# Forest Roads, Drainage, and Sediment Delivery in the Kilchis River Watershed

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# EXECUTIVE SUMMARY

This report describes the forest road system in the Kilchis River watershed. This inventory was generally conducted prior to major storms in 1995–96. The objective of this study was to determine the relative potential for forest roads to deliver sediment to the watershed. Roads were then reinspected to identify landslides and washouts. The study was designed for use in a watershed analysis of sediment delivery for the forested portions of the Kilchis River watershed.

Because of the significant alteration to slopes and channels, roads, rather than timber management, are the primary source of sediment from forest management activities in the west (Megahan and Ketcheson 1996). There are two ways to mitigate sediment delivery to streams: (1) reduce the volume of erosion through on-site control practices; and (2) reduce sediment delivery by increasing sediment retention on the hillside (Megahan and Ketcheson 1996).

Because of the high potential for sediment delivery to streams, many forestry best management practices deal with road construction and maintenance. A "best management practice" is a practice or combination of practices that, after problem assessment, examination of alternative practices, and public participation is determined to be the most effective and practicable means of preventing or reducing nonpoint source pollution to a level compatible with water quality goals. The State of Oregon regulates forest road construction and maintenance through the forest practice rules.

Research conducted over the last 40 years in the Pacific Northwest has investigated ditch erosion, condition of drainage structures, surface erosion, hillslope erosion, landslides, sediment travel and delivery, turbidity, and sediment budgets as related to forest roads. Over the period of this research, there have been major changes in accepted road management practices, and also major differences in year to year climate. Geology and soils also vary tremendously around the region. Therefore, quantitative results of any one study may have only very limited applicability to roads in the Kilchis River watershed.

Most of the forest roads in the basin were constructed between about 1920 (old railroad grades) and 1970. Roads have also been constructed over the past twenty years in the lower third (unburned) portions of the basin. A large but unknown percent of the old roads have been abandoned, and are no longer driveable or easily identified as roads.

Every "official" forest road (those used for forest management purposes since 1972) in the Kilchis watershed, or with drainage directed to the Kilchis watershed, was driven or walked to collect the necessary data. The field survey gathered information on: (1) general road characteristics; (2) the condition of surveyed roads in locations where sediment is generated (between discharge locations); and (3) specific locations of surface water discharges, including potential for sediment delivery to waters.

This survey evaluated 106.7 miles (172 km) of forest roads in the Kilchis River watershed. Twenty five percent of road segment length in the basin clearly delivered (flow and any sediment carried by the flow) to streams, while an additional 14% were given a possible delivery rating; a total of up to 39% possible delivery to channels.

A total of 57 landslides associated with the storms of 1995 and 1996 were identified. Forty-eight of the road- or landing-associated landslides that occurred during the winter of 1995–96 in the Kilchis watershed involved more than 10 $yd^3$ of material. In addition, there were 22 washouts which eroded > 10 $yd^3$ of material.  There were at least another 28 washouts of <10 $yd^3$ volume.

The percentage of the road system delivering sediments to streams in the Kilchis watershed (between 25 and 39%) was lower than the 57.3% reported by Wemple (1994) or the 75% reported by Reid and Dunne (1984).  It was comparable with the 34% reported by Bilby *et al*. (1989).  It was exactly the same as the western Oregon random survey (ODF 1996).  Average segment lengths from stream crossings to the first cross drainages above the stream crossings was 436 ft (133 m), while average spacing for the entire road system was 381 ft (116 m).  This suggests that roads are designed and maintained for efficient delivery of water to channels.  This is in contrast to the current forest practices rules, which require filtering of muddy runoff water through the forest floor.

At the present time, the two principal surface erosion concerns in the Kilchis basin are:

1. excessive length of ditches routed to deliver sediment directly to channels, and

2. steep gradient roads (≥13%) with excessively spaced cross-drainage structures.

Landslides and washouts are clearly the dominant erosional processes associated with forest roads in the Kilchis watershed, especially in years when there are major storms.  Analysis of the road-related landslides data will be conducted with the historical landslides analysis of the Kilchis watershed, and will be compared with the Wilson River Storm of 1996 monitoring study site, as well.

As part of this study and a similar study conducted over all of western Oregon, a road inventories protocol was developed for forest land managers use and to provide information needed in order to prioritize road management decisions, especially maintenance and repair activities.  It is intended for priority use in areas where roads pose higher risks to anadromous fish and their habitats.  This report also includes several specific recommendations for road managers in the Kilchis watershed.

# ACKNOWLEDGEMENTS

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Dr. Arne Skaugset, Assistant Professor of Forest Hydrology at Oregon State University, coordinated protocol development and managed the project. The field surveys were conducted by Kami Ellingson, Keith Martin, Ruth Willis, and Steven Schmidt. Special thanks go to Kami for her diligent efforts with the global positioning system and in helping prepare this report. Data analysis was performed in large part by Keith Martin.

# FOREST ROADS, DRAINAGE, AND SEDIMENT DELIVERY IN THE KILCHIS RIVER WATERSHED

## Introduction

This report describes the forest road system in the Kilchis River watershed. All official forest roads in the watershed were inspected on site. For this study, a forest road is any road that has been used for forest management activities since 1972 (the legal interpretation recognized by the Oregon Forest Practices Act). This survey did not include roads abandoned before 1972. There are many miles of abandoned road grades in the Kilchis watershed.

Road system elements that either produce or control sediment delivery were measured or categorized. This inventory was generally conducted in the summer of 1995, prior to major storms the following winter. The objective of this study was to determine the relative potential for forest roads to deliver sediment to the watershed. These roads were reinspected during the summer of 1996 to identify landslides, washouts, and conditions associated with damage caused by storms.

The study was designed for use in a watershed analysis of sediment delivery for the forested portions of the Kilchis River watershed. This report will provide information relevant to two of the three goals of the Tillamook Bay National Estuary Project, which are to: "protect and enhance anadromous fish habitat" and "restore the bay from the impacts of sedimentation." This study is intended to compliment a historical analysis of landslides in the Kilchis watershed (in progress).

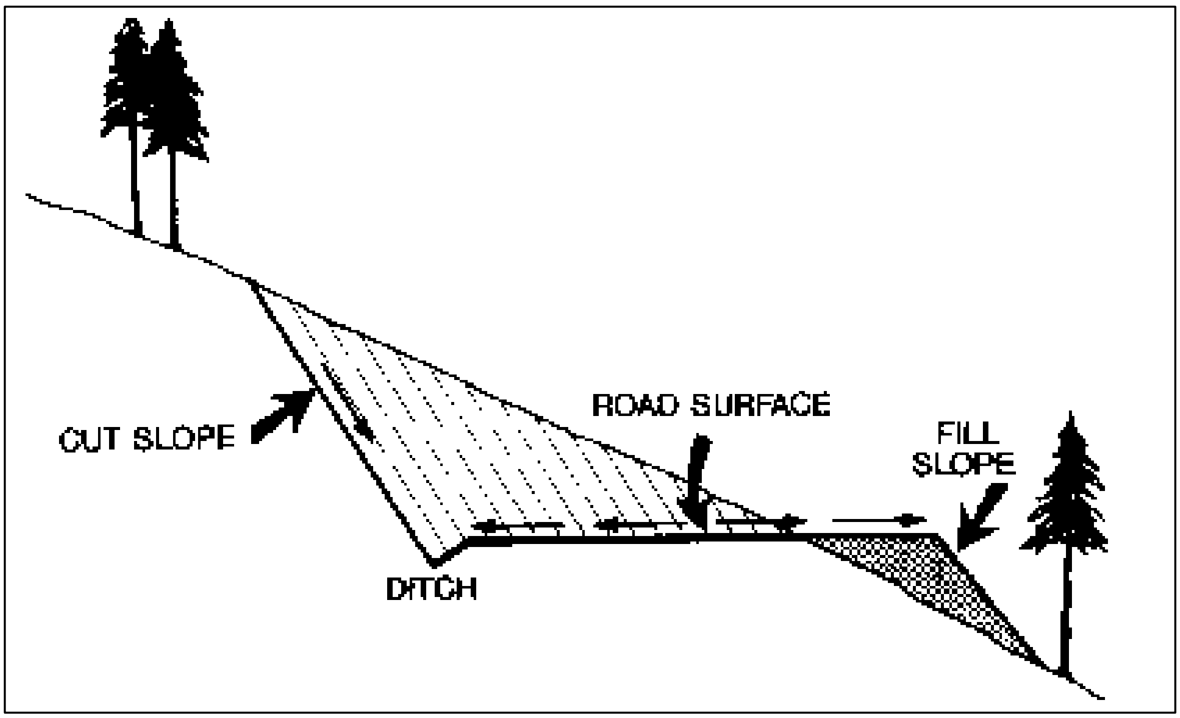


**Figure 1. Typical Cross-Section (Prism) of a Forest Road.**

## Roads, Erosion, and Sediment Delivery

Roads create a contiguous linear physical alteration to hillslopes, as shown in Figure 1. To create the running surface, or tread, it is necessary to excavate into the natural hillslope. Normally this excavated material is used as fill, to make a portion of the running surface. Both cut and fill slopes are steeper than the natural slopes, and, at least for some period of time after construction, are unvegetated. Cut and fill slopes have a higher erosion potential than the native hillslopes, both because of the steeper slope and because of the exposed, relatively loose soil. On steeper hillslopes the risk of mass erosion (landslides) from roads is also elevated.

Roads also alter the flow of water. Road cuts may intercept groundwater, and the road surface normally collects surface water. This water is routed down the road to a location where it is discharged away from the road. Roads must also cross streams. Most stream crossing structures are culverts. During high flows, stream flows can exceed culvert capacity. When culvert capacity is exceeded, fill washout or channel diversion may occur. Drainage waters remove eroded sediments from the roadway, and sometimes into streams.

Traffic on gravel surface roads also increases the potential for sediment delivery to streams. Reid and Dunne (1984) found that sediment yield from road surfaces in western Washington on actively used logging roads was 1000 times that of the yield from abandoned roads (up to 500 tons/km). However, a separate study found that sediment yield from secondary roads was 10 tons/km of road, while for active roads it was 26 tons/km (Bilby *et al*. 1989). This is an order of magnitude difference from Reid and Dunne (1984), even though the studies were conducted on areas of similar geology and climate. Sediment delivery to streams is extremely variable, depending on traffic levels, quality of road surfacing, climate, drainage design, maintenance practices, and other factors.

## Road Management Practices

Because of the significant alteration to slopes and channels, roads, rather than timber management, are the primary source of sediment from forest management activities in the west (Megahan and Ketcheson 1996). There are two ways to mitigate sediment delivery to streams: (1) reduce the volume of erosion through on-site control practices, and (2) reduce sediment delivery by increasing sediment retention on the hillside (Megahan and Ketcheson 1996).

Because of the high potential for sediment delivery to streams, many forestry best management practices (BMPs) deal with road construction and maintenance. A "best management practice" is a practice or combination of practices that, after problem assessment, examination of alternative practices, and public participation is determined to be the most effective and practicable means of preventing or reducing nonpoint source pollution to a level compatible with water quality goals.

The State of Oregon regulates forest road construction and maintenance through administration of forest practice rules. These rules address the following topics:

- activities requiring prior approval by the State Forester;
- road location;
- design of the road prism, stream crossing and drainage structures, and waste disposal areas;
- construction practices including disposal of waste, drainage stream protection, and stabilization;
- development, use, and abandonment of rock pits and quarries;
- road maintenance; and
- vacating forest roads.

Applicable rules are found in OAR 629-625-000 through 629-625-650, and are included as Appendix 1. Specific practices required under these rules include: road location away from streams, the steepest slopes, and unstable areas; cut and fill slopes designed at generally stable angles; design of stream crossing structures for the 50-year flow with no ponding behind the fill; control, dispersion, and filtering of drainage waters; revegetation and stabilization of exposed soil; and maintenance of the road surface and drainage structures.

## Studies on Road Erosion

Research conducted over the last 40 years in the Pacific Northwest has investigated ditch erosion, condition of drainage structures, surface erosion, hillslope erosion, landslides, sediment travel and delivery, turbidity, and sediment budgets as related to forest roads. Over the period of this research, there have been major changes in accepted road management practices, and also periods of major storms, and relative periods of climatic calm (storms drive much of the potential for erosion from roadways). Geology and soils also vary tremendously around the region. Therefore, quantitative results of any one study may have only very limited applicability to roads in the Kilchis River watershed.

Ditch erosion was the major factor used to recommend culvert spacing in guidelines developed for the USDA Forest Service (Arnold 1957). These guidelines were developed based on experience with roads in the Cascade Mountains. Piehl *et al.* (1988) evaluated ditch relief culverts in the central Coast Range (Lincoln to Coos Counties) and compared culvert spacing to that recommended by Arnold (1957). The Piehl study found that actual culvert spacing averaged 1.7 times that recommended by Arnold (1957), and also found average outlet erosion of 0.7 $m^3$ associated with each ditch relief culvert (excluding two landslides which together resulted in twice the erosion volume of all the surface erosion combined).

Generalized surface erosion from roads has been evaluated by many studies (Bilby *et al.* 1989; Burroughs and King 1989; Ketcheson and Megahan 1996). These studies found that most surface erosion from forest roads occurs in the first year or few years after construction (Ketcheson and Megahan 1996). Sediment production from roads is extremely variable, depending in part on local climate, soils, geology, landform, and relative disturbance by the road of the hillslope and channels. Even within a single study location, in one case the southwest Idaho batholith, researchers found from 6 to 49.5 $m^3$/ha/yr of sediment production on average; and from 1.9 to 149.9 $m^3$/ha/yr over the four years of the study (Ketcheson and Megahan 1996).

Most of the studies which have evaluated sediment production from roads have taken place during periods of normal precipitation. How estimates of sediment production from other regions conducted during more typical weather relate to the Kilchis River is unclear, especially when considering the extreme storms of November 1995 and February 1996. Large, infrequent storms tend to produce landslides and washouts. It is generally not possible to reliably sample sediment movement associated with landslides and washouts during such large storms. Erosion volumes from landslides and washouts are generally based on site-specific measurements which estimate dimensions of the remaining void.

An ongoing study is investigating surface erosion from forest roads in the central Oregon Coast Range west of Eugene (Black, T. Personnel Communication 1997). In this study, segments of road were carefully selected to evaluate the influence of basic road design parameters on sediment production. Sediment production was measured using water bars on the road surface which routed all sediment into large plastic bins (sediment traps). For most of the sample plots in this study, cutslopes were cleared of vegetation. This was done in order to reflect conditions more typical of new roads. Preliminary results found sediment production to be less than expected, at least based on the results of other studies. Average sediment production varied from 60 kg for untreated roads, and 391 kg for roads with disturbed cutslope and ditch (plots were 40 to 110 meters in length). Plots with coarser soil (gravelly loam) produced about nine times less sediment than plots where soils were mapped as silty clay loam.

Prevention of eroded material delivery to streams is the main objective of most BMPs. Eroded materials can be transported to streams or hillslopes. The volume of erosion and obstructions on the hillside have the greatest influence on sediment travel below all points of discharge, while hillside steepness and runoff source area also affect sediment travel distances below culverts (Megahan and Ketcheson 1996). Bilby *et al.* (1984) concluded that the most effective and least costly approach to stream protection was to drain ditches onto the forest floor. Forest soils of the Pacific Northwest typically have very high infiltration rates. When muddy runoff is diverted onto uncompacted soils, water flows into the soil, leaving the sediment on the hillslope. This process ceases when soils become saturated and overland flow occurs. The more water directed onto the hillslope, the more likely overland flow will occur.

Only a portion of material eroded from the road prism enters streams. The remaining materials are stored somewhere in the road prism, or on hillslopes below the roadway. Sediment delivery to streams depends on the percentage of the road drainage system discharging directly into streams; the proximity of nonstream discharges to channels; the volume of water and the potential for gully development (stream extension); and the volume of eroded material available. Reid and Dunne (1984) found that 75% of road drainage in their western Washington study site was discharged directly to streams, while Bilby *et al.* (1989) found that 34% of road drainage points flowed directly to the channel. Wemple (1994) found that 57.3% of road drainage in the Blue River area of the western Cascades, Oregon, either delivered to channels or gullies.

The major concern with sediment is its effect on streams and water quality. Stream effects include possible increases in fine sediment deposition in gravel (used for fish spawning; increased water turbidity; and downstream channel aggradation and associated changes in channel morphology. Oregon has a state water quality standard for turbidity and a general antidegradation policy that applies to the other water quality and channel effects.

Bilby *et al*. (1989) found that 21% of the annual sediment load at their study site was due to road erosion. They also found peak turbidity below the road of 110 nephelometric turbidity units (NTU) and of 40 NTU above the road. Additionally, most sediment was fine (typically very grained silts which generally moved through the channel system without significant deposition). Turbidity is an extremely variable parameter, and normally cannot be directly related to sediment loading (Anderson and Potts 1987).

Landslides and washouts are generally the most dramatic means by which road sediments are delivered to streams. Landslides are movements where shear failure occurs on a surface or combination of surfaces, and a mass of soil, rock and/or debris (rather than a particle) moves downslope. Washouts are fluvial processes where streamflows either overtop fills or are diverted down roads, resulting in significant erosion of the roadway and high sediment delivery to channels.

In areas with steep slopes, landslides are the dominant erosional mechanism. Landslide frequency can be greatly accelerated by road management practices (Sidle *et al.* 1985). Megahan and Kidd (1972) found that 70% of accelerated sediment production in an Idaho batholith study site was associated with road related landslides. Piehl *et al.* (1988) identified that only 2 landslides at culvert outlets comprised 72% of the total outlet erosion associated with 515 cross-drainage culverts.

Road construction on steep slopes requires significant excavation into and further steepening of these slopes. For traditional road construction, excavated material is used as a fill to make the outside edge of the roadway. The resulting cut and hillslopes are always, by simple geometry, steeper than the original, natural slope. With other factors being equal, the steeper the slope, the lower the relative stability. Therefore, some increase in landslides is the obvious outcome.

The location of landslide occurrence has a tremendous influence on potential sediment delivery to streams. Landslides affecting the cutslope portion of the road are typically deposited in the road. Cutslope landslides may be eroded by road surface waters, or may divert surface waters away from designed drainage structures. Failures of the fillslope, however, are more likely to become debris flows, increasing in size and then entering channels. Almost all major (delivering sediment to streams) road-related landslides investigated by ODF are related to road fills or road sidecast (Mills 1991).

Sidecast is a term used to describe uncompacted excavated fill material pushed on the downhill side of the road, and not designed to be part of the running surface. Current regulations (OAR 629-625-310(2) and others) prohibit sidecasting to the extent that landslides and channel damages are likely. A technique known as end-hauling is used to transport excess excavated materials to more stable locations. Using steeper grades to keep roads on ridgetops is a far less expensive road construction technique than end-hauling, and is also effective at landslide prevention. However, where this is not possible, end-hauling has been shown to be an effective, albeit expensive, technique for reducing landslides (Sessions *et al*. 1987). Regulations for end-hauling have been in place since 1983. However, most existing roads, especially those in the "Tillamook Burn" were constructed prior to 1983, when sidecasting was the common construction practice.

In 1990, a major storm occurred in the Deschutes River basin in western Washington. A road damage inventory conducted after that storm found that roads constructed in the last 15 years survived the storm with minimal damage, while roads constructed earlier had very high damage rates (Toth 1991). Department of Forestry landslide monitoring has made similar findings (Mills 1991). Therefore, although most surface erosion tends to occur in the first few years after construction or during periods of heavy traffic use, landslides can occur many decades after original construction.

Department of Forestry monitoring has also found that road drainage is associated with about one-third of the investigated road-related landslides (Mills 1991). Culverts were associated with 29% of the damage sites in the Deschutes River study (Toth 1991). Concentration of road drainage can also be associated with integration of road networks and channels in steep terrain, sometimes resulting in landslides (Montgomery 1994).

Culverted stream crossings are subject to plugging and/or capacity being exceeded by high flows. If water backs up and flows over the surface, a washout type failure similar to a dam breaching may occur. When roads climb through the stream crossing, there may be a high potential for channel diversion down the road (Weaver and Hagans 1994). Such diversions can cause large gullies running long distances down the road, and can cause additional landslides and washouts as well.

## Watershed Description

The area of study includes all forest lands within the Kilchis River watershed, and also those roads adjacent to the watershed which discharge drainage waters to the Kilchis basin. The Kilchis watershed is approximately 47,000 acres (19,035 ha). It is located in the northern Oregon Coast Range. The Kilchis

River flows into Tillamook Bay near the town of Bay City. Figure 2 locates the Kilchis watershed in relation to the Tillamook Bay and major streams.

The Kilchis basin is in the Coast Range Georegion (ODF 1997). Hillslopes are typically very steep (60% to more than 100%), except near larger valleys and on scattered bench type landforms. Geologic units are dominated by subaerial and submarine flow basalts, with some intrusive rocks, and fine grained sedimentary rocks near the bay (Wells *et al.* 1994). Rocks are highly sheared and often deeply weathered. Soils are typically shallow and noncohesive.

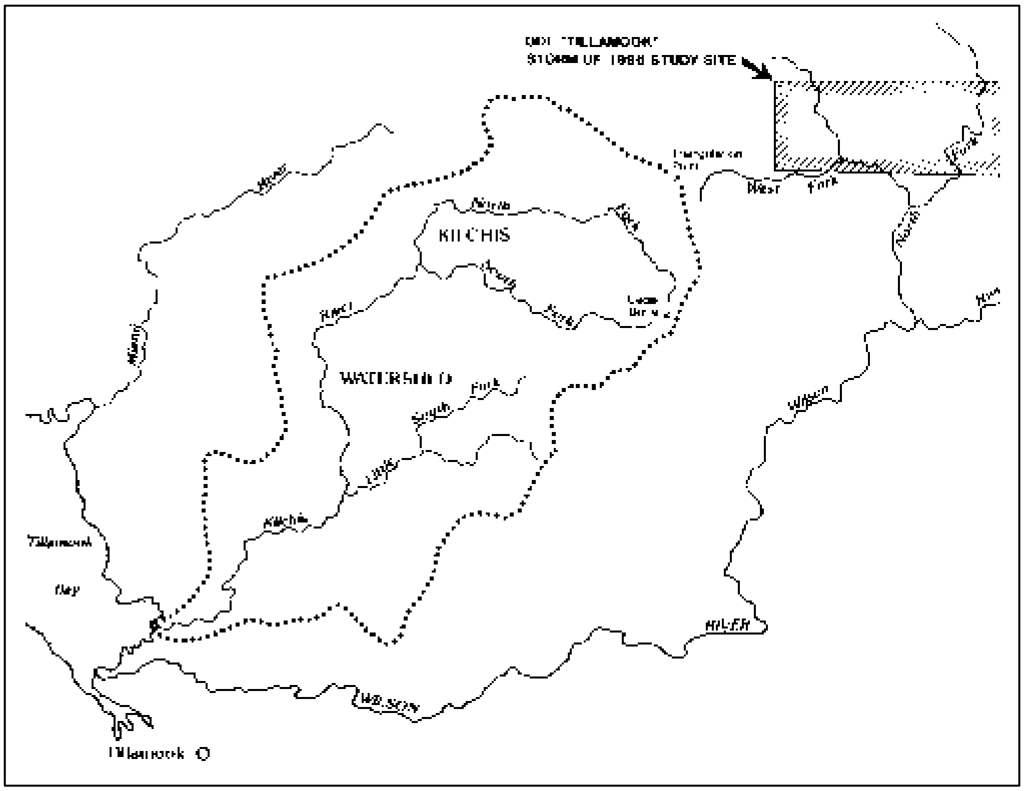


**Figure 2. Study Area Watershed and Location of Oregon Department of Forestry "Tillamook" 1996 Storm Study Site.**

Average annual precipitation varies from less than 100 inches (254 cm) in lowlands near the bay to about 180 inches (457 cm) (Taylor 1993). Major winter storms occurred over this area during November 1995 and February 1996. The November storm was of short duration, < 24 hours, and was most intense in an area between 3 and 8 miles (4.8 and 12.9 km) inland from Tillamook Bay. The February storm lasted four days, and the most severe impacts occurred 12 to 20 miles (19.3 to 32.2 km) inland from the bay (generally east of the Kilchis watershed) and produced upwards of 20 inches (51 cm) of combined rainfall-snowmelt in many locations during this time period.

Most of the forest roads in the basin were constructed between about 1920 (old railroad grades) and 1970. Roads have also been constructed over the past twenty years in the lower third (unburned) portions of the basin. A large but unknown percent of the old roads have been abandoned, and are no longer driveable or easily identified as roads.

Fires played a major role in the erosional processes and management of the upper 2/3 of the Kilchis watershed. The 1918 Cedar Butte Fire and the 1933, 1939, and 1945 Tillamook Fires all burned in portions of the upper 2/3 of the basin. Salvage logging of burned timber in the Kilchis watershed began in the 1950s and continued through the 1970s.

## Methods

### *Development and Testing*

Oregon Department of Forestry's Forest Practices staff initiated a process to scope potential approaches for monitoring forest road sediment BMPs in 1993. Forest Practices staff worked closely with the Forest Engineering Department at Oregon State University (OSU). The monitoring protocol was developed with input from forest landowners, agency personnel, and other interested landowners. This protocol was field tested on 18 miles (29 km) of forest roads in northwest Oregon during 1994.

### *Surface Erosion and Delivery Methods*

Every open forest road in the Kilchis watershed, or with drainage directed to the Kilchis watershed, was driven or walked to collect the necessary data. When possible, a global positioning system (GPS) was used to identify locations of drainage discharge. The field survey gathered information on: (1) general road characteristics; (2) the condition of surveyed roads in locations where sediment is generated (between discharge locations); and (3) specific locations of surface water discharges, including potential for sediment delivery to waters.

### *General Characteristics*

The survey collected the following data to describe the overall road:

1. legal location (section, township, range) and name;
2. forest practices maintenance status (active, inactive, or vacated); and
3. road surfacing material (clean rock, dirty rock, or dirt).

A typical length of road is shown in Figure 3, which illustrates some of the road characteristics investigated during this study.

### *Source Area*

The source area is the length of road draining to any one location. Data were gathered for every segment of road in the survey area. Information collected was designated to evaluate the potential for erosion (sediments generation). Data were collected to describe:

1. the length and average slope of each road segment;
2. road surface shape (crown, inslope, outslope);
3. the condition of the ditch;
4. height and vegetative cover of the cutslope; and
5. the presence of landslides or active erosion sites.

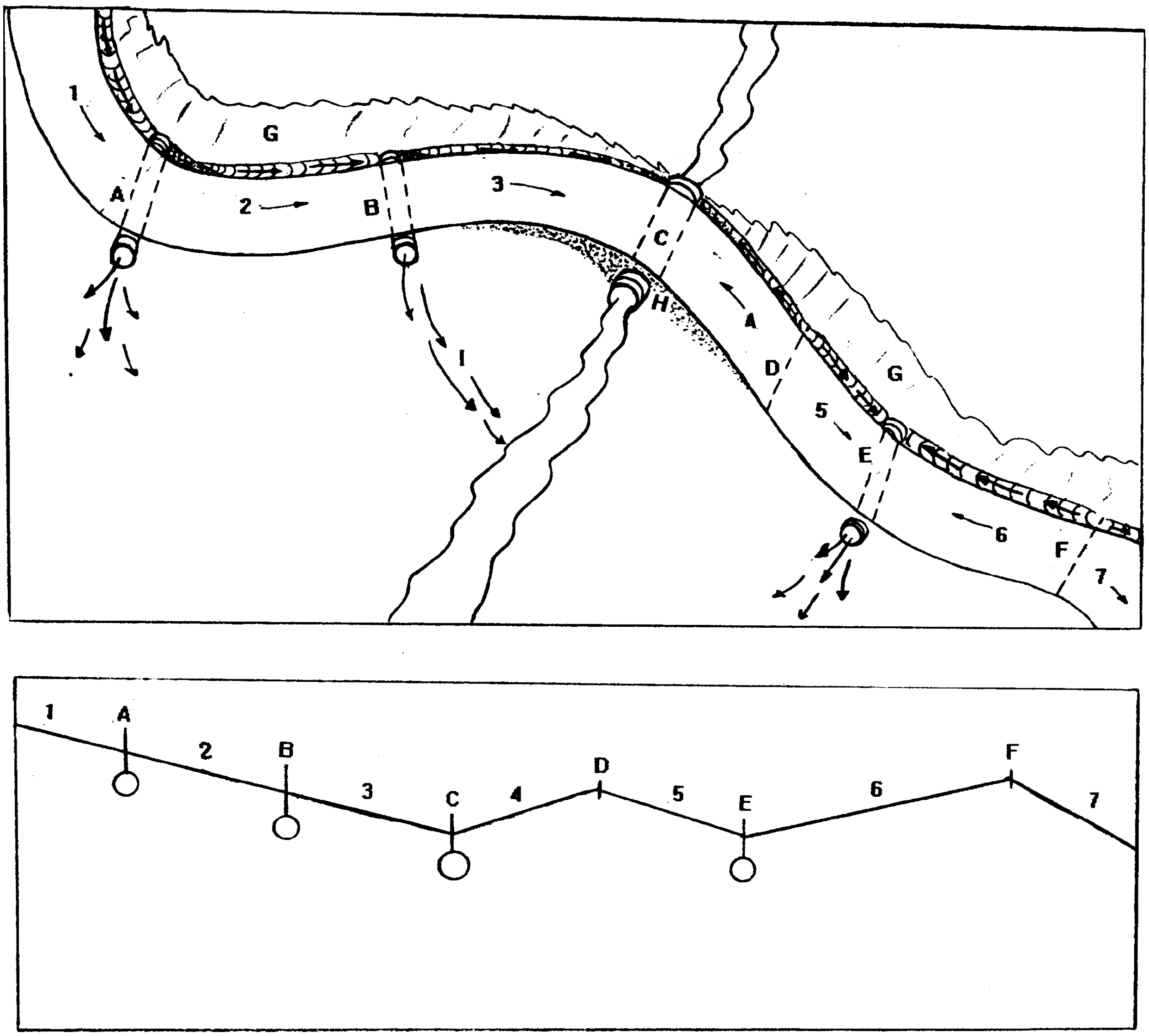


**Figure 3. Typical length of road near a stream showing most elements of the surface erosion-drainage inventory.** A: Cross-drainage culvert with sediment filtering B: Stream crossing culvert C: Ditch D; E: Cutslopes F: Stream crossing fill. Numbers are segments, or portions of segments.

### *Discharge*

Locations of discharges from the road surface included cross-drainage culverts, live stream crossings, waterbars, rolling dips, grade reversals, natural saddles, and random points of discharge. The survey collected information on drainage characteristics and potential sediment delivery at all locations of discharge.

The diameters of all cross drainage and live stream crossing culverts were measured. The condition of the culvert inlet was gaged by estimating what percentage of original culvert area was open. When effective inlet opening was reduced, the principal cause was recorded (mechanical crushing, filling by debris, or age related deterioration).

The outlet or discharge point was evaluated for evidence of flow (delivery) to a waterbody. Discharge directly into a stream was given a "yes" rating for delivery, as was a location which discharged into a gully when the gully entered a channel. Locations where there was with either no erosion or deposition immediately below the discharge were given a “no” sediment delivery rating. Areas with minor erosion for a short, well-defined distance, into a large flat deposition area were also given a "no" sediment delivery rating. All other locations were given a "possible" delivery rating.

### *Data Collection*

Data were collected on site in the field using either a distance measuring instrument (DMI) which records vehicle travel in feet or a hip chain for distance measurements. Slope measurements were made using a clinometer, interpolating average road grade between discharge points when actual road grade was not constant. Data were collected by two student workers under geotechnical specialist supervision. Road surveys were conducted during the summer of 1995. Information was directly entered into a relational database on a personal computer.

Originally, this study was to include limited sampling of sediment movement through discharge structures. This element of the study was eliminated after the storms, since much fine material may have been eroded from the roads, and also because the storm created a unique opportunity to compare road drainage with major storm impacts (landslides and washouts).

### *Landslides and Washouts Resurvey*

All forest roads in the Kilchis watershed were resurveyed during the summer and early fall of 1996 (after the major storms). Road-related landslides and fill washouts were located and mapped. The mode of failures and impacts to the roads were described. Lengths, widths, and depths of the original failure masses were measured. Conditions of the roads including percent of bench and fill, width before and after failure, fill depth at the shoulder, cutslope height, and any other drainage features were described. Geomorphic conditions, including the hillslope steepness above and below the failure were measured. A description of the dominant vegetation, significant wood in the road fill, presence of large amounts of slash, soil type, and delivery to streams are also included in the database.

### *Concurrent Oregon Department of Forestry Studies*

Three studies of relevance to the Kilchis road erosion studies are currently underway. A historical analysis of landslides in the Kilchis watershed is being conducted using aerial photographs and is partially completed. A road erosion study of randomly selected roads throughout western Oregon has just been completed (ODF 1996).

The final study is a comprehensive assessment of landslide and channel impacts which occurred during the February 1996 storm at six locations within the storm impacted area of western Oregon. The Storm of 1996 study included an on-the-ground survey of every channel in the study sites, to identify all landslides which entered channels, and the impacts associated with those landslides. One of these "Storm of 1996" study sites is located in the Wilson River watershed [5 to 10 miles (8 to16 km) east of the Kilchis watershed]. This area has similar geology, landforms, and soils to those found in the Kilchis watershed. This "Tillamook" study site is shown in Figure 2.

An area of 7.75 $m^2$ (12.5 $km^2$) in the North Fork Wilson River watershed was surveyed for landslides and channel impacts during the summer of 1996. A total of 70 landslides which entered channels were identified during this survey. Approximately 75% of the channels in the study site had "high"impacts (typical of debris torrent scour). Of these 70 landslides, 8 were related to active roads, and 15 were associated with abandoned roads and skid roads. The remaining 47 landslides occurred in 30 to 50 year old forests where there was no evidence of physical slope alterations. Total volume of sediment moved by these landslides (initial slope failure and volume of debris flow added) were as follows:

| | | |
|---|---|---|
| Active road landslides | 32,408 $yd^3$ | 41% |
| Abandoned road landslides | 15,720 $yd^3$ | 20% |
| Non-road related landslides | 30,416 $yd^3$ | 39% |
| Total landslide volume | 78,544 $yd^3$ | 100% |

## Results

All "open" roads in the Kilchis watershed were surveyed using this protocol. Most of the surveying was conducted during the summer of 1995, with some resurvey work done in 1996 to fill in data gaps. In addition, all roads were reinspected in 1996 to locate and describe landslides and washouts which occurred during the winter of 1995–96.

There are 563,350 (171,709 m) of "open" forest roads in the Kilchis River watershed [106.7 miles (171.7 km)]. Ninety-five percent of the these roads were classified as inactive (no log hauling), and 96% were rocked (dirty rock classification). Fifty-three percent of the roads were classified as midslope, 25% as valley bottom, and 22% as ridgetop.

### *Drainage Discharges*

Every location where collected waters flowed off or under the road (drainage discharges) was identified and surveyed. The most common type of drainage was a waterbar (21%), followed by stream crossing culverts (19%) and cross-drain culverts (16%) (Table 1). Nonengineered (random) relief made up 16% of the drainage points. There are 18 bridges on forest roads in the Kilchis watershed. A total of 1,202 distinct discharge points were evaluated by this survey.

Twenty five percent of road segment length in the basin clearly delivered (flow and any sediment carried by the flow) to streams, while an additional 14% were given a possible delivery rating for the total of 39% as shown in Table 1.

**Table 1. Summary statistics for drainage discharge points and segment lengths (all lengths in feet).** [Entire survey, and that portion of the survey with obvious delivery to channels.]

| Description | **Entire Kilchis Data Base** | | | | | **Positive Delivery to Channels** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Discharge Points** | | **Discharge Length** | | | **Discharge Points** | | **Discharge Length** | | |
| | **#** | **Percent** | **Length** | **Percent** | **n** | **#f** | **Percent** | **Length** | **Percent** | **# Seg.** |
| Cross-Drain Culvert | 197 | 16 | 122731 | 22 | 228 | 78 | 40 | 52365 | 43 | 95 |
| Live Stream Culvert | 224 | 19 | 106508 | 19 | 255 | 224 | 100 | 106508 | 98 | 255 |
| Bridge | 18 | 1 | 12352 | 2 | 29 | 18 | 100 | 12287 | 99 | 29 |
| Ditch Relief | 49 | 4 | 28851 | 5 | 53 | 7 | 14 | 3503 | 12 | 8 |
| Water Bar | 252 | 21 | 87060 | 15 | 259 | 56 | 22 | 17524 | 20 | 57 |
| Saddle | 10 | 1 | 7907 | 1 | 14 | 0 | 0 | 0 | 0 | 0 |
| Grade Break* | 181 | 15 | 79381 | 14 | 344 | 10 | 6 | 3485 | 4 | 19 |
| Other | 22 | 2 | 11275 | 2 | 25 | 5 | 23 | 2781 | 25 | 6 |
| Road Junction | 62 | 5 | 29744 | 5 | 62 | 10 | 16 | 3318 | 11 | 10 |
| Nonengineered Relief | 187 | 16 | 77541 | 14 | 209 | 51 | 27 | 17986 | 23 | 54 |
| **Total =** | **1202** | **100** | **563350** | **100** | **1478** | **459** | **38** | **219757** | **39** | **532** |

### *Culvert Condition*

The condition of a culvert inlet has a potentially large influence on the ability of that culvert to pass drainage water, especially during high flow periods. When surveyed, 67% of the stream crossing culverts and 47% of the cross-drainage culverts were fully open. On the other extreme, 5% of the stream crossing and 10% of the cross-drainage culverts had inlet openings reduced by at least 50% of the original openings. Twenty-nine percent of the cross-drain pipes were at least partially blocked by sediment, while 11% of the stream crossing pipes were affected by sediment. Mechanical crushing affected 19% of the cross drains and 9% of the stream crossings. Table 2 summarizes culvert inlet openings as a percent of original pipe cross-sectional area on all measured culverts [stream crossings (CSX) and cross drains (XRD)] in the Kilchis basin. (About 20 structures could not be reliably measured for various reasons.)

### *Road Segments and Drainage Routing to Channels*

A segment is defined as a length of road where water is directed toward a single discharge point. This is the road length that can deliver eroded materials to that discharge point. (This can change if discharge structures cease to function and water flows past the discharge point.)

A total of 1,478 distinct road segments were identified in the Kilchis watershed. The average length of these segments was 380 ft (116 m). Maximum segment spacing was 2,310 ft (704 m). Table 3 summarizes spacing by gradient. Most of the road segments (702) were in the 0–4% gradient class, while 98 segments had slopes of ≥18% (very steep roads).

**Table 2. Culvert inlet opening as a percent of original cross-sectional area**

| % Open | Stream Crossing Culverts | | Cross-Drainage Culverts | |
|---|---|---|---|---|
| | # | % | # | % |
| 100 | 141 | 67 | 92 | 47 |
| 80–99 | 41 | 19 | 51 | 26 |
| 50–79 | 20 | 9 | 34 | 17 |
| 25–49 | 3 | 1 | 6 | 3 |
| 1–24 | 5 | 2 | 9 | 5 |
| 0 | 5 | 2 | 3 | 2 |
| **Total=** | **215** | **100** | **195** | **100** |

**Table 3. Road segment spacing by road gradient (in feet)**

| Road Grade | Entire Data Base | | | | | |
|---|---|---|---|---|---|---|
| | Average | Range | Median | Sum | No. of Segments | Relative Frequency |
| 0 to 4 | 295 | 10–2240 | 175 | 207,989 | 702 | 37 |
| 5 to 8 | 435 | 20–2310 | 345 | 96,197 | 222 | 17 |
| 9 to 12 | 510 | 30–1950 | 415 | 119,190 | 233 | 21 |
| 13 to 18 | 480 | 45–2110 | 360 | 107,316 | 223 | 19 |
| >18 | 335 | 55–1830 | 260 | 32,658 | 98 | 6 |
| **Total =** | **380** | **10–2310** | **270** | **563,350** | **1478** | **100** |

A total of 459 of these segments delivered directly to channels. The average length of the segments with delivery to channels was 436 ft (133 m). Twenty-five percent of the road system was observed to have direct sediment delivery potential (ditches either to streams or to gullies connected to streams), while another 14% was given a possible sediment delivery rating. The distribution of discharge lengths above stream crossings (to the next cross drainage) are shown in Figure 3. Those discharges under 300 ft (91 m) generally indicate a spacing to accommodate filtering, while those more than 300 ft indicate significant potential flow and sediment accumulation. Forty-five percent of the discharge points had drainage lengths conducive to filtering.

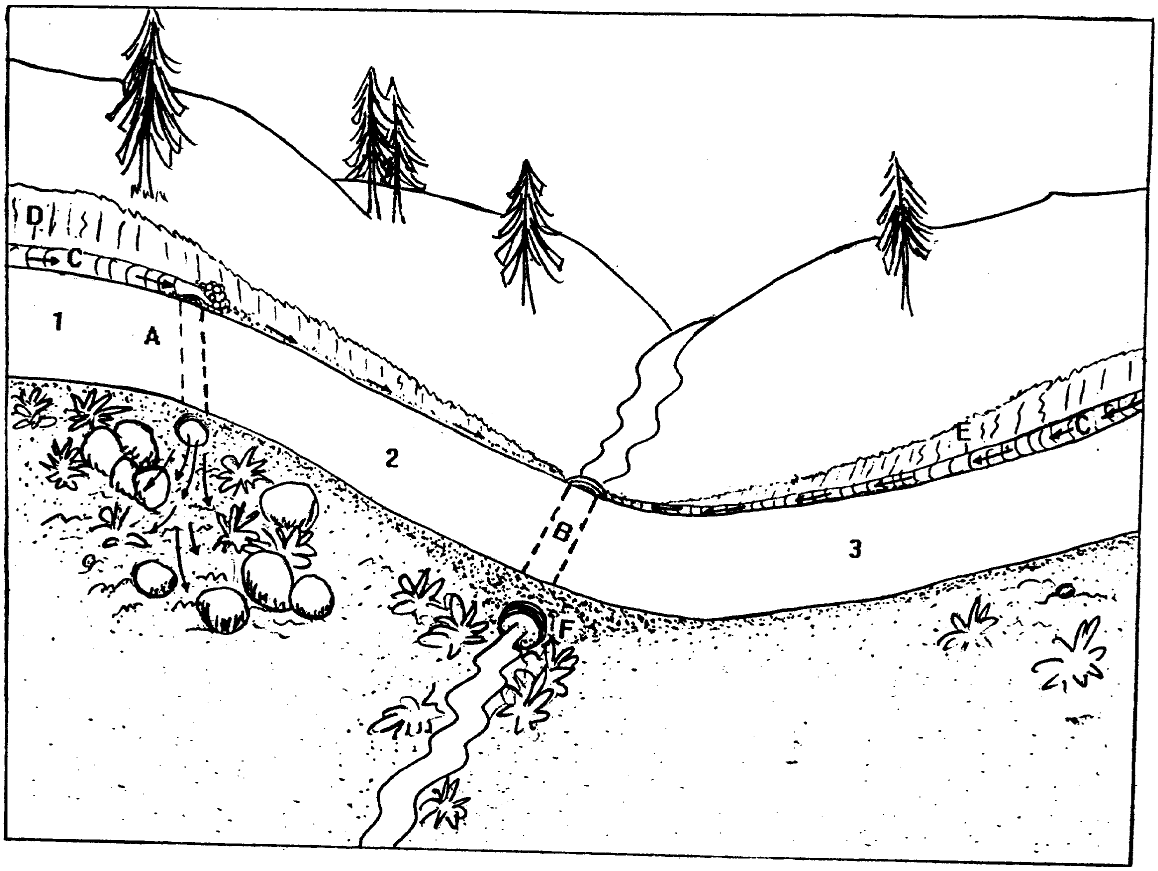


**Figure 4. Length of roads segments delivering directly to a steams.** (Length expressed as relative frequency to the number of these discharges).

### *Sources of Surface Erosion*

The conditions of ditches were examined to detect either excess flow in the ditches or insufficient size of ditches to carry flow. Thirty-nine percent of the surveyed road lengths had no ditch, although only 3% of the roads were outsloped. Most crowned roads (85% of the Kilchis system) are normally designed with ditches. For a significant portion of the Kilchis system water flows on the inside edge of the road and not in a ditch. Most of the ditches (32% of the entire system) were functioning without excess blockage or erosion. Thirteen percent of the segments had excess sediment in ditches, and another 8% had ditches partially impeded by vegetative growth. Six percent of the ditches had evidence of excess flows and ditch downcutting (prior to the winter of 1995–96).

Most of the road cutslopes (87%) were covered with vegetation. The average cutslope height was 8 ft (2.4 m). Forty-four percent of culvert outlets showed no signs of significant erosion, while 27% had significant erosion scour-holes below the outlet. Another 23% had channels or gullies developed below the outlet.

Ninety-five percent of the roads were classified as inactive (no log hauling). Forty-six percent of road surfaces were smooth (minimal erosion and well drained) while 5% were rutted. Thirty-three percent had irregular surface shapes. Ninety-six percent of road surfacing material was classified as "dirty rock" (gravel with an abundance of fines), while 4% of the roads were dirt surfaced.

### *Landslides and Washouts*

A total of 57 landslides were identified. Forty-eight of the road- or landing-associated landslides that occurred during the winter of 1995–96 in the Kilchis watershed involved more than 10 $yd^3$ of material. Another nine landslides that were <10 $yd^3$ were also investigated during this study. There were 22 washouts which eroded >10 $yd^3$ of material, and there were another 28 washouts of <10 $yd^3$ volume.

Forty-five (94%) of the large landslides were failures of fill materials. Only three of the large landslides were cutslope failures. Most of the landslides (19) occurred where hillslopes were between 70 and 80% (Figure 4). Seven of the large landslides occurred at cross-drainage locations, and another 10 of these landslides occurred where water diverted down the road flowed onto fill or sidecast slopes. Thirty-one of the large landslides (65%) were not associated with road drainage waters. At 11 of the landslide sites, significant volumes of wood were observed in the fills. Most of the large landslides (37) occurred on relatively straight sections of road (77%).

**Figure 5. Road-related landslide occurrence by slope steepness. (No Figure)**

Twenty-nine (60%) of the large landslides definitely entered channels, while another 10 (21%) may have entered channels. Nine of the large landslides (19%) did not enter a channel. The total volume of landslides which entered, or may have entered, channels was 5,400 $yd^3$ (excluding debris flows). The largest landslide observed was 710 $yd^3$.

Twelve of the large washouts occurred at stream crossings, while the other 10 were associated with water diverted down the roads. Three of the large washouts were associated with fills ≥15 ft (≥4.6 m) in depth. The total sediment delivery to streams associated with large washouts was about 3,700 $yd^3$. It is of significance to note that a single diversion/washout on Sam Downs Road eroded 2,425 $yd^3$ (66% of total washout volume).

## Discussion

### *Culvert Spacing*

The concurrent random road survey (ODF 1996), and a study by Piehl *et al.* (1988) evaluated culvert conditions and lengths of drainage segments. Piehl *et al.* (1988) compared culvert spacings measured in the central Oregon coast range to those recommended by Arnold (1957). Measured spacings were compared against those that Arnold (1957) recommended for silt-loam soils and a rainfall intensity of 1–2 inches per hour (Table 4).

**Table 4. Arnold's recommended spacings for silt loam soil**

| Slope Class | Excess Length (Over Arnold's) Criteria feet (meters) |
|---|---|
| 0–4 | 1500 (457) |
| 5–8 | 865 (264) |
| 9–12 | 480 (146) |
| 13–18 | 335 (102) |
| >18 | 250 (76) |

The average spacing of drainage discharges in the Kilchis watershed was 380 ft (116 m). For the random data base as a whole, it was 369 ft (112 m), and for the Coast Range Georegion, it was 384 ft (117 m) (ODF 1996). The Piehl *et al*. study (1988) found that the average cross-drain culvert spacing on state lands was 1.36 times that recommended by Arnold (1957) and was 1.69 times that recommended on private lands. In the Kilchis watershed, 42% of the cross-drainage spacings exceeded that recommended by Arnold (1957). Most of these "over Arnold's" segments had road grades of more than 9%, with the majority in the 13 to 18% classification.

### *Delivery to Streams*

The percentage of the road system delivering sediments to streams (between 25 and 39%) was lower than the 57.3% reported by Wemple (1994) or the 75% reported by Reid and Dunne (1984). It was comparable with the 34% reported by Bilby *et al*. (1989). It was exactly the same as the western Oregon random survey.

The average segment length from stream crossings to the first cross drainages above the stream crossings was 436 ft (133 m), while the average spacing on the overall roads in general was 381 ft (116 m). This suggests that roads are designed and maintained for efficient delivery of water to channels, rather than for filtering. OAR 629-625-330(3) states "*Operators shall locate dips, water bars, or cross-drainage culverts above and away from stream crossings so that road drainage waters may be filtered before entering waters of the state*." Although this rule was recently modified for clarity and specificity, it has been in place since 1978. However, many, probably most, of the roads surveyed were constructed prior to 1978. The average segment length delivering to streams in the random survey of western Oregon was 458 ft (140 m). Though the Kilchis distance was slightly smaller, this finding suggests that roads in western Oregon in general, including the Kilchis watershed, are not in the condition suggested by this rule.

The condition of stream crossing culverts in the Kilchis watershed were compared with those of the random survey. Sixty-seven percent of the stream crossing pipes in the Kilchis watershed were completely open, compared with 57% in the overall random survey, and 47% in the Coast Range Georegion portion of the random survey. Forty-seven percent of the cross-drainage culverts were completely open in this survey, compared with 50% in the entire random data set, and 45% in the Coast Range portion of the random data set. Piehl *et al*. (1988) found that average stream crossing culvert area was 88% of original. The culverts in the Kilchis watershed have average inlet openings of 90% original (*e.g.*, reduced by no less than 10%). Therefore, maintenance of stream crossing culverts in the Kilchis watershed slightly exceeds that of western Oregon in general, while maintenance of cross-drainage culverts is similar to western Oregon in general.

### *Landslides and Washouts*

Landslides and washouts are clearly the dominant erosional processes associated with forest roads in the Kilchis watershed, especially in years when there are major storms. Analysis of the road-related landslides data will be conducted with the historical landslides analysis of the Kilchis watershed, and will be compared with the Wilson River Storm of 1996 monitoring study site, as well. Preliminary results indicate that landslide impacts in the Kilchis watershed are not as great as those experienced on the North Fork of the Wilson River. Washout volume was about 60% of landslide volume, due mainly to a single diversion of a relatively small stream down a roadway, resulting in a gully up to 15 ft (4.6 m) deep and 1200 ft (366 m) in length.

**Road Inventory Protocol**

One of the original objectives of this project and the western Oregon random study was to develop a road sediment inventory protocol for use by state and private landowners. Additional emphasis was placed on this project by the Governor's Coastal Salmon Restoration Initiative (CSRI). The Oregon Forest Industries Council has volunteered to implement a "Road Hazard and Risk Reduction Project." To implement this project, a road inventory that assesses surface erosion, washouts, landslides, and fish passage hazards was required. The surface erosion and washout parts of the inventory have been taken from the road drainage inventory used in this study. The landslides and fish passage parts of the inventory were based on other ODF projects.

The final protocol is attached as Appendix 3. This protocol was designed for forest land managers use and to provide information needed in order to prioritize road management decisions, especially maintenance and repair activities. It is intended for priority use in areas where roads pose higher risks to anadromous fish and their habitats.

### *Relative Sources of Road Sediment*

One objective of this study is to provide information for the Kilchis watershed analysis. In particular, two questions raised during the Kilchis watershed analysis working group meeting can be answered, at least in part, by this study.

1. What is the relative proportion of sediment delivered to streams from shallow landslides, deep landslides, surface erosion on roads, culverts, surface erosion in the uplands, and surface erosion in the lowlands?

2. Do we have enough information to produce a quantified volume estimate of the sediment delivered from shallow landslides, deep landslides, road surfaces, culverts, and surface erosion sources?

At the present time, it is possible to put the Kilchis forest roads into a relative sediment delivery perspective. It is also possible to estimate road-related sediment delivery. When the ODF study of landslides in the Kilchis watershed is complete, additional information on background, fire related, and upland management related sediment loadings should be available.

There are several hillslope processes that move sediment from hillslopes to channels. These processes are usually categorized as surface erosion, mass erosion, solute transport, and channel bank erosion. As previously stated, surface erosion from forest lands of the Pacific Northwest is usually related to soil compaction or forest fires, which can both cause overland flow. Burning also causes dry ravel, where coarse sediment travels down steep slopes under the influence of gravity. After intense fires, intense precipitation often results in gully formation and channel extension.

Mass erosion includes landslides and creep. Creep is distinguished from landslides by the very slow movement (millimeters per year) and the lack of a failure surface (which for landslides clearly separates the landslide from "stable" land on the margins of the landslide).

Landslides are extremely variable in size, velocity, and mechanics of movement. Landslides are sometimes classified as "shallow-rapid" and “deep-seated.” "Shallow-rapid" slides are typical on steep forest hillslopes. These landslides often begin as small translational failures (where a block of soil fails at the soil-rock interface). When these small landslides continue moving downslope, they become debris flows. Debris flows typically scour most soil and organic matter along their paths. Upon entering and continuing down channels debris flows are considered debris torrents (Van Dine 1985). Debris flows and torrents transport a great deal more sediment than the initiating landslide (usually between about 5 and 100 times the volume of the initiating landslide).

“Deep-seated” landslides are commonly slow moving and highly variable in size. However, in 1991, a rapidly moving “deep-seated” slide occurred along the Wilson River. This landslide moved approximately 500,000 $yd^3$ of mostly rock and some soil, and resulted in a partial landslide dam on the river.

High streamflows cause erosion of streambanks and alluvial terraces. Erosion by streamflow is accelerated by creep and earthflow movement of hillslopes around the channel. High streamflows also can also erode and sometimes washout roadway fill material, especially at stream crossings.

Hillslope erosional processes fall in a temporal continuum, from uniform to rare episodic, as shown below:

Continuous ================================> Very infrequent episodic

Creep ==> road surface erosion ==> channel erosion ==> slow landslides ==> rapid landslides

Large rainstorms, major wildfires, and earthquakes are likely to dominate sediment production in the Kilchis watershed. Therefore, the following estimates of sediment delivery consider both chronic and episodic processes.

**Basis of Estimations**

Of all studies of surface erosion from roads, the Black study was considered to have the most relevance to the Kilchis watershed (Black, T. 1997. Personal Communication). The Black study measured surface erosion sediment production for roads in the central coast range of Oregon from November 1995 to February 1996. The Black study sites are located in areas of sedimentary and volcanic rocks, and soils with similar properties to those in the Kilchis watershed. Average erosion for stable low traffic roads with vegetated cutslopes and ditches was found to be 1 kg/m of road length per year for roads of similar width to Kilchis forest roads. A 1 to 10 kg/m erosion rate was applied to the Kilchis road system, using the finding that up to 40% of the Kilchis road system delivers its sediment load to channels (the other

60% is filtered by the forest floor).

The sediment production estimation for washouts is based on direct measurements made on Kilchis watershed roads. These estimates reflect a "major" storm, but not an "extreme" storm. The sediment production estimates for landslides are based on the landslide scar measurements made during the resurvey of the Kilchis watershed roads and on data from the ODF "Tillamook" study site. The road resurvey collected information on landslides, but not associated debris flows. Again, the resurvey data is representative of a "major," but not “extreme” storm. Estimates of debris flow volume (most of the sediment production) and "extreme" storm sediment production were developed using the "Tillamook" study site information.

**Table 5. Estimates for sediment budget of the Kilchis watershed**

| Source Type | Normal Year | Major Storm | Extreme Storm |
|---|---|---|---|
| Road Surface Erosion | 50–500 $yd^3$ | 50–1,000 $yd^3$ | 100–5,000 $yd^3$ |
| Road Washouts | 100 $yd^3$ | 2,500 $yd^3$ | 25,000 $yd^3$ |
| Road Landslides | 2,000 $yd^3$ | 20,000 $yd^3$ | 200,000 $yd^3$ |
| Abandoned Road Slides | 0 | 5,000 $yd^3$ | 100,000 $yd^3$ |
| Background Landslides | 100–1,000 $yd^3$ | 1,000–100,000 $yd^3$ | 100,000–500,000 $yd^3$ |

Estimates are for the entire 47,000 acre (19,021 ha) watershed. Estimates do not include creep, bank erosion, or the effects of fire or earthquake. Effects of fire will be included in the landslides analysis study. An increase in road traffic could potentially increase surface erosion by a factor of 2 or more.

## *Conclusions*

The condition of the road drainage system of the Kilchis watershed better minimizes delivery of sediment from surface erosion than the average of other forest roads in western Oregon. However, landslides, and washouts are the dominant erosional processes in this watershed, and represent the most pressing concerns for road system management. Surface erosion of the road surfaces will become a much greater concern if winter log truck traffic increases significantly. Just prior to that time, road resurfacing and adding extra culverts for filtering above stream crossings would be appropriate. Additional analysis of the landslides situation will be completed with the Kilchis landslide study currently underway.

At the present time, the two principal surface erosion concerns in the Kilchis basin are:

1. excessive length of ditch routed to deliver sediment directly to channels; and

2. steep gradient roads (generally over 13%) with excessively spaced cross-drainage structures.

Although road surfaces are in many cases very uneven, the amount of rock and the lack of truck traffic poses only a low risk of erosion, as are presently used and maintained. Most cutslopes and fillslopes are very well vegetated (87% cover, on average) so generally pose low surface erosion hazards. However, there are specific isolated locations where road ravel is a serious problem. Slopes prone to ravel are quite difficult to stabilize, and normally must be dealt with by increased maintenance activity.

This study was originally designed to investigate surface erosion. It is now clear that landslides are the dominant source of road related erosion in the watershed. Landslides and washouts result in 90 to 99% of the sediment that enters Kilchis watershed streams. However, localized surface erosion, especially that associated with heavy traffic, may be significant. Erosion of fine surface materials can increase turbidity and the deposition of fine sediments in streambed gravels.

And, as a final note, although this study did not address fish passage through culverts, the road inventory protocol now addresses this important issue.

### *Road Management Recommendations (in order of priority)*

1. Replace failing cedar puncheon culverts with steel culverts or bridges. Modify road grades to lower fills during this process to the extent road function is maintained.

2. Begin a program to pull back fills on excess width roads [over 19 ft (5.8 m) and excluding turnouts] where sideslopes exceed 70% and downslope risk of stream entry is high. Set a yearly goal for feet of pullback on high hazard locations.

3. Where possible, regrade stream crossings on midslope roads to allow streamflows to flow over the roads at the edges of the fills, rather than to flow down the roads (create a slight dip just before the crossing). Fill ditches at these locations.

4. Utilize the road inventory protocol to survey other roads in the Tillamook Bay Watershed to collect information on landslide hazard, fish passage, washout hazard, and surface erosion hazard.

5. Remove existing berms on the outside edges of sidecast constructed roads.

6. Use the road database to find steep gradient roads (more than 13%) with lengths more than 1000 ft (305 m), and provide additional cross-drainage.

7. Prior to significant winter log truck traffic, resurface roads with crushed high quality aggregate (few fines) and add additional cross-drainage culverts for filtering within 100 to 200 ft (30 to 60 m) of stream crossings.

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# APPENDIX 1

## OREGON'S FOREST ROAD CONSTRUCTION AND MAINTENANCE RULES

## DIVISION 625
## FOREST ROADS

### Road Construction and Maintenance

**Purpose**

**629-625-000** (1) Forest roads are essential to forest management and contribute to providing jobs, products, tax base and other social and economic benefits.

(2) OAR 629-625-000 through 629-625-650 shall be known as the road construction and maintenance rules.

(3) The purpose of the road construction and maintenance rules is to establish standards for locating, designing, constructing and maintaining efficient and beneficial forest roads; locating and operating rock pits and quarries; and vacating roads, rock pits, and quarries that are no longer needed; in manners that provide the maximum practical protection to maintain forest productivity, water quality, and fish and wildlife habitat.

(4) The road construction and maintenance rules shall apply to all forest practices regions unless otherwise indicated.

**Prior Approval**

**629-625-100** (1) A properly located, designed, and constructed road greatly reduces potential impacts to water quality, forest productivity, fish, and wildlife habitat. To prevent improperly located, designed, or constructed roads, prior approval of the State Forester is required in the sections listed below.

(2) In addition to the requirements of the water protection rules, operators shall obtain prior approval from the State Forester before:

(a) Constructing a road where there is an apparent risk of road-generated materials entering waters of the state from direct placement, rolling, falling, blasting, landslide or debris flow.

(b) Conducting machine activity in Type F or Type D streams, lakes or significant wetlands.

(c) Constructing roads in riparian management areas.

(3) In the Northwest Oregon and Southwest Oregon Regions, operators shall obtain prior approval from the State Forester before constructing roads on high risk sites.

(4) Operators shall obtain written prior approval from the State Forester of a written plan, as described in OAR 629-625-320(1)(b)(B), before constructing any stream crossing fill over 15 ft (4.6 m) deep.

(5) In addition to the requirements of the water protection rules, operators shall obtain prior approval from the State Forester before placing woody debris or boulders in stream channels for stream enhancement.

**Road Location**

**629-625-200** (1) The purpose of this rule is to ensure roads are located where potential impacts to waters of the state are minimized.

(2) When locating roads, operators shall designate road locations which minimize the risk of materials entering waters of the state and minimize disturbance to channels, lakes, wetlands and floodplains.

(3) Operators shall avoid locating roads on steep slopes, slide areas, high risk sites, and in wetlands, riparian management areas, channels or floodplains where viable alternatives exist.

(4) Operators shall minimize the number of stream crossings.

(5) To reduce the duplication of road systems and associated ground disturbance, operators shall

make use of existing roads where practical.  Where roads traverse land in another ownership and will adequately serve the operation, investigate options for using those roads before constructing new roads.

**Road Design**

**629-625-300** (1) The purpose of OARs 629-625-300 through 629-625-340 is to provide design specifications for forest roads that protect water quality.

(2) Operators shall design and construct roads to limit the alteration of natural slopes and drainage patterns to that which will safely accommodate the anticipated use of the road and will also protect waters of the state.

**Road Prism**

**629-625-310**(1) Operators shall use variable grades and alignments to avoid less suitable terrain so that the road prism is the least disturbing to protected resources, avoids steep sidehill areas, wet areas and potentially unstable areas as safe, effective vehicle use requirements allow.

(2) Operators shall end-haul excess material from steep slopes or high risk sites where needed to prevent landslides.

(3) Operators shall design roads no wider than necessary to accommodate the anticipated use.

(4) Operators shall design cut and fill slopes to minimize the risk of landslides.

(5) Operators shall stabilize road fills as needed to prevent fill failure and subsequent damage to waters of the state using compaction, buttressing, subsurface drainage, rock facing or other effective means.

**Stream Crossing Structures**

**629-625-320** (1) Operators shall design and construct stream crossing structures (culverts, bridges and fords) to:

(a) Minimize excavation of side slopes near the channel.

(b) Minimize the volume of material in the fill.

(A) Minimizing fill material is accomplished by restricting the width and height of the fill to the amount needed for safe use of the road by vehicles, and by providing adequate cover over the culvert or other drainage structure.

(B) Fills over 15 ft (4.6 m) deep contain a large volume of material that can be a considerable risk to downstream beneficial uses if the material moves downstream by water.  Consequently, for any fill over 15 ft (4.6 m)deep operators shall obtain approval of the State Forester of a written plan that describes the fill and drainage structure design.  Approval of such written plans shall require that the design be adequate for minimizing the likelihood of surface erosion, embankment failure, and other downstream movement of fill material.

(c) Prevent erosion of the fill and channel.

(2) Operators shall design and construct stream crossings (culverts, bridges, and fords) to:

(a) Pass a peak flow that at least corresponds to the 50-year return interval.  When determining the size of culvert needed to pass a peak flow corresponding to the 50-year return interval, operators shall select a size that is adequate to preclude ponding of water higher than the top of the culvert; and

(b) Allow migration of adult and juvenile fish upstream and downstream during conditions when fish movement in that stream normally occurs.

(3) An exception to the requirements in subsection (2)(a) of this rule is allowed to reduce the height of fills where roads cross wide flood plains.  Such an exception shall be allowed if:

(a) The stream crossing site includes a wide flood plain ; and

(b) The stream crossing structure matches the size of the active channel and is covered by the minimum fill necessary to protect the structure;

(c) Except for culvert cover, soil fill is not placed in the flood plain: and

(d) The downstream edge of all fill is armored with rock of sufficient size and depth to protect the fill from eroding when a flood flow occurs.

**Drainage**

**629-625-330** (1) Operators shall provide a drainage system using grade reversals, surface sloping, ditches, culverts and/or waterbars as necessary to effectively control and disperse surface water to minimize erosion of the road.

(2) Operators shall not divert water from channels except as necessary to construct stream crossings.

(3) Operators shall locate dips, water bars, or cross-drainage culverts above and away from stream crossings so that road drainage water may be filtered before entering waters of the state.

(4) Operators shall provide drainage when roads cross or expose springs, seeps, or wet areas.

(5) Operators shall not concentrate road drainage water into headwalls, slide areas, or high risk sites.

**Waste Disposal Areas**

**629-625-340** Operators shall select stable areas for the disposal of end-haul materials, and shall prevent overloading areas which may become unstable from additional material loading.

**Road Construction**

**629-625-400** OARs 629-625-400 through 629-625-440 provide standards for disposal of waste materials, drainage, stream protection, and stabilization to protect water quality during and after road construction.

**Disposal of Waste Materials**

**629-625-410** Operators shall not place debris, sidecast, waste, and other excess materials associated with road construction in locations where these materials may enter waters of the state during or after construction.

**Drainage**

**629-625-420** (1) Operators shall clear channels and ditches of slash and other road construction debris which interferes with effective roadway drainage.

(2) Operators shall provide effective cross drainage on all roads, including temporary roads.

(3) Operators shall install drainage structures on flowing streams as soon as feasible.

(4) Operators shall effectively drain uncompleted roads which are subject to erosion.

(5) Operators shall remove berms on the edges of roads or provide effective drainage through these berms, except for those berms intentionally designed to protect road fills.

**Stream Protection**

**629-625-430** (1) When constructing stream crossings, operators shall minimize disturbance to banks, existing channels, and riparian management areas.

(2) In addition to the requirements of the water protection rules, operators shall keep machine activity in beds of streams to an absolute minimum. Acceptable activities where machines are allowed in streambeds, such as installing culverts, shall be restricted to periods of low water levels. Prior approval of the State Forester for machine activity in Type F or Type D streams, lakes, and significant wetlands is

required by 629-625-100(2)(c).

(3) For all roads constructed or reconstructed operators shall install water crossing structures where needed to maintain the flow of water and passage of adult and juvenile fish between side channels or wetlands and main channels.

(4) Operators shall leave or re-establish areas of vegetation between roads and waters of the state to protect water quality.

(5) Operators shall remove temporary stream crossing structures promptly after use, and shall construct effective sediment barriers at approaches to channels.

**Stabilization**

**629-625-440** (1) Operators shall stabilize exposed material which is potentially unstable or erodible by use of seeding, mulching, riprapping, leaving light slashing, pull-back, or other effective means.

(2) During wet periods operators shall construct roads in a manner which prevents sediment from entering waters of the state.

(3) Operators shall not incorporate slash, logs, or other large quantities of organic material into road fills.

**Rock Pits and Quarries**

**629-625-500** (1) The development, use and abandonment of rock pits or quarries which are located on forestland and used for forest management shall be conducted using practices which maintain stable slopes and protect water quality.

(2) Operators shall not locate quarry sites in channels.

(3) When using rock pits or quarries, operators shall prevent overburden, solid wastes, or petroleum products from entering waters of the state.

(4) Operators shall stabilize banks, headwalls, and other surfaces of quarries and rock pits to prevent surface erosion or landslides.

(5) When a quarry or rock pit is inactive or vacated, operators shall leave it in the conditions described in section (4) of this rule, shall remove from the forest all petroleum-related waste material associated with the operation; and shall dispose of all other debris so that such materials do not enter waters of the state.

**Road Maintenance**

**629-625-600** (1) The purpose of this rule is to protect water quality by timely maintenance of all active and inactive roads.

(2) Operators shall maintain active and inactive roads in a manner sufficient both to provide a stable surface and to keep the drainage system operating as necessary to protect water quality.

(3) Operators shall inspect and maintain culvert inlets and outlets, drainage structures and ditches before and during the rainy season as necessary to diminish the likelihood of clogging and the possibility of washouts.

(4) Operators shall provide effective road surface drainage, such as water barring, surface crowning, constructing sediment barriers, or outsloping, prior to the rainy and runoff seasons.

(5) When applying road oil or other surface stabilizing materials, operators shall plan and conduct the operation in a manner as to prevent entry of these materials into waters of the state.

(6) In the Northwest and Southwest Oregon Regions, operators shall maintain and repair active and inactive roads as needed to minimize damage to waters of the state. This may include maintenance and repair of all portions of the road prism during and after intense winter storms, as safety, weather, soil

moisture and other considerations permit.

(7) Operators shall place material removed from ditches in a stable location.

(8) In order to maintain fish passage through water crossing structures, operators shall:

(a) Maintain conditions at the structures so that passage of adult and juvenile fish is not impaired during periods when fish movement normally occurs. This standard is required only for roads constructed or reconstructed after September 1994, but is encouraged for all other roads; and

(b) As reasonably practicable, keep structures cleared of woody debris and deposits of sediment that would impair fish passage.

(c) Other fish passage requirements under the authority of ORS 498.268 and 509.605 that are administered by other state agencies may be applicable to water crossing structures, including those constructed before September 1, 1994.

**Vacating Forest Roads**

**629-625-650** (1) The purpose of this rule is to ensure that when landowners choose to vacate roads under their control, the roads are left in a condition where road related damage to waters of the state is unlikely.

(2) To vacate a forest road, landowners shall effectively block the road to prevent continued use by vehicular traffic; and shall take all reasonable actions to leave the road in a condition where road-related damage to waters of the state is unlikely.

(3) Reasonable actions to vacate a forest road may include: removal of stream crossing fills; pullback of fills on steep slopes, frequent cross ditching, and/or vegetative stabilization.

(4) Damage which may occur from a vacated road, consistent with Sections (2) and (3) of the rule, will not be subject to remedy under the provisions of the Oregon Forest Practices Act.

# APPENDIX 2

## Oregon Department of Forestry's Forest Practices Monitoring Program

The Forest Practices Monitoring Program (FPMP) is designed to assess the effectiveness, implementation and assumptions of the forest practice rules in achieving the goals of the Oregon Forest Practices Act (FPA). The goal of the FPMP is to provide timely information and analysis of the forest practice rules. Findings and recommendations are made to the Oregon Board of Forestry. The foundation of the program is a group of monitoring questions developed with input from interested public, private and public landmanagers, the research community and forest practices staff. The questions address monitoring and research issues in four key resource areas requiring protection under the FPA. Those categories are: (1) forest and soil productivity, (2) fish and wildlife, (3) water quality, and (4) air quality. The specific objectives of the FPMP are to:

- Evaluate the effectiveness of the FPA and rules to encourage economically efficient forest practices while protecting forest productivity, water quality, air quality and fish and wildlife at a variety of scales and over time.
- Assess the implementation of the act and rules.
- Assess the assumptions built into the Act and rules.
- Foster a general consensus on monitoring priorities and approach.
- Provide timely feedback on the effectiveness of the rules.
- Approach all issues efficiently.
- Facilitate coordination and cooperation on monitoring efforts.
- Approach all monitoring questions from a sound scientific foundation.
- Encourage research that will provide information on intensively managed forest systems and the effects of regulated forest practices.
- Synthesize and report other relevant information on the effects of forest practices.

In the context of the Forest Practices Act, adaptive management is a continuous process of rule refinement, implementation, monitoring, evaluation, and adjustment. The overall strategy of the monitoring program is to focus on integrating information and evaluation efforts through coordinated monitoring, research and the synthesis of other studies and information. The resulting body of information will be used in the adaptive management process. The following is a brief description of individual projects designed to answer questions from the FPMP Strategic plan that are being implemented (1–4) or planned for implementation (5–7).

1. **Statewide Basin and Reach-level Stream Temperature Monitoring**

- *Are the stream protection rules effective in maintaining stream temperature within the context of the inherent basin trend?*
- *What stream, basin and vegetation characteristics influence the temperature regime and how do these vary across the state?*

These projects are designed to assess stream temperature at a reach and basin scale. Effects of units harvested using the 1994 protection rules and environmental controls on stream temperature are being monitored.

2. **Riparian Condition and Implementation**

- *What levels of large wood will be maintained in channels and through a watershed under the vegetation retention standards?*
- *Are the vegetation retention rules resulting in conditions that are consistent with the goal of achieving mature forest conditions within the next rotation?*

This project is designed to assess the effect of forest practices on riparian function and structure. Riparian shade and composition, large woody debris recruitment and wildlife habitat components are being monitored in riparian areas left under the 1994 stream protection rules.

3. **1996 Storm Impacts Monitoring Project**

- *Were the forest practices in the sample areas appropriate for the time of the operation and did they minimize or contribute to impacts?*
- *How are hillslope processes and forest practices linked to channel responses or impacts?*

This project was initialized in response to the February 1996 storm which affected mostly northwestern Oregon. Landslide frequency and size, channel impacts and fish habitat are beginning assessed under varying management and road conditions.

4. **Road Sediment Monitoring and Protocol Development and Kilchis Watershed Analysis**

- *Are best management practices minimizing the delivery of sediment to waters of the state?*

These projects are designed to inventory roads throughout the state. A protocol was designed for use by landowners to assess the condition of roads and potential delivery of sediment to stream channels from the roadway. In addition sediment contributions from roads and landslides was monitored throughout an entire watershed.

5. **Determining Fish Passage through Culverts**

- *Are water crossing structures passing fish as anticipated?*

Information from this project will be used to define easy-to-measure parameters that landowners and operators can use to install culverts properly and determine if existing culverts pass fish.

6. **Protection of Waters of the State during Pesticide Application**

- *Is water quality including the integrity of aquatic communities and public health, being effectively protected when forest management chemicals are applied?*

This project is designed to test the effectiveness of chemical rules adopted in 1996 as well as the effect of increasing the miles of stream that receive greater protection due to the 1994 reclassification of streams.

7. **Statewide Implementation of the Forest Practice Rules**

- *What percentage of forest practice operations result in proper implementation of the Forest Practice rules?*

This project is in the protocol development stage and will be a statewide sample of forest operations.

# APPENDIX 3

## Road Erosion Hazard Inventory Protocol

## CSRI ROAD INVENTORY PROTOCOL - FINAL DRAFT
## 12-30-96

### Introduction

Timely inspection and subsequent maintenance or repair activity on forest roads can greatly reduce the potential for sediment to enter streams. The Department of Forestry is committed to working cooperatively with forest landowners to reduce erosion from forest roads. This will first require an assessment of forest roads for erosion and possible sediment delivery to streams. Analysis of erosion risk by landowners and setting priorities for repair are the next step, followed by maintenance or repair activity. A suggested database format for data collection is nearing completion.

This publication describes a protocol that land managers can use to provide information needed in order to prioritize road management decisions, especially maintenance and repair activities. This protocol has been redesigned to be the first part of the Coastal Salmon Restoration Initiative (CSRI) Road Erosion and Risk Reduction Project. Road inventories should first be conducted in areas where roads pose higher risk to anadromous fish and their habitats. A road management guidebook which will provide cost effective technical options for reduction of road erosion hazard should be completed in about one year. **This inventory is designed as a means to identify roads of concern and to prioritize repair activity, but is not meant to collect all information necessary for those repairs.**

| Three major areas of concern | Three major elements of inventory |
|---|---|
| Washouts of stream crossings/fish passage | Stream crossing structures |
| Sidecast related landslides entering channels | Sidecast (where risk of failure is high) |
| Muddy drainage waters delivered to streams | Surface drainage |

### Background

The Department of Forestry, with the Forest Engineering Department at Oregon State University developed a road sediment monitoring protocol. The monitoring procedures were further refined using input from forest landowners, agency personnel and other interested parties. Monitoring surveys of drainage systems on over 200 miles of forest roads on industrial, non-industrial and state lands in western Oregon were completed in 1995. This monitoring found that most surface drainage systems on roads are performing well, with two areas of possible concern. One concern is excess spacing of cross drainage on steep gradient roads, the other concern is ditches routed over long distances to channels (no cross drainage installed before the stream crossing). Another road hazard assessment project, conducted cooperatively by ODF and several private landowners, looked at landslide and washout hazard. Road-related landslides and washouts are the focus of ongoing ODF monitoring. Past ODF monitoring has shown most road landslides related to steep sidecast, though road drainage can also be an important factor. All of this monitoring and assessment information was used in development of this protocol.

## Methods

Useful information requires inspection of entire road systems on-the-ground. This protocol requires a minimum level of training. Information is collected through direct measurements, combined measurement/estimations, and direct observations. Road junctions and ownership boundaries provide the starting points for these surveys. Information is either directly entered into a computer or data logger, or recorded on forms for subsequent entry into a relational database.

**Tools and Measurements:** A vehicle (pick-up or utility rig) is preferred for road access, though a mountain bike can also be used. A single person can collect the necessary data. Distance measurements are made by travelling along the road. We recommend using a distance measuring instrument (DMI) or other device that records vehicle travel in feet (a normal vehicle odometer alone is not very accurate). Impassable roads are measured with a hip chain (string box). A clinometer is used to measure road gradient, culvert gradient, and other slopes. Short distance measurements require a scaled rod or staff rod and a measuring (loggers) tape. Much of the data collected is determined by direct observation. A ODF stream classification map (on USGS 15 minute quad maps) and/or other maps showing roads and streams is also needed.

**Information needed:** Priority information includes:
1. A general road description;
2. The condition of each stream crossing structure;
3. Symptoms of erosion along the road;
4. The potential for sediment delivery to a stream; and
5. The risk of landslides entering streams.

### General Road Characteristics

Each road should be identified by name or number, as per the system normally used by the landowner. Each road is classified by:
*Road identification* by name, numbering system or other means;
*Road use* by management activity (active roads have been used for timber haul in the past year; inactive roads include all other roads used for management since 1972; and legacy roads are abandoned, overgrown, and not used since 1972. Legacy roads include rail road grades.
*Surfacing material* is described as clean rock (new quarry rock); old rock (more common); or dirt);
*Slope position* is described as ridge, midslope, or valley as the location of most of the road;
Average road *width* in feet for the entire road is estimated (from the outside edge to the base of the cutslope).
For ownerships where *georegion, geology or soils* are variable and have a great influence on erosion, these should also be documented.

**Figure 1. Typical Road Inventory Features (No Figure)**

A: XRD Cross road drainage (possible delivery due to proximity and channeling at outlet)
B: XRD Cross road drainage (yes delivery)
C: CSX Culvert @ live stream crossing
D: Grade break
E: XRD Cross road drainage (no delivery)
F: Grade break
G: Cut bank Cut_hgt 10-20
H: Road fill at culvert=medium
I: Gullied channel at XRD (8) delivers to CSX (C)

Road segments:

1: Drains to XRD (A)
2: Drains to XRD (B)
3: Drains to CSX (C)
4: Drains to CSX (C)
5: Drains to XRD (E)
6: Drains to XRD (E)
7: Drains off sample plot, due to change in grade

## Stream Crossings

Stream crossings are an extremely important part of the road system. Improperly functioning stream crossings can result in loss of the roadway through washouts and channel diversions, and they can also be a barrier to fish movement. At each crossing structure, information should be collected by getting out of the vehicle and taking measurements, usually at the inlet end, and by observations from the road surface of the outlet end of the structure.

The following information should be collected at each stream crossing (figure 2):
*Fish presence* (species if known, from ODF classification maps or other sources);
*Type* of structure (bridge, round culvert, arch culvert, log puncheon, or ford;
*Size* or diameter of the culvert (diameter for round, rise and span for arch) or length (for bridge);
*Length* of the culvert is estimated, to the nearest ten feet;
Structure *condition* whether there is age related deterioration (good, rusted, bottom out, partial collapse, and total collapse); and
Inlet *blockage* described as due to beavers, sediment, damage, mechanical, or vegetation;
Percent *opening* estimated as a percent or original (design) opening;
*Fill height* is estimated from the channel bottom to the road surface at the downstream end; and
*Outlet drop* is the distance from the bottom of the pipe to the elevation of the pool, in feet;
Sediment *filtering* opportunities around the crossing are noted as utilized, not utilized, or not available.

Additional measurements are needed for Type F stream crossings, especially for crossings where fish use changes from Type F to Type N, and other structures where fish use is expected, as follows:
*Culvert slope* can be measured with a clinometer, to the closest percent (clinometer calibration is very important); and
*Resting Pool* below the pipe is categorized as good (at least 2 feet deep and six feet long); fair (at least 1 foot deep and 4 feet long); or absent.

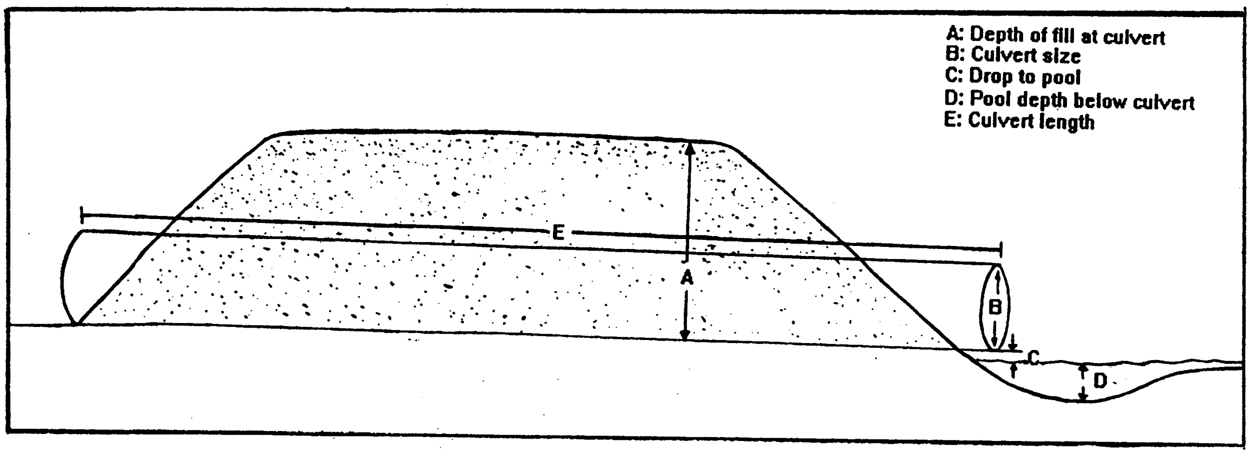


**Figure 2. Stream crossing culvert with key dimensions.**

**Surface drainage**

The source area is the length of road draining to any one location. This length is referred to as a "segment." The information collected along each segment is designed to identify potential for severe erosion. A "relief" is any location where a collected water leaves the roadway. For properly functioning outsloped roads there are no reliefs. Of special concern are the lengths of road segments draining directly to streams.

Source area

The following observations/measurements are made to identify symptoms of high erosion on road segments, as best describe the condition of the entire segment:
*Length* in feet as measured as accurately as possible by driving or walking the segment;
Average *gradient* (slope in percent, with an estimated average when the slope changes);
Road *surface* drainage is described as good, rutted, bermed, or gullied;
*ditch* function is described as good, downcutting, stream diverted, near full, or blocked; and
*cutslope* condition is described as by stable rock, vegetated; bare; ravel/erosion or slides.

Relief

Locations where concentrated water leaves the road surface can include cross drainage culverts; live stream crossings; waterbars; rolling dips; grade reversals (drainage divides); natural saddles and ditch-outs. The survey will collect the following information on drainage characteristics and potential sediment delivery at all structured relief (culvert) locations, and at other locations only where there are problems:
type of *structure* as stream crossing (see additional information needed on page 1) or cross drain culvert (waterbar, ditch-out, dip, etc. only if there a problems with these structures);
type of *problem* described as none, mechanical crushing, filling by debris, bypassed; or outlet erosion;
*evidence of flow (delivery)* to a waterbody as yes, possible, or no.

**Sidecast/landslides (only for high risk segments):**

High risk segments include sidecast constructed roads where sidecast related landslides are reasonably expected. Depending on georegion, geology, soil, and drainage, the natural slopes for high risk segments may be as gentle as 50 percent (in wet areas with weak sidecast and drainage problems or in areas with well drained materials, uniform slopes and no or very limited signs of old slides high risk segments exist when natural slopes exceed 65 or 70 percent. High risk segments are also those which have experienced past sidecast related landslides. For the high risk segments only, the following information should be collected:

average *natural slope steepness* under the sidecast;
*evidence* of active failure as outside cracking, or prism dropping;
*proximity to waters* described as qualitative rating of slope to nearest stream channel low, moderate or high based on the presence and size of bench terrain between the site and the nearest channel;
*history of slides* along road (are there old scars visible, and if so, how many)
sidecast *depth* an estimated average, to the nearest foot
road *alignment* (straight or winding)
*vegetation* on sidecast as bare, brush, reproduction, or forest.

**Options**

Landowners are encouraged to use this protocol for road management purposes other than erosion hazard reduction. Possible uses include routine maintenance and surfacing decisions, which require additional information on surface condition. Global positioning systems may be used to help map information from the survey, though can result in a significant reduction in productivity for steep areas with canopy cover, especially when the canopy is wet. Direct data entry into a field data-logger as it is being collected can be very efficient. The inventory person or crew can also be used to mark culverts and to flag locations needing immediate maintenance attention.

**Decision Making**

Immediate action should be taken on forest practices compliance related issues. These may include: failing stream crossing pipes; non-functional cross drainage; active gullies down the road, and sidecast beginning to slide downslope.

Inventory information should be entered into relational databases. An example database is attached. To help landowners make risk reduction priority decisions, a road management guidebook is being developed in cooperation with practicing road engineers and the Forest Engineering Department at Oregon State University.

**Database for Road Inventory Protocol**

Road:

ID: (Road name or number)
Use: (Active) (Inactive) (Vacated) (Abandoned)
Location: (Ridge) (Midslope) (Valley)
Surfacing: (Dirt) (Rock) (Clean rock)
Width: In feet
Option: geology/georegion: (Landowner choice)

Stream X:

Type: (Round culvert) (Arch culvert) (Bridge)
Fish: (Anad) (F) (N)
Size: Diameter of span in feet
Length: of pipe in feet
Condition: (Good) (Rusted) (Bottom out) (Collapse)
Blockage: (Beaver) (Sediment) (Damage) (Mech) (Veg)
% Open: Percent of original area
Drop: in feet

For Fish Only:

Pool: (Good) (Fair) (Poor)
Slope: in percent

Source Area:

Length: in feet
Gradient: in percent
Surface: (Good) (Rutted) (Berms) (Gullies)
Ditch: (Good) (Cutting) (Diverted) (Full) (None)
Cutslope: (Stable) (Ravel) (Slides)

Relief:

Type: (CMP) (Wbar) (Other)
Problems: (None) (Blocked) (ByPassed) (Crushed) (Outlet Erosion)
Delivery: (Y) (N) (P)

Sidecast (high risk segments only):

Slope: in percent
Evidence: (Cracks) (Drop)
Proximity: (Low) (Moderate) (High)
History: Number of old slides
Alignment: (Straight) (Winding)
Vegetation: (Bare) (Brush) (Reprod) (Forest)