Enhancing Moist Forest Restoration Opportunities in Riparian Systems

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Abstract*—In northern Rocky Mountain moist forests, riparian systems contain many attributes that create unique biophysical conditions that alter disturbances and microenvironments; thus creating distinct forest structures, species composition, and management challenges. For example, browsing, limited opening size, competition from surrounding ground vegetation, high soil moisture, and cold air drainage challenge the application of any silvicultural method, but if these aspects are considered prior to applying restoration efforts, they can also facilitate a successful result. This paper discusses a series of silvicultural tools that can be used in riparian restoration, including integrating knowledge on competitive thresholds for western white pine (*Pinus monticola*) (occupancy, competitive advantage, and free-to-grow status), maintaining overstory canopy for modifying cold air drainage, and using coarse woody debris and other vegetation to decrease browsing damage while minimizing sedimentation input and soil compaction. Although applying an integrated silvicultural system is critical in any restoration project, non-technical expertise concentrating on the interactions among people during project implementation is needed to achieve successful restoration results.*

Introduction

In northern Rocky Mountain moist forests, riparian systems contain many attributes different from upland forests. These systems are characterized as areas where vegetation and physical components (soils, topography) contribute directly to a stream or lake's physical and biological characteristics (i.e., shading, stream fauna habitat) (Swanson and Franklin 1992). Depending on the stream type, the associated riparian areas contain diverse environmental conditions that affect the composition, regeneration, establishment, and growth of plants. Herbivory, competition, microsite topography, floods, erosion, abrasion, drought, frost, and variable nutrition directly affect these plants. Riparian plants also are indirectly affected by landscape components including topography, geomorphology, stream shape, soil type, water quality, elevation, climate, and surrounding upland vegetation (Odum 1971). Fire, ice, windstorms, and insect infestations, although less common, can directly or indirectly influence riparian systems (Agee 1988, Naiman and Dècamps 1997).

Plants that colonize and grow in riparian areas have evolved to adapt to these diverse environments and disturbances by invading, enduring, or resisting these conditions (Agee 1988, Naiman and Dècamps 1997). Therefore, it is important to understand both the riparian environment and a plant's adaptations and life history prior to applying silvicultural methods for restoring these systems. The objective of this paper is to discuss the role of

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silviculture in riparian restoration. Topic areas include the ecological aspects of the northern Rocky Mountain moist forest riparian environment, which can affect silvicultural applications, the applicability of integrating multiple spatial and temporal scales into the silvicultural system or method, and providing silvicultural tools useful in riparian restoration.

Riparian Environment

Three classes of perennial streams occur in moist forest settings: riffle-pool, cascade-pool, and meandering glide (Rabe and others 1994, Savage and Rabe 1979). Riffle-pool streams have moderate gradients and contain riffles (shallow, turbulent flow over rock) alternating with smooth-flowing glides or deep, quiet pools (figure 1). These occur in valleys with narrow flood plains. Shrubs, grasses, and sedges are the primary riparian vegetation on the flood plains, and trees occupy settings above these plains (Savage and Rabe 1979). Since they contain a diverse aquatic insect community and favorable fish habitat, these streams are often fish bearing. Cascade-pool streams have torrential flows over large rocks and logs; these streams dissect steep slopes and have narrow riparian zones (figure 2). Logs are an important component in cascade-pool streams and are largely responsible for creating the cascades. Bedrock is usually exposed in the channel and heavy shading from trees is common. Fish rarely occur in these streams because the cascades create barriers during low water flow, water velocity is too high during spring runoff, and resting areas for fish are less abundant (Savage and Rabe 1979).

Figure 1—Canyon Creek at Priest River Experimental Forest in northern Idaho is an example of a riffle-pool stream. These streams are often fish bearing and contain a diversity of aquatic insects.

Figure 2—Benton Creek at Priest River Experimental Forest in northern Idaho is an example of a cascade-pool stream type. This is characterized as containing very narrow riparian areas often with trees and logs in the stream and along the riparian area.

Riffle-pool and cascade-pool streams in northern Rocky Mountain moist forests are characterized by two habitat types: western redcedar (*Thuja plicata*)/devil's club (*Oplopanax horridum*) and western hemlock (*Tsuga heterophylla*)/wild ginger (*Asarum cadatum*) (Cooper and others 1991). Dominant tree species include western redcedar and western hemlock, but Engelmann spruce (*Picea engelmannii*), western white pine (*Pinus monticola*), western larch (*Larix occidentalis*), and grand fir (*Abies grandis*) can also occur. Soils are quartzite and alluvial mixtures of metasediments, siltite, ash, and mica schist. These soils have fairly coarse textures (gravelly loamy sands to sandy loams) with up to 40 to 50 percent gravel content. The riparian areas contain deep forest floors and no bare soils or rock (Cooper and others 1991).

Meandering glide streams contain many curves and meander along a shallow gradient (approximately 1 percent) (Savage and Rabe 1979). These streams have riparian areas that support significant wetland communities maintained by high water tables and are frequently flooded (figure 3). The stream biota is adapted to soft substrate, slow water velocities, and sometimes-low oxygen saturation. These conditions often favor only plant species (sedges, grasses, and forbs) adapted to these conditions. Although many tree species do not grow in the wetland surrounding the stream or lake, trees may grow along the edge (poorly drained areas often occur between, but are not limited to, permanent open water zones and uplands) (Rabe and Bursik 1991, Tiner 1999). For example, some of these areas were once occupied by large old western redcedar forming shady groves (figure 4).

Figure 3—Meandering glide streams have low gradients and considerable sinuosity. They support wetland ecosystems consisting of grasses, sedges, and shrubs. This is the North Fork of the Clearwater River in northern Idaho.

Figure 4—This picture shows a western redcedar riparian grove along Cedar Creek above the North Fork of the Clearwater in northern Idaho. These western redcedar are approximately 400+ years, and the understory consists of dense herbaceous cover.

Why Restore Riparian Areas?

There are many physical, biological, and social reasons for managing or restoring riparian areas. Streams and associated riparian areas influence hydrologic characteristics (Naiman and Dècamps 1997, Windell and others 1986). Depending on the soil type and permeability, they alter biogeochemistry, ground water discharge and recharge, erosion control, water purification, and flood control; moderate air temperatures; contribute water vapor to the atmosphere; and produce gasses from biomass decomposition and nutrient cycling (Windell and others 1986). Biologically, they provide habitat and corridors for a wide range of wildlife species and the vegetation, soils, and micro-topographical environments favor insect populations (a requirement for maintaining fisheries). Socially, they are prime areas for recreational use such as providing spiritual, physical, aesthetic, and recreation values (Windell and others 1986). In addition, they can also be quite valuable for timber production (Berg 1994, Newton and others 1996).

Historically, riparian areas (particularly, meandering glide and riffle-pool stream types) were frequently the first places developed by European immigrants because the floodplains provided excellent farmlands. Trees (narrowleaf cottonwood [*Populus angustifolia*], western redcedar, western hemlock, and western white pine) were used for firewood, timber, house building material, or for a combination of uses (Windell and others 1986). In the moist forests, channelization often occurred in streams and rivers, thus decreasing sinuosity (Hann and others 1997, Windell and others 1986). Excessive cattle grazing damages vegetation, increases soil compaction and erosion, introduces exotic plants, and degrades water quality with fecal contamination (Dobkin and others 1998). Because riparian zones are highly valued for a variety of purposes and represent a limited fraction of the landscape, and because past use has led to degraded conditions (Windell and others 1986), riparian restoration has become an increasingly important issue.

Restoration of Moist Forest Riparian Ecosystems

Knowing where to begin is the first step in any restoration effort. Landscape attributes can provide a biophysical template for setting restoration priorities. Some have suggested a step-down process from broad to fine scales for planning restoration activities (Jensen and Greene 1991, Naiman and others 1993). For example, in the Coeur d'Alene River Basin of the northern Rocky Mountains, Jain and others (2002) used multiple spatial scales combined with historical pattern of western white pine abundance to define possible restoration priorities. They determined western white pine was most abundant and most productive in places where subsurface flow of water and water retention occurred in areas found on slopes highly dissected by streams, slopes adjacent to streams, toeslopes, benches, or wide stream bottom riparian areas. Camp and others (1997) identified fire refugia based on physical landscape attributes occurring at multiple spatial scales in the eastern Cascades. They too found these protected areas occurred near or adjacent to riparian areas. Jensen and Greene (1991) used a hierarchical approach to describe and map riparian areas. They used this information to identify location, extent, and diversity of riparian areas, evaluate existing condition, and identify reasonable desired future conditions for management. Because the approach was hierarchical in nature, broad scales provided context for fine scale prioritization; and the approach identified relative uniqueness of stream and riparian areas, current condition relative to other riparian areas, and whether a particular future desired condition was possible (Jensen and Greene 1991). Using a multiple scale approach at least by linking the entire watershed to site-specific treatments of riparian areas is one key area that has proven effective in restoration projects (Cannin 1991).

Temporally, understanding the past history relative to the current condition can help identify the time frame needed to attain a future desired goal in restoration efforts. Moreover, time can provide an indication of what might be a feasible desired future condition. For example, if old growth western redcedar once occupied the site, but was harvested in the early part of the 20th century, a possible desired future condition is to restore this area to a western redcedar grove. However, the conditions for regeneration may be vastly different today when compared to 400 years ago, when the original western redcedar regenerated. Furthermore, over time, intermittent disturbances probably encouraged the development of the grove. The climate, stream morphology, and other physical and biological aspects may also be quite different today when compared to historical conditions. Chambers and others (1998) discovered that riparian areas in Nevada could not be restored to conditions that existed prior to the past 150-200 years. They determined climate change and stream incision from recent floods prevented these riparian areas from attaining characteristic forest compositions and structures of the past. If similar changes occurred in riparian areas that once held large old western redcedar, it may not be appropriate to plant western redcedar (late-seral species) in hopes of obtaining a historical condition. This may be particularly true if current plant communities reflect an early successional stage. In this case, early-successional tree species (western white pine, lodgepole pine, Engelmann spruce) may be more appropriate with future western redcedar reintroductions possible underneath an established canopy. Therefore, the time frame to achieve the desired condition may take multiple centuries rather than one or two centuries.

Two silvicultural objectives often applied in riparian restoration include establishing desirable high cover (>12 m in height) or improving forest ground cover (<3.5 m in height). Large conifers play important roles in riparian and stream sustainability (such as wood input, wildlife habitat, and long-term nutrition); hence, maintaining or regenerating conifers is often a goal in riparian restoration (Newton and others 1996). Meandering glide or riffle-pool streams occur in valley bottoms and have been most likely harvested in the past or have roads along the streams. Therefore, the following discussion will be most applicable in these stream types but may also be applied to other types (i.e., lakes, small springs) of riparian restoration.

Restoration activities associated with silvicultural systems occurring along cascade-pool streams will be most similar to upland regeneration techniques. Minimum competition from shrubs and grasses will tend to occur in these settings, since the dominant vegetation is often composed of trees. Browsing damage can occur from deer (*Odocoileus* spp.) and elk (*Cervus elaphus nelsoni*) but will be similar to damage occurring in the upland forest. Regeneration in riffle-pool stream riparian areas will have some competition from grass and shrubs, but if regeneration occurs far enough from the stream, competition may be minimized. However, browsing may impact regeneration efforts, since riffle-pool streams attract both ungulates and small animals. In the meandering-glide streams, a silvicultural system will need to address competition, high water tables, browsing, and sedimentation from flooding.

Restoration techniques that include enhancing current forest structure or composition may include cleanings, weedings, and thinnings. Historically, these treatments were associated with altering tree structure and composition. Silvicultural methods could be applied to encourage sprouting in deciduous trees such as narrowleaf cottonwood (*Populus angustifolia*), paper birch (*Betula papyrifera*), and aspen (*Populus trimuloides*). Silvicultural treatments can also be used to develop desired shrub communities. For instance, coppicing can be applied to favor large shrubs like alder (*Alnus* spp.), willow (*Salix* spp.), or Rocky Mountain maple (*Acer glabrum*). However, care must be taken as not to have adverse outcomes such as introducing exotic plants, compacting or displacing soil, or losing excessive surface organic matter.

Establishing Trees

To meet many restoration goals, species presence may be as important as ensuring tree numbers. In many restoration efforts, regeneration and establishment of conifers is difficult and often fails without some type of disturbance (Newton and others 1996). However, these treatments must minimize erosion, avoid harmful levels of water contamination by silt or herbicides, and maintain adequate stream cover (Newton and others 1996). In riparian settings prone to aggressive colonization by ground level vegetation, large planting stock (3-0 or greater) is preferred no matter what species or combination of species is selected. Grasses, forbs, and sedges not only compete for nutrients and light but they can also mechanically injure trees and attract trampling animals. Moreover, overstory competition (trees, shrubs) should be irregularly spaced to maximize sunfleck duration and decrease sunfleck density (Jain 2001). Large seedlings are more resilient to damage from browsing or other animal damage and once established can compete more readily with other plants (Cafferata 1992; Giusti and others 1992; Graham and others 1992; Marsh and Steele 1992; Newton 2002; Rochelle 1992). However, the planting of large seedlings requires additional care and handling to ensure they have proper root to shoot ratios, are not bent or twisted (j-rooted) when planted, and have good root to soil contact.

Species Preference

In moist forests, suggested species include western white pine, lodgepole pine, western redcedar, western hemlock, and Engelmann spruce. In stream reaches that tend to pool cold air creating frost pockets, lodgepole pine, western white pine, and Engelmann spruce are the favored species, because of their tolerance to frost when dormant (Minore 1979). In settings with high forest cover and minimal competition from ground level vegetation, western redcedar, western hemlock and/or western white pine may be more applicable.

Although western white pine is an early to mid-successional species, it is well suited to growing in many riparian settings since it can tolerate a range of growing conditions and endemic diseases in northern Rocky Mountains moist forests. The species is well suited for planting in small openings within riparian systems and its growth is predicated on the size of opening or gap in which it is located. Jain and others (2002) determined openings within riparian areas might only need to be 0.25 ha in size for western white pine to achieve competitive advantage and 0.5 ha in size to achieve free-to-grow status (i.e., when a seedling or small tree is free from competition from other plants) (Helms 1998).

Controlling Competition

In many riparian areas, successful conifer establishment and growth is dependent upon the ability to control competing vegetation. Most often, overtopping of seedlings needs to be minimized until they become established and are able to obtain free-to-grow status (figure 5). In riparian areas, grasses tend to be tall (sometimes 2 meters) and there is often a high density of shrubs and various herbaceous plants (figure 6). Moreover, when overtopping grass or forbs die or collapse, seedlings can be crushed and/or covered by the grass (especially under snow). Therefore, competing vegetation control needs to extend beyond the immediate planting area (possibly up to a 2 meter radius around a tree) (figure 7). The preferred method for controlling competition depends on cost, impacts, method efficacy, and personal safety when applied (Newton and others 1996), but it can include mechanical or chemical treatments.

Mechanically removing vegetation can elevate sediment input, increase soil compaction, and may be difficult to apply to small areas (Harvey and others 1989). Furthermore, results may be short lived. Mechanical applications often favor sprouting of shrubs, and forbs and grasses may colonize areas before a tree becomes established and achieves free-to-grow status (Miller 1986). Applying a second mechanical treatment risks injuring or destroying planted seedlings. Mechanical treatments may also present risks for exotic plant invasion, since mineral soil exposure is an ideal seedbed for many plant species (Haig and others 1941). Manually cutting and removing competition

Figure 5—In riparian restoration, grass and shrubs are considered part of the canopy when establishing new seedlings. Under tall grass, this canopy opening is approximately 60 percent and would not achieve free-to-grow status for western white pine.

Figure 6—Riparian areas tend to have high concentrations of grass, forbs, and shrubs that are usually quite tall. In this picture, the grass is at least 1 m tall. If the objective is to establish conifers, some site preparation and competition control is required.

Figure 7—Western white pine seedling with competition removed in planting spot that was not large enough to avoid being crushed by surrounding grass and other vegetation.

minimizes compaction and sediment input, but it is extremely labor intensive and may require several treatments per year (Newton and others 1996).

Another option is to use herbicides to control competition. Spot herbicide application has several advantages over broadcast application (Boyd 1986). First, it is less costly because there is less chemical used per unit area. Second, spot application is usually more environmentally acceptable and desirable over broadcast application, because small areas are treated and application is possible under a wider variety of weather conditions. Finally, this treatment provides a diversity of habitats that may benefit wildlife and prevent the concentration of animals that could physically damage trees. If the herbicide is applied conservatively and the appropriate herbicide (glyphyosate, imazapyr, metsulfuron, and/or triclopyr) is used, this method can provide systemic and non-systemic herb and shrub control with no water contamination (Newton and others 1996, Newton 2002). Disadvantages include greater labor costs compared to broadcast application, more hazardous to workers because they most likely will be applying it by hand or intimately working with the herbicide, and if used in site preparation, spots may be difficult to locate at planting time so flags may need to be placed in applied areas (Boyd 1986). Herbicides used for shrub control in forests include 2,4-D, glyphosate, imazapyr, picloram, or triclopyr. To control herbaceous plants (grasses and forbs), Atrizine, 2,4-D, sulfometuron, and hexazinone are suggested (Newton 2002). However, specific time of application and effectiveness of herbicide to affect targeted vegetation varies. Specific details on application and target species are available through the Pacific Northwest Experiment Station Weed Management Handbook (Newton 2002).

If one cannot treat competition either mechanically or chemically, the only viable option is planting Engelmann spruce, since it has a stiff enough stem to avoid crushing or bending under grasses or other vegetation (Robert Hassoldt, personnel communication) (figure 8). Additionally, there is some evidence that spruce may grow relatively well in places with moderate amounts of competition. For example, white spruce (*Picea glauca*) has been shown to perform similarly or better in places with low and medium shrub densities when compared to areas with no shrubs. White spruce growth was only affected in places with high shrub densities (Posner and Jordan 2002).

Figure 8—Engelmann spruce seedling planted with no competition control.

Browsing

A variety of animals (insects, rodents, omnivores, ungulates, and livestock) may eat or damage tree seedlings. Livestock and wildlife damage can occur from browsing, trampling, and rubbing, and most western tree species are susceptible. Wildlife species including, but not limited to, beaver (*Castor canadensis*), porcupines (*Erethizon dorsatum*), lagomorphs (*Lepus* spp. and *Sylvilagus* spp.), black bear (*Ursus americanus*), deer, and elk can damage seedlings. Riparian areas attract a wide range of these wildlife and livestock, making animal conflicts an issue in many restoration efforts. Hence, the potential for browse damage should be thoroughly evaluated prior to implementing the silvicultural system (Knapp and Brodie 1992, Nolte 2003a). Nolte (2003a) suggested using a five step process: (1) assess the severity and potential damage if no action is taken, (2) evaluate the feasibility of alleviating the problem, (3) develop a strategy prior to browse damage prevention measures, (4) implement program, and (5) monitor consequences.

It may also be wise to evaluate potential browse impacts at multiple spatial scales, to help identify how a riparian area contributes to the overall wildlife habitat matrix (McComb 1992). The size of the area to evaluate will depend on the species of interest (figure 9). If the species is beaver, then an evaluation of riparian attributes will be sufficient; however, if deer or elk are the species of interest then a landscape (watershed) perspective may be more appropriate. If the riparian area to be restored is the only source of water or has unique habitat attributes favoring a particular species, then it may receive abundant use. Under these circumstances seedlings may require considerable protection or else damage can be severe enough to reevaluate restoration objectives.

A variety of preventive and remedial techniques have been tested, with mixed results. These have included providing alternative food source or planting unpalatable trees species, silviculturally modifying habitat to disfavor specific browsing species, physically or chemically protecting tree seedlings, frightening browsers away, or trapping or killing browsing threats. Unfortunately, there is not one method that solves all browsing problems. The preferred approach will depend on assessment results and the most effective treatment may require integrating several methods.

Sometimes, providing a preferred food source decreases the probability of trees being browsed (Nolte 2003b). This method, in theory, provides benefits like the maintenance of plant diversity and water quality, and can be relatively cost-effective compared to fencing or other types of plant protection. But extensive evaluation of methods is limited and results are highly variable (Cafferata 1992; Giusti and others 1992; Graham and others 1992; Marsh and Steele 1992; Newton 2002; Rochelle 1992). With spot application of herbicides, fewer food sources are eliminated, which may potentially diminish browsing problems. Another technique is to plant tree species that are tolerant to or less susceptible of being browsed (Black and Lawrence 1992). Unfortunately, in the moist forests, western redcedar (which is very palatable)

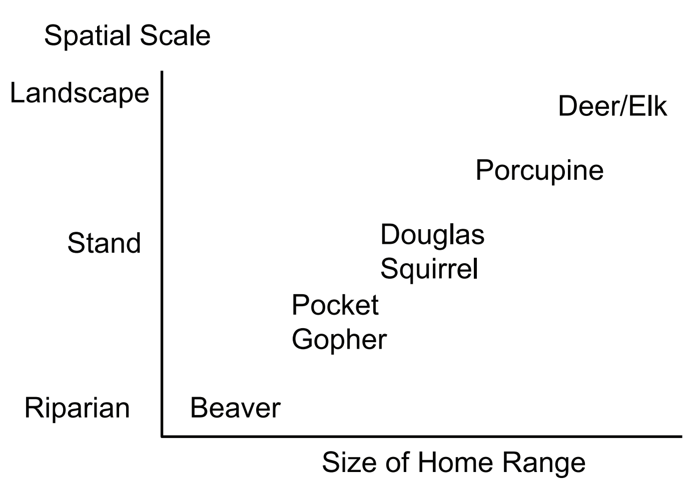

Figure 9—Wildlife habitats occur at different spatial scales (McComb 1992). Therefore, riparian restoration efforts should consider multiple spatial scales when evaluating potential animal damage.

is the preferred species used in riparian restoration; therefore seedling damage from wildlife can be prohibitive to its establishment. Many recommend large planting stock because it typically is less vulnerable to animal damage (Cafferata 1992; Giusti and others 1992; Graham and others 1992; Marsh and Steele 1992; Newton 2002; Rochelle 1992).

Physical protection of seedlings with polypropylene mesh tubes is an option and appears to be successful in some cases (Black and Lawrence 1992). Fencing riparian areas to keep livestock out can be effective, but expense limits its use (Nolte 2003c). Other forms of physical deterrents might be possible. Graham and others (1992) noted that when coarse woody debris (>7.5 cm in diameter) was greater than 50 Mg/ha before livestock utilization fell below 10 percent. These are well within the recommended amounts (37 to 74 Mg/Ha) necessary for maintaining long-term soil productivity (Graham and others 1994). In some cases, minimizing disturbance avoids creating habitat that may increase pocket gopher (*Thomomys talpoides*) populations (Marsh and Steele 1992).

In riparian restoration, application of chemical repellents or poisons may not be an acceptable option unless the browsing problem is severe and positive results are substantial. First, water quality issues should be investigated before using any repellents or poisons. In some cases repellents have had inconsistent results, making chemical treatment an impractical option (Nolte 2003d). Moreover, competition and browsing issues are often interdependent. In these situations, herbicide application for competition control may take precedence over the use of chemical repellents. Removing, killing, trapping, or frightening the animal may be valid options. Studies have shown that controlling pocket gopher populations with strychnine baiting poses relatively little risk to non-target species (Arjo 2003). But the effects of removal may be short-lived since a replacement mammal usually occupies the vacant habitat, necessitating the continuous application of treatments. This option may also prove socially unacceptable (Schmidt and others 1992). Frightening devices are usually ineffective in deterring ungulates; however, other methods are currently under evaluation and testing (Nolte 2003c).

Biological methods may be useful for decreasing populations of unwanted browsers. For example, a recent study considered the interaction between weasels (*Mustela* spp.) and pocket gophers (Arjo 2003). In this study, 80 percent of the weasels killed and consumed healthy pocket gophers. All weasels ate strychnine-baited gopher carcasses 72 hours after gophers died, but no weasels died from secondary poisoning.

Successful Restoration Requires More Than Technical Expertise

Riparian restoration can be enhanced and successful only when treatments are integrated into a silvicultural system. However, the application of a silvicultural system by itself will not lead to a successful restoration project; other aspects also need ample consideration. Cannin (1991) summarized attributes characteristic of successful riparian restoration projects. Many were not technical application of treatments but rather the interaction of people in conducting the project. Strong leadership from a few designated people was critical, as was a political environment that promoted creativity, financial support, and effective implementation.

A multiple scale approach when planning projects is essential to recognize riparian zones as a part of the landscape rather than treating them as isolated areas. Pretreatment evaluation and surveys that clarify goals at the beginning allow participants to develop effective solutions to address problems. Post-treatment monitoring to evaluate success (or failure) allows for adaptive management. Increased public awareness through demonstration projects and proper land use practices should positively influence human behavior toward respecting sensitive riparian areas. Community involvement in project implementation is critical as is close communication between agencies, local governments, and landowners. In conclusion, it takes both technical and social expertise to implement a successful restoration project with ingenuity and imagination.

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