

Restoration and Monitoring in the Middle Rio Grande Bosque: Current Status of Flood Pulse Related Efforts

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Abstract—Extensive regulation of the Middle Rio Grande's natural flow regime, together with the effects of introduced tree species, landscape fragmentation, and increasing wildfires, are obstacles for any level of restoration of its native riparian forest (bosque). However, carefully monitored partial restoration is possible and greatly needed to prevent the bosque's serious decline. Monitoring can reveal temporal and spatial changes in the bosque's ecological dynamics. The Bosque Ecosystem Monitoring Program, which currently uses volunteers to synchronously record changes in biological populations and ecological processes at four sites in the middle valley, shows how this can be done. Partial restoration depends on well timed releases following heavy spring runoff. When these exceed bankfull stage, overbank flooding will (1) establish new cottonwood-willow stands at suitable locations and (2) enhance ecological maintenance of mature stands. Partial restoration can potentially involve alternative, non mutually exclusive manipulations of the river's hydrology within a given reach. A different approach, currently exemplified by the Albuquerque Overbank Project, involves lowering a bank so that natural flooding can establish new native vegetation. These conceptual and empirical efforts can build a foundation for bosque managers to assess where modified native bosque can persist, and can be the beginning of a comprehensive program to manage the riparian forest on a sustainable basis.

Regulation of the Rio Grande's flow regime in the 20th century has drastically altered the ecological dynamics of its riparian zone (Crawford and others 1993, 1996a). Historically, the river's channel shifted laterally across a generally wide floodplain (Biella and Chapman 1977, Gile and others 1981). Following wet winters, snowmelt in mountain watersheds would have produced overbank flooding downstream, which would have enabled seeds of native cottonwood, *Populus deltoides* ssp. *wislizenii*, and willow, *Salix* spp., to

germinate on newly deposited point bars and freshly scoured banks. Flooding, as inferred from Ellis and others (1998, Molles and others 1998) would also have enhanced decomposition and mineralization of wood and leaf litter on the forest floor, making nutrients available for uptake by already established bosque vegetation (Ellis and others 1998). Thus the basin's hydrology, conditioned by climate (Molles and others 1992), would have brought about a changing mosaic of bosque stands in varying states of development throughout the Holocene (Crawford and others 1996a).

The present landscape of the basin is very different, even along the so-called Middle Rio Grande between Cochiti Dam and Elephant Butte Reservoir, where one of the most extensive native riparian forests in the southwestern United States still exists (Howe and Knopf 1991). There, as elsewhere along the Rio Grande, the flow regime no longer exhibits flood pulses of historic proportions. The last great pulse resulted in the devastating spring flood of 1941, which may have been responsible for most of the bosque's remaining cottonwoods.

Currently, controlled releases, especially in the downcut reach between Cochiti and Bernalillo, seldom exceed bankfull stage and therefore seldom produce conditions conducive to bosque establishment or maintenance. Meanwhile, the nearly continuous strip of native and introduced trees along the entire middle reach reflects the fact that the river is now stabilized in space by reservoirs, levees, jetty jacks, diversion dams, irrigation systems, roads, and bridges. Thus in historical terms the Middle Rio Grande is a new river with a new bosque. Its flows are about half of what they were six decades ago (Crawford and others 1993) and much of its bosque is hydrologically "disconnected" from the river (Molles and others 1998). As a result, the native bosque is in a state of decline (Howe and Knopf 1991) and has been called an endangered ecosystem (Crawford and others 1996a). How to halt that decline and bring about some degree of partial (functional) restoration is the problem we now address.

Monitoring

There is now widespread recognition of the importance of environmental monitoring (Bricker and Ruggiero 1998). Riparian monitoring is receiving increasing attention (National Research Council 1992) and is emphasized in recommendations of the Middle Rio Grande Ecosystem: Bosque Biological Management Plan (Crawford and others 1993).

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Several agencies, for example the Bureau of Reclamation, have for years monitored shallow groundwater, streamflow rates, and other factors relevant to bosque functioning in the Middle Rio Grande valley.

In contrast, monitoring of a suite of ecosystem variables that both impact and reflect bosque functioning has begun only recently, but has already demonstrated the value of long-term data to support restoration efforts. Monitoring the local bosque's ecology began a decade ago with "Bosque Biology," a University of New Mexico course in which students periodically sample certain elements such as litterfall or arthropod activity. Data collected over the years have proven to be effective indicators of the deteriorating condition of the riparian forest in central Albuquerque (Molles and others 1998). In 1991, lessons learned and ideas developed in the course were applied to a 6-year study (supported through the Fish and Wildlife Service by the Bosque Initiative, in addition to National Science Foundation funds, and performed mainly at the Bosque del Apache National Wildlife Refuge) of the effects of flooding on the bosque's ecology. During that project, the results of year-round monitoring of key biological populations and ecological processes revealed much about the expected magnitude and timing of ecosystem reorganization accompanying experimental flooding (Molles and others 1998). Such insight would not have been possible without adherence to a rigid monitoring protocol.

The Bosque Ecosystem Monitoring Program

Since 1996, the Bosque Ecosystem Monitoring Program, in which biologists at The University of New Mexico and educators from Bosque Prep School work together closely, has incorporated procedures from both of the above studies. Supported initially by the National Science Foundation and now by the Bosque Initiative and Bosque Prep School, the program presently focuses on synchronous monitoring of four identically designed but structurally different sites between northern Albuquerque and Belen. Two of the sites undergo partial flooding in years of high spring flows while the other two, both in Albuquerque, have not been flooded for decades. Data are collected by volunteers (these include students and their teachers at Bosque Prep and in other Albuquerque, Los Lunas and Belen secondary schools, as well as older citizens). Following analysis in The University of New Mexico's Biology Department, the data will become available to bosque managers. Meanwhile, all participants are encouraged to inform their communities of their bosque activities.

Restoration

Preventing the irreversible decline of the Middle Rio Grande bosque is central to the goal of the Middle Rio Grande Ecosystem: Bosque Biological Management Plan. It is also an avowed objective of a variety of federal and state agencies, and of environmental organizations concerned with the condition of the basin's environment. Yet while a number of the plan's management recommendations are being implemented and certain habits are being protected, little is being done to return degraded parts of the bosque to

a state approximating past structure and function. To some extent this is because agencies charged with managing the riverine/riparian ecosystem do not have mandates that contend with ecosystem-level problems. Also, there appears to be no stated consensus among managing agencies as to what "bosque restoration" actually means. Finally, the bosque's relationship with the river brings up the issue of interfering with flow regulation and perhaps water rights, complex matters that are troubling to many.

Still, these difficulties are not insurmountable. Having studied the bosque for many years, we feel that "restoration" is feasible if applied in the context of its limitations. In our view, returning the bosque to some designated historical state makes little sense. Too much change has occurred to the system for that to be a realistic option. We prefer the more flexible concept of "partial restoration" (Crawford and others 1996b), which advocates seasonal soil wetting at carefully selected riparian locations in order to bring about establishment and/or maintenance of native woody vegetation. Such a practice would promote decomposition, mineralization, and nutrient cycling (Ellis and others 1998, Molles and others 1998), thereby reducing the fuel load of accumulated litter (Stuever and others 1997). We contend that a combination of methods, such as simulated flooding, manipulation of flow regime, and alteration of bank structure can be used to this end.

Partial Restoration: Potential Obstacles and Solutions

Flood Pulse Disruption

Because the Middle Rio Grande's late spring flood pulse is more predictable but less extreme than it was before regulation, the opportunity for water to flood overbank is consistently low to the north and high to the south, except during drought years when it is low all over. Assuming continued growth in the basin and concomitant increases in human consumption of Rio Grande water, it is likely that overbank inundation will decline progressively south of Albuquerque. In that case we anticipate two broad solutions to the problem of native bosque establishment and maintenance. One is to mechanically lower the river bank in select places, while the other is to create more sites (mainly point bars) for seedling establishment by increasing the frequency of river meanders and/or braids. Both would effectively return the flood pulse to limited stretches along the river. Examples of both approaches are discussed below.

Exotic Trees

Saltcedar, *Tamarix ramosissima*, is rampant to the south and Russian olive, *Eleagnus angustifolia*, tends to dominate in the north of the Middle Rio Grande riparian forest. In Corrales and other places, Siberian elm, *Ulmus pumila*, is strongly represented in the understory and will likely become the main overstory tree as the old cottonwoods die off in the next century. While these and other exotic trees are difficult to control and have become, for practical purposes, fixtures in the bosque landscape, a degree of containment of these trees is possible, as pointed out in Recommendation

No. 17 of the Bosque Biological Management Plan. Mechanical means (for example bulldozing followed by root plowing) are suggested, and herbicides may be needed as well. As the recommendation points out, if cleared areas are near the river and subject to flooding, they can be converted to new stands of native trees. Recent research by Sher (1998) provides evidence that seedlings of the native cottonwood are competitively superior to those of saltcedar whenever abiotic conditions allow establishment.

Landscape Fragmentation

Recommendation No. 7 of the Bosque Biological Management Plan addresses the problem of bosque fragmentation by multiple forces. Partial restoration of highly fragmented areas some distance from the river but still between the levees may be possible, depending on the kind of disturbance. Further clearing and mechanical lowering of the disturbed site, when combined with soil wetting (using runoff water or other sources) in late spring could be used to recruit native tree seedlings. Pole planting has been successful for small scale restoration and could be useful in many fragmented sites as a supplement to, rather than a replacement for natural cottonwood regeneration.

Bosque Wildfires

Unmanaged bosque wildfires, caused mainly by humans, are on the increase (Stuever and others 1997). Depending on their intensity, they can seriously restrict or inhibit cottonwood regrowth while promoting stump sprouting of exotic trees. For a short time following a fire in late spring, it may be possible to thoroughly wet the soil column by various means (for example flooding from the river or pumped groundwater) to allow pole planting and/or natural cottonwood-willow seedling startup to restore native bosque. Shade provided by mature cottonwoods can greatly reduce saltcedar development (Everitt 1995 and many personal observations), but shade tolerant Russian olive is not so easily constrained.

Beavers and Defoliating Insects

Beavers, *Castor canadensis*, were largely eliminated from the valley in the 19th century, were restocked in the mid-1900s (Crawford and others 1993) and are now common along the Middle Rio Grande, where they live in holes in the bank. Beavers depredate all age classes of cottonwoods (Campbell 1990), but young trees seem especially vulnerable when present. New cottonwoods established by overbank flooding may have to be screened with chicken wire where beavers are active. Alternately, local populations may have to be trapped out and re-located.

Several species of insects account for substantial defoliation of cottonwoods in the bosque (Yong and Crawford 1997, also ongoing research by K. Eichhorst). In particular, the cottonwood leaf beetle, *Chrysomela stricta*, can affect over 60 percent of the leaves produced in the vicinity of Albuquerque, but far less at sites studied to the south. Reasons for this are under current study. Leaf consumption occurs mainly in late spring and early summer, which means that new leaves

form the beetle's diet. Defoliation of seedlings and young trees could be a setback for partial restoration in areas where beetle populations are high.

Partial Restoration: Current Approaches

Hydrologic Manipulation: Alternatives Based on Geomorphology

While there may be fairly broad support for improving the bosque's riverine and terrestrial habitats by "mimicking typical natural hydrographs," and for allowing "fluvial processes to occur within the river channel and the adjacent bosque to the extent possible" (Recommendations 1 and 2, respectively, in the Bosque Biological Management Plan), a consensus has still not been reached on how to achieve these goals.

A consensus based on principles of fluvial geomorphology could be reached, however, because river regulation has resulted in a series of discharge gradients generated by impoundments and/or other diversions that trap sediment moving downstream. The gradients begin with downcutting below such structures, causing what can be termed F or G type channels (Rosgen 1996). As the balance between aggradation and degradation shifts downstream with the addition of sediment from banks and tributaries, the channel tends to take on more of a sinuous or C type configuration. Below that, the increasingly aggraded river becomes wider and more braided, in effect a D type system.

This repeated pattern of flows offers opportunities to apply a variety of hydrologic manipulations to achieve partial bosque restoration. The confined river with its reduced flows provides a hydrologic template that is substantially different from those of the past. Decisions based on cross sectional stream morphology at any location can lead to relatively confident estimates of the discharge required for seasonal overbank flooding at specific sites along a given gradient. The next step, how to manipulate the flow regime in order to make that happen, is more problematic.

Several approaches presently are being considered. One is to move the levees back from the river. Where possible, that would increase the width of the active floodplain. The river then would be able to form new channels, which would create new establishment sites for native woody vegetation. Locations for such a project between Bosque del Apache and the upper end of Elephant Butte Reservoir have been seriously considered by the Corps of Engineers and the Bureau of Reclamation, with some input by environmentalists and non-agency experts, but the matter remains unresolved.

Another option is to increase the degree of braiding of the river bed. As a rule, the river's historic pattern was braided and slightly sinuous (Biella and Chapman 1997). Riparian vegetation would have become established on periodically inundated river bars associated with this pattern, as currently happens in locations characterized by aggraded beds. Mechanically induced braiding could open up additional establishment sites, if desired. The reach below the mouths of the Rio Puerco and the Rio Salado would be a candidate for this approach; it tends to be shallow and wide, and is already braided to some extent.

A third approach is to spatially change the river's flow regime by increasing the number of meanders in given lengths of river. The argument for this is based on the fact that while present meanders were created by heavy flows before the levees were built, regulation has negated future flows of such magnitude. Moreover, since on average the channel contains only about half the water it held in the days before flood control was strongly implemented (Crawford and others 1993), and since river width is a function of river wavelength (Leopold 1994), a given reach can sustain additional sinuosity. That in turn means more point bars for cottonwood-willow establishment.

How these approaches would affect the survival of the endangered silvery minnow, *Hybognathus amarus*, has not been sufficiently examined. If they were to promote overbank flooding during the breeding season, young fish might benefit from nutrient rich water moving slowly through the riparian forest. Other unresolved questions addressing restoration related river manipulation include how and where to do it, who would pay for it, and what political obstacles might impede it. Nevertheless, combinations of manipulation based approaches to partial bosque restoration, when carefully planned and executed, seem reasonable. Flexibility in implementing them would be critical, as would motivation within key agencies. Doing nothing, however, will lead to a collapse of the native bosque.

Albuquerque Overbank Project: an Experiment in Restoration

At this writing the Albuquerque Overbank Project (AOP) is an ongoing experiment to mechanically create a cottonwood-willow establishment site along the Rio Grande within the city limits. The AOP was initiated by a team from the Bureau of Reclamation, The University of New Mexico Biology Department, the City of Albuquerque Open Space, the New Mexico Natural Heritage Program, the State of New Mexico Environment Department, the Middle Rio Grande Conservancy District, the Fish and Wildlife Service, and the Corps of Engineers. It is funded largely by the Bureau of Reclamation, although each of the other entities as well as several volunteers have contributed various forms of support. Rather than dealing directly with the river's hydrology, the AOP is manipulating the river's west bank approximately 5 kilometers south of the Bridge Street Bridge to allow overbank flooding.

The project, diagrammed in figure 1, first involved clearing about 1.6 hectares of dense Russian olive from the downstream half of an alternate river bar. The trees were stockpiled and later removed and chipped. Next, 0.96 hectares of the cleared area by the river were lowered by about 0.6 meters. Roughly 6117 cubic meters of the exposed soil were root plowed and root ripped, then used to cover part of a large sand bar extending downstream from the alternate bar. Undulations throughout the cleared area were created to enhance the chances of cottonwood and willow seedling establishment during the initial phase of post-flood drawdown in late June.

Meanwhile, 18 equally spaced shallow groundwater wells (piezometers) were installed in five equidistant lines leading from the levee to the west, through the existing old bosque, and out to the river. Five wells were placed north of the undisturbed zone as controls and seven more are in the old bosque by the western levee. All wells were surveyed for elevations above sea level; this will enable the team to determine whether site treatment has any influence of groundwater changes. Well monitoring for water depth and chemistry is performed at monthly intervals, or more frequently during peak flooding. Vegetation transects were set up adjacent to the well lines and plant surveys were conducted prior to tree removal. Quadrat sampling along the transects took place prior to tree removal and commenced again following floodwater subsidence. Site patterns of soil salinity were measured twice before overbank flooding began in April.

The AOP's underlying hypothesis is that the treatment will produce a natural plantation of native tree seedlings. Success in the first year of operation will depend on the timing of post-flood drawdown relative to seed arrival. Runoffs in subsequent years will vary and may or may not contribute to what could be the uneven beginning of a new patch of native bosque. The approach is admittedly something of a gamble, but it follows the paradigm of "something is better than nothing."

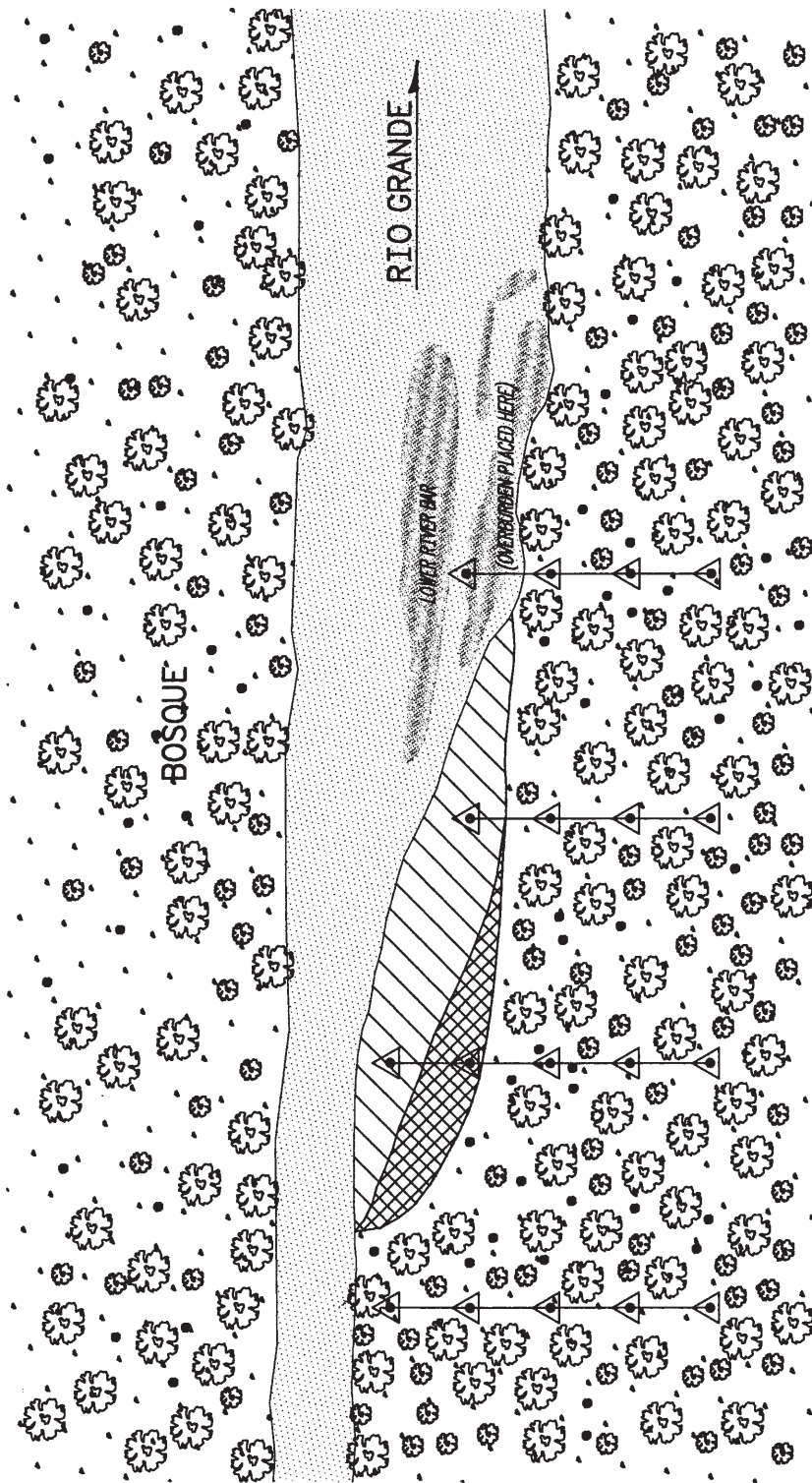
Conclusions

Partial restoration and monitoring of the Middle Rio Grande bosque should be integral to its management. Enough is now known about the ecosystem and its relationship to the river's flow regime and hydrology to efficiently manage for a sustainable riparian forest containing a substantial number of native trees. A flexible program of establishment and maintenance by manipulated overbank flooding will make such management possible, provided resource agencies and environmentally concerned citizen groups work together, acquire funding, and argue successfully for keeping sufficient water in the river for this purpose.

Working together on relatively small restoration projects like the AOP is one way to create a climate of trust and cooperation that can extend to larger, reach length restoration projects. We recommend that such a "bottom up" approach be given increased recognition among agencies responsible for sustainable management of the Middle Rio Grande bosque ecosystem.

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Centerline of
Atrisco Riverside Drain.

PLAN VIEW

ALBUQUERQUE OVERBANK

PHASE I
(NO SCALE)

KEY

Groundwater Monitoring Well

Vegetation Cleared Area

Vegetation Cleared Area (Lowered 0.6± meters)

OCTOBER, 1998

NOTE

Distances between wells on transect lines are 38.1± meters and distances between transect lines are 137.2± meters.

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Figure 1—Diagram based on an aerial photograph of the Albuquerque Overbank Project site on the west bank of the Rio Grande approximately 5 kilometers south of the Avenida Caesar Chavez Bridge in Albuquerque, NM. All vegetation was stripped from the barred elliptical zone, and the area between the river and the zone's dividing line was lowered by about two-thirds of a meter in February 1998. Soil removed in the process was deposited on the lower river bar to the right of center. Triangles represent locations of shallow groundwater piezometers along transects also used to study vegetation cover.