Managing coastal forest roads to mitigate surface erosion and sedimentation: An operational perspective

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People in British Columbia have long been concerned about soil erosion from forest roads and how it can threaten water quality. To address this concern, the Forest Practices Code of BC Act (FPC) set out regulations that address ways to minimize the potential for timber harvesting activities to cause catastrophic and short-term mass wasting events. The code does this by requiring resource extractors to conduct soil erosion field assessments and terrain stability field assessments before they build roads within community watersheds.

While industry in British Columbia has routinely conducted terrain stability assessments, the same diligence has not been applied to soil erosion field assessments. A recent audit (Younie, 1999) revealed that industry had failed to complete approximately 60% of the soil erosion field assessments that FPC legislation required.

The problem? Compared with the clear expectations set out by government and professional organizations for terrain stability field assessments, industry personnel indicated that the FPC lacks this clarity when it comes to soil erosion field assessments. This has caused confusion and has led to poor implementation of applicable regulations. Given that chronic soil erosion can have adverse impacts on drinking water supply over a much longer term than mass wasting events, it is imperative to define best management practices (BMPs). BMPs minimize erosion and sedimentation within a set of guidelines designed to avoid confusion and facilitate implementation of existing regulations. This article describes such mitigation techniques and strategies, focusing on chronic surface erosion and sedimentation processes based on thirteen case studies in British Columbia's coastal region.

Watershed managers have identified forest roads as the primary source of chronic sediment mobilization, regardless of region. This article is based on a project that addressed chronic surface erosion and sedimentation in coastal situations only. However, the processes we discuss are also of significant concern in the interior of the province, and many of our suggestions apply equally well to interior forest roads. Readers should note that episodic mass movements (i.e., earthflows, landslides, debris flows, etc.) are beyond the scope of this discussion.

We acknowledge, however, that surface erosion from forest roads can also be episodic in nature; plugged culverts, for instance, may lead to mass movements with subsequent erosion of exposed soils. In addition to degrading drinking-water quality, high sedimentation rates can also harm fish—fine sediment clogs gills, obscures prey, and fills gravel interstices, resulting in decreased oxygen availability and waste removal for developing fish embryos. Excessive turbidity may impact productivity of aquatic habitat by reducing the total amount of solar radiation it receives. Managing sediment from all forest roads is therefore critical, and it is this issue that we address here.

Our first objective is to identify realistic best practices for sedimentation and erosion control associated with management of coastal forest roads. Secondly, we hope to encourage road construction personnel to adopt a technically sound approach to constructing forest roads on the coast. One of the original aims of this project was to develop a guidebook to support soil erosion field assessments under the FPC. With the move towards a results-based code, we hope that the approach we put forward here will become part of industry's suite of best management practices (BMPs), and that industry personnel will implement these routinely as part of their due diligence obligation.

Study Area

We have used thirteen case studies to illustrate the range of sedimentation and erosion control problems that arise in coastal B.C., as well as the mitigation techniques appropriate to these problems. We chose gravel forest road networks in the vicinity of Mission, Vancouver, Gibsons, Sechelt, and Powell River. We made no attempt to compare roads with similar ages, maintenance schedules, or construction standards—we simply wanted to alert people to typical problems and solutions. The study areas are within the Coastal Western Hemlock Biogeoclimatic Zone and the Georgia Basin Hydrologic Zone. Mean annual temperatures for the area are approximately 10°C with mean annual precipitation ranging from 1250 mm to 3000 mm, depending on elevation. The elevation of the thirteen case studies was generally below 500 m.

For each case study, Carson (2002) estimated:

- surface erosion that had occurred
- surface erosion that would likely occur
- sediment transport from the road segment to streams
- impact of road segment on water quality of streams
- effectiveness of mitigation works present at the site

Observed Results

Results of the case studies indicated that it is critical to consider physical and hydrological conditions when designing, constructing, and maintaining roads. Case studies demonstrated that it is possible to design, construct, and maintain even potentially high hazard road alignments to prevent degradation of water quality. Study results confirmed that those working in the field are aware of and use the majority of these sediment and erosion control techniques. The result is adequate protection for water quality, primarily as a result of the use of these techniques. We indicate in Figure 1 many of the various mitigation techniques we observed at the sites. Which technique is appropriate at a given site depends on the physical situation (e.g. soil type, hydrology, and availability of slash, rock, etc.).

The study results also demonstrated that the amount of erosion generated from a road segment did not always provide a reliable measure of the segment's effect on stream water quality. The most important factors that influenced road segment impact on stream water quality in the case studies included:

- the amount of fine sediment the road generated,
- the amount of surface and subsurface water the road concentrated, and
- connection between road drainage and natural drainage.

The study suggests that it is essential to understand the inter-relationships between the three factors at each road segment. In particular, some case studies demonstrated that water quality impacts were significant only when considered in the context of all three factors. In these cases, segment assessments in isolation of the other two factors would have suggested no apparent impact. Moreover, to assess the impact of each of these factors on a particular road segment requires evaluation of other parameters. For example, an evaluation of the fine sediment supply requires knowledge of specifics such as the amount of vehicle use, the age of the road, erodibility of the sediment, and hydrology.

Management Implications

The common message drawn from our thirteen case studies was that road builders can mitigate soil erosion through careful design, construction, and maintenance of roads in accordance with mitigation techniques that are well described in existing guidebooks (Ministry of Forests 2002a; 2002b) and technical documents (Ministry of Forests 1980; Ministry of Forests 2001) (Figure 1). As the case studies show, satisfactory mitigation is achievable with a sufficiently strong commitment on the part of personnel.

The Forest Practices Code stipulated that a qualified registered professional complete soil erosion field assessments prior to road construction within community watersheds. These assessments are important, particularly for initial design considerations. However, our analysis suggests that road construction personnel should place a greater emphasis on information they can gain by walking the road alignment, both during and after construction, especially in wet conditions. These additional assessments will allow personnel to identify problems and implement any necessary mitigation. Following this protocol when working in sensitive areas (i.e., community watersheds, streams with downstream fish values) ensures that field workers can readily observe and understand unique site conditions and the interactions between hydrology and surficial materials. This understanding will result in a well-built road that should not require a significant amount of maintenance over the long term.

Techniques that worked extremely well in the case studies to mitigate surface erosion from road segments on the coast included the following:
(Note that the road shown in Figure 1, on page 12, features several of these techniques in use. The illustrated techniques are numbered 1-6 in the list, and are so marked in the figure.)

- Use coarse ballast for road surfacing and ditch lining near streams (1)
- Use overland construction techniques wherever possible, but especially in areas with groundwater tables at or near the surface
- Disconnect ditches from stream crossings by frequent use of cross ditches or drainage culverts, allowing water and sediment to be trapped by the forest floor (2)
- Construct bridge running surfaces slightly above grade of approaching roads where possible, and armour approaches with non-erodible ballast (3)
- Use swales in road as perennial water bars (4)
- Disperse all ditch and surface water rather than concentrating it
- Avoid traffic during wet conditions
- Outslope roads as much as possible
- Revegetate promptly using hand or hydroseeding to reduce sediment supply and to minimize need for culvert and ditch cleaning operations (5)
- Maintain cutslopes at mechanically stable angles (6)
- Maintain a rough surface on cutslopes, ditches, and fill-slopes to promote natural revegetation-smooth surfaces do not allow seeds to collect

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- Sort, store, and seed spoil materials for use in deactivation at a later time
- Keep spoil materials out of riparian management areas
- Minimize right-of-way width at stream crossings

The above list is not exhaustive and not all techniques will be relevant in all situations. In particular, we have omitted silt fencing from the above list as our experience shows that it is rarely installed correctly and requires constant maintenance. Silt fencing is useful in some instances for short-term sedimentation control, but we do not consider silt fencing to be an appropriate long-term solution. Our goal is to implement practices that are effective at controlling erosion and sedimentation in both the long and short term.

In general, road construction personnel are familiar with the techniques we found to be effective—most are defined well in existing guidebooks and technical circulars. In case studies where we identified problems, road construction personnel had seemed reluctant to employ these techniques. This reluctance appears to be commonplace on the coast, regardless of factors such as the age of the road or the site characteristics. We have found that the most important factor in determining the end result of a new forest road is the commitment of road construction personnel to implement these techniques.

A critical component of this system is its use within the context of adaptive management. This system is designed to be consistent with the framework of the new Forest and Range Practices Act. While addressing potential soil erosion problems may increase operational costs in the short term, such costs will not be prohibitive. Experienced road construction personnel suggest that a well-designed, well-built road will cost less over the long term. For example, a road with successfully revegetated cutslopes and ditches will remain stable, eliminating the need for frequent unplugging of culverts and ditch cleaning.

In sensitive areas, controlling surface soil erosion is essential, and public expectations of management frequently centre on adequate protection of non-timber resources. If we fail to manage roads adequately, public opinion may lean toward denying resource-management opportunities.

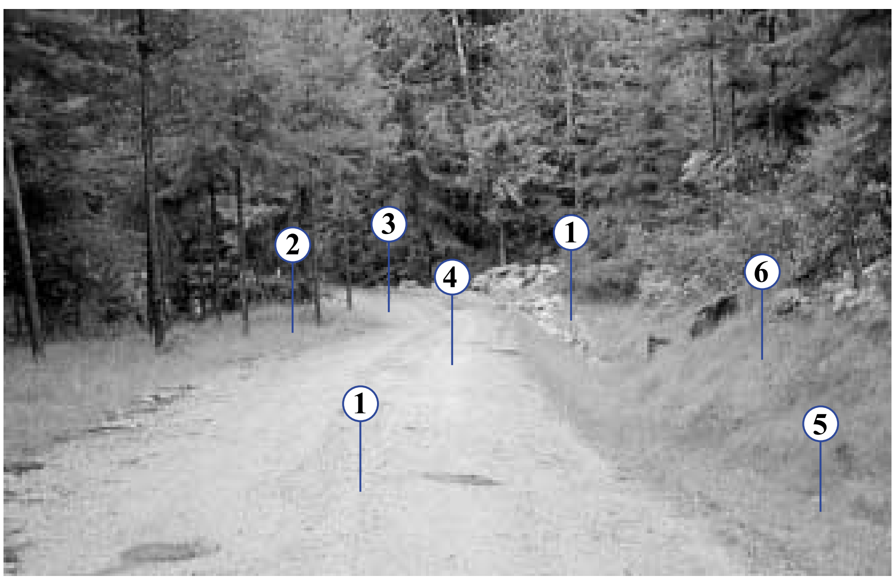

Figure 1. Effective mitigation techniques

Project Extension and Evaluation

We have planned a variety of extension activities designed to heighten awareness of effective road management practices. One of these, an interactive CD, will highlight the importance of sediment and erosion control. In addition, the CD will list a variety of mitigation techniques and will describe the best management practices that form an important component of the new results-based Forest and Range Practices Act. When complete, the CD will be available free of charge to those involved with designing, constructing, and maintaining forest roads. Please contact the authors for your copy.

Other extension products include articles and presentations at various conferences including the International Erosion Control Pacific Northwest Chapter Annual Conference and the 56th Canadian Water Resources Association (CWRA) Annual Conference.

We anticipate that the Ministry of Water, Land and Air Protection, as part of its monitoring role, will conduct a follow-up audit to the project on which this article has been based. This audit will evaluate project and extension product success. The long-term goal of the government is to confirm that industry personnel, when they are constructing and managing forest roads in coastal British Columbia, are routinely implementing sediment and erosion control measures that are effective in protecting water quality.

Summary

Three important factors to consider when assessing sediment production potential are the amount of fine textured sediment, the nature of water flow at the site, and the connection between road drainage and natural drainage features. We found that existing guidebooks and technical circulars provided good

Carson (2002) has designed a five-step system for managing forest roads to reduce water-quality impacts in sensitive areas. The following is a partial list featuring highlights of the five steps in this system:

1. Plan Road Layout

Communicate with water licensees.

Acquire and study applicable terrain information.

Budget for costs associated with best management practices.

Thoroughly review road layout in the field and identify areas that will require mitigation techniques.

2. Design Road

Design road according to expected use. Consider temporary roads in places where roads will not be required after harvesting is complete (i.e., spur roads).

Dissipate rather than concentrate water through frequent culverts, swales, and cross ditches.

Maintain separation between road drainage and natural drainage wherever feasible.

3. Construct Road

Use contractors with good performance records.

Implement best management practices: coarse ballast, operational shut down criteria, etc.

Identify segments of roads as individual catchments in relation to natural drainage.

Remain flexible: road design may have to change as previously unidentified site conditions arise. Allow experienced construction personnel the freedom to manage.

4. Operate and Maintain Road

Ensure that culverts and ditches are functional.

Implement best management practices: operational shut down criteria, cross ditches and water-bars, etc.

Ensure grading operations do not have adverse impacts on water quality.

5. Monitor and Evaluate Road

Initiate and support a water-quality monitoring program.

Monitor roads in wet weather.

descriptions of techniques that our observations confirm are appropriate for sedimentation and erosion control.

Our results indicate that it is possible to protect water quality from road-related sediment; however, this requires a strong commitment on the part of road construction personnel, who must use best management practices appropriate to site conditions. While these practices may result in slightly higher costs in the short term, our analysis of results achieved in case studies suggests that over the long term, a properly designed and built road will have lower maintenance costs than a poorly constructed road.

Implementation of the five-step process we've described above will help to maintain water quality, meeting the needs of human and fish populations while allowing resource extraction to continue.

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