Conceptual Restoration Plan
Active Floodplain of the Rio Grande
San Acacia to San Marcial, NM

Phase III. Concepts and Strategies for River Restoration Activities

Final Report

Prepared for

Save Our Bosque Task Force

Prepared by

Tetra Tech, Inc.
Infrastructure Services Group

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MISSION STATEMENT

The ***SOCORRO SAVE OUR BOSQUE TASK FORCE*** works to preserve, protect, and enhance the Rio Grande river and its adjoining riparian area (bosque, wetlands, grasslands) while respecting the customs and cultures of the residents of Socorro County to provide for public recreation, allow for historical resource use, and plan for public safety, all within the confines of current infrastructure and political limitations.

The task force is composed of but not limited to:

- New Mexico State Forestry
- Middle Rio Grande Conservancy District
- County of Socorro
- City of Socorro
- Natural Resources Conservation Service
- U.S. Bureau of Reclamation
- U.S. Bureau of Land Management
- U.S. Fish and Wildlife Service:
  - Sevilleta NWR
  - Bosque del Apache NWR
- Socorro Soil & Water Conservation District
- Socorro Chamber of Commerce
- Socorro Citizens and Local landowners

With assistance from:

- New Mexico State Police
- New Mexico Department of Game and Fish
- New Mexico Youth Conservation Corp.
- New Mexico Institute of Mining & Technology
- Bosque Improvement Group
- Boy Scouts-USA
- Jornada RC&D
- Tree New Mexico
- Dia del Rio
- Bank of America
- NRAO
- EMRTC

VISION STATEMENT

A riparian ecosystem that functions as natural as possible within the confines of the 21st Century infrastructure and political limitations while respecting the traditional customs and cultures of the citizens of Socorro County.

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Phase III. Concepts and Strategies for River Restoration Activities

Introduction

This document presents the selection criteria for restoration techniques to support a conceptual floodplain restoration plan for the Middle Rio Grande reach from San Acacia to San Marcial. The overall goal of the project is to develop a comprehensive river and floodplain restoration plan for the Rio Grande reach from San Acacia to San Marcial. This report discusses Phase III of a six phase process that includes:

I. Data Collection and Analysis
II. Specific River Issues
III. Development of the Restoration Concepts and Strategies
IV. Development of the Restoration Plan for the Riparian Corridor
V. Preparation of the Monitoring Plan
VI. General Instructions and Information

Phase III builds on the compiled data base and analysis of specific river issues in Phases I and II. The Phase I and II reports were completed and submitted to the Save Our Bosque Task Force. The Phase I scope of work was divided into four general categories and 16 individual tasks. Specific tasks were:

Coordination

- Coordinate First Oversight Committee Meeting
- Prepare a Working Bibliography
- GIS Base Maps

Review of Historical Information

- Compile Historical Maps and Aerial Photos
- Comparative Analysis of Historical Geomorphic and Vegetative Changes
- Compile Historic Hydrographs for USGS Gages
- Coordinate Oversight Committee Review

Fluvial Geomorphology

- Bed Slope Analysis
- Bed Load, Suspended Load and Wash Load Analysis
- Geologic, Geomorphic and Sediment Yield Analysis
- Delineate Subreaches
- Analyze Bed Aggradation/Degradation Trends
- Analyze Overbank Flooding and Flood Frequency
- Display Results on GIS Mapping

Habitat Analysis
- Vegetation Classification and Mapping
- Wildlife Inventory

These four categories encompass the key elements of the river restoration plan including hydrology, geomorphology, biological resources, and water resource development. The intent of Phase I was to compile a database and library of reference material to support future conceptual restoration designs. One of the focuses of the Phase I investigation was to explore river restoration from a historical perspective considering hydrology, channel morphology and vegetation composition. Understanding channel morphology and the changes that occurred in response to water and related land resource development would serve as a basis for exploring restoration opportunities.

In Phase II a number of issues were investigated including flood frequency, sediment loading, channel capacity, areas of high flood potential, restoration components, riparian and aquatic habitat, evapotranspiration, institutional constraints and potential for water salvage. The issues and constraints discussed in the Phase II report would lead to the development of specific project area restoration component designs in Phase IV. The tasks completed in Phase II included:

Channel Capacity
- Determine bankfull discharge by subreach
- Analyze in-channel maintenance flows
- Develop a spring flushing flow hydrograph
- Assess sediment loading for restoration river functions
- Describe problem areas and subreaches for restoration

Identify Areas of High Flood Potential
- Identify flood inundation areas
- High water surface surveys
- Assess flood frequency and channel forming discharges

Characterize Condition of Riparian and Aquatic Habitat
- Assessment of habitat value
- Describe threats
- GIS mapping of habitat
- Assess trends and conditions with and without restoration

Determine Water Budget
- Evaluate ET estimates
- Determine losses associated with overbank flows
- Evaluate groundwater/surface water interface
- Develop a method for determining water salvage

Rio Grande Compact Commitments
- Describe compact commitments
- Assess compact limitations on delivery

Establish Criteria for Restoration Areas
- Identify areas for potential restoration on GIS mapping
- Describe factors contributing to restoration needs
- Determine restoration criteria and constraints
- Analyze geomorphic trends for restoration concepts
- Landownership mapping and constraints
- Groundwater, salt and other factors

Phase III Scope of Work

This report presents the results of the Phase III restoration component selection process that included a matrix evaluation of habitats and restoration techniques. Phase III included the following tasks:

- Completion of an evaluation matrix of habitat values and restoration activities.
- Restoration components linkage based on functionality, geomorphic compatibility, benefits and impacts.
- Prioritizing subreaches, project areas and restoration techniques.
- Presenting the selection process and ranking of the proposed restoration project areas.

Researching site specific details and additional data needs will be accomplished in Phase IV of the project in which the selected restoration components will be linked together in a conceptual plan. The conceptual restoration plan will include a strategy for a phased implementation of the project components and areas. General instructions and implementation design information will be prepared for the plan. Required data to bring the conceptual design to a feasibility design level will also be outlined. A monitoring program and adaptive management strategy will be developed in Phase V of the project.

The Focus of this Document

The focus of this report is to present the ranking of the restoration techniques selected by workshop participants using a matrix evaluation processes. This report will discuss the matrix formulation, the matrix evaluation workshops, analysis of the matrix results and the final ranking of the restoration techniques. It will serve as basis for formulating the conceptual restoration plan by ranking of the subreaches, the habitat values and the restoration techniques.

Restoration Vision

The goal to this project is to create riparian restoration opportunities by establishing favorable hydrogeomorphic conditions in the San Acacia to San Marcial reach of the Middle Rio Grande. Such opportunities may take the form of providing a greater range of flow regimes, enhancing river dynamics, removing constraints on channel processes such as invasive vegetation, expanding the active floodplain, increasing channel floodplain connectivity, physical reformation of the channel geometry, enhancement of the riparian system, and management of the sediment load. The Save Our Bosque restoration vision statement is still evolving. One proposed vision statement outlined at the beginning of the project is:

> *A riparian ecosystem that functions as natural as possible within the confines of 21st Century infrastructure and political limitations while respecting the traditional customs and cultures of the citizens of Socorro County.*

One of the key elements in the restoration plan is "a naturally functioning riparian ecosystem." It is recognized that resource values and utilization change over time and restoration in the San Acacia to San Marcial reach may be integrated with system wide river restoration plans in the future. Sustainable restoration with a reasonable maintenance budget is a long term focus. It is probable that not all restoration objectives will be achieved. Failure of some restoration components is likely and an adaptive management strategy will be necessary to mitigate some of the restoration plan shortcomings.

Background

Extensive background information and data on the biological, morphological and historical resources of the Middle Rio Grande were presented in the Phase I and II reports. A brief synopsis is presented here. Historically the Rio Grande had a natural cycle of removal and regeneration of native plant communities that occurred with flooding and channel migration. Cottonwood bosques existing along the river in varying age groups mixed with salt grass meadows. Woody debris provided coverage and habitat in the river channel. Large flood events filled the valley with ponded water. It is apparent that the wetlands, marshes, open scrublands, alkali flats and meadows were a significant portion of the floodplain community when the Spanish arrived in the 16th Century.

Our knowledge of the pre-historic "natural" Rio Grande floodplain is only anecdotal. With the advent of agriculture in the Rio Grande valley about 1,500 years ago, the native vegetation composition and distribution was gradually altered. Landscape fragmentation occurred with deliberate fires and cropland clearing. Increasing populations (both Pueblo and European) and land cultivation was accompanied by expanded irrigation systems that gradually decreased flows in the system. Eventually upstream reservoir storage attenuated flood peaks and the channel morphology was altered. As seasonal flooding became less frequent and of shorter duration, many of the riparian vegetation regenerative processes were impacted. Prominently missing in the river's hydrologic cycles are the destructive flows that initiated channel migration and bank erosion to remove the riparian vegetation. Gone are the spring flood flows that created the wet substrate in large open areas for germination of native riparian plant species. In response to decreased flooding and reduced sediment loads, the channel has narrowed and the floodplain has become dominated by non-native salt cedar. Over time, the Middle Rio Grande experienced a loss of channel complexity and a loss of channel-floodplain connectivity.

The concept of river restoration in the Middle Rio Grande is to create a mosaic of floodplain vegetation communities and have channel-forming flows of sufficient magnitude and frequency to sustain a wide, active channel. The hydrologic relationship between the channel flows and the flooded bottomlands must be mechanically re-established within the current range of discharges and sediment loads. Flushing flows are needed to rework the channel and scour sediment and vegetation from low velocity habitats. When peak flows are unsuccessful in creating diverse habitat and complex channel features, channel narrowing ensues and aquatic habitat diversity is diminished. Infrequent high flows in excess of bankfull discharge may be required to create the full suite of channel and floodplain features. The key to successful restoration activities is to have the appropriate balance of sediment and water discharge to sustain an active channel.

Subreach Delineation

In Phase II, the San Acacia to San Marcial reach was been divided into three subreaches based on geomorphic trends. Nine project areas within those subreaches were also outlined that will be adjusted in the Phase IV plan development. The San Acacia to San Marcial reach was divided into three subreaches for the purpose of identifying compatible restoration activities for the existing channel morphological trends outlined in Phase I of the restoration study. The three subreaches are:

1. *Escondida Reach* - San Acacia Diversion Dam to the Socorro North Diversion Channel (13.5 miles).

2. *San Antonio Reach* - North Socorro Diversion Channel to the North Boundary Bosque del Apache National Wildlife Refuge (18.5 miles).

3. *Refuge Reach* - North Boundary Bosque del Apache National Wildlife Refuge to San Marcial Bridge (15.6 miles).

The purpose of this delineation was to address similar channel morphology issues for each subreach. Within each subreach, the river has both narrow and wide channel segments, has different stages of an active channel, varying extents of vegetation encroachment and highly variable overbank flooding. Much of the variation in channel morphology has been impacted by river training and maintenance activities including channel relocation and dredging. The entire San Acacia to San Marcial reach has relative uniform sand bed material.

Restoration Technique Matrix Formulation

Restoration technique selection requires a process that identifies those riparian habitats and river geomorphic processes that are most important to the biological diversity of the river. A linked-matrix approach was researched and designed to evaluate riparian habitat values and river functions. Initially, a number of matrix approaches were considered. A linked matrix approach was selected that could be completed by Middle Rio Grande researchers and scientists. This matrix method is similar to that applied to analyze "Priorities for Geomorphology Research in Endangered Fish Habitat of the Upper Colorado River Basin" in 2003 by Argonne National Laboratories, Argonne, Illinois. The Argonne linked matrices were developed with fixed weighting factors that were completed by the Argonne staff. The Tetra Tech staff participated in the workshops that provided input to the Argonne matrices. From these workshops, Tetra Tech formulated the Phase III matrix concepts and methods. The Phase III matrices were different from Argonne matrices by using variable weighting factors and a workshop approach allowing researchers to complete the matrices.

A series of three workshops were organized to introduce researchers to the matrices and to collaboratively discuss restoration issues. The first workshop, 'Planning Workshop No. 1: Planning Matrix Design and Components', was held on May 13, 2003. Over 40 people attended the first workshop. The Workshop consisted of the following:

- Overview of the CRP Project, Restoration Strategy, Purpose of the Workshops.
- Description of Three Workshop Process, Concept of the Planning Matrix.
- Discussion of Planning Matrix Assumptions, Definitions, Constraints and Opportunities.
- Review Reach Attributes and Delineations, Subreach Delineations, Habitat Descriptions.
- Discussion of Matrix Constructs, Linkage and Weighting Factors.

A Biology Workshop to discuss habitat issues and A Geomorphology Workshop to discuss river and floodplain issues were held on June 17 and 19 respectively. During these workshops, discussions were enjoined on the matrix component attributes and habitat and morphology definitions. Suggestions to revise the matrix factors and definitions were incorporated into the documentation and distributed to the workshop participants. The revisions were divided into matrix structure revisions and editorial changes.

Matrix Structural Revisions

Use the following references to review the changes made to the matrices:

M1 = Physical Importance Matrix – Worksheet 1
M2 = Habitat Value Matrix – Worksheet 2
M3 = Resource Use Matrix – Worksheet 3
M4 = Benefits Matrix – Worksheet 4
M5 = Adverse Impacts Matrix – Worksheet 5
M6 = Techniques Matrix – Worksheet 6
M7 = Ranking Matrix – Worksheet 7

1. M1, M2, M3. Replaced 'Pools' and 'Riffles/Runs' in Main Channel Habitat with 'Single Thread Channel' and 'Multiple Channels (braided at low flows)'.

2. M1, M2, M3. Revised Channel Characteristics to the following categories:

   Hydraulic Variability/Morphology Complexity
   Inter-annual Stability
   Intra-annual Stability

3. M4. Revised column title 'Create Water Salvage' to 'Create Water Salvage/Lessen Drought Effects'.

4. M5. Added column to Impacts titled 'Increase Drought Impacts'.

5. M5. Changed 'Accessibility' Column to 'Increase Exotic Herbaceous Species'.

6. M7. Added column to Ranking titled 'Regulatory Constraints'.

7. M4, M5, M6. Removed row 'Recreational Access' under 'Floodplain Activities'.

8. M4, M5, M6. Removed row 'Sediment Plug Removal' under 'Channel Activities'.

9. M2, M3. Relative Occurrence for the new categories of 'Single Thread Channel' and 'Multiple Channels' were edited.

10. M6. The original six riparian habitats that included:

    Mature cottonwood bosque
    Mature willow forest
    Mid-aged cotton-willow /salt cedar-Russian olive
    Monotypic salt cedar stands
    Young successional stage stands
    Wetlands

These classifications were edited and expanded to include the following columns:

Cottonwood bosque
Willow forest
Mixed stands
Monotypic salt cedar stands
Young success ional stage stands
Grasslands, savannah, alkali shrub
Groundwater wetland
Surface water wetland

Matrix Editorial Revisions

The following editorial changes were made to the matrix worksheets.

1. M1, M2, M3. Added to Shorelines '(banks and sandbars)' to indicate that shoreline habitat includes both river margin shoreline and channel sandbar shoreline.

2. M1, M2, M3. A light green background was added to distinguish channel habitat from riparian habitat.

3. M4. Changed column title "Increase groundwater storage" to "Increase groundwater connectivity".

4. M5. Changed column title 'Potential flood impacts' to 'Increase flood impacts'.

5. M1, M2, M3. Habitat 'attributes' was changed to habitat 'features' where appropriate.

6. M1, M2, M3. Riparian habitat names were edited and the definitions changed in the handout to match suggestions made at the workshop.

The workshop participants were requested to complete the Excel worksheet matrices using selected weighting factors that reflected their value assignments. Variable sets of weighting factors were created to assign qualitative values to the following matrix groups:

- Geomorphic, hydrologic, habitat attributes and their relative occurrence;
- Resource use impact;
- Technique contribution to restoration;
- Restoration technique issues;
- Capital cost, maintenance, expected life factors.

The spreadsheet linkages and the mathematical operations used to calculate reach habitat value and restoration technique ranking involved a series of seven worksheets:

- Determine habitat value by reach - habitat attribute scoring;
- Resource use impact on habitat attributes by reach - relative impact scoring;
- Compute overall habitat attribute value by reach weight;
- Restoration technique contribution to restoration goals/objectives - relative restoration technique weight;
- Determine restoration technique value to habitat;
- Determine restoration technique value by reach and final restoration technique ranking.

The Tetra Tech staff generated the relative occurrence of the various habitat types and attributes using GIS mapping data base and aerial photos. Estimates of some of the acreages or reach lengths were necessary because of limited data, infrequent occurrence of the habitat type or mixed habitat conditions (overlapping vegetation stands). The relative occurrence of the various habitat types were input into Matrix worksheets 2 and 3 prior to the distribution of the linked matrix to the workshop participants.

Linked Matrix Analyses to Determine Restoration Priorities

The steps for completing the linked matrix are outlined below. Attribute scores were multiplied by reach occurrence to determine the habitat value in most cases. These overall values, in turn, were summed or multiplied after applying weighting factors to determine overall reach priorities.

Step-by-Step Matrix Outline

Step 1. Determine Habitat Value By Reach

Worksheet 1. Physical Importance

Worksheet 2. Habitat Value

Geomorphic and Hydrologic Relationship to Habitat Attributes + Reach Delineation of Habitat Value X Relative Occurrence in Reach

= **Habitat Attribute Scoring**

Worksheet 2. Habitat Value

Step 2. Evaluate Resource Use Impact on Habitat Attributes by Reach

Worksheet 3. Resource Use

Resource Use Impact X Relative Occurrence in Reach

= **Relative Impact Scoring**

Step 3. Compute Overall Habitat Attribute Value by Reach

Worksheet 3. Resource Use

Habitat Attribute Scoring - Potential Impact Scoring =

Relative Habitat Value and Reach Weight

Worksheet 4. Contributions

Technique Contribution to Restoration

-

Worksheet 5. Issues

Restoration Technique Issues

=

Relative Restoration Technique Weight

Worksheet 5. Issues

Step 4. Restoration Technique Contribution to Restoration Goals/Objectives

Step 5. Determine Restoration Technique Value to Habitat

Worksheet 5. Issues

Restoration Technique Weight

x

Worksheet 3. Resource Use

Relative Habitat Value

x

Worksheet 6. Techniques

Restoration Effect on Habitat Scoring

=

Restoration Technique Value

Worksheet 6. Techniques

Step 6. Determine Restoration Technique Value by Reach

Worksheet 6. Techniques

Restoration Technique Score

x

Worksheet 3. Resource Use

Reach Weight

=

Worksheet 7. Ranking

Restoration Activity Value by Reach

x

Worksheet 7. Ranking

Capital Cost, O & M, Expected Life Factors, Regulatory Constraints

=

Final Restoration Technique Ranking

Worksheet 7. Ranking

The matrix spreadsheets were created to have variable scores such as 0.0, 0.2, 0.5, 1.0 or 0., 0.1, 0.2, 0.3 to represent relative importance of (1) dependencies between habitat characteristics and hydrologic and geomorphic parameters, (2) reach habitat value, (3) relative habitat occurrence within the reach, and (4) restoration activity value. Each of the four scores was assigned a ranking value of 1 to 4. The actual scores were hidden in the worksheet. The weighting factors were designed to permit flexibility in scoring. Different sets of weighting factors could be applied on different worksheets to illustrate the importance of a particular habitat value or restoration technique in the linked matrix sequence. This scoring system combines quantitative values (e.g., percentage of relative occurrence) with a qualitative scoring where adequate data are not consistently available for habitat types and values.

The basic steps to fill in the ranking matrix were:

1. Start with the first Matrix 'Physical Importance' and use the horizontal and vertical slides to adjust the matrix display to view the possible weighting factors at the top of the spreadsheet.
2. Select a Weighting Factor Method by inputting a value of 1 to 4 in the 'Selected Method' red highlighted box just above the matrix.
3. Assign weighting factors in one of the empty columns of the weighting factor table or change weighting factors one at time while completing any of the matrices. The weighting factors were only applicable to the spreadsheet matrix that was displayed. Each matrix had its own set of weighting factors.
4. Proceed to fill in the matrix by changing the value of '1' in the matrix cells (or leave '1' in the cell). A table of definitions for each of the listed habitat factors, impact or restoration techniques was provided along with a list of assumptions and other general information to assist in the matrix selection process.
5. Complete all the matrices by entering a value in all cells with a '1'.
6. Review the ranking and adjust any of the weighting factors.

Matrix Assumptions and Definitions

The restoration matrix criteria required an understanding of how the restoration technique would benefit the restoration objectives of enhanced river function and increased habitat diversity. In addition, a separate worksheet focused on constraints, potential impacts and areal limitations on the restoration components. In this manner restoration activities that have severe constraints could receive the lowest priority matrix ranking.

Assumptions

A number of assumptions were inherent to the matrix evaluation. These include assumptions regarding administrative and legal issues, hydrologic, geomorphic and hydraulic concerns, biological and ecological factors and specific assumptions related to the matrix construction.

<u>General Assumptions</u>

Administrative/Legal:

- Funding is not a consideration in the selection of restoration activities except where cost is identified as a factor in the matrix.
- Proposed restoration projects will not interfere with or be adversely impacted by other restoration projects.
- Private land ownership will not constrain the restoration activities except where identified as a factor in the matrix.
- Project management and coordination between the agencies is not a consideration.
- Restoration maintenance will be adequate for the life of the project except where noted as a factor in the matrix.

Hydrologic

- Water availability will not be consideration in the selection of restoration activities except where identified as a factor in the matrix.
- Groundwater hydrology will not limit the selection of restoration projects. The lack of groundwater data limits the opportunity to consider groundwater hydrology in more detail.
- Selection of habitat restoration projects assumes that water will be available to meet Rio Grande Compact deliveries.
- The inter-connectivity between the river and Low Flow Conveyance Channel (LFCC) is a concern with respect to project selection and should be considered in the matrix evaluation.

Geomorphic/Hydraulic

- The selection of restoration techniques should not be affected by the future disposition or operation of the LFCC.
- The final restoration plan selection will incorporate the Bureau of Reclamation's new pilot channel.
- Investigations related to the San Acacia diversion dam that could affect future restoration activities will not be considered in this matrix analysis.
- Levee rehabilitation in the San Acacia reach that could affect future restoration activities will not be considered in this matrix analysis.
- Potential future operations of the LFCC that could affect future restoration activities will not be considered in this matrix analysis.
- San Marcial Railroad Bridge conveyance capacity or possible relocation will not be considered in this matrix analysis.
- Investigations of the river relocation downstream of San Marcial will not be considered in the matrix analysis.
- Long term sediment supply concerns are an issue the matrix evaluation.

Biological and Ecological

- All planned restoration projects would consider potential effects on endangered species habitat.
- Removal of exotic vegetation coupled with re-establishing native vegetation would be considered habitat enhancement for the southwestern willow flycatcher.
- None of the restoration components would result in a decrease in low flow habitat.
- A focus of the restoration project would be to reduce the stress on the agricultural community to provide suitable wildlife habitat.
- Fire management for old growth cottonwood/willow bosque would be considered in the restoration plan.

Specific Matrix Assumptions

Not every hydrologic variable, habitat value, geomorphic trend, management issue or resource use impact could be folded into the matrix analysis. The intent was to address the major variables, values, trends, issues and impacts as well as the primary restoration activities such that the conceptual restoration plan would be focused and flexible. The goals and objectives of the restoration plan are represented in the matrix design. Several assumptions with the matrix construct are:

- Sediment bed material size in the San Acacia to San Marcial is relatively uniform and is not anticipated to change during the life of the project.
- Different scales of habitat values could be considered such as a geomorphic scales (reach wide slope variation), macro scales (sand bar habitat) or meso scales (backwater habitats). The user could consider the appropriate scale in applying the ranking values.
- Biological Opinion requirements could be considered when working through the matrix.
- Habitat enhancement objectives include habitat sustainability over the long term.
- Incidental impacts on other native or endangered species or habitat could be considered as an adverse effect.
- Private and agency land issues may include permitting and monitoring requirements.
- Supplemental water requirements such as pumping or groundwater extraction to mitigate project demands could be considered as a water loss.

Any habitat values, restoration activities, or impacts that were identified as critical to the restoration prioritization could be considered in the matrix evaluation.

Each of the seven matrices (represented by a worksheet) in the Excel spreadsheet were designed to answer a specific question:

Matrix M1. Physical Importance. 'What is the relative importance of the various geomorphic and hydrologic variables to habitat conditions, dynamics diversity and sustainability?'

Matrix M2. Habitat Value. 'What is the value of habitat features and attributes to endangered species and habitat diversity?'

Matrix M3. Resource Use. 'How do various resource uses adversely impact the habitat features.'

Matrix M4. Benefits. 'What is the benefit on the restoration techniques and activities to the restoration goals and objectives?'

Matrix M5. Adverse Impacts. 'What are the potential adverse impacts related to implementing the different restoration techniques and activities?'

Matrix M6. Techniques. 'How will the restoration techniques and activities enhance or impact the different channel and riparian habitats?'

Matrix M7. Ranking. 'What restoration techniques and activities should be considered as highest priority for planning purposes in the San Acacia to San Marcial reach of the Middle Rio Grande?'

Definitions

Definitions of the primary categories and variables in the matrices are presented in the following tables.

HABITAT FEATURES	
Main Channel Features	
Single thread channel	A single channel when most of the channel bottom has been inundated. May have some exposed sandbars. Evidence of a continuous single channel deep thalweg.
Multiple channel (braided at low flows)	A number of exposed sandbars at moderate flows covering the channel bed. Appears braided at a moderate or low flow condition.
Channel Margin Features	
Connected backwaters	Backwater channel with a blocked inlet at lower flows and connected outlet with the channel.
Secondary or multiple channels	Split flow or braided channels within the main channel.
Shorelines (banks and sandbars)	Shallow water habitat area along the channel or island margins, typically sand, roots or grass. Includes the shoreline habitat associated with both banks and sandbars.
Off-Channel Features	
Flooded bottomlands	Area on the river floodplain with standing water. May be a remnant channel feature, depression or floodplain terrace.
Overbank side channels	Small, isolated channel on the floodplain that may reconnect with the channel downstream.
Riparian Habitat Features	
Cottonwood bosque	Native woodlands characterized by an overstory of cottonwood and black willow with understories of New Mexico olive, screwbean mesquite, and seepwillow. May include an understory of either sparse or dense Russian olive and/or salt cedar.
Willow forest	Black willow trees with salt cedar understory. Occurs in only a small portion of the bosque (~65 acres).
Mixed Stands	A vegetation community with five sub-types, ranging from native communities of cottonwoods and willows to dense nonnative species communities such as Russian olive.
Monotypic salt cedar stands	A vegetative community composed almost exclusively of introduced salt cedar.
Young successional stands	This community includes early stages of revegetation that may occur in areas previously disturbed by fire, vegetation clearing and active sandbars. Some sandbars may have established stands of cottonwood, coyote willow, salt cedar, and Russian olive. Includes grasslands, savannahs, alkali scrub.
Wetlands (groundwater and surface water)	Includes marshes, wet meadows, and open water habitats that may be supported by either groundwater or surface water. Wetlands were historically a significant part of the Middle Rio Grande floodplain biological community commonly the result of flooding and channel migration.

HABITAT DEPENDENCIES ON CHANNEL MORPHOLOGY AND RIVER HYDROLOGY	
Channel Morphology	
Width/depth	Channel width divided by the thalweg depth. In the MRG higher width/depth is favorable to restoring habitat.
Slope	River bed slope as measured by the thalweg. A mild slope, meandering river pattern is preferable in MRG.
Sinuosity	Measure of river meandering; channel length divided by valley length. A higher sinuosity is preferable in the MRG.
Arroyo Impact	Arroyos can effect channel planform and slope control. Arroyo confluences may enhance aquatic habitat in a reach.
Sediment Transport	
Main Channel Supply	Long term sediment supply in the MRG from upstream sources; may control some channel morphology features.
Arroyo Supply	Local sediment supply to a reach; may control local bed material size and channel slope.
Bed Material Size	The dominant size of sediment in the bed; primarily fine to medium sand in this reach of the MRG.
High Flow Hydrology	
Peak Flow Magnitude	Highest discharge that occurs during spring runoff.
Peak Flow Duration	Spring-runoff period or the length of time above a threshold flow (e.g., bankfull flow).
Peak Flow Frequency	Percentage of years that the annual peak flows exceed a given threshold flow.
Peak Flow Timing	Date of spring runoff peak discharge. Important for cottonwood seed dispersal and germination.
Peak Flow Variability	Variation in peak-flow magnitude from year to year (inter-annual) or variation during runoff period (intra-annual).
Base Flow Hydrology	
Base Flow Magnitude	Discharge level during the base-flow period.
Base Flow Duration	Length of time from the start of base flow in early summer and to the start of snowmelt runoff in the following spring.
Base Flow Timing	Date of the onset of the base-flow period.
Base Flow Variability	Variation in base-flow magnitude from year to year (inter-annual), within years (intra-annual) and within-days.

HOW TO MEASURE VALUE OF HABITAT ATTRIBUTES	
Endangered Species	Is the habitat attribute critical to the survival of endangered species? Does the habitat community provide endangered species habitat? Can the endangered species use other habitat?
Native Species	How important is the habitat attribute to the overall biological diversity of habitat to all native species? Is this habitat attribute unique in its use by native species?
Biological Diversity	Is the habitat attribute an important component of biological diversity in a reach? Does the attribute fill a critical niche in the biological diversity of a riparian area?
Habitat Regeneration	Is the habitat attribute important to the regeneration of native species in the area?
Habitat Dynamics	Does the habitat attribute play a role in the biological succession in a reach or area?
Habitat Sustainability	Is the habitat attribute important to the long term biological integrity of a given reach?

IMPORTANT HABITAT CHARACTERISTICS	
Size and Number	Provides an indication of the amount of habitat available in terms of individual size and number of available habitats.
Connections	Related to river habitat such as pools. Are the pool or riffle habitats connected or isolated?
Intra-annual Stability	Are the individual habitats stable through the year from high flow through low flow?
Form – Braided	Riffles and runs through active, mobile channel sand bars.
Inter-annual Availability	Habitat availability from year to year.
Complexity	Variability in the habitats including sand substrate, flow depth and velocity, roots, vertical and overhanging banks, vegetation.
Daily Stability	Habitat variability throughout the day. Is the habitat dry or non-existent with diurnal variation?
Bank Composition	Habitat related to substrate, vegetation, roots.
Ground Composition	Includes substrate, forest litter, sediment size.
Availability and Timing	Is the habitat available when required for lifestage or regeneration?
Connectivity	Refers to hydrological connectivity. Can the habitat be flooded?
Size and Density	Identifies the vegetation age group and density.
Connectivity/floodability	Refers to hydrologic connectivity and flood frequency.
Floor Litter	Density of floor organic material within a given habitat group.
Understory Diversity	Density of the predominant understory vegetative community.
Recruitment	Potential for habitat regeneration.
Sediment Deposition	Overbank flooding results in sediment deposition.
Habitat Availability	Provide fauna habitat.

HOW TO MEASURE RESOURCE USE IMPACT ON HABITAT ATTRIBUTES	
Land Ownership	How does landownership affect maximizing habitat availability or enhancement?
Water Diversion/Use	Does water diversion for irrigation or domestic use impact habitat availability or enhancement?
Levees	Do the levees restrict channel migration and thereby impact habitat availability? Do the levees result in a loss of habitat?
Jack Lines	Do the jack lines fragment habitat or limit channel migration? Do jack inhibit accessibility for restoration?
Fire Hazard	Are the habitat communities subject to fire hazard because of management practices?
Water Loss	Is there potential for additional water loss in order to improve biological diversity of habitats?
Resource Management	How does resource management impact habitat availability or enhancement?

DESCRIPTION OF RESTORATION TECHNIQUES	
Channel Activities	
Disc and mow sand bar vegetation	Remove and eliminate vegetation on active sand bars in the river.
Plow and rake islands	Islands are stable features and have to be reworked to enable the river to absorb them.
Remove bank vegetation (deformable bank lines)	Stabilizing bank vegetation (particularly tamarisk and Russian olive) would be removed to enhance channel migration.
Destabilize and lower banks (terrace lowering)	Remove vegetation, lower terraces with plowing to increase flooding.
Channel widening (bank destabilization)	Remove vegetation and rework channel banks into the channel to widen the river.
Create high flow side channels	Secondary channels would be cut into the floodplain to enhance overbank flooding.
Cut pilot channels (initiate channel avulsions)	Pilot channels would be developed to encourage channel migration and initiate avulsions.
Channel realignment	This involves moving the river away from the LFCC to reduce channel seepage.
Placement of large woody debris	The placement of large woody debris piles encourages bank instability and channel migration.
Reconnect oxbow and old channels	Relocating the channel to the east, enhance wetland connections and increase sinuosity.
Training dikes/spurs/rock weirs	Features to enhance relocation or stabilize the location of newly constructed channels.
Raise channel bed (grade restoration facilities)	Improve overbank flooding, eliminate channel incision.
Curve and bank shaping	Stabilize channel locations, improve bank configurations.
Sediment management (increase sediment loading)	Enhance channel migration, increase width to depth ratio.
Floodplain Activities	
Remove exotic vegetation (selective and clear cut)	Open floodplain for regeneration and recruitment of native vegetation species.

Plant and seed native vegetation	Encourage regrowth of native vegetation on reworked riparian floodplains.
Create wetlands and marshes	Enhance overbank flooding in old meander bends and other floodplain depressions.
Variable floodplain topography	Rework floodplain terraces to enhance overbank floodplain and create floodplain diversity.
Create flooded bottomlands	Create and enhance channel/floodplain hydrologic connectivity.
Enhance groundwater storage and interaction	Channel relocations/overbank flooding can improve groundwater storage and wetland creation.
Woody debris removal (mechanical)	Reduce fire hazard by eliminating dense woody debris and down timber.
Remove jetty jacks	Increase channel mobility, improve floodplain habitat by reducing fragmentation.
Manage livestock grazing	Improve native vegetation distribution.
Create larger floodplain corridor - stabilize levees	Reduce the potential adverse impact of enhancing channel migration.
Eliminate structural limitations on flooding	Remove structures that limit the prescribed peak discharges from reservoir releases.
Manage future development	Keep development off the active floodplain to avoid flood impacts (e.g. conservation easements).
Water Management	
Spring flushing flows	Enhance the magnitude, duration, frequency, timing and variability of spring flushing flows.
Fall maintenance flows	Management of fall flows to enhance reworking the active channel and sand bars.
LFCC low flow return to channel	Increase and optimize LFCC return flows to the river channel during low flow conditions.
Increase frequency/duration of flooding	Manage Cochiti releases (and other reservoirs) to improve flood frequency and duration.
Time flood with seed dispersal	Manage reservoir spring releases to coincide with cottonwood seed dispersal.
Increase groundwater storage on east side	Raise groundwater levels with overbank flooding on the east side of the river.

ANALYZING POTENTIAL RESTORATION ADVERSE IMPACTS	
Reduce Channel Dynamics	Does a restoration activity reduce channel activity (e.g. channelization or bank stabilization)?
Increase Flood Impacts	Does increased peak flow frequency, duration or magnitude impact structures or infrastructure?
Increase Drought Effects	Will the restoration activity result more frequent or longer duration low flows or dry channels or effect floodplain habitat?
Levee Stability Issues	Does the restoration activity increase potential to migrate and erode levees?
Potential Channel Incision	Is channel incision a potential ramification of the restoration activity?
Increase in Water Loss	Is increased water loss through ET or surface water evaporation a possibility?
Channel Narrowing/Vegetation Encroachment	As a result of the restoration activity, is the channel likely to have increase vegetation encroachment and potential channel narrowing?
Private Land/Grazing Issues	Will the restoration activity negatively affect private land or grazing?
Impact on Aquatic Habitat	Is the restoration activity likely to have any negative effects on aquatic habitat (e.g. decreased low flows)?
Increase Exotic Herbaceous Species	Will restoration increase proliferation of exotics such as perennial pepperweed or Russian knapweed?
Fire Hazard Issues	Will the restoration activity increase the potential fire hazard (e.g. increase bosque litter)?
Negative Impact on Endangered Species	Are any adverse impacts on endangered species expected?

Matrix Results

A total of fourteen completed matrices were submitted by the various agency personnel, private citizens and researchers. To compare the various matrix results, the scoring for the individual matrix results were totaled and the percentage scoring assessed. By reducing the scores to a scalar percentage, all the individual scores could be compared. The following table rankings constitute an average percentage of the total score for each submitted matrix.

The conceptual restoration plan will incorporate opportunities for enhancing habitat diversity in all subreaches. The implementation of a specific restoration activity in a given subreach may based on the subreach ranking. The three subreaches were ranked or weighted based on habitat attributes. The ranking score was derived from the last column in Matrix Worksheet 3 that reflected the habitat value minus the potential resource impacts. The results are shown in the following table:

SUBREACH RANKING		
	average	std. dev.
Escondida	27.8	8.44
San Antonio	34.9	6.50
Refuge	37.3	8.18

The Refuge subreach ranks as having the highest habitat value but the San Antonio reach had the most consistent scoring based on the standard deviation. The scoring between these two reaches is not significantly different. The Escondida subreach was ranked substantially lower in habitat value. These results indicate that certain preferred restoration activities should be focused on the San Antonio and Refuge subreaches. This subreach ranking was generally expected based on the incised channel and hydrologically disconnected floodplain of the Escondida subreach.

The habitat value by subreach and habitat type is displayed in the Subreach Habitat Value table. This table reveals habitat ranking of the various habitat type existing conditions. The San Antonio and Refuge main channel habitats along with the San Antonio wetlands and marshes scored significantly higher than the other habitat types. Some habitat types scored low because there was little or no frequency of occurrence in a given subreach not because the habitat was not preferred. The habitat ranking shown in this table is embedded in the restoration technique scoring. It is important to note that the Escondida subreach habitat types scored consistently at the bottom of the table reflecting the subreach ranking in the previous table.

SUBREACH HABITAT VALUE			
Subreach	**Habitat Type**	**Habitat Attributes**	**Score**
San Antonio	*Main channel habitats*	Multiple thread channels (braided at low flows)	8.19
San Antonio	*Wetlands*	Marshes, wet meadows	7.27
Refuge	*Main channel habitats*	Multiple thread channels (braided at low flows)	7.24
Escondida	*Young successional stage stands*	Fire, vegetation clearing, sandbars	5.87
Refuge	*Main channel habitats*	Single thread channels	5.65
Refuge	*Young successional stage stands*	Fire, vegetation clearing, sandbars	5.43
San Antonio	*Young successional stage stands*	Fire, vegetation clearing, sandbars	5.39
Escondida	*Cottonwood bosque*	New Mexico olive, seepwillow understory	4.99
Escondida	*Main channel habitats*	Multiple thread channels (braided at low flows)	4.92
Escondida	*Main channel habitats*	Single thread channels	4.64
Refuge	*Wetlands*	Marshes, wet meadows	3.83
San Antonio	*Cottonwood bosque*	New Mexico olive, seepwillow understory	3.68
San Antonio	*Main channel habitats*	Single thread channels	3.62
Escondida	*Wetlands*	Marshes, wet meadows	3.46
Refuge	*Cottonwood bosque*	New Mexico olive, seepwillow understory	3.17
Refuge	*Monotypic salt cedar stands*		2.21
Refuge	*Off channel habitats*	Flooded bottomlands	2.13
Refuge	*Channel margin habitats*	Secondary or multiple channels	2.07
Refuge	*Off channel habitats*	Overbank side channels	1.91
San Antonio	*Mixed Stands*	Five sub-types	1.70
Escondida	*Mixed Stands*	Five sub-types	1.49
Refuge	*Mixed Stands*	Five sub-types	1.47
Refuge	*Channel margin habitats*	Connected backwaters	1.18
San Antonio	*Off channel habitats*	Flooded bottomlands	0.95
San Antonio	*Monotypic salt cedar stands*		0.95
San Antonio	*Off channel habitats*	Overbank side channels	0.90
San Antonio	*Channel margin habitats*	Shorelines (banks and sandbars)	0.89
Escondida	*Channel margin habitats*	Secondary or multiple channels	0.85
San Antonio	*Channel margin habitats*	Secondary or multiple channels	0.74
Refuge	*Channel margin habitats*	Shorelines (banks and sandbars)	0.73
Escondida	*Monotypic salt cedar stands*		0.72
Escondida	*Channel margin habitats*	Shorelines (banks and sandbars)	0.55
San Antonio	*Channel margin habitats*	Connected backwaters	0.55
Escondida	*Channel margin habitats*	Connected backwaters	0.41
Refuge	*Willow forest*	Mature black willow w/salt cedar understory	0.25
Escondida	*Off channel habitats*	Flooded bottomlands	0.00
Escondida	*Off channel habitats*	Overbank side channels	0.00
Escondida	*Willow forest*	Mature black willow w/salt cedar understory	0.00
San Antonio	*Willow forest*	Mature black willow w/salt cedar understory	0.00

The restoration technique ranking considers habitat values, reach weight, habitat value benefits and impacts. The ranking for all restoration activities in all subreaches is shown in the following table. The average score (or ranking) is based on a percentage of the total restoration technique score submitted on each completed matrix. The sum of the scores for each individual matrix and for the combined average scores in the following table is equal to 100%. The standard deviations associated with each restoration technique and the 95% confidence intervals are also displayed.

RESTORATION TECHNIQUE RANKING – ALL SUBREACHES					
Restoration Technique	Subreach	Average Score	Standard Deviation	95% Confidence Interval	
1. Spring flushing flows	Refuge	2.78	1.13	2.188	3.372
2. Spring flushing flows	San Antonio	2.74	1.12	2.153	3.327
3. Eliminate structural limitations on flooding	Refuge	2.60	1.69	1.715	3.485
4. Manage future development	Refuge	2.40	1.82	1.446	3.354
5. Eliminate structural limitations on flooding	San Antonio	2.31	1.23	1.666	2.954
6. Increase frequency/duration of flooding	San Antonio	2.30	1.23	1.656	2.944
7. Remove exotic vegetation (selective and clear cut)	San Antonio	2.25	1.73	1.343	3.156
8. Increase frequency/duration of flooding	Refuge	2.24	0.91	1.763	2.717
9. Spring flushing flows	Escondida	2.22	1.24	1.570	2.870
10. Remove exotic vegetation (selective and clear cut)	Refuge	2.22	1.32	1.528	2.912
11 Manage future development	San Antonio	2.13	1.11	1.548	2.712
12. Increase frequency/duration of flooding	Escondida	1.87	0.90	1.398	2.342
13. Eliminate structural limitations on flooding	Escondida	1.85	1.31	1.164	2.536
14. Remove exotic vegetation (selective and clear cut)	Escondida	1.75	1.55	0.938	2.562
15. Create wetlands and marshes	Refuge	1.71	1.12	1.123	2.297
16. Create wetlands and marshes	San Antonio	1.67	1.20	1.041	2.299
17. Manage future development	Escondida	1.66	1.11	1.078	2.242
18. Enhance groundwater storage and interaction	Refuge	1.56	1.68	0.680	2.440
19. Plant and seed native vegetation	San Antonio	1.55	1.75	0.633	2.467
20. Create flooded bottomlands	Refuge	1.51	0.94	1.017	2.003
21. Plant and seed native vegetation	Refuge	1.48	1.40	0.747	2.214
22. Create flooded bottomlands	San Antonio	1.46	1.09	0.889	2.031
23. Variable floodplain topography	Refuge	1.46	1.02	0.926	1.994
24. Reconnect oxbow and old channels	San Antonio	1.39	0.73	1.008	1.773
25. Channel widening	Refuge	1.36	1.10	0.784	1.936
26. Increase groundwater storage on east side	Refuge	1.35	1.30	0.669	2.031
27. Reconnect oxbow and old channels	Refuge	1.35	0.54	1.067	1.633
28. Destabilize and lower banks (terrace lowering)	Refuge	1.33	0.94	0.838	1.823
29. Plant and seed native vegetation	Escondida	1.31	1.74	0.398	2.222
30. Create wetlands and marshes	Escondida	1.30	1.00	0.776	1.824
31. Channel widening	San Antonio	1.27	1.08	0.704	1.836
32. Fall maintenance flows	San Antonio	1.27	1.03	0.730	1.810
33. Destabilize and lower banks (terrace lowering)	San Antonio	1.25	0.99	0.731	1.769
34. Time flood with seed dispersal	San Antonio	1.25	0.90	0.779	1.722
35. Variable floodplain topography	San Antonio	1.23	0.54	0.947	1.513
36. Increase groundwater storage on east side	San Antonio	1.21	1.00	0.686	1.734
37. Enhance groundwater storage and interaction	San Antonio	1.21	0.87	0.754	1.666
38. Fall maintenance flows	Refuge	1.20	0.92	0.718	1.682
39. Time flood with seed dispersal	Refuge	1.17	0.65	0.829	1.511
40. Reconnect oxbow and old channels	Escondida	1.16	0.82	0.730	1.590
41. Fall maintenance flows	Escondida	1.05	1.03	0.510	1.590
42. Create flooded bottomlands	Escondida	1.04	0.65	0.699	1.381
43. Time flood with seed dispersal	Escondida	1.04	0.93	0.553	1.527
44. Create high flow side channels	Refuge	1.01	0.78	0.601	1.419
45. Variable floodplain topography	Escondida	1.00	0.60	0.686	1.314
46. Destabilize and lower banks (terrace lowering)	Escondida	1.00	0.97	0.492	1.508
47. Create high flow side channels	San Antonio	0.96	0.84	0.520	1.400

48. Remove bank vegetation (deformable banklines)	Refuge	0.95	0.99	0.431	1.469
49. Increase groundwater storage on east side	Escondida	0.94	0.95	0.442	1.438
50. Enhance groundwater storage and interaction	Escondida	0.94	0.71	0.568	1.312
51. Channel widening	Escondida	0.93	0.96	0.427	1.433
52. Sediment management (increase sediment loading)	Refuge	0.85	0.75	0.457	1.243
53. Remove bank vegetation (deformable banklines)	San Antonio	0.85	0.83	0.415	1.285
54. Sediment management (increase sediment loading)	San Antonio	0.85	0.73	0.468	1.233
55. Raise channel bed (grade restoration facilities)	Refuge	0.82	0.81	0.396	1.244
56. Create larger floodplain corridor - stabilize levees	Refuge	0.80	0.77	0.397	1.203
57. Create larger floodplain corridor - stabilize levees	San Antonio	0.78	0.61	0.460	1.100
58. Create high flow side channels	Escondida	0.78	0.77	0.377	1.183
59. Sediment management (increase sediment loading)	Escondida	0.77	0.74	0.382	1.158
60. Cut pilot channels (initiate channel avulsions)	Refuge	0.77	0.83	0.335	1.205
61. Create larger floodplain corridor - stabilize levees	Escondida	0.73	0.62	0.405	1.055
62. Raise channel bed (grade restoration facilities)	San Antonio	0.69	0.67	0.339	1.041
63. Cut pilot channels (initiate channel avulsions)	San Antonio	0.68	1.02	0.146	1.214
64. Manage livestock grazing	Refuge	0.65	0.65	0.309	0.991
65. Raise channel bed (grade restoration facilities)	Escondida	0.62	0.73	0.238	1.003
66. LFCC low flow return to channel	Refuge	0.59	0.70	0.223	0.957
67. Manage livestock grazing	San Antonio	0.59	0.62	0.265	0.915
68. Remove jetty jacks	Refuge	0.59	0.67	0.239	0.941
69. LFCC low flow return to channel	San Antonio	0.58	0.70	0.213	0.947
70. Remove bank vegetation (deformable banklines)	Escondida	0.57	0.63	0.240	0.900
71. Cut pilot channels (initiate channel avulsions)	Escondida	0.56	0.95	0.062	1.058
72. Remove jetty jacks	San Antonio	0.55	0.61	0.230	0.870
73. Manage livestock grazing	Escondida	0.53	0.59	0.221	0.839
74. LFCC low flow return to channel	Escondida	0.52	0.65	0.179	0.861
75. Remove jetty jacks	Escondida	0.49	0.65	0.149	0.831
76. Woody debris removal (mechanical)	Refuge	0.47	0.69	0.109	0.832
77. Woody debris removal (mechanical)	San Antonio	0.43	0.59	0.121	0.739
78. Disc and mow sand bar vegetation	San Antonio	0.37	0.82	-0.060	0.800
79. Plow and rake islands	San Antonio	0.36	0.49	0.103	0.617
80. Disc and mow sand bar vegetation	Refuge	0.34	0.66	-0.006	0.686
81. Channel realignment	Refuge	0.32	0.75	-0.730	0.713
82. Placement of large woody debris	San Antonio	0.32	0.55	0.032	0.608
83. Plow and rake islands	Refuge	0.32	0.38	0.121	0.519
84. Woody debris removal (mechanical)	Escondida	0.31	0.50	0.048	0.572
85. Channel realignment	San Antonio	0.27	0.91	-0.207	0.747
86. Curve and bank shaping	Refuge	0.27	0.37	0.076	0.464
87. Placement of large woody debris	Escondida	0.27	0.50	0.008	0.532
88. Placement of large woody debris	Refuge	0.26	0.42	0.040	0.480
89. Plow and rake islands	Escondida	0.23	0.30	0.073	0.387
90. Curve and bank shaping	San Antonio	0.22	0.26	0.084	0.356
91. Disc and mow sand bar vegetation	Escondida	0.22	0.68	-0.136	0.576
92. Channel realignment	Escondida	0.19	0.87	-0.266	0.646
93. Curve and bank shaping	Escondida	0.16	0.24	0.034	0.286
94. Training dikes/spurs/rock weirs	Refuge	0.10	0.22	-0.015	0.216
95. Training dikes/spurs/rock weirs	San Antonio	0.09	0.20	-0.015	0.195
96. Training dikes/spurs/rock weirs	Escondida	0.08	0.18	-0.014	0.174
	average	1.04	0.86		
	sum	100.00			

The six highest ranked restoration techniques in the fourteen completed matrices are non-mechanical restoration activities including:

- Providing spring flushing flows;
- Eliminating structural constraints on flooding;
- Managing future development on the floodplain in the San Antonio and Refuge reaches.

The median score is approximately 1.0. Those restoration activities ranked in the top 50% have the highest potential for implementation. Based on the above table, the conventional river training activities such as dikes, spurs and rock weirs that have been typically used for river maintenance were ranked at the very bottom of the table. This represents a departure from the type of river maintenance activities that have been applied to the Middle Rio Grande in the past. The Escondida subreach dominates the bottom portion of the restoration techniques ranking table.

The restoration activities independent of the three subreaches were ranked and displayed in the following table. The restorations activities that would most likely be integrated into a restoration plan were ranked in the top fifty percent. Some activities that require little funding or resources may be recommended on the basis that they would support overall restoration goals or objectives. The last three ranked restoration techniques: channel realignment, curve and bank shaping and training dikes/spurs/rock weirs should be considered as having limited restoration value.

The top five restoration activities involving some construction or mechanical application are:

- Removal of exotic vegetation from the floodplain;
- Creation of wetlands and marshes;
- Planting and seeding native vegetation
- Creation of flooded bottomlands;
- Reconnecting oxbows and old channels.

The last restoration technique is a channel activity. The other four were related to the floodplain enhancement.

RESTORATION ACTIVITY RANKING		
Restoration Technique	Type	Ranking
Spring flushing flows	Water	7.74
Eliminate structural limitations on flooding	Floodplain	6.76
Increase frequency/duration of flooding	Water	6.41
Remove exotic vegetation (selective and clear cut)	Floodplain	6.21
Manage future development	Floodplain	6.19
Create wetlands and marshes	Floodplain	4.67
Plant and seed native vegetation	Floodplain	4.34
Create flooded bottomlands	Floodplain	4.02
Reconnect oxbow and old channels	Channel	3.90
Enhance groundwater storage and interaction	Floodplain	3.71
Variable floodplain topography	Floodplain	3.69
Destabilize and lower banks (terrace lowering)	Channel	3.58
Channel widening	Channel	3.56
Fall maintenance flows	Water	3.52
Increase groundwater storage on east side	Water	3.50
Time flood with seed dispersal	Water	3.46
Create high flow side channels	Channel	2.75
Sediment management (increase sediment loading)	Channel	2.48
Remove bank vegetation (deformable banklines)	Channel	2.37
Create larger floodplain corridor - stabilize levees	Floodplain	2.31
Raise channel bed (grade restoration facilities)	Channel	2.13
Cut pilot channels (initiate channel avulsions)	Channel	2.02
Manage livestock grazing	Floodplain	1.77
LFCC low flow return to channel	Water	1.69
Remove jetty jacks	Floodplain	1.63
Woody debris removal (mechanical)	Floodplain	1.21
Disc and mow sand bar vegetation	Channel	0.93
Plow and rake islands	Channel	0.91
Placement of large woody debris	Channel	0.84
Channel realignment	Channel	0.79
Curve and bank shaping	Channel	0.65
Training dikes/spurs/rock weirs	Channel	0.27

The following table lists the benefits of the restoration techniques to the two restoration objectives, enhancing river function and increasing habitat diversity. This ranking is derived from Matrix Worksheet M4, ‘Benefits’. This matrix ranking closely follows the scores for the individual subreaches and includes the categories: enhance channel dynamics, promote overbank flooding, increase groundwater storage, and expand marshes and wet meadows. The habitat diversity categories included: create water salvage, expand native riparian habitat, improve aquatic habitat, promote cottonwood/willow regeneration and support endangered species.

RESTORATION ACTIVITY BENEFITS		
Restoration Technique	Type	Ranking
Spring flushing flows	Water	5.30
Increase frequency/duration of flooding	Water	4.89
Eliminate structural limitations on flooding	Floodplain	4.73
Manage future development	Floodplain	4.71
Remove exotic vegetation (selective and clear cut)	Floodplain	3.92
Reconnect oxbow and old channels	Channel	3.91
Channel widening	Channel	3.78
Create flooded bottomlands	Floodplain	3.77
Create wetlands and marshes	Floodplain	3.76
Increase groundwater storage on east side	Water	3.64
Destabilize and lower banks (terrace lowering)	Channel	3.63
Sediment management (increase sediment loading)	Channel	3.60
Create high flow side channels	Channel	3.46
Variable floodplain topography	Floodplain	3.42
Enhance groundwater storage and interaction	Floodplain	3.30
Fall maintenance flows	Water	3.22
Time flood with seed dispersal	Water	3.14
Cut pilot channels (initiate channel avulsions)	Channel	3.07
Plant and seed native vegetation	Floodplain	3.05
Raise channel bed (grade restoration facilities)	Channel	3.00
Create larger floodplain corridor - stabilize levees	Floodplain	2.93
Remove bank vegetation (deformable banklines)	Channel	2.92
LFCC low flow return to channel	Water	2.37
Channel realignment	Channel	2.28
Remove jetty jacks	Floodplain	2.25
Manage livestock grazing	Floodplain	2.03
Plow and rake islands	Channel	1.94
Disc and mow sand bar vegetation	Channel	1.86
Placement of large woody debris	Channel	1.79
Woody debris removal (mechanical)	Floodplain	1.46
Curve and bank shaping	Channel	1.43
Training dikes/spurs/rock weirs	Channel	1.43

A similar restoration activity ranking was developed to assess potential impacts of the proposed restoration techniques including reducing channel dynamics, potential flood impacts, levee stability issues, potential channel incision, potential increase in water loss, channel narrowing/vegetation encroachment, private land and grazing issues, impacts on aquatic habitat, accessibility, fire hazard issues and negative impact on endangered species. The restoration activities that will have the greatest impact are listed at the top of the table. This table is essentially the inverse of the previous table.

RESTORATION ACTIVITY POTENTIAL IMPACTS		
Restoration Technique	Type	Ranking
Training dikes/spurs/rock weirs	Channel	6.88
Channel widening	Channel	6.62
Channel realignment	Channel	5.70
Create high flow side channels	Channel	5.07
Increase frequency/duration of flooding	Water	4.80
Destabilize and lower banks (terrace lowering)	Channel	4.66
Raise channel bed (grade restoration facilities)	Channel	4.52
Cut pilot channels (initiate channel avulsions)	Channel	4.43
Remove jetty jacks	Floodplain	4.39
Sediment management (increase sediment loading)	Channel	4.39
Curve and bank shaping	Channel	4.09
Spring flushing flows	Water	4.07
Create flooded bottomlands	Floodplain	4.04
Remove bank vegetation (deformable banklines)	Channel	3.78
Eliminate structural limitations on flooding	Floodplain	3.26
Create larger floodplain corridor - stabilize levees	Floodplain	3.18
Create wetlands and marshes	Floodplain	3.02
Placement of large woody debris	Channel	2.94
Reconnect oxbow and old channels	Channel	2.81
Woody debris removal (mechanical)	Floodplain	2.42
Disc and mow sand bar vegetation	Channel	2.06
Manage livestock grazing	Floodplain	1.91
Plow and rake islands	Channel	1.76
LFCC low flow return to channel	Water	1.38
Variable floodplain topography	Floodplain	1.32
Plant and seed native vegetation	Floodplain	1.32
Remove exotic vegetation (selective and clear cut)	Floodplain	1.30
Manage future development	Floodplain	1.01
Enhance groundwater storage and interaction	Floodplain	0.97
Fall maintenance flows	Water	0.75
Increase groundwater storage on east side	Water	0.69
Time flood with seed dispersal	Water	0.45

Approximately 40 different people attended the first planning workshop and the combined biology and geomorphology workshops. Fourteen individuals submitted completed matrices. The standard deviation and confidence interval were relatively high as a result of the small number of completed matrix. While the number of completed matrices responses was less than expected, it unlikely that the overall results would be appreciably different if a larger number of matrices were completed. This is because of the significant number of computations were necessary to derive the final rankings. To reduce the confidence interval by 50%, 56 completed matrices would be required.

The restoration technique rankings were essentially what were anticipated for the overall scoring. The highest rank was assigned to non-structural, resource management activities and the results were consistent from reach to reach. In general, floodplain activities were preferred over channel restoration activities. One surprising result was that channel maintenance activities such as disking and mowing open channel sand bars covered with vegetation scored low (in the bottom five of the restoration techniques). This particular channel maintenance activity may be required to limit the vegetation encroachment in the channel during successive dry years and may be a cornerstone of a channel adaptive management strategy.

Only about half the submitted matrices had completed sections on the cost, maintenance, expected life and regulatory constraints. Of those matrices with this section completed, at least two matrices had misrepresented the relationship of the weighting factors associated with restoration component cost. The results from this section were widely varying and essentially constituted a guess of these factors. For these reasons, the cost, maintenance, expected life and regulatory constraints will be revisited in the Phase IV formulation of the conceptual restoration plan. During this phase, the Tetra Tech staff will evaluate the potential capital cost, maintenance costs, expected project component life and any regulatory limitations on the proposed project restoration activity. These factors will be quantitatively evaluated on the basis of project component site, areal extent and estimated construction costs.

Selection of Restoration Activities

The ranking of restoration techniques will help guide the formulation of a conceptual restoration plan for the San Acacia to San Marcial reach. The ranking process will inform water resource management agencies of the potential value of implementing various restoration techniques in prioritized project areas. While some of the restoration activities may have scored low for improving habitat diversity or restoring river function, their value to a given restoration site or floodplain area should not be dismissed. For example, mowing and disking vegetated sand bars in the river channel may be identified during a monitoring and adaptive management program as a critical component to sustaining an active channel during a drought period. In addition, some restoration activities that had a low overall priority will have more importance when considered in conjunction with other components in a conceptual restoration plan. The ranking was not intended to limit restoration to only a few prescribed activities.

In formulating the conceptual restoration plan, each technique will be considered in how it supports the objective functions for enhancing river functions or increasing riparian/aquatic habitat diversity in each subreach. Those objective river functions include enhancing channel dynamics, promoting overbank flooding, increasing groundwater storage, and expanding marshes/wet meadows. To expand the riparian habitat diversity, the objectives will include re-establishment of a mosaic of native riparian habitat including cottonwood and willow forest and improving aquatic habitat. Each subreach or project area will have specific issues or needs that will have to be addressed in more detail. Specific river issues such as potential water salvage and supporting endangered species will be considered in the individual project component designs and the overall plan implementation. It may be necessary to consult the individual objective matrix scoring (as opposed to the ranking) to design restoration components that compliment each other. For example, the following technique scoring was compiled for enhancing channel dynamics. These are the raw scores resulting from summing the individual scores on each completed matrix rather than the percent ranking.

ENHANCE CHANNEL DYNAMICS		
Restoration Technique	Type	Score
Spring flushing flows	Water	8.40
Eliminate structural limitations on flooding	Floodplain	8.20
Increase frequency/duration of flooding	Water	7.90
Manage future development	Floodplain	6.60
Destabilize and lower banks (terrace lowering)	Channel	6.50
Sediment management (increase sediment loading)	Channel	6.50
Channel widening (bank destabilization and removal of lateral confinement)	Channel	6.40
Fall maintenance flows	Water	6.10
Disc and mow sand bar vegetation	Channel	5.80
Plow and rake islands	Channel	5.80
Cut pilot channels (initiate channel avulsions)	Channel	5.40
Remove bank vegetation (deformable banklines)	Channel	5.10
Channel realignment	Channel	4.90
Reconnect oxbow and old channels	Channel	4.80
Raise channel bed (grade restoration facilities)	Channel	4.80
Create larger floodplain corridor - stabilize levees	Floodplain	4.70
Remove jetty jacks	Floodplain	4.50
Create high flow side channels	Channel	4.00
LFCC low flow return to channel	Water	4.00
Create flooded bottomlands	Floodplain	3.30
Training dikes/spurs/rock weirs	Channel	3.20
Create wetlands and marshes	Floodplain	3.00
Time flood with seed dispersal	Water	3.00
Variable floodplain topography	Floodplain	2.90
Remove exotic vegetation (selective and clear cut)	Floodplain	2.80
Enhance groundwater storage and interaction	Floodplain	2.70
Placement of large woody debris	Channel	1.90
Increase groundwater storage on east side	Water	1.90
Curve and bank shaping	Channel	1.80
Woody debris removal (mechanical)	Floodplain	1.80
Manage livestock grazing	Floodplain	1.60
Plant and seed native vegetation	Floodplain	1.50

This table illustrates the consistency of the scoring related to the active channel. Those restoration techniques uniquely suited to the channel scored high and those related to floodplain activities scored low for enhancing channel dynamics. This table could be useful in planning the restoration in the Escondida reach. For the comparable floodplain restoration activities, consulting the scoring for expanding the native riparian habitat would be appropriate. The following table illustrates the consistency of results related to floodplain restoration for this objective. In this case, the channel restoration techniques were scored low because they did not contribute to floodplain restoration. These two examples how the other objective scoring for each subreach could be applied.

EXPAND NATIVE RIPARIAN HABITAT		
Restoration Technique	Type	Score
Remove exotic vegetation (selective and clear cut)	Floodplain	8.40
Plant and seed native vegetation	Floodplain	8.40
Spring flushing flows	Water	7.80
Time flood with seed dispersal	Water	7.70
Eliminate structural limitations on flooding	Floodplain	7.30
Manage future development	Floodplain	7.30
Reconnect oxbow and old channels	Channel	7.20
Increase frequency/duration of flooding	Water	6.90
Destabilize and lower banks (terrace lowering)	Channel	6.50
Channel widening (bank destabilization and removal of lateral confinement)	Channel	6.50
Create flooded bottomlands	Floodplain	6.40
Create wetlands and marshes	Floodplain	6.10
Create high flow side channels	Channel	5.80
Manage livestock grazing	Floodplain	5.80
Sediment management (increase sediment loading)	Channel	5.70
Variable floodplain topography	Floodplain	5.60
Create larger floodplain corridor - stabilize levees	Floodplain	5.50
Enhance groundwater storage and interaction	Floodplain	5.00
Remove jetty jacks	Floodplain	5.00
Fall maintenance flows	Water	5.00
Cut pilot channels (initiate channel avulsions)	Channel	4.80
Increase groundwater storage on east side	Water	4.50
Raise channel bed (grade restoration facilities)	Channel	4.20
Remove bank vegetation (deformable banklines)	Channel	3.80
Woody debris removal (mechanical)	Floodplain	3.80
Channel realignment	Channel	2.70
LFCC low flow return to channel	Water	2.40
Curve and bank shaping	Channel	1.70
Disc and mow sand bar vegetation	Channel	1.60
Placement of large woody debris	Channel	1.60
Plow and rake islands	Channel	1.30
Training dikes/spurs/rock weirs	Channel	1.30

Based on the matrix Restoration Technique Ranking for all subreaches (pages 23-24), a concerted effort to organize and recommend spring flushing flows of an appropriate magnitude, frequency and duration should be coordinated with the federal agencies. Spring flushing flows were ranked 1,2 and 9 for the Refuge, San Antonio, and Escondida reaches respectively. Increasing the frequency and duration of flooding were ranked number 6 and 8. The spring flows should be approximately bankfull discharge (channel forming flow) at least 4 out of every 10 years with no more than 2 consecutively years without bankfull discharge to avoid vegetation encroachment within the active channel. In concert with the spring flushing flows, eliminating structural floodplain limitations on flooding and management of future development on the floodplain will remove constraints on flood magnitude and duration. Eight of out the top ten ranked restoration activities were related to enhancing the channel-floodplain hydrologic connection.

Increased flood magnitude, duration and frequency are non-structural restoration activities that would be accomplished by coordinating water resource management with the federal and state agencies. The goal is to increase water resource option from upstream reservoirs including flushing flow releases that would support the active channel. This may require institutional changes in the storage and release authority and patterns in upstream reservoirs, particularly Cochiti Reservoir, for spring flows or storm inflows. The structural restoration activities would be supported by channel forming flows and overbank flooding. As part of the conceptual restoration plan, the opportunities for increased high spring flows will be further examined in Phase IV. High springs flushing flows will be an important component of the conceptual restoration plan. Bankfull discharge and overbank flood magnitude, frequency and duration will be established to sustain the channel restoration activities and active channel.

The only structural restoration activity in the top ten ranking (7 and 10) is the removal of exotic floodplain vegetation from the San Antonio and Refuge subreaches. Exotic vegetation removal is a current restoration activity in these reaches. Creating wetlands and marshes in the San Antonio and Refuge subreaches were the highest ranked new structural restoration activities. A list of the preferred structural restoration techniques was created by eliminating the water or landuse management activities. The first four structural restoration techniques are floodplain based activities. Reconnecting oxbows and old channels is the highest ranked channel restoration activity.

STRUCTURAL RESTORATION ACTIVITY RANKING		
Restoration Technique	Type	Ranking
Remove exotic vegetation (selective and clear cut)	Floodplain	6.21
Create wetlands and marshes	Floodplain	4.67
Plant and seed native vegetation	Floodplain	4.34
Create flooded bottomlands	Floodplain	4.02
Reconnect oxbow and old channels	Channel	3.90
Variable floodplain topography	Floodplain	3.69
Destabilize and lower banks (terrace lowering)	Channel	3.58
Channel widening	Channel	3.56
Create high flow side channels	Channel	2.75
Remove bank vegetation (deformable banklines)	Channel	2.37
Create larger floodplain corridor - stabilize levees	Floodplain	2.31
Raise channel bed (grade restoration facilities)	Channel	2.13
Cut pilot channels (initiate channel avulsions)	Channel	2.02
Remove jetty jacks	Floodplain	1.63
Woody debris removal (mechanical)	Floodplain	1.21
Disc and mow sand bar vegetation	Channel	0.93
Plow and rake islands	Channel	0.91
Placement of large woody debris	Channel	0.84
Channel realignment	Channel	0.79
Curve and bank shaping	Channel	0.65
Training dikes/spurs/rock weirs	Channel	0.27

Example graphics are included in Appendix A of this report illustrating some of the higher ranked structural restoration activities by sub-reach. These graphics correlate with the preliminary project maps that were included in the final Phase I / II report.

Conceptual Restoration Plan Formulation

The conceptual restoration plan will be formulated in Phase IV of the SOB project. It will include applying the selected restoration techniques to project areas within the subreaches using cost and feasibility criteria for site evaluation. The potential application of the various restoration activities will vary according to subreach where the ranking indicated a preferred subreach restoration component. The restoration plan components will be designed and linked based on consistency of functionality, environmental compatibility, likelihood of success, consistency with restoration activities in other subreaches, cost, construction feasibility, environmental contribution, long term sustainability, adaptive management response, potential water salvage, and potential conflicts.

In a drought cycle, it may be prudent to focus on those restoration activities that would be best suited for a drier river condition that might include several years without high spring flows and possible reaches of dry channel during the summer or fall low flow conditions. In terms of structural restoration activities that may be beneficial during with a dry series of years, the following list is suggested.

DROUGHT RELATED STRUCTURAL RESTORATION ACTIVITY RANKING		
Restoration Technique	Type	Ranking
Remove exotic vegetation (selective and clear cut)	Floodplain	6.21
Variable floodplain topography	Floodplain	3.69
Destabilize and lower banks (terrace lowering)	Channel	3.58
Remove bank vegetation (deformable banklines)	Channel	2.37
Create larger floodplain corridor - stabilize levees	Floodplain	2.31
Remove jetty jacks	Floodplain	1.63
Woody debris removal (mechanical)	Floodplain	1.21
Disc and mow sand bar vegetation	Channel	0.93
Plow and rake islands	Channel	0.91

In this list, the channel expansion activities have been removed and the focus has been placed on the floodplain activities. Creating new side channels or reconnecting old meander bends during a period when there may not be overbank flows for several years would not be prudent and may require additional maintenance until high flows were capable of sustaining the restoration construction. Through monitoring and adaptive management, it may be observed that fall maintenance of the active channel may be required (mow and disc encroaching channel vegetation). The theme of drought related restoration can be further explored in the development of the conceptual restoration plan in Phase IV.

In Phase IV, the selected restoration activities will evolve into an overall restoration strategy based on the phased implementation of project components. The restoration plan will attempt to match those preferred restoration components in subreach project areas to address the best opportunities habitat diversity and natural channel functions. The actual selection of the components will include supporting background data and information in Phase I and the analyses of issues and restoration constraints in Phase II. In addition, the restoration plan will be tested using the FLO-2D model to predict the potential response of the restoration components to high flows and to identify any possible impacts on the flood protection levee system. The actual design and preparation of the conceptual restoration plan and draft report will also be formulated on the research and investigation of site specific restoration details. Understanding the restoration details will help to identify the additional data needed to bring the conceptual restoration plan to a feasibility level design. An adaptive management and monitoring plan will be prepared in Phase IV and channel maintenance flows will be proposed.

Summary

The selection and ranking of preferred restoration activities was accomplished in this phase of the Save Our Bosque Conceptual Restoration Plan. The concept of "restoration" is the enhancement of the natural river function and riparian system by creating or expanding desirable habitat communities that function over the long term under current physical and institution constraints. Returning river subreaches to 'historic conditions' is recognized to be infeasible. At some sites, the selected restoration activities may be limited to minimizing negative impacts to contiguous subreaches.

The project restoration components and subreaches were ranked and prioritized according to their contribution to restoration objectives. The concept of selecting restoration activities in the Save Our Bosque Task Force proposal was to create an evaluation matrix to quantify and rank proposed restoration. The linked matrix approach was developed by Tetra Tech for this project with the knowledge that the Save Our Bosque Task Force was interested in an inclusive selection process. The matrix worksheets were designed so that they could be completed by Rio Grande researchers, agency personnel and private citizens. Three workshops were organized to assist the participants in filling out the matrices. A considerable effort was expended in developing background material and information to support the matrix development. Videos of a Rio Grande flyover of the study area were distributed to the workshop participants. Definitions of all the habitat attributes were developed and disseminated to assist in the matrix completion.

The linked matrix approach was developed through research of various planning matrices methods and types. Workshops on developing a matrix evaluation approach for selecting geomorphology research priorities for endangered fishes in the upper Colorado River basin were attended by the Tetra Tech staff. Carefully consideration went into preparing the matrix components, individual worksheets and variable weighting factor approach. The matrix internal linkages required extensive mathematical design and testing,

The Phase III product was a selection of restoration activities and proposed project areas as shown in the table on pages 23-24. The ranking of restoration techniques was accomplished in the linked matrix approach by the workshop participants. The final ranking was based on averaging or combining the results of all the completed matrices. The Refuge and San Antonio subreaches were selected as preferred subreaches, but all subreaches will be included in the plan. The restoration priorities with the highest ranking were:

- Spring flushing flows
- Eliminate structural limitations on flooding
- Manage future development
- Increase frequency/duration of flooding
- Remove exotic vegetation (selective and clear cut)
- Create wetlands and marshes

- Enhance groundwater storage and interaction
- Plant and seed native vegetation
- Create flooded bottomlands
- Variable floodplain topography
- Reconnect oxbow and old channels
- Channel widening
- Increase groundwater storage on east side
- Reconnect oxbow and old channels
- Destabilize and lower banks (terrace lowering)
- Fall maintenance flows

These restoration activities are listed regardless the of the subreach designation. The complete list is presented on pages 23 and 24.

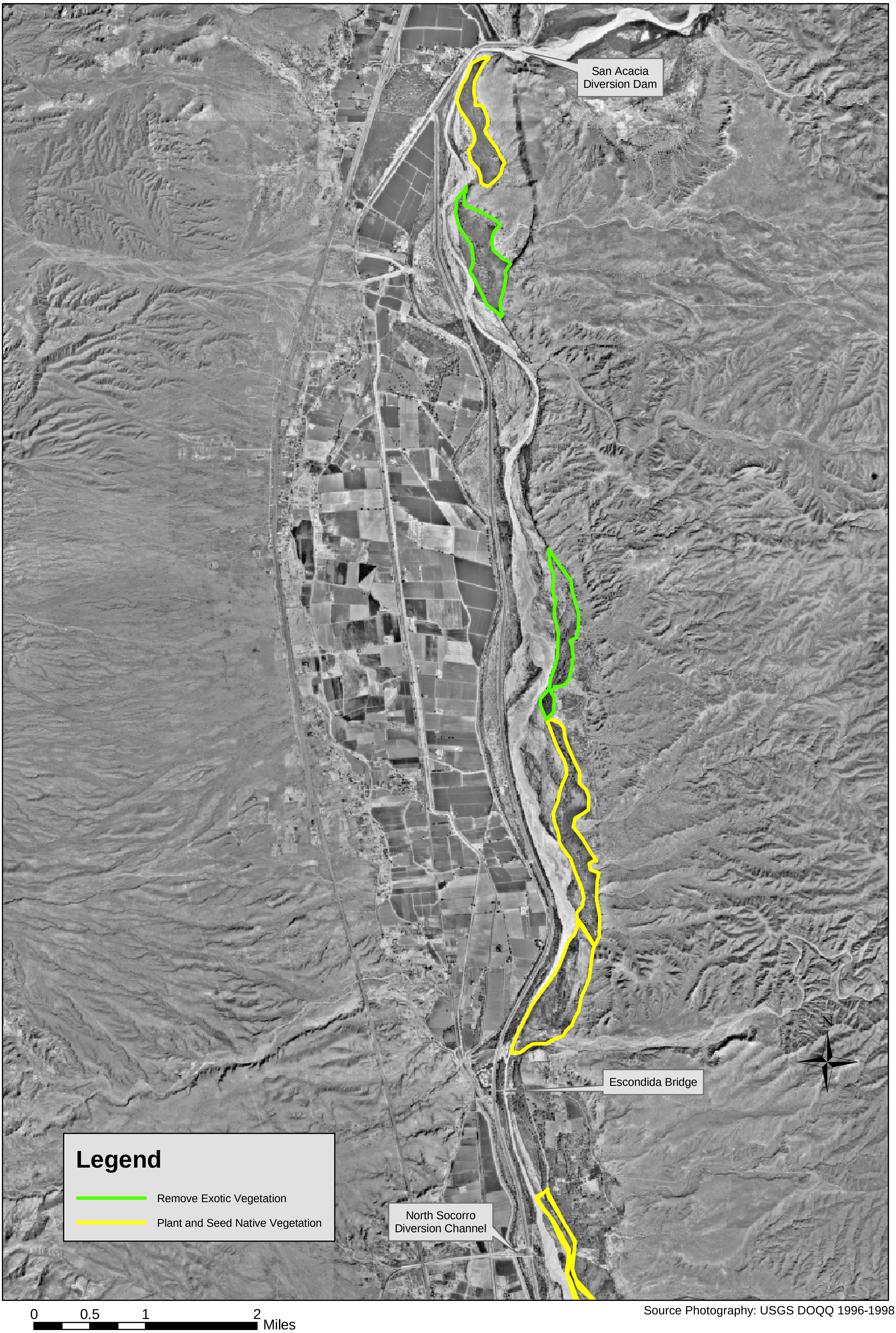
A restoration plan will be formulated that focuses on these restoration priorities but could include all restoration activities to varying degrees. The restoration plan will include improving river-floodplain hydrologic connectivity, increasing the cottonwood/willow bosque and creating wetlands, marshes, savannahs, grasslands and salt grass meadows. According to ranked restoration priorities in terms of enhancing channel dynamics, a flow regime within existing administrative, legal, and physical constraints will be formulated to sustain a prescribed active channel. The restoration plan will include a phased approach for structural activities and drought related design alternatives to address restoration during a series of dry years.

All submitted comments were beneficial to improving the discussion of the potential application of the selection restoration techniques in the conceptual restoration plan.
All the comments were addressed and incorporated into the report. A few editorial changes were made in addition to suggestions for expanding the discussion. Since the submitted comments were relatively few and informal in nature, a formal comment and response format was not applied in addressing the comments. 39

APPENDIX A

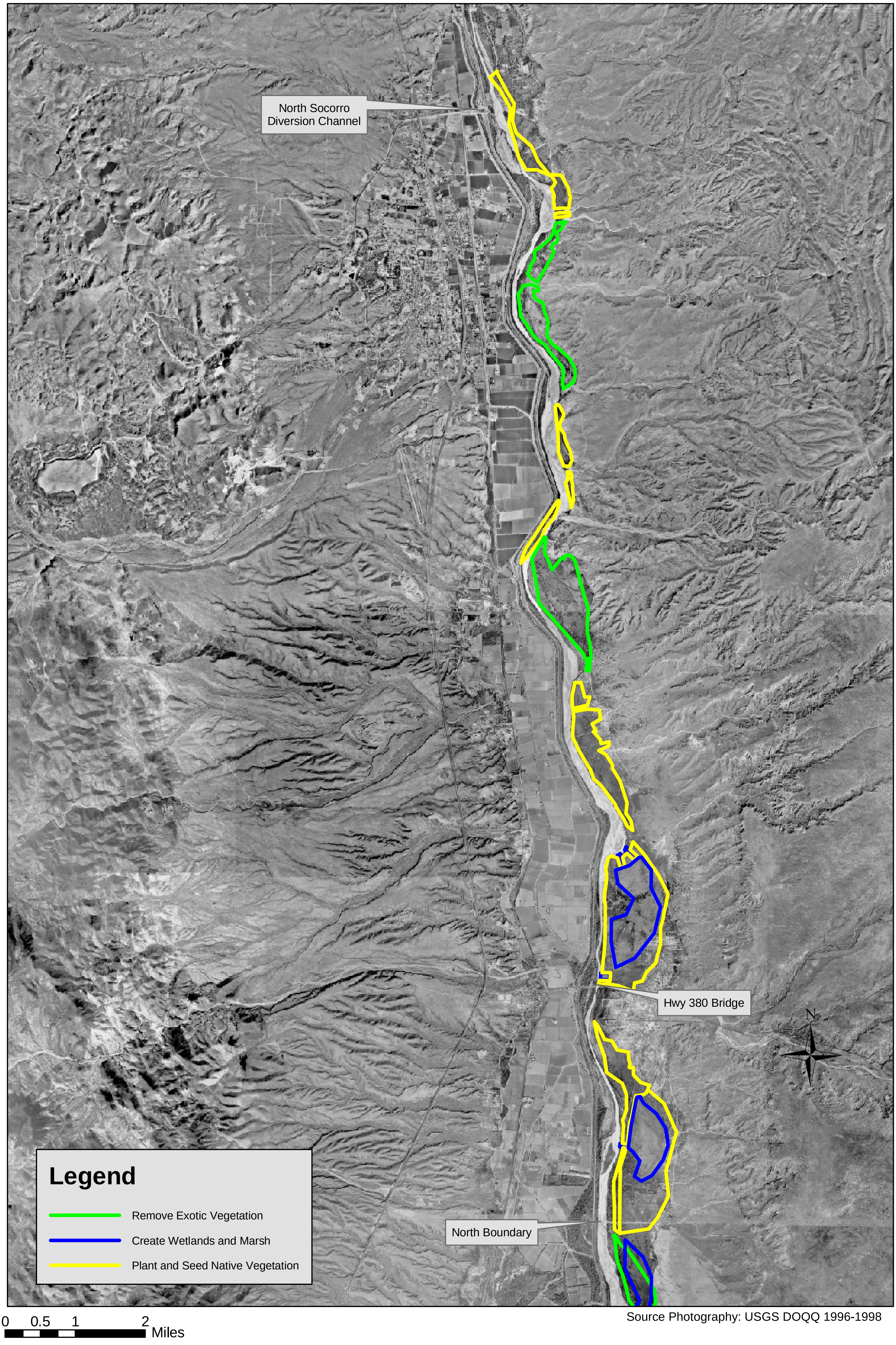
EXAMPLE GRAPHICS: STRUCTURAL RESTORATION TECHNIQUES BY SUB-REACH

Matrix Restoration Techniques Prioritized
Escondida Reach



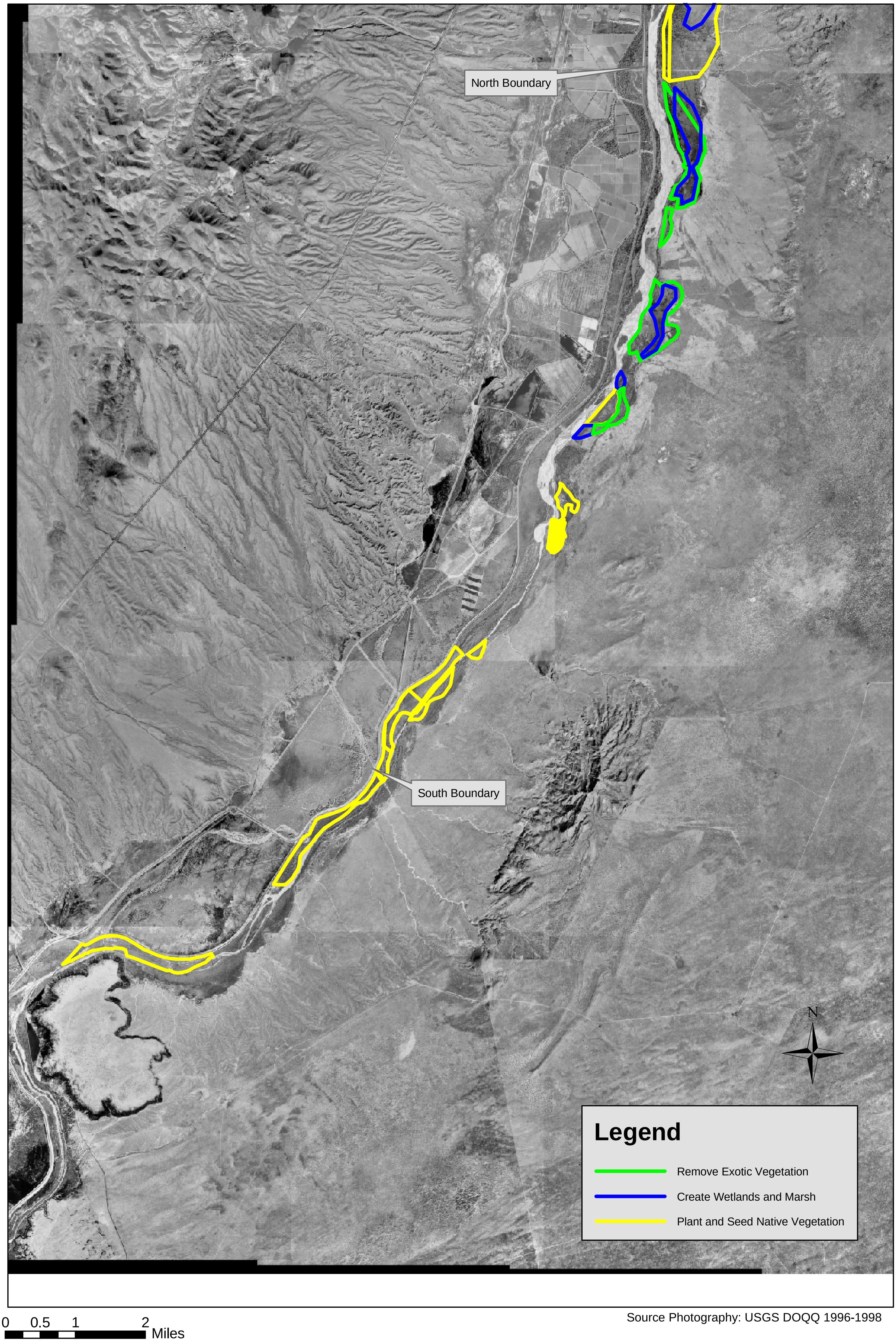
Source Photography: USGS DOQQ 1996-1998

Matrix Restoration Techniques Prioritized
San Antonio Reach



Source Photography: USGS DOQQ 1996-1998

Matrix Restoration Techniques Prioritized
Refuge Reach



Source Photography: USGS DOQQ 1996-1998

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