Roadside and road-related disturbances often represent an "extreme" restoration ecology challenge. Steep slopes, little or no topsoil, high erosion by wind and water, lack of beneficial microorganisms, rapid invasion by weeds, high exposure to winds, and constant visibility to the driving public are some of the factors that add to the challenge. Many of the lessons to be learned in these harsh conditions are applicable to restoration efforts on other drastically disturbed sites. At the same time, one unique factor is involved in revegetating roadsides and other disturbance areas associated with


KEY WORDS
DFCs, roadside ecosystems, roadside management, revegetating, restoration ecology

Figure 1. The benefits of establishing desirable roadside vegetation are more than ecological. Native plants on roadsides can improve the safety, efficiency, and effectiveness of roads and associated management. (Glacier National Park, photo by Tara Luna)
road construction, modification, or obliteration: road-related disturbances are planned—allowing for several years of lead-time to protect and salvage existing vegetation, as well as to propagate the quality and quantity of native plant materials required to revegetate these sites.

Many recent advances in collaborative processes as well as in the science and practice of restoration with native plants have expanded capabilities to revegetate roadside environments (Figure 1). Internally, the Federal Highway Administration (FHWA) has invested in several initiatives to improve integration of ecological concerns with road planning. These programs include the Eco-Logical approach, Context Sensitive Solutions, Exemplary Ecosystem Initiatives, the newly forming Green Highways Partnership, and other cutting-edge initiatives and policies. While advances are being made within FHWA and the transportation community, progress is underway in the science and practice of restoration ecology and native plant propagation. The Society for Ecological Restoration International published guidelines and principles applicable to restoring ecological function to degraded sites (SER 2004; Clewell and others 2005; Clewell and Aronson 2008). Plant geneticists at a number of federal agencies came to a consensus about what defines a “native” plant and developed seed collection, transfer, and propagation guidelines to ensure that locally adapted materials are used with optimum results (Withrow-Robinson and Johnson 2006). And in both the public and private sectors, seed and plant producers and installers developed innovative methods to meet unique site conditions. The new publications Roadside Revegetation: An Integrated Approach to Establishing Native Plants (Steinfeld and others 2007a) and A Manager’s Guide to Roadside Revegetation Using Native Plants (Steinfeld and others 2007b) bring these advances to bear on the challenge of establishing native plants on roadsides. The publications provide both technical information and an emphasis on cooperative, interdisciplinary processes. This article summarizes key aspects of the integrated approach covered in these 2 publications.

WHY ESTABLISH NATIVE PLANTS ON ROADSIDES?

The ecological effects of roads do not end at the edge of the pavement. The total road corridor (paved road plus roadside) extends over 1% of the nation’s surface, an area the size of South Carolina (Forman and Alexander 1998). If unpaved roads are also included, such as the millions of miles of roads in USDA Forest Service (USFS) lands, the percentages dramatically increase. When the broader effects of roads are accounted for (habitat fragmentation, wildlife mortality, noise and chemical pollution, hydrologic cycle disruption, water quality and erosion effects, and noxious weed invasions), the estimate is that about 15% of the US is ecologically affected by roads (Forman and Alexander 1988). In comparison, all of the protected areas of the US—federal, state, county, and tribal protected areas combined—total only about 16% of our country’s land area. Therefore, the enormous challenge of understanding and mitigating the ecological effects of roads deserves attention and dedication on local, regional, and national scales.

Native plants are a foundation of ecological health and function. Revegetating roadsides with native plants is a key practice for managing environmental impacts and improving conditions for healthy ecosystems. In past cases of failed revegetation efforts, revegetation was considered important to improve the appearance of the roadside disturbance, but efforts often emphasized seeding of exotic species because these were perceived as cheap, readily available, and quick to establish on disturbed sites. These exotics either spread to become problematic weeds or failed to persist because they were not locally appropriate. Establishing locally appropriate native plants supports greater recovery of natural ecosystem structure and function, and helps safeguard complex plant–pollinator and plant–animal interactions vital to ecological health. The ability to establish native plant communities on roadsides is central to determining whether the transportation corridor will be a healthy environment providing vital ecological services—or a damaged environment presenting more problems.

TRENDS IN ROAD CONSTRUCTION AND ECOLOGICAL AWARENESS

Much of the existing road network was designed and constructed prior to the 1970s, before ecological health became a widespread concern among American citizens and before ecological science had evolved to address large-scale issues (Forman and others 2003) (Figure 2). Safety and efficiency were the primary goals of transportation programs in the past, and the ecological impacts were largely overlooked in road planning, construction, and maintenance efforts. The impacts of roads on natural systems were not well understood or considered. Lack of awareness about these factors led to a largely antagonistic perception
of the relationships between natural systems and road systems. For example, without proactive revegetation of the road disturbance, undesirable vegetation encroaches on the roadway. Undesirable vegetation can disrupt safety and visibility, leading to expensive and potentially hazardous maintenance measures. Conflicts with neighboring land uses could result if corridors for invasive weeds are established or if herbicide use is viewed as a health or safety concern by the community. These issues arise when integration of ecology and road design is not considered during road construction or modification. Eventually, poorly integrated natural processes can threaten the function and integrity of the road itself, leading to premature deterioration of the road's infrastructure (Berger 2005).

Most road projects today involve modifications to existing roads rather than new construction. Current modifications predominantly involve updating infrastructure to increase capacity and to improve safety, including widening roads, replacing bridges, and reducing or altering curves and grades to make the road safer for motorists (NRC 2005). The opportunity to integrate ecological goals with transportation was largely overlooked when the road networks were originally constructed. As the nation's roads are updated and modified, however, each project presents opportunities for correcting past oversights.

Fortunately, for the past 20 y, the ecological effects of roads have been increasingly recognized by the FHWA and by state and local transportation agencies (NRC 2005). Today, road effects on ecology are major concerns of the transportation community, land management agencies, and private citizens who are attempting to integrate ecological concerns into all phases of road design and construction processes. For example, legislation in some areas now requires road modification and construction projects to restore aquatic connectivity; fish passages have been built to reconnect natural water flows under roads. Other projects have dealt with roads that were deemed particularly dangerous to endangered species. These roads are being made more permeable to wildlife, greatly reducing losses by improving habitat connectivity, ensuring better vision for drivers and animals, and creating safer underpasses or overpasses for wildlife (Forman and others 2003). Efforts to limit inappropriate road expansion and to obliterate unnecessary roads remain important.

Where modification and increased capacity are needed, ecological health, safety, and efficient transport should not be seen as mutually exclusive goals. Understanding roadside environments, how they interface with adjoining lands, and how to minimize environmental impacts has become a key focus of the FHWA (Fekaris 2006). Given political will and proper levels of attention, integration of environmental concerns with transportation can result in significant gains.

Although efforts to integrate ecological factors are positive, much of the potential for improvement is still largely unrealized. Establishing desirable roadside vegetation is widely recognized as an essential and cost-effective practice.
Figure 3. Past approaches to revegetation often failed if focus was on quick cover rather than on long-term goals. Integration of revegetation issues into road planning and construction processes increases chances of successful long-term establishment. From Steinfeld and others 2007a

to improve the safety, efficiency, and effectiveness of roads and associated management (Forman and others 2003; Berger 2005; Armstrong and others 2007). Yet, many past attempts at native revegetation along roadsides have failed. Failures have been due, in part, to a shortage of practical information and the absence of an integrated approach to the challenge. Revegetation with native plants cannot be approached in piecemeal fashion or as an afterthought. Instead, revegetation must be an integral part of the process of designing and constructing roads (Figure 3). To address this issue, the FHWA partnered with the USFS to develop an integrated approach. The approach has been published in 2 reports (see sidebar), and trainings are being developed to share the approach.

KEY FEATURES OF THE APPROACH

To be successful, an integrated and collaborative approach to roadside revegetation is needed. The process must be collaborative, focused on long-term goals for ecological health, and fully integrated with larger design and construction issues.

The new publications (Steinfeld and others 2007a, b) outline an approach to roadside revegetation that focuses on 3 aspects:

- **Goal-oriented**, which integrates long-term revegetation and ecological health objectives with larger transportation goals including safety, mobility, and cost effectiveness;
- **Collaborative**, which incorporates the knowledge of engineering and natural sciences through collaborative processes and interagency cooperation; and
- **Context-sensitive**, which recognizes that each project has unique ecological characteristics and that source-identified, locally adapted plant materials ensure functional, long-term, self-sustaining plant communities, not just quick cover.

**Goal-Oriented**

Goals that are focused on long-term, locally adapted, functional communities of native plants, not just quick cover, are necessary. Real economic, ecological, and aesthetic gains are realized when the objective is to establish plant communities that are resilient and largely self-sustaining, with the capacity to stabilize soil, improve water quality, and resist invasions of undesirable plants. The scope of revegetation efforts encompasses true healing of the road scar.

The FHWA has 3 performance objectives for every road project: safety, mobility, and (since 2002) environmental stewardship (Armstrong and others 2007). The setting and meeting of revegetation goals should therefore be integrated with larger transportation goals of safety and mobility.

Native plants along roadsides offer ecological, economic, and safety benefits. Ecologically, healthy native plant communities often are the best long-term defense against problematic weeds. Economically, maintenance costs for managing problematic vegetation are reduced, as are the concerns that sometimes result when weeds from roadsides invade neighboring lands or when herbicides drift off target. The ineffectiveness of past roadside revegetation efforts resulted in problems such as erosion and sediment loading, thereby affecting soil and water quality. Visually, when road disturbance is not healed properly, the aesthetic experience of the road user is diminished. In terms of efficiency and cost savings, poorly integrated natural processes can threaten the function and structural integrity of the road itself, leading to premature deterioration of the road’s infrastructure.

Safety is the overriding goal of any road construction or modification project. The establishment of native plant communities supports transportation safety goals in a number of ways. One of the most important is by improving the function of roadside engineering. For example, appropriate vegetation can enhance visibility and support design features to help drivers recover if their vehicles leave the pavement (Figure 4).

**Collaborative**

Collaborative approaches are a key to success. The publications illustrate timelines and processes for effective collaboration at any phase in the project. The early stages of project development include key opportunities for integration. When disturbances to soils and vegetation are being discussed by the design engineers, a revegetation specialist can be involved to help determine what types of disturbances can be feasibly revegetated.
Effective establishment of native plants can support safety goals. This graphic shows revegetation zone planning to protect driver visibility and the ability of a vehicle to recover if the vehicle's tires should leave the pavement. From Steinfeld and others 2007a

with native plants. Even small revisions can result in greatly improved conditions for native plant establishment. If a planned disturbance will not allow for revegetation, alternatives to that type of disturbance can be considered. The work of the revegetation specialist in developing the revegetation plan, as well as efforts to reduce the construction footprint and protect native vegetation on the project site, will become an integral part of the road construction plans.

Coordination of schedules, milestones, and budgets must be emphasized so the appropriate people are involved at key times to avoid problems and optimize results. Problem-solving in a collaborative and integrated manner is encouraged. To accomplish these goals of revegetation and environmental stewardship, people from different disciplines and organizations must come together in an effort to integrate engineering and natural sciences. Even within the natural sciences, specialists need to collaborate to overcome limitations to establishing plants on drastically disturbed sites. Team members should be oriented to larger processes in order to create key relationships and navigate the decision-making process effectively. This input helps to optimize results, save money and time, and ensure that any disturbances planned can be effectively revegetated with native plants. Essential points to coordinate revegetation efforts with road planning and construction are illustrated in Figure 5, including budgetary and scheduling issues.

It is important to note (as illustrated on Figure 6) that the implementation phase of revegetation begins well before road construction begins. Waiting until construction begins is not feasible because locally adapted native plant
Figure 5. Coordinating revegetation with the larger processes of road construction is essential. Although the timelines and agencies involved will vary, this figure illustrates some of the key opportunities for communication and integration. From Staatsfeld and others 2007a
materials almost always must be propagated in advance. With many road projects, 3 y of advanced notice is available, providing time to collect and propagate the appropriate native plant materials for the site.

After construction is complete and native plants are established, coordination remains important to monitor results, to intervene if necessary, and to ensure that maintenance activities do not undo portions of the revegetation.

Context-Sensitive

Given the unique ecological factors at play in each project, the approach outlined by Steinfeld and others (2007a, b) is not prescriptive but rather provides principles and a step-by-step process for practitioners to take into the field to generate their own locally appropriate, context-sensitive revegetation plan. Because the goal is to foster plant communities that are functional in the long term, the approach is intended to facilitate the process of developing locally appropriate solutions on a project-by-project basis. For example, no “one-size-fits-all” plant mix exists that could be applied under any circumstances and be successful. Instead, practitioners are guided through steps to arrive at appropriate species and installation methods to revegetate their roadside project. Tools and resources are provided to support the process (Figure 7).

Because revegetation aspects will be dictated by the context and site conditions, no generic success criteria exist that apply to all revegetation projects. Instead, the revegetation specialist develops revegetation objectives based on the site conditions (Figure 8). General goals of aesthetics, stability, function, and health can be provided in advance. Specific, measurable objectives, usually called Desired Future Conditions (DFCs), will be set by the revegetation specialist early in the planning phase and monitored following installation. Some measurements will be qualitative and some may be quantitative. Goals usually include some short-term needs, such as stabilizing soils, and long-term objectives for healthy plant communities.

AN EVOLVING PRACTICE

Moving beyond piecemeal, mitigation-driven processes and into proactive environmental stewardship is an ongoing challenge. Restoration ecology is an evolving science and native plant propagation is an evolving practice with continual advances as new knowledge is developed (Figure 9). Lessons from revegetation practices, failures as well as successes, should be documented and shared. It is hoped that continuing improvements in interagency cooperation, enlightened
Figure 6. Example revegetation timeline for implementation. Note that revegetation tasks may begin 3 y prior to road construction. Coordination of budgets and timelines is essential. From Sternfeld and others 2007a

Figure 7. Context-sensitive revegetation planning includes mapping revegetation units on the project site to account for variations in soils, climate, management considerations, and other factors. Goals will be set that are appropriate to the site conditions in each unit. From Sternfeld and others 2007a
Two Publications Are Available

Roadside Revegetation: An Integrated Approach to Establishing Native Plants and
A Manager’s Guide to Roadside Revegetation using Native Plants

Roadside Revegetation: An Integrated Approach to Establishing Native Plants shares an approach to effectively revegetating roadsides and other disturbance areas associated with road construction, modification, or obliteration. By incorporating an integrated approach to revegetation into road project management, ecological health is improved and the end product, the finished road, is a better product.

Roadside Revegetation synthesizes an integrated approach that can be used for effective revegetation of roadsides and other disturbed areas associated with road construction, modification, or obliteration. The 4 stages of the revegetation process are initiation, planning, implementation, and monitoring/management. The first stage, initiation, involves creating key relationships to navigate the decision process to initiate a project. There are essential steps to coordinate revegetation efforts with road planning and construction activities, including funding and scheduling issues. In addition, initiation involves creating bridges between non-engineers and engineers regarding terminology and technical concepts to improve communication.

The second stage is planning—the process of defining project objectives, assessing the site, overcoming limitations, strategizing revegetation procedures, and integrating the revegetation activities with the road project. This stage culminates in the creation of a Revegetation Plan for the project.

The third stage is implementation—executing the Revegetation Plan in the field, including coordinating contracts and managing budgets and schedules. Implementation involves carrying out site treatments, mitigation measures, and revegetation tactics. This includes tasks to stabilize soils, overcome limiting factors, improve site conditions, and establish communities of native plants.

Finally, the monitoring stage involves assessing the effectiveness of the revegetation project, correcting any shortcomings if goals were not yet met, and adding to future knowledge. Monitoring protocols are available appropriate to goals. Once vegetation has been established, long-term management dovetails with the practices outlined in Integrated Roadside Vegetation Management (IRVM) programs.

Roadside Revegetation is a comprehensive manual intended to serve field-level practitioners and planners. A second publication, A Manager’s Guide to Roadside Revegetation Using Native Plants (Steinfeld and others 2007b), outlines the key points of the approach for supervisors and planners. These publications offer a goal-oriented, context-sensitive, collaborative approach to produce long-term ecological, economic, and aesthetic gains from establishing native plants on roadsides. In addition to necessary technical information, the process outlined shows how native vegetation concerns may be fully integrated into the larger processes of road design and construction.

Copies of the publications can be downloaded free of charge from http://www.wfl.fha.dot.gov/td/revegetation.htm. Practitioners working to establish native plants on disturbed sites are invited to use and comment on these publications to expand on the success of native plant efforts.
policies, better science and technology, and the dedication and innovation of field-based practitioners will continue to build a foundation for a more healthy and sustainable transportation corridor.

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