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

Phase V. Monitoring and Adaptive Management Strategy for the River/Riparian Restoration Plan

Final Draft Report

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Save Our Bosque Task Force

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Executive Summary

The Save Our Bosque Conceptual Restoration Plan for the Rio Grande from San Acacia to San Marcial was developed in Phase IV of five phase process that included:

Phase I. Compilation of data and reference material;
Phase II. Investigation of specific river and riparian issues;
Phase III. Ranking of restoration priorities and components;
Phase IV. Development of the Conceptual Restoration Plan.
Phase V. Monitoring and Adaptive Management Strategy

The main goals of the restoration plan are to enhance river functions and increase riparian and aquatic diversity. This report presents Phase V, the Adaptive Management Plan and Monitoring Program. An effective adaptive management program would be necessary to sustain the restoration projects over the long term. The goals of the adaptive management plan are:

- Define baseline condition for river and riparian habitat restoration projects;
- Sustain the active channel to prescribed restoration geometries;
- Sustain native riparian vegetation and associated restored habitats;
- Monitor and identify long term trends and changes in aquatic and riparian habitat.

The Adaptive Management Plan embodies five actions that include: 1) The formulation of Work Group consisting of scientists, planner or management personnel from federal, state and local agencies and stakeholders in the Rio Grande water resources; 2) The establishment of the specific elements of the AMP based on specific channel and floodplain morphology and habitat criteria that will identify river restoration program success or failure; 3) The design of a baseline hydrographic, biological, vegetation and geomorphic data collection program to establish post-restoration conditions; 4) The development of a long term monitoring program; and 5) The implementation of a set of rules and practices that will guide agency application of the AMP to sustain the restoration projects.

A primary component of adaptive management is a Work Group that would meet several times a year to make site visits to restoration projects, make recommendations for additional channel monitoring activities and flushing flows and make recommendations for channel and floodplain riparian maintenance. The Work Group will also establish criteria to measure the success or failure of restoration projects and would focus on establishing and refining methods for long term monitoring. One of it roles would be to promote agency cooperation with respect to monitoring and restoration maintenance.

A baseline condition for the restored project areas must be established to set in motion the monitoring plan. A baseline data set would include cross section surveys, inventory of potential endangered species habitat, vegetation mapping, floodplain topography, groundwater levels, soil salinity, water quality, aquatic and terrestrial species abundances and diversity, and nutrient levels. Monitoring is necessary to assess the geomorphological and ecological trends. It is the heart of the adaptive management plan. Monitoring post-restoration conditions will provide a roadmap to future trends and the probability of the success of the various restoration projects. It will be important to select key variables to monitor during flooding and identify. Possible monitoring parameters were outlined and discussed in detail in the report.

To remove the subjectivity of applying an adaptive management plan to a restoration project, a set response rules and guidelines were proposed. The rules depend on identifying the adverse condition or trend and then outlining a proposed resource management response to eliminate or mitigate the adverse changes. The proposed rules address the following resource management issues and conditions:

- Flood frequency and channel forming flow
- Vegetation encroachment in the active channel
- Vegetation regrowth on the floodplain
- Potential levee instability
- Bank erosion and channel migration
- Failure to induce overbank flooding

- River desiccation
- Sediment plugs
- High soil salinity
- Fall maintenance flows

Implementing an Adaptive Management Plan represents a long term commitment to monitoring the renewal of river ecosystem. A minimum of fifteen years as indicated in the Biological Opinion (FWS, 2001) should be planned and funded for the monitoring the ecosystem and administering the AMP. The goal is to establish flexible adaptive management principles and practices that can adjust to both success and failures. An agency team approach to adaptive resource management in response to changing climatic conditions, water availability, sediment loading and evolving vegetation composition will solve many of the problems facing the Middle Rio Grande.

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Introduction

A conceptual restoration plan for the Rio Grande riparian corridor from San Acacia to San Marcial was prepared for the Save Our Bosque Task Force. The concept of "restoration" is to enhance channel dynamics and increase diversity of the riparian system. Restoration would be achieved by creating or expanding desirable habitat communities that will be sustained over the long term under current physical and institution constraints. This report discusses a proposed monitoring and adaptive management plan constituting Phase V of a six phase project 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 and Adaptive Management Strategy

The adaptive management plan and monitoring program will support the implementation and long term maintenance of the restoration activities. The selected projects in the restoration plan were organized into a series of restoration plan scenarios that focus on several themes including:

A. Restoration light (lyte) plan
B. Water salvage plan
C. Drought reduction plan
D. Habitat diversity and endangered species habitat plan;
E. River dynamics plan
F. Long term comprehensive plan

The long term comprehensive plan consists of all the selected projects from each theme. The restoration projects have been selected based on consistency of functionality, environmental compatibility, likelihood of success, consistency with other restoration activities in the subreach, cost, construction feasibility, long term sustainability, potential response to adaptive management, potential water salvage, and potential conflicts. The conceptual restoration plan has attempted to match those preferred projects in each subreach to address the best opportunities for increasing habitat diversity and restoring natural channel functions. The Save Our Bosque Task Force will select restoration projects based on a phased implementation strategy and available budget.

Implementing restoration projects will create an urgent need to understand the ecological effects of restoration and develop new management options to sustain the projects. The first priority will be to develop a set of principals to guide post-restoration adaptive management. The second priority will be to implement a monitoring program to assess restoration success or failure. The third priority is to develop a set of rules for responding to ecosystem changes observed in the monitoring program.

The focus of this report is to present an adaptive management plan and monitoring program to support ecosystem restoration of the San Acacia to San Marcial reach. The adaptive management plan will address habitat and resource evaluation methods and establish decision rules for initiating channel and riparian area maintenance. Annual water resource allocation decisions to sustaining the active channel and the functionality of restoration projects will be based on documented channel morphology and habitat changes. The development of an adaptive management strategy and monitoring program will also address habitat quality issues including habitat for the Rio Grande silvery minnow and Southwest willow flycatcher.

While the proposed restoration components should sustained by the prescribed flow recommendations, the success of some restoration activities will be contingent on an adaptive management plan that has an appropriate maintenance response. Adaptive management approaches to river restoration have been widely discussed for rivers in the Western United States. Implementing an adaptive management plan will involve marshalling resources to sustain the benefits of restoration activities over the long term. The intent of the adaptive management plan is to reverse adverse trends that may evolve after restoration implementation. The key to a successful AMP is to have an efficient application of resources and be flexible with AMP methods from year to year. Agency cooperation is a cornerstone in any adaptive management program.

Some of the restoration projects have been designed to enhance, or in some cases, restore habitat for both the endangered Rio Grande silvery minnow and Southwestern willow flycatcher. The BO (2001) states that the Bureau will annually monitor each restoration project for effectiveness to benefit the silvery minnow and flycatcher for a period of at least fifteen years post-project completion to assess whether native riparian habitats are self-sustaining and successfully regenerating, and whether the habitats are maintaining suitability for recovery of listed species.

The key to long-term river restoration sustainability is to design an effective set of adaptive management options including mechanical maintenance and flexible flushing flows. The primary objectives of an adaptive resource management plan will be:

1. Establishing baseline conditions for monitoring;
2. Sustaining the restored active channel;
3. Managing flows to maintain channel flood conveyance capacity;
4. Sustaining and enhancing aquatic and riparian habitat for the silvery minnow and southwestern willow flycatcher;

5. Reducing fire potential;
6. Enhancing sediment movement through reaches;
7. Monitoring and maintaining habitat diversity.

The foundation of the monitoring program is a baseline assessment of hydrology, channel morphology, habitat conditions, vegetation composition and distribution, and river and riparian biology. This will include hydrographic surveys at high flows of the proposed restoration reaches. The long term hydrographic data collection effort will be an important component of the adaptive management plan.

The formation of an Adaptive Management Strategy Work Group is proposed to conduct in-field monitoring activities in the fall and make recommendations on potential management of high flows the following spring. The Group should be organized to meet several times a year (once in the fall) to assess changes in the river channel and the riparian ecosystem. This Work Group should be considered as a long term commitment whose responsibilities will increase as Rio Grande water management becomes more focused on the relationship between flow variability, peak flows, sediment transport, vegetation encroachment, overbank flooding and channel maintenance. The Adaptive Management Plan (AMP) should be flexible and should recognize and adapt to failures as well as successes. A product of this work will be a set of management response rules and options to evaluate channel morphology response to high flows and restoration activities.

Restoration Vision

The overall goal of this five phase project is to prepare a river and riparian conceptual restoration plan for the San Acacia to San Marcial reach of the Middle Rio Grande. Restoration projects are presented that will create favorable hydrogeomorphic conditions for river and riparian restoration. The restoration vision encompasses 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 Task Force restoration vision statement 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.*

A key to the restoration vision is "a naturally functioning riparian ecosystem" with potential long term sustainability. The vision statement indicates that restoration to a pre-historical condition is not intended. It is also recognized that resource values and water utilization change over time and that restoration projects in the San Acacia to San Marcial reach may evolve or be integrated with system wide river restoration plans in the future. It is unlikely that every restoration objective will be achieved. An adaptive management strategy will be necessary to sustain some of the restoration projects over the long term.

Rio Grande (Discharge = 0 cfs), October 29, 2003

Adaptive Management Strategy

Introduction

In a little less than 100 years, the Middle Rio Grande has gone from the dominant feature in a river valley to a canal-like floodway with only limited natural river processes. In some reaches, key river functions such as drainage, channel migration and pulse flooding have been permanently altered or curtailed. The curtailment of some processes has severely affected other river hydrologic functions. For example, drainage to the river channel from the west was terminated by construction of the Low Flow Conveyance Channel (LFCC) and the river is no longer the lowest point of the valley. This has affected the surface water–groundwater interface and river water is now lost to the LFCC. At low flow conditions the river goes dry in this reach. River migration was curtailed by river training facilities and activities such as levees, berms, jetty jacks, pilot channels and dredging. The loss of frequent overbank flooding has encouraged vegetation encroachment, sand bar accretion and channel narrowing. Upstream reservoir regulation has altered the frequency, duration, timing and magnitude of seasonal flooding that has in turn affected sediment transport in the river and adversely impacted river channel morphology.

The rapid vegetation encroachment and channel narrowing observed throughout the middle Rio Grande over the last five years highlights how the river has responded to recent climatic conditions and regulated flows. Restoration activities and river training and maintenance practices that have been in place for years have been ineffective in sustaining the channel morphology. River training methods that may work well under one set of hydrologic conditions can fail or be ineffective in a changing climate. Jetty jacks were implemented to stabilize the river channel in a sediment deposition environment, but now the river has a sediment deficient and the jetty jacks have become an environmental hazard. As river restoration projects are implemented, the most important message is to learn from experience and be flexible in flow management. Some restoration projects will fail and it is critical from a budget perspective to learn from failure and apply improved approaches and techniques. This is the concept of adaptive management. Restoration experimentation provides key information and knowledge on which to base future resource management decisions when confronting uncertainty and risk associated with changing hydrologic conditions.

There are two types of restoration activities planned for channel restoration; those restoration projects that will reconstruct the physical system and those activities that will initiate processes to renew channel functions. Channel widening, bank destabilization and channel relocation are examples of reconstructing the physical system. Channel mowing and disking is an example of a process that will initial a more dynamic, migrating channel. River restoration is dependent on future frequency of channel forming flows and without these flows on frequent basis, restoration maintenance will be perpetual, costly and dependent on the application of an adaptive management strategy.

At the present time there is limited Rio Grande restoration experience to draw on and it is possible that initial adaptive management decisions may increase uncertainty rather than provide answers. Ecosystem response to restoration will not be immediate. The development of wet meadow vegetation may take years. Similarly, the response of target species may not be immediately apparent. The intent of restoration and the subsequent adaptive management actions is to provide opportunities for species. The response of these species to restoration may require years to measure.

Adaptive Management Goals

The strategy of any adaptive management program is to achieve long term restoration stability and sustainability. The primary goals are:

- ✓ Define baseline condition for river and riparian habitat restoration projects;
- ✓ Sustain the active channel to prescribed restoration geometries;
- ✓ Sustain native riparian vegetation and associated restored habitats;
- ✓ Monitor and identify long term trends and changes in aquatic and riparian habitat.

An effective adaptive management program is the core of the river restoration plan. It is a necessity because there is fundamental disagreement between researchers and resource administrators over habitat needs and management. In particular, there is uncertainty over the role of seasonal flushing flows and over targets for species numbers and habitat acreage. There are also management questions regarding when to implement restoration, how effective it will be or what flushing flow frequency and durations are necessary. The AMP should be engaged at several levels by all the management agencies and should include funding priorities, a decision making work group, a structure for changes in the adaptive management plan, monitoring requirements, restoration target goals and methods of conflict resolution. The adaptive management plan will evolve over time, but the intent of this report is to provide a framework to proceed with adaptive management and monitoring in the next year.

Adaptive Management Process

The *Adaptive Management Plan and Monitoring Program* will provide guidance to evaluate ecosystem response to restoration projects and it will establish a basis for management recommendations for maintenance activities and spring high flows during successive years. The June 2001 Biological Opinion (BO) recognized the importance of adaptive management principles. For example, the BO stated that "(a)daptive management principles will be used, if necessary, to obtain successful restoration of the silvery minnow and flycatcher habitats." (p. 109). The BO also called for a meeting that will be scheduled in the post-runoff irrigation season to assess the status of the system. The fall meeting is promoted in this adaptive management plan. The proposed Work Group will consist of agency personnel and other stakeholders who will meet several times a year. The fall Work Group meeting will be coordinated to assess the river system and make recommendations for potential spring high flow or restoration maintenance.

The adaptive management process will benefit all water resource stakeholders within the study reach by providing a method to assess changes in river morphology and riparian habitat. The agency/stakeholder workgroup will evaluate water operations opportunities to mitigate adverse impacts of consecutive years of low flows. This report will define adaptive management rules and practices for those project areas and reaches where desired habitat and geomorphic restoration results were not initially achieved. The primary objectives of the adaptive management process are to:

1. Convene an **Adaptive Management Plan Work Group** (Work Group) consisting of the federal, state and local agencies and water resource stakeholders to evaluate channel and riparian habitat changes and make management recommendations for flushing flows and channel and habitat maintenance.
2. Establish project baseline conditions for future monitoring.
3. Adopt adaptive management rules for assessing adverse habitat changes.
4. Develop biology and morphology monitoring techniques.

Over time, the Work Group will review other restoration projects throughout the Rio Grande and will adjust the adaptive management process. It is likely that a system wide approach to adaptive management on restoration projects will evolve. Over the short term, the Work Group would focus on:

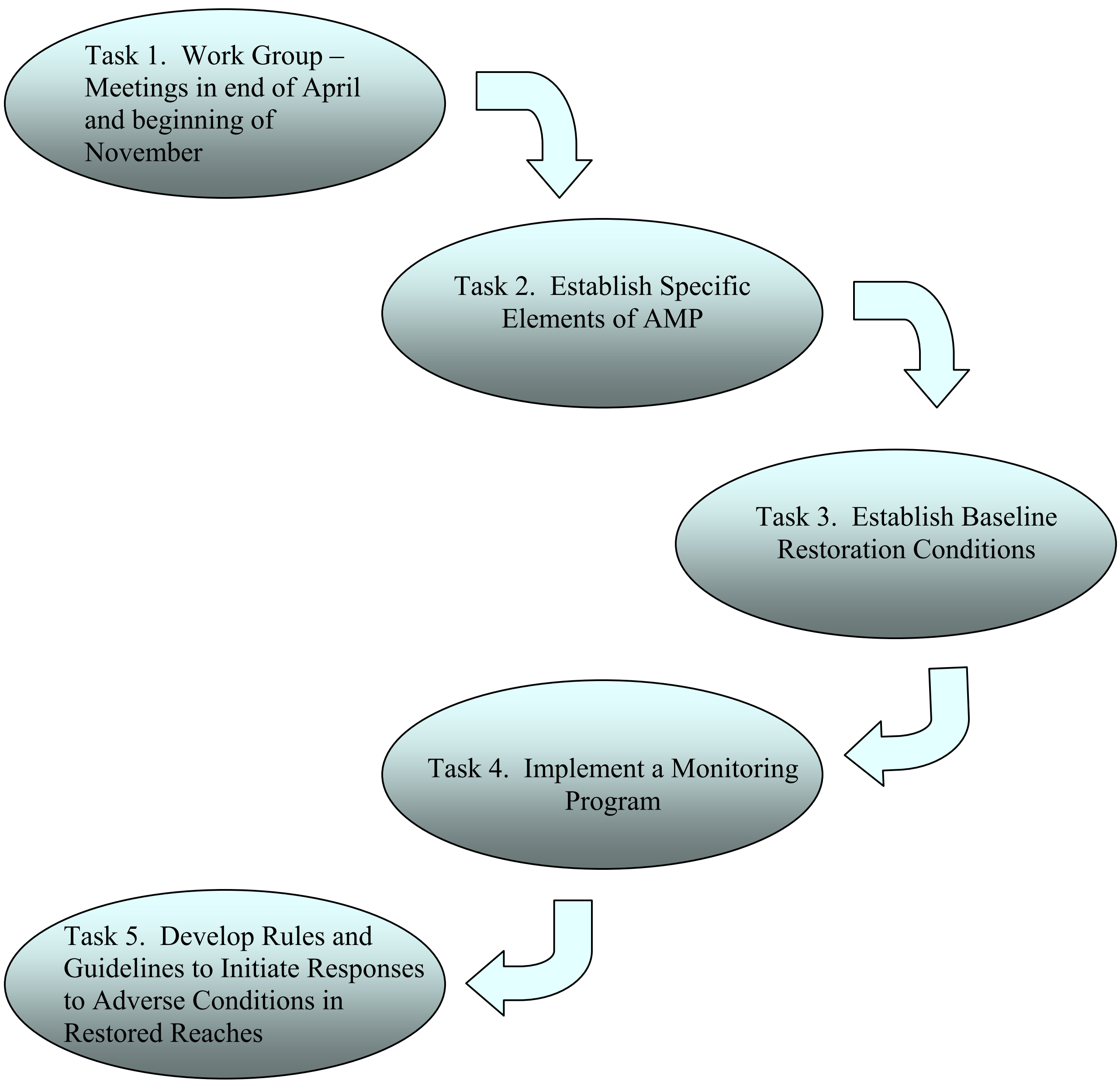
- Establishing procedures and methods for long term monitoring of channel morphology changes and vegetation encroachment.
- Reviewing monitoring data from all Middle Rio Grande restoration projects to develop a comprehensive background on restoration methods and responses.
- Monitoring the effects of fuel reduction and other on-going riparian projects in the study reach.
- Promoting an understanding of the relationship between successive years of high and low flow patterns and vegetation encroachment in the channel.
- Identifying the flow magnitude, duration, and frequency necessary to promote sand bar mobility and overbank flooding.
- Agency cooperation to conduct channel maintenance activities such as flushing flows and mechanical reworking of sand bar surfaces.

Prescribed responses to morphology changes should be prepared to avoid subjective maintenance application. Morphology changes may include vegetation encroachment in the channel, changes in vegetation composition and distribution on the floodplain, channel narrowing, loss of active channel or a decrease in overbank flood frequency.

The Platte River Whooping Crane Trust on the Central Platte River has been implementing an adaptive management approach for the last two decades. The Trust has concluded that some management will always be required to maintain the physical structure of vegetation free, wide channels and open wet meadows (Currier, 2002). The habitat management by the Trust is constrained by site physical limitations, land ownership and access, willingness of land owners to implement management regimes, financial resources, river flows, staff and equipment. Similar obstacles confront restoration on the Middle Rio Grande, but considering all these factors, the Trust perceives that their adaptive management approach as a successful endeavor (Currier, 2002). Tetra Tech toured the Central Platte in November 2002 with the Trust and identified those adaptive management principles and techniques that would be applicable to the Rio Grande.

Adaptive Management Plan Structure

The adaptive management strategy will include a set of management rules or guidelines for responses to measurable changes in channel morphology and riparian habitat. This may include changes in riparian vegetation composition, changes in the active channel morphology or a change in overbank flood frequency. To support these management guidelines, specific monitoring methods and techniques are outlined in a following section. The monitoring program will establish an unbiased, consistent record of the response of the active channel and its adjacent riparian floodplain to the various restoration projects. The following tasks are outlined to implement the Adaptive Management Plan (AMP).



Task 1. Formulate an **Adaptive Management Plan Work Group** consisting of ten scientists, planners or management personnel from federal, state and local agencies and stakeholders (such as landowners and water users) involved in Rio Grande resources. The Work Group will meet several times a year to engage in the following activities:

- Developing baseline restoration data.
- Monitoring recommendations including establishing and maintaining a photographic record with both ground and aerial photos.
- Conducting meetings every fall for two days during the first two weeks in November to review changes in the channel morphology and riparian vegetation.
- Monitoring channel restoration projects.
- Identifying research reaches and sites to monitor changes in sandbar evolution and vegetation encroachment.
- Making recommendations to promote sandbar and macroform mobility including, but not limited to, spring peak flow augmentation, increased high flow duration, extended fall releases and mechanical removal of sand bar vegetation.
- Reviewing previous seasonal flow patterns including tributary flooding.
- Making recommendations for restoration maintenance including active channel vegetation removal, channel morphology maintenance, bank destabilization and other channel enhancement activities.
- Fostering agency cooperation and develop funding mechanisms for channel maintenance.
- Reviewing potential for the next spring runoff season and make flow recommendations for the coming year to enhance channel morphology.
- Reviewing targets for endangered species numbers and habitat acreage.

The Work Group would be a central coordinating entity for the AMP and could consist of individuals from the following agencies and organizations:

1. One representative from the U.S. Army Corps of Engineers;
2. One representative from the U.S. Bureau of Reclamation;
3. One representative from the U.S. Fish and Wildlife Service;
4. One representative from New Mexico Interstate Stream Commission;
5. One representative from the Middle Rio Grande Conservancy District;
6. One representative from the New Mexico Forestry Division;
7. One representative from the Save Our Bosque Task Force;
8. One representative from environmental organizations;
9. One representative from a local community;
10. One representative from the research/scientific community.
11. One non-voting Technical Coordinator (paid position).

The first seven members of the work group would be appointed or delegated by their respective agencies. The remaining four representatives would be invited by consensus of the original seven appointees.

The first Work Group field reconnaissance meeting would convene in the fall 2004. An information package outline the proposed adaptive management plan, the role of the work group, selection of field reconnaissance sites and formulation of adaptive management rules and guidelines for the work group to consider would prepared by the technical coordinator. The first Work Group reconnaissance visit would focus on:

- Potential restoration sites for coming the year.
- Possible need for adaptive management actions in the coming year.
- Selection of sensitive reaches for establishing long term monitoring.
- A discussion of current fall maintenance flows and potential for high flows next spring.
- A discussion of existing sandbar vegetation encroachment.
- A review of native and exotic riparian vegetation density and composition at existing restoration project sites.
- Funding and planning needs for the future restoration.

During dry years, the focus would be in-channel bar maintenance and site clearing for overbank habitat restoration. During wet years, the focus would shift to floodplain riparian and bank-full channel restoration. Members of the Work Group who were not government employees would be allocated a stipend and expenses for participating in the Work Group. Stipend and expenses would be established by the Work Group. Recommendations and decisions would be documented by the Technical Coordinator or a paid staff administrator. Decisions by the Work Group would be based on a simple majority vote of at least seven members constituting a quorum. The Technical Coordinator would facilitate collecting, disseminating and storing adaptive management related data and information.

Task 2. The Work Group will review and establish the specific elements of the AMP based on specific channel and floodplain morphology and habitat criteria that will identify river restoration program success or failure. This will include a list of channel and floodplain morphology and any biological criteria that would initiate a resource management response. It will also include a list of potential resource management responses. This information will be disseminated to the agencies for review. The elements of the adaptive management plan will include:

- Target reaches or sites that will trigger adaptive management responses such as high flow recommendations.
- A list of riparian plant species together with composition, distribution and growth criteria that will initiate remedial measures.
- A fall annual report (prepared by the Technical Coordinator) on the status of the river system including a description of flows throughout the year, changes in channel morphology, vegetation growth and density on sand bars and floodplains, water resources management actions and other relevant information.
- Recommendations for the coming year including spring high flow targets, timing and duration.
- Recommendations for future additional monitoring including target species and reaches.

An initial outline of the specific elements of the AMP follows these tasks. The Work Group will make the final determination of what constitutes the AMP. The suggested elements are for guidance only.

Task 3. Design a hydrographic, biological, vegetation and geomorphic data collection program to establish restoration baseline conditions to support the AMP. The post-restoration baseline conditions data base are recommended in the next section of the report. This data base should be expanded and refined following a review by the Work Group. These baseline conditions will serve as the foundation for the monitoring program defined by Task 4.

Task 4. Task 4 proposes that the Work Group implement a reach wide monitoring program. The elements of the monitoring program are presented later in this report. The Work Group will establish a formal monitoring program based on reviews by the participating agencies. The Work Group will also review methods to monitor biological and ecosystem triggers for maintenance activity with emphasis on diversity and abundance of native species and the functional hydrologic connectivity of the channel and floodplain (Crawford, et al., 1993). To finalize restoration monitoring details, the Work Group will make decisions regarding the monitoring program including:

- Required cross section surveys at **high flows** to access channel morphological adjustments.
- Recommendations on new channel cross section locations.
- Required cross section surveys at low flows to review long term morphology channel changes.
- Suggested long term bed material sampling to track channel bed coarsening.
- Methods to access vegetation encroachment on the active channel.
- Methods to access vegetation composition and age groups on active sand bars.
- Recommended methods and locations to determine channel conveyance capacity.
- Selection of biological indicators and target species.
- Standard biological sampling and survey methods.
- Methods to assess species populations, abundance and diversity.

Some of the monitoring tasks could be performed by volunteers, students or community participants. This would stimulate an interest in the community for the restoration program and reduce the burden of data collection by researchers. The Work Group could publish a field guide for data collection by non-technical participants for each restoration project. A model field guide has been prepared and included as Appendix A. This field guide would be expanded, refined and adopted by the Work Group. The guide book includes a number of details such as: an equipment list, plant identification guide and data collection instructions.

Task 5. Task 5 is to implement a set of rules, techniques, methods, principles and practices that will guide agency application of an Adaptive Management Strategy to sustain the restored Rio Grande riparian system. This set of rules and guidelines will be set forth to identify water resource management options on an annual basis. The rules will trigger a response(s) to adverse conditions that are evolving in restored reaches. Such responses may be augmentation of high flows in the spring or disk and mowing maintenance in the active channel. Possible response rules are presented in a later section.

Optional Task A. Perform a review of adaptive management strategies and plans and river monitoring techniques involving other rivers. This will include attending and participating in adaptive management programs and meetings that have been organized on other rivers.

To implement the above tasks, it will be necessary to formulate the Work Group, select a Technical Coordinator, and organize and hold the first scheduled adaptive management field reconnaissance site visit. The remainder of the tasks would then follow in succession over the course of the first year of the AMP. On an annual basis, the Technical Coordinator will be responsible for the following technical and administrative tasks:

Technical Tasks:

1. Overseeing and organizing the establishment and documentation of restoration baseline conditions on all new projects.
2. Documenting and disseminating all AMP rules and guidelines to agencies and stakeholders.
3. Coordinating all AMP activities and monitoring with the appropriate agencies.
4. Updating and distributing the project field guide for community monitoring activities.
5. The Technical Coordinator would be responsible for various technical progress reports and memos including:
    - Technical Memorandums on monitoring program data collected each project.
    - Technical Memorandum listing specific channel and floodplain morphology and related habitat criteria that will identify a restoration project success or failure. The potential resource management responses will be outlined.
    - Technical Memorandum summarizing the design of a hydrographic, geomorphic and biological data collection for monitoring program for each restoration project.
    - Publishing a set of rules, techniques, methods, principles and response that will guide agency implementation of the AMP for each project. This set of

rules and guidelines will be set forth to identify water resource management options on an annual basis.

Administrative Tasks:

1. Assuming responsibility for all administrative and financial tasks of implementing the AMP.
2. Prepare an annual report that includes:
   - ✓ Goals, objectives, and on-going tasks of the Adaptive Management Plan;
   - ✓ Actions of the Work Group;
   - ✓ Status of each restoration project.
   - ✓ Annual findings and recommendations of the Work Group;
   - ✓ Definitively establish and update the techniques, methods, principals, practices and options for water resource management to support and sustain the natural functions of the river channel and riparian floodplain;
   - ✓ The baseline restored project condition and monitoring/data collection program for each restoration project;
   - ✓ Target parameters for assessing restoration successes and failures;
   - ✓ An update the response rules and guidelines.
   - ✓ Annual budget and funding.
3. The Technical Coordinator would be responsible for various administrative reports and memos including:
   - Information packet to describe the activities and responsibilities of the Adaptive Management Work Group.
   - Schedules and agendas for Adaptive Management field reconnaissance meetings.

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Elements of the Adaptive Management Plan

Introduction

This section describes the specific details of the Adaptive Management Plan including establishing baseline conditions, rules and guidelines for implementing mitigation, maintenance and other response measures, and monitoring methods. A short discussion follows on limitation and assumptions associated with the AMP. It is anticipated that the details outlined in the following sections will be reviewed and revised by the Work Group. Eventually a formal set of baseline data collection, monitoring methods and response mechanisms will be published by the Work Group with input from the various agencies and interested stakeholders.

Plan Assumptions and Limitations

The AMP will be subject to some of the same assumptions and limitation as the conceptual restoration plan. As previously stated not every hydrologic variable, habitat value, geomorphic trend, management issue or resource use impact could be folded into the conceptual plan and likewise, adaptive management methods may require some hard choices between different restoration projects or habitat values. Some issues and conflicts that arose during restoration will have to be resolved through adaptive management. The adaptive management plan will seek to reverse adverse trends that may evolve after restoration. A number of assumptions and specific limitations that may affect the adaptive management process are acknowledged. These are:

- The comprehensive restoration plan will require a relatively long period of implementation of perhaps ten years or more. During that period, some restoration techniques and practices will be revised and some may require re-working. The AMP will have to be flexible to adjust to changing conditions and priorities.
- Some maintenance of restoration activities may require immediate attention related to renewed vegetation encroachment in the active channel. Identification of the need for maintenance crucial. The benefit of some restoration projects may be lost if the response to adverse conditions is ill-timed or limited in scope.
- All AMP activities will require cooperation or agreement with the landowner or administrator whether a private citizen or agency or institution.
- Some AMP activities may require further evaluation before implementation. Cost, permitting and agency compliance may limit some AMP project application.
- Other restoration projects upstream or in the study reach may influence the approach or application of AMP activities.
- The existing groundwater data base is limited as discussed in Phase II. The lack of groundwater data limits the opportunity to consider groundwater hydrology in more detail in the AMP. Where practical, and contingent on funding, groundwater wells should be drilled and monitored in support of the AMP. In

general, the groundwater connection between the river and Low Flow Conveyance Channel (LFCC) remains a major concern with respect to restoration project design and potential AMP procedures.

- Operation of the San Acacia diversion dam can be considered in the AMP applications. Specifically, flushing of sediments of the dam is a possible method to aid channel restoration in the Escondida subreach.
- The AMP should review the response of the Bureau of Reclamation's new pilot channel and restored floodplain and other new projects as they are implemented.
- Levee stability in the San Acacia to San Marcial reach should be considered in any AMP applications.
- The San Marcial Railroad Bridge conveyance capacity or possible relocation of the bridge should be considered in the AMP project applications.
- The lowering of Elephant Butte Reservoir over a long period will eventually affect the channel bed slope at San Marcial or even further upstream. This may impact proposed restoration projects in the Refuge reach. The bed elevation at cross section near the San Marcial Bridge should be part of any monitoring program to identify potential headcutting.
- Potential river relocation downstream of San Marcial would necessitate monitoring cross sections in the vicinity of the San Marcial Bridge for potential headcutting.
- Long term sediment supply concerns are a continuing issue that should be considered in the AMP applications.
- All AMP maintenance projects should consider the potential effects on endangered species habitat.
- The AMP applications would not adversely affect low flow velocity aquatic habitat.
- AMP maintenance projects will reduce the stress on the agricultural community to provide suitable wildlife habitat.
- AMP maintenance applications will enhance fire protection for old growth cottonwood/willow bosque.
- Conflict resolution may be necessary for the implementation of some AMP project applications.
- Incidental impacts on other native or endangered species or habitat may occur during AMP maintenance activities, but should be relatively shorted lived.

Adaptive management activities could be limited by funding and agency cooperation. Potential AMP applications may affect current resource administration. The foremost factor that will impact restoration project effectiveness thus requiring adaptive management will be water availability. The Platte River Trust (Currier, 2002) found that "…mechanical clearing and disking could be employed very successfully as long as sufficient 'scouring flows' reworked the bed of the river following our treatments." Providing spring bankfull discharge with the required frequency and duration is greatest challenge facing the adaptive management program.

Establishing Baseline Restoration Conditions

To support the Adaptive Management Plan, a baseline assessment of a restoration project and contiguous areas must be conducted. It was acknowledged in the Bosque Biological Management Plan (Crawford et al., 1993) that monitoring is vital to the implementation of all future management actions. Monitoring is essential to assess ecological trends in restoration areas over a long period of time. Recommendations 18 and 19 in the Bosque Biological Management Plan address the need for a coordinated monitoring program to study ecological processes and biotic communities.

The baseline conditions for most restoration projects would be two-fold; 1) baseline conditions immediately prior to restoration, and 2) post-restoration baseline conditions. The purpose of the pre-restoration baseline data is to establish the impacts of restoration. The post-restoration data base will establish the baseline condition for future monitoring of trends and changes. Some long term monitoring programs may not be implemented immediately after restoration, but establishing post restoration baseline conditions is critical to support any possible future monitoring. Baseline conditions would include channel geometry surveys at high flows of the proposed restoration reaches, aquatic and terrestrial habitat diversity, vegetation composition and density, and all biotic and abiotic factors that can be used as metrics for success on individual projects. The following table provides a list of the required data to establish a baseline for future monitoring of the restoration project areas. A brief description of each of the data collection efforts is presented after the table.

To establish baseline data, additional data requirements for restoration should be reviewed. An additional data list was presented in Phase IV and is repeated here for further consideration.

- Aerial video and photographs of the area of inundation during overbank flooding. The video and photographs should be correlated with discharge data at the San Acacia and San Marcial gaging stations. Water surface elevations surveys at cross sections together with ground photos of flooding should be coordinated with the aerial photography. Additional discharge measurements within the reach should also be considered.
- Surveys for channel realignment, secondary and pilot channels and wetlands enhancement. This includes channel centerline surveys to determine new channel slopes. Topographic surveys will support estimates of excavation and spoils hauling. The number of survey points must be sufficient to generate an accurate digital topographic map of the restoration area. Access and road construction will have to be considered when preparing feasibility level studies.

- Inventory of archaeology sites in areas that may experience some disturbance.
- Inventory of endangered species in areas that may experience some temporary disturbance.
- Private land boundary surveys for conservation easements and restoration work on private lands.
- A detailed evaluation of site vegetation to accurately define vegetation removal practices.
- Post restoration construction surveys to prepare as-built drawings for future monitoring of flooding and sedimentation.
- Pre- and post-construction ground photos and aerial photos to document the restoration potential response to flooding and sedimentation.
- Groundwater monitoring wells in grid systems.
- Soil salinity measurements to determine site suitability for revegetation.

BASELINE DATA COLLECTION FOR RESTORATION PROJECTS

Restoration Technique	Cross Section Surveys and Bed Material Size	Endangered Species Habitat	Vegetation Mapping	Vegetation Diversity and Composition[1]	Floodplain DTM	Groundwater Levels	Soil Salinity	Water Quality	Aquatic Species Abundance and Diversity	Terrestrial Species Abundance and Diversity	Nutrient Levels
Sandbar Maintenance	✓	✓	✓	✓					✓		
Floodplain Reshaping	✓	✓	✓	✓	✓		✓			✓	✓
Channel Widening	✓	✓				✓		✓	✓		
Bank Destabilization	✓	✓	✓		✓	✓		✓	✓	✓	
High Flow Side Channels	✓	✓	✓		✓	✓	✓		✓		
Floodplain Vegetation		✓	✓	✓		✓	✓			✓	✓
Lower Floodplain		✓	✓	✓	✓	✓	✓			✓	✓
Pilot/Secondary Channels	✓	✓				✓		✓	✓		
Enhance Wetlands		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Fire Breaks		✓	✓	✓						✓	
Grade Controls	✓	✓				✓			✓		

[1]Density, growth and survival.

Hydrographic Data Collection – Hydrographic data collection will provide the baseline condition for all channel restoration activities. Existing channel cross sections should be resurveyed immediately following restoration construction. Additional cross sections should be considered for abrupt channel geometry transitions. If no cross sections have been previously surveyed in the reach, appropriate cross section spacing should be designed. Along with the cross section surveys, bed material samples should be collected to document the bed material size at the time of restoration. Photos should be taken upstream and downstream from mid-channel and from left and right bank across the river.

Data Needs:

- Cross section surveys (preferable at or near bankfull discharge)
- High water surface elevations (at or near bankfull discharge)
- Bed material samples
- Ground photos
- Arial photography or videos at high flows

Endangered Species Habitat – Following riparian restoration it is not expected that the restored area will initially support willow flycatcher habitat. Long term monitoring must be undertaken to assess the spatial and temporal variation in terrestrial habitat and its potential use by willow flycatchers. For that reason, environment baseline conditions for terrestrial species must be established following restoration. The baseline conditions to establish terrestrial biological quality include: diversity and abundance of endangered and native species, territorial, nesting and breeding sites, population dynamics, hydrologic and soil conditions at the site, diversity of plant species composition and complexity, prey species and food sources. For aquatic endangered species baseline conditions would include cross section surveys, bed material samples, hydraulic measurements, discharge measurements, bed forms, temperature, native and nonnative fish populations and distributions.

Data Needs:

- Population surveys
- Habitat use
- Habitat site conditions

Vegetation Mapping – Vegetation mapping was compiled in Phase II and is available in GIS format. Baseline vegetation mapping on location and extent of the riparian forests are necessary for comparison with future changes (Crawford et al., 1993). Size, structure, species composition are required for estimates of minimum patch sizes and fragmentation. Buffer zones for use by wildlife should also be quantified. Mapping should include sensitive wildlife habitats, access, road closures, treated areas, burns, exotic plant removal and revegetation acreage and density.

Monitoring the success of revegetation in terms of diversity and composition is critical to the developing effective management techniques (Crawford et al., 1993). Again, it is recognized that initial surveys after restoration will show limited revegetation, however, monitoring must be continued for the long term to evaluate success or failure of the restoration techniques. The baseline data should include records of the date of planting, source of material, species and numbers of plantings and quantification of size (Crawford et al., 1993). Exotic plant species invasion must be well documented and mapped. Soil types, moisture and salinity data should also be recorded.

Data Needs:

- Aerial photos of restored areas
- Vegetation surveys (species, composition and structure)
- Acreage of exotic vegetation removed
- Acreage of new vegetation established
- Acreage of potential new threatened and endangered species habitat
- Planting and seeding records
- Soil data (moisture, texture, elevation and salinity)
- Depth to water table

Floodplain DTM – Following restoration activities on the floodplain, a digital terrain model (DTM) should be developed to establish the post-restoration baseline conditions. Horizontal and vertical accuracy of DTM data within a tenth of a foot with approximately 100 to 200 points per acre is sufficient to generate a surface for future comparisons. The primary purpose of the DTM data base is to monitor floodplain aggradation and channel migration. For that reason, additional DTM points should be collected along the top of bank and in depressions on the floodplain.

Data Needs:

- Ground topography survey

Groundwater Levels – The focus of collecting groundwater baseline data is to establish the surface water/groundwater relationships, monitor response to river flooding, monitor floodplain inundation and measure water depletions. The Bosque Biological Management Plan indicated a need to reestablish the historic association between groundwater and overbank flooding (Crawford et al., 1993). A monitoring well pattern should be established to discern seasonal groundwater gradients and responses to vegetation growth. Special attention should be paid to groundwater observation wells for restoration projects on the east side of the river. Groundwater monitoring is especially important with channel restoration, floodplain lowering, wetland restoration projects and revegetation. Baseline groundwater quality should also be established. Observations well location should be coordinated with respect to existing wells.

Data Needs:

- Well location and distance to the river
- Groundwater observation well data (~5 to 10 wells per restoration site) by season including depth to groundwater and response to flooding

Soil Salinity – Soil salinity and depth to water are the primary physical limitations to revegetation of restored floodplain areas (Taylor and McDaniel, 1998a). Soil salinity measurements can determine the suitability of restoration sites for plant species. Long term monitoring of salinity with water depth at restoration sites can be correlated with overbank flooding and revegetation growth rates. Electro-magnetic induction (EM) has been documented as a cost effective method for determining soil salinity (Sheets et al., 1994).

Data Needs:

- Soil salinity magnitude and spatially variability (mapping)
- Soil texture
- Soil temperature
- Laboratory soil samples
- Depth to water table

Water Quality – The Bosque Biological Management Plan identifies the analysis of specific water quality impacts on restoration projects as a major research need (Crawford et al., 1993). The primary areas of water quality concerns are wetlands and flooded backwater habitats. The number of point source pollution sites in the San Acacia to San Marcial reach is limited to point discharges at the various irrigation drain outlets. River water quality issues are primarily important at low flows. The discharge of agricultural waters through drains is a special concern when the river is spatially intermittent. Baseline water quality measurements should include temperature, dissolved oxygen, nitrates, phosphates, pH, ammonia, chlorine and other pollutants.

Data Needs:

- Water quality measurements in wetland and marshes including total dissolved solids, dissolved oxygen, temperature, nitrates, phosphates, pH, etc.
- Spatially distributed water quality measurements downstream of drains at low flow

Aquatic Species Abundance and Diversity – Baseline conditions of aquatic habitat in the San Acacia to San Marcial reach is necessary to assess temporal and spatial variations in restored habitat. It is necessary to develop relationships between flow regimes and available aquatic habitat. The number one recommendation of the Bosque Biological Management Plan is (Crawford et al., 1993) to coordinate Rio Grande water management activities to support habitat with "…special emphasis on mimicking typical natural hydrographs." This baseline data should include both native and non-native fish community dynamics including populations, distribution and habitat associations.

Data Needs:

- Native and nonnative fish populations and distributions
- Fish movements and habitat use by life stage
- Invertebrate populations and distributions
- Relationship between fish populations and flow regimes
- Habitat quality and diversity as function of flows
- Food source availability
- Fish stocking data in restored areas

Terrestrial Species Abundance and Diversity – To monitor the long term variability in plant and animal community associations, it is necessary to establish a baseline restoration habitat data base. This will support studies on the fragmentation of bosque habitats. This addresses recommendations 7, 9 18 and 19 of the Bosque Biological Management Plan. Floodplain restoration may effect fragmentation and habitat buffer zones. Specific species may be selected to measure population diversity.

Data Needs:

- Select target species
- Native and nonnative species populations numbers
- Seasonal use of habitat
- Mapping to quantify habitat fragmentation and use of buffer zones

Nutrient Levels – Some baseline data in restored areas should be collected to establish soil nutrient levels prior to and after restoration. Nutrient cycling would be monitored with flooding and revegetation to observe nitrogen levels available for plant life. Frequent flooding increases the nutrient transport into the bosque and restored riparian habitat areas.

Data Needs:

- Measure soil nitrogen and phosphorous levels at restored sites

Adaptive Management Response Rules

A fundamental part of the Adaptive Management Plan is the program response to evolving adverse habitat conditions. During restoration, it is recognized that the ecosystem cannot achieve a steady state condition with passage through a developmental phase. Different restoration components reorganize at different rates (Molles, et al. 1998). To recognize deteriorating habitat conditions, a baseline survey of restoration project conditions must be completed (as discussed in the previous section) and a long term monitoring program must be implemented (discussed in the following section). To remove the subjectivity of applying the AMP to a restored project when adverse habitat trends are observed, response rules can be formulated and finalized by the Work Group. The response rules are a set of guidelines for adaptive management practices that will be triggered by an observed adverse condition. These rules can be revised over time and will require the cooperation of the resource management agencies. Suggested initial rules are outlined below as a starting point for consideration by the Work Group.

Rule 1. Flood Frequency and Channel Forming Flows
Adverse Trend or Condition: Infrequent overbank flooding or long periods between spring bankfull flows. Bankfull discharge is recommended on a frequency of a 2-year return period flood. This is a peak discharge of approximately 5,660 cfs at the San Acacia USGS gage as determined in the Phase II analysis. To limit vegetation encroachment on the active channel, bankfull discharge is required at least every third year. There should be no more than 2 consecutive years without a discharge approaching 5,660 cfs for a duration of least six days. The frequency of this discharge should be no less than 4 out of every ten years.
Recommended Response: If the Work Group determines that the spring peak flows previous two years did not reach 5,660 cfs at San Acacia gage and that the active channel conditions (vegetated sand bars) warrant a flushing flow, then the water resource management agencies should be informed. A formal request should be made to the agencies for a spring peak flow event of 5,660 cfs at San Acacia for six days during the period from about May 15 to June 7. This is essentially Recommendation 1 of the Bosque Biological Management Plan to coordinate Rio Grande water management activities to support the bosque riverine habitats by "…mimicking typical natural hydrographs."

Discussion: As was discussed in Phase II , there is some operational latitude in Cochiti and Jemez reservoir operation contingent on the endorsement of the Rio Grande Compact Commission. While reservoir operation by the Corps of Engineers is set forth in federal law, there is some flexibility in adjusting releases within the constraints associated with delivery contracts and state water laws. By refining storage and release timing, shorter duration, higher peak discharges can be formulated to support the active channel restoration. It is critical for the Work Group to address this possibility at the outset to sustain those channel restoration projects that may have already been implemented and to set the stage for future restoration projects.

Rule 2. Vegetation Encroachment in the Active Channel
Adverse Trend or Condition: Similar to Rule 1, the purpose of this rule is to sustain the active channel integrity and infrequent bankfull flows. Rule 2 focuses on bankfull discharge frequency and duration from the perspective of the channel environment rather than the hydrology. Vegetation encroachment on the channel sand bars will result in sediment deposition, vertical accretion of the sand bar, eventually attachment of the sand bar to banks or islands resulting in a permanent loss of channel conveyance capacity. Monitoring channel restoration will help to identify reaches where vegetation growth on sandbars could result in channel narrowing. The adverse condition is sandbar vegetation reach 3 ft to 4 ft in height (about two years growth) on sand bars. Plants reaching this height would not be removed by bankfull discharge.
Recommended Response: It is necessary to mobilize the entire sand bar to remove vegetation. The response is the same as Rule 1, to coordinate a spring peak flow of 5,660 cfs at San Acacia for six days during the period from May 15 to June 7. If the spring peak flows fail to remove the vegetation or if there is no appreciable spring peak discharge, then river reaches should be identified for mechanical restoration by disk and mowing. The trigger for vegetation removal will be vegetation height, density and sand bar coverage. Mowing and disking should be accomplished during the summer low flows following the third year of growth on the sand bar.

Discussion: A channel that is managed to be wider and more active will have greater aquatic habitat diversity. A wider channel with additional flow area and increased channel conveyance capacity would reduce the potential impact on the flood control levees. Channel restoration would increase the amount of sandy substrate, shallow water habitats. It is widely acknowledged that vegetation encroachment has resulted in channel narrowing throughout the Middle Rio Grande (see channel morphology discussion in Phase II). Vegetation encroachment has accelerated during the last several years in the absence of bankfull peak flows. During October 2003 reconnaissance trips to the San Acacia–San Marcial reach, it was observed that fall flooding inundated plants by 1 ft or more and created ripple bed forms. This small flood event, however, failed to remove the 1 ft to 2 ft height group of salt cedar plants (see the following two photos). This leads to the conclusion that inundation of plants must be of sufficient depth and shear stress to generate dune bed forms or higher sediment transport regimes are associated with sand bar mobilization.

Tamarisk plants after flooding in October, 2003.
Note: Ripple bed forms and plant detritus indicating a flow depth on the order of 1 ft.

Variable vegetation encroachment on sand bars in October, 2003.

Rule 3. Vegetation Regrowth on the Floodplain
Adverse Trend or Condition: In areas where exotic vegetation, especially dense tamarisk and Russian olive have been removed, revegetation must be monitored. There are several trends and conditions that should be considered to trigger possible mitigation. These include exotic vegetation population numbers, native versus non-native plant growth rates, composition, and density. Initial establishment by exotic plants may not be a mandate to consider restoration maintenance. If the native vegetation can out-compete the exotics, then remedial action may not be necessary. Several years of regrowth may be necessary to discern that exotic plant density requires additional restoration action. Additional removal of exotic vegetation may be warranted where restoration objectives are to maintain an open canopy or fuel break. A high variation in seedling recruitment is expected and survival rates are a function of a number of factors including water stress, soil moisture conditions and salinity levels (Taylor et al., 1999). Undesirable vegetation community composition through monitoring of salt cedar and Russian olive densities and growth rate will be justification for further restoration activity. The Work Group will have to establish criteria for undesirable plant community composition.
Recommended Response: If adequate criteria can be established for undesirable exotic plant densities and growth rates, then it would be cost effective to treat the restoration site again where necessary during the seedling life stage of the plants. Treatments could range from individual plant eradication with chemical control to complete control with disking or mechanical plow and raking. Mechanical control may be more appropriate where mature cottonwoods are present and herbicides may be useful where there are wet conditions (Sprenger et al., 2002). For appropriate native plant survival and plant densities refer to Taylor and McDaniel (1998a and 1998b) where based on results, mimicking natural flood processes can facilitate regeneration of native species. Every effort should be made to coordinate removal of exotic vegetation from riparian floodplain areas in concert with overbank flooding in the restored area the following spring. In established forest areas, Ellis et al. (1996) recommend flood pulses of 3 to 4 days during spring runoff to maintain the ecological integrity. Removal of competing vegetation and river flow management are critical factors influencing survival and establishment of riparian seedlings (Taylor et al., 1999). In restored areas where exotic plants are overtaking native vegetation, it may be necessary to completely clear the project site again. While clearing is not a requisite for native seedling emergence, it is important for seedling survival (Taylor et al., 1999).

Discussion: The diversity of habitats and the desired native plant mosaic in the San Acacia to San Marcial reach has been reduced. Open habitats, such as grasslands, wet meadows, and wetlands have been declining for more than a century. Some of this habitat loss can be attributed to the hydrologic disconnection of the river channel and floodplain. The predominant biotic factor threatening the native bosque is the invasion of nonnative plants, primarily salt cedar and Russian olive. It is widely accepted that salt cedar invasion adversely affects riparian ecosystems. The loss of native riparian forest to monotypic salt cedar stands has reduced habitat diversity. Limited habitat diversity in turn limits wildlife diversity (Crawford et al., 1993). Salt cedar provides lower quality bird habitat than native forests and increases the frequency and extent of fire. Monotypic stands of salt cedar have already excluded native cottonwood and willow from the canopy in extensive areas.

The potential for successful revegetation with native plant species should be investigated prior to removing salt cedar. Salt tolerant species such as salt grass and shrubs are recommended for flood levels from 5,660 cfs to 7,440 cfs depending on the site location and upland vegetation communities are suggested for areas flooded at 7,440 cfs or higher. Acceptable numbers of exotic plant revegetation in restored riparian habitat areas has to be established. In lieu of any technical criteria, it may be necessary to evaluate individual restoration projects on a site by site basis to assess the undesirable exotic plant populations. Taylor and McDaniel (1998b) reported that during optimum seed fall periods an average of 16 native seedlings/m^2 and 320 salt cedar seedlings/m^2 germinated on moist substrates on cleared areas. Declining water level rates of 2 cm/day can reduce salt cedar survival by 97% while native seedlings have a 75% mortality rate. Following salt cedar clearing, close attention should be paid to flood duration, timing and the rate of declining discharge of the recessional limb of the hydrograph.

Rule 4. Potential Levee Instability
Adverse Trend or Condition: Renewed or enhanced overbank flooding with terrace lowering, bank destabilization, secondary channels or channel relocation could result in flood waters reaching the levee. It is generally acknowledged that flow against the levee would be an adverse condition that could lead to levee failure because of the poor consolidation of the levee material and lack of an impervious core. The levee south of San Acacia was primarily constructed of the spoils materials from the excavation of the Low Flow Conveyance Channel. If it appears that unanticipated flooding may flow against the levee, then mitigation measures should be applied immediately following the recession of the flood waters.
Recommended Response: There are two approaches to mitigating floodwaters on the levee. The first approach is to keep the overbank flows from reaching the levee. This would require remedial action related to the restoration project, possible bank stabilization, creating of berms or secondary channels. The second method is to apply levee maintenance techniques such as installing riprap on the riverside levee face and toe, using filter material to avoid erosion of the levee face or reconstructing the levee with an impervious core. The Corps of Engineers is in the process of evaluating levee reconstruction from San Acacia to San Marcial and as a result this may be a moot issue in the future. In its present condition potential flooding inundation of the levee is a serious issue that would require an immediate response.

Discussion: Flow against the levee is more frequent and occurs at lower discharge south of the Highway 380 Bridge. In the Refuge reach damages from levee failure would not be extensive. Upstream of the Highway 380 Bridge, however, levee failure could have serious consequences for ranches and residential areas. Thus, where the potential for levee failure is greatest, the potential for flood damage is smallest. It should be noted that there was flooding along the levee south of the Bosque del Apache NWR several times in the 1990s and failure did not occur.

Rule 5. Bank Erosion and Channel Migration
Adverse Trend or Condition: In general, an active river channel with bank erosion and potential for avulsion is a desired restoration condition for the Rio Grande. The river, however, is confined to a relatively narrow floodplain and extensive bank erosion could impact the levee stability. Monitoring the river channel after flood events would be required in restoration reaches where bank destabilization has been applied.
Recommended Response: The recommended response to excessive channel bank erosion or channel migration is the same as for Rule 4. There are two approaches to mitigating flood inundation of the levee. The first approach is to keep the overbank flows from reaching the levee. The second method is to stabilize the levee.

Discussion: Restoration activities that promote a wide active channel including bank destabilization and secondary channels may initiate channel migration trends. The potential for bank erosion and channel migration will be evaluated on a project basis during the feasibility design. In those areas where channel migration may occur, levee stabilization can be considered concurrently with restoration project construction. This would enable the river to have more freedom to migrate across the floodplain.

Bank erosion is generally considered to be beneficial to the active river channel.

Rule 6. Failure to Induce Overbank Flooding
Adverse Trend or Condition: If no flood inundation occurs in areas where overbank flooding was planned, additional restoration work may be necessary.
Recommended Response: First the peak discharge and duration from the flood event should be reviewed with respect to other gages including San Acacia, San Marcial Bernardo and Rio Puerco. The FLO-2D model results should also be checked in the vicinity of the restored site. If the flood peak discharge and duration appear to be above the restoration design discharge for flooding, the cross sections should be reviewed and possibly resurveyed. Roughness (n-value) adjustments should be made in the FLO-2D model for high water surface elevations at the cross sections. The new cross section data should be input to the model. If it appears that the FLO-2D model still predicts overbank flow, channel scour and upper regime sediment transport may have occurred that either lowered the channel bed elevation or significantly reduced the n-value. If it is determined that additional restoration work is required, there are several approaches to help induce overbank flooding depending on the project goals. The various restoration techniques should be reviewed and perhaps a different restoration activity should be selected would be more suitable for project goals.

Discussion: Failure to induce overbank flooding at a restoration project can be due to a number of factors. The simplest approach is to conduct an analysis of the local flooding using new cross section data and high water surface elevations from the recent flood event. It is necessary to discern if the flooding was imminent or if a much higher peak discharge and duration would be required to initiate floodplain inundation. Once the analysis is complete based on a review of project goals and objectives, decisions can be made by the Work Group on the level of required mitigation to initiate flooding at lower discharge. Alternative restoration techniques may have to be applied depending on required discharge and additional costs to induce flooding.

Rule 7. River Desiccation
Adverse Trend or Condition: During low flow conditions, the river has a propensity to become dry for long reaches from San Acacia to San Marcial.
Recommended Response: Most of the water that is lost to channel infiltration becomes seepage to the Low Flow Conveyance Channel. The LFCC bed is lower than the river bed. The drainage water in the LFCC is pumped back to the river in four locations. These are locations where the river is close to the LFCC and the returned pump water begins again to be lost to seepage to the LFCC. A detailed analysis of alternatives for river and LFCC water management should be undertaken including changing the invert elevation of the LFCC, removing the LFCC, lining or piping the LFCC flows, changing the river bed elevation, increasing the minimum river flows or a combination of the above should be undertaken. These alternatives would involve either reducing the seepage from the river to the LFCC, raising the groundwater levels or just providing sufficient river flow to exceed the seepage.

Discussion: The need to restore the dynamics of the surface water and groundwater exchange is Recommendation 3 of the Bosque Biological Management Plan. This cannot be accomplished in the San Acacia to San Marcial reach with current location of the LFCC. Raising the bed of the LFCC to that of approximately the river channel from about Escondida Bridge to San Marcial should be considered. This would eliminate virtually all the low flow issues regarding the maintaining a wet river channel. Raising the bed of the LFCC would necessitate a drop structure downstream of San Marcial and it would require pumping of drainage water into the LFCC at several return points. The cost associated with raising the LFCC, lining the channel, constructing any necessary raised channel berms and consolidating drains for pump return to the LFCC would be expensive but it may be considered a reasonable expense considering the benefits in resolving water resource management conflicts associated with desiccating the river. The Work Group should work with the agencies to seriously examine the potential of redesigning and relocating the LFCC to allow the river to naturally function as a drainage channel.

Rule 8. Sediment Plugs
Adverse Trend or Condition: Sediment plugs occur when the sediment transport capacity is less than the upstream sediment supply and large sediment deposition occurs in a short reach of river. This generally occurs in backwater conditions related to channel constrictions or slope reductions and results in a loss of channel conveyance capacity and overbank flooding. Sediment plugs have historically occurred in the Refuge subreach, but could occur any where in the San Acacia to San Marcial reach in response to a large influx of bed material from an upstream tributary.
Recommended Response: Historically, sediment plugs have been viewed as an adverse geomorphic condition reducing the flood conveyance to Elephant Butte Reservoir and increasing the flood hazard associated with overtopping the levees. Maintenance measures such as dredging the channel, reconstructing the channel or raising the levees were employed to restore the channel conveyance capacity. Unless the overbank flooding associated with the sediment plug creates a potential levee hazard or adversely impacts private lands, the opportunity to initiate channel avulsion should be viewed as beneficial geomorphic activity. The Work Group should examine the sediment plug reach and determine if channel avulsion could proceed. Topography and vegetation are the key components to the review process. If the topography supports channel relocation, vegetation removal in that area should be considered along with either pilot or secondary channels to initiate the avulsion process. Some levee stabilization may be necessary if the sediment plug results in overbank flows along the levee.

Discussion: The natural process of channel avulsion should be considered when the development of sediment plugs is observed. The potential for adverse impacts on private land or habitat resources should be reviewed. This is a process that will maintain the active river channel dynamics and avoid the perched river system. Sediment deposition and channel aggradation the Refuge subreach will continue over the long term in response to the base level elevation control at the headwaters of Elephant Butte Reservoir. The alternative action is to continually dredge the river and maintain a narrow channel to force the sediment downstream. In response to massive quantities of sediment delivered to the Refuge subreach by large flood events in upstream arroyos, the best approach is to permit storage of the sediment on floodplain and allow the channel to rework and deposit sediment across the entire the floodplain surface. A wider floodplain in the Refuge reach would provide additional sediment storage and help to limit the perching of the river channel.

Rule 9. High Soil Salinity
Adverse Trend or Condition: High soil salinity can limit the suitability of restoration areas for revegetation of native plant species. Salinity levels above 3.0 dS/m will affect native plant productivity and diversity (Sheets et al., 1994). Salinity levels should be monitored at floodplain restoration sites.
Recommended Response: Periodic flooding can reduce salinity levels in restoration areas. Overbank flooding should be analyzed for all riparian restoration areas. Those areas that are not flooded at the prescribed 2-year return period design flood, should be revegetated with salt tolerant plant species. If high salinity levels are observed in areas that are inundated by prescribed flooding, overbank flooding should be considered on a more frequent basis.

Discussion: In floodplain areas along the Rio Grande where seasonal flooding has been altered or agricultural drainage is extensive, high soil salinity can occur. In healthy western riparian ecosystems, the annual spring floods remove excess salts. High soil salinities can reduce the seedling growth of many native species. Salt cedar is tolerate higher of higher soil salinities. Research with seasonal flooding has shown that native vegetation can out-compete exotics in moderately saline soils if other factors, such as rate of groundwater drawdown and soil texture are favorable. Restoration projects are prescribed for regenerating native riparian vegetation in areas that will be frequently flooded at discharge of 5,660 cfs or less at the San Acacia gage. Salt tolerant species such as salt grass and shrubs are recommended for flood levels from 5,660 cfs to 7,440 cfs depending on the site location and upland vegetation communities are suggested for areas flooded at 7,440 cfs or higher. The mixing of some salt tolerant species in this delineated flood zones is expected.

Rule 10. Fall Maintenance Flows
Adverse Trend or Condition: Fall maintenance flows are of insufficient magnitude and duration for reworking some of the sandbars. If it is apparent that spring high flows and fall maintenance will not sustain the active channel, it may be necessary to implement mechanical clearing and reworking of the active channel sandbars. A review of channel sand bars in November 2003 revealed significant seedling establishment and very limiting reworking during the previous spring high flows.
Recommended Response: There are several possible responses if the late season high flow fails to rework the sand bars in the channel. First, if there is available storage, release higher flows in the fall. Adjust the fall releases for a few weeks and then release a fall flushing flow of perhaps 1,000 cfs for several days. Second, prescribe spring flushing flows to insure that the entire channel is reworked. During drought conditions, spring flushing flows may be unavailable. In that case, if a prolonged drought appears to be imminent, mechanical clearing such as mow and disking should be considered.

Discussion: Every fall in late October through mid-November when irrigation diversions decrease, river discharge increases to an average of about 500 cfs for approximately three weeks (see the Phase II discussion). This fall maintenance is important during dry years to laterally erode sand bars and rework the active channel. It has the benefit of removing new seeding growth on sand bars and flushing fines off the sand bars that may have been deposited during late summer or early fall tributary flooding. The silt and clay deposits have the effect of stabilizing some of the sandbar surfaces. It is recommended that the Work Group tour the river channel and make an assessment of the need for higher fall maintenance flows in late October. This channel monitoring assessment should consider the potential and availability for the subsequent spring overbank restoration flows.

Rule 11. Increased Fire Hazard
Adverse Trend or Condition: Build-up of fuel loading in the riparian bosque in various vegetation densities and compositions with both native and exotic species represents a fire danger to existing mature native plant communities. This includes a build-up of floor debris and litter that can be particularly acute in dense salt cedar stands. Of specific importance is the regrowth of vegetation is previously cleared fire breaks.
Recommended Response: There are several potential responses to an increased fire hazard. These include an increased frequency, duration and magnitude of flooding, mechanical or chemical reduction of the fuel loading, exotic vegetation removal, riparian habitat restoration, selective thinning of live vegetation, additional fire breaks and prescribed burns. There are a number of monitoring tests and triggers that can be considered to address increased fire hazards. The prevention and suppression of wildfires in the bosque requires coordination of a number of agencies and organizations. An integrated fire management plan is needed.

Discussion: Reducing fire hazards can be accomplished through a number of restoration activities that will enhance the native riparian habitat. Two primary methods are establishing fire breaks and the control of litter accumulation. Accumulated litter can be reduced or controlled by frequent overbank flooding. In addition, wetlands could be enhanced or expanded to serve as firebreaks. The removal of deadwood is another possible method for reducing fuel loads, but this needs to balance against the appropriate level of woody material for ecosystem processes. Some deadwood could be collected as fire wood. An integrated fire management plan, would involve coordination the New Mexico Forestry and Resources Conservation Division and other fire fighting agencies.

Monitoring Program

Introduction

Monitoring to determine the long term response of the restoration projects and subsequent management actions is critical to the success of the any restoration program. Monitoring is necessary to assess the geomorphological and biological trends in the San Acacia to San Marcial reach (Recommendations 18 and 19 of the Bosque Biological Management Plan). The Bosque Biological Management Plan specifically addresses monitoring restoration sites in Recommendation 4 indicating that the long term evaluation of specific construction sites is necessary "…to assess the impacts of management actions and mitigation efforts on aquatic habitat and species." It is important to quantify both temporal and spatial variability in riparian habitat as well. Similarly monitoring the success of revegetation and restoration of riparian and wetland sites is critical to developing long term effective management techniques and response (Recommendation 14 of the Bosque Biology Management Plan). It is anticipated that some of the long term monitoring parameters will vary from the initial baseline data variables as restoration projects evolve and various habitat trends are identified.

The importance of monitoring restoration projects is widely recognized. The Biological Opinion (USFWS, 2001) states that for prescribe restoration sites throughout the Middle Rio Grande "(m)onitoring for the effectiveness of each restoration project to benefit the silvery minnow and flycatcher will be conducted at each site annually for a period of at least *fifteen years* post-project completion in order to assess whether native riparian habitats are self-sustaining and successfully regenerating…". The Biological Opinion also stipulates that monitoring reports are to be prepared annually.

The biotic and abiotic conditions in the ecosystem define the composition and functionality of riparian and aquatic habitat. Monitoring these conditions will provide a roadmap to future trends and the probability of the success of restoration projects. An effective restoration plan must enhance favorable biotic and abiotic conditions that support desired habitat and reduce or eliminate those conditions that stress the habitat. One focus of the monitoring program is to identify the most important stressors and learn how to mitigate their impact. The Phase II report discusses the important biotic and abiotic conditions for restoration in the study reach. The elements of a monitoring program are presented in the following section.

Elements of the Monitoring Program

In the Ellis et al. (1996) report on "Seasonal Flooding and Riparian Forest Restoration in the Middle Rio Grande Valley," practical methods for monitoring seasonal and annual changes in habitat, species populations and ecological processes were discussed. The report identifies that long-term records of ecosystem change will provide the basis for adjusting adaptive management strategies and responses. The importance of long term monitoring was demonstrated by University of New Mexico decade long data collection program that indicated the deteriorating conditions of the Albuquerque riparian forest (Crawford, et al., 1999). The commitment to a long term monitoring program requires an interagency cooperation and interactive structure that can be fostered by the Work Group. The key monitoring variables as well as the procedures to monitor restoration success can be adjusted over time as restoration knowledge is assimilated. Monitoring may be uniquely designed for each restoration project and should consider the project goals and objectives.

The Work Group will have to determine the frequency and long term status of monitoring the various biological or geomorphological parameters. It will be important to select key variables to monitor during short duration flooding and conversely, identify those parameters to monitor either seasonally or year round. The results of year round monitoring of key biological populations and ecological processes were valuable to assessing the magnitude and timing of ecosystem reorganization associated with flooding (Crawford, et al., 1999). Bosque Ecological Monitoring Program (BEMP) monitoring sites can be considered for monitoring some of the ecological variables. This program is conducted through the University of New Mexico (UNM) Department of Biology.

Special consideration should be given to monitoring burn areas in restoration projects or in contiguous areas. Monitoring could document revegetation in burn areas compared to restoration projects. Burn areas should also be monitored to determine the areal extent of the burn, loss of native species, the invasion of exotic plants and the effects of fragmentation on the habitat with respect to restoration. Following a burn in a restoration area, the impacts of the burn on the restoration project could be assessed.

Some restoration projects may proceed on private land. Landowners can be involved in the developing and participating in the monitoring program. Private landuse in or around restoration projects should be monitored to identify and compare management practices and their impact on restoration. Management practices such as grazing, agriculture or domestic use on private land may be important to habitat change.

It is recognized that complexity and cost may limit the scope of monitoring some ecological or geomorphological variables. Volunteer data collection may reduce the monitoring costs. Photography, sand bar sizes, sediment size samples, vegetation plot counts and other data can be collected by volunteers or students. These are sampling procedures and methods that are relatively simple, quick and inexpensive and can be dedicated to volunteers to indicate status and trends associated with plants, soil, water and animal resources. An example field guide for volunteers is presented in Appendix A.

The following table identifies some of the variables that could be monitored to assess geomorphic trends and to determine biological quality at the restoration sites. Biological quality refers to species diversity, distribution and abundance in conjunction with the processes and environments that sustain them (Crawford, et al, 1993). The monitoring table has three parts; geomorphic assessment, annual hydrology – geomorphology data, and annual biological data. Not all of the variables need to be monitored at each restoration project. Selecting variables to monitor for a given project depends on the established monitoring program already in place at other sites. As parat of the ESA Collaborative Program and the willow flycatcher data collection, infrared aerial photography will be taken every three years. It is recommended that the Work Group use this photography to conduct a geomorphic assessment on a three year cycle. The photograph could also be applied to various biological assessments such as updating vegetation mapping. The table is followed by a brief description of the monitoring variables.

MONITORING PARAMETERS – GEOMORPHIC ASSESSMENT (CONDUCTED EVERY 3 YEARS)						
Parameter	River or Riparian	Project Site or Reach Wide	Frequency	Long or Short Term	Volunteer Data Collection	Comments
1. Aerial photography and video	Both	Reach wide	During floods	Long term		During flooding
2. Cross section surveys	River	Project site	During floods	Long term		Both high flow surveys
3. Cross section photos	River	Project site	During floods	Long term		Four per cross section
4. Water surface elevations	River	Project site	During floods	Long term		At each cross section
5. Hydrology, river flows and bankfull discharge	River	Reach wide	During floods	Long term		One data set is required with aerial photos
6. Unvegetated channel area	River	Reach wide	During floods	Long term		Use aerial photographs
6. Area of inundation	Riparian	Reach wide	During floods	Long term		Use video flyover, compliment w/surveys
7. Revegetation, density and composition	Riparian	Project site	Every 3 years	Short term		Combine w/ET data, compute net depletion
8. Floodplain topography and sediment deposition	Riparian	Project site	After floods	Short term		Infrequent measurements after floods
9. Soil data and salinity	Riparian	Project site	Every 3 years	Short term		Soil moisture and texture, salinity
Supplementary Cross Section Data						
10. Bed form description	River	Project site	W/aerial photo	Long term		With each cross section survey
11. Bed material size	River	Project site	W/aerial photo	Long term		Composite sample at cross section
12. Sand bar size and shape	River	Project site	W/aerial photo	Shrot term		Aerial video and photos
13 Sand bar vegetation encroachment (density)	River	Project site	W/aerial video	Short term	X	Ground photos and survey with aerial video
14. Sand bar vegetation encroachment (composition)	River	Project site	W/aerial video	Short term	X	Ground photos and survey with aerial video
15. Groundwater well depth and water quality	Riparian	Project site	With Q meas.	Long term		To review high flow response
16. Sediment transport measurements	River	Reach wide	With Q meas.	Short term		To compliment discharge measurement

MONITORING PARAMETERS – ANNUAL HYDROLOGY AND GEOMORPHOLOGY DATA						
Parameter	River or Riparian	Project Site or Reach Wide	Frequency	Long or Short Term	Volunteer Data Collection	Comments
1. Hydrology, river flows and bankfull discharge	River	Reach wide	During floods	Long term		One data set is critically needed
2. Area of inundation	Riparian	Reach wide	During floods	Long term		Use video flyover, compliment w/surveys
3. Cross section surveys	River	Project site	Annual	Long term		Both high and low flow surveys
4. Cross section photos	River	Project site	Annual	Long term		Four per cross section
5. Water surface elevations	River	Project site	Annual	Long term		At each cross section
6. Bed form description	River	Project site	Annual	Long term		With each cross section survey
7. Bed material size	River	Project site	Biannual	Long term		Composite sample at cross section
8. Sand bar size and shape	River	Project site	Annual	Long term	X	Initial surveys w/equipment, then volunteers
9. Sand bar vegetation encroachment (density)	River	Project site	Annual	Long term	X	Use guide book
10. Sand bar vegetation encroachment (composition)	River	Project site	Annual	Long term	X	Volunteers can do this
Supporting Data – Recommended Additional Data Collection						
11. Meteorological data	Riparian	Reach wide	Monthly	Long term		Air and soil temperature, rainfall
12. Water quality	River	Project site	Seasonal	Long term		Phosphates, DO, nitrates, pH, etc.
13. Groundwater well depth and water quality	Riparian	Project site	Seasonal	Long term		Set a grid pattern or transect
14. Aerial photography and video	Both	Reach wide	During floods	Long term		During flooding
15. Sediment transport measurements	River	Reach wide	Seasonal	Long term		Sediment load measurements at SO-1470.5

MONITORING PARAMETERS – ANNUAL BIOLOGICAL DATA						
Parameter	River or Riparian	Project Site or Reach Wide	Frequency	Long or Short Term	Volunteer Data Collection	Comments
1. Litter production	Riparian	Project site	Annual	Short term	X	10 x 10 cm samples of all litter
2. Leaf decomposition and leaching	Riparian	Project site	Annual	Short term	X	See Ellis, et al., 1999
3. Log decomposition	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
4. Forest floor litter	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
5. Biomass of woody vegetation	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
6. Understory species abundance and diversity	Riparian	Project site	Annual	Short term		Follow other restoration project methods
7. Herbaceous biomass	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
8. Foliage density and diversity	Riparian	Project site	Biannual	Short term	X	Follow other restoration project methods
9. Tree growth	Riparian	Project site	Biannual	Long term	X	Follow other restoration project methods
10. Cottonwood recruitment	Riparian	Project site	Biannual	Long term	X	Follow other restoration project methods
11. Tree and shrub density	Riparian	Project site	Biannual	Short term		Follow other restoration project methods
12. Soil microbes and fungi	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
13. Surface-active arthropods	Riparian	Project site	Annual	Short term	X	Follow other restoration project methods
14. Aerial insects	Riparian	Project site	Annual	Short term		Follow other restoration project methods
15. Vertebrates abundance and diversity	Riparian	Project site	Biannual	Long term	X	Follow other restoration project methods
Potential Additional Monitoring Data						
16. Fish population and habitat usage	River	Project site	Annual	Long term		Use ESA Collaborative Program Data
17. Fish invertebrates population and habitat usage	River	Project site	Annual	Long term		Secondary Importance
18. Flycatcher presence/nesting and avian species	Riparian	Project site	Annual	Long term	X	Use ESA Collaborative Program Data

Meteorology: Some restoration sites could be monitored for seasonal meteorological data. This data base could be applied over a reach wide set of restoration projects. The primary data would include:

- ✓ Precipitation
- ✓ Air temperature
- ✓ Soil temperature
- ✓ Wind speed
- ✓ Humidity

This data would be useful for both biological conditions as well as evaporation and evapotranspiration sites. The University of New Mexico has established a tower equipped with meteorological instruments for estimating ET at Bosque del Apache National Wildlife Refuge. This station may be sufficient for providing meteorological data for most of the restoration sites in the San Antonio and Refuge subreaches.

Monitoring hydrology and channel morphology: Hydrology is the primary factor affecting Middle Rio Grande aquatic habitat. Historically, the Middle Rio Grande had a seasonal high variability of flows characterized by spring flooding and low flows in late summer and fall punctuated by summer convective thunderstorms. Low flow periods now result in major portions of the channel going dry causing fragmentation of aquatic habitat. The isolated pools become the last refuge for populations of fish and invertebrates. Native aquatic species have adapted to survive low flow conditions until high flows reestablish habitat continuity and availability. The water regulation infrastructure has created longer and more frequent periods of channel desiccation and habitat fragmentation. It important to monitor river flows throughout the San Acacia to San Marcial reach and determine exactly where the river is going dry in relationship to the San Acacia gage discharge.

The purpose of monitoring the channel cross sections is to evaluate the impacts of restoration on channel morphology. Cross section surveys constitute a key element of the monitoring program and are critical to the adaptive management program. Cross sections should be surveyed during and after spring runoff. If there are no significant peak flows, then no post-runoff surveys are required. Summer and fall tributary flooding should be considered when surveys are scheduled. It may not be necessary to resurvey every cross section in a given subreach. Some cross sections will be more stable than others. Every effort should be made to survey the cross sections at bankfull discharge over a relative short period of a few days. At least one discharge measurement should be completed during the cross section surveys. The hydrographic data based should include:

- ✓ USGS gage record
- ✓ Observations of the location where the river goes dry as function of discharge at San Acacia
- ✓ Cross section data conforming to Bureau of Reclamation standards for Rio Grande hydrographic surveys
- ✓ A set of four photos, upstream and downstream about mid cross section and one from each bank toward the opposite bank

- ✓ Bed material size samples at one cross section per restoration project (at three samples per cross section that can be combined into one composite sample)
- ✓ Bankfull discharge measurement
- ✓ Observations of the bed forms
- ✓ Observation of the bank and overbank vegetation
- ✓ Water surface elevations at bankfull discharge

If the restoration project results in significant channel bank erosion or sediment deposition, additional cross sections can be considered for transitions from wide to narrow reaches or vice versa. Additional cross sections should also be considered if the cross section spacing is inappropriate around restoration sites. High water surface elevation surveys can be accomplished with the cross section surveys, but they should also be coordinated with the aerial photography and videos of the flooded areas. In conjunction with water surface elevation surveys, discharge data should be retrieved from the nearest gage. The aerial photography will also be useful in analyzing the sand bar evolution. The following cross sections should be considered for long term monitoring. These cross sections have a long history of surveys, but as restoration is implemented and the channel geometry is altered, comparison of the thalweg elevations may have the only relevance to historical surveys.

SA-1226	CEB-56	SO-1428	SO-1502	SO-1576	SO-1652.7
SA-1236	SO-1339	SO-1443	SO-1508.9	SO-1585	SO-1668
SA-1252	SO-1346	SO-1456	SO-1531	SO-1596.6	SO-1683
SA-1274	SO-1380	SO-1470.5	SO-1550	SO-1603.7	SO-1692
SA-1292	SO-1410	SO-1496	SO-1554	SO-1626	SO-1701.3

This is by no means an exhaustive list. More cross sections should be established and monitored in the vicinity of restoration projects. The cross sections listed above will monitor long term, reach wide morphological trends.

Sediment transport measurements: Collecting sediment load is a major commitment and expense. In terms of monitoring the potential response to channel restoration, it is vital data for the AMP. Long term sediment load measurements are required at San Acacia, San Marcial and perhaps at the Highway 380 Bridge. Previous sediment measurements have been collected at cross section SO-1470.5 approximately 2,000 ft upstream of the bridge. Over the long term, this data base would indicate the potential aggradation and degradation trends in the three subreaches. It would support the assessment of success or failure of the channel restoration and would help identify opportunities for future restoration projects. Aggradation and incision trends would be correlated with cross section changes. The sediment measurements would include:

- ✓ Cross section survey
- ✓ Discharge measurement (velocity and depth)
- ✓ Water surface elevation
- ✓ Bed material samples
- ✓ Suspended load measurements
- ✓ Bedload measurements

The Work Group would have to decide on the frequency of sediment measurements. This is a difficult decision because of the daily variability in the sediment load. Different sampling frequencies can be prescribed on a seasonal basis. Daily sediment load measurements should be considered for the spring high flow season. Infrequent sediment load measurements can be taken for flows less than 500 cfs. Consideration should be given to sediment load measurements during tributary floods from summer and fall thunderstorms. Agency cooperation is required to insure adequate sediment sampling at the San Acacia and San Marcial gages. If daily sediment load measurements for flows over 500 cfs are not feasible, it is recommended that between 50 and 100 sediment load measurements be collected per year with the majority of those during spring high flows.

Sand bar morphology and vegetation. The key to maintaining the channel dynamics in a reach will be implementing the appropriate response to vegetation encroachment on sand bars. Monitoring the sand bar size and vegetation growth is critical to adaptive management decisions regarding control of the encroaching vegetation. A recommendation for bankfull spring flooding is the primary objective of the monitoring effort. The sand bar monitoring can be accomplished by volunteers and through aerial surveys. It is important to maintain control sites on the selected sand bars for review by the Work Group in the fall. The required data includes:

- ✓ Sand bar dimensions
- ✓ Sand bar elevation (for deposit estimates)
- ✓ Vegetation surveys (populations, density and composition)
- ✓ Sediment samples and observations of silt and clay deposits
- ✓ Observations of aeolian (wind blown) sand movement
- ✓ Photographs

An example of a field guide for volunteers is presented in Appendix A to illustrate data collection methods and procedures.

Groundwater well depth and water quality: There is a paucity of groundwater observation well data in the San Acacia to San Marcial reach. An array of groundwater wells should be established with each major restoration project. The connectivity between groundwater and river flows should be established. This is particularly important along the reach where seepage to the LFCC is an issue. River mile 95 to 100 is a reach where groundwater wells are required. All restoration projects south of Highway 380 should be considered for groundwater monitoring. The number of groundwater wells will vary with restoration projects, but wells should be considered on both sides of the river. Projects that involve channel relocation, secondary channels or wetland enhancement are priority projects for groundwater observation wells. Floodplain terrace projects, drop structures and bank destabilization projects are also candidate projects for groundwater wells. Finally, groundwater wells should be considered for floodplain areas where exotic vegetation removal will be extensive. Depth to groundwater will be important for water salvage and depletion analyses. It is also important for soil salinity assessment and determining site suitability for vegetation regeneration. To establish a observation well array, the following monitoring tasks are required:

- ✓ Locate well transects using GPS
- ✓ Groundwater depths on a daily or weekly basis (may vary with season)
- ✓ Groundwater quality

Groundwater depths and fluctuations should be correlated with river stage and vegetation parameters.

Water quality data: For monitoring the Los Lunas Project it was recommended that Hydrolab five-port sondes be used to monitor basic water quality parameters (Corps and BOR, 2002). This data would be analyzed to determine if water quality could inhibit aquatic species use and locate any point source pollution at or near restoration projects. The water quality data could also be analyzed in conjunction with groundwater data. Possible monitoring parameters include:

- ✓ Water temperature
- ✓ Dissolved oxygen
- ✓ Total dissolved solids
- ✓ Ammonium
- ✓ Nitrates
- ✓ Phosphorous
- ✓ Chlorine
- ✓ pH
- ✓ Turbidity
- ✓ Specific conductivity

Soil and Salinity Data: Soil salinity should be moderate for native riparian vegetation regeneration. Soil salinity will define the type of native vegetation that may thrive at a restoration site. It varies with flooding, soil type and depth to groundwater. Salinity data should be supplemented with the following data:

- ✓ Soil moisture
- ✓ Depth to groundwater
- ✓ Soil texture
- ✓ Fine sediment size fraction
- ✓ Soil temperature
- ✓ Soil chemistry

Cottonwoods and willows grow best in sandy soils. Recruitment of these species is essentially restricted to sites that are moist and open enough for seedling establishment. Soil data should be collected either annually or seasonally at restoration sites where flooding occurs frequently. The soil monitoring data should be combined with site surveys following large flood events.

Floodplain topography and sediment deposition: Following construction of a restoration project, the post restoration baseline data collection should include a topographic survey of the site. This will enable future monitoring of sediment deposition at restoration sites where overbank flooding is encouraged. Following significant flood events or project maintenance with vegetation removal, the site should be resurveyed to determine the changes in topography. The preferred method would be to record sufficient digital terrain elevation points to create a surface in a CADD program and compare pre- and post-flood CADD surfaces to determine sediment deposition volumes. Soil analyses and sediment samples will identify the impacts of flooding on soil suitability for regenerating native vegetation.

Aerial photography and video: Aerial photos and videos are valuable tools to assess restoration projects. The video should be filmed during the spring peak discharge every year that there is overbank flow. A digital video can be used to evaluate the area of inundation and the response to river stage. The aerial video should be shot at an altitude of approximately 1,200 ft with multiple passes in both upstream and downstream directions to ensure adequate lighting and to avoid sun glare. The best video can be obtained by removing the passenger door in the rear of the plane and by not flying directly over the river. The video and aerial photographs (taken on the same flight) can be correlated with the following data collection:

- ✓ River discharge at the San Acacia and San Marcial gages
- ✓ Water surface elevation surveys taken by a ground crew at selection cross sections
- ✓ Measurement of water depth at restoration sites by a ground crew

High flow videos are critically important to obtain. There have been no spring high flows in this reach for several years. Wetted surface areas of the channel or floodplain are urgently needed for FLO-2D model calibration, to assess changes in channel morphology with high flows, and to monitor changes in habitat flooding. Low flow videos and aerial photography should be collected at least once every three years to monitor vegetation encroachment in the channel as well as restoration progress.

Revegetation density and diversity: Vegetation monitoring at restoration sites is multifaceted. It will document the success of cottonwood recruitment, the effectiveness of planting native species, the natural establishment of riparian vegetation, the regrowth of exotic species, the development of noxious weeds, and will characterize the restored vegetative communities in terms of composition, diversity, structure, and plant species abundance. Plant diversity and abundance data can be correlated with habitat use, flooding and groundwater levels. Noxious weeds need to located and documented for removal. The following data and tasks can be considered for vegetation monitoring:

- ✓ Select and mark transects with metal t-posts
- ✓ Record coordinates of transect with GPS
- ✓ Measure cover along the transects using the point intercept method
- ✓ Establish quadrats for woody species composition and stem density
- ✓ Document new seedlings, pole plant survival, plant heights
- ✓ Map vegetative communities on site basis
- ✓ Document site with photos
- ✓ Establish sampling plots and intervals for density, species composition, distribution, average height, stem diameter, cover, canopy closure and mortality
- ✓ Collect tree data including species, density, diameter at breast height and height Identify noxious weed and exotic species locations

The factors used to assess habitat include density, structure and species diversity:

- *Structural diversity* is determined by the combination of overstory and understory plants in the same community. For example, a mature cottonwood forest with sparse vegetation or no understory is considered to have low structural diversity, whereas a riparian forest with dense understory vegetation is considered to have high structural diversity. In wet meadow communities where there are few overstory trees, structural diversity is not considered as important as plant diversity in assessing habitat value.
- *Species diversity* is determined by the species variety. In general, communities containing multiple species are rated as having higher habitat value than monotypic species communities.
- *Native or nonnative* composition is based on the dominant vegetation species in each sub-type. Sub-types with native species as the dominant vegetation are rated as having higher habitat value than nonnative dominated communities.

The Los Lunas Project monitoring report can be referred to as an example of specific criteria on vegetation data collection (Corps and BOR, 2002). This data base can then be used in conjunction with aerial photos and videos and vegetation mapping to ground truth the different ground cover communities and densities. The data base can then be applied to computations of the net water depletions using evapotranspiration models. Some indicator species of special note include Ripley milkvetch, Warnock's willow, grama grass cactus, Great Plains spiranthes, giant helleborine, catchfly dentian, Pecos sunflower, La Jooa prairie clover, and Parish's alkali grass (Corps and BOR, 2002).

Litter production, forest floor litter, leaf decomposition and leaching, log decomposition: Insufficient flooding and soil moisture leads to decreased rates of decomposition, inhibits nutrient cycling and may inhibit plant growth (Ellis et al., 1999). This study suggest that a decade of annual flooding may be required to restore the organic debris to historical levels. Specific monitoring of litter production is accomplished by collecting standing stock of organic matter and 10 x 10 cm samples of all litter above the soil. Samples are dried, weighed and ashed to determine the average ash-free dry weight of litter. For leaf decomposition, cottonwood leaves are collected, dried and placed in bags at reference sites for varying periods of time up to one year. The bags of leaves are then collected, dried, weighed and ashed to compare ash-free dry weights at different sites. Cottonwood logs can be placed at reference sites to estimate the rate of wood decomposition. Each log is weighed and marked and placed at the site. Subsequently over the following year the logs are collected, dried and samples taken from each log to determine decay rates. Different decay rates can be determined for logs that were flooded versus those logs that were on floodplain areas that were not flooded. Ellis et al. (1999) determine that flooding can increase rates of leaf and wood decomposition thus increasing nutrient cycling. The flooded site can have significantly less litter accumulations and reduce fire potential. A periodic assessment of litter quality may be important in project sites where salt cedar have been removed. Correlating soluble sugars, lignins, and other phenolics can aid in understand decomposition rates.

- ✓ Litter quantity
- ✓ Leaf and log decomposition

Biomass of woody vegetation, understory species abundance and diversity, herbaceous biomass, foliage density and diversity, tree growth, species recruitment, and tree and shrub density: These parameters are a measure of primary production of the bosques and can be used to characterize forest species richness and abundance and estimate the effects of flooding on the forest structure. It may not be necessary to measure all such related parameters. Some of this data base can be collected by volunteers. The Work Group will have to assess the need for monitoring variables of forest productivity. A good reference for this data collection is Ellis et al. (1996).

- ✓ Transects for plant species and numbers (shrubs, forbs, grasses)
- ✓ Samples for herbaceous understory growth
- ✓ Transects for foliage measurements of density, distribution and diversity
- ✓ Selection of trees for diameter at breast height measurements of tree growth
- ✓ Plots for species seedling recruitment
- ✓ Plots for woody plant species density

Habitat diversity for soil microbes and fungi, surface-active and aerial insects, and vertebrates: Habitat diversity can be measured through population and diversity estimates of consumers. Flooding has been shown to increase the species diversity of the microbial community which also indicates increased decomposition. Flooding also alters the structure of surface insects. The Work Group should investigate both the need and the budget for consumer habitat studies. Data collection efforts may include:

- ✓ Soil cores for fungal and microbial parameters
- ✓ Pitfall traps for surface active arthropods
- ✓ Live traps with drift fences and funnels for small mammals, reptiles and amphibians

The following is a brief description of the major vegetation categories supporting wildlife:

- *Mature cottonwood forest (bosque).* Cottonwood-dominated community types support greater numbers of bird species than monotypic exotic stands. Native woodlands are characterized by an overstory of cottonwood and black willow with understories of New Mexico olive, screwbean mesquite, and seepwillow. This vegetation community also includes forests composed of mature cottonwoods with an understory of either sparse or dense Russian olive and/or salt cedar. This vegetation community supports a most of riparian wildlife species found along the river. Cavity nesting birds are generally associated with mature cottonwood forests.

- *Mature willow forest.* This vegetation community is generally composed of mature black willow trees with a dense salt cedar understory. Wildlife associated with this community includes a variety of migratory bird species that nest in dense shrub habitats including species that use monotypic salt cedar stands.

- *Mid-aged cottonwood-willow or salt cedar-Russian olive stands.* This vegetation community contains five sub-types, ranging from native communities of cottonwoods and willows to dense nonnative species communities such as Russian olive. This community will support a variety of the riparian wildlife found along the Rio Grande.
- *Monotypic salt cedar stands.* Salt cedar stands are communities composed almost exclusively of introduced salt cedar. Summer resident birds in salt cedar stands include mockingbird, lark sparrow, western meadowlark, black-throated sparrow, blue-gray gnatcatcher and crissal thrasher (Crawford et al. 1993).
- *Young successional stage stands and open sand bars.* This community generally refers to the early stages of revegetation. Sandbars and floodplains with young vegetation have a mixed community of cottonwood, coyote willow, salt cedar, and Russian olive. While vegetated bars and islands provide excellent habitat for many riparian species, others species require the open and dynamic nature of true sandbars.
- *Wetlands and open waters.* This category includes marshes, wet meadows, and open water habitats. Species commonly associated with marshes include pied-billed grebe, Virginia rail, sora, yellow-headed blackbird, American coot, mallard, marsh wren, song sparrow, swamp sparrow, chorus frog, bullfrog, tiger salamander, muskrat, Great Plains spiranthes, catchfly gentian, Pecos sunflower, and Parish's alkali grass. Wet meadows provide habitat for some rare and declining species including New Mexican jumping mouse, white-faced ibis, long-billed curlew, common black-hawk, and leopard frog (Crawford et al. 1993).

Indicator mammal species include beaver, muskrat, tawny-bellied cotton rat, meadow jumping mouse. Indicator reptile and amphibian indicator species include northern leopard frog, woodhouse toad, western painted turtle, bullfrog, tiger salamander, New Mexico garter snake, western chorus frog, and spiny soft-shell turtle.

Willow flycatcher presence and habitat and other avian species: The relative abundance and diversity of birds should be used an indicator of the success of habitat restoration. As vegetation develops at restored sites, different levels of avian monitoring can be employed. Species diversity and nesting productivity are two indicators of habitat use in woody riparian vegetation. The data collection program should consist of:

- ✓ Selection of reference and control sites
- ✓ Transect locations for standardized point counts of breeding birds
- ✓ Surveys for Southwestern willow flycatcher done by trained and permitted biologists
- ✓ Nest searching for Southwestern willow flycatcher by trained and permitted biologists
- ✓ Nest data including clutch size, number and age of young, presence of cowbird eggs
- ✓ Avian counts for abundance and species diversity
- ✓ Avian nest counts for the number young birds per nest

The Los Lunas monitoring report has some detail specifications on avian monitoring that would be valuable for the Work Group to review (Corps and BOR, 2002). Indicator species for restoration habitat include: Southwestern willow flycatcher, bald eagle, sandhill crane, interior least tern, Bell's vireo, yellow-billed cuckoo, common blackhawk and summer tanager. The following are potential monitoring species by habitat type.

- *Cottonwood forest:* Yellow billed cuckoo, ladder-backed woodpecker, blue grosbeak, ash-throated flycatcher, turkey, and summer tanager.
- *Understory native riparian shrub:* Southwestern willow flycatcher, Gambel's quail, ash-throated flycatcher, and summer tanager.
- *Sandbars and shoreline:* Spotted sandpiper, killdeer, interior least tern, piping plover, sandhill cranes and snowy plover.

Fish population and habitat use: Studies have focused on the distribution, abundance, life history and habitat use of the Rio Grande silvery minnow. These studies have addressed entrainment, reproduction and effects of fragmentation (USFWS, 1999). The federally listed endangered Rio Grande silvery minnow was formerly one of the most widespread and abundant species in the Rio Grande. By the 1960s, it had been eliminated from most of its original range. The San Acacia portion of the Rio Grande supports the largest population of this species (USFWS 1999) in the Middle Rio Grande. The San Acacia to San Marcial reach of the Rio Grande is within the designated critical habitat for this species. To assess the success of river restoration it will be necessary to determine the relationship between stream flow and spawning, larval fish migration and habitat availability. Restoration monitoring includes fish populations, status, distribution, habitat usage, interaction of native and nonnative fish species and water quality impacts. Monitoring activities include:

- ✓ Sampling site selection
- ✓ Silvery minnow egg surveys by trained and qualified technicians
- ✓ Population surveys of native and nonnative fish
- ✓ Hydraulic data at sampling sites, flow depth, velocity, substrate
- ✓ Suspended and bed material sediment samples
- ✓ Water quality data
- ✓ Water temperature

Relatively good aquatic habitat remains in the reach below the San Acacia diversion dam. In general, the silvery minnow prefer habitat of 4 to 7.8 inches of flow depth, low flow velocities, and silt substrate or occasionally a sandy substrate during spring, summer, and fall. These conditions are primarily found in pools, backwaters and side channels. During moderate flows, typical habitat consists of shallow and braided runs over shifting sand substrate. Backwaters constitute only about two percent of the aquatic habitat in the San Acacia to San Marcial reach. The Rio Grande lacks the extensive backwater pool and side channel areas that historically provided habitat for native fish. The aquatic habitat changes support nonnative fish species that have been introduced by sportfish stocking or accidentally through bait fish use. Nonnative fish species affect native fish populations through predation or displacement from preferred habitat. This is a particular concern during extreme low flow events when the effectiveness of predatory fish, such as the white crappie, increases due to lack of pools and small pool size. The BOR (BOR, 2003)monitored the fish population monthly at seven sampling sites between San Acacia and San Marcial from January to November 2002. There were 16 different species in this reach of the Rio Grande:

Fish Species Observed in 2002 in the San Acacia to San Marcial Reach			
Channel catfish	Gizzard shad	River carpsucker	White bass
Common carp	Longnose dace	Smallmouth buffalo	White crappie
Fathead chub	Red shiner	Walleye	White sucker
Fathead minnow	Rio Grande silvery minnow	Western mosquitofish	Yellow bullhead

Emphasis should be placed on monitoring the status and trends of the fish community, flow and habitat relationships, habitat use by life stage, water quality changes and population changes. The restoration sites should be sampled for presence of silvery minnow, abundance and diversity of native and nonnative fish, habitat conditions over a range of flows, water quality degradation and reproduction success.

Aquatic Invertebrates: In assessing the habitat conditions, invertebrate species abundance and diversity should be surveyed. Aquatic invertebrates make up a large portion of the food for native and nonnative fish species in the reach. The major aquatic invertebrate orders historically occurring in New Mexico are Diptera (flies and midges), Ephemeroptera (mayflies), Plecoptera (stoneflies) and Tricoptera (caddisflies). Chironomid midge larvae are common in freshwater ecosystems and are a significant food source to fish. Members of Tricoptera and Diptera orders are commonly found in submerged gravel bars, whereas Ephemeroptera can be found in fine sediment bed material and exist in shifting sand habitat. Macroinvertebrates are important components of stream ecosystems as intermediate consumers of plant materials and nutrient recyclers (Crawford et al. 1993).

- ✓ Establish sample sites in relationship to restoration projects and fish habitat
- ✓ Sample Invertebrate species diversity, distribution and abundance
- ✓ Conduct population surveys with silvery minnow sampling
- ✓ Correlate with water quality samples
- ✓ Correlate with silvery minnow habitat

Macroinvertebrates generally have an expansive habitat preference and are relatively good indicators of a healthy environment. For that reason, they should be monitored to determine the effects of channel restoration projects. In addition, a important measure of aquatic habitat quality is the net primary production. Diatoms, planktonic algae, grazers and consumers can indicate shifts in aquatic food-web dynamics.

Monitoring Approach

The ecosystem approach to monitoring and analyzing a full spectrum of biotic and abiotic factors should be applied using a variety of scale-dependent correlations that are useful in understanding the structure and function of the system. The correlations and their interpretation with respect to restoration goals and objectives will ultimately constitute a measure of restoration success or failure. Not all biotic and abiotic factors may be fully understood with respect to spatial or temporal scales in various assemblages, but over time meaningful correlations may emerge that will systematically relate distributions, abundance and diversity to indices of ecosystem health. For that reason, every effort should be to collect as much data as practical with the financial and logistical framework of the project.

Sensitive Areas

There are several sensitive areas in the San Acacia to San Marcial reach that should be monitored for morphological changes including channel geometry and slope, overbank flooding and vegetation composition. These channel reaches and areas should be monitored with or without restoration projects associated with them.

SENSITIVE REACH OR AREAS TO BE MONITORED

Reach or Area	River Mile	Reason for Monitoring
Near Arroyo Alamill	111-113	Channel incision and widening, river sinuosity
Near Lemitar	107-109	Wide reach, potential vegetation encroachment, river migration
N, Socorro Diversion	102	Sediment loading and channel response from NSD channel
Near Browns Arroyo	96-100	Channel desiccation, note SA discharge and start of dry channel location
Arroyo de las Canas	95-98	Wide channel, potential narrowing and vegetation encroachment
Near Bosquecito	89-93	Wide channel, potential narrowing and vegetation encroachment
Near BDANWR	80-84	Wetland areas on the east side of the river, flooding and desiccation
North BDANWR	79-86	Wide channel, potential narrowing and vegetation encroachment
BOR New Channel	76-78	Overbank flooding, evolution of new channel
Tiffany Junction	71-74	Overbank flooding, cross section changes, habitat changes
Black Mesa	69-71	Overbank flooding, wetlands changes, channel bed aggradation
Black Mesa	70	Willow flycatcher habitat

Summary

The Save Our Bosque Conceptual Restoration Plan for the Rio Grande from San Acacia to San Marcial was created through a process involving five phases that included:

Phase I. Compilation of data and reference material;

Phase II. Investigation of specific river and riparian issues;

Phase III. Ranking of restoration priorities and components;

Phase IV. Development of the Conceptual Restoration Plan.

Phase V. Monitoring and Adaptive Management Strategy

This report presents Phase V, the Adaptive Management Plan and Monitoring Program for the restoration projects that were designed in Phase IV. The product of Phase IV was a series of maps and site descriptions that depict the restoration projects that can be implemented in a phased approach. To facilitate the selection of restoration projects, the projects were grouped into six themes:

- Restoration light (lyte) plan
- Water salvage plan
- Drought reduction plan
- Habitat diversity and endangered species habitat plan
- River dynamics plan
- Long term comprehensive plan

The long term comprehensive plan encompasses all the proposed restoration projects. Each theme was presented on an individual set of plan maps.

The conceptual restoration plan embodies several key elements involving the physical processes of natural river evolution. These include channel forming flows of a prescribed frequency and duration, an active channel that is free from vegetation encroachment and has some ability to rework the floodplain, a hydrologic connection between river and floodplain that will regenerate native riparian vegetation and sustain wetlands and marshes and a dynamic system that has capacity to respond to large flood events. The main objectives of the restoration plan are to enhance river functions and increase riparian and aquatic diversity. The restoration plan will also improve the conveyance efficiency of water delivery to Elephant Butte Reservoir.

Restoration efforts in the San Acacia to San Marcial reach would improve riparian and aquatic habitats. The area of native vegetation communities, such as cottonwood/willow forest, saltgrass meadow and wetlands would be increased resulting in improved native wildlife habitat and increased habitat diversity. Wetlands and wet meadow habitats would be protected, enhanced, and in some cases, created through management of exotic vegetation and improved hydrology. Management of riparian vegetation could result in water salvage by reducing water lost to evapotranspiration. The distribution and areal extent of native vegetation would increase by replacing nonnative plant communities and with native species. Due to the extensive areas of nonnative species, this change could benefit wildlife species habitat availability. Removing nonnative vegetation in channels and along banks would enhance dynamic channel behavior. Channel restoration would improve aquatic habitat for native fish species by increasing the available low depth and low velocity habitat in the main channel and increasing the spatial distribution of backwater and side channel habitats.

An effective adaptive management program would be necessary to sustain these restoration enhancements over the long term. The goals of the adaptive management plan are:

- Define baseline condition for river and riparian habitat restoration projects;
- Sustain the active channel to prescribed restoration geometries;
- Sustain native riparian vegetation and associated restored habitats;
- Monitor and identify long term trends and changes in aquatic and riparian habitat.

The Adaptive Management Plan (AMP) embodies five tasks including: 1) The formulation of Work Group consisting of scientists, planning or management personnel from federal, state and local agencies and stakeholders; 2) The establishment of the specific elements of the AMP based on specific channel and floodplain morphology and habitat criteria that will identify river restoration program success or failure; 3) The design of a baseline hydrographic, biological, vegetation and geomorphic data collection program to establish post-restoration conditions; 4) The development of a long term monitoring program; and 5) The implementation of a set of rules and practices that will guide agency application of the AMP to sustain the restoration projects.

It is recommended that the Work Group meet several times a year to review the hydrographic data base, make site visits to target channel reaches to monitor morphological changes, make site visits to restoration projects, make recommendations for additional channel monitoring activities, make recommendations for flushing flows and make recommendations for channel and floodplain riparian maintenance. The Work Group will also establish criteria to measure the success or failure of restoration projects. Over time, the Work Group will coordinate with other restoration projects and will adjust the adaptive management process. The Work Group would focus on establishing and refining methods for long term biotic and abiotic monitoring, developing a relationship between successive years of high and low flows and channel vegetation encroachment, identifying the flow patterns to sustain restoration and promote agency cooperation to perform channel maintenance activities. Biological monitoring would include habitat diversity, fire danger and wildlife use.

A pre-restoration baseline condition for the project areas must be established to set in motion the monitoring plan. Monitoring is essential to assess ecological trends in restoration areas over the long term. A baseline data set would include cross section surveys, inventory of potential endangered species habitat, vegetation mapping, floodplain topography, groundwater levels, soil salinity, water quality, aquatic and terrestrial species abundances and diversity, and nutrient levels. The post-restoration baseline data collected following the completion of the projects would then be the foundation of all future monitoring efforts.

To remove the subjectivity of applying an adaptive management plan to a restoration project, a set of response rules would be formulated and finalized by the Work Group. These rules and guidelines will be revised over time and will require the cooperation of the various resource management agencies. A series of ten initial rules were outlined as a starting point. The rules depend on identifying the adverse condition or trend and then outlining a proposed resource management response to eliminate or mitigate the adverse changes. The rules address the following resource management issues and conditions:

- Flood frequency and channel forming flow
- Vegetation encroachment in the active channel
- Vegetation regrowth on the floodplain
- Potential levee instability
- Bank erosion and channel migration
- Failure to induce overbank flooding
- River desiccation
- Sediment plugs
- High soil salinity
- Fall maintenance flows

Monitoring is necessary to assess the geomorphological and ecological trends in the San Acacia to San Marcial reach as well as provide data and information about the diversity and abundance of native species. It is the heart of the adaptive management plan. Monitoring pre- and post-restoration conditions will provide a starting point to analyze future trends and help determine the success or failure of the projects. It will define what specific functions need to be altered in future restoration projects to achieve desired goals. The Work Group will have to determine the frequency and long term status of monitoring various biological or geomorphological parameters to capture potential trends and variation. It will be important to select key variables to monitor during flooding. Possible monitoring parameters were outlined and discussed in detail in the report.

Implementing an Adaptive Management Plan represents a long term commitment to monitoring the renewal of river ecosystem. A minimum of fifteen years as indicated in the Biological Opinion should be planned and funded for the monitoring the ecosystem and administering the AMP. The AMP requires interagency cooperation that can be fostered by the Work Group. The goal is to establish flexible adaptive management principles and practices that can adjust to both success and failures. It is likely that more knowledge will be gained from analyzing restoration failures than from recognizing successes. For this reason, facilitating the AMP in the future will include expanding geomorphic and biological response criteria, developing new tools and techniques for adaptive management, visiting other river systems, designing new monitoring practices and expanding the monitored reaches. An agency team approach to adaptive resource management in response to changing climatic conditions, water availability, sediment loading and evolving vegetation composition will solve many of the problems facing the Middle Rio Grande.

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Appendix A

Example Monitoring Field Guide for Rio Grande Restoration

San Acacia to San Marcial

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6121 Indian School Road
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