 2008a), the *Final Restoration Analysis and Recommendations for the San Acacia Reach of the Middle Rio Grande* (Parametrix 2008b), and the *Pueblo of Sandia Habitat Restoration Analysis and Recommendations* (SWCA 2008) have been used as guiding documents. Information has been derived from the *Revised Draft Albuquerque Reach Plan* (Collaborative Program 2006a), environmental assessments, and biological assessments for projects already constructed or planned in the Albuquerque Reach, as well as recent planning documents from the MRG Bosque Restoration Project (MRG BRP) (U.S. Army Corps of Engineers [Corps] 2010). The project team has consulted with the HRW project review team and the Corps Technical Coordinator to obtain guidance on specific habitat restoration goals and coordinate with the MRG BRP. Updated data developed for the MRG BRP, such as the FLO-2D model and vegetation mapping for the reach, have been updated and used for the preliminary investigations.

Specific project objectives include:

1. Summarize the historical and current physical and biological conditions of the Albuquerque Reach. Included is a description of existing and planned habitat restoration projects.
2. Identify key physical, biological, and ecological parameters that may limit the habitat, abundance, and distribution of the listed species.
3. Develop a restoration model to identify and prioritize habitat restoration projects.

4. Propose habitat restoration recommendations. The habitat recommendations apply the Habitat Restoration Plan (Tetra Tech 2004) to specific objectives of the recovery and maintenance of the silvery minnow and the flycatcher in the Albuquerque Reach. The habitat restoration recommendations are intended to contribute to wider habitat improvement efforts throughout the MRG.
5. Conduct a future-state analysis describing anticipated ecological, hydrological, and geomorphic changes.
6. Propose evaluation criteria to monitor the effectiveness of habitat restoration projects in the Albuquerque Reach.

The habitat restoration recommendations presented here are based on the best available scientific knowledge, comply with all current laws and regulations, and are compatible with other natural resource management objectives of the Collaborative Program and its member signatories. Recommendations proposed in this document are intended to guide planning and development of habitat restoration projects that would benefit the endangered silvery minnow and flycatcher.

1.2 The Middle Rio Grande Endangered Species Collaborative Program

The Collaborative Program is a partnership of federal, state, tribal, and local governmental and non-governmental entities. As of July 2009, 17 signatories comprise the Collaborative Program, which was organized with the task of protecting and improving the status of endangered species associated with the MRG of New Mexico while simultaneously protecting existing and future water uses (Collaborative Program 2009). The Collaborative Program's main objectives are to provide guidelines and procedures for the preservation of threatened and endangered species, while at the same time accommodating current and future regional water needs. The two species of concern are the silvery minnow and the flycatcher.

1.2.1 Program Goals

The following goals serve to define the policy domain in which the Collaborative Program operates and the purposes of its cooperative existence:

1. Alleviate jeopardy to the listed species in the program area.
    a. Identify and articulate the critical scientific questions that will help evaluate flexibility in the system that was not known to be there in 2003.
    b. Understand the system well enough to develop adaptive management tools to support a sustainable Biological Opinion (BO).
2. Conserve and contribute to the recovery of the listed species.
    a. Stabilize existing populations.
    b. Develop self-sustaining populations.
3. Protect existing and future water uses.
4. Report to the community at large about the work of the Collaborative Program.

1.2.2 PROGRAM FOCUS

The Collaborative Program's HRW is responsible for coordinating the "long-term MRG-wide, habitat restoration plans that actively integrate river function, riparian community, and hydrology resulting in improved habitats for endangered species in support of the Biological Opinion" (Collaborative Program 2007). In 2004, Tetra Tech collaborated with the HRW to produce the Habitat Restoration Plan (Tetra Tech 2004), which is designed to identify and prioritize restoration opportunities and provide a framework for the implementation and integration of habitat restoration activities that focus on the water, riparian bosque, and endangered species of the MRG. The Habitat Restoration Plan identifies goals and objectives and provides a framework from which reach-specific plans would be developed. The HRW has since begun to guide the development of the reach-specific planning documents, including the *Final Restoration Analysis and Recommendations for the Isleta Reach of the Middle Rio Grande* (Parametrix 2008a), the *Final Restoration Analysis and Recommendations for the San Acacia Reach of the Middle Rio Grande* (Parametrix 2008b), and the *Pueblo of Sandia Habitat Restoration Analysis and Recommendations* (SWCA 2008).

1.3 2003 BIOLOGICAL OPINION

The Collaborative Program guidelines and recommendations were developed in response to the 2003 BO (USFWS 2003) relative to the 2003 Biological Assessment (U.S. Bureau of Reclamation [Reclamation] and Corps 2003). After review of the 2003 Biological Assessment, the USFWS concluded that the proposed river maintenance activities would jeopardize the continued existence of the silvery minnow and the flycatcher and would adversely modify critical habitat of the silvery minnow (USFWS 2003). The BO was further amended in 2005 (USFWS 2005a) to include an incidental take statement for consideration of increased silvery minnow populations and in 2006 (USFWS 2006a) to account for the USFWS designation of critical habitat for the flycatcher.

The BO presents a reasonable and prudent alternative (RPA) with 32 elements to alleviate jeopardy to the silvery minnow and the flycatcher. The 32 elements of the RPA address long-term recovery needs of the listed species and are partitioned into four sections: 1) water operations, 2) habitat improvement, 3) population management, and 4) water quality. RPA elements A through O address water operations to be adopted by the action agencies. These include specific guidelines for flow manipulation in order to support silvery minnow spawning in late spring/early summer, ensure sufficient surface water availability around nest sites throughout flycatcher breeding periods, and develop water management guidelines to promote silvery minnow survival and reproductive success. Habitat improvement elements (P–X) include such procedures as completing a fish passage at San Acacia Diversion Dam; designing ecosystem restoration/bioengineering projects, such as bank lowering, channel widening, and backwater creation; and implementing extensive monitoring programs. Population management considerations (RPA elements Y–CC) focus on captive propagation activities and augmentation for the silvery minnow. Supplemental to this are silvery minnow surveys and habitat assessments by appropriate entities along each reach of the MRG. Finally, RPA elements DD and EE discuss establishing water quality assessment and monitoring specifically related to the silvery minnow along the MRG. The habitat restoration recommendations presented here apply to the above mentioned RPA elements of the 2003 BO (USFWS 2003), with applications specifically intended for the Albuquerque Reach.

2.0 REACH DESCRIPTION

2.1 PROJECT LOCATION, LAND OWNERSHIP, AND INFRASTRUCTURE

2.1.1 ALBUQUERQUE REACH LOCATION

The Albuquerque Reach is located in Bernalillo and Sandoval counties, New Mexico, and extends 64.9 km (40.3 miles) from Angostura Diversion Dam (River Mile [RM] 209.7) in the north to Isleta Diversion Dam (RM 169.4) (Collaborative Program 2006b) (Figure 2.1). The Collaborative Program defines the MRG as “the headwaters of the Rio Chama watershed and the Rio Grande, including tributaries, from the New Mexico-Colorado state line downstream to an elevation 1,356 m (4,450 feet) above mean sea level, the elevation of the spillway crest of the Elephant Butte Dam” Collaborative Program 2006b). Pueblo and tribal lands are included in the Collaborative Program’s project area only with the express written consent of the pueblo(s) or tribe(s) (Collaborative Program 2006b). However, this same geographic area also is known as the “Upper Rio Grande Basin” relative to the entire Rio Grande watershed from Colorado to the Gulf of Mexico (Corps et al. 2006). The Study length of the river here is considered to be the Rio Grande within the length of the Albuquerque Reach of the MRG, as defined by the Collaborative Program’s Long-Term Plan (Collaborative Program 2006b) (Figure 2.2).

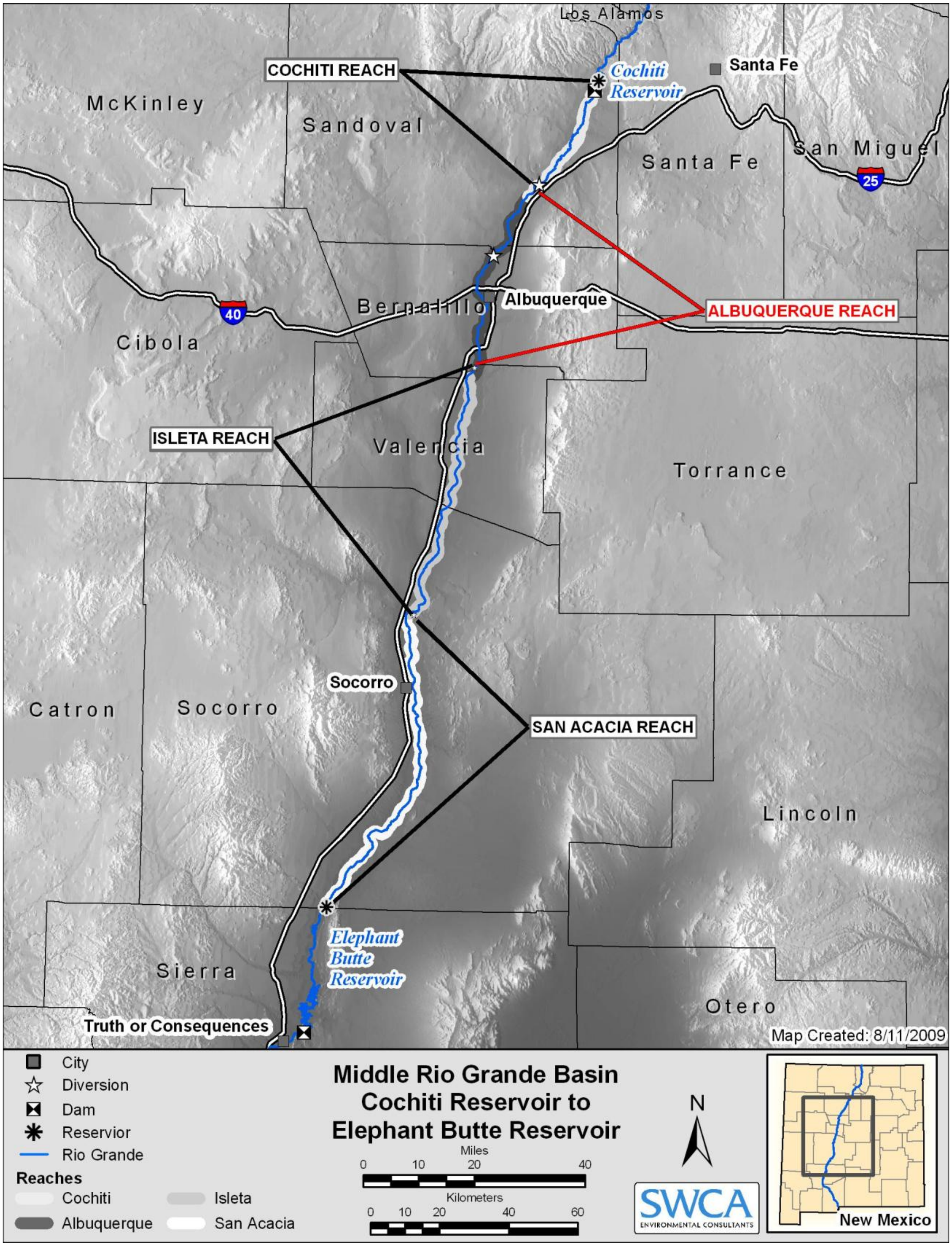

Figure 2.1. Middle Rio Grande Basin map.

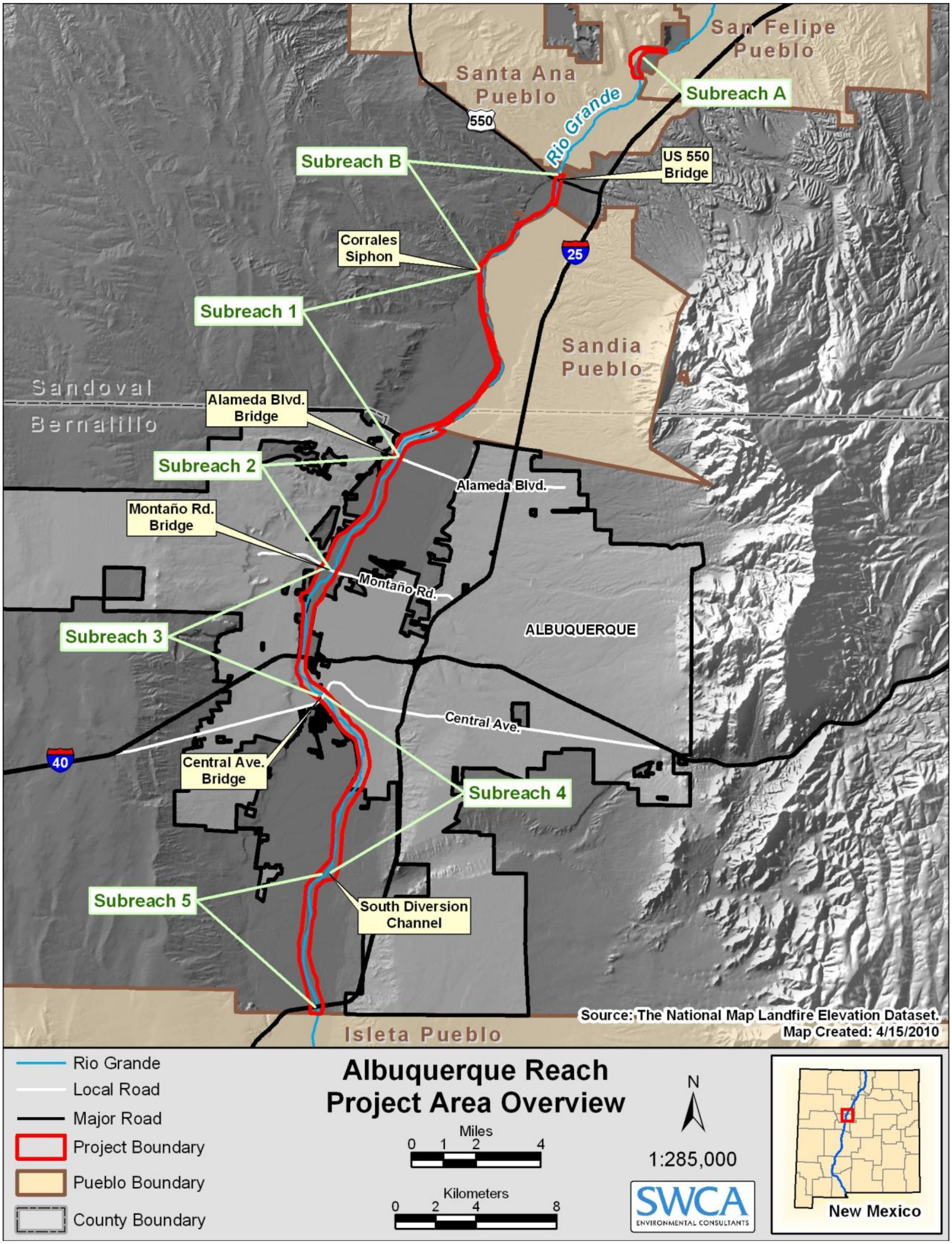

Figure 2.2. Overview of the Albuquerque Reach.

2.1.2 LANDOWNERS AND LAND USE IN THE ALBUQUERQUE REACH

Within its levees, the Albuquerque Reach consists of lands that include pueblo (Pueblo of Santa Ana, Pueblo of Sandia, and Pueblo of Isleta), U.S. Bureau of Reclamation, Rio Rancho Open Space, Village of Corrales, and Rio Grande Valley State Park ownership. The Middle Rio Grande Conservancy District (MRGCD) and the City of Albuquerque co-manage Rio Grande Valley State Park, providing recreational opportunities including river access and trails for hiking, biking, and horseback riding. Additionally, some private lands are just below Angostura Diversion Dam, and the New Mexico State Land Office owns a small track of land just north of the Interstate 25 (I-25) Bridge.

Many of the flat lands immediately outside the bosque within the Albuquerque Reach are used for agriculture. These lands are actively irrigated using water diverted from the Rio Grande at Angostura Diversion Dam and from shallow groundwater wells, and farmers grow a wide variety of crops and pasture lands.

The Albuquerque Reach is the most highly urbanized reach of the MRG; the majority of the population of the MRG is concentrated in this reach in the cities of Bernalillo, Corrales, Rio Rancho, and Albuquerque. The population of the Albuquerque metropolitan area in 2007 is estimated at 835,120 (U.S. Census Bureau 2008). This population has driven the need for water to be extracted from the Rio Grande in this reach by the City of Albuquerque for use by the Albuquerque Bernalillo County Water Utility Authority.

2.1.3 WATER USE INFRASTRUCTURE IN THE ALBUQUERQUE REACH

Water infrastructure in the Albuquerque Reach is composed of structures to reduce flooding and divert, convey, store, and drain water. This infrastructure was constructed in 1934 and is maintained and operated by the MRGCD.

At the north end of the Albuquerque Reach lies Angostura Diversion Dam, a structure built in 1934 to divert up to 650 cubic feet per second (cfs) of water into the Albuquerque Main Canal, which moves water south and laterally to privately owned farmlands and the Pueblos of Santa Ana and Sandia. This structure is maintained by the MRGCD.

The floodplain of the MRG is bisected by more than 2,092 km (1,300 miles) of irrigation ditches and drains (U.S. Geological Survey [USGS] 2001). The Albuquerque Reach alone contains hundreds of miles of irrigation canals, which are integral to moving water from Angostura Diversion Dam to irrigated fields throughout the reach. In addition to canals, the MRGCD is also responsible for the maintenance of drains. Drains were an integral part in the establishment of the MGRCD; in the early twentieth century, the MRG, including the Albuquerque Reach, was plagued by water-logged fields that resulted from a high water table. The establishment of drains helped convey water from these fields after irrigation occurred back to the river. Many of these drains remain operational today and provide habitat for wildlife in addition to transporting water back into the Rio Grande.

Jetty jacks were installed by several entities in the Albuquerque Reach as a method of controlling the river and protecting the existing levees. Floodplain and terrace jetty jacks perform this function by obstructively reducing the water flow velocities and thus causing suspended sediments (SSED) to settle out of the water column (Corps 2003). Bankline jetty jacks control the channel, maintain the modern channel width, and reduce open water evaporation. Jetty jacks are currently owned and maintained by the Corps, MRGCD, and Reclamation and remain on both sides of the river running parallel to the river channel throughout the Albuquerque Reach.

A 2003 study by the Corps states:

> In many areas the jetty jack fields have become a non-functional eyesore that often complicate efforts toward restoration and fuels reduction activities (a preemptive measure in the reduction of fire threat and/or severity by the removal of dead-and-downed vegetation). Although not a permanent structure, the jetty jacks are often entrained within depositional sediments and/or vegetation and thus defy easy removal. (Corps 2003)

Some jetty jacks, approximately 8,000 out of 30,000, have been removed by the Corps, particularly near Central Avenue, for the purposes of fire access and vegetation removal. The New Mexico Interstate Stream Commission (NMISC) has also removed jetty jacks, partially funded through the Collaborative Program, as part of its restoration activities.

In December 2008, the City of Albuquerque began diverting water from the Rio Grande for the purposes of the Albuquerque Drinking Water Project. Water is diverted from the river at a partially retractable dam crossing the Rio Grande just south of Alameda Boulevard. According to the Albuquerque Drinking Water Project Environmental Impact Statement,

> The City would begin to curtail diversion of its [San Juan-Chama] water from the Rio Grande when the native flows above the diversion point reached 260 cfs or less. As the flows continue to decline, the City would reduce diversions until the river reaches 195 cfs of native water at the diversion point. At that point, the City would suspend surface water diversions until flows recover, and temporarily would rely solely on ground water for drinking water. The City must then replace a portion of its withdrawals at its Wastewater Treatment Plant on the south end of Albuquerque. (Reclamation 2004)

Albuquerque's Wastewater Treatment Plant (WWTP) is located on the east side of the MRG, south of Rio Bravo Boulevard. The plant is responsible for treating effluent materials and returning wastewater that meets or exceeds Clean Water Act standards to the river. The Albuquerque WWTP is the largest site of water re-introduced into the Rio Grande in the Albuquerque Reach.

2.1.3.1 WATER USE

Water use in the Albuquerque Reach is much different than that of the rest of the MRG because of the high population along the reach and a proportionately lower concentration of agricultural lands because of urban development within the historic floodplain of the Rio

Grande. Water use originates in four main sources: 1) withdrawals from the river at Angostura Diversion Dam, 2) use of return flows from other users, 3) extraction by the City of Albuquerque at the new Albuquerque Drinking Water Project diversion dam near Alameda Boulevard, and 4) groundwater pumping for both municipal and private wells.

With the Albuquerque Drinking Water Project becoming operational in December 2008, the source of water extraction in the Albuquerque Reach has changed. The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) is beginning to reduce groundwater withdrawals and is increasing surface water diversions. When hydrologic conditions allow, the ABCWUA, under its permit, can divert up to 94,000 acre-feet annually at the drinking water facility—half of this must be returned at the Albuquerque WWTP (Reclamation 2004). This will result in lower stream flows between the water diversion near Alameda Boulevard and the WWTP in Albuquerque's South Valley.

Agricultural water for the Albuquerque Reach is withdrawn from the Rio Grande at Angostura Diversion Dam, near Algodones, approximately 40 km (25 miles) north of Albuquerque. Diversions at Algodones average 140,000 acre-feet annually, but can vary due to hydrologic availability and demand. Some of this water returns to the Rio Grande in the form of return flows, through MRGCD drains, and other water infiltrates, recharging shallow groundwater caches.

2.2 Environmental History

Detailed information on the environmental history for the MRG can be found in Crawford et al. (1993), Scurlock (1998), Robert (2005), and Cartron et al. (2008). Knowledge of the environmental history of the Albuquerque Reach is important in order to gain an understanding of the purposes and goals of the habitat restoration recommendations outlined in this document.

2.2.1 River Dynamics

The Rio Grande's flow regime can be characterized by its high annual and seasonal flow variability. At the USGS Otowi gage in northern New Mexico, the standard deviation of flow in the Rio Grande is nearly half the mean annual flow (S.S. Papadopulos and Associates [SSPA] 2000). Water volume in the Rio Grande has historically peaked during the spring months due to snowmelt runoff and subsided to low flow levels by late summer. At least 82 major Rio Grande flood events have been recorded in the MRG prior to 1942. The largest estimated flood was from spring runoff in 1872 at 100,000-cfs flow in the MRG (Beadle 1973). Historic records for Rio Grande measured flow rates date back to the installation of gaging stations in 1889 at Embudo, New Mexico. Figure 2.3 shows flow records for the USGS Albuquerque gage from 1973 to 2008, following construction of Cochiti Dam and Reservoir.

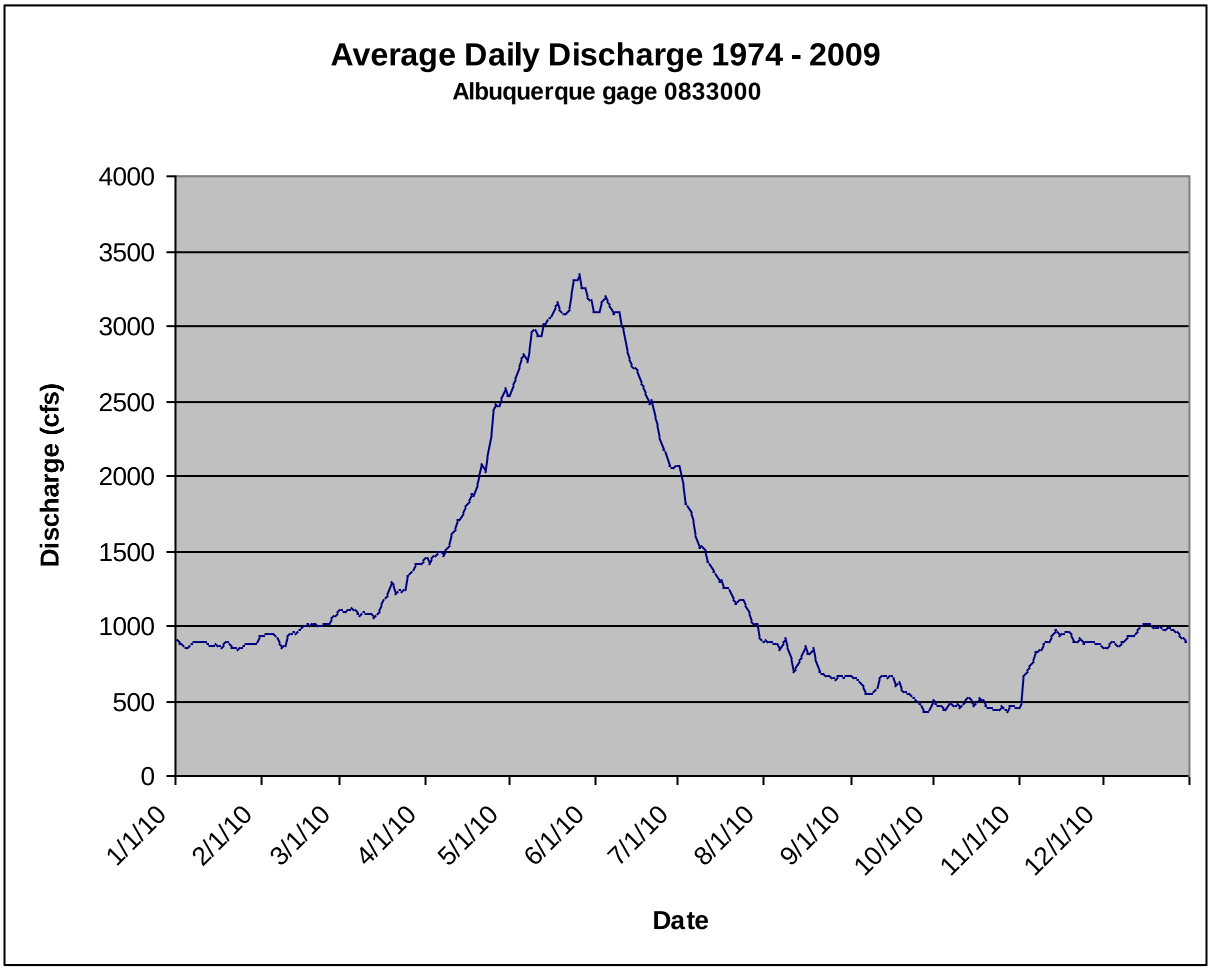

Figure 2.3. Annual average daily discharge at USGS Albuquerque gage 08330000, 1974–2009 (USGS 2010).

Rio Grande Discharge at Albuquerque

Prior to the construction of dams and widespread river regulation, large flooding events associated with changes in river channels were common. Spring floods of 20,000 to 30,000 cfs resulting from snowmelt runoff have been fairly common since gaging stations were installed in the late 1800s. Record levels of rainfall and snow led to high Rio Grande flow rates from 1940 through early 1942, resulting in extensive flooding, but peak flow rates remained around 20,000 cfs. The largest measured Rio Grande flood within the MRG resulted from summer convectional storms in August 1929 and reached 47,000 cfs. In contrast, channel drying has also been recorded, particularly during the 1880s downstream from Albuquerque. Recently, channel drying events have become more frequent downstream of Albuquerque.

Prior to the construction of dams and water diversion projects, the Rio Grande consisted of numerous braided channels that were dynamic and changed frequently across a broad floodplain in the Albuquerque Reach (see TetraTech 2004:28). Numerous channels, oxbows, and wetlands were common (Crawford et al. 1993; Scurlock 1998). During the 1700s, the Rio Grande channel shifted considerably to the west in several reaches of the MRG, including at the settlement of Bernalillo and likely the northern portion of the Pueblo of Sandia. The Rio Grande at Albuquerque was described as about 91 m (~300 feet) wide, shallow, and sandy (Beadle 1973). However in 1873, the Rio Grande at Albuquerque was described as being 183 m (~604 feet) wide and about 1.2 m (4 feet) deep (Beadle 1973).

2.2.1.1 SEDIMENTATION

Historically, Rio Grande sediment loads likely were highest during the spring months under maximum flow conditions and also following summer convectional storms and watershed erosion and runoff. Historic records describe the Albuquerque Reach as experiencing considerable riverbed sediment aggradation during the late 1800s and early 1900s. Reduced river flow from water diversions and growing agricultural practices caused soil erosion throughout the watershed, resulting in heavy sediment loads. The increased riverbed aggradation of sediments during that time apparently had profound influences on the dynamics of the Rio Grande channels and associated water tables. The channel bed of the MRG apparently consisted mostly of sand, whereas the riverbed above the confluence of the Rio Jemez consisted largely of rocks and cobble (Crawford et al. 1993). Sediment loads have declined considerably since the construction of the Rio Jemez Dam in the early 1950s and Cochiti Dam in 1975. Rio Grande sediment loads have been reduced from average annual SSED concentrations of about 4,000 parts per million (ppm) by water volume to about 500 ppm in the Albuquerque Reach since the construction of Cochiti Dam (Corps et al. 2006).

The decrease in upstream sediment has increased channel cutting, reduced the active channel width, and impacted such features as mobile sand bars within the channel (Figure 2.4). A less active channel and reduced high-flow events result in sand bars becoming stabilized with vegetation.

Figure 2.4. This island near Paseo del Norte possesses young vegetation in the foreground, indicating recent disturbance, and more permanent vegetation in the background.

2.2.2 *AQUATIC ENVIRONMENTS*

Human water use of the Rio Grande began as far back as the 1500s by native pueblo people practicing limited agricultural irrigation along the MRG. Irrigation practices increased up through the 1700s with Spanish settlement, and a considerable increase in water use and diversions occurred in the late 1800s. Extensive Rio Grande water manipulations began in the 1930s with the construction of dams and water diversions and the formation and activities of the MRGCD in 1925. Even with those controls in place, more severe flooding occurred during 1941 and 1942, forcing the Corps to implement even more widespread channel modifications to control MRG flows. Further water regulation activities were initiated by Reclamation and the Corps with the implementation of the Middle Rio Grande Project in 1950. Drainage systems, water diversion channels, and increased groundwater pumping eventually served to effectively limit overbank flooding and lower the water tables of the floodplain (Scurlock 1998). These activities ultimately disrupted the ancient connection between river water and groundwater in the adjacent floodplain, which is essential to native riparian vegetation. The river was straightened and confined between two parallel levees, and large iron Kellner jetty jacks were fixed to the bank to protect the newly created levees. Jetty jacks collected sediment that in turn became a seedbed for the establishment of Rio Grande cottonwood (*Populus deltoides* ssp. *wislizenii*) (Muldavin et al. 2004). The result was the transformation of what was by that time a relatively open riparian zone into a nearly continuous, even-aged gallery forest along a narrow and restricted channel (Crawford et al. 1993). Furthermore, the sediment and flood control structures constructed along the MRG caused accelerated channel degradation, creating a riverbed that is and will continue to be more incised and channelized (Crawford et al. 1993).

2.2.3 *TERRESTRIAL RIPARIAN ENVIRONMENTS*

Historic information indicates that the riparian corridor of the entire MRG was much broader and variable than it is currently (Crawford et al. 1993; Scurlock 1998; Cartron et al. 2008). The dynamic meandering channels of the historic Rio Grande resulted in broad floodplains without well-defined riparian zones as are found today. Frequent flooding events apparently caused changes in the position and structure of Rio Grande riparian environments.

Changes in the position and flow rates of Rio Grande channels resulted in associated changes in the spatial arrangement of riparian areas. Riparian vegetation developed and changed in response to Rio Grande floods, sediment deposition, and low flow (Crawford et al. 1993). Historical accounts describe an extensive cottonwood bosque along the east side of the Rio Grande from the historic Alameda Pueblo to Albuquerque and extensive wetlands and ponds in the Albuquerque area during the 1600s (Crawford et al. 1993; Scurlock 1998). Construction of dams on the Rio Grande and riverside irrigation ditches and levees in the 1930s stabilized the terrestrial riparian corridor of the Rio Grande, ending the evolution of the riparian environment resulting from river dynamics. Fluctuating flow rates, sediment deposition, and bank erosion all resulted in spatially and temporally dynamic riparian zones.

The dynamics of the riparian zones probably resulted in soils being renewed frequently due to flooding and sediment deposition, as well as bank overflow erosion. Although there are no data on the structure and chemistry of historic Rio Grande riparian soils, data from other similar river systems indicate that riparian soils consisted largely of recent river sediments and little aggregation of organic litter. A wide range of soil textures is present, but most are characterized by sand, loamy sand, or sandy loam. These soils range from slightly saline to strongly saline and moderately alkali affected. Areas of saline soils occur where the water table is near the soil surface, and salts accumulate as water evaporates (Crawford et al. 1993).

2.3 CURRENT ENVIRONMENTAL CONDITIONS

2.3.1 CLIMATE

Most of the Albuquerque Reach is a continental plateau with a semiarid climate. Climate characteristics include annual precipitation averages of less than 30.5 cm (12 inches), low relative humidity, evaporation rates that exceed precipitation levels, high evapotranspiration rates, and a wide range of diurnal and seasonal temperatures.

Since the onset of the Holocene about 10,000 years ago, the climate of northern New Mexico has been semiarid with a history of repeated drought and wet periods (Swetnam and Betancourt 1999). For the past 600 years, there is little evidence for any major changes in the climate of the Rio Grande Basin, other than a cool period from about 1450 to 1850 and the recent global warming trend (Hall et al. 2006; Rahmstorf et al. 2007). At least 52 major droughts have been recorded in the Rio Grande Basin over the past 448 years, occurring about every nine years. In more recent times, increased occurrences of El Niño Southern Oscillation (ENSO) events have resulted in numerous short-term changes in precipitation and temperature, affecting flow volumes and rates in the Rio Grande (Swetnam and Betancourt 1999; Lee et al. 2004). Snowmelt runoff from the San Juan, Sangre de Cristo, and Jemez mountains have historically been the primary source of water for the Rio Grande, with additional local input from summer storms. Hall et al. (2006) demonstrate that in recent times (since the 1960s), the timing of spring runoff and subsequent Rio Grande flow rates have begun to occur earlier in the season in response to variations in temperature and precipitation over the past 40 years.

The climate in the Albuquerque Reach is strongly influenced by the basin's topography. Topographic barriers such as the Sandia Mountains influence atmospheric circulation, causing orographic precipitation and resulting in areas of "rain shadows." This causes substantial localized variation in precipitation levels.

In areas such as the MRG, dry years and their persistence are important considerations in the storage and operation of water facilities in the region. The relationship between these manifestations of climate and other natural and human disturbances may be among the most significant factors influencing ecological systems in New Mexico (Finch and Tainter 1995).

The Rio Grande Basin lies within three climatic subtypes: 1) the valley reach and lowlands (less than 1,524 m [5,000 feet] above mean sea level [amsl]) from the town of Bernalillo to Elephant Butte Reservoir have an arid climate; 2) the adjacent uplands (to 2,743 m [9,000 feet] amsl) to the east, west, and north of Albuquerque have a semiarid climate; and 3) the mountains (above 2,743 m [9,000 feet] amsl) have a sub-humid climate. In the arid areas, temperatures and evaporation are high, and annual precipitation is less than 25 cm (10 inches). The frost-free season ranges from 180 to 200 days. The average annual rainfall at the Albuquerque Sunport is 22.1 cm (8.70 inches). Table 2.1 summarizes climate data from the Desert Research Institute's Western Regional Climate Center (WRCC 2009) for the Albuquerque Sunport weather station from 1914 to 2008. The 30-year annual temperature and precipitation averages are represented in Figure 2.5.

Table 2.1. Mean Temperatures at Albuquerque International Sunport (1914–2008)

Measurement	Jan	Feb	May	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Annual
Daily Avg. High Temp (°F)	46.8	53.5	61.4	70.8	79.7	90.0	92.5	89.0	81.9	71.0	57.3	47.5	70.1 (avg.)
Daily Avg. Low Temp (°F)	21.7	26.4	32.2	39.6	48.6	58.3	64.4	62.6	55.2	43.0	31.2	23.1	42.2 (avg.)
Ave. Precip-Water Equivalent (inches)	0.44	0.46	0.54	0.52	0.50	0.59	1.37	1.64	1.00	0.89	0.43	0.50	8.88 (total)

°F = degrees Fahrenheit.
Source: WRCC (2009).

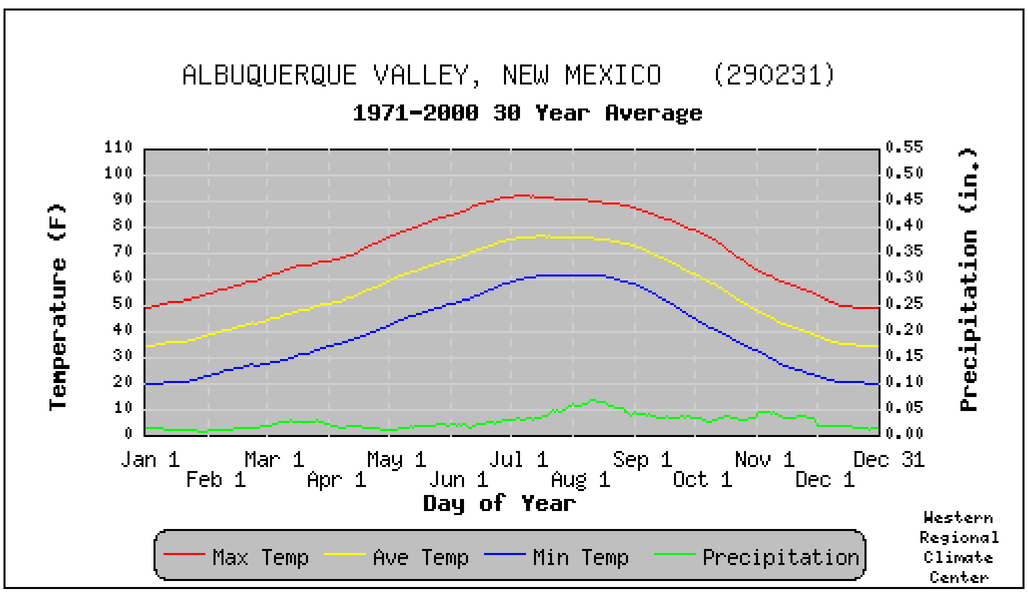

Figure 2.5. Annual temperature and precipitation averages in Albuquerque (WRCC 2009).

The semiarid portions of the region, sometimes referred to as grasslands, have average temperatures in the warmest months in the 20s in degrees Celsius (°C) (70s in degrees Fahrenheit [°F]) and in the coolest months around 0°C (32°F). Annual precipitation ranges from 26 to 46 cm (11–18 inches); the average is 38 cm (15 inches). The semiarid climate extends over most of the region, and temperatures are somewhat lower than in the arid subtype. The annual moisture deficiency is between 25 and 53 cm (10–21 inches). Spring winds with blowing dust are annual events (Tuan et al. 1973). Temperatures generally decrease 5°F for every 305 m (1,000 feet) in elevation gain.

In the Rio Grande Basin, precipitation falls during two distinct periods: winter and summer (early July to late September). The principal sources of moisture for this precipitation are the Gulf of Mexico and the Pacific Ocean. About 50% of the annual precipitation falls in summer from thunderstorms. Snowfall derives mostly from cyclonic storms of moist Pacific air masses, generally moving eastward over the mountains. November and May or June receive the least amounts of precipitation (Figure 2.6).

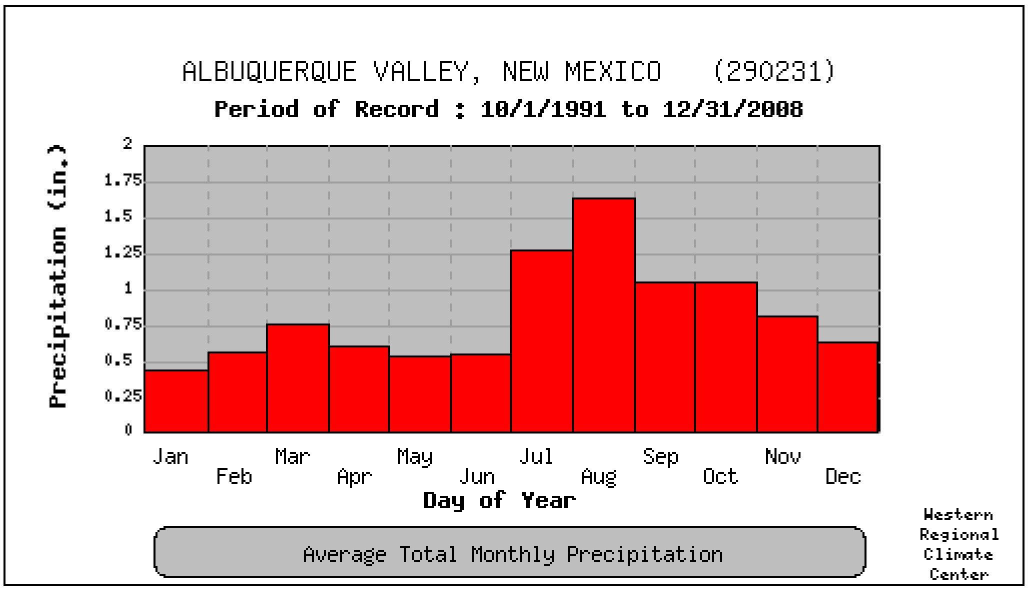

Figure 2.6. Annual precipitation averages in Albuquerque (WRCC 2009).

Weather in the MRG is strongly affected by climatic patterns related to oceanic circulation. Oceanic fluctuations result in considerable fluctuation in precipitation and stream flows for a given year. ENSO years are typically periods of higher winter and spring precipitation, lower temperatures, and higher stream flow. In contrast, La Niña years exhibit lower overall precipitation (but often higher late summer precipitation), higher temperatures, and lower stream flows (Cayan 1996; Lee et al. 2004). Peak stream flows in La Niña years also have been observed to occur earlier (generally during March) than ENSO-associated peaks. As stated above, recent global warming has resulted in overall earlier spring snowmelt runoff in the Rio Grande (Hall et al. 2006).

2.3.2 *GEOLOGY*

The Albuquerque Reach is situated at the northern end of the Southern Rio Grande Rift Valley, located at the western base of the Sandia Mountains in the physiographic Basin and Range Province of North America (Hawley 1978). The Southern Rio Grande Rift Valley becomes broad in the Albuquerque Reach, where the MRG transitions from a region of steeper elevation gradients (~10 feet/mile), narrow valleys (Rio Grande channel widths ~91 m [~300 feet]), and canyons to the north to a more gradual grade (~5 feet/mile) over a broad valley (~122- to 142-m-wide [~400- to 500-foot-wide] channels) with historic floodplains to the south (Corps et al. 2006). Elevation of the Albuquerque Reach ranges from 1,555 m [5,101 feet] amsl at Angostura Diversion Dam on the north end to 1,490 m (4,887 feet) amsl at Isleta Diversion Dam on the south end, resulting in an overall elevation difference of 65 m (214 feet).

The current Southern Rio Grande Rift Valley has resulted from extensive tectonic activity producing horst/graben physiography with fault block mountains, volcanic activity, and a subsidence rift valley during the early Miocene, approximately 20 million years ago (Hawley 1978; Hunt 1983). This rift valley extends approximately 805 km (500 miles) starting in southern Colorado and extending the length of New Mexico. The region is still experiencing tectonic lifting, increasing the vertical relief between peaks and the valley floor. Erosion of the uplands alleviates some of this effect. The subsequent erosion results in a valley rich in alluvial materials as deep as 3,962 m (13,000 feet) in some locations.

The Rio Grande historically began flowing through the vicinity of the Albuquerque Reach of the Southern Rio Grande Rift Valley during the Miocene, initiating the present river course an estimated 5 million years ago (Hunt 1983; Crawford et al. 1993).

2.3.3 River Geomorphology

The MRG lies in an asymmetric, elongated valley along the Rio Grande Rift (Hawley 1978; Chapin 1988). Connected alluvium-filled sub-basins defined by normally faulted mountain ranges dominate the rift valley. The land flanking the Rio Grande Basin on the east is predominantly mountainous, with merging colluvial-alluvial fans and stream terraces sloping down and westward toward the Rio Grande. The geologic surface west of the river is ancestral Rio Grande alluvial deposits with isolated volcanic cones and bedrock covering the fluvial sediments. West of Albuquerque, the land surface gently slopes up toward the watershed divide with the Rio Puerco (this surface is known as the Llano de Albuquerque) (Bartolino and Cole 2002). The river channel flows in a wide valley with a fertile but narrow (3.2–4.8 km [2–3 miles] wide) floodplain that has been cultivated for centuries.

In the twentieth and twenty-first centuries, floodway constriction and channel stabilization projects have altered the natural course of the Rio Grande. Historically, the Rio Grande has continuously reworked valley deposits on the active floodplain. Water resource development in the Rio Grande Basin above Albuquerque has significantly altered the historic Rio Grande channel and floodplain. Flood control and water supply dams have been constructed on the major tributaries (e.g., El Vado, Abiquiu, Galisteo, and Jemez dams) and on the mainstem of the Rio Grande (e.g., Cochiti Dam).

The MRGCD began rehabilitation of the Rio Grande channel in the 1930s. Further channelization occurred in the 1950s, as initial spoil bank levees were improved and Kellner jetty jack fields were installed along the floodway to control the channel and sediment deposition locations (Massong et al. 2005a, 2005b, 2007). This anchored the channel in place and limited its migration, a primary mechanism for maintaining the active wide channel.

From the period of the 1950s to 1975, largely in response to this upstream development, the Albuquerque Reach was relatively stable from a geomorphic perspective. A relatively uniform floodway through the project reach was created. The active channel width was approximately 183 m (600 feet), and in-channel sand bars were likely dynamic. Kellner jetty jack fields anchored the channel in place, limiting its migration. The constructed floodway was noticeably narrower than the original channel, while the general location of the river did not change significantly (Massong et al. 2005a, 2005b). Additionally, several bends and active side channels were abandoned during this process.

A number of studies have been carried out to characterize the geomorphology of the MRG. Data compiled from these studies describe the change in river morphology from the early 1900s. The Rio Grande upstream of the Pueblo of Sandia has converted from a sand bed, braided morphology to a gravel bed, single-threaded form. The bed material is described as gravel/cobble with numerous high-flow channels and abandoned bars and islands. Throughout most of the Sandia Subreach (defined here as the reach extending from the northern Sandia Pueblo boundary to the southern Sandia Pueblo boundary), the Rio Grande is characterized as transitional, changing from the single-threaded form to a slightly meandering thalweg/single-threaded form to a low-flow, braided channel (Massong et al. 2005a, 2005b).

Using hydraulic modeling and geographic information system (GIS) analysis, Leon (1998) describes the Albuquerque Reach as a straight, single-threaded channel. Using a measure of sinuosity, which examines the relationship among the mean annual discharge in cfs and slope in drop per foot, Leon et al. (2003) later describe the Albuquerque Reach as an intermediate sand bed stream. The planform is intermediated between a straight, braided system and a meandering system, although tending toward the straight, single-threaded channel. Further, this pattern has changed little since 1918. Analyses of the longitudinal profile of the channel reveal an overall degradation trend since 1971. Between 1962 and 1972, aggradation of sediments has caused the river bed to rise by up to 1 m (3 feet), followed by a degradation trend of 1.5 m (5 feet) from 1972 to 2001. This bed lowering trend has meant that side channels are becoming abandoned as the channel bed incision process continues (Ortiz 2003). Thalweg elevations have decreased considerably since the early 1970s (Bauer 2004), while the presence of in-channel islands and bars has meant that a decrease in mean bed elevation is less extreme.

Channel width of the Albuquerque Reach has noticeably decreased since the 1900s. The greatest change in channel width occurred from 1918 to 1935, with a less significant change from 1942 to 1992. From 1992 to 2001, the channel width has narrowed at a rate of 3.4 m (11 feet) per year. Much of this narrowing has resulted from reduction in peak flows due to drought, upstream flow regulation, channel degradation, increased amounts of riparian vegetation, and mid-channel bar stabilization (Leon et al. 2003). During this same period, the channel has also become incised, which has led to increased flow depths and decreased width-to-depth ratios (W/D). The cross-sectional area has also increased while the mean flow velocity has decreased. The narrow channel can still convey high flows without any overbank flooding because of the simultaneous channel depth increases (Leon et al. 2003). Moreover, high flows are contained within the channel because of an increase in bank height (Ortiz 2003; Massong et al. 2005a, 2005b). Also noted in the studies is a decreasing channel slope and accompanying reduced water velocity, (i.e., the channel profile has flattened).

2.3.3.1 River Sediments

SSED mass curves from the Albuquerque Reach reflect higher sediments in 1956 though 1973 followed by a decrease in loads in the mid to late 1970s (Leon et al. 2003) (Table 2.2). Massong et al. (2002) attribute the decline in sediment to the closure of Cochiti Dam in 1975, which subsequently acted as a sediment trap. The resultant decline in aggradation initiated the system-wide degradation trend and channel incision described above (Massong et al. 2002; Leon et al. 2003). Supply of sand-sized material is not expected to return to historic levels since supply is now maintained only through the arroyos that drain into the Albuquerque reach (i.e., Arroyo de las Montoyas and Arroyo de las Barrancas). Downstream displacement of fine sediment is expected to increase, leading to further coarsening of the bed (Massong 2003).

Table 2.2. Average Yearly Amount of SSED Measured at the USGS Rio Grande Gages at Albuquerque and Bernalillo, New Mexico

Time Period	Average SSED (million tons/year)
1956–1958	10.8
1958–1972	3.0
1972–1973	7.6
1973–1985	1.2
1985–1993	0.3
1989–1992	No data collected
1993–1995	2.8
1995–1999	0.8

Source Massong et al. (2005a, 2005b).

Within the Albuquerque Reach, the widespread bed material has coarsened from sand to gravel, vegetation has stabilized on previously unstable/dynamic islands, and the river planform has changed from braided to a single, deep channel (Massong et al. 2005a, 2005b). Leon et al. (2003) describe the bed material from 1962 to 2001 as fine sand in 1962, fine to medium sand in 1972, medium sand to very fine and medium gravel in 1992, and medium sand to very coarse gravel in 2001. The increases in bed material size are likely to be a result of degradation of the bed, with material too large to transport being left behind (Bauer 2004). Massong (2003) has observed two transitional stages. The upper section of the Albuquerque Reach is a single-threaded gravel bed (gravel/cobble) with only occasional sand deposits. This is characteristic of the channel immediately downstream of Angostura Diversion Dam extending into the Sandia Subreach. The lower section is characterized as an upstream depositional zone with finer gravel bed material and a generally thicker overlying sand layer.

In summary, grain size has coarsened with distance and time downstream from the Bernalillo Bridge. Data from Leon et al. (2003) and Ortiz (2003) suggest that the transition from sand to gravel bed in the Albuquerque Reach began in the 1980s and is expected to persist in the upstream reaches under the current Cochiti Dam regime; the transition zone, roughly at the Barranca Arroyo, may continue to move further downstream at an unknown rate (Ortiz 2003).

2.3.4 SURFACE WATER HYDROLOGY

The natural flows of the Rio Grande are controlled by the climatic, geologic, and physical characteristics of the contributing watershed (Lee et al. 2004) and are derived largely from snowmelt (predominantly upstream) and summer thunderstorms often localized at lower elevations (Corps et al. 2006). ENSO strongly influences the timing and volume of flows because of its influence on seasonal cycles of temperature and precipitation (Lee et al. 2004). These cycles are exemplified by the dry period observed from the early 1940s to mid 1970s and the wet period from 1981 to the mid 1990s (Swetnam and Betancourt 1999; National Oceanic and Atmospheric Administration 2002). Spring snowmelt runoff is currently occurring earlier in the spring season, due to changes in temperature and precipitation (Hall et al. 2006).

Historically, the Rio Grande through Albuquerque was characterized as a braided river at low to moderate flows. The river was generally wide and shallow with many sand bars. Significant overbank flooding occurred in most years during the spring runoff period, and the active channel experienced avulsions that shifted it across the broad valley floor. The Rio Jemez, Arroyo de las Montoyas, Calabacillas Arroyo, and the Tijeras Arroyo were significant tributaries contributing additional flooding and sediment loads to those that were already coming unimpeded down the main channel. The net result was a dynamic system providing habitat diversity for the silvery minnow and the flycatcher over a wide range of flows.

Following the closure of Cochiti Dam in 1975, reduced peak discharges have accelerated the encroachment of vegetation on sand bars and the evolution of sand bars into permanently attached banks or islands. Since about 1992, narrowing has begun at approximately 1.5 m (5 feet) per year from the U.S. 550 Bridge to Montaño Bridge (Albert et al. 2003). Since the channel bank locations appear largely unchanged, the decrease in channel width appears to be primarily due to island establishment and growth within the active channel (Massong et al. 2005b). In recent history, there has not been sufficient spring discharge to reverse this trend and reshape the island and bars, the 2005 spring runoff notwithstanding.

The post-Cochiti hydrograph is similar to the historic hydrograph, although the peaks have been attenuated. The greatest seasonal flow rates occur from April through June, corresponding to winter snowpack runoff. Precipitation from summer rainstorms has little effect on overall Rio Grande flow rates. The effect of river regulation has been to decrease the high flows and increase the low flows from historic conditions. Monthly flow rates of the Rio Grande at Albuquerque averaged over the years 1974 through 2009 are presented in Figure 2.7.

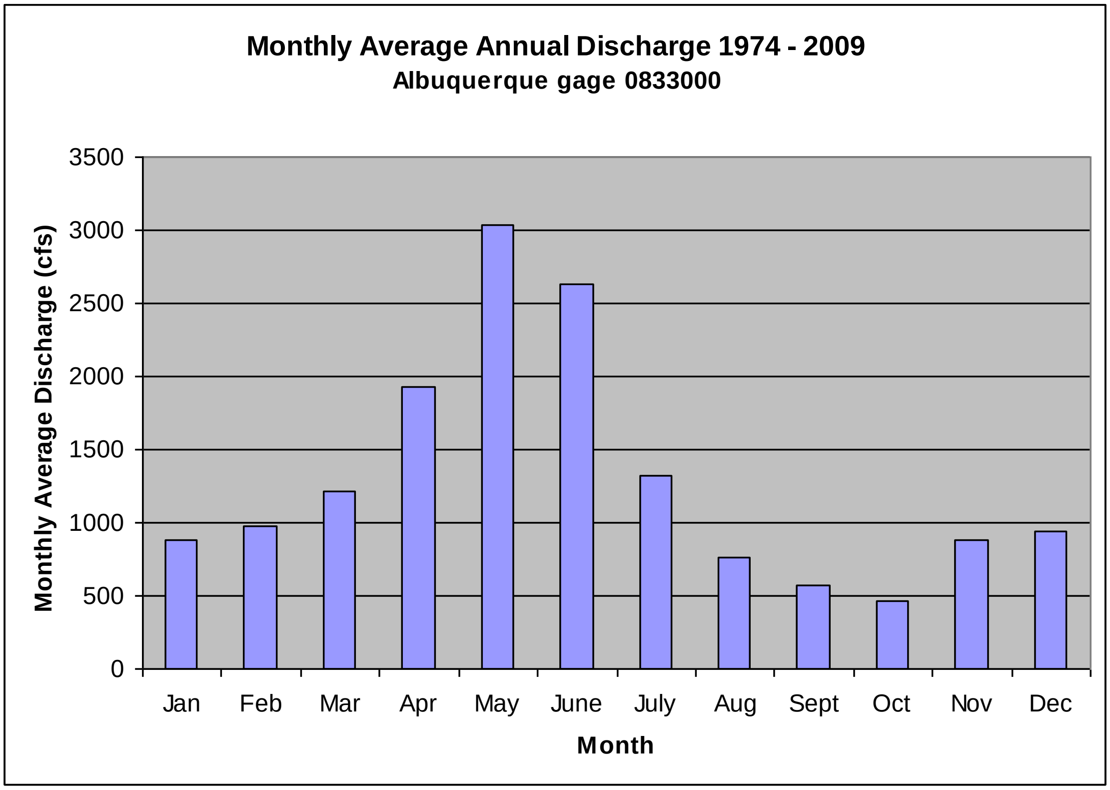

Figure 2.7. Monthly average annual flows recorded from the USGS Albuquerque gage (08330000), 1974–2009 (USGS 2010).

The post-Cochiti spring hydrograph maintains the shape of the pre-Cochiti hydrograph, although it is attenuated and may be occurring earlier in the year. Flow rates vary from year to year depending on winter snowpack and seasonal temperatures, but overall, peaks tend to occur during the late spring and early summer. Figure 2.8 illustrates the variability of spring flows from 2005 to 2007 and compares it with the mean daily flow as calculated by Mussetter Engineering, Inc. (MEI 2007).

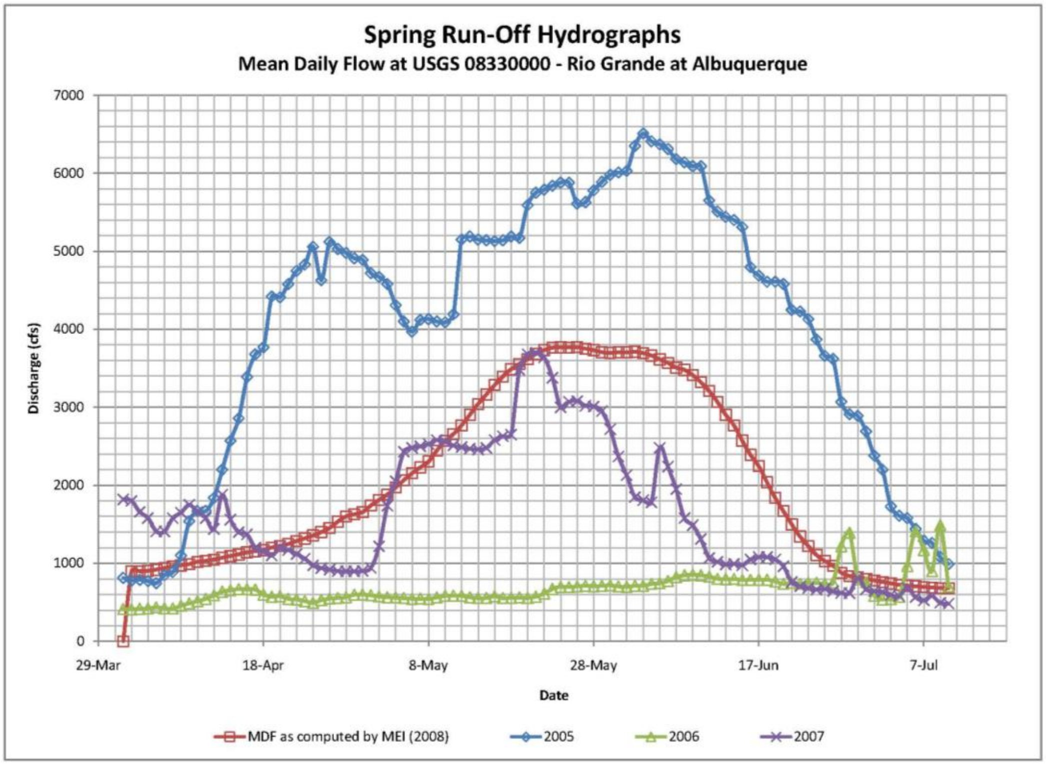

Figure 2.8. Representative spring runoff hydrographs for the Rio Grande at Albuquerque versus mean daily flow, 2005–2007 (Wolf Engineering 2008).

2.3.5 Groundwater Hydrology

Groundwater levels in the Albuquerque Reach have declined significantly due to groundwater pumping, particularly by municipalities. Historically, groundwater rose as a result of increased flood irrigation within the floodplain. As a result, total irrigated acreage within the MRG was reduced by more than 40,470 ha (100,000 acres) as a result of waterlogged fields and alkali conditions (Berry and Lewis 1997). The MRGCD Plan (Burkholder 1928) stated that roughly 72% of farmlands in the valley had a water table within 0.0 to 1.2 m (0.0–4.0 feet) of the land surface, making the land nearly impossible to farm (Berry and Lewis 1997; Parametrix 2008a). This was a major catalyst for the MRGCD's construction of drains throughout the MRG.

A 2003 study was conducted under the Collaborative Program by SSPA and the NMISC to study surface water and groundwater interactions of the MRG from Angostura Diversion Dam to Interstate 40 (I-40) in central Albuquerque. This study was designed to support analysis of water management and riparian restoration projects on the MRG (i.e., identifying impacts of channel structure and vegetation type on surface water and groundwater interactions). The models used recent hydrological data, including a 1994 Reclamation study of surface water and groundwater interactions near the North Diversion Channel outfall to simulate groundwater interactions under varying flow regimes (Hansen 1994) and the New Mexico Atlas (New Mexico Environment Department 2007). The modeling results are illustrated in Figure 2.9.

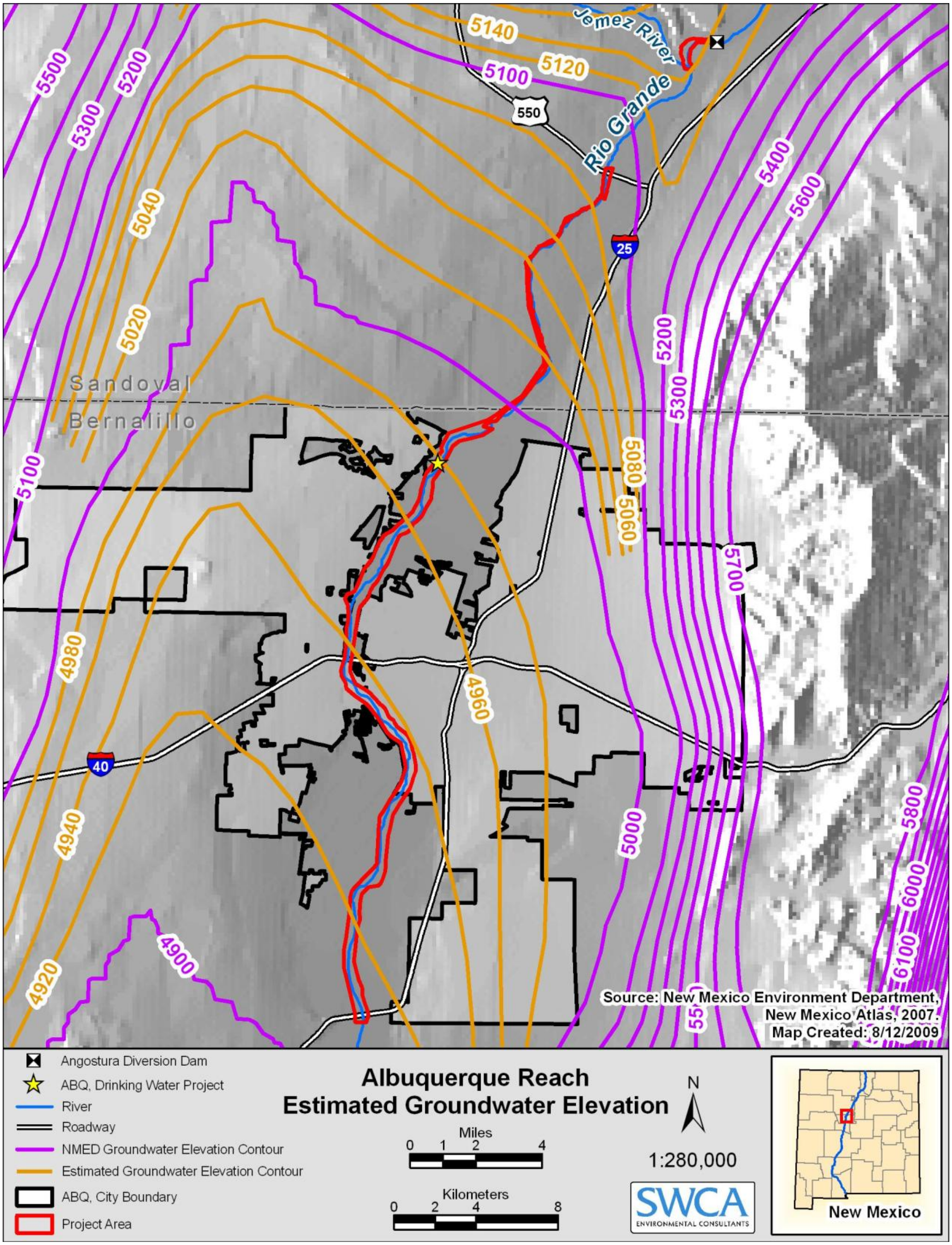

Figure 2.9. Estimated groundwater elevation.

Background data revealed that long-term trends in groundwater elevation varied by well location, but for wells located near Alameda Boulevard there was a linear decrease in groundwater elevation at rates of 0.23 to 0.35 m/year (0.75–1.15 feet/year) over a 16- to 48-year period (SSPA 2005). These declines were attributed to municipal and industrial water uses in the Albuquerque area. Groundwater fluctuations also occurred seasonally. In the Alameda area, the fluctuations varied from well to well but averaged about 0.3 m (1 foot) in magnitude. Greater fluctuations were evident at other wells located between the riverside drains, and peak groundwater elevations occurred between April and June.

Today, groundwater pumping for municipal and industrial purposes has caused a rapid reduction in groundwater levels in certain subreaches of the Albuquerque Reach. These drops coincide with the use of large municipal wells. Fears of subsidence have arisen as the result of large-scale groundwater pumping. To counteract this fear, the ABCWUA is increasing its use of its San Juan-Chama water rights and has begun a series of groundwater recharge pilot projects, such as Bear Canyon Arroyo (Figure 2.10). At the Bear Canyon Arroyo site, treated water from the river is allowed to slowly infiltrate through the arroyo and recharge groundwater. Monitoring wells have been installed to gauge changes in the depth to groundwater.

Figure 2.10. Bear Canyon Arroyo recharge pilot project.

2.3.6 WATER QUALITY

Current information on water quality of the MRG system is available from the USGS, the Corps, Reclamation, the University of New Mexico, the New Mexico Environment Department, the USFWS, and other sources. The Pueblo of Sandia applied for “treatment as a state” status in 1988, gaining U.S. Environmental Protection Agency (EPA) approval in

1990. The Pueblo of Sandia's water quality standards are more stringent than standards implemented by the State of New Mexico and prescribe acceptable levels for constituents including surface water temperature, pH, turbidity, dissolved oxygen (DO), SSED, conductivity/total dissolved solids (TDS), and fecal coliform. Water quality of the Albuquerque Reach is contingent on the degree of both point sources (PS) (e.g., discharges from a pipe) and non-point sources (NPS) (diffuse sources like fertilizer, pesticide application, and water diversion) of pollution. The Albuquerque, Rio Rancho, and Bernalillo WWTPs are the main PS pollutants on the Albuquerque Reach. The available data for the Albuquerque Reach are characterized by a high degree of seasonal variability for several water quality measures, as detailed in Table 2.3.

Table 2.3. Average Water Quality Data by Constituent for the Central Avenue Gage (1975–2001)

Season	Turbidity (NTU)	DO (mg/L)	pH	Conductivity (mg/L)	Water Temp (°C)	TDS (mg/L)	Fecal coliform (col/100mL)	SSED (mg/L)
Nov–Feb	9.12	10.19	8.08	391.86	6.66	255.08	N/A	539.01
Mar–June	45.57	8.66	7.97	359.11	15.90	209.74	82.50	1,167.12
July–Oct	25.67	8.03	8.13	387.95	18.89	273.17	8.00	2,114.67

NTU=nephelometric turbidity unit.
Source: USGS (2003).

According to the 2003 BO (USFWS 2003), many are concerned that water quality of the MRG could be a contributing factor to silvery minnow population decline. The 2003 BO outlines contaminants to river water that may be dangerous to silvery minnow populations, including both PS and NPS examples. WWTP discharges from Bernalillo and Rio Rancho (that affect the Albuquerque Reach) are discussed with specific relation to the silvery minnow. Elevated levels of ammonia and chlorine have been recorded from a Rio Rancho discharge release in 2000 that could be at levels great enough to have significant impacts to the silvery minnow (thought to be concentrations greater than 0.013 mg/l of chlorine and 3.1 mg/l of ammonia) (USFWS 2003). Additional compounds found in WWTP effluent include cyanide, chloroform, organophosphate pesticides, volatile compounds, heavy metals, and pharmaceuticals. Since empirical studies are limited, a definitive description of suitable water quality for the silvery minnow is unavailable at present (USFWS 2010); however, each of those pollutants in high enough concentration is likely to pose a serious threat to the silvery minnow (USFWS 2003).

NPS pollutants from stormwater runoff can also be a threat to the silvery minnow. Storm drain runoff constituents include aluminum, cadmium, lead, mercury, and zinc, as well as industrial solvents like trichloroethane and tetrachloroethane (USGS 2001). In 1995, Harwood (1995) carried out a study of the North Diversion Channel that crosses Pueblo of Sandia lands. The Pueblo of Sandia requested an EPA toxicity test that revealed high levels of dissolved lead, zinc, and aluminum in stormwater discharges. In a comparison with control sites, aquatic crustaceans subjected to water samples from the reach had significant reproductive impairment and mortality, with similar conclusions also made for larval fish. This implies that water quality in the reach could be detrimental to silvery minnow populations. Sensitive periods for the silvery minnow are likely to be during low flow when contaminates can become concentrated in isolated pools. Special monitoring should be carried out to assess impacts on silvery minnow populations during such low-flow periods.

2.3.7 FLOODPLAIN SOILS

The soils of the Rio Grande valley floor are generally derived from recent alluvial deposits. These soils are highly stratified and composed largely of clay-rich overbank deposits and sandy channel and channel bar deposits. Variable stratigraphy of those soils results from the lateral and vertical migrations of the historic Rio Grande. A wide range of soil textures is found in the typical soil profile (Table 2.4), but textures are mostly characterized by a surface layer of loam, with sand, loamy sand, or sandy loam found in the subsurface horizons. These soils vary from poorly drained to well drained.

Table 2.4. Soil Survey for Alameda Bridge to Central Avenue on the East Side of the Rio Grande

Map Unit Symbol	Map Unit Name	Percent of Study Area
Af	Agua loam	5.2%
Ag	Agua silty clay loam	5.5%
An	Anapra silt loam	2.1%
Br	Brazito fine sandy loam	1.2%
Bs	Brazito silty clay loam	2.9%
Bt	Brazito complex	0.3%
Gb	Gila loam	36.8%
Gd	Gila loam, moderately alkali	1.7%
Ge	Gila clay loam	25.5%
GF	Gila complex, moderately alkali	0.0%
Gk	Glendale loam	0.2%
Gm	Glendale clay loam	2.1%
TP	Torrifluvents, frequently flooded	0.0%
Va	Vinton loamy sand	1.8%
VbA	Vinton sandy loam, 0 to 1 percent slopes	10.0%
Vc	Vinton clay loam	4.2%
VF	Vinton and Brazito soils, occasionally flooded	0.6%
Totals for Area of Interest		**100.0%**

Note: Percentage total may not sum exactly due to rounding.
Source: NRCS (2008).

Soil water-holding capacity is particularly important because of its impact on native vegetation. Soils with high water-holding capacity have the potential to provide the necessary water for plant growth and root development because they have the ability to retain moisture for long periods. Poor water-holding capacity is a limitation for seed germination, and moderate to deep water table conditions limit mature cottonwood growth and persistence (Buscher 2003). Willow (*Salix* ssp.) species are especially sensitive to groundwater decline (Natural Resources Conservation Service [NRCS] 2007). Soil salinity may also be a limiting factor for cottonwood and willow regeneration, though further studies would be required to be conclusive on that subject. Salinity maps remain a data gap for this particular Study. Further information regarding saline soils is provided in Shafroth et al. (1995).

2.4 FLORA

2.4.1 AQUATIC FLORA

The aquatic flora of the MRG are poorly known and documented. Van Cleave (1935) describes floating plant communities of algae (*Spirogyra, Vaucheria, Oedogonium*) and duckweed (*Lemna minor*), with muskgrass (*Chara* spp.), milfoil (*Myriophyllum spicatum*), and hornwort (*Ceratophyllum demersum*) in small lakes along the MRG (Crawford et al. 1993). The construction of dams and water diversion projects have resulted in the decline of lake and marshland communities (Hink and Ohmart 1984) and the invasion by saltcedar (*Tamarix* spp.) and Russian olive (*Elaeagnus angustifolia*). Vegetation communities similar to those found in the former lakes have been observed along channel drains but are limited in extent due to steep slopes and flowing water (Crawford et al. 1993). Lists of potential aquatic floral species based on surveys of the Albuquerque Reach are presented in Appendix A.

The current aquatic fish food base of the MRG is composed mainly of algae, aquatic plants, and invertebrates, all of which are affected by changes to the hydrologic regime, substrate, temperature, and sediment inputs (Corps et al. 2006; Valdez and Beck 2007). Reduced nutrient supply to the riparian system has contributed to the demise of many aquatic species of plants and animals or has confined them to restricted habitats (Crawford et al. 1993). Periphyton (matrix of algae, diatoms, fungi, cyanobacteria, bacteria, and organic detritus) is attached to aquatic substrate surfaces and is apparently a key food resource for the silvery minnow (Cowley et al. 2006; USFWS 2010). However, the spatial and temporal distribution and the composition of periphyton are not known from the Albuquerque Reach or other reaches of the MRG.

2.5 FLOODPLAIN FLORA

Historically, the MRG was a somewhat sinuous and braided river system that had a tendency to aggrade. The river channel migrated freely across a wide floodplain (1.6–6.4 km [1–4 miles]) (Crawford et al. 1993) supporting a wide diversity of riparian vegetation types, such as forests, shrublands, and wetlands (Scurlock 1998). According to fossil records, the riparian cottonwood bosque currently found along the MRG was very similar in composition more than 2 million years ago (Knight et al. n.d.); the wetter conditions at that time also supported species like birch (*Betula* ssp.) and western chokecherry (*Prunus virginiana*), now more commonly seen at higher elevations.

Information prior to European settlement was largely anecdotal (Hink and Ohmart 1984), but it is generally understood that when Europeans arrived in the sixteenth century, the dominant plant communities of the bosque included Rio Grande cottonwood with an understory dominated by willow and inland saltgrass (*Distichlis spicata*) (Scurlock 1998). Overbank flooding from late spring snowmelt and summer monsoonal thunderstorm events provided the cottonwood/willow communities with the hydrologic conditions necessary for successful seedling establishment along the riparian corridor (Crawford et al. 1993). These communities were frequently isolated by newly forming channels on which younger cottonwood stands established, creating a patchwork of successional and uneven-aged vegetation interspersed with open grass meadows, ponds, small lakes, and marshes (Crawford et al. 1993; Muldavin et al. 2005).

More detailed information was published by Watson (1912), who described two floristic associations of riparian vegetation in the vicinity of Albuquerque. The first was cottonwood forest with other major plant associations, including wolfberry (*Lycium* ssp.), New Mexico olive (*Forestiera pubescens*), baccharis (*Baccharis wrightii*), and false indigobush (*Amorpha fruticosa*). The second was a wet meadow association that formed as a result of flood-generated avulsion, which frequently induced new channel formation across the wide floodplain (Muldavin et al. 2004). Such flood-induced channel evolution produced isolated oxbow areas that supported cattails (*Typha* spp.), sedges (*Carex* spp.), spikerush (*Eleochris* spp.), reed grass (*Phragmites australis*), pepperwort (*Marsilea vestita vestita*), and various rushes (*Juncus* spp.) (Crawford et al. 1993).

The patterns of large-scale disturbance that shaped the vegetation of the bosque probably characterized the MRG riparian ecosystem until around the 1920s (Hink and Ohmart 1984). Throughout the last century, the intricate fluvial, geomorphic, and biological processes that formed the dynamic Rio Grande ecosystem have been severely interrupted by anthropogenic activities, resulting in a dramatically altered riparian landscape (Muldavin et al. 2004). Although humans have used the Rio Grande riparian area for centuries, serious human alteration of hydrology did not begin until the nineteenth century, with livestock grazing, extensive logging, and increased demand for irrigated agriculture (Crawford et al. 1998; Scurlock 1998).

Hydrology strongly influences plant species composition of riparian ecosystems. Willow-dominated communities require frequent surface saturation and shallow groundwater for survival (Corps et al. 2006), while cottonwood-dominated communities require spring overbank flooding every few years to scour away existing vegetation and make new seedbeds for seedling establishment and early success (Crawford et al. 1993). Overbank flooding is now infrequent along much of the MRG, and therefore suitable habitat for Rio Grande cottonwood reproduction and establishment has become limited. Exotic trees, shrubs, and herbaceous species that do not depend on flood cycles for seedling establishment have invaded the riparian ecosystems, subsequently displacing native species throughout the river corridor (Muldavin et al. 2004). An increase in non-native vegetation has been identified as the most significant indicator of failing ecological health in the riparian ecosystem.

Hink and Ohmart (1984) conducted an extensive biological survey of the MRG, including an intensive assessment of the reach from Bernalillo to the Jarales Bridge (NM 346). The Hink and Ohmart vegetation classification defined vegetation by community and structural types. Community types throughout the MRG were largely cottonwood dominated with varying understory associations, including cottonwood/coyote willow (C/CW), cottonwood/Russian olive (C/RO), cottonwood/juniper (C/J), and species associated predominantly with the sandbar (SB) and river channel (RV). The classification further recognized six structural types based on vegetation height and density of vegetation in the lower layers. Vegetation throughout the study area was assigned to various community-structural types based on initial qualitative assessment of transects and subsequent quantification by vegetation measurements, including density, relative cover, and relative frequency (Hink and Ohmart 1984) (Figure 2.11). The Hink and Ohmart vegetation structural classes are described below:

Type I—Mixed to mature age class stands dominated by cottonwood 15 to 18 m (50–60 feet) tall with well-developed woody understory foliage layers, providing relatively dense vegetation canopy foliage from ground level to the tops of trees.

Type II—Mixed mature trees from 15 to 18 m (50–60 feet) tall with sparse to no understory so that the vegetation canopy foliage cover is mostly limited to the tops of the trees.

Type III—Intermediate-aged stands of cottonwood trees up to about 9 m (30 feet) tall with a dense continuous vertical foliage canopy profile of mixed species from ground level to treetops.

Type IV—Intermediate-aged stands of cottonwood trees up to about 9 m (30 feet) tall but lacking understory foliage canopy layers so that vegetation canopy foliage is limited to treetops.

Type V—Dense vegetation foliage of mixed tree and shrub species from ground level up to 4.6 to 6.1 m (15–20 feet) tall, often with dense ground layers of herbaceous grasses and forbs.

Type VI—Low sparse herbaceous and/or shrubby vegetation with foliage heights of 1.5 m (5 feet) or less, typical of sandbars with saltcedar, cottonwood, willow, and other seedlings.

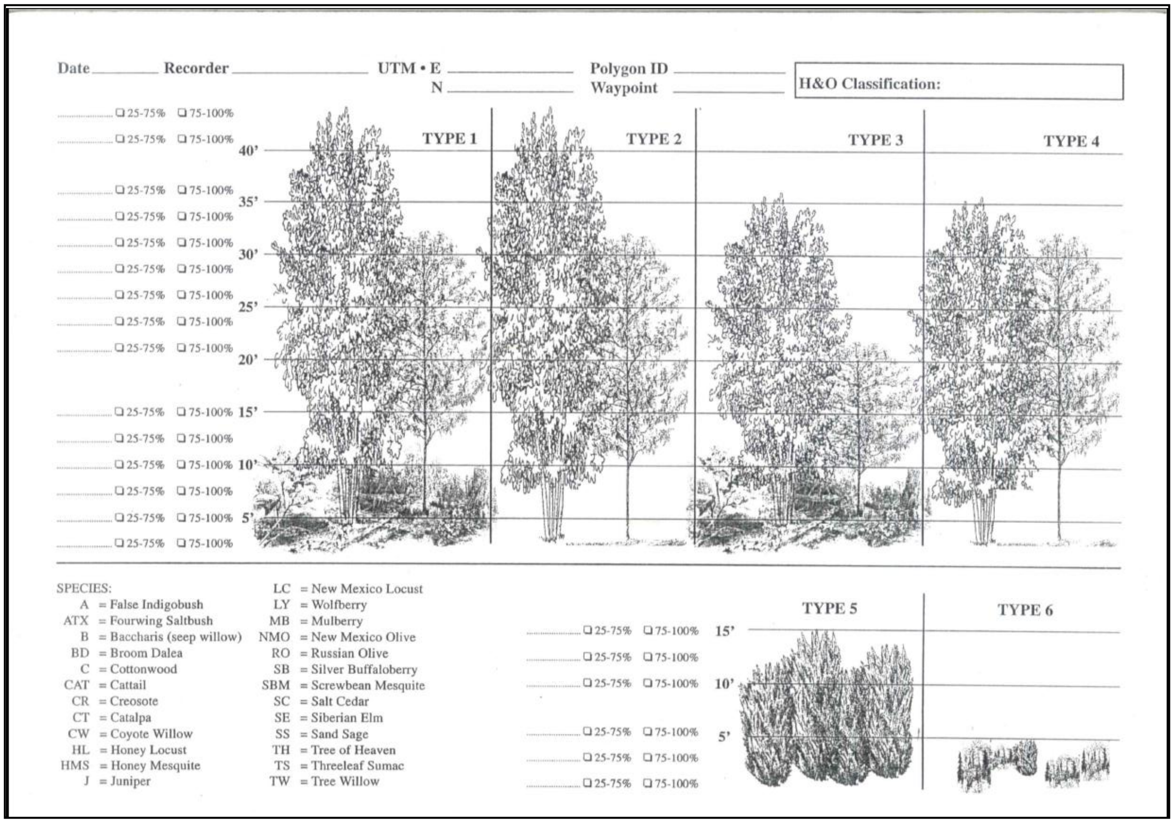

Figure 2.11. Hink and Ohmart (1984) structural classification.

Hink and Ohmart (1984) reported cottonwood forest of structure Type I to be the most abundant vegetation in their intensive study area. Russian olive was the most common understory species often found in association with saltcedar (Figure 2.12). Much of the Albuquerque Reach bosque was characterized by thick, mixed native and non-native shrubs and trees. The midstory vegetation was dominated by Russian olive, scattered saltcedar, and fourwing saltbush (*Atriplex canescens*). Canopy vegetation, where present, was dominated by scattered Rio Grande cottonwood with occasional Siberian elm (*Ulmus pumila*). Understory herbaceous vegetation was sparse in areas that have thick woody growth; however, in areas that were more open, alkali sacaton (*Sporobolus airoides*) and giant sacaton (*S. wrightii*) dominated.

Figure 2.12. Cottonwood/Russian olive, Hink and Ohmart (1984) structural type I classification, Albuquerque Reach bosque.

The original Hink and Ohmart (1984) plots were resampled in 2005 and 2006 (Milford et al. 2006, 2007). Updated Hink and Ohmart maps were produced indicating changes in the vegetation composition; however, much of the Albuquerque Reach is still dominated by the non-native vegetation described above. Recent vegetation management efforts, in response to fires in the bosque, have removed much of the non-native shrub and tree density and biomass.

The 2004 Upper Rio Grande Water Operations Review and Environmental Impact Statement (EIS) (Corps et al. 2006) also provided extensive vegetation mapping of the Albuquerque Reach using a modified Hink and Ohmart (1984) methodology. Cartron et al. (2008) provided accounts for many plant species known to occur in the MRG bosque, as well.

A complete list of the terrestrial flora of the MRG compiled from numerous sources and a list of rare plant species for Bernalillo and Sandoval counties are presented in Appendix A.

2.5.1.1 WILDFIRE

Wildfire was not a common disturbance in the MRG bosque until recent times (Busch and Smith 1995; Williams et al. 2007). Fire was virtually unknown in the naturally functioning, low-elevation riparian ecosystems of the American Southwest (Busch and Smith 1993; Stuever 1997). Two major human-caused wildfires that occurred in the Albuquerque Reach in 2003 have raised awareness of the threats of fire throughout the MRG bosque, prompting the City of Albuquerque to undertake a large fuels reduction project to clear more than 1,012 ha (2,500 acres) of the existing invasive species in the MRG bosque. Altered flood regimes, increased fire-tolerant non-native vegetation, droughts, and increased human presence all will likely contribute to increased bosque fire frequencies and intensities. Native cottonwood and Goodding's or black willow (*Salix gooddingii*) trees are not fire-adapted and thus are less able to recover from the effects of fire than non-native saltcedar and Russian olive (Busch and Smith 1995; Stuever 1997; Stromberg et al. 2002). Native coyote willow (*Salix exigua*) is relatively resilient to fire, and plants that are top-killed by fire tend to resprout from root crowns following fire (Barro et al. 1989; Davis et al. 1989). Mount et al. (1996) have examined vegetation recovery from 33 wildfires in the Belen Reach bosque and find that coyote willow is the first tree species to recover and colonize, followed by saltcedar, Russian olive, and cottonwood. In a study examining avian community response to wildfire, Smith et al. (2006) find few cottonwoods and cottonwood-associated bird species in post-fire sites along the MRG and suggest that riparian specialist bird species may decline after fire following the loss of native trees.

2.5.1.2 River Sandbar and Island Vegetation

Despite the considerable attention that has been devoted to the ecology and biodiversity of the riparian bosque (Hink and Ohmart 1984; Crawford et al. 1993), until recently little was known about the in-channel sandbars and islands. These dynamic environments support young wetland and riparian vegetation (Figure 2.13) and most of the natural regeneration of Rio Grande cottonwoods in the river corridor (Milford and Muldavin 2004). Perhaps due in part to the lack of flood peaks during the current drought, vegetated islands and sidebars currently support approximately 13% of the vegetated floodplain throughout the Albuquerque Reach (Milford et al. 2003).

Figure 2.13. Inundated river bar and vegetation growth in the Albuquerque Reach.

Milford et al. (2003, 2005) conducted a more extensive survey and mapping effort for vegetation of sandbars and islands of the MRG. River islands and bars from the Bernalillo

Bridge to the Alameda drainage inflow accounted for 24% (209 ha [517 acres]) of the floodplain, with upper terraces 62% (538 ha [1,329 acres]), and active channels 14% (125 ha [309 acres]). River islands and bars from the I-25 Bridge to the Belen Railroad Bridge accounted for 19% (422 ha [1,043 acres]) of the floodplain, with upper terraces 68% (1,486 ha [3,671 acres]), and active channels 13% (294 ha [727 acres] (Milford et al. 2005). Dominant vegetation types found on the bars in these two reaches were composed of cottonwood and Siberian elm woodlands (6% of the total island and bar vegetation); coyote willow, immature cottonwood, saltcedar, and Russian olive shrublands (44% of the total island and bar vegetation); and various herbaceous species (48% of the total island and bar vegetation) (Milford et al. 2005).

Shrubland vegetation is the dominant cover type of the northern area surveyed; however, exotic-dominated bars accounted for 59% of these shrublands. Notably the southern area surveyed in this Study is dominated by herbaceous species; Milford et al. (2005) attribute this difference to shifting sediment inputs, channel incision, and stability downstream. River bars and islands are dynamic, ephemeral, early successional environments that support many plant species, both herbaceous species that are colonizers of early successional environments and seedlings of woody species that may or may not become established over time. The importance of this Study is to establish the extent of river bars and islands in the Rio Grande basin and prioritize areas for restoration. Although islands and bars within the MRG consist of less than 20% of the total river floodplain (Milford et al. 2003, 2005), plant species diversity is higher in those areas than in the adjacent mature cottonwood bosque, with many of the species unique to the bar habitat (Milford and Muldavin 2004), thus highlighting their importance to riparian ecosystems.

2.5.2 NON-NATIVE FLORA

The establishment of non-native riparian trees along the riparian zone of the MRG has become a significant environmental and natural resource management concern (Parker et al. 2005). Saltcedar (Figure 2.14) is a non-native tree introduced from central Asia that has become an ever-increasing component of the Rio Grande bosque since the mid 1930s (Crawford et al. 1993). Two species of saltcedar, *Tamarix ramosissima* and *T. chinensis*, were apparently introduced to the MRG in the early twentieth century, and both species now occur throughout the region. The two species are difficult to tell apart, and they are known to hybridize. Our references to saltcedar are inclusive for both species and for hybrids. In many areas, saltcedar has replaced native riparian plant communities, decreasing habitat quality for the flycatcher and many neotropical birds (Anderson et al. 1977; Smith et al. 2006). Moore and Ahlers (2008) find that productivity of flycatcher nests in the MRG is significantly greater in native willow-dominated habitats than in saltcedar habitats, and the authors conclude that flycatchers prefer native willow-dominated habitat when available over saltcedar habitats. Saltcedar seeds germinate readily in most areas that are frequently disturbed (Stromberg 1997), and the plant commonly forms impenetrable thickets, making it highly competitive. Furthermore, the ability of saltcedar to stabilize banks has supplemented human-made channelization of the river (Dahm et al. 2002), a feature of MRG morphology that has reduced habitat quality for the silvery minnow. Saltcedar also is a fire-adapted and highly flammable species, therefore increasing fire hazards in the riparian bosque and out-competing cottonwood and native willow after fires (Busch and Smith 1995). Saltcedar also is believed to exhibit increased transpiration rates and deposit salts on soils through extrusion of salt from its leaves; the species has therefore been associated with highly saline growth environments, with levels greater than are tolerated by native species (Shafroth et al. 1995). However, Stromberg et al. (2009) argue that saltcedar transpiration rates have been exaggerated and are generally similar to the transpiration rates of native riparian vegetation, and salinization of soils by saltcedar is not as important as previously thought. Although simulation models (SSPA 2005) indicate that non-native vegetation may have transpiration rates 20% higher than native vegetation, no empirical data comparing actual transpiration rates between native and non-native vegetation are available within the MRG.

Figure 2.14. Coyote willow and saltcedar on the interior section of an Albuquerque Reach point bar.

Russian olive (Figure 2.15) was introduced to the MRG between 1900 and 1915 (Hink and Ohmart 1984) and spread throughout the MRG to become a dominant component of riparian vegetation by 1960 (Campbell and Dick-Peddie 1964). Like saltcedar, Russian olive is highly competitive due largely to its ability to survive environmental stresses such as low light and drought conditions. Russian olive also contributes to channel stabilization (Waring and Tremble 1993), reducing river sinuosity and overbank flooding. Hink and Ohmart (1984) recognize that the widespread establishment of saltcedar and Russian olive coincided with the period of significant disturbance associated with the Middle Rio Grande Project (1925–1935). Hink and Ohmart (1984) and Dick-Peddie (1993) note that Russian olive is the dominant invasive tree found along riparian reaches north of Albuquerque, while saltcedar tends to proliferate along more southern reaches.

Figure 2.15. Russian olive in the Albuquerque Reach colonizing channel margin (background) with cottonwood behind.

Other non-native invasive plant species of concern for the MRG (as identified in a 2005 U.S. Forest Service exotics management strategy) are Siberian elm, tree of heaven (*Ailanthus altissima*), Russian thistle (*Salsola kali*), kochia (*Kochia* ssp.), Russian knapweed (*Acroptilon repens*), perennial pepperweed (*Lepidium latifolium*), camelthorn (*Alhagi pseudalhagi*), and leafy spurge (*Euphorbia esula*). Exotic annual herbaceous species such as kochia and Russian thistle readily invade disturbed soil and produce large quantities of herbaceous plant biomass. Following the summer growing season, the dead, dry standing biomass remains through the winter and spring months, providing fine fuels for wildfire. A listing of non-native plant species of the Albuquerque Reach region is presented in Appendix A.

2.6 FAUNA

2.6.1 AQUATIC FAUNA

Site-specific data relating to historic aquatic fauna are limited, but European settlers generally found the Rio Grande to have supported 17 to 27 native fish species, including gray redhorse (*Moxostoma congestum*), blue sucker (*Cycleptus elongatus*), Rio Grande shiner (*Notropis jemezanus*), phantom shiner (*N. orca*), Rio Grande bluntnose shiner (*N. simus simus*), shovelnose sturgeon (*Scaphirhynchus platorhynchus*), and freshwater drum (*Aplodinotus grunniens*) (Crawford et al. 1998). Historically, orders of major aquatic invertebrate include Diptera (flies and midges), Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (Valdez and Beck 2007).

By 1990, only 12 species of native fish remained in the MRG (Sublette et al. 1990). Contemporary MRG fish collections suggest that eight native species are present in the

Albuquerque Reach (Dudley and Platania 2008)[1]. Extirpation of many species is attributed to over fishing, increased sedimentation, pollution, introduction of exotic species, and alterations to natural flow regimes (Sublette et al. 1990; Crawford et al. 1998; Scurlock 1998). Flow regime is an important factor characterizing aquatic habitats and associated species (Crawford et al. 1998; Stalnaker 1981) because of the effect it can have on habitat characteristics, such as velocity, substrate, channel shape, and depth (Stalnaker 1981).

Platania (1991) has commented on the longitudinal variation of the MRG aquatic habitats. Lower water temperatures (compared to pre-1970 data) have also been recorded in the MRG below Cochiti Dam, perhaps contributing to the decline of many native warmwater species (Crawford et al. 1998). Many of these fish species are also threatened by declining sediment and increased gravel substrates associated with current flow regimes and incision of the MRG. The decline in native species also has coincided with the introduction of non-native species (Bestgen and Platania 1991; Burke 1992) like common carp (*Cyprinus carpio*) and white sucker (*Catostomus commersoni*), now widespread throughout the MRG.

Reclamation annually conducts fish surveys in the Rio Grande to document trends in fish community structure and evaluate impacts of river operations. According to data from the 2006 field season (February 2006), the most common species caught in the Bernalillo and Alameda sampling areas were river carpsucker (*Carpoides carpio*), common carp, channel catfish (*Ictalurus punctatus*), and red shiner (*Cyprinella lutrensis*) (Reclamation 2006a). Information regarding the population of non-native fishes and other natives is important to efforts to restore the status of the silvery minnow, because the species may be competing with these other species for common resources. The silvery minnow is the only state and federally protected fish species currently inhabiting the MRG, but Rio Grande sucker (*Catostomus plebeius*) and Rio Grande chub (*Gila pandora*) may warrant state protection (Propst 1999). A species list from the Reclamation fish sampling studies is presented in Appendix A (Remshardt et al. 2003).

The lack of comprehensive macroinvertebrate studies (Shirey 2004; Magaña 2007; Valdez and Beck 2007) constrain detailed estimates of species composition and abundance in the Albuquerque Reach. Filtering collector aquatic macroinvertebrates, organisms that live in or near the sediments of the river channel and predominate upstream of Cochiti Reservoir, are replaced immediately downstream of Cochiti Dam, all the way to Elephant Butte Reservoir by gathering collectors. This suggests an alteration of system inputs, caused by Cochiti Dam, from fine particulate organic matter suspended in the water column to organic matter stored in sediments (derived from data attendant to Jacobi et al. 2001). The inability of the system to revert to normal carbon-cycling pathways can be attributed to the paucity of tributaries in the MRG that provide inputs of organic materials.

[1] Assuming that the absence of fish from the current population monitoring data accurately indicates extirpation of species from the Albuquerque Reach.

2.6.2 *FLOODPLAIN FAUNA*

Crawford et al. (1993) and Scurlock (1998) provide detailed accounts of terrestrial riparian fauna historically associated with the MRG. Historic accounts of conditions with the Albuquerque Reach include statements of abundant fish and mammal species during the period of European settlement. Intensive hunting has been blamed for the extirpation of many large mammals that used to be occasional users of the valley resources, including jaguar (*Felis onca*), gray wolf (*Canis lupus*), and brown bear (*Ursus arctos*). The whooping crane (*Grus americana*) is thought to have suffered the same plight (Crawford et al. 1993). Non-native species now commonly found along the MRG may also have been introduced during the settlement era, such as the European starling (*Sturnus vulgaris*), house sparrow (*Passer domesticus*), and domestic pigeon (*Columbia livia*) (Crawford et al. 1993).

Lists of the principal animal species of the Albuquerque Reach are available from a number of sources (Hink and Ohmart 1984; Crawford et al. 1998; Corps et al. 2006; Chung-MacCoubrey and Bateman 2006; Smith et al. 2006; Walker 2006; Bateman, Chung-MacCoubrey, and Snell 2008; Bateman, Chung-MacCoubrey et al. 2008; Bateman, Harner, and Chung-MacCoubrey 2008; Cartron et al. 2008; Bateman et al. 2009). Many of those more recent above-cited studies have addressed the effects of MRG bosque habitat restoration practices on the fauna (see below). A complete list of potential faunal species found in the riparian corridor of the Albuquerque Reach and the vicinity is provided in Appendix A. Additionally, Cartron et al. 2008 provide complete listings of vertebrate species and many invertebrates of the MRG bosque, along with biological and ecological information for each species. The following sections describe various elements of the fauna.

2.6.2.1 ARTHROPODS

The MRG bosque supports characteristic assemblages of arthropods associated with different meso- and microhabitats, and Cartron et al. (2008) provide the most complete listing of known arthropods associated with the MRG bosque along with habitat associations. Eichhorst et al. (2006) provide a listing of ground-dwelling macroarthropod species recorded from a number of Bosque Ecosystem Monitoring Program (BEMP) sites across the MRG bosque, along with summaries of species richness and abundance from a number of sites, including several within the Albuquerque Reach.

Two of the dominant species of bosque ground arthropods are non-native species of isopods (pill bugs or woodlice) (*Armadillidium vulgare* and *Porcellio laevis*) that feed on dead-and-down woody material. Ellis et al. (1999) have found the species, composition, and richness of MRG bosque ground-dwelling arthropods to be similar between native cottonwood and saltcedar habitats, and cottonwood habitats support greater densities of non-native isopods. Ellis et al. (2000) further find that MRG experimental flooding has caused a change in MRG bosque ground arthropod species composition, but the effects vary among different arthropod groups and overall species richness does not change. Crickets (Gryllidae) and ground beetles (Carabidae) increase after flooding, while isopods and spiders decrease. Cartron et al. (2003) have also studied the ground arthropod fauna of a series of regularly flooded and non-flooded MRG bosque sites. The authors have found carabid ground beetles to be consistently associated with regularly flooded sites, while other arthropods are not.

Milford and Muldavin (2004) have studied ground-dwelling terrestrial beetles and vegetation of MRG sandbars, islands, and adjacent riparian bosque, and find distinct assemblages of beetles associated with sandy shore lines. The authors also note that willow sites have the greatest species richness, followed by mixed vegetation and, lastly, cottonwood bosque. Sample points for that study include sites near Coronado Monument, Corrales, and Alameda Boulevard in Albuquerque. The research suggests that biodiversity can be enhanced in those ecosystems by removing Russian olive on river bars and encouraging willow and cottonwood establishment by restoration efforts like overbank flooding (Milford and Muldavin 2004).

Mund-Meyreson (1998) has comparatively studied the foliage canopy arthropod fauna associated with non-native saltcedar and Russian olive and native cottonwood trees along the MRG. The author has found that all three tree species support similar abundances and diversity of foliage arthropods per unit area of tree volume, but larger cottonwood trees support more arthropods because of the larger foliage volumes of the larger trees. However, saltcedar supports more arthropods on a per foliage volume basis during the end of the avian breeding season, but Mund-Meyreson (1998) does not address whether those arthropods are taxa used by birds as food resources relative to those found on native trees. Wildfire has become common in the bosque, and Smith et al. (2006) report that bosque wildfire has reduced the numbers of emerging cicadas (Cicadidae), which are an important food resource for many bird species.

2.6.2.2 Reptiles and Amphibians

The Hink and Ohmart (1984) study reveals that reptile and amphibian populations tend to be greater in areas of open vegetation along the MRG bosque. Common species captured include the eastern fence lizard (*Sceloporus undulatus*), New Mexican whiptail (*Cnemidophorus neomexicanus*), and Woodhouse's toad (*Bufo woodhousei*). A principal species favoring denser vegetation and moister areas is the Great Plains skink (*Eumeces obsoletus*), and open water supports bullfrogs (*Rana catesbeiana*), chorus frogs (*Pseudacris* ssp.), and tiger salamanders (*Ambystoma tigrinum*) (Hink and Ohmart 1984). More recent studies of MRG bosque reptiles and amphibians (Chung-MacCoubrey and Bateman 2006; Bateman, Chung-MacCoubrey, and Snell 2008; Bateman, Chung-MacCoubrey et al. 2008; Bateman, Harner, and Chung-MacCoubrey 2008; Bateman et al. 2009) have focused on the effects of habitat restoration projects involving exotic tree and wildfire fuels reduction on reptile and amphibian communities. Those studies have found no effects of restoration activities on snakes (Bateman et al. 2009) but do have significant but variable effects on lizards (Bateman, Chung-MacCoubrey, and Snell 2008), both positively and negatively affecting different species. Cartron et al. (2008) provide species accounts along with habitat associations for all reptiles and amphibians known to occur in the MRG bosque.

2.6.2.3 Birds

Throughout the year, riparian communities of the MRG provide important habitat during breeding and migration for many bird species. Hink and Ohmart (1984) have recorded 277 species of birds within 262 km (163 miles) of the MRG bosque habitat. Ohmart and Anderson (1986) suggest that species and abundance of birds of the MRG, most notably insectivorous species (e.g., the flycatcher), increase with higher foliage density in the middle and upper vegetative layers. Hink and Ohmart's (1984) vegetation structural types are based on differences in foliage density, emphasizing the significance of density in dictating habitat use. Vegetation change in the MRG bosque from dynamic stands of young native willow and cottonwood to mature stands of saltcedar, Russian olive, and older cottonwood trees probably has had a great effect on avian communities (Mount et al. 1996). Walker (2006) has conducted a comparative study of MRG bird communities associated with native cottonwood bosque and exotic saltcedar stands and has found that cottonwood bosque habitats support considerably more species of birds than saltcedar stands.

Potential bird species for the Albuquerque Reach could be inferred from Hink and Ohmart (1984) surveys made of the wider MRG and their intensive survey section (Bernalillo to the bridge at NM 346). Principal resident species associated with cottonwood communities of the MRG include mourning dove (*Zenaida macroura),* black-chinned hummingbird (*Archilochus alexandri*), Gambel's quail (*Callipepla gambelii*), northern flicker (*Colaptes auratus*), ash-throated flycatcher (*Myiarchus cinerascens*), and ring-necked pheasant (*Phasianus colchicus*). Of the six vegetation communities identified under the Hink and Ohmart classification, the preferred cover types for a large proportion of the bird species surveyed is cottonwood/coyote willow and cottonwood/Russian olive associations.

Reclamation and the Corps have conducted periodic repeat avian surveys on the original Hink and Ohmart (1984) transects from 2003 to 2007 in conjunction with vegetation measurements on the same transects by Natural Heritage New Mexico (Hawks Aloft 2008a, 2008b). In 2007, the researchers found that cottonwood stands with dense understory vegetation supported the greatest diversity of birds, that New Mexico olive and Russian olive appeared to provide important food resources to birds, and that the lowest bird diversity was found in areas cleared of non-native vegetation for habitat restoration (Hawks Aloft 2008a). Finch et al. (2006) and Bateman, Chung-MacCoubrey, et al. (2008) have reported on the effects of MRG bosque habitat restoration activities involving the removal of exotic trees and fire fuels. The authors have found that bird species that utilize mid-level vegetation structure for nesting initially declined following restoration activities but speculate that densities of those species should again increase as understory woody vegetation develops following restoration. Other than avian surveys of Hink and Ohmart transects, avian surveys specific to the Albuquerque Reach have focused on the federally endangered flycatcher and potential nesting sites and are usually carried out annually from April 15 to September 15. The Collaborative Program has funded flycatcher surveys of the Albuquerque Reach, conducted by Reclamation and the Corps since 2004 (Corps 2004, 2005; Hawks Aloft 2005, 2006, 2009), and two single flycatchers were observed within the Albuquerque Reach in 2009

(Hawks Aloft 2009), but no breeding pairs have been observed within the Albuquerque Reach.

Listings of MRG bird species associated with the Albuquerque Reach may be found in Finch et al. (2006), Smith et al. (2006), and Hawks Aloft (2008a). Cartron et al. (2008) provide a complete listing of birds known to occur in the MRG bosque, along with habitat information. A list of potential bird species for the Albuquerque Reach is presented in Appendix A.

2.6.2.4 MAMMALS

Several native large mammals associated with the riparian habitat of the MRG are beaver (*Castor canadensis*), muskrat *(Ondatra zibethicus*), raccoon *(Procyon lotor*), coyote (*Canis latrans*), gray fox (*Urocyon cinereoargentus*), bobcat (*Lynx rufus*), and striped skunk (*Mephitis mephitis*). Principal small mammal species of the Albuquerque Reach are native white-footed mouse (*Peromyscus leucopus*) and western harvest mouse (*Reithrodontomys megalotis*), as well as non-native house mouse (*Mus musculus*) (Hink and Ohmart 1984). The abundance and distribution of small mammal species relates to the structure and mosaic of the vegetation community and the moisture regime of the riparian belt (Crawford et al. 1993). Ellis et al. (1997) have found both saltcedar and cottonwood MRG bosque habitats to be dominated by white-footed mice, but the saltcedar habitats supported more rodent species, including the more typically upland species and the non-native house mouse. The authors find the white-throated woodrat (*Neotoma albigula*) to be only associated with cottonwood habitats. Bateman, Harner, and Chung-MacCoubrey (2008) report that bat activity is higher in MRG bosque sites where exotic trees and fire fuels have been removed compared to non-treated site. Cartron et al. (2008) provide species accounts for mammals known to occur in the MRG bosque, along with habitat information. A list of potential mammal species for the Albuquerque Reach is presented in Appendix A.

2.6.3 *NON-NATIVE FAUNA*

Many species of non-native animals occur along the MRG, including several species of fishes, mammals, and arthropods. At least 22 species of non-native fishes have been introduced and become naturalized in the MRG. Of those 22 species, several predatory sport fishes, such as brown trout (*Salmo trutta*), northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), and striped (*Morone saxatilis*), white (*Morone chrysops*), largemouth (*Micropterus salmoides*), and smallmouth bass (*Micropterus dolomieu*), are all potential predators of native fishes, including the silvery minnow. Others may compete with native fishes for habitat and food resources.

Two of the dominant macroarthropods of the riparian bosque are introduced isopods (Crusteacea). Both species are detritivores that feed on organic forest floor litter, and they often occur in very high densities, potentially competing with native detritivore arthropods for habitat and food resources. Several other non-native arthropod species such as the ring-legged earwig (*Euborellia annulipes [Lucas])* and field cockroach (*Blatella vaga*) also occur in leaf litter along the MRG (Cartron et al. 2008). The European honeybee (*Apis mellifera*) has been introduced along the MRG, and honey bees compete with native bees and other pollinators for flower nectar and pollen resources. Potential competitive interactions between non-native and native arthropods have not been studied.

3.0 SPECIES BIOLOGY AND HABITAT ECOLOGY

3.1 Rio Grande Silvery Minnow

3.1.1 Biological Characteristics

The silvery minnow is a moderate-sized, stout minnow, reaching 9.2 cm (3.6 inches) standard length (Gonzales and Hatch 2009) (Figure 3.1). Typically the back and upper sides are silvery to olive, with a broad greenish mid-dorsal stripe and abdominal sides that are silver with dark lateral speckles present. During spawning, reproductively mature females are identifiable from males by an expanded body cavity, which is the only readily apparent sexual dimorphic trait for the species (Bestgen and Propst 1996).

Figure 3.1. Rio Grande silvery minnow.

3.1.1.1 Reproduction

Silvery minnows are iteroparous, opportunistic, pelagic spawners. Generally, age class I (after January 1 of the first year) and older silvery minnows are reproductively mature. Potential female fecundity has been reported to be between 621 and 5,300 eggs and is greater for larger, older-aged fish (Platania and Altenbach 1996). Although older-aged fish comprise a relatively small portion of the population, their increased fecundity indicates the potential for substantial contributions to the population's annual reproductive output (e.g., findings from Rees et al. [2005][2] for the plains minnow [*Hybognathus placitus*]).

The silvery minnow produces up to 5,300 neutrally buoyant eggs (Platania and Altenbach 1996), which have been observed both in main river channel habitat (Platania 1995) and backwaters and low- and no-flow floodplain habitats (Beck and Fluder 2006; SWCA 2007; Hatch and Gonzales 2008). The species typically spawns during late spring and early summer, coinciding with high spring snowmelt (Sublette et al. 1990). The eggs hatch in two to three days, and the larvae may drift in the main channel or remain in low-velocity areas. Shallow, low-velocity areas formed on inundated floodplains are likely ideal nursery habitat

[2] Rees et al. 2005 developed a simple life stage model showing that age-3 plains minnow makes up only 5% of the population, but contributes as much as the age 1and age 2 fish because the age 3 fish have the capacity of giving off more eggs.

sites for the silvery minnow, as these habitats provide forage (periphyton) and cover (debris and emergent vegetation) for both larval and adult fish (Massong et al. 2004; Hatch and Gonzales 2008). The creation of nursery habitat by lowering banklines and creating channels into previously isolated floodplain habitats has been a major habitat restoration goal in the MRG (Massong et al. 2004; SWCA 2008). Natural flow regimes, movement within the limited remaining range, and the availability of diverse habitats are important to completion of the life cycle.

3.1.1.2 Diet

The silvery minnow has been assumed to be herbivorous because the species possesses a long coiled gut typical of other herbivorous minnows (Sublette et al. 1990). Cowley et al. (2006) and Shirey (2004) find that the silvery minnow feeds on organic detritus, tree pollen, cyanobacteria, and algae, including a wide diversity of diatoms associated with sand, mud, rock, and plant substrates. Laboratory-reared silvery minnows have been observed feeding on aquarium algae (Platania 1995). Aquatic and terrestrial insects have also been observed among the stomach contents of larger silvery minnow specimens (Magaña 2007; Michael Hatch, personal communication 2009).

3.1.2 Status and Distribution

Until the 1950s, the silvery minnow was distributed throughout many of the larger-order streams of the Rio Grande Basin upstream of Brownsville, Texas, to points north in New Mexico, primarily below 1,676 m (5,500 feet) amsl. This elevation coincides with the approximate vicinities of Abiquiu on the Chama River, Velarde on the Rio Grande, and Santa Rosa on the Pecos River (Sublette et al. 1990). Today, absent from much of its historic range, the silvery minnow is restricted to a variably perennial reach of the Rio Grande in New Mexico, from the vicinity of Bernalillo downstream to the head of Elephant Butte Reservoir, a distance that fluctuates as the size of the pool of water in storage in Elephant Butte Reservoir changes but approximates 241 km (150 river miles). Most descriptions of the contemporary range of the silvery minnow cite the entire reach of the Rio Grande between Cochiti Dam and Elephant Butte Reservoir. However, this assertion cannot be made with certainty. The species' status in the Rio Grande between Cochiti Dam and Angostura Diversion Dam is unknown; however, recent surveys in this reach of river have not produced silvery minnow (Torres 2007).

3.1.2.1 Reasons for Listing

The silvery minnow is currently listed as endangered by the State of New Mexico, having first been listed on May 25, 1979, as an endangered endemic population of the Mississippi silvery minnow (*Hybognathus nuchalis*) (New Mexico Department of Game and Fish 1988). On July 20, 1994, the USFWS published a final rule to list the silvery minnow as a federal endangered species with proposed critical habitat (Federal Register 1994). Over the course of history, 13 native fish taxa representing eight families (48% of the region's native fish fauna) have been extirpated from the Rio Grande of New Mexico or have become extinct (Sublette et al. 1990). Anthropogenic alteration of the natural flow regime resulting in river drying, has factored prominently in the decline of native fish species in the MRG, the incipient effects of which, for some species, predate the 1900s (Sublette et al. 1990). The expanse of river that has gone dry in recent years represents approximately 45% of the contemporary range of the silvery minnow

3.1.2.2 Critical Habitat Designation

Critical habitat is defined as an area(s) occupied by the species at the time of listing that contains those physical and biological features that are essential to the conservation of the species and that may require special management considerations or protection. These general requirements include, but are not limited to, space for individual and population growth and normal behavior; food, water, air, light, minerals, or other nutritional or physiological requirements; cover or shelter; sites for breeding, reproduction, and rearing or development of offspring; and habitats that are protected from disturbance or are representative of the historic geographical and ecological distributions of a species.

In 2003, the USFWS designated critical habitat for the silvery minnow in the MRG. The designation extends from Cochiti Dam downstream about 252 km (157 miles) to the utility line crossing the Rio Grande in Socorro County, which corresponds to the southern limit of the Collaborative Program boundary. This location is 1,356 m (4,450 feet) amsl, corresponding to the elevation of the spillway crest for Elephant Butte Dam. The lateral limits (width) of critical habitat extend between the existing levees or, in areas without levees, 91.4 m (300 feet) of riparian zone adjacent to each side of the bankfull stage of the MRG. The critical habitat designation includes the San Felipe Subreach. Tribal lands of Santo Domingo, Santa Ana, Sandia, and Isleta within this area are not included in the critical habitat designation (USFWS 2003).

3.1.2.3 Primary Constituent Elements

Primary constituent elements are those physical and biological features of the habitat that are essential to the conservation of the species and that may require special management considerations or protection. The primary constituent elements of silvery minnow critical habitat, as defined by USFWS (2003:8117), are:

1. A hydrologic regime that provides sufficient flowing water with low to moderate currents capable of forming and maintaining a diversity of aquatic habitats, such as, backwaters (a body of water connected to the main channel, but with no appreciable flow), shallow side channels, pools (the portion of the river that is deep with relatively little velocity compared to the rest of the channel), eddies (a pool with water moving opposite to that in the river channel), and runs (flowing water in the river channel without obstructions) of varying depth and velocity—all of which are necessary for each of the particular silvery minnow life-history stages in appropriate seasons. The silvery minnow requires habitat with sufficient flows from early spring (March) to early summer (June) to trigger spawning, flows in the summer (June) and fall (October) that do not increase prolonged periods of low or no flow, and a relatively constant winter flow (November through February).

2. The presence of low-velocity habitat (including eddies created by debris piles, pools, backwaters, or other refuge habitat [e.g., connected oxbows or braided channels]) within unimpounded stretches of flowing water of sufficient length (i.e., river miles) that provide a variety of habitats with a wide range of depth and velocities.
3. Substrates of predominantly sand or silt.
4. Water of sufficient quality to maintain natural, daily, and seasonally variable water temperatures in the approximate range of greater than 1degree Celsius (°C) (35 degrees Fahrenheit [°F]) and less than 30°C (85°F) and to reduce degraded water quality conditions (decreased DO, increased pH, etc.).

3.1.2.4 POPULATION TRENDS/DISTRIBUTION WITHIN ALBUQUERQUE REACH

Silvery minnow population surveys in the Albuquerque Reach have occurred since 1994 on an ongoing basis (surveys were not conducted in 1998) by the American Southwest Ichthyological Research Foundation (Dudley and Platania 2007a, 2007b, 2008), Reclamation, the NMISC, and the USFWS. The silvery minnow population has fluctuated dramatically since monitoring began with the lowest abundance occurring 2001 through 2004 (Dudley and Platania 2008). Despite annual fluctuations of silvery minnow abundance, recent monitoring indicates that species abundance is increasing in both the Angostura and Isleta reaches. In 2004, an increased abundance of silvery minnow was observed (Dudley et al. 2005). Monitoring early in 2005 revealed low silvery minnow numbers (Dudley et al. 2006; Dudley and Platania 2007a); however, numbers rose drastically in June 2005 and remained high into 2006. Existing population data are lacking estimates of catchability, making their use to address recovery goals based on silvery minnow abundance difficult.

3.1.3 HABITAT CHARACTERISTICS

Silvery minnow habitat preferences are characterized by Dudley and Platania (1997) as:

- Water velocity: Silvery minnow are most abundant (86.5%) in areas with little or no water velocity (<10 cm/s [4 inches/s]), are seen occasionally (11.0%) in areas of moderate velocity (11–30 cm/s [4.3–11.8 inches/s]), and are seen rarely (0.8%) in habitats with water velocities greater than 40 cm/s (16 inches/s).
- Water depth: The species is most commonly caught in depths of less than 20 cm (7.9 inches) or 31 to 40 cm (12.2–15.8 inches). Few individuals use areas with depths greater than 50 cm (19.7 inches).
- Substrate: The species is most commonly (91.3%) caught over silt. Sand is the second most common substrate (8.1%), while gravel and cobble account for less than 1% of the substrate frequented.
- Mesohabitat: The most frequently used habitats are eddies formed by debris piles (40.5%), pools (35.9%), and backwaters (13.8%), reflecting a preference for low-velocity areas. Main channel runs (the most abundant mesohabitat) are avoided; only 1.3% of silvery minnows utilize them.

Habitat use differs from summer (April–September) to winter (October–March). Summer habitats include pools and backwaters. In winter, preferred habitat is found near instream debris piles; at that time, more than 70% of specimens are found in or adjacent to debris piles (Dudley and Platania 1996). The silvery minnow travels in schools and typically occupies stream reaches dominated by straight, narrow, or incised channels with rapid flows (Bestgen and Platania 1991; Sublette et al. 1990). Diminished water velocity appears to be a major factor influencing winter habitat selection. The species also shifts to deeper waters in winter. Typically, the silvery minnow occupies low-velocity (<0.3 feet per second [fps]), shallow (<0.4 m [1.3 feet]) water over a sand and silt substrate (Dudley and Platania 1997) in the summer months, transitioning to deeper water (31–40 cm [12.2–15.8 inches]) in the winter. Deeper areas generally have lower water velocities. Individuals are found almost exclusively over silt and sand substrata in both summer and winter; however, all substrate classes, except boulders, are utilized to some degree.

Mesohabitat associations include eddies formed by debris piles, pools, and backwaters (Dudley and Platania 1997). In addition, recent investigations have documented the occurrence of substantial numbers of reproductively mature silvery minnow on floodplain habitats during spring runoff at flows greater than 2,000 cfs (Hatch and Gonzales 2008).

3.1.3.1 Breeding Habitat/Spawning and Nursery

Little or no information exists regarding silvery minnow habitat preferences during spawning. However, recent studies suggest that floodplain connectivity is important for egg retention and larval development (Fluder et al. 2007). Suitable habitat for overbank flooding habitats should show connectivity at both upstream and downstream points in order to provide positive flow-through and prevent stranding of larvae and adults after floodwaters recede.

Recent investigations during a significant spring runoff (peak discharge greater than 5,000 cfs) have resulted in collections of reproductively mature silvery minnow and their eggs in low-velocity, low water exchange lateral habitats, including backwater and other hydrologically retentive floodplain features (Hatch and Gonzales 2008; Gonzales and Hatch 2009). These habitats serve to reduce the displacement of larvae and eggs during flooding and provide suitable nursery habitat for larval and proto-larval fish (Pease et al. 2006; Hatch and Gonzales 2008).

Porter and Massong (2003, 2004, and 2006) conducted studies to determine how geomorphology and hydrology affect silvery minnow egg and larval fish retention. In 2003, Porter and Massong (2003) examined egg drift and retention in constructed inlets by releasing known quantities of gellan beads, which have the same buoyancy as silvery minnow eggs. The results suggest that sites with a large drift zone area (areas of no measurable velocity or flow direction) and substantial inflow and outflow at the inlet mouth are most effective for retention. Retention is influenced by the length of the inlet, inlet shape, and location of the exit flow. Inlets that have through-flows at the back are found to have reduced retention. In 2004, a low water year, Porter and Massong (2004) examined natural habitat features at the confluences of arroyos. The results suggest that inundated shelves are the most effective at retaining eggs and larval fish. In 2005, Porter and Massong (2006) characterized capacity of egg drift retention for the geomorphological features defined in the NMISC/MEI 2005 bar classification system (MEI 2006a) (e.g., linguoid bars, Level 1 and 2 braid bars, Level 1 and 2 mid-channel bars, alternate bars, and Level 1 and 2 bank-attached bars). The results indicate that a range of macro-habitat features may provide nursery habitat and is a function of flow levels. Surrogate gellan beads (and presumably silvery minnow eggs) were reported highest on mid-channel bars and Level 2 braid bars, while bank-attached bars hold more larval fish. Microhabitat characteristics influence egg retention; areas with wide-ranging shelf depths provide the best conditions for capturing and retaining eggs. Porter and Massong (2006:38) conclude that "these patterns suggest that egg drift below the flow threshold for inundating pointbars and islands results in massive downstream transport of silvery minnow eggs and larvae, reducing survival and recruitment. As flows increase the time and area of inundated terrestrial surfaces, egg drift decreases and egg retention increases with corresponding survival and recruitment."

Widmer et al. (2010) conducted experiments with artificial eggs (gellan beads) to simulate silvery minnow egg transport and retention in the Albuquerque and Isleta reaches of the Middle Rio Grande. They found that bead retention varied by reach, discharge, and the shape of the hydrograph during expected spawning times for the species. The highest observed retention in the Albuquerque (6.9% per km) and Isleta (9.7% per km) reaches occurred on the ascending limb of a high flow in areas where there was substantial floodplain inundation that also corresponded to highest densities of silvery minnow. Lowest retention in the Albuquerque (2.1% per km) and Isleta reaches (1.7% per km) occurred on the descending limb of high and low flows, respectively, and in areas with the lowest densities of silvery minnow. The findings from Widmer et al. (2010) suggest that there is considerable retention in the Middle Rio Grande that can be enhanced through management actions, in particular habitat restoration aimed at increasing channel complexity and floodplain main channel coupling.

When threshold flows for inundation are met, inundated floodplains of the MRG provide an increased abundance of low-velocity habitats that serve as refuge and nursery habitat for developing stages of fish relative to the active channel (Valett et al. 2005; Pease et al. 2006). Silvery minnow growth can be especially rapid in newly flooded habitats that support a highly productive food chain (Schlosser 1991; Valett et al. 2005). Floodplain productivity is further enhanced by the lower water exchange rates, the subsidy of allochthonous energy inputs, and heightened temperatures that are characteristic of such areas (Schlosser 1991; Valett et al. 2005). The productivity of these habitats can be lost if the river channel-floodplain becomes uncoupled prematurely (i.e., before eggs hatch and fish mature to post larval stages) or if flows are abruptly reduced to strand fish.

3.1.3.2 Refugial Habitat

Assertions about the habitat preferences of the silvery minnow are clearly predicated on a relative abundance of water. However, such conditions are exceptional or at best episodic in much of the species' historic range in the Rio Grande Basin. In fact, it seems that a monotonous "wide channel, shallow, low-velocity" condition, so often cited as attributes of preferred habitat of the silvery minnow, may be disadvantageous during an "ecologic crunch" period associated with drought—a time in which habitat used by the silvery minnow is limiting, both in terms of quantity and quality. During the height of summer and during times of hydrologic scarcity, such habitats have the potential to become very warm with low levels of dissolved oxygen. Furthermore, these habitats offer little protection from predation. In recent "fish rescue collections," silvery minnows were not commonly found in such habitats (USFWS 2006b). Instead, the species sought out deeper habitats, generally in reaches relatively heterogeneous in channel features, often in association with relatively well-defined channels. During periods of extreme water scarcity, the species appears to seek out habitats that are cooler and deeper, including pools and an array of habitats in association with overhead cover, irrigation drain return flows, and shallow groundwater.

During periods of river intermittency, Hatch et al. (2008) find that longer and deeper pools with abruptly steep sides (i.e., low surface area to depth ratio) are inherently superior as refugial habitats for fish due primarily to their enhanced temporal environmental stability compared to smaller pools. Baker and Ross (1981), Gorman (1988a, 1988b), and Labbe and Fausch (2000) all report similar relationships between environmental stability and water depth. Larger pools tend to support a greater diversity of fish species, which is conducive to the maintenance of stable and persistent fish assemblages. Plausible mechanistic explanations for this relationship include habitat selection coupled with habitat heterogeneity and increased probabilities of local extinction in small areas (e.g., MacArthur and Wilson 1967).

Logically, environmental stability of prospective refugial pools would be enhanced to the degree that they are periodically refreshed with water from unpolluted surface or groundwater sources. Likewise, the incidence of fish disease is expected to be negatively correlated with increased rates of water exchange and reduced crowding of fish (Hatch et al. 2008). Also, in concurrence with Power (1987), Hatch et al. (2008) generally observe that deep, steep-sided pools offer greater protection against avian predators compared to shallow, high W/D pools. Piscivory is expected to be higher for fish in isolated refugial pools; however it is unknown how the physical structure of refugial pools may influence predator-prey interactions.

Corroborating the findings of Detenbeck et al. (1992), Hatch et al. (2008) find that pools adjacent to flowing river segments have a heightened degree of environmental stability and, due to proximity, a heightened potential for rapid fish recolonization, especially by the silvery minnow given its apparent high vagility. Hatch et al. (2008) hypothesize that closely spaced pools, aligned with the thalweg and at intervals no greater than five to seven times the active channel width,[3] are of particular importance to conservation purposes because they would allow for dispersal success of the silvery minnow and would serve to reduce silvery minnow mortality that often attends pulsed (short-term), small-volume, expansion-contraction flow disturbances. Such reserve design considerations are consistent in concept with the ideas advanced by Diamond (1975).

[3] The theoretical longitudinal pool-riffle spatial sequencing in unbound rivers is five to seven times the stream width (Leopold and Langbein 1966).

3.2 Southwestern Willow Flycatcher

3.2.1 *Biological Characteristics*

The flycatcher is a small passerine bird about 15 cm (6 inches) long and one of 11 species of the genus *Empidonax* flycatchers that occur in North America (Figure 3.2). The flycatcher is a migratory species that winters in Mexico and Central America and breeds in the southwestern United States and northern Mexico. The flycatcher's geographic distribution has not declined significantly, but habitat and numbers of breeding birds have.

Figure 3.2. Southwestern Willow Flycatcher

3.2.1.1 Reproduction

Flycatchers have historically migrated to New Mexico in early May from wintering sites in Mexico and Central America (Tetra Tech 2004). Males establish territories prior to arrival of females. Territories tend to be aggregated along reaches of the river rather than spread throughout suitable habitat, and mating pairs are highly territorial. The species has shown signs of site fidelity, often returning to the same breeding area for multiple years (USFWS 2002). Flycatchers can live for up to eight years, though the average lifespan is one to four years. Summer migration of adults and juveniles to the south occurs around July or August. In the Southwest, most flycatcher breeding territories are found within small breeding sites containing five or fewer territories (Sogge et al. 2003). One of the last long-distance neotropical migrants to arrive in North America in spring, the flycatcher has a short, approximately 100-day breeding season, with individuals typically arriving in May or June and departing in August (Sogge et al. 1997). Breeding pairs generally produce one clutch per season, but may produce two clutches per breeding season (May–July). Moore and Ahlers (2008) have found average successful clutch sizes over a nine-year period (1999–2007, 43 successful nests) in the Sevilleta/La Joya Reach to be 2.3 chicks/nest, and over a 12-year period (1996–2007, 472 successful nests) in the San Marcial Reach to be 2.7 chicks/nest. Over the nine-year period from 1999 to 2007, nest success is reported to be 57% over 997 nests monitored, and nest success is similar in habitats dominated by willow (764 nests) and saltcedar (49 nests) (Moore and Ahlers 2008).

3.2.1.2 DIET

The flycatcher is an insectivorous species that forages above and within the vegetation canopy layer. The species also forages over open water, catching insects on the wing, or gleans prey from foliage or ground surfaces. Flycatcher diet comprises mostly small to medium invertebrate prey of largely terrestrial origin (Tetra Tech 2004). The flycatcher has been described as a generalist species (USFWS 2002) with common prey including flying ants, wasps, and bees (Hymenoptera); flies (Diptera); beetles (Coleoptera); and butterflies and moths (Lepidoptera) (note: the preceding are mostly flying insects associated with vegetation, especially flowers).

3.2.2 STATUS AND DISTRIBUTION

The flycatcher is federally and state-listed as endangered and is one of four subspecies of willow flycatcher currently recognized (Unitt 1987), although Browning (1993) posits a fifth subspecies (*E. t. campestris*) occurring in the central portions of the United States (Figure 3.3). The flycatcher breeds in dense, mesic riparian habitats at scattered, isolated sites in New Mexico, Arizona, southern California, southern Nevada, southern Utah, southwestern Colorado, and, at least historically, extreme northwestern Mexico and western Texas (Unitt 1987).

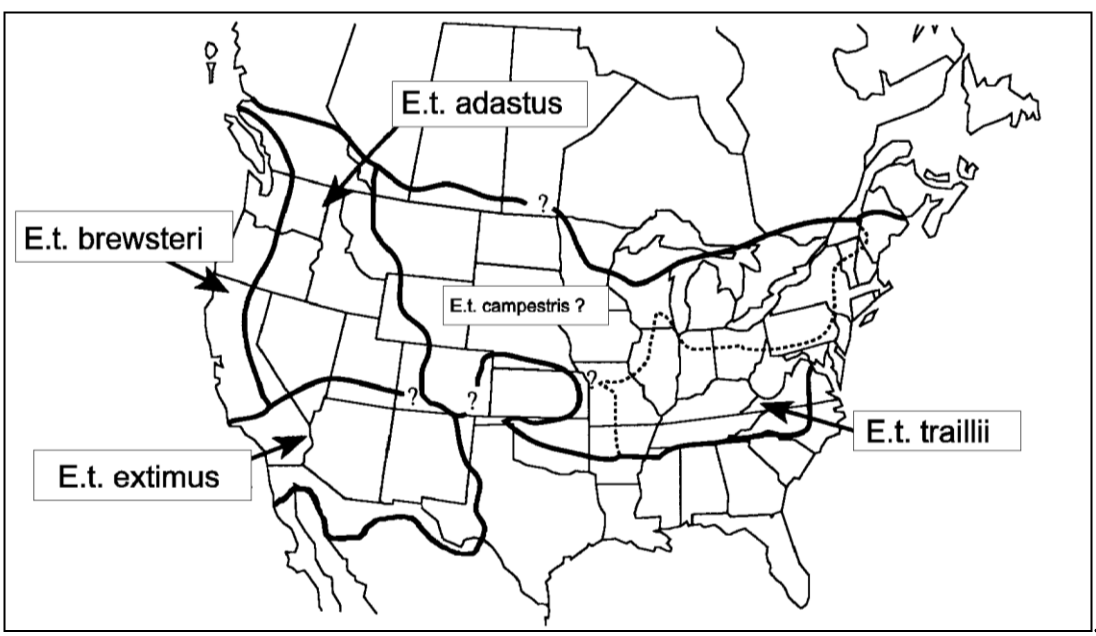

Figure 3.3. Breeding range distribution of the subspecies of the willow flycatcher. Adapted from Unitt (1987), Browning (1993), and Sogge et al. (1997).

The flycatcher currently is known to use six breeding areas along the MRG in New Mexico: 1) Velarde to San Juan Pueblo, 2) Isleta Pueblo, 3) Sevilleta National Wildlife Refuge, 4) San Acacia Dam to Bosque del Apache National Wildlife Refuge, 5) Bosque del Apache National Wildlife Refuge, and 6) San Marcial to Elephant Butte Reservoir. The highest densities of breeding pairs occur in the San Marcial Reach (Reclamation 2006b), and the flycatcher is not known to breed within the Albuquerque Reach. Flycatcher surveys have been conducted in the Albuquerque Reach since 2004 (Corps 2004, 2005; Hawks Aloft 2005, 2006, 2009), and no breeding pairs have been found. However, two individual territorial flycatchers were observed in 2009, one near the Montaño Bridge, and one near the Rio Bravo Bridge (Hawks Aloft 2009).

3.2.2.1 Reasons for Listing

The flycatcher was federally listed as endangered in 1994 due to extensive loss of habitat, brood parasitism by the brown-headed cowbird (*Molothrus ater*), and lack of adequate protective regulation (Federal Register 1994). The flycatcher also is listed as endangered by the states of New Mexico, Colorado, California, and Texas, and is listed as wildlife of special concern in Arizona and critically impaired in Nevada.

3.2.2.2 Critical Habitat Designations

The USFWS (2002) designated critical habitat for the flycatcher along three reaches of the Rio Grande: 1) from the southern boundary of the Isleta Pueblo to the northern boundary of the Sevilleta National Wildlife Refuge, 2) from the southern boundary of the Sevilleta National Wildlife Refuge to the northern boundary of Bosque del Apache National Wildlife Refuge, and 3) from the southern boundary of Bosque del Apache National Wildlife Refuge to a location 20.1 km (12.5 miles) south. Critical habitat was excluded in the Albuquerque Reach because the City of Albuquerque prepared and submitted a habitat conservation plan (City of Albuquerque 2005).

3.2.2.3 Primary Constituent Elements

The primary constituent elements considered to provide critical habitat for the flycatcher have been defined by the USFWS (2005b:60912) as:

1. Riparian habitat in a dynamic successional riverine environment (for nesting, foraging, migration, dispersal, and shelter) that comprises:
    a. Trees and shrubs that include Goodding's willow (*Salix gooddingii*), coyote willow, Geyer's willow (*S. geyerana*), arroyo willow (*S. lasiolepis*), red willow (*S. laevigata*), yewleaf willow (*S. taxifolia*), pacific willow (*S. lasiandra*), boxelder (*Acer negundo*), saltcedar, Russian olive, buttonbush (*Cephalanthus occidentalis*), cottonwood, stinging nettle (*Urtica dioica*), alder (*Alnus rhombifolia, A. oblongifolia, A. tenuifolia*), velvet ash (*Fraxinus velutina*), poison hemlock (*Conium maculatum*), blackberry (*Rubus ursinus*), seep willow (*Baccharis salicifolia*, *B. glutinosa*), oak (*Quercus agrifolia, Q. chrysolepis*), rose (*Rosa californica, R. arizonica, R. multiflora*), sycamore (*Platinus wrightii*), false indigobush, Pacific poison ivy (*Toxicodendron*

diversilobum), grape (*Vitus arizonica*), Virginia creeper (*Parthenocissus quinquefolia*), Siberian elm, and walnut (*Juglans hindsii*).

b. Dense riparian vegetation with thickets of trees and shrubs ranging in height from 2 to 30 m (6.6–98 feet). Lower-stature thickets (2–4 m [6.6–13 feet] tall) are found at higher elevation riparian forests, and tall-stature thickets are found at middle- and lower-elevation riparian forests.

c. Areas of dense riparian foliage at least from the ground level up to approximately 4 m (13 feet) above ground or dense foliage only at the shrub level or as a low, dense tree canopy.

d. Sites for nesting that contain a dense tree and/or shrub canopy (the amount of cover provided by tree and shrub branches measured from the ground) (i.e., a tree or shrub canopy with densities ranging from 50% to 100%).

e. Dense patches of riparian forests that are interspersed with small openings of open water or marsh, or shorter/sparser vegetation that creates a mosaic that is not uniformly dense. Patch size may be as small as 0.1 ha (0.25 acre) or as large as 70 ha (175 acres).

2. A variety of insect prey populations found within or adjacent to riparian floodplains or moist environments, including flying ants, wasps, and bees; dragonflies (Odonata); flies; true bugs (Hemiptera); beetles; butterflies/moths and caterpillars (Lepidoptera); and spittlebugs (Homoptera).

3.2.2.4 Flycatcher Population Trends/Distribution within the Albuquerque Reach

The most recent (2006 breeding season) range-wide flycatcher population estimate is approximately 1,262 territories (Durst et al. 2008). In New Mexico, the species has been observed in the Rio Grande, Rio Chama, Zuni River, San Francisco River, and Gila River drainages, with 443 territories recorded statewide in 2006 (Durst et al. 2008). Including the San Luis Valley, 280 territories were identified in the Rio Grande Basin in 2006 (Durst et al. 2008).

Based on historical breeding records, the current range of the flycatcher within the MRG drainage is nearly the same as its historical range (Unitt 1987). Although the species has disappeared from portions of the MRG drainage, such as the vicinity of Las Cruces and Española, the drainage still contains one of the largest breeding metapopulations of flycatchers in the United States (USFWS 2002). In the MRG valley, the San Marcial site has continued to grow, from approximately 20 flycatcher territories in 1999 (Ahlers and White 2000) to 232 territories in 2007 (Moore and Ahlers 2008). Demographic studies conducted from Velarde to the delta of the Elephant Butte Reservoir have shown large, stable breeding populations within the reservoir fringe (Ahlers and White 1998, 2000; Ahlers et al. 2001; Ahlers et al. 2002; Moore and Ahlers 2003, 2004, 2005, 2006a, 2006b, 2008).

The only flycatcher nesting territories recorded within the Albuquerque Reach have occurred at the Isleta Pueblo, with seven pairs (14 adults) recorded in 2004; habitat at Isleta consisted of Russian olive, coyote willow, and saltcedar (Smith and Johnson 2005, 2008). A 1994 survey conducted in the Corrales bosque area detected no flycatchers (Mehlhop and Tonne 1994). Surveys for flycatchers in the greater Albuquerque metropolitan area were conducted at the I-40, Central Avenue, and Montaño bridges; Tingley Beach; Zoo Sidebar; and Calabacillas Islands in 1995 and 1996 by Reclamation and the USFWS. No flycatchers were detected during these surveys (Cooper 1996, 1997). Surveys performed in 2001 at the Albuquerque Drinking Water Project diversion site detected no flycatchers in the construction areas along the Rio Grande (EMI 2001). Flycatcher surveys have been conducted in the Albuquerque Reach by the Corps since 2004 (Corps 2004, 2005; Hawks Aloft 2005, 2006, 2009), and although no breeding pairs have been found, two individual territorial flycatchers were observed in 2009, one near the Montaño Bridge and one near the Rio Bravo Bridge (Hawks Aloft 2009).

The Albuquerque Reach lies within the Rio Grande Recovery Unit for the Southwestern Willow Flycatcher (USFWS 2002). This unit encompasses the Rio Grande watershed from its headwaters in southwestern Colorado downstream to the Pecos River confluence in southwestern Texas. Also included is the Pecos River watershed in New Mexico and Texas (where no breeding sites are known) and one site on Coyote Creek in the upper Canadian River watershed. The majority of New Mexico's 443 flycatcher territories (35% of the range-wide total) are found within the Rio Grande Basin (Durst et al. 2007). The minimum number of flycatcher territories needed for federal reclassification in the MRG recovery management unit is 250 (USFWS 2002). Including the San Luis Valley, there were 280 territories identified in the Rio Grande Recovery Unit in 2006 (Durst et al. 2007). The USFWS recommends that a portion of those efforts should be focused on the Rio Grande from I-25 Bridge to Elephant Butte Dam.

3.2.3 Habitat Characteristics

Sogge et al. (1997) identify four basic habitat types: monotypic willow, monotypic exotic, native broadleaf-dominated, and mixed native/exotic. Willow species are used most frequently (56% of nest sites) (Sogge et al. 2003). Flycatchers will use non-native vegetation; however, they will tend to use native vegetation when available. Sogge et al. (2003) report that 31% of nest sites were found in native vegetation (>90% native); 32% of nest sites were found in mostly native vegetation (>50–90% native); 20% of nest sites were found in mostly exotic vegetation (>50–90% exotic); 5% of nest sites were found in exotic vegetation (>90% exotic); and 12% of nest sites were unknown.). In the MRG, flycatchers prefer native willow over exotic saltcedar and Russian olive, and nest success is higher when situated in native willows (Moore 2007, Moore and Ahlers 2008). Other habitat requirements and descriptions as adapted from the flycatcher recovery plan (USFWS 2002), Biological Opinion (USFWS 2003), and ongoing flycatcher studies along the MRG (Moore 2007, Moore and Ahlers 2008) include:

- Open water, marshes, or saturated soils are usually in the vicinity of territories and nests.
- Associated water is usually lentic (slow velocity or standing) in character.

- Occupied sites are commonly in dense vegetation (trees/shrubs) occurring within 3 to 4 m (10–13 feet) above ground. Dense branch and twig structure usually appears in the lower 2 m (6.6 feet) of the vegetation, and live foliage density is high from the ground to canopy.
- Patch size is greater than 0.1 ha (0.25 acre) in size. Dense patches are often situated among a variety of structural stages of vegetation, forming a mosaic of habitat types.
- Patch size and distribution of patches across the landscape are thought to be important but are not currently well understood. Widely spaced, narrow patches less than 10 m (33 feet) are thought to be inadequate for nesting pairs.
- Species composition of habitat can be mixed or monotypic, native or exotic, and even or uneven aged, but are usually dense. Tree species composition of occupied habitat mixed or monotypic, native or exotic but with a preference for native Goodding's willow in the Middle Rio Grande; single or multi-aged stands, but usually dense.

Currently, this definition of habitat suitability is based solely on habitat characteristics, not on measures of flycatcher productivity or survival. Suitable habitat may be occupied or unoccupied; any habitat in which flycatchers are found breeding is, by definition, suitable. Definitions of occupancy are as follows:

- Occupied suitable habitat is that in which flycatchers are currently breeding or have established territories.
- Unoccupied suitable habitat appears to have physical, hydrological, and vegetative characteristics within the range of those found at occupied sites but does not currently support breeding or territorial flycatchers. Some sites that appear suitable may be unoccupied because they may be missing an important habitat component not yet characterized. Other sites are currently suitable but unoccupied because the flycatcher population is currently small and spatially fragmented, and flycatchers have not yet colonized every patch where suitable habitat has developed.
- Potentially suitable habitat (potential habitat) is defined as a riparian system that does not currently have all the components needed to provide conditions suitable for nesting flycatchers (as described above), but could—if managed appropriately—develop these components over time.
- Regenerating potential habitats are those areas that are degraded or in early successional stages but have the correct hydrological and ecological setting to be become, under appropriate management, suitable flycatcher habitat.

Restorable potential habitats are those areas that could have the appropriate hydrological and ecological characteristics to develop into suitable habitat if not for one or more major stressors and that may require active abatement of stressors in order to become suitable. Potential habitat occurs where the floodplain conditions, sediment characteristics, and hydrological setting provide potential for development of dense riparian vegetation. Stressors in the Albuquerque Reach that may be preventing regenerating and restorable habitats from becoming suitable include, but are not limited to, dewatering from surface diversion or groundwater extraction, channelization, mowing, recreational activities, overgrazing by domestic livestock or native ungulates, exotic vegetation, and fire. Note that this analysis and recommendations report does not address all of those stressors.

3.2.3.1 Breeding Habitat

The flycatcher breeds in dense, mesic riparian habitats at scattered, isolated sites. In the Southwest, most flycatcher breeding territories are found within small breeding sites containing five or fewer territories (Sogge et al. 2003). Riparian vegetation at flycatcher breeding sites can be dominated by either native or exotic species. Trees and shrubs recorded at breeding sites throughout the geographic distribution of the flycatcher (FR 1995; 2005) include Goodding's willow, coyote willow, Geyer's willow, arroyo willow, red willow, yewleaf willow, pacific willow, boxelder, saltcedar, Russian olive, buttonbush, cottonwood, stinging nettle, alder, velvet ash, poison hemlock, blackberry, seep willow, oak, rose, sycamore, false indigobush, Pacific poison ivy, grape, Virginia creeper, Siberian elm, and walnut.

Plant species composition, however, appears less important than vegetation structure. Sogge and Marshall (2000), Allison et al. (2003), and McLeod et al. (2008) have concluded that breeding riparian birds in the Southwest are exposed to extreme environmental conditions and that dense vegetation at the nest may be needed to provide a more suitable microclimate for raising offspring. Results of a five-year vegetation study (2003–2007) conducted by McLeod et al. (2008) along the lower Colorado and Virgin rivers and tributaries show that vertical foliage density at flycatcher nest sites is generally greatest around mean nest height (3.2 m [10.5 feet]; standard error = 0.1). This vegetation study provides strong evidence that vegetation structure and microclimate influence habitat selection by the flycatcher. McLeod et al. (2008) find that manipulation of vegetation structure is the most practical means for restoration practitioners to create or restore the preferred microclimate for flycatcher nesting habitat. A summary of the researchers' vegetation structure recommendations for the creation and/or restoration of flycatcher nesting habitat, the recommended direction in which to manipulate each vegetation characteristic, and important microclimate variables can be found in Table 3.1 and Table 3.2. As a guide to monitoring the success of restoration efforts in duplicating vegetation and microclimate conditions of occupied flycatcher habitat, McLeod et al. (2008) also calculate the minimum, 25th percentile, median, 75th percentile, and maximum values observed for each of the vegetation and microclimate variables at occupied and unoccupied flycatcher sites; these values are shown in Table 3.3. Likewise, vegetation and microclimate ranges provided by the researchers can also be used to determine potential suitability of existing riparian habitat for the flycatcher.

Table 3.1. Vegetation Variables, Management Actions, Microclimate Response, and Recommended Ranges for the Creation of Suitable Nesting Habitat for the Flycatcher along the Lower Colorado River and Tributaries*

Vegetation Variables	Recommended Management Action[1]	Recommended Statistical Range of Variable (mean ± standard error)
Canopy height (m)	Increase	6.1 ± 0.1
Canopy closure (%)	**Increase**	**92.8 ± 0.3**
No. shrub stems (<2.5 cm dbh) per ha	**Decrease or minimize**	**<6714.9**
No. shrub stems (2.5–8.0 cm dbh) per ha	Increase	8,349.1 ± 246.1
No. shrub stems (>8.0 cm dbh) per ha	**Increase**	**893.1 ± 60.0**
Percent basal area that is native	**Increase**	**41.4 ± 2.2**
Vertical foliage density (hits) above nest	Increase	69.0 ± 2.1
Vertical foliage density (hits) at nest	Ignore	N/A
Vertical foliage density(hits) below nest	Decrease or minimize	<48.2

* These recommendations are based on findings from single- and multiple-effects models. Data from flycatcher nest sites and territories (total sample size = 350) provide the basis for recommendations, including the recommended statistical range for each vegetation variable. Vegetation variables shown in **bold** are those that are significant predictors of flycatcher nest locations in models combining vegetation and microclimate variables. dbh = diameter at breast height; N/A = not applicable.

[1] Vegetation variables should be managed simultaneously, not separately, to meet the recommended range for each.

Source: McLeod et al. (2008).

Table 3.2. Recommended Microclimate Goals for Flycatcher Microclimate Measures*

Microclimate Variable	Recommended Statistical Range of Variable (mean ± standard error)
Soil Moisture	
Mean soil moisture (mV), 2005–2007	751.9 ± 15.5
Temperature	
Mean maximum diurnal temperature (°C)	43.0 ± 0.2
Mean diurnal temperature (°C)	31.1 ± 0.1
Mean no. of 15-min. intervals above 41°C each day	4.5 ± 0.3
Mean minimum nocturnal temperature (°C)	16.4 ± 0.1
Mean nocturnal temperature (°C)	24.6 ± 0.1
Mean daily temperature range (°C)	**19.6 ± 0.2**
Humidity	
Mean diurnal relative humidity (%)	53.0 ± 0.6
Mean diurnal vapor pressure (Pa)	2,200.2 ± 26.0
Mean nocturnal relative humidity (%)	64.6 ± 0.5
Mean nocturnal vapor pressure (Pa)	**1,964.7 ± 20.6**

* These measures are the mean and standard errors for occupied flycatcher territory (nest sites and within territory plots combined). **Bold** indicates the microclimate variables that were significant in regression models comparing occupied to unoccupied flycatcher habitat.

Source: McLeod et al. (2008).

Table 3.3. Recommended Minimum, 25th Percentile, Median, 75th Percentile, and Maximum Vegetation and Microclimate Values for Occupied and Unoccupied Flycatcher Sites along the Lower Colorado River and Tributaries

Variable	Within Territory Sites (nest sites and within territory plots combined)					Unoccupied Sites				
	Min	25%	Median	75%	Max	Min	25%	Median	75%	Max
Soil moisture (mV)	128.5	649.0	819.5	911.3	994.0	94.5	334.3	597.2	807.1	955.4
Diurnal temperature (°C)	26.1	29.5	30.9	32.4	39.7	25.2	31.6	33.7	36.2	41.4
Nocturnal temperature (°C)	19.2	23.2	24.9	26.1	29.3	18.0	23.2	24.8	26.1	29.4
Diurnal relative humidity (%)	24.7	46.1	53.7	59.9	87.4	18.4	36.8	44.6	51.9	72.6
Diurnal vapor pressure (Pa)	996.0	1,899.9	2,235.3	2,529.6	3,307.5	883.0	1,696.4	1,973.4	2,385.8	3,157.9
Nocturnal relative humidity (%)	36.7	58.8	65.3	71.3	95.6	36.3	56.9	63.3	69.3	91.2
Nocturnal vapor pressure (Pa)	1,016.0	1,758.9	2,024.3	2,215.8	2,730.8	981.8	1,625.5	1,891.9	2,156.9	2,523.5
Canopy height (m)	2.8	5.0	6.0	7.0	13.4	1.0	3.5	4.5	5.5	11.0
Canopy closure (%)	55.7	90.0	94.2	97.0	100.0	4.2	73.0	88.0	94.8	100.0
No. shrub stems (<2.5 cm dbh) per ha	0.0	3,437.9	5,602.5	9,040.4	29,158.5	127.3	3,947.2	6,748.5	10,441.1	57,680.4
No. shrub stems (2.5–8.0 cm dbh) per ha	254.6	5,093.2	7,767.1	11,205.0	29,413.2	0.0	2,801.3	6,239.2	10,059.1	24,829.3
No. tree stems (> 8.0 cm dbh) per ha	0.0	127.3	636.6	1,400.6	14,643.0	0.0	0.0	254.6	891.3	3,947.2
Percent basal area that is native	0.0	0.0	29.7	88.4	100.0	0.0	0.0	0.0	44.0	100.0
Vertical foliage density above nest (hits)	5.0	42.0	61.3	93.0	266.0	0.0	9.0	25.0	54.0	152.0
Vertical foliage density at nest (hits)	5.0	19.0	25.0	33.0	60.0	0.0	15.0	24.0	34.0	76.0
Vertical foliage density below nest (hits)	0.0	23.0	38.0	66.0	198.0	4.0	26.0	45.0	82.0	213.0
Distance to water (m)	0.0	1.0	5.0	27.0	675.0	0.0	7.0	38.0	80.0	740.0

dbh = diameter at breast height.
Source: McLeod et al. (2008).

Allison et al. (2003) find the greatest foliage density to be at nest height at three large flycatcher breeding sites in Arizona. Paradzick (2005) also reports occupied flycatcher sites to have denser foliage in the upper (7–9 m [23–30 feet]) strata of the canopy than unoccupied sites. Greater canopy closure, taller canopy height, and denser foliage at or immediately above nest height may facilitate a more favorable nesting microclimate and may be useful parameters in predicting preferred flycatcher riparian breeding habitat within the larger expanses of riparian vegetation (McLeod et al. 2008). However, Moore (2007) states that occupied nesting sites in the southern portion of the MRG lack the upper strata of vegetation canopy. Four main types of preferred flycatcher habitat have been described (adapted from Sogge et al. 1997):

- Monotypic high-elevation willow: nearly monotypic stands of willow, 3 to 9 m (10–23 feet) in height with no distinct overstory layer; often associated with sedges, rushes, nettles and other herbaceous wetland plants; usually very dense structure in the lower 2 m (6.6 feet); live foliage density is high from the ground to the canopy.
- Monotypic non-native: nearly monotypic, dense stands of non-natives, such as saltcedar or Russian olive, 4 to 10 m (13–33 feet) high forming a nearly continuous, closed canopy (with no distinct overstory layer); the lower 2 m (6.6 feet) often is difficult to penetrate due to branches; however, live foliage density may be relatively low, 1 to 2 m (3–6.6 feet) above ground, but increases higher in the canopy; canopy density uniformly high.
- Native broadleaf-dominated: composed of single species or mixtures of native broadleaf trees and shrubs, including cottonwood, willow, boxelder, ash, alder, and buttonbush from 3 to 15 m (10–50 feet) tall; characterized by trees of different size classes; often a distinct overstory of cottonwood, willow, or other broadleaf tree, with recognizable subcanopy layers and a dense understory of mixed species; non-native/introduced species may be a rare component, particularly in the understory.
- Mixed native/non-native: Dense mixtures of native broadleaf trees and shrubs mixed with non-native/introduced species, such as saltcedar or Russian olive; non-natives are often primarily in the understory, but may be a component of overstory; the native and non-native components may be dispersed throughout the habitat or concentrated as a distinct patch within a larger matrix of habitat; overall, a particular site may be dominated primarily by natives or non-natives or be a roughly equal mixture.

Flycatchers typically breed in dense riparian vegetation near surface water and/or saturated soil. Regardless of plant species composition, occupied sites usually have dense vegetation within 3 to 6 m (10–20 feet) of the ground, and nests are usually situated over standing water and/or saturated soil. Although flycatchers breed in widely different types of riparian habitat across a large elevational range and geographical area in the Southwest, certain vegetation structure patterns emerge and are seen at most sites (Sogge and Marshall 2000; Koronkiewicz et al. 2006). Vegetation studies designed to quantitatively describe flycatcher breeding habitat (see Alison et al. 2003; Paradzick 2005; Moore 2007; McLeod et al. 2008) suggest no major structural differences at sites across the Southwest. Structural similarity regardless of plant species composition at flycatcher sites across the species range is important in terms of habitat creation and restoration because the results derived from habitat studies designed to describe and replicate flycatcher habitat at one site or river drainage are likely applicable for restoration purposes at other sites at similar elevations.

Paradzick (2005) has found occupied flycatcher sites in south-central Arizona to have denser foliage in the upper strata (7–9 m [23–30 feet]) of the canopy than unoccupied sites. At seven flycatcher breeding sites along the Lower Colorado River and its tributaries, McLeod et al. (2007) report that vertical foliage density was greatest at and immediately above mean nest height. Allison et al. (2003) also find the greatest foliage density to be at nest height at three large flycatcher breeding sites in Arizona. McLeod et al. (2008) and Allison et al. (2003) show that the vertical foliage density profiles at flycatcher nest sites across a large portion of the species range exhibit a unimodal vertical structural profile (Figure 3.4–Figure 3.8). This unimodal vertical structure is similar to the Type III vegetation structural type identified by Anderson and Ohmart (1984). Greater canopy closure, taller canopy height, and denser foliage at or immediately above nest height may facilitate a more favorable nesting microclimate and may be useful parameters in predicting preferred flycatcher riparian breeding habitat within the larger expanses of riparian vegetation (McLeod et al. 2008).

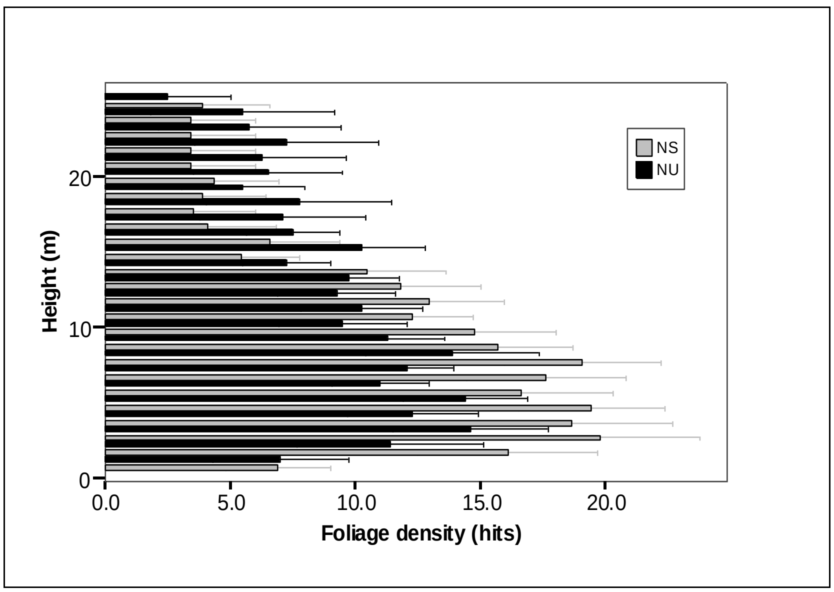

Figure 3.4. Vertical foliage density and standard error at flycatcher nest (NS) versus non-use sites (NU) at Pahranagat National Wildlife Refuge, Nevada, 2007 (McLeod et al. 2008).

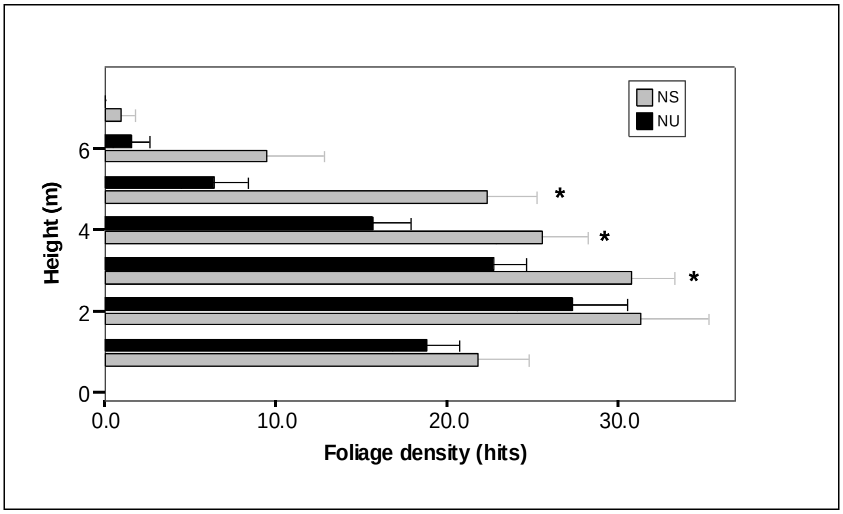

Figure 3.5. Vertical foliage density and standard error at flycatcher nest (NS) vs. non-use (NU) sites at Mesquite, Nevada, 2007. Differences (Student's t-test, α=0.05) between NS and NU sites within a given meter interval are indicated by asterisks (McLeod et al. 2008).

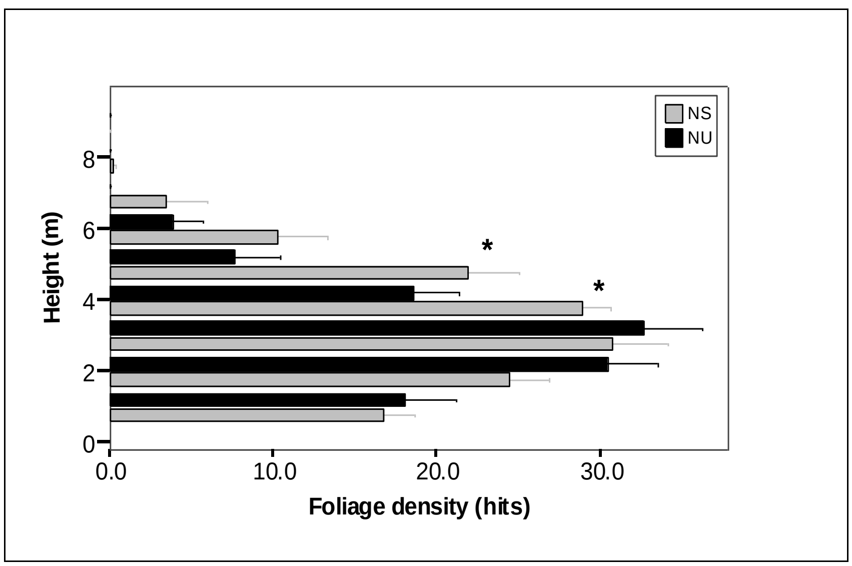

Figure 3.6. Vertical foliage density and standard error at flycatcher nest (NS) vs. non-use (NU) sites at Mormon Mesa, Nevada, 2007. Differences (Student's t-test, α=0.05) between NS and NU sites within a given meter interval are indicated by asterisks (McLeod et al. 2008).

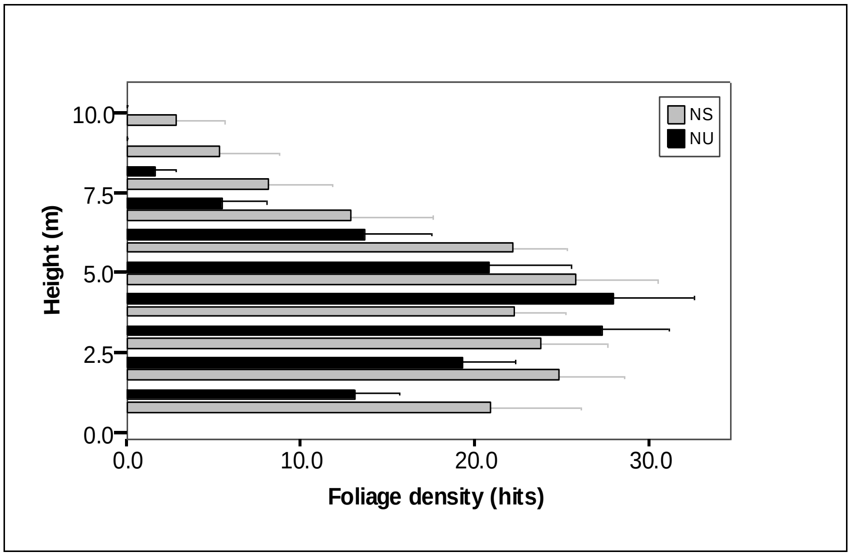

Figure 3.7. Vertical foliage density and standard error at flycatcher nest (NS) vs. non-use (NU) sites at Topock Marsh, Arizona, 2007 (McLeod et al. 2008).

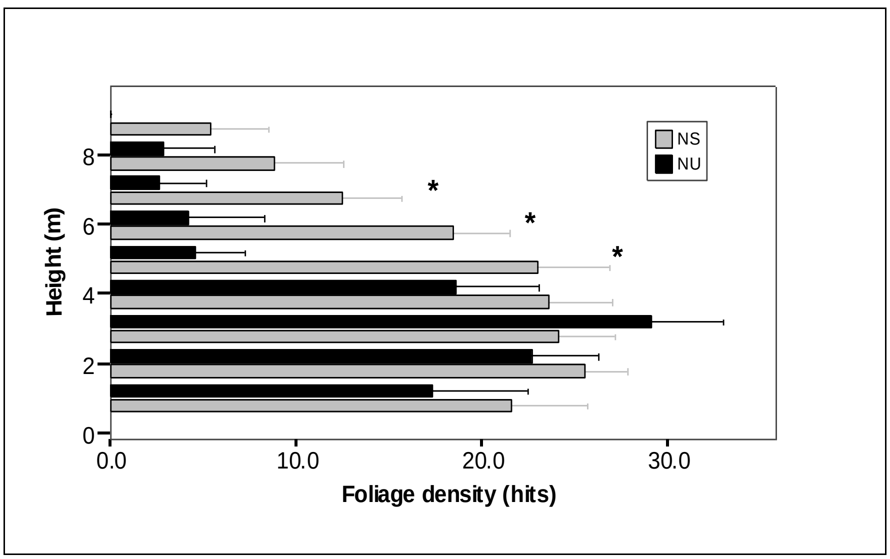

Figure 3.8. Vertical foliage density and standard error at flycatcher nest (NS) vs. non-use (NU) sites at Muddy River, Nevada, 2007. Differences (Student's t-test, α=0.05) between NS and NU sites within a given meter interval are indicated by asterisks (McLeod et al. 2008).

Quantitative vegetation studies conducted by Moore (2007) at flycatcher breeding sites along the southern MRG have been designed for the purpose of habitat assessments and to act as a guide for restoration efforts aimed at creating flycatcher breeding habitat. Results of that study support the findings of Allison et al. (2003) and McLeod et al. (2008), showing that flycatchers preferred nesting sites with dense vegetation in the mid-canopy layer between 3 and 4 m (10–13 feet) high. At all study areas, Moore (2007) finds the average density and height of mid-canopy trees are significantly higher in flycatcher nest plots than at random sites, and vertical foliage density is greatest at and immediately above mean nest height (3.0 m [9.8 feet]; n = 112). Importantly, the research has shown that if one looks at plant density based on size class, canopy class (upper vs. mid vs. shrub layer), or canopy cover by height zone, vegetation densities are higher at flycatcher nest sites at the mid-canopy or just above flycatcher nest height.

Some researchers have suggested that saltcedar is unsuitable habitat for the flycatcher, primarily because it is assumed that saltcedar supports a smaller and less diverse invertebrate community than native habitats (Liesner 1971; Yong and Finch 1997; DeLoach et al. 2000; Dudley and DeLoach 2004). However, Owen et al. (2005) have captured and blood sampled 130 flycatchers breeding in native and saltcedar-dominated habitats in Arizona and New Mexico and measured variables of physiological condition. Owen et al. (2005) report few habitat-based differences in flycatcher physiological condition and no evidence that flycatchers breeding in saltcedar habitats exhibit poorer nutritional condition or suffer negative physiological effects. Furthermore, although most flycatcher breeding sites are dominated by native vegetation, approximately 22% of breeding territories range-wide are in habitats dominated by saltcedar (Durst et al. 2008). Recent flycatcher productivity studies have found no negative effects from breeding in saltcedar-dominated habitats (Paxton et al. 2007; McLeod et al. 2008).

In a nine-year study of nesting success in the MRG, Moore and Ahlers (2008) report that 79.5% of flycatcher nests were in willow-dominated stands (defined as greater than 90% *Salix* species), 14.1% were in mixed-dominance territories, and 6.3% of the nests were in saltcedar-dominated stands. However, the nesting success in willow-dominated territories, saltcedar-dominated territories, and mixed territories is similar: 56.8%, n = 764; 57.1%, n = 9; and 46.7%, n = 135; respectively. Moore (2007) examines vegetation characteristics associated with flycatcher nesting sites in the MRG and finds flycatcher habitat use to be uncommonly associated with typical MRG riparian woodlands with a high overstory (Figure 3.9) and more often associated with willow stands lacking an overstory layer (Figure 3.10). Details of Moore's (2007) summary data are presented in Table 3.4.

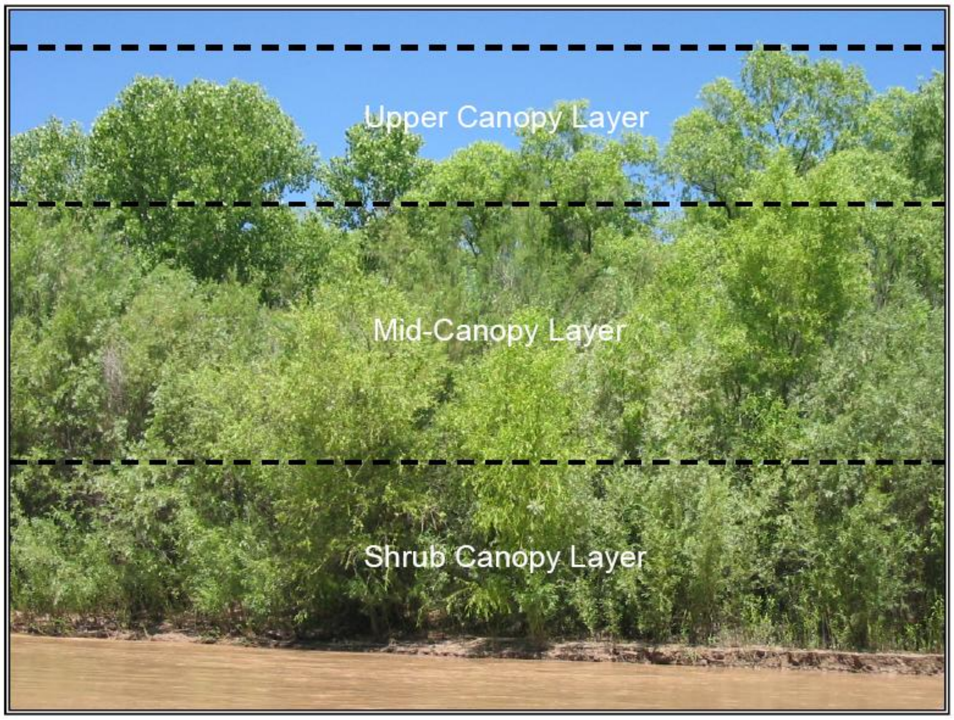

Figure 3.9. Photograph from Moore (2007) showing typical MRG riparian woodland habitat with three different canopy height layers.

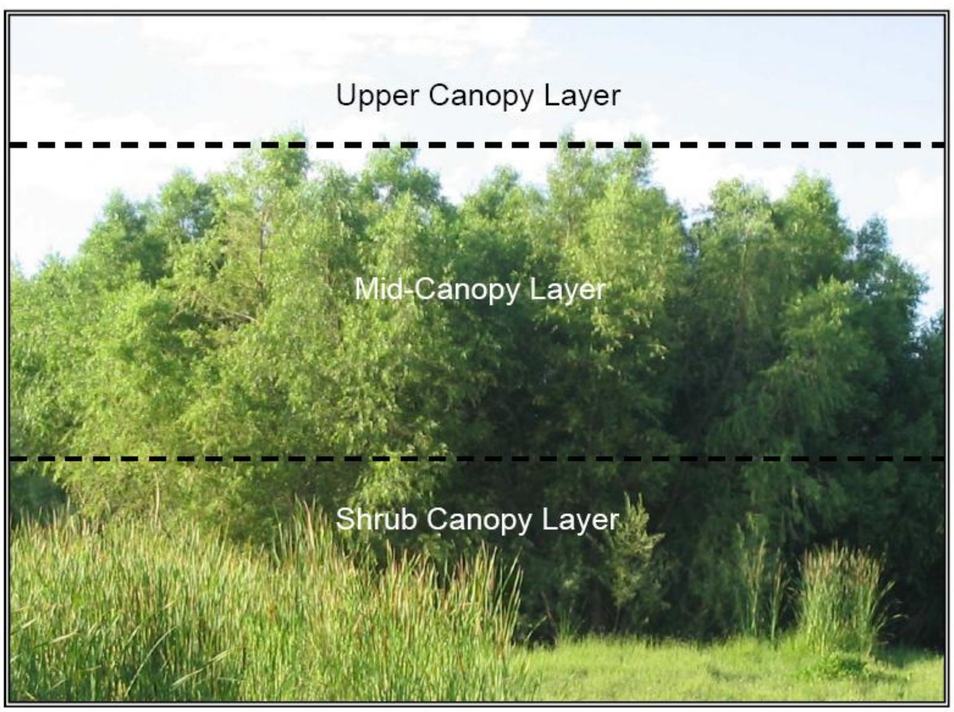

Figure 3.10. Photograph from Moore (2007) showing typical southern MRG flycatcher habitat lacking an upper canopy layer.

Table 3.4. Summary of Vegetation Characteristics of Flycatcher Nest Sites Compared to Adjacent Random Points in the Southern MRG

Vegetation parameter	Nest site (n = 112)	Random site (n = 89)
Shrub Stem Density #/m^2 (sd)	3.64 (2.4)	3.5 (2.6) [W = 4,721.0, *P* = 0.522]
Shrub Stem Species Composition % (sd)		
Salix gooddingii	37.2 (38.6)	31.5 (37.2) [W = 4,486.5, *P* = 0.465]
Salix exigua	31.4 (34.6)	34.6 (35.8) [W = 5,027.0, *P* = 0.518]
Both *Salix* species	68.5 (37.0)	66.1 (36.5) [W = 4,727.0, *P* = 0.907]
Populus deltoides	1.3 (4.6)	1.4 (6.5) [W = 4,541.0, *P* = 0.305]
Tamarix sp.	23.4 (33.1)	27.8 (34.3) [W = 5,030.0, *P* = 0.499]
Eleagnus angustifolia	6.1 (19.2)	2.5 (9.5) [W = 4,559.5, P = 0.353]
Dead Shrubs %	37.0 (21.3)	35.4 (29.0) [W = 4,399.0, *P* = 0.154]
Tree Stem Density #/ha (sd)	**2,829 (1,330)**	**2,019 (1,101) [t = 4.60, *P* < 0.001]**
Tree Stem Species Composition % (sd)		
Salix gooddingii	71.5 (38.3)	68.8 (40.7) [W = 4,947.5, *P* = 0.962]
Salix exigua	5.1 (12.8)	3.7 (11.3) [W = 4,301.5, *P* = 0.060]
Both *Salix* species	76.6 (38.1)	72.4 (38.8) [W = 4,563.5, *P* = 0.357]
Populus deltoides	3.4 (9.7)	7.9 (19.8) [W = 5,043.5, *P* = 0.737]
Tamarix sp.	11.9 (26.8)	12.8 (24.2) [W = 5,379.5, *P* = 0.213]
Eleagnus angustifolia	8.1 (24.2)	5.6 (18.7) [W = 4,828.5, P = 0.691]
Dead Trees % (sd)	4.0 (6.5)	6.2 (9.5) [W = 5,202.0, *P* = 0.479]
Tree DBH Size Class Composition % (sd)		
Class 1	70.1 (16.3)	74.1 (18.0) [W = 5,703.0, *P* = 0.057]
Class 2	**29.0 (15.9)**	**24.3 (16.6) [W = 4,047.5, *P* = 0.030]**
Class 3	0.9 (2.1)	1.6 (3.9) [W = 5,175.5, *P* = 0.448]

Table 4. Summary of 2004-2006 nest and random plot shrub and tree stem count data and statistics (α = 0.5) for all nests in study **(boldface = significant difference between nest and random plots)**.

Vegetation parameter	Nest site (n = 112)	Random site (n = 98)
Shrub Canopy Layer		
Mean Plant Density (sd)	7,470/ha (7,533)	5,991/ha (6,185) [W = 5,013.5, *P* = 0.157]
Mean Plant Height (sd)	2.69 m (0.77)	2.61 m (0.69) [W = 5,329.5, *P* = 0.475]
Mean Plant Crown Width (sd)	1.00 m (0.35)	0.97 m (0.41) [W = 5,096.0, *P* = 0.215]
Mid-Canopy Layer		
Mean Plant Density (sd)	**3,079/ha (2,318)**	**2,079/ha (1,602) [W = 4,000.0, *P* < 0.001]**
Mean Plant Height (sd)	**8.05 m (1.56)**	**7.50 m (1.21) [W = 4,133.5, *P* = 0.002]**
Mean Plant Crown Width (sd)	2.89 m (1.03)	2.90 m (1.13) [W = 5,477.0, *P* = 0.893]
Upper Canopy Layer	n = 11	n = 8
Mean Plant Density (sd)	850/ha (698)	916/ha (812) [W = 49.0, *P* = 0.710]
Mean Plant Height (sd)	11.98 m (1.80)	11.80 m (2.42) [W = 43.5, *P* = 1.000]
Mean Plant Crown Width (sd)	6.08 m (3.01)	4.56 m (1.88) [t = 1.25, *P* = 0.227]
Mean Cover Value (sd)*		
0 – 3 m	28.6% (14.3%)	29.9% (17.1%) [W = 5,628.5, *P* = 0.950]
3 – 6 m	**33.4% (13.6%)**	**25.4% (12.5%) [W = 3,566.0, *P* < 0.001]**
>6 m	**20.1% (12.4%)**	**13.2% (12.8%) [W = 3,371.0, *P* < 0.001]**

* Values based on mid-point of Daubenmire ranking of 0 to 6: 0 = 0%; 1 = 5%(1-10%); 2 =18%(11-25%); 3 = 38%(26-50%); 4 = 63% (51-75%); 5 = 83%(76-90%); 6 =95%(>90%)

Statistical tests included parametric t-tests (t) and non-parametric Mann-Whitney tests (W) for both normally distributed and non-normally distributed data respectively.

Source: Moore (2007).

The affinity of breeding flycatchers with standing water and saturated soil is noted consistently in the literature, and the presence of water may be a factor in sustaining particular vegetation features at breeding sites (Paradzick 2005) and providing a more suitable microclimate for raising offspring (Sogge and Marshall 2000; McLeod et al. 2008). Moreover, the fluctuating availability of surface water at flycatcher breeding sites is likely one factor influencing residency and breeding at a site in any given year, with flycatchers breeding in years when sites contain standing water (Weddle et al. 2007; McLeod et al. 2008).

Anthropogenic or natural modifications to surface water resources (e.g., fluvial hydrology and geomorphology) can modify existing and potential flycatcher breeding habitat and therefore have the potential to modify flycatcher abundance, distribution, and nesting success (Graf et al. 2002). For example, nine flycatcher territories at San Marcial on the MRG exhibited a near absence of nesting attempts in 1996 when a combination of drought, upstream dam operations, and upstream withdrawals for irrigation removed all surface water (Johnson et al. 1999). This is in contrast to previous (1994, 1995) and subsequent (1997) years when active nests were documented at the site, with the river flowing in those years. A nearby control site that contained water exhibited multiple nesting attempts during all four years, leading Johnson et al. (1999) to suggest that the presence of water is a fundamental requirement for nesting. A similar pattern was observed along the Lower Gila River in Arizona when decreased stream flow from 2002 to 2004 resulted in the number of flycatcher territories declining by nearly half each year (Munzer et al. 2005). Since 2004, flows within the Gila River have been greater and more consistent, resulting in a continuing increase in flycatcher territories (14 to 62) from 2004 to 2008 (Graber and Koronkiewicz 2008). The high degree to which flycatchers are associated with standing water can also be seen by correlating flycatcher habitat occupancy and breeding patterns with the presence/absence of standing water in areas like Bill Williams River in Arizona, with flycatchers breeding only in years when sites contained standing water (McLeod et al. 2008).

Studies conducted by McLeod et al. (2008) along the Lower Colorado River and its tributaries have found flycatcher nest sites to be significantly closer to surface water or saturated soil during nesting than at unoccupied sites within the same breeding patches. McLeod and Koronkiewicz (2008) have found that the hydrological conditions recorded in occupied territories showed flycatcher territories containing damp or wet soils, with the distance to surface water generally being less than 30 m (98 feet), and in most cases between 10% and 50% of the surrounding area within 50 m (164 feet) containing saturated or inundated soils during each visit to the site; the soil moisture conditions observed in occupied territories generally mirror those observed at the same sites in previous years (Koronkiewicz et al. 2004, 2006; McLeod et al. 2005, 2007; McLeod et al. 2008).

Along the MRG, Moore and Ahlers (2008) compare site hydrology data (dry all season, saturated/flooded then dry, saturated all season, flooded all season) to flycatcher nest productivity measures (success, productivity, predation, and brood parasitism rates). The researchers have found 95% of flycatcher nests were within 50 m (164 feet) of water. Nest success, predation, and brood parasitism rates are similar among all hydrologic conditions, regardless of nest distance to water and hydrology under the nest. However, in areas that were flooded all season, first nests have been reported more successful than subsequent nests, and successful nests that were either above saturated soil all season or above standing water all season have produced more young than successful nests that were above dry soil all season. Therefore, standing water and/or saturated soil under flycatcher nests may increase juvenile flycatcher survivorship because flycatchers that fledge late in the season have been shown to have a lower survival rate than those that fledge early in the season (Paxton et al. 2007). McLeod et al. (2008) have also found similar effects of fledge date on juvenile survival to those reported by Paxton et al. (2007), with juvenile survival decreasing with later fledge dates.

3.2.4 Migratory Habitat

All four subspecies of willow flycatchers spend the non-breeding season in portions of southern Mexico, Central America, and northwestern South America (Stiles and Skutch 1989; Ridgely and Tudor 1994; Howell and Webb 1995; Unitt 1997), with wintering ground habitat similar to breeding grounds (Lynn et al. 2003). On wintering grounds, both sexes maintain and defend mutually exclusive territories using song and aggressive behaviors similar to those exhibited on breeding grounds (Sogge et al. 2007). Willow flycatchers have been recorded on wintering grounds from central Mexico to southern Central America as early as mid-August (Stiles and Skutch 1989; Howell and Webb 1995), and wintering, resident individuals have been recorded in southern Central America as late as the end of May (Koronkiewicz et al. 2006).

4.0 RESTORATION ISSUES AND OPPORTUNITIES

4.1 DEFINING A RESTORATION APPROACH

Factors limiting silvery minnow and flycatcher habitat availability throughout the Albuquerque Reach are driven by interrupted hydrological processes through river modification and manipulation of river discharge and the introduction and proliferation of invasive phreatophytes (MEI 2002, 2006a; SWCA 2008). Hydrologic modifications, including river regulation, diversion of water, and the structural alteration and development of the floodplain, are key factors that limit the availability of habitat for the silvery minnow and the flycatcher.

Channelization and a reduced sediment supply have increased channel incision, resulting in a reduced diversity of aquatic habitats. These changes have reduced the availability of low-velocity habitat over the vast majority of flows, decreased the amount of wetted areas through the loss of meandering side channels, and isolated the main channel from its floodplain.

In the MRG, the construction of flood control dams on the mainstem and its primary tributaries have resulted in modified flows (including reductions in peak flows, increases in base flows, and, on occasion, truncated snowmelt and summer monsoon flows) and the realignment of the river channel, including river channelization activities, such as jetty jack installation. These factors have contributed to a system with modified hydrology and geomorphology, including isolating an incised main channel from the historic floodplain.

During summer months, the loss of sinuous side channel, backwater, and oxbow habitats results in the loss of low-velocity habitat that is preferred by the silvery minnow. Channel incision results in a monotonous, high-velocity main channel habitat that is beneficial for water transport but detrimental for various life stages of the silvery minnow. Habitat that is considered to be preferred by the silvery minnow comprises only a small portion of the available habitat (Dudley and Platania 1997), making additional losses of an already rare habitat especially problematic (USFWS 2010).

During spring runoff, the loss of floodplain connectivity results in the reduction of low-velocity refuge habitat during high flows (Schlosser 1991; Valett et al. 2005), habitats suitable for larval fish and egg retention (Porter and Massong 2003, 2004, 2006; Fluder et al. 2007; Hatch and Gonzales 2008), and nursery habitat for larval and proto-larval fish (Pease et al. 2006; Hatch and Gonzales 2008).

The impacts on the system can be summarized in the flow chart presented in Figure 4.1. In this conceptual model, the identified stressors would be manifested in ecological and geomorphic effects on the system. These are the conditions that may be observed and measured. The ecological and geomorphic conditions determine the changes in habitat attributes. Changes in habitat attributes operate in a deterministic manner to influence metapopulation responses.

An effective restoration program would operate to mitigate the stressors in order to restore the ecological and geomorphic condition of the system, which would in turn alter the habitat attributes and ultimately provide for a positive metapopulation response. In practice, it will not be possible to reverse the stressors, which is recognized as the constraints under which we operate. Habitat restoration is therefore often implemented to manipulate the ecological and geomorphic conditions and in the MRG may require changes in river operations in order to affect the desired changes. We measure these changes through assessing whether desired habitat attributes are achieved and whether we are affecting a positive population response.

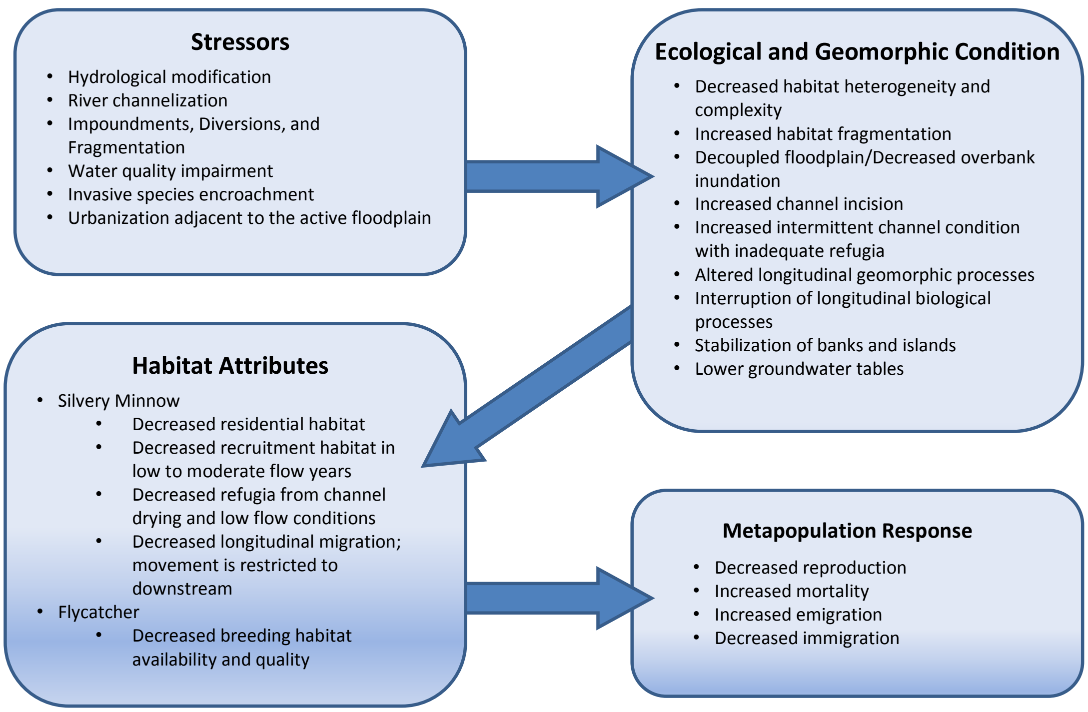

Figure 4.1. Flow chart depicting the Albuquerque Reach problem statement. Stressors and the Ecological and Geomorphic Condition operate at the system level and thus apply to both species. Effects on habitat attributes are identified by species, and metapopulation response applies to both species.

4.2 Hydrologic and Hydraulic Conditions

In order to assess the effects the geomorphic and hydrologic changes (refer to Chapter 2, Sections 2.3.3 and 2.3.4) have on silvery minnow and flycatcher habitat availability and condition, the project team conducted an analysis of hydrologic and hydraulic conditions. Hydrological analysis was conducted by Wolf Engineering using the Albuquerque gage (USGS gage 08330000) to analyze flow duration, volume duration frequency, and flood frequency. These analyses build upon similar work completed by MEI (2007, 2008a).

Hydraulic conditions were analyzed using existing hydraulic modeling extending from Cochiti Dam to Elephant Butte Reservoir. For the purposes of this Study, HEC-RAS and FLO-2D models have been shortened to the reach between Angostura Diversion Dam and Isleta Diversion Dam. To provide consistency with ongoing work being accomplished for the Corps MRG BRP (Corps 2010), the overall project reach is subdivided into seven subreaches. The lower five reaches match those identified in previous work (MEI 2008a). The upper two reaches capture the areas between the south boundary of Santa Ana Pueblo and the Corrales Siphon (Subreach B) and the short reach immediately downstream of Angostura Diversion Dam (Subreach A). The subreach delineation is shown graphically on the overview map presented in Figure 2.2.

To aid in the interpretation of model results, MEI (2008a) developed a station line that represents the distance along the approximate centroid of the flow, with the downstream end (Station 0+00) at Isleta Diversion Dam. The upstream end of the reach modeled for this Study is 2102+00, thus covering approximately 64 river km (39.8 river miles). The station line is available in the *Technical Memorandum Rio Grande - Albuquerque Reach Existing Conditions Hydrology and Hydraulic Modeling* (Wolf Engineering 2008) provided in the Technical Appendix.

The following discussion on the hydrologic and hydraulic conditions of the Albuquerque Reach is taken from Wolf Engineering (2008). Please refer to the Technical Appendix for more detailed information.

4.2.1 FLOW DURATION

The available mean daily flow data for the Albuquerque gage were used to develop a flow duration curve that illustrates the magnitude and duration of flows (Figure 4.2). The complete period available (including provisional data for water year [WY] 2008) was used for this analysis. Further, the spring runoff period (March 1–June 30) was extracted from the records, and separate curves were produced for these data. Observation of these curves shows that flows of about 6,000 cfs have increased between the pre- and post-Cochiti periods. Table 4.1 provides a summary of the flow duration data.

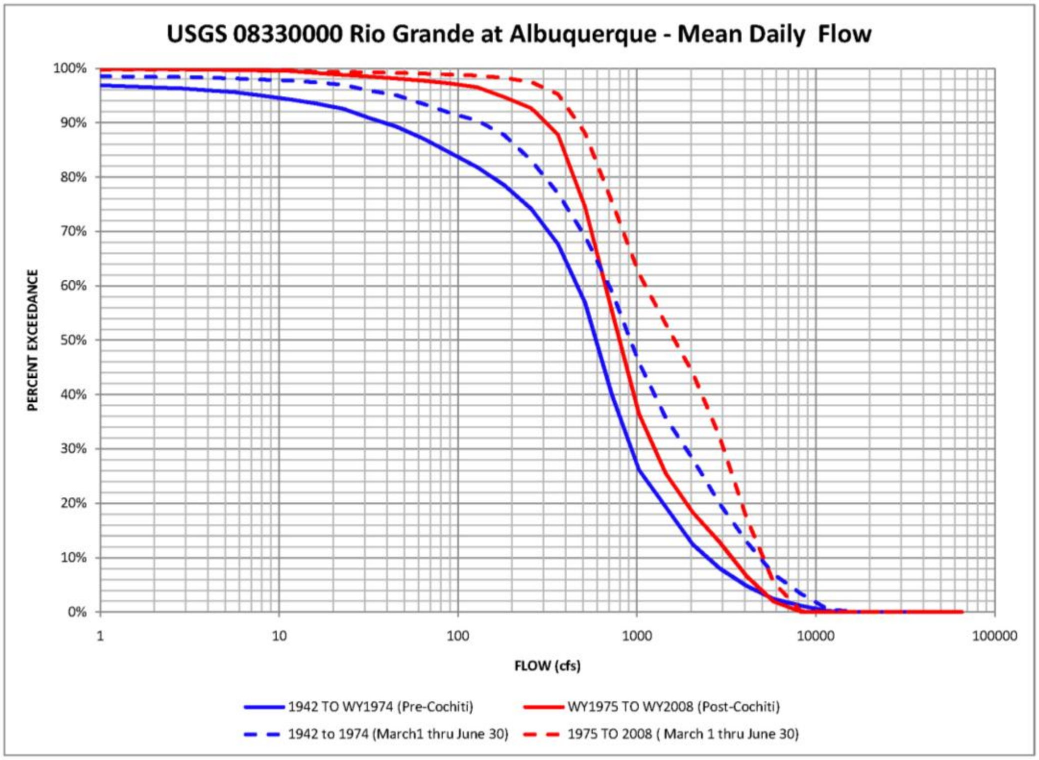

Figure 4.2. Flow duration curve for pre- and post-Cochiti Dam – USGS gage 08330000, Rio Grande at Albuquerque.

Table 4.1. Flow Duration Data (cfs) – Rio Grande at Albuquerque

Percent Exceedance	Pre-Cochiti Annual	Post-Cochiti Annual	Pre-Cochiti Spring	Post-Cochiti Spring
10%	2,500	3,400	4,700	5,100
50%	590	800	910	1,750
90%	40	310	130	470

Source: Wolf Engineering (2008).

4.2.2 VOLUME DURATION FREQUENCY ANALYSIS

Understanding and quantifying the likelihood of sustained periods of flow within the project reach is important to the process of formulating and designing channel restoration alternatives for the silvery minnow. To support this data need, Wolf Engineering computed a series of volume duration frequency curves for the Albuquerque gage using available mean daily flow data for the period of record. The analyses were completed using the Corps software package HEC-SSP (Corps 2008a) and were accomplished for two durations: a 7-day period and a 25-day period. The period of record for the Albuquerque gage was separated into pre- and post-Cochiti periods and was further segmented into seasonal periods consisting of spring (March 1–June 30), summer (July 1–September 30), and fall/winter (October 1–February 28). Volume duration frequency curves were computed for each of these periods using both a minimum and maximum flow analysis on the respective period (Wolf Engineering 2008).

The historical record suggests that flows in the Rio Grande have been variable with periods of dry conditions and periods of wet conditions (Scurlock 1998). This indicates the importance of evaluating and quantifying the likelihood of sustained low-flow periods when formulating and designing in-channel restoration alternatives for the silvery minnow.

To evaluate the low-flow periods, it is helpful to use a minimum flow analysis (Dunne and Leopold 1978). The minimum flow analysis predicts the probability of not exceeding a given value for a given duration. Minimum flow curves were computed for the same 7-day and 25-day duration periods as the flow duration analysis. The results are presented in Table 4.2, Table 4.3, Figure 4.3, and Figure 4.4. The minimum flow analysis is similar to the flood frequency analysis (see Section 4.2.3), except the minimum flow analysis computes the probability of a flow not exceeding a given value. For example, the 10% non-exceedance flow for the spring period in the pre-Cochiti period suggests that there is a 10% probability of flows occurring that are 12 cfs or less. Comparing the pre-Cochiti period with the post-Cochiti period suggests a greater likelihood of encountering low-flow periods in the pre-Cochiti period. The evidence is the higher flow values in the post-Cochiti period. This trend holds true for the 7-day flow duration across all non-exceedance probabilities and the 25-day flow duration at the 10% and 50% non-exceedance probabilities. However, the trend changes at the 90% non-exceedance probability, which shows a decrease in the post-Cochiti period, suggesting that higher magnitude flow events occurred prior to the closure of Cochiti Dam.

The duration periods were selected to represent the minimum period (thought to be 7–10 days) and an optimal period (approximately 25 days) required for silvery minnow recruitment. The 7- to 10-day flow-duration period represents what is thought to be a minimum time required for silvery minnow recruitment, while the 25-day period is hypothesized to be a desired flow duration period. As is shown in Section 4.3.3.2 Reproductive Biology—Hydrologic Dynamics Linkages, there appears to be correlation between maximum annual consecutive days of strong recruitment stage discharge flows and average estimated density of silvery minnow.

Table 4.2. Volume Duration Frequency Data (cfs), 7-Day Minimum Flow Analysis

Percent Chance Non-exceedance	Pre-Cochiti Period			Post-Cochiti Period		
	Spring	Summer	Fall/Winter	Spring	Summer	Fall/Winter
10%	12	1	3	212	31	27
50%	146	18	50	623	224	242
90%	1,057	279	442	1,176	764	701

Table 4.3. Volume Duration Frequency Data (cfs), 25-Day Minimum Flow Analysis

Percent Chance Non-exceedance	Pre-Cochiti Period			Post-Cochiti Period		
	Spring	Summer	Fall/Winter	Spring	Summer	Fall/Winter
10%	20	9	2	282	143	67
50%	294	73	88	897	452	340
90%	2,273	560	1,416	1,719	854	764

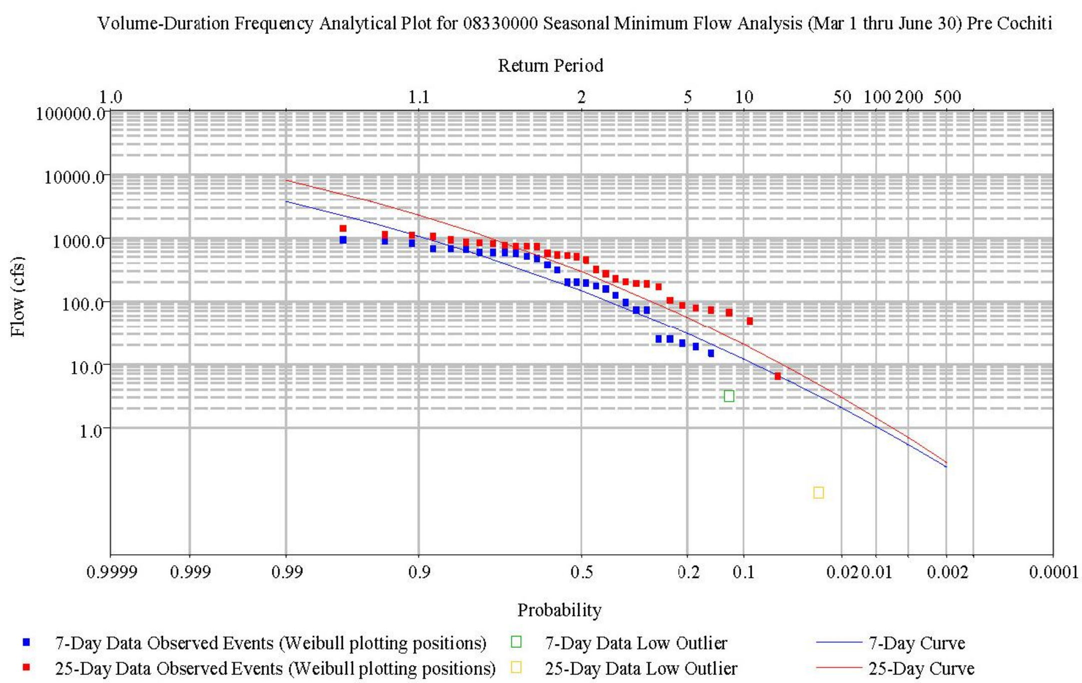

Figure 4.3. 7-day and 25-day volume duration frequency plots – minimum flow analysis pre-Cochiti, WY1942–WY1974 (Wolf Engineering 2008).

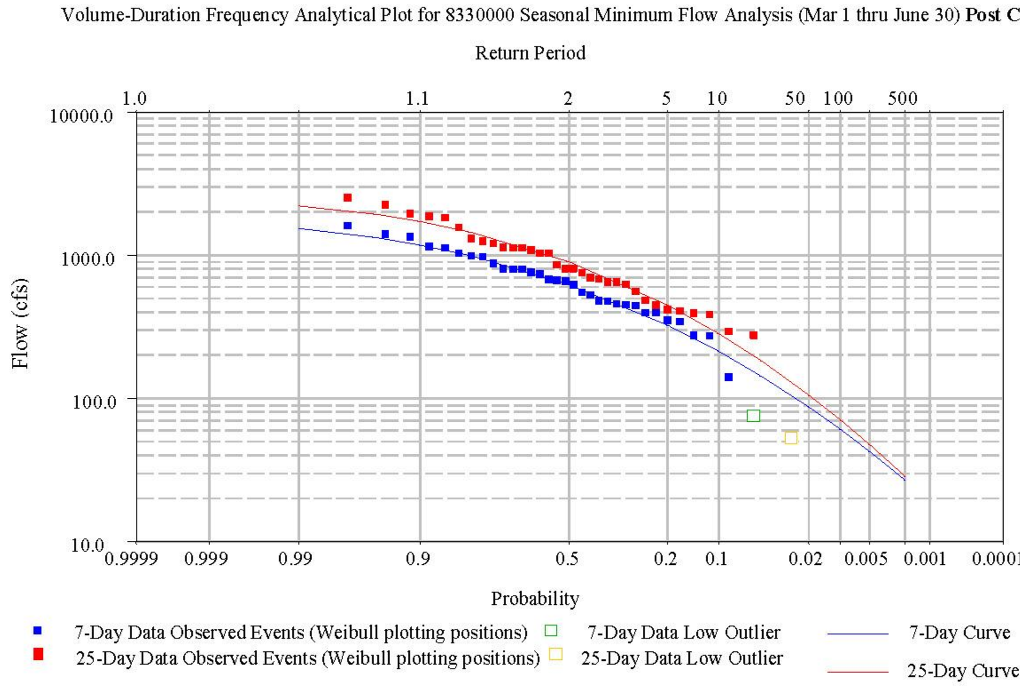

Figure 4.4. 7-day and 25-day volume duration frequency plots – minimum flow analysis post–Cochiti, WY 1975–WY 2008 (Wolf Engineering 2008).

4.2.3 Flood Frequency Analysis

Dam operations on the river subsequently alter natural flows and ultimately determine actual flow rates by storing and releasing water in a manner that generally decreases the flood peaks and alters timing of the hydrograph but not necessarily annual flow volume (Corps et al. 2006). Dams, such as the one constructed at Cochiti, not only reduce flood peaks but also the inundation frequencies of the floodplain (Petts 1984). It has been well documented that the average annual maximum mean daily flow and infrequent large magnitude peak discharges have decreased in all reaches south of Cochiti Dam (Corps et al. 2006; MEI 2008b; Parametrix 2008a; SWCA 2008). This has implications for downstream ecosystem productivity and species diversity (Pollock et al. 1998). MEI (2008b) reports that prior to the closure of Cochiti Dam, peak discharges regularly exceeded 10,000 cfs. However, since the closure of Cochiti Dam, no peak discharges exceeded 10,000 cfs, although the annual runoff volume increased from approximately 714,000 acre-feet to approximately 1,011,000 acre-feet. Parametrix (2008a) describes the effect of upstream water regulation as flattening the mean annual hydrograph by limiting peak flows to 7,000 cfs to prevent damage to levees and other infrastructure. The maximum flow analysis results conducted by Wolf Engineering (2008) are presented in Table 4.4, and flood frequency curves are presented in Figure 4.5.

Table 4.4. Post-Cochiti Era Computed Discharge Frequency at the Rio Grande Albuquerque Gage

Return Interval (Years)	Pre-Cochiti Peak Discharge (cfs)	Post-Cochiti Peak Discharge (cfs)
2	6,887	4,894
5	10,763	7,131
10	13,463	8,551
25	16,116	9,858
50	16,269	11,477
100	22,318	12,643

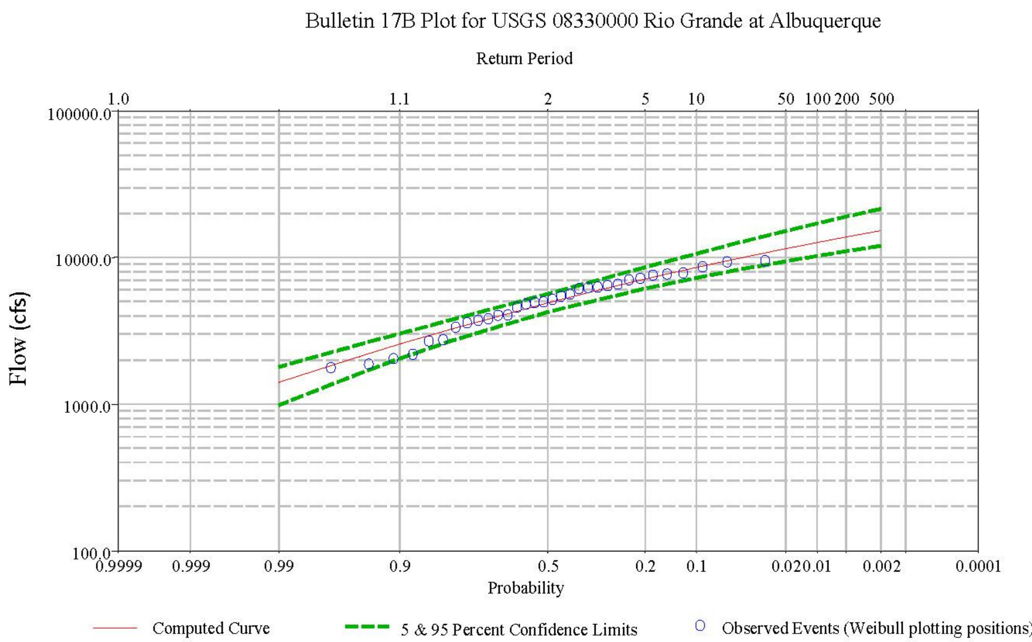

Figure 4.5. Computed flood frequency curve for the Rio Grande at Albuquerque – post-Cochiti period (WY 1975–WY 2007) (Wolf Engineering 2008).

4.2.4 HEC-RAS MODELING

HEC-RAS modeling was used to evaluate the in-channel conditions and restoration alternatives. The Study modeling was based on the previously developed and calibrated HEC-RAS model (MEI 2008a) that was used to determine in-channel flow depths and average flow velocities for a range of steady-state discharges. The model was originally developed by Reclamation using the aggradation/degradation range lines that were digitized from 2002 aerial photography. The range lines are uniformly spaced approximately every 152 m (500 feet) along the Albuquerque Reach. The Corps and its consultant (MEI 2006b) modified and updated the original model with recently surveyed cross sections and refined and added ineffective flow areas. As reported in the Pueblo of Sandia Hydraulic Modeling project (MEI 2007), the model was calibrated at discharges of 347 cfs and 6,300 cfs using a constant

Manning's n value of 0.03 in the main channel. The HEC-RAS model (Corps 2008b) predicted water surface elevations versus in-field measured water surface elevations and showed very good agreement (MEI 2006b, 2007).

4.2.4.1 HEC-RAS Results

The HEC-RAS model provides an assessment of in-channel flows through computing water surface elevations over a range profile data for discharges of 1,500, 3,500, and 6,000 cfs. Water velocity profiles were created for each subreach, but it was not possible to map each bar and island to model inundation depth and duration due to the lack of a suitable topographic model. The effort was limited by an outdated Light Detection and Ranging (LiDAR) topographic data and a digital elevation model (DEM) that lacked a sufficiently high resolution.

However, analysis of the profiles shows that flows up to approximately 3,500 cfs are confined to the active channel and that the 6,000-cfs profile approximates the bankfull conditions with intermittent areas of overbank flows. These results are in agreement with the analysis conducted by MEI (2008a) in support of the MRG BRP and are corroborated by the data collected during overbank monitoring of the 2005 spring high flow events (Tetra Tech 2005). The channel velocities are relatively uniform throughout the project area. Flow velocities vary from approximately 2 to 3 fps at 1,500 cfs to approximately 3 to 5 fps at 6,000 cfs. However, upon closer examination, there are areas where the velocity profiles converge, dip, or cross (with 1,500-cfs discharges having a higher discharge than the 3,500- and 6,000-cfs discharges). These results suggest areas where islands and bars are inundated, representing potential silvery minnow habitat.

A review of the thalweg depth elevations using 2002 aggradation/degradation surveys and the MEI (2008a) results suggests that the channel incision has progressed to just upstream of Montaño Bridge. These results may be an artifact of the data collected in 2002, but generally corroborate the results reported by Leon (1998), Ortiz (2003), Bauer (2004), Massong et al. (2005a, 2005b), and Massong et al. (2007) of continuing channel degradation.

Average computed channel velocity profiles are plotted in profile in Appendix B and are available in Wolf Engineering (2008) (see Technical Appendix).

4.2.5 FLO-2D Modeling

The FLO-2D model used for the Study is the Middle Rio Grande Cochiti Dam to Elephant Butte Reservoir 250 Foot Grid System developed by Riada Engineering, Inc. (2007, 2008) and MEI (2008a). This model was developed for the Corps and is an updated version of a previous model covering the same reach, but with a grid system of 500 feet. The 250-foot model includes updated cross sections, refined Manning's n values, spatially varied channel and floodplain infiltration, an evaporation component, and updated and refined levee elevations. In addition, MEI (2007) updated the 250-foot system's grid elevations for the reach through the Pueblo of Sandia with data from a LiDAR survey performed in December 2006; the LiDAR data included the area between the levees. Flow in the river during the data collection was approximately 700 cfs as measured at the Albuquerque gage. No adjustments were made to the channel cross sections as a result of the updated grid elevations (MEI 2008a).

The primary database used to calibrate the 250-foot grid model was the Corps 2005 overbank monitoring project (Riada Engineering, Inc. 2007, 2008). The calibration was accomplished by the following methods:

1. Comparison of the computed water surface elevations with the high water surveys collected during the 2005 high flow (~6,300 cfs through the Albuquerque Reach) inundation mapping (Horner and Sanders 2007).
2. Comparison of the predicted overbank inundation areas with aerial photography and digitized flood mapping collected by the Corps during the 2005 high flows (Horner and Sanders 2007).
3. Comparison of computed discharge hydrographs and USGS-recorded hydrographs through the Study reach. Model parameters were adjusted to match hydrograph shape (volume) and timing.

In general, the calibration to the June 2005 spring high flows for the period during the overbank monitoring is excellent (Riada Engineering, Inc. 2007, 2008).

The FLO-2D model was used to assess channel capacity, predict and track the locations of overbank flow, predict the duration of overbank flow, and provide depth-averaged (based on computed depth) hydraulic conditions for the main channel (depth, velocity, top width, and energy slope). The calibrated FLO-2D model was run for the following hydrologic scenarios:

1. Scenario 1: A stepped hydrograph from 500 to 6,500 cfs with the discharge increasing in 500-cfs increments every 60 hours.
2. Scenario 2: A steady release from Cochiti Dam of 1,500 cfs for 10 days.
3. Scenario 3: The spring runoff hydrograph from 2007 as recorded at the Albuquerque gage.
4. Scenario 4: A steady release of 6,000 cfs from Cochiti Dam for 25 days.
5. Scenario 5: A steady release of 7,000 cfs from Cochiti Dam for 25 days.

The primary purpose of modeling each scenario is as follows:

1. To provide a tool for quickly computing depth-averaged hydraulic conditions within any subreach of the overall Albuquerque Reach.
2. To evaluate flood routing, flow depths, and flow velocity for a dryer than normal spring runoff.
3. To evaluate flood routing, flow depths, and flow velocity for a normal spring runoff.

4. To evaluate flood routing, flow depths, and flow velocity in the channel and overbank, as well as for duration of inundation in the overbank for a wetter than normal spring runoff.

5. To evaluate flood routing, flow depths, and flow velocity in the channel and overbank, as well as for duration of inundation in the overbank for the maximum controlled release from Cochiti Dam.

4.2.5.1 FLO-2D RESULTS

A review of the FLO-2D results indicates that overbank inundation is predicted to occur in the lower portion of the project area (Subreach 5) where inundation occurs below 6,000 cfs. Inundation at 6,000 and 7,000 cfs occurs in Subreaches 4 and 5 (downstream of the Central Avenue Bridge). Overbank inundation upstream of the Central Avenue Bridge occurs only in the vicinity of the Montaño Oxbow, which experiences overbank inundation at 6,000 cfs. The results of the existing conditions FLO-2D modeling are presented in Appendix C as a series of maps indicating overbank inundation depths at 6,000 cfs.

The depth-averaged hydraulic condition parameters selected include W/D, thalweg depth, velocity, top width, and energy slope and are thought to be important indicators of suitable silvery minnow habitat. The parameters represent the average conditions for each subreach modeled based on the water surface elevation at the given discharge. The subreaches, as defined by MEI (2008a) are broken down into tiles to facilitate analysis. Each hydraulic condition parameter is averaged for each tile and for each subreach. In order to analyze the conditions over the range of flows most likely to be encountered under the current operations, we analyzed a range of flows from 500 to 6,500 cfs with the discharge increasing in 500-cfs intervals, as described in hydrologic scenario 1 above. Table 4.5 summarizes the depth-averaged hydraulic conditions averaged over each subreach. The table in Appendix D presents the average hydraulic conditions for each tile within the subreach.

The results of this exercise are informative and are used to define habitat types (see Section 4.3.4) and in Chapter 5 to develop the conceptual restoration model and restoration recommendations. The depth-averaged hydraulic conditions are used as a proxy for habitat suitability. The W/D is particularly useful because it is an indicator of channel entrenchment and is thought to be an important parameter for determining habitat heterogeneity over a range of flows. W/Ds that remain constant over the range of flows modeled may indicate the degree to which the channel may experience overbanking or the degree of habitat heterogeneity. Conversely, a decreasing W/D over the range of flows is thought to be an indicator of entrenchment and is associated with narrow, incised channel sections. Thalweg depth and velocity are other parameters that are indicative of silvery minnow habitat. Channel sections that have a relatively shallower thalweg depth and relatively slower velocities over the range of flows modeled are thought to be indicators of habitat heterogeneity.

Table 4.5. 250-foot FLO-2D Computed Channel Hydraulic Conditions

Depth-averaged Channel Hydraulic Conditions within the Albuquerque Reach							
Subreach	Discharge (cfs)						
	500	1,000	2,000	3,000	4,000	5,000	6,000
	Thalweg Depth (feet)						
A	5.0	6.6	7.8	8.6	9.0	9.5	9.9
B	3.5	4.7	6.0	6.7	7.3	7.7	8.1
1	2.5	3.5	4.3	4.8	5.1	5.5	5.8
2	2.8	3.4	4.2	4.7	5.1	5.5	5.7
3	2.5	3.1	3.9	4.5	5.0	5.4	5.8
4	2.3	3.0	3.7	4.2	4.6	4.9	5.3
5	2.4	3.4	4.2	4.8	5.3	5.8	5.9
Velocity (fps)							
A	0.98	1.24	1.55	1.77	2.02	2.24	2.44
B	1.43	1.88	2.20	2.51	2.79	3.07	3.28
1	0.93	1.40	1.82	2.15	2.44	2.70	2.95
2	1.17	1.43	1.78	2.07	2.32	2.55	2.81
3	1.00	1.36	1.85	2.24	2.56	2.86	3.11
4	0.87	1.25	1.68	2.03	2.34	2.61	2.87
5	0.92	1.40	1.90	2.30	2.65	2.94	3.10
Top Width (feet)							
A	214	330	479	572	578	582	586
B	173	247	363	426	461	482	496
1	232	501	594	633	649	655	658
2	387	493	607	664	690	699	703
3	429	441	451	457	463	468	474
4	457	541	573	580	583	586	588
5	363	424	437	444	447	450	482
W/D							
A	39	51	62	68	65	62	60
B	46	53	61	64	64	63	61
1	103	148	146	139	131	124	118
2	145	149	148	143	137	130	124
3	180	150	122	107	98	91	86
4	189	187	158	141	129	120	112
5	134	130	109	97	88	82	84
Energy Slope (feet/feet)							
A	0.000276	0.000324	0.000385	0.000400	0.000411	0.000422	0.000425
B	0.000552	0.000584	0.000582	0.000580	0.000581	0.000581	0.000586
1	0.000486	0.000648	0.000659	0.000658	0.000658	0.000658	0.000656
2	0.000667	0.000658	0.000637	0.000631	0.000626	0.000621	0.000622
3	0.000649	0.000637	0.000623	0.000622	0.000619	0.000617	0.000607
4	0.000581	0.000640	0.000635	0.000637	0.000637	0.000638	0.000642
5	0.000484	0.000539	0.000525	0.000523	0.000517	0.000515	0.000563

4.3 Rio Grande Silvery Minnow Habitat

4.3.1 Approach to Habitat Improvement Planning

To be effective, habitat improvement planning must be based on information about factors that limit membership of the fish community at various spatial scales and thereby point to specific intervention measures needed to achieve desired management objectives. Spatial scales of environmental units possess a hierarchical structure whose physical attributes are accompanied by characteristic temporal scales that vary from long-term (100,000–1,000,000) to near-term (0.10–1.0) years and from landscapes to microhabitats, respectively (Frissell et al. 1986). The hierarchical nature of environmental units implies that the larger, more stable, environmental units impose limits on the smaller, more variable environmental units and thus lend themselves to statistically nested designs for detecting and understanding habitat-fauna linkages.

Effective strategic planning for silvery minnow conservation requires that environmental variables be examined to reveal nonrandom patterns to aid in determining how fish assemblages are structured by underlying hydrologic, geomorphic, and biotic features of their environment. Conceptually, such partitioning of aquatic habitats is expected to facilitate discussions of management circumstances (problems, constraints, and opportunities) where system effects of proposed management actions may be anticipated. Furthermore, managers will be more likely to plan effective management strategies and incorporate adaptive strategies if the array of aquatic habitats is partitioned into distinct management classes.

Two practical questions exist as important foci of the Study: 1) how are assemblages of fish species, specifically those that include silvery minnow, structured by underlying environmental variables; and 2) how can ecosystem processes and fish community structure be manipulated to achieve management goals? Answers to these and other related questions depend on an inventory of habitat features, including the nature and location of properly or adequately functioning states and degraded habitats.

4.3.2 Silvery Minnow Demography

Understanding the links between species' fitness characteristics and habitat features is crucial for the effective management and restoration of running water ecosystems. Planning for the adequacy of conservation measures to overcome various habitat limitations ultimately requires that a quantitative relationship between habitat and population size be established for the species and that sufficient habitat be maintained to meet an established recovery target based on the habitat-population relationship. For the silvery minnow, this relationship, although unquantified, is known to vary profoundly by life stage and with varying hydrologic circumstances (Hatch et al. 2008). As such, habitat-population relationships will be complicated by the necessary consideration of age- or stage-specific estimates of survival (i.e., the fraction of the population that successfully recruits to the next age or life history stage) and separate relationships between habitat and abundance for each life stage over a range of hydrologic conditions.

Knowledge of how habitat quality and quantity limit the abundance of different life stages is fundamental to the identification of habitat essential to species conservation. To be successful, management for the conservation of small animal populations, such as the silvery minnow, must strive to increase the rate of population growth while minimizing the between-generation variance of the rate of population growth. Management actions that increase population growth reduce the probability of species extinction.

Birth, death, immigration, and emigration represent the primary population processes responsible for changes in population size. Management activities directed at influencing these key population processes form the logical basis for formulating intervention strategies intended to enhance the short- and long-term prospects of species survival—intervention strategies that complement the species' life history, targeting age-specific schedules of reproduction, recruitment, and mortality.

4.3.2.1 HABITAT-SPECIFIC DEMOGRAPHY

Dudley and Platania (1997) have studied habitat preferences of the silvery minnow in the MRG at Rio Rancho and Socorro, and they characterize habitat preference and habitat availability in terms of water depth, water velocity, and stream substrate. Both juvenile and adult silvery minnow primarily use mesohabitats with moderate depths (15–40 cm [6–16 inches]), low water velocities (4–9 cm/s [1.6–3.5 inches/s]), and silt/sand substrates (Dudley and Platania 1997). Such avoidance of swift water velocities by the silvery minnow is one means of conserving energy, a general life strategy shared by many lotic fish species (Facey and Grossman 1992). But it remains untested how rates of primary biological processes might be linked to the preferred habitat. Without knowledge of habitat-specific demography, observations of spatial variation in species density associated with various habitat features do not yield reliable inferences about species fitness or dynamics of populations inhabiting such areas (e.g., Pulliam 1988).

Stream depth, velocity, and substrate are often perceived as independent variables when, in fact, they covary. In many fisheries studies, available habitat is quantified with the implicit assumption that fish abundance is regulated by habitat availability. Yet, many examples exist in which year-to-year variation in fish abundance is large even though available habitat is held constant (e.g., Moyle and Blatz 1985). Conversely, at times of high abundance, fish are found in apparently marginal habitats from which they are otherwise missing MacKenzie et al. 2006). Short-term changes in flow, excluding events of total channel drying, may cause changes in the distribution rather than the abundance of fish.

The results of studies by Hatch and Gonzales (2008), coupled with those reported by Buhl (2006) and Cowley et al. (2006), suggest that the silvery minnow is physiologically flexible—capable of surviving absolute extremes and daily fluctuations in chemical and physical conditions. Short of complete or near desiccation of habitat, the silvery minnow exhibits a capacity to withstand the wide variety of environmental conditions common to standing and running water habitats of the MRG.

4.3.3 HABITAT DETERMINANTS OF SILVERY MINNOW PERSISTENCE AND POPULATION GROWTH

4.3.3.1 ADAPTATION TO FLOW DISTURBANCE REGIMES

Ecologically, floods and drought represent flow disturbance regimes in the MRG that serve to differentially advantage or disadvantage species, thereby regulating species diversity and species abundance across a range of spatial and temporal scales. Frequent and predictable extremes in flow tend to operate selectively to produce life history strategies in native fish species that optimize the allocation of resources to critical life functions, notably including maintenance, growth, and reproduction. Adaptive traits emerge over evolutionary time that enables species to survive flow disturbance regimes (Lytle and Poff 2004).

The mode of adaptation determines an organism's vulnerability to flow patterns, including disturbance regimes. Generalist species tend to dominate variable discharge running water ecosystems in response to uncertainty of critical resources, whereas ecological specialists tend to be more common in streams that have predictable discharge (Horwitz 1978; Poff and Allan 1995). Species exposed to strong environmental variation within generations often exhibit a broad tolerance to diverse conditions through physiological flexibility (Levins 1968; Matthews 1987). Understanding the links between species' fitness and flow regime is crucial for the effective management and restoration of running water ecosystems.

The species of diatoms foraged by the silvery minnow provide information about the environmental conditions of the Rio Grande. Shirey (2004) has compiled frequencies of diatoms with varying environmental associations with trophic state, saprobity, oxygen saturation, pH, salinity, and nitrogen uptake metabolism. Shirey's (2004) results show that the silvery minnow forages in nutrient-enriched eutrophic conditions, with 40% of the diatoms typically found in highly productive waters and 10% indicative of highly enriched environments with high production of organic matter. Shirey (2004) finds further evidence of nutrient-enriched waters in 1874. At this time, there was a clear dominance (approximately 90%) of diatom taxa that were associated with low to moderate oxygen saturation and moderate to high biological oxygen demand (Van Dam et al. 1994). More than 20% of the diatom taxa were obligate nitrogen heterotrophic species (Shirey 2004), indicating a requirement for continuously elevated concentrations of nitrogen (Van Dam et al. 1994). A majority of the diatom species foraged by the silvery minnow were alkaliphilous. Thus, the gut content analyses indicate that the silvery minnow can tolerate nutrient-enrichment, alkaline waters, and low oxygen concentrations (Cowley et al. 2006).

Laboratory studies of silvery minnow physiological tolerance by Buhl (2006) are consistent with the findings of Shirey (2004) and Cowley et al. (2006). Maximum lethal limits (LL_{50}) for temperature and maximum lethal concentrations (LC_{50}) of dissolved oxygen and ammonia for the silvery minnow have been investigated by Buhl (2006) for four age groups of silvery minnow (i.e., 3–4 days post-hatch [dph] larvae, 32–33 dph juveniles, 93–95 dph juveniles, and 11-month-old subadults) in reconstituted water that simulated conditions in the MRG. Larvae and juveniles were determined to be more tolerant of high temperatures and hypoxic conditions (LL_{50} 35°C–37°C [95°F–98.6°F]; LC_{50} 0.6–0.8 mg/L dissolved oxygen) compared to subadults (LL_{50} 32°C –33°C [89.6°F–91.4°F]; LC_{50} 0.9–1.1 mg/L dissolved oxygen). Based on nominal total ammonia concentrations, Buhl (2006) found that larvae were about twice as sensitive (96-hour LC_{50} for all pulses, 16–23 mg/L as N) as both juvenile age groups (96-hour LC_{50} for all pulses, 39–70 mg/L as N).

Planning for the provision of habitat to overcome flow disturbance regime limitations requires that a quantitative relationship between habitat and population size be established for the species and that sufficient habitat be maintained to meet an established recovery target based on the habitat-population relationship. The importance of each population segment to species persistence and population growth will depend on relative rates of birth, death, growth, and survival, as well as various expressions of habitat quality, including habitat size and stability and a suite of associated natural and anthropogenic threats (e.g., point sources of mortality-causing water pollution). The more expansive perennial habitats are vital to silvery minnow survival due to enhanced temporal environmental stability intrinsic to such habitats. These habitats have a heightened capacity to support silvery minnow across generations and often exist as the source stock to repatriate empty habitat patches. Habitat patches that are subject to periodic discontinuity of flow exhibit variation in the long-term frequency, magnitude, and predictability of mortality-causing events, and as such vary in their ability to support silvery minnow across generations.

The implications of diminished wetted habitat for the conservation of the silvery minnow will be different for population sources versus population sinks. Naturally, the loss of habitat that affects source populations will have a greater impact on long-term population trajectories than it would on sink populations. Predicting silvery minnow population dynamics under randomly varying circumstances, including situations in which species persistence is threatened by the loss of large tracts of habitat, must ultimately account for exchanges between population sources and sinks and how rates of birth, death, and dispersal vary between different habitat patch types and how these processes affect population persistence.

4.3.3.2 Reproductive Biology—Hydrologic Dynamics Linkages

Because the reproductive biology and early life history of the silvery minnow are intricately linked to hydrologic dynamics of the basin, it is instructive to characterize the hydrologic characteristics that would have occurred in the MRG with sufficient predictability and frequency to produce adaptive traits to the peculiar environmental circumstances of the MRG. Flow records from Otowi for the period of 1895 to 1930 provide a perspective of the relatively unaltered hydrograph for the northern portion of the MRG prior to the construction of Cochiti Dam. Figure 4.6 illustrates both the infrequent extremes (maximum and minimum discharge values) and the more frequent, but extreme conditions (i.e., plus or minus two times the standard error) associated with the long-term average dynamics of the flow regime in the northern portion of the MRG (at the USGS gage at Otowi).

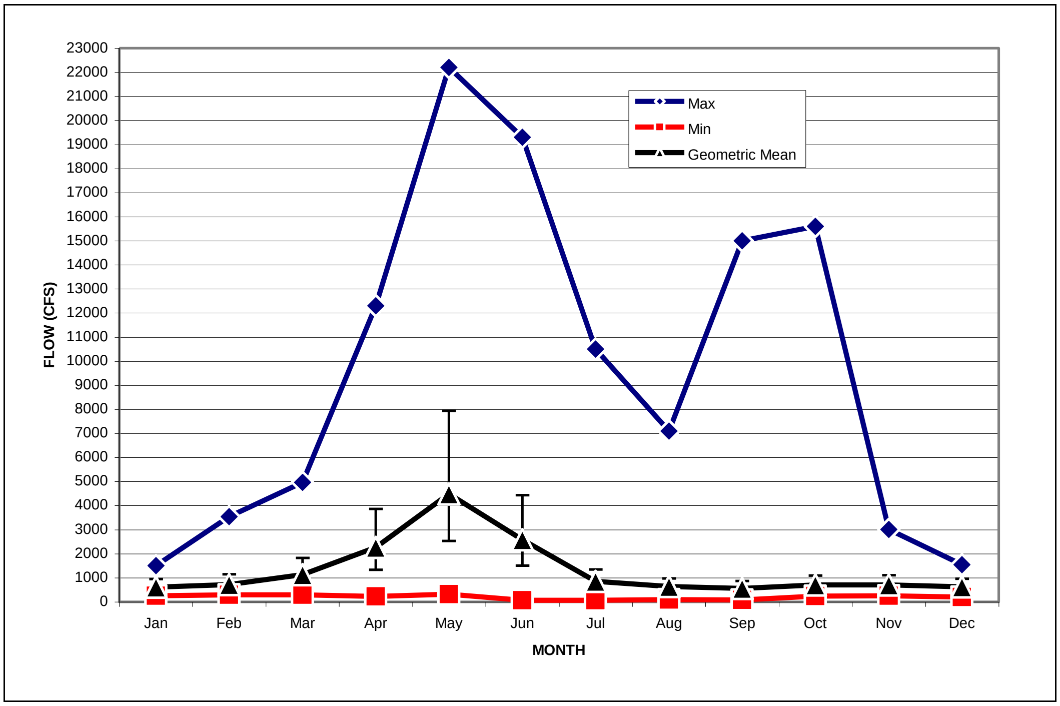

Figure 4.6. Monthly discharge statistics at the Otowi gage for the period of 1895–1930 (with a hiatus in records from January 1, 1906–June 30, 1909). Error bars on geometric mean flow represent plus or minus two times the standard error (accounting for skewed distribution). Data are derived from flow records published by the USGS (2009).

After the construction of Cochiti Dam, it is notable that extreme high-flow events have been eliminated from the MRG. Compared to the early settlement (pre-1931) hydrograph, the contemporary (post-1975) hydrograph is characterized by reduced monthly average flow, most profoundly for April through June, and reduced variation across and between months. Analysis of the Albuquerque gage (USGS 08330000) pre- and post-Cochiti Dam confirms this trend (see Table 4.1). Despite these changes, broad temporal patterns in the hydrologic regime have been retained over time. The highest hydrologic discharge events in the MRG have remained linked most predictably over time to snowmelt, the height of which generally occurs each year during May, but also occurs with high frequency as early as April and as late as June.

Dudley and Platania (2008) report the importance of spring runoff events to silvery minnow recruitment. Annually, silvery minnow densities in October were positively correlated with peak discharge and duration of high flows during the May through June spawning season (Dudley and Platania 2008). Silvery minnow densities were lowest in the period from 2001 to 2004, which corresponded to periods of reduced spring runoff (Figure 4.7). Silvery minnow densities increased dramatically in the period of 2005 to 2007, particularly in 2005 following a prolonged high-flow spring runoff event. Prolonged inundation of vegetated overbank areas and inundated habitats within the channel (such as bankline features and backwaters) were cited as essential habitats to the successful recruitment of early life-stage fish (Dudley and Platania 2008).

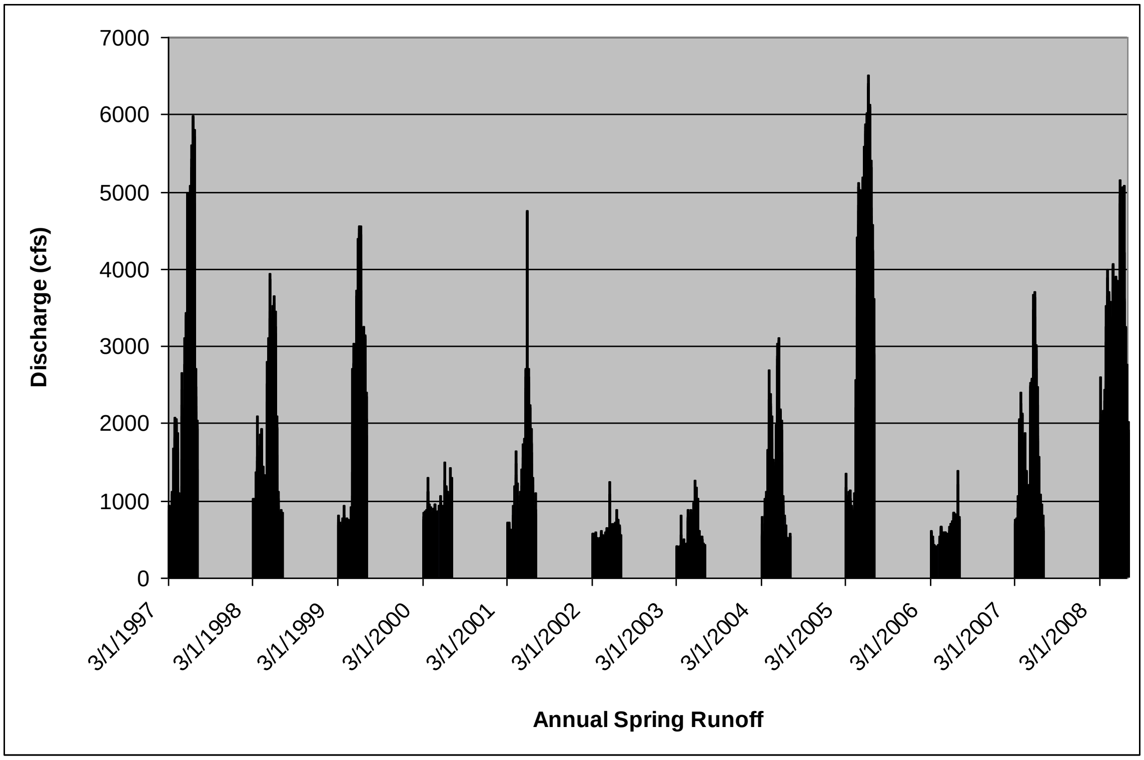

Figure 4.7. Spring runoff peak discharge for the period 1997–2008 for the Albuquerque gage (USGS 08330000). Runoff period presented is March–June in each year.

Note that in 2001, the peak discharge was for a brief period of only a couple days. Analysis of Dudley and Platania (2008) data indicates that this was a poor recruitment year, varying only slightly from the previous year. Hatch and Gonzales (2008) suggest that flows that inundate the floodplain will contribute to strong silvery minnow recruitment classes so long as the sustained duration of river channel-floodplain coupling is maintained above a minimal threshold that will provide time for the parental stock to occupy the floodplain and spawn, for embryo development and hatching, and for young-of-year to develop to the juvenile stage to successfully evacuate the draining floodplain habitats We hypothesize that moderate to high flows that inundate the floodplain for a minimum period of 7 to 10 days is required to stimulate silvery minnow recruitment.

It is not surprising that the species coordinates its spawning with periods of hydrologic abundance. Likewise, it seems adaptive that, in the context of suboptimal conditions, the timing and duration of silvery minnow spawning seems strategically more aligned with an opportunistic approach to reproduction—spanning a range of conditions and time that correspond to different possible future environmental states with variable probabilities for species recruitment (Lytle and Poff 2004). Indeed, low-flow spawning by silvery minnow, although limited, has been documented during 2006, resulting in recruitment of silvery minnows to at least the juvenile stage (USFWS 2010).

Prolonged low-flow conditions are also expected to adversely affect silvery minnow populations. Low-flow conditions that result in fish mortality may be linked to climatic variability[4] exacerbated by extractive us of water in the basin. Dudley and Platania (2008) suggest that October densities of silvery minnow are negatively correlated with extended low-flow periods. In particular, poor spring runoff and low-flow conditions leading to intermittent channel drying, which occurs in the Isleta Reach, are cited as conditions that lead to reduced silvery minnow survival. Suggested contributing factors include crowding, stress, contaminant concentration, and poor habitat quality.

In the Albuquerque Reach, the river has not experienced intermittent drying since the closure of Cochiti Dam under current water management scenarios. However, prior to the closure of Cochiti Dam, the historical record indicates that intermittent channel drying had occurred, albeit relatively infrequently. FLO-2D[5] modeling suggests that the Albuquerque Reach would not experience intermittent drying during extremely dry years, but that very low flow conditions could persist throughout the lower parts of the reach.

4.3.3.3 METAPOPULATION FEATURES

An overarching theme, one critical to the consideration in the conservation of small animal populations, pertains to spatial aspects of the structure of silvery minnow populations. Spatially structured populations are generically referred to as "metapopulations." A population's spatial structure depends fundamentally on habitat quality, spatial configuration of subpopulations, and dynamics of species abundance, as well as the dispersal characteristics of individuals in a population. Effective recovery efforts for species inhabiting variable environments require the consideration of processes operating at multiple scales, ranging from landscape-level processes that create and maintain residential and refugial habitats, along with floodplain habitats conducive to species spawning and recruitment, to fine-scale processes that govern local features of habitat regardless of overarching patterns of the river continuum (Vannote et al. 1980; Labbe and Fausch 2000). Clearly, the discussions of residential, refugial, and floodplain habitats for silvery minnow are pivotal to the species' metapopulation structure and are of critical concern for species conservation. These concepts represent a logical basis for formulating intervention strategies that complement the species' life history, targeting age-specific schedules of reproduction, recruitment, and mortality

[4] Dating back at least to recent prehistoric times, conditions of extreme climatic and hydrologic variation have prevailed over much of the Southwest, including the Rio Grande Basin. During the Holocene Epoch, deep and long-lasting periods of drought have punctuated various millennially spaced episodes of increased precipitation, the most recent of which coincided with the Little Ice Age (Castigilia and Fawcett 2006). The most significant recent long-lasting periods of drought occurred during the years between approximately A.D. 300 and 500 and again between approximately A.D. 1400 and 1600 (Grissino-Mayer 1996). Compared to these late prehistoric and early historic periods of drought, periods of aridity and variation in water supply over the past 400 years have been mild, including the period of aridity during the 1950s—the most severe drought of the twentieth century.

[5] FLO-2D modeling was completed to simulate conditions when the Albuquerque Drinking Water Project passed the minimum of 196 cfs over the diversion dam as specified by the USFWS (2004). The simulation indicated a 20% reduction in peak flows between the diversion dam and the bottom of the Study reach during summer months. Thus, the reach is not expected to experience channel drying but could experience very low flow periods.

intended to enhance the short- and long-term prospects of species survival. Pivotal concepts that pertain to the provision of residential and refugial habitats for the silvery minnow conservation are discussed below.

Source-Sink Population Structure

The fact that habitat patch quality in the MRG is heterogeneous and that the silvery minnow differentially occupies different kinds of patches is an important determinant of long-term population trajectories (Hatch et al. 2008). It is important to understand how demographic processes that affect population size vary over the array of available habitat patch types. In simple terms, population growth can be regarded as a function of reproduction, recruitment, age-specific schedules of mortality, and rates of dispersal in the form of immigration and emigration. Areas or locations where local reproductive success is greater than local mortality are referred to as population *sources*.[6] Poorer quality patches that lead to low birth rates and high death rates are regarded as population *sinks*. To understand the patch dynamics of a population in which some individuals reside in source habitats and others in sink habitats, it is necessary to consider the population dynamics of each source and sink subpopulation, and then consider how the distribution of individuals in sources and sinks influences the dynamics of the greater source-sink system. In reality, mapping of silvery minnow source-sink population segments exclusively on the basis of population demographics will be effectively impossible. However, incorporation of auxiliary information relevant to the mortality-causing disturbance and gradients of habitat conditions should provide a robust and managerially basis for partitioning silvery minnow population sources and sinks (Hatch et al. 2008).

Distinguishing between source and sink populations is fundamental in the process of identifying populations essential for species persistence. Failure to distinguish this dichotomy among silvery minnow populations may result in protection of sinks instead of sources and unrealistic assessments of extinction risk. Likewise, identification of threats for different populations is essential for determining which populations are critical for species persistence and whether recovery actions need to focus on increasing population size and habitat quality or on reducing risk from human impacts.

Source-sink theory is dependent on the identification of habitat patch types and understanding how silvery minnow population dynamics are structured by underlying local environmental conditions. The spatio-temporal dynamics of wetted habitat offer clues of the relative ease (or difficulty) of maintaining refugia for the silvery minnow. The frequency and interval duration of river expansion-contraction cycles, along with the extent of perennial habitat created by a given volume of water, are metrics of evaluation that would likely be useful in identifying sites where the maintenance of refugia would prove to be most economical in terms of required water resources. Likewise, areas where the abundance of silvery minnow is greatest would theoretically represent areas where the development and maintenance of refugia would prove most beneficial to the species. The areas in which the

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[6] Inference about habitat suitability requires knowledge about species abundance and rates of vital biological processes along with knowledge about how long-term patch dynamics are structured by underlying physical, chemical, and climatic features of their environment.

paired values for the suggested metrics of evaluation are greatest would conceivably represent the locations where silvery minnow refugia can be developed and maintained most economically.

The most important influence of the spatial arrangement of habitat types on overall species viability is the extent to which populations of silvery minnow at different sites share the same fate at the same time. The risk of extinction is reduced with an increased number of high-quality (extinction resistant) populations with independent fates. The larger residential patches offer a heightened level of resistance to mortality that often accompanies low or nonexistent river flows. Such habitats have the capacity to support silvery minnow across generations and often exist as the source stock to repatriate empty habitat patches (Lake 2003). Habitat patches that are subject to periodic discontinuity of flow are expected to vary in their ability to serve as silvery minnow refugia, as manifested in the long-term frequency, magnitude, and predictability of mortality-causing events. The implications of diminished wetted habitat for the conservation of the silvery minnow will be different for population sources versus population sinks. Naturally, the loss of habitat that affects source populations will have a greater impact on long-term population trajectories than it would on sink populations.

The implications of diminished wetted habitat for the conservation of the silvery minnow will be different for river segments designated as population sources versus those designated as population sinks. Naturally, the loss of habitat that affects source populations will have a greater impact on long-term population trajectories than it would on sink populations. It is imperative that every effort be made to identify and conserve source populations in an effort to maximize overall capacity for population growth.

Prospects of species survival are enhanced to the extent that population densities can be maintained above levels subject to depensatory deterministic effects. Minimum population size needed to achieve some standard of viability will occur at the highest survival rate of young-of-year and no population-wide year class failures (Cowley 2007). Viable population size increases as the failure rate for the younger age classes increases. Therefore, it is prudent to maximize survival and manage for larger population sizes to accommodate temporal variation in demography and habitat quality (Cowley 2007).

4.3.4 HABITAT FEATURES

The variability of flow characteristics in the contemporary MRG, resulting either from natural or regulated causes, imparts a patchiness of environmental types at the scale of river segments, including the extremes represented by hydrologic abundance and periodic discontinuity of flow, with a continuum of intermediate types between these extremes. The magnitude and variance of flow within and between seasons is a direct determinant of silvery minnow reproduction, dispersal, and survival, the effects of which are reflected in patterns of species distribution and age composition (e.g., Hatch et al. 2008).

4.3.4.1 RESIDENTIAL HABITATS

Residential habitats represent the conditions the silvery minnow requires to meet its day-to-day needs for survival. Residential habitats comprise segments of the active river channel with contemporary long-term perennial flow patterns maintained at or above reach-specific, long-term seasonal baseline discharge volumes. Such habitats are conducive to the long-term persistence of the silvery minnow. River segments with predominant sand or finer substratum and contemporary long-term perennial flow patterns maintained at or above reach-specific, long-term seasonal baseline discharge volumes and contemporary long-term irrigation season-specific probabilities of flow intermittency less than 0.10 are classified as residential habitats. The larger perennial-flowing river segments offer a heightened level of resistance to environmentally driven fluctuations in population growth rate mortality. Residential habitats encompass the silvery minnow habitat preferences suggested by Dudley and Platania (1997) as described in Section 3.1.3.

4.3.4.2 RECRUITMENT HABITAT FEATURES

Seasonally inundated floodplains of the pre-1930 (early development) era MRG routinely provided heightened heterogeneity of habitat and structural refugia for developing stages of fish relative to the active channel. Growth of the silvery minnow can be especially rapid in newly flooded habitats that support highly productive food chains founded on the bacterial conditioning of retained fine and course particulate organic material and newly inundated terrestrial vegetation. Heightened floodplain productivity is further enhanced by lower water exchange rates, heightened subsidy of allochthonous energy inputs at the aquatic-land interface, and heightened temperatures characteristic of such areas (Schlosser 1991; Valett et al. 2005). However, the productivity of these habitats can be lost if the river channel floodplain become uncoupled prematurely (i.e., before eggs hatch and fish mature to post-larval stages) or if flows are abruptly reduced and, as a consequence, strand fish.

Minimal sustained duration of river channel-floodplain coupling, including an extended period over which flow is gradually reduced to levels confined to the main channel, is essential to allow silvery minnow adults a chance to occupy the floodplain and spawn, to allow time for embryo development and hatching, and finally to allow sufficient time for young-of-year silvery minnow development to at least the juvenile stage to effectively enable fish to evacuate draining floodplain habitats. Higher levels of recruitment can be expected with longer periods of sustained floodplain inundation

Recruitment habitat subtypes may be identified to distinguish habitat segments lateral[7] to the active river channel on the basis of the relative extent and duration of floodplain-river coupling and in terms of site attributes that determine the nature of localized biophysical/chemical processes[8] and environmental stability that collectively concern habitat

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[7] Lateral refers to the channel margins away from the thalweg where slower velocity and shallower conditions may be present.

[8] Biophysical/chemical processes include nutrient cycling (Meyer and Likens 1997), primary and secondary productivity enhanced by lower water exchange rates and heightened subsidy of allochthonous energy inputs at the aquatic-land interface and heightened temperatures characteristic of such areas (Schlosser 1991; Valett et al. 2005), water chemistry conditioning (Meyer 1979), and the generation of structurally complex aquatic habitats (Cowley 2006).

quality. The timing and extent of floodplain-river coupling is vitally linked to species reproduction, whereas ecosystem services and environmental stability relate to the utility of these areas as nursery habitats with cascading effects on species recruitment to the juvenile stage.

4.3.4.3 Refugial Habitats

Periodic severe drought-related perturbations, coupled with poor recruitment, have resulted in immediate reductions in silvery minnow abundance and weak age classes with negative consequences for population viability (e.g., Dudley et al. 2004). However, habitats that reduce the mortality of future parental stock, often by even a few percent, can have profound effects on future population trajectories by maintaining a positive capacity for population growth. Such refugial habitats that embrace habitat features that convey spatial and temporal resistance to species and communities impacted by biophysical disturbance are critical to the conservation of the silvery minnow.

While intermittent channel drying in the Albuquerque Reach has not been observed under current water operations scenarios since the closure of Cochiti Dam, we propose two refugial habitat subtypes based on our understanding of the entire system and observed conditions in the adjacent Isleta Reach: 1) high intermittence disturbance habitats and 2) transitional habitats.

High intermittence disturbance habitats represent poorer quality patches due to their ephemeral nature and are linked to high rates of silvery minnow mortality. Accounting for these habitats in habitat improvement planning is important because intermittence results in silvery minnow mortality, and heightened environmentally driven fluctuations in population growth rate will place the species at risk of extirpation at early time horizons. We regard river segments with contemporary long-term irrigation season-specific probabilities of flow intermittency in excess of 0.45 to comprise high intermittence disturbance habitats.

River segments with contemporary long-term flow patterns that would qualify as **transitional (or intermediate) environmental types** are of particular managerial interest because provision and periodic maintenance of wetted habitat, including in the form of large and deep refugial pools, is more feasible in such areas compared to areas of high intermittence disturbance, especially when hydrological resources are limited. Two management classes of transitional environmental habitats are proposed based on variable probabilities for continuity of running water habitat in time and space, and in terms of site attributes that determine the nature of localized biophysical/chemical processes and environmental stability that collectively concern habitat quality. In this Study, we hypothesize river segments with contemporary long-term irrigation season-specific probabilities of irrigation season flow intermittency between 0.10 and 0.20 to comprise **primary transitional habitats**, whereas probabilities of irrigation season flow intermittency between 0.20 and 0.45 comprise **intermittence refugia**. We hypothesize that the primary transitional habitats could occur in the Albuquerque Reach in a worst-case scenario during drought conditions where the minimum flows of 196 cfs are passed over the Albuquerque Drinking Water Project diversion dam (Reclamation 2004).

Key Refugial Habitat Features

A single large population of a species is buffered from demographic stochasticity. Multiple small reserves can buffer an entire species from extinction due to local catastrophes and environmental stochasticity, but such populations are the ones that may be vulnerable to inbreeding depression, mutation load, and loss of adaptive potential.

Prospects of species survival are enhanced to the extent that population densities can be maintained above levels subject to depensatory deterministic effects. Minimum population size needed to achieve some standard of viability will occur at the highest survival rate of young-of-year and no population-wide year class failures (Cowley 2007). Viable population size increases as the failure rate for the younger age classes increases. Therefore, it is prudent to maximize survival and manage for larger population sizes to accommodate temporal variation in demography and habitat quality (Cowley 2007).

Refugial habitats designed to reduce the mortality of future parental stock, often by even a fraction of a percent, can have profound effects on future population trajectories. An exponential increase in the number of silvery minnow, observed in surveys for fish that coincided with channel-drying events over the period of 2003 to 2005 (USFWS 2006b, 2007), suggests that the species has an inherent capacity for high rates of population growth, apparently regulated by compensatory density-dependent factors operational over a wide range of parental stock abundance. Because viable population size increases as the failure rate for the younger age classes increases, it is prudent to maximize survival and manage for larger population sizes to accommodate temporal variation in demography and habitat quality (Cowley 2007).

Lateral Distribution of Prospective Refugial Habitats

The period of pool isolation is an important consideration in the provision and maintenance of refugial pools. Galat et al. (2004) have found that larval fish taxa richness increased in lateral pools of the lower Missouri River with increased coupling with running water due largely to the addition of rheophilic larval taxa, including *Hybognathus* species. As running water habitats recede in the MRG, the period of pool isolation tends to be longer for those positioned lateral to the thalweg as opposed to those aligned along or adjacent to the thalweg. As such, pools associated with the thalweg will inevitably exhibit greater environmental stability over a longer period.

Longitudinal Spacing of Pools

The theoretical longitudinal pool-riffle spatial sequencing in unbound rivers is five to seven times the stream width (Leopold and Langbein 1966). It has been hypothesized that this spacing of refugial pools would allow for dispersal success of the silvery minnow and would serve to reduce mortality that often attends pulsed (short-term), small volume, expansion-contraction flow disturbances. In sand bed rivers, high sediment transport discharges are required to rework geomorphic surfaces that constitute the silvery minnow's habitat, including large and deep refugial pools (approximately 50–75 cm [20–30 inches] s^{-1} for coarse sand) (Allan 1995). This geomorphic process is enhanced by flow-deflecting objects (e.g., large woody debris), which serve to focus pool-scouring water velocity. Ideally, the incorporation of large woody debris (snags) in a habitat improvement project would be guided by estimates of the density of such habitat features before the MRG was channelized. Unfortunately, similar data for the MRG have not been located. As a surrogate, Sedell and Beschta (1991) offer early settlement records of the number of snags per kilometer for other large sand bed rivers, although that report includes few records for Southwest rivers.

Pool Morphology

Longer and deeper pools with abruptly steep sides (low surface area to depth ratio) have been found to be inherently superior as refugial habitats for fish due primarily to their enhanced temporal environmental stability compared to smaller pools. Pools that are at least 1.5 m (4.9 feet) deep and 25 m (82 feet) on their long axes are common in the MRG following sustained high discharge (Hatch et al. 2008).

Functioning Condition and Habitat Coverage

The number, quality, and spatial arrangement of habitat features, along with the probability of successful inter-patch movement, greatly affect the ability of the silvery minnow to survive the effects of mortality-causing drought. At a localized scale, each population segment would have a given (non-zero) probability of extinction if isolated from other populations. Certainly, at the scale of river reach, irrigation diversion dams represent physical barriers that restrict the movement of the silvery minnow to downstream transport processes. However, at the scale of localized habitats, silvery minnow population segments are linked with others by the possibility of inter-habitat movement driven by active habitat selection. Active habitat selection has been interpreted as an adaptive response that maximizes species fitness by avoiding the harmful effects of natural selection. It is hypothesized that high spatial heterogeneity of river channel features (e.g., defined by the ratio of river width to depth over different flow regimes) would allow for dispersal success of the silvery minnow to habitat patches favorable to species survival as the site-specific habitat features change over variable hydrologic conditions.

Habitat Refreshing

The periodic influx of water to refugial pools from unpolluted surface water or groundwater sources is necessary for the maintenance of suitable water quality to reduce the incidence of fish mortality due to disease. The periodic need for water refreshing/replenishing will vary inversely with the longitudinal spacing of pools and with pool depth and size.

4.3.5 EXISTING HABITAT AVAILABILITY

Analysis of the FLO-2D model results developed for the MRG BRP reveal a relative scarcity of potential suitable recruitment habitat for silvery minnow at flows below 6,000 cfs (Table 4.6). The current FLO-2D model relies on a 250-foot grid scale and is likely too coarse to adequately capture microhabitat features that provide suitable habitat for the silvery minnow at flows below 6,000 cfs. At 6,000 and 7,000 cfs, floodplain inundation results in potential high-flow recruitment habitat for silvery minnow at three and five different reaches, respectively. At 6,000 cfs, floodplain inundation occurs at Subreaches 3, 4, and 5 and is greatest at Subreach 4. At 7,000 cfs, floodplain inundation occurs at Subreaches B, 2, 3, 4, and 5, and increases consistently from upstream to downstream sites. Throughout the entire Albuquerque Reach, the area of inundation is 56% greater at 7,000 cfs (361 ha [891 acres]) than at 6,000 cfs (202 ha [499 acres]). The lack of overbank inundation at discharge less than 6,000 cfs suggests a lack of intermediate-flow or low-flow recruitment habitats. See Appendix C for the FLO-2D modeling results of existing conditions.

Table 4.6. Modeled Potential Silvery Minnow High-flow Recruitment Habitat at 6,000 and 7,000 cfs by Project Subreach

Subreach Name and Location	6,000 cfs		7,000 cfs	
	Area in Acres	Area in Hectares	Area in Acres	Area in Hectares
A - Angostura	0	0	0	0
B - US 550 to Corrales Siphon	0	0	4.30	1.74
1 - Corrales Siphon to Alameda	0	0	0	0
2 - Alameda to Montaño	0	0	11.48	4.65
3 - Montaño to Central	2.87	1.16	31.57	12.77
4 - Central to SDC	253.96	102.77	367.31	148.64
5 - SDC to Isleta Pueblo	242.48	98.13	476.35	192.77
Total	**499.31**	**202.06**	**891.01**	**360.57**

Note: Preferred habitat criteria are based on depths less than or equal to 0.6 m (2 feet) and velocities less than or equal to 1 fps.
SDC = South Diversion Channel.

The number of bank-attached bars and islands is indicative of potential habitat heterogeneity. A high degree of habitat heterogeneity may be expected to provide residential and refugial habitat, as well as low to intermediate-flow recruitment habitat. A qualitative census was conducted to enumerate the number of bank-attached bars and vegetated islands throughout the project reach (Table 4.7). A total of 56 vegetated islands and 37 bank-attached bars was identified. Vegetated islands were most numerous in Subreach 2, while attached bars were most numerous in Subreach 4. Collectively, the highest number of both features was recorded in Subreach 2. No vegetated islands were recorded in Subreach A, and only one island was recorded in Subreach B.

Table 4.7. Bank-attached Bars and Vegetated Islands by Project Subreach

Subreach Name and Location	Bank-attached Bars	Vegetated Islands
A - Angostura	3	0
B - US 550 to Corrales Siphon	2	1
1 - Corrales Siphon to Alameda	4	8
2 - Alameda to Montaño	7	17
3 - Montaño to Central	7	9
4 - Central to SDC	8	7
5 - SDC to Isleta Pueblo	6	14
Total	**37**	**56**

SDC = South Diversion Channel.

4.3.6 Factors Limiting Habitat Availability in the Albuquerque Reach

Silvery minnow habitat availability throughout the Albuquerque Reach is a result of disrupted ecological, hydrological, and fluvial processes. River channelization, reduced magnitude of frequently occurring peak flows, and reduced upstream sediment supply have resulted in channel degradation, and the presence of non-native vegetation (MEI 2002, 2006a; SWCA 2008) that has hardened islands and bars. Channelization and a reduced sediment supply have increased channel incision, resulting in a reduced diversity of aquatic habitats. These changes have reduced the availability of low-velocity habitats, decreased the amount of wetted area through the loss of meandering side channels, and isolated the main channel from its floodplain.

4.3.6.1 River Modification

In the MRG, the construction of flood control dams on the main stem and its primary tributaries have resulted in modified flows (including reductions in some peak flows, increases in base flows, and, on occasion, truncated snowmelt and summer monsoon flows) and the realignment of the river channel, including straightening the river, installing jetty jacks, and placing spoil embankments. In recent years, the spring discharge has not been sufficient to reshape the islands and bars, resulting in an increase in vegetation and hardening of the islands and bars. These factors have contributed to a system with modified hydrology and geomorphology, including isolating an incised main channel from the historic floodplain.

During summer months the loss of sinuous side channel, backwater, and oxbow habitats results in the loss of low-velocity habitat that is preferred by the silvery minnow. Channel incision results in a monotonous, high-velocity main channel habitat that is beneficial for water transport but detrimental for residential habitats that are important for various life stages of the silvery minnow. Habitat that is preferred by silvery minnow comprises only a small portion of the available habitat (Dudley and Platania 1997), making additional losses of an already rare habitat especially problematic (USFWS 2010).

During spring runoff, the loss of floodplain connectivity results in the reduction of low-velocity refuge habitat during high flows (Schlosser 1991; Valett et al. 2005), a reduction in habitats suitable for larval fish and egg retention (Porter and Massong 2003, 2004, 2006; Fluder et al. 2007; Hatch and Gonzales 2008), and a reduction in nursery habitat for larval and proto-larval fish (Pease et al. 2006; Hatch and Gonzales 2008).

4.4 Southwestern Willow Flycatcher Habitat

4.4.1 Habitat Requirements

The flycatcher requires at least two principal habitats—nesting habitats and migratory corridor stopover habitats—for two distinct portions of its spring and summer season lifecycle in the breeding regions of North America. Critical habitat elements include nesting habitat, food resources, hydrology, vegetation composition and structure, and microclimate. The habitat elements relevant to restoring habitat in the Albuquerque Reach are described below.

4.4.1.1 Nesting Habitat

Flycatcher nesting habitat is critical to the recruitment and maintenance of the Rio Grande flycatcher metapopulation. The geographic distribution of breeding locations are also likely an important population variable in terms of both gene flow and the possible establishment of new flycatcher populations.

On the breeding grounds, male flycatchers typically arrive one to two weeks before females and establish relatively large territories using primary song, calls, and stereotypical physical displays. Once females arrive, male territory size typically decreases as females select nest sites and construct nests. If nesting is successful, both sexes rear offspring until fledglings are approximately two to three weeks old. Flycatchers are known to return to the same nesting area each year, but not necessarily the same nesting territories (USFWS 2002). Multiple breeding pairs often establish individual territories but nest together in a complex of non-overlapping territories within a single site. Most nesting sites contain one to five nesting pairs and territories, but some sites may contain up to 100 nesting pairs and territories, depending on the size of the site (Durst et al. 2008).

4.4.1.2 Food Resources

Adult and young flycatchers depend primarily on flying insects as food in and around the nesting territory until they migrate south in mid to late August. Insects such leafhoppers, beetles, bees, wasps, damselflies, and dragonflies are documented flycatcher food items across the Southwest (DeLay et al. 1999; Drost et al. 2001). Such insects are likely to be associated with the dense vegetation foliage and proximity to water (especially damselflies and dragonflies) that characterizes flycatcher nesting habitats. Dietary specialization is uncertain. Drost et al. (2001) conclude that flycatchers are dietary generalists, feeding on what insects are available and switching to those most abundant in their nesting territories.

4.4.1.3 Hydrology

Hydrology also is an important feature of flycatcher nesting habitat. Most occupied flycatcher nest sites are known to be associated with and often situated directly over lentic (standing or slow-moving) water (Cooper 1997; USFWS 2002). Such lentic environments include slow-moving streams, river backwaters, oxbows, marshes, and pond margins. Habitats that are suitable for flycatcher nesting habitat along moving streams are dependent on scouring floods, sediment deposition, periodic inundation, and groundwater recharge (USFWS 2002).

Paxton et al. (2007), McLeod et al. (2008) and Moore and Ahlers (2008) have reported that nesting success is increased in sites that are either above saturated soil or standing water all season. In areas that are flooded all season, first nests are more successful than subsequent nests. Additionally, nests above saturated soils or standing water yield more young than successful nests that are above dry soil all season. Therefore, standing water and/or saturated soil under flycatcher nests may increase productivity and juvenile flycatcher survivorship because flycatchers that fledge late in the season have lower survival rates than those that fledge early in the season (Paxton et al. 2007; McLeod et al. 2008).

4.4.1.4 Vegetation

Flycatchers nest in dense riparian vegetation near surface water and/or saturated soil. Regardless of plant species composition, occupied nest sites always have dense vegetation within 3 to 6 m (10–20 feet) of the ground surface and are situated over standing water and/or saturated soil. Studies from the lower Colorado River, the Salt River, and the MRG demonstrate consistent findings that flycatchers prefer nesting sites within the mid-level riparian vegetation canopy layer from 3 to 6 m (10–20 feet) aboveground, where vegetation structure is complex and dense from the ground level to just above average nest heights (~3 m [10 feet] above ground level) (Sogge and Marshall 2000; Allison et al. 2003; Moore 2007; McLeod et al. 2008; Moore and Ahlers 2008). This unimodal vertical structure is similar to the Type III vegetation structural type identified by Hink and Ohmart (1984). Flycatchers construct their nests within cup-like structures of multiple small diameter tree stems, which frequently occur within willow tree branches (McCabe 1991).

Most flycatcher studies across the Southwest have found nesting habitat to be composed of native plant species, especially willow, but 22% have been found to be composed of non-native saltcedar (*Tamarix* spp.; *T. ramosissima* and *T. chinensis*) and Russian olive (Durst et al. 2008). Along the MRG, the greatest numbers of flycatcher nests are known from the San Marcial Reach and Rio Grande delta, at the upper end of Elephant Butte Reservoir. Most of these nesting sites have been found in dense native willow stands, which also are more common there than along upstream reaches (Moore 2007; Moore and Ahlers 2008). Moore (2007) and Moore and Ahlers (2008) have found most flycatcher nesting sites in the San Marcial Reach to be located within dense stands of Goodding's willow (also referred to as black or tree willow) and to a lesser extent in mixed stands of both Goodding's willow and coyote willow.

Upstream from the San Marcial Reach, both flycatcher nesting territories and dense, tall-canopy willow stands have been uncommon, and flycatcher nests are often found in saltcedar stands with a similar dense mid-canopy structure. Both *Salix* species still have dominated the stem counts at those upstream nesting sites (Moore and Ahlers 2006a, 2006b, 2008; Moore 2007), and the most nests have been found in mixed stands of native and exotic tree species. While there are no negative effects known to be associated with flycatchers nesting in saltcedar compared to willow (Paxton et al. 2007; McLeod et al. 2008), the majority of flycatcher nesting sites that are known from the MRG are in dense willow stands in the southern MRG, indicating a preference for willow stands, or some suite of environmental factors associated with willow stands, over saltcedar stands.

The flycatcher nesting locations that are nearest to the Albuquerque Reach are those reported from the Pueblo of Isleta where flycatchers have been known to nest since 1994 (Smith and Johnson 2008). Within the Isleta Reach, south of the Pueblo of Isleta, nesting flycatchers are located near the confluence of the Rio Puerco and south through the Sevilleta National Wildlife Refuge to the confluence of the Rio Salado (Parametrix 2008a). Moore and Ahlers (2006a, 2006b) reported 15 nesting flycatcher pairs between the Rio Puerco and Rio Salado in 2006, while only four nesting flycatcher pairs were found north of the Rio Puerco to the south boundary of the Pueblo of Isleta during the same time. Flycatcher-occupied nesting habitats within the Isleta Reach tended to located near the main river channel and in vegetation stands dominated by exotic saltcedar (six nests over 2006 and 2007), mixed stands of native willows and exotic saltcedar and Russian olive (nine nests over 2006 and 2007), or stands of largely native willows (five nests over 2006 and 2007) (Parametrix 2008a).

4.4.1.5 MICROCLIMATE

Low-elevation riparian environments in the Southwest are characterized by extreme high ambient temperatures, low relative humidity, and frequent winds. The microclimates associated with dense and tall willow stands growing over standing water or saturated soils may be a key component to flycatcher habitat. McLeod et al. (2008) have studied stand structure and microclimate parameters of known flycatcher nesting sites along the Lower Colorado River. The authors conclude that greater canopy closure, taller canopy height, and dense foliage at or immediately above nest height may facilitate a more favorable nesting microclimate with cooler ambient temperatures and higher relative humidity. McLeod et al. (2008) suggest that those microclimate characteristics may be useful parameters in predicting preferred flycatcher riparian nesting habitat within the larger expanses of riparian vegetation. Values associated with these microclimate values could be used as target conditions for flycatcher habitat restoration.

4.4.2 HABITAT PATCH SIZE, SHAPE AND SPATIAL ARRANGEMENT

Riparian nesting habitats for flycatcher tend to consist of particular patches of the appropriate vegetation composition and structure and hydrology as stated above, surrounded by other less suitable types of habitats or environments. Cooper (1997) has found flycatcher nesting habitat patches to range from 0.1 to 70 ha (0.25–173 acres) along the Rio Grande. Across the Southwest, the mean size of flycatcher nesting habitat patches have been 8.5 ha (21 acres), but the majority of nesting habitat patches are smaller, with a median size of 1.8 ha (4.4 acres) (USFWS 2002). Mean nesting habitat patches supporting 10 or more nesting pairs of flycatchers have been 24.9 ha (61.5 acres) (USFWS 2002). Flycatchers do not nest in linear riparian habitat patches less than 10 m (33 feet) wide along confined floodplains (USFWS 2002).

The size, shape, and configuration of flycatcher nesting territories have been well documented along the Salt River in Arizona by Cardinal et al. (2005). The researchers have found that territory size of 15 breeding males changed across the breeding season, between pre-nesting, nesting, and post-nesting periods. Pre-nesting and nesting territories have averaged less than 0.5 ha (1.2 acres) in size, and post-nesting (fledglings present) territories have increased to about 100 ha (247 acres) in size. The shapes of nesting territories tend to have similar lengths to widths. In the particular area studied, Cardinal et al. (2005) have found nesting pairs to be grouped in clusters across favorable habitat with contiguous, non-overlapping territories. These findings indicate that flycatchers along the Salt River tend to nest in groups in large patches of favorable habitat. Moore and Ahlers (2008) also have found flycatcher nesting sites in the San Marcial Reach of the MRG to be clustered together across large patches of favorable habitat, but they do not measure the sizes or shapes of individual territories. Although flycatchers are known to aggregate their nesting territories in large sites of suitable habitat, major portions of those large habitat patches tend to be unoccupied; the flycatcher does not pack its territories into all available space (USFWS 2002).

4.4.3 MIGRATORY STOPOVER HABITATS

In addition to nesting habitat, migratory stopover habitat along rivers is an important component of overall flycatcher habitat requirements in the Southwest. In order to reach and select nesting sites, migrating adult flycatchers must first traverse vast geographic distances from neotropical wintering areas to potential nesting sites along the MRG. These migration stopover habitats, even though not used for breeding, are likely important for both reproduction and survival. For most long-distance neotropical migrant passerines, migration stopover habitats are needed to replenish energy reserves to continue north- or southbound migration.

Migration routes used by flycatchers are not well documented, though more is known of northbound migration in spring than the southbound migration in fall because spring is the only time that migrant flycatchers sing and can therefore be distinguished from other *Empidonax* species. During northbound migration, all subspecies of willow flycatchers use riparian habitats similar to breeding habitat along major river drainages in the Southwest, such as the Rio Grande (Finch and Kelly 1999), Colorado River (McKernan and Braden 1999), and San Juan River (Johnson and Sogge 1997). Yong and Finch (1997) have found that migrating flycatchers favor young, native riparian willow habitats along the MRG.

4.4.4 EXISTING HABITAT AVAILABILITY

4.4.4.1 ASSESSMENT OF POTENTIAL SUITABLE FLYCATCHER HABITAT

Based upon the known characteristics of flycatcher habitat, SWCA completed a Level-1 GIS assessment of potential suitable flycatcher habitat within the Albuquerque Reach through an examination of the most recent available GIS map layers representing 1) resampled Hink and Ohmart vegetation transects (Milford et al. 2006), 2) wetlands (USFWS 2008), 3) aerial images (Mid-Region Council of Governments 2006), and 4) FLO-2D inundation models (see Appendix C). Updated Hink and Ohmart vegetation types, wetland status, and aerial image data layers were first visually examined simultaneously to identify and mark polygons representing potential flycatcher habitat throughout the entire Albuquerque Reach. The FLO-2D layer was then applied to those selected polygons to assess inundation potential. Those select polygons were marked and numbered, and the amount of land area was determined for each by subreach.

Particular criteria were used to determine which GIS polygons represented potential flycatcher habitat. Hink and Ohmart (1984) vegetation Type 3, and to a lesser extent Type 4, is most likely to represent potential suitable flycatcher habitat based on the vertical structure and complexity of woody vegetation, particularly in the zone of 3 to 15 m (10–49 feet) above the ground surface. Suitable flycatcher habitat also should include contiguous areas of appropriate vegetation and hydrological features that cover a spatial area of a minimum of

100 m (328 feet) in length by 10 m (33 feet) in width, or an equivalent area of 0.1 ha (0.25 acre). Thus only Type 3 and Type 4 polygons of at least 0.1 ha (0.25 acre) with a minimum width of 10 m (33 feet) were considered. An aerial photography overlay also was examined to help identify potential flycatcher habitat. Only Type 3 and Type 4 polygons that appeared to have more than 75% ground cover by woody vegetation as viewed from aerial imagery were chosen as potential habitat. Some of the Type 3 and Type 4 vegetation polygons, or large portions of the polygons, were represented by open barren areas not suitable for flycatcher habitat.

Assessing potential flycatcher habitat and restoration sites should include examination and mapping of perennial, intermittent, and ephemeral water, as well as the status of groundwater table data. Areas that contain high water tables and receive intermittent flows should be considered the most potentially suitable for flycatchers. In areas where hydrology and stream flow are human controlled, inundation of riparian habitat should occur prior to flycatcher settlement in spring (late April–early May). Although the exact timing of when sites should be inundated has yet to be determined, inundation should be timed such that the riparian vegetation has enough time to reach its zenith (i.e., leaf out) prior to flycatcher arrival in spring, thus potentially increasing the chances of flycatcher settlement. Complete leaf out of the riparian vegetation prior to flycatcher arrival and standing water and/or saturated soils under the vegetation also ensure increased biomass of the local arthropod communities (i.e., the flycatcher's prey base). Additionally, sites should remain inundated as long as possible because it has been shown that first nesting attempts at sites that are inundated all season are more successful than subsequent nests, and inundated sites produce more young than dry sites (Moore and Ahlers 2008), which in turn may increase juvenile flycatcher survivorship (Paxton et al. 2007).

Wetland polygons that overlapped with Type 3 and Type 4 vegetation polygons and/or wetlands classified as having woody vegetation and of 0.1 ha (0.25 acre) in size also were included as potential flycatcher habitat, assuming that such areas provided wet soil or surface water during the flycatcher breeding season. Finally, an overlay of FLO-2D inundation polygons were used to determine Type 3 and Type 4 vegetation polygons that were not also wetland and that would be inundated by river water at Rio Grande flow rates of 3,400 and 6,000 cfs. All appropriate polygons based on the above assessment that were inundated at 3,400 cfs were chosen to represent potential flycatcher habitat. Inundation at 6,000 cfs was noted for all polygons chosen as positive or negative relative to restoration potential.

A complete listing of all polygons representing potential flycatcher habitat throughout the Albuquerque Reach and their characteristics are presented in Appendix E. Individual site polygons and summed total potential flycatcher habitat areas are portioned by subreach in Appendix E to provide both a total reach and subreach assessment of existing potential flycatcher habitat area. Note that this assessment of potential flycatcher habitat within the Albuquerque Reach is based entirely from a Level-1 GIS analysis of existing map data and includes no site visits or on-the-ground assessments of polygons. This assessment is therefore only as accurate as the GIS data layers that were used to produce the potential habitat polygons.

4.4.5 *Factors Limiting Habitat Availability*

The flycatcher recovery plan (USFWS 2002) identifies loss of habitat as the primary threat to the flycatcher in New Mexico. The plan emphasizes the need to restore vegetation communities that provide habitat to the flycatcher, along with establishing the physical integrity of the river systems. The factors limiting flycatcher habitat in the Albuquerque Reach appear to be largely due to the loss of pre-existing native riparian vegetation communities, along with critical hydrological features and functions that are necessary to maintain such vegetation communities and habitat. Although there are currently no known existing nesting flycatcher sites in the Albuquerque Reach, flycatchers are known to nest to the south as close as the Isleta Reach (Smith and Johnson 2005, 2008), and territorial individuals have been observed during surveys near the Montaño and Rio Bravo bridges (Hawks Aloft 2009). It is unknown why flycatchers are not currently utilizing potential existing nesting habitat within the Albuquerque Reach. We recommend ground studies to verify and document the vertical structure, size, and hydrological conditions of the areas we have labeled as potential suitable habitat patches.

One could hypothesize about the factors limiting habitat availability. As stated above, the hydrology during breeding season is a critical factor. Open water or moist soil conditions throughout the nesting season are an important parameter. The structure of the vegetation, particularly vertical structure and stem density, may also be a factor. Minimum patch sizes may not be met, and suitable migratory corridors may be absent. We were unable to differentiate species composition and stem density through the GIS analysis. Nest predation from the brown-headed cowbird may also be a factor, especially in Albuquerque's South Valley where agriculture persists. A unique environmental feature of the Albuquerque Reach relative to reaches to the south where flycatchers do nest is the potential influence of human activity and the surrounding urban environment. An assessment of the proximity of potential existing habitat locations to human activity and disturbances, such as roads, residential areas, recreational activities, etc., should also be conducted. Further, the known nesting territories to the south may simply not be saturated. If known nesting sites are not saturated there may be no mechanism for forcing dispersal. Finally, ongoing management to reduce hazardous fire fuels may reduce the availability of understory and mid-canopy vegetation that may be used by flycatchers.

Our assessment of potential existing flycatcher habitat availability was based entirely from an analysis of existing GIS map information. The results of the Level-1 GIS analysis suggest there may be potential suitable flycatcher habitat within the Albuquerque Reach that meets geomorphic, hydrological, and vegetation structural requirements. We will use available information on known habitat requirements to best select sites and restoration treatments for the benefit of the flycatcher.

4.4.6 *Spatial Placement of Southwestern Willow Flycatcher Restoration Sites*

Flycatcher habitat creation and restoration projects are likely to be most effective, in terms of colonization by flycatchers, if they are located near existing breeding sites. Natal dispersal is greater than adult dispersal in most passerine birds (Gill 1995), including the flycatcher, and occasional juvenile dispersal between flycatcher subpopulations is likely an important population variable in terms of both gene flow and the establishment of new populations (Paxton et al. 2007; McLeod et al. 2008). Juvenile movements contribute to an understanding of the observed patterns of high genetic diversity within and low genetic isolation among flycatcher populations (Busch et al. 2000). Long-term flycatcher demographic data collected as part of the Lower Colorado Multi-species Conservation Program at breeding sites along the Lower Colorado, Virgin, Muddy, and Bill Williams rivers and tributaries (McLeod et al. 2008) and those of the USGS at Roosevelt Lake Reservoir and along the San Pedro and Gila rivers (Paxton et al. 2007) indicate that flycatcher juvenile dispersal among local populations is largely limited to within river drainages, and most dispersal distances are between 30 and 40 km (19–25 miles) or less. The frequency of flycatcher dispersal generally decreases as the distance between patches increases, and although more remote sites can be colonized, the frequency of flycatcher dispersal to more distant sites is lower. Strategically placing riparian improvement or creation projects near existing flycatcher breeding areas can also serve to strengthen the local metapopulation.

4.5 Issues and Opportunities for Using Managed Flows

4.5.1 Water Operations Coordination

Water operations coordination is an important component of a successful restoration strategy for both the silvery minnow and the flycatcher. Management of the river for water delivery, flood control, and other uses has disrupted key ecological, geomorphological, and hydrologic processes. Both species are tied to the hydrology of the system and require periods of inundation to complete their life cycles. As shown above, the silvery minnow requires the inundation of floodplain and channel margin habitats for a minimum of 10 days to complete spawning and larval development to the point where they are strong enough to enter the current. Flycatcher nesting success is strongly correlated to inundated floodplains.

Water operations coordination goals include:

1. Providing recruitment flows of a minimum of 3,500 to 5,000 cfs for a period of 10 to 25 days every two out of three years.
2. Reducing flows on the receding limb of the hydrograph slowly to avoid stranding silvery minnow in floodplain nursery habitats.

Water operations coordination is expected to support restoration goals by providing the following benefits:

1. Meet the objective of reproductive success in no less than two of three years.
2. Minimize stranding and isolation of year-of-young silvery minnow.
3. Enhance natural recruitment of cottonwood and willow species (see Parametrix 2008a, 2008b).

4. Maintain channel function to redistribute sediment and scour out young seedlings to minimize island and bar hardening.

In the absence of key ecological, geomorphic, and hydrological processes, it is critical that management actions replicate natural processes to the extent possible. We recognize that there are constraints on the system, not the least of which is the current drought conditions and the over-allocation of the river, which may make tweaking the system challenging. Nonetheless, water operations coordination will be an important component of a successful habitat restoration program and should compliment on-the-ground habitat restoration. The Corps and Reclamation have made great strides with the recently completed *Upper Rio Grande Basin Water Operations Review* (URGWOPS) (Corps et al. 2007) and the Cochiti Deviation (Corps 2009). The Cochiti Deviation (Corps 2009) is a temporary deviation in the operations of Cochiti Lake and Jemez Canyon Dam to meet the RPA requirement of the 2003 BO to provide an increase in flow to cue spawning of the silvery minnow and ensure seasonal overbank flooding to increase the recurrence of inundation to produce suitable riparian habitat for the flycatcher. There are two potential actions: 1) temporary pool storage between 5,000 to 20,000 acre-feet at Cochiti Lake followed by a release of water sufficient to maintain 3,000 cfs at the Albuquerque gage for seven days and 2) temporary storage of 45,000 acre-feet at the Jemez Canyon Dam and Cochiti Lake followed by a release of water sufficient to maintain 5,800 cfs at the Albuquerque gage for five days. Water for both options would be stored during the ascending limb of the runoff hydrograph and would be released at the peak and descending limb. The Cochiti Deviation is in effect for five years, beginning in 2009.

We encourage continuation of these efforts so that as we learn more about the lifecycle needs of the silvery minnow and its habitat requirements, water operations may be tweaked to provide a sufficient quantity of water at the appropriate time to better meet the needs of the species, as well as the requirements of the Rio Grande Compact (1939) and the needs of water users.

4.5.2 Low-flow Supplemental Sources

During extremely low-flow events, it may be desirable to provide supplemental water sources to maintain critical reaches of wetted surface habitat. These supplemental water sources may include 1) the strategic use of irrigation infrastructure, such as irrigation returns, wasteways, and drains; and 2) the strategic use of wells.

The purposes of using these supplemental water sources include 1) keeping sections that are in danger of drying wetted or to refresh isolated refugial pools, and 2) mitigating for water quality concerns when low water conditions could negatively impact fish. While current hydraulic modeling suggests that the river is not expected to dry, it is possible for the river to experience extremely low flows, which could create disconnected pools. The reach where this is most likely to occur is in the downstream reaches south of Central Avenue. Coincidentally, this is where there may be water quality concerns related to the Albuquerque WWTP return.

Based on the FLO-2D and HEC-RAS modeling, there is a high potential for increasing the availability of recruitment habitat with restoration. Successful habitat restoration is expected to increase silvery minnow recruitment, which would be reflected in the population demographic metrics, such as age-class structure. This reach also has a high degree of channel heterogeneity, which we propose is an important characteristic in providing residential habitat over a wide range of flows. Finally, the reach may be subject to drying or have minimal flows in a worst-case scenario, which we have modeled as the minimum flow over the Albuquerque Drinking Water Project diversion dam.

The development of low-flow supplemental water contingencies would require further analysis, including monitoring the restoration projects, population responses, and modeling river flows. Coordination and buy-in from the MRGCD would be required as would concurrence and permitting from the New Mexico Office of State Engineer (NMOSE).

4.6 EXISTING AND PLANNED HABITAT RESTORATION PROJECTS

4.6.1 HABITAT RESTORATION PROJECT OBJECTIVES AND TECHNIQUES

Numerous habitat restoration and river maintenance projects have been initiated in the Albuquerque Reach since 2003 (see Appendix F for locations of completed and proposed habitat restoration projects). Some habitat restoration projects have been completed, while others are still in the planning phase. Understanding project goals and objectives and identifying the project locations is essential to planning future restoration projects.

Habitat restoration projects funded by the Collaborative Program are required to meet the objectives identified in the 2003 BO (USFWS 2003). These objectives include increasing measurable habitat complexity to support various life stages of the silvery minnow and the flycatcher by facilitating lateral migration of the river across islands, bars, and riverbanks during various flow stages to establish diverse mesohabitats and microhabitats. Other objectives of habitat restoration activities involve water conveyance efficiency, ecosystem recovery, water conservation, and fire hazard reduction. To this end, the habitat restoration projects document and evaluate the effectiveness of specific restoration techniques, as discussed in the Habitat Restoration Plan (Tetra Tech 2004), in establishing diverse mesohabitats and microhabitats at a range of river flows. Tetra Tech (2004) identifies 13 aquatic restoration/rehabilitation techniques and five riparian vegetation restoration/ rehabilitation techniques on the basis of their theoretical ability to improve available habitat for the silvery minnow and the flycatcher. The benefits of the 18 techniques may provide benefits to both the silvery minnow and the flycatcher. Aquatic habitat restoration techniques designed primarily to enhance silvery minnow habitat may also promote riparian functionality and interconnectedness, which may potentially increase habitat for the flycatcher. For example, bank lowering would increase the frequency of inundation during periods of above base flow discharge (not annual events). The overbank areas would not remain flooded for significant periods of time and would not be intended to provide mesohabitat for adult silvery minnow, but instead to provide the necessary conditions for other processes that would result in residual habitat improvements and nursery habitat.

4.6.2 PREVIOUS HABITAT RESTORATION AND RIVER MAINTENANCE PROJECTS

Habitat restoration and river maintenance projects have been implemented in riparian habitats to benefit the flycatcher and in riverine environments to benefit the silvery minnow in the Albuquerque Reach. Projects have been implemented to provide mesohabitat features as defined by the Habitat Restoration Plan (Tetra Tech 2004) and have included features such as embayments, ephemeral channels, and island/bar modification. Invasive species removal to reduce the threat of wildfire has been implemented in the bosque. As we have learned from these projects, the treatment types have been revised to better define silvery minnow and flycatcher habitat targets. The challenge presented in the Study is to incorporate the previous work into habitat restoration recommendations that will benefit the silvery minnow and the flycatcher.

Habitat restoration projects to benefit the silvery minnow that have been constructed in the Albuquerque Reach include Reclamation's I-40 Bar Restoration (2005); the NMISC's Riverine Restoration Project, Phase I (2006); the NMISC's Riverine Restoration Project, Phase II (2007); City of Albuquerque Open Space Division Rio Bravo North and Rio Bravo South Restoration Projects (2007); Reclamation's Bernalillo Priority Site (2007); and the Corps' Rio Grande Nature Center Project (2008).

4.6.2.1 BUREAU OF RECLAMATION I-40 BAR PROJECT

Reclamation completed construction of this silvery minnow habitat restoration demonstration project immediately downstream of I-40 in August 2005 (Table 4.8). The project was designed to evaluate habitat features for silvery minnow spawning and rearing habitat at flows between 500 and 6,000 cfs (Reclamation 2005). The site was inundated at flows between 700 and 4,000 cfs during summer rainstorm events in 2006. Many of the features on the I–40 Bar Project are still inundated and providing habitat for the silvery minnow during spring runoff periods.

Table 4.8. I-40 Bar Project Restoration Treatment Techniques

Restoration Treatment	Action Sites (2005)	Acres Treated
Berms	3 sites	2.2
Bank Scouring and Scalloping	8 sites	1.9
Ephemeral Channels	6 sites	2.4
Contouring	Multiple sites	0.5
Total Acres by Action Site		**7.0**

4.6.2.2 BUREAU OF RECLAMATION ALBUQUERQUE OVERBANK PROJECT

The Albuquerque Overbank Project was one of the first habitat/riparian restoration projects in the Albuquerque Reach. Designed as a five-year pilot project, the project goal was to evaluate the efficacy of two treatments—non-native species clearing and bank lowering and backwater channel to encourage overbank inundation—on restoring the native riparian vegetation community (Muldavin et al. 2004). Overbank inundation and the construction of backwater channels and small islands enhanced riparian vegetation (e.g., cottonwood, willow species) regeneration.

4.6.2.3 NMISC Riverine Restoration Project, Phase I

The NMISC completed construction for Phase I of the Riverine Restoration Project in April 2006 and implemented various habitat restoration techniques, which have been identified by the Collaborative Program to benefit the silvery minnow within the Albuquerque Reach (Table 4.9). The objective of the project was to design, implement, and test techniques to increase measurable habitat complexity that supports various life stages of the silvery minnow, including egg retention, larval development and recruitment of young-of-year, and over-wintering habitats to retain adult minnows (USFWS 2005b). This phase of habitat restoration focused on island and bar modification in the North Diversion Channel, I-40/Central, and South Diversion Channel subreaches of the Albuquerque Reach. Monitoring and evaluation of the project are ongoing.

Table 4.9. NMISC Phase I Restoration Technique Treatment Areas, by Subreach

Restoration Treatment	Phase I Action Sites (2005–2006)	Phase I Acres Treated*		
		North Diversion Channel	*I-40/ Central*	*South Diversion Channel*
Vegetated Island Modification and Evaluation	11 sites	10.6	4.1	4.0
Bank Scouring and Scalloping	8 sites	0.5	0.9	1.9
Ephemeral Channels	7 sites	0.5	0.7	0.5
Large Woody Debris	Multiple sites	TBD	TBD	TBD
Total Acres by Action Site	**26**	**11.6**	**5.7**	**6.4**

* Numbers in the table above are pre-construction acreages.

4.6.2.4 NMISC Riverine Restoration Project, Phase II and Phase IIa

The NMISC applied lessons learned from the Albuquerque Reach Phase I project to design and implement various habitat restoration projects to increase measurable habitat complexity that supports various life stages of the silvery minnow, including egg retention, larval development and recruitment of young-of-year, and over-wintering habitat to retain adult minnows (USFWS 2007a, 2009a). The NMISC completed construction for Phase II of the Riverine Restoration Project in April 2007 (Table 4.10). The Phase IIa project applied five restoration treatments in the I-40/Central and South Diversion Channel subreaches (SWCA 2010a, 2010b). The treatment types implemented included 1) vegetated island treatments to remove vegetation and mobilize sediment during high flows; 2) construction of high-flow ephemeral side channels on banks, bars, and islands; 3) riverbank expansion/terracing; 4) removal of in-channel lateral confinements in the form of non-native bankline woody vegetation; and 5) placement of large woody debris (LWD) within main channel or constructed modification areas. Adaptive maintenance (e.g., sediment and vegetation removal and redistribution) was required on some of the sites constructed during the Phase II project to re-establish the original design inundation levels. Construction for Phase IIa was completed in November 2009 (Table 4.11). Monitoring and evaluation of these projects are ongoing.

Table 4.10. NMISC Phase II Restoration Technique Treatment Areas, by Subreach

Restoration Treatment	Phase II Action Sites (2006–2007)	Phase II Acres Treated			
		U.S. 550	***Paseo del Norte***	***I-40/ Central***	***South Diversion Channel***
Vegetated Island Modification and Evaluation	16 islands	0.0	22.4	1.4	10.5
Riverbank Expansion/Terracing	12 sites	0.0	1.9	24.0	5.1
Ephemeral Channels	8 sites	8.7	1.5	0.0	1.1
Drain Enhancement	1 site	0	0.0	6.1	0.0
Backwater Channels	2 sites	0	0.0	4.4	0.0
Embayment Area	1 site	0.0	0.0	0.6	0.0
Jetty Jack Removal	2 sites	0.0	0.3	0.0	0.2
Large Woody Debris	Multiple sites	TBD	TBD	TBD	TBD
Total Acres by Action Site	**42**	**8.7**	**26.1**	**36.5**	**16.9**

* Numbers in the table above are pre-construction acreages.

Table 4.11. Phase IIa Restoration Technique Treatment Areas, by Subreach

Subreach	Number of Sites	Feature Area (acres)*
I40/Central	4	3.02
South Diversion Channel	12	19.42
Total	16	22.44

*The Feature Area provides an estimate of the benefit of the project at each site.
Table adapted from SWCA (2010a, 2010b).

4.6.2.5 City of Albuquerque Open Space Division Rio Bravo Project

The City of Albuquerque Open Space Division completed construction of the Rio Bravo Project in May 2007. The project, funded through the Collaborative Program, involved the design and implementation of various habitat restoration/rehabilitation techniques to restore aquatic and riparian habitat for the benefit of the silvery minnow and the flycatcher within the Albuquerque Reach (Table 4.12). Specific rehabilitation and restoration activities occurred within the river floodplain at three locations within the Rio Bravo to South Diversion Channel Subreach. Site-specific projects were implemented for the benefit of the silvery minnow, the flycatcher, and the riverine ecosystem as a whole (USFWS 2007b).

Table 4.12. City of Albuquerque Restoration Technique Treatment Areas

Restoration Treatment	Action Sites (2007)	Acres Treated
Vegetated Island Modification and Evaluation	2 sites	17.6
Bank Scouring and Scalloping	6 sites	2.0
Ephemeral Channels	6 sites	8.2
Vegetation Management	Multiple sites	30.5
Total Acres by Action Site	**TBD**	**58.3**

* Numbers in the table above are pre-construction acreages.

4.6.2.6 CITY OF ALBUQUERQUE OPEN SPACE DIVISION ENVIRONMENTAL ENHANCEMENT PLAN

The Environmental Enhancement Plan (EEP) (City of Albuquerque 2005) addressed three issues: fire control, invasive species, and maintenance and management. The EEP provided a detailed analysis and implementation of numerous restoration goals that were previously set out in previous plans. Recommendations included removal of heavy fuel loads that contributed to the devastating wildfires in 2003, removal of non-native species, maintenance and management of the initial response (e.g., invasive annuals and resprouting), and revegetation. The City of Albuquerque Open Space Division identified 12 community types and recommended species to guide revegetation efforts. Community types include forest, savannah, shrub thicket, shrubs and grasses, open meadow, overbank flooding, moist soil depression (forest), moist soil depression (shrub, thicket), primary fire break, secondary fire break, and wetland (high-flow channel and constructed or existing). A number of these community types are compatible with the recommendations presented in this Study and offer opportunities for synergism and collaboration.

4.6.2.7 U.S. ARMY CORPS OF ENGINEERS HABITAT RESTORATION PROJECTS

The Corps has implemented, or is planning to implement, a number of habitat restoration projects, including the Bosque Wildfire Project, the Rio Grande Nature Center Project, the Ecosystem Revitalization @ Route 66 Project (Route 66 Project), and the MRG BRP.

The purpose of the Bosque Wildfire Project (Corps 2004) was to selectively thin areas with high fuel loads and/or non-native species, remove jetty jacks, improve drain crossings levee roads and construct turn-arounds to improve emergency access, and revegetate burned and thinned areas with native vegetation. The project area included the bosque in the Albuquerque Reach, including the Corrales Bosque Preserve and portions of the Pueblo of Sandia.

The Rio Grande Nature Center Project was designed to partially fulfill the requirement of habitat restoration under RPA Element S of the 2003 BO. This project proposed to conduct habitat restoration projects in the MRG to benefit the silvery minnow and the flycatcher through reconnecting side channels at the project area (Corps 2010). Embayments were constructed at the upstream and downstream of the channel. This project is located in the MRG bosque on the east side of the river at Rio Grande Boulevard and Candelaria Road in

Albuquerque at the Rio Grande Nature Center State Park. The project site comprises approximately 6 ha (15 acres).

The Route 66 Project, implemented under the authority of Section 1135 of the Water Resources Development Act of 1986, was designed to restore riparian and riverine habitat on the west side of the river near the Central Avenue Bridge. The project included the removal of 720 jetty jacks, construction of two willow swales (7.7 ha [19 acres]), enhancement of three existing high-flow channels (2.4 ha [6 acres]), and restoration of outfall wetlands to improve floodplain function, and non-native vegetation removal on 49 ha (121 acres) (Corps 2008c).

The proposed MRG BRP will focus on bank stabilization (28.7 ha [71 acres]), willow swale construction (27.5 ha [68 acres]), vegetation management (268 ha [662 acres]), and creating water features (46 ha [114 acres]) in the floodplain throughout the Albuquerque Reach (Corps 2010). The Corps brought forward numerous projects from the Bosque Feasibility Study. In consultation with the Corps, some of the proposed treatments that did not make it through to the final MRG BRP are included in the restoration recommendations listed in Chapter 5.

4.6.2.8 PUEBLO HABITAT RESTORATION PROJECTS

The three pueblos within the Albuquerque Reach have been actively planning and implementing habitat restoration projects on the reaches that traverse their lands. The Pueblo of Santa Ana has implemented projects to restore the channel grade, create mesohabitat features for the silvery minnow, create flycatcher habitat, and reduce non-native phreatophytes (Corps 2002; Corps 2008d; Reclamation 1999). The Pueblo of Sandia has implemented river restoration work to improve habitat conditions for the silvery minnow (Reclamation 2008), completed the Sandia Subreach Habitat Analysis and Recommendations Study (SWCA 2008), cleared non-native phreatophytes in the bosque, (A. Puglisi, personal communication 2008), and implemented the bosque rehabilitation channel project (USFWS 2009b). The Pueblo of Isleta has implemented projects to increase the hydrologic connectivity in low-lying overbank areas, has monitored extant flycatcher populations on Pueblo of Isleta lands, is completing the Isleta Reach Habitat Analysis and Recommendations Study, and is engaged in a planning effort for the diversion dam to address sediment transport and fish passage issues (J. Sorrell, personal communication 2009).

4.6.2.9 BUREAU OF RECLAMATION BERNALILLO AND SANDIA PRIORITY PROJECTS

Reclamation completed environmental compliance for the Levee Priority Site Project at Bernalillo and began construction in summer 2005. The project designs incorporated hydraulic protection features by redirecting flow away from the levees. These features also increased habitat complexity that should benefit the silvery minnow and other fish species (USFWS 2006c).

Reclamation implemented the Sandia Priority Project to prevent damage to the east levee system and provide additional bank stability. A secondary purpose is to restore, improve, and enhance habitat for the silvery minnow and the flycatcher. The project was constructed on the Pueblo of Sandia, near the north boundary.

While the goal of these projects was not to provide habitat for the silvery minnow, each project included elements that were designed to provide a secondary benefit to the species. For example, bendway weirs create eddies, which in turn create pools during low-flow periods. Kinzli and Myrick (2009) conclude that bendway weirs, properly designed and constructed to provide eddy velocities at the toe of the weirs and behind the weirs, provide habitat beneficial to the silvery minnow.

4.6.2.10 OTHER PROJECTS

Other aquatic and riparian habitat restoration and maintenance projects that have been proposed or implemented in the Albuquerque Reach include the Albuquerque West Levee Project (Corps 2008e) and Albuquerque Bernalillo County Water Utility Authority Drinking Water Project Mitigation (USFWS 2004).

5.0 HABITAT RESTORATION RECOMMENDATIONS

5.1 RESTORATION GOALS

Habitat restoration in the Albuquerque Reach will involve the manipulation of the river channel applied in conjunction with passive restoration techniques to meet the life cycle needs of the silvery minnow and the flycatcher. Restoration goals should be consistent with Collaborative Program goals, the HRW mandate, and USFWS recovery goals (USFWS 2002, 2010). Within this context, overall restoration goals could be stated as follows:

1. Prevent extinction, preserve reproductive integrity, improve habitat, support scientific analysis, and promote recovery of the silvery minnow and the flycatcher.
2. Promote overall ecosystem health through the restoration of key ecological and physical processes and restoration of aquatic and terrestrial community assemblages.
3. Promote the hydrological connectivity between the active river channel and the floodplain.

5.1.1 RIO GRANDE SILVERY MINNOW RESTORATION GOALS

Silvery minnow habitat restoration should contribute to the recovery of the species as defined by the Rio Grande silvery minnow *(Hybognathus amarus) Recovery Plan – First Revision* (USFWS 2010). Recovery goals are to 1) prevent extinction, 2) downlist the species, and, finally, 3) delist the species. For each goal, the USFWS (2010) lists demographic criteria based on population and reproductive parameters and threat-based criteria centered on habitat quantity and quality and water quality parameters. To effect a positive change in silvery minnow populations and contribute to recovery, the focus of silvery minnow habitat restoration will be to apply restoration activities to meet demographic requirements. Therefore, the principal goal for habitat restoration in the Albuquerque Reach could be stated as:

1. Provide sufficient habitat quantity and quality to affect a positive metapopulation response that will contribute to recovery through maintaining a viable population of silvery minnow in the Albuquerque Reach.

Habitat quantity and quality should be sufficient to provide the conditions to meet the silvery minnow lifecycle needs and include increased nursery habitat and overall channel complexity. To achieve these conditions, the USFWS (2010) has identified restoration and flow management as activities that may be necessary to achieve the desired conditions.

Recovery objectives call for establishing "three self-sustaining populations within the Rio Grande silvery minnow's historical range, as defined by criteria related to extinction risk, population size, and distribution" (USFWS 2010:70). A viable population of silvery minnow is self-sustaining in the absence of active management intervention and is composed of a sufficient number of individuals to permit adaptation and long-term persistence to occur.[9] A viable population is defined to have less than a 10% chance of extinction in 100 years[10] (Mace and Lande 1991; USFWS 2009c) and less than a 10% decline in any annual period.

Proposed silvery minnow habitat restoration objectives are focused on specific population and demographic criteria thought to be indicators of the species response to habitat restoration and management within the Albuquerque Reach. Proposed objectives are based on identifying recruitment and survival rates that will contribute to a positive population response. We recommend revisiting and revising the proposed objectives as the Collaborative Program increases its collective understanding of the species, based on the current Population Viability Analysis/Population and Habitat Viability Assessment (PVA/PVHA) modeling and continued monitoring. We propose the following objectives

1. A viable population of silvery minnow has successful reproduction at least two out of three years on average.
2. Spring samples that coincide with spawning for population monitoring have no more than one missing age class for age classes 1–4.
3. Silvery minnow are present at three-fourths of all sites sampled in October.
4. Viable populations of silvery minnow are free of non-native congeners (e.g., plains minnow).

5.1.2 SOUTHWESTERN WILLOW FLYCATCHER RESTORATION GOALS

The Study's focus for the flycatcher will be to improve breeding conditions. The principal habitat restoration goal for the flycatcher in the Albuquerque Reach is to:

1. Increase the size and stability of the MRG flycatcher metapopulation.

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[9] Because population viability is an element of the purpose and need for management intervention to achieve the goals of the Collaborative Program that benefit the silvery minnow, it is useful to review the information required for an assessment of population viability. This information pertains to 1) species composition (exotic congeners represent a documented threat to population viability); 2) effective population size (including sex ratio, variance in numbers of progeny contributed by any female, temporal fluctuations in reproductive success, overlapping generations, and breeding structure); 3) total population size; 4) proportion of breeding adults; and 5) rate of reproductive failure.

The viability of the silvery minnow in the MRG of New Mexico is governed by the physical and biological setting in which the species occurs, notably including spatial arrangement, persistence, quality and volume of habitat, supply of food (although contemporary population-level evidence of food resource depletion is lacking or confounded in the effects of other stressors), population dynamics, and maintenance of genetic diversity.

[10] Current PVA modeling used by the USFWS (2009c) for the Big Bend reintroduction projects uses a 50-year time period. The current PVA conducted by the Collaborative Program is still in development. We adopt the 100-year time period that was identified by the USFWS (2009b) as the criteria for delisting the species.

A primary need is to provide adequate breeding habitat within the Albuquerque Reach. Flycatchers are currently nesting in all reaches between the Albuquerque Reach and Elephant Butte Reservoir and upstream of the Albuquerque Reach in the Chama River watershed. There are no known nesting locations are known within the Albuquerque Reach, presumably due to a lack of suitable habitat. Another need is to create riparian habitat connectivity along the Albuquerque Reach to create migration stopover habitat and facilitate the dispersal of resident flycatchers throughout the MRG riparian corridor.

Specific flycatcher habitat restoration objectives include:

1. Developing new flycatcher habitat near extant populations by providing and/or increasing the extent, distribution, and quality of nesting habitat close to (30–40 km [19–25 miles]) extant populations (i.e., the Isleta Reach). This will increase the stability of local subpopulations by providing new habitat through
    a. replacing habitat in the event of destruction of some habitat elsewhere within the MRG, and
    b. creating new habitat for colonization, which will enhance connectivity between sites once occupied.
2. Enhancing migratory stopover habitat to improve dispersal and migration throughout the MRG and Upper Rio Grande.
3. Facilitating the establishment of new, large populations in areas where none exist. Through habitat restoration, new large populations (e.g., >25 territories) would be established in areas where few or no flycatchers exist, but where there is a potential for suitable nesting habitat and population establishment.

5.2 HABITAT RESTORATION MODEL

Habitat restoration recommendations presented in this Study are based on an examination of habitat needs and existing conditions. The habitat requirements presented above are based on current knowledge and understanding of the system. Through an analysis of existing geomorphic and hydrologic using the hydraulic modeling conducted by MEI for the MRF BRP and an analysis of biotic conditions, we can determine deviations from the current habitat conditions and the required habitat needs and use this information to develop a Habitat Restoration Model. The resulting Habitat Restoration Model identifies similar units, which we call **conservation units**. Conservation units are based on the variability and spatial distribution of habitat features. We used the depth-averaged hydraulic condition parameters (see Section 4.2.5.1 and Appendix D) and the results of the hydraulic modeling to define the conservation units. The depth-averaged hydraulic conditions parameters were used as a proxy for habitat sutiability. The W/D is particularly useful because it is an indicator of channel entrenchment and is thought to be an important parameter for determining habitat heterogeneity over a range of flows. W/Ds that remain constant over the range of flows modeled may indicate the degree to which the channel may experience overbanking or the degree of habitat heterogeneity. Conversely, a decreasing W/D over the range of flows is thought to be an indicator of entrenchment and is associated with narrow, incised channel sections. Thalweg depth and velocity are other parameters that are indicative of silvery minnow habitat. Channel sections that have a relatively shallower thalweg depth and relatively slower velocities over the range of flows modeled are thought to be indicators of habitat heterogeneity. Despite the modeling limitations, FLO-2D modeling output is a useful indicator of the potential for overbank inundation.

We identify four conservation units that represent a range of habitat conditions, from intact units with most, if not all, habitat elements present to heavily disturbed areas with most habitat elements absent. The four conservation units are:

1. Core Conservation Unit (CCU)
2. Reserve Conservation Unit (RCU)
3. Primary Restoration Unit (PRU)
4. Secondary Restoration Unit (SRU)

Areas that meet all of the required habitat elements to meet the critical lifecycle needs for the target species are considered CCUs. These areas would support self-sustaining populations and would thus have the highest conservation priority. CCUs for the silvery minnow and the flycatcher are not found in the Albuquerque Reach as is evidenced by the overall lack of a stable, self-sustaining silvery minnow population and the lack of breeding flycatchers. RCUs would have most required habitat elements present and thus would require the least amount of effort to restore to the CCU condition. These areas would be expected to have the greatest return for the level of effort and thus would be considered to have the highest restoration priority. PRUs would have a greater departure from the CCU condition and thus would require a greater level of effort to restore to the CCU condition. Finally, the SRUs would have the greatest departure from the CCU condition and would require extensive restoration to obtain the CCU condition. Ecological processes and functions may be so severely disrupted that habitat restoration may not be sustainable without some level of constant management or intervention (e.g., channel incision and a lowered groundwater table leading to the lack of natural vegetation regeneration and maintenance). These areas would have the lowest priority.

Conservation units for the silvery minnow and the flycatcher would each have different requirements. However, since hydrology is a driving factor in determining the extent and condition of habitat features (see Section 4.3.4 for the silvery minnow and Section 4.4.1 for the flycatcher) for both species, the sufficient overlap allows us to identify and map conservation units in the Albuquerque Reach through an analysis of geomorphic, hydrologic, and biotic conditions. In the Albuquerque Reach, we have identified two RCUs based on habitat heterogeneity and frequency of overbank inundation and one PRU based on the lack of overbank inundation but retaining some habitat heterogeneity. All subreaches upstream of the North Diversion Channel are considered to be SRUs because of the lack of overbank inundation as indicated by the FLO-2D modeling, homogeneous habitats, or the existence of pueblo management further limiting opportunities for restoration within the scope of the Study. Appendix G illustrates the conservation units identified in the Albuquerque Reach.

5.2.1 SILVERY MINNOW RESTORATION MODEL CHARACTERISTICS

Silvery minnow conservation units are defined based on the characteristics of the three primary habitat types: residential, recruitment, and intermittence refugia. Using depth-averaged channel hydraulic conditions derived from the 250-foot FLO-2D model results (see Appendix D), we have been able to define characteristics for residential, recruitment, and refugial habitat conditions within the Albuquerque Reach. For each cell in the FLO-2D model, a water surface elevation is calculated at a given discharge. The model calculates depth-averaged conditions (based on the calculated surface water elevation) across the channel cross section for W/D, thalweg depth, velocity, top-width, and energy slope. We have used these parameters to define criteria for residential, recruitment, and refugial habitat types. Of these parameters, we have found the W/D to be the most useful diagnostic tool. Other parameters lack the requisite resolution, because they are averaged for the reach and the cell size for the FLO-2D model. The habitat types and the parameters used to define them are presented in Table 5.1.

Table 5.1. Silvery Minnow Habitat Model

Habitat Type	Habitat Subtype	Geomorphic/Hydrologic Characteristics			
		Discharge Range (cfs)	Average W/D*	Average Thalweg Depth (feet)*	Average Channel Velocity (fps)*
Residential	Low	<1,500	96–111	3.1–5.9	1.3–3.2
	Intermediate	1,500–3,500	139–151	3.2–5.4	1.1–2.6
	High	>3,500	181–187	2.5–5.2	1.2–2.5
Recruitment	Primary	>3,000	–	–	–
	Secondary	2,500–3,000	–	–	–
	Tertiary	<2,500	–	–	–
Refugial	Primary Transitional	<200	–	–	–

* W/D, thalweg depth, and channel velocity averaged over range of flows, from 500–5,000 cfs.

Three **residential habitat** subtypes (refer to Section 4.3.4.1) are proposed based on the modeled flows (annual flows ranging from 500–5,000 cfs in 500-cfs increments) and the depth-averaged hydraulic conditions (see Appendix D): low discharge (<1,500 cfs), intermediate discharge (1,500–3,500 cfs), and high discharge (> 3,500 cfs). *Low residential habitat* is found in river sections where the channel is confined. Often channel incision is evident and the river stays within its banks at moderate to high discharge events. This is represented in a decreasing W/D over the range of flows modeled. These areas tend to have the deepest average thalweg depth and the highest average velocity. The *intermediate residential habitat* is found in river sections where there are islands and bank-attached bars, but these may not be inundated over the range of flows modeled, resulting in a decreasing W/D. These areas have intermediate average thalweg depths and average velocities. The *high residential habitat* represents areas where bank-attached bars and islands experience inundation over the range of flows modeled. The W/D remains relatively constant over the range of flows modeled. These areas have the shallowest average thalweg depth and the lowest average velocity.

Three **recruitment habitat** subtypes (refer to Section 4.3.4.2) are proposed to span the range of possible levels of continuity of floodplain-river coupling and size attributes related to habitat quality. These subtypes are based on the need to provide consistent recruitment classes over a range of flows during spring runoff to meet the objective of providing recruitment no less than two out of three years. *High-flow recruitment habitat subtypes* constitute moderate water exchange (i.e., overall average water velocity less than 0.7 fps) areas of at least 0.4 ha (1 acre) in which incipient inundation occurs at river discharges greater than 3,000 cfs. These areas would be found in the floodplain, with modification, and are associated with high-flow events and strong recruitment classes. Effort will be given to increasing the area and frequency of overbank inundation throughout the Albuquerque Reach. *Intermediate-flow recruitment habitat subtypes* constitute moderate water exchange (i.e., overall average water velocity less than 0.5 fps) areas of at least 0.4 ha (1 acre) in which incipient inundation occurs at river discharges of 2,500 to 3,000 cfs. These areas typically occupy higher bank-attached bars and channel margins. *Low-flow recruitment habitat subtypes* constitute low water exchange (i.e., overall average water velocity less than 0.3 fps) areas of at least 0.4 ha (1 acre) in which incipient inundation occurs at river discharges less than 2,500 cfs. These are primarily bank-attached bars and would be expected to be inundated on an annual basis. Restoration of the *intermediate-flow* and *low-flow* recruitment habitat subtypes is important to maintain recruitment classes on an annual basis.

Identification of recruitment habitat subtypes will facilitate choosing appropriate management alternatives for different river segments and will facilitate prioritizing management efforts. Sites within habitat subtypes can be prioritized with respect to one another using data regarding the lowest level of incipient inundation, the maximal areal extent of inundation represented by low water exchange conditions over the contemporary range of flow, and maximum depth of inundation (greater depth confers enhanced temporal environmental stability). Low-flow lateral silvery minnow reproduction and nursery habitat sites comprise the highest priority sites for conservation and management protection to ensure strong recruitment over the highly variable range of discharge intrinsic to the Albuquerque Reach. Intermediate-flow and high-flow lateral sites represent high-priority candidate sites for habitat modification designed to improve reproductive success. These management classes would require progressively greater intervention to achieve a desired functioning condition.

While the Albuquerque Reach has not experienced intermittent channel drying since the closure of Cochiti Dam, the reach has experienced drying during the pre-Cochiti era.[11] FLO-2D simulations run by Wolf Engineering to model the minimum flow of approximately 200 cfs to be passed over the Albuquerque Drinking Water Project diversion dam (USFWS 2004) suggest a 20% reduction in the peak between the diversion dam and the bottom of the Study

[11] Minimum flow analysis conducted by Wolf Engineering (2008) for this project suggests that in the Pre-Cochiti era there was a 10% chance that the flows would be less than 12 cfs for a seven-day period.

reach. Thus, we do not expect intermittency refugia habitat needs within the Albuquerque Reach. However, very low flows passing over the diversion dam could result in river discharges of less than 200 cfs in the southernmost subreaches. The modeling does not specifically include return flows from the Albuquerque WWTP, which may further reduce the probability of channel drying; however, there may be water quality issues associated with Albuquerque WWTP return flows. We classify these sections as the **primary transitional refugial habitat** subtype (refer to Section 4.3.4.3) recognizing the potential for very low-flow periods associated extreme drought conditions.

Other characteristics that have been considered in determining the conservation units are **habitat heterogeneity** and **longitudinal spatial variability**. Habitat heterogeneity refers to the diversity of low-velocity habitat available over a range river discharge. Habitat heterogeneity is a result of bank-attached bars, islands, and channel margin banklines that experience inundation throughout the range of river flows. Longitudinal spatial variability refers to the longitudinal variability in channel width, W/D, and thalweg depth. In looking at the aerial imagery, it is easy to pick out subreaches (indicated by the tile reference numbers [e.g., 1/6]) where the channel is narrower and those subreaches where the channel is wider. This can also be represented graphically by looking at the average W/D and the variability over the range of flows (Figure 5.1). Figure 5.1 represents the variability in channel condition using W/D as the primary parameter and reflects the degree of habitat variability in each subreach. The error bars associated with each W/D point is an indication of the variability of W/D. High variability (indicated by high standard error bars) suggests that the W/D decreases over higher flows, indicating that the channel is confined at higher flows. Low variability (indicated by short standard error bars) suggests that W/D remains relatively constant over the range of modeled flows, indicating the inundation of bank-attached and channel margin features throughout the range of flows. Maintaining high longitudinal spatial variability in adjacent subreaches is desirable because it provides suitable low-flow habitats for fish at a variety of flows.

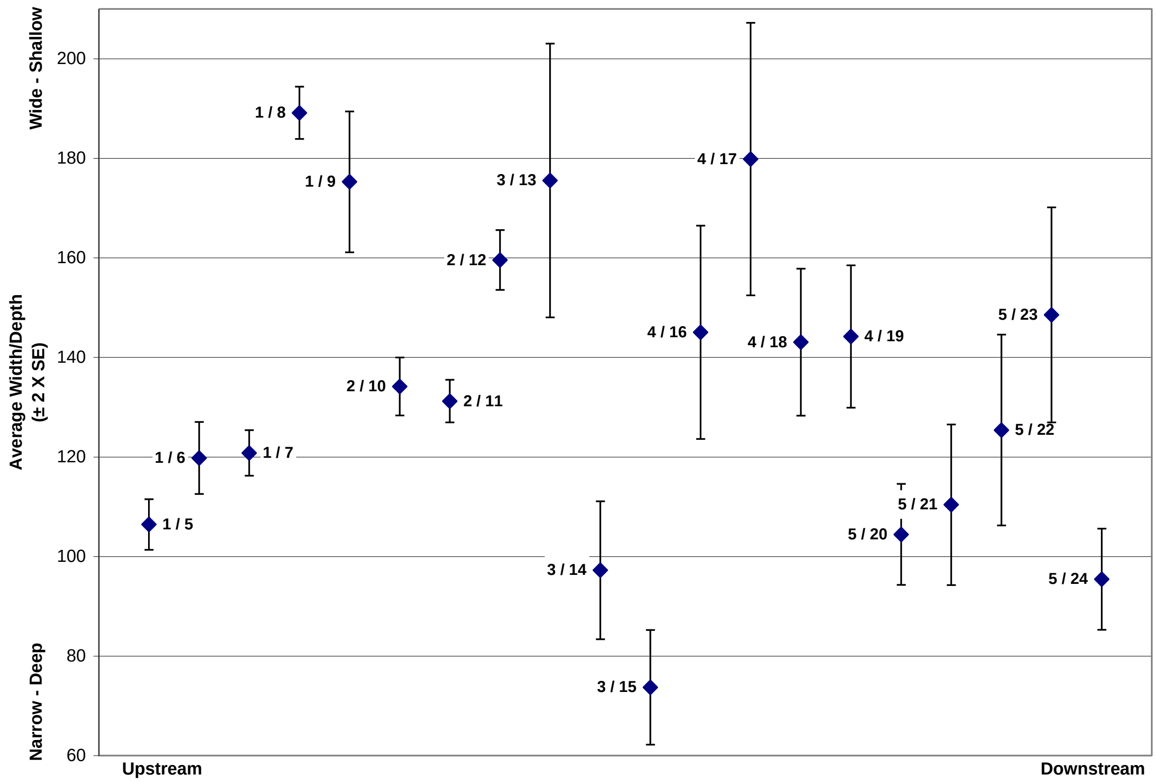

Figure 5.1. Longitudinal spatial diversity and average W/D for the Albuquerque Reach. Note: numerical references indicate the subreach/tile used in the hydraulic modeling conducted for the MRG BRP. The W/D is plotted with the standard error bars for each subreach.

The conservation unit characteristics for the silvery minnow are presented in Table 5.2.

Table 5.2. Conservation Unit Characteristics and Management Level for Silvery Minnow Habitat

Conservation Unit	Habitat Features			Geomorphic Characteristics	Spatial Features	Management Level
	Residential	Recruitment	Intermittent Disturbance			
Core Conservation Unit (CCU)	High habitat heterogeneity over range of flows	Floodplain inundation: <3,000 cfs for a minimum of 7–10 days	No drying events; may have primary transitional refugia	High W/D over range of flows (e.g., low variability of W/D) over discharge range from 500–5,000 cfs	High spatial heterogeneity (longitudinally) to facilitate dispersal	Priority area; maintain current condition
Reserve Conservation Unit (RCU)	High to moderate habitat heterogeneity over range of flows	Floodplain inundation at high discharges: >3,000 cfs	No drying events; may have primary transitional refugia	Decreasing W/D over range of flows, but low variability of W/D from 500–5,000 cfs	High to moderate longitudinal spatial heterogeneity	Restoration required to obtain CCU condition; potential to increase frequency of floodplain inundation at lower discharges or increase habitat heterogeneity; minor environmental modification required
Primary Restoration Unit (PRU)	Monotypic low habitat heterogeneity over range of flows	No floodplain inundation	Potential for Intermittent drying or extremely low discharge periods	Decreasing W/D over range of flows, but low variability of W/D from 500–5,000 cfs	Low to moderate longitudinal spatial heterogeneity	Transitional habitats; restoration required to obtain CCU condition; moderate to extensive environmental modification required to increase frequency of inundation at even high river discharges or increase habitat heterogeneity
Secondary Restoration Unit (SRU)	Monotypic low habitat heterogeneity over range of flows	No floodplain inundation or infrequent floodplain inundation events	Potential for frequent channel drying events or extremely low discharge periods	Decreasing W/D over range of flows, but low variability of W/D from 500–5,000 cfs	Low longitudinal spatial heterogeneity	Transitional habitats; restoration required to obtain CCU condition; extensive environmental modification required; unlikely that extensive areas of floodplain inundation could be achieved at even high discharges; supplemental water sources may be required

5.2.2 Flycatcher Restoration Model Characteristics

Given that migrating flycatchers are known to prefer riparian habitats similar to nesting habitats and show a preference for willow stands, habitat restoration along the Albuquerque Reach should emphasize the establishment of native willow stands for migrating flycatchers and nesting sites. Habitat restoration needs presented below generally combine nesting and migratory habitat, since both should be similar.

The premise of the overall flycatcher habitat model is that persistent Rio Grande water on the floodplain or lateral channels is necessary to produce dense and tall willow stands composed of Goodding's and coyote willow, with persistent standing water or saturated soil underneath, and patches at least 1 ha (2.5 acres) in size to provide habitat for the flycatcher. Areas meeting these criteria are typically occupied by nesting flycatchers, would represent suitable MRG flycatcher nesting habitat, and would be considered CCUs. Currently, no such sites are known within the Albuquerque Reach. We recognize that these habitat characteristics may exist at the San Antonio Oxbow; however, nesting pairs have not yet been documented. Flycatcher CCUs may exist on Pueblo of Isleta (Smith and Johnson 2008) and downstream (Moore and Ahlers 2003, 2004, 2005, 2006a, 2006b, 2007) since breeding pairs have been documented. Such sites may also be considered as reference sites relative to environmental characteristics to be achieved for habitat restoration goals. Such sites also would provide suitable migratory stopover habitat. Based on GIS analysis, several potential RCU sites are available in the Albuquerque Reach.

Alternatively, sites providing ephemeral wetlands and sparse and/or short (< 4 m [13 feet] tall) willow stands are lacking one or more significant environmental characteristics to be considered potential habitat for flycatchers. Such sites are considered RCUs, and those missing environmental characteristics may potentially be obtained through habitat restoration. Such RCU sites have the potential to become CCU sites through habitat restoration.

The attributes or characteristics of flycatcher conservation units for the flycatcher in the Albuquerque Reach are provided in Table 5.3. Table 5.4 provides specific vegetation and microclimate characteristics that serve as criteria for defining flycatcher CCU conditions. Table 5.4 is based on parameters measured by McLeod et al. (2008) from nest sites along the Lower Colorado River.

Table 5.3. Conservation Unit Characteristics and Management Objectives for Flycatcher Habitat

Conservation Unit	Geomorphology	Hydrology	Vegetation	Spatial Features	Management Objectives
Core Conservation Unit (CCU)	Floodplains, oxbows, and side channels	Persistent wetland, standing water, or saturated soils much of the year, especially April–August; floodplain inundation at 1,500 cfs; depth to groundwater sufficient to support willows (< 2 m [<7 feet])	*Salix* spp., especially Goodding's willow; dense canopy up to 5 m (16 feet) high	>1.0 ha (2.5 acres) in size, up to 200 ha (494 acres); similar diameter to width for small patches, linear but > 50-m (164-foot) width for large patches	Maintain current condition
Reserve Conservation Unit (RCU)	Floodplains, oxbows, side channels, and islands	Ephemeral wetland, standing water, or saturated soils or high potential for such; floodplain inundation at >3,000 cfs; depth to groundwater sufficient to support willows (<2 m [<7 feet])	*Salix* spp. and/or *Tamarix* spp., present,; < 5 m (16 feet) high; high potential for *Salix* spp. to develop dense stands with restoration	>1.0 ha (2.5 acres) in size, up to 200 ha (494 acres); similar diameter to width for small patches, linear but > 50-m (164-foot) width for large patches	Restoration required to obtain CCU condition, which may include active revegetation with geomorphic manipulation to encourage natural revegetation and fluvial processes; active management of invasive species may be required
Primary Restoration Unit (PRU)	See RCU above; similar to CCU	See RCU above; inundation at >4,500 cfs; moderate potential for persistent (April– August) standing water or saturated soils with restoration; depth to groundwater insufficient to support willows (> 2 m [>7 feet]) without surface modification (e.g. willow swales)	See RCU above; high potential for *Salix* spp. to develop dense stands with restoration (e.g., groundwater depth < 1.5–2.1 m [5–7 feet], low soil salinity/sodicity)	See RCU above; high potential to develop large patch sizes	See RCU above; minor environmental modification required; restoration likely to include construction of willow swales and active management to control invasive species; active management and maintenance likely required
Secondary Restoration Unit (SRU)	See RCU above; not similar to CCU	See RCU above; inundation at >4,500 cfs; low potential for persistent (April– August) standing water or saturated soils with restoration; depth to groundwater insufficient to support willows (> 2 m [>7 feet]) without surface modification (e.g. willow swales)	See RCU above; low potential for *Salix* spp. to occupy site with restoration (e.g., groundwater depth > 1.5–2.1 m [5–7 feet], high soil salinity)	See RCU above; low potential for large patch sizes	See RCU above; major environmental modification required, including construction of willow swales, soil modification, and active management to control invasive species; long-term management and maintenance likely required

Table 5.4. Flycatcher Habitat Characteristic Variables

Vegetation Variables*	**Recommended Statistical Range of Variable (mean ± standard error)**
Vegetation height and density by canopy layer	
Upper canopy (>6 m [20 feet]) height (m)	11.98 ± 1.8
Mid-canopy (3–6 m [10–20 feet]) height (m)	8.05 ± 1.56
Shrub canopy (0–3 m) height (m)	2.69 ± 0.77
Upper canopy (>6 m [20 feet]) stem density (/ha)	850 ± 698
Mid-canopy (3–6 m [10–20 feet]) stem density (/ha)	3,079 ± 2,318
Shrub canopy (0–3 m [0–10 feet]) stem density (/ha)	7,470 ± 7,533
Tree Species Density (/ha)	
Salix gooddingii	71.5 ± 38.3
Salix exigua	5.1 ± 12.8
Both *Salix* species	76.6 ± 38.1
Populus deltoides	3.4 ± 9.7
Tamarix spp.	11.9 ± 26.8
Eleagnus angustifoilia	8.1 ± 24.2
Nest Position	No standard error reported
Nest height (m)	3.0
Nest substrate height (m)	5.5
Nest substrate dbh (cm)	4.4
Distance to riparian edge (m)	83
Microclimate Variables**	**Recommended Statistical Range of Variable (mean ± standard error)**
Soil Moisture	
Mean soil moisture (mV), 2005–2007	751.9 ± 15.5
Temperature	
Mean maximum diurnal temperature (°C)	43.0 ± 0.2
Mean diurnal temperature (°C)	31.1 ± 0.1
Mean no. of 15-min. intervals above 41°C per day	4.5 ± 0.3
Mean minimum nocturnal temperature (°C)	16.4 ± 0.1
Mean nocturnal temperature (°C)	24.6 ± 0.1
Mean daily temperature range (°C)	**19.6 ± 0.2**
Humidity	
Mean diurnal relative humidity (%)	53.0 ± 0.6
Mean diurnal vapor pressure (Pa)	2,200.2 ± 26.0
Mean nocturnal relative humidity (%)	64.6 ± 0.5
Mean nocturnal vapor pressure (Pa)	**1,964.7 ± 20.6**

* Vegetation structure and composition variables from Moore (2007) are based on measurements from nest sites (n-112).
**Microclimate variables shown in bold are those that are significant predictors of flycatcher nest locations in models combining vegetation and microclimate variables (adapted from McLeod et al. 2008).
Note: dbh = diameter at breast height

5.3 Restoration and Management Strategies

5.3.1 *Restoration Treatments*

The Albuquerque Reach is not very geomorphically active (refer to section 2.3.3 for a discussion on the changes in the river geomorphology). The channel response to the recent high flows in 2005 has been to stabilize the system through enlarging existing bars and islands resulting in little channel migration and minimal changes in channel geometry. It is difficult for small localized projects to sustain their desired outcome without changing fluvial processes (D. Wolf, personal communication 2009). Combining individual, site-scale restoration treatments into larger projects are proposed to affect key ecological or geomorphic factors that limit silvery minnow or flycatcher populations. Within each conservation unit, key factors and processes have been identified that are hypothesized to enhance populations for both species. We propose a set of restoration strategies in each conservation unit to address these key factors. Restoration strategies developed for each conservation unit will employ a variety of treatments and hydrologic management options.

The habitat restoration treatments proposed by Tetra Tech (2004) provide a starting point for developing a "toolbox" of available treatments and strategies available for implementing habitat restoration for the silvery minnow and the flycatcher. Restoration treatments typically involve the manipulation of bank-attached bars, islands, banklines, or floodplains to construct a desired mesohabitat feature. These mesohabitat features are thought to provide key habitat elements that meet various lifecycle needs for the silvery minnow or breeding habitat for the flycatcher. This approach has typically been taken for habitat restoration projects in the MRG. Each treatment serves to affect the geomorphic or ecological condition in such a manner to enhance a residential, recruitment, or refugial habitat feature in a specific manner. The treatment objectives are designed provide the basis for monitoring and measuring species response.

Hydrological management of the system is an important component of the restoration and management strategy and is intended to complement physical manipulation of the riverine and riparian environments. Parametrix (2008a, 2008b) suggests that decreasing the slope of the receding limb of the hydrograph will enable root elongation for willows and cottonwoods and thus enhance natural recruitment of these species. Similarly, decreasing the slope of the receding limb of the spring runoff hydrograph would be expected to provide benefits to the silvery minnow through decreasing the probability of stranding fish in the floodplain. The proposed restoration treatments are summarized in Table 5.5.

Table 5.5. Restoration Treatments

	Treatment	Description	Benefits of Treatment	Silvery Minnow Habitat Feature Target	Flycatcher Habitat Target
Residential Habitat	High-flow ephemeral channels	Construction of ephemeral channels on bars and islands to carry flow from the main river channel during high-flow events.	Normally dry, but creates shallow, ephemeral, low-velocity aquatic habitats important for silvery minnow egg and larval development during medium- and high-flow events.	Provides habitat heterogeneity over a range of river discharge.	Improves breeding and migratory habitat.
	Island/Bar modification	Creation of shelves and terraces on islands and bars to increase inundation frequency. This technique is targeted for islands and bars that have an overtopping discharge greater than 3,000 cfs and less than 10 exceedance days per year.	Increases habitat heterogeneity and availability by increasing the inundated area at lower flows. May also destabilize bars and islands, slowing the rate of vegetation stabilization and/or armoring and facilitating sediment mobilization. Bar/island modification may also provide functional floodplain habitat to facilitate low and intermediate-flow recruitment habitat.	Provides habitat heterogeneity over a range of river discharge.	–
	Island/Bar destabilization	Clearing of vegetation, including above- and belowground biomass, on stabilized islands and bank-attached bars to encourage the redistribution of sediments.	Could encourage the redistribution of sediment and natural fluvial geomorphic processes.	Provides/Maintains habitat heterogeneity over a range of river discharge.	–
	Removal of lateral confinements	Elimination or reduction of some structural features and maintenance practices that decrease bank erosion potential to allow lateral movement of the channel in areas that would not negatively impact flood control and other infrastructure.	Could increase floodplain sinuosity and width with more diverse channel and floodplain features, resulting in increased low-velocity habitat for silvery minnow.	Provides habitat heterogeneity over a range of river discharge.	Improves breeding and migratory habitat.
	Passive restoration	Allows for higher magnitude peak flows to accelerate natural channel-forming process and improve floodplain habitat.	Increases sinuosity and allows for development of complex and diverse habitat, including bars, islands, side channels, sloughs, and braided channels.	Provides/maintains habitat heterogeneity over a range of river discharge.	Improves breeding and migratory habitat.
	Sediment management	Increase of sediment supply through mobilization behind dams, arroyo reconnection, or introduction and redistribution of spoils associated with construction of mesohabitat features.	Enhances geomorphic function of the river system through encouraging natural fluvial processes.	Provides habitat heterogeneity over a range of river discharge.	–
	Hard structures	Engineered structures, such as bendway weirs, constructed along the channel margins to facilitate lateral channel migration and creation of pools and eddies.	Facilitates the increase in sinuosity, which allows for the development of complex and diverse habitat, including bars, islands, side channels, sloughs, and braided channels. Creates aquatic habitat diversity by providing pools and slackwater areas.	Provides habitat heterogeneity over a range of river discharge and low-flow recruitment habitat at low discharge (<3,000 cfs).	–
	Gradient-control structures	Low head weirs constructed perpendicular to the channel with aprons to simulate natural riffles.	Creates aquatic habitat diversity by producing variable flow velocities and depths. Also may increase groundwater and regeneration of willows for flycatcher habitat.	Provides habitat heterogeneity over a range of river discharge and low to intermediate recruitment habitat.	–

Table 5.5. Restoration Treatments, continued

	Treatment	Description	Benefits of Treatment	Silvery Minnow Habitat Feature Target	Flycatcher Habitat Target
Recruitment Habitat	Creation of backwaters and embayments	Areas cut into banks and bank-attached bars to allow water to enter to create slackwater habitat, primarily during mid- to high-flow events, including spring runoff and floods.	Increases habitat diversity by increasing backwaters, pools, and eddies at various depths and velocities. Intended to retain drifting silvery minnow eggs and provide rearing habitat and enhance food supplies for developing silvery minnow larvae.	Creates secondary and tertiary recruitment habitat along channel margins.	Improves breeding and migratory habitat, cover, and food resources through encouraging natural revegetation or active planting.
	Creation of bankline benches	Removal of vegetation and excavation of soils adjacent to the main channel to create benches that would be inundated at a range of discharges.	Provides shallow water habitat at a range of discharges that could provide spawning habitat and increased retention of silvery minnow eggs and larvae. Increased inundation would benefit native vegetation, potentially increasing habitat for the flycatcher.	Creates secondary and tertiary recruitment habitat along channel margins.	Improves breeding and migratory habitat, cover, and food resources through encouraging natural revegetation or active planting.
	Floodplain coupling - overbank inundation channels	Construction of ephemeral channels in the floodplain to carry flow from the main river channel during high-flow events.	Creates shallow, ephemeral, low-velocity aquatic habitats in the bosque during high-flow events. Provides silvery minnow egg retention and larval habitat associated with silvery minnow spawning. Enhances hydrologic connectivity with the floodplain. Could improve flycatcher habitat.	Creates primary recruitment habitat through providing floodplain inundation at target river discharge (3,000 cfs).	Improves breeding and migratory habitat, cover, and food resources through encouraging natural revegetation or active planting.
	Floodplain coupling - lower bankline	Removal of natural berms, jetty jacks, and non-native vegetation that are associated with channel margins. Removal of the berms may increase the frequency of floodplain inundation where modeling indicates floodplain inundation occurs at higher flows.	Creates shallow, ephemeral, low-velocity aquatic habitats in the bosque during high-flow events. Provides silvery minnow egg retention and larval habitat associated with silvery minnow spawning. Enhances hydrologic connectivity with the floodplain. Could improve flycatcher habitat.	Creates primary recruitment habitat through providing floodplain inundation at target river discharge (3,000 cfs).	Improves breeding and migratory habitat, cover, and food resources through encouraging natural revegetation or active planting.
	Floodplain vegetation management	Management of vegetation within the floodplain through actively planting desired native vegetation and controlling non-native vegetation to restore riparian habitat.	Increases habitat availability and diversifies habitat structure for the flycatcher in heavily disturbed sites. Combined with passive restoration techniques to promote natural revegetation, active planting has the potential to increase flycatcher habitat availability.	Provides canopy cover to moderate diel variation in water temperature in floodplain water catchments.	Improves breeding and migratory habitat through control of non-native phreatophytes and actively planting native riparian vegetation. Provides food resources.

Table 5.5. Restoration Treatments, continued

	Treatment	Description	Benefits of Treatment	Silvery Minnow Habitat Feature Target	Flycatcher Habitat Target
Recruitment Habitat, continued	Willow swales	Creation of swales through excavating to a depth above the groundwater table and establishing dense willow plantings. Swales may be connected to the river through overbank inundation channels or disconnected from the river channel.	Creates dense mid-sized native willow-dominated vegetation, ephemeral standing water, insect sources, and cover for flycatchers.	–	Provides flycatcher breeding and migratory habitat, cover, and food resources habitat through the establishment of dense willow-dominated vegetation stands.
	Moist soil depressions	Management of moist soil depressions to provide habitat for flycatchers. May include connecting depressions to the river through overbank inundation channels to create ephemeral standing water conditions and may include vegetation management to create dense willow-dominated stands.	Create dense mid-sized native willow-dominated vegetation, ephemeral standing water, insect sources, and cover for flycatchers.	–	Provides flycatcher breeding and migratory habitat, cover, and food resources through the establishment of dense willow-dominated vegetation stands.
	Arroyo connectivity	Clearing of vegetation and/or excavation of pilot channels to bring stranded arroyos to grade with the mainstem Rio Grande.	Could re-establish eddies associated with the mouths of arroyos, which may help to retain silvery minnow eggs and larvae and increase the supply of sediment to the river.	Improves secondary and tertiary recruitment habitats at low to moderate river discharge.	–
	Water operations coordination and management of the hydrograph to provide river channel/floodplain coupling over a minimal sustained period	Management of the hydrograph to replicate key fluvial and ecological processes that have been disrupted. Water operations management would be tied to design discharge criteria (3,000 – 3,500 cfs) to provide inundation of floodplain habitat at specified discharge for a sufficient duration (7–10 days) to meet the recruitment goals and objectives. Also includes management of the receding limb of the hydrograph to minimize silvery minnow entrainment in the floodplain.	Meets silvery minnow goals of ensuring recruitment classes no less than every two out of three years and reduces silvery minnow loss through entrapment.	Improves recruitment habitat function through providing inundation frequency and duration to increase recruitment and to reduce entrapment losses.	Improves breeding and migratory habitat and facilitates regeneration of willow habitat through maintaining water availability to elongating root systems.

Table 5.5. Restoration Treatments, continued

	Treatment	Description	Benefits of Treatment	Silvery Minnow Habitat Feature Target	Flycatcher Habitat Target
Refugia Habitat	Large woody debris	Placement of trees, root wads, stumps, or branches in the main river channel or along its banks to create pools. Large woody debris may be anchored into the bank or unanchored.	Creates low-flow refugial habitat (pools and slow-water habitats), provides shelter from predators and winter habitat, and provides structure for periphyton growth to improve food availability for silvery minnow.	Provides low-flow refugial habitat. Enhances spatial sequencing of pools and pool morphology through providing and maintaining channel pools. Creates eddies to maintain opening at backwaters and embayments for recruitment habitat.	–
	Strategic use of irrigation infrastructure to maintain critical reaches of wetted surface habitat	Use of irrigation returns and other infrastructure to maintain or refresh wetted pools during channel drying events. May be subject to permitting requirements and require depletions offsets.	Maintains wetted surface habitat during periods of intermittent channel drying.	Increases survivorship during stress periods.	Maintains or improves breeding and migratory habitat through ensuring hydrologic conditions throughout the flycatcher breeding season.
	Strategic utilization of wells to maintain critical reaches of wetted surface habitat	Supplemental water through shallow groundwater pumping to maintain or refresh wetted pools during channel drying events.	Maintains wetted surface habitat during periods of intermittent channel drying.	Increases survivorship during stress periods.	Maintains or improves breeding and migratory habitat through ensuring hydrologic conditions throughout the flycatcher breeding season.
	Supplement main channel flow with contingency water supply	Supplemental water to refresh or minimize intermittent channel drying.	Maintains wetted surface habitat during periods of intermittent channel drying.	Increases survivorship during stress periods.	–
	Fish passage	Installation of fish passage structures at impoundments to improve longitudinal connectivity of the river.	Allows upstream movement of silvery minnow and reduces habitat fragmentation.	Facilitates migration.	–

5.3.2 RESTORATION STRATEGIES

Restoration strategies are targeted to improving the condition for each conservation unit. Within each conservation unit, key factors and processes have been identified that limit the status of the silvery minnow and the flycatcher. Key factors and processes for the silvery minnow include geomorphic factors, demographic processes, and infrastructure constraints. Geomorphic factors are related to the habitat conditions and include the extent of coupling of riverine and riparian habitat, the degree of habitat heterogeneity, longitudinal spatial diversity, availability of refugia habitat, and degree of channel incision. Demographic processes refer to the population responses to the condition of the habitat and include the population growth potential, annual variability in recruitment and age class survival, retention of eggs and larvae, and downstream emigration. Infrastructure constraints, which may inhibit the implementation of habitat restoration projects, have been also identified. These include features such as bridges, proximity to levees, and so on.

For the flycatcher we have identified geomorphic factors, biological factors, and demographic processes. Geomorphic factors address the degree of groundwater and surface water coupling in the floodplain with the river channel. Biological factors include nest parasitism[12] and vegetation structure. Demographic processes include the distance from known nesting territories and the degree of possible human-induced breeding season disturbance.

We have used this information to develop a set of restoration strategies for the silvery minnow and the flycatcher in each identified conservation unit. Table 5.6 summarizes the restoration strategies for the Albuquerque Reach.

[12] The Albuquerque Reach is within a region with considerable agriculture, livestock, and brown-headed cow birds are common. Nest parasitism is likely within the Albuquerque Reach.

Table 5.6. Restoration Strategies

Conservation Unit	Tile #	Silvery Minnow Factors	Silvery Minnow Restoration Strategies	Flycatcher Factors	Flycatcher Restoration Strategies
SRU	1-5 1-6 1-7	<u>Geomorphic Factors</u> ▪ Lateral uncoupling of riverine/ riparian habitat ▪ Reduced volume and areal extent of residential habitat ▪ Longitudinal monotony of residential geomorphic habitat features ▪ Longitudinally altered processes (e.g., channel incision transition zone) <u>Demographic Processes</u> ▪ Low population growth potential ▪ Reduced egg and larvae retention ▪ Downstream emigration processes ▪ Large inter-annual variation in reproductive success	▪ Enhance riverine restoration work planned by the Pueblo of Sandia ▪ Establish channel-margin recruitment habitat at a river discharge of 1,500–2,500 cfs	<u>Geomorphic Factors</u> ▪ Hydrologic decoupling – surface water ▪ Hydrologic decoupling – groundwater (?) <u>Biologic Factors</u> ▪ Inadequate breeding habitat structure ▪ Nest parasitism/ predation <u>Demographic Processes</u> ▪ Distance from known occupied nesting territory	▪ Establish willow-dominated (Gooddingʼs willow and coyote willow) habitat along channel margins and bank-attached bars ▪ Reduce and control non-native phreatophytes to a minor component of the floodplain vegetation
RCU-1	1-8 1-9 2-10 2-11	<u>Geomorphic Factors</u> ▪ Lateral uncoupling of riverine/ riparian habitat ▪ Longitudinal monotony of residential geomorphic habitat features <u>Demographic Processes</u> ▪ Low population growth potential ▪ Reduced egg and larvae retention ▪ Large inter-annual variation in reproductive success <u>Infrastructure Constraints</u> ▪ Bridge crossings (Alameda, Paseo del Norte) ▪ Levee encroachment ▪ Albuquerque Drinking Water Project	▪ Connect floodplain at moderate (3,000 cfs) river discharge ▪ Provide channel margin recruitment habitat at a river discharge of 1,500 cfs ▪ Reconnect arroyos	<u>Geomorphic Factors</u> ▪ Hydrologic decoupling – surface water ▪ Hydrologic decoupling – groundwater (?) <u>Biologic Factors</u> ▪ Inadequate breeding habitat structure ▪ Nest parasitism/ predation <u>Demographic Processes</u> ▪ Distance from known occupied nesting territory	▪ Create willow-dominated habitat in conjunction with low-flow channel margin silvery minnow recruitment habitat

Table 5.6. Restoration Strategies, continued

Conservation Unit	Tile #	Silvery Minnow Factors	Silvery Minnow Restoration Strategies	Flycatcher Factors	Flycatcher Restoration Strategies
PRU	2-12 3-13 3-14 3-15	Geomorphic Factors ▪ Lateral uncoupling of riverine/ riparian habitat ▪ Reduced volume and areal extent of residential habitat ▪ Longitudinal monotony of residential geomorphic habitat features Demographic Processes ▪ Low population growth potential ▪ Reduced egg and larvae retention ▪ Large inter-annual variation in reproductive success Infrastructure Constraints ▪ Bridge crossings (Montaño) ▪ Levee encroachment ▪ Jetty jacks	▪ Connect floodplain at a river discharge of 3,000 cfs ▪ Provide channel margin recruitment habitat at a river discharge of 1,500 cfs ▪ Increase residential habitat heterogeneity	Geomorphic Factors ▪ Hydrologic decoupling – surface water ▪ Hydrologic decoupling – groundwater (?) Biologic Factors ▪ Inadequate breeding habitat structure ▪ Nest parasitism/ predation Demographic Processes ▪ Distance from known occupied nesting ▪ Human-induced breeding season disturbance (?)	▪ Establish large areas of willow-dominated habitat at the San Antonio Oxbow ▪ Establish large willow-dominated areas outside the San Antonio Oxbow ▪ Implement outreach targeted to adjacent developments and Rio Grande Valley State Park users during breeding season
RCU-2	4-16 4-17 4-18 4-16 5-20 5-21 5-22 5-23 5-24	Geomorphic Factors ▪ Inadequate intermittence refugia Demographic Processes ▪ Large inter-annual variation in reproductive success ▪ Floodplain stranded young-of-year Infrastructure Constraints ▪ Bridge crossings (I-40, Bridge Road) ▪ Tingley Beach ▪ Levee encroachment ▪ Albuquerque WWTP	▪ Connect floodplain at a river discharge of 3,000 cfs ▪ Increase channel margin recruitment habitat at river discharge of 1,500 cfs ▪ Provide intermittence refugia in event of extremely low flows ▪ Develop supplemental water supply to maintain wetted surface habitat during extremely low flow events ▪ Reconnect South Diversion Channel	Geomorphic Factors ▪ Hydrologic decoupling – surface water ▪ Hydrologic decoupling – groundwater (?) Biologic Factors ▪ Inadequate breeding habitat structure ▪ Nest parasitism/ predation Demographic Processes ▪ Distance from known occupied nesting ▪ Human-induced breeding season disturbance (?)	▪ Establish large areas of willow-dominated habitat in floodplain areas inundated at a river discharge of 3,000 cfs

5.3.2.1 SILVERY MINNOW RESTORATION STRATEGIES

Silvery minnow habitat restoration strategies focus on providing mesohabitat features that will improve residential, recruitment, and refugia habitat types. Residential habitat would be enhanced through the provision of varying mesohabitat features designed to be inundated at a range of river discharges. This would provide areas for silvery minnow to find low-velocity areas out of main channel flows, which would be expected to affect demographic processes through decreasing the death rate and decreasing downstream emigration.

Recruitment habitat restoration would focus on providing floodplain inundation at flows of 3,000 cfs. As discussed above, inundation of the floodplain has been associated with large recruitment classes. However, it is equally important to provide recruitment habitats at intermediate and low flows that would normally be contained to the active river channel. These features, to be constructed on the channel margins and along bank-attached bars, would provide stability through minimizing the loss of an age class. While these recruitment classes would be expected to be smaller, they would nonetheless be important to maintaining a viable population.

Provision of refugia habitats of the primary transition subtype would be important in the southern portions of the Albuquerque Reach. In a worst-case scenario, such as the dry year minimum flows as prescribed by the 2003 BO or when the Albuquerque Drinking Water Project passes the minimum flow of 196 cfs over the diversion dam, low-flow conditions in this reach could be expected. FLO-2D simulations conducted by Wolf Engineering (2008) indicate that there is an approximately 20% reduction in peak flows, potentially resulting in very low flow conditions in this subreach.

Individual, site-scale restoration treatments would be combined into larger projects to affect geomorphic factors and demographic processes within a specified conservation unit. Proposed restoration treatments would also work in conjunction with completed (e.g., NMISC [Reclamation 2007a], Pueblo of Sandia [SWCA 2008; Reclamation 2008], Corps Route 66 [Corps 2008c], and City of Albuquerque [Reclamation 2007b]) and proposed restoration projects (e.g. Corps MRG BRP [Corps 2010]).

5.3.2.2 FLYCATCHER RESTORATION STRATEGIES

Habitat restoration strategies targeting flycatcher habitat will focus on techniques designed to increase or simulate floodplain or overbank flooding and the creation of densely vegetated persistent wetlands dominated by native willow species, especially Goodding's willow, greater than 1 ha (2.5 acres) in size. Flycatcher habitat restoration would create dense native willow-dominated vegetation patches that are above or adjacent to moist soil or standing water. Such patches are intended to be dense with complex branch structure up to 4 m (13 feet) tall. Active restoration techniques that will be employed primarily for silvery minnow habitat restoration also may provide benefits to the flycatcher. For example, backwater wetlands may be planted with willows, which should benefit both species. The restoration strategies for enhancing flycatcher habitat include the following:

1. Increase bosque inundation and/or increase the availability of groundwater resources to create habitats with native willow vegetation, especially Goodding's willow.
2. In existing wetland areas, create willow-dominated patches of sufficient density (especially Goodding's willow but also coyote willow), structure, and spatial extent through active planting or promoting natural revegetation to attract breeding flycatchers.
3. Enhance flycatcher migratory stopover habitat through creating willow swales restoring moist soils depressions and diverse native riparian willow habitats and the riparian corridor.

5.4 CONCEPTUAL RESTORATION PROJECTS

5.4.1 DESCRIPTION AND ANALYSIS OF ALBUQUERQUE REACH RESTORATION SITES

5.4.1.1 SITE SELECTION BACKGROUND

The general hydrologic, geomorphic and hydraulic conditions for the Study reach are presented in Chapter 4 – Restoration Issues and Opportunities. These conditions, in part, have guided the development of proposed restoration alternatives within the Albuquerque Reach and are summarized below.

- Prehistorically, flows in the Rio Grande through the Albuquerque Reach were typical of southwestern rivers. Spring to early summer would bring high flows resulting from melting mountain snowpack, and midsummer through winter would most often be periods of low flow.
- During extended periods with below average spring runoff, vegetation establishment occurs on bars and islands. Once established, there are insufficient shear stress forces to remove vegetation and mobilize sediments (MEI 2006a). When high flows then occur, the bars and islands accrete due to fine sediment deposition. This is what occurred in 2005, when high spring runoff followed several years of below average spring runoff.
- Currently, spring peak flows have been reduced in magnitude and duration (largely as a result of upstream and tributary water resource development).
- Under today's operating criteria, peak releases from Cochiti Dam are limited to 7,000 cfs to prevent damage to spoil bank levees.
- The computed 2-, 5-, and 100-year peak discharges at the Albuquerque gage are 4,890, 7,130, and 12,640 cfs, respectively.
- An average "dry year" spring runoff at the Central Avenue gage peaks at about 1,500 cfs for a minimum of seven days.
- An average "moderate year" spring runoff at the Central Avenue gage peaks at about 3,500 cfs for a minimum of seven days.

- An average "wet year" spring runoff at the Central Avenue gage peaks at about 6,000 cfs for a minimum of seven days.
- Prior to human intervention, the Rio Grande through Albuquerque was generally wide and shallow with many sandbars and could be characterized as braided at low to moderate flows.
- Since the 1930's, water resource development in the Rio Grande Basin above Albuquerque has significantly altered the historic Rio Grande channel and floodplain.
- Following the closure of Cochiti Dam in 1975, reduced peak discharges accelerated the encroachment of vegetation bars and islands and the evolution into permanently attached banks and islands.
- The channel in the Albuquerque Reach is not very active, and the recent response to high flows has been to stabilize the existing bars and islands.
- There is little to no channel migration or channel geometry changes.
- An existing HEC-RAS model (MEI 2008a) is used to determine in-channel flow depths and average flow velocities for a range of steady-state discharges.
- HEC-RAS results indicate that flows up to about 3,500 cfs are confined to the active channel, whereas the 6,000-cfs profile generally defines "bankfull" conditions with intermittent areas of overbank flows.
- Channel average velocity is relatively uniform throughout the project reach varying from about 2 to 3 fps at 1,500 cfs to about 3 to 5 fps at 6,000 cfs.
- The MRG FLO-2D model is used to further assess channel capacity, predict and track the locations of overbank flow, predict the duration of overbank flow, and provide reach-averaged hydraulic conditions (based on computed depth) for the main channel (depth, velocity, top width, and energy slope).
- An important output from the FLO-2D modeling is to understand the relationship between the volume in the channel and the volume on the floodplain.
- MRG FLO-2D model results of the existing conditions indicate that very little overbank inundation occurs for peak discharges below 6,000 cfs in the Albuquerque Reach.

5.4.1.2 Site Selection Criteria and Refinement

Selection criteria have been developed to provide a basis for identifying sites at which it may be possible to meet restoration objectives for the silvery minnow and/ the flycatcher by improving riparian and channel functionality while not adversely affecting water delivery requirements and public safety. The overall intent of the projects is to create a more functional active channel with enhanced floodplain connectivity while considering infrastructure and water operational constraints. The proposed projects also include the ancillary benefits of enhanced recreational and aesthetic values in the bosque. A review of the specific criteria that were considered for the preliminary site selection includes:

- Existing channel morphology
- Potential for enhancing channel-floodplain connectivity
- Existing and potential habitat conditions
- Subreach average channel hydraulic conditions (W/D)
- Potential for overbank flood inundation
- Existing ground cover (vegetation)
- Areal extent of the site
- Proximity of site to existing infrastructure (levees and bridges)
- Proximity of site to existing or planned restoration projects
- Potential contribution to reach-wide restoration objectives ("linkability" of projects)
- Access to supplemental water (surface or ground)
- Cost of implementation

A comprehensive list of potential projects has been developed by the project team using these criteria. After detailed review of site-specific hydraulic data in the vicinity of each potential site, along with a detailed analysis of site-specific digital terrain data provided in the 1999 Bernalillo County LiDAR data set (Bohannon-Huston, Inc. [BHI] 1999) and cross section survey data of the active river channel, the list of potential features has been refined.

Based on the above work, a final list of ten restoration projects has been developed. Each of these projects typically has multiple features that vary in complexity and cost. With implementation of these projects, the underlying goal of creating or enhancing preferential habitat for the silvery at its different life stages, under variable flow conditions, would be achieved.

The final project selection and implementation should consider the following:

1. Projects should be expanded and linked in an effort to support reach-wide improvements in channel morphology and habitat.
2. Small projects involving channel connections with flow-through channels (such as high-flow ephemeral channels) and quiescent water conditions (such as embayments and backwaters), are prone to sediment deposition, closure, and/or rapid vegetation encroachment. Unless concurrent channel morphology enhancements are included in the project design, periodic maintenance of ephemeral high-flow channels and embayments would be required.
3. In the prehistoric Rio Grande context, typically slow-velocity habitat, such as abandoned meander bends, served as backwater habitat. There were braided parts of the channel that became quickly isolated on the recessional limb of a spring hydrograph. The functionality of these backwater features was erratic from year to year, being open some years and closed for others for the same flow. There were,

however, many backwater habitats in the wide channel morphology and, thus, slow-velocity habitat was plentiful at high flows.

4. A coordinated adaptive water management program designed to provide bankfull discharge on the order of once every two to three years may provide the shear stresses necessary to maintain constructed habitat features.

5. Projects constructed outside of the nominal 183-m (600-foot) channel width will require an evaluation of potential net depletions and coordination with New Mexico Office of State Engineer (NMOSE). Supplemental water may be required to offset depletions and must be accounted for in project budgets.

Preferred silvery minnow habitat in the Albuquerque Reach represents only a small fraction of what existed prehistorically. Ultimately, extensive reach-wide silvery minnow habitat enhancement would provide the best opportunity for species recovery. Those projects that create or enhance wide, shallow channel morphology would have the most beneficial impact on the marginal fish habitat. Reach-scale projects are necessary to provide a substantive contribution to recovery. Projects that are linked and large in areal extent are preferred over small isolated projects.

5.5 FUTURE TRENDS ANALYSIS

An analysis of the future conditions (with restoration) has been conducted for the Albuquerque Reach. Anticipated changes in hydrology, hydraulics, geomorphology, vegetation, and other characteristics resulting from the implementation of proposed restoration projects have been analyzed. Based on this analysis, the anticipated future conditions (with restoration) are described below.

To accomplish the Study objectives, Wolf Engineering, under subcontract to SWCA, has performed the following:

1. Optimized the configuration, distribution, and location of the proposed channel and floodplain restoration projects.
2. Conducted additional hydraulic analyses (incorporating the various restoration features in the models) for dry, average, and wet spring hydrologic scenarios, as well as quantified changes in channel/floodplain connectivity, channel and floodplain flow velocities and depths, and the spatial and temporal distribution of inundation limits.
3. Described the anticipated future geomorphic, hydrologic, and hydraulic conditions (with restoration).
4. Developed estimates of quantities (earthwork in particular) required for implementation of the various habitat improvement projects. This information has been used develop preliminary budgetary cost estimates for project construction.

The existing condition FLO-2D model and the existing condition HEC-RAS model for the Albuquerque Reach has served as the baseline models for these analyses. Results from the

HEC-RAS modeling have been used to aid in the selection and establishment of target inundation elevations for projects and features that are connected to the active river channel. To assess the effect on the channel/floodplain flow distribution and duration, the FLO-2D model has been used. The FLO-2D model has been modified to represent each of the major restoration features by making appropriate adjustments to 1) channel cross-sectional geometry, 2) floodplain grid elevations, and 3) floodplain and channel roughness parameters (n-values).

Due in large part to the variability of the hydrologic cycle in the MRG, proposed project features along the Albuquerque Reach have been designed to function (providing preferential habitat for the silvery minnow) for main channel discharges ranging between 1,500 and 3,500 cfs. At higher discharges, the proposed projects would continue to function and, in most cases, provide additional preferential habitat as additional floodplain areas become inundated.

Following the completion of the hydraulic modeling of the "with restoration" condition, SWCA has analyzed the effects of each project on silvery minnow and flycatcher habitat, vegetation, and existing habitat restoration projects implemented by others. The restoration site prescriptions and analysis are described below, including estimates of earthwork quantities for each site. the Conceptual Restoration Plan is provided in Appendix H, and the results of the "with restoration" FLO-2D modeling (3,500 and 6,000 cfs) are presented in Appendix I. Excavation quantity estimates and cost estimates for the completion of project designs and construction are included in Appendix J.

5.5.1 SECONDARY CONSERVATION UNIT

5.5.1.1 CORRALES FLYCATCHER HABITAT ENHANCEMENT PROJECT

General Description

The proposed project area is spread out over approximately 13 river km (8 river miles), beginning just downstream of Arroyo Venada and the Reclamation Sandia Priority Site (Reclamation 2006c) and extending to the outfall of the North Diversion Channel. Since the closure of Cochiti Dam, the channel has experienced some incision, especially in the upper portions of the subreach. The invert slope averages about 0.0010 feet/feet through the subreach. The left and right bank elevations are predominately stable and vary between 1.2 and 1.5 m (8–9 feet) above the thalweg. The subreach has a relatively constant W/D throughout the in-channel range of flows and is relatively low, ranging from about 46 at 500 cfs to about 61 at 6000 cfs. The floodplain does not experience inundation at flows below 7,000 cfs. There are numerous Reclamation river monitoring cross sections (including long-term cross sections [Cochiti Rangelines] that reflect recent changes in the active channel.

The Pueblo of Sandia has been active in implementing habitat restoration projects throughout the project area. The Pueblo of Sandia has implemented the Sandia Management of Exotics for Recovery of Endangered Species project (Reclamation 2008), a non-Collaborative Program project on a large bank-attached bar across from Barranca Arroyo, has constructed an overbank inundation channel funded by the Collaborative Program, and has conducted vegetation management throughout the bosque. The Pueblo of Sandia has completed the Sandia Subreach Habitat Analysis and Recommendations study (SWCA 2008) and is planning to implement a riverine habitat restoration project near the North Diversion Channel based on these recommendations (Reclamation 2010).

In addition, the Corps has identified habitat restoration projects to benefit the flycatcher through the MRG BRP. Reclamation (2006c) has completed the Sandia Priority Site project in the northern portion of the subreach, which was designed to provide some benefits to the silvery minnow.

Proposed Project

The Corrales Flycatcher Habitat Enhancement Project objectives are to increase the availability of flycatcher habitat through adding value to projects planned by the Corps through the MRG BRP. The Corps has identified several locations for willow swales, and we propose additional locations for flycatcher habitat through the creation of additional swales and flycatcher habitat enhancement through an active planting program. Flycatcher habitat enhancement would focus on establishing Goodding's and coyote willow. Additionally, three bars that were identified in the Sandia Subreach Habitat Analysis and Recommendations report (SWCA 2008) would be incorporated into the project to provide additional low-velocity habitat. These bar modifications would include construction of high-flow ephemeral channels, backwater/embayments, and bar terracing. Project data are summarized in Table 5.7.

Table 5.7. Corrales Flycatcher Habitat Enhancement Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PRb-a	B	4	SRU	Bar/Island Modification	42.16	1,500–2500	Residential habitat		Incorporate from Sandia Subreach Analysis and Recommendations, embayments and ephemeral channels on bar.
PRb-b	B	5	SRU	Bar/Island Modification	9.07	1,500–2,500	Residential habitat		Incorporate from Sandia Subreach Analysis and Recommendations, embayments and ephemeral channels on bar.
PRb-c	B	5	SRU	Bar/Island Modification	14.07	1,500–2,500	Residential habitat		Incorporate from Sandia Subreach Analysis and Recommendations, embayments and ephemeral channels on bar.
				Bar/Island Modification Total	**65.30**				
PRb-01	B	B-3	SRU	Flycatcher Habitat Enhancement	2.98			Establish large Goodding's willow stands within inundated floodplain.	Manage vegetation to control non-native invasive species and encourage native willow stands, especially Goodding's willow.
PRb-05	B	B-3	SRU	Flycatcher Habitat Enhancement	9.78			Establish large Goodding's willow stands within inundated floodplain.	Manage vegetation to control non-native invasive species and encourage native willow stands, especially Goodding's willow.
				Flycatcher Habitat Enhancement Total	**12.76**				
PRb-02	B	B-3	SRU	Willow Swales	0.39			Establish coyote and Goodding's willow habitat.	Excavate depressions then plant coyote and Goodding's willow.
PRb-03	B	B-3	SRU	Willow Swales	0.42			Establish coyote and Goodding's willow habitat.	Excavate depressions then plant coyote and Goodding's willow.
PRb-04	B	B-3	SRU	Willow Swales	1.44			Establish coyote and Goodding's willow habitat.	Excavate depressions then plant coyote and Goodding's willow.
PRb-06	B	B-3	SRU	Willow Swales	4.28			Establish coyote and Goodding's willow habitat.	Excavate depressions then plant coyote and Goodding's willow.
PRb-07	B	B-3	SRU	Willow Swales	9.12			Establish coyote and Goodding's willow habitat.	Excavate depressions then plant coyote and Goodding's willow.
				Willow Swales Total	**15.65**				
				Grand Total	**93.71**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

Anticipated Channel Morphology Response

Significant channel morphology response is not anticipated. Most of the proposed work consists of constructing flycatcher habitat in the historic floodplain. The bar modifications would provide additional shallow water areas at the threshold discharges; however, the entrenchment of the channel and the stabilized banks would preclude a significant change in the channel morphology.

Project Habitat Improvements

The project area is in an SRU, which in our conceptual model is a lower priority, requiring extensive habitat manipulations to create the affect the desired outcomes. The project would provide additional flycatcher habitat for migratory birds through increasing the availability of willow-dominated habitat. The depth to groundwater and availability of moist soil conditions during breeding season would be determining factors on whether the potential habitat could potentially develop to suitable breeding habitat.

Bar modifications have the potential to provide low-flow recruitment habitat and increase silvery minnow habitat heterogeneity within the subreach.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Any work completed in this subreach should include coordination with the Pueblo of Sandia. Coordination with the Pueblo of Sandia would include, but not limited to, addressing water quality concerns and potential impacts on the Pueblo of Sandia's habitat restoration projects, natural resources, and cultural resources. Additionally, the project area includes treatments that have been proposed in the Sandia Subreach Habitat Analysis and Recommendations report (SWCA 2008), which will require an additional level of coordination. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. If jetty jacks are to be removed as a part of the project, coordination with the Corps and/or Reclamation will be required. Coordination with the ABCWUA is also recommended on upstream sites to avoid interference with potential mitigation sites and to avoid potential problems with operating Alameda Diversion Dam. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels outside the 183-m (600-foot) nominal channel width. In the Corrales Flycatcher Habitat Enhancement Project area, the landowners and/or agencies include:

- Village of Corrales
- City of Rio Rancho
- Pueblo of Sandia

- Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA)
- Corps
- Reclamation
- MRGCD
- NMOSE
- Other private landowners

5.5.2 RESERVATION CONSERVATION UNIT 1 (RCU-1)

5.5.2.1 NORTH DIVERSION CHANNEL ACTIVE RIVER CHANNEL IMPROVEMENTS

General Description

The area proposed for restoration is adjacent to the outfall of the North Diversion Channel. Within Subreach 1, the river has variable cross section geometry with a series of bank-attached bars and islands that are covered with mature vegetation. There are four Reclamation river monitoring cross sections within the 3,048-m (10,000-foot) subreach (including one long-term cross section, CO-34) that reflect recent changes in the active channel. The invert slope of the active channel varies between 0.0008 and 0.0016 feet/feet. The left and right bank elevations are relatively consistent through this subreach and vary between 1.2 and 1.5 m (4–5 feet) above the thalweg. The W/D is relatively consistent throughout the in-channel range of flows.

Habitat restoration in the project area includes the NMISC Phase I and Corps MRG BRP recommendations. NMISC habitat restoration projects involve the modification or destabilization of bank-attached bars and islands and the creation of ephemeral channels and scallops. The proposed MRG BRP projects include bank destabilization, willow swale construction, water feature creation, and bosque vegetation management. The Pueblo of Sandia has identified habitat restoration projects on bank-attached bars and islands along the southern boundary (SWCA 2008) and is planning on implementing habitat restoration on bank-attached bars and islands around the North Diversion Channel (Reclamation 2010)

Proposed Project

The project objectives are to enhance wide, shallow channel morphology to enrich residential habitat diversity and increase intermediate and low-flow recruitment habitat. The project is intended to work in concert with bar modification projects already accomplished by the NMISC, as well as future bar and overbank projects planned by the NMISC, the Corps through the MRG BRP, and the Pueblo of Sandia. Proposed components of the project include bankline terrace modifications to promote floodplain coupling, two overbank inundation channels within the west overbank area with backwater/embayments at the inlet and outlet of each side channel, and the modification two stable bars on the east side of the river. North Diversion Channel Active River Channel Improvements project data are summarized in Table 5.8.

Table 5.8. North Diversion Channel Active River Channel Improvements Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR1-02	1	9	RCU-1	Backwater/ Embayment	0.18	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at entry of overbank inundation channel.
PR1-04	1	9	RCU-1	Backwater/ Embayment	3.86	1,500–2,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at downstream end of overbank inundation channel.
PR1-08	1	9	RCU-1	Backwater/ Embayment	0.32	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet of overbank inundation channel.
PR1-10	1	9	RCU-1	Backwater/ Embayment	1.45	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at downstream end of overbank inundation channel.
				Backwater/Embayment Total	**5.81**				
PR1-06	1	9	RCU-1	Bar/Island Modification	10.43	1,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Clear vegetation, lower bar through excavating approximately 0.3 to 0.6 m (1–2 feet) to create benches.
PR1-a	1	8	RCU-1	Bar/Island Modification	21.32	1,500–2,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Incorporate from Sandia Subreach Analysis and Recommendations, embayments and ephemeral channels on bar.
				Bar/Island Modification Total	**31.75**				
PR1-07	1	9	RCU-1	Floodplain Coupling/Bankline Lowering	1.34	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
				Floodplain Coupling/Bankline Lowering Total	**1.34**				

1 Table 5.8. North Diversion Channel Active River Channel Improvements Project Data Summary, continued

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR1-01	1	8	RCU-1	Hard Structure/Bendway Weirs	3.40	1,500	Residential habitat		Stabilize bank using bendway weirs or similar structure to push river to the west bank and create low-flow residential habitat.
PR1-05	1	9	RCU-1	Hard Structure/Bendway Weirs	3.14	1,500	Residential habitat		Stabilize bank using bendway weirs or similar structure to push river to the west bank and create low-flow residential habitat.
Hard Structure/Bendway Weirs Total					**6.53**				
PR1-03	1	9	RCU-1	Overbank Inundation Channel	3.06	3,000	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Create overbank inundation channel to connect with wetland feature proposed by the Corps MRG BRP.
PR1-09	1	9	RCU-1	Overbank Inundation Channel	2.98	3,000	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Create floodplain inundation channel to connect with willow swales proposed by the Corps MRG BRP.
Overbank Inundation Channel Total					**6.04**				
Grand Total					**51.47**				

2 * Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

The overbank inundation channels are expected to create suitable silvery minnow habitat at the threshold discharges. It is recognized that once these features begin to flow with a couple feet of depth, the velocities increase and suitable habitat may be affected. However, by limiting the engineering and "hardening" of these features such that their banks may erode during high flow, suitable habitat may be created in the overbank. Scallops, or small embayments, may be introduced within the channel to increase the likelihood of the desired outcome. Other factors that may increase effectiveness of the overbank inundation channels include constructing shallow side slopes constructed at a 4:1 or 5:1 slope instead of a 3:1 slope and avoiding placing sediments immediately adjacent to the channel in such a manner that limits the inundation of the surrounding landscape.

It is anticipated that a portion of the island modification work accomplished by the NMISC may have to be reworked when the overall project is implemented. Destabilization of the bars and the creation of the side channels would create additional shallow low-velocity habitat. The spoils material from the channel and embayment excavation would be used to create bank-attached bars on the opposite side of the river. These bars would be stabilized with willow plantings or bendway weirs. As with all of the proposed restoration projects, the specifics would need to be addressed in the final design and specifications. Figure 5.2 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Anticipated Channel Morphology Response

In addition to creating a more active channel, the objective is to improve the channel response to North Diversion Channel flooding. By stabilizing the proposed bank-attached bars on the east side of the river (with willow plantings and bendway weirs), the levee would be better protected. During flooding, the river would attack the west bank, altering the channel morphology and shifting the thalweg to the west side. The bank destabilization proposed for the west bank would encourage channel shifting. With sufficiently frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the channel would maintain a higher W/D and would maintain the bars and islands vegetation free. A slight increase in channel sinuosity would be observed over time, and the river would tend to meander slightly to the west. The project is located in Subreach 1, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should have a slightly net aggradational tendency over the next 50 years. Short-term channel responses to flooding or sediment loads can deviate from long-term trends and may require periodic adaptive management and maintenance.

Figure 5.2. Aerial photographs of the North Diversion Channel Active River Channel Improvements project vicinity.

Project Habitat Improvements

The projected silvery minnow habitat improvements would increase residential habitat diversity through the range of flows and increase high-flow recruitment habitat. Approximately 21 ha (51 acres) of new habitat would be created by this project. The project would arrest the channel narrowing in the subreach and improve the aquatic habitat diversity during high flows. With prescribed frequency of bankfull discharge, the channel bars and islands should remain mobile and free of vegetation, increasing the active channel habitat by approximately 20% of surface area.

Flycatcher habitat would be improved through a combination of implementation of the Corps MRG BRP projects and construction of the bosque inundation channel. Connecting the floodplain inundation channels with the proposed Corps MRG BRP willow swales and wetland features would be expected to increase productivity of the swale through inputs of nutrients and sediments carried by inundation flows. Inundation of the swales would be expected to increase the attractiveness of the sites as breeding habitat.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Coordination with the ABCWUA is also recommended on upstream sites to avoid interference with potential mitigation sites and to avoid potential problems with operating Alameda Diversion Dam. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels outside the 183-m (600-foot) nominal channel width. In the North Diversion Channel Active River Channel Improvement project area, the landowners and/or agencies include:

- City of Albuquerque
- Village of Corrales
- Pueblo of Sandia
- AMAFCA
- Corps
- Reclamation
- MRGCD
- ABCWUA
- NMOSE
- Other private landowners as appropriate

5.5.2.2 Paseo del Norte Floodplain/Channel Coupling

General Description

The area proposed for restoration extends from the Calabacillas Arroyo upstream of the Paseo del Norte Bridge downstream for about 2.4 km (1.5 miles). This subreach (Subreach 2) is relatively dynamic, and the active channel width varies reasonably well throughout the subreach most likely due to the sediment loading from the Calabacillas Arroyo upstream of the Paseo del Norte Bridge. The invert slope of the active channel through this subreach is slightly steeper than other subreaches within the Albuquerque Reach and is approximately 0.0014 feet/feet. The left and right bank elevations vary slightly and are generally between 1.8 and 2.4 m (6–8 feet) (relative to channel thalweg). The W/D is average for the range of in-channel flow. Additionally, six Reclamation river monitoring cross sections within the subreach reflect the recent channel conditions and depict the effects of sediment loading and channel diversity attributable to the Calabacillas Arroyo upstream of the project area.

The NMISC has implemented in-channel habitat restoration projects on the bank-attached bars and islands as part of Phase II and Phase IIa of the Riverine Restoration Project. The ABCWUA has identified sites in this subreach as part of the mitigation requirements for the Albuquerque Drinking Water Project (USFWS 2004). The Corps has proposed developing habitat features including additional willow swales and bosque vegetation management as a part of the MRG BRP.

Proposed Project

The objective of this project is to create recruitment habitat and high-flow residential habitat through bank-attached bar modification, constructing overbank inundation channels and a large backwater feature. The project consists of connecting the Calabacillas Arroyo to the river channel; modifying the west side bank-attached bar immediately downstream of the arroyo; constructing two overbank inundation channels (one within the west overbank and the other within the east overbank), each with excavated embayments at the inlets and outlets; and constructing a large backwater on the east side of the river. The goal at the Calabacillas Arroyo is to mobilize sediments. Arroyo connectivity will be enhanced through the removal of sediment at the mouth to create an embayment. The modification will include creating a terrace to inundate at lower flows along the channel margin. Recent upstream development on the Calabacillas Arroyo (e.g., urbanization and flood/sediment control structures) has altered the hydrology and morphology of this tributary. It is rationalized that disturbing some of the vegetated areas near the confluence will help create a more active main channel in which variable habitat will naturally occur with the ebb and flow of the arroyo.

The overbank inundation channels follow remnant flow lines as much as possible to minimize excavation on the project. The inlet and outlet points of these channels have been carefully analyzed and designed in order to prevent sedimentation and potential closure. Channel modifications include creating a moist soil depression in the middle of the channel to provide silvery minnow habitat across a wider range of flows and to facilitate flycatcher habitat regeneration. Other design considerations that would need to be addressed include the side slope and sediment disposal. The overbank inundation channels would add overall channel diversity at mid to high flows by creating additional low-depth, low-velocity habitat for fish.

The backwater connects to a depression, assumed to have been created during the construction of the levee. This offers an opportunity to minimize excavation costs and create a large backwater feature that remains wetted during low-flow periods. Bankline jetty jacks would likely need to be removed at the backwater. Project data are summarized in Table 5.9, and Figure 5.3 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.9. Paseo del Norte Floodplain/Channel Coupling Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR2-01	2	10	RCU-1	Arroyo Connectivity	2.10	2,500	Residential habitat		Destabilize through vegetation removal; excavate to increase inundation.
				Arroyo Connectivity Total	**2.10**				
PR2-03	2	10	RCU-1	Backwater/ Embayment	8.39	1,500–2,500	Low- to Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create bankline embayment; connect to "ditch" by levee (from Bosque Feasibility Study [Corps 2010]).
PR2-04	2	11	RCU-1	Backwater/ Embayment	0.48	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at upstream entry of overbank inundation channel.
PR2-06	2	11	RCU-1	Backwater/ Embayment	0.50	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at downstream end of overbank inundation channel.
PR2-07	2	11	RCU-1	Backwater/ Embayment	0.46	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at entry of overbank inundation channel.
PR2-09	2	11	RCU-1	Backwater/ Embayment	0.85	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at downstream end of floodplain inundation channel.
				Backwater/Embayment Total	**10.68**				
PR2-02	2	10	RCU-1	Bar/Island Modification	6.49	1,500	Low- to Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create terrace on bar to increase inundation at lower flows.
				Bar/Island Modification Total	**6.49**				
PR2-05	2	11	RCU-1	Overbank Inundation Channel	4.40	3,000	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Create floodplain inundation channel following existing contours to link low-lying depressions; enhance flycatcher habitat in floodplain depressions.
PR2-08	2	11	RCU-1	Overbank Inundation Channel	1.73	3,000	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Create floodplain inundation channel; connect to MRG BRP feature.
				Overbank Inundation Channel Total	**6.14**				
				Grand Total	**25.40**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

Figure 5.3. Aerial photographs of the Paseo del Norte Floodplain/Channel Coupling project vicinity.

Flycatcher habitat would be established in relation to the floodplain inundation channels, embayments, and backwaters. Goodding's willow would be established in swales and along the floodplain channel margins through an active revegetation program, and coyote willow would be established in the backwaters and embayments either through an active revegetation program or through encouraging natural regeneration. Noise and human activity associated with the Paseo del Norte Bridge may be a negative factor, reducing the potential of habitats in this area to support flycatchers.

Anticipated Channel Morphology Response

There would be no significant change in the overall Rio Grande channel morphology of the subreach. The project is located in Subreach 2, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should be approximately in equilibrium over the next 50 years. Therefore, the inlets and outlets for the side channels have a reasonable chance of staying functional for the design discharges over the project life. With sufficiently frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the main channel should maintain its diversity and favorable heterogeneity throughout the subreach.

Project Habitat Improvements

The projected silvery minnow habitat improvements would include additional shallow, low-velocity habitat at mid to high flows, while increasing retention and residential habitat during high flows. Approximately 10 ha (25 acres) of new habitat would be created at the threshold discharge conditions by this project. With appropriate frequency of bankfull discharge, the existing, active channel bars and islands would remain mobile and free of vegetation, preserving the diversity of active channel habitat at the range of in-channel flow.

Flycatcher habitat would be improved through the establishment of dense willow stands associated with frequently inundated floodplain. The bosque inundation channels would be expected to increase soil moisture and nutrient inputs into willow swales and floodplain depressions, thereby enhancing productivity and enhancing the effectiveness of these areas and increasing the attractiveness of the sites as breeding habitat.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. The ABCWUA is planning mitigation projects associated with the Albuquerque Drinking Water Project in this subreach. Coordination with the ABCWUA is also recommended on upstream sites to avoid potential problems with operating Alameda Diversion Dam. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels outside the (183-m) 600-foot nominal channel width. In the Paseo del Norte High-flow Side Channels project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation
- MRGCD
- ABCWUA
- NMOSE

5.5.3 Primary Restoration Unit (PRU)

5.5.3.1 Montaño Wetlands

General Description

The area proposed for restoration is a 1.6-km (1-mile) subreach of the west side floodplain between the Corrales Main Wasteway (CORWW) (also known as the La Orilla drain outfall) to the river (upstream end) and the Montaño Bridge. The concept presented in this proposed project is to take advantage of a supplemental water source provided by the CORWW to create and maintain willow swales and moist soil environments for the benefit of the flycatcher. An overbank inundation channel excavated in the floodplain would convey the water and provide silvery minnow recruitment habitat.

This overbank area is not currently inundated by a discharge less than 7,000 cfs. A series of jetty jack lines extends from the active channel westward onto the floodplain throughout the subreach that would be removed. In this subreach, the river has a relatively uniform cross section at high flows. At low flows, however, there is some variation in the channel geometry with alternating bank-attached bars along the subreach. The invert slope of the active channel varies between 0.001 feet/feet in the upper half of the subreach to 0.0002 feet/feet near the Montaño Bridge. The left and right bank elevations are relatively uniform throughout the subreach and vary between 2.1 and 2.4 m (7–8 feet) (relative to channel thalweg). The W/D for the range of flows up to bankfull discharge is about the average W/D for most of the Albuquerque Reach. Three river monitoring cross sections are within the 1.6-km (1-mile) subreach (including one long-term section, CO-35) that provide recent context regarding changes in the active channel.

The NMISC has implemented in-channel habitat restoration projects, including the modification of the bank-attached bars and islands and the removal of a line of jetty jacks.

Proposed Project

The proposed project involves developing a large wetland (moist soil habitat enhancement) and constructing willow swales. Dense stands of Goodding's and coyote willow would be planted in the moist soil habitat enhancement area and in the willow swales. The wetland area and the willow swales would be connected hydrologically to a floodplain overbank channel that meanders through the floodplain. The floodplain overbank channel would be somewhat sinuous to provide silvery minnow habitat over a range of flows. Embayments/backwaters would be excavated at the inlet and outlet of the channel to provide silvery minnow recruitment habitat.

To provide flexibility in introducing flow into or out of the proposed project, control structures could be constructed on the upstream end of the overbank inundation channel at the CORWW and at the downstream end of the channel. The hydraulic control constructed in the CORWW (e.g., gated weir/turnout) would divert flow through the overbank channel to the wetlands and the willow swales to provide moist soil conditions during flycatcher breeding season or during low-flow conditions. The downstream hydraulic control could be constructed near the wetland/backwater interface to permit the wetlands to be periodically drained and to allow native fish to return to the river during the descending limb of the hydrograph. The elevations of the control structures at the river connection points are set such that water can be introduced to the side channel and wetland area at main channel discharge of about 1,500 cfs. During the flycatcher breeding season or during the summer months, the drain could provide water to enhance the riparian wetland habitat. Jetty jacks on the west floodplain would be removed with the floodplain channel excavation. Project refinements that may need to be addressed during the design and specifications phase include modifying the location of the inlet and outlets to ensure a sufficient gradient to minimize silvery minnow entrapment, modifying the location of the hydraulic control (e.g., may be located at the Lower Corrales Riverside Drain), incorporating additional measures to address storm water-quality[13] and availability, or ensuring adequate water supply through groundwater pumping.

Project data are summarized in Table 5.10. Figure 5.4 shows a series of aerial photographs of the project vicinity, identifying proposed features.

[13] While water quality is a concern due to the nature of the source of water, passing the water through a wetland instead of directly inputting into the river may provide some benefits.

Table 5.10. Montaño Wetlands Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR3-01	2	12	PRU	Backwater/ Embayment	0.06	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create entry to the overbank channel from La Orilla Drain. Use a hydraulic control (e.g., gated weir) in the drain to control water diversion into the floodplain. Construct downstream hydraulic control to control water levels in the created wetland.
PR3-03	2	12	PRU	Backwater/ Embayment	1.36	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at upstream entry of overbank inundation channel.
PR3-05	2	12	PRU	Backwater/ Embayment	1.95	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at downstream mouth of overbank inundation channel.
Backwater/Embayment Total					**3.37**				
PR3-04	2	12	PRU	Moist Soil Habitat Enhancement	13.75	1,500	High-flow recruitment habitat	Establish large Goodding's willow stands within inundated floodplain.	Establish wetland feature through enhancing existing wetland depressions adjacent to the floodplain inundation channel.
Moist Soil Habitat Enhancement Total					**13.75**				
PR3-02	2	12	PRU	Overbank Inundation Channel	8.64	1,500	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Construct large floodplain inundation feature; may be connected to the La Orilla Drain and the river with backwater outlets using hydraulic controls.
Overbank Inundation Channel Total					**8.64**				
PR3-w	2	12	PRU	Willow Swales	4.89			Establish Goodding's willow and coyote willow.	Excavate depressions then plant coyote and Goodding's willow. Depressions may be connected hydrologically to the overbank inundation channel.
Willow Swales Total					**4.89**				
Grand Total					**30.66**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

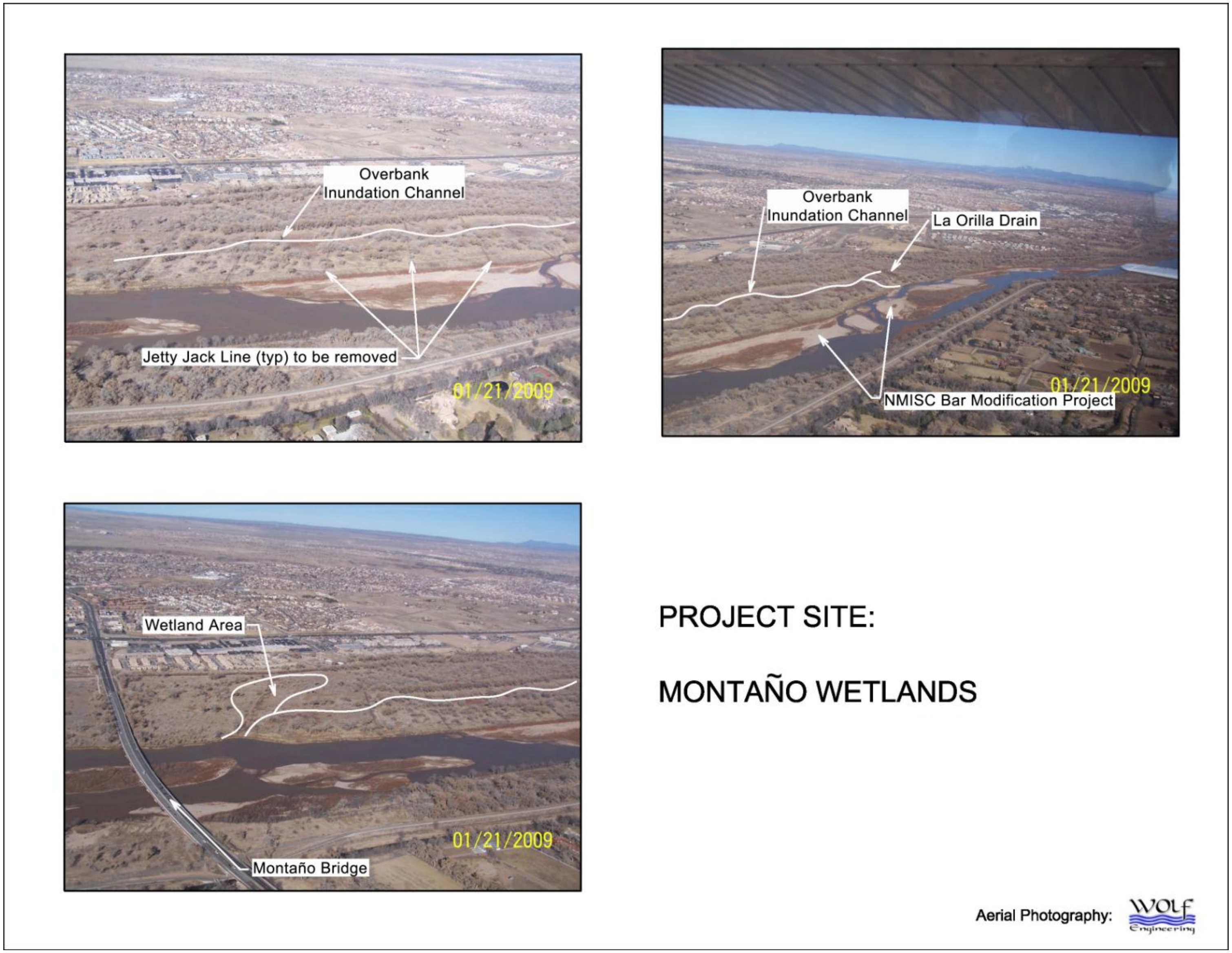

Figure 5.4. Aerial photographs of the Montaño Wetlands project vicinity.

This site provides an opportunity to establish large patches of flycatcher habitat associated with the floodplain wetlands. Existing stands of coyote willow that have regenerated since the City of Albuquerque implemented invasive vegetation control management suggests that the depth to groundwater is sufficient to support willow growth. However, the site is unproductive and lacks the hydrologic characteristics necessary to support flycatcher breeding habitat. The site would therefore likely be suitable for willow swale construction. Connecting the willow swales to the overbank inundation channel could provide the hydrologic connection and nutrients necessary to increase productivity on the site to support breeding flycatcher habitat. Flycatcher habitat enhancements would include planting Goodding's willow and coyote willow in the wetland area. Coyote willow would be the predominant species planted in the willow swales and are appropriate at the channel edge associated with the embayments and backwaters. As with other sites near roadways and infrastructure, human activity and disturbance may hinder flycatcher establishment here; however, migratory flycatchers have been observed at the San Antonio Oxbow. This remains a data gap and needs further investigation and monitoring (see Chapter 7).

Anticipated Channel Morphology Response

The objective of this project is to create wetland, backwater, and floodplain side channel habitat in conjunction with the enhanced active channel. There would be no significant change in the overall channel morphology of the subreach. The project is located in Subreach 2, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should be approximately in equilibrium over the next 50 years. Therefore, the inlets and outlets for the side channels have a reasonable chance of staying functional for the design discharges over the project life. With sufficiently frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the channel would maintain a higher W/D and would sustain vegetation-free bars and islands.

Project Habitat Improvements

The projected silvery minnow habitat improvements include river backwater habitat upstream of the Montaño Bridge and at the location of the upstream overbank channel inlet, a floodplain side channel, and constructed wetlands. Approximately 12.5 ha (31 acres) of new habitat, including 8 ha (20 acres) of flycatcher habitat in the created wetland (moist soil habitat enhancement) area, and willow swales would be created by this project. It is proposed that fish would enter the floodplain side channel at both ends and use the wetland area during high flows. As the flow recedes, the native fish would seek return to the river channel. Hydraulic controls at both the upstream and downstream ends would enable the wetlands to be maintained throughout the year. Augmentation flow would be diverted from the drain return during low-flow conditions to sustain the wetlands during stress periods or during flycatcher breeding season. The downstream control can also be used to periodically drain and dry out the wetland. Observation of the inlet and outlet conditions following high flows would be necessary to perform any required sediment deposition maintenance. With appropriate frequency of bankfull discharge, the reworked channel bars and islands would remain mobile and free of vegetation, increasing the active channel habitat by +/-10% of surface area.

Flycatcher habitat improvements would result from the establishment of large tracts of Goodding's willow in the wetland and coyote willow in the willow swales. Goodding's willow is not prevalent in the Albuquerque Reach; however, it achieves the height and stem structure that coyote willow often does not. The large area and the opportunity to provide a consistent water supply make this area an attractive option.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. The City of Albuquerque is the fee-simple owner of land from the La Orilla outfall channel to the south end of the San Antonio Oxbow. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. The ABCWUA is planning mitigation projects associated with the Albuquerque Drinking Water Project in this subreach. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels and other habitat features outside the 183-m (600-foot) nominal channel width. In the Montaño Bridge Wetlands project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation
- MRGCD
- ABCWUA
- NMOSE

5.5.3.2 San Antonio Oxbow Wetland Enhancements

General Description

The river channel is relatively uniform through the broad bend subreach near the San Antonio Oxbow. The subreach is generally free of vegetated bars and islands, and the area proposed for restoration is a 1,219-m (4,000-foot) subreach along the west overbank of the river at the oxbow site. The oxbow wetland area typically is saturated through connection to groundwater. The invert slope of the active channel adjacent to the oxbow is approximately 0.0009 feet/feet. The left and right channel bank elevations are relatively uniform, varying between 1.8 and 2.1 m (6–7 feet) above the thalweg. The W/D for low flows is more favorable for the silvery minnow and less beneficial as flow increases. There are three Reclamation cross sections within the subreach that reflect the changes in the active channel since the 1990s. This subreach of the river is unique within the Albuquerque Reach in that it retains some semblance of the historical floodplain attributes. This is a high-priority area that currently functions as historic riparian floodplain.

The Corps plans to destabilize the west bank of the active channel adjacent to the San Antonio Oxbow, restore water features, and implement vegetation management as a part of its MRG BRP. The Corps has already constructed a bosque inundation channel on the east side of the river near the Rio Grande Nature Center.

Proposed Project

The goal of the San Antonio Oxbow Wetland Enhancement project is to enhance and increase the availability of flycatcher habitat. Habitat enhancements would include activities to augment the Corps' proposed work as a part of the MRG BRP, as well as establishing dense Goodding's willow stands and managing vegetation in the San Antonio Oxbow to provide the vegetation structure and density characteristic of breeding habitat. Additional flycatcher habitat would consist of constructing willow swales on the east side of the river. The proposed swales take advantage of existing depressions in the floodplain.

Project data are summarized in Table 5.11. Figure 5.5 shows a series of aerial photographs of the project vicinity, identifying proposed features.

1 Table 5.11. San Antonio Oxbow Wetland Enhancements Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR4-2	3	13	PRU	Floodplain Coupling/Bankline Lowering	0.10	3,500	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood.	Remove natural levee along bankline to permit more frequent floodplain inundation.
PR4-4	3	13	PRU	Floodplain Coupling/Bankline Lowering	0.35	3,500	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood.	Remove natural levee along bankline to permit more frequent floodplain inundation.
Floodplain Coupling/Bankline Lowering Total					**0.45**				
PR4-a	3	13	PRU	Flycatcher Habitat Enhancement	75.52			Establish large Goodding's willow stands within inundated floodplain.	Manage vegetation to control non-native invasive species and encourage native willow stands, especially Goodding's willow; included in MRG BRP.
Flycatcher Habitat Enhancement Total					**75.52**				
PR4-1	3	13	PRU	Willow Swales	12.45			Establish Goodding's willow and coyote willow.	Excavate depressions in the floodplain and plant coyote and Goodding's willow.
PR4-3	3	13	PRU	Willow Swales	4.32			Establish Goodding's willow and coyote willow.	Excavate depressions in the floodplain and plant coyote and Goodding's willow.
Willow Swales Total					**16.76**				
Grand Total					**92.73**				

2 * Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

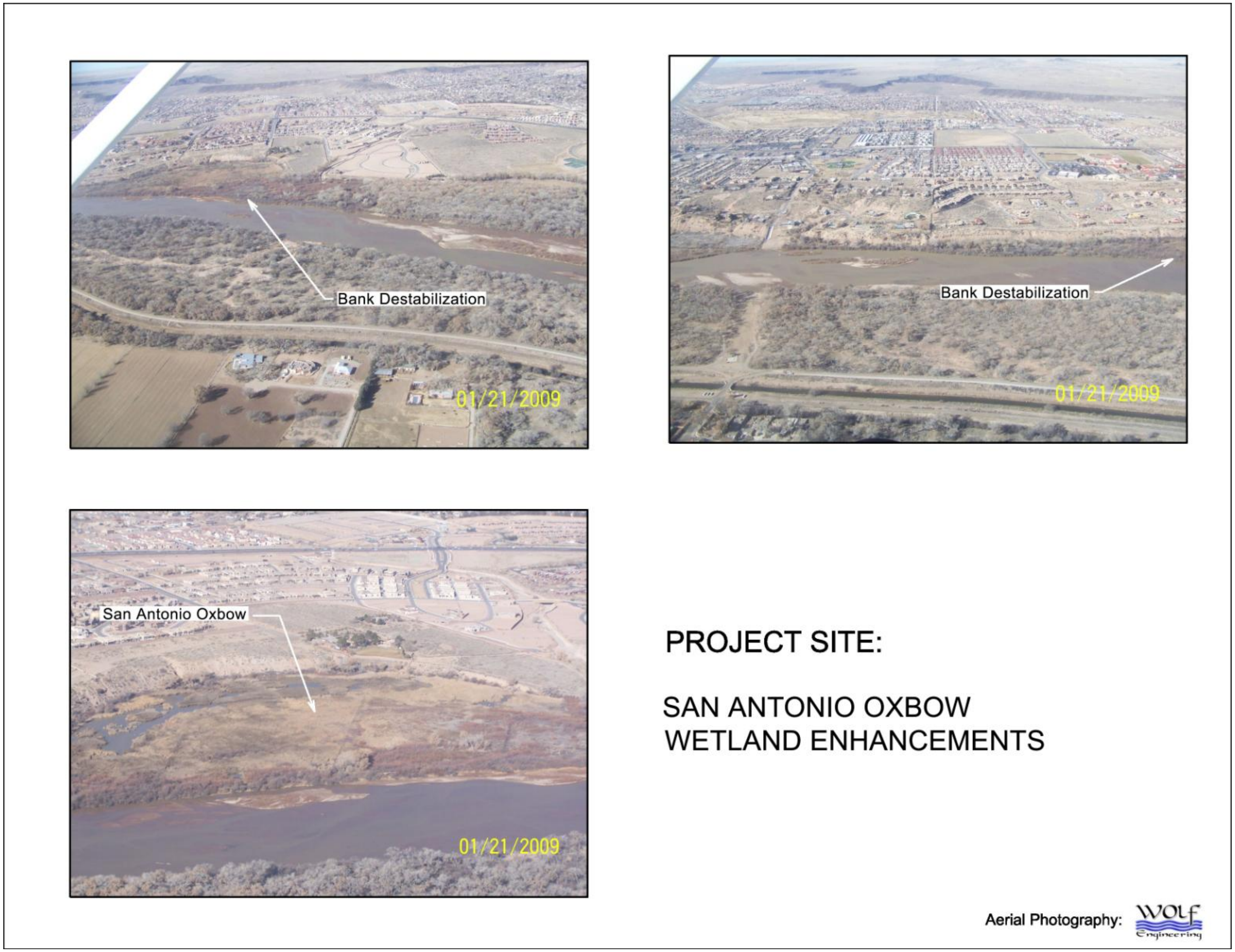

Figure 5.5. Aerial photographs of the San Antonio Oxbow Wetland Enhancements project vicinity.

Anticipated Channel Morphology Response

The objective of this project is to create and enhance flycatcher habitat in the floodplain. No modifications to the river channel are proposed. The project is located in Subreach 3, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should be slightly degradational over the next 50 years. With the Corps' proposed destabilization of the west river bank between the wetland inlet and outlet, there may be some minor river channel migration to the west over time that would enhance and sustain the natural function of the wetlands. Any lateral shift of the channel would be accompanied by some sand bar development on the opposite bank. There would be no significant change in the overall channel geometry of the subreach.

Project Habitat Improvements

The projected habitat improvements include enhanced wetlands functionality and fish access. It is proposed that fish would enter the wetlands from both ends and use the wetland area during high flows. As the flow recedes, the native fish would seek return to the river channel. Hydraulic controls (gated weir) at both the upstream and downstream ends would enable the wetlands to be maintained throughout dry years. Augmentation flow from the drain would be diverted to the wetlands during stress periods. The downstream control can also be used to drain and dry out the wetland periodically. Observation of the inlet and outlet conditions following high flows would be necessary to perform any required sediment removal.

The San Antonio Oxbow is a critical area for establishing flycatcher breeding habitat because of its consistent water supply and relative large size. This site, in conjunction with Montaño Wetlands project, will provide relatively close, large habitat patches. Thus, these sites are a priority for flycatcher habitat restoration in the middle sections of the Albuquerque Reach.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. The City of Albuquerque is the fee-simple owner of land from the La Orilla outfall channel to the south end of the San Antonio Oxbow. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Although the restoration recommendations do not include work outside of the 183-m (600-foot) nominal channel width, coordination with the NMOSE is nonetheless recommended to ensure that restoration activities will not result in net depletions. In the San Antonio Oxbow Wetlands Enhancement project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps

- Reclamation
- MRGCD
- NMOSE

5.5.4 Reserve Conservation Unit 2 (RCU-2)

5.5.4.1 I-40 High-flow Ephemeral Channel

General Description

The area proposed for restoration is a 1.6-km (1-mile) river subreach upstream of I-40 crossing over the river. This subreach is relatively straight and narrow with a high bluff along the entire west side located approximately 122 m (400 feet) from the west bank of the active channel. Largely because of the bluff, the river is constricted through this subreach. The proposed project area on the west-side bank attached bar is privately owned. There may be landownership concerns in this subreach that would need to be addressed before initiating further analysis of this project area.

The invert slope of the active channel through this subreach is approximately 0.0009 feet/feet. The opportunity for overbank flooding in this subreach is not significant, as the bank elevations vary between 1.8 and 2.1 m (6–7 feet) above the channel thalweg. The W/D is favorable for fish habitat at low flows, but it decreases at higher flows, becoming less favorable. There are three short-term Reclamation river monitoring cross sections within the subreach that reflect the recent channel conditions.

The NMISC has completed bar modification and large woody debris projects within this project area. The City of Albuquerque and the Corps have implemented bosque thinning projects following the 2003 bosque fire. Reclamation has completed extensive modification of the bank-attached bar, known locally as "Mickey's bar," on the left bank downstream from I-40, including the creation of embayments. Downstream from the project area, the NMISC has created extensive silvery minnow habitat features in and around the Atrisco Drain.

Proposed Project

The project is designed to provide residential habitat at higher flows by creating a parallel high-flow ephemeral channel with embayments at the inlet and outlet of the channel on the west bank-attached bar. The channel would be somewhat sinuous with scallops or embayments within the interior to create more diverse habitat and mitigate against sedimentation. Backwater/embayment features would be constructed at the inlet and outlet of the high-flow ephemeral channel. In addition to the upstream and downstream connection points to the active channel, the project would have one mid-channel connection point in which a small embayment outlet would be excavated to promote and enhance the reconnection to the river at a range of flows. The channel and embayment are aligned along the lowest remnant channel threads and existing low-lying areas in an effort to minimize excavation. The ephemeral channel would add overall channel diversity at mid to high flow by creating additional low-depth, low-velocity habitat for fish. The site has been closely analyzed and modeled for water surface elevations in order to successfully get flow into the overbank channel and backwater. The elevations of the river connection points have been set such that water can be introduced to the ephemeral channel at main channel discharge of 2,500 cfs. In addition, the project proposes to modify the island at the outlet to mobilize sediment and increase overbank inundation. We are also proposing a moist soil habitat management treatment on the bank-attached bar on the east side of the river, immediately downstream from the I-40 Bridge. The purpose is to provide additional flycatcher habitat that would augment existing work completed by the NMISC and Reclamation. Project data are summarized in Table 5.12. Figure 5.6 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.12. I-40 High-flow Ephemeral Channel Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR5-01	3	14	PRU	Backwater/ Embayment	0.17	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at entry of ephemeral channel.
PR5-03	3	14	PRU	Backwater/ Embayment	0.22	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment/backwater at mouth of side ephemeral channel.
PR5-06	3	14	PRU	Backwater/ Embayment	0.07	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment/backwater at downstream mouth of ephemeral channel.
Backwater/Embayment Total					**0.46**				
PR5-02	3	14	PRU	High-flow Ephemeral Channel	7.50	2,500	Residential habitat		Create high-flow ephemeral channel on bank-attached bar.
High Flow Ephemeral Channel Total					**7.50**				
PR5-05	3	14	PRU	Island/Bar Destabilization	3.70	1,500	Residential habitat		Remove vegetation and destabilize island to promote geomorphic response.
Island/Bar Destabilization Total					**3.70**				
PR5-07	3	15	PRU	Moist Soil Habitat Enhancement	11.99	2,500	Intermediate-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Connect to existing restored habitat features; establish dense willow stands through natural revegetation.
Moist Soil Habitat Enhancement Total					**11.99**				
PR5-04	3	14	PRU	Willow Swales	4.09			Establish coyote willow habitat.	Create willow swale along length of the bluff.
Willow Swales Total					**4.09**				
Grand Total					**27.75**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

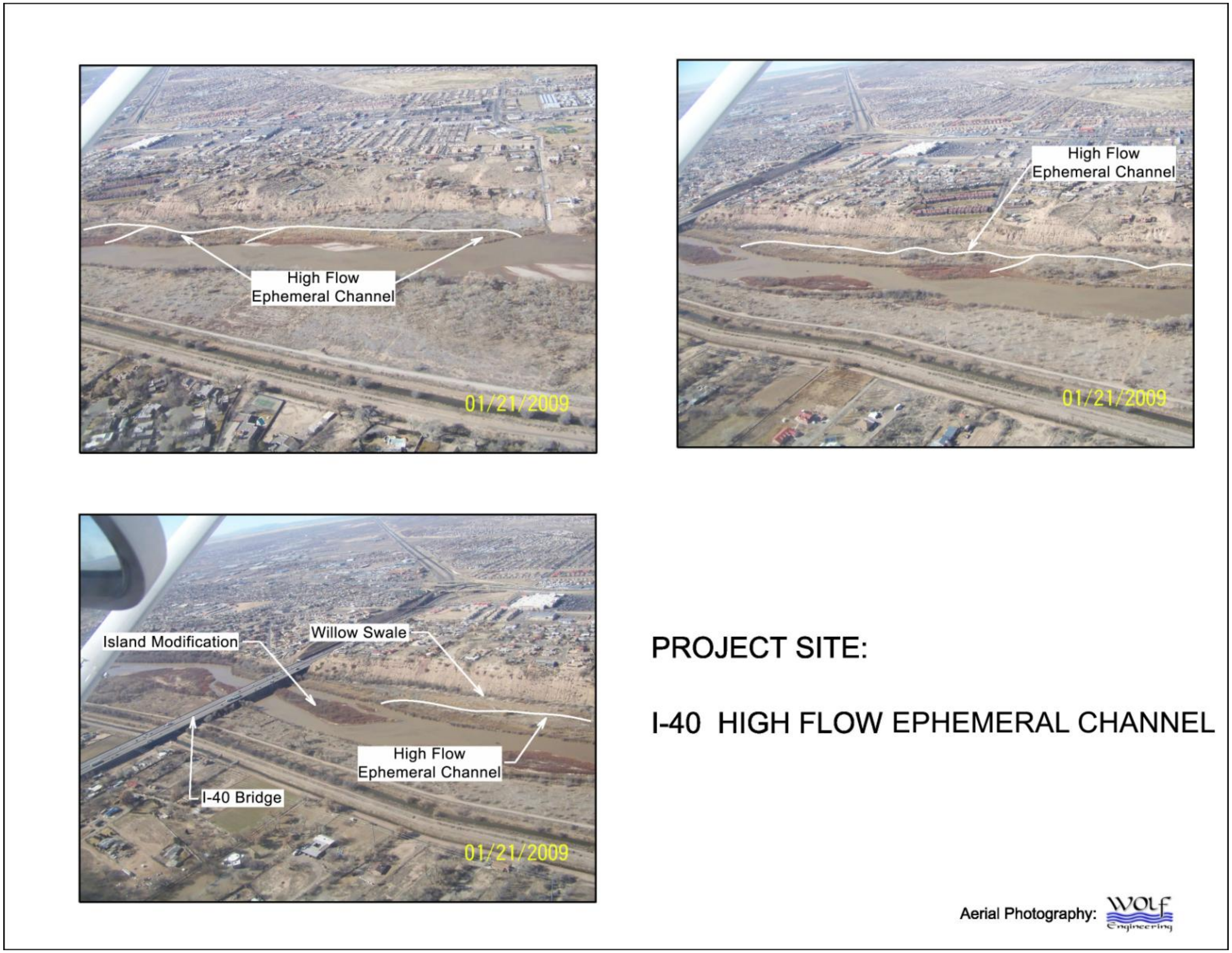

Figure 5.6. Aerial photographs of the I-40 High-flow Ephemeral Channel project vicinity.

Coyote willow plantings would be implemented at the base of the bluff to provide bank protection and additional flycatcher habitat. These plantings would consist of two rows and extend throughout the length of the ephemeral channels. Permission from the landowners on the west side would need to be obtained prior to implementing this project.

Anticipated Channel Morphology Response

The objective of this project is to create low- to mid-flow recruitment and residential habitat through a relatively long floodplain side channel. There would be no significant change in the overall channel morphology of the subreach. With the island/bar near the bottom of this subreach reworked as part of the recommended plan, there would be a slight increase in favorable habitat across the range of active channel flows. Similar to the Montaño Bridge Wetlands project, this project is located in Subreach 2, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should be slightly degradational over the next 50 years that may enhance the opportunity for long-term connectivity. With sufficiently frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the channel would maintain a slightly higher W/D.

Project Habitat Improvements

The projected silvery minnow habitat improvements would increase the availability of shallow low-velocity habitat at higher flows and increase recruitment habitat during high flows. Approximately 11 ha (28 acres) of new habitat would be created by this project. The project would decrease the uniformity of flow conditions during high flows. With appropriate frequency of bankfull discharge, the existing active channel bars would remain mobile and free of vegetation, increasing the diversity of active channel habitat at low flow.

Flycatcher habitat would be provided through the establishment of coyote willow along the base of the bluff. Coyote willows would be expected to spread clonally and provide migratory habitat. In time, if moist soil conditions exist during the breeding season, breeding habitat may be provided.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. The bank-attached bar on the west side of the river is privately owned with more than 20 individual landowners. Construction access will also need to be coordinated early in the project planning. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. All proposed work would be within the 183-m (600-foot) nominal channel width, nonetheless coordination with the NMOSE is recommended. In the I-40 High-flow Side Channel project area, the landowners and/or agencies include:

- City of Albuquerque
- Corps
- Reclamation
- MRGCD
- NMISC
- NMOSE
- Private Landowners

5.5.4.2 Bridge Street Floodplain/Channel Coupling

General Description

The area proposed for restoration is a 1.6-km (1-mile) river subreach centered on the Bridge Street river crossing in Subreach 4. The river makes a wide southwesterly turn through this subreach and has a relatively constant active channel width of 183 m (600 feet) at bankfull flow. At lower flows the active channel exhibits alternating bank-attached bars and two mid-channel islands downstream of Bridge Street. The invert slope of the active channel through this subreach is approximately 0.0009 feet/feet. The left bank of the active channel is slightly lower than the right bank; thus, there is the opportunity for overbank inundation along the outside of the channel curve in this subreach. Under current conditions, the overbank areas on both sides of the active channel around and downstream of Bridge Street experience some inundation at higher flows (> 5,000 cfs). The average W/D through this subreach is more favorable for residential habitat at higher discharges than other subreaches through the Albuquerque Reach. There are four short-term Reclamation river monitoring cross sections within the subreach that reflect the recent channel conditions.

The Corps has implemented the Route 66 Project in the Bridge Street Channel-Floodplain Coupling project area and proposes to construct wetland features near Tingley Beach, construct willow swales, and implement bosque vegetation management. The NMISC has modified the bank-attached bars to create ephemeral channels and destabilize vegetation. The Reclamation Albuquerque Overbank Project is just downstream of the project area, and the Tingley Beach ponds are upstream of the project area.

Proposed Project

The project is designed to provide mid- to high-flow recruitment habitat by creating a floodplain/active channel coupling at a more frequent peak discharge and to provide flycatcher habitat. The project involves lowering the bank of the left (east) side of the active channel in three locations and at one location on the right (west) side of the channel. The locations have been selected in areas where a discernable "lip" or natural levee has formed on the active channel bank. These natural levees are created by sediment deposition during overbank flows in dense vegetation along the bank (Hudson 2005) and can be removed at relatively low cost to increase overbank flood inundation. Bank excavation would enable inundation to initiate at discharges between 3,000 and 3,500 cfs. Additionally, an overbank inundation channel would be constructed on the right side of the channel to further bring water into the floodplain and a large backwater feature would be cut into the floodplain to take advantage of a moist soil depression to create a slackwater area for silvery minnow recruitment and provide willow habitat for the flycatcher. The overbank inundation channel would be follow to the extent possible existing natural depressions in the floodplain and would be somewhat sinuous and contain scallops or embayments to provide habitat for the silvery minnow at a broader range of flows and to mitigate against sedimentation. The backwater treatment is brought forth from projects proposed by the Corps in the Bosque Feasibility Study, but not included in the final site selection for the MRG BRP. Flycatcher habitat enhancements also would consist of the construction of two large willow swales. Project data are summarized in Table 5.13. Figure 5.7 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.13. Bridge Street Floodplain/Channel Coupling Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR6-08	4	17	RCU-2	Backwater/ Embayment	6.57	2,500–3000	Intermediate- to high-flow recruitment habitat	Establish large Goodding's willow stands along floodplain depression, embayment; establish coyote willow stands adjacent to river channel.	Create large embayment into bankline and connect to floodplain depression (from Corps Bosque Feasibility Study).
				Backwater/Embayment Total	**6.57**				
PR6-01	4	16	RCU-2	Floodplain Coupling/Bankline Lowering	1.78	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
PR6-05	4	17	RCU-2	Floodplain Coupling/Bankline Lowering	0.58	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
PR6-06	4	17	RCU-2	Floodplain Coupling/Bankline Lowering	0.58	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
PR6-07	4	17	RCU-2	Floodplain Coupling/Bankline Lowering	0.58	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
PR6-09	4	17	RCU-2	Floodplain Coupling/Bankline Lowering	0.37	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
				Floodplain Coupling/Bankline Lowering Total	**3.90**				
PR 6-04	4	17	RCU-2	Overbank Inundation channel	2.91	3,000	High-flow recruitment habitat	Establish Goodding's willow and coyote willow.	Create floodplain inundation channel following existing contours to link low-lying depressions; enhance flycatcher habitat in floodplain depressions.
				Overbank Inundation Channel Total	**2.91**				
PR6-02	4	16	RCU-2	Willow Swales	5.50			Establish Goodding's willow and coyote willow.	Excavate depressions then plant coyote and Goodding's willow.
PR6-03	4	16	RCU-2	Willow Swales	5.65			Establish Goodding's willow and coyote willow.	Excavate depressions then plant coyote and Goodding's willow.
				Willow Swales Total	**11.14**				
				Grand Total	**24.52**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

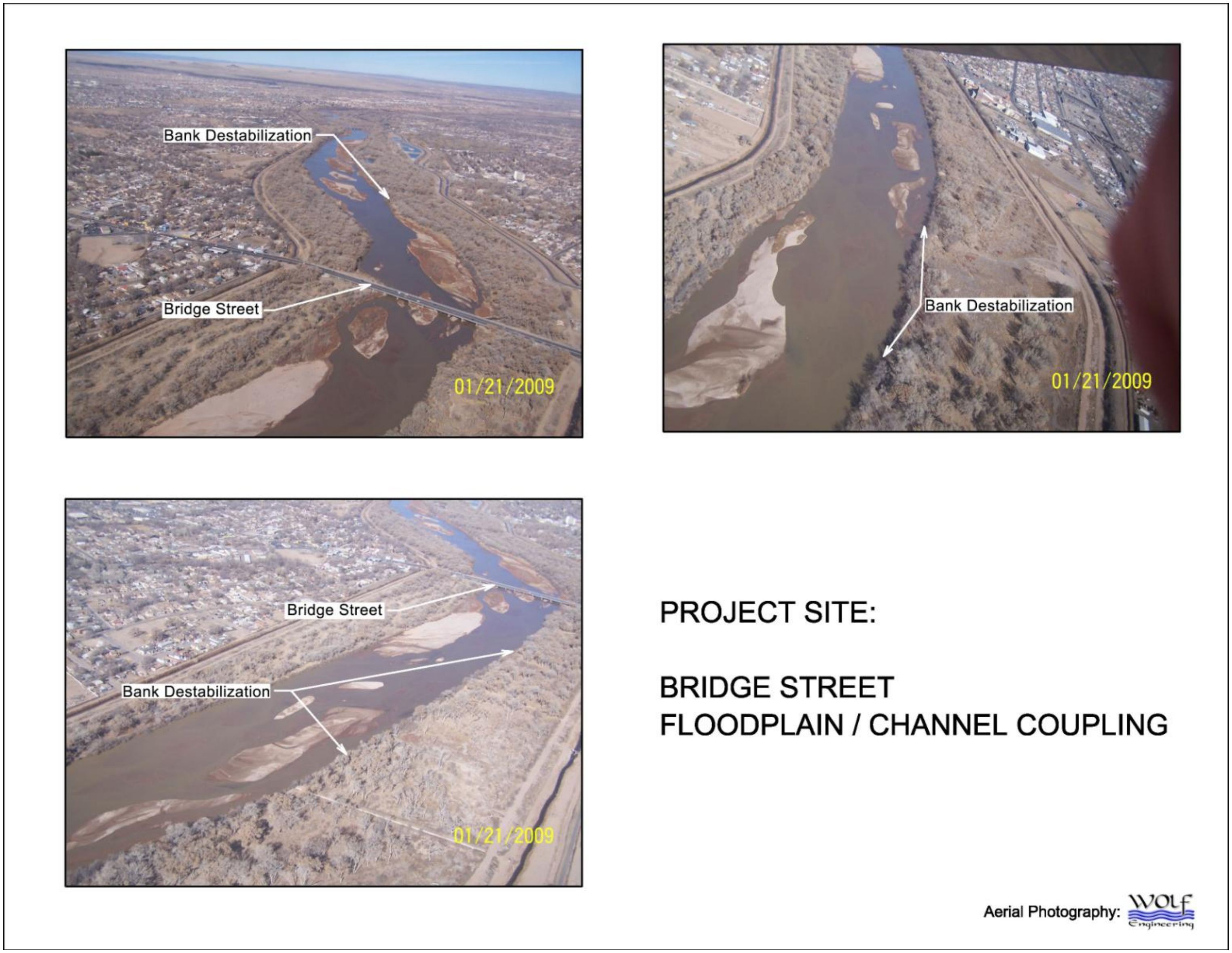

Figure 5.7. Aerial photographs of the Bridge Street Floodplain/Channel Coupling project vicinity.

Anticipated Channel Morphology Response

The objective of this project is to create recruitment habitat by enhancing overbank flooding. While there would be no significant change in the overall channel morphology of the subreach, the increase in overbank flooding would extend the low-velocity habitat at high flow—habitat that is currently marginal in the Albuquerque Reach. The project is located in Subreach 4, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should have a slightly net aggradational tendency over the next 50 years. Should the main channel bed be slightly aggraded with time, it may increase the frequency of overbank inundation. With sufficiently frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the channel morphology in this subreach would reduce its narrowing trend.

Project Habitat Improvements

The projected habitat improvements would include shallower, low-velocity habitat at higher flows. The proposed bankline modifications would result in approximately 1.6 ha (4 acres) of new floodplain inundation for main channel discharges near the 3,500-cfs range. An additional 3.6 ha (9 acres) of floodplain habitat would be provided through the construction of the backwater and overbank inundation channel. These areas need to be monitored for fish occupation and use during high flow.

Approximately 4.5 ha (11 acres) of flycatcher habitat improvements are proposed. Goodding's willow or coyote willow plantings associated with the willow swales and backwater would provide the vegetation density and structure.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. The National Hispanic Cultural Center owns some land within the project area. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels outside the 183-m (600-foot) nominal channel width. In the Bridge Street Channel-Floodplain Coupling project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation
- MRGCD

- NMOSE
- National Hispanic Cultural Center

5.5.4.3 RIO BRAVO FLOODPLAIN/CHANNEL COUPLING

General Description

The area proposed for restoration is a 457-m (1,500-foot) subreach upstream of the Rio Bravo Bridge river crossing. The river makes a southeasterly turn through this subreach and has a relatively constant active channel width of 183 m (600 feet) at bankfull flow. At lower flow the active channel exhibits a large sand bar on the inside portion of this curve. The invert slope of the active channel through this subreach is slightly steeper than the other reaches through Albuquerque at approximately 0.0010 feet/feet. The banks of the active channel are approximately 1.8 m (6 feet) above the active channel thalweg. Existing condition FLO-2D simulations support general overbank flooding as it is predicted for discharges in the 6,000- to 6,500-cfs range. The average W/D through this subreach is more favorable for residential habitat at mid-range flows at the project site. One short-term Reclamation river monitoring cross section is within the subreach that reflects the recent channel conditions.

The City of Albuquerque has implemented bosque restoration in the project area. The Albuquerque Overbank Project has been constructed on the large bank-attached bar on the west side of the river. The City of Albuquerque's silvery minnow sanctuary is immediately upstream of proposed treatments on the east side. The NMISC has implemented habitat restoration projects in the area from 2005 – 2009. The proposed project is adjacent to work completed by the NMISC in 2006.

Proposed Project

The project is designed to provide mid- to high-flow recruitment habitat by creating a floodplain/active channel coupling at a more frequent peak discharge. The project involves lowering the bank of the left side of the active channel and creating a backwater in a portion of the bar where the Albuquerque Overbank Project has been implemented. Comparable to the Bridge Street site, the bank lowering location has been selected in an area where a natural levee has developed along the bank. The bank would be lowered and the natural levee removed to initiate overbank inundation at discharges near 3,500 cfs. The backwater provides additional slackwater habitat for silvery minnow recruitment. This project is brought forth from projects proposed by the Corps in the Bosque Feasibility Study, but not included in the final site selection for the MRG BRP. Project data are summarized in Table 5.14. Figure 5.8 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.14. Rio Bravo Floodplain/Channel Coupling Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR7-01	4	18	RCU-2	Floodplain Coupling/Bankline Lowering	3.29	3,500	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
Floodplain Coupling/Bankline Lowering Total					**3.29**				
PR7-02	4	18	RCU-2	Willow Swales	14.73			Establish Goodding's willow and coyote willow.	Excavate depressions then plant coyote and Goodding's willow.
Willow Swales Total					**14.73**				
PR7-03	4	18	RCU-2	Backwater/ Embayment	4.05	1,500–3000	Low- to intermediate-flow recruitment habitat	Establish large Goodding's willow stands along floodplain depression and embayment; establish coyote willow stands adjacent to river channel.	Create large embayment on bar and floodplain and connect to floodplain depression (Albuquerque Overbank Project site).
Backwater/Embayment Total					**4.05**				
Grand Total					**22.07**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

Figure 5.8. Aerial photographs of the Rio Bravo Channel-Floodplain Coupling project vicinity.

Anticipated Channel Morphology Response

The objective of this project is to create recruitment habitat by enhancing overbank flooding. While there would be no significant change in the overall channel morphology of the subreach, the increase in overbank flooding would make more low-velocity habitat accessible at high flows. As with the Bridge Street bank lowering, this project is located in Subreach 4, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should have a slightly net aggradational tendency over the next 50 years. Over the long-term the frequency of overbank flooding may increase.

Project Habitat Improvements

The projected habitat improvements provides approximately 2.8 ha (7 acres) of shallower, low-velocity habitat at higher flows. Flycatcher habitat would be enhanced through the enhancement of approximately 5.6 ha (14 acres) of willow swales using Goodding's and coyote willow.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. Finally, coordination with the NMOSE will be required for depletions associated with the construction of habitat features outside the 183-m (600-foot) nominal channel width. In the Rio Bravo Channel-Floodplain Coupling project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation
- MRGCD
- NMOSE

5.5.4.4 SOUTH DIVERSION CHANNEL ACTIVE CHANNEL IMPROVEMENTS

General Description

The area proposed for restoration is a 3.2-km (2-mile) subreach adjacent to and downstream of the outfall of the South Diversion Channel. This subreach has experienced channel narrowing through bar vegetation encroachment and bar attachment to the banks, and the river has become slightly sinuous in response. The invert slope of the active channel through this subreach is approximately 0.0009 feet/feet. Observation of the limited digital elevation model (DEM) data available suggests that downstream of the confluence the opportunity for overbank flooding is high, as the bank elevations vary between 1.2 and 1.5 m (4–5 feet) above the channel thalweg. The W/D for low flows is favorable for residential habitat but decreases at higher flows, becoming less favorable and indicating channel confinement. Three Reclamation river monitoring cross sections are within the subreach that reflect the recent channel conditions and depict the channel narrowing.

The area in and around the South Diversion Channel has received a lot of attention. The Corps proposes to construct water features, willow swales, and bosque vegetation management activities as a part of the MRG BRP. The NMISC has implemented several in-channel habitat restoration projects for the silvery minnow, and the City of Albuquerque has modified a bank-attached bar and island through creating embayments and ephemeral channels and has implemented bosque thinning projects with the New Mexico State Land Office (NMSLO).

Proposed Project

The project is designed to work in concert with existing and planned habitat restoration projects in this subreach. The proposed enhancements would add channel diversity and improve aquatic habitat diversity through constructing ephemeral channels on the bank-attached bars, modifying bars and islands, constructing backwater features, and constructing two overbank inundation channels within the floodplain in the 3.2-km (2-mile) subreach. Vegetation would be removed and small embayments would be excavated at the inlet and outlet of each overbank inundation channel. The overbank inundation channels would include meanders and/or embayments (moist soil depressions) to provide silvery minnow habitat conditions over a wider range of flows. The elevations of the river connection points for the side channels are set such that water can be introduced at main channel discharges between 1,500 and 3,500 cfs. A key feature is the relatively large embayment on the west side (Treatment #PR8-8). This feature is intended to provide a connection to several other features. This type of feature provides an opportunity to test hypotheses regarding silvery minnow use of the floodplain and would be expected to be a key feature of a monitoring program. The feature is similar to one recently constructed by the NMISC in the Isleta Reach near Belen (Reclamation 2009). In addition, vegetation removal and bar modification of selected bank-attached bars would increase the active channel width. Project data are summarized in Table 5.15. Figure 5.9 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.15. South Diversion Channel Active Channel Improvements Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR8-01	4	19	RCU-2	Backwater/ Embayment	0.57	2,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet to ephemeral channel.
PR8-03	4	20	RCU-2	Backwater/ Embayment	0.30	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at outlet of ephemeral channel.
PR8-04	4	20	RCU-2	Backwater/ Embayment	0.33	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at outlet of ephemeral channel.
PR8-05	4	20	RCU-2	Backwater/ Embayment	0.26	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet to floodplain inundation channel.
PR8-07	4	20	RCU-2	Backwater/ Embayment	1.04	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet to floodplain inundation channel.
PR8-08	4	20	RCU-2	Backwater/ Embayment	2.90	2,500–3,000	Intermediate-flow recruitment habitat	Establish large Goodding's willow stands along floodplain inundation channel, embayment, and Corps MRG BRP willow swale; establish coyote willow stands adjacent to river channel.	Create large embayment into bankline, connected to floodplain inundation channel. Embayment to grade from 3,000 cfs to inundation discharge along adjacent linguoid bar. Embayment would connect with Corps MRG BRP willow swale.
PR8-09	4	20	RCU-2	Backwater/ Embayment	0.44	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet to ephemeral channel.
PR8-10	4	20	RCU-2	Backwater/ Embayment	1.79	1,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater/embayment.
PR8-13	4	20	RCU-2	Backwater/ Embayment	0.21	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet to floodplain inundation channel.
PR8-16	5	21	RCU-2	Backwater/ Embayment	3.99	1,500–2,500	Low-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create large backwater to drain floodplain inundation channel and connect to bank-attached bar.
Backwater/Embayment Total					**11.83**				

Table 5.15. South Diversion Channel Active Channel Improvements Project Data Summary, continued

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR8-11	5	20	RCU-2	Bar/Island Modification	10.90	2,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Remove vegetation; lower bar by creating terraces.
PR8-12	4	20	RCU-2	Bar/Island Modification	6.24	2,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Remove vegetation; lower bar by creating terraces.
PR8-15	5	21	RCU-2	Bar/Island Modification	6.26	1,500	Residential habitat	Establish coyote willow habitat through natural regeneration.	Remove vegetation; lower bar by creating terraces.
				Bar/Island Modification Total	**23.40**				
PR8-02	4	19	RCU-2	High-flow Ephemeral Channel	2.76	2,500	Residential habitat		Create ephemeral channels on the bank-attached bar.
PR8-06	5	20	RCU-2	High-flow Ephemeral Channel	1.69	2,500–3,000	Intermediate-flow recruitment habitat		Create ephemeral channel on the bank-attached bar and floodplain inundation channel.
				High-flow Ephemeral Channel Total	**4.45**				
PR8-14	5	20	RCU-2	Overbank Inundation Channel	4.43	3,000	High-flow recruitment habitat	Establish Goodding's willow or coyote willow in Corps Bosque Feasibility Study area.	Create floodplain inundation channel; connect with Corps MRG BRP willow swales.
				Overbank Inundation Channel Total	**4.43**				
				Grand Total	**44.11**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

Figure 5.9. Aerial photographs of the South Diversion Active Channel Improvements project vicinity.

Flycatcher habitat improvements, consisting of Goodding's willow and/or coyote willow, would be completed in conjunction with the water feature proposed by the Corps MRG BRP upstream of the South Diversion Channel. Additionally, floodplain inundation channels on the east bank, downstream of the South Diversion Channel, are designed to connect the willow swales proposed by the Corps MRG BRP.

Anticipated Channel Morphology Response

The purpose of the project is to improve the channel dynamics and increase habitat diversity. By arresting the channel narrowing, the channel may straighten slightly and increase the W/D in response to reworking the existing vegetated islands. One of the objectives is to enable the channel to respond beneficially to South Diversion Channel flooding by forcing the flows to the right bank and develop a sand bar along the left bank downstream of the diversion. It is anticipated that bars would form in this subreach during the recessional limb of the runoff hydrograph, and the focus should be to keep the vegetation from stabilizing the bars. The project is located in Subreaches 4 and 5, which according to previous long-term sediment continuity studies (MEI 2007, 2008a) should be slightly degradational over the next 50 years. Restoration project designs should experience a longer lifetime in the presence of a sediment deficit river system.

With frequent bankfull discharge (on the order of once every two to three years based on coordinated adaptive water management), the channel would maintain the bars and islands vegetation free. The high-flow channels would provide added recruitment habitat for fish during the spring spawn.

Project Habitat Improvements

The projected habitat improvements would include an increase in the availability shallow low-flow habitat and in-channel habitat heterogeneity during high flows. Approximately 17.8 ha (44 acres) of new habitat would be created by this project. The project would decrease the uniformity of flow conditions during high flows, and more diverse channel geometry at high flows would increase silvery minnow residential habitat heterogeneity. The project would arrest the channel narrowing in the subreach and decrease the uniformity of flow conditions during high flows. With appropriate frequency of bankfull discharge, the channel bars and islands would remain mobile and free of vegetation, increasing the active channel habitat. This is critical for the project to have any long-term habitat benefits. As with the proposed effort at the North Diversion Channel confluence, it is important that all the activity planned within this subreach occur within reasonable proximity in time in order to obtain the desired high-flow channel hydraulic response.

Additional flycatcher habitat would be established in conjunction with features proposed by the Corps MRG BRP. These features would be expected to provide a consistent water source to maintain inundation during the breeding season. This is an important area for flycatcher habitat restoration because of its relative proximity to existing occupied breeding flycatcher territories on the Isleta Pueblo.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. There is a historic Isleta Pueblo acequia on the east side that should be avoided. The NMSLO owns pockets of land on the east side. Finally, coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels, backwaters/embayments, and other habitat features outside the 183-m (600-foot) nominal channel width. In the South Diversion Channel Improvements project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation
- MRGCD
- Pueblo of Isleta
- NMSLO
- NMOSE

5.5.4.5 I-25 Floodplain/Channel Coupling

General Description

The area proposed for restoration is a 2.4-km (1.5-mile) subreach upstream of the I-25 Bridge crossing over the river. This subreach is relatively narrow when considered from levee to levee. The channel exhibits some braiding with small active lingoid and braid bars at low flows. For much of this subreach the river is in proximity (<91 m [<300 feet]) to the west levee. The invert slope of the active channel through the subreach is slightly flatter than upstream reaches (attributable to the approaching Isleta Diversion Dam) and is approximately 0.0008 feet/feet. There is opportunity for overbank flooding here as the bank elevations vary between 1.5 to 1.8 m (5–6 feet) above the channel thalweg. The W/D is favorable for residential habitat at low flows, but it becomes less favorable with higher flows. Four Reclamation river monitoring cross sections are within the subreach that reflect the recent channel conditions and depict the channel narrowing.

The NMISC has completed a number of treatments on islands, bank-attached bars, and banklines. The Corps plans on constructing willow swales as a part of the MRG BRP.

Proposed Project

The project is designed to create favorable habitat by constructing a large overbank inundation channel in the east floodplain, excavating seven backwater/embayment features, and lowering the bank line. The proposed channel would include small excavated embayments at each inlet and outlet, and the channel would follow remnant channel threads and existing low-lying areas in an effort to increase favorable habitat for the flycatcher and the silvery minnow. Mid-channel depressions would be excavated to enlarge the natural existing low-lying areas. The backwater/embayments would add overall channel diversity at mid to high flow by creating additional low-depth, low-velocity habitat for fish. Project data are summarized in Table 5.16. Figure 5.10 shows a series of aerial photographs of the project vicinity, identifying proposed features.

Table 5.16. I-25 Floodplain/Channel Coupling Project Data Summary

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR9-01	5	22	RCU-2	Backwater/ Embayment	0.13	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayments cut into the bank under openings in the canopy.
PR9-03	5	22	RCU-2	Backwater/ Embayment	0.31	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayments cut into the bank under openings in the canopy.
PR9-04	5	22	RCU-2	Backwater/ Embayment	0.41	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayments cut into the bank under openings in the canopy.
PR9-06	5	22	RCU-2	Backwater/ Embayment	2.40	2,500–3,000	Intermediate-flow recruitment habitat	Establish large Goodding's willow stands along floodplain inundation channel, embayment, and Corps MRG BRP willow swale; establish coyote willow stands adjacent to river channel.	Create large embayment into floodplain connecting to moist soil depression.
PR9-07	5	22	RCU-2	Backwater/ Embayment	0.17	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create backwater at downstream end of the bank-attached bar.
PR9-08	5	23	RCU-2	Backwater/ Embayment	1.70	2,500	Intermediate-flow recruitment habitat	Establish coyote willow habitat through natural regeneration.	Create embayment at inlet of floodplain inundation channel.
PR9-10	5	23	RCU-2	Backwater/ Embayment	1.87	2,500–3,000	Intermediate-flow recruitment habitat	Establish Goodding's willow within inundated area in floodplain connected to floodplain inundation channel.	Create backwater at outlet of the overbank inundation channel.
				Backwater/Embayment Total	**6.99**				

Table 5.16. I-25 Floodplain/Channel Coupling Project Data Summary, continued

ID	Sub-reach	Tile #	Conservation Unit	Treatment	Area (acres)	Target Discharge (cfs)	Silvery Minnow Habitat Target	Flycatcher Habitat Target	Treatment Description
PR9-02	5	23	RCU-2	Floodplain Coupling/Bankline Lowering	1.00	3,000	High-flow recruitment habitat	Encourage natural revegetation of native willows and cottonwood; actively plant Goodding's willow and coyote willow.	Remove natural levee along bankline to permit more frequent floodplain inundation.
Floodplain Coupling/Bankline Lowering Total					**1.00**				
PR9-05	5	22	RCU-2	Moist Soil Habitat Enhancement	4.07			Establish Goodding's willow within inundated area in floodplain connected to backwater/embayment.	Manage vegetation to control non-native phreatophytes and actively plant desired species.
Moist Soil Habitat Enhancement Total					**4.07**				
PR9-09	5	22	RCU-2	Overbank Inundation Channel	11.53	3,000	High-flow recruitment habitat	Create floodplain inundation channel following existing contours to link low-lying depressions; enhance flycatcher habitat in floodplain depressions.	Create floodplain inundation channel; link low-lying depressions to reduce the possibility of isolated ephemeral floodplain catchments and to increase the range of flows the channel would effectively provide the desired condition.
Overbank Inundation Channel Total					**11.53**				
Grand Total					**23.59**				

* Subreach and Tile Sheet references indicate the map in Appendix H –Conceptual Restoration Plan that delineates the footprint for the feature.

Figure 5.10. Aerial photographs of the I-25 Floodplain/Channel Coupling project vicinity.

Anticipated Channel Morphology Response

The objective of this project is to create high-flow recruitment habitat through floodplain side channels and backwaters/embayments. There would be no significant change in the overall channel morphology of the subreach. With appropriate frequency of bankfull discharge, the existing active channel bars and islands would remain mobile and free of vegetation, increasing the diversity of active channel habitat at low flow.

Project Habitat Improvements

The projected habitat improvements would include increased availability of residential habitat during high flows. Approximately 9.6 ha (23.6 acres) of new habitat (4.7 ha [11.5 acres] in the overbank inundation channel and about 3.2 ha [8 acres] in the backwater embayments and bankline lowering) would be created by this project. The project would decrease the uniformity of flow conditions during high flows. More diverse channel geometry at high flows would retain more fish in the Albuquerque Reach. Fish drifting downstream of this subreach during high flows are more likely to pass Isleta Diversion Dam and be lost to the Albuquerque Reach.

This area, along with the previous, upstream project, is important for restoring flycatcher habitat, because these areas are in relative proximity to existing occupied territories on the Isleta Pueblo (Smith and Johnson 2005, 2008). Creating floodplain depressions and increasing the frequency of floodplain inundation would provide large areas of potential flycatcher habitat and augment the willow swales proposed in the Corps MRG BRP.

Agency/Landowner Coordination

Prior to implementing work, coordination with the appropriate land management agencies, municipalities, pueblos, landowners, other project sponsors, and interested stakeholders will be required to obtain the necessary permits and agreements. Agency/landowner coordination should take place during the initial planning stages of project implementation. Coordination with agencies and entities that have implemented or are planning on implementing habitat restoration projects in the vicinity is recommended. Jetty jack removal, if required, will require coordination with the Corps, Reclamation, and the MRGCD. The NMSLO is a fee-simple owner of a large portion of the proposed project area and has proposed some habitat restoration work on its lands. Coordination with the NMOSE will be required for depletions associated with the construction of overbank inundation channels outside the 183-m (600-foot) nominal channel width. Finally, project sponsors should coordinate with the Pueblo of Isleta to address concerns the tribe may have in regards to potential impacts on Pueblo of Isleta projects and/or sediment issues relating to Isleta Diversion Dam. In the I-25 Side Channels project area, the landowners and/or agencies include:

- City of Albuquerque
- AMAFCA
- Corps
- Reclamation

- MRGCD
- NMSLO
- Pueblo of Isleta

5.6 Net Depletions Analysis of Proposed Projects

The Rio Grande Compact (1939) determines the amount of surface water that can be depleted annually in the MRG based on the natural flow of the river measured at the Otowi gage. In addition, the NMOSE has determined that the MRG is fully appropriated. Any increase in water use must be offset by a reduction in use by another water right; this can be accomplished by "retiring" an existing water right or increasing the efficiency of a water use, thereby reducing its consumptive use and transferring the net savings in consumptive amount to the offset of the new water depletion (New Mexico Statutes Annotated 72-5-18 2007).

The 2003 BO (USFWS 2003), the Collaborative Program, and the NMOSE require that proposed projects demonstrate that they will not result in any increases in net water depletions or that any increases are offset by releases of stored water or purchased or leased water rights, and that the Collaborative Program comply with state water laws. Much of the proposed habitat restoration work will occur along the banks of the channel and is therefore within the nominal 183-m (600-foot) width of the channel (the original river channel design width for the Albuquerque Reach to maintain flow delivery efficiency and reduce flood risk). The NMOSE considers instream formations to be dynamic aspects of the channel; therefore, no depletion offsets are required for modifications conducted within the 183-m (600-foot) area.

For the work that occurs outside the channel (e.g., in the floodplain), the project may require depletion offsets. For example, some of the restoration work the Corps is proposing in the bosque as part of the MRG BRP would be outside the 183-m (600-foot) channel. If the NMOSE were to determine that the proposed water features would increase net depletions, the Corps would be responsible for obtaining water rights prior to construction. Similarly, the Collaborative Program, or project sponsors, would be required to obtain water rights prior to implementation of projects constructed in the floodplain.

The NMOSE is responsible for quantifying the volume of water rights required to offset the increase in net depletions and for approving the transfer of water rights for the purpose of offsetting those depletions. Specific rules have not yet been released by the NMOSE for the quantification of net depletions, and they are currently being evaluated on an ad-hoc basis.

5.7 Sediment Management

Sediment management associated with creating habitat remains an issue that must be addressed during the planning and design phase of project development. The NMISC has successfully placed excavation materials behind temporary silt fences installed in the river immediately adjacent to the treatment site (Reclamation 2005, 2006d, 2009). This requires that an area be identified that is sufficient to accommodate the volume of material to be excavated from the site. This can be accomplished during the design and specifications stage of project development. The advantage of this method is that material is returned to the river (where many will argue that it belongs), creates additional low-flow habitat, and is relatively inexpensive. The drawback is that there may be downstream effects, such as effects on Isleta Diversion Dam.

Other options include spreading the sediment adjacent to the constructed feature or hauling. Neither are particularly palatable options. Spreading sediment spoils adjacent to the created habitat feature reduces the effectiveness of the feature and creates sites for noxious weed invasion. For example, sediments stockpiled along a high-flow ephemeral channel or bosque inundation channel may act as a berm, confining water as flows increase. The concept is that as the water flows increase, the water should be allowed to spread out to inundate a wider area. Also, sediment spread over a bank-attached bar or island adjacent to a treatment site increases the discharge at which the island would be inundated. Finally hauling sediment spoils and incurring tipping fees may be cost-prohibitive (although the material often has characteristics that may make it valuable for fill or may have sufficient gravel deposits to make it worthwhile to screen if a suitable buyer can be found).

6.0 EVALUATION CRITERIA AND MONITORING

6.1 GENERAL OVERVIEW

Any effective habitat restoration program or project must have specific goals and objectives relative to the outcomes of restoration, and those goals and objectives must be developed in advance of the implementation of restoration treatments. Restoration goals and objectives that are developed during the pre-treatment planning process should then serve to guide the development and implementation of restoration treatments to achieve the original restoration goals. Conditions or attributes of specific parameters that provide target goals and objectives for habitat restoration should be quantifiable by metrics, which also should be defined during the pre-treatment planning process. Likewise, in order to assess the effectiveness of habitat restoration once treatments have been implemented, monitoring of those specific habitat parameters used to define restoration goals also must be conducted in order to evaluate whether the restoration treatments have achieved the desired outcomes relative to those original restoration goals (Block et al. 2001; Elzinga et al. 2001; Downes et al. 2002; Roni et al. 2005). The development of specific evaluation criteria for all habitat restoration treatments and projects within the Albuquerque Reach will be a large and complex process. For this report, we do not develop all of those criteria, but rather present a proposed process by which appropriate evaluation criteria may be developed for each restoration project along with sound monitoring approaches by which to collect and evaluate data representing those criteria.

The evaluation of habitat restoration effectiveness is generally conducted by determining whether the goals and objectives of particular projects and treatments have been achieved by developing and assessing evaluation criteria. Evaluation criteria are defined as those desired environmental (i.e., habitat) or species population (e.g., density, mortality, age class distribution, etc.) attributes or conditions that are represented by measurable parameters or variables that define the desired attributes that restoration is attempting to achieve. Parameters representing evaluation criteria are monitored before and following restoration treatments, and restoration is considered successful if those environmental and/or population parameters change in ways that trend toward the desired goals and objectives of the restoration program, project, or treatments. Additionally, if specific quantified desired goal values for parameters are known in advance, those quantified values of parameters may be considered as the target conditions or target goal values for which restoration is meant to achieve. Once target goal values have been achieved, restoration may be considered successful. However, both ecological systems and management goals change over time, so once target conditions have been achieved, monitoring should continue to determine how those conditions change over time for as long as the resources of interest are being managed.

In order to determine cause and effect of habitat restoration treatments, an experimental scientific or research monitoring and evaluation approach should be used, including baseline data, replicate sites, treatments and controls, and reference conditions (Elzinga et al. 2001; Roni et al. 2005). Non-experimental monitoring and evaluation approaches will only document post-restoration changes in environmental and population parameters over time and cannot be used to evaluate the cause and effect of restoration treatments on conditions of those parameters (Elzinga et al. 2001; Roni et al. 2005). An experimental research approach also provides data for the generation and evaluation of new information to guide the adaptive management process in order to make positive changes in management approaches. Ultimately, this process will allow management to evolve and improve over time. New information learned from initial restoration efforts and subsequent monitoring and evaluation will lead to a better understanding of the MRG ecosystem and biotic species, inform managers, and improve upon management strategies for that system.

The overall goals for Albuquerque Reach habitat restoration projects for the silvery minnow and the flycatcher are defined in Chapter 5, Section 5.1. This Study addresses those restoration goals over a broad range of management from Collaborative Program management goals, through reach, subreach, and site-based habitat restoration project goals, to individual habitat restoration treatment objectives. Each category of goals and objectives also address both direct population attributes/parameters of the silvery minnow and the flycatcher and a wide range of environmental or habitat attributes/parameters that in turn directly affect silvery minnow and flycatcher population structure parameters. Habitat restoration evaluation and monitoring must also correspond to that same range of goals and objectives.

Figure 6.1 provides a proposed general conceptual model for the overall approach and context for a habitat restoration evaluation and monitoring process for Albuquerque Reach habitat restoration projects as overseen by the Collaborative Program. This model is within the context of an overall regional programmatic setting, including a variety of restoration projects, all driven by particular programmatic restoration goals and objectives relative to enhancing populations of the silvery minnow and the flycatcher. The important aspect of this model is that programmatic resource management goals determine habitat restoration projects. Monitoring and evaluation of restoration project success then determine if those management goals have been met. Results from the project-level evaluation process then feed back up to the programmatic level. If the evaluation process determines that management goals have been met, then that information provides positive feedback for the continuation of current management strategies with slight modifications based on new information. If the evaluation process determines that management goals have not been met, then adaptive management strategies are employed to change and improve management practices, and those new practices are implemented and evaluated through the same process as above. A salient feature of this model is that management structure and process may remain relatively stable over time, but management goals and methods are allowed to evolve and improve as more is learned about the system. Additionally, management structure and subsequent goals and objectives are subject to change from influences both outside and within the Collaborative Program, and this conceptual model is meant to allow flexibility for those changes too.

Figure 6.2 provides a more detailed proposed conceptual model focusing on the process for habitat restoration effectiveness evaluation and monitoring across the range of management and component levels for the Albuquerque Reach. This model provides an example of the flow of information relative to a particular hypothetical restoration treatment within a particular restoration project. An important aspect of this conceptual model is that restoration management decisions flow from top (broad restoration and species recovery goals) to bottom (specific restoration objectives), whereas restoration effectiveness evaluation information flows from the bottom to the top. The overall function of this proposed model is to provide an information feedback loop, where the process of resource management decisions (top-down) is driven by the evaluation of management practices, ultimately through the combined and cumulative evaluations of individual restoration treatments at individual restoration sites within projects (bottom-up) over time. The model allows the evaluation results of individual habitat restoration treatments within individual projects to provide cumulative feedback through individual projects and reaches, back up to the overall programmatic management decision-making process. As with the more generalized model in Figure 6.1, this detailed model also is meant to employ adaptive management as more is learned about restoration effectiveness, and thus the entire system. This approach also assumes that top-down management goals and objectives may change for reasons other than habitat restoration effectiveness (i.e., politics, economics, science, etc. outside the program). This proposed model accommodates the silvery minnow and the flycatcher, as well as information about habitat features and population structure.

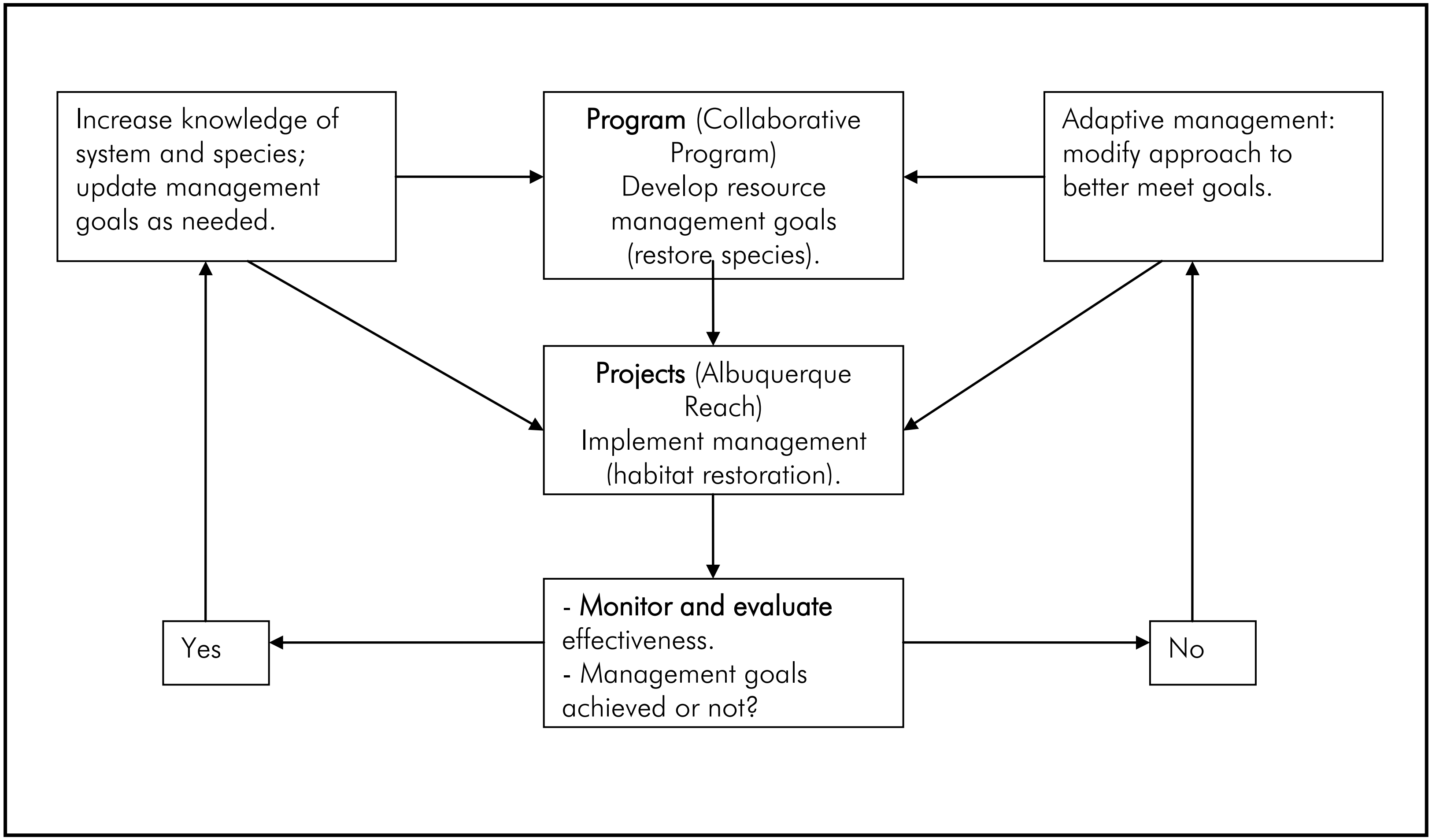

Figure 6.1. Conceptual model for Albuquerque Reach habitat restoration management goal development, habitat restoration projects, and restoration project and treatment evaluation.

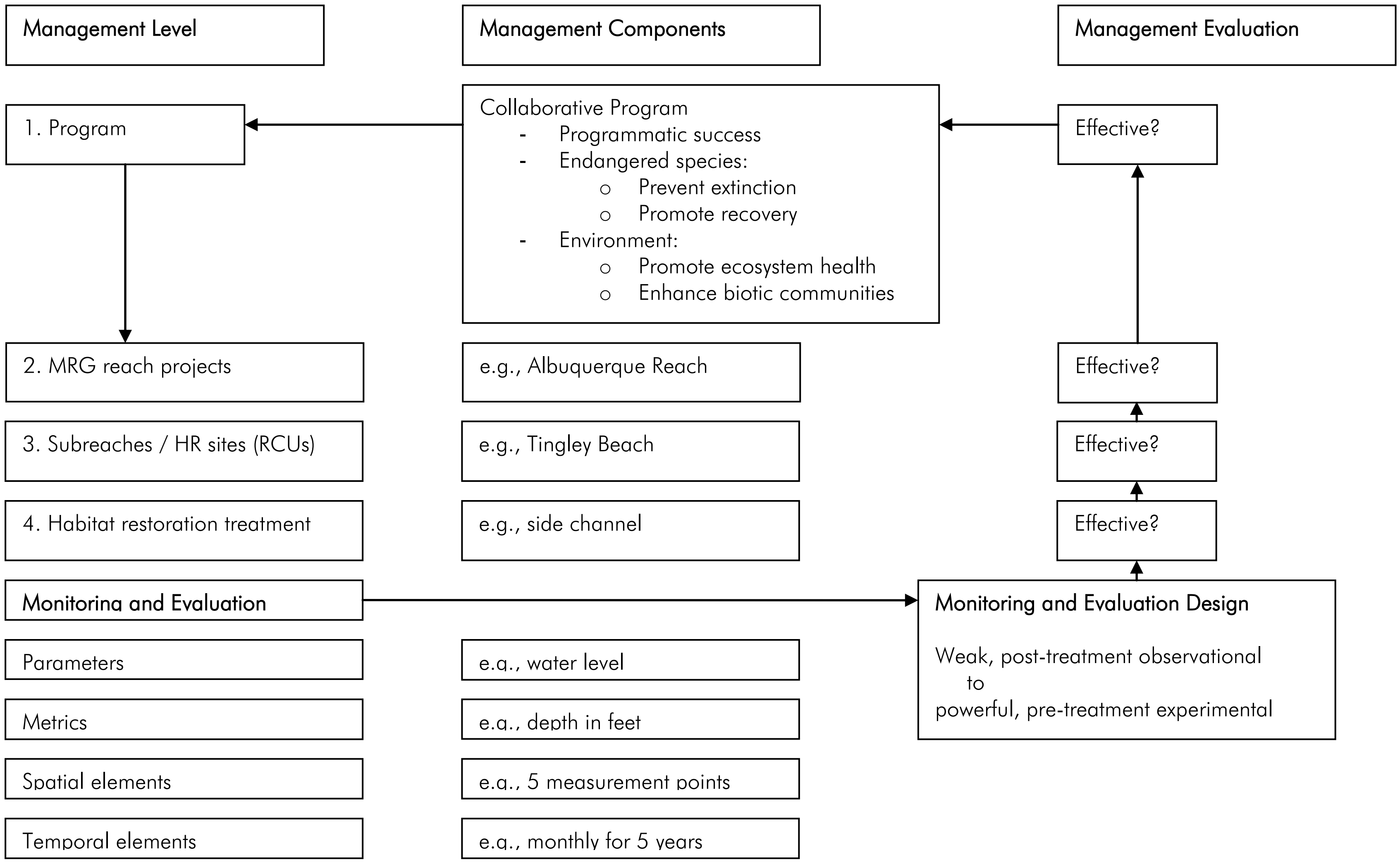

Figure 6.2. The conceptual context and components of habitat restoration monitoring and evaluation information feedback loop toward better management over time as more is learned about the system and the species (HR=Habitat Restoration, RCUs=Reserve Conservation Units).

Each habitat restoration project and/or treatment has a particular set of goals and objectives aimed at modifying the environment to provide improved conditions for each species and ultimately improved population structure parameters and viability. The particular desired states or parameters of environmental conditions may then be used both as objectives for specific restoration treatments and as specific criteria to evaluate habitat restoration effectiveness monitoring following restoration treatments.

Specific restoration treatments may enhance environmental conditions for some particular life stage or biological process that will enhance the species, while other treatments may enhance other environmental conditions for the same or different life stages or processes of the species. Together, several different restoration treatments may be used in a particular restoration project to enhance the overall ecological status for a species and meet the goals of that restoration project. In order to determine whether the goals of a restoration project and the specific objectives of restoration treatments have been met, monitoring or standardized repeated observations and measurements of parameters must be taken over time and compared to the predetermined evaluation criteria in order to evaluate restoration success. Such effectiveness monitoring spans a range of sampling designs and intensities from simple post-restoration treatment monitoring aimed at simply observing and recording environmental conditions over time relative to desired restoration goals or evaluation criteria to more complex and useful experimental or research monitoring designs that can actually test the effectiveness of restoration treatments with pre-treatment baseline data and experimental control sites (see Habitat Restoration Monitoring below). However, non-experimental monitoring and evaluation approaches cannot be used to evaluate the cause and effect of restoration treatments on conditions of those parameters.

Habitat restoration goals and evaluation criteria, for a given location or region, are best determined by:

1. Understanding and evaluating the local environmental needs of a species by conducting background research on the ecology and population dynamics of the species and determining which parameters (variables) are important habitat components for the species;
2. Identifying reference sites or locations that provide habitats where those particular favorable environmental conditions and parameters support viable or ecologically successful subpopulations of the species; and
3. Using the information representing those environmental conditions and parameters from literature or data directly measured from reference sites to provide knowledge about the attributes of environmental and species population structure parameters. This information then provides target parameter conditions for both restoration goals and habitat restoration evaluation criteria.

Since local environments tend to differ from the environments of distant locations (climate, geology, soils, water chemistry, physical morphology, biota, disturbances, etc.), environmental comparisons to locations within the region of planned habitat restoration should be preferred to reference site data from outside the region or area. Similarly, comparisons to historical environmental conditions may also be problematic given that the exact historical conditions may not be known and/or the local environment has been altered so much that restoration to pre-existing environmental conditions may not be practical or possible. If current favorable local environments for the species do occur within the region, then those locations serve as the best reference sites for each species and its habitats within that particular region at that current time. The environmental characteristics of those reference locations should provide the best available measures for conditions of environmental parameters to serve as restoration goals and evaluation criteria for habitat restoration of other less suitable environments that are being restored elsewhere in the region.

In the context of this Study, CCUs (see Section 5.2) may serve as reference sites (controls) for restoration treatments. Qualitative (general descriptive conditions or categories of parameters) and quantitative (measured parameter values) characteristics of key habitat parameter metrics for the species, obtained from the CCUs, may then serve both as objectives for habitat restoration treatments and evaluation criteria for post-restoration effectiveness monitoring of RCUs. The objectives of habitat restoration treatments are then to modify the key environmental habitat features at degraded RCU sites to be similar to the conditions of those same key environmental habitat parameters at reference locations or CCUs. If model CCUs are not available within the reach, then the geographically closest CCUs may be used from other reaches such as San Acacia, San Marcial, or others. This process will then guide habitat restoration plans to provide improved suitable habitat for the species in areas where the existing habitats are deficient by some important environmental attributes required by the species and evaluation criteria to assess the effectiveness of habitat restoration.

For example, the flycatcher is not known to nest in the Albuquerque Reach, so a goal of Albuquerque Reach habitat restoration is to create suitable nesting habitat for the flycatcher within the reach. Researchers have observed and measured some of the environmental habitat attributes or parameters of successful nesting sites within the San Marcial Reach of the MRG (Moore 2007) and along the Lower Colorado River (McLeod et al. 2008). The known qualitative conditions and/or quantitative values or ranges of those habitat parameters then provide both objectives for specific habitat restoration treatments, evaluation criteria, and target goal values for post-restoration monitoring within the Albuquerque Reach. Priority should be given for parameter conditions obtained from successful nesting sites within the regional San Marcial Reach over those from the distant Lower Colorado River; however, a greater number of successful nesting site habitat parameters have been measured along the Lower Colorado River. Therefore, one would prioritize habitat parameter data from the local San Marcial Reach, such as tree species composition and tree foliage height, and supplement other parameters that were not measured from the local San Marcial Reach with those measured from the more distant Lower Colorado River sites.

Evaluation criteria would include both qualitative conditions for parameters, such as saturated soil under successful nests observed in the San Marcial Reach, and quantitative soil moisture target goal values, such as mean soil moisture (mV) values of 751.9 +/- 15.5 or qualitative

Hink and Ohmart (1984) vegetation structural types (Type 3 was observed at the San Marcial Reach), along with target goal values for mean tree canopy height of 6.1 m (20 feet) +/- 0.1 m and percent basal area of native trees of 41.4% +/- 2.2%, among others also measured from the San Marcial Reach. All of these qualitative and quantitative environmental parameter values may then be used as objectives for specific restoration treatments and as evaluation criteria for effectiveness monitoring of flycatcher habitat restoration treatments within the Albuquerque Reach. Changes in those conditions or values may then serve as the evaluation criteria to assess restoration success.

Quantitative data for the specific range of values for some habitat parameters may not be available, but instead qualitative information and known qualitative or categorical values of key habitat parameters from reference sites may also be used as evaluation criteria; however, target goal values are lacking. For example, a key habitat feature of successful flycatcher nesting sites is saturated soil or standing water below nesting trees. If precise quantitative data for soil moisture are not available, then restoration treatment objectives and effectiveness monitoring criteria could simply state that the soil needs to be saturated with water or that standing water is present during the nesting season, rather than some quantified range of measured target goal values for soil moisture from a reference site as presented above. Such qualitative or categorical parameters may be used for habitat restoration objectives and evaluation criteria when actual quantitative measurements for such key habitat parameters are not available or when the acquisition of quantitative measurements are too costly. However, lack of target goal values may lead to problems of objectively determining when desired conditions have actually been achieved.

Evaluation criteria in the above example would simply be used to determine whether particular restoration treatment or project post-restoration increases in the density, cover, and heights of native willow trees as improving habitat for the flycatcher. The restoration treatments may be considered successful depending on whether native willows significantly increased following restoration treatments, but the degree of success would not necessarily be quantifiable. Target goal values do consist of actual known target qualitative and/or quantitative categories or values for particular habitat parameters from reference sites or hypothetical reference conditions. Restoration success would be achieved when the post-restoration categories or values of parameters fall within the range of known target goal values obtained from reference sites. Evaluation criteria could then be used to determine if restoration has successfully altered the habitat toward conditions favorable to the species, but may not be able to determine if the restoration has modified the habitat to be within the range of environmental conditions required by the species. Target goal values would provide an assessment of whether restoration has in fact created environmental conditions suitable for the species based on known reference conditions. Restoration goals and objectives vary and include those that target the silvery minnow, the flycatcher, and both species and/or others. Again, the objectives of individual restoration treatments and goals for restoration projects define the parameters and criteria that will be used to evaluate restoration success.

Evaluation criteria are best assessed by the use of statistical experimental design approaches to habitat restoration monitoring. Statistical tests of metric values for parameters are used to determine whether there are significant changes in parameter attributes following restoration treatments. Assessment of target goals should be accomplished by simply noting when the post-restoration values of parameters (e.g., means and associated variances) fall within the known ranges of those parameters from reference sites.

Identifying habitat restoration evaluation criteria is a complex process that must address multiple species, parameters, spatial and temporal scales, and management components. In that respect, a simple one-dimensional list of evaluation criteria is not sufficient; instead multi-dimensional matrices or tables of evaluation criteria must be developed to meet the complexities of MRG habitat restoration goals. Particular habitat restoration evaluation criteria for the Albuquerque Reach must represent: 1) both the silvery minnow and the flycatcher, 2) both environmental or habitat parameters and population structure parameters, and 3) all management and evaluation levels and associated spatial and temporal components presented in Figure 6.1 and Figure 6.2.

As stated above, this document presents a proposed process or approach for identifying Albuquerque Reach habitat restoration criteria for the silvery minnow and the flycatcher, including habitat, population, and different spatial and temporal aspects of management. Rather than developing a list of all potential parameters, metrics, and evaluation criteria for each project, treatment, and species, we propose a process for identifying specific habitat restoration evaluation criteria, along with some specific examples. Specific evaluation criteria may then be identified for each project and treatment within the Albuquerque Reach as specific plans are developed for each restoration project. Approaches to identifying evaluation criteria for the silvery minnow are presented first, followed by example evaluation criteria for the flycatcher.

6.2 SILVERY MINNOW EVALUATION CRITERIA

Evaluation criteria for the recovery of the silvery minnow in the Albuquerque Reach focus on habitat parameters relative to MRG geomorphology and hydrology, as well as population parameters relative to abundance, age class distribution, reproductive success, and habitat selection.

6.2.1 SILVERY MINNOW HABITAT EVALUATION CRITERIA

Within the Albuquerque Reach, bar stabilization with vegetation establishment has become more prevalent over the past 30 years since the closure of Cochiti Dam. This phenomenon is primarily in response to reduced spring peak flows and reduced sediment loads from both upstream and tributary sources. The encroachment accelerated from 1997 to 2004 when spring bankfull discharge did not occur following 20 years of mostly average spring runoff discharges. Bars that once were active and mobile have evolved into permanent bank-attached bars and islands. As these features vertically accrete, they cause channel narrowing and adversely impact the aquatic habitat by confining flows and increasing overall channel velocity. Silvery minnow habitat restoration is intended create mesohabitat features to meet specific life stage requirements (e.g., recruitment habitat and residential habitat) at a range of discharges and to destabilize stabilized bars, islands, and banklines. The intent of these activities is to enhance channel dynamics, increase the active channel width, improve W/D, increase floodplain connectivity, and increase habitat heterogeneity for the silvery minnow. Specific treatments and their details are provided in Section 5.5 above and in the Restoration Matrix presented in Appendix I.

Restoration treatments to promote an active channel and enhance aquatic habitat diversity for the Albuquerque Reach are proposed at the confluence of the North Diversion Channel, in the vicinity of Bridge Street, and at the confluence of the South Diversion Channel. The goal of restoration recommendations is to improve aquatic habitat by positively affecting channel dynamics and floodplain connectivity in areas where there is potential to do so due to the local hydrologic and/or geomorphic conditions. In order for the prescribed restoration treatments to be successful over the long term, bankfull flow conditions must occur every two to three years, or the opportunities for future vegetation encroachment in the active channel will persist in the presence of reduced sediment loads. The removal of vegetation from active bars requires sand mobilization to expose the root system and sweep the plant away. After three consecutive years without bankfull flow, the vegetation growth cannot be removed by high flow, and the slower flow velocity through the vegetation will promote vertical bar accretion.

The proposed restoration treatments are intended to improve aquatic habitat by restoring channel dynamics and floodplain connectivity, including:

- Increasing silvery minnow channel habitat diversity, which will be characterized by:
    1. Increased average W/D.
    2. Increased low-velocity habitat (less than 1 fps) over a range of flows.
    3. Increased probability of observing lower regime bed forms (i.e., dunes) compared to higher regime bed forms (i.e., plane bed) at high flows.
- Enhancing fluvial geomorphic activity as characterized by:
    1. Increased bar and island mobility.
    2. Enhanced bankline erosion and localized channel migration.

The parameters and metrics outlined below are considered important habitat evaluation criteria for the silvery minnow in terms of channel geomorphic processes and subsequent benefit to the silvery minnow. These parameters and their metrics may be used as evaluation criteria to assess the effectiveness of habitat restoration treatments for the silvery minnow.

1. **Areal extent of low-velocity habitat (less than 1 fps) over a range of flows.** To estimate the amount of low-velocity habitat, it is necessary to take a series of representative measurements and extrapolate them over the treatment area. The amount of low-velocity habitat can be estimated within a project area at a specific discharge by monitoring the velocity profile across multiple cross sections within a project site. The average velocity

profile within a segment of the project reach can provide an estimated proportion of the active channel area that has low-velocity habitat at the specific discharge that the cross sections were monitored. Using the total area of the active channel and the estimated proportion of low-velocity habitat within the active channel, a rough estimate of the amount of low-velocity habitat present within the restoration area can be calculated. If channel morphology is not similar throughout the site, the site can be broken into segments that have similar channel morphology to assess the amount of low-velocity habitat present in each segment.

2. **Changes in W/D.** The results can be analyzed by comparing changes in the W/D of the surveyed cross sections within the project areas over time and by comparing changes at treatment sites with those at control sites. W/D is defined as from bank to bank (water's edge to water's edge).

3. **Bar mobility.** Bar and island stabilization through vegetation encroachment is thought to be a principal driver of channel narrowing in the Albuquerque Reach. Islands and bars targeted for destabilization treatments should be identified on aerial photographs, and changes should be tracked with subsequent aerial photographs and cross section monitoring. In addition, direct field measurements of new vegetation establishment and growth should be documented on the restored islands and bars. This information is important for comparing with post-treatment hydrologic conditions and will provide meaningful insight as to what flows are required to scour seedlings. If monitoring indicates that vegetation is stabilizing the treated bars, these results could be used to develop a follow-up mechanical maintenance treatment program.

4. **Bankline erosion.** Cross sections should be established with each destabilization project so that local erosion rates can be monitored. Bank destabilization treatments are often used to obtain a downstream response. Cross section surveys should be established at a sufficient distance downstream to capture the anticipated response. Each cross section should be surveyed annually after spring runoff peak flows. With established cross section end points some distance away from the active channel banklines, it is possible to monitor changes in local erosion rates following high-flow events compared to the erosion rates at control sites outside the project areas. The collected data should be documented with global positioning system (GPS) data and compared in GIS after all high-flow events to help understand processes associated with changes in the bankline. Bed material size changes should also be monitored.

5. **Water quality.** Silvery minnow embryos are highly sensitive to water salinity. The salinity at which one-half of the silvery minnow embryos died (LC_{50}) was calculated to be 4.2 parts per thousand (ppt) (Cowley, New Mexico State University, personal communication, 2008).

   Maximum lethal limits (LL_{50}) for temperature and maximum lethal concentrations (LC_{50}) of dissolved oxygen and ammonia for the silvery minnow have been investigated by Buhl (2006) for four age groups (3–4 dph larvae, 32–33 dph juveniles, 93–95 dph juveniles, and 11-month-old subadults) in reconstituted water that simulated conditions in the MRG. The upper 24-hour and 96-hour LL_{50} for all four age groups fell between 35°C and 37°C (95°F–99°F). The 24-hour and 96-hour LC_{50} for dissolved oxygen ranged from about 0.6 to 0.8 mg/L for silvery minnow that had access to the water surface (to gulp air) and 0.8 to 1.1 mg/L for fish denied access to the surface. In the pulsed ammonia tests, exposures to high ammonia concentrations for only 1.5 hours were nearly as toxic as exposures to the same concentrations for 96 hours. Based on nominal total ammonia concentrations, the larvae (96-hour LC_{50} for all pulses, 16–23 mg/L as N) were about twice as sensitive as both juvenile age groups (96-hour LC_{50} for all pulses, 39–70 mg/L as N).

State of New Mexico standards for interstate and intrastate waters apply to the Albuquerque Reach, with separate criteria upstream and downstream of Alameda Bridge (20.6.4 New Mexico Administrative Code [NMAC], 2005; Effective December 29, 2006).

Silvery Minnow Population Parameter Evaluation Criteria

Broadly speaking, the goal of implementing habitat restoration is to affect a positive change in the silvery minnow population in the Albuquerque Reach and the entire MRG. Therefore, in addition to evaluating potential silvery minnow habitat following restoration, even more direct evaluation of silvery minnow performance may be accomplished by evaluating important population parameters for the species. Below are five proposed silvery minnow population parameters that could be monitored and evaluated as indicators of silvery minnow success following habitat restoration. The following discussion and recommendations are meant to complement and build upon current Collaborative Program initiatives regarding population viability analysis modeling. The criteria presented below are meant as a model of a comprehensive monitoring program to detect changes in the silvery minnow population in the Albuquerque Reach over time. We recognize and acknowledge that there are other factors that affect population parameters and the need to take caution in interpreting population trends as solely due to habitat restoration.

1. Population abundance and density. Estimates of population abundance and density are useful parameters of silvery minnow response and are essential for determining the amount of habitat needed to meet established management objectives based on a quantitative relationship between habitat and population size or density. Interpretation of a time series of population estimates is also important for determining risk of extinction. In a temporally varying environment such as the MRG, the long-run population growth rate governs the vulnerability of a population to extinction. This concept is expressed mathematically as $r - Ve / 2$, where r is the intrinsic rate of population growth and Ve is the between-generation variance of population growth rate (National Research Council 1995). When $Ve / 2 > r$, the population will decline toward extinction deterministically. The expected time to extinction will vary with population size, depending on the ratio of the mean to the variance of the rate of population growth: $\sim r / Ve$.

Methods have been developed specifically for producing estimates of population size and density with known statistical properties; these methods conform to two primary models:

closed population models and *open population models*. A closed population has a constant size in the period of time during which the Study is conducted. In other words, there is no birth, death, immigration, or emigration during the course of the Study. Closed population models are limited to studies of short duration where population size can be considered reasonably to be constant. Because they are simpler, closed population models have received considerable attention in the last 10 to 15 years. Estimation of population size, fish density per unit area, or standing crop per unit area is often the main objective under a closed population model. Closed populations can be studied with two field survey methods, tag-recapture surveys and multipass depletion (removal) surveys.

An open population is one in which birth, death, immigration, and emigration can take place during the Study period. The most basic open population model is the "Jolly-Seber" model. Open population models are applied typically to long-term studies, and their application is often made to estimate survival rate and/or other demographic population parameters. Open populations are typically studied with tag-recapture surveys.

2. Age- or stage-based record of survival and mortality. Estimates of the survival and mortality of a population within a defined spatial and temporal context provide useful evaluation criteria in order to assess the health of that population relative to declines based on mortality. Since survival rates tend to vary among age classes or life-history stages, survival rates should be partitioned by age. An age- or life-stage-specific record of survival and mortality is essential for understanding observed patterns of population growth and decline. Likewise, an age- or life-stage-based record of survival and mortality is essential for predicting the future growth or decline of populations of concern, including management intervention strategies that are expected to alter rates of birth and death.

Mortality and survival can be estimated from survey data, assuming we are able to estimate the ages of the sampled animals. Age estimation is best conducted through the use of an age-body length key in which the probabilities of ages within discrete body length classes are used to convert numbers-at-length into numbers-at-age. Analysis of numbers-at-age data sets to estimate mortality and survival is based on the assumption that year class strength and annual survival rates per year class are constant over the sampled set of age classes. We further assume that the sample yields an unbiased representation of relative year class strength.[14] The linear function of the logarithm ($\log_{10}$) of the number of fish caught by age class provides an index of the relative strength of year classes, along with a perspective of the influence of management on instantaneous rates of mortality. Depending on the timing and circumstances of sampling, the resultant curve (i.e., $\log_{10}$ of the number of fish caught by age class) may consist of three parts: 1) a steeply ascending left limb, which can result from under-sampling young fish in relation to their abundance (most problematic in spring and early summer samples); 2) a dome-shaped apex representing the strongest and the youngest year class that is fully vulnerable to the sampling gear type; and 3) a long descending right limb, which is used to estimate mortality and survival rates. A straight line is fit to the data

[14] Hatch and Gonzales (2008) report an obvious but unquantified difference in silvery minnow size class frequency distributions derived from fyke net samples versus seine net samples in floodplain habitats; fyke net samples generally have a greater frequency of larger silvery minnow.

points of the right limb by least squares. The slope of this line is equal to the average instantaneous mortality rate. Survival represents the antilog of the slope. Mortality equals one minus survival. Relative year class strength and instantaneous rates of mortality may also be correlated with environmental factors or with management practices such as population augmentation with hatchery-produced fish.

Life table analysis of age class frequency provides an alternative index of age-specific rates of survival and life expectancy. Preliminary analysis of the silvery minnow's survival patterns are consistent with a Type III survivorship curve indicating that future population growth or decline will be modulated most profoundly by the younger age classes. Management of river flows to facilitate recruitment will be most important when silvery minnow populations are decreasing. Such management actions can increase the prospect of species survival by enhancing densities to a level that results in a self-sustaining population. The minimum viable population size will occur when survival for young-of-year is maximized and there are no population-wide year class failures. Population size increases as the failure rate for the younger age classes decreases. Management should strive to maximize survival and manage for larger population sizes to accommodate temporal variation in demography and habitat quality (Cowley et al. 2007).

Estimates of silvery minnow survivorship represent static measures that are poor at elucidating relationships between dynamic environmental factors. The silvery minnow does not experience a single rate of survival over time and space, and *instantaneous* expressions of survival rates can give the false impression of environmental stasis. Instantaneous survival rates do not reveal the variability that accompanies environmentally driven variation in habitat quality and quantity that is known to be extreme in the MRG.

3. Young-adult ratio. A young-adult ratio founded on age-specific rates of reproduction and survival may be used as population evaluation metric. Such a metric may provide an early indication of problematic demographic trends that may warrant directed management adjustments.

Age estimation is best conducted through the use of an age-body-length key in which the probabilities of ages within discrete length classes are used to convert numbers-at-length into numbers-at-age. The young-adult ratio is the number of young-of-year silvery minnow divided by the number of silvery minnow that are aged one year old or older. Favorable ratios for balanced populations are based on a long-term stable age class distribution derived from population matrix model projections over 25 years that simulate scenarios that approximate asymptotic population growth ($\lambda \approx 1$). Ratios indicative of balanced populations for fall month samples range from 8.5:1 to 12.5:1, assuming that at least two age classes comprise the adult component of the sample. This wide range of proportional values results in a population whose abundance fluctuates in response to short-term changes in environmental conditions and is characterized by periods of rapid population growth followed by periods of declining population growth. Higher ratio values, including values higher than the stated range for a balanced population) are desirable when the population is decreasing ($\lambda < 1$), i.e., the value of each offspring increases when the population is decreasing. Conversely, the value of each future offspring is diluted when the finite rate of increase (λ) is greater than one. In this instance, low or static index values are not a cause for concern.

4. Indices of active habitat selection. Active selection of specific habitat types by silvery minnow can be interpreted as an adaptive response that maximizes species fitness. Determination of habitat actively being selected by silvery minnow details opportunities for directed management to leverage primary population processes (i.e., birth, death, immigration, and emigration) to achieve management purposes. Evidence of active habitat selection is also central to the evaluation of restored habitat features.

The work by Hatch and Gonzales (2008) and Gonzales and Hatch (2009) demonstrates the possibility of developing an index of active habitat selection linked to reproduction and recruitment founded on the rate of capture of reproductively mature silvery minnow in fyke nets strategically deployed at floodplain habitat restoration sites. It is hypothesized that silvery minnow actively select sheltered, low water exchange lateral habitats for spawning—including most importantly shallow, vegetated, hydrologically retentive floodplain habitats—which is regarded as a behavioral adaptation to reduce downstream displacement of eggs and larvae that would otherwise occur in the event of spawning over exposed surfaces of the main channel. Hatch and Gonzales (2008) report that reproductively mature male and female silvery minnow are most commonly found at floodplain sample sites where low-velocity flows predominate. Furthermore, the researchers relate floodplain occupation by reproductively mature males and females to changes in flow. However, additional measures of active floodplain habitat selection, involving multiple sites and multiple cohorts over varying hydrological conditions, will be necessary to develop an unbiased index of active habitat selection.

5. Indices of spawning activity. Rates of capture of downstream-drifting eggs in Moore egg collectors (MECs) are often employed by managers as an index of silvery minnow spawning. As a measure of the effectiveness of habitat restoration, egg monitoring may have an inverse relationship, meaning that successful detection of downstream drifting eggs may be an indication of inadequate recruitment habitat.

It is possible to standardize many factors that exist to produce variable sampling detection probabilities (e.g., sampling effort, sampling equipment, time and place of sampling). In theory, it is possible to identify factors that simultaneously influence detection probability of incubating embryos (e.g., water velocity, volumetric measures of river discharge, and volumetric measures of the amount of water filtered to obtain the sample), without affecting animal abundance, and incorporate them as covariates in an analysis of count statistics. To date, sampling protocol for downstream-drifting eggs has not been standardized across varied survey teams.

The rate of capture of downstream-drifting eggs is meaningful only in the context of repeated measures over time and between equivalent data sets from different sites. Interpretation of results relies on detectable change in index values. However, comparisons of index values of rates of capture over time and space are complicated by data sets that are inherently characterized by a large number of zeros, hence an inability to normalize the data. Not properly normalizing the data (via some transformation such as log transformation) will reduce the sensitivity of analysis of variance (ANOVA) and increase the likelihood of concluding that no effect exists when, in fact, one does (Type II error). One way around this problem is to increase the sample unit size (to eliminate zeros and increase the count per collection). Realistically, it may be necessary to base statistical inference about observed survey results on a negative binomial probability distribution.

Table 6.1 presents examples of proposed habitat parameter evaluation criteria for the silvery minnow, and Table 6.2 presents examples of proposed slivery minnow population evaluation criteria. Proposed parameters, metrics, and metric goal values have been developed here or are derived from existing literature sources. Area and time are based on habitat restoration goals and objectives for each management level. Note that question marks indicate that actual target goal values still need to be determined. Also, area and time values presented in Table 6.1 are somewhat arbitrary, and values presented are meant to show how area and time values may vary across different management levels. Actual criteria and their component values will need to be determined as individual projects are planned. Following this approach, potential habitat restoration evaluation criteria for any project and treatments may be identified for the Albuquerque Reach.

Table 6.1. Examples of Proposed Habitat Parameter Evaluation Criteria for the Silvery Minnow

Management Level	Entity	Habitat Evaluation Criteria					
		Parameter	**Metric**	**Criteria**	**Target Goal Values**	**Area**	**Time**
Program	Collaborative Program	Residential habitat	Change in W/D	>150	10% increase over the range of flows	? ha	20 years
		Residential / Refugial habitat	Areal extent of low-velocity habitat	< 1 fps	10% increase over the range of flows	? ha	20 years
		Residential / Refugial habitat	Bed material gradation	>	Sand substrate	? ha	20 years
		Residential / Refugial habitat	Bar mobility	>	50% success	? ha	20 years
		Additional...					
Project	Albuquerque	Residential habitat	Change in W/D	>150	10% increase over the range of flows	? ha	10 years
		Residential / Refugial habitat	Areal extent of low-velocity habitat	< 1 fps	10% increase over the range of flows	? ha	10 years
		Residential / Refugial habitat	Bed material gradation	>	Sand substrate	? ha	10 years
		Residential / Refugial habitat	Bar mobility	>	50% success	? ha	10 years
		Additional...					
Subreach / Conservation Unit	RCU-2	Residential habitat	Change in W/D	>200	10% increase over the range of flows		10 years
		Residential / Refugial habitat	Areal extent of low-velocity habitat	< 1 fps	10% increase over the range of flows		10 years
		Residential / Refugial habitat	Bankline erosion	>	5% increase		10 years
		Residential / Refugial habitat	Bar mobility	>	50% success		10 years
	Additional...	*Additional...*					
Treatment	Side channel	Residential habitat	Change in W/D	>200	10% increase over the range of flows	? ha	10 years
		Residential / Refugial habitat	Areal extent of low-velocity habitat	< 1 fps	10% increase over the range of flows	? ha	10 years
		Residential / Refugial habitat	Bankline erosion	>	5% increase	? ha	10 years
		Residential / Refugial habitat	Bar mobility	>	50% success		10 years
	Additional...	*Additional...*					

Note: *Additional* means that more entities exist beyond the examples provided.

Table 6.2. Examples of Proposed Species Population Evaluation Criteria for the Silvery Minnow

Management Level	Entity	Population Evaluation Criteria					
		Parameter	Metric	Criteria	Target Goal Values	Area	Time
Program	Collaborative Program	Spawning activity	Egg count/sample interval	>, stable	?	? ha	20 years
		Age class survival rate	Count/age class/interval	>, stable	?	? ha	20 years
		Additional...					
Reach	Albuquerque	Spawning activity	Egg count/sample interval	>, stable	?	? ha	10 years
		Age class survival rate	Count/age class/interval	>, stable	?	? ha	10 years
		Additional...					
Subreach / Conservation Unit	RCU-2	Spawning activity	Egg count/sample interval	>, stable	?	? ha	10 years
		Age class survival rate	Count/age class/interval	>, stable	?	? ha	10 years
	Additional...	*Additional...*					
Project	Tingley	Spawning activity	Egg count/sample interval	>, stable	?	? ha	10 years
		Age class survival rate	Count/age class/interval	>, stable	?	? ha	10 years
	Additional...	*Additional...*					
Treatment	Side channel	Spawning activity	Egg count/sample interval	>, stable	?	? ha	10 years
		Age class survival rate	Count/age class	>, stable	?	? ha	10 years
	Additional...	*Additional...*					

Note: *Additional* means that more entities exist beyond the examples provided.

6.2.2 EXPRESSIONS OF PROGRAM EFFECTIVENESS RELATIVE TO THE SILVERY MINNOW

Effects assessment consists largely of making observations about program elements—the problem, management activities, and the outcomes of interest—and relating them to one another. This assessment is best conducted with an experimental monitoring approach including baseline, controls, and replication of treatments. Also critical are well-formulated comparative questions framed by a series of relevant hypotheses.

The difference between the resultant state and the no-services baseline is a basic quantifier of efficacy (impact) and is expressed as:

$$\text{Effectiveness} = R - NS \qquad (1.1)$$

where *R* is the resultant state, and *NS* is the no-services baseline (or alternatively the "control" condition). Selection of a dependent (response) variable will vary with the questions being asked. Estimates of population abundance and density are logical and compelling variables of response to management, especially for single-species conservation programs. When the scale of measurements are numeric with known statistical properties, the comparison expressed in Equation 1.1 can be reframed as a formal statistical test of the null hypothesis (H_o) that the statistics are equal (i.e., H_o: $\theta_1 = \theta_2$, or equivalently, H_o: $\theta_1 - \theta_2 = 0$).

Notice that the impact quantifier represented in Equation 1.1 requires no standard of performance (i.e., a management objective). This is generally possible or practical only when *R* and *NS* represent intrinsically meaningful and understood units (e.g., inches, dollars, time). More often, *R* and *NS* represent metrics that, although valued (or potentially valued), are not easily interpreted. For instance, is the capture of 15 silvery minnow larvae along a 10-m (33-foot) transect in the floodplain high or low? In such instances, a management objective is needed for interpretive purposes. Equation 1.1 can be modified to incorporate the planning objective (*P*) as follows:

$$\text{Effectiveness} = \frac{R - NS}{P - NS} \qquad (1.2)$$

Alternative to the planned state is the extent to which a problem is ameliorated, usually indicated by the estimate of the no-services baseline itself. This yields another quantifier of program accomplishment:

$$\text{Adequacy ratio} = 1 - \frac{R}{NS} \qquad (2.1)$$

Ideas such as rates of survival and population growth cannot readily be expressed as undesirable; they have no reverse side that is *bad* in exactly the same way that they themselves are *good*. The remedy for the adequacy ratio when measurement has been expressed in terms of a desirable trait is to render the measures of *R* and *NS* in terms of a gap (a *shortfall* or *true problem*):

$$\text{Adequacy ratio} = 1 - \frac{R - TP}{NS - TP} \qquad (2.2)$$

where *TP* represents the true problem.

Although not explicitly stated up to this point, the standards of evaluation that are represented in Equations 1.2, 2.1, and 2.2 represent absolute (threshold) standards (e.g., maximums or minimums). Often such standards are ill suited for the decision.[15] In lieu of absolute criteria, relative (e.g., scaled) criteria may be better suited to the type of decision to be made (e.g., involving a ranked ordering of observations). When the response variable is scaled, the measure is presumed to be the difference between two variables or the ratio of two variables.

6.2.3 *Evaluation Criteria Checklist for Program Performance and Effects Assessment for the Silvery Minnow*

Silvery minnow populations will react in a varied but often categorical manner to a broad array of environmental influences. The following checklist presents a general overview of a selection of common stressors (i.e., problems) and associated responses of silvery minnow populations.

Demographic Evaluation Parameters and Indices

- ☐ Population abundance – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include increasing or stable index values.
- ☐ Population density – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; average silvery minnow density estimates can also be employed to determine the minimum amount of wetted habitat needed to achieve management objectives.
- ☐ Instantaneous rate of survival – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include increasing or stable index values.
- ☐ Instantaneous rate of mortality – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include decreasing or stable index values.
- ☐ Age-specific rate of survival – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include increasing or stable index values.

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[15]Absolute standards imply that program administrators are prepared to make accept-reject decisions. Often in reality, the intent of decision-makers does not involve the tradeoffs of accept-reject. Instead, the decisions that administrators often contemplate involve weighted constraint types of decisions, for example.

- ☐ Age-specific life expectancy – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include increasing or stable index values.
- ☐ Young-adult ratio – an average of 8.5:1 to 12.5:1 for fall samples, assuming that at least two age classes comprise the adult component of the sample. This index may be evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment. Higher ratio values are desirable when the population is decreasing ($\lambda < 1$), i.e., the value of each offspring is increased when the population is decreasing. Conversely, the value of each future offspring is diluted when the finite rate of increase (λ) is greater than one.
- ☐ Index of spawning activity – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of river reach/river segment; desired responses would include increasing or stable index values.

Habitat-specific Population Evaluation Metrics

- ☐ Index of active habitat selection – evaluated by Equations 1.1, 1.2, 2.1, or 2.2 at the scale of localized habitat features; desired responses would include increasing or stable index values.
- ☐ Floodplain coupling – sustained period of 10 or more consecutive days, achieved by maintaining a mono-modal hydrograph. Discharge is reduced gradually (e.g., 50 cfs per day) following periods of high discharge to reduce fish mortality caused by stranding. Evaluation can be performed by the separate elements of evaluation using Equations 1.1, 1.2, 2.1, or 2.2 at multiple scales ranging from localized habitat features to river reaches.

Critical Environmental Exceedance Threshold Criteria

- ☐ New Mexico standards for interstate and intrastate waters apply to the Albuquerque Reach, with separate criteria upstream and downstream of Alameda Bridge (20.6.4 NMAC, 2005; effective December 29, 2006).
- ☐ Salinity – < 4.0 ppt during May and June; evaluated at the scale of localized habitat features.
- ☐ Dissolved oxygen – > 0.6 to 0.8 mg/L for 24-hour and 96-hour, respectively; evaluated at the scale of localized habitat features.
- ☐ Ammonia concentrations – < 16 mg/L as N for 96-hour during spring and summer; < 39 mg/L as N for 96-hour during late summer and fall. Evaluation is conducted at the scale of localized habitat features.

6.3 SOUTHWESTERN WILLOW FLYCATCHER EVALUATION CRITERIA

Like the silvery minnow, habitat restoration criteria for the flycatcher include those relative to population parameters, as well as those that represent the physical environment or habitats.

In contrast to the silvery minnow, the flycatcher is not a year-round resident species along the MRG, and the goals of habitat restoration focus on spring, summer, and autumn use of the MRG by flycatchers. Particular emphasis for restoration is to provide suitable nesting habitat for the flycatcher during the spring and early summer months. Also, much more is known about the quantitative attributes of flycatcher nesting habitat than is known about the physical habitat necessary for silvery minnow reproduction, and flycatcher habitat is terrestrial riparian rather than aquatic. Important habitat parameters of interest for the flycatcher include terrestrial vegetation and soil moisture conditions discussed above (see Chapter 5, Table 5.4 for a summary of flycatcher habitat characteristic variables). Population parameters for the flycatcher range from documenting occurrence by the presence of individuals to documenting habitat use, breeding pairs and nests, and demographic parameters of clutch size, mortality, age class survivorship, etc. The entire population biology and sampling procedures for the flycatcher also differ from the silvery minnow, such that documenting individual birds in particular locations, nesting territories, nests, and numbers of young/nest provide the most useful population evaluation criteria. Table 6.3 presents some proposed examples of habitat parameter evaluation criteria for the flycatcher, and Table 6.4 presents a listing of proposed species population evaluation criteria. Proposed parameters, metrics, and metric goal values are taken from existing literature sources. As with Table 6.1 and Table 6.2, Table 6.3 and Table 6.4 are meant to show how parameters, criteria, and their values may change across management levels; actual values will need to be developed for each individual project.

Table 6.1 through Table 6.4 present some examples of possible evaluation criteria for both qualitative conditions and specific quantitative measurable parameter goal or target values that represent desired habitat restoration success for habitat based on geomorphology and hydrology, as well as the silvery minnow and flycatcher population parameters within the Albuquerque Reach, based on the known environmental needs of both species. Development of a complete listing of such goal or target values of parameters representing those desired environmental habitat conditions and the population structure conditions will serve as a process by which to evaluate habitat restoration projects within the Albuquerque Reach for the silvery minnow and the flycatcher. Table 6.1 through Table 6.4 provides a basic conceptual approach to developing habitat restoration effectiveness criteria for both species. In practice, these tables would likely be expanded to include monitoring approaches and methods appropriate for measuring the parameters listed, and a series of different tables or matrices might be developed representing different levels of management (e.g., MRG, reach, subreach), rather than combining all management levels in one.

Over time, as more is learned about the system and each species, and as environments and management goals change, evaluation criteria and their goals will likely change as well. We propose that this process be adopted to develop evaluation criteria for all habitat restoration projects and individual treatments within the Albuquerque Reach. Once specific evaluation criteria have been determined for each habitat restoration project, then monitoring designs and evaluation processes must be developed in order to collect data from which evaluations will be made. Section 6.4 presents a proposed approach to the monitoring methods by which data should be collected and evaluated relative to Albuquerque Reach habitat restoration projects.

Table 6.3. Examples of Proposed Habitat Parameter Evaluation Criteria for the Flycatcher

Management Level	Entity	Habitat Evaluation Criteria					
		Parameter	**Metric**	**Criteria**	**Target Goal Values**	**Area**	**Time**
Program	Collaborative Program	Native tree (esp. SAGO) basal area	% basal area	>	41.4% +/- 2.2%	10,000 ha	20 years
		Hink & Ohmart Type 4 vegetation	Categorical; type class	>	Type 4	10,000 ha	20 years
		Soil moisture qualitative	Categorical; saturated: yes or no	>	Yes	10,000 ha	20 years
		Soil moisture quantitative	mV	>	751.9 +/- 15.5	10,000 ha	20 years
		Mean diurnal ambient temperature	°C	<	43.0 +/- 0.2	10,000 ha	20 years
		Additional...					
Reach	Albuquerque	Native tree (esp. SAGO) basal area	% basal area	>	41.4% +/- 2.2%	1,000 ha	10 years
		Hink & Ohmart Type 4 vegetation	Categorical; type class	>	Type 4	1,000 ha	10 years
		Soil moisture qualitative	Categorical; saturated: yes or no	>	Yes	1,000 ha	10 years
		Soil moisture quantitative	mV	>	751.9 +/- 15.5	1,000 ha	10 years
		Mean diurnal ambient temperature	°C	<	43.0 +/- 0.2	1,000 ha	10 years
		Additional...					
Subreach / Conservation Unit	RCU-2	Native tree (esp. SAGO) basal area	% basal area	>	41.4% +/- 2.2%	100 ha	10 years
		Hink & Ohmart Type 4 vegetation	Categorical; type class	>	Type 4	100 ha	10 years
		Soil moisture qualitative	Categorical; saturated: yes or no	>	Yes	100 ha	10 years
		Soil moisture quantitative	mV	>	751.9 +/- 15.5	100 ha	10 years
		Mean diurnal ambient temperature	°C	<	43.0 +/- 0.2	100 ha	10 years
	Additional...	*Additional...*					
Project	Tingley	Native tree (esp. SAGO) basal area	% basal area	>	41.4% +/- 2.2%	10 ha	10 years
		Hink & Ohmart Type 4 vegetation	Categorical; type class	>	Type 4	10 ha	10 years
		Soil moisture qualitative	Categorical; saturated: yes or no	>	Yes	10 ha	10 years
		Soil moisture quantitative	mV	>	751.9 +/- 15.5	10 ha	10 years
		Mean diurnal ambient temperature	°C	<	43.0 +/- 0.2	10 ha	10 years
	Additional...	*Additional...*					
Treatment	Side channel	Native tree (esp. SAGO) basal area	% basal area	>	41.4% +/- 2.2%	1 ha	10 years
		Hink & Ohmart Type 4 vegetation	Categorical; type class	>	Type 4	1 ha	10 years
		Soil moisture qualitative	Categorical; saturated: yes or no	>	Yes	1 ha	10 years
		Soil moisture quantitative	mV	>	751.9 +/- 15.5	1 ha	10 years
		Mean diurnal ambient temperature	°C	<	43.0 +/- 0.2	1 ha	10 years
	Additional...	*Additional...*					

Note: *Additional* means that more entities exist beyond the examples provided.
SAGO = *Salix gooddingii*; mV = millivolts.

Table 6.4. Examples of Proposed Species Population Evaluation Criteria for the Flycatcher

Management Level	Entity	Population Evaluation Criteria					
		Parameter	Metric	Criteria	Target Goal Values	Area	Time
Program	Collaborative Program	Number of breeding pairs	Count / HR treatment area	>	1/ha	10,000 ha	20 years
		Number of migratory individuals	Count / Treatment area	>	1/ha	10,000 ha	20 years
		Average clutch size	Count / Nest / Treatment area	>	3	10,000 ha	20 years
		Additional...					
Reach	Albuquerque	Number of breeding pairs	Count / HR treatment area	>	1/ha	1,000 ha	10 years
		Number of migratory individuals	Count / Treatment area	>	1/ha	1,000 ha	10 years
		Average clutch size	Count / Nest / Treatment area	>	3	1,000 ha	10 years
		Additional...					
Subreach / Conservation Unit	RCU-2	Number of breeding pairs	Count / HR treatment area	>	1/ha	100 ha	10 years
		Number of migratory individuals	Count / Treatment area	>	1/ha	100 ha	10 years
		Average clutch size	Count / Nest / Treatment area	>	3	100 ha	10 years
	Additional...	*Additional...*					
Project	Tingley	Number of breeding pairs	Count / HR treatment area	>	1/ha	10 ha	
		Number of migratory individuals	Count / Treatment area	>	1/ha	10 ha	
		Average clutch size	Count / Nest / Treatment area	>	3	10 ha	
	Additional...	*Additional...*					
Treatment	Side channel	Number of breeding pairs	Count / HR treatment area	>	1/ha	1 ha	10 years
		Number of migratory individuals	Count / Treatment area	>	1/ha	1 ha	10 years
		Average clutch size	Count / Nest / Treatment area	>	3	1 ha	10 years
	Additional...	*Additional...*					

Note: *Additional* means that more entities exist beyond the examples provided.
HR = habitat restoration.

6.4 HABITAT RESTORATION MONITORING

6.4.1 GENERAL OVERVIEW

Monitoring is simply the repeated observation or measurement of some particular entity or set of entities within given spatial and temporal domains over some period of time in order to evaluate change in those entities over time. The purpose of monitoring may vary from simply observing and noting change over time to critically evaluating change over time relative to desired or anticipated target goals or objectives. The purpose for monitoring habitat restoration effectiveness relative to the Study is to scientifically determine whether restoration treatments have effectively achieved the initial restoration goals, based on the evaluation criteria presented above. In this sense, monitoring is needed to evaluate the effectiveness of management goals and objectives. Elzinga et al. (2001:1) define such monitoring as "the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective." This definition is appropriate for the habitat restoration monitoring proposed here.

Terminology for habitat restoration effectiveness monitoring has been variable and somewhat confusing. Ecological monitoring relative to stream water quality has been partitioned into several different categories by McDonald et al. (1991) to address different needs for assessing changes in water quality over time relative to forestry management impacts, modified by Roni et al. (2005) relative to watershed and stream habitat restoration. These categories include: 1) baseline monitoring to characterize existing, pre-impact conditions; 2) status monitoring to characterize population structure or other biological attributes of species over a broad geographic area; 3) trend monitoring to determine change in environmental conditions or biota over time; 4) implementation or compliance monitoring to determine if a project has been implemented as planned; 5) effectiveness monitoring to determine if actions or impacts have had desired effects on the system as planned (often restricted to abiotic parameters); and 6) validation monitoring to evaluate whether the impact or treatment has had the desired cause and effect on the system as planned (often focusing on biota and their broader habitat parameters). Baseline, implementation, effectiveness, and validation monitoring apply to habitat restoration effectiveness monitoring and have been adopted for stream and watershed restoration activities (Roni et al. 2005).

The interpretation and word usage of effectiveness and validation monitoring have been variable and confusing, and the two terms have been used both exclusively and interchangeably (Roni et al. 2005). The term effectiveness monitoring has historically referred to either: 1) an evaluation of specific restoration treatment goals and objectives only relative to those specific abiotic conditions that restoration was directly intended to change, and/or 2) this previous definition, but also including an evaluation of the effectiveness of treatments on general habitat conditions indirectly affected by restoration conditions and the effects of restoration on the target species responses to those changes. The term validation monitoring has historically been used only in reference to number 2 above (Roni et al. 2005) and also is relative to assessing the cause and effect relationships between restoration treatments and habitat and species responses, often at a broader spatial and temporal scale than effectiveness monitoring.

For the purposes of this Study, we propose to simplify habitat restoration monitoring terminology to: 1) "implementation assessment," which is synonymous with implementation monitoring as defined by Roni et al. (2005), and 2) "effectiveness monitoring," which is equivalent to the second defined usage of the term as stated above, and includes validation monitoring as defined by Roni et al. (2005). Evaluations of implementation success are often one-time assessments and usually do not involve multiple repeated measurements or assessments over time, as effectiveness monitoring does. Effectiveness monitoring may address multiple spatial, temporal, and management scales, may involve repeated measurements over time, and may include both abiotic and biotic parameters, target species, and cause and effect research to preclude the need for a separate term, i.e., validation monitoring. Implementation assessments and effectiveness monitoring following the above terminology are incorporated into the proposed conceptual models for Albuquerque Reach habitat restoration evaluation as presented in Table 6.1 through Table 6.4 above. Effectiveness monitoring is the principal method by which metric data are collected on both environmental and species population parameters in order to evaluate habitat restoration effectiveness.

As stated above, implementation assessment is a one-time, or short-term, evaluation of whether habitat restoration treatments have been implemented as planned. Implementation assessment is generally observational rather than experimental in design and generally has the objective to provide quality assurance that restoration construction has been completed according to plans. Implementation assessment generally involves a simple observational and qualitative assessment of the immediate post-restoration treatment conditions relative to the planned treatment. Ideally, implementation assessments will be initiated with the collection of pre-treatment baseline information (e.g., photographs, descriptions, etc.) on environmental parameters that will be altered by the treatment, and an initial post-treatment assessment of physical environmental conditions should then be made within a short period of time (e.g., days) following the treatment to determine whether the treatment has been completed as planned. Implementation assessment is an evaluation of the restoration treatment itself, not the habitats or biota for which the treatment is designed to enhance.

Habitat restoration effectiveness monitoring, as defined here, provides data not only for evaluations of the effectiveness of the habitat restoration on both the physical environment or habitat, but also for the species or biota for which the restoration was designed, including both monitoring of species habitat parameters and population structure parameters. Effectiveness monitoring may be either qualitative and observational or quantitative and experimental. As stated above, the quantitative experimental approach is the only way to determine cause and effect of restoration treatments on habitat and species parameters and should be used over observational monitoring whenever possible. The actual parameters selected for monitoring, and the metrics used to measure those parameters, should be those identified as habitat restoration evaluation criteria (see Table 6.1–Table 6.4). Monitoring should be designed as a quantitative experimental monitoring approach, including the use of baseline data, comparative treatment and control conditions, spatial replication of both treatments and controls, and reference conditions to provide parameter evaluation criteria for testing hypotheses of treatment effectiveness.

Some of the most comprehensive and progressive riverine habitat restoration effectiveness monitoring plans and practices have been developed for salmon (Salmonidae) and other fish of the lower Columbia River drainage in the Pacific Northwest (Roni et al. 2005, and chapters within). Although the MRG environments and the silvery minnow's ecology differ from the Columbia River and species of salmon, many of the management goals and objectives for habitat restoration and species recovery are similar. In our opinion, the resource management goals, environmental complexity, and array of parameters and target species for Columbia River fisheries restoration and monitoring are more complex than for the MRG. Therefore, approaches and methodologies developed for the Columbia River system also should be appropriate for the management, environment, and species complexities of MRG habitat restoration, and we have adopted many of those more general approaches and methods to effectiveness monitoring in this Albuquerque Reach Study.

The effectiveness monitoring process is a component of the overall habitat restoration evaluation process presented above in Table 6.1 through Table 6.4. Monitoring is the method or process where metric data for chosen parameters is collected and evaluated relative to restoration treatment/program success or effectiveness. Habitat restoration effectiveness monitoring should proceed through a series of steps, and a proposed sequence of those steps is presented below. Note that the ideal process for monitoring and evaluation begins with the actual restoration planning, prior to implementation of any restoration treatments. If monitoring and evaluation for projects and treatments are initiated after the treatments have been initiated, the value of monitoring will be considerably less. The evaluation will likely be simply observational (see below) and not as informative as experimental monitoring with baseline and control site data.

1. Clearly state all goals and objectives for monitoring particular response parameters (variables) for each particular habitat restoration project. The first and most important step to monitoring and evaluating habitat restoration projects and treatments is the development of goals and objectives for evaluation. As discussed above under Sections 6.2 and 6.3, the goals and objectives of evaluation are directly related to the goals and objectives of the restoration projects and treatments. Therefore, habitat restoration evaluation and monitoring should be planned at the same time as restoration projects and treatments are planned so that the goals and objectives of monitoring and evaluation are consistent with the goals and objectives of the restoration projects and treatments.

2. Determine parameters, metrics, monitoring sampling design (spatial and temporal) that will be used to address the objectives for monitoring those response parameters (including need for control and/or reference sites). Consider appropriate parameters and combinations of parameters to monitor and the appropriate spatial and temporal resolution of monitoring.

If monitoring is to be used as a tool to evaluate changes in condition toward meeting a management objective, and the changes in condition are due to an imposed treatment or impact, then the monitoring design must be conducted in a scientific way using experimental design in order to statistically determine cause and effect relative to imposed treatments. In this sense, monitoring becomes a designed field experiment, where hypotheses are formulated and tested to assess the cause and effect of treatments (Quinn and Keough 2007). Such experimental monitoring has been called "research monitoring" (Elzinga et al. 2001), but note that validation monitoring also has been called research monitoring (Roni et al. 2005). Research is simply inquiry in order to learn about something, so all types of monitoring are performing research, and we feel that the term research monitoring is inappropriate to define only some types of monitoring. To avoid confusion, the term experimental effectiveness monitoring, or simply experimental monitoring, will be used in this Study, rather than research monitoring. Experimental monitoring refers to monitoring designs that are appropriate to provide unbiased statistical tests of treatment effects by use of baseline data, comparative treatment and control conditions, spatial and temporal replication of both treatments and controls, and use of reference conditions (if available) to provide target parameter evaluation criteria for testing the hypotheses of treatment effectiveness. Experimental monitoring design in this sense is similar to standard ecological experimental design used to test any kind of imposed treatment or environmental impact on a particular system defined by measurable parameters (Green 1979; Downes et al. 2002; Quinn and Keough 2007).

Non-experimental monitoring designs have been called "observational monitoring" (Elzinga et al. 2001), where observations and/or parameter measurements are taken, but the monitoring design may lack baseline data, control conditions, and/or spatial replication of treatments and controls. Observational monitoring can detect change over time after a treatment has been imposed, but usually without baseline and/or control conditions for comparison or replication to account for the effects of environmental factors other than the specific treatment. Observational monitoring cannot provide data for statistical tests of treatment effects, or in other words, the effects of restoration treatment effects on habitat or species population parameters. We will adopt the term observational effectiveness monitoring, or observational monitoring, as simple but less effective form of effectiveness monitoring than experimental effectiveness monitoring approaches.

As stated above, the most effective and useful effectiveness monitoring designs are experimental, where cause and effect of restoration treatments may be assessed in a scientific and unbiased way. Monitoring designs range from simple post-restoration treatment observational monitoring to pre- and post-restoration treatment experimental monitoring with baseline data and replicated treatment/control sites (Elzinga et al. 2001; Roni et al. 2005). The most common monitoring designs used for aquatic/riparian habitat restoration evaluation projects tend to be simple post-treatment (PT) and before/after (BA) designs, and particularly those with controls, called BA control-impact, or BACI, monitoring designs (Downes et al. 2002; Roni et al. 2005). As discussed above, simple PT designs lack baseline data and are not suited to determine cause and effect of restoration treatments.

Since many Albuquerque Reach habitat restoration treatments have already been constructed prior to any effectiveness monitoring plans, many PT designs will need to be implemented in the Albuquerque Reach. PT designs are generally either intensive (IPT) sampling designs, where considerable effectiveness monitoring sampling efforts are concentrated in one or few locations, or extensive (EPT) sampling designs, where minimal sampling efforts are dispersed over a wide array of treatment locations or projects. The strength of IPT designs is in providing considerable information for one treatment or project, but at the expense of spatial replication, whereas the strength of EPT designs is in providing better spatial replication, but often at the expense of more intensive sampling and data. In general, EPT designs with considerable spatial replication and controls should be used over IPT designs with little spatial replications and/or controls (Hicks et al. 1991; Roni et al. 2005). EPT designs can provide useful evaluation data; however, the designs should employ considerable spatial replication (e.g., more than 10 sites) and paired controls in order to be useful.

The most robust monitoring designs are extensive BA designs that employ considerable spatial replication (generally 10 or more sites), as opposed to intensive designs with little or no spatial replication (Hicks et al. 1991; Roni et al. 2005). Extensive BA designs may provide even better results than intensive BACI designs. Extensive BACI designs (MBACI designs of Downes et al. 2002) provide the most powerful and useful of all monitoring designs, but also tend to be the most costly because of the need for considerable spatial and temporal replication along with control sites. Intensive BACI designs still provide better results than simple intensive BA designs for situations where spatial replication is limited. Downes et al. (2002) and Roni et al. (2005) discuss potential statistical problems with BACI designs, particularly relative to using appropriate control conditions and avoiding temporal autocorrelation of data. For the purpose of the Study, we recommend using extensive BA designs and/or extensive and intensive BACI designs with paired treatment and control experimental monitoring designs. We propose limiting the use of simple and less informative observational PT monitoring designs, but favoring EPT over IPT approaches for those projects where treatments have already been imposed, but no effectiveness monitoring has commenced.

The financial cost of habitat restoration effectiveness monitoring is not only a function of sampling design, but also a function of the number of parameters and metrics used. Given that many habitat restoration projects will not have adequate budgets for the best case or ideal effectiveness monitoring designs (i.e., extensive BACI) and arrays of parameters, we recommend that all habitat restoration projects include at least a minimum or core set of parameters and metrics for low intensity effectiveness monitoring. Core parameters should be measured by simple but meaningful metrics to provide evaluations of restoration goals and objectives, and core parameter metrics may be qualitative or quantitative. If all habitat restoration projects within the Albuquerque Reach adopt the concept of low intensity core parameters and metrics to evaluate restoration success, an array of extensive PT, BA, and BACI designs could then provide considerable spatial replication for effectiveness monitoring throughout the Albuquerque Reach.

However, some subset of projects with adequate funding should, in addition to monitoring core parameters, also employ more robust intensive BACI monitoring designs in order to adequately evaluate cause and effect of habitat restoration treatments on key parameters. Those projects employing more elaborate intensive monitoring designs could then serve to provide valuable cross-reference data between extensive and extensive core parameters and metrics to help validate the wider use of extensive sampling designs and metrics. An example of potentially useful core parameters and metrics would be monitoring terrestrial vegetation using modified a Hink and Ohmart (1984) vegetation structure classification with metrics that include dominant species, provide maps of vegetation type polygons at restoration sites, and monitor change in those polygons over time, as an alternative to more detailed quantitative vegetation measurement transects or plots. Other restoration projects should then provide comparable intensive sampling designs that employ both simple vegetation mapping, in addition to more intensive quantitative vegetation measurements, and the detailed vegetation data could be used to validate the more general mapping. Cross-project planning would be necessary in order to provide a balance of simple extensive effectiveness monitoring for a subset of projects, along with more complex intensive effectiveness monitoring for other projects, along with comparable sets of parameters, goals, and objectives.

Other ways to reduce costs, and increase cost-effectiveness include pulse monitoring (Roni et al. 2005), where some parameters that are intensively measured, and thus expensive to sample, are measured at less frequent intervals over time as appropriate, reducing seasonal or annual costs associated with more frequent sampling. Pulse sampling may be appropriate for parameters that change slowly over time, such as tree establishment and growth, but may not be appropriate for parameters that require seasonal or annual samples, such as animal species population parameters, in order to evaluate habitat restoration effectiveness.

As discussed above in Sections 6.2 and 6.3, the use of reference sites and their reference conditions for parameters of interest are a very important component of monitoring design (Elzinga et al. 2001; Downes et al. 2002; Roni et al. 2005). Reference locations or conditions represent the desired habitat characteristics and/or species population structure characteristics, or parameter conditions and values, that habitat restoration is attempting to achieve. Reference conditions are generally obtained from reference sites, ideally geographically near restoration sites. Data from parameters may be obtained from those reference sites to provide habitat restoration goals and objectives, as well as evaluation criteria. Ideally, actual reference sites should also be sampled as part of the same monitoring design, employing the same spatial and temporal scales as the treatment and control sites that they are being compared to. If physical reference sites or conditions are lacking, then hypothetical models for desired evaluation goals and objectives may be used (Downes et al. 2002; Roni et al. 2005). In riverine systems such as the MRG where few or possibly no reference conditions for habitat restoration exist today, retrospective reference conditions (Roni et al. 2005) may be obtained from historical information to provide at least an indication of desired reference conditions.

The temporal component of monitoring design and planning is as important as spatial considerations. The duration of monitoring depends on the initial research questions based on management objectives and goals and the nature of the system and parameters being monitored. If the principal objective is to determine the immediate effects of restoration on some parameters, with no regard for longer-term changes over time, then short-term monitoring of one to five years may be appropriate. If long-term change is important to document, then long-term monitoring for durations of five to 10 years or longer are needed. The longer any system is monitored, the better that system may be understood relative to temporal change. The MRG is in a region greatly affected by both short- and long-term climate variation, particularly relative to annual precipitation and snow runoff; therefore, long-term monitoring would be most useful relative to MRG habitat restoration evaluation to encompass both wet and dry years and longer-term patterns related to El Niño and La Niña cycles.

The timing of sampling for monitoring within each year is a function of the parameters being measured, and which season or time of day is most appropriate to measure those parameters relative to the goals and objectives of restoration. For example, parameters of the silvery minnow related to reproduction and spawning must be measured during spring runoff when reproduction occurs. Daily sampling of flycatchers is best conducted at dawn when individual birds are actively displaying or foraging. Perennial vegetation is best measured at the end of the growing season when live biomass peaks. Temporal replication of sampling also may be important to monitor habitat or population parameters across seasons or other temporal events.

Ideally, all habitat restoration monitoring and evaluation should be planned and implemented prior to initiating restoration treatments. Defining habitat restoration evaluation objectives and goals should be done at the same time that the objectives and goals for the restoration project and treatments are planned, in advance of implementing treatments. Such an approach is important to 1) provide baseline, pre-treatment, implementation, and initial post-treatment response data and 2) ensure that evaluation objectives and goals are consistent with project and treatment objectives and goals. Once habitat restoration evaluation goals and objectives have been defined and a monitoring design has been chosen, the next step is to establish sampling units for collecting monitoring data. Sampling units will be a function of monitoring design and will consist of entire restoration sites for GIS-level sampling or study plots, quadrats, or transects established within restoration sites. The evaluation criteria presented above include entire sites as sampling units for geomorphology, Hink and Ohmart (1984) vegetation type mapping (along with smaller transects and study plots for vegetation measurements), and river environment patches for silvery minnow sampling. Data collection methods need to be specific to parameters being measured and are usually adopted or adapted from existing literature that reports standard techniques. For example, quadrat or line-intercept measurements for vegetation, observation or trapping for wildlife, netting or egg drift samplers for the silvery minnow, etc., are methods for collecting data.

3. Establish monitoring sites and sampling locations (study plots, transects, etc.). Once an effectiveness monitoring design is determined, monitoring sites will be based on the locations of restoration projects and treatments, and sampling locations will be a function of the monitoring design and where parameters are to be measured and monitored. Ideally, sampling units (e.g., plots, transects) should be randomly or systematically located to be spatially independent, and to avoid researcher bias, sampling units should be replicated to achieve statistical power. Independence of subsample units (e.g., quads within plots) is less critical. Data analysis approaches should be determined at the same time that sampling designs are developed in order to ensure that sampling designs will provide data appropriate for the desired analyzes. This step is very important and often overlooked.

4. Collect pre-treatment data (ideally several years prior to treatments, but at least one year prior) using the chosen sampling design.

5. Initiate data management, including quality assurance/quality control (QA/QC), storage, access, updates, and reporting. A critical part of the monitoring and evaluation process is the development of rigorous data management. Data management includes the planning and oversight of all aspects of data collection, analysis, archiving, and reporting. Key aspects of data management include protocols for field collection, data entry, storage, and QA/QC of data. Careful planning should ensure that data will be structured in appropriate ways for analysis and presentation. A data management plan will need to be developed specifically for Albuquerque Reach habitat restoration monitoring and evaluation data files to provide consistency in data structure, accuracy, and analysis across all habitat restoration projects within the reach. Such standard approaches allow for the comparison of data across treatments and projects and provide a consistency at the program level for the evaluation of the effectiveness of habitat restoration projects and treatments.

6. Analyze and interpret year-one data for appropriate sample sizes and adequacy of sampling design. Again, as stated above, analytical approaches should be determined at the time that sampling designs are developed to ensure appropriate data for these analyzes. Data analysis provides the critical tool for evaluating the effectiveness of habitat restoration treatments, using data representing parameters, and testing hypotheses and questions relative to the effectiveness of habitat restoration based on goals and objectives. Results of data analysis such as summaries and graphics may also be archived as part of data management. Principal approaches to data analysis that will likely be used for Albuquerque Reach habitat restoration effectiveness evaluation include:

A. Treatment assessment: Have treatments changed parameter values or conditions toward a significant increase or decrease in parameter values? Standard experimental statistical analysis (e.g., t-test or ANOVA and non-parametric equivalents) includes tests for differences in treatments versus controls, relative to baseline, and tests for treatment effects on parameters (Quinn and Keough 2002). A significant increase or decrease fulfils evaluation criteria. When all predictor variables are categorical, the relationship between variables involves ANOVA models. The relative importance of each predictor variable in multiple regression models is revealed with F or t statistics and their associated P values from the null hypothesis test that the population intercept equals zero. For non-experimental monitoring designs, visual presentations of qualitative and quantitative data tables, charts, or graphs may be used to evaluate change over time, although such analyses do not allow one to determine if changes are in fact significant or not.

B. Goal assessment: Have treatments caused parameter values or conditions to meet evaluation criteria values or conditions? No statistical testing is involved, but the assessment must determine when means and variances of parameters are within ranges of desired conditions. Parameter values within known reference condition ranges satisfy evaluation criteria. Statistical approaches to determine whether or not parameter values have reached restoration criteria success values, such as bioequivalence analysis (Downes et al. 2002), are available, but are still somewhat problematic in practice.

C. Cause and effect relationships (correlation, regression analyses, and non-parametric equivalents): Are there significant predictor parameters (e.g., habitat) for particular response parameters (e.g., species population) of interest to help explain cause and effect for habitat restoration treatments? For example, the relationship between areas of floodplain inundated during breeding season and numbers of individual flycatchers can be analyzed. The relationship between two continuous variables is accomplished with an analysis of correlation and covariance. Correlation determines if two data sets are dependent on each other, whereas covariance determines the degree to which the two data sets are related or how they vary together. Linear regression analysis is typically used in biology to describe the relationship between bivariate data sets and explain the variability in the response variable by the linear relationship with the predictor variable. A common extension of simple linear regression is multiple regression, where more than one continuous predictor variable is recorded.

D. Descriptive community composition assessments: Are there changes in overall plant or animal communities based on species composition and relative abundance? Biotic community analyses methods include similarity indices, diversity indices, cluster analysis, ordination, indicator species analysis, and analysis of similarity and other non-parametric group difference tests to detect changes in overall biotic community composition relative to habitat restoration treatments (McCune and Grace 2002).

E. Species population structure analyses, including population modeling to determine the status of various attributes of species populations, such as reproduction, mortality, etc.

7. Modify sampling as needed or continue with initial design. Repeat Steps 4, 5, and 6 with year two and year three data for short-term monitoring. Continue for five to 10 years or more for long-term monitoring. Based on analysis of pre-treatment data (or year-one post-treatment data), adjust sampling as needed. For example, sample units may not be the appropriate size or configuration, sample sizes may be too small for analysis, or sample sizes may be larger than necessary. This is an important step to minimize the needs for changes in monitoring design in the future.

8. Implement habitat restoration treatments (construction or alteration of the environment). Once baseline sampling designs, pre-treatment data analyses, evaluation of the initial monitoring and design, and changes to the monitoring design have been completed as needed, then implementation of habitat restoration treatments should commence.

9. Initiate restoration treatment implementation assessment to determine if restoration construction has been conducted properly. If not, modify until treatments are correct. Implementation assessments should be conducted as soon as possible following treatments to determine whether the construction or other treatment activities have been completed as planned. If not, construction or other treatments must be modified as soon as possible until the treatments have been correctly implemented. If possible, treatments should be imposed at a time of year that is most appropriate relative to the sampling schedule for restoration evaluation parameters that will be measured. For example, to accommodate post-restoration measurements of perennial vegetation, treatments should be imposed during the winter, spring, or early summer, so that vegetation may be measured during the late summer when most appropriately measured following restoration treatments.

10. Continue response variable monitoring using the same pre-treatment sampling design for at least three years after treatments (short-term), preferably up to 10 years following treatments (long-term). The duration of monitoring depends on the temporal dynamics of the variables being measured and management needs.

Habitat and population evaluation parameter measurements should then commence as soon as possible, and at the appropriate time of year, following the restoration treatments and completion of the treatment implementation assessments. Parameter monitoring should then continue using the same pre-treatment sampling design (or altered design if needed) for at least three years after treatments, preferably up to 10 years following treatments. Data management and analysis activities also should proceed with modifications as needed to improve the process. In order for habitat restoration evaluation to proceed in a meaningful way, analysis and interpretation of each year's data are essential in order to detect changes relative to restoration treatments and to identify possible problems with monitoring and sampling designs so that adjustments and improvements can be made as quickly as possible. Regularly scheduled reporting of evaluation findings also is important in order to keep managers informed and allow for upper-level programmatic feedback to the monitoring and evaluation process.

11. Continue data management, QA/QC, storage, access, updates, and reporting.

12. Analyze and interpret each year's data relative to evaluation criteria for evaluating restoration treatment effectiveness on target species habitat and population structure parameters.

13. Modify sampling approaches, design, and analyses as needed over time if information needs change (adaptive management).

Monitoring plans for existing restoration projects and treatments will need to be implemented at Steps 1–3, skipped for Steps 4, 8, and 9, and continued with Steps 5, 6, 7, and 10–13. Critical evaluations of the success of Albuquerque Reach habitat restoration projects and treatments should follow the guidelines proposed above in order to ensure that restoration projects and treatments are providing the desired habitats and population structure for the silvery minnow and the flycatcher, according to the goals and objectives for habitat restoration presented in this Study. Below are specific recommendations for monitoring geomorphology and hydrology, and the silvery minnow and flycatcher, relative to Albuquerque Reach habitat restoration.

6.4.2 Monitoring for Evaluation of Geomorphology and Hydrology Habitat Parameters for the Silvery Minnow

Much of the information needed for evaluating bar, island, and bankline destabilization treatments can be collected during surveys of existing and/or new cross sections at the restoration sites. Cross section surveys (repetitive) are a key element of the monitoring program and are critical to an adaptive management program. Cross sections should be surveyed during (ideally) and after spring runoff. If there are no significant peak flows, then no post-runoff surveys are required. The channel monitoring database associated with cross section surveys should include several of the parameters listed below. Some of these parameters link directly to monitoring and the expected restoration treatment results specified above, while others provide important additional information that may be valuable to understanding broader trends. Parameters to consider include:

- USGS gage records of flow and stage.
- Observations of active channel "overbanking."
- Cross section survey data.
- A set of four photos: upstream and downstream at mid cross section and one from each bank toward the opposite bank.
- Observation of channel bed form.
- Bed material size samples at one or more cross sections per restoration site.
- Suspended sediment samples at one or more cross sections per restoration site.
- Bankfull discharge measurements.
- Velocity profiles and review of cross section stations with low velocity.
- Observation of the bank and overbank vegetation.
- Water surface elevations at bankfull discharge.
- Active channel bank locations and heights documented in GIS.

In addition to these parameters, the areal extent of overbank flooding from spring runoff peak flows should be documented with aerial photography (and possibly videos). This database coupled with an on-the-ground data collection program would yield invaluable information from which adaptive management decisions can be made.

6.4.3 MONITORING OF SILVERY MINNOW POPULATION PARAMETERS FOR EVALUATION

Depth, velocity, substrate, and mesohabitat type are key habitat parameters for the silvery minnow (Dudley and Platania 2007a) and should be recorded during monitoring regardless of gear type used. Depth and velocity can be easily measured with a top-setting wading rod fit with a flow meter. Substrate may be classified visually or more intensively using methods, such as the Wolman Pebble Count. Mesohabitat types may be classified from a fine to coarse scale using definitions tailored to the MRG following those outlined by Armantrout (1998). Mesohabitat boundaries should be identified by means of visible changes in depth, velocity, substrate, water surface disturbances, current separation zones, bedforms, and other variables representative of the geomorphic setting (Roper and Scarnecchia 1995; Vadas and Orth 1998; Kehmeier et al. 2007). The collection of key habitat parameters allows managers the ability to increase the precision of parameter estimation through post-stratification schemes.

We propose that several sampling methods be employed, depending on the sampling goals and objectives. There are limitations and biases to all sampling methods, and gear efficiency can be highly variable. The analysis and interpretation of fish community indices are largely influenced by the quality and quantity of data collected (Patton et al. 2000; Meador et al. 2003). It is important to assess sampling biases that may lead to inaccurate assessments of community structure, obscure or suggest false relationships, and ultimately result in faulty conclusions about a fish community (Paller 1995; Kwak and Peterson 2007). Sampling methods that are appropriate to monitor the silvery minnow by season and life stage include:

1. Fyke nets to monitor for adult silvery minnow occupying off-channel floodplain and backwater habitats during spring runoff.
2. MECs to monitor for the presence of silvery minnow eggs in main channel drift during spring runoff and after significant summer monsoon events.
3. Larval fish light traps to monitor for young-of-year silvery minnow in low-velocity off-channel habitats during spring runoff.
4. D-frame kick nets to monitor for silvery minnow eggs and young-of-year in low-velocity off-channel habitats during spring runoff.
5. Fyke nets to monitor for silvery minnow movement during periods of river intermittency or low flow events.
6. Seine nets, fyke nets, and electrofishing to monitor main channel occupancy during summer, fall, and winter.

Detection probability often varies by sampling method. Furthermore, each sampling method has a unique set of limitations that governs its utility in gathering unbiased samples in various physical circumstances. For example, Hatch and Gonzales (2008) note a disparity of sampling efficiency for silvery minnow between fyke nets and seining in floodplain habitats. The researchers speculate that this is probably a consequence of the heightened existence of hazards in floodplain habitats, such as uneven ground, emergent plants, and organic debris. Relative to seining, fyke nets are less affected by these limitations because they operate passively. Hatch and Gonzales (2008) report that the average rate of silvery minnow catch in fyke nets in floodplain habitats was 70 times higher than the rate of catch with seine nets. Hatch and Gonzales (2008) also report an obvious but unquantified difference in representation of silvery minnow size class frequency between sampling methods in floodplain samples. Fyke net samples generally have a greater frequency of larger specimens. This suggests that silvery minnow length frequency derived will generally and imperfectly reflect the true magnitude of variation at the population level. The exception to this generality is the special circumstance in which fish are sampled from a large number of isolated pools in which it is possible to deplete-sample the populations.

The standardization of each monitoring technique is necessary to ensure that parameters are comparable between data sets. The decision to use any one or a combination of the above monitoring techniques will need to consider season, river conditions (discharge, temperature etc.), and silvery minnow life stage. A combination of techniques would be most desirable for inferring changes in population parameters as capture probabilities vary by gear type, key habitat parameters, and fish size. Using only one technique with unknown statistical properties (i.e., capture probability, bias, etc.) could result in faulty conclusions, negatively affecting the population through management decisions based on the erroneous interpretation of data.

6.4.4 Monitoring of Flycatcher Habitat Parameters for Evaluation

Terrestrial vegetation structure and species composition, soil moisture, and distance from standing water are the key habitat parameters typically measured and monitored relative to flycatcher habitat suitability. Vegetation may be measured in a number of ways, ranging from qualitative stand structure categories, such as Hink and Ohmart (1984) vegetation types, to quantification of vegetation canopy cover, canopy height, vertical structure density, ground cover, and stem density, species, and size. Vegetation typing may be conducted as a census of vegetation structural types on entire treatment sites, but quantitative measurements must usually be restricted to samples of the vegetation on a site, measured from study plots or transects. Data collected from sampling units (sites, plots, transects, quadrats) include each plant species encountered, foliage canopy cover, foliage height above ground surface, and counts of individual plants or stems. To reduce negative human impacts to breeding flycatchers, vegetation measurements are generally taken on an annual basis at the end of the breeding season in late summer when birds have departed.

Vegetation sampling methods that are appropriate to measure and monitor the vegetation component of flycatcher habitat include:

1. Hink and Ohmart vegetation structural type classifications (Hink and Ohmart 1984).
2. Modifications of the sampling methods of James and Shugart (1970).
3. Aerial photography and GIS applications/predictive models (Hatten and Paradzick 2003) for measuring vegetation type polygons (Allison et al. 2003; USFWS 2008)

4. Vegetation line-intercept measurement transects, including both continuous and point-line-intercept, often representing subsamples of larger transects or study sites (Elzinga et al. 2001).
5. Belt transects, plots, and quadrats, generally representing subsamples of larger transects or study sites (Elzinga et al. 2001).
6. Tree dimension measurements including diameter, height, crown structure (U.S. Forest Service 2007).
7. Combinations of the above, such as U.S. Forest Service Inventory and Monitoring plot designs (U.S. Forest Service 2007).
8. Modified BBIRD breeding bird monitoring methods (Martin et al. 1997; Moore 2007) to quantify vegetation around existing flycatcher nests and adjacent random locations. This approach has worked well for MRG riparian environments.

For this Study, a combination of the above methods are most appropriate, where the decision to use any one or combination of measurement techniques should made relative to the spatial and temporal aspects of the projects and treatments and the goals of restoration. However, methods that have already been tested and used for flycatcher habitat measurements such as those used by Allison et al. (2003) and Moore (2007) are likely to be the most appropriate for the Albuquerque Reach. Use of existing methods will also allow for better comparisons of findings across monitoring studies.

Ambient temperature, relative humidity, and soil moisture conditions (habitat microclimate) at nesting and/or territory locations have been measured and monitored for the flycatcher (McLeod et al. 2008). Simple handheld devices or instruments with data-loggers may be installed at predetermined sampling locations at restoration sites to ascertain flycatcher habitat microclimate suitability. Such measurements should be taken within a similar spatial and temporal sampling protocol similar to that for vegetation and population parameters so that data may be directly compared across space and time.

6.4.5 Monitoring of Flycatcher Population Parameters for Evaluation

Monitoring for flycatcher population parameters should follow a sequence of steps, from attempting to detect flycatchers within project sites to more detailed demographic measurements once flycatchers are detected and occupancy of sites confirmed. Initially flycatcher monitoring should focus on presence/absence or site occupancy surveys in order to determine if flycatchers are present in restored areas. Such surveys should be initiated along with habitat monitoring above. Flycatcher occurrence sampling is based on visual observations of individual flycatchers, along with acoustical detection of calls and songs (Johnson and Sogge 1997; Finch and Kelly 1999; Moore and Ahlers 2008). Repeated point counts or pedestrian transects are generally used to sample for flycatchers, and such sampling should be conducted throughout the spring and summer months. If flycatchers are detected at a given site, then more intensive surveys should be conducted to determine if the site is occupied and whether a breeding pair (or pairs) has established a nest, as well as habitat use (Cardinal and Paxton 2005). Once site occupancy has been determined, then more detailed measurements of demographic parameters should be measured, such as nest success, clutch sizes, mortality, predation and parasitism (brown-headed cowbird), and other demographic parameters (Durst et al. 2008; McLeod et al. 2008). Such demographic studies are more time consuming but provide valuable information about the performance or success of flycatchers at particular sites, and thus comparative data for assessing restoration effectiveness. Flycatcher population monitoring should be designed to maximize comparisons with habitat parameters, yet actual spatial and temporal aspects of population monitoring will differ from habitat monitoring, given the differences in the spatial and temporal attributes of flycatchers relative to their habitat features.

7.0 DATA GAP ANALYSIS

The purpose conducting the data gap analysis is two-fold. The first is to review the existing data to identify gaps in information pertaining to the current conditions with regards to physical habitat criteria for the silvery minnow and the flycatcher. The second purpose is to review species biology information and data as they pertain to the Albuquerque Reach. The data gaps analysis for both species builds upon the existing body of literature and identifies gaps in our knowledge regarding species biology and habitat ecology. The types of information and data discussed could inform and improve management strategies and could also be used to develop habitat restoration recommendations and inform the development of evaluation criteria and monitoring methods.

7.1 GENERAL RESTORATION

The information and data gaps identified in this section are often required for planning and implementing specific habitat restoration projects. Data regarding soil salinity, soil surveys, vegetation surveys, and jetty jack locations should be obtained and analyzed prior to implementing specific habitat restoration projects. General restoration information and data gaps are presented in Table 7.1.

Table 7.1. General Restoration Information and Data Gap Analysis

Gap	Comments	Recommended Action
Soil/Salinity data	The NRCS Soil Survey for Bernalillo County is available. In addition, select site specific data from the installation of monitoring wells and other restoration/ monitoring projects are available throughout the reach (see for example Caplan and McKenna 2005 and BEMP studies). These surveys are useful for identifying general soil types but lack the specificity desired for habitat restoration planning. Soil salinity, productivity, and soil contamination studies would be helpful in designing habitat restoration projects. An absence of comprehensive soil salinity data for the Albuquerque Reach may affect the success of restoration activities. Recent changes to groundwater levels, drought, and the presence of saltcedar are likely to have contributed to elevated salinity levels. Many riparian species, including cottonwood and coyote willow, are intolerant of high salinity levels.	All vegetation restoration projects require soil conductivity, soil texture, and depth to groundwater data to design features effectively. Soil conductivity and salinity data could be used to target low salinity areas that would provide the greatest potential for riparian vegetation establishment and long-term survival. Comprehensive soil surveys and salinity mapping should be conducted throughout the MRG bosque. Site productivity reflects upon the availability of food resources for both the flycatcher and the silvery minnow. A fine-scale soil survey could be conducted in the bosque in the Albuquerque Reach, and sampling would be conducted at discreet locations and tracked as part of a longitudinal study so changes in productivity can be tracked.
Albuquerque Drinking Water Project data	The Albuquerque Drinking Water Project has begun to divert large quantities of water from the Rio Grande between the Alameda Bridge and the WWTP off of Rio Bravo Boulevard.	Water quality, river flows, and sediment changes should be monitored between where water is withdrawn and returned in the river.
Vegetation classification	Knowledge of vegetation consistency, density, and age structure is a critical component of existing and future ecosystem restoration, as well as wildfire planning efforts.	Studies, such as the 2005 Hink and Ohmart analysis (Milford et al. 2006) and the MRG River Bar Vegetation Map (Milford et al. 2003), should be ground-truthed prior to implementing habitat restoration projects. Albuquerque Reach-wide vegetation mapping would have utility for future habitat restoration planning. While a significant upfront cost, this would facilitate future restoration initiatives.

Table 7.1. General Restoration Information and Data Gap Analysis, continued

Gap	Comments	Recommended Action
Infrastructure modifications/ maintenance	Various entities, including the MRGCD, Reclamation, the Corps, and the City of Albuquerque routinely conduct maintenance on infrastructure in and around the bosque. No central depository exists for data showing modifications and impacts to the riparian corridor.	A central depository should be created. This would likely entail compiling reports as well as GIS data.
Identification of contractor access and staging areas	Large and/or specialized equipment would likely be required for project implementation. Identification of suitable access and staging within the bosque would be important.	Delineation of contractor staging and access areas should be performed as part of the specific project design and specification.
Consolidated information on location of remaining Kellner jetty jacks	SWCA possesses GIS data indicating the location of jetty jacks. Reclamation and the Corps have mapped jack locations and have removed numerous jacks as part of various restoration efforts.	Databases should be consolidated and remaining jetty jack locations should be field verified. Consolidated shapefiles should be created and maintained.

Note: NRCS = Natural Resources Conservations Service.

7.2 Rio Grande Silvery Minnow

7.2.1 Information Needs and Future Research

Habitat restoration can be an effective tool in species recovery only if it is based on a sound understanding of basic species principles. The restoration goals and objectives suggested in this Study are based on population biology parameters and not simply the area restored or the number of habitat restoration projects implemented. The information presented below defines information a restoration ecologist needs to design effective habitat restoration projects. Additionally, ecological restoration represents our understanding of the species biology and the ecosystems the species inhabits. The following discussion identifies gaps in our knowledge that may be answered, in part, through an effective monitoring program and a focused research program. The information obtained from these activities would then flow back into habitat restoration design in an adaptive management program.

Most contemporary investigations of silvery minnow life history are relevant to a limited subset of the environmental conditions that would have likely served as a selective basis for life-history adaptation. This incomplete perspective is largely a consequence of anthropogenic regulation of hydrologic conditions in the MRG, resulting in contemporary measures of central tendency and variation of discharge that deviate from pre-impoundment conditions, along with altered fluvial processes and basin geomorphology. Observations of the silvery minnow under such restrictive conditions can easily lead to misinterpretation of its needs and misidentification of causes for observed phenomena.[16] Knowledge of the habitat conditions under which the silvery minnow would be reasonably expected to maintain viable populations is vital to efforts to manage for a functioning condition that is aligned with fitness characteristics of the species.

Although numerous descriptions of quantitative and qualitative aspects of the flow regime of the MRG have been published, little attention has been paid to the evolutionary linkages of the natural flow regime and the fitness of the silvery minnow to live in this environment. Understanding the links between species' fitness and flow regime is crucial for the effective management and restoration of running water ecosystems. Although the importance of hydrologic dynamics to silvery minnow reproductive biology and resultant population trajectories is now generally acknowledged, the challenge remains to develop a mechanistic understanding of observed effects.

Information deficits presently preclude credible inferences about habitat limitation based on accurate information on the quantity and distribution of different habitats available to the silvery minnow along with direct measures of the consequences (growth, survival, fecundity, reproductive success) of occupying different habitat types. The role of habitat in limiting silvery

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[16] Some of the more pivotal advancements in elucidating adaptive aspects of the silvery minnow's life history and behavior come from recent observations of the species over successive years of contrasting and extreme hydrologic conditions that are unusual to the contemporary MRG, but nonetheless reflective of an undeveloped MRG. Only under such variable and extreme environmental circumstances can one hope to learn about silvery minnow life history traits and behaviors that appear to be adaptive to hydrologic extremes, such as the occupation or avoidance of various drought- or flood-prone habitats.

minnow population abundance and growth can best be understood by considering habitat effects over successive life stages because of differential life stage utilization of available habitats over variable discharge regimes (Halpern et al. 2005). Silvery minnow spawning and recruitment to the juvenile stage tends to vary positively with high-discharge events during spring and summer, especially discharge levels that inundate the floodplain. Recruitment to the adult life stage varies with habitat type, habitat quantity and quality, and the continuity of surface water habitat in time and space. Conditions of drought coupled with extractive use of water frequently result in the loss of multiple expansive segments of running water habitat in the MRG as the principal proximate factor linked to significant silvery minnow mortality. In each instance, life stage dynamics are linked to population consequences of habitat loss or gain. The probability that an individual will survive to reproduce will be the product of a series of stage-specific survival probabilities that depend on habitat conditions experienced by each life stage. Under normal contemporary conditions of environmental variation, successive life cycle stages represent unique leverage opportunities for directed management to enhance the long-term probability of species survival.

Research is needed to identify alternate means of creating and maintaining desired discrete habitat features that will serve the needs of different life stages of the silvery minnow over a broad range of hydrologic conditions. Large water impoundments combine with sediment and flood control structures and large-scale extractive use of water to profoundly alter the landscape-level fluvial processes that formerly operated to maintain physical habitat features common to the pre-development MRG. From historic records of fish collections in the MRG (Sublette et al. 1990), we can surmise that pre-development habitat features of the MRG were aligned with fitness characteristics of a diverse native ichthyofauna, including the silvery minnow. Such discrete habitat features will persist only if the processes that generate them are maintained in a broader landscape context. Unfortunately, the practicality of this seems precluded by the contemporary constraints of large-scale water development on geomorphic processes in the basin coupled with water scarcity, a condition exacerbated by frequent recurring conditions of drought.

Planning for the provision of refugial habitats to overcome drought-associated habitat limitations requires that a quantitative relationship between habitat and population size be established for the species and that sufficient habitat be maintained to meet an established recovery target based on the habitat-population relationship. For silvery minnow, this relationship, although unquantified, is known to vary profoundly by life stage and with varying hydrologic circumstances. As such, habitat-population relationships will be complicated by the necessary consideration of stage-specific estimates of survival (i.e., the fraction of the population that successfully recruits to each life history stage) and separate relationships between habitat and abundance for each life stage over a range of hydrologic conditions.

Several options exist to achieve a desired outcome involving refugia to protect against mortality-causing drought (emphasizing the need to conserve source populations). It seems possible that critical reaches of wetted surface habitat can be maintained over short periods of intermittent flow by strategic utilization of the irrigation infrastructure of the MRG to surgically convey water, ancillary to consumptive needs, to various delivery points along the river.

Likewise, strategically placed wells could be used for the same purpose with a heightened assurance of water delivery to meet critical time- and space-dependent needs. These engineered hydrological measures can be coupled with measures to enhance geomorphic processes utilizing flow-deflecting structures (e.g., large woody debris or other revetment structures) that serve to focus pool-scouring water velocity. Experimental design should focus on a variety of refugial habitat designs comprising several spatial configurations. Fundamental aspects of evaluation should include considerations of efficiency and effectiveness, including conditions under which a management alternative will succeed or fail and considerations of longevity of benefits. The best indices of habitat quality are direct measures of the fitness consequences to individuals (growth, survival, fecundity, reproductive success) of using different habitat types, ideally in the absence of competition (i.e., at low density).

7.2.2 PRIMARY BIOLOGICAL PROCESSES AND VITAL RATES

Demographic parameters for many animal populations vary with the age of individuals in the population. An age- or life-stage-specific record of survival, mortality, and fecundity is essential for understanding observed patterns of population growth and decline. Likewise, an age- or stage-based record of survival, mortality, and fecundity is essential for predicting the future growth or decline of populations of concern, including management intervention strategies that are expected to alter rates of birth and death. These data are fundamental to understanding past observed *sawtooth* population dynamics, characterized by periods of exponential growth followed by exponential decay.

Cowley et al. (2006) observed five age classes (I–V) of silvery minnows in an 1874 sample from San Ildefonso, New Mexico, based on an examination of scales for annuli. This lifespan is characteristic of other species of *Hybognathus* (Becker 1983; Lehtinen and Layzer 1988). Nonetheless, length alone is regarded as an imperfect index of silvery minnow age, especially on a regional scale, because growth of fish is known to vary longitudinally with energy inputs and length of the growing season, and because the species' extended spawning season generally does not provide for a clear demarcation of age by size without validation of age founded on known age individuals or from evidence of annual growth that is often discernable on scales and otoliths.

Current understanding of silvery minnow age class strength and contemporary rates of survival and mortality can only be considered provisional; however, based on the chronological record of count-based indices of species status,[17] age class strength and the vital rates of birth and death are thought to be highly variable in time and space, primarily due to hydrologic variability linked either to strong recruitment or death.

The USFWS (2003) has determined that the silvery minnow experiences high levels of mortality after maturation. Seemingly, contemporary impressions of silvery minnow mortality and survival rates come from apparent *trends* in silvery minnow density over time. Density

[17] The referenced chronological record of count-based indices of species status is derived variously from records of the Division of Fishes, Museum of Southwestern Biology, University of New Mexico and the American Southwest Ichthyological Research Foundation.

estimates result from count data standardized to some unit of area. Traditionally, in the case of the silvery minnow, density is expressed in terms of fish captured per 100 m^2 of surface water sampled. At any given point in time and space, silvery minnow abundance and density is a function of reproduction, recruitment, and age-specific schedules of mortality and growth, along with varying rates of immigration and emigration. Complicating matters, density can have an effect on mortality and survival. Teasing out the partial effects of individual variables that govern productivity is a daunting task. Suffice it to say, fish abundance (or fish density) and survival (or the antithetical concept of mortality), while related, are not equivalent concepts.

Without judging the veracity of the claim that the silvery minnow experiences high levels of mortality after maturation, it is interesting to note that estimates of mortality and survival rates of silvery minnow populations that might be regarded as *baseline* have never actually been quantified. So while we may be interested in the rates of survival of salvaged silvery minnow in the wild, we actually do not have a meaningful context in which to interpret these rates at the population level of biological organization. This is problematic, because to properly evaluate projects we need to be able to relate their outputs to the amelioration of the problems to which they are relevant.

Table 7.2 summarizes silvery minnow information and data gaps. The information presented above and in Table 7.2 will inform the habitat analysis and restoration recommendations while providing the basis for evaluation criteria and monitoring recommendations.

Table 7.2. Silvery Minnow Information and Data Gap Analysis

Gap	Comments	Recommended Action
Habitat availability	Although existing literature documents silvery minnow preferred habitat, little or no literature exists that documents spatial and temporal amounts of spawning, nursery, and adult habitat.	Studies should be conducted to define spawning habitat for the species and map the amount of available habitat using habitat preferences defined by Dudley and Platania (1997) spatially and temporally over a range of flow regimes.
Demographics (longevity of contemporary population)	Cowley et al. (2006) documented the presence of five age classes from specimens collected in 1874 from San Ildefonso, New Mexico. The majority of contemporary spawning silvery minnows are age 1+, with 2+ fish generally making up less than 10% of the population. This information is not verified through scale age analysis. The main advantage of age-based stock assessment over more traditional approaches, such as catch per effort, as an index of population abundance, is that this assessment can be applied without knowledge of effective sampling effort, catchability, or gear type selectivity.	Scales should be collected from silvery minnow recorded during monitoring. Recent collections have documented the presence of multiple age classes of silvery minnow in the Albuquerque Reach; however, researchers were not permitted to collect scales to verify the observations (Hatch and Gonzales 2008). In addition, silvery minnow from the Albuquerque Reach appear to achieve a larger maximum size than fish collected from the Isleta Reach, possibly indicating an older aged population in the Albuquerque Reach. The presence of older aged silvery minnow may be attributable to the reach's perennial flow.
Growth	Little or no information exists that documents growth rates of wild silvery minnows. Remshardt (2005) has reported growth rates of wild fish.	Size information (length and weight) should be collected from all silvery minnow collected during monitoring. Studies can then be conducted to determine which occupied habitats are the most suitable for silvery minnow growth. Studies can include growth rates for wild fish (see Remshardt 2005). If growth data are collected from silvery minnow throughout the MRG, then managers could start to determine what habitats, reaches, months, years, etc., result in maximized silvery minnow growth and how management could affect growth.

Table 7.2. Silvery Minnow Information and Data Gap Analysis, continued

Gap	Comments	Recommended Action
Reproduction (fecundity)	Currently, one can only speculate about the year class or life-stage-specific reproductive potential of the silvery minnow; formal analysis of reproductive potential awaits the accumulation of requisite managerial or research-grade data. This is unfortunate because such information is vital to understanding observed population dynamics and assessing risks associated with a wide array of management alternatives, especially as they relate to the management and administration of limited water resources considering that the reproductive biology and early life history of the silvery minnow are so intricately linked to hydrologic dynamics.	Studies should be conducted to document the fecundity for silvery minnow over the range of encountered sizes.
Population monitoring/trends	Population monitoring and population estimates have been and continue to be conducted, including before and after spawning. However, a sound management program should periodically check the metrics being used against a robust survey approach with desirable statistical properties, such as estimates of abundance. If an index of abundance (i.e., fish/ 100 m^2) data does not correlate with absolute abundance, that what do the trends mean from a management standpoint? One fundamental problem of trend extrapolation presumes, contrary to experience, that the future will be like the past. Formal assertions of trends through traditional regression analysis of such data sets are dependent on a constant variation in observations (i.e., constant capture probabilities) over time. In the case of count data for the silvery minnow, a schooling species exhibiting uneven distributions and dissimilar capture probabilities, such assumptions cannot be satisfied. It is probable that variance gets larger as density of a schooling species gets smaller. In all likelihood, such data are ill suited for even simple retrospective characterizations of trends based on traditional regression analysis.	Some suggestions include closed population (depletion or mark-recapture) or open population (mark-recapture) studies to estimate catchability of the species for commonly used gear types.

Table 7.2. Silvery Minnow Information and Data Gap Analysis, continued

Gap	Comments	Recommended Action
Abundance of spawning silvery minnow ("escapement")	Estimates of the number of spawning adults would provide managers with an index of population status and expected recruitment. This index would provide managers with information that would allow for annual adaptive management of water in the MRG.	Silvery minnow should be monitored immediately prior to and during spawning. These data can then be used to develop index values of the minimum number of adults necessary for a viable population.

7.3 SOUTHWESTERN WILLOW FLYCATCHER

The flycatcher is a difficult species to track, and much of the information about the species has been derived from studies of its habitat. As such, many of the identified data gaps in the Albuquerque Reach are related to habitat. Below are the identified data gaps and recommendations to identify suitable habitat locations within the Albuquerque Reach and the greater MRG.

Quantitative studies designed to identify the critical relationships between the presence of and/or proximity to standing water and flycatcher site/territory occupancy are needed. Although much flycatcher life history and habitat research has been conducted over the last 10 years, there is a paucity of *quantitative* studies focused on the habitat requirements of the species as related to water. Typically, flycatcher studies incorporating water investigations record hydrological conditions at sites using *qualitative* means, such as general habitat descriptions for entire breeding sites or survey areas. Manipulative experiments at restoration sites that attempt to duplicate hydrological conditions at breeding sites may provide managers information regarding the amount and duration of standing water needed to create and maintain the structural characteristics of vegetation found at occupied flycatcher habitat. Experiments should include different types of water impoundment structures and materials to identify those that are best suited for riparian ecosystem replication. Examining the critical relationships between the presence of and/or proximity to standing water may help guide habitat restoration and site enhancement efforts for the flycatcher within the Albuquerque Reach and elsewhere.

Although much funding and effort is currently being focused on creating and restoring riparian habitat along the MRG for the flycatcher, the degree to which the species uses the river corridor as a migratory flyway and/or prospective existing habitat is unknown and should be investigated. Determining if, how, and where the flycatcher prospects in existing habitat along the MRG may provide insight as to where restoration and enhancement sites should be located to best facilitate colonization.

Habitat use by unpaired resident and non-territorial floater (including returning juveniles) flycatchers remains largely unknown, and future studies (e.g., using radio telemetry) should document habitat use for unpaired resident and non-territorial floater flycatchers. These data may help guide restoration efforts and promote recovery of the species by providing quantitative information regarding how the spatial patterning of habitats within the greater landscape best facilitates flycatcher immigration and establishment of new populations.

The affinity of breeding flycatchers to standing water and saturated soil is noted consistently in the literature, and presence of water may be a factor in sustaining particular vegetation features at breeding sites (Paradzick 2005) and providing a more suitable microclimate for raising offspring (Sogge and Marshall 2000; McLeod et al. 2008). Moreover, the fluctuating availability of surface water at flycatcher breeding sites is likely one factor influencing residency and breeding at a site in any given year, with flycatchers breeding in years when sites contain standing water (Weddle et al. 2007; McLeod et al. 2008). Vegetation studies conducted by McLeod et al. (2008) have found flycatcher nest sites to be significantly closer to surface water or saturated soil during nesting than at unoccupied sites within the same breeding patches. Assessing potential flycatcher habitat within the Albuquerque Reach should include examination and mapping of perennial, intermittent, and ephemeral water as well as groundwater table data. Areas along the reach that contain high water tables and receive intermittent flows should be considered the most potentially suitable for flycatchers. Data analysis gap results are summarized in Table .

Table 7.3. Flycatcher Information and Data Gap Analysis

Gap	Comments	Recommended Action
Habitat use by unpaired resident and non-territorial floater flycatchers (including returning juveniles)	Typically, flycatcher studies incorporating water investigations record hydrological conditions at sites using *qualitative* means, such as general habitat descriptions for entire breeding sites or survey areas.	Use a delphic process involving avian ecologists, biologists, and landscape ecologists to ensure habitat assessments conducted along the Albuquerque Reach to produce data that best facilitate habitat restoration and site enhancement efforts for the flycatcher.
The degree to which the species uses the river corridor as a migratory flyway and/or prospects in existing habitat, including effects of surrounding urban environments and activities on habitat quality	Determining if, how, and where the flycatcher prospects in existing habitat along the MRG may provide insight as to where restoration and enhancement sites should be located to best facilitate colonization. Locations near human environments and activities may limit habitat suitability.	Map perennial, intermittent, and ephemeral water sources in the MRG. Use LiDAR as a method to delineate suitable habitat. Use high-resolution aerial photographs to delineate suitable habitat, and prioritize areas away from human activity. Identify potential habitat areas as being proximate to high or low human activities, and compare occupancy by flycatchers (migratory and breeding) over time.
Critical relationships between the presence of and/or proximity to standing water and flycatcher site/territory occupancy	These data may help guide restoration efforts and promote recovery of the species by providing quantitative information regarding how the spatial patterning of habitats within the greater landscape best facilitates flycatcher immigration and establishment.	Examine and map perennial, intermittent, and ephemeral water and groundwater table data to assess potential habitat suitability. Future studies (e.g., using radio telemetry) should document habitat use for unpaired resident and non-territorial floater flycatchers.

7.4 HYDROLOGY, HYDRAULICS, AND GEOMORPHOLOGY

Many hydrologic studies have been conducted related to the MRG. Because the river dynamic and geomorphic changes impact hydrology along the MRG's riparian corridor, studies require constant revision and updating. The information and data gap analysis presented in Table 7.4 is based on initial information and data gaps for the Study. This list focuses on what we believe will be required to advance the recommended restoration projects to final design and ultimately construction. We anticipate that this list will evolve and may expand as we progress with our work.

Table 7.4. Hydrology Hydraulics and Geomorphology Information and Data Gap Analysis

Subreach Specific Data

Sub-Reach ID	River Mile Start	River Mile End	Description
Reach 1	201.5	192.2	Barranca Arroyo to Alameda Bridge

Gap	Comments	Recommended Action
Active channel cross section surveys	Existing sections: BB-323, 327, 338–342, 345; CR-355, 361, 367, 372, 378, 382, 386, 388, 394, 400, 413; CA-1; CO-31-34. Good coverage. Recent surveys 2004–2006.	Prior to project implementation, resurvey existing lines. Add cross sections at key locations. Verify existing condition hydraulics. Create site-specific models with new survey data to support final design of in-channel projects.
High-resolution topographic data	Data exists for Sandoval County (TRM 2000). Bernalillo County/ AMAFCA/ Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are suitable for project identification and preliminary design and quantity computation.	Site-specific ground-based data collection (RTK, GPS, or total station) should take place prior to final design and development of P&S. Important for bars, banks, and islands that may be modified.

Sub-Reach ID	River Mile Start	River Mile End	Description
Reach 2	192.2	187.9	Alameda Bridge to Montaño Bridge

Gap	Comments	Recommended Action
Active channel cross section surveys	Existing sections: CR-435, 436, 438, 440, 441, 443, 448, 458, 462; CA-2-13; CO-35. Good coverage. Most surveyed in 2004–2005.	Prior to project implementation, resurvey existing lines. Add cross sections at key locations. Verify existing condition hydraulics. Create site-specific models with new survey data to support final design of in-channel projects.
High-resolution topographic data	Bernalillo County/AMAFCA/Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are suitable for project identification and preliminary design and quantity computation.	Site-specific ground-based data collection (RTK, GPS, or total station) should take place prior to final design and development of P&S. Important for bars, banks, and islands that may be modified.

Sub-Reach ID	River Mile Start	River Mile End	Description
Reach 3	187.9	183.4	Montaño Bridge to Central Bridge

Gap	Comments	Recommended Action
Active channel cross section surveys	Existing sections: AQ-467, 472, 476, 480, 487, 488, 503, 507. Limited coverage. Surveyed in 2004.	Prior to project implementation, resurvey existing lines. Add cross sections at key locations. Verify existing condition hydraulics. Create site-specific models with new survey data to support final design of in-channel projects.
High-resolution topographic data	Bernalillo County/AMAFCA/Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are suitable for project identification and preliminary design and quantity computation.	Site-specific ground-based data collection (RTK, GPS, or total station) should take place prior to final design and development of P&S. Important for bars, banks, and islands that may be modified.

Table 7.4. Hydrology Hydraulics and Geomorphology Information and Data Gap Analysis, continued

Subreach Specific Data, continued			
Sub-Reach ID	**River Mile Start**	**River Mile End**	**Description**
Reach 4	183.4	177.1	Central Bridge to Tijeras Arroyo
Gap	**Comments**		**Recommended Action**
Active channel cross section surveys	Existing sections: AQ-521, 526, 531, 535; A-1-9; CO-36, 37. Fair coverage. AQs and COs surveyed in 2004–2005. A lines surveyed in 1999.		Prior to project implementation, resurvey existing lines. Add cross sections at key locations. Verify existing condition hydraulics. Create site-specific models with new survey data to support final design of in-channel projects.
High-resolution topographic data	Bernalillo County/AMAFCA/Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are suitable for project identification and preliminary design and quantity computation.		Site-specific ground-based data collection (RTK, GPS, or total station) should take place prior to final design and development of P&S. Important for bars, banks, and islands that may be modified.
Sub-Reach ID	**River Mile Start**	**River Mile End**	**Description**
Reach 5	177.1	169.3	Tijeras Arroyo to Isleta Diversion Dam
Gap	**Comments**		**Recommended Action**
Active channel cross section surveys	Existing sections: AQ-563, 567, 578, 589, 595, 600, 606, 609, 621, 625, 643; CO-38. Limited coverage. Surveyed in 2004.		Prior to project implementation, resurvey existing lines. Add cross sections at key locations. Verify existing condition hydraulics. Create site-specific models with new survey data to support final design of in-channel projects.
High-resolution topographic data	Bernalillo County/AMAFCA/Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are suitable for project identification and preliminary design and quantity computation.		Site-specific ground-based data collection (RTK, GPS, or total station) should take place prior to final design and development of P&S. Important for bars, banks, and islands that may be modified.

Table 7.4. Hydrology Hydraulics and Geomorphology Information and Data Gap Analysis, continued

Reach-wide Data		
Gap	**Comments**	**Recommended Action**
High-resolution topographic data	Bernalillo County/AMAFCA/Corps digital mapping project (BHI 2000) provides high-resolution LiDAR within levees. Data are dated and does not provide the resolution from current technology.	Acquire aerial LiDAR topographic data for the entire Albuquerque Reach. Create a DEM to be used for final designs and plans and the development of P&S.
Soils data - active channel	NRCS Soil Survey for Bernalillo County is available. In addition, Reclamation bed material sediment gradations are available for select cross sections within the reach.	Prior to project implementation, collect bed material samples at historic locations of sample collection. Compare data and adjust designs or criteria if warranted.
Groundwater information	Many shallow groundwater monitoring wells and/or piezometers exist within the project (BEMP, RMRS, etc.) reach but have a limited associated database.	Consolidate databases and continue to monitor water levels. Adjust designs and or criteria if necessary based on most current data.
Groundwater/Surface water interaction	The interaction between groundwater and surface water is important in an area managed with a policy of conjunctive management. Groundwater/surface water interactions are important in assessing flycatcher habitat.	The Collaborative Program has funded recent studies to analyze groundwater and surface water interactions (conducted by the NMISC and USGS). The NMISC and the USGS should be contacted for the results of these studies.
Detailed hydraulic model	Existing 250-foot grid FLO-2D model is suitable for project identification and feasibility analysis.	Create site specific HEC-RAS files with most current field surveyed cross sections. Use for final design of restoration projects.
Updated flow frequency/duration information	Construction contract would require a time window for implementation. Care and diversion of water would be critical for successful construction of in-channel projects. Most current data available should be used to estimate flow magnitudes and durations.	During P&S, update existing analysis with most current USGS data to provide flow duration information.

AMAFCA = Albuquerque Metropolitan Arroyo Flood Control Authority; AQ = Albuquerque Range Lines; BHI = Bohannan Huston, Inc.; CO = Cochiti Range Lines; NRCS = Natural Resources Conservation Service; P&S = Plans and Specifications; RMRS = Rocky Mountain Research Station; RTK = Real Time Kinematic; TRM = Thomas R. Mann and Associates.

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