PROTECTING SOIL AND WATER IN FOREST ROAD MANAGEMENT

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ABSTRACT. *The National Forest road system is the network that supports public recreation, which has become the primary use of the public lands. The pattern of use of National Forest roads for recreation has increased dramatically since the late 1940s and is expected to continue to increase beyond the rates observed today. However, research over the past 60 years clearly presents forest roads as a major source of sediment and soil erosion from forest watersheds. Threats to healthy forests have received increased attention in the past decade. In particular, roads, road management, and travel management will likely be critical to addressing the four threats to the health of the nation's forests and grasslands that were identified by USDA Forest Service. Road management is an important component in preserving and maintaining healthy forests throughout the nation. Sediment export from the existing forest road network is an issue of great concern in forest management. The objective of this article is to provide an overview of issues involved in managing the nation's public forest roads for the protection of soil and water. This article explores the benefit and efficacy of erosion mitigation, sediment control, and road BMPs in protecting soil and water. This article also suggests areas requiring additional research and development to satisfy the goals of protecting forest soil and water.*

Keywords. *BMPs, Conservation, Forest roads, Sediment control, Soil, Soil erosion, Water resources.*

The USDA Forest Service has been involved in controversy and debate over its management of the public lands since its creation in 1905. These issues, which originated in the 1890s over management philosophies, have raged on for 100 years and continue to be debated. Forest Service Chiefs from Gifford Pinchot to Abigail Kimbell have been charged to manage the public lands to satisfy multiple uses. Issues related to healthy forests have received increased attention in recent years. In particular, President George W. Bush's Healthy Forests Initiative was launched to reduce the risks of wildfires to people and the environment, and to restore forest and rangeland health. Road management is an important component in preserving and maintaining healthy forests throughout the nation. Roads are a vital link to accomplishing the initiative's goals because they provide access to assess current conditions, prescribe treatments, and conduct and evaluate effectiveness of practices (Grace, 2002d). However, forest roads have clearly been presented as a potential and present source of sediments on the forest landscape (Grace, 2005b). Sediment export from the existing forest road network is an issue of great concern in forest management.

In 2003, USDA Forest Service former Chief Dale Bosworth unveiled the "four threats to the nation's forests and grasslands in the 21st century." These four threats include: fire and fuels, invasive species, loss of open space, and unmanaged recreation (USDA Forest Service, 2004). Each of the four threats has a common component, the Forest Service road system. This road system consists of over 600,000 km of roads of varying classes. These roads are necessary for the majority of forest management activities as well as for recreation. Most of these roads were initially constructed for management activities such as harvesting and fire prevention. These lower-standard roads were not intended to serve the purposes that they have evolved to serve. Revisions in the Forest Service timber management practices during the 1990s limited the activity for which the existing roads were designed, timber harvest. Consequently, timber harvesting only accounts for 0.5% of all forest road use.

Research on the effects of forest roads has shown that forest roads can result in accelerated erosion and water quality impacts (Patric, 1976; Yoho, 1980; Swift, 1985; Binkley and Brown, 1993; Grace et al., 1998; Grace, 2002a, 2002b, 2002c, 2003, 2005a). For example, a survey conducted in one watershed in the southeast U.S. revealed that 80% of the sources of sediment delivery to streams and rivers were from the road prism, i.e., road surface, ditches, and banks (van Lear et al., 1995). In an attempt to minimize the impact of roads on the nation's public lands, the Forest Service has developed the Road Maintenance Management System (RMMS). The purpose of this article is to detail the current Forest Service RMMS and provide an overview of issues involved in managing the nation's forest roads. This article also suggests areas requiring additional research and development to satisfy the goals of protecting forest soil and water resources.

ROAD MAINTENANCE PRACTICES AND SEDIMENT

In the past 60 years, recreational use of National Forests has dramatically increased to greater than 18 times the levels

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seen in the late 1940s (USDA Forest Service, 2004). Forest roads have also received increased pressure and account for the largest recreational use (driving for pleasure) of National Forests (USDA Forest Service, 1999a). Coinciding with the increased recreational use of National Forests, there has been an 11-fold increase in traffic in National Forests in comparison to the 1950s. Recreational use (and traffic) in National Forests is expected to continue to increase dramatically as the U.S. population increases over the next century (USDA Forest Service, 2004).

The increased use of forest roads presents a challenge to National Forest road management related to road maintenance. Traffic and road maintenance are two components of road management that have the potential to influence sediment movement from forest roads. In general, there is a direct link between traffic level and maintenance intensity. Increased erosion losses can require increased maintenance to maintain drainage patterns and prevent (or minimize) the impact on downslope resources. At the same time, maintenance operations can increase soil erosion by removing armoring layers on the road surface and in the ditch that develop over time (Black and Luce, 1999; Sugden and Woods, 2007).

Criteria have been established in the RMMS describing how roads are to be maintained to consider adjacent resources, smoothness required for user comfort, season for road use, volume and type of traffic, and road operation and management strategies. The objective of the RMMS (FSH 7709.58, 10) is "to maintain the forest transportation system to support resource programs; to protect the investment, environment, and adjacent resources; to meet applicable air and water quality standards; and to provide for user economy and convenience" (USDA Forest Service, 1995). Five levels of maintenance are supported:

- Level 1: Intermittent service roads of any type, class, or construction standard that are closed (>1 year) to vehicular traffic and receiving custodial maintenance (to prevent damage to adjacent resources).
- Level 2: Roads open for minor use by high-clearance vehicles.
- Level 3: Roads open and maintained for travel by a prudent driver in a passenger car; however, user comfort and convenience are not priorities. Roads are typically single lane with turnouts and may be surfaced with native or processed material.
- Level 4: Roads that provide a moderate degree of comfort and convenience at moderate travel speeds. Roads are typically double lane and aggregate surfaced.
- Level 5: Roads are typically double-lane, surfaced structures that provide a high degree of comfort and convenience.

These roads are the arteries that support recreation and management uses in National Forests. However, the combination of increased traffic and below-standard (problem) roads has led to environmental concerns that must be resolved to fulfill the objectives of the RMMS. These "problem" roads have the potential to cause accelerated erosion losses and mass failures (Luce et al., 2001), which may lead to sediment introduction into forest water bodies. Fulfillment of the RMMS's objectives requires work in the area of traffic and maintenance influence on sediment movement. Upgrading roads in critical areas with alternative practices to mitigate sediment movement and reduce maintenance operations is likely key to reducing the environmental impact of roads. Improvement of critical roads can allow more efficient use of the funding provided for the maintenance of the road system. Upgraded roads can provide access to areas for management and at the same time provide recreational users access to their public lands with minimal environmental costs.

Increased soil erosion has been attributed to traffic in previous roads research conducted in mountainous regions (Reid and Dunne, 1984; Bilby et al., 1989; Burroughs and King, 1989; Foltz, 1999). However, in an investigation of the influence of traffic and road maintenance on sediment production from forest roads in the Oregon Coast Range (Luce and Black, 2001), ditch grading had a greater effect on increased soil erosion than traffic. The investigators concluded that there was little difference between traffic and no traffic given a graded ditch. Cleaning ditches and removing vegetation also results in an increase in soil erosion (6 times greater) in comparison to erosion losses from untreated and treated road surfaces (Luce and Black, 1999).

In a study of road surfacing types on sediment yield in the Pacific Northwest, Reid and Dunne (1984) found that over a 1-year period, graveled road segments receiving heavy traffic produced 130 times more sediment than road segments receiving no traffic. In this study, traffic intensity greatly influenced (7.5 times the rate measured during periods of no traffic) soil loss and suspended sediment concentrations in runoff. It was hypothesized that soil loss from the road segments was influenced by the frequency of road maintenance and grading. The investigators presented the extent that maintenance operations influence soil loss as an area for future research. However, there has been little published work in this area, and maintenance operation's influence on soil loss remains a critical gap in forest road management.

In the southern Appalachians, the influence of surfacing types and maintenance on soil erosion has also been explored at the Coweeta Hydrologic Laboratory (Kochenderfer et al., 1984; Swift, 1984). Kochenderfer (1984) found that roads with high coarse fragment content have accelerated erosion losses and can expose gravel surfacing once fines erode from the road surface. Swift (1984) investigated the influence of graveled, ungraveled, and grassed road surfaces on soil erosion. Grass surfaced roads produced half the erosion as the ungraveled road surface receiving similar traffic. The investigator concluded that grassed road surfaces with low traffic intensity (20 to 30 trips per month) require low maintenance (Swift, 1985, 1988). The graveled road surface with vegetated sideslopes was found to have the lowest soil loss in comparison to the ungraveled and grassed road surfaces.

In one of the few published studies investigating road surfacing and maintenance impacts on water quality, Clinton and Vose (2003) assessed varying levels of maintenance for one paved and three graveled road surfacing types. The gravel surfacing types were subjected to varying maintenance intensities, which included unimproved gravel with grading annually, improved gravel with sediment control structures installed with grading three times a year, and improved gravel with grading four times a year. Predictably, the paved road surface had lower total suspended solid (TSS) concentrations in comparison to graveled road surfaces. Improved gravel surfacing with grading four times a year had the highest TSS concentrations at sampling locations closest to the road. The unimproved gravel surface generated higher TSS concentrations at greater distances downslope from road segments. The further sediment travels, the more likely it is to reach a water course. With that in mind, even on the improved gravel road where BMPs were installed at the time of construction, failure of BMPs (due to lack of maintenance) resulted in high TSS concentrations at great distances from the road. The investigators concluded that sediment movement was highly variable and influenced by maintenance intensity and road drainage. However, additional factors that have been reported to influence soil loss, i.e., traffic intensity and the interaction of traffic intensity and maintenance intensity, were not measured in the investigation.

Road Management Issues

Road Network Assessment

The Forest Service began a fact-finding and research initiative in 1997 to determine what information was available on the impacts of forest roads. The result was a 222-page document entitled “Roads Analysis: Informing Decisions about Managing the National Forest Transportation System.” This document lays out a preliminary science-based tool for management of National Forest roads, which considers the ecological, social, and economic aspects of forest road management. Indicators for the analysis of water/road interactions and hydrologic condition assessment tools are presented. The research synthesized in this document makes giant strides in providing scientists and policy makers with an assessment tool to aid in the development of standards and policies to address the roads issue (USDA Forest Service, 1999b).

Assessment of current road conditions and shortfalls will aid managers in designing and maintaining a road system that meets social, environmental, and economic needs. The Roads Analysis Procedure (USDA Forest Service, 1999c) sets forth assessment procedures related to providing a road system that is feasible to manage, addresses public needs and safety, and considers environmental sustainability. This analysis procedure was defined to facilitate an interdisciplinary approach to identify modifications to the forest road system that may be required to meet existing and future management objectives in National Forests. Six fundamental steps are described in the Roads Analysis Procedure, which include setting up the analysis (planning), description of the situation, issue identification, benefits and risks analysis, description of opportunities and setting priorities, and reporting (USDA Forest Service, 1999c). This procedure provides guidelines for a holistic approach to attain information required to make informed and sustainable decisions related to future road systems.

Road Construction Decisions

The Forest Service road system is more extensive than the U.S. Interstate Highway System but handles only a fraction of the vehicles per day (1.7 million vehicles per day) (USDA Forest Service, 1999b). Many of these roads were designed to handle local traffic or traffic from timber harvesting operations. A large portion of these roads were constructed simply to serve as access into stands for management purposes when alternative approaches to access areas may have been more effective and environmentally acceptable.

One alternative in road management is to limit the effects of new roads on the environment by making sounder decisions in road building. Stricter decisions will lead to the construction of only those roads necessary to promote multiple uses and sustained yield. Additional considerations, not considered in the past, have become the focus of the planning process for road building. The environmental, aesthetic, and social cost must enter into the road planning process.

Road Construction and Maintenance Standards

As mentioned above, many of the existing roads in the National Forest system were built for a single intended purpose and not for multiple uses. This fact presents one of the major problems with the existing road system: below-standard roads used for greater traffic volumes than they were designed to handle. Increased recreational use has led to roads being used for purposes not intended when they were constructed. The combination of increased traffic and below-standard roads has led to safety and environmental concerns that must be resolved in road planning and management. Minimum-standard or below-standard roads can result in accelerated soil erosion losses and mass failures, which can lead to sediment introduction into the nation’s waterways. The impact of sedimentation on the nation’s waterways was not a major consideration when these roads were constructed (Swift and Burns, 1999) and has resulted in many of the environmental concerns related to forest road management.

Once the decision to construct a new road has been made, it is important to consider the construction standards involved to serve the purpose intended. Commonly, Forest Service roads are designed by a team made up of engineers, soil scientists, and other natural resource specialists. However, this has not always been the case. For example, many roads in the National Forest road system were inherited from previous ownership. As a result, some of these roads are more than 100 years old and were not built to current construction standards or BMP recommendations (Swift and Burns, 1999). Many of these roads were constructed along streams because this was often the easiest and quickest route, and soil and water conservation was not a consideration. Consequently, management of these poorly planned and located roads to reduce environmental impacts is a major focus of public land managers.

Upgrading and Decommissioning Roads

Perhaps the most acceptable alternative to manage forest roads for soil and water protection is upgrading the most critical roads. Since some kilometers in the National Forest road system are below standards acceptable today and fail to incorporate sustainable sediment control practices, it only seems reasonable to upgrade these roads first. Upgrading critical roads would allow more efficient use of the maintenance funding. The new RMMS provides the framework for improved management of forest roads, with soil and water protection as a major consideration. Improved management of roads provides access to areas for management and at the same time gives recreational users access to their public lands. Two concerns arise associated with this alternative: (1) how to identify and manage critical roads, and (2) how to manage non-critical roads. The RMMS assigns levels of maintenance to the road network in an attempt to address the concerns associated with this alternative.

Identifying critical roads is not as straightforward as it may seem on initial investigation. Roads critical to the Forest Service for forest management are not necessarily the same roads that are critical to the public for recreation. Non-critical roads have perhaps greater environmental impacts than critical roads because maintenance is typically less intensive on these roads, which can result in accelerated erosion losses. Decommissioning unneeded roads has gained support in recent years. Decommissioning can take place on several levels, which range from road closure by locking gates to complete removal of the road and re-contouring the slope. In some regions, road decommissioning has been met with fierce opposition from local communities and leadership. Historical use of roads, no matter their condition, is viewed by many as a public resource and their closure as an infringement on the public's right to access. In addition, the idea of decommissioning roads has received attention in the scientific community regarding the sustainability of this alternative. Past investigations have shown that roads continue to produce sediment whether traveled or not, and poor maintenance can result in greatly accelerated soil erosion losses (Grace, 1999, 2002b, 2005a). However, total removal of the road from the landscape can cause accelerated erosion loss in the short term (Switalski et al., 2004), and the risk of mass failure may exist (Luce et al., 2001). Hence, road decommissioning is a multi-dimensional issue. Additional roads research is required to determine the effect of upgrading, decommissioning, or removing roads as a basis for sound policies relating to road management for soil and water protection.

Reducing the Impacts of Existing Road Systems

Sustainable development and management of forest road systems for multiple uses while protecting natural resources requires a holistic approach to address issues related to road management. That is, sustainable development not only depends on administrative controls as defined by the RMMS but also requires engineering controls that focus on designs for storm runoff and sediment control alternatives. This combination of administrative and engineering controls can minimize the impacts of the existing road system while providing forest access necessary for multiple uses.

Engineering controls represented by alternative road designs, such as broad-based dips and outsloping, have been explored in previous research (Packer, 1967; Cook and Hewlett, 1979; Swift, 1985; Kochenderfer and Helvey, 1987). Designs proposed to minimize the impacts of forest roads have a common element, runoff control. The objective of runoff control is to direct water from the road prism at a non-erosive velocity. This reduces the energy of storm runoff and its ability to detach and transport soil particles. Broad-based dips are a runoff control design feature that minimizes erosion on the road surface by intercepting storm runoff and dispersing it across the forest floor. Outsloping is another design feature proposed to minimize erosion on the road surface by dispersing the storm runoff across the fillslope and minimizing flow concentration in the roadside ditch. Previous investigations of both of these design features have shown variable results (Haupt, 1959; Cook and Hewlett, 1979; Eck and Morgan, 1987; Kochenderfer and Helvey, 1987).

Reducing the impacts of existing road systems also requires erosion control or soil stabilization, i.e., reducing soil erosion from the road surface, sideslopes, and ditches. Erosion control practices have been a consideration in forest road management as early as the 1930s (Hursh, 1938, 1939) and have become common practice in road management in recent years as a result of recent studies covering a wide range of geographic areas (Cline et al., 1981; Swift, 1984; Burroughs and King, 1989; Benkobi et al., 1993; Foltz, 1999; Grace, 2000, 2002b). These previous studies focused on techniques to minimize soil migration from the forest road prism, which is perhaps the most important element in minimizing environmental impacts.

However, reductions in soil erosion losses achieved through runoff control and soil stabilization techniques may not always be environmentally acceptable (e.g., in areas that may contain sensitive terrestrial or aquatic species). In those situations, sediment and storm water control practices are essential to reducing the quantity of sediment introduced into forest stands and available for transport directly to stream systems. Sediment control practices are installed in the path of sediment-laden storm runoff and are used to capture sediment as close to the source (e.g., the road prism) as possible (Grace, 2002c). These practices vary in efficacy and may include sediment basins, fences, traps, barriers, containment structures, dams, and inlet protection. Silt fences and sediment barriers (hay bale barriers) are typically the most common practices used in forest road applications.

Summary

In summary, the National Forest road system is the artery that supports public recreation, which has become the primary use of public lands. The pattern of use of National Forest roads for recreation has increased dramatically since the late 1940s and is expected to continue to increase beyond the rates observed today. Administrative controls have been employed in efforts to minimize the impacts of forest roads on the forest landscape by relieving traffic pressure on non-critical roads and improving road maintenance procedures. In addition, research investigations continue to evaluate engineering controls related to the effect of alternative road designs on soil erosion.

Research over the past 60 years indicates that traffic intensity and maintenance are two of the primary causes of erosion from forest road surfaces. Maintenance prescriptions have been developed and continue to be refined based on previous research. However, previous research fails to fill critical gaps in understanding the relationship between traffic and maintenance on sediment movement. Traffic intensity, road maintenance, and the interaction between traffic and maintenance on unpaved road surfaces are issues that have to be explored for the development of designs and practices that minimize sediment movement from road systems. In addition, increased traffic pressure on the forest road system can influence the frequency of the maintenance required to satisfy road management objectives. Maintenance intensity in turn affects maintenance costs in forest road management. Development and evaluation of alternative approaches to control sediment movement from forest road surfaces while reducing maintenance intensity may provide a solution to prevent degradation of forest soil and water, two of the nation's most valuable natural resources.

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