Rio Grande Valley State Park,

Central to Montaño Project:

Environmental Monitoring Plan and Baseline Data Report

Prepared for
City of Albuquerque

Prepared by
SWCA Environmental Consultants

October 29, 2014

RIO GRANDE VALLEY STATE PARK, CENTRAL TO MONTAÑO PROJECT:

ENVIRONMENTAL MONITORING PLAN AND BASELINE DATA REPORT

Prepared for:

CITY OF ALBUQUERQUE
OPEN SPACE DIVISION
Dr. Matthew Schmader
3615 Los Picaros SE
Albuquerque, New Mexico 87105

Prepared by:
SWCA ENVIRONMENTAL CONSULTANTS
5647 Jefferson Street NE
Albuquerque, New Mexico 87109
www.swca.com

SWCA Project No. 26561

October 29, 2014

EXECUTIVE SUMMARY

The City of Albuquerque is considering improvements, additions, or changes to existing public amenities and habitat restoration within Rio Grande Valley State Park from Central Avenue to Montaño Boulevard ("project"). The proposed project may include alterations to existing interior pedestrian and user trails throughout the area and possible closures of unofficial side-trails if warranted. Trail improvements under consideration may consist of widening in places as needed for better visitor access, and compacting soft areas of the trail with stabilized crusher fine gravel to improve usability and to prevent physical degradation of the trail. Interpretive wayside signs and kiosks may be installed to provide general information or place-specific environmental, historical, or cultural information. In addition, the City proposes to upgrade existing trailhead and access parking areas at Central Avenue on the west side of the Rio Grande. The goal of the project is to protect the natural environment of the bosque, to better provide for a variety of user experiences, and to improve and manage that range of experiences.

In order to evaluate potential consequences of any proposed actions, the City has contracted SWCA Environmental Consultants (SWCA) to conduct environmental monitoring of soils, vegetation, and bird communities in the project area. The baseline environmental monitoring will be used to determine if any sensitive habitats or ecological concerns exist. Baseline information will be used to guide future planning efforts including location and design of trails and proposed improvements. Baseline information can be used to determine if any future management actions might result in positive or detrimental effects within the project area.

Baseline environmental monitoring was conducted by SWCA along the existing primary interior bosque trail in the project area in 2014 (pre-project baseline monitoring). This monitoring effort will be repeated again in 2015 (post-project effects monitoring). Environmental monitoring will establish baseline conditions along the existing primary bosque interior trail, and along existing unofficial trails that could be closed and restored. This environmental monitoring is intended to anticipate whether components of the proposed project will have positive or negative effects on adjacent soil surfaces and native plant and bird communities.

SWCA has produced this background information report on existing environmental conditions within the proposed project area to provide the City and the public with an understanding of human environmental disturbance already present in the project area. Such understanding provides context for evaluating current environmental conditions and to anticipate effects of any future project actions. This document presents information on the historical and existing environment of the project area, providing context for how monitoring data will be evaluated relative to the goals of the project, and to assess any potential future environmental effects. This environmental baseline report and planned environmental monitoring focuses on biological resources and soil conditions.

This report first presents an overview of the environmental history of the middle Rio Grande, along with information on the current environments and biota of the bosque with an emphasis on the Albuquerque Reach. Understanding the environmental history and the current setting of the bosque is important because the bosque has already experienced considerable ecological impacts from human activities. Geomorphologic features, hydrology, and plants and animals found in the bosque today are largely represented by biotic communities that resulted from human intervention, and which are greatly changed from their former pre-human disturbance conditions. Regulation of Rio Grande water, including the termination of natural flow and flooding events, loss of multiple dynamic river channels and associated natural overbank flooding, is the primary source of decline in bosque ecosystems, biotic communities, and ecosystemic function. The current Rio Grande bosque is a human-altered environment that requires human management to emulate former "natural" conditions. This report evaluates how the proposed project relates to a number of existing Rio Grande bosque environmental management plans, and provides recommendations for habitat restoration that could help restore physical environments and biotic communities to more natural pre-human disturbance conditions.

Results from initial baseline measurements of vegetation, birds, and soil conditions by SWCA indicate that there are no significant differences between a series of paired control transects (locations away from the main trail corridor) and treatment transects (locations along the main trail corridor). Based on background reviews and evaluation of current bosque environmental conditions, SWCA concludes that activity within the monitored areas is not likely to result in expectable adverse environmental impacts or degradation to this area of the bosque. Post-treatment monitoring data from 2015 and future years will determine if the this project does or does not significantly affect vegetation, birds, and soils, and if so, in what ways. The information obtained from this environmental monitoring may then be used in an adaptive management process by the City to achieve long-term management goals without causing adverse environmental impacts.

TABLE OF CONTENTS

1 INTRODUCTION 1
2 ENVIRONMENTAL HISTORY OF THE MIDDLE RIO GRANDE BOSQUE .. 10
2.1 River Dynamics 11
2.2 Floodplain and Bosque Environments 12
3 CURRENT ENVIRONMENTAL CONDITIONS OF THE MIDDLE RIO GRANDE BOSQUE 13
3.1 River Dynamics 13
3.2 Climate Change 17
3.3 Floodplain and Bosque Environments 18
3.3.1 Vegetation 18
3.3.2 Wildlife 29
4 RELEVANT ENVIRONMENTAL PROJECTS 36
4.1 Albuquerque Bernalillo County Water Utility Authority Drinking Water Project Mitigation 39
4.2 Albuquerque Bernalillo County Water Utility Authority San Juan Chama Drinking Water Project 39
4.3 Bosque Ecosystem Monitoring Program 39
4.4 Bureau of Reclamation Albuquerque Overbank Project 40
4.5 Bureau of Reclamation I-40 Bar Project 40
4.6 Bureau of Reclamation Bernalillo and Sandia Priority Projects 40
4.7 NMISC Riverine Restoration Project, Phase I 40
4.8 NMISC Riverine Restoration Project, Phase II and Phase IIa 41
4.9 NMISC Riverine Restoration Project, Atrisco Restoration 41
4.10 NMISC Rio Rancho Willow Creek and North Beach Habitat Restoration Project ... 41
4.11 City of Albuquerque Open Space Division Environmental Enhancement Plan 42
4.12 City of Albuquerque Open Space Division Rio Bravo Project 42
4.13 U.S. Army Corps of Engineers Habitat Restoration Projects 42
4.14 Pueblo Habitat Restoration Projects 43
5 MIDDLE RIO GRANDE BOSQUE MANAGEMENT PLANS 45
5.1 Bosque Action Plan 45
5.2 Middle Rio Grande Ecosystem: Bosque Biological Management Plan 49
5.3 Middle Rio Grande Conservation Initiative 51
6 POTENTIAL ENVIRONMENTAL EFFECTS OF THE RGVSP CENTRAL TO MONTAÑO PROJECT 52
6.1 Trail and Associated Recreational Amenities Environmental Monitoring 55
6.1.1 Objectives of Environmental Monitoring 55
6.1.2 Evaluation Criteria for Environmental Monitoring 55
6.1.3 Environmental Monitoring Design and Methods 58
7 ENVIRONMENTAL MONITORING RESULTS 63
7.1 Soil and Vegetation Monitoring Results 63
7.1.1 Soil Surface Features 63
7.2 Bird Community Monitoring Results 70
7.3 Repeat Photo Monitoring Initial Baseline Photographs 81
8 RECOMMENDATIONS FOR HABITAT RESTORATION AND VISITOR MANAGEMENT ASSOCIATED WITH THE PROJECT 82

8.1 Vegetation, Wildlife, and Habitat Management 82
8.2 Visitor Management 83
9 CONCLUSIONS 84
10 REFERENCES 86
APPENDIX A HINK AND OHMART (1984) CODE DEFINITIONS 102

LIST OF FIGURES

Figure 1.1. Location of the proposed RGVSP Central to Montaño Project. 3
Figure 1.2. Northern portion of the proposed RGVSP Central to Montaño Project. 4
Figure 1.3. Central portion of the proposed RGVSP Central to Montaño Project. 5
Figure 1.4. Southern portion of the proposed RGVSP Central to Montaño Project. 6
Figure 1.5. Example of an existing soil-based trail at the Rio Grande Nature Center State Park. 7
Figure 1.6. An example of the existing trail with fine-crush rock at the Rio Grande Nature Center State Park. 7
Figure 1.7. Example unofficial side trail at the Rio Grande Nature Center State Park, showing soil erosion and damage to vegetation. 8
Figure 3.1. Monthly average annual flows recorded from the USGS Albuquerque gage (08330000), 1974–2013 (USGS 2014). 14
Figure 3.2. Estimated groundwater elevation. 16
Figure 3.3. Cottonwood/Russian olive, Hink and Ohmart (1984) structural type I classification, Albuquerque Reach bosque. 20
Figure 3.4. Hink and Ohmart (1984) structural classification images (USACE et al. 2007). 21
Figure 3.5. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions. 22
Figure 3.6. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions. 23
Figure 3.7. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions. 24
Figure 3.8. Inundated river bar and vegetation growth in the Albuquerque Reach. 25
Figure 3.9. Coyote willow and saltcedar on the interior section of an Albuquerque Reach point bar. 27
Figure 3.10. Russian olive in the Albuquerque Reach colonizing channel margin (background) with cottonwood behind. 28
Figure 4.1. Past and existing habitat restoration projects of the MRG Albuquerque Subreach. 37
Figure 4.2. Detail of prior projects completed within current project area, RGVSP from Central to Montaño 38
Figure 6.1. Diagram of a BEMP plot as used for soil and vegetation monitoring. 58
Figure 6.2. Locations of vegetation and soil measurement BEMP plot and bird transect locations across the project area. 59
Figure 6.3. Diagram of control and treatment vegetation and soils plot placements. 60
Figure 7.1. Mean percent canopy cover of bare soil measured from control and treatment vegetation and soils plots. 63

Figure 7.2. Mean percent canopy cover of soil surface biotic crust measured from control and treatment vegetation and soils plots....64
Figure 7.3. Mean percent canopy cover of soil surface organic litter measured from control and treatment vegetation and soils plots....64
Figure 7.4. Mean percent canopy cover of soil surface dead, downed woody material measured from control and treatment vegetation and soils plots. 65
Figure 7.5. Mean percent canopy cover of human-caused soil surface disturbance measured from control and treatment vegetation and soils plots. 65
Figure 7.6. Dendrogram resulting from cluster analysis of all 20 control and treatment vegetation and soils plots based on similarities in species composition. Numeric values on the vertical axis represent site locations, C and T values represent control or treatment plots. Similarity distance is Euclidean distance. 67
Figure 7.7. Sum counts of woody trees and shrubs across all control and treatment vegetation plots by size class. Size class DBH: 1) <10 cm, 2) 10-20 cm, 3) >20 cm. 68
Figure 7.8. Average heights of woody trees and shrubs across all control and treatment vegetation plots by size class. Size class DBH: 1) <10 cm, 2) 10-20 cm, 3) >20 cm. 69
Figure 7.9. Mean percent canopy cover of native herbaceous vegetation measured from control and treatment vegetation and soils plots. 69
Figure 7.10. Mean percent canopy cover of exotic herbaceous vegetation measured from control and treatment vegetation and soils plots. 70
Figure 7.11. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. February 2014 surveys....71
Figure 7.12. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. May 2014 surveys....72
Figure 7.13. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. June 2014 surveys....73
Figure 7.14. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. July 2014 surveys. 74
Figure 7.15. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during February 2014 surveys. ..78
Figure 7.16. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during July 2014 surveys. 79
Figure 7.17. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during June 2014 surveys. 80
Figure 7.18. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during July 2014 surveys. 811

LIST OF TABLES

Table 3.1. Special Status Species Occurring in Bernalillo County, New Mexico 33
Table 6.1. Principal Anticipated Impact Categories and Natural Resources That May Be Affected by Those Impacts and Expected Outcomes 54
Table 6.2. Evaluation Criteria for Environmental Monitoring Determinations of the Trails Project Impacts to Soils, Vegetation, and Birds 57
Table 7.1. List of All Plant Species Found on all 20 Vegetation and Soils BEMP Plots 66
Table 7.2. Results of Multi-Response Permutation Procedures Testing for Differences in Plant Species Compositions Between All Control and Treatment Plots. 677
Table 7.3. Observed Species Indicator Analysis Value of Plant Species Measured From All Control and Treatment Vegetation Plots... 67
Table 7.4. Results of Multi-Response Permutation Procedures... 75
Table 7.5. Observed Species Indicator Analysis Value of Bird Species Detected during February Surveys and Results of Monte Carlo Procedure...................................... 75
Table 7.6. Observed Species Indicator Analysis Value of Bird Species Detected during May Surveys and Results of Monte Carlo Procedure.. 76
Table 7.7. Observed Species Indicator Analysis Value of Bird Species Detected during June Surveys and Results of Monte Carlo Procedure 76
Table 7.8. Observed Species Indicator Analysis Value of Bird Species Detected during July Surveys and Results of Monte Carlo Procedure.. 77

LIST OF ACRONYMS

COA	City of Albuquerque
OSD	Open Space Division
MRG	Middle Rio Grande
MRGCD	Middle Rio Grande Conservancy District
NMISC	New Mexico Interstate Stream Commission NMISC
RGVSP	Rio Grande Valley State Park
SWCA	SWCA Environmental Consultants
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation

1 INTRODUCTION

The City of Albuquerque is proposing habitat restoration and improvements to existing trails and facilities within Rio Grande Valley State Park (RGVSP) in Albuquerque, New Mexico. This project proposes to provide a variety of recreational features, to manage the primary unpaved interior pedestrian trail from Central Avenue to Montaño Boulevard within RGVSP, and to improve associated trailhead parking areas. It will also consider whether to close or restore user-made side trails. The primary goal of the project is to protect natural resources and visitor experiences throughout the project area while managing public use and providing amenities for visitors to this part of RGVSP. The project is located within the Albuquerque Reach of the middle Rio Grande (MRG), between Pueblo of Sandia on the north and the Pueblo of Isleta Pueblo on the south (Figure 1.1). The specific location of the existing primary trail is between Montaño Boulevard and Central Avenue (Figure 1.2 - Figure 1.4). The length of the current project area constitutes about 20% of the overall extent of RGVSP.

The current project proposes several kinds of recreational, educational, restoration, and management features within the project area. Trailside signage, wayfinding signs, and entry signage may be installed to provide directional information. Interpretive wayside signs and kiosks may be installed to provide general information or place-specific environmental, historical, or cultural details. Short sections of boardwalk might be needed to protect areas of sensitive soils, occasionally inundated areas, and vegetation such as river shorelines to improve accessibility. A wooden viewing platform may be constructed just south of Central Avenue to provide visitors with a view of the Rio Grande. Benches and shade structures may also be built as trailside features or in conjunction with viewing platforms. Existing trailhead parking areas adjacent to Central Avenue are proposed for expansion or upgrades to accommodate visitors. Areas of poor habitat quality should be restored or enhanced to improve environmental conditions for wildlife.

The existing RGVSP primary interior trail (see Figure 1.2 - Figure 1.4) is proposed for formal trail improvements. In order to identify the main trail, directional signs and other visual or management tools will be needed. The trail may be narrowed or widened as needed and portions of the trail could require stabilized soil or crusher fines. The trail cross-section is proposed to vary from approximately 1.2 meters to 2.4 meters (4 to 8 feet) in width. Much of the existing main trail is presently 0.9 meters to1.8 meters (3 to 6 feet) wide and in places the base soil is loose and eroding (Figure 1.5). Where needed, the trail may be stabilized by leveling and compacting the soil, and in places where the soil is prone to erosion, crusher fine rock may be spread over the soil base (Figure 1.6). Crusher fine material is defined as rock material 0.64 cm (0.25 inch) in diameter or smaller. Where needed, loose soils will be made additionally durable to recreational traffic by the addition of soil stabilizers. Soil stabilizer is mixed with crusher fines and water, rolled, and allowed to dry. This type of stabilized crusher fine has been used in many City Open Space Division areas and has a use-life of at least 10 to 15 years in bosque environments without deterioration.

Currently there are numerous unofficial side trails throughout the project area (see Figure 1.2 - Figure 1.4). Closure and restoration of some user-made side trails is a proposed action for visitor management to achieve the purpose of designating a single main trail; some side-trails may remain for retention of bosque experience. User-made side trails may cause damage to soils and vegetation (Figure 1.7) and permit unsanctioned access for users to wander throughout the bosque, with an increased potential to disturb wildlife and resources. If any unofficial trails are selected for closure, restoration work will be done to promote soil health and for native vegetation to become re-established. Some user-made side-trails may be left in place to provide for a broader range of visitor experiences. Decisions on the design of a future trail system, the range of visitors and experiences, and whether to designate some segments as limited use or multiple use will be based on ecological and existing physical conditions. Alternative designs based on existing conditions will be developed after this baseline monitoring plan has been finalized and evaluated. Construction of any proposed amenities or of improvements to the main trail would not occur until late 2014 or early 2015, depending upon results of public review and any needed approvals.

SWCA Environmental Consultants (SWCA) was retained by the City to conduct environmental monitoring of soils, vegetation, and bird communities within the existing primary trail corridor in 2014 (pre-project baseline monitoring). This monitoring effort will be repeated again in 2015 (post-project effects monitoring). This analysis is being done to establish baseline conditions, to anticipate potential future environmental changes, and to specifically determine if proposed management and restoration activity will have positive or negative effects on adjacent native plant and animal communities and individual species. As part of that monitoring effort, SWCA has produced this report on existing environmental conditions of the proposed management and restoration areas. In order to assess the effects of the project on the existing environment, one must understand the level of human disturbance already present and imposed on current environments. Such background information provides context for evaluating the possible environmental effects of the project. This document presents information on the both the historical and existing environment of the project area, providing context for how monitoring data will be evaluated relative to the goals of the restoration project and to assess potential future effects. This environmental baseline report and planned environmental monitoring focuses on biological resources and ecological function. SWCA was not contracted to address social/economic, cultural resource aspects, or environmental regulatory aspects of the project.

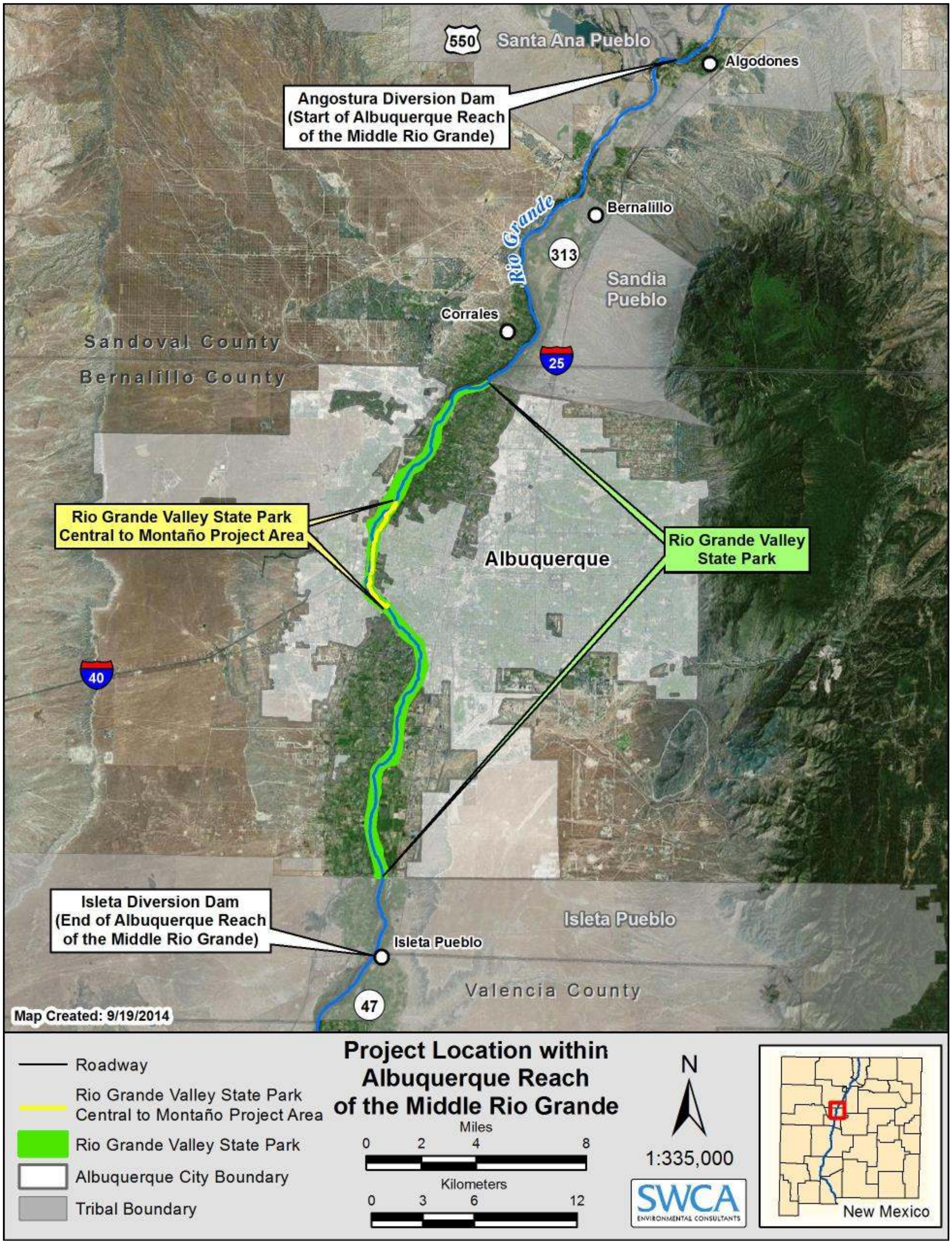


Figure 1.1. Location of the proposed RGVSP Central to Montaño Project.

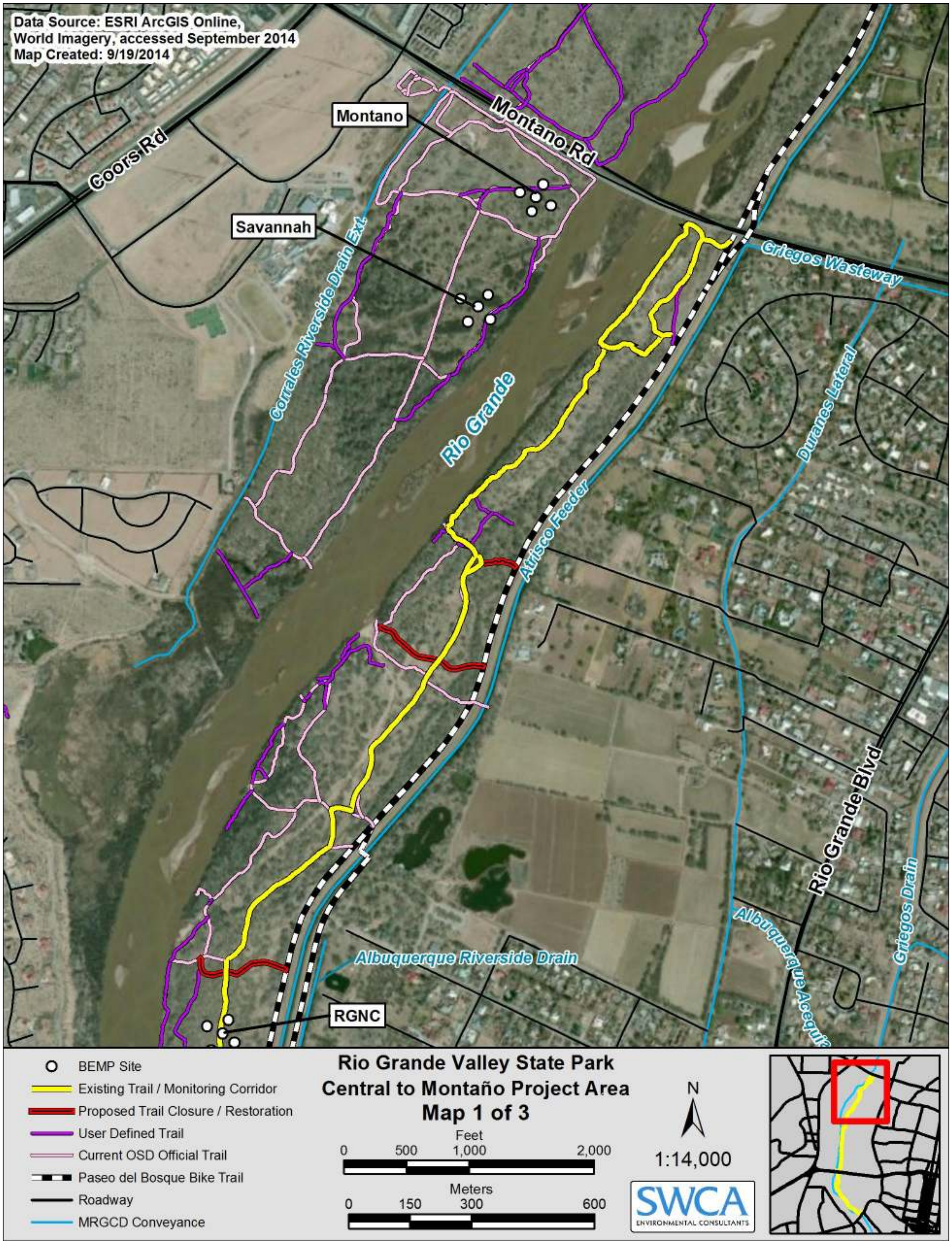


Figure 1.2. Northern portion of the proposed RGVSP Central to Montaño Project.

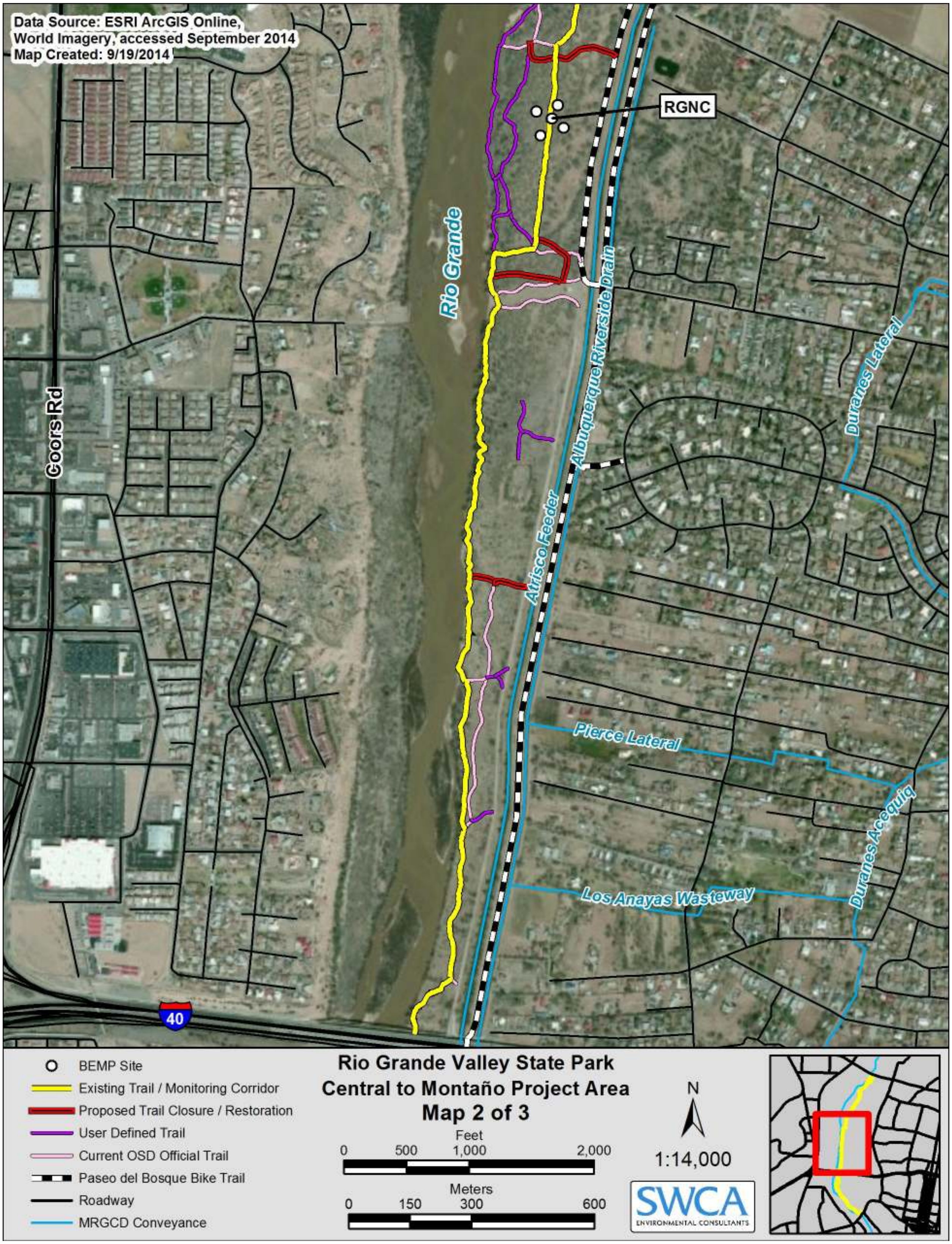


Figure 1.3. Central portion of the proposed RGVSP Central to Montaño Project.

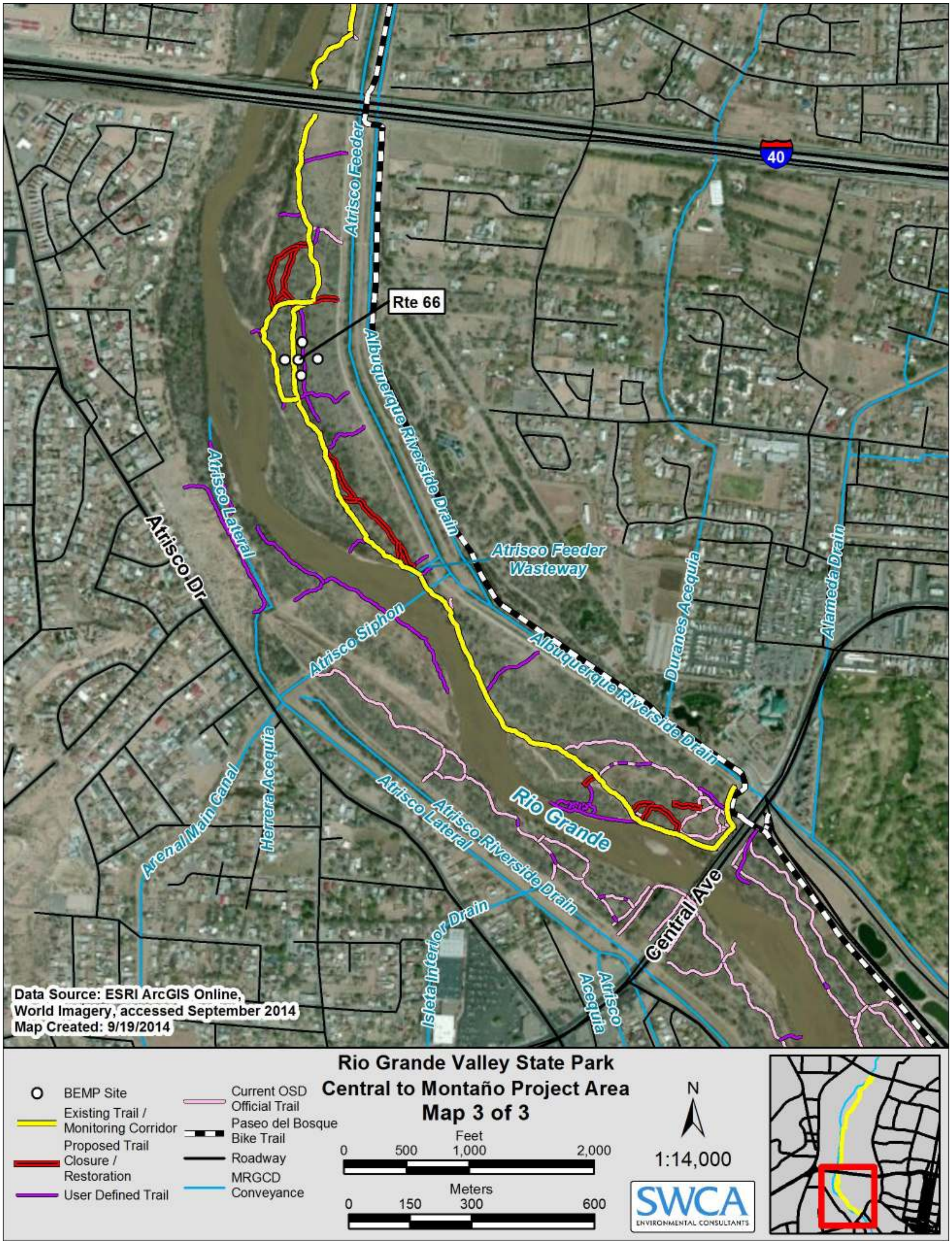


Figure 1.4. Southern portion of the proposed RGVSP Central to Montaño Project.

Figure 1.5. Example of an existing soil-based trail at the Rio Grande Nature Center State Park.

Figure 1.6. An example of the existing trail with fine-crush rock at the Rio Grande Nature Center State Park.

Figure 1.7. Example of unofficial side trail at the Rio Grande Nature Center State Park, showing soil erosion and damage to vegetation.

This environmental baseline report of the project area first presents an overview of the environmental history of the MRG along with information on the current environments and biota of the MRG bosque with an emphasis on the Albuquerque Reach. Understanding the environmental history and the current setting of the MRG bosque is important because the bosque has already experienced considerable environmental impacts from human activities, and the geomorphological features, hydrology, and plants and animals that occur there now are largely represented by biotic communities living in environments resulting from human disturbance (Crawford et al. 1993; Scurlock 1998; Robert 2005). The primary form of human disturbance to the MRG has been the regulation of Rio Grande water, including the termination of natural flow and flooding events, loss of multiple dynamic river channels, and natural overbank flooding. The native Rio Grande bosque plant and animal species and natural biotic communities that occur along the MRG today are adapted to, and in many cases rely upon, natural hydrological processes that no longer occur due to water regulation. The current Rio Grande bosque is a human-altered environment that requires human management in order to emulate former "natural" conditions.

Given that the MRG bosque is a human-altered system that does require management of natural resources, considerable efforts and funds have been and are currently being devoted to the environmental management of this system to restore or rehabilitate native species and ecosystem processes, especially relative to the federally endangered Rio Grande silvery minnow (*Hybognathus amarus*; silvery minnow) and southwestern willow flycatcher (*Empidonax traillii extimus*; flycatcher). Several key documents have been produced to inform and guide natural resource conservation of the MRG and the bosque (e.g., Crawford et al. 1993; Robert 2005;

Secretary's Committee for the Middle Rio Grande Conservation Initiative 2012; U.S. Army Corps of Engineers [USACE] 2013). This report evaluates how the proposed Project corresponds with key aspects of those important natural resource management plans. Additionally, the report provides recommendations for habitat restoration coincident with the trail enhancement project that would help restore the physical environments and biotic communities to more natural pre-human disturbance conditions. The report is organized as follows:

1) An introduction to the project;
2) An overview of the environmental history of the MRG;
3) Descriptions of the current environmental conditions including plant and animal species and a listing of protected federal and state environmentally sensitive plant and animal species that are known to potentially occur in the area;
4) A summary of some of the recent relevant environmental projects that have occurred in the MRG;
5) An overview of MRG conservation management plans and current MRG bosque habitat restoration activities;
6) Discussion of potential environmental effects of the restoration project and a summary of environmental monitoring objectives and design;
7) Monitoring results;
8) Recommended associated habitat restoration methods; and
9) Concluding remarks.

2 ENVIRONMENTAL HISTORY OF THE MIDDLE RIO GRANDE BOSQUE

In order to understand the current environmental conditions of the MRG bosque, one must understand the environmental history of the system. Information on the environmental history for the MRG can be found in *Middle Rio Grande Ecosystem: Bosque Biological Management Plan* (Crawford et al. 1993), *From the Rio to the Sierra: An Environmental History of the Rio Grande Basin* (Scurlock 1998), *Middle Rio Grande Ecosystem Bosque Biological Management Plan, The First Decade: A Review & Update* (Robert (2005), and *A Field Guide to the Plants and Animals of the Middle Rio Grande Bosque* (Cartron et al. (2008).

The Rio Grande was once a free-flowing river that meandered across its floodplain, frequently changing course (Cartron et al. 2008, see Scurlock 1998 for details). Frequent and often severe flooding in the spring from winter snowmelt intermixed with occasional droughts led to the establishment of diverse and always changing riparian communities (Cartron et al. 2008). Oxbows, wetlands, and woodlands (bosques) of native Rio Grande cottonwood (*Populus deltoides wislizeni*) and willows (*Salix* sp.) were located throughout the riparian areas with a mosaic of successional stages present due to the river's constantly changing environment composed of ever-changing channels and riparian woodlands created by variable spring and summer floods.

As immigration and settlement increased throughout the 1800s, grazing and logging activities in northern and central New Mexico led to increased watershed soil erosion and sediment loads in the Rio Grande (Scurlock 1998, see summary in Cartron et al. 2008). By the early 1900s, increased sediment loads raised the level of the riverbed and led to higher intensity flooding and increased salt buildup on the floodplain. The need for flood control and a reliable water source for irrigation in the MRG and downstream led to the authorization of the Rio Grande Project in 1905, which included the construction of Elephant Butte Dam in 1916. In 1923 the Middle Rio Grande Conservancy District (MRGCD) was formed in order to control flooding, drain marshlands and create a system of canals for irrigation (Scurlock 1998). The MRGCD and federal agencies undertook a variety of projects within the MRG over the next 50 years, including straightening the river by dredging and confining the river to a narrow channel; constructing a series of diversions and water storage facilities; constructing over 161 hectares (100 miles) of canals, ditches, and levees; and installing jetty jacks to stabilize the river bank.

The construction of Cochiti Dam in 1973 ended the natural flooding regime in the MRG (Scurlock 1998). These projects led to a disconnection of the floodplain from the river and resulted in the once scattered dynamic cottonwood stands becoming a barely regenerating continuous cottonwood bosque, lacking natural overbank flooding that is required for the broad-scale establishment of cottonwood seedlings. Non-native vegetation such as saltcedar (*Tamarix* sp.), Siberian elm (*Ulmus pumila*), Russian olive (*Elaeagnus angustifolia*), Russian thistle (*Salsola tragus*), and kochia (*Bassia* [formerly *Kochia*] *scoparia*) rapidly invaded the bosque beginning in the early 1900s, replacing native cottonwood and willow stands in many areas (Scurlock 1998; Cartron et al. 2008). Fires are an increased risk to the bosque due to the lack of flooding and accumulation of fuels from litter and exotic plant species (Cartron et al. 2008). River regulation, invasive species, and fire have greatly altered the riparian habitats of the MRG and active management is required to restore and maintain conditions favorable to native species.

The MRG bosque of today is no longer the self-perpetuating ecosystem of the pre-water regulation past. The primary way that Rio Grande cottonwood stands can be maintained today is through proactive restoration activities, including habitat restoration efforts to simulate natural overbank flooding of the now narrow and restricted floodplain; removal of exotic trees such as saltcedar, Russian olive, and Siberian elm; and the active planting of native tree species such as Rio Grande cottonwood and willows.

Without human management of this now human-regulated system, Rio Grande cottonwoods will continue to decline and could largely disappear from most reaches, while being replaced by non-native saltcedar, Russian olive, and Siberian elm, which are better adapted to the new bosque environments that lack overbank flooding and dynamic river channels. Considerable funding and effort are now being directed to the MRG in attempts to restore at least portions of the system to previously more natural environmental conditions suitable for native species that once lived there.

2.1 River Dynamics

The Rio Grande's flow regime can be characterized by high annual spring runoff and seasonal summer and fall low-flow periods. Prior to the construction of dams and widespread river regulation, large floods commonly altered the river channel. Historically, spring floods of 20,000 to 30,000 cfs resulting from snowmelt runoff were fairly common. Record levels of rainfall and snow led to high Rio Grande flow rates from 1940 through early 1942, resulting in extensive flooding, with peak flow rates around 20,000 cfs. The largest measured MRG flood (47,000 cfs) resulted from summer monsoons in August 1929. Conversely, channel drying has also been recorded, particularly during the 1880s downstream from Albuquerque. Currently, channel drying have become more frequent downstream of Albuquerque.

Historically, Rio Grande sediment load was highest during the spring months under maximum flow conditions and also following summer monsoons. Historic records describe the Albuquerque Reach of the MRG as experiencing considerable riverbed sediment aggradation during the late 1800s and early 1900s. Reduced water flow from diversions and agricultural practices caused soil erosion throughout the watershed, resulting in heavy sediment loads. 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 1973. Rio Grande sediment loads have been reduced from average annual suspended sediment 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 (USACE et al. 2006).

Water diversion of the Rio Grande may have occurred as early as the 1500s by Pueblo people practicing limited floodwater irrigation for crops. Non-indigenous irrigation practices were introduced throughout 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 after 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).

The river was straightened and confined between two parallel levees. Jetty fences were installed in the 1930s, later replaced by large iron Kellner jetty jacks in the 1950s and 1960s to protect the newly created levees (Grassel 2002). Jetty jacks collected sediment that in turn became a seedbed for the establishment of Rio Grande cottonwood (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 Floodplain and Bosque 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 meandering channels of the historic Rio Grande resulted in broad floodplains without well-defined riparian zones as are found today. Frequent flooding caused changes in the position and structure of riparian environments. Riparian vegetation developed and changed in response to floods, sediment deposition, and low flow periods (Crawford et al. 1993). 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 dynamic nature of the riparian environment.

3 CURRENT ENVIRONMENTAL CONDITIONS OF THE MIDDLE RIO GRANDE BOSQUE

3.1 RIVER DYNAMICS

In the twentieth and twenty-first centuries, floodway constriction and channel stabilization projects have altered the natural course of the Rio Grande. Water resource development in the Rio Grande Basin above Albuquerque has significantly altered the historic 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). Aggradation and degradation of the channel bed has resulted in the floodplain being disconnected (Valett et al. 2005). Overbank flooding into the bosque has been practically eliminated due to channelization and water regulation (Molles et al. 1998). Regulating the flow of water has led to a disconnection between the floodplain and its river, virtually eliminating the possibility of the floodplain being inundated on a regular basis (Valett et al. 2005).

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 through maintenance activities of the U.S. Bureau of Reclamation (USBR). The active channel width was approximately 183 meters (600 feet). 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.

Channel width of the Albuquerque Reach has noticeably decreased since the 1900s. 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. High flows are contained within the channel because of an increase in bank height (Ortiz 2003; Massong et al. 2005a, 2005b). The natural flows of the Rio Grande are controlled by the climatic, geologic, and physical characteristics (Lee et al. 2004) derived largely from snowmelt (predominantly upstream) and summer thunderstorms often localized at lower elevations (Corps et al. 2006). El Niño Southern Oscillation 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). Following the construction of Cochiti Dam in 1973, reduced peak discharges have accelerated the encroachment of vegetation on sand bars and the evolution of sand bars into permanently attached banks or islands.

The post-Cochiti hydrograph is similar to the historic hydrograph, although the peaks have been reduced. 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 (Western Regional Climate Center 2014). 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 2013 are presented in Figure 3.1.

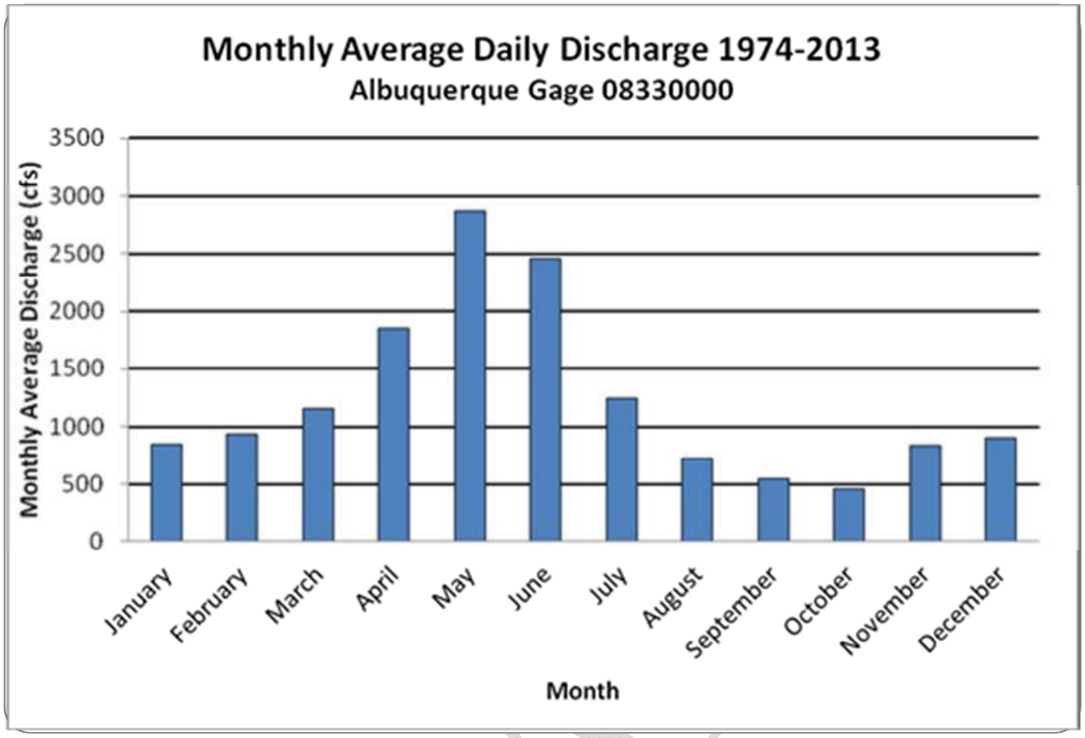


Figure 3.1. Monthly average annual flows recorded from the USGS Albuquerque gage (08330000), 1974–2013 (USGS 2014).

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.

Groundwater in the Albuquerque Reach has declined significantly due to pumping by municipalities. Historically, groundwater recharge was high as a result of increased irrigation within the floodplain. Total irrigated acreage within the MRG was reduced by more than 40,470 hectares (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 meters (0.0 to 4.0 feet) of the land surface, making the land nearly impossible to farm (Berry and Lewis 1997; Parametrix 2008). This was a major catalyst for the MRGCD's construction of drains throughout the MRG.

A 2003 study was conducted under the Middle Rio Grande Endangered Species Collaborative Program by S.S. Papadopulos and Associates, Inc. (SSPA) and the New Mexico Interstate Stream Commission to study surface water and groundwater interactions of the MRG from Angostura Diversion Dam to Interstate 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 U.S. Bureau of

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 3.2.

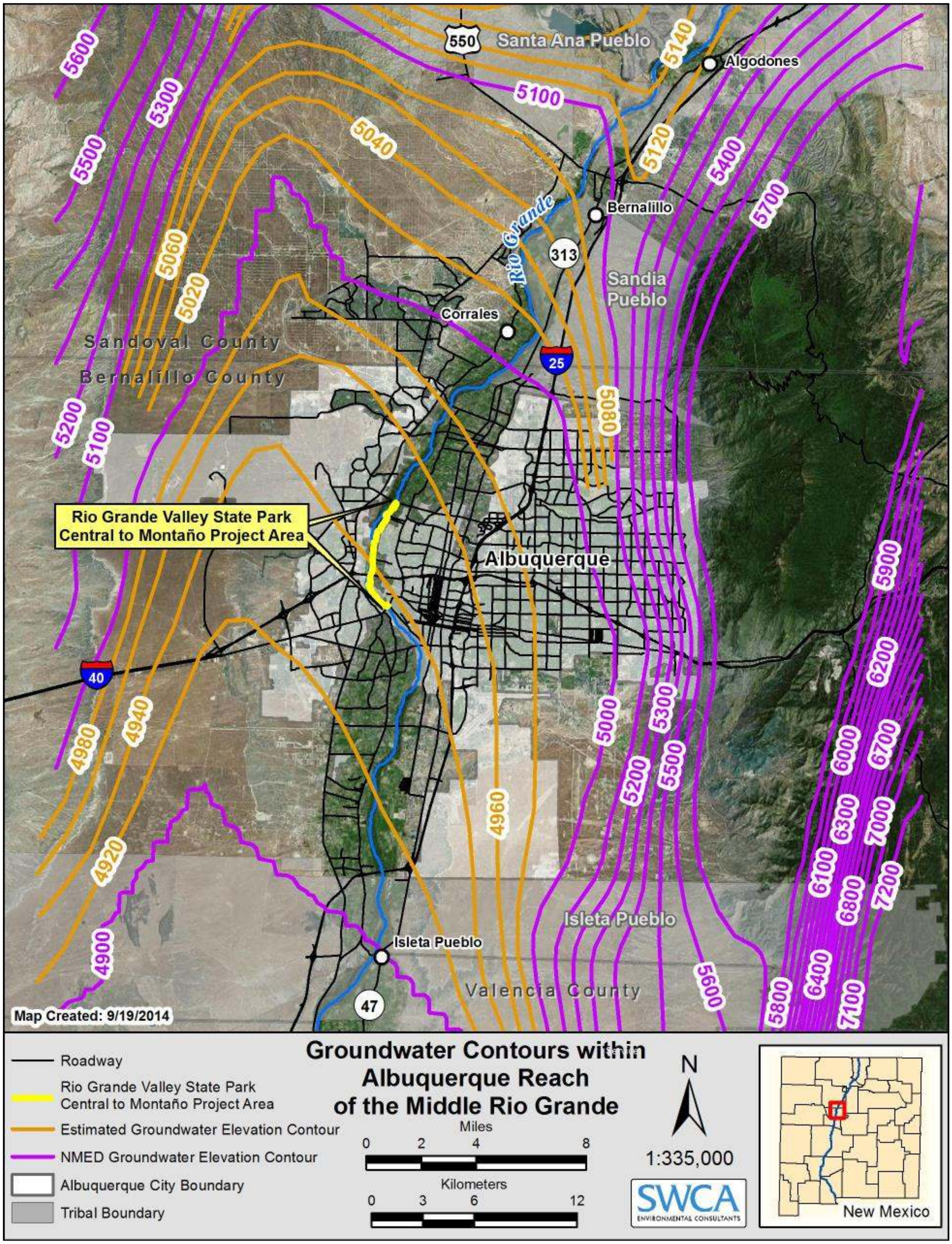


Figure 3.2. Estimated groundwater elevation.

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.

Fluctuations near the river are directly affected by river discharge. During periods of high discharge when there is overbank inundation groundwater levels rise. During drought periods, decreases in groundwater levels typically occur. Riverside drains contribute to the declining groundwater levels by draining groundwater, which is one reason they were originally installed. Today, groundwater pumping for municipal and industrial purposes has caused a rapid reduction in groundwater levels in the Albuquerque Reach. These drops coincide with the use of large municipal wells. Restoration treatments have shown little to no effect on groundwater levels (Eichhorst et al. 2012).

3.2 CLIMATE CHANGE

Climate change is likely to significantly affect the MRG and its ecological function over the coming years as drought intensifies and temperatures increase across New Mexico. Recent key articles on changing Southwest and New Mexico climate by Gutzler (2013) and Llewellyn and Vaddey (2013) document how the climate of the Southwest is becoming warmer and less predictable, and how drought is becoming more common and more severe than in the past. The average annual ambient temperatures for the Upper Rio Grande Region of New Mexico (Colorado border to Truth or Consequences) has increased from 1971-2012 by 2.5º F, and in mountainous areas, that increase has been even greater at 2.7º F (Llewellyn and Vaddey 2013).

Long-term episodic droughts have occurred in the Southwest region for centuries (Gutzler 2013), but the region is strongly affected by ongoing and projected century-scale climate change (Llewellyn and Vaddey 2013). Gutzler (2013) and Llewellyn and Vaddey (2013) attribute this climate change to human-caused increases in greenhouse gases and report on a strong regional warming trend in recent temperature data that modifies natural drought/high precipitation fluctuations by enhancing evaporative losses and decreasing snowpack in mountainous regions to the north.

As climate warms, intense storms are expected to increase in the region (Gutzler 2013), and a greater fraction of total annual precipitation is expected to come from single intense rainfall or snowfall events as compared to more frequent low-intensity events. The periodic drought and intense rainfall patterns projected for the region are expected to result in significantly diminished stream flow and drier surface conditions (Seager et al. 2008, Llewellyn and Vaddey 2013), causing the Southwest climate to become even more arid over the coming decades. The impacts of a warming and drying climate are likely to be significant for the MRG bosque, and likely far greater than other human caused environmental impacts.

3.3 FLOODPLAIN AND BOSQUE ENVIRONMENTS

3.3.1 VEGETATION

Historically, the river channel migrated freely across a one- to four-mile wide (1.6 to 6.4 kilometer) floodplain (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 similar in composition more than 2 million years ago (Knight et al. 1996). 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 is largely anecdotal (Hink and Ohmart 1984), but generally 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 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-formed 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 by Watson (1912) 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 (*Eleocharis* spp.), reed grass (*Phragmites australis*), pepperwort (*Marsilea vestita vestita*), and various rushes (*Juncus* spp.) (Crawford et al. 1993).

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, 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 (USACE 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 declined. Non-native 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).

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). Hink and Ohmart vegetation structural classes are described below:

Type I—Mixed to mature age class stands dominated by cottonwood 15 to 18 meters (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 meters (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 meters (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 meters (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 meters (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 meters (5 feet) or less, typical of sandbars with saltcedar, cottonwood, willow, and other seedlings.

Hink and Ohmart (1984) reported cottonwood forest of structure Type I to be the most abundant vegetation in their intensive study area (Figure 3.3). Russian olive was the most common understory species, often found in association with saltcedar. 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. 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. Sample images of Hink and Ohmart structural classes are in Figure 3.4 (USACE et al. 2007).

Figure 3.3. Cottonwood/Russian olive, Hink and Ohmart (1984) structural type I classification, Albuquerque Reach bosque.

Figure 3.4. Hink and Ohmart (1984) structural classification images (USACE et al. 2007).

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 (USACE et al. 2006) also provided extensive vegetation mapping of the Albuquerque Reach using a modified Hink and Ohmart (1984) methodology (Figure 3.5–Figure 3.7). Descriptions of the Hink and Ohmart codes are listed in Appendix A. Cartron et al. (2008) provided accounts for many plant species known to occur in the MRG bosque, as well. Many of the common plant species that occur in the MRG bosque are presented in Cartron et al. (2008).

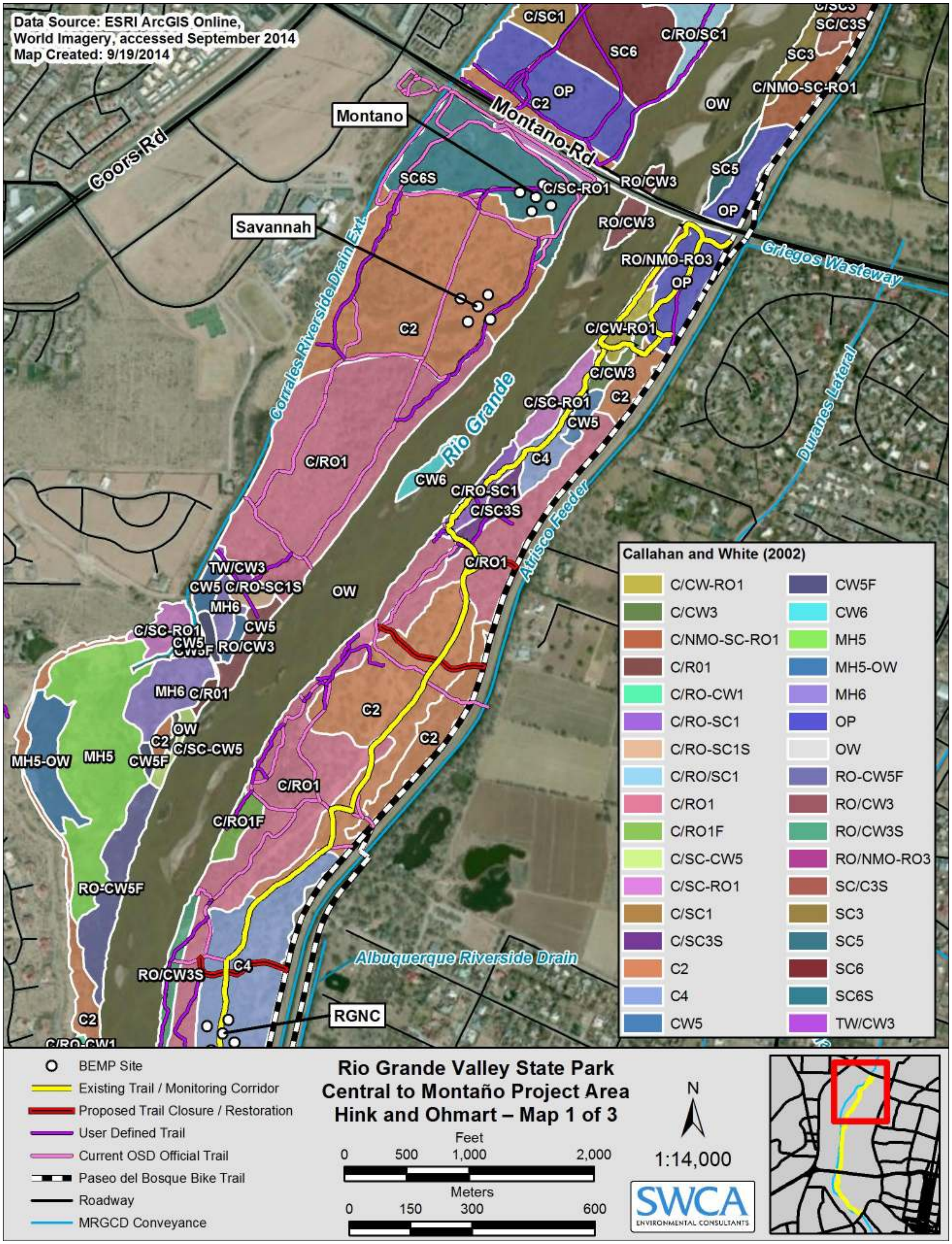


Figure 3.5. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions.

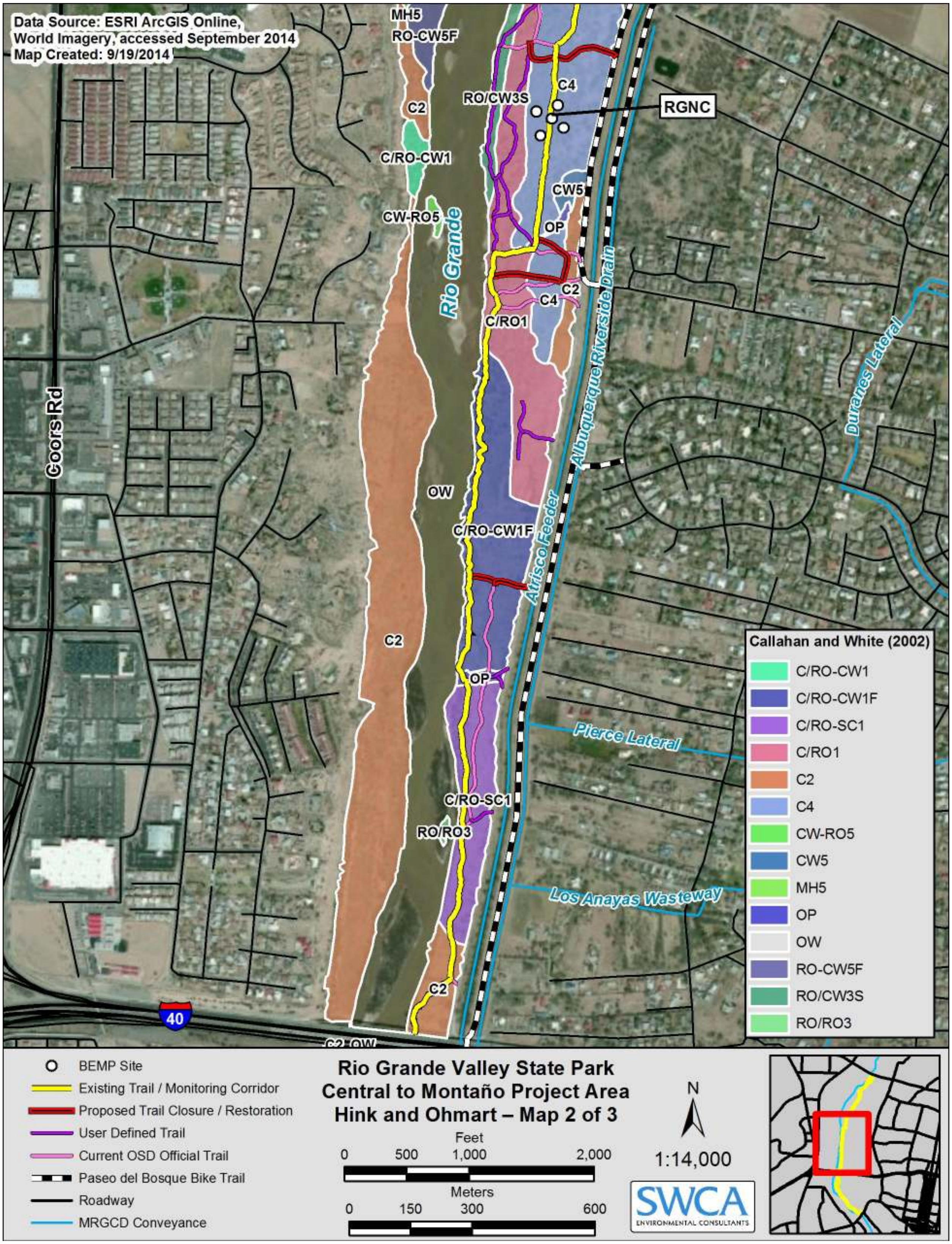


Figure 3.6. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions.

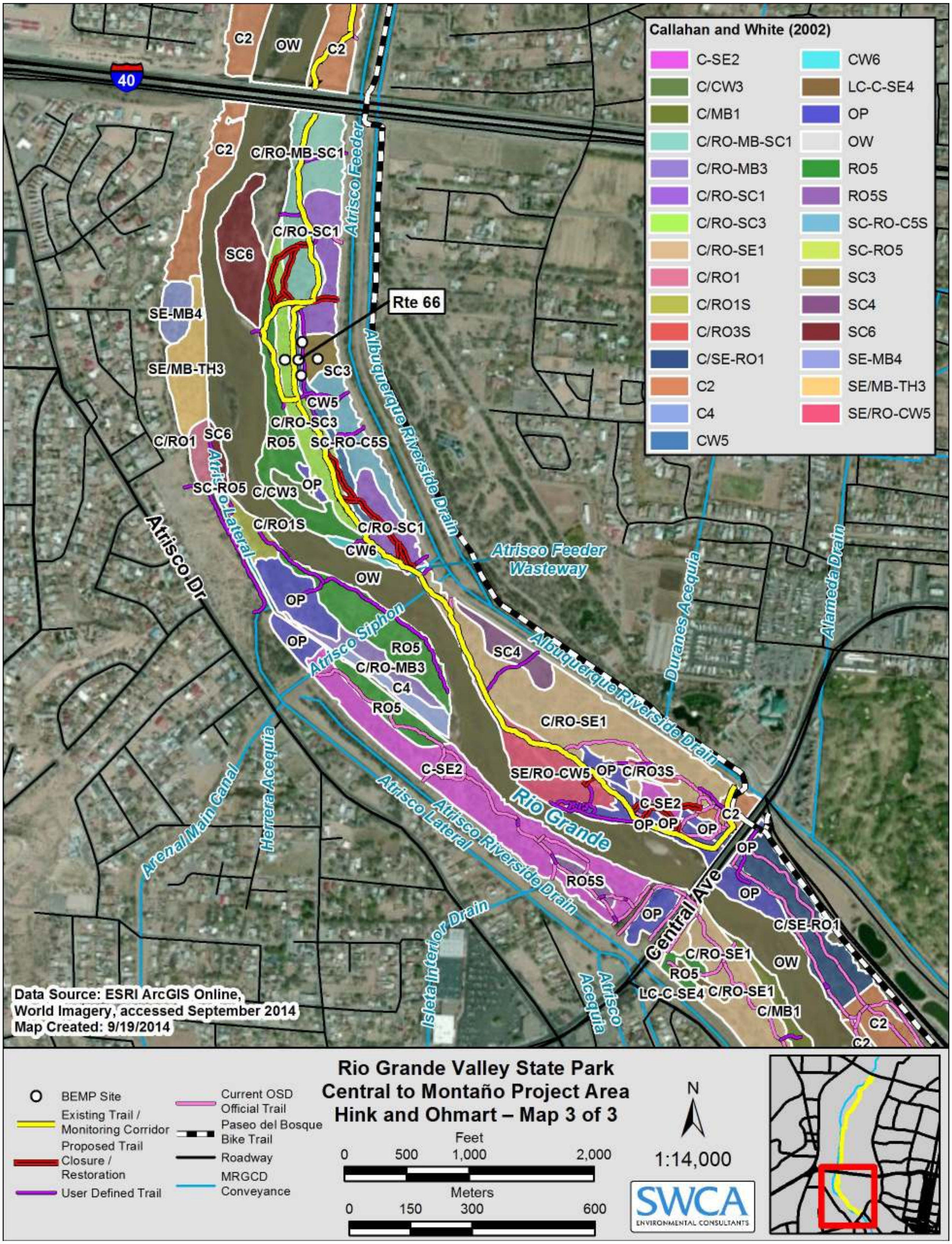


Figure 3.7. Hink and Ohmart vegetation in the project area (Callahan and White 2002). See Appendix A for legend code definitions.

FLOODPLAIN VEGETATION AND RIVER SANDBAR/ISLAND VEGETATION

Despite considerable attention 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 3.8) 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 3.8. 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 hectares or 517 acres] of the floodplain, with upper terraces 62% (538 hectares or 1,329 acres), and active channels 14% (125 hectares or309 acres). River islands and bars from the Interstate 25 (I-25) Bridge to the Belen Railroad Bridge accounted for 19% (422 hectares or 1,043 acres) of the floodplain, with upper terraces 68% (1,486 hectares or 3,671 acres), and active channels 13% (294 hectares or 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 (*Salix exigua*), 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.

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 3.9) 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 understory 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.

Saltcedar leaf beetles (*Diorhabda* sp.) are small leaf beetles that feed only on the foliage of saltcedar and were introduced to Utah, Colorado, and west Texas from Asia to control saltcedar (Tamarisk Coalition 2014). *D. elongata* has now spread from central Utah into northwest New Mexico, and appeared in the Albuquerque Reach for the first time in 2012.

Figure 3.9. Coyote willow and saltcedar on the interior section of an Albuquerque Reach point bar.

Saltcedar leaf beetles consume the foliage of saltcedar, defoliating the plants and reducing their growth and flower and seed production. These beetles are likely to have a negative impact on saltcedar throughout the MRG as they already have had elsewhere, including northwestern New Mexico. The presence of these beetles may result in a decline of saltcedar throughout the MRG.

Russian olive (Figure 3.10) 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 3.10. Russian olive in the Albuquerque Reach colonizing channel margin (background) with cottonwood behind.

Other non-native invasive plant species of concern for the MRG (Parker et al. 2005) are Siberian elm, tree of heaven (*Ailanthus altissima*), Russian thistle, kochia, 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.

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 to undertake a large fuels reduction project to clear more than 1,012 hectares (2,500 acres) of fuel load and 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.

3.3.2 Wildlife

Invertebrates

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-Meyerson (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-Meyerson (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.

FISH

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). 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). Longitudinal variation in water temperature may be contributing to the decline of many native warmwater species in the MRG below Cochiti Dam (Platania 1991; Crawford et al. 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). This 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.

U.S. Bureau of 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 (*Carpiodes carpio*), common carp, channel catfish (*Ictalurus punctatus*), and red shiner (*Cyprinella lutrensis*) (USBR 2006). 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).

AMPHIBIANS AND REPTILES

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* sp.), and tiger salamanders (*Ambystoma tigrinum*) (Hink and Ohmart 1984). More recent studies of MRG bosque reptiles and amphibians (Chung-MacCoubrey and Bateman 2006a; Chung-MacCoubrey and Bateman

2006b; Bateman et al. 2008a; Bateman et al. 2008b; Bateman et al. 2008c; 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 et al. 2008a), 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.

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 kilometers (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.

The composition of bird species for the Albuquerque Reach are well known 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.

U.S. Bureau of Reclamation and the U.S. Army Corps of Engineers have conducted periodic repeat avian surveys on the original Hink and Ohmart (1984) transects from 2003 to 2007 in conjunction with vegetation measurements on Natural Heritage New Mexico transects (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 southwestern willow 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 USBR and the USACE since 2004 (USACE 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.

Avian monitoring by Hawks Aloft (2013) shows that pure stands of the non-native Russian olive are currently associated with the highest bird densities and species richness during winter months. Bird densities and species richness are also highest in the bosque where extensive amounts of New Mexico olive are present. In contrast, low species richness and abundance are typical characteristics of cottonwood stands where the understory has been mechanically removed (Hawks Aloft 2013). During summer months, marsh vegetation has the highest species richness and abundance of birds, followed by some vegetation types dominated by Russian olive or New Mexico olive.

Hawks Aloft (2013) mentions the importance of Russian olive as a source of food particularly for migrants and winter residents, and as nesting substrate for a number of avian species. As a result of Hawks Aloft's (2013) research, 43 bird species have been documented foraging on Russian olive fruit, including gray catbird (*Dumetella carolinensis*), hermit thrush (*Catharus guttatus*), and yellow-rumped warbler (*Setophaga coronata*). Mourning dove and black-chinned hummingbirds both use Russian olive extensively for nesting; the majority of bushtit (*Psaltriparus minimus*) nests found by Hawks Aloft (2013) have been in Russian olive. Hawks Aloft (2013) reports recent, yet notable, population declines of the mourning dove and the black-chinned hummingbird, indicating also that these two species nest in dense vegetation and that their densities are much lower in cottonwood stands where the understory has been removed mechanically. The gray catbird is another bird, which has apparently been negatively impacted by mechanical thinning is the gray catbird, its range having contracted in the bosque (Hawks Aloft 2013).

From 2003 through 2006, point-count surveys were conducted in the bosque at Santa Ana Pueblo, Sandoval County (Walker 2007). The main objective of Walker's (2007) study was to gather baseline information on seasonal patterns of avian species abundance, richness, and composition for future comparisons after restoration efforts. Results of the surveys were somewhat different than those from Hawks Aloft's (2013) study. They indicated that avian community structure and species composition at Santa Ana varied from year to year in a positive way with rainfall, but the extent of annual variation was unrelated to whether the study area had already been subjected to restoration treatments. Spatial variation in avian community structure and species composition was the result of and related to both pre-treatment conditions and restoration history (Walker 2007).

Clearly, some species respond to vegetation treatment within the bosque, but not all birds prefer a dense understory of shrubs. Some birds of the bosque prefer a sparse understory, including ash-throated flycatcher (*Myiarchus cinerascens*) and eastern bluebird (*Sialia sialis*) (Cartron et al. 2007; Smith and Finch 2007). The latter species is even thought to have colonized the MRG bosque during the 2000s in part due to large-scale, mechanical removal of understory vegetation along the river (Cartron et al. 2007). Altogether, studies of avian communities in the MRG bosque show the importance of preserving some diversity in the structure of the vegetation at the appropriate spatial scale.

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 (2013). Cartron et al. (2008) provide a complete listing of birds known to occur in the MRG bosque, along with habitat information. In total, 130 passerine migrants have been documented in the project area, while approximately 70 land bird species are known to nest there regularly.

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 sites. Cartron et al. (2008) provide species accounts for mammals known to occur in the MRG bosque, along with habitat information.

SPECIAL STATUS SPECIES

A number of federally and/or state protected species are known to occur in the Albuquerque Reach of the MRG bosque. Table 3.1 lists the U.S. Fish and Wildlife Service (USFWS) and New Mexico Department of Game and Fish (NMDGF) threatened and endangered species occurring in Bernalillo County, New Mexico (NMDGF 2013; USFWS 2013a).

Table 3.1. Special Status Species Occurring in Bernalillo County, New Mexico

Common Name	Scientific Name	Status	Habitat
Plants			
Lady tresses orchid	*Spiranthes magnicamporum*	State E	Grows in damp, saline/alkaline areas along rivers, primarily in wetland/riparian habitats below 1,829 m (6,000 feet) in northern New Mexico.
Fish			
Rio Grande silvery minnow	*Hybognathus amarus*	USFWS E State E	While it tolerates a wide variety of habitats, the species prefers large streams with slow to moderate current over a mud, sand, or gravel bottom.
Birds			
Northern goshawk	*Accipiter gentilis*	USFWS SOC	Populations in New Mexico occur in mature, closed canopied coniferous forests of mountains and high mesas.
Baird's sparrow	*Ammodramus bairdii*	USFWS SOC State T	Grassland species occurring mainly in the eastern plains and southern lowlands of New Mexico.

Common Name	Scientific Name	Status	Habitat
Western burrowing owl	*Athene cunicularia hypugaea*	USFWS SOC	Found typically in semiarid grasslands and prairies in association with prairie dog (*Cynomys* sp.) towns; also occurs in desert scrub and in open, disturbed, rural or urban areas including along canals and arroyos. Most nests in the state are in prairie dog towns, but in some areas the species uses old burrows of rock squirrels, badgers, or banner-tailed kangaroo rats.
Common black-hawk	*Buteogallus anthracinus*	State T	Occupies mature, well-developed riparian gallery forests located near permanent streams where principal aquatic prey species (e.g., frogs and crayfish) are available.
Black tern	*Chlidonias niger*	USFWS SOC	Associated with large wetlands, sandbars, and mud flats along some of the state's main rivers.
Yellow-billed cuckoo	*Coccyzus americanus*	USFWS T	Western subspecies nests preferentially in large patches of moist cottonwood-willow woodland with high canopy closure (Laymon et al. 1997). Found in cottonwood woodland and in tall willows along ditches along the MRG.
Broad-billed hummingbird	*Cynanthus latirostris*	State T	Migratory species. Breeds in Guadalupe Canyon in southwestern New Mexico and rarely found in canyons of the Peloncillo Mountains. Accidental anywhere else in the state. Occupies desert riparian deciduous woodland (especially of cottonwoods) and marshes. Occurs where desert streams provide sufficient moisture for a narrow band of trees and shrubs along the margins
Southwestern willow flycatcher	*Empidonax traillii extimus*	USFWS E State E	Found in dense riparian habitats along streams, rivers, and other wetlands where cottonwood, willow, saltcedar, and Russian olive are present. Nests along the MRG are usually associated with tall dense willows, and associated with wet soil or standing water. Nests are found in thickets of trees and shrubs, primarily those that are 4 to 7 m (13–23 feet) tall, among dense, homogeneous foliage. Habitat occurs at elevations below 2,590 m (8,500 feet).
American peregrine falcon	*Falco peregrinus anatum*	USFWS SOC State T	Breeds in areas of steep topography (mountains and cliffs) near wooded/ forested habitats with available nearby updrafts for foraging. Water is often present. Winters in areas where abundant prey and large roosting trees are available such as along the Rio Grande and Pecos River, especially near large wetland complexes.
Arctic peregrine falcon	*Falco peregrinus tundrius*	USFWS SOC State T	Primarily a migrant in the state. Where it occurs, this species is found in the same habitats as the more common American peregrine falcon.
Bald eagle	*Haliaeetus leucocephalus*	State T	The species is primarily water-oriented, and the majority of the populations occurring in New Mexico are found near streams and lakes. New Mexico harbors a small breeding population along the shores of lakes primarily in the northern part of the state. Preys on prairie dogs, waterfowl, and fish. Known to winter roost along the Rio Grande.
White-eared hummingbird	*Hylocharis leucotis*	State T	Migratory species with a breeding distribution that includes southwestern and western New Mexico. Migrates south in the early fall. Species typically occupies mountain canyons and coniferous and oak woodlands or forests near streams. Accidental in areas of desert scrub/rocky slopes, juniper savannah, and piñon/juniper woodland near montane regions.
Brown pelican	*Pelecanus occidentalis carolinensis*	State E	Rare visitors to New Mexico; found in large lakes and along major rivers.
Neotropic cormorant	*Phalacrocorax brasilianus*	State T	Inhabits various wetlands and large reservoirs, including fresh, brackish, and saltwater habitats. Nests and roosts mostly in trees, but also on cliffs and human-made structures.
Bell's vireo	*Vireo bellii*	State T	Occurs in dense lowland shrubby vegetation areas with understory vegetation, including extensive riparian shrubby thickets, second-growth forests, and mesquite brushlands.
Mammals			
Townsend's big-eared bat	*Corynorhinus townsendii*	USFWS SOC	Occurs in a variety of xeric to mesic habitats: scrub-grassland, desertscrub, semidesert shrublands, chaparral, saxicoline brush, tundra, open montane forests, spruce-fir, mixed hardwood-conifer, and oak woodlands and forests. Can be found roosting in caves, mine tunnels, or abandoned buildings. Known to regularly occur in New Mexico in the winter in caves and mine shafts.

Common Name	Scientific Name	Status	Habitat
Spotted bat	*Euderma maculatum*	State T	Occurs in montane ponderosa pine of forests, piñon-juniper woodlands, and open semi-desert shrublands. Roosts in cracks and crevices in rocky cliffs.
Black-footed ferret	*Mustela nigripes*	USFWS E	Occurs mainly in mixed shrub habitat type. Closely associated with the prairie dog whose burrows provide excellent retreats for ferrets. The dependency of the black-footed ferret on this food item is so great that reduction in numbers of ferrets is directly related to reduction in prairie dogs. This species is apparently extirpated in New Mexico, having been last confirmed there in 1934. Reintroduction is currently occurring at the Vermejo Park Ranch in northern New Mexico.
New Mexican meadow jumping mouse	*Zapus hudsonius luteus*	USFWS E	Occupies mesic habitats in lowland valleys and along montane streams, and in riparian zones along permanent waterways. It is also found along irrigation ditches and in wet meadow areas within some river floodplains. Known to occur along the MRG at Isleta Marsh and the Bosque del Apache National Wildlife Refuge. Associated with thick, tall grasses and sedges in wetlands.

Sources: Cartron et al. (2008), Cartron (2010).
Listing status: E = endangered, T = threatened, PE = proposed endangered; PT = proposed threatened; C = candidate, SOC = species of concern; EXPN = experimental non-essential population.

4 RELEVANT ENVIRONMENTAL 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 of the MRG. 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.

Habitat restoration projects to benefit the silvery minnow and flycatcher that have been constructed in the Albuquerque Reach include USBR'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); USBR's Bernalillo Priority Site (2007); and the USACE' Rio Grande Nature Center Project (2008). The following section gives a brief description of some of these projects. Figure 4.1 shows the geographic distributions of various past MRG habitat restoration projects within the Albuquerque Subreach of the MRG. Figure 4.2. shows a detail view of the prior habitat projects implemented within the present Central to Montaño segment of RGVSP. The following text provides a brief description of major habitat projects and related activity conducted within RGVSP in the past decade.

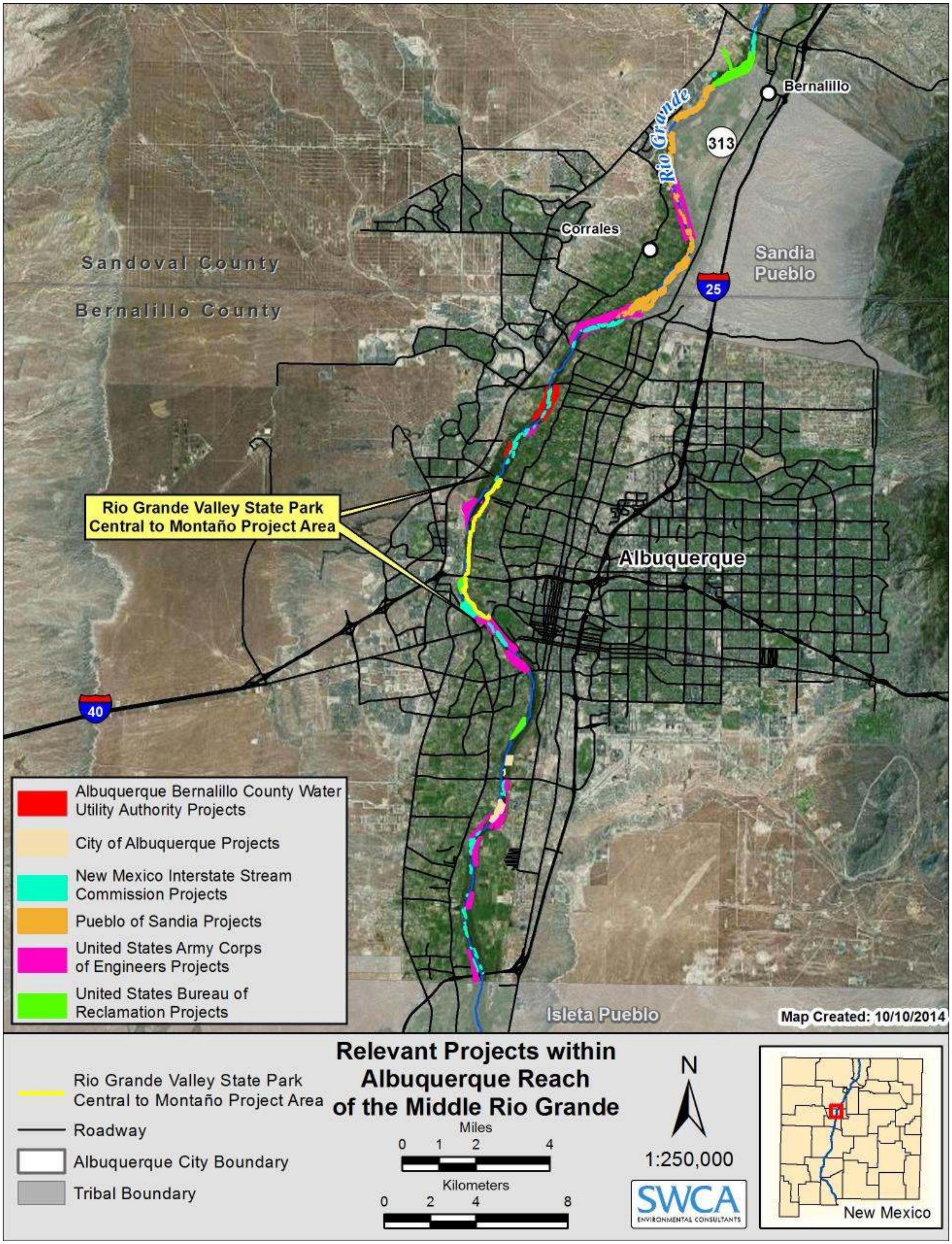


Figure 4.1. Past and existing habitat restoration projects of the MRG Albuquerque Subreach.

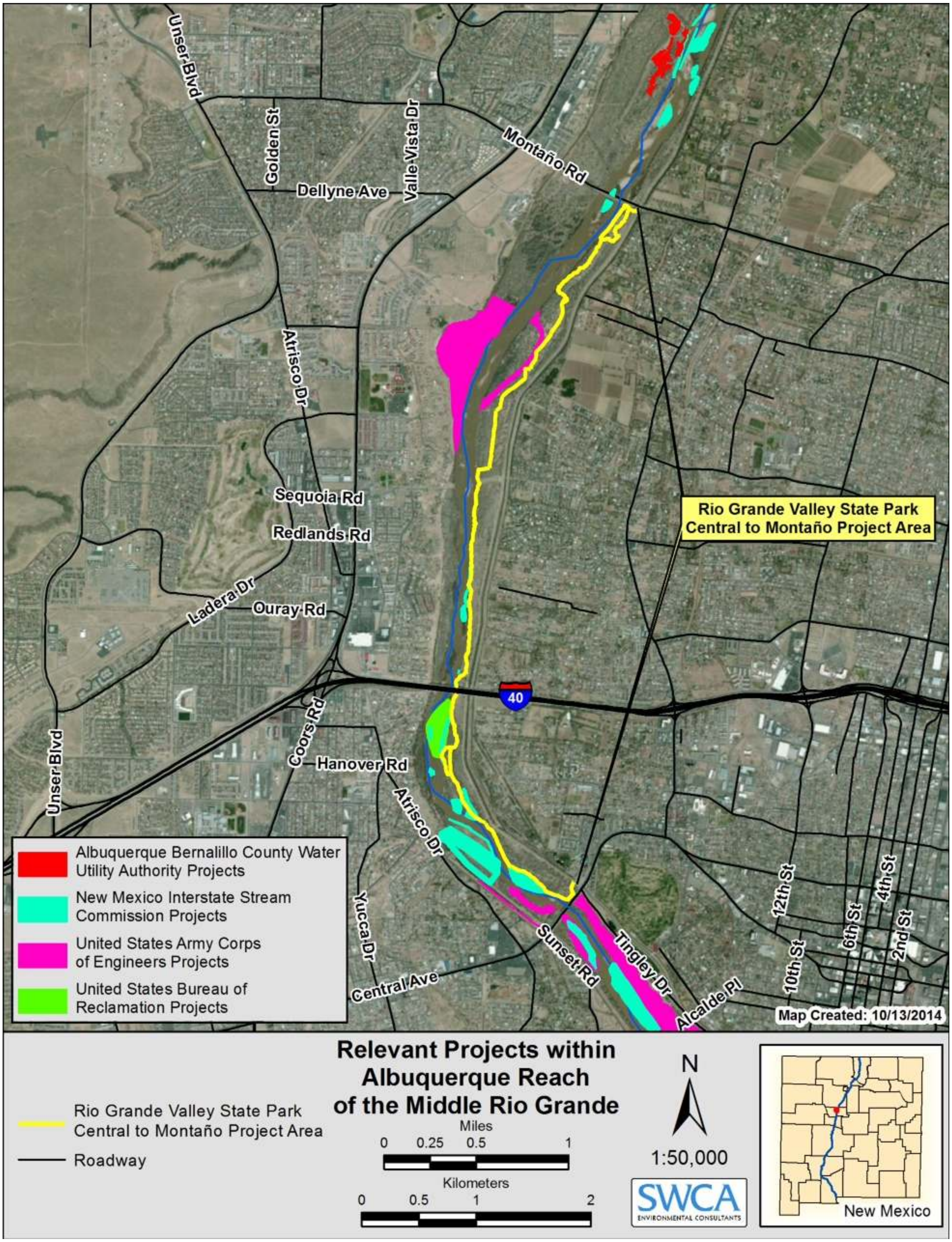


Figure 4.2. Detail of prior projects completed within current project area, RGVSP from Central to Montaño

4.1 ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY DRINKING WATER PROJECT MITIGATION

The Albuquerque Bernalillo County Water Utility Authority (ABCWUA) restored habitat for the benefit of the southwestern willow flycatcher on a 20-acre section of the MRG near the La Orilla Drain (SWCA 2011). This project created a 10-acre swale that is dominated by coyote willow and a 10-acre buffer area with native riparian shrubs typical of the surrounding floodplain. The site is on lands that are owned by the City of Albuquerque and managed by the city of Albuquerque Open Space Division. The project contributed to the Middle Rio Grande Endangered Species Collaborative Program goal of meeting the habitat restoration requirements as stated in Element S of the Reasonable and Prudent Alternatives in the March 2003 Biological Opinion (USFWS 2003).

4.2 ALBUQUERQUE BERNALILLO COUNTY WATER UTILITY AUTHORITY SAN JUAN CHAMA DRINKING WATER PROJECT

The San Juan-Chama Drinking Water Environmental Mitigation Project applied habitat restoration techniques within the Albuquerque Reach of the MRG at three sites collectively referred to as the Paseo del Norte (PDN) Site Grouping. The PDN Site Grouping represents the Water Utility Authority's selection of preferred sites to meet the conservation measures detailed in the 2012 BO for the and Conference on the Effects of the Albuquerque Bernalillo County Water Utility Authority's San Juan-Chama Drinking Water Environmental Mitigation Project (USFWS 2012). The project consisted of habitat restoration treatments designed to mechanically promote inundation of designed river features to provide habitat for all life stages of the silvery minnow, with a secondary goal of improving riparian habitat for the flycatcher. Construction was completed April 2014 with post-construction revegetation and monitoring activities continuing through December 2015.

4.3 BOSQUE ECOSYSTEM MONITORING PROGRAM

The Bosque Ecosystem Monitoring Program (BEMP) is a joint effort coordinated by the University of New Mexico's (UNM) Long Term Ecological Research (LTER) network and the Bosque School. BEMP research is conducted by student and citizen volunteers along the Middle Rio Grande and its associated riparian bosque forest. Through this project, citizen and student groups accept responsibility for gathering long-term data related to the overall condition of the forest ecosystem located along New Mexico's most prominent river. With this approach, citizen volunteers build direct connections with their local environment and in so doing, increase public understanding of a complex ecosystem as well as fulfill essential research needs. The program consists of a series of 27 research sites along 560 km (350 miles) of the Rio Grande. Sites are presently located between Ohkay Owingeh pueblo and Mesilla Valley Bosque State Park. Monitoring activities are synchronized between sites with volunteers (primarily grade K-12 students and their teachers) collecting long-term data on core weather data, shallow groundwater table depth, monthly precipitation, surface active arthropod activity, and measurements of forest production such as leaf litter biomass/plant productivity, tree diameter and growth rates, and woody and herbaceous plant distribution (Eichhorst et al 2006; 2012).

4.4 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.

4.5 BUREAU OF RECLAMATION I-40 BAR PROJECT

USBR completed construction of the silvery minnow habitat restoration demonstration project immediately downstream of I-40 in August 2005. The project was designed to evaluate habitat features for silvery minnow spawning and rearing habitat at flows between 500 and 6,000 cfs (USBR 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.

4.6 BUREAU OF RECLAMATION BERNALILLO AND SANDIA PRIORITY PROJECTS

USBR 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 2006).

USBR 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.

4.7 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 at 26 sites totaling 9.6 hectares (23.7 acres) benefiting the silvery minnow within the Albuquerque Reach. 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 2005). 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 of the project sites is ongoing.

4.8 NMISC Riverine Restoration Project, Phase II and Phase IIa

The NMISC applied lessons learned from the 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 and implemented various habitat restoration techniques at 42 sites totaling 35.7 hectares (88.2 acres) benefiting the silvery minnow within the Albuquerque Reach. Monitoring of the project sites is ongoing.

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 at 38 sites totaling 18.9 hectares (46.8 acres) benefiting the silvery minnow within the Albuquerque Reach (USFWS 2007a, 2009a). Monitoring of the project sites is ongoing.

4.9 NMISC Riverine Restoration Project, Atrisco Restoration

The Atrisco Restoration Project consisted of a diversion channel with an associated overbanking area located in the Rio Grande floodplain bosque adjacent to the river in central Albuquerque (USFWS 2007a). The Project is located adjacent to the west side of the Rio Grande between the I-40 and Central Avenue Bridges. The site was designed primarily to use surface water from the Rio Grande, but occasionally requires supplementation with pumped groundwater. Approximately 6.1 acres were modified in the Project area, including diversion restoration, reshaping and reconnection. The site provides habitat for the silvery minnow to spawn and develop due to passive overbanking and flooding during intermittent periods of high river flow. Additionally, the site is kept inundated by groundwater during prolonged periods of river drying to act as an off-channel refugium for the silvery minnow.

4.10 NMISC Rio Rancho Willow Creek and North Beach Habitat Restoration Project

The Rio Rancho Open Space Habitat Restoration Project provided restoration in the Rio Rancho Bosque at three sites in Rio Rancho. The project consists of habitat restoration treatments with goals of 1) increasing in-channel structural diversity and resulting aquatic habitat; 2) creating a more natural and functional floodplain relationship; and 3) improving and maintaining existing wetland habitats (USFWS 2013b). Associated wetland rehabilitation and upland wildlife habitat improvements will benefit the ecosystem overall and increase the recreational opportunities for citizens of Rio Rancho and adjacent communities. The project will also restore a degraded wetland, improve wildlife habitat, and improve recreational access to the river. The Willow Creek meadow area represents about 4.0 hectares (10 acres) that was affected by a severe die-back of the cottonwood forest in the early 2000's. About 2 hectares (5 acres) will receive sediment from the river restoration activities. Dead and down trees will be removed and the area will be sculpted to increase pedestrian access. Native vegetation will be replanted to increase wildlife habitat values and control weeds. Construction began in February 2013 continuing through fall 2013 and winter 2014, with completion expected by April 2014. Post-construction revegetation activities will continue through April 2017. Monitoring of project performance and success is expected for two years following construction.

4.11 City of Albuquerque Open Space Division Environmental Enhancement Plan

The Environmental Enhancement Plan (EEP) (City 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 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.

4.12 City of Albuquerque Open Space Division Rio Bravo Project

The City 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. 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 totaling 23.6 hectares (58.3 acres) for the benefit of the silvery minnow, the flycatcher, and the riverine ecosystem as a whole (USFWS 2007b).

4.13 U.S. Army Corps of Engineers Habitat Restoration Projects

The USACE 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 Bosque Restoration Project (BRP).

The purpose of the Bosque Wildfire Project (USACE 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 (USFWS 2003). 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 (USACE 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 6.1 hectares (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 and replacement of non-native vegetation with native species (cottonwoods and other tree species, willows, and understory shrub species); clearing of approximately 1,000 jetty jacks from the riparian zone; and the removal of 10,000 cubic yards of construction debris. In addition, the project constructs three high flow channels (which also function as backwater channels at lower flows); willow swales; two bendway weirs for both bank protection and shoreline habitat; a recreational trail with benches; 6 pedestrian bridges that cross the high-flow channels; an overlook platform just south of Central bridge; a trail connection from the Valle del Bosque park that is ADA compliant with a pedestrian bridge over the riverside drain; a boardwalk; and an overlook (USACE 2008a). Currently this project is in post-construction monitoring and adaptive management.

The MRG BRP (USACE 2010) is an ecosystem restoration project that restored 370.7 hectares (916 acres) of the Middle Rio Grande bosque by 1) improving hydrologic function by constructing high-flow channels, willow swales, and wetlands; 2) restoring native vegetation and habitat by removing jetty jacks, exotic species/fuel reduction, riparian gallery forest restoration; and 3) creating opportunities for recreational, educational and interpretive features. This project extends for approximately 26 miles from the northern boundary of the Corrales Bosque Preserve to the Pueblo of Isleta on the south. The project focused on bank stabilization on 29 hectares (71 acres), willow swale construction on 28 hectares (68 acres), vegetation management on 268 hectares (662 acres), and creating water features on 46 hectares (114 acres) in the floodplain throughout the Albuquerque Reach (USACE 2010). Currently this project is in post-construction monitoring and adaptive management.

4.14 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 (USACE 2002; USACE 2008b; USBR 1999). The Pueblo of Sandia has implemented river restoration work to improve habitat conditions for the silvery minnow (USBR 2008), completed the Sandia Subreach Habitat Analysis and Recommendations Study (SWCA 2008a), 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).

5 MIDDLE RIO GRANDE BOSQUE MANAGEMENT PLANS

Several comprehensive environmental management plans have been developed during recent decades to provide guidance for natural resource managers and the public for conserving natural resources along the MRG bosque and the RGVSP. Key documents and plans that are relevant to this project include

- Rio Grande Valley State Park Management Plan (COA 1986)
- Bosque Action Plan (BAP; COA 1993),
- Middle Rio Grande Ecosystem Bosque Biological Management Plan (Crawford et al. 1993)
- Middle Rio Grande Ecosystem Bosque Biological Management Plan update (Robert 2005)
- Environmental Enhancement Plan for Rio Grande Valley State Park (COA 2005)
- Middle Rio Grande Bosque Initiative (Abeyta 2009),
- Middle Rio Grande Ecosystem Restoration Project (USACE 2013),
- Middle Rio Grande Conservation Initiative (Secretary's Committee 2012)

All of these plans focus on natural resource management and conservation, and all advocate conservation, public environmental education, and habitat restoration of the MRG bosque.

5.1 BOSQUE ACTION PLAN

The Bosque Action Plan (BAP) is the guiding document relevant to the proposed project, since the project area is within the boundaries of an approved plan for the RGVSP (COA 1993). The currently proposed project is required to comply with the BAP. The BAP identifies the RGVSP as a valuable riparian area of the Southwest, located within a major metropolitan area. The purpose of the BAP is to identify specific environmental and recreational improvements to the RGVSP, to be implemented in such ways as to minimize impacts on the bosque environment and to ensure continued survival of bosque plants and animals, as well as protection and enhancement of their habitats, and provide for low-impact recreation and environmental education.

Policies 1 through 7 of the BAP address environmental restoration and preservation, policies 8 through 16 address recreation and access, and policies 17 through 24 address environmental education and administration. The primary goal of the BAP for the environment and wildlife is to protect and enhance natural resources of the RGVSP. Below is a listing of the BAP policy statements. Refer to the BAP for each of the specific action items listed under each policy statement.

A. <u>Environment and Wildlife</u>. The goal is to protect and enhance the natural resources of the RGVSP.

Policy 1: Land use decisions shall be compatible with ecological opportunities and constraints characteristic of the identified biophysical land units (BLUs). Action items A through H call for establishing wildlife preserves in sensitive habitats, reclamation preserves in damaged areas, restoration of closed trails, creation of ponds and wetlands, and the evaluation of development proposals with recommendations based on the BAP.

Policy 2: Comprehensive programs shall be established for monitoring environmental ecological systems. Action items A through O call for environmental monitoring of vegetation, wildlife, particular special status species, and groundwater, with sampling distributed among BLUs. Monitoring should be conducted every 3 to 5 years.

Policy 3: The RGVSP shall be managed to preserve and enhance its ecological diversity. Action items A through J call for controlling exotic invasive trees and other plants, reintroduction of native plants and animals that historically occurred in the RGVSP, improvement of wildlife habitat, establishment of fire break clearings for wildfire control, use of controlled burns for vegetation management, and the closure of trails in ecologically sensitive areas.

Policy 4: Regeneration of cottonwood trees shall be emphasized to perpetuate their existence. Action items A through E call for maintaining genetic diversity of cottonwood forests, use temporary flooding to enhance cottonwoods, and replant disturbed areas with cottonwood.

Policy 5: Habitat for rare and endangered plant and animal species shall be protected. Action items A through C call for protecting special status species habitats and limiting the use of chemically based pesticides.

Policy 6: All submittals for development, both private and public, on property located on or adjacent to the boundaries of the RGVSP shall include a complete extraordinary facilities form to be submitted to the Open Space Advisory Board for their action. Action A states that all submittals will be checked for compliance with the BAP and other ordinances and policies. The City of Albuquerque's extraordinary facilities ordinance (O79-1989) requires that any improvement other than "trails, fencing, signs, incidental parking lots, and access roads" on Open Space be evaluated by the Open Space Advisory Board and approved by the Environmental Planning Commission.

Policy 7: Any disturbance within the RGVSP not approved by Open Space Division shall be mitigated by the party responsible for the disturbance. Action items A through E call for responsible parties to replace natural resources that are removed.

B. <u>Recreation and Other Public Uses</u>. The goal is to protect and enhance the natural character by facilitation appropriate management practices and public uses.

Policy 8: Improvements shall be located in non-sensitive areas that are appropriate for such developments, considering ecological sensitivity, as well as user satisfaction. Action items A and B call for acquiring additional property to provide access, parking, low impact recreation and education centers adjacent to the park, and outside of the riverside drains.

Policy 9: Encourage developed recreation and other public uses between the area north of Barelas Bridge and south from I-40. Action items A through E call for the construction of trails, picnic areas, connections to the Albuquerque Bio Park, and an information booth.

Policy 10: Access points shall be developed in appropriate areas. Action items A through G call for the development of public access points in locations representing cottonwood woodlands, open meadows, and potential wetlands throughout the RGVSP, including parking areas, Americans with Disabilities Act (ADA) compliance, trash bins, bike and horse tie-ups, increased ranger patrols, and information signs.

Policy 11: An ecologically compatible, multi-use trail system shall be developed. Action items A through F call for the development of stabilized surface trails from access points into non-sensitive areas, use existing trails if possible, monitoring to determine if trails are excess degradation of surrounding areas is occurring, provide ADA accessible trails, and provide interpretative signs.

Policy 12: The Paseo del Bosque Trail shall be extended outside the bosque north and south of the existing trail. Action items A through F call for the development of a continuous stabilized surface trail that traverses the park from north to south and is located along the levee or riverside drain, avoiding sensitive areas, providing natural materials seating and bike racks, mile markers and signs, and natural surface equestrian trail adjacent to the main trail, some realignments of existing trails, and exclusion of bikes and horses from some trails.

Policy 13: Appropriate fishing areas shall be developed. Action items A and B call for the establishment of fishing locations along the riverside drains, including access and ADA-compliant fishing piers.

Policy 14: Non-motorized boating areas shall be developed. Action items A through D call for public boat, raft, canoe, and kayak put-in and take-out facilities in non-sensitive areas, and prohibit use of home-made water craft containing toxic chemicals, motorized boats, and facilities in sensitive locations.

Policy 15: Special use permits shall be required for all organized events. Action items A through E call for allowing all public events compatible with policies of the RGVSP, evaluation of all event applications, measures to reduce noise and other ecological impacts, and mitigation for unauthorized surface disturbances.

Policy 16: Trails shall be rerouted in areas where emergency vehicles cannot access the levee roads. Action items A and B call for emergency vehicle access to trails.

C. <u>Education</u>. The goal is to enhance environmental education within the RGVSP.

Policy 17: Educational opportunities and improvements shall be identified in appropriate areas. Action items A through H call for providing interpretative trails from I-40 to the Barelas

Bridge, and environmental education center, observation blinds to view wildlife, a digital database on species, habitats, etc.

Policy 18: Educational programs and materials shall be developed and implemented. Action items A through G call for developing environmental education, including signs, tours, workshops, and an environmental monitoring program with the University of New Mexico.

Policy 19: Use of the environmental education area shall be coordinated with the Open Space Division prior to that use. Action items A through C call for the establishment of an environmental education area (on the west side of the Rio Grande, just north of Paseo del Norte) along with programs to enhance wildlife habitat and a place for public school environmental education activities.

D. <u>Administration.</u> The goal is to protect and enhance the natural character by facilitating appropriate management practices and public use.

Policy 20: Construction methods and materials shall be compatible with the preservation of the natural character of the RGVSP. Action items A through G call for minimizing vegetation removal, using natural or recycled construction material, monitoring construction for compliance, and using natural barriers such as wetlands to control visitor access. Prior to construction, project boundaries, methods, and materials must be reviewed by the Open Space Division.

Policy 21: Construction methods and materials used shall preserve the cultural character of the park. Action items A through E call for protecting significant cultural resources, including documenting all historic sites more than 50 years old, conducting archeological clearance surveys in some areas, and monitoring surface disturbances for archeological artifacts.

Policy 22: Emergency training shall be allowed to occur consistent with the policies of the RGVSP. Action items A through F call for coordinating all emergency training with the Albuquerque Fire Department and Bernalillo County Aquatic Rescue Teams, requiring Special Use Permits if motorized boats are used, not allowing motorized boats in sensitive areas, and designating rescue team entry points.

Policy 23: The principal use of the area within the Rio Grande levee roads shall be recognized for conveyance of water for beneficial use, and as a floodway. Action items A and B call for acknowledging Section 6 of the 1983 Rio Grande Valley State Park Act and recognize the existence of and need for future stormwater discharge facilities.

Policy 24: A volunteer patrol shall be formed and coordinated by Open Space Division to provide a safe environment for the park users and protection to natural resources. Action items A through F call for trained volunteer patrols on foot, horse, or bicycle with uniforms or badges and radios.

Policy 25: Fire suppression shall utilize wildland fire techniques. Action item A calls for the use and incorporation of a separately prepared Fire Management Plan.

Policy 26: Rio Grande Valley State Park Task Force shall be created to provide ongoing public involvement. Action items A and B call for the establishment of by-laws for the Task Force within six months of adoption of the BAP and sets out roles for the Task Force (only makes recommendations, monitors implementation of the BAP, keeps public informed on goals and purposes).

Policies 1, 2, 3, 4, 5, 6, 8, 10, 11, 12, 16, 17, 18, 20, 21, 24, and 26 are particularly relevant to the Project since they specifically address environmental impacts, restoration, public education, low-impact recreation, and administrative management that specifically relate to the trail and associated amenities. The current project area and related improvements is specifically shown in BAP Maps 6, 7, 8, 9, and 10.

5.2 MIDDLE RIO GRANDE ECOSYSTEM: BOSQUE BIOLOGICAL MANAGEMENT PLAN

The Middle Rio Grande Ecosystem Bosque Biological Management Plan (Crawford et al. 1993; Robert 2005) is a key document developed by an interagency team that provided guidelines for the environmental management of the MRG bosque. The Middle Rio Grande Ecosystem Bosque Biological Management Plan made the following 22 recommendations for the management of the MRG bosque:

- **Recommendation 1:** Coordinate Rio Grande water management activities to support and improve the bosque's riverine and terrestrial habitats, with special emphasis on mimicking typical natural hydrographs.
- **Recommendation 2:** Implement measures to allow fluvial processes to occur within the river channel and the adjacent bosque to the extent possible.
- **Recommendation 3:** Reintroduce the dynamics of surface water/groundwater exchange, manage groundwater withdrawal, and restrict contamination.
- **Recommendation 4:** Protect, extend, and enhance the structure of aquatic habitat to the benefit of native communities.
- **Recommendation 5:** Protect and enhance surface-water quality.
- **Recommendation 6:** Integrate management of nonnative and native fish species in all aquatic environments in the MRG riparian ecosystem including wetlands, canals, and drains.
- **Recommendation 7:** Protect the geographic extent of the Rio Grande bosque and avoid further fragmentation of the riparian ecosystem and component habitats.
- **Recommendation 8:** Protect, extend, and enhance riparian vegetation in noncontiguous areas in the floodplain.
- **Recommendation 9:** Manage the buffer zone of the contiguous bosque to protect ecosystem processes, enhance wildlife habitat values, and maintain rural and semirural conditions.

- **Recommendation 10:** Manage livestock grazing in a manner compatible with biological quality and ecosystem integrity.
- **Recommendation 11:** Manage activities that remove dead wood in a manner compatible with biological quality and ecosystem integrity.
- **Recommendation 12:** Manage recreational activities in the bosque in a manner compatible with biological quality and ecosystem integrity.
- **Recommendation 13:** Prevent unmanaged fires in all reaches of the bosque.
- **Recommendation 14:** Use native plant species and local genetic stock in vegetation establishment and management efforts throughout the bosque.
- **Recommendation 15:** Protect, enhance, and extend (create) wetlands throughout the MRG riparian zone.
- **Recommendation 16:** Sustain and enhance existing cottonwood communities, and create new native cottonwood communities wherever possible throughout the MRG riparian zone.
- **Recommendation 17:** Contain the expansion of existing large stands of non-native vegetation in the MRG riparian zone. At the same time, study the ecology of these stands and develop creative ways of maximizing their biological values.
- **Recommendation 18:** Develop a coordinated program to monitor biological quality (with emphasis on the diversity and abundance of native species) and ecosystem integrity (with emphasis on restoring the functional connection between the river and riparian zone) of the MRG ecosystem.
- **Recommendation 19:** Develop a coordinated research program to study the ecological processes and biotic communities that characterize the MRG riparian ecosystem.
- **Recommendation 20:** Regularly review and update the Middle Rio Grande Ecosystem Bosque Biological Management Plan.
- **Recommendation 21**: Integrate resources management activities along the Rio Grande and within the contributing watersheds to protect and enhance biological quality and ecosystem integrity.
- **Recommendation 22**: Develop outreach initiatives through public education programs and events, and community participation activities and projects, to broaden public understanding of and generate more active interest in bosque restoration and river ecosystem management in the MRG.

Recommendations 7, 8, 9, 12, 13, 14, 15, 16, 17 and 18 are particularly relevant to the project, all advocating compatibility with biological quality and ecosystem integrity. Recommendation 22 is advanced by the proposed project by encouraging public appreciation and providing onsite information and environmental education.

5.3 MIDDLE RIO GRANDE CONSERVATION INITIATIVE

The Middle Rio Grande Conservation Initiative (MRGCI) was convened by former U.S. Secretary of the Interior Salazar and developed by a panel of local citizens and agencies (Secretary's Committee 2012). Its goal was to provide recommendations for the MRG that are consistent with the objectives of the America's Great Outdoors initiative. The primary objectives of these initiatives are to provide recommendations to enhance conservation, public recreation, and public environmental education relative to natural resources. The Secretary's Committee for the MRGCI consulted with many public and private organizations and with the general public in New Mexico, and produced the MRGCI report on its findings. MRGCI's vision statements for conservation, recreation, and education are respectively:

- **Conservation**: "A Middle Rio Grande watershed with integrated natural and cultural resource management for diverse uses and a balanced water use with renewable supply. This will ensure a vibrant, resilient, healthy ecosystem that supports biological processes, integrity, and diversity of the watershed in concert with sustainable human uses, cultural heritage, and thriving communities"

- **Recreation**: "A Middle Rio Grande corridor that supports diverse land- and water-based outdoor recreation opportunities serving multi-generational and multi-cultural populations, and that are accessible to all economic levels and physical abilities. Recreation should facilitate low-impact, sustainable activities, promote enjoyable experiences, and support conservation, education, tourism and health/wellness goals—nourishing mind, body, and spirit"

- **Education**: "An educated citizenry that understands, values, and protects the Middle Rio Grande; a population that at all ages is engaged with the natural and cultural resources of the region and that is guaranteed universal access to lifelong, experiential learning opportunities that promote stewardship and inform organizational and community decision-making in the region to foster sustainability" (Secretary's Committee for the MRGCI 2012, pages 25, 53, 79).

6 POTENTIAL ENVIRONMENTAL EFFECTS OF THE RGVSP CENTRAL TO MONTAÑO PROJECT

Recreation can have physical and biological impacts on ecosystems. These impacts include soil loss and compaction, trampling of vegetation, littering, wildlife disturbance, and an increase in fire frequency (Sun and Walsh 1998). Recreational trails can also act as corridors to transmit non-native plants (Wells et al. 2012). In general, impacts from recreation on ecosystems increase with level of use. The relationship has generally been described as curvilinear, with proportionally greater impacts occurring at lower levels of human visitation (Hammitt and Cole 1998). However, a new study (Monz et al. 2013) suggests instead that curvilinear relationships may be true only in relation to vegetation trampling and only for some plant communities; other impacts may increase linearly or non-linearly.

Potential impacts on wildlife from recreation activity may range from trampling of habitat to disturbance of animals (Boyle and Samson 1985). Bird species found in the bosque may experience negative impacts including disturbance of nesting and foraging, and nest depredation by dogs. Some studies, however, suggest that rates of predation may be lower along trails (Miller and Hobbs 2000), perhaps due to natural predators avoiding areas associated with the scent of dogs. Miller et al. (2003) studied the response of riparian bird communities to varying levels of landscape- and local-scale development in Colorado. Riparian areas in more urbanized settings tended to be associated with fewer native trees and shrubs, less ground and shrub cover, and higher tree densities. The observed number of bird species was lower, but resident and cavity-nesting species tended to be more abundant. Areas associated with lower development at a landscape scale tended to have more migrants and more low-nesting species. The intensity of trail use explained more than 60% of the variation in the occurrence of low-foraging species and nearly 90% of the variation in habitat use by species that forage on the ground for insects or seeds (Miller et al. 2003).

Hawks Aloft's avian monitoring of the Rio Rancho Willow Creek bosque just north of the project area suggests bird numbers might have decreased since 2008 (Garber 2013). Following mechanical clearing of non-native, woody vegetation, a crusher-fine loop trail was installed that year, resulting in an immediate increase of human visitors of the area. Species utilizing the shrub understory and ground-dwelling birds apparently have shown the most conspicuous declines since then (Garber 2013). Hawks Aloft attributed the trends to human visitation, particularly the observed increase in the number of dogs on and off leashes; to clearing of non-native, woody vegetation, particularly Russian olive; and to mowing of sunflower (*Helianthus annuus*) patches (Garber 2013). However, the sampling design was not appropriate to separately evaluate the potential effects of those variables from pre-existing differences in other environmental factors, including other spatial factors such as vegetation composition and structure, and temporal variation from climate/weather over time. A multivariate experimental sampling design with replicated and spatially inter-mixed sampling locations would be needed to actually test for the effects of an array of such environmental factors on bird communities.

The current project is intended to manage usage within the bosque environment by encouraging visitors (including pet dogs) to use a primary trail that could accommodate multiple users, while at the same limiting access to the surrounding bosque to prevent further degradation of soils, vegetation, and disturbance to wildlife. This type of trail management is common to parks and other public recreation lands and wildlife refuges. Evaluation of the proposed project requires comparisons of potential impacts against potential benefits from the project over an adequate period of time. The primary anticipated environmental impacts of the trail enhancement will be

1) During the upgrade construction phase (e.g., trucks, noise and activity)
2) Post-construction impacts by visitors (e.g., noise, possible effects from increased usage, potential off-trail impacts such as soil, vegetation, and wildlife disturbance), and
3) Future trail maintenance activities (e.g., regrading, needed repairs).

The natural resources that may be affected by these activities include 1) landscape geomorphology, 2) soils, 3) vegetation, and 4) wildlife. Table 6.1 presents a cross matrix of impacts and resources with intersecting cells showing anticipated effects or impacts.

Table 6.1. Principal Anticipated Impact Categories and Natural Resources That May Be Affected by Those Impacts and Expected Outcomes

Impact Categories	Impacts	Natural Resource Categories Potentially Affected and Mitigation Efforts			
		Geomorphology	Soils	Vegetation	Wildlife
Construction	Grading and leveling, limited trail-side vegetation removal, noise, possible fuel and lubricant spills.	**Resource Effect** Minor initial but permanent impacts due to grading and leveling. **Mitigation** Sensitive areas such as wetlands will not be impacted.	**Resource Effect** Soil disturbance along trail route and parking areas. Protection of soils in areas away from trail and parking. **Mitigation Measures** Revegetation and soils restoration on closed side trails. Best management will be used to avoid fuel and lubricant spills.	**Resource Effect** Some vegetation removal along trail route and parking areas. **Mitigation** Vegetation protection away from trail and parking areas. Native vegetation restoration on any closed side trails. Trail margin revegetation with native plant species.	**Resource Effect** Temporary noise and disturbance during construction activities. **Mitigation** Construction during winter months so as not to affect breeding birds and other wildlife.
Visitors	On-trail and parking area activities (desired), off trail activities (discouraged).	None.	None, except for off-trail visitor use that will be discouraged.	**Resource Effect** Off-trail visitor use could damage native vegetation and will be discouraged. Potential for wildfire ignition is possible. **Mitigation** Closing some side trails can be beneficial to vegetation.	**Resource effect** Disturbance from sound and human and dog activity along the trail route and adjacent to parking areas. **Mitigation** Off-trail use would be discouraged.
Maintenance	Regrading and applying fine-crush gravel as needed; removal of fallen trees, exotic weeds as needed.	None.	None, other than already disturbed trail surfaces and parking area soils.	**Resource Effect** Limited removal of fallen trees, branches, and exotic weeds along trail and parking areas and margins. **Mitigation** Off-trail and parking area activities will be avoided.	**Resource Effect** Temporary noise and disturbance during maintenance activities. **Mitigation** Maintenance scheduled to avoid sensitive breeding periods.

6.1 TRAIL AND ASSOCIATED RECREATIONAL AMENITIES ENVIRONMENTAL MONITORING

SWCA has conducted environmental monitoring of the potential effects on soils, vegetation, and bird communities in order to determine whether any proposed trail the enhancement and possible increased public use of associated recreation amenities has a measureable effect on those resources. The monitoring is intended to be consistent with the requirements of the BAP, Policy 1, Action H. The monitoring will follow an experimental design, where trail and trail amenity enhancements are the "treatments." Data on soils, vegetation, and birds will be collected from the proposed treated areas and compared to adjacent untreated or impacted areas, including pre-treatment baseline and several years of post-treatment data collection.

6.1.1 OBJECTIVES OF ENVIRONMENTAL MONITORING

The objectives of environmental monitoring for the main trail, trail-related, and trailhead parking area enhancements are to document environmental conditions prior to project implementation, and then again following construction, both within the areas to be developed and in the adjacent surrounding areas that will not be developed.

The objectives of monitoring closed trails are to document whether any restored trails trend toward natural soil surface and vegetation conditions. Soil surface conditions and vegetation will be measured by use of photographic monitoring (use of permanent repeat photo points) and rapid assessment methods for categorically scoring environmental conditions over time. This monitoring will be conducted from three points at each of two trailhead locations and from five (5) to ten (10) locations to be determined once the trail closure plan has been completed.

Trail enhancement and trail closure/restoration activities will most likely affect the surrounding environment through

1) Direct impacts related to new trail construction and closing and restoring informal trails (e.g., vehicles and workers impacting soils, vegetation, and wildlife)
2) Post-construction/restoration impacts of hikers and bicyclists on trailside environments trampling soils and vegetation and harassing wildlife, and
3) Trail maintenance.

6.1.2 EVALUATION CRITERIA FOR ENVIRONMENTAL MONITORING

Criteria used to evaluate the effects of the project on the environment are based on the objectives of the project and the objectives of environmental monitoring. The objectives of the trails project are to manage users who visit and enjoy the natural resources of the project area, while at the same time protecting those natural resources (see Sections 1 and 4). This environmental monitoring focuses on the later objective of protecting the environment such that construction activities, visitor use, and maintenance activities should have no <u>measureable</u> negative effects. This monitoring project further focuses on the effects of construction and visitors on the initial enhancement and use of the main trail and amenities, and the closing of side trails.

Environmental impact evaluations for the initial construction of the trail enhancement and amenities, as well as visitor use, will be based on statistical comparisons of

1) Soil surface disturbance
2) Native vegetation canopy cover, species richness, and proportion of native versus exotic species, and
3) Breeding season bird numbers, species diversity (richness and evenness), and changes in key species.

An experimental monitoring design is being employed with control (areas with no impacts) and treatment (areas including and adjacent to impacts), with before-impact and after-impact measurements. Table 6.2 provides a matrix of how the impacts of the project will be evaluated for impacts to soils, vegetation, and birds relative to the construction and visitor use phases. In most cases, statistical tests of measured values will be compared for change between treated (developed or restored) locations and control (non-developed or restored), both before and after treatment activities. SWCA has chosen to focus monitoring efforts on soil surfaces, vegetation and birds because they are the most cost-effective natural resources to monitor in terms of providing measurable responses to the project. Soils and vegetation will likely be the most affected natural resource, and some bird species are sensitive to human activity and disturbance. Mammals, amphibians, reptiles and arthropods that occur in the project area are much more difficult and expensive to measure and monitor due to their abundance patterns and sensitivity to potential impacts, and appropriate sampling efforts to acquire useful data would be very expensive. They are more likely to be indirectly affected by impacts to soil and vegetation that constitute their habitats.

Table 6.2. Evaluation Criteria for Environmental Monitoring Determinations of the Trails Project Impacts to Soils, Vegetation, and Birds

Activity		Soils (surface disturbance)				Vegetation (native canopy cover and number of native species [opposite for exotic species])				Birds (numbers of individuals and species, number of individuals of key species)			
		Control		Treatment		Control		Treatment		Control		Treatment	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Construction	Main trail (enhanced)	BL	NC, <	BL	NC, <	BL	NC	BL	NC, >	BL	NC	BL	NC, >
	Parking areas (enhanced)	BL	NC, <	BL	NC, <	BL	NC	BL	NC, >	BL	NC	BL	NC, >
	Side trails (closed)	BL	<	BL	<	BL	NC	BL	>	-	-	-	-
Visitor Use	Main trail (enhanced)	BL	NC, <	BL	NC, <	BL	NC	BL	NC, >	BL	NC	BL	NC, >
	Parking areas (enhanced)	BL	NC, <	BL	NC, <	BL	NC	BL	NC, >	BL	NC	BL	NC, >
	Side trails (closed)	BL	<	BL	<	BL	NC	BL	>	-	-	-	-

Note: BL = Baseline conditions, NC = No change in measured values, < = Values less than baseline and treatment conditions, > = Values greater than baseline and treatment conditions, - = Will not be measured. Statistical testing of data will be performed to test for significant differences (5%; $p < 0.05$) between control and treatment locations over time.

6.1.3 ENVIRONMENTAL MONITORING DESIGN AND METHODS

Environmental monitoring is being conducted by using a Before-After-Control-Impact (treatment) (BACI) experimental sampling design, with paired (adjacent pairs in similar environments) treatment and control study plots/transects. BACI designs are considered to be the most powerful ways to measure for impact effects (Green 1979; Elzinga et al. 2001; Downes et al. 2002). Statistical testing is being applied to data collected from monitoring to test for significant differences (at the 5% level or chance of obtaining the observed result if no real difference exists) in soil, vegetation, and bird measurements between control and treatment locations. Parametric or non-parametric testing are both being performed, depending on which is most appropriate given the nature of the data collected (normally distributed with equal variances or not).

The specific sampling design was installed in 2014 and consists of 20 modified 5-meter by 30-meter BEMP plots (Eichhorst et al. 2012) to measure vegetation and soils (Figure 6.1). Ten sampling sites were systematically located at equal distances apart, along the main trail to provide unbiased and consistent sampling throughout the project area between Central Ave. and Montano Blvd. (Figure 6.2). At each of the sampling sites, a treatment (exposed to direct trail enhancement activities) was located with one side of the plot precisely along the edge of the existing trail, and extending 5-meters away from the trail to the other side of the plot. Each of the 10 treatment plots was paired with a control plot (not directly affected by main trail activities), located 30-meters away from each treatment plot. If a human-created structural feature (e.g., unofficial side trail, jettyjacks, etc.) was situated in the position where a control plot was meant to be, it was moved north or south to the nearest closest location so as not to be influenced by that feature. Figure 6.3 is a diagram showing how control and treatment BEMP plots were positioned relative to the main trail. Vegetation and soil surface features were first measured in August, 2014, and will be measured in August of subsequent years from the BEMP plots.

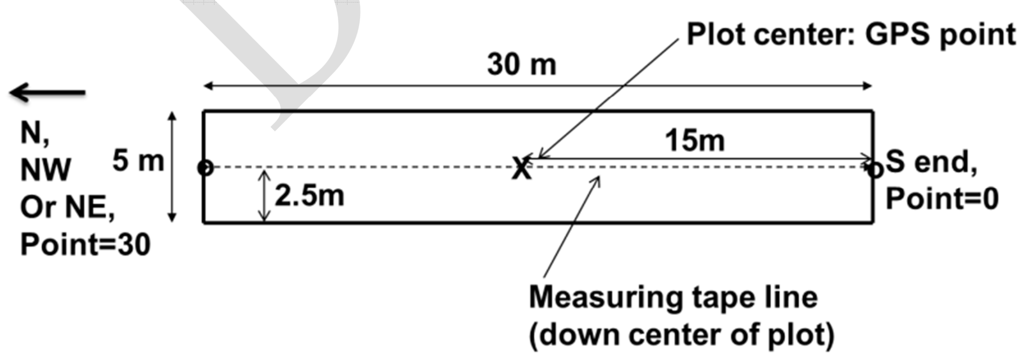


Figure 6.1. Diagram of a BEMP plot as used for soil and vegetation monitoring.

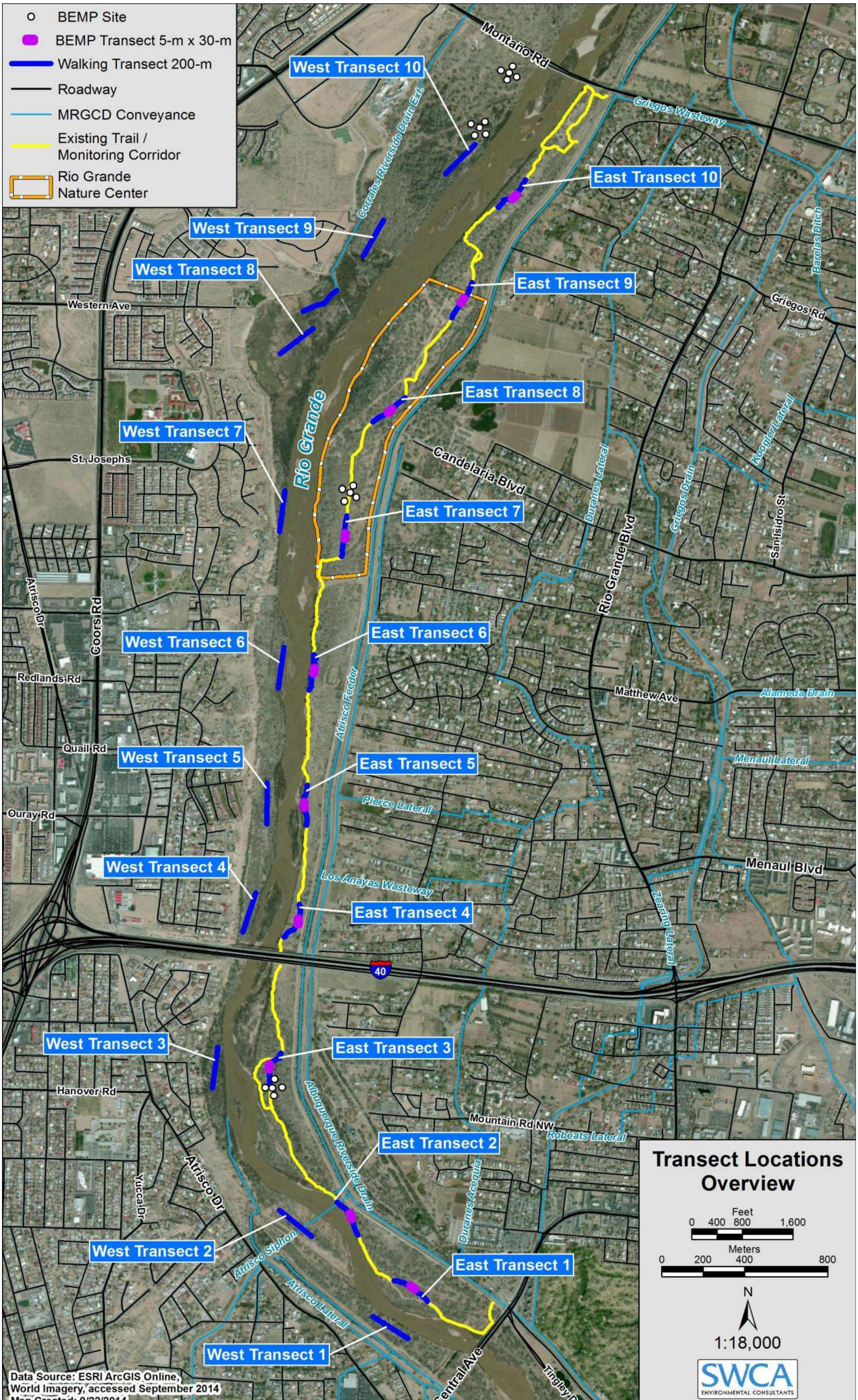


Figure 6.2. Locations of vegetation and soil measurement BEMP plot and bird transect locations across the project area.

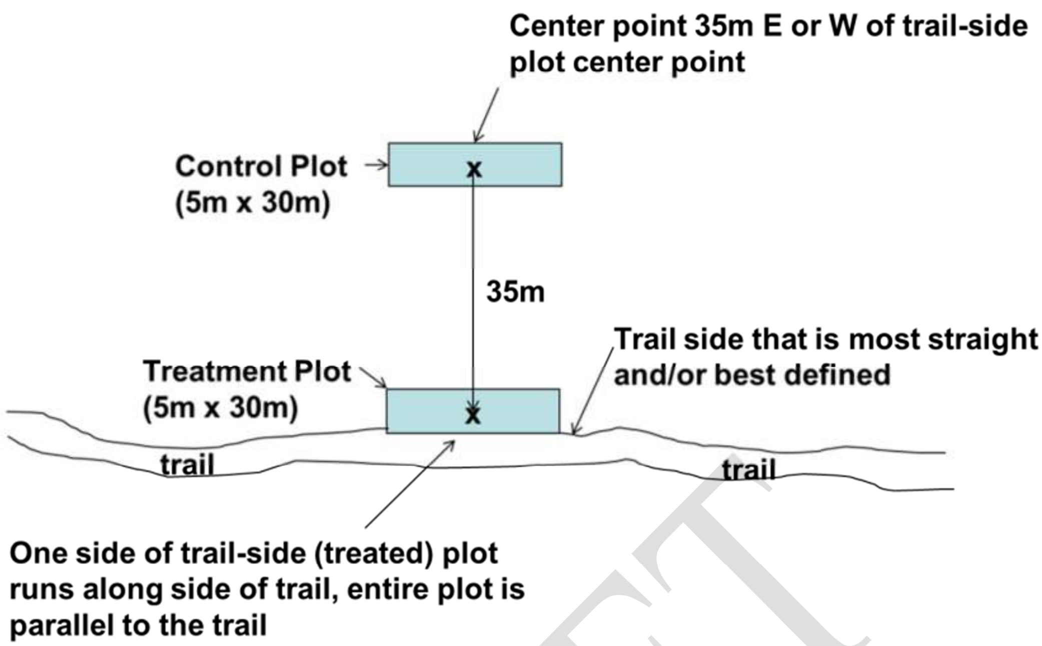


Figure 6.3. Diagram of control and treatment vegetation and soils plot placements.

Herbaceous and woody vegetation was measured along a 30-meter line down the center of each BEMP plot using the line-point-intercept method following the protocols of Herrick et al. (2005), at 1-meter intervals along the line, for at total of 30 point measurements per BEMP plot. Note that BEMP uses continuous line-intercept measurements for vegetation; this is one way that we modified the BEMP sampling design. We chose to use line-point-intercept instead because it is much more efficient, is subject to less observer bias, and is as accurate as the continuous line-intercept method (Elzinga et al. 2001). Each plant species intercepted at each of the 30 points per plot was recorded, and the condition of the soil surface at each of the 30 points per plot was recorded as bare ground, biotic soil crust, organic leaf litter, dead, downed wood (>2-centimeters diameter), and whether or not there was indication of human-caused soil disturbance (e.g., human or domestic animal foot prints, vehicle tire tracks, etc.).

Trees and large shrubs with diameters at breast height (DBH) of 2-centimeters or greater were counted and tallied by species over each entire BEMP plot to provide counts of trees and shrubs by species. Note that BEMP tags and measures cottonwood trees, this is the other way that we modified the BEMP sampling design. Trees and shrubs were further categorized by three size classes based on DBH measurements of: 1) <10 centimeters, 2) 10-20 centimeters, and 3) >20 centimeters. Additionally, human caused soil surface disturbance was measured as a percentage of the area of each entire BEMP plot, to supplement the line-point-intercept measures of soil surface disturbance.

Repeat photo points were established at the north and south ends of each BEMP plot, providing photographic views of each plot, with a view from each end of the plot looking into an across each plot. Repeat photo points will used in addition to the actual measurements to evaluate changes in vegetation and soils over time (see repeat photo points below).

Bird community sampling is being conducted using a design similar to vegetation and soils, where ten 100-meter (328-foot-long) long pedestrian survey bird transects are centered at the 10 BEMP plot locations. The project area on the east side of the river is too narrow to include control bird transects since birds are affected by human activity from greater distances than plants and soils, so control bird transects were located in the bosque on the west side of the Rio Grande, where each of the 10 control transects are located directly across the river from each of the 10 treatment transects (Figure 6.2). Bird transects were sampled in 2014 once during the winter (February) for year-round and winter resident bird species, and three times during the early summer breeding season (May, June, July) for year-round and summer resident bird species. All 20 bird transects were sampled in the morning hours after sunrise and all within a one-week time period. All surveys were conducted by a single observer, who recorded the occurrence and abundance of bird species while walking the length of each transect. Detections were based on both visual observations and hearing the song or calls of the species. Data for all individuals of each bird species observed or heard on each transect were recorded. The same sampling will be employed for post-treatment bird monitoring surveys in subsequent years.

Analysis of data collected by the above field methods are being summarized and analyzed in two different ways. Univariate data analysis for testing differences in mean (parametric) or sums of scores (non-paramentric) values of parameters or variables measured are being used to test for significant differences in the values of those variables between paired control and treatment plots (vegetation and soils) and transects (birds). SAS (SAS Institute 2013) statistical software is being used for those univariate statistical testing analyses. Multivariate community data analyses are being used to compare the plant and bird entire community species compositions between control and treatment plots and transects. Cluster analysis (McCune and Grace 2002)., based on similarities of plant or bird species assemblages between all possible pair-wise combinations of the 20 plots or transects produces dendrogram (tree diagrams) showing groupings of plots or transects with similar species compositions, for qualitative, visual evaluations. The closer terminal branches are in those diagrams, the more similar the corresponding sets of species are in terms of composition and relative abundance. The Multi-Response Permutation Procedures (MRPP) (McCune and Grace 2002) were used (PC-ORD 5.10, McCune and Medford 1999) to determine whether treatments were different from controls. MRPP multivariate analysis is used to test for statistically significant differences in the species compositions of vegetation and birds of the control and treatment plots or transects, also based on the assemblages of species found at all plots or transects. Indicator Species Analysis (ISA) is then being used to test for statistically significant associations of individual species between control and treatment plots or transects (Dufrêne and Legendre 1997, McCune and Grace 2002). An indicator value is calculated for each species and for each clustering level. It is highest when all individuals of a species are found in a single group of sites and when the species occurs in all sites of that group.

Repeat photographic (repeat photo point) monitoring is being used to evaluate change in vegetation and soils at two locations where trailhead parking areas will be expanded; one on the west side of the Rio Grande at Central Ave., and one on the east side of the Rio Grande at Central Ave. Repeat photo monitoring also is being used to evaluate change in vegetation and soils from a series of unofficial side trails that are proposed to be closed and restored. A rapid assessment change scoring procedure will be used to compare the scenes of photographs taken at each photo point to score change in vegetation and soil features as positive, negative or neutral relative to visible impacts to vegetation and soil caused by construction and/or visitors over time.

All initial baseline photo point photographs were taken in August, 2014. Time series comparisons of repeat photos and analysis of those photographs will first be conducted in 2105 after the second set of post-treatment repeat photographs are taken.

In addition to this experimental monitoring, data from existing BEMP study sites (Eichhorst et al. 2012) and from Hawks Aloft bird transects in the area also will be used for comparison of long-term trends in vegetation and birds of the greater bosque of Albuquerque Subreach of the Rio Grande to provide larger-scale context for this particular monitoring study.

7 ENVIRONMENTAL MONITORING RESULTS

The results of 2014 baseline pre-treatment environmental monitoring data for birds, vegetation, soil surfaces and initial photo point photographs are presented below. Purposes, methods, and analytical approaches for the environmental monitoring of soils, vegetation and birds were mentioned above. Results from the baseline monitoring data collected in 2014 are presented here to document the pre-treatment (main trail enhancements, side trail closures) baseline conditions for the comparisons to future post-treatment monitoring data.

7.1 SOIL AND VEGETATION MONITORING RESULTS

7.1.1 SOIL SURFACE FEATURES

Both parametric t-tests for differences in mean values, and non-parametric Wilcoxon tests for differences in rank-sum values revealed that there were no significant differences in the percent ground cover of 1) bare soil, 2) biotic soil surface crusts, 3) organic leaf litter, 4) dead, downed woody material, and 5) human caused soil disturbance between control and treatment BEMP plots. Figure 7.1, Figure 7.2, Figure 7.3, Figure 7.4 and Figure 7.5 respectively, display the means and associated standard error bars for each of those variables. Note that only very small amounts of dead, downed woody material were encountered so as not to show in Figure 7.4, and no human caused soil disturbance was found so as not to provide data for Figure 7.5. No human caused soil surface disturbance was detected from the entire BEMP plot measurements (in addition to the line-point-intercept measurements) either. The measurements of soil surface disturbance are based on one-time per year measurements, and probably would include minor surface disturbances made within a week or two, and major disturbances made within months.

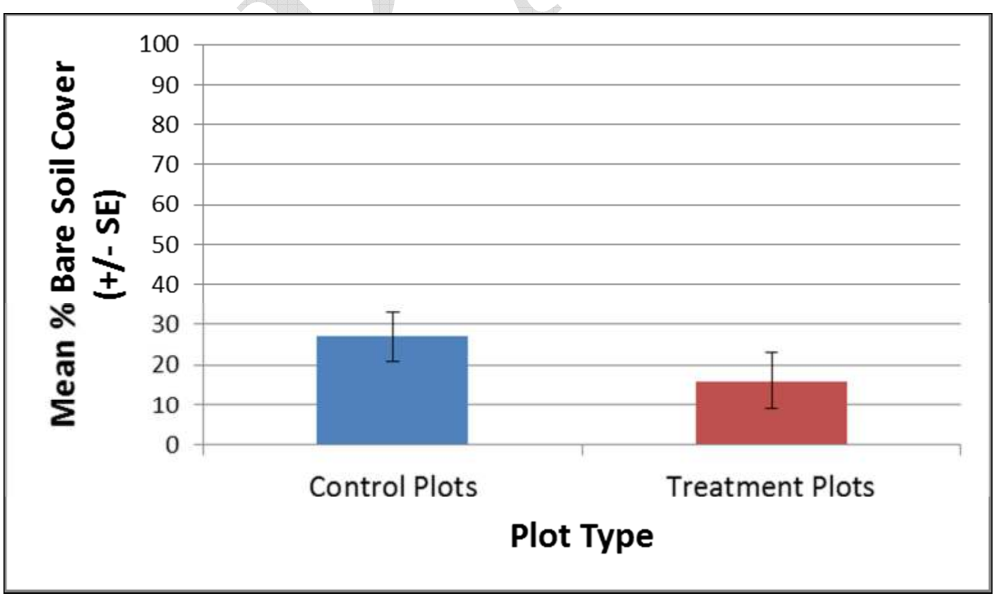


Figure 7.1. Mean percent canopy cover of bare soil measured from control and treatment vegetation and soils plots.

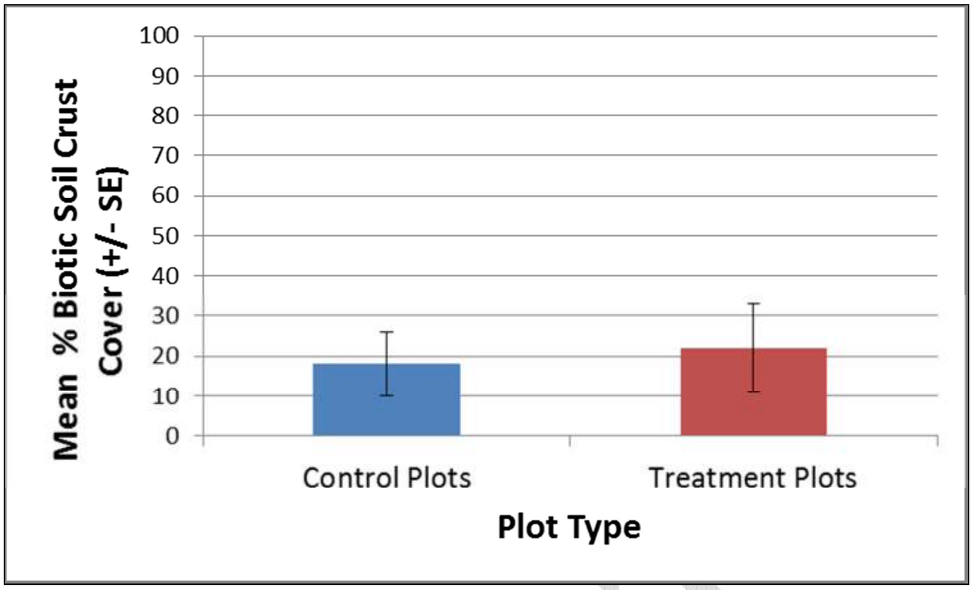


Figure 7.2. Mean percent canopy cover of soil surface biotic crust measured from control and treatment vegetation and soils plots.

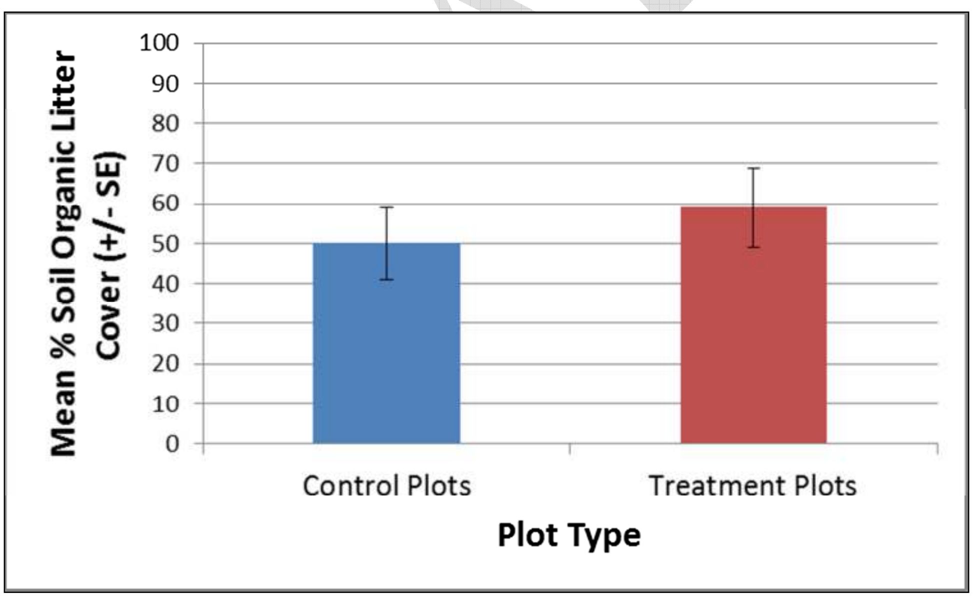


Figure 7.3. Mean percent canopy cover of soil surface organic litter measured from control and treatment vegetation and soils plots.

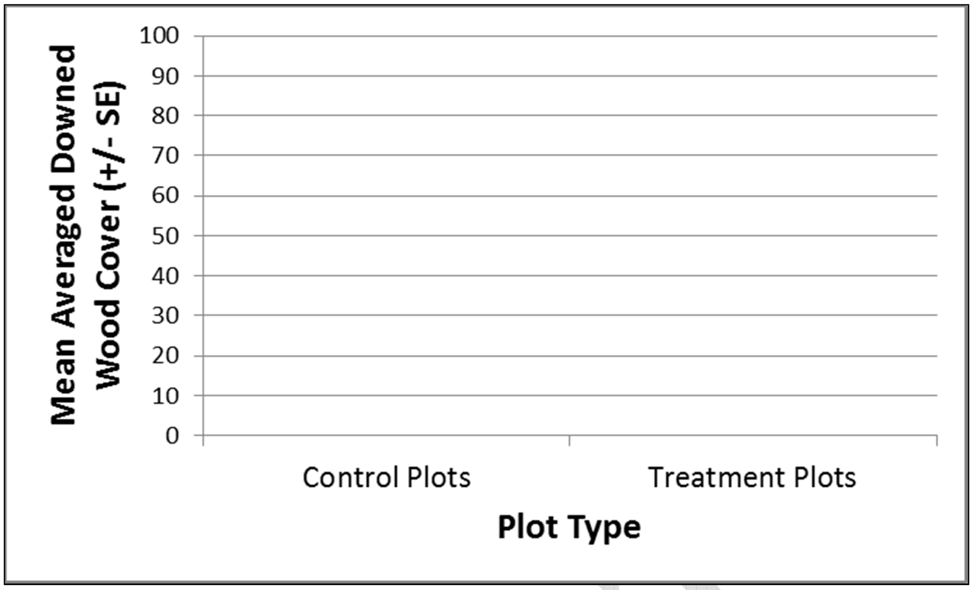


Figure 7.4. Mean percent canopy cover of soil surface dead, downed woody material measured from control and treatment vegetation and soils plots.

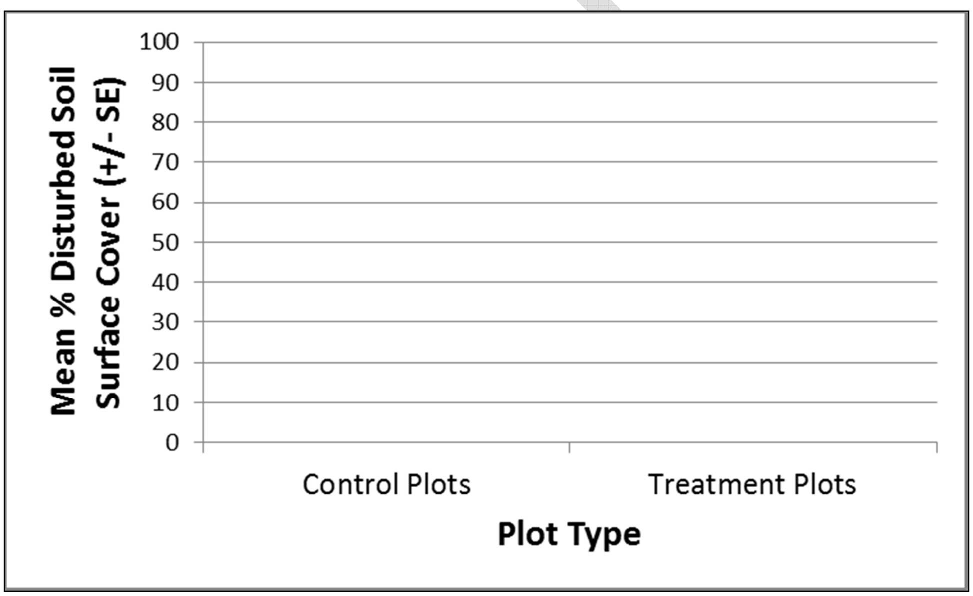


Figure 7.5. Mean percent canopy cover of human-caused soil surface disturbance measured from control and treatment vegetation and soils plots.

A list of all plant species found across the 20 vegetation and soils BEMP plots is presented in Table 7.1. All plant common names, scientific names, codes, growth form and native status follow the USDA Plants Database, 2014. Multivariate cluster analysis of all 20 control and treatment vegetation and soils plots revealed no groupings of control or treatment plots, indicating that there were no patterns of particular species associated with control or treatment locations (Figure 7.6). Results of MRPP analysis revealed that there were no significant differences in the plant species compositions between the 10 control and 10 treatment vegetation and soils plots (Table 7.2), and ISA revealed that no plant species were significantly associated with, or significant indicators of either control or treatment plots (Table 7.3).

Table 7.1. List of All Plant Species Found on all 20 Vegetation and Soils BEMP Plots

Common Name	Scientific Name	Family	Code	Growth Form	Native Status
Alkali sacaton	*Sporobolus airoides* (Torr.) Torr.	Poaceae	SPAI	Grass	Native
Alkali swainsonpea	*Sphaerophysa salsula* (Pall.) DC.	Fabaceae	SPSA3	Forb	Native
Annual ragweed	*Ambrosia artemisiifolia* L.	Asteraceae	AMAR2	Forb	Native
Blue grama	*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths	Poaceae	BOGR2	Grass	Native
Broom snakeweed	*Gutierrezia sarothrae* (Pursh) Britton & Rusby	Asteraceae	GUSA	Shrub	Native
Burningbush	*Bassia scoparia* (L.) A.J. Scott	Chenopodiaceae	BASC5	Forb	Exotic
Copper globemallow	*Sphaeralcea angustifolia* (Cav.) G. Don	Malvaceae	SPAN3	Forb	Native
False indigo bush	*Amorpha fruticosa* L.	Fabaceae	AMFR	Shrub	Native
Five-stamen tamarisk	*Tamarix chinensis* Lour.	Tamaricaceae	TACH2	Tree	Exotic
Flaxflowered ipomopsis	*Ipomopsis longiflora* (Torr.) V.E. Grant	Polemoniaceae	IPLO2	Forb	Native
Fourwing saltbush	*Atriplex canescens* (Pursh) Nutt.	Chenopodiaceae	ATCA2	Shrub	Native
Giant dropseed	*Sporobolus giganteus* Nash	Poaceae	SPGI	Grass	Native
Hoary tansyaster	*Machaeranthera canescens* (Pursh) A. Gray	Asteraceae	MACA2	Forb	Native
Indian ricegrass	*Achnatherum hymenoides* (Roem. & Schult.) Barkworth	Poaceae	ACHY	Grass	Native
James' galleta	*Pleuraphis jamesii* Torr.	Poaceae	PLJA	Grass	Native
Narrowleaf willow	*Salix exigua* Nutt.	Salicaceae	SAEX	Shrub	Native
Prickly Russian thistle	*Salsola tragus* L.	Chenopodiaceae	SATR12	Forb	Exotic
Purple threeawn	*Aristida purpurea* Nutt.	Poaceae	ARPU9	Grass	Native
Riddell's ragwort	*Senecio riddellii* Torr. & A. Gray	Asteraceae	SERI2	Forb	Native
Rio Grande cottonwood	*Populus wislizeni* (S. Watson) Sarg.	Salicaceae	PODEW	Tree	Native
Rock clematis	*Clematis columbiana* (Nutt.) Torr. & A. Gray	Ranunculaceae	CLCO2	Vine	Native
Russian olive	Elaeagnus angustifolia L.	Elaeagnaceae	ELAN	Tree	Exotic
Sand dropseed	*Sporobolus cryptandrus* (Torr.) A. Gray	Poaceae	SPCR	Grass	Native
Siberian elm	*Ulmus pumila* L.	Ulmaceae	ULPU	Tree	Exotic
Sixweeks grama	*Bouteloua barbata* Lag.	Poaceae	BOBA2	Grass	Native
Squirreltail	*Elymus elymoides* (Raf.) Swezey	Poaceae	ELEL5	Grass	Native
Sweetclover	*Melilotus officinalis* (L.) Lam.	Fabaceae	MEOF	Forb	Exotic
Switchgrass	*Panicum virgatum* L.	Poaceae	PAVI5	Grass	Native
Texas sleepydaisy	*Xanthisma texanum* DC.	Asteraceae	XATE	Forb	Native
Thymeleaf sandmat	*Chamaesyce serpyllifolia* (Pers.) Small	Euphorbiaceae	CHSE6	Forb	Native
Touristplant	*Dimorphocarpa wislizeni* (Engelm.) Rollins	Brassicaceae	DIWI2	Forb	Native
Tree of heaven	*Ailanthus altissima* (Mill.) Swingle	Simaroubaceae	AIAL	Tree	Exotic
Velvetweed	*Gaura parviflora Douglas* ex Lehm.	Onagraceae	GAPA6	Forb	Native
Vine mesquite	*Panicum obtusum* Kunth	Poaceae	PAOB	Grass	Native
White clover	*Trifolium repens* L.	Fabaceae	TRTE	Forb	Exotic
White prairie clover	*Dalea candida* Michx. ex Willd.	Fabaceae	DACA7	Forb	Native

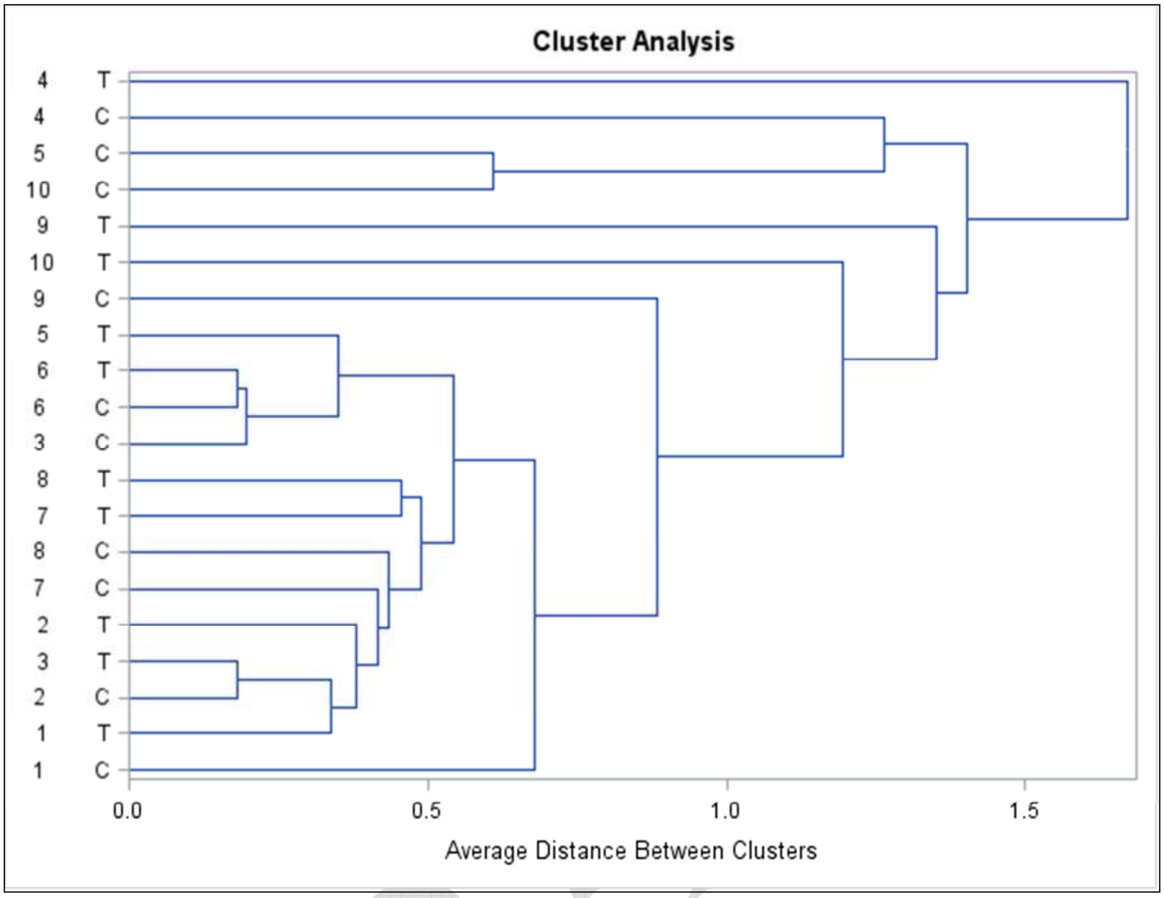


Figure 7.6. Dendrogram resulting from cluster analysis of all 20 control and treatment vegetation and soils plots based on similarities in species composition. Numeric values on the vertical axis represent site locations, C and T values represent control or treatment plots. Similarity distance is Euclidean distance.

Table 7.2. Results of Multi-Response Permutation Procedures Testing for Differences in Plant Species Compositions Between All Control and Treatment Plots.

Observed Delta-value	Expected Delta-value	Probability of a smaller or equal Delta
31.7	31.5	P=0.61

Table 7.3. Observed Species Indicator Analysis Value of Plant Species Measured From All Control and Treatment Vegetation Plots.

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
Burning bush (kochia)	35.7	37.6	10.54	0.5037
Tourist plant	15.7	21.4	8.78	0.8700
Sand dropseed	18.0	28.5	9.39	1.0000
Hoary tansyaster	12.5	16.9	6.96	1.0000
Sweetclover	2.5	19.7	8.46	0.8598
Prickly Russian thistle	50.9	42.3	10.14	0.2108
Giant dropseed	10.0	10.0	0.14	1.0000
White prairie clover	10.0	10.0	0.14	1.0000

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
Annual ragweed	10.0	10.0	0.14	1.0000
Flaxflowered ipomopsis	30.4	23.2	9.12	0.2450
Riddell's ragwor	5.0	12.0	7.49	1.0000
Copper globmallow	12.0	19.8	8.38	1.0000
White clover	10.0	10.0	0.14	1.0000
Velvet weed	10.0	10.0	0.14	1.0000
Switchgrass	10.0	10.0	0.14	1.0000
Thymeleaf sandmat	7.5	13.5	6.25	1.0000
Blue grama	20.0	12.2	7.50	0.4813
Jame's galleta	10.0	10.0	0.14	1.0000
Purple threeawn	6.7	12.9	6.66	1.0000
Squirreltail	10.0	10.0	0.14	1.0000
Broom snakeweed	10.0	10.0	0.14	1.0000
Alkali sacaton	10.0	10.0	0.14	1.0000
Rock clematis	10.0	10.0	0.14	1.0000
Sixweeks grama	8.0	13.5	5.98	1.0000
Texas sleepydaisy	10.0	10.0	0.14	1.0000
Alkali swainsonpea	10.0	10.0	0.14	1.0000
Indian ricegrass	10.0	10.0	0.14	1.0000

[1] proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
* Significant p-value; (*) marginally significant value

WOODY VEGETATION

The dominant trees across all 20 vegetation and soils plots were Rio Grande cottonwood, saltcedar, Russian Olive, and Siberian elm. The total counts and heights of all woody trees and shrubs by three size classes were similar across control and treatment vegetation and soils BEMP plots (Figure 7.7 and Figure 7.8).

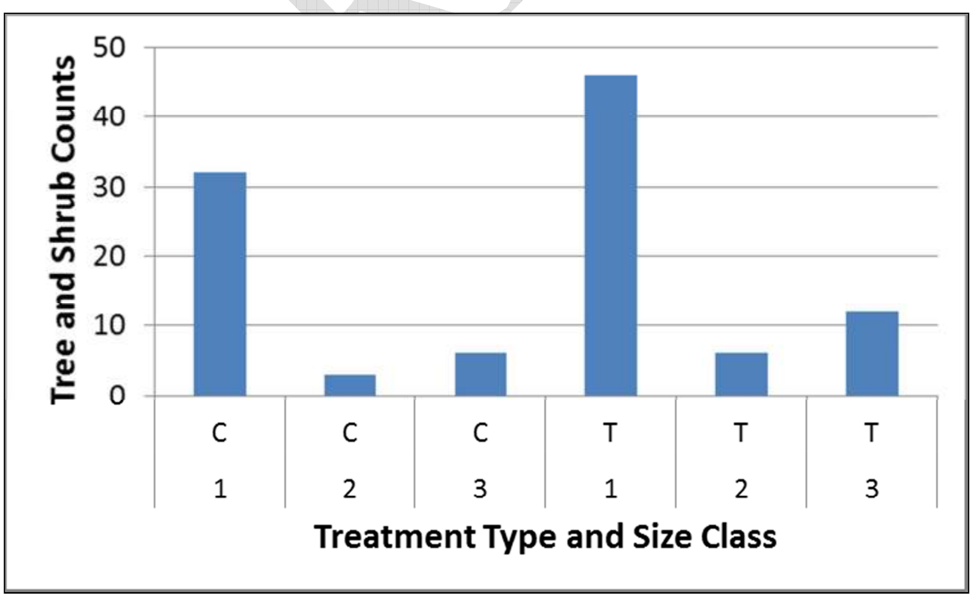


Figure 7.7. Sum counts of woody trees and shrubs across all control and treatment vegetation plots by size class. Size class DBH: 1) <10 cm, 2) 10-20 cm, 3) >20 cm.

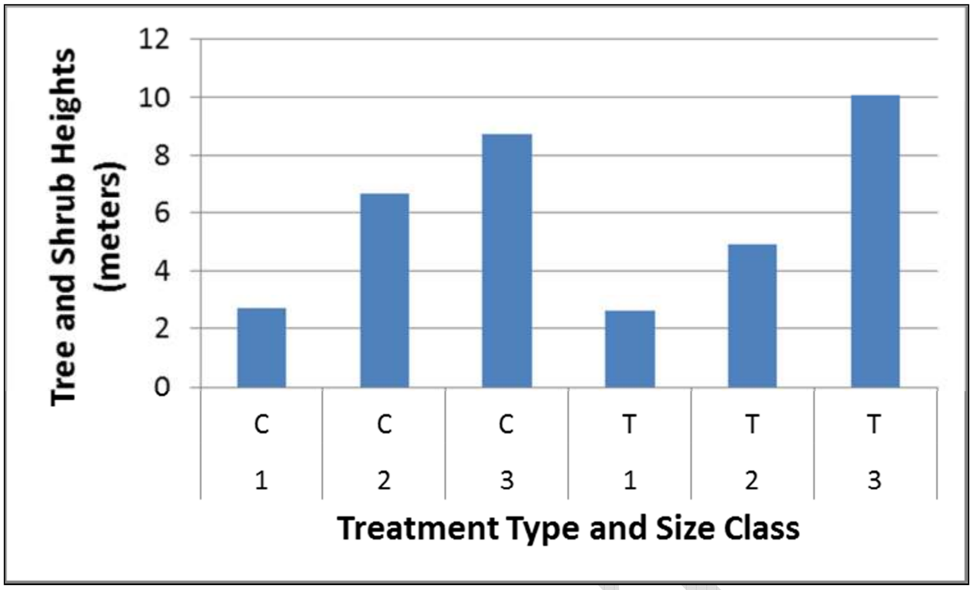


Figure 7.8. Average heights of woody trees and shrubs across all control and treatment vegetation plots by size class. Size class DBH: 1) <10 cm, 2) 10-20 cm, 3) >20 cm.

HERBACEOUS VEGETATION

Both parametric t-tests and non-parametric Wilcoxon rank-sum tests revealed no significant differences between the canopy cover of 1) native herbaceous vegetation and 2) exotic herbaceous vegetation between the control and treatment plots. Figure 7.9 and Figure 7.10 display the mean cover values and standard error bars respectively for those variables. The figures also show that canopy cover of native plant species and exotic plant species were approximately the same across control and treatment BEMP plots.

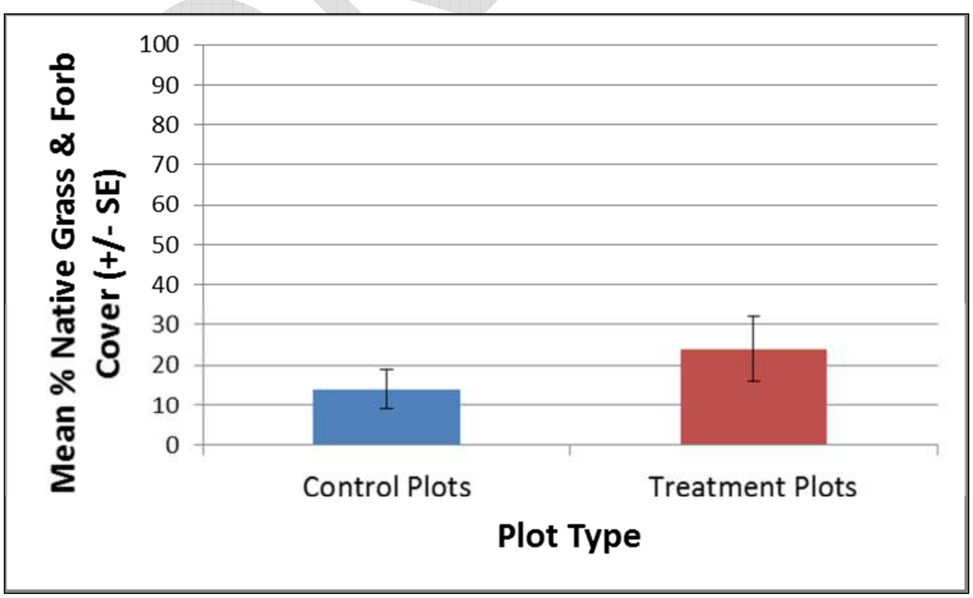


Figure 7.9. Mean percent canopy cover of native herbaceous vegetation measured from control and treatment vegetation and soils plots.

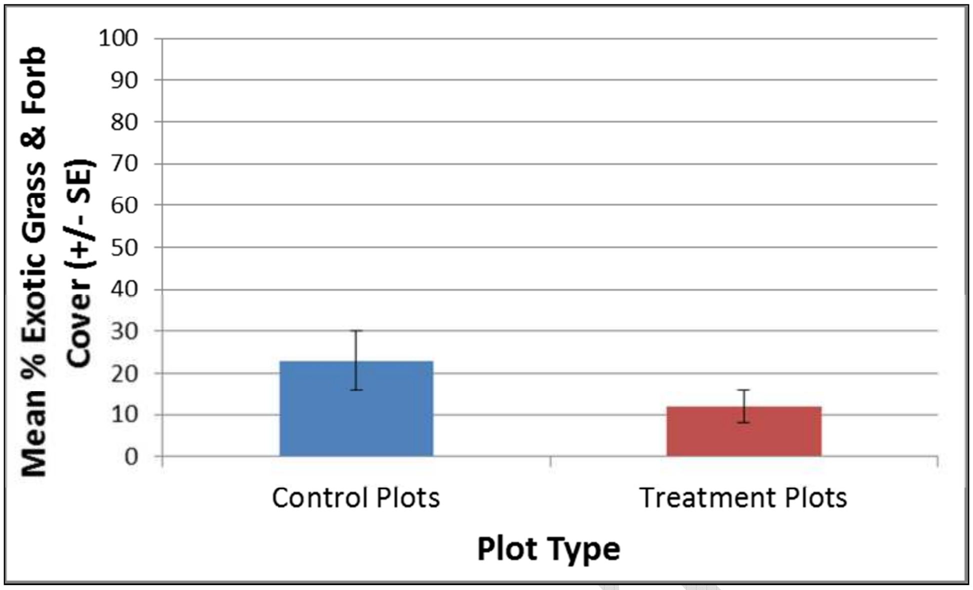
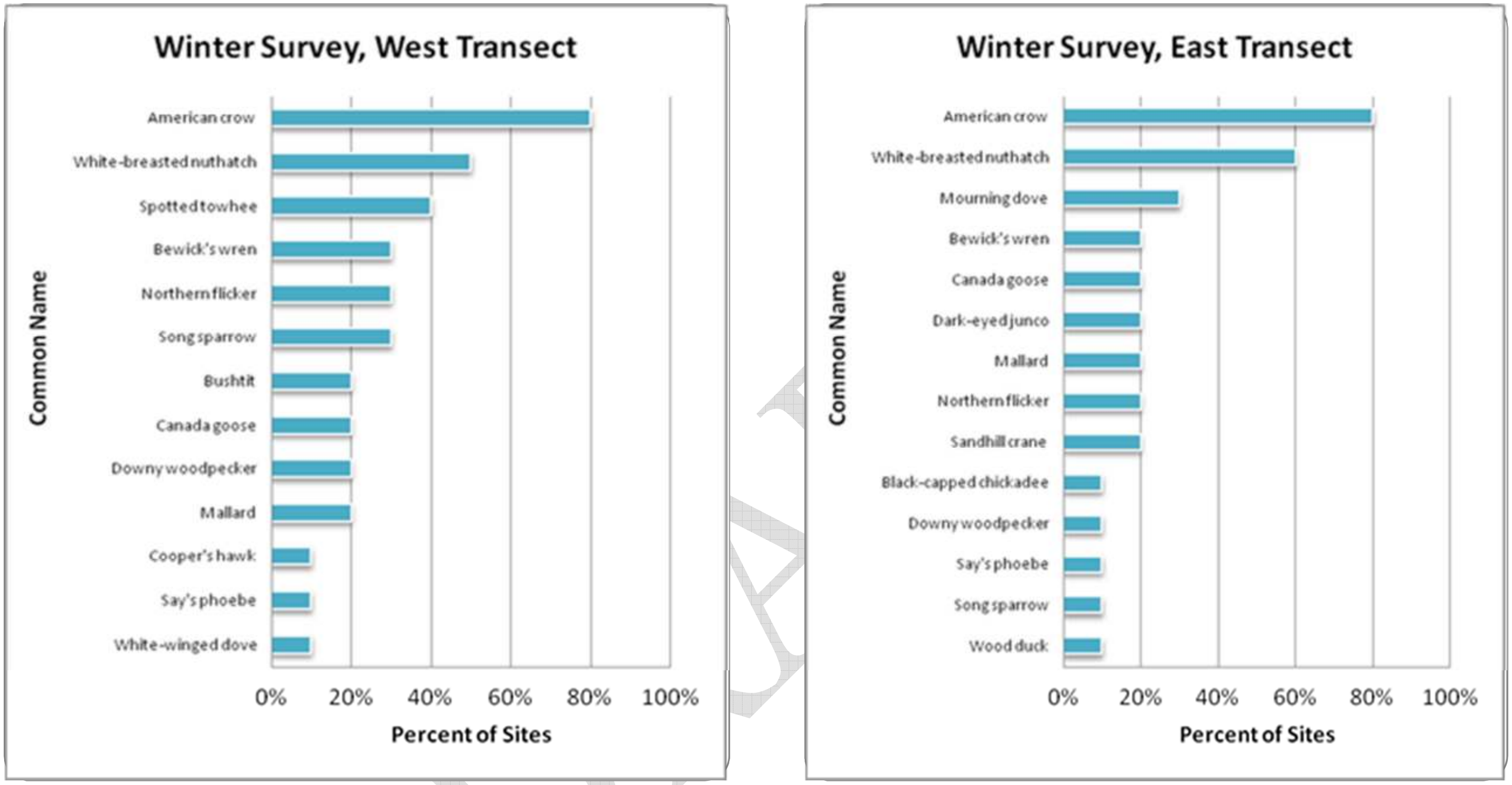


Figure 7.10. Mean percent canopy cover of exotic herbaceous vegetation measured from control and treatment vegetation and soils plots.

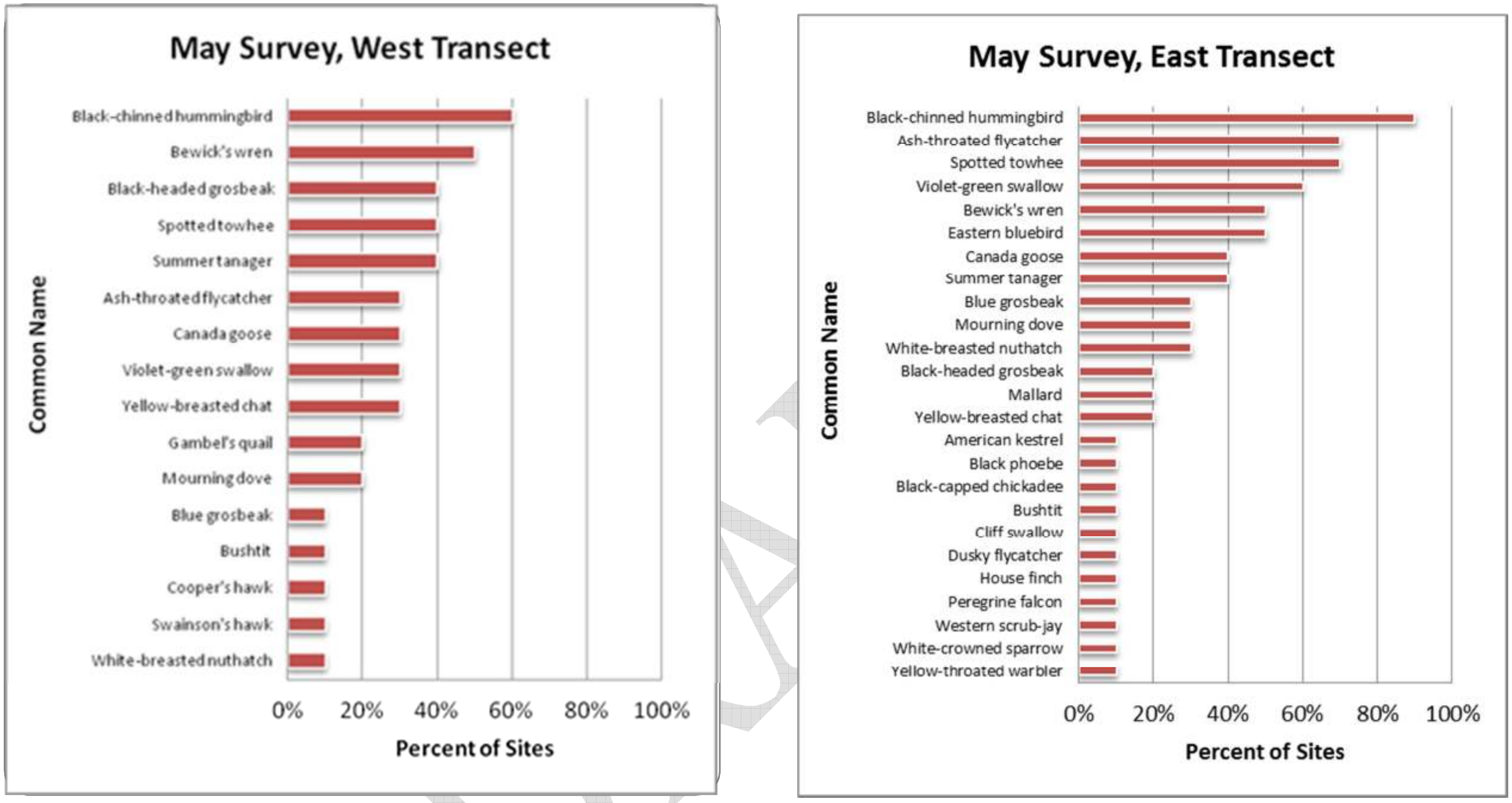
7.2 Bird Community Monitoring Results

In February, the American crow and the white-breasted nuthatch were the species most frequently detected both on the west and east sides (Figure 7.11). In May, the black-chinned hummingbird was associated with the highest detection frequency on the east and west sides Figure 7.12). In June, that same species was among the two species most often recorded along both sides of the river (Figure 7.13). In July, the black-chinned hummingbird, yellow-breasted chat, and ash-throated flycatcher were the species most frequently detected both on the west and east sides (Figure 7.14).



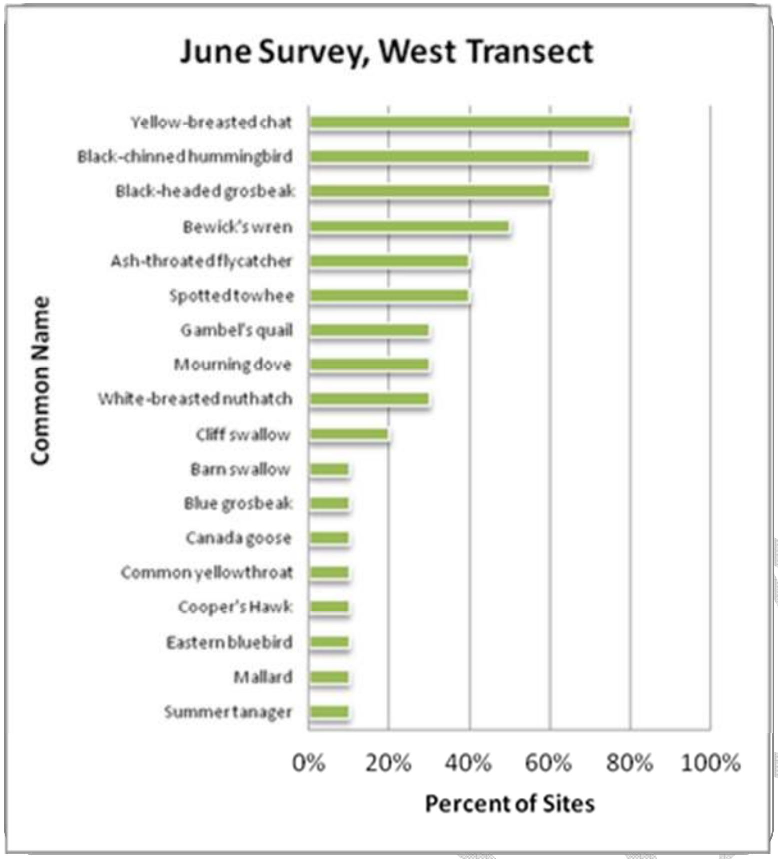
(a) (b)

Figure 7.11. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. February 2014 surveys.

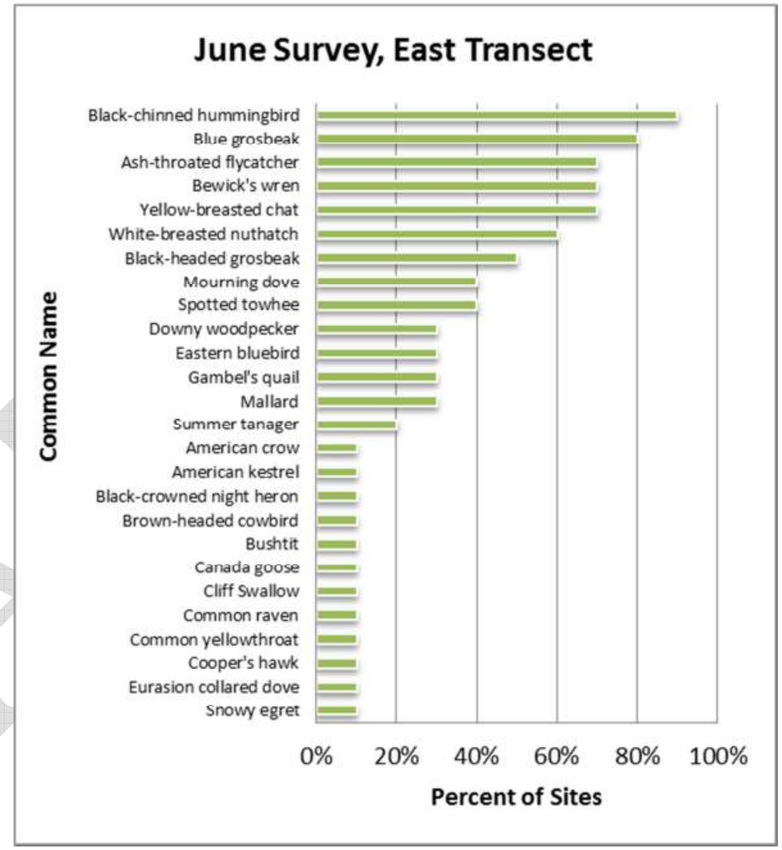


(a) (b)

Figure 7.12. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. May 2014 surveys.

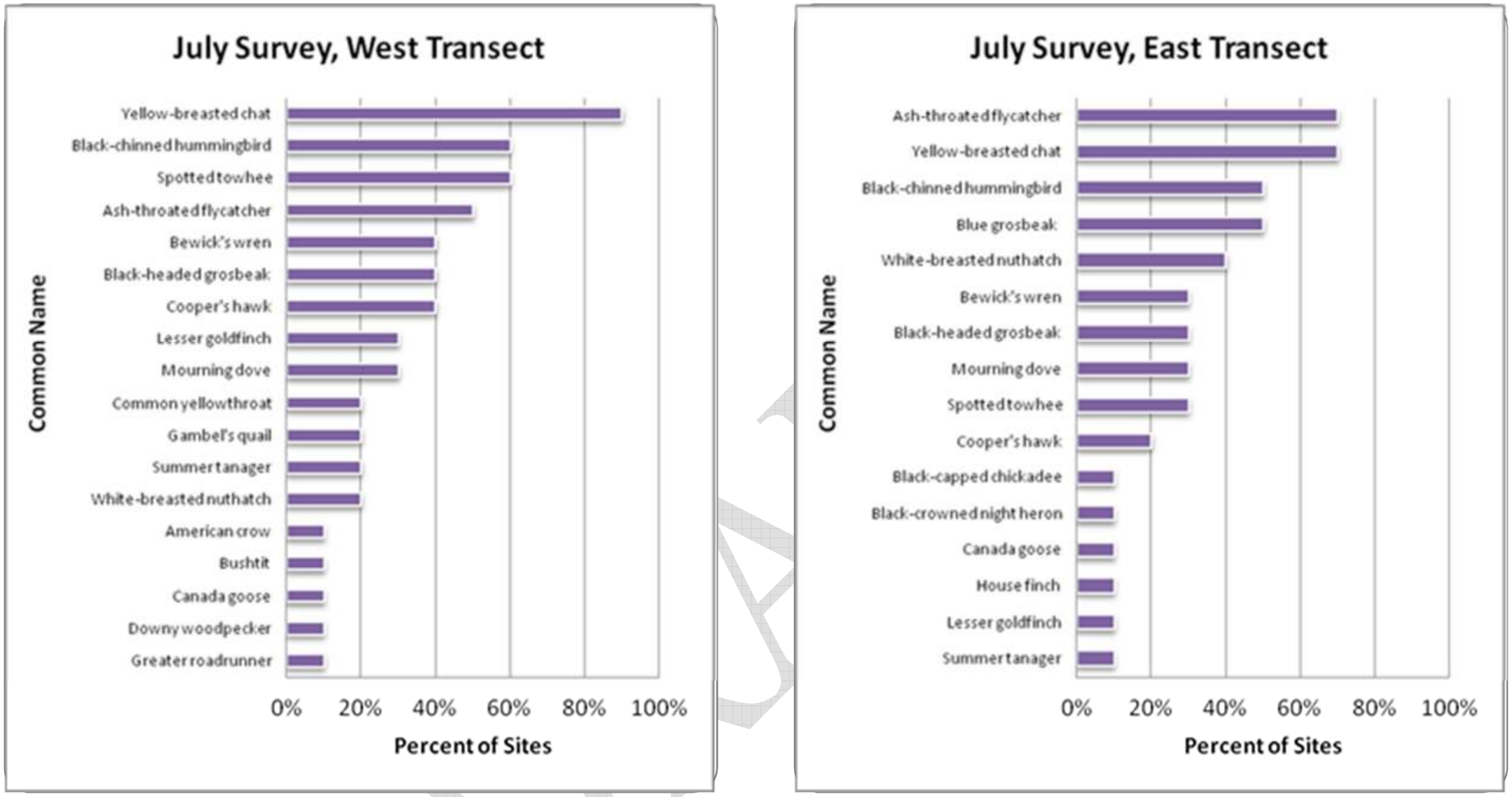


(a)



(b)

Figure 7.13. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. June 2014 surveys.



(a) (b)

Figure 7.14. Species Detection Frequency, expressed as the Percentage of Sites where a Species was Recorded. July 2014 surveys.

Cluster analysis dendrograms examining the similarities of all transects in terms of their associated sets of species are presented in Figure 7.15-Figure 7.18. No trend existed toward clusters composed of just east transects (T1-T10) or west transects (C1-C10).

The results of the MRPP are presented in Table 7.4. None of the results were statistically significant, indicating that east transects were no more similar among themselves than expected by chance alone.

Table 7.4. Results of Multi-Response Permutation Procedures.

	Observed Delta-value	Expected Delta-value	Probability of a smaller or equal Delta
February surveys	7.0543980	6.9646777	0.82499923
May surveys	9.4524790	9.4767919	0.30748329
June surveys	6.8562460	6.8943634	0.19245034
July surveys	3.4744209	3.5170237	0.11152725

Table 7.5-Table 7.8 provide the results of Species Indicator Analysis (SIA) on birds over the four sampling periods for specific associations to treatments. A few species had observed indicator values significantly or marginally significantly higher than expected by chance alone: the spotted towhee in February, the eastern bluebird in May, the blue grosbeak in July, and the yellow-breasted chat both in June and July.

Table 7.5. Observed Species Indicator Analysis Value of Bird Species Detected during February Surveys and Results of Monte Carlo Procedure

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
American crow	46.5	50.0	7.74	0.6675
Bushtit	20.0	12.2	7.50	0.4815
Downy woodpecker	13.3	16.6	6.65	1.0000
White-breasted nuthatch	24.6	29.3	9.68	0.7149
White-crowned sparrow	24.5	23.3	8.90	0.5113
Northern flicker	18.0	22.8	7.91	1.0000
Bewick's wren	15.0	22.8	8.27	1.0000
Song sparrow	24.0	19.6	8.26	0.4497
Mallard	14.3	21.1	8.79	0.8744
Say's phoebe	5.0	12.0	7.48	1.0000
Spotted towhee	40.0	19.6	8.32	0.0856[(*)]
White-winged dove	10.0	10.0	0.14	1.0000
Cooper's hawk	10.0	10.0	0.14	1.0000
Canada goose	13.3	23.0	8.98	0.9266
Hermit thrush	10.0	10.0	0.14	1.0000
Ring-necked pheasant	10.0	10.0	0.14	1.0000
Dark-eyed junco	20.0	13.0	6.66	0.4745
Mourning dove	30.0	16.9	6.83	0.2134
Sandhill crane	20.0	13.7	6.00	0.4741
Wood duck	10.0	10.0	0.14	1.0000
Black-crowned night-heron	10.0	10.0	0.14	1.0000

[1] proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
* Significant p-value; [(*)] marginally significant value

Table 7.6. Observed Species Indicator Analysis Value of Bird Species Detected during May Surveys and Results of Monte Carlo Procedure

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
Bushtit	5.0	12.0	7.49	1.0000
White-breasted nuthatch	22.5	18.9	8.85	0.5895
White-crowned sparrow	10.0	10.0	0.14	1.0000
Northern flicker	10.0	10.0	0.14	1.0000
Bewick's wren	27.3	35.6	8.66	1.0000
Mallard	20.0	12.1	7.49	0.4723
Spotted towhee	35.0	40.5	8.43	0.6967
Cooper's hawk	20.0	12.1	7.49	0.4729
Canada goose	25.3	31.4	9.58	0.7445
Mourning dove	18.7	25.1	9.19	0.7708
Black-crowned chickadee	10.0	10.0	0.14	1.0000
Ash-throated flycatcher	46.7	35.5	9.14	0.1702
Common yellowthroat	10.0	10.0	0.14	1.0000
Summer tanager	30.8	33.6	9.18	0.6017
Yellow-breasted chat	26.7	24.4	9.21	0.6233
Black-chinned hummingbird	48.9	46.9	7.42	0.3253
Black-headed grosbeak	26.7	24.7	9.58	0.6249
Lesser goldfinch	10.0	10.0	0.14	1.0000
Gambel's quail	20.0	12.9	6.66	0.4687
Black phoebe	10.0	10.0	0.14	1.0000
Red-winged blackbird	10.0	10.0	0.14	1.0000
Blue grosbeak	24.0	19.5	8.23	0.4455
House finch	10.0	10.0	0.14	1.0000
Cliff swallow	10.0	10.0	0.14	1.0000
Eastern bluebird	50.0	23.5	9.54	0.0396*
Common raven	10.0	10.0	0.14	1.0000
Violet-green swallow	35.4	36.3	9.39	0.4817
Great blue heron	10.0	10.0	0.14	1.0000
Swainson's hawk	10.0	10.0	0.14	1.0000
Western scrub-jay	10.0	10.0	0.14	1.0000
Yellow warbler	10.0	10.0	0.14	1.0000
American kestrel	10.0	10.0	0.14	1.0000
Peregrine falcon	10.0	10.0	0.14	1.0000
Dusky flycatcher	10.0	10.0	0.14	1.0000

[1] proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
* Significant p-value; (*) marginally significant value

Table 7.7. Observed Species Indicator Analysis Value of Bird Species Detected during June Surveys and Results of Monte Carlo Procedure

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
American crow	10.0	10.0	0.14	1.0000
Bushtit	10.0	10.0	0.14	1.0000
Downy woodpecker	30.0	16.9	7.19	0.2158
White-breasted nuthatch	40.0	33.6	8.45	0.3827
Bewick's wren	35.0	42.6	7.88	1.0000
Mallard	25.0	19.4	8.75	0.3439
Say's phoebe	10.0	10.0	0.14	1.0000

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
Spotted towhee	10.0	10.0	0.14	1.0000
Cooper's hawk	10.0	10.0	0.14	1.0000
Canada goose	10.0	10.0	0.14	1.0000
Ring-necked pheasant	10.0	10.0	0.14	1.0000
Mourning dove	22.2	28.3	8.84	0.9108
Ash-throated flycatcher	46.7	38.0	8.60	0.2242
Common yellowthroat	10.0	10.0	0.14	1.0000
Summer tanager	10.0	10.0	0.14	1.0000
Yellow-breasted chat	63.5	49.5	7.49	0.0630(*)
Black-chinned hummingbird	40.6	49.3	7.28	1.0000
Black-headed grosbeak	42.0	40.6	8.48	0.4467
Gambel's quail	15.0	25.0	9.01	1.0000
Brown-headed cowbird	5.00	11.9	7.48	1.0000
Red-winged blackbird	10.0	10.0	0.14	1.0000
Blue grosbeak	48.9	37.2	9.71	0.1250
Black-crowned night-heron	10.0	10.0	0.14	1.0000
Cliff swallow	17.1	17.1	7.55	0.4913
Barn swallow	20.0	13.0	6.66	0.4727
Eastern bluebird	26.3	19.3	8.65	0.3297
Common raven	10.0	10.0	0.14	1.0000
Snowy egret	10.0	10.0	0.14	1.0000
American kestrel	10.0	10.0	0.14	1.0000
Eurasian collared-dove	10.0	10.0	0.14	1.0000

[1] proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
* Significant p-value; (*) marginally significant value

Table 7.8. Observed Species Indicator Analysis Value of Bird Species Detected during July Surveys and Results of Monte Carlo Procedure

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
American crow	10.0	10.0	0.14	1.0000
Bushtit	10.0	10.0	0.14	1.0000
Downy woodpecker	10.0	10.0	0.14	1.0000
White-breasted nuthatch	26.7	24.6	9.24	0.6325
Bewick's wren	22.9	28.2	8.22	1.0000
Spotted towhee	50.9	35.7	8.72	0.1266
Cooper's hawk	26.7	24.8	9.46	0.6329
Canada goose	5.0	12.1	7.49	1.0000
Ring-necked pheasant	10.0	10.0	0.14	1.0000
Mourning dove	17.1	25.6	9.02	1.0000
Black-crowned chickadee	10.0	10.0	0.14	1.0000
Ash-throated flycatcher	43.7	40.3	8.84	0.3757
Common yellowthroat	30.0	16.8	7.00	0.2034
Summer tanager	10.0	16.9	7.14	1.0000
Yellow-breasted chat	66.7	50.5	6.06	0.0286*
Black-chinned hummingbird	36.8	40.3	8.40	0.6223
Black-headed grosbeak	33.3	30.6	8.74	0.4651
Lesser goldfinch	22.5	18.7	8.86	0.5731
Gambel's quail	20.0	12.3	7.50	0.4875
Greater roadrunner	10.0	10.0	0.14	1.0000

Species	Observed Indicator Value (IV)	IV from randomized groups		p-value[1]
		Mean	St. Dev.	
Brown-headed cowbird	10.0	10.0	0.14	1.0000
Black phoebe	10.0	10.0	0.14	1.0000
Red-winged blackbird	10.0	10.0	0.14	1.0000
Western wood-pewee	10.0	10.0	0.14	1.0000
Blue grosbeak	50.0	22.7	8.02	0.0356*
Black-crowned night-heron	10.0	10.0	0.14	1.0000
House finch	10.0	10.0	0.14	1.0000

[1] proportion of randomized trials with indicator value equal to or exceeding the observed indicator value.
p = (1 + number of runs >= observed)/(1 + number of randomized runs)
* Significant p-value; (*) marginally significant value

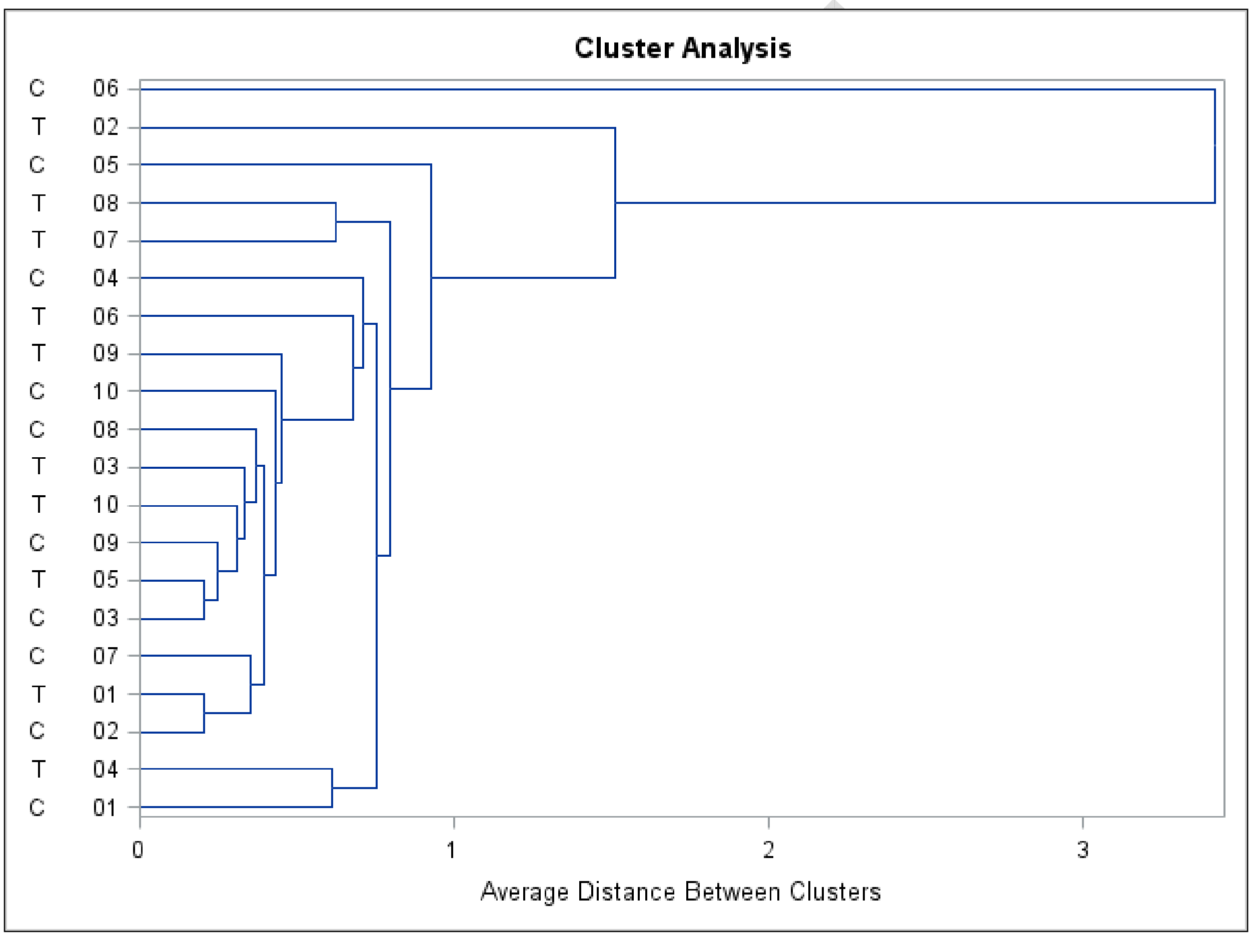


Figure 7.15. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during February 2014 surveys.

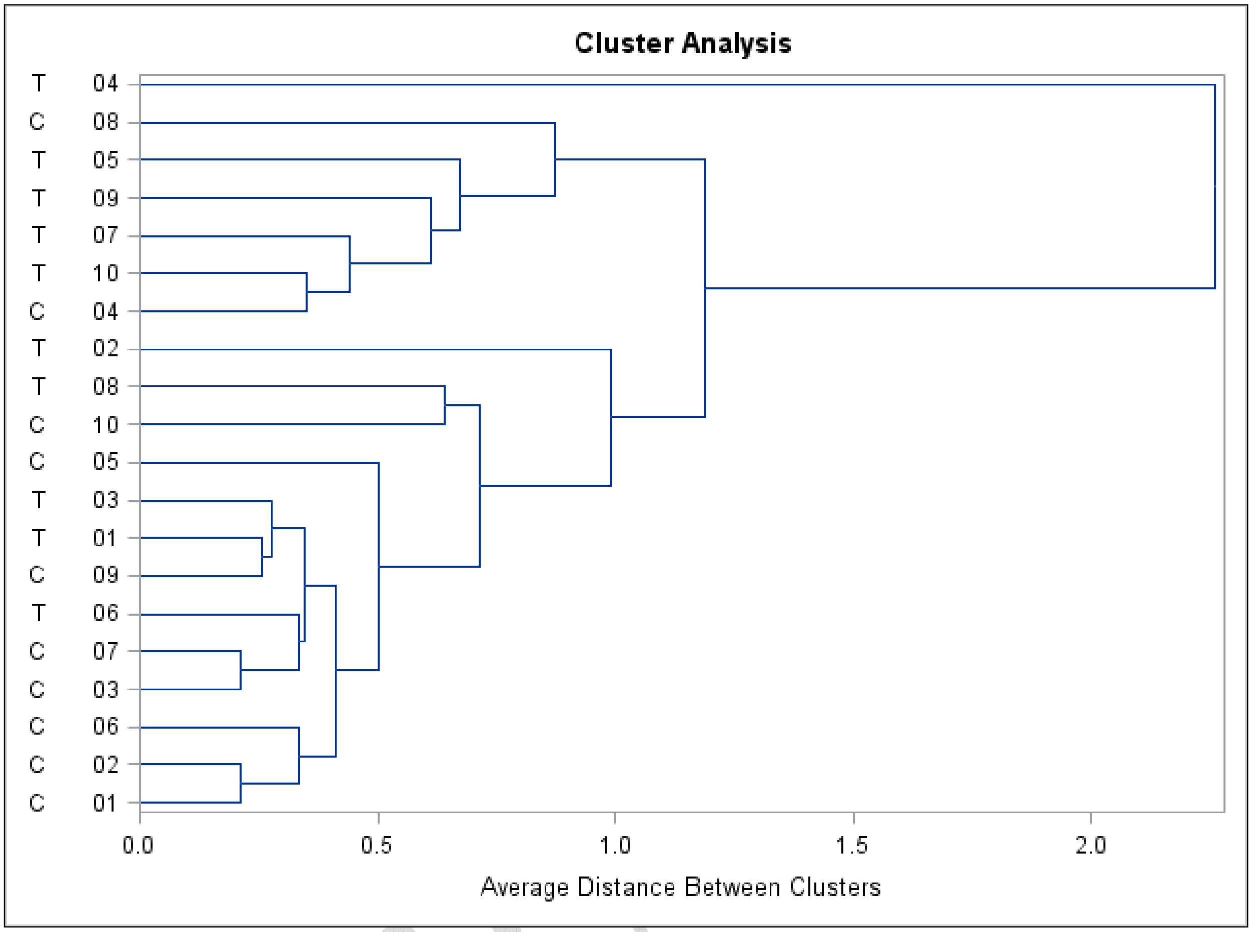


Figure 7.16. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during July 2014 surveys.

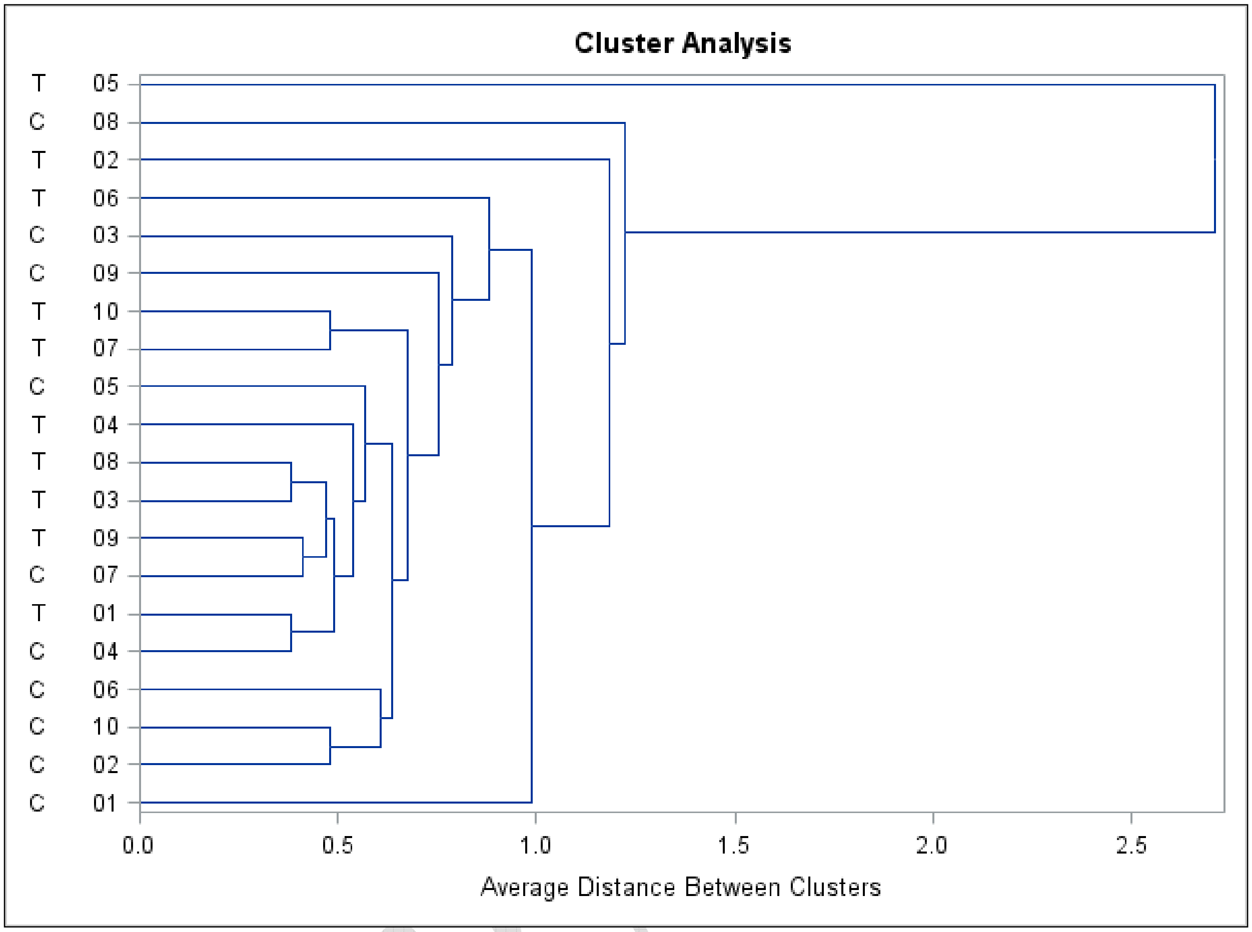


Figure 7.17. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during June 2014 surveys.

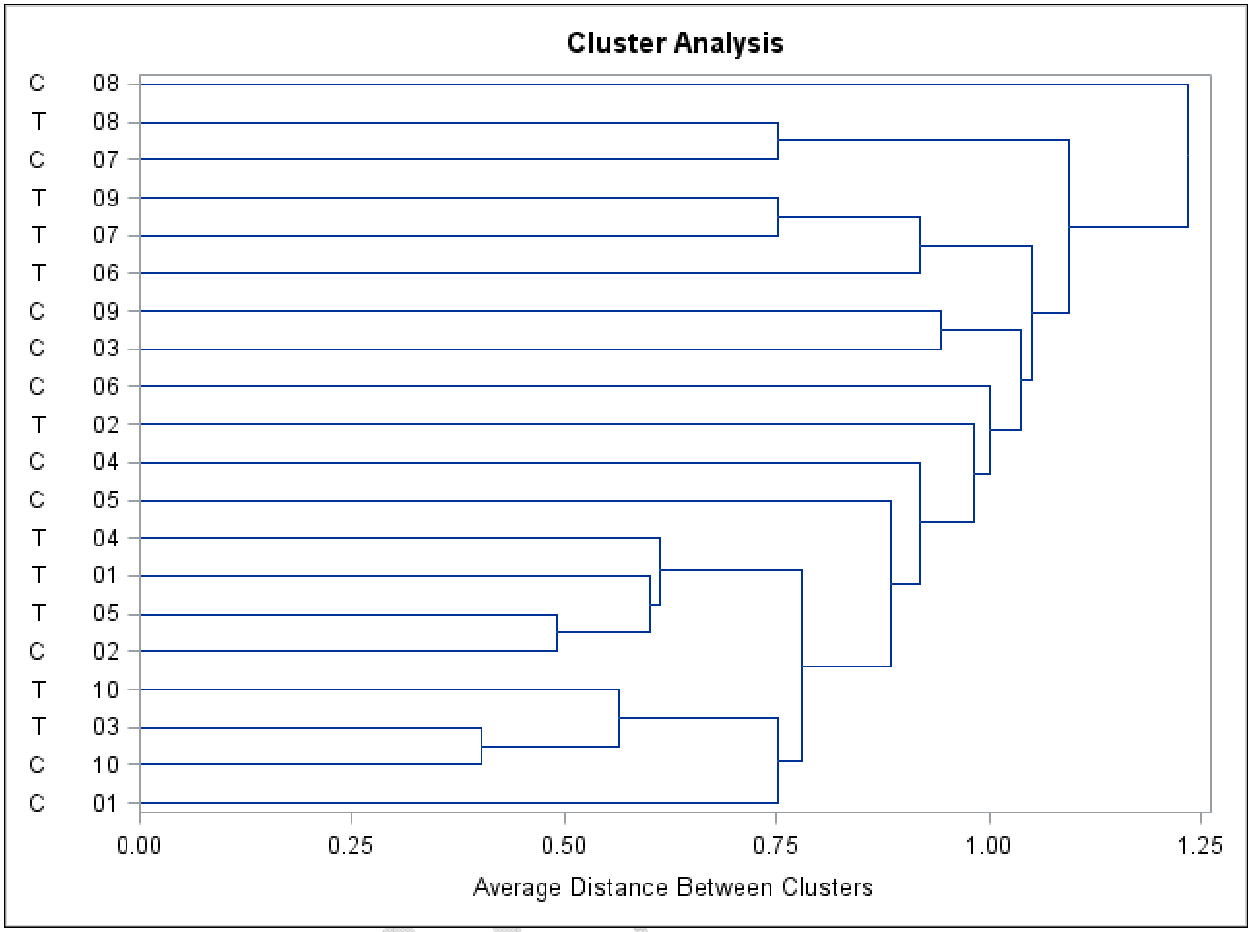


Figure 7.18. Dendrogram representing similarities among transects based on species relative abundance and relative frequency of occurrence during July 2014 surveys.

Overall findings from the baseline bird survey data reveal that the species compositions of the control and treatment transects were not significantly different in 2014.

7.3 Repeat Photo Monitoring Initial Baseline Photographs

Figure 1.2, Figure 1.3 and Figure 1.4 above show the locations of unofficial side trails that the City proposes to close and restore (to non-trail environments), and locations of repeat photo points where the initial set of photographs were taken in August, 2014. Analysis of those photographs will not be conducted until the next set of photographs are taken in August of 2015, and each pair of photographs (2014 and 2015) will be compared and scored for visible changes in soils surfaces and vegetation composition and structure.

8 RECOMMENDATIONS FOR HABITAT RESTORATION AND VISITOR MANAGEMENT ASSOCIATED WITH THE PROJECT

8.1 VEGETATION, WILDLIFE, AND HABITAT MANAGEMENT

Given that the historical natural environments of the MRG and associated bosque have greatly declined over the last century and have been largely replaced by human-created environments dominated by non-native species, habitat rehabilitation has become an important aspect of MRG natural resources management, as demonstrated by bosque management plans (Crawford et al. 1993; Robert 2005). Considerable habitat restoration work has already been completed in the project area, including removal of exotic trees such as saltcedar and Russian olive by the City (City 2005) and the Corps (2013). Those projects have been aimed largely at reducing wildfire fuels to reduce catastrophic wildfire threats, as well as attempting to restore a more natural bosque dominated by native trees and shrubs. A number of riverine habitat restoration projects have also been conducted in the project area by the Corps, Reclamation, and NMISC to restore breeding habitats for the silvery minnow and flycatcher.

Within the Albuquerque Reach, the City, USACE, NMISC, USBR, New Mexico State Land Office, and Albuquerque Bernalillo County Water Utility Authority have all contributed to restoration activities including the excavation of high-flow ephemeral channels, terrace and bank lowering, the excavation of high-flow embayments, the removal of lateral confinements (i.e., Kellner jetty jacks), the modification of islands and bars, the addition of woody debris, and the active planting of native vegetation (SWCA 2006; SWCA 2008a; SWCA 2008b; SWCA 2010a; NMSLO 2010; USACE 2013; ABCWUA 2013).

SWCA recommends that the City and other agencies continue habitat restoration work within the project area and create more natural habitats for native plant and animal species, in addition to public enjoyment. In particular, SWCA recommends the enhancement or construction of moist soils and wetland areas, including planting with native wetland vegetation. Such wetland areas could be protected by planting their perimeters with native shrubs such as coyote willow, wolfberry, New Mexico olive, skunkbush sumac (*Rhus trilobata*), and fourwing saltbush, all of which provide important structural habitat and food resources for native wildlife. Removal of dense stands of non-native saltcedar and Russian olive should continue to reduce catastrophic wildfire and allow for the expansion of native trees and shrubs. However, exotic tree removal treatments should avoid mastication of exotic trees and instead utilize chipping and wood-chip spreading practices to stabilize soil surfaces. Further, native trees, shrubs, and grasses should be planted in treated areas to replace any removed exotic trees. Native plantings should not only include important overstory species such as Rio Grande cottonwood and Goodding's willow, but also important understory shrubs such as wolfberry and New Mexico olive that produce fruit that are important to wildlife. Native grasses such as alkali sacaton should be planted on bare open soil areas to help replace exotic invasive herbs such as Russian thistle and kochia. Since the project is intended to bring more people to the bosque to enjoy its natural beauty and flora and fauna, efforts should be made to restore the environment and flora and fauna to more natural conditions. Such restoration activities in this one area also will add to restoration efforts throughout the entire MRG.

8.2 VISITOR MANAGEMENT

An important aspect of managing the project area for natural and scenic appeal for visitors, and for conserving habitats and native plant and animal species, will be appropriate management of visitors. The project is intended to create better access to the bosque for visitors, while at the same time protecting and conserving the natural resources that occur there. As discussed above, visitors may cause environmental impacts to natural resources that they intend to enjoy. The best way to protect those natural resources is to manage visitor activities in such ways as to protect those resources. SWCA recommends that the future visitor management elements of the project use public education about the natural resources and how to avoid damaging those resources as a primary way to project the bosque. Interpretive and education signs at trailhead parking areas, along with interpretive and educational signs referring to sensitive environments throughout the trail system, should be considered. Another approach to visitor management is imposing regulations on undesirable activities that may harm natural resources. Such regulations often counter some visitors' behaviors. However, if many people are going to share the bosque, they also must share the responsibility of protecting the bosque. SWCA recommend that visitors be encouraged to stay on the main trails, but allow for some low-impact off-trail activities such as wildlife viewing, photography, and solitude. Pet dogs should be managed so that leashes and waste pickup are required. The addition of educational signs reminding visitors about how dogs can disturb wildlife and the placement of dog waste bag stations and waste receptacles should be considered.

9 CONCLUSIONS

The RGVSP project proposes to consider amendments to the existing interior bosque trail extending from Central Avenue to Montaño Blvd. on the east side of the Rio Grande. Other trail-related recreational amenities such as signage are proposed, and parking access will be enhanced, The existing trail system will be assessed to determine how to best manage different uses and which smaller side trails should be closed or retained. This environmental baseline report presents information on the historic and current environmental conditions and the flora and fauna of the project area, a listing of sensitive plant and animal species that may occur in the area, and recommendations for habitat restoration associated with the project.

The current riparian bosque environment of the project area is already in poor ecological health because the entire MRG has undergone tremendous human impacts, especially resulting from flood control dams or levees and an extensive ditch system to provide water for agricultural irrigation. The former natural bosque was subject to periodic flooding, especially following spring snowmelt runoff, and the former Rio Grande was a dynamic river with many different channels and side channels, and it frequently flooded large areas of the current floodplain. The native plants and animals that live along the Rio Grande have life histories and biological adaptations to live in a dynamic and highly variable riverine/riparian environment. However, the Rio Grande is now channelized to one main course confined between levees. Flow rates are controlled, persistent drought has reduced overall flow rates, natural flooding on the floodplain has ceased, exotic invasive trees and weeds now dominate many areas, wildfire has become a new and significant threat. The project is within a major metropolitan area which is subject to numerous possible human-caused visitor impacts. Habitat restoration and recovery efforts for two federally endangered species are now significant management efforts within the MRG and its bosque.

Initial baseline monitoring data on soil surfaces, vegetation and bird communities collected by SWCA in 2014 reveals that there are currently no existing significant differences in those attributes when comparing environments within the existing primary trail to those found outside of the primary trail corridor. Future monitoring data will determine whether or not elements of this project has had measureable effects on soil surfaces, vegetation and birds of the bosque project area.

Given the already environmentally disturbed condition of the MRG bosque, the proposed project is not anticipated to have a significant negative environmental impact on the area. The project could improve the environmental conditions of the bosque by managing visitors to allow recovery from prior visitor impacts. The proposed project also is in agreement with the recommendations of several key MRG bosque natural resource management plans (e.g., Middle Rio Grande Ecosystem Bosque Biological Management Plan, Bosque Action Plan, Rio Grande Conservation Initiative) that call for improved low-impact recreational and environmental educational facilities, and restoration efforts to enhance native plant and animal species and ecosystem function. SWCA recommends that the City integrate visitor management and habitat restoration efforts as part of the project to protect and enhance native plant and animal species and their habitats, and to provide improved low-impact recreation and educational activities.

SWCA has begun monitoring the environment within the project area on soils, vegetation, and birds to determine if this project has no effect, negative effects, or positive effects on those natural resources. The outcome of the monitoring study will provide information to guide the City through the adaptive management process, on how to best manage this project in order to protect natural resources while at the same time providing low-impact recreation and environmental education opportunities to a broad cross-section of visitors. The City plans to prepare a follow-up study on the relationship between recreation and visitors, and that information along with the environmental monitoring should result in a sound evaluation of whether or not this project is achieving its intended goals.

10 REFERENCES

Abeyta, C. 2009. Middle Rio Grande Bosque Initiative. Available at: http://www.fws.gov/southwest/mrgbi/. Accessed December 3, 2013.

Ahlers, D. 2009. A Review of Vegetation and Hydrological Parameters Associated with the Southwestern Willow Flycatcher – 2002-2008: Elephant Butte Reservoir Delta. Denver: Bureau of Reclamation.

Ahlers, D., and L. White. 1998. 1997 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

———. 2000. 1999 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

Ahlers, D., E. Best, and J. Sechrist. 2001. 2000 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

Ahlers, D., C. Solohub, E. Best, and J. Sechrist. 2002. Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

Albert, J., M. Sixta, C. Leon, and P. Julien. 2003. Corrales Reach, Hydraulic Modeling Analysis 1962-2001, Middle Rio Grande, NM. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

Anderson, B.W., A. Higgins, and R.D. Ohmart. 1977. Avian use of saltcedar communities in the lower Colorado River Valley. In Importance, Preservation and Management of Riparian Habitat: A Symposium, coordinated by R.R. Johnson and D. A. Jones, pp. 128–136. General Technical Report RM-43. Fort Collins, Colorado: U.S. Department of Agriculture Forest Service.

Barro, S.C., P.M. Wohlgemuth, and A.G. Campbell. 1989. Post-fire interactions between riparian vegetation and channel morphology and the implications for stream channel rehabilitation choices. In Proceedings of the California Riparian Systems Conference: Protection, Management, and Restoration for the 1990s, coordinated by D. L. Abell, pp. 51–53. U.S. Department of Agriculture, Forest Service General Technical Report PSW-110.

Bartolino, J.R., and J.C. Cole. 2002. Ground-water resources of the Middle Rio Grande Basin. U.S. Geological Survey Circular 1222.

Bateman, H.L., A. Chung-MacCoubrey, D.M. Finch, H.L. Snell, and D.L. Hawksworth. 2008a. Impacts of non-native plant removal on vertebrates along the Middle Rio Grande (New Mexico). Ecological Restoration. 26:193-195.

Bateman, H.L., A. Chung-MacCoubrey, and H.L. Snell. 2008b. Impact of non-native plant removal on lizards in riparian habitats in the southwestern United States. Restoration Ecology. 16(1):180-190.

Bateman, H.L., M.J. Harner, and A. Chung-MacCoubrey. 2008c. Abundance and reproduction of toads (Bufo) along a regulated river in the southwestern United States: Importance of flooding in riparian ecosystems. Journal of Arid Environments 72:1613–1619.

Bateman, H.L., A. Chung-MacCoubrey, H.L. Snell, and D.M. Finch. 2009. Abundance and species richness of snakes along the Middle Rio Grande riparian forest in New Mexico. Herpetological Conservation and Biology. 4:1-8.

Bauer, T. 2004. Sediment Transport Modeling in the Albuquerque Transition Zone. Prepared for the U.S. Department of the Interior, Bureau of Reclamation.

Beadle, J.H. 1973. The Undeveloped West: Or, Five Years in the Territories. New York: Arno Press.

Berry, K.L., and K. Lewis. 1997. Historical Documentation of Middle Rio Grande Flood Projection Projects, Corrales to San Marcial. Report submitted to U.S. Army Corps of Engineers. Albuquerque: Office of Contract Archeology, University of New Mexico.

Bestgen, K.R., and S.P. Platania. 1991. Status and conservation of the Rio Grande silvery minnow, Hybognathus amarus. The Southwestern Naturalist 36:225–232.

Bosque Ecosystem Monitoring Program (BEMP). 2011. Bosque Ecosystem Monitoring Program Intern Handbook. Department of Biology, University of New Mexico. Available at: http://www.bosqueschool.org/bemp.guidebook.htm. Accessed December 13, 2013

Boyle, S.A., and F.B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildlife Society Bulletin 13:110–116.

Brown, B.T. 1994. Rates of brood parasitism by brown-headed cowbirds on riparian passerines in Arizona. J. Field Ornithology 65:160-168.

Burke, T.A. 1992. Effects of de-silting by dam construction on biodiversity along the lower Colorado River. Proceedings of the Wildlife Society and American Fisheries Society Joint Annual Meeting. Phoenix: Arizona Chapter of the Wildlife Society.

Burkholder, J.L. 1928. Report of the Chief Engineer, Submitting a Plan for Flood Control, Drainage and Irrigation of the Middle Rio Grande Conservancy District. Albuquerque: Middle Rio Grande Conservancy District.

Busch, D.E., and S.D. Smith. 1993. Effects of fire on water and salinity relations of riparian woodland taxa. Oecologia 94:186–194.

———. 1995. Mechanisms associated with the decline of woody species in riparian ecosystems of the Southwestern United States. Ecological Monographs 65:347–370.

Callahan and White (2002). Vegetation Mapping of the Rio Grande Floodplain. U.S. Bureau of Reclamation, Denver Technical Center.

Campbell, C.J., and W.A. Dick-Peddie. 1964. Comparison of phreatophyte communities on the Rio Grande in New Mexico. Ecology 45:492–502.

Cartron, J.E. 2010. Raptors of New Mexico. University of New Mexico Press, Albuquerque, New Mexico.

Cartron, J.E., D.C. Lightfoot, J.E. Mygatt, S.L. Brantley and T.K. Lowrey. 2008. A Field Guide to the Plants and Animals of the Middle Rio Grande Bosque. Albuquerque: University of New Mexico Press.

Cartron, J.E., M. D. Means, D. L Hawksworth, and D. M. Finch. 2007. Colonization of the eastern bluebird along the Middle Rio Grande in New Mexico. Western Birds 38:206–215.

Cartron, J.E., M.C. Molles, Jr., J.F. Schuetz, C.S. Crawford, and C.N. Daham. 2003. Ground arthropods as potential indicators of flooding regime in the riparian forest of the Middle Rio Grande, New Mexico. Environmental Entomology 32:1075–1084.

Chapin, C. E. 1988. Axial basins of the northern and central Rio Grande rifts. In Sedimentary Cover, North American Craton: US (Geology of North America), edited by L.L. Sloss, pp. 165–170. Boulder, Colorado: U.S. Geological Society of America, DNAG Volume D-2.

Chung-MacCoubrey, A. and H.L. Bateman. 2006a. Bosque restoration effects on bats and herpetofauna. Chapter 4 in D.M. Finch, A. Chung-MacCoubrey, R. Jemison, D. Merritt, B. Johnson and M. Campana (eds), Effects of fuel reduction and exotic plant removal on vertebrates, vegetation and water resources in the Middle Rio Grande, New Mexico. Final report by USDA Forest Service Rocky Mountain Research Station for Joint Fire Sciences Program. www.firescience.gov/projects/01-1-3-19/01-1-3-19_final_report.pdf

Chung-MacCoubrey, A.L., and H. L. Bateman. 2006b. Herpetological Communities of the Middle Rio Grande Bosque: What Do We Know, What Should We Know, and Why? U.S. Department of Agriculture, Forest Service Proceedings RMRS-P-42CD:57-66.

City of Albuquerque (City). 1986. Rio Grande Valley State Park: Management Plan. Albuquerque: City of Albuquerque Parks and Recreation Department, Open Space Division.

———. 1993. Bosque Action Plan. Rio Grande Valley State Park. Final Plan. Albuquerque: City of Albuquerque Parks and General Services Department.

———. 2005. Environmental Enhancement Plan for Rio Grande Valley State Park. Parks and Recreation Department – Open Space Division. Albuquerque: City of Albuquerque.

Crawford, C.S., A.C. Cully, R. Leutheuser, M.S. Sifuentes, L.H. White, and J.P. Wilbur. 1993. Middle Rio Grande Ecosystem: Bosque Biological Management Plan. Albuquerque: Middle Rio Grande Biological Interagency Team.

Crawford, C.S., L.M. Ellis, and M.C. Moles, Jr., 1998. The middle Rio Grande Bosque: an endangered ecosystem. New Mexico Journal of Science 36:277–299.

Dahm, C.N., J.R. Cleverly, J.E. Allred Coonrod, J.R Thibault, D.E. McDonnell, and D.J. Gilroy. 2002. Evapotranspiration at the land/water interface in a semi-arid drainage basin. Freshwater Biology 47:831–843.

Davis, F.W., E.A. Keller, A. Parikh, and J. Florsheim. 1989. Recovery of the Chaparral Riparian Zone Following Wildfire. U.S. Department of Agriculture, Forest Service General Technical Report PSW 110:194-203.

DeLoach, C.J., R.I. Carruthers, J.E. Lovich, T.L. Dudley, and S.D. Smith. 2000. Ecological interactions in the biological control of saltcedar (*Tamarix* spp.) in the United States: toward a new understanding. In Proceedings of the 10th International Symposium on the Biological Control of Weeds, edited by N.R. Spencer, pp. 819–873. Bozeman, Montana: Montana State University.

Dick-Peddie, W.A. 1993. New Mexico Vegetation—Past, Present and Future. Albuquerque: University of New Mexico Press.

Downes, B.J., L.A. Barmuta, P.G. Fairweather, D.P. Faith, M,J. Keough, P.S. Lake, B.D. Mapstone, and G.P Quinn. 2002. Monitoring Ecological Impacts: Concepts and Practice in Flowing Water. Cambridge, England: Cambridge University Press.

Dudley, R.K., and S.P. Platania. 2008. Rio Grande Silvery Minnow Population Monitoring Program Results from December 2006 to October 2007. Prepared for Middle Rio Grande Endangered Species Collaborative Program by American Southwest Ichthyological Researchers, Albuquerque. Dufrene, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Dufrene, M., and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monographs 67:345-366.

Durst, S.L., M.K. Sogge, S.D. Stump, S.O. Williams, B.E. Kus, and S.J. Sferra. 2007. Southwestern Willow Flycatcher Breeding Site and Territory Summary – 2006. U.S. Geological Survey Open-File Report 2007-1391.

———. 2008. Southwestern Willow Flycatcher Breeding Site and Territory Summary – 2007. U.S. Geological Survey Open-File Report 2008-1303.

eBird. 2013. eBird database. Cornell Lab of Ornithology. Available at: http://ebird.org/content/ebird/. Accessed on December 3, 2013.

Eichhorst, K.D., D.C. Shaw, J.F. Schuetz, A. D. Gebauer, and C.S. Crawford. 2006. Bosque Ecosystem Monitoring Program (BEMP): Third supplement: 2004–2005.

Eichhorst, K.D., D.C. Shaw, J.F. Schuetz, K. Scheerer, M. Keithley and C.S. Crawford. 2012. Bosque Ecosystem Monitoring Program (BEMP) Comprehensive Report: 1997-2009. Albuquerque: Department of Biology, University of New Mexico.

Ellis, L.M., C.S. Crawford, and M.C. Molles, Jr. 1997. Rodent communities in native and exotic riparian vegetation in the Middle Rio Grande valley of central New Mexico. The Southwestern Naturalist 42:13–19.

Ellis, L.M., M.C. Molles, Jr., and C.S. Crawford. 1999. Influence of experimental flooding on litter dynamics in a Rio Grande riparian forest in central New Mexico. Restoration Ecology 7:1–13.

Ellis, L.M., M.C. Molles, Jr., C.S. Crawford, and F. Heinzelmann. 2000. Surface-active arthropod communities in native and exotic riparian vegetation in the Middle Rio Grande Valley, New Mexico. Southwestern Naturalist 45:456–471.

Elzinga, C.L., D.W. Salzer, J.W. Willoughby, and J.P. Gibbs. 2001. Monitoring Plant and Animal Populations. Malden, Massachusetts: Blackwell Science, Inc.

Federal Register. 1995. Endangered and Threatened Wildlife and Plants: Final Rule Determining Endangered Status for the Southwestern Willow Flycatcher. Volume 60, No.38 / Monday February 27, 1995 / Final Rule. Pp. 10694–10715.

———. 2005. Endangered and Threatened Wildlife and Plants: Designation of Critical Habitat for the Southwestern Willow Flycatcher (Empidonax traillii extimus). Volume 70, No. 20 / Wednesday, October 19, 2995 / Final Rule. Pp. 60886–61009.

Finch, D.M., J. Galloway, and D. Hawksworth. 2006. Monitoring bird populations in relation to fuel loads and fuel treatments in riparian woodlands with tamarisk and Russian olive understories. U.S. Department of Agriculture, Forest Service Proceedings RMRS-P-42CD:113–120.

———, and S.H. Stoleson. 2000. Status, ecology, and conservation of the Southwestern Willow Flycatcher. Gen. Tech. Rep. RMRS-GTR-60. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

———, and W. Yong. 2000. Landbird migration in riparian habitats of the middle Rio Grande: a case study. Studies in Avian Biology 20:88-98.

Garber 2013. Letter to Mayor Richard Berry, dated September 3, 2013. Available at: http://hawksaloft.org/2013/09/04/protect-our-bosque-from-the-proposed-rio-grande-vision-plan/. Accessed December 3, 2013.

Grassel, K. 2002. Taking out the jacks. Issues of jetty jack removal in bosque and river restoration planning. Publication No. WRP-6, Water Resources Program, The University of New Mexico, Albuquerque, New Mexico, 46 p.

Green, R.H. 1979. Sampling Design and Statistical Methods for Environmental Biologists. New York: Wiley and Sons, Inc.

Gutzler, D.S. 2013. Special feature: sustainability on the U.S./Mexico border, regional climatic considerations for borderlands sustainability. Ecosphere 4 (1) 7:1–12.

Hall, A.W., P.H. Whitfield, and A.J. Cannon. 2006. Recent variations in temperature, precipitation, and streamflow in the Rio Grande and Pecos River Basins of New Mexico and Colorado. Reviews in Fisheries Science 14(1–2):51–78.

Hammitt, W.E., and D.N. Cole. 1998. Wildland Recreation: Ecology and Management (2nd ed.). New York, NY: John Wiley.

Hansen, S. 1994. Riparian Corridor Alluvium Steady State Ground Water Investigation Concerning Rio Grande Channel Loss Contributions to Recharge. Middle Rio Grande Water Assessment, Bureau of Reclamation Albuquerque Projects Office, Final Draft.

Hawks Aloft. 2005. The United States Army Corps of Engineers 2005 Southwestern Willow Flycatcher Surveys at Graham Property. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

———. 2006. 2006 Willow Flycatcher Surveys at Two Albuquerque Sites: Montano Southwest and the Rio Grande Nature Center. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

———. 2008a. Bird and Vegetation Community Relationships in the Middle Rio Grande Bosque: 2007 Interim Report. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

———. 2008b. Raptor Monitoring in the Middle Rio Grande Bosque of Central New Mexico. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

———. 2009. 2009 Willow Flycatcher Surveys at Two Albuquerque Sites: Montano Southwest and the Rio Grande Nature Center. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

———. 2013. Bird and Vegetation Community Relationships in the Middle Rio Grande Bosque: 2012 Interim Report. Prepared for the U.S. Army Corps of Engineers, Albuquerque.

Hawley, J.W. 1978. Guidebook to the Rio Grande Rift in New Mexico and Colorado. New Mexico Bureau of Minds and Mineral Resources, Circular 163.

Herrick, J. E., J. W. Van Zee, K. M. Havstad, L. M. Burkett, and W. G. Whitford. 2005. Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems. Quick Start. Design, Supplementary Methods and Interpretation, 1 and 2. USDA-ARS Jornada Experimental Range, Las Cruces, New Mexico. Tucson: University of Arizona Press.

Hink, V.C., and R.D. Ohmart. 1984. Middle Rio Grande Biological Survey. Contract No. DACW47-81-C-0015, Arizona State University. Albuquerque: U.S. Army Corps of Engineer Albuquerque District.

Jacobi, G.Z., J.E. Sublette, S.J. Herrmann, D.E. Cowley, and M.D. Hatch. 2001. Investigations of Indices of Biotic Condition for Streams in New Mexico. New Mexico Department of Game and Fish, Federal Aid Grant F-59-R-10.

Kinzli, K.-D., and C.A. Myrick. 2009. Bendway weirs: could they create habitat for the endangered Rio Grande silvery minnow. River Research and Applications 26(7): 806-822.

Knight, P.J., S.G. Lucas, and A. Cully. 1996. Early Pleistocene Plants from the Albuquerque Area, New Mexico. Report on file, U.S. Fish and Wildlife Service, Ecological Services, Albuquerque.

Laymon, S.A. 1997. Yellow-billed Cuckoo (*Coccycus americanus*). In The Riparian Bird Conservation Plan:a strategy for reversing the decline of riparian-associated birds in California. California Partners in Flight. Available at: http://www.prbo.org/calpif/htmldocs/riparian_v-2.html. Accessed on December 3, 2013.

Lee, S., A Klein, and T. Ovr. 2004. Effects of the El Niño Southern Oscillation on temperature, precipitation, water equivalent and resulting streamflow in the Upper Rio Grande River Basin. Hydrological Process 18:1053–1071.

Leon, C. 1998. Morphology of the Middle Rio Grande from Cochiti Dam to Bernalillo Bridge, New Mexico. M.S. Thesis. Fort Collins, Colorado: Colorado State University.

Leon, C., M. Sixta, J. Albert and P.Y. Julien. 2003. Bernalillo Bridge Reach, Highway 550 bridge to Corrales Flood Channel Outfall, hydraulic modeling analysis, 1962-2001. In Geomorphological Summary of the Bernalillo Bridge Reach, edited by T.M Massong. Final Technical Report, U.S. Bureau of Reclamation, Albuquerque.

Llewellyn, D. and S. Vaddey. 2013. West-Wide climate risk assessment: Upper Rio Grande Impact Assessment. U.S. Department of Interior, Bureau of Reclamation, Upper Colorado Region, Albuquerque Office Area. Albuquerque, NM. 138 pages, plus appendices.

Magaña, H.A. 2007. A case for classifying the Rio Grande silvery minnow (Hybognathus amarus) as an omnivore. Doctoral dissertation, University of New Mexico, Albuquerque.

Marshall, R.M., and S.H. Stoleson. 2000. Threats. In Status, ecology, and conservation of the Southwestern Willow Flycatcher, edited by D.M. Finch and S.H. Stoleson, pp.13-24. Gen. Tech. Rep. RMRS-GTR-60. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Massong, T.M. 2003. Current Fluvial Conditions, Rio Grande Bernalillo Bridge Reach. Final Technical Report. Albuquerque: U.S. Bureau of Reclamation.

Massong, T., M.D. Porter, and T. Bauer. 2004. Design Improvements for Constructed Rio Grande Silvery Minnow Nursery Habitat. Albuquerque: U.S. Bureau of Reclamation.

———. 2005a. Geomorphology Summary Rio Grande – Bernalillo Bridge Reach. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

———. 2005b. Geomorphology Summary Rio Grande – Corrales Reach. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

Massong, T., P. Maker, T. Bauer. 2007. Geomorphic Summary of the Middle Rio Grande: Velarde to Caballo. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

McCune, B. and J.B.Grace. 2002. Analysis of ecological communities. MjM Software, Glenden Beach, Oregon.

McCune, B. and M. J. Mefford. 1999. PC-ORD. Multivariate analysis of Ecological Data, Version 4.0 for Windows. MjM Software, Glenden Beach, Oregon.

Milford, E., and E. Muldavin. 2004. River Bars of the Middle Rio Grande, A Comparative Study of Plant and Arthropod Diversity. Albuquerque: Natural Heritage New Mexico, University of New Mexico.

Milford, E., E. Muldavin, and T. Neville. 2003. Middle Rio Grande River Bar Vegetation Map: The Albuquerque Reach. Report 03-GTR-244 submitted to the U.S. Fish and Wildlife Service, Albuquerque.

Milford, E., E. Muldavin, and T. Neville. 2005. Middle Rio Grande Vegetation Map II. Bernalillo to Alameda and I-25 to Belen. Final Report. Natural Heritage New Mexico Report 05-GTR-291.

Milford, E., E. Muldavin, and K. Mann. 2006. Vegetation Sampling for the Middle Rio Grande: Re-sampling the 1984 Hink and Ohmart Transects. Progress report to the U.S. Army Corps of Engineers. Natural Heritage New Mexico Report- 06-GTR-294.

Milford, E., E. Muldavin, and A. Browder. 2007. Vegetation Sampling for the Middle Rio Grande: Re-sampling the 1984 Hink and Ohmart Transects, Year II. Progress report to the U.S. Army Corps of Engineers. Natural Heritage New Mexico Report- 06-GTR-294.

Miller, J.R., and N. Thompson Hobbs. 2000. Recreational trails, human activity, and nest predation in lowland riparian areas. Landscape and Urban Planning 50:227–236.

Miller, J.R., J.A. Wiens, N. Thompson Hobbs, and D.M. Theobald. 2003. Effects of human settlement on bird communities in lowland riparian areas of Colorado. Ecological Applications 4:1041–1059.

Molles M.C., C.S. Crawford, L.M. Ellis, H.M. Valett, and C.N. Dahm. 1998. Managed flooding for riparian ecosystem restoration. Bioscience 48(9):749–756.

Monz, C.A., C.M. Pickering, and W.L. Hadwen. 2013. Recent advances in recreation ecology and the implications of different relationships between recreation use and ecological impacts. Frontiers in Ecology and the Environment 11:441–446.

Moore, D. 2007. Vegetation Quantification of Southwestern Willow Flycatcher Nest Sites: Rio Grande from La Joya to Elephant Butte Reservoir Delta, New Mexico 2004–2006. Denver: U.S. Bureau of Reclamation, Fisheries and Wildlife Resources.

———. 2009. An Assessment of Potential Southwestern Willow Flycatcher Habitat. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

Moore, D., and D. Ahlers. 2003. 2002 Southwestern Willow Flycatcher Study Results – 2002: Selected Sites along the Rio Grande from Velarde, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

———. 2004. 2003 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Highway 60 to Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Ecological Planning and Assessment.

———. 2005. 2004 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2006a. 2005 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2006b. 2006 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico, to the Headwaters of Elephant Butte Reservoir. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2007. 2006 Southwestern Willow Flycatcher Study Results: Selected Sites Along the Rio Grande From Velarde to Elephant Butte Reservoir, New Mexico. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2008. 2007 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2009. 2009 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Velarde to Elephant Butte Reservoir, New Mexico. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

———. 2012. 2012 Southwestern Willow Flycatcher Study Results: Selected Sites along the Rio Grande from Bandelier National Monument to Elephant Butte Reservoir, New Mexico. Denver: U.S. Bureau of Reclamation, Technical Service Center, Fisheries and Wildlife Resources.

Mount, J., W. Krausman, and D.M. Finch. 1996. Riparian habitat change along the Isleta-Belen Reach of the Rio Grande. In Desired Future Conditions for Southwestern Riparian Ecosystems: Bringing Interests and Concerns Together, coordinated by D.W. Shaw and D.M. Finch, pp. 58–61. General Technical Report RM-GTR-272. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Muldavin, E., C.S. Crawford, and N. Umbreit. 2004. The Albuquerque Overbank Project: A Model for Large River Riparian Restoration in the Southwest. Albuquerque: Natural Heritage New Mexico, U.S. Bureau of Reclamation, and University of New Mexico.

Muldavin, E., A. Browder, and E. Milford. 2005. Cottonwood Growth and Restoration along the Middle Rio Grande at Santa Ana Pueblo, NM. Albuquerque: New Mexico Natural Heritage Program, University of New Mexico.

Mund-Myerson, M.J. 1998. Arthropod abundance and composition on native and exotic trees in the Middle Rio Grande riparian forest as related to avian foraging. M.S. thesis, Department of Biology, University of New Mexico, Albuquerque, New Mexico.

Mussetter Engineering, Inc. (MEI). 2007. Sandia Pueblo Hydraulic Modeling, Rio Grande, NM. Prepared for SWCA Environmental Consultants, Albuquerque. Albuquerque: MEI.

National Oceanic and Atmospheric Administration. 2002. Climatological Data Annual Summary, New Mexico, 2002. Volume 106, no. 13.

New Mexico Department of Game and Fish (NMDGF). 2013. Biota Information System of New Mexico (BISON-M). 2013. BISON-M home page. Available at: http://www.bison-m.org. Accessed December 3, 2013.

New Mexico Environment Department. 2007. New Mexico Atlas, 2007. (groundwater) http://www.nmenv.state.nm.us/NMAtlas/index.html. Accessed December 3, 2013.

New Mexico State Land Office (NMSLO). 2010. New Mexico State Trust Land Biological Assessment for the Riverine Restoration Project within the Albuquerque Reach of the Middle Rio Grande. Santa Fe, New Mexico.

Ohmart, R.D., and B.W. Anderson. 1986. Riparian habitat. In Inventory and Monitoring of Wildlife Habitat, edited by A.Y. Cooperider, R.J. Boyd, and H.R. Stuart, pp. 169–193. Denver: U.S. Bureau of Land Management.

Ortiz, R.M. 2003. Preliminary Geomorphic Assessment of the Bernalillo-Albuquerque Reach, Middle Rio Grande near Albuquerque, NM. In Geomorphological Summary of the Bernalillo Bridge Reach. Final Technical Report, edited by T.M. Massong. Albuquerque: Bureau of Reclamation.

Owen, J.C., M.K. Sogge, and M.D. Kern. 2005. Habitat and sex differences in physiological condition of breeding Southwestern Willow Flycatchers (Empidonax traillii extimus). The Auk 122(4):1261–1270.

Parametrix. 2008. Restoration Analysis and Recommendations for the Isleta Reach of the Middle Rio Grande, NM. Prepared for the Middle Rio Grande Endangered Species Collaborative Program, U.S. Bureau of Reclamation Contract No. 06CR408146.

Parker, D.L., M. Renz, A. Fletcher, F. Miller, and J. Gosz. 2005. Strategy for Long-Term Management of Exotic Trees in Riparian Areas for New Mexico’s Five River Systems, 2005–2014. U.S. Department of Agriculture, Forest Service and New Mexico Energy, Minerals and Natural Resources Department, Forestry Division Publication.

Paxton, E.H., M.K. Sogge, S.L. Durst, T.C. Theimer, and J. Hatten. 2007. The Ecology of the Southwestern Willow Flycatcher in Central Arizona – a 10-year Synthesis Report. U.S. Geological Survey Open-File Report 2007-1381.

Platania, S.P. 1991. Fishes of the Rio Chama and Upper Rio Grande, New Mexico, with preliminary comments on the longitudinal distribution. Southwestern Naturalist. 36(2):186–193.

Propst, D.L. 1999. Threatened and Endangered Fishes of New Mexico. Technical Report No. 1. Santa Fe: New Mexico Department of Game and Fish.

Robert, L. 2005. Middle Rio Grande Ecosystem Bosque Biological Management Plan, The First Decade: A Review & Update. Prepared in cooperation with the Middle Rio Grande Bosque Initiative and the Bosque Improvement Group. Albuquerque: Aurora Publishing, LLC.

SAS. 2014. SAS Version 9.3. SAS Institute, Cary, North Carolina.

S.S. Papadopulos and Associates, Inc. (SSPA). 2005. River Flow Monitoring and Observation for Silvery Minnow Rescue, “River Eyes,” Final project Deliverable: SSPA Work Order SSPA2-RG16. Report submitted to the New Mexico Interstate Stream Commission, Albuquerque.

Secretary's Committee for the Middle Rio Grande Conservation Initiative. 2012. Middle Rio Grande Conservation Initiative: A Citizen's Report of the Secretary's (i.e., US Secretary of the Department of Interior) Committee for the Middle Rio Grande Conservation Initiative. Available at: http://www.middleriogrande.com/LinkClick.aspx?fileticket=fUo9q2PXTPY%3D&tabid=488&mid=1401. Accessed December 14, 2013.

Scurlock D. 1998. From the Rio to the Sierra: An Environmental History of the Rio Grande Basin. General Technical Report RMRS-GTR-5. Fort Collins, Colorado: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Shafroth, P.B., J.M. Friedman, and L.S. Ischinger. 1995. Effects of salinity on establishment of *Populus fremontii* (cottonwood) and *Tamarix ramosissima* (saltcedar) in Southwestern United States. Great Basin Naturalist 55:58–65.

Shirey, P.D. 2004. Foraging habits and habitat utilization of Rio Grande silvery minnow (Hybognathus amarus) as inferred by diatom frustules. M.S. Thesis, New Mexico State University Las Cruces, New Mexico.

Smith, D.M., J.F. Kelly and D.M. Finch. 2006. Wildfire, Exotic Vegetation, and Breeding Bird Habitat in the Rio Grande Bosque. U.S. Department of Agriculture, Forest Service Proceedings RMRS-P-42CD.

———. 2007. Avian nest box selection and nest success in burned and unburned southwestern riparian forest. Journal of Wildlife Management 71:411–421.

Sogge, M.K., R.M. Marshall, S.J. Sferra, and T.J. Tibbits. 1997. A Southwestern Willow Flycatcher Natural History Summary and Survey Protocol. National Park Service Technical Report USGS/NAUCPRS/NRTR-97/12.

Sogge, M.K., S.J. Sferra, T.D. McCarthey, S.O. Williams, and B.E. Kus. 2003. Distribution and characteristics of Southwestern Willow Flycatcher breeding sites and territories: 1993–2001. In Ecology and Conservation of the Willow Flycatcher, edited by M.K. Sogge, B.E. Kus, S.J. Sferra and M.J. Whitfield, pp. 5–11. Studies in Avian Biology No. 26. Cooper Ornithological Society.

Stalnaker, C.B. 1981. Low flow as a limiting factor in warm water streams. In The Warm Water Streams Symposium: A National Symposium on Fisheries Aspects of Warm Water Streams, edited by L.A. Krunholz, pp. 192–199. Lawrence, Kansas: Allen Press, Inc.

Stromberg, J.C. 1997. Growth and survivorship of Fremont cottonwood, Goodding's willow and saltcedar seedlings after large floods in central Arizona. Great Basin Naturalist 57:198–208.

Stromberg, J.C., M. Sogge, and B. Valentine. 2002. Riparian ecology and fire management. In U.S. Fish and Wildlife Service Southwestern Willow Flycatcher Recovery Plan. U.S. Fish and Wildlife Service.

Stromberg, J.C., M.K. Chew, P.L. Nagler, and E.P. Glenn. 2009. Changing perceptions of change: the role of scientists in Tamarix and river management. Restoration Ecology 17:177–186.

Stuever, M.C. 1997. Fire induced mortality of Rio Grande cottonwood. M.S. Thesis, University of New Mexico, Albuquerque, New Mexico.

Sublette, J.E., M.D. Hatch, and M. Sublette. 1990. The Fishes of New Mexico. Albuquerque: University of New Mexico Press.

Sun, D., and D. Walsh. 1998. Review of studies on environmental impacts of recreation and tourism in Australia. Journal of Environmental Management 53:323–338.

Swetnam, T.W. and J. L. Betancourt. 1999. Mesoscale disturbance and ecological response to decadal climatic variability in the American Southwest. Journal of Climate 11:3128–3147.

SWCA Environmental Consultants (SWCA). 2006. City of Albuquerque Habitat Restoration Project Biological Assessment. Albuquerque: City of Albuquerque Open Space Division.

———. 2008a. Pueblo of Sandia Habitat Restoration Analysis and Recommendations, Middle Rio Grande Endangered Species Collaborative Program, Bernalillo County, New Mexico. Prepared for the U.S. Bureau of Reclamation, Albuquerque, and Pueblo of Sandia, Bernalillo, New Mexico. Albuquerque: SWCA Environmental Consultants.

———. 2008b. New Mexico Interstate Stream Commission Middle Rio Grande Riverine Restoration Project Phase I 2007 Monitoring Report. Albuquerque: New Mexico Interstate Stream Commission.

———. 2008c. New Mexico Interstate Stream Commission Middle Rio Grande Riverine Restoration Project Phase II 2007 Monitoring Report. Albuquerque: New Mexico Interstate Stream Commission.

———. 2010. U.S. Army Corps of Engineers Albuquerque Reach Habitat Analysis and Recommendations Study, Middle Rio Grande Endangered Species Collaborative Program. Albuquerque: U.S. Army Corps of Engineers.

———. 2011. Albuquerque Bernalillo County Water Utility Authority Southwestern Willow Flycatcher Habitat Restoration Project Biological Assessment. Albuquerque: New Mexico. Albuquerque Bernalillo County Water Utility Authority.

———. 2013. Albuquerque Bernalillo County Water Utility Authority. San Juan Chama Drinking Water Project – Environmental Mitigation Environmental Assessment. Albuquerque: Albuquerque Bernalillo County Water Utility Authority.

Tamarisk Coalition. 2014. Tamarisk Beetle and Tamarisk Leaf Beetle Monitoring Program. Available at http://www.tamariskcoalition.org/programs/tamarisk-beetle. Accessed December 3, 2013.

Tetra Tech, Inc. 2004. Habitat restoration plan for the Middle Rio Grande. Prepared for Middle Rio Grande Endangered Species Collaborative Program, Habitat Restoration Subcommittee. Albuquerque.

Unitt, P. 1987. Empidonax traillii extimus: an endangered subspecies. Western Birds 18:137–162.

U.S. Army Corps of Engineers (USACE). 2002. Detailed Project Report and Environmental Assessment for Riparian and Wetland Restoration, Pueblo of Santa Ana Reservation, New Mexico. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2004. Bosque Wildfire, New Mexico, Bernalillo and Sandoval Counties, Southwestern Willow Flycatcher 2004 Survey Report. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2005. Bosque Wildfire Project, Southwestern Willow Flycatcher 2005 Survey Report. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2008a. Ecosystem Revitalization @ Route 66, Albuquerque, New Mexico Section 1135 Project. Detailed Project Report and Environmental Assessment. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2008b. Aquatic Habitat Restoration at Santa Ana Pueblo, New Mexico. Environmental Assessment. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2010. Draft Environmental Assessment for the Middle Rio Grande Bosque Restoration Project. Albuquerque: U.S. Army Corps of Engineers, Albuquerque District.

———. 2013. Middle Rio Grande Ecosystem Restoration Project, New Mexico. http://www.spa.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2135/Article/1476/middle-rio-grande-ecosystem-restoration-project-new-mexico.aspx. Accessed December 3, 2013.

U.S. Army Corps of Engineers (USACE), Albuquerque District, U.S Department of Interior, Bureau of Reclamation, New Mexico Interstate Stream Commission. 2006. Upper Rio Grande Basin Water Operations Review: Draft Environmental Impact Statement (URGWOPS). Volumes 1 and 2. January 2006.

———. 2007. Upper Rio Grande Basin Water Operations Review: Final Environmental Impact Statement (URGWOPS). Volumes 1 and 2. April 2007.

U.S. Bureau of Reclamation (USBR). 1999. Biological Assessment, Rio Grande Restoration at Santa Ana Pueblo, Terrestrial Habitat Enhancement Plan. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

———. 2006. Reclamation: Managing Water in the West. Annual Report, Rio Grande Fish Community Surveys. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

———. 2008. Pueblo of Sandia Management of Exotics for the Recovery of Endangered Species Habitat Restoration Project Environmental Assessment. Albuquerque: U.S. Bureau of Reclamation, Albuquerque Area Office.

USDA Plants Database. 2014. http://plants.usda.gov/java/ (accessed 2014).

U.S. Fish and Wildlife Service (USFWS). 2002. Final Recovery Plan Southwestern Willow Flycatcher (*Empidonax traillii extimus*). Southwestern Willow Flycatcher Recovery Team Technical Subgroup. Albuquerque: U.S. Fish and Wildlife Service, Region 2

———. 2003. Biological and Conference Opinions on the Effects of Actions Associated with the Programmatic Biological Assessment of Bureau of Reclamation's Water and River Maintenance Operations, Army Corps of Engineers' Flood Control Operation, and Related Non-Federal Actions on the Middle Rio Grande, Albuquerque. Consultation Number 2-22-03-F-0129. March 17.

———. 2005. Biological Opinion of the Effects of the Middle Rio Grande Riverine Habitat Restoration Project Proposed by the Interstate Stream Commission. Consultation Number 22420-2006-F-02. November 22. Albuquerque: U.S. Fish and Wildlife Service.

———. 2006. U.S. Fish and Wildlife Service's Biological Opinion on the Effects of the Bernalillo Priority Site Project Proposed by the Bureau of Reclamation. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office. May 5, 2006.

———. 2007a. U.S. Fish and Wildlife Service's Biological Opinion on the Effects of the Middle Rio Grande Riverine Habitat Restoration Phase II Project proposed by the Interstate Stream Commission – Correction. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office. January 24, 2007.

———. 2007b. U.S. Fish and Wildlife Service's Biological Opinion on the Effects of the City of Albuquerque's Habitat Restoration Project. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office. February 15, 2007.

———. 2009a. U.S. Fish and Wildlife Service's Biological Opinion on the Effects of the Middle Rio Grande Riverine Habitat Restoration Phase IIa Project Proposed by the Interstate Stream Commission. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office. July 29, 2009.

———. 2009b. U.S. Fish and Wildlife Service's Biological Opinion on the Pueblo of Sandia Bosque Rehabilitation Project. Albuquerque: U.S. Fish and Wildlife Service, New Mexico Ecological Services Field Office. May 14, 2009.

———. 2012. U.S. Fish and Wildlife Service's Biological Opinion and Conference on the Effects of the Albuquerque Bernalillo County Water Utility Authority's San Juan-Chama Drinking Water Environmental Mitigation Project. Consultation Number 22420-2003-F-0146. December 11, 2012.

———. 2013a. Endangered, Threatened, Proposed and Candidate Species of Bernalillo County, New Mexico. Southwest Region Ecological Services. Available at: http://www.fws.gov/southwest/es/EndangeredSpecies/lists/default.cfm. Accessed December 3, 2013.

———. 2013b. U.S. Fish and Wildlife Service's Biological Opinion on the Effects of the Middle Rio Grande Rio Rancho Open Space Habitat Restoration Project. Consultation Number 02ENNM00-2013-F-0029.

U.S. Geological Survey (USGS). 2014. Water data. Available at: http://waterdata.usgs.gov/nm/nwis/uv/?site_no=08330000&PARAmeter_cd=00065,00060. Accessed January 14, 2014.

Valdez, R.A., and S.E. Beck. 2007. Documentation and Quantification of Food Types Available to the Middle Rio Grande Fish Community, New Mexico (2005–2006). Santa Fe: New Mexico Interstate Stream Commission.

Valett M.H., A.M. Baker, A.J. Morrice, C.S. Crawford, M.C. Molles, C.N. Dahm, L.D. Moyer, R.J. Thibault, and L.M. Ellis. 2005. Biogeochemical and metabolic responses to the flood pulse in a semiarid floodplain. Ecol Soc Am 86(1):220–234.

Walker, H.A. 2006. Southwestern avian community organization in exotic Tamarisk: Current patterns and future needs. In Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere, edited by C. Aguirre-Bravo, P.J. Pellicane, D.P. Burns, S. Draggan. September 20–24, 2004. Denver. Proceedings RMRS-P-42CD:274-286.

Waring, G.L., and M. Tremble. 1993. The impact of exotic plants on faunal diversity along a Southwestern river. Unpublished report to the Nature Conservancy.

Watson, J.R. 1912. Plant geography of north central New Mexico. Contribution from the Hull Botanical Laboratory 160:194–217.

Wells, F.H., W.K. Lauenroth, and J.B. Bradford. 2012. Recreational trails as corridors for alien plants in the Rocky Mountains, USA. Western North American Naturalist 72:507-533.

Western Regional Climate Center. 2014. Albuquerque Climate Data. Available at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?nm0222. Accessed January 14, 2014.

Williams, V. David, P. and Fluder, J. 2007. Middle Rio Grande Bosque Community Wildfire Protection Plan. Prepared for the Middle Rio Grande Conservancy District. December 2007. 89pp.

Wolf Engineering. 2008. Draft Technical Memorandum: Rio Grande - Albuquerque Reach Existing Conditions Hydrology and Hydraulic Modeling.

APPENDIX A
HINK AND OHMART (1984) CODE DEFINITIONS

Hink and Ohmart (1984) code definitions. Note that the letters in front of the "/" represent top canopy, and those under the "/" represent lower canopy and understory.

HO2002 Code	Description
C/CW3	Cottonwood/Coyote willow 3
C/CW-RO1	Cottonwood/Coyote willow/Russian olive 1
C/MB1	Cottonwood/Mulberry 1
C/NMO-SC-RO1	Cottonwood/New Mexico olive/Saltcedar/Russian olive 1
C/R01	Cottonwood Russian olive 1
C/RO/SC1	Cottonwood/Russian olive/Saltcedar 1
C/RO1	Cottonwood/Russian olive 1
C/RO1F	Cottonwood/Russian olive 1 flycatcher habitat
C/RO1S	Cottonwood/Russian olive 1 sparse
C/RO3S	Cottonwood/Russian olive 3 sparse
C/RO-CW1	Cottonwood/Russian olive -Coyote willow 1
C/RO-CW1F	Cottonwood/Russian olive -Coyote willow; 1 flycatcher habitat
C/RO-MB1	Cottonwood/Russian olive-Mulberry 1
C/RO-MB3	Cottonwood/Russian olive-Mulberry 3
C/RO-MB-SC1	Cottonwood/Russian olive-Mulberry-Saltcedar 1
C/RO-SC1	Cottonwood/Russian olive-Saltcedar 1
C/RO-SC1S	Cottonwood/Russian olive-Saltcedar 1 sparse
C/RO-SC3	Cottonwood/Russian olive-Saltcedar 3
C/RO-SE1	Cottonwood/Russian olive-Siberian elm 1
C/SC1	Cottonwood/Saltcedar 1
C/SC3	Cottonwood/Saltcedar 3
C/SC3S	Cottonwood/Saltcedar 3 sparse
C/SC-CW5	Cottonwood/Saltcedar-Coyote willow 5
C/SC-RO1	Cottonwood/Saltcedar-Russian olive 1
C2	Cottonwood 2
C4	Cottonwood 4
C-SE2	Cottonwood-Siberian elm
CW5	Coyote willow 5
CW5F	Coyote willow 5 flycatcher habitat
CW6	Coyote willow 6
CW-RO5	Coyote willow- Russian olive 5
LC-C-SE4	New Mexico Locust- Cottonwood-Siberian elm 4
MH5	Marsh Habitat 5
MH5-OW	Marsh Habitat-Open Water 5
MH6	Marsh Habitat 6
OP	Open
OW	Open Water
RO/CW3	Russian olive/Coyote willow 3
RO/CW3S	Russian olive/Coyote willow 3 sparse
RO/NMO-RO3	Russian olive/New Mexico olive-Russian olive 3
RO/RO3	Russian olive/Russian olive 3
RO5	Russian olive 5
RO5S	Russian olive 5 sparse
RO-CW5F	Russian olive-Coyote willow
SC/C3S	Saltcedar/Cottonwood 3 sparse
SC3	Saltcedar 3
SC4	Saltcedar 4
SC5	Saltcedar 5
SC6	Saltcedar 6
SC6S	Saltcedar 6 sparse
SC-RO5	Saltcedar- Russian olive 5
SC-RO-C5S	Saltcedar- Russian olive-Cottonwood 5 sparse
SE/MB-TH3	Siberian elm/Mulberry-Tree of Heaven
SE/RO-CW5	Siberian elm/Russian olive-Coyote willow 5
SE-MB4	Siberian elm-Mulberry 4
TW/CW3	Tree willow/Coyote willow 3