RECOMMENDATION 1: Coordinate Rio Grande water management activities to support and improve the bosque's riverine and terrestrial habitats, with special emphasis on mimicking typical natural hydrographs.

Need: As documented in this plan, there has been a decline in abundance and diversity of native species in the Rio Grande riparian ecosystem. The reproductive strategies of riparian species are strongly linked to the river's natural hydrograph—its characteristic rise and fall. The decline of riparian species has coincided with the increasing control over water in the river, which has resulted in changes in amount of peak runoff, duration of high water periods, summer and autumnal spikes in response to thunderstorms, and perennial flows. There is a need to restore or mimic, to the extent possible, the natural hydrograph that was characteristic of the Rio Grande prior to construction of dams in the watershed in order to support the continued survival of river-dependent organisms.

Description of Recommendation: Water management releases from Cochiti and Jemez Canyon dams should continue to follow the spring runoff, with gradual decline after the peak (see sections on hydrology, current hydrological regime and its effects on the riparian vegetation, and aquatic organisms and habitat). Using runoff as the annual cue for releases of water from Cochiti and Jemez Canyon dams allows the present water management system to mimic the natural flows that existed prior to dam construction. These should be tied each year to existing runoff conditions. Releases of water from Cochiti and Jemez Canyon dams during periods not associated with high natural flows, such as winter releases, should be avoided, if possible, or managed to minimize unseasonal impacts on downstream terrestrial and riverine communities.

Opportunities and Constraints: It is fortunate that Cochiti and Jemez Canyon dams are operated for the purposes of flood control rather than for water storage and generation of hydroelectric power. Hydroelectric generation requires release of stored water, with daily and seasonal fluctuations based on need for electric power. The resulting river flows are distinctly different than the natural flows of most western rivers, which respond to seasonal runoff and precipitation. As presently operated, water releases from Cochiti and Jemez Canyon dams allow the river to partially resemble its pre-dam condition although changes in peak flows, duration of runoff, and presence of high water in winter have altered the riverine and riparian systems.

Benefits which may result from operating dams in a manner that reflects the runoff are seasonal flooding along some parts of the river, contributions to the seasonal recharge of ground-water tables throughout the middle valley, and seasonal movement of sediments and shifting of channels. These peaks of water availability and physical changes in the river channel influence riparian species' survival and the composition of riparian communities. Species and communities, ranging from those found in the hyporheic zone through native fishes to those in terrestrial habitats, should also benefit from this type of water management.

There are serious constraints on the present water management system that prevent full realization of recreating the natural hydrograph in rate of flow and duration. Because of development in the floodplain of the Rio Grande, construction of levees, and restrictions in the river channel, the capacity of the existing waterway to transport large floods (>10,000 cfs) is greatly diminished. Thus, the ability of the river to scour portions of the floodplain and to

transport large sediment loads to new locations is also diminished as are opportunities for overbank flows. Because of this, creation of new habitats for native aquatic and terrestrial organisms has decreased.

Operational criteria for the COE dams are set forth in federal law. Some operational latitude is allowed contingent upon endorsement by the Rio Grande Compact Commission. Should any significant alteration of the COE's operational regime be recommended to enhance biological values, it is likely that a change in federal legislation would be required. Likewise, the delivery of San Juan-Chama Project water must be in accordance with federal law, contracts between water users and BOR, state water laws, and terms of the Rio Grande Compact. Within these confines, however, there is some flexibility for adjusting deliveries.

Implementation Considerations: The COE currently releases flows from Cochiti and Jemez Canyon dams which mimic the natural hydrologic regime of the river to a certain extent. Operation of the dams under existing mandates and constraints requires this type of release. We recommend that this practice be refined and continued. Releases not coordinated with runoff may have a negative effect on the native fish fauna if the time, magnitude, and duration of the releases do not mimic natural, seasonal flow events.

Action: We recommend that water be released from Cochiti and Jemez Canyon dams in such a way as to mimic natural flows in the river. This includes coordinating releases with inflows from upstream runoff. Length of peak flow and amount of release should continue to be adjusted to runoff. The stepdown of releases from peak flow to maintenance flow should be incremental, based on amount and duration of runoff, as well as comparison to monthly averages of discharge at Otowi Bridge for duration of measurement (see hydrology and geomorphology in the Existing Conditions section).

At a minimum, channel capacity should be maintained at 8,000-10,000 cfs and increased if possible. Further restrictions on channel capacity should be avoided. Development in the floodplain adjacent to the river (e.g., the residence recently built within the 2-year floodplain near Socorro) will increase the risk of damage to human lives and properties from uncontrolled flooding due to tributary sources and will seriously diminish management options for controlled releases from upstream dams.

Prior to the late 1800's, when increased diversions for agriculture caused portions of the river to dry up (see Historical Conditions section), the Rio Grande probably flowed year-round. Since the 1800's, the river has continued to be dry in some areas during irrigation season in some years (see U.S. Bureau of Reclamation 1977). Opportunities to maintain perennial flows in the Middle Rio Grande should be actively pursued, and agreements negotiated and signed. A recent example of this type of action is the agreement reached between the City of Albuquerque and the MRGCD to maintain over the next 10 years a minimum flow of 250 cfs as measured at the Albuquerque gauge during irrigation season.

Monitoring and Research: The greatest need is to develop an interactive hydrologic model for the Middle Rio Grande that can be used in developing and evaluating water management alternatives. The model should be designed so that it can be adapted to multiple uses and be

compatible with other hydrologic models in the Rio Grande Basin. The relationship of discharge to channel depth, overbank flooding, ground-water depth and recharge, evaporation, transpiration, and other relevant characteristics should be included in future studies. The relationship between river flows and native fish species and their habitat should be studied (see Recommendation 4 on aquatic habitats).

Agencies Currently Investigating Rio Grande Flow Regimes and/or Involved in Hydrologic Modeling:

City of Albuquerque Department of Public Works
New Mexico Bureau of Mines and Mineral Resources
New Mexico Interstate Stream Commission
U.S. Geological Survey
U.S. Bureau of Reclamation, Albuquerque Projects Office
U.S. Army Corps of Engineers, Albuquerque District Office
U.S. Fish and Wildlife Service, Region 2
U.S. Fish and Wildlife Service, National Ecology Research Center

RECOMMENDATION 2: Implement measures to allow fluvial processes to occur within the river channel and the adjacent bosque to the extent possible.

Need: The Rio Grande is highly controlled and physically altered in the Middle Rio Grande Valley. The normal fluvial processes that maintained the aquatic and riparian communities of the Rio Grande in the past, such as flooding, channel meandering, and sediment transport and deposition, have been diminished or eliminated by water management structures and activities. The Rio Grande should be allowed to recreate fluvial processes as much as possible; because whatever work the river cannot do to support ecosystem process and riparian communities, we will have to attempt to provide.

Description of Recommendation: In the full range of the management spectrum, possibilities include placing virtually no controls on the river to converting the river into a riprap lined, straightened channel. This recommendation tends to deal with those options and possibilities that are somewhere in the middle of this spectrum.

In some areas, levees could be moved or removed to expand the influence of the river. Building new levees in areas where none now exist should be avoided. Development should be restricted in areas that are likely to flood, and lands should be acquired (from willing sellers only) in the floodplain adjacent to the river. These areas could then be managed as riparian zone and floodplain habitat for native riparian plant and animal communities. The most likely possibilities for these management options are in the Belen and Socorro reaches of the Rio Grande. There, sediment input from major tributaries (and other factors) has caused the river to become broader and shallower than in the other reaches of the river, and in some areas there are no existing levees on the east side of the river.

In areas where it is not possible to expand the influence of the river outside the existing levee system, the Rio Grande should be allowed to find its own course within the floodway to the greatest extent possible. Ongoing management could be modified to encourage disturbance and instability inside the levees, thereby creating suitable sites for the reproduction of native riparian plant species. Potential modifications to management include ceasing to use jetty jacks for channel modification and stabilization, and using vegetation stabilization instead of riprap where feasible at erosional points. Sediment plugs or portions of them could be allowed to remain in place to provide sediment for riparian processes.

Constricting or inhibiting flows during construction of new facilities and modification of existing ones should be avoided. Existing structures (e.g., railroad embankments, bridges, headgates, etc.) that restrict the amount of water released into the channel should be moved or modified to allow higher peak flows to be released from dams without damage.

River and land management activities continue to affect the sediment inflow to the Middle Rio Grande, which in turn directly influences the channel morphology. The upper reaches, especially Cochiti, now have an incised river channel partly due to the capturing of sediment behind dams. This has greatly reduced the potential for overbank flows from controlled releases. The San Acacia Reach in the south, on the other hand, is experiencing significant sediment

loading, primarily from the Rio Puerco. This contributes to decreased channel capacity, which influences maximum flows the channel can handle.

The effects of sediment inflows on the fluvial processes and the adjacent bosque vegetation need to be included in sediment and river channel management decisions. The Middle Rio Grande historically has been an aggrading river. This systematic aggradation provided conditions for the bosque to fluctuate both spatially and temporally in the middle valley. Recent water and river management has stabilized the depth of the river channel in the Cochiti Reach. This stabilization is proceeding through the Albuquerque Reach and may continue on through a portion of the Belen Reach. Below the confluence with the Rio Salado, the riverbed continues to aggrade. In the Socorro Reach, no river management activities should be undertaken to reverse channel aggradation although aggradation likely will have to be managed. In addition, the benefits of specific sediment management decisions on the Rio Grande have to be balanced with the needs of the contributing watersheds. We recommend that sediment be managed in the upper reaches in such a manner as to allow *localized* channel instability.

Wetlands can be created or constructed either inside or outside the levees. In the past, fluvial processes caused wetlands in old oxbows, areas of high water table, and side channels which carried water during flood stages. Allowing fluvial processes to take place in the floodway and in areas without levees may increase wetlands and aquatic habitat without human intervention.

The BOR's Low Flow Conveyance Channel is designed to direct 2,000 cfs of water from the river in the Socorro and San Marcial reaches under certain flow conditions. We recommend that the purpose of construction and use of the channel be reevaluated in the context of concerns about the Rio Grande riparian ecosystem.

Ultimately, it may be possible to develop a biological management plan that includes the establishment of areas where, by a combination of land acquisition (from willing sellers) and modifications of existing management, the river will be allowed to run its course in portions of the floodplain. Removal or repositioning of levees in some areas and strengthening of them (and other structures) in areas where flooding would be destructive to lives or property would be major factors in the accomplishment of such a plan.

At one extreme of the management spectrum, we could recommend that all restraints on the river, including levees and dams, be removed. This would allow the river to influence the riverine, riparian, and floodplain zones as it did in the past. It would mean removing farms, houses, businesses, roads, and other infrastructure elements from the river's path on the floodplain, or accepting their presence there at great risk. Wetlands and bosque would be allowed to slow and absorb flood waters and release them gradually into the river. Allowing the floodplain to accommodate seasonal flooding may be the best way to live with a major river. However, this option would require changes in our society's values and commitment of significant resources to managing development on the floodplain rather than following current courses of action.

Opportunities and Constraints: Water managers at the federal, state, and local levels have authority to determine the feasibility of these ideas and to implement the options included in this

recommendation. Some options could be addressed on an experimental basis to assess their practicality for use on the river. The constraints in the system are private property rights, public safety, and the need to fulfill water obligations to users.

Implementation Considerations: Should the feasibility of implementing some of the structural solutions, such as relocating levees, be established, monetary costs may become a constraint. Ultimately it would be societal values and willingness to publicly finance such endeavors that would decide whether or not to proceed.

Action: Agencies should review their current management guidelines and identify opportunities that allow fluvial processes to occur without, or with reduced, interference. They should also review upcoming rehabilitation and maintenance activities that may provide opportunities to remove impediments to high peak flows. Efforts to identify areas with potential for flooding should begin. Depending on ownership, these areas could be targeted for conservation easements, or acquisition (where indicated). Agencies should also complete a reevaluation of the Low Flow Conveyance Channel to determine its compatibility with the concepts of riparian ecosystem management.

Monitoring and Research: Agencies can begin conducting experimental removal of jetty jacks in some areas (perhaps in some places where vegetation has not become densely intertwined) to see if water will cause disturbance and consequent recolonization of native species. Experiments using material such as root wads and vegetation plantings for bank stabilization, instead of riprap, should begin. Experiments with high release flows (most recently up to 7,500 cfs) should continue; these could be coordinated with river profile studies to predict areas of highest potential for overbank flooding and the locations where the infrastructure of river controls is weakest. Any proposal to modify the degree of sediment loading in the Middle Rio Grande would require a comprehensive evaluation not only of the implications for the river channel and the riparian ecosystem but also of impacts on the contributing watersheds. Models predicting the river's sinuosity within existing constraints should be developed. This will provide information needed for future comprehensive river and floodplain management that will allow the river as much freedom as possible in affecting its ecosystem.

Agencies with Experience in Managing River Channel Characteristics:

U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
The Nature Conservancy, Boulder, Colorado

RECOMMENDATION 3: Reintroduce the dynamics of surface-water/ground-water exchange, manage ground-water withdrawal, and restrict contamination.

Need: There is a need to reestablish the historic association between ground water and overbank flooding in order to assure availability of water and to promote nutrient availability for bosque vegetation. Recent evidence indicates that the bosque may be severely nitrogen-limited when not flooded for decades. Overbank flooding appears to oxygenate ground water and generate an energy source (dissolved organic carbon in rapidly rising ground water) that allows soil nitrogen to be mobilized.

Another need is to restrict ground-water withdrawal unless rapid recharge is assured. In the Albuquerque area, ground-water withdrawal for municipal use has already reversed the direction of its flow in some areas; and increased withdrawal by a swelling population is likely to lower the water table in the floodplain. Native trees and shrubs in the riparian zone are more susceptible to the lowering of ground-water levels than are nonnative species. Thus a lowered water table in the bosque could negatively affect the already unfavorable relationship between native and introduced woody vegetation. It could also jeopardize the existence of the few remaining wetlands in the riparian zone.

An additional need is to restrict ground-water contamination from point and nonpoint sources throughout the inner valley. Such contamination tends to increase in proportion to the size of the human population, which gives the problem added urgency. Because of the nature of the valley's topography and soils, movement of contaminants in ground water can be rapid. These materials have potentially degrading effects on terrestrial and aquatic communities.

Description of Recommendation: Localized (spot) flooding should be considered as a management tool in order to mobilize nutrients, via elevated ground water, in the bosque. Diversion and/or drain water can be used for this purpose, as can water channelled from the river during periods of high flow. Appropriate use of ditches and groin dikes with stop-log structures controls flows and backs up water to create flood conditions. During low flows, flood water can be channelled back to the river from flooded areas if so desired.

No additional ground-water withdrawal programs should be undertaken that lower ground-water levels in the riparian zone until a comprehensive assessment of the biological impacts has been completed. Special care needs to be taken that municipal water supply systems and irrigation delivery systems do not lower ground-water levels in the bosque and wetlands. Management of local ground-water levels to the benefit of native riparian vegetation and wetlands should be considered in conjunction with wastewater treatment and agricultural practices.

The effects of urban turfgrass watering on ground-water levels needs to be studied. The enormous amount of water currently used in Albuquerque for turfgrass watering needs to be reconsidered in light of the area's potential for xeriscaping parks and residences.

Existing federal, state, municipal, pueblo, and local controls on protecting ground-water quality should be rigorously enforced, especially in the floodplain where ground water is most

vulnerable to contamination. Adequate alternatives to septic tank/field systems currently serving high density residential areas should be developed and put in place.

An integrated system of observation wells should be established in the riparian zone to monitor ground-water levels and quality. This system should take full advantage of existing wells. Additional research addressing the impacts of agriculture on ground water, similar to that sponsored by the Resource Conservation and Development Council and the BOR in the Las Nutrias area, should be encouraged.

Opportunities and Constraints: Opportunities to initiate spot flooding are greatest in areas where water delivery can be readily arranged within the existing framework of water allocation along the Rio Grande. Experienced personnel at Bosque del Apache NWR can give expert advice on the subject. However, earth moving and dike construction are not inexpensive matter and involve the use of heavy equipment. New Mexico State Parks and Recreation Division has used above-ground irrigation pipe to supply water to areas at the Rio Grande Nature Center.

There are readily available opportunities to expand our understanding of the inner valley's shallow ground-water system. Currently, a number of agencies and entities (e.g., City of Albuquerque, New Mexico Bureau of Mines and Mineral Resources, USGS, BOR, FWS, UNM) are studying various aspects of this system throughout the Middle Rio Grande Valley. The challenge is to expand the present ad hoc forums and to provide a practical long-term mechanism for these groups to coordinate their activities and secure funding for those aspects not being addressed.

The MRGCD's existing irrigation water delivery and drain infrastructure presents the best immediate opportunity to manage shallow ground-water levels. The challenge is to balance the management of this system with other traditional and nontraditional needs.

Implementation Considerations: State water law would have to be considered in any activity that deviates from current management practices.

Action: Agencies should evaluate current management practices for opportunities to use flooding at the appropriate time of year in order to enhance ecosystem processes.

Monitoring and Research: Monitoring of the response of ground water to flow releases from upstream dams should begin. This monitoring should continue at intervals throughout the year and consider seasonal changes in ground water. Flow release information should be coordinated with ground-water information. Research on the hyporheic zone and its possible dependence on ground-water recharge from all sources should begin. This information should be part of data collection for the interactive hydrologic model called for in Recommendation 1.

Agencies with Experience in Surface-water/Ground-water Relationships:

Middle Rio Grande Conservancy District
New Mexico State Parks and Recreation Division
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge

U.S. Fish and Wildlife Service, National Ecology Research Center
U.S. Bureau of Reclamation
U.S. Geological Survey
The Nature Conservancy, Boulder, Colorado
City of Albuquerque

RECOMMENDATION 4: Protect, extend, and enhance the structure of aquatic habitat to the benefit of native communities.

Need: Loss of riverine habitat, especially native aquatic habitat, is a major problem in warmwater streams of the Southwest. The complexity of aquatic habitat in the Middle Rio Grande has been impacted by human perturbations such as main channel storage and diversion structures, flow regime alterations, and channel maintenance activities. Loss of habitat equates directly with a decrease in carrying capacity and a concomitant reduction in diversity and abundance of aquatic communities. The current noncontiguous distribution of the Rio Grande silvery minnow suggests a reduction and fragmentation of aquatic habitat in the Middle Rio Grande. The replacement of native habitat with disturbance-induced habitat often selects against native species. The preservation and enhancement of native aquatic habitat are critical in maintaining viable native aquatic communities.

Description of Recommendation: *Prevent the loss of native aquatic habitat*—Recent studies (Platania 1993) have attempted to quantify the distribution of aquatic habitat in the Middle Rio Grande by river reach. Research is also underway to identify the fish use of aquatic habitat throughout the Middle Rio Grande. Currently, however, we do not know all the habitat requirements of all native fish (e.g., Rio Grande silvery minnow). Invertebrate use of specific aquatic habitat is only generally known. Native aquatic organisms have likely adapted to and thrive in selected native aquatic habitats. It is therefore important to preserve the integrity of native aquatic habitat to the greatest extent possible because the magnitude of impact of habitat loss on native communities is unclear.

Habitat loss can occur from physical disturbances or changes in hydrology. Habitat loss due to human or natural disturbance is generally more apparent. However, as mentioned, changes in flow patterns can have both short- and long-term impacts on available aquatic habitat. Thus, water management agencies should attempt to maintain the spatial and temporal availability of native aquatic habitat by maintaining the patterns and variability of the natural hydrograph.

Channel maintenance activities should be minimized and directed to maintain and expand aquatic habitat conditions. Cessation of pilot channeling in the 1980's significantly reduced degradation of the aquatic ecosystem. The extent of current bank stabilization should be restricted to high priority areas to alleviate potential cumulative impacts. Environmentally sensitive and innovative methods of bank stabilization should be considered.

Enhance and create aquatic habitat where appropriate—In some cases, physical modifications are required to restore aquatic habitat that has been lost to channel perturbations. These opportunities should be pursued with consideration of species and life stage selectivity and community equilibrium. The riparian ecosystem will respond differently to modifications due to a new environmental baseline based on both natural and human stressors. For example, even the restoration of a native habitat type may now favor nonnative species. Backwaters created in the Cochiti Reach seasonally support abundant populations of nonnative, predatory white crappie. Habitat enhancements should be designed to meet habitat needs of native species while selecting against nonnative species.

Opportunities and Constraints: Opportunities include the management of flows to meet both aquatic and terrestrial needs. High flows that are needed to benefit riparian areas also provide critical habitat for various life stages of aquatic communities. The timing and duration of different flow regimes will affect habitat utility (see Recommendation 1 on mimicking natural hydrographs).

Bureau of Reclamation river maintenance activities provide an opportunity to integrate the goals of efficient sediment transport, floodplain protection, and habitat enhancement. The use of environmentally sound maintenance techniques that benefit native species should be encouraged.

Current river management objectives often conflict with the preservation and maintenance of aquatic habitat. Habitat should be created and maintained through natural processes whenever possible. However, when artificial modifications to the system occur, priority should be assigned to protection of native aquatic habitat and species.

Implementation Considerations: Cumulative effects of channel maintenance activities must be considered. The benefits of bank stabilization must be balanced with potential costs, such as localized loss and/or fragmentation of shoreline habitat.

Current enhancement practices, such as construction of groins, boulder groupings, backwaters, etc., provide additional aquatic habitats but must be continually assessed relative to their effectiveness in supporting native communities. Also, the longevity of these structures should be monitored. Alternative techniques, such as using natural material (e.g., trees and root wads) in bank stabilization, should be explored.

Relationships need to be developed between varying flow regimes and availability of aquatic habitat. The appropriate level of resolution of this analysis must be considered and should account for reach-specific and seasonal variability. Water management agencies will require some level of predictability when attempting to benefit native aquatic habitat and species with management activities.

Management goals should be continually reevaluated to identify areas of flexibility within which aquatic habitat can be protected. Physical creation of habitat should be approached cautiously to assure that needs of the target species, population, or community are met. Consultation with a qualified aquatic biologist is important prior to any modification or enhancement.

Prior to any channel maintenance or enhancement activities, all sites should be evaluated for occurrence of the Rio Grande silvery minnow, a species proposed for listing under the Endangered Species Act. Consideration should be given to the Rio Grande silvery minnow, as appropriate, when protecting and enhancing aquatic habitat.

Action: Agencies should develop aquatic habitat enhancement and creation guidelines for specific reaches of the river. The guidelines should encourage activities that are appropriate for local aquatic habitat conditions and that will support existing native communities.

Monitoring and Research: Studies are currently being developed to identify habitat requirements of the Rio Grande silvery minnow. This ongoing research will further quantify the availability and use of aquatic habitat and should be supported. Long-term monitoring of aquatic habitat in the Middle Rio Grande should be established to assess temporal and spatial variations in habitat, especially as environmental baseline conditions change over time. This could be a multiple agency/entity effort.

An additional monitoring priority will be the long-term evaluation of specific construction sites to assess impacts of management actions and mitigation efforts on aquatic habitat and species. The BOR and COE could be lead agencies in this effort.

Research opportunities are as follows: (1) develop relationships between varying flow regimes and aquatic habitat availability, (2) quantify the habitat use of all native fish species, especially the Rio Grande silvery minnow, (3) study invertebrate use of different habitat types, (4) quantify the vegetative component of aquatic habitat when applicable, and (5) study short- and long-term impacts of physical habitat enhancement and creation. Specific consideration should be given to species and life stage selectivity and community equilibrium.

Agencies with Aquatic Habitat Protection and Enhancement Experience:

New Mexico Department of Game and Fish
U.S. Fish and Wildlife Service, New Mexico State Ecological Services Field Office
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

RECOMMENDATION 5: Protect and enhance surface-water quality.

Need: Surface-water quality in the Middle Rio Grande has been altered over the last century due to mainstream dams and diversions, watershed development, and point and nonpoint sources of pollution. Surface-water quality is a key component of the riparian ecosystem affecting not only riverine resources but also influencing the riparian zone, wetlands, and ground-water chemistry.

Current baseline surface-water quality levels appear to be within the tolerance limits of most aquatic communities; however, extreme conditions may subject organisms to increased stress and possibly mortality. Wastewater treatment facility discharges, increasing urban runoff, and discharge of agricultural waters via drains have the potential to create suboptimal conditions for aquatic communities. Nonpoint sources of urban storm-water runoff have been shown to increase loading of coliform fecal bacteria and total suspended solids within the Albuquerque Reach (Tague and Drypolcher 1979). Also, wastewater effluent may contain elevated concentrations of ammonia, chlorine, and other constituents. Contaminant levels of irrigation return water are unknown. These potential water quality problems may also be exacerbated during periods of low flow.

Description of Recommendation: *Provide sufficient flows in critical reaches of the river during specific times of the year to alleviate water quality problems*—Water quality is a special concern during periods of low flow when the river becomes spatially intermittent and fish are confined in isolated pools. Concentration of pollutants and extreme fluctuations in physical water quality parameters, such as temperature and dissolved oxygen, elevate stress levels in aquatic organisms and reduce survivability. Baseflows that would maintain a continuous wetted channel in critical reaches during specified time periods could alleviate water quality problems.

Develop a model to simulate spatial and temporal variation in water quality parameters—The water quality model should incorporate both natural and human influences and should be responsive to varying flow regimes. A water quality model is an essential component of a larger system-wide operations/hydrology model. The model should also be interactive and capable of answering "what if" management questions.

Consider the use of riparian forests and/or wetlands as buffers to reduce the impacts of point and nonpoint pollution—Recent studies have shown that riparian forests can remove large amounts of dissolved nitrates and phosphorous from surface runoff (Chauvet and Décamps 1989, Gregory et al. 1991). Studies to determine the utility of these natural ecosystem components in the treatment of effluent discharges should be encouraged. These and other proactive strategies may help prevent further degradation of surface-water quality.

Integrative water quality based programs should be supported—The FWS has created the Biomonitoring for Environmental Status and Trends (BEST) program to evaluate, anticipate, and minimize the effects of environmental contaminants on natural resources. The City of Albuquerque is conducting a Use Attainability Analysis (UAA) to assess the factors affecting the attainment of designated uses of surface water in the Middle Rio Grande. The USGS National Water Quality Assessment (NAWQUA) program is designed to inventory and monitor the quality

of the nation's water resources. All of these programs use a holistic, "ecosystem," approach to water quality monitoring, integrating both physical habitats and biological resources.

Evaluate the limited warmwater fishery use designation for Section 2-105 of the New Mexico Water Quality Standards—The reach of the Middle Rio Grande from Alameda Bridge to the headwaters of Elephant Butte Reservoir, Section 2-105, is designated to support a limited warmwater fishery. A warmwater fishery use designation usually represents an associated sportfishery. The sportfishery interpretation does not apply to the reaches of the Middle Rio Grande below the Cochiti Dam tailwater. Current state and federal management activities within this reach address native warmwater fisheries.

Opportunities and Constraints: Factors influencing water quality in any river system are very complex. Attempting to analyze system variability and specific sources of system inputs to determine impacts is a difficult task. Knowledge of all sources of input to the system, as required in a water quality model, is critical when determining causative agents of localized impacts. A comprehensive approach to water quality management provides the opportunity to address the interrelatedness of all activities on water quality.

Given the water management infrastructure of the Middle Rio Grande, including storm-water diversion channels and irrigation system drains and wasteways, most nonpoint sources of pollution enter the river through point discharges. This allows for a reasonably high level of analysis and potential control of many complex system inputs.

The need to provide some form of instream flows (in this case to lessen water quality problems) is a common element in several recommendations focusing on protection and enhancement of bosque biological resources. Integrating these needs and recommendation affords an opportunity to better manage the Middle Rio Grande system for the benefit of multiple resources. Designing and implementing flow strategies will require a significant amount of time and resources from a variety of entities, both public and private. Effective coordination between all parties is critical so that goals and objectives for the resource and its users can be attained.

Altering the magnitude or composition of system inputs, such as wastewater effluent, storm-water runoff, and irrigation returns, is generally technically feasible but cost limiting. Identifying the most cost effective alternatives to minimizing deleterious inputs to the Rio Grande system is important.

The potential for using riparian forests and/or wetlands as a buffer for point and nonpoint sources of pollution presents an opportunity to both manage water quality and extend and enhance riparian vegetation, aquatic habitat, and wetlands within the bosque.

Implementation Considerations: It is important to fully identify and quantify the needs and requirements of all system users and resources before attempting to initiate an improvement to the system. Initiatives such as NAWQUA, UAA, and BEST are important first steps. Approved and proposed pueblo stream standards for the Middle Rio Grande must be integrated with state standards when analyzing system needs and requirements.

Consideration should be given to evaluating the effectiveness of designating the Rio Grande from Alameda Bridge to the headwaters of Elephant Butte as a single reach for water quality standard purposes.

Timing is an important consideration in providing flows to alleviate water quality problems. Native fish species are often more tolerant of low flow periods than nonnative species. However, unseasonal periods of high flow may negatively affect native species. Therefore, artificial baseflows need to be carefully integrated with the natural hydrograph to maximize the benefits to native species.

As mentioned in the wetlands recommendation (Recommendation 15), the design of wetlands to serve as buffers for water quality benefit must also consider the diversification of wetland function and configuration.

Action: Water quality modeling must be integrated or at least compatible with hydrologic modeling efforts. Coordination should occur early in the development process. Consideration should be given to determining the most important parameters to model. To effectively represent water quality impacts on aquatic communities, the model should consider natural diel fluctuations in certain parameters (e.g., temperature and dissolved oxygen). The time step of the model is also important.

Current water quality standards define a warmwater fishery as a stream reach "suitable for the support and propagation of warmwater fishes such as largemouth black bass, small-mouth black bass, crappie, white bass, bluegill, flathead catfish, or channel catfish." This definition allows for flexibility in characterizing a warmwater fishery as it would best apply to the Middle Rio Grande aquatic resource. Either a more appropriate interpretation or a redefinition of the Middle Rio Grande warmwater fishery should be considered. The initiation of a UAA offers a good opportunity to analyze the appropriateness and attainability of the designated uses of the Middle Rio Grande.

Monitoring and Research: A major research need is the analysis of specific water quality impacts on various components of the riparian ecosystem. For example, an understanding of the specific impacts of wastewater effluent discharge on native fishes is important, especially with the proposal to list the Rio Grande silvery minnow as an endangered species.

As mentioned previously, laboratory research has been conducted to study the impacts of pesticides on the aquatic resource. Further laboratory-controlled exposure studies with all life stages of selected and/or surrogate fish species would provide valuable additional data. No in situ research has been conducted to date. Caged fish studies is one technique for quantifying species specific water quality impacts. Quantification of the environmental concentrations of pollutants in irrigation return waters is also a research need.

As a component of the modeling effort, sources of point and nonpoint pollution should be monitored both short and long term to quantify the magnitude and variability of their influence on water quality.

The impact of main channel dams and diversion on organic input to the Middle Rio Grande needs further study. Research could be conducted to quantify energy input and energy transportation throughout the system.

Agencies and Municipalities with Surface-Water Related Experience:

U.S. Geological Survey
City of Albuquerque
New Mexico Department of Health and Environment, Surface Water Quality Bureau
U.S. Fish and Wildlife Service
U.S. Bureau of Reclamation
U.S. Corps of Engineers
Albuquerque Metropolitan Arroyo Flood Control Authority
Middle Rio Grande Conservancy District
All Indian Pueblo Council

RECOMMENDATION 6: Integrate management of nonnative and native fish species in all aquatic environments in the Middle Rio Grande riparian ecosystem including wetlands, canals, and drains.

Need: Increased human activity in warmwater streams in the Southwest has generally led to a concomitant reduction in native fish populations (Edwards and Contreras-Balderas 1991). The native fish community of the Middle Rio Grande has declined in both abundance and diversity of species. Changes in flow regimes and aquatic habitat are significant factors contributing to the decline of native fish species. However, purposeful and accidental (e.g., bait bucket) introductions of nonnative fish species also negatively impact native species through predation, hybridization, and competition for resources.

Sportfish management in New Mexico is under the control of the NMDGF. Native species management in the Middle Rio Grande is beginning to be integrated with the policies and management practices for nonnative species. However, without an extensive system of biological checks and balances relative to species introductions, nonnative fish in the Middle Rio Grande will continue to affect native species.

The Rio Grande silvery minnow, a species proposed for listing under the Endangered Species Act, occurs exclusively in the Middle Rio Grande. Fish management activities in the Middle Rio Grande currently address the protection and expansion of this species' distribution, abundance, and habitat. As a potential indicator of the health and status of the native fish community, the Rio Grande silvery minnow is a critical component of all aquatic resource issues and activities, such as nonnative fish management.

Description of Recommendation: *Develop an implementation plan integrating management of nonnative sportfish and native fish in the Middle Rio Grande*—The current system of sportfish management in New Mexico is driven by both biologic and economic factors. Anglers purchase fishing licenses that partially support the stocking of sportfish. Also, federal funding to states for fishery management focuses on sportfish restoration. Often, nonnative fish stockings are assessed only for their viability to support a recreational fishery and not for interactions with and impacts on the native aquatic ecosystem.

The NMDGF should continue to develop and implement strategies to manage sportfish in concert with native fish. The biology of the system should be the driving force within a sportfish management program to ensure the continued existence and success of associated native fish and other biological components of the ecosystem.

Enhance methods to regulate, control, and enforce accidental introductions of nonnative fish—Accidental introductions of nonnative fish are the most difficult to control and may have the most devastating effects on the native ecosystem. As mentioned previously, bait bucket introduction of the plains minnow to the Pecos River led to extirpation of the Rio Grande silvery minnow from that drainage. A similar introduction to the Middle Rio Grande could lead to extinction of the Rio Grande silvery minnow. Strict regulations, enforcement, and penalties are critical to managing this problem. The NMDGF should continue to attempt to both regulate the use and commercial sale of bait minnows and prohibit the interdrainage transport of baitfish.

Opportunities and Constraints: Management of nonnative introductions is a component of many native and endangered species management and recovery plans. The NMDGF should continue its coordination with other management and resource agencies (e.g., FWS, BOR, COE) in developing creative and integrative management strategies for the Middle Rio Grande. A proactive strategy integrating the management of these species will greatly reduce the threat to the existing native aquatic community.

The current proposal to list the Rio Grande silvery minnow as federally endangered will likely lead to establishment of an interagency team to protect, stabilize, and recover Rio Grande silvery minnow populations and the associated native fish community of the Middle Rio Grande. Future management, research, and coordination of nonnative fish issues will likely be carried out within the framework of the Endangered Species Act activities but with an ecosystem focus.

Constraints on these recommendations are the political and economic considerations of altering sportfish management policies and the logistical problems with regulating and enforcing accidental nonnative fish introductions. The initial constraint should be manageable within the purview of the NMDGF. Fish stockings using federal funding are subject to Endangered Species Act consultations. Program goals and objectives may need continued redefinition. However, the integration of native and nonnative fish management strategies should reflect the changing attitudes of the general public in supporting nongame programs.

Implementation Considerations: An interagency team should be established to address native fish management. As mentioned above, the team could be established within the existing and future framework of the Rio Grande silvery minnow endangered species process. This process should provide the forum for key entities to work cooperatively. All entities with landownership along the Middle Rio Grande, including the pueblos, should be involved with this process so that the system can be considered as a whole. It will be critical to maintain an ecosystem focus for the development of a management plan within the single species environment of the endangered species process.

Action: As a component of an integrative management plan for nonnative and native fishes, water management activities associated with Cochiti Lake should attempt to benefit reservoir fisheries (considering such issues as storage ration, water retention, and seasonal storage) while minimizing negative impacts on the downstream native fish community. In all actions, priority should be given to native communities.

Increased biological sampling in the Middle Rio Grande has raised the question of data comparability. The use of various study designs, sampling techniques, and collection management practices increases the difficulty of comparing data from different studies. The importance of aquatic resource data in management decisions affecting the Middle Rio Grande requires that all data meet some level of acceptability. Biologists and policymakers should agree on appropriate levels of standardization and/or data compatibility. The scientific collecting permit processes employed by the NMDGF and FWS may provide the institutional framework to accomplish this goal.

Monitoring and Research: Fish research in the Middle Rio Grande currently addresses the Rio Grande silvery minnow but, by design, also studies the distribution and abundance of the entire fish community, including nonnative fishes. The research will also address the impacts of nonnative species on native fish during periods of low flow.

Additional research needs are as follows. (1) Study short- and long-term movements of nonnative fish into and within the Middle Rio Grande. (2) Further quantify the impacts of nonnative fish on the native fish and invertebrate community. Additional sampling specifically for nonnative species might enhance the understanding of their distribution, abundance, and habitat associations in the Middle Rio Grande. (3) Experiment with techniques to limit the emigration of nonnative fish from stocking locations. For example, methods of limiting downstream passage of fish during Cochiti Dam releases should be explored.

Long-term monitoring of the entire fish community is critical to understanding native/nonnative fish community dynamics. This data is essential for developing appropriate management actions. Monitoring also plays a critical role in the regulation and, hopefully, control of accidental introductions.

Agencies and Groups with Middle Rio Grande Nonnative/Native Fish Experience:

New Mexico Department of Game and Fish
U.S. Fish and Wildlife Service, New Mexico State Ecological Services Field Office
University of New Mexico, Ichthyofaunal Studies Program
New Mexico State University, Department of Fisheries and Wildlife Sciences
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

RECOMMENDATION 7: Protect the geographic extent of the Rio Grande bosque and avoid further fragmentation of the riparian ecosystem and component habitats.

Need: The Rio Grande floodplain has been used for habitation and for agriculture since prehistoric times. More recently, population growth and associated development have expanded into previously unoccupied and unused areas and caused losses of riparian bosque and wetlands. Development in the vicinity of Albuquerque and other urban areas threatens the extent of the riparian plant communities and includes both reduction of the bosque area by housing, shopping centers, and agriculture as well as fragmentation of contiguous bosque habitat by powerlines, bridges, transportation corridors, and other projects that cross the riparian zone. Large-scale (in terms of kilometers or miles) fragmentation of a narrow, linear ecosystem like the riparian has serious implications for natural resources. Interruption of riparian habitats for long distances separates populations of plants and animals, disrupts migration and dispersal of some species (e.g., neotropical migrants), and may reduce species richness and diversity within the remaining fragments. On a smaller scale, fragmentation of the component parts of the ecosystem (i.e., community types or habitats) may disrupt the lives of a different set of organisms supported by the system.

Description of Recommendation: The remaining riparian habitats in the Middle Rio Grande Valley should be protected from development and fragmentation. This could be accomplished by management policies, land purchases, zoning, cooperative agreements with private landowners, and other methods.

Opportunities and Constraints: Recent national and regional concern over the future of the Rio Grande has brought an awareness of riparian ecosystem issues to land and water managers and to the public. The remnant riparian ecosystem of the Rio Grande is recognized by national groups, municipalities, agencies, and private citizens as an asset to our cities, to our state, and to our region. Thus, the time is right for these entities to begin to work together to provide protection to water and lands that contain surviving riparian communities.

Ownership and management responsibilities for the Middle Rio Grande riparian zone include MRGCD, pueblos, New Mexico State Parks and Recreation Department, NMDGF, FWS, BOR, various municipalities, and private individuals. Constraints on the accomplishment of this recommendation include the need for municipalities and agencies to meet essential goals that may have nothing to do with protection of riparian ecosystems. The rights of private landowners to use and dispose of their property as they see fit (within the guidelines of state, county, or municipal regulations) must be recognized. However, these constraints should not prevent protection and conservation of many riparian areas where landowners and land managers are willing to participate in such activities.

Implementation Considerations: Because of the mixed ownership status of bosque lands and the lack of certainty of ownership in some cases, defining and clarifying land status in the riparian zone are necessary prerequisites for protection planning. Riparian habitats of high quality (those with native species as dominants within the plant community) should be selected for cooperative agreements or acquisition (only from willing sellers). The Nature Conservancy, the New Mexico Natural Lands Protection Committee, the FWS "Partners for Wildlife," and other

private lands programs also work with private citizens and nonfederal groups or agencies to protect and sometimes acquire lands of biological importance.

It is also important to recognize that disturbances in the bosque vary. Projects that are large in scale and involve clearing many acres of cottonwood habitat for residential, business, or agricultural development are clearly destructive to plant and animal communities. Activities in these developed areas may have continued effects on adjacent bosque in the form of noise, air, and water pollution. Powerlines or pipelines require removal of vegetation. The narrow nature of these types of disturbances, however, may not be sufficient to disrupt dispersal or migration. Bridges are another form of disturbance that may not be extensive enough in area to interrupt dispersal or migration, but the disturbance resulting from their construction and use is intensive and continuous. The physical damage, the constant noise, and the access points to previously interior woodland areas are serious disruptions to some wildlife species. Agriculture does have some benefits to wildlife (see Recommendation 9 on buffer zone).

Because of these deleterious effects, we recommend that clearing and fragmentation of habitats and of the linear riparian ecosystem be avoided by protecting the geographic extent of the existing bosque and by minimizing the number and extent of projects that cut across the slender band of woodland. Transportation, pipeline, and powerline corridors should be combined to restrict impacts.

Action: Develop a definitive ownership map of the riparian zone in the Middle Rio Grande Valley so that protection by appropriate entities can be extended to the bosque whenever possible.

Pueblos, agencies, and municipalities should review their policies for operation, development, and management that are related to riparian issues. Appropriate policies could be revised or new ones developed to protect riparian habitats. These policies could be coordinated with other management entities through a state riparian task force and/or riparian coordinators (see Recommendation 20 on plan review and update).

Federal and state agencies and other entities involved in planning, implementing, and reviewing projects in the riparian zone should include fragmentation issues when considering projects and mitigation measures in the bosque.

Private citizens (and nonfederal agencies and municipalities) should be made aware of programs such as "Partners for Wildlife" and other cooperative agreements with the FWS that support the protection, enhancement, and creation of wildlife habitat, including habitats found in the riparian zone. They should also be made aware of conservation easements, acquisition programs, and other options with The Nature Conservancy and the New Mexico Natural Lands Protection Committee. No riparian sites are currently on an acquisition list; future coordinating groups should work with the New Mexico Energy, Minerals, and Natural Resources Department to nominate sites that qualify under the Natural Lands Protection Act (78-5-1 et seq. NMSA 1978).

Monitoring and Research: Fragmentation of ecosystems and habitats is a poorly understood topic. There is little information on minimum size of habitat units needed to support the full

range of species in riparian communities. The Rio Grande ecosystem has not been adequately studied in this regard. We recommend that research on the consequences of fragmentation of the bosque habitats be undertaken as soon as possible, so that information on this important topic can be incorporated into riparian management plans.

When disturbances of bosque habitats are unavoidable, the effects should be monitored. Baseline, or predisturbance information, should be gathered, and postdisturbance data should be collected at regular intervals. Monitoring should include assessments of plant and animal community composition. This information should be evaluated and incorporated into management plans for future activities. (See Recommendations 18 and 19 on monitoring and research for additional guidance on these topics.)

Agencies and Municipalities with Existing Plans for Riparian Management:

U.S. Bureau of Land Management
City of Albuquerque, Open Spaces Division

Agencies and Groups with Funds and Resources Available for Habitat Improvement:

New Mexico Natural Lands Protection Committee
New Mexico State Forestry and Resources Conservation Division
U.S. Fish and Wildlife Service, Private Lands Coordinator
The Nature Conservancy, Santa Fe
Tree New Mexico
Soil Conservation Service, Plant Material Center

RECOMMENDATION 8: Protect, extend, and enhance riparian vegetation in noncontiguous areas in the floodplain.

Need: Most of the native riparian plant communities are restricted to areas between the riverbanks and levees alongside the river, but there are also stands of cottonwood trees and other native species outside of these boundaries in the surrounding floodplain. These may be remnant stands of native communities left from previous riverine processes, or the result of suitable environmental conditions and seed availability at these locations. Native plant communities outside the contiguous bosque increase the wildlife habitat beyond the narrow band along the river and provide islands of shelter and resources for resident, migratory, or dispersing animals. Development in the floodplain most often affects riparian communities outside the levees; the effects of development range from complete clearing to removal of understory with a few mature trees left to enhance the landscaping.

Description of Recommendation: Existing riparian communities outside the levees should be protected from development. Riparian habitat in these locations could be extended to link up with the river bosque, to form larger islands of habitat, or to join isolated patches of bosque with each other. The value of existing stands could be enhanced by providing buffer areas around them, by supplementing the stand with plantings of native species, and by controlling nonnative species within and around the stand.

Opportunities and Constraints: Opportunities include the current existence of riparian vegetation in the floodplain and overall site suitability (soils, ground water, agriculture, and water distribution system). Opportunities also include the current awareness of the value of riparian habitat for wildlife use and human enjoyment. Agencies and many private interests involved in development often recognize the value of native plant communities (especially cottonwood bosque) and are willing to protect it as much as possible during project planning and construction. Techniques for enhancement of the bosque by pole planting and planting of native species of shrubby understory are well developed and widely practiced. Constraints include the large amounts of privately owned land and the availability of suitable sites for establishment of new riparian communities.

Private lands in the floodway are especially valuable in urban areas because they are easy to develop and because of their semirural atmosphere. Development of these lands may conflict with the ideals of bosque protection, enhancement, and extension. However, development does not necessarily preclude carrying out these ideals; indeed, especially for housing developments, the presence of cottonwood woodlands enhances the monetary value of residential properties. Various state, federal, and private programs, including those of the New Mexico Natural Lands Protection Committee, FWS, and The Nature Conservancy are available for protection and enhancement of cottonwood habitats by willing landowners.

Other constraints are mainly related to changes in physical conditions that allow regeneration of cottonwoods and other native species in the floodplain away from the existing river channel. Because the river has shifted its bed frequently in the past (prior to the construction of levees and other river training devices), existing stands of mature cottonwoods outside the levees were probably created when the river was nearby and when it provided adequate moisture for

germination and establishment of trees. Once established, their roots were able to reach water even after the river channel was shifted away from them. Now, however, ground water may be too deep to supply pole plantings or seedlings with adequate moisture for survival. For this reason, extension and enhancement of outlying stands of cottonwood bosque (or other riparian species) should be attempted only after studying local conditions to assess the likelihood of success.

Implementation Considerations: Implementation of plans to protect, enhance, and extend noncontiguous native riparian species in the floodplain of the Rio Grande is dependent on the location and identification of areas where such bosque occurs, and also on landownership status.

Other considerations for protection, enhancement, and extension of these vegetation types can be found in Recommendation 16 on protection and enhancement of the contiguous cottonwood forest, Recommendation 9 on buffer zone, and Recommendation 17 on removal on nonnative species. These include site assessment for suitability, site preparation, and techniques for revegetation.

Action: Develop detailed site location and ownership maps for noncontiguous cottonwood bosque and other native communities in the Middle Rio Grande Valley; in conjunction with this, develop land status ownership maps so that owners or managers will have the opportunity to protect, enhance, and extend the riparian forest. A set of criteria, including biological and social considerations, should be developed to rank noncontiguous areas in terms of need for preservation, enhancement, and establishment.

Landowners and managers should be made aware of the resources and the opportunities for protection and enhancement of riparian communities by using state, federal, and private sources, including the New Mexico Natural Lands Protection Act, FWS private lands programs, and The Nature Conservancy.

Lands with high value (based on species composition, size, and condition) riparian habitat should be acquired for protection and management by appropriate municipality, state, or federal agency.

Programs specifically for riparian habitat protection, enhancement, and extension should be developed by state, federal, and private entities.

Monitoring and Research: Any enhancement or restoration efforts should be accompanied by monitoring studies, including acquisition of baseline information on location and extent of the riparian forests for comparison to future changes. Research on these noncontiguous riparian community areas may provide information on size of fragment or patch and number and type of associated animal species. Estimates of minimum fragment or patch size necessary to support and sustain native animal communities could be developed from these studies (see Recommendations 18 and 19 on monitoring and research).

Research on size, configuration, vegetation species composition, juxtaposition to other areas, etc., should be completed as required to develop the biological ranking criteria.

Agencies and Groups with Funds and Resources Available for Habitat Improvement:

New Mexico Natural Lands Protection Committee
New Mexico State Forestry and Resources Conservation
U.S. Fish and Wildlife Service, Private Lands Coordinator
Tree New Mexico
Soil Conservation Service, Plant Materials Center

RECOMMENDATION 9: Manage the buffer zone of the contiguous bosque to protect ecosystem processes, enhance wildlife habitat values, and maintain rural and semirural conditions.

Need: Agricultural activities in the floodplain surrounding riparian areas have created what could be called a buffer zone between the bosque and adjacent urban development in many areas in the middle valley. Undeveloped uplands that extend into the floodplain and the bosque may also form part of the buffer zone. This buffer zone provides protection from some forms of urban human disturbances and provides food and resting areas for migratory waterfowl and other wildlife. The combination of water, cover, and feeding areas presented by the juxtaposition of river, bosque, and agricultural fields is extremely valuable to sandhill cranes, snow geese, Canada geese, and other species. In addition, this combination of attributes is particularly pleasing and important to people in the area who value rural and semirural ways of life typical of the Middle Rio Grande Valley.

Irrigation agriculture also provides, to a certain extent, replacement of the riverine floodplain functions; these include spreading out of flood waters and the recharge of sediments, nutrients, and ground water on floodplain lands. Ditches and canals that carry water to fields in the floodplain provide water and emergent vegetation that supports wildlife, including waterfowl, other bird species, muskrats, and beavers, throughout the floodplain.

Undeveloped upland areas that come very close to the river provide a different habitat type within the floodplain as well as access to water and riparian food sources for upland animal species.

The buffer zone is particularly important in maintaining the high wildlife value of the bosque and associated communities, as well as maintaining the rural atmosphere and character of the Middle Rio Grande Valley. Population is expanding in the floodplain of the middle valley, and there is a steady conversion of these buffer zone agricultural lands to residential uses.

Description of Recommendation: This recommendation encourages the continued agricultural use of floodplain land by maintaining property tax relief for agriculture (e.g., Bernalillo County's "green belt" policy) in municipalities where it exists now and for instituting similar programs in areas lacking such policies. Landowners should be encouraged with economic incentives to continue farming. Zoning laws, even though they are unpalatable to many small municipalities, would help to keep developed land parcels large (minimum size 0.4-1.2 ha [1-3 acres]), with access to irrigation, so that buffer zone functions can continue and rural values be maintained as much as possible.

Opportunities and Constraints: The buffer zone in Bernalillo County is supported by the green belt policy; land holdings of 0.4 ha (1 acre) or more that are in agricultural production are taxed at a lower rate. The county land-use plan requires 0.4 ha (1 acre) zoning in many areas outside the City of Albuquerque boundaries. Counties and municipalities outside the urban influence of Albuquerque have the opportunity to institute green belt policies and zoning regulations that would allow growth but in ways that will help sustain bosque values for both wildlife and humans.

Albuquerque zoning policies allow for denser development on floodplain lands (now protected by levees) within the city boundaries. Density of development in both city and county jurisdictions is also dependent on availability of services, such as water and sewage, which are regulated by the New Mexico Environment Department. Existing zoning regulations may be a constraint on protection of the buffer zone but, with changes, could easily become an opportunity for maintaining that protection.

There are economic constraints on carrying out this recommendation. As population in the Middle Rio Grande Valley grows, development is inevitable, and floodplain land under agriculture increases in its potential value for development. However, economic assistance for farmers and control of the nature of development can provide some opportunities for implementing this recommendation.

Irrigated farmlands can be managed to provide suitable crops for wildlife. Land could be leased or acquired for the purposes of growing agricultural crops that are beneficial to wildlife.

Implementation Considerations: Counties, municipalities, and pueblos have the local control necessary to develop and implement policies and regulations for growth in ways that preserve agricultural, wildlife, and rural values.

Action: Counties, municipalities, and pueblos should develop and implement policies for protection of riparian buffer zone lands for their wildlife and human values.

Land leasing and acquisition from willing owners could be undertaken to grow crops such as corn, milo, and other grains that support migratory and resident bird species. Personnel at the Rio Grande Nature Center and Candelaria Farms in Albuquerque and at Bosque del Apache Wildlife Refuge have experience in farming and managing irrigated lands to attract and maintain wildlife.

Monitoring and Research: Use of buffer zones by wildlife should be quantified; information on species using these areas, numbers of individuals, and seasonality of use should be collected.

Counties with Property Tax Provisions for Agriculture:

Bernalillo County

Agencies with Programs for Farming for Wildlife:

New Mexico Parks and Recreation Division
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
City of Albuquerque, Open Space Division
New Mexico Department of Game and Fish

RECOMMENDATION 10: Manage livestock grazing in a manner compatible with biological quality and ecosystem integrity.

Need: Livestock grazing in the Rio Grande bosque and floodplain needs to be managed so that its detrimental effects on riparian habitats are minimized while its beneficial effects on habitat diversity are promoted. Livestock grazing has removed much of the undergrowth in cottonwood stands in parts of the Middle Rio Grande bosque. These stands now exhibit structural simplicity and are not expected to have high biotic diversity. Also, livestock have, over historic time, eaten back cottonwood and willow seedlings and saplings along the river. This has inhibited the regeneration of native vegetation and reduced resultant community biological quality. Heavy grazing in Rio Grande watersheds has contributed, via erosion, to high sediment loads in the river. Likewise, in those watersheds that are contributing high sediment loads to the Middle Rio Grande, livestock grazing practices should be reviewed and improved if necessary.

Description of Recommendation: In order to allow regeneration and areal expansion of native bosque vegetation, grazing should be controlled in severely damaged parts of the ecosystem.

On the other hand, if managed carefully, livestock grazing can be used to increase the diversity of bosque habitats, as well as the diversity of plants and animals in those habitats. Increased diversity can be achieved by using livestock to create and maintain a variety of successional stages. Stocking rates and graze-rest cycles must be monitored in such operations. Livestock can be used to control introduced vegetation. Seedlings and saplings of salt cedar in particular can be controlled this way.

Grazing should be more creatively managed on those lands not held in private ownership (e.g., MRGCD lands). Management entities should develop and enforce comprehensive grazing plans that incorporate riparian biological values. Incentives for modifying grazing activities on privately owned lands in and adjacent to the bosque should also be developed. These could be in the form of tax incentives, payments, or easements. Finally, the existing governmental cooperative services that provide advice to agricultural interests should expand their riparian grazing programs.

Opportunities and Constraints: Livestock grazing, if planned carefully, can play an important role in ecosystem management along the Middle Rio Grande. This is most likely to be the case where land users do not rely entirely on financial returns from their land. Such individuals may have greater flexibility to use different pasture sizes, mixtures of plant species, and different kinds of livestock, stocking rates, and grazing schemes than land users who depend more completely on grazing for a living.

Resource managers should anticipate opposition by farming and ranching communities to activities perceived to be attempts to limit grazing. Hence the need, referred to above, for sound riparian grazing education programs. Managers should also recognize that working with ranchers using nonprivate lands, as opposed to those on private lands, can produce results affecting relatively large blocks of land. On the other hand, working with private landowners has the value of being voluntary (on their part) and allowing for the development of incentive packages resulting in both short- and long-term economic benefits.

Implementation Considerations: Most of the necessary information is already known and most of the technology has already been developed to use livestock to enhance the riparian areas along the Rio Grande (Clary and Webster 1990). This knowledge should be used by management agencies and landowners to make management decisions. Transfer of this knowledge and technology can be accomplished through an extensive education program for public and private land users. Grazing pressure should be monitored, and duration and season of use should be determined to achieve desired plant communities.

Action: There is no simple solution to the problem of overgrazing in the riparian zone. Incentives (e.g., payments to not graze or to modify grazing) may be an alternative for private landowners who otherwise may not restrict their livestock from entering sensitive areas. Another approach might be for a government agency, or private organization such as The Nature Conservancy, to develop conservation easements for riparian areas with landowners, or to purchase and restore overgrazed riparian land. Passage of legislation that tightens controls on grazing practices is yet another approach; it might be tied to the use of incentives.

The benefits of improving habitat diversity by carefully managed livestock grazing should be publicized, and the practice should be encouraged where feasible. Livestock owners who use their animals to control introduced vegetation, especially salt cedar, should be rewarded for doing so, particularly if the control is carried out on public land. This type of action should be made part of a coordinated program of salt cedar management.

Agencies that manage public lands along the Middle Rio Grande should work together to develop guidelines for livestock grazing on those lands. Once this is done, those agencies should routinely monitor grazing practices and habitat responses over long periods in order to make recommendations and/or enforce changes.

Monitoring and Research: Public and private land users should be instructed on how to monitor plant, soil, water, and animal resources. Some relatively quick, simple, and inexpensive methods can be used to indicate seral status and trends (Range Improvement Task Force 1981). Photography points and range inventory plots should be established to monitor vegetation changes.

Field experiments should be undertaken to further test the effectiveness of livestock grazing on creation of riparian habitat diversity and biodiversity. Results should be compared against those from similar but ungrazed control sites. The use of livestock to control introduced vegetation such as salt cedar should also continue to be tested.

Agencies with Riparian Protection Programs and Grazing Management Responsibilities:

U.S. Bureau of Land Management
U.S. Forest Service

Individuals with Expertise on Grazing Management:

Dr. Karl Wood, New Mexico State University

RECOMMENDATION 11: Manage activities that remove dead wood in a manner compatible with biological quality and ecosystem integrity.

Need: A variety of animals reproduce, forage, and find shelter in tree cavities. For example, in cottonwood riparian habitats, cavity-nesting birds comprise 32-43% of the breeding birds (Sedgwick and Knopf 1986). Cavity trees are standing dead trees (snags) and trees with dead limbs. Both provide the majority of substrate for animals that use cavities. Dead and downed logs also provide a valuable biological component. Snags and dead limbs of cottonwood and willows have more value for cavity nesters than do some introduced tree species (Brush et al. 1983). The value of Siberian elm and Russian olive to cavity nesters in the bosque is unknown.

Firewood cutting is the major current threat to snags or live trees with dead limbs. Demand for wood in the future may increase this threat. A secondary threat could be indiscriminant removal of snags and dead limbs for safety or appearance considerations. In addition, in an aging cottonwood forest without adequate concurrent regeneration, there would be a eventual decline in large, mature trees with dead limbs as well as a decline in numbers of snags.

While snags and fallen dead wood are important to a healthy forest, the absence of flooding in the Rio Grande bosque for the last 30-50 years has caused a build-up of dry, woody combustible material in some areas on the forest floor. This material burns with intense heat that is lethal to cottonwoods. There is a need to determine the appropriate balance between the desirable amount of dead material available for forest processes with maintaining low fuel loads to prevent high intensity fires.

Description of Recommendation: *Cavity trees*—To support a diversity of plants and animals associated with snags, riparian forest habitats should include a component of dead and decadent standing trees. In general, a cottonwood-willow tree community with a wide range of tree heights, diameters, and age classes would accommodate the entire community of cavity dependent species. The following are general guidelines to maximize the value of the riparian forest habitats for cavity nesting animals.

For maximum diversity and abundance of cavity nesting species, an average of 7.5 cavity trees per hectare (3 per acre) should be present in mature forest habitats. The minimum density should be 2.3 cavity trees per hectare. These trees should be as large as possible with at least 6 cavity trees per hectare (2.5 per acre) at least 30 cm (12 inches) d.b.h. An occasional cavity tree should be at least 54 cm (21 inches) d.b.h. Retain cavity trees with dead limbs greater than 14 cm (6 inches) in diameter. As a general rule, larger trees and limbs are more valuable because they meet the requirements of a greater number of species.

Cavity trees should be well distributed throughout forest stands to meet the territorial requirements of different species. It is also important to protect areas with clusters of cavity trees to maintain habitat for species that require secondary nest sites.

Areas without adequate density and distribution of cavity trees should be closed to wood cutting. Fuelwood cutters should be restricted from cutting all standing dead or decadent

cottonwood and willow trees greater than 54 cm (21 inches) d.b.h. Access roads to selected riparian forest stands should be closed to vehicular traffic to discourage woodcutting.

In mature riparian forests with a low density dead wood component, snags could be created by girdling selected trees and limbs, or nest boxes could be provided for selected species. This type of management should be approached with caution because primary excavators may not always use such created snags, nor do the primary excavators use nest boxes.

Snags or dead limbs near water that have potential for rookeries or perch sites for fish-eating birds should be protected.

Dead and downed woody material—To maintain a healthy riparian forest ecosystem the dead and down component must be maintained. Firewood gathering and burning should be coordinated with plans for maintaining dead, woody material on the forest floor.

Firewood gathering should be monitored to ensure that large stands of bosque are not completely cleared of downed logs. A minimum average of least 5 downed logs per hectare (2 per acre) should be maintained in riparian forests. Areas identified as "wildlife areas" should contain a greater density of downed logs in different stages of decomposition well distributed over the riparian forest floor.

Downed logs on the riverbank and in the water should not be removed to the extent possible. Prescriptions for controlled burns should contain measures to maintain larger downed logs.

Opportunities and Constraints: The requirement for permitting fuelwood harvesting provides an opportunity to coordinate firewood collecting and maintenance of dead and downed material. Constraints is lack of staffing for proper monitoring and enforcement.

Implementation Considerations: Management of cavity trees should be incorporated into an integrated firewood management plan. Alternative sources of firewood could be provided such as felling of exotic trees or thinning of dense intermediate-aged stands of cottonwood. Retention of minimum snag densities should be considered in burned forest habitats before cutting of standing burned trees.

Because firewood cutting requires a permit under state law (68-2-22 NMSA 1978), coordination of management of fuelwood harvesting should include the New Mexico Forestry and Resources Conservation Division.

A public education program should include awareness of the value of snags and dead and downed trees to the ecosystem.

Action: Agencies, municipalities, and landowners should develop guidelines that maintain desired densities of cavity trees and downed logs in concert with management plans and activities. Examples of specific actions include:

- Vehicle access restrictions may be required in areas where cutting of dead and decadent trees (both standing and downed) may be impacting cavity nesters. Alternative sources of firewood could be provided.

- Minimum densities of standing burned trees and downed logs should be left in burned areas when cleared for revegetation or in areas targeted for prescribed burns.

- Efforts should be made to identify and protect cavity trees, roosting trees, and downed logs during rehabilitation and maintenance projects in riparian forests.

Monitoring and Research: Inventories of cavity trees should be conducted throughout the bosque. Areas of high value to cavity nesters should be identified. Cavity tree management goals should be established in areas where firewood is collected.

Research on this recommendation should be coordinated with experiments on controlled burns (see Recommendation 13 on fire prevention) and with restoration of flooding in the bosque (Recommendation 3).

Firewood gathering should be monitored to ensure that desired densities of snags are maintained and large stands of bosque are not completely cleared of downed logs.

As stands of introduced trees such as Russian olive and Siberian elm mature and become senescent, research is needed to compare the use by cavity nesters of these trees with cottonwood and willows.

Agencies and Municipalities with Responsibilities that Involve Removal of Dead Wood:

City of Albuquerque, Open Space Division
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
New Mexico Department of Game and Fish
New Mexico Parks and Recreation Division
New Mexico Forestry and Resources Conservation Division
Pueblo Governments: Isleta, Sandia, Santa Ana, San Felipe, Santo Domingo, Cochiti
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

RECOMMENDATION 12: Manage recreational activities in the bosque in a manner compatible with biological quality and ecosystem integrity.

Need: The Rio Grande and its riparian forest have provided recreational opportunities for humans since their presence in the middle valley. The river has also served as a focal point for social and community activities. In an arid and sparsely vegetated region, the riparian corridor is an oasis providing shade and opportunities for hunting and fishing, picnicking, aesthetic appreciation, nature observation, education, and exercise. With increasing population densities there is a commensurate increase in recreational use of the bosque with concomitant demands on its resources and disturbance of its ecosystem. Recreational use of the bosque is heaviest in urbanized areas, decreasing with distance from population centers.

Uncontrolled vehicular access (on- and off-road) as well as some forms of recreational use and access are adversely affecting vegetation, wildlife habitat, and sensitive plant and animal species. Uncontrolled access is promoting the dumping of waste, firewood cutting, fires, poaching, and use of all-terrain vehicles. These activities not only physically destroy and degrade wildlife and wildlife habitat, but the accompanying disturbance also adversely affects wildlife presence and behavior. There are higher value plant communities and animal species that are sensitive to disturbance or are rare, or both, that can be adversely affected. Also, there are periods (e.g., the breeding season) during which some species are particularly sensitive to disturbance. Unrestrained dogs harass and kill wildlife and can be a public safety hazard. Unmanaged access also promotes the indiscriminant use of firearms. The continuing intensification of public use will correspondingly intensify impacts from uncontrolled access.

Commensurate with the increasing attractiveness and enjoyment of the bosque is a need to maintain an awareness of how recreational use can affect the well-being of those biological attributes that are found so desirable and to plan recreational use and development so as to preserve those desirable qualities. The need to manage these uses and to maintain the biological and associated recreational quality of the bosque is exemplified by management plans and measures instituted in the Rio Grande Valley State Park and by the Village of Corrales.

Description of Recommendations: *Directed access of motorized vehicular traffic*—Managed access of motorized vehicular traffic is the single most important management tool that eliminates much habitat degradation and wildlife disturbance and promotes improved recreational quality. This measure can be achieved (and has been implemented in certain reaches) by managing access to levee roads, primarily at bridge crossings and at a few intervening roads that cross the drains. Also, the degree to which control is needed may be dependent on the potential intensity of use—more control may be necessary in urbanized areas and less in rural areas.

Access (and egress) to the riparian corridor and river for recreational use is paramount and must be preserved. Motorized vehicular traffic should be redirected to formally developed parking sites. These sites may be in the riparian zone near bridges, sites landward of the riverside drains/canals, or at the mouths of tributary arroyos. Pedestrian access to the bosque would be required from parking sites landward of the riverside drains/canals. Pedestrian bridges over water features would be necessary in many cases. Parking sites within the bosque would have to be defined to restrict further access into the bosque. This basic concept of controlling

vehicular access to the bosque should also be employed in areas without a levee or riverside drain.

Vehicular access to the levee or bosque for hunting should be allowed in rural areas where hunting is permitted during designated seasons. The existing levee should be widened at approximately 1.6-3.2 km (1-2 mi) intervals to provide parallel parking. Widened levee sections should be incorporated in levee rehabilitation measures planned by the COE.

Siting of formal parking areas and access and egress points should be planned to avoid adverse impacts to a particularly valuable plant community, such as wetlands, young cottonwood forest, habitat for animal species of concern, or a particularly important nesting site. Surveys of species or habitats of concern should be accomplished during plan formulation to guide placement (see City of Albuquerque Parks and General Services Department 1993). To the extent possible, these areas should be placed adjacent to a variety of plant communities that exemplify the diversity of habitat that comprises the bosque.

Use of motorized craft on the river should be managed for safety and rescue use only. The interior of the riverine corridor provides seclusion and isolation for a large number of wildlife species, and this isolation should be preserved. Use of canoes and rafts is generally a compatible activity although increasing intensity of use should be monitored to ensure that the level remains compatible with the goal of sustaining biological resources.

Location of developed recreation areas and level of development—In general, major recreational development should be located outside of the bosque, with only limited development (e.g., trails, observation blinds, etc.) within the bosque proper. An integrated public access and trail plan should be developed that allows a variety of recreational opportunities (e.g. hiking, biking, equestrian, nature study in relative solitude). This would require restrictions in certain sensitive areas such as strategic trail routing and closures. Certain access points should be provided with information/interpretive signs and other facilities. Conflicts with private land use should be addressed. Fencing or explanatory signs, or both, should be considered to protect sensitive habitats.

Again, the biological value of a particular plant community is an important consideration in plan formulation. As a general planning concept, and to the extent feasible, significant recreational development should be concentrated in or near areas of urban development, particularly in currently used areas. This concept would reserve greater areas with less disturbance, thereby enhancing wildlife use.

The landward levee edge is a zone of high wildlife use, particularly intermediate aged cottonwood and dense, shrubby vegetation. These edge community types should be preserved to the extent feasible. Edges without vegetation, or sparsely vegetated edges, could be used. Trails should be placed on the levee crest or elsewhere rather than on the river side (or toe) that typically has a distinct community type and provides higher wildlife use.

Although developed trails should be limited within the bosque, it is important from an educational and aesthetic perspective that some be placed in a variety of plant communities (again

avoiding high use and sensitive areas). Priority areas would be in already disturbed and urbanized areas.

Avoidance of fragmentation—As discussed, the size and integrity of a particular plant community/structure type are of significant importance to a number of animal species. Not only can physical division occur due to developmental features, but activity and noise also can divide in a like manner. Therefore, planning for recreational development and use should strive to locate these areas near the edges of plant communities.

Hunting within the riparian zone—Hunting along the river has been a favorite recreational activity for generations of sportsmen and continues with even greater demand. Hunting should remain a priority use of bosque resources, recognizing that safety, especially in heavily urbanized and developed areas adjacent to the bosque, should govern where hunting is to be allowed.

Uncontrolled pets—Develop and distribute a handout for pet owners adjacent to the bosque to inform about impacts of dogs and cats on wildlife. Enforce leash laws in the bosque, and control feral dogs and cats.

Opportunities and Constraints: Recreation management measures are being implemented and planned in the Rio Grande Valley State Park to preserve and enhance biological values. Because a significant portion of the remainder of the bosque is under the administration of a public or tribal governing body, implementation of this plan has a high potential for success. A challenging element of this recommendation is acquisition of property and development of formal vehicular/pedestrian access points. An integrated vehicle and recreation plan would require coordination and cooperation of the MRGCD, land management agencies, private landowners, and pueblos.

The City of Albuquerque has developed a management plan that contains a recreation-vehicle plan for the Rio Grande Valley State Park and could serve as a model. Wherever possible, existing roads should be used. Also, site selection should consider potential disturbance to any adjacent private landowners.

Cochiti Lake has expanded opportunities for sportfishing in the Rio Grande to at least Angostura Diversion Dam and perhaps farther downstream. Access to a significant length of the river above Albuquerque, as well as egress, is restricted by tribal ownership. Any future public access and egress through pueblo lands for fishing or other water-based recreational activities (e.g., hunting, canoeing, and rafting) should be based on management objectives by the individual or collective pueblos.

There is an appreciable demand for nearby recreational fishing; Sandia, Shady, and Isleta lakes and Tingley Beach are examples of developed and managed sportfishing facilities within or near the riparian zone. Several of these areas have been developed with a sensitivity toward preserving riparian vegetation. A very real constraint could be a perception by some that recreational management would be another limitation of their use of the bosque. Conversely, an urban population may be very likely to endorse management and be willing to pay for it.

Implementation Considerations: A major consideration in implementing this recommendation is the willingness and ability of management entities to actively develop and manage recreational activities. After these are established then the ability to fund these activities becomes a significant element, followed by planning and associated public involvement. Planning considerations include the following: (1) landownership/administration; (2) land acquisition and trusts; (3) community education/partnership; (4) site location-relationship to adjacent plant communities, Rio Grande, and floodplain development; (5) biological planning information-identification of community/structural type, associated animal use and abundance, areal extent, edge, sensitivity, adjacent biological communities, etc.; (6) soils; (7) existing recreational use; (8) light versus heavy recreational use; (9) access; and (10) minimize vegetation clearing with an emphasis on retaining native species.

Action: Implement a coordinated, comprehensive access and use management plan among involved federal and state agencies, municipalities (including pueblos), and associated landowners.

Monitoring and Research: All recreational areas should be continually monitored for any deterioration of habitat or changing biological conditions that may require a change in recreational use. A prime example is the increasing population of wintering bald eagles along the Rio Grande, especially in the Albuquerque area. Because of their seasonal presence, a heavy recreational use designation may need to be changed to light use. Also, intensive recreational use may cause soil compaction or vegetation abuse that may require that an area be temporarily withdrawn from use to allow restoration.

There is a need to inventory and map the following: (1) sensitive wildlife habitats where public access should be restricted, (2) existing roads that should be closed and revegetated, (3) existing trails to be closed and revegetated, (4) access points for recreation opportunities, (5) potential routes of trails, and (6) area(s) that could support off-road vehicle use. Again, the Rio Grande Valley State Park plan is a good example.

Monitoring would be necessary, and adjustments to the plan would be made when habitat disturbance is documented or further recreational demand requires additional developments.

Agencies and Groups with Experience and Information in Recreational Management:

There are ample information, experience, and examples to manage recreational activities in the bosque in a manner compatible with biological values. Sources include the following:

City of Albuquerque Open Space Division
New Mexico Parks and Outdoor Recreation
New Mexico Department of Game and Fish
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
Pueblo Governments: Sandia and Isleta

An appreciable number of entities would play a role in implementation of this recommendation, key among which would be the MRGCD. Each municipality, pueblo, county, and element of federal or state government would play a vital role.

RECOMMENDATION 13: Prevent unmanaged fires in all reaches of the bosque

Need: Human-caused fires have especially deleterious effects on the bosque's cottonwood communities because these communities are less fire adapted than other forest types. Salt cedar, Russian olive, and other exotic species quickly invade after fires in cottonwood communities. High intensity fires usually kill cottonwood trees, which rarely regenerate following a fire. Conversely, salt cedar and Russian olive quickly sprout new growth from their root crowns. With the loss of periodic flooding, which removes accumulated litter, fuel densities and fire intensities have greatly increased. Cottonwood stands with dense understories (type I) are the most flammable, while those with sparse understory (type II) appear to be more resistant to catastrophic fires (Sivinski et al. 1990).

There is a high frequency of human-caused fires in the bosque. Many of these fires, especially those in dense, mature stands, are resistant to suppression due to high fuel loads and salt cedar-induced fire storms. A large amount of cottonwood forest is at risk from future fires.

The New Mexico State Forester has identified two major preventable causes of wildfires. These are spring ditch burning and Fourth-of-July fireworks (Sivinski et al. 1990).

Description of Recommendation: Increased fire prevention in the bosque should be accomplished by public awareness programs and access restrictions. Control of fireworks and spring ditch burning would reduce the frequency of wildfires. Fire contained in charcoal grills or campfires should be discouraged within the bosque.

An integrated fire management plan needs to be developed to improve fire suppression in the bosque. This would involve coordination with New Mexico Forestry and Resources Conservation Division, pueblo fire-fighting organizations, municipal and rural fire departments, and federal interagency fire organizations. There is need for funding, training, and equipment (G. Fitch, pers. comm.). Access to remote areas of the bosque, use of heavy equipment, and dispersal of standing burned cottonwood trees are actions that need biological input. The plan also needs biological input on rehabilitation of burned groves, snag removal, and location and design of fire breaks.

Fire hazards could be reduced by establishing fire breaks and control of accumulated litter. Fire breaks should be 4.5-6.0 m (15-20 ft) wide (Sivinski et al. 1990). Fire breaks up to 75 m (246 ft) wide have been used successfully at Bosque del Apache NWR (J. Taylor, pers. comm.). These breaks should be located in vegetation without mature cottonwoods. Wetlands could be designed and constructed to retard the spread of fires. Strips could be cut into large salt cedar stands or in younger growth cottonwood stands. Accumulated litter could be managed by controlled burning and flooding. Removal of dead wood for firewood may be a potential tool for reducing fuel loads (see Recommendation 11 on dead wood removal), but this should be balanced with the need to have dead, woody material and litter for ecosystem processes.

Opportunities and Constraints: Increased prevention, suppression, and control of wildfires in the bosque would require coordination with the agencies and organizations mentioned above. The New Mexico Forestry and Resources Conservation Division is developing joint powers

agreements with federal, municipal, and county governments for wildfire protection. There is opportunity to both control wildfires and enhance the biological value of the bosque with well-designed fire breaks.

Implementation Considerations: There is a need for a central land management agency to coordinate a biologically sound wildfire prevention, suppression, and rehabilitation program specifically for the bosque.

Action: An integrated fire management plan needs to be developed for the bosque. The New Mexico Forestry and Resources Conservation Division could be the coordinating agency. Input would be required from pueblo fire-fighting organizations, municipal and rural fire departments, and the U.S. Bureau of Land Management.

To ensure that biological values are considered, the fire management plan would also require biological input from entities such as the Middle Rio Grande Coordinating Council and/or the Middle Rio Grande Bosque Coordinator (see Recommendation 20). Biological aspects of the plan would include design and location of fire breaks, use of heavy equipment in sensitive habitats, and retention of minimum snag densities in burned areas.

Monitoring and Research: Research should be concerned with the effectiveness of fuel breaks and revegetation techniques in burned areas. Studies of induced vegetative reproduction (suckering) should be conducted in burn-killed cottonwood stands.

There is also a need to determine whether low-intensity fires could be used to prevent build-up of fuel load in the understory without killing cottonwood trees. Research on burning should be coordinated with that for dead wood removal (see Recommendation 11).

Monitoring is needed to document the areal extent of burns, the subsequent loss of native plant species, and the spread of exotics and the effects of fragmentation. Revegetation efforts need to be monitored and replanted when necessary.

Agencies and Groups with Fire Prevention and Suppression Responsibilities:

New Mexico Forestry and Resources Conservation Division
Pueblo Fire-fighting Organizations: Sandia, Isleta, San Felipe, Santa Ana, Santo Domingo, Cochiti
Municipal and Rural Fire Departments: City of Albuquerque, Bernalillo County
U.S. Bureau of Land Management
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
City of Albuquerque, Open Space Division

RECOMMENDATION 14: Use native plant species and local genetic stock in vegetation establishment and management efforts throughout the bosque.

Need: Nonnative plant species have been used for erosion control, ground cover, and ornamentals in the southwestern United States since Europeans arrived. Other species have been introduced accidentally in forage or crop seeds. Many of them have escaped and become troublesome weeds or pests; the most notorious of these are salt cedar, Russian olive, summer cypress (*Kochia scoparia*), tumbleweed (*Salsola kali*), goathead stickers (*Tribulus terrestris*), and cheat grass (*Bromus tectorum*). Both purposeful and accidental introductions have often resulted in the proliferation of nonnatives at the expense of indigenous species, particularly in the riparian ecosystem where salt cedar and Russian olive have replaced native plants and are now the dominant or subdominant species in many areas. In order to mitigate the effects of these and future introductions, native species should be used in revegetation projects and riparian management in the Rio Grande bosque. By native species, we mean those that are indigenous to the Middle Rio Grande Valley and the life zones and floristic provinces through which the river flows.

Description of Recommendation: Species for revegetation should be native to the region and selected from those that occur in the area from sites of similar elevation, soil type, and moisture regime. Local genetic stock should be used, when possible, in all revegetation projects. In any given area, material should be collected from a variety of sources; for example, cuttings should be taken from more than one or two trees. This will ensure that plants adapted to local conditions of soil, moisture, and temperature (or to some unknown but critical environmental factors), and that have the full array of genetic characteristics, will be used.

Opportunities and Constraints: Native species have been used in revegetation projects by various agencies, including the BOR, COE, FWS, and the City of Albuquerque. Native species are adapted to the southwestern climate and environmental conditions, and most (if not all) revegetation requirements can be fulfilled with plant species from this region. Local genetic stock is usually readily available and can be used if there is adequate time allowed for collection and preparation of the material. Cottonwood or willow poles, for example, can be collected from the local area and used in plantings to revegetate burned areas or in other projects. The BOR has adjusted its mowing schedule on the riverbanks (for maintaining a 183-m [600-ft] floodway) to allow the growth of cottonwood and willow seedlings to a size suitable for pole planting. These are collected and used in BOR revegetation projects. Seedling trees or shrubs may require longer term planning. Seeds should be collected from species within the local area and held for direct planting (some seeds require a period of dormancy before germination), or they should be grown in a greenhouse until they are large enough to plant.

Implementation Considerations: If agencies and municipalities expect to plant native species, they should either have the expertise and facilities to acquire their own native planting material, or, ideally, use another organization such as the SCS Plant Materials Center to help them with collection and use of this material. The Plant Materials Center has assisted agencies in collection and production of poles and seedlings. However, the Center has lacked funding for research and development of the use of native species and local genetic stock for revegetation and restoration

projects. For this reason, materials for use in some projects, especially constructed or created wetlands, have sometimes been acquired from out of the region.

Action: Agencies and municipalities should develop or expand revegetation and restoration guidelines that require the use of native species and local genetic stock to prevent ecological disasters (such as the invasion of salt cedar and Russian olive) caused by introductions of nonnatives and to reestablish (to the degree possible) native riparian plant communities.

Monitoring and Research: Monitoring the success of revegetation or restoration of riparian and wetland sites is critical to developing effective management techniques. All such efforts should be monitored for a long enough time period to evaluate success. Baseline information should be collected for comparison to future data; this baseline should include records about date of planting, source of material, species and numbers of planting, and some quantification of size. Additional data should be collected at regular intervals and used in an assessment of the success or failure of the project. This information should be made available to interested parties.

The SCS Plant Materials Center is a source for cottonwood and willow poles, as well as for shrub seedlings. Funding should be provided to the Plant Materials Center to study the genetic characteristics of cottonwoods and willow in particular and how these characteristics may affect revegetation success.

The Plant Materials Center should also be provided funding and, if necessary, additional personnel, to investigate the suitability of other native species for revegetation, including shrubs, herbaceous forbs and grasses, and wetland plants. Suitable species for restoration and revegetation could be kept on hand, or techniques could be developed for collection and preparation for planting of local material, that would minimize or eliminate the need for using nonlocal and nonnative species.

Agencies and Municipalities with Related Experience:

City of Albuquerque, Open Space Division
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
Soil Conservation Service, Plant Materials Center
Tree New Mexico
New Mexico State Forestry and Resources Conservation Division
New Mexico Parks and Recreation Division

RECOMMENDATION 15: Protect, enhance, and extend (create) wetlands throughout the Middle Rio Grande riparian zone.

Need: Wetlands consist of marshes, wet meadows, drains, and seasonal ponds that typically support water loving plants such as cattails, bulrush, sedges, rushes, saltgrass, pondweed, milfoil, and watercress. Wetlands are an integral component of the bosque ecosystem, not only increasing its diversity but also enhancing the value of surrounding plant communities for wildlife. They provide habitat for a high diversity and abundance of wildlife, many of which are rare and declining. A significant portion of the animal community is dependent on wetlands, including waterfowl, shore- and wading birds, muskrats, beaver, frogs, kingfishers, turtles, and a multitude of aquatic invertebrates. The interface of wetlands with other plant communities provides increased habitat diversity and is reflected in higher animal species and abundance. Wetlands are also a potentially important factor in maintenance and improvement of water quality.

Wetlands are important to many special status (considered rare, threatened, or endangered by state or federal agency) species. In addition to the more common species, special status species will benefit from wetland protection and creation. Protecting, enhancing, and creating wet meadows and marsh habitats and communities would protect meadow jumping mice and tawny-bellied cotton rats, as would maintaining herbaceous vegetation along drains. The creation of additional ponds and/or marshes could potentially benefit both the leopard frog and the painted turtle, as well as other species associated with wet habitats. Planting willows directly adjacent to wetlands would enhance nesting habitat for southwestern willow flycatchers.

Wetlands have experienced the greatest historical decline of any floodplain plant community and are currently limited to relic and human-made or caused wetlands, e.g., Santo Domingo Marsh, North and South Diversion channel outfalls, Oxbow Marsh, Isleta Marsh, Madrone Ponds, Bernardo and La Joya waterfowl areas, and Bosque del Apache NWR (see Table 22 for a more comprehensive list). There are also several small, scattered wetlands throughout the bosque. From 1918 to the present, wetlands (represented by marsh, open water, saltgrass meadow, and alkali) have been reduced from about 21,052 ha (52,000 acres) to about 1,498 ha (3,700 acres)—a 93% reduction. The majority of human-developed or caused wetlands that are currently being managed will likely be perpetuated. However, wetlands such as Santo Domingo and Isleta marshes and Madrone Ponds will continue to mature and progress toward more mesic terrestrial communities.

Among the greatest needs of the riparian ecosystem are the preservation of existing wetlands, management of these wetlands for optimum benefit, and expansion or creation of additional wetlands. These measures would aid in restoring some of the biological values historically lost and in enriching the habitat value of the bosque ecosystem. Also of significant importance in the expansion or creation of wetlands is the need to emphasize local genetic stock and native species.

Description of Recommendation: *Protection of existing wetlands*—The limited area of wetlands places a high value on those remaining. Existing landowners and administrators not presently managing wetlands located on their land need to consider implementing measures to ensure the future preservation of biological values. Existing landowners or administrators currently managing wetlands should continue to emphasize wetland values. Planning studies in areas of

known or potential wetlands need to locate these areas and formulate alternatives that preserve this resource.

Enhancement of existing wetlands—There are several measures that can be taken to enhance the value of unmanaged wetlands. These include management of human use, grazing, water, vegetation, depredation, and sedimentation. Existing riverside drains represent one of the largest wetlands in the middle valley, and inclusion of biological values as an integral part of their management would make an appreciable contribution toward enhancing not only wetland values but also wildlife use of the adjacent bosque. An assessment of current management practices may demonstrate opportunities to benefit wildlife use of this important existing resource. Often, minor changes in existing practices can produce large improvements in wetland values.

Expansion of wetlands—There are numerous opportunities for expanding wetlands and enhancing wetland values in the Middle Rio Grande Valley. While all reaches of the middle valley would benefit from wetland creation, the Belen and Socorro reaches historically had more wetlands, and wetland restoration should be emphasized in these reaches. The use of constructed wetlands has a high potential for accomplishing this recommendation and can be achieved in several ways. These are as follows:

(1) Ground-water wetlands. The presence of a high ground-water table in the riparian zone (and in various areas in the adjacent floodplain) offers the opportunity to create wetlands by excavating into the water table. This proven method does not require water containment, control, or supply facilities; employs simple construction methods and a minimum of construction equipment; can be constructed at a moderate cost or in conjunction with other construction projects requiring borrow; and requires very little maintenance. Wetlands of this type, however, may be affected by restoration of peak flow regime (i.e., by sedimentation). Examples are the COE wetland at Los Lunas and the State of New Mexico's wetland at the Rio Grande Nature Center. This technique can also be used to convert sand and gravel pits located within the riparian zone or adjacent floodplain into productive wetlands. The Albuquerque to San Acacia reach has a relatively high water table that would favor this type of wetland development. However, other reaches also have favorable sites.

(2) Drain return flows. The Oxbow Marsh is an example of wetland development at the discharge point of a riverside drain into the Rio Grande. Excavation of depressions of diverse sizes, configurations, and depths at the discharge points could be achieved easily, at moderate cost, with few if any structural facilities, and with minimal maintenance. Drain discharges should not contain significant amounts of sediment acquired from irrigation water.

(3) Floodplain wetlands (small scale). Similar to excavated riparian wetlands, depressions can be excavated within the floodplain. Examples of these wetland types are at the Rio Grande Nature Center and Bernardo Waterfowl Area. If the minimum water table is not high (above about 2 m [6 ft]), an alternate water supply is required for filling and to compensate for evapotranspiration losses. This alternate water supply can be provided by pumping or by diversion. A waterproof liner (Polyolefin, PVC, Hypalon, Permalon, clay, or bentonite) is required to prevent water loss if the wetland bottom is in porous substrate. The Rio Grande Nature Center uses a liner in their primary wetland and Sandia Lakes uses both liners and

bentonite. Initial investment costs are higher than those of ground-water wetlands, and operation and maintenance costs are also involved.

(4) Floodplain wetlands (large scale). Impoundments can be created by excavation, berms, dikes, or a combination of measures to form large wetlands, such as those at La Joya Waterfowl Area and Bosque del Apache NWR. Water is obtained by diversion or pumping and controlled by gates and weirs. Sandia Lakes utilizes water diverted from the riverside drain. Engineering design and construction can range from simple to complex, and construction and maintenance costs vary according to complexity. This wetland design is quite adaptable for treating wastewater, storm runoff, and irrigation return flow from large and small population centers. This wetland creation measure would generally be on a scale too large to be compatible with riparian segments of limited width. However, this concept could be adapted on a smaller scale to large openings, areas of sparse vegetation, or vegetation with a demonstrated low wildlife use (e.g., salt cedar).

(5) Storm-water conveyance channels. The outfall channels of the AMAFCA's North and South Diversion channels are good examples of how wetlands can develop from trickle flows in unlined, storm-water conveyance channels. These flows can be high in pollutants which can be substantially reduced by wetland plants and microbial action before entering the Rio Grande. However, major runoff events present engineering challenges for treatment and sediment loading. Also, the infrequent nature of precipitation and the discharge of large volumes of water in the span of 1 or 2 hours are major concerns.

Special status species—Protection of wetlands and incorporation of certain design elements into constructed wetlands will benefit the special status species. Following is a brief description of requirements for leopard frogs, southwestern willow flycatchers, and meadow jumping mice:

Leopard frog—to maximize the habitat value of marshes to leopard frogs and painted turtles, Applegarth (1983) recommended the following features be incorporated into wetland design:

- Provide a combination of wet meadow with shallow, clear ponds holding water in April.
- Provide shallow ponds at least 1 km (0.6 mi) away from deeper ponds.
- Ponds should range form 10-100 m (33-328 ft) wide by 100-1,000 m (328-3,281 ft) long—the longer ones should parallel the river to resemble old river channels.
- Excavate depressions for ponds halfway to average annual low water table or excavate in winter to top of winter water table.
- Ponds should not have steep side slopes.
- Ponds should be a variety of shapes, sizes, and depths.

Southwestern willow flycatcher—plant willows directly adjacent to wetlands to provide the overhanging cover required for nesting habitat.

Jumping mouse—intensive human activities, such as construction gravel operations, off-road vehicle use, and grazing, can cause serious damage to sensitive habitats. If located in or near jumping mouse habitat, these activities could alter the area's vegetation, microclimate, and

hydrology; disrupt breeding, nesting, and hibernation activity; and destroy cover vegetation, food sources, and nesting materials.

Dredging permanent ditches and clearing, moving, or burning ditchside willow/grass/forb vegetation could alter or destroy jumping mouse habitat. These activities could remove vegetation, decrease abundance of preferred plant species, and destroy nests.

To avoid or minimize impacts and disturbances from the various agencies' construction or operation and management activities, the following measures should be implemented:

- Prior to initiating any activities, all potential work sites would be evaluated to identify any areas of jumping mouse preferred habitat of permanent marsh, wet meadow, or willow/grass/forb ditchside habitats. Potential habitat would then be evaluated by a qualified biologist to determine the occurrence of the subspecies.

- Selection of sites for projects and associated features such as access roads, dredge spoil disposal, borrow pits, temporary equipment and material storage yards, vegetation control and planting, and other related activities would be made with full consideration to protect potential jumping mouse habitat.

- Major disturbances along both sides of ditches that remove significant amounts of bank vegetation and along large continuous areas of willow/grass/forb ditch habitat should be avoided. Cleaning and dredging activities that steepen ditchbanks should be avoided. Mowing of willow/grass/forb vegetation close to the water along ditches should be scheduled in alternate years. Ditch maintenance activities at sites determined to be in or adjacent to nesting habitat should be deferred until fall or winter, when juveniles are out of the nest and able to move away from maintenance equipment.

- Efforts should be made to regulate flows so that occasional controlled flooding of ditchbanks and meadow areas can occur. Growth of plant species preferred by jumping mice should be enhanced by seeding and periodically cutting back tall willows that shade out grasses and forbs.

If wetland areas are created or restored, wet meadows with vegetation preferred by jumping mice should be a part of the design. Efforts should be made to reintroduce jumping mice into such created wetlands.

Opportunities and Constraints: The protection, extension (creation), and enhancement of wetlands are the most achievable recommendations in this plan. Most of the major wetlands are under some form of governmental control, and if not directly protected and managed for wetland values, the potential to do so is present. Isolated wetlands in private ownership need to be located and owners encouraged to protect and enhance their wetlands. Creation of wetlands is highly achievable, and the technology is available. Creation of wetlands can be accomplished in concert with planned construction measures to rehabilitate the existing levee system in the Albuquerque, Belen, and Socorro reaches. Table 22 and Fig. 33 list some areas with potential for wetland protection, enhancement, and creation. Also, the expansion of agency missions, both

federal and state, to restore the extensive, historic loss of wetlands would provide a positive method for directly focusing on the creation, expansion, and management of wetlands.

Potential constraints are considered to be manageable. As with all recommendations, landownership/administration is a primary consideration. Several wetland creation measures involve diversion of water (including exposing ground water), and acquisition of water rights would be a major consideration. Alteration of land management practices, either in conjunction with enhancing existing wetlands or creating new ones, would have to be addressed by the managing agency or individual(s).

Implementation Considerations: There is little published literature regarding wetland creation and enhancement in western and semiarid landscapes. However, there are several governmental agencies and private entities with knowledge and experience in this subject area. The NMDGF, New Mexico State Parks and Outdoor Recreation, COE, FWS, and the SCS are local governmental agencies with expertise and experience in wetland creation. Some fundamental considerations are as follows:

Preservation of Existing Wetlands: (1) identification, (2) landownership, (3) laws and regulations, (4) partnership, (5) incentives, (6) acquisition, (7) planning objectives, and (8) water supply.

Enhancement of Existing Wetlands: (1) grazing management, (2) open water/emergent vegetation ratio, (3) strategy for management of riverside drains, (4) vegetation management, (5) human-use management, and (6) water supply.

Creation of wetlands—A major design concept to be emphasized in wetland design is the diversification of wetland function and configuration. This diversity will optimize both the diversity of plants and animals. Also, the design should consider target species such as the leopard frog, the painted turtle, the southwestern willow flycatcher, and other wetland species whose numbers have declined as a result of wetland drainage. Although just about any size wetland will have some benefits, wetlands 0.8 ha (2 acres) and larger will achieve the greatest benefits. The concept of "bigger is better" applies to wetlands. Factors that should be considered in the planning and designing of wetlands include the following: (1) goals; (2) landownership/administration and management; (3) site location—relationship to adjacent plant communities, Rio Grande, channel configuration, and floodplain development; (4) site attributes—soils, vegetation, biological values, ground-water depth, and ground-water fluctuation regime; (5) monitoring of ground-water fluctuation for wetland design; (6) design options—optimum shallow/deep water diversity, wet meadow, seasonal flooding/permanent water, open water/emergent vegetation ratio, sideslope ratio and variability, and enhancement of species of concern; (7) public use; (8) access—construction and any public use; (9) preference for native species (same genotype) for planting; and (10) size.

Action: *Creation of wetlands*—Develop site suitability maps based on biological value of plant communities to be displaced, relationship to biological value to adjacent plant communities and floodplain development, soils, ground-water depth, and annual fluctuation, locations that offer maximum protection from flood-flow scouring and sedimentation, and water quality.

Develop a comprehensive plan of wetland development and design that not only emphasizes diversity within each wetland developed, but also diversity among a system of wetlands redeveloped along the entire length of the middle valley.

Pursue wetland development in conjunction with planned levee rehabilitation efforts from the Village of Corrales to San Marcial, in conjunction with storm-water or wastewater treatment plans, and consider sand and gravel needs. This strategy takes advantage of measures that strongly lend themselves to wetland creation with minimal direct costs for wetland features.

Wetland creation as a specific goal should also be pursued, particularly in areas where there are none, where they existed historically, or where there are no foreseeable opportunities for their creation. Monies for their creation should likewise be budgeted for this purpose.

Address possibility of expanding agency missions to include wetland restoration.

Existing wetlands—Existing wetlands should be identified as areas of high biological value as well as areas of high potential for enhancement of these values. Many wetlands are not managed for their intrinsic values, and even small management efforts can be of significant value. Existing wetlands should be evaluated for their existing biological use and for factors that limit their full potential; measures should then be developed to optimize biological values. Human and livestock management, water management, vegetation management, and judicious dredging are measures that can appreciably increase these values. As with creation of wetlands, the possible expansion of agency missions to address wetland management should be pursued.

The MRGCD holds title to a significant amount of the riparian zone, including the drains, and has excavation capability. Because of these features, the MRGCD will play a major role in wetland creation and management.

Monitoring and Research: All actions taken to enhance and create wetlands should be monitored to evaluate the effectiveness of management actions and the development of wetland plant and animal communities, respectively. Wetlands developed for treatment of wastewater should be monitored for effectiveness and possible high levels of various elements and compounds including any bioaccumulation.

Research is needed to develop native stocks of wetland plants that can be used in the creation of wetlands (see Recommendation 14 on native plant species). Currently, there are no developed sources of local or regional wetland plants.

Long-term research into wetland design for optimum development of wetland plant and animal communities should be undertaken by local, state, and federal agencies and regional universities.

Agencies or Entities with Implementation Roles and Related Experience:

Middle Rio Grande Conservancy District
All Municipalities, including Pueblos

U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
New Mexico Department of Game and Fish
Ducks Unlimited
New Mexico Energy, Minerals, and Natural Resources
U.S. Fish and Wildlife Service
Soil Conservation Service
New Mexico Parks and Outdoor Recreation
Hydra, Inc.

RECOMMENDATION 16: Sustain and enhance existing cottonwood communities, and create new native cottonwood communities wherever possible throughout the Middle Rio Grande riparian zone.

Need: Restriction of the river between levees and reduction of scouring flows have reduced the number of sites and opportunities for the establishment of native riparian vegetation, especially cottonwoods. Nonnative species, many of which have reproductive strategies that allow them to reproduce under existing conditions, have become established in the riparian zone and often are the dominant members of plant communities or form a significant part of them. As the native cottonwoods age and die, these nonnatives will become more abundant and may eventually entirely replace native species. In order to protect the geographic extent of the bosque and avoid fragmentation, steps should be taken to preserve the existing cottonwood forest. However, preservation is not enough. There is also a need to sustain existing cottonwood communities and to create new communities where possible. The biological benefits from following this recommendation are not restricted to maintaining plant communities; riparian zones and the native species which compose them support diverse and abundant populations of wildlife, especially in contrast to adjacent upland areas.

Description of Recommendation: Sustaining and enhancing the bosque require providing suitable sites and conditions for germination and establishment and also the presence of adequate ground water to support new and existing stands (see Recommendations 1-3 on maintaining natural hydrograph, fluvial processes, and ground-water levels). Creating new cottonwood communities in appropriate locations will maintain populations of native species in the bosque and prevent those areas from being colonized and dominated by nonnatives.

Opportunities and Constraints: As currently managed, water releases from Cochiti Dam somewhat resemble the natural hydrograph (see Recommendation 1 on the natural hydrograph). Peak flows provide a pulse of water at approximately the same time as conditions prevalent before dams were constructed on the main river stem and its tributaries. This type of flow, presumably, supports to a certain extent existing plant communities (and other riparian organisms) by providing ground-water replenishment at optimum times during the year.

There are also opportunities to manage water in such a way that conditions for germination and establishment could be produced during a specific year. In a year of abundant runoff, water could be stored until cottonwood and willow seed dispersal begins, and then released at maximum capacity. In areas where overbank flooding is possible, and where suitable open spaces are naturally available or created (especially in the Belen and Socorro reaches of the river, below the confluence of the Rio Puerco), new cottonwood communities could become established. Since there are relatively few sites where overbank flooding takes place under the present reservoir management regime, this strategy will probably have limited success, especially in the Cochiti and Albuquerque reaches. However, locations where overbank flooding does not take place, but where damp soils are produced by seepage and rising ground water in open areas, may also be sites for new cottonwood communities. A significant constraint to overbank flooding is the limited channel capacity due to the poor condition of spoilbank levees (except in the Albuquerque Reach).

In addition to the presence of spoilbank levees, there are other constraints preventing establishment of new stands of cottonwoods along the northern reaches of the Rio Grande. There, the river channel is degrading rather than aggrading, or building up. Vegetation has grown along the banks of the river channel in some areas, thus stabilizing the channel and enhancing the tendency for degradation rather than bank erosion and channel shifting. Stabilization and deepening of the channel (the result of natural processes and the implementation of a bank stabilization program) have reduced lateral movement of the river and resulting erosion and scouring effects. Established stands of cottonwoods are not being eroded and removed by flooding but are remaining in place. Consequently, there are few open areas available for younger generations of cottonwood and other native species, even if moisture conditions were made suitable by flooding. It is critical to the future of the bosque that disturbed areas be revegetated with native cottonwoods; it may also be necessary to institute forestry practices (including purposeful clearing of senescent cottonwood stands) to sustain the bosque over a long period of time.

Active land and vegetation management will be required to supplement in some cases, or replace in others, the Rio Grande's hydrologic and fluvial processes that are favorable to the support and creation of cottonwood communities. The human "energy" investment could vary from mechanically preparing a site for natural spring flooding, to artificially applying water to particular sites, or to planting acres of individual cottonwood trees.

Fires in the bosque present both opportunities and constraints. High intensity fire is a major disturbance, resulting in the death of cottonwood trees of all ages. Fires may clear out old trees, but unless something is done after the conflagration, the burned areas will be invaded almost entirely by nonnative species such as salt cedar, Russian olive, mulberry, and Siberian elm.

As with the protection of the bosque recommendation (Recommendation 7), landownership is an important factor in enhancement of existing native species communities and creation of new ones. Land management agencies and private landowners have the potential for managing their lands for the benefit of native plant species. There are state, federal, and private sources with economic assistance for these purposes.

Implementation Considerations: Because of mixed ownership status of bosque lands and lack of certainty of ownership in some cases, defining and clarifying land status in the riparian zone would be useful for planning. Ownership/management of riparian habitats of high quality could be identified, and owners/managers would have the option of protecting and enhancing those areas. Ownership/management of areas of high potential for revegetation could also be identified, and the owners/managers would then have the opportunity to replant with native species.

Personnel at the Bosque del Apache NWR, BOR, COE, the SCS Plant Materials Center, and the City of Albuquerque have experience in establishing cottonwood, willow, and native shrubs. Research on the hydrological regime required for germination of cottonwoods has been conducted by the FWS National Ecology Research Center in Fort Collins, Colorado.

Flooding of particular areas along the bosque, in all reaches, could be accomplished with the construction of headgates to enable the use of irrigation canals to carry water to specific locations,

pumping from the river or ditches, or the use of inflatable dams across the river. This kind of "spot flooding" would produce germination of native species if done at the appropriate time of year and if open substrate is available.

Preparation of a site for receiving seeds and moisture is very important. If the site is occupied by dense vegetation, cottonwood seedings will not be successful. Use of heavy equipment to plow up the soil in advance of flooding should create suitable conditions for germination. This is now being investigated at Bosque del Apache NWR.

Until additional research shows how low intensity fire might be used in management of the bosque, we believe that fire suppression is extremely important to prevent the deaths of large numbers of trees. If a fire does take place, the dead trees should be removed (leaving some snags and dead wood) and regeneration of cottonwoods and other native species should be attempted. Pole planting has been the predominant method used, but methods such as planting seedlings or saplings have been used successfully in other areas (see Appendix V for methods and information sources). Post-fire seeding and flooding may also provide effective reestablishment.

Action: Develop an ownership map of the riparian zone in the Middle Rio Grande Valley so that protection, enhancement, and revegetation can be extended where possible to the bosque by the appropriate entities.

Develop site suitability maps for revegetation based on topography, known ground-water levels, soil characteristics (especially salinity), and other relevant features of the landscape. These maps could then be used as a guide for revegetation plans along the Middle Rio Grande Valley. Until these detailed maps are developed, it may be possible to achieve successful revegetation based on individual assessments of particular areas to establish the appropriate species and revegetation techniques (see Appendix V for additional information on species, techniques, and sources of material).

Revegetation by seed—Recently exposed or deposited sediments that may be suitable for establishment of riparian vegetation by means of flooding are found mostly below the confluences of the Rio Puerco and the Rio Salado with the Rio Grande. Spot flooding to create similar conditions could be used in open areas along the river reaches north of the Rio Puerco. If flooding occurs at the appropriate time (during dispersal of cottonwood seeds), the combination of exposed, bare areas and suitable moisture conditions may produce new stands of cottonwood trees.

Revegetation by pole planting—Areas suitable for revegetation by pole planting include disturbed locations and areas in the river reaches above the confluences of the Rio Puerco and Rio Salado that are not likely to be affected by overbank flooding.

Revegetation by planting rooted saplings—Planting rooted cuttings is an alternative to using pole plantings. Successful projects have included using "deep tillage." Like pole planting, deep tillage requires an auger, which is used to drill holes to the water table. The auger should be of a large diameter (30.5 cm [about 12 inches]) to create a cylinder of loosened soil into which roots

can spread. After planting, the rooted cuttings are irrigated for varying lengths of time, depending on local conditions. (See Appendix V for additional details.)

Areas suitable for revegetation—Figure 28 shows locations of burned areas that could be targeted for surveys and assessment of suitability for revegetation by using any of the above techniques.

Vegetative reproduction-root sprouting—Judging from size-class distributions of cottonwood on several sites along the Middle Rio Grande, root sprouting occurs in the absence of overbank flooding. This form of reproduction could be enhanced by mechanical means although this appears not to have been well studied. Places where cottonwood roots have been impacted by heavy equipment definitely show evidence of root sprouting. This form of revegetation should be considered in the future pending the results of research (see Recommendation 19 on research) especially in parklike areas with native stands and little or no understory and in burned locations.

Agencies and municipalities are encouraged to review operation, development, and management policies that are related to riparian issues especially cottonwood regeneration. Appropriate policies could be revised or new ones developed to protect and enhance riparian habitats. These policies could be coordinated with other agencies and municipalities through a state riparian task force and/or riparian coordinators.

Private citizens (and nonfederal agencies and municipalities) should be made aware of programs such as "Partners for Wildlife" and other cooperative agreements with the FWS that support the preservation and creation of wildlife habitat, including habitats found in the riparian zone. They should also be made aware of conservation easements, acquisition programs, and other options with The Nature Conservancy and the New Mexico Natural Lands Protection Committee all of which could be used to protect, enhance, or create cottonwood communities.

New federal, state, and private programs providing incentives for improving cottonwood habitats should be initiated and developed.

Monitoring and Research: Any revegetation effort in the bosque should be accompanied by monitoring so that an assessment of the success of the project can be made and the resulting information and conclusions applied to future plans. Baseline information on species, numbers, and sizes of plants should be collected. The same information should be collected at regular intervals to determine success of the project.

Research into forestry practices should begin in order to determine effective ways to establish new stands of cottonwoods. This is especially applicable in areas where the bosque is contiguous for long distances and where disturbance is not likely to take place from fluvial processes. These practices may include removal of senescent stands of trees to allow juveniles to become established and removal of extensive stands of nonnative species and replanting with natives.

Studies of controlled burns should begin to see if low temperature fires could be used to prevent build-up of a substantial fuel load and to control the understory in order to protect

existing cottonwood stands from high intensity fires. Dead wood removal and flooding (see Recommendations 2, 3, and 11) may help maintain appropriate amounts of dead wood.

Research on methods of revegetation by pole planting, rooted cuttings, and seeds should be continued, including planting season, plant size, relationship of origin of poles, cuttings, and seeds to successful establishment, soil characteristics (especially salinity), and other relevant topics. Existing information on many of these topics may not have been documented; and in some cases, additional work is needed to verify or quantify perceived trends. This research should be linked to that discussed in Recommendation 14 on using native plant species and local genetic stock in revegetation. Studies should investigate the potential for generating significant numbers of new cottonwood trees in existing cottonwood forest from root sprouting. Research should also examine salinity tolerance of native and introduced species.

Agencies and Municipalities with Existing Plans for Revegetation:

City of Albuquerque, Open Space Division
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers

Agencies and Groups with Funds or Resources Available for Habitat Improvement:

New Mexico Natural Lands Protection Committee
U.S. Fish and Wildlife Service, Private Lands Coordinator
New Mexico State Forestry and Resources Conservation Division
Tree New Mexico
Soil Conservation Service, Plant Materials Center

RECOMMENDATION 17: Contain the expansion of existing large stands of nonnative vegetation in the Middle Rio Grande riparian zone. At the same time, study the ecology of these stands and develop creative ways of maximizing their biological values.

Need: If the decline of cottonwood forests along the Middle Rio Grande continues, Russian olive will become the dominant tree in the north and salt cedar will increase its dominant position in the south. Both trees, salt cedar in particular, form large, homogeneous stands with relatively low-diversity undergrowth (however, the numbers and kinds of animals that inhabit these stands can be impressive).

Large cottonwood stands cannot easily be maintained if correspondingly large stands of nonnative trees close to them are not brought under control. So far, such control has proven especially difficult with salt cedar, but the effort needs to be continued. Russian olive and salt cedar stands are here to stay, and therefore must be regarded as integral parts of the bosque. As such, they can be used to enhance the bosque's biological diversity. Clearly, there is a need to study these relatively new ecosystems and to experiment with ways of managing them.

Description of Recommendation: Containment of the spread of large stands of nonnative trees is possible using combinations of bulldozing and root ripping, at least in the case of salt cedar. This has proved successful at Bosque del Apache NWR, where herbicides have also been used. Since the side effects of herbicides are not always apparent, we hesitate to recommend them. Containment of Russian olive stands may seem less of a problem now, but the species spreads rapidly and does well in the absence of shade. Even in the semishade of a cottonwood forest, Russian olive contributes a significant understory. Both species seem to survive burning better than cottonwood; therefore, that form of control should be used with extreme care, if at all.

Because eradication is unrealistic, and because both trees have much to offer wildlife (see earlier discussions), it is sensible to manage them for the enhanced diversity of consumer organisms. This can be done in several ways. One way is to break up large stands mechanically, creating increased forest edges in the process. If cleared areas are near the river and subject to flooding, the clearings could, with correctly timed flood drawdown, be converted to cottonwood/willow stands. This is now being attempted at Bosque del Apache NWR.

Another way of managing these stands for diversity is to create wetlands, cottonwood stands, and open spaces (grasslands, shrublands) inside them. Again, these procedures are best done mechanically. Discussion elsewhere in this document considers wetland establishment in landscapes dominated by native and nonnative forests.

Opportunities and Constraints: Now is the best time to prevent further intrusion of cottonwood forests by expanding stands of nonnative trees. As the years go by the opportunity to contain the intrusion will diminish, especially if cottonwood reestablishment is not vigorously promoted.

Likewise, the existence of large homogeneous stands of nonnative trees now presents an excellent opportunity to experiment with creation of habitat and species diversity within those stands. Establishing "islands" and "corridors" of wetlands, cottonwood forests, and open areas within these often great expanses of exotic vegetation, tends to help keep them under control.

Implementation Considerations: Although implementation of this recommendation applies to stands of both Russian olive and salt cedar, the latter are more extensive and uniform. For the time being, therefore, enhancing the diversity of vegetation would be most practical in areas dominated by salt cedar. Lessons learned could then possibly be applied in Russian olive stands, which now are located mainly between the riverbank and interior forest with good cottonwood representation.

As implied above, use of heavy equipment is the key to diversifying vegetation and creating habitats. Since operation of earth moving machinery is expensive, initial efforts at implementing this recommendation would best be accomplished on public lands, such as those in the Socorro Reach, and by large agencies such as the FWS, BOR, and MRGCD. An example of collaboration between the first two of these is seen at Bosque del Apache NWR, where acre-size plots along the Rio Grande were removed in the spring of 1993 in an attempt to establish cottonwood after overbank flooding. Following that example, cottonwood germination could be promoted by extensive mechanical removal of salt cedar on both banks of the river (levees exist only on the west bank in that area) shortly before expected overbank flooding in late spring.

Wide fire breaks in large salt cedar stands at Bosque del Apache NWR are created with heavy earth moving equipment. When maintained, these are good examples of salt cedar containment. During the growing season, they are rapidly colonized by Russian thistle and summer cypress which are annuals and can be easily plowed under. Similar newly bared expanses could be planted with grasses and native shrubs (information available from the SCS Plant Materials Center) to create open spaces throughout the salt cedar forests.

Such open spaces could also be used to create wetlands, perhaps fringed with cottonwood planted on shallow banks as poles or cuttings, or separate stands of cottonwood. Excavation to the water table (2-4 m [6-13 ft] deep) in the old riverbed should be considered. Emergent vegetation should be planted soon after to improve habitat diversity.

Action: Maps charting the expansion of major nonnative trees along the Middle Rio Grande are available in this document and from the FWS National Ecology Research Center in Fort Collins, Colorado. These maps should be examined for information leading to decisions about where to perform the above-mentioned manipulations. They show, for example, the location of large tracts occupied by salt cedar.

Activities such as those being undertaken at the Bosque del Apache NWR should be continued and expanded. Other public agencies should inventory their land; and where large expanses of salt cedar are present, they should seek funding and implement vegetation diversity programs.

Monitoring and Research: Any actions under this recommendation should include monitoring over a length of time sufficient to determine the success or failure of the projects. The effects of mature salt cedar stands on surficial soil chemistry (with a focus on salts and boron), which may inhibit or prevent germination and establishment of native species, should be investigated.

Agencies and Other Organizations with Related Experience:

U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service, Bosque del Apache National Wildlife Refuge
U.S. Army Corps of Engineers
U.S. Fish and Wildlife Service, National Ecology Research Center
Hydra, Inc.

RECOMMENDATION 18: Develop a coordinated program to monitor biological quality (with emphasis on the diversity and abundance of native species) and ecosystem integrity (with emphasis on restoring the functional connection between the river and riparian zone) of the Middle Rio Grande ecosystem.

Need: Insufficient long-term data exist for managers of the ecosystem to develop the kind of comprehensive management strategy described in the introduction to this section. Systematic, coordinated monitoring of key ecological variables and indicators of ecosystem integrity along the Middle Rio Grande is needed to provide this kind of information. Monitoring will be useful for testing assumptions, improving predictions, and identifying cause and effect relationships. All of these are important to ecosystem management. The program should minimize interagency overlap and maximize information return to a central, management-related data base.

Description of Recommendation: As discussed in the next section of this document, a broad-based interagency management unit consisting of a central coordinator and agency coordinators should first be created as a framework for storage and exchange of monitored data and other relevant information. The central coordinator should call for a series of meetings in which all interested and involved organizations (federal, state, municipal, pueblo, private) would address development of a comprehensive, long-term monitoring program for the Middle Rio Grande. This would be done in conjunction with development of a long-term research program (see Recommendation 19) because both functions have close ties. We recommend that the monitoring program focus on critical aspects of riverine hydrology and morphology, aquatic ecology, and terrestrial ecology.

It is true that certain of these critical features are presently monitored by a number of organizations, which are generally willing to release their data. However, such monitoring tends to be mission-specific (directed, for example, at flood control or bird migration) and not driven by a need to consider the health of the entire ecosystem. It can also involve several organizations monitoring the same thing (e.g., ground water). Therefore, we propose that special emphasis be placed on the coordinated monitoring of factors that affect the broad question of biological quality and integrity of the Middle Rio Grande ecosystem.

Specifically, we propose that the following be monitored in a standardized manner at designated points along the reach: (1) changes in the morphology of the river; (2) transport of particulates and dissolved compounds that influence the viability of aquatic and riparian communities; (3) changes in ground- and surface-water levels, soil moisture, and soil salinity and their relationship to river flows; (4) cycling of nutrients in riparian communities; (5) changes in structure and composition of plant and animal communities in the bosque, the river, and wetlands; (6) recruitment and establishment of cottonwoods and willows; (7) changes in distribution and abundance of populations of plants and animals highly sensitive to disturbance; (8) changes in the rate of incursion and population growth of introduced species; (9) changes in seasonal and annual meteorological conditions in diverse forest habitats; (10) frequency and effects of fires; (11) intensity and effects of livestock grazing; and (12) extent and effects of recreational use.

Monitoring of these factors will help analyze the effects of regularly occurring events such as seasonal changes in plant and animal communities, disturbance events such as wildfires, and

management practices such as cottonwood reintroduction. Baseline monitoring should be started as soon as possible where disturbance and management effects are likely to occur.

Opportunities and Constraints: Managing an ecosystem as complex as the Middle Rio Grande requires (1) an appreciation of its ecology, (2) an ability to monitor ecological functions as they relate to management goals, and (3) a mechanism to coordinate such monitoring among managing agencies. The first of these is widespread, although it needs to be nurtured. The second can be found in agencies that manage aspects of the Middle Rio Grande ecosystem; however, development of skills and techniques relative to the monitoring of nutrient fluxes could be improved. It is the coordination of monitoring that needs the most emphasis. Ecological monitoring along the Middle Rio Grande currently lacks the level of coordination needed for a comprehensive management strategy. Additional coordination would reduce monitoring redundancy, allow all parties to monitor with full knowledge of current and past information, and contribute to a long-term data base available for ecosystem management.

Implementation Considerations: Development and implementation of a centralized monitoring clearinghouse and planning function will require the cooperation and good will of the various agencies that presently manage the Middle Rio Grande's resources. It will also require funding to create a computerized network for information transfer and storage. Coordination costs to the agencies concerned will probably be minimal if they assign existing employees as agency coordinators. The main expense is expected to fall on the central coordinator, who may need to subcontract some or all coordination and information storage functions to another source.

The monitoring program will serve the ecosystem's managers. Its authority will be credible only if it has the continued support of the associated federal agencies and strong backing of the pueblos and state government, the state's congressional delegation, and the agencies that now manage the Middle Rio Grande.

Action: The recommended monitoring program should address the following questions: Which agencies or other organizations should do what monitoring? When and where should that monitoring occur? How should monitored data be coded, transmitted to the central coordinator, and ultimately made available to managers and other users? Ideally, many of the critical factors listed above should be monitored at each of the four distinct reaches identified in this document.

Agencies or Entities with Potential for Involvement in Monitoring:

All those agencies and entities listed in Appendix IV with appropriate biological or hydrological expertise.

RECOMMENDATION 19: Develop a coordinated research program to study the ecological processes and biotic communities that characterize the Middle Rio Grande riparian ecosystem.

Need: It is difficult to predict the effects of management on an ecosystem without having a thorough understanding of the processes that drive it and the biotic communities that inhabit it. When early resource managers in the Middle Rio Grande riparian ecosystem began to practice large-scale water management, they could not foresee that their operations would lead to the conditions that produced the need for this biological management plan.

Even today, because our understanding of how the Rio Grande functions as an ecosystem is far from complete, we are unsure of the long-term consequences of current management practices. For example, while the effect of flooding on cottonwood regeneration seems obvious and is often taken for granted, how flooding actually influences nutrient cycling and the lives of many key organisms in the aging cottonwood bosque is largely unexplored. Yet until these basic features are illuminated through carefully planned research, the consequences of implementing many of our present recommendations will remain unclear.

Many agencies and groups are now conducting research in the Middle Rio Grande riparian ecosystem and larger watersheds. Although there is admirable coordination among many of these activities, it is not comprehensive. As with the ongoing monitoring programs, rarely are ecosystem-level issues being addressed although they could be incorporated into the ongoing research.

Description of Recommendation: We recommend establishment of a long-term, integrated program of ecological research that will interact, where possible, with independent research activities along the Middle Rio Grande. As with the monitoring program (see Recommendation 18), this effort should also minimize interagency overlap and maximize information return to a central, management-related data base. In addition, the research program should interact with other national and international programs that study the ecology of large floodplain river systems.

It is important that all researchers involved be aware of what others are investigating in order to avoid unnecessary duplication of effort. Therefore, a series of meetings, not unlike those suggested for the monitoring program, should be an effective way to organize a comprehensive research program. Ongoing and completed studies (referenced and discussed earlier in this document) could provide a partial basis for the ultimate design of the program.

Whenever feasible there should be a close association of the research program with the recommended monitoring program. Likewise, as with the monitoring, the research should focus on critical aspects of and connections among hydrology, aquatic ecology, and terrestrial ecology. Strong emphasis should be placed on the relationship of hydrological regimes and fluvial dynamics to community-level regeneration and successional trajectories. Another strong emphasis should be placed on the dynamics of ground-water/surface-water interactions, which are clearly related to nutrient cycling and therefore to the productivity and diversity of riparian communities. An important related goal should be to understand—and possibly model—the relationship of Rio Grande flow regimes to water levels and water quality in wetlands, irrigation channels, and ground-water drains.

Terrestrial research should emphasize relationships among nutrient cycling (which is a fundamental process driven by hydrology and climate), primary and secondary production, and community dynamics. Although these interactions are broad and complex, a balanced program could examine specific, management-directed questions including the following: (1) Can a study of the genetics of dominant native and nonnative plants be used to create more salinity-tolerant cottonwood forests? (2) What are the effects of bosque fragmentation on key populations and communities? (3) What kinds of bosque habitats lead to optimal wildlife diversity?

The impacts of various forms of disturbance are also in need of study. Examples of pertinent questions here are: (1) How do native and nonnative organisms respond to air and water pollution? (2) Do bridges across the Rio Grande have demonstrable effects on dispersal of small mammals? (3) Can burning, even though it usually kills cottonwood, be used as a management tool?

We know little, at present, about conditions that lead to the establishment and maintenance of adjacent, but very different, communities in the bosque. Knowledge of these conditions will help us understand and predict the success of created wetlands and artificially established native vegetation within stands of introduced vegetation.

Some aspects of aquatic ecology research (e.g., fish population dynamics in the river) are ongoing. However, the causes of fish population changes are imperfectly understood. Aquatic invertebrates (potential fish food, among other things) are often highly responsive to changes in water quality and could tell us a great deal about pollution effects. Yet, the diversity of such organisms, to say nothing of the diversity of floating and emergent plant life in the region's aquatic systems, remains poorly known.

Opportunities and Constraints: The opportunities for useful research in the Middle Rio Grande riparian ecosystem are endless. For one thing, the natural history of most organisms inhabiting the zone is a virtual blank. Natural history is not cutting-edge science and does not command big budgets. Nevertheless, its study yields information that managers need in order to understand how the pieces of an ecological puzzle fit together. Natural history can be studied by amateurs, as well as by professionals. Organizations such as the Rio Grande Nature Center, the New Mexico Museum of Natural History, the Albuquerque Public School system, and the UNM Continuing Education program could promote natural history studies. Perhaps the New Mexico Riparian Council or the Museum of Natural History could be used as a clearinghouse for the results of these studies.

Major, somewhat interrelated, constraints to setting up a coordinated program of research include inertia and lack of funds. Inertia may involve a reluctance to depart from traditional research practices in which an organization (university department, federal or state agency) considers itself the recognized authority. The concept of "turf" plays a role here. However, interagency cooperation will be indispensable if any kind of coordinated program is to become a reality.

Environmentally related research funds are not easy to obtain at any level. But this constraint could be surmounted to some extent by organizing the research program in such a way

that those agencies already active in special fields (e.g., pollution control, fish population biology) would continue to concentrate in those fields. Thus, a premium would be put on efficiency and lack of overlap. Much valuable research in outdoor environments can be done at little expense.

Agency scientists have their own internal sources of funding; however, such resources may not at first be sufficient to support the coordinated program we envision. Scientists who wish to contribute independently to riverine and riparian research, and who require funding to conduct their studies, will have to apply for grants and contracts from a variety of sponsoring organizations ranging from the National Science Foundation to the New Mexico Water Resources Institute.

Implementation Considerations: Implementation of a coordinated research program that interacts with more independent research studies and utilizes natural history information generated by amateurs and professionals should be promoted by the newly created coordinating council. It will be up to the council's membership to set the agenda. We recommend that this biological management plan be carefully read prior to setting the research agenda.

Action: The same interactive coordinating structure recommended to handle monitoring should decide on research priorities, and it could suggest research assignments for organizations wishing to be involved in the coordinated program. The assignments could be based in part on monitoring data and ongoing research. As with monitoring, similar questions should be asked, and similar approaches taken where possible, for all four of the Middle Rio Grande reaches delineated in this document. At the same time, because management needs vary along the Middle Rio Grande, the program will have to allow for a certain amount of flexibility.

Academic institutions have an important potential role to play in Middle Rio Grande ecosystem research as do management agencies and private organizations. These groups should consider interacting at the national level with the newly formed Sustainable Biosphere Initiative, which has taken a particular interest in environmental management of the entire Rio Grande Basin.

Communication among researchers will be critical to success of the program. They should be strongly encouraged to publish research results in the open literature, whether or not these results are also submitted as agency reports. Finally, researchers should be encouraged to participate in local, regional, national, and international conferences, and to confer with other scientists studying large floodplain river systems.

Agencies with Potential for Involvement in Research:

All Indian Pueblo Council
University of New Mexico
New Mexico State University
U.S. Fish and Wildlife Service
U.S. Geological Survey
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation

New Mexico Department of Game and Fish
New Mexico Forestry and Resources Conservation Division
New Mexico Museum of Natural History
All others with appropriate biological or hydrological expertise

RECOMMENDATION 20: Regularly review and update the Middle Rio Grande Ecosystem: Bosque Biological Management Plan.

Need: This biological management plan requires regular review and update if it is to realize its potential for influencing management decisions that affect the Middle Rio Grande riparian ecosystem. More and more Middle Rio Grande management entities are consulting with one another, sharing resources, and addressing biological considerations when planning and implementing programs. The community of "cooperators" needs to be expanded, and the consistency of cooperation needs to be enhanced in order to achieve integrated ecosystem management. This plan can provide the focal point to reach the next level of cooperation and implementation of the plan. In addition, there is a need for a central repository of information applicable to the Middle Rio Grande riparian ecosystem. As it is now, data, analyses, and reports are generally retained by the agencies that generated them. Distribution is fragmented and incomplete.

Description of Recommendation: We recommend formation of a Middle Rio Grande Coordinating Council. It should be composed of a Middle Rio Grande Bosque Coordinator, riverine and riparian managers, and other interested parties. The Middle Rio Grande Bosque Coordinator should set up a clearinghouse for management-related information and arrange for meetings of the Council.

Primary duties of the Council would be to review and update the biological management plan and to make recommendations for monitoring and research in the Middle Rio Grande. The Council would also serve to provide opportunities for managers to discuss implementation of the plan and to develop cooperative agreements for broad-based management actions.

Opportunities and Constraints: There is a strong public interest at this time in the Rio Grande bosque and its future. Management agencies such as the BOR, COE, and FWS have taken an active interest in cooperative management. The formation of the Coordinating Council will make this cooperation more formal and bring other management entities into the process.

Implementation Considerations: The Middle Rio Grande Bosque Coordinator, with appropriate interagency and public participation, should prepare an annual progress and status report to be distributed to all interested agencies, entities, and persons. The annual report should include, at a minimum, summaries of recent management, monitoring, and research activities, and progress made on accomplishing specific recommendations. In addition, the present plan should be revised and updated every 5 years, the first update to be completed in 1998. The update should include the incorporation of new information and the review of (and modifications to, if determined appropriate) all recommendations. The Middle Rio Grande Coordinating Council should determine who should update the plan and should identify the source of funding.

Action: The FWS (or some other agency with substantial funding and support) should take the lead by selecting a Middle Rio Grande Bosque Coordinator and convening a conference of potential coordinating council members. The current biological management plan will provide a focus for the first conference, where the participants could address implementation of the plan

and the mechanism for updating it. (Additional details for this recommendation are to be found in the next section of this document.)

Agencies with Potential Contributions to the Middle Rio Grande Ecosystem:

All agencies and entities listed in Appendix IV.

RECOMMENDATION 21: Integrate resource management activities along the Rio Grande and within the contributing watersheds to protect and enhance biological quality and ecosystem integrity.

Need: The Rio Grande through the middle valley is influenced by all the events and activities that occur upstream and upslope in its drainage area. The Rio Grande is the spout and the watersheds are the funnel. The amount of snowfall in the San Juan or Sangre de Cristo mountains largely determines the amount of water that will be in the system. Urbanization in the Albuquerque metropolitan area affects ground-water quantity and quality, runoff patterns and discharge points, and surface-water quantity and quality. Past mining activities in the Rio San Jose drainage (tributary to the Rio Puerco) affect water quality, and land management in the Rio Puerco watershed impacts sediment deposition in the Rio Grande. The total drainage area for the Rio Grande above San Marcial is 64,150 km^2 (24,760 mi^2); the direct tributary drainage area for the Middle Rio Grande is about 33,160 km^2 (12,800 $mi)^2$. The Rio Puerco alone constitutes 15,180 km^2 (5,860 mi^2). The 71,939 ha (177,689 acres) of bosque are indirectly or directly affected by the entire area.

Description of Recommendation: Ultimately, integrated management of all of the watersheds that collectively make up the Rio Grande drainage is required to manage the bosque. All studies and resultant actions to improve conditions upstream on the Rio Grande and in the tributaries and their watersheds should be actively supported by bosque management interests. In addition, activities in the watersheds should be monitored for their potential impacts to the bosque. Bosque interests need to be represented in the decision-making process for those which are considered to be of particular importance. Likewise, where bosque managers identify watershed conditions to be deleterious to the biological well-being of the bosque, they need to promote appropriate studies or actions to reduce or eliminate the problems.

In addition, bosque managers have responsibilities to those resource managers and users downstream from them, whether in the middle valley, or in Las Cruces, New Mexico, or in Texas or México. We must also consider what our management actions may have on them, and solicit their inputs to our proposed actions.

Opportunities and Constraints: New forums are not necessarily required for integrated management of the drainage. Numerous formal/informal groups and comprehensive study efforts already exist. These include, but are not limited to:

- U.S. Geological Survey's National Water Quality Assessment
- All-Indian Pueblo Council
- New Mexico Water Resource Research Institute's annual water resource management conferences
- Rio Grande Consortium
- Rio Grande Joint Initiatives sponsored by the COE, BOR, and FWS
- Rio Puerco Watershed Work Group led by BLM
- Albuquerque Basin ground-water research cooperators coordinated by the City of Albuquerque
- Sustainable Biosphere Initiative

Participation in these groups by Middle Rio Grande bosque managers and researchers is of paramount importance to maximize communication to effect beneficial changes throughout the watershed.

Implementation Considerations: The challenge, obviously, is the breadth of the physical and human landscape. There are innumerable private, Native American, and governmental forces at work throughout the 64,000 km^2 of watersheds. There is no easy answer on how to coordinate interests and activities. Constant communication is the key, and bosque managers need to invest the necessary resources.

Agencies Active in Rio Grande Basin Watershed-oriented Management, Research, and Monitoring:

U.S. Soil Conservation Service
U.S. Bureau of Land Management
U.S. Forest Service
U.S. Bureau of Indian Affairs
U.S. Geological Survey
New Mexico Bureau of Mines and Mineral Resources
U.S. Bureau of Reclamation
U.S. Army Corps of Engineers
U.S. Fish and Wildlife Service
All Indian Pueblo Council
Sustainable Biosphere Initiative