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A citizens' guide to wildland road removal

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A Citizens' Guide to Wildland Road Removal

by

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Abstract

Roads are a pervasive element of the landscape, especially on public lands used extensively for resource production. Roads are directly or indirectly responsible for a variety of ecological problems. Destroyed and fragmented habitat, increased frequency and magnitude of landslides, and increased stream sedimentation are just a few of the more common ecological impacts associated with roads. Roads also greatly increase natural erosion rates and increase the efficiency of water flow through a watershed by intercepting subsurface water flow and decreasing the amount of water that can infiltrate into the ground. Closing roads primarily addresses road impacts by improving wildlife security, but active road removal is necessary to stop all road-caused ecological degradation.

Actively removing roads from the landscape involves implementing a number of different treatments, including removing stream crossings, outsloping, recontouring, ripping, and constructing cross road drains. These treatments are all carried out using heavy equipment such as tracked excavators, bulldozers with attached winged subsoilers, and dump trucks. Road removal costs vary depending on site-specific conditions, but are primarily related to heavy equipment costs and the number and size of stream crossings that must be removed.

To ensure that the most detrimental roads are removed first, priorities must be set. Setting priorities is an exercise that requires a knowledge of the area, and is best done by conducting a field inventory to identify locations in need of special attention.

Land management agencies such as the Forest Service, the Park Service, and the Bureau of Land Management design projects and implement them either by contracting with private contractors, who complete the project based on written instructions, or by renting equipment and directing operators as the project proceeds. Citizens can use their knowledge of watersheds and roads to assure that projects are implemented appropriately. This publication provides guidelines for citizens to assess projects, and provides information on how projects can be monitored after they are completed.

Preface

Actively removing roads is the only way to fully address road-caused ecological degradation. Closing roads is important for wildlife security, but does little to reduce the aquatic impacts of roads. The goal of this paper is to help concerned citizens assure that road removal projects on public lands are implemented effectively and restore watersheds rather than result in additional damage or continued road-related impacts. Although similar techniques may be used in removing temporary ("roll-up") roads, this paper focuses on roads that were constructed to be more permanent fixtures on the landscape.

Chapter 1 offers a quick summary of why roads should be removed, by noting the impacts of roads and the advantages and potential impacts of removing them. Chapter 2 describes the relationship between roads, watersheds, and soil erosion. An entire section is devoted to describing basic road construction techniques and design features, to familiarize the reader with terms and concepts that are commonly used when discussing roads. Also included is a section that summarizes basic watershed processes such as water flow and erosion.

Chapter 3 discusses the details of road removal, including site-specific treatments and general approaches to road removal. Heavy equipment required for removing roads is summarized, as are road removal costs and the costs of NOT removing roads.

Chapter 4 describes how priorities should be set to ensure that the most detrimental roads are removed first. This involves getting to know watersheds in a region and performing field inventories to identify specific roads that are most in need of treatment. The basic characteristics of an effective project are provided. A section on revegetation details the importance of and options for establishing a vegetative cover following heavy equipment work. Monitoring activities are also summarized, including establishing photopoints and conducting qualitative and quantitative surveys. Finally, a methodology for assessing road removal projects is outlined.

An adaptation of this professional paper was published by Wildlands Center for Preventing Roads, "The Road-Ripper's Guide to Wildland Road Removal." Many readers will find the guide published by Wildlands CPR to be more condensed and user-friendly than the information provided herein.

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Chapter 1: Why Remove Roads?

Roads are a pervasive element of the landscape, especially on public lands used extensively for resource production. With over 440,000 miles of known roads throughout 191 million acres, the USFS is responsible for over nine times the total road length of the Federal Interstate Highway System. The BLM maintains over 79,000 miles of road on its 270 million acres (Stotter 1996). The overall impacts of roads on aquatic and terrestrial ecosystems reach far beyond what their numerical extent suggests. This chapter explains the impacts of roads (ecological, hydrologic, and geomorphic) and the advantages and potential impacts of removing roads.

Impacts of Roads

Ecological Impacts

Roads have both direct and indirect ecological effects on wildlands (Noss 1996). The most direct impact is habitat destruction. Constructing one mile of logging road destroys approximately 10 acres of habitat, though this number varies depending on the width of the road (Noss 1996). In addition, direct habitat loss may occur due to road-induced landslides and increased human impact due to increased access. Other direct impacts include roadkill, noise pollution, chemical pollution, and changes in wildlife behavior. Roads also fragment and isolate plant and animal populations, cause edge effects, and act as corridors for non-native species invasions (Noss 1996).

Roads also directly impact aquatic ecosystems. Large amounts of sediment originating from roads reach streams and rivers, degrading habitat and impairing fish reproduction (Harr and Nichols 1993). Fine sediments impact spawning habitat by settling into and covering spawning gravels, interfering with salmonid redd (nest) construction. Excessive sediments can impede intergravel water flow that provides oxygen and removes waste products from stream beds, both of which are necessary for successful egg development. Excessive sediments can also reduce or eliminate suitable habitat for macroinvertebrates, which the juvenile fish use as food. Roads that cross streams may act as barriers to migrating adult and juvenile salmonids and the macroinvertebrates they depend on (Furniss et al. 1991).

Roads indirectly affect wildland ecosystems by providing access for humans, resulting in hunting mortality (legal and illegal), collection of rare plants, animals, fungus, and minerals, snag removal for firewood, human-ignited fires, illegal waste disposal, and increased development (Noss 1996). Scarcely-understood additive and synergistic interactions of the individual impacts of roads, together with other management activities, can also degrade wildland ecosystems.

Hydrologic and Geomorphic Impacts

Roads fundamentally disrupt natural drainage patterns by diverting water and preventing water infiltration into soil. Roads can affect both the volume of water available as surface runoff and the efficiency by which water flows through a watershed (Wemple et al. 1996). Roads increase the volume of surface runoff in two ways. First, compacted road surfaces do not readily absorb water. Second, road cuts intercept subsurface water flow and convert it to surface flow. Water moving through a watershed as surface runoff moves more quickly because it has less resistance to flow compared to water percolating through soil, and thereby accelerates soil erosion. Roads cause more water to reach stream channels in a shorter time during a storm or snowmelt event, so channels must accommodate the additional volume of water and road-related sediment. More water and sediment in channels alters their physical structure, which can negatively modify aquatic habitat. See "Understanding Watersheds and Soil Erosion" in Chapter 2 for a more detailed description of how roads disrupt hydrologic patterns.

Mass failures such as landslides occur naturally, but roads dramatically increase their frequency and magnitude, from several to hundreds of times (Furniss et al. 1991). See "Mass Failure" in Chapter 2 for a more detailed description of mass failures.

Advantages of Removing Roads

Removing roads is the best and most long-term solution to addressing the well-documented impacts of roads on wildland ecosystems. Advantages of road removal include:

- Curtailing adverse ecological impacts

Road removal has the potential to help habitat directly destroyed by roads to recover, reconnect fragmented habitat, and reduce edge effects. Revegetation and slope stabilization reduces sedimentation, improving aquatic habitat. Reducing soil loss due to erosion increases vegetation productivity and enhances nutrient cycling.

- Curtailing adverse hydrologic impacts

Road obliteration and recontouring help restore pre-construction drainage patterns by dispersing concentrated water. Removing roads has the potential to reduce subsurface water interception and enhance water infiltration, both of which reduce erosive surface runoff. Recontouring has the potential to improve slope stability, reducing the likelihood of road-related mass failures.

- Reducing impacts associated with motorized access

Fully obliterated and recontoured roads have the potential to decrease motorized access to public lands, reducing roadkill, poaching, and human-caused fires. Additionally, stopping motorized access slows invading non-native plants that use vehicles as vectors for seed dispersal.

- Saving money

Properly removed roads require no maintenance, saving millions of taxpayer dollars. Reducing road-related sedimentation extends the useful life of reservoirs and reduces the dredging requirements of navigable rivers. Preventing erosion is more economically efficient than attempting to remove sediment after it has been deposited into waterways through road-related mass failure and surface erosion (McCullah 1994; McCullah 1997). In addition, preventing habitat degradation reduces recovery costs for threatened and/or endangered species.

Impacts of Removing Roads

Actively removing roads from the landscape also causes impacts. Decompacting and excavating soil is likely to increase short-term erosion and sedimentation, and may facilitate non-native plant species invasion. Agencies may use herbicides, biological controls, and mechanical techniques to control the spread of non-native species. In addition, the presence of heavy equipment may cause noise and chemical pollution. Impacts may also occur if heavy equipment disturbs the adjacent ground and vegetation. If the site continues to receive motorized use following removal, use-related impacts will occur. Some road reconstruction may be necessary since previous mass failures and surface erosion may have damaged roads. For instance, if a stream crossing is damaged due to a plugged culvert, it may need to be reconstructed in order to access and treat the remainder of the road.

Chapter 2: Understanding Roads, Watersheds, and Soil Erosion

Understanding the technical jargon associated with roads, how watersheds function, and the erosional processes associated with roads is the first step to effectively assessing road removal projects. This chapter provides background information that will help you gain this understanding.

Part One: What is a Road?

Recognizing roads is easy, but knowing how they are constructed and function helps in understanding how they impact ecosystems. This section describes the components of roads, different types of design, drainage structures, and common maintenance activities. It also defines many of the basic technical terms used to describe roads.

Components of a Road

The road prism is the area spanning from the top of the cutslope to the bottom of the fillslope (Figure 1 in Appendix C). The cutslope (also called cutbank or backslope) is the soil and rock slope on the uphill side of the road. The fillslope is the slope between the outside edge of the road bed and the natural ground surface. The road bed or bench is the portion of the road prism where vehicles drive. Fill is the material (soil and rock) used when the road bed is not original ground. Fill may be used on a road segment for a road running parallel to slope contours, or for constructing stream crossings. When large amounts of fill are needed, fill materials are imported from "borrow" pits. In other instances, material excavated from a slope in excess of what is necessary for road construction may be pushed downslope (sidecast) or removed and transported to a stable location where it cannot enter a stream (endhauled). An inboard ditch (also called upslope ditch) is a small channel paralleling a road at the foot of the cutslope. The road grade refers to the steepness or incline of a section of road (i.e. a steep grade or gentle grade).

Types of Road Construction

Roads in sloping terrain are built using three basic methods full fill, cut-and-fill, and full bench construction (Figure 2 in Appendix C). A full fill road is constructed using imported fill materials, with no cut into the slope (except to roughen the slope to provide a hold for fill materials). The roadbed of a cut-and-fill road (also called partial bench, partial fill, or balanced construction) is formed from both fill materials and the bench that results from cutting into the slope. A full bench road is completely excavated into a slope with no fill materials used to support the road bed; the excavated spoil materials are endhauled, used to construct stream crossings, or sidecast downslope. Cut-and-fill construction is the most common road building method, since it minimizes the amount and cost of moving fill materials. All three construction types are used to build roads, depending on site-specific factors. For example, a stream crossing is full fill, a road section approaching a stream may be cut-and-fill, and a road section going around the "nose" of a ridge may be full bench (with the cut material being used as fill for nearby stream crossings).

Road Surface Shapes

A road surface may be outsloped, insloped, or crowned to facilitate drainage (Figure 3 in Appendix C). Outsloped road surfaces angle away from the cutslope, allowing water flowing on the road surface to disperse along the downhill side of the road. Insloped road surfaces angle toward the cutslope. Roads may be insloped with inboard ditches where subsurface water flows from the cutslope or where fills are highly erodible or unstable. Insloping is also used where surface drainage would otherwise flow directly into stream channels or where outsloping would result in unsafe driving conditions. A crowned road surface slopes gently away from the center of the road, resulting in roughly half of the surface water draining to the inboard ditch, and half to the downhill side of the road. Larger roads are typically crowned to drain runoff rapidly from the road surface.

Road Surface Drainage

In addition to the road surface shapes explained above, other design features are utilized to drain surface runoff. Rolling dips (also called drain dips) are smooth, angled depressions where a road grade reverses for a short distance to direct surface runoff or ditch water outward over the fillslope (Figure 4a in Appendix C). They do not present a clearance problem for vehicles. Rolling dips should also be constructed at stream crossings to prevent diversions if culverts plug. Waterbars are deep (over one foot), abrupt ditches angled across roads to prevent water from concentrating on the road surface and in the inboard ditch (Figure 4b in Appendix C). Waterbars are constructed on roads that do not receive continuous use. They hinder most vehicle use, but ORVs and high clearance four-wheel drive trucks can maneuver over them. Rubber flaps set into the road surface also function as waterbars, but do not hinder vehicle use.

Drainage Structures

Culverts (usually made of corrugated metal pipe (CMP) or plastic) are structures used to pass water under roads at stream crossings. They are also used to drain inboard ditches. A culvert draining an inboard ditch is referred to as a ditch relief culvert, since it "relieves" the ditch of concentrated water (Figure 5 in Appendix C). When properly constructed, culvert inlets are armored (usually with rocks) to prevent water from eroding and undercutting the culverts. Armoring is also placed at the outflow to dissipate the emerging water's erosive energy.

Less common drainage structures include bridges, fords, and log crossings. Bridges, typically wood, steel, or concrete, are often used on roads that cross larger streams and rivers. Fords are utilized as stream crossings where the stream bottom is stable and traffic is light. Fords that cross running streams are called "wet fords," and are generally composed of streambed gravels. Fords are sometimes paved where regular traffic occurs. Log crossings are soil-covered logs laid in and parallel to a stream channel. Prior to the mid-1980s, log crossings were used as "permanent" stream crossings as alternatives to culverts. They are highly susceptible to plugging, but are still used today as temporary crossings.

Diversion Potential

Given enough time, water, and debris, all culverts eventually fail, whether by plugging with wood and sediment, or by deteriorating due to rust (Figure 6 in Appendix C). Properly designed stream crossings allow water to flow back into the stream channel if the culvert plugs. Diversion potential refers to the likelihood that backed up water behind a plugged culvert will be diverted down the inboard ditch, road surface, or onto the adjacent natural slope, rather than back into the stream channel. Often, large gullies form and mass failures are triggered when water is diverted from stream channels. "Fail safe" is a misleading expression that describes a stream crossing that has no diversion potential; a rolling dip constructed at the crossing prevents the water from diverting out of the channel (Figure 7 in Appendix C). The crossing can still fail, but when a culvert plugs and the fill erodes, less damage occurs if the water flows directly back into the channel.

Road Maintenance

Continual maintenance is required for roads and their associated components to function properly. Some common maintenance activities include (Adams 1991):

- cleaning culverts to remove debris
- grading road surfaces to repair damage from concentrated water
- cleaning inboard ditches to remove accumulated materials, including organic debris, soil, rocks, and vegetation growing in the ditch
- reconstructing waterbars and rolling dips
- clearing vegetation along the road right-of-way
- clearing downed trees that block the roadway
- replacing old and undersized culverts

Part Two: Understanding Watersheds and Soil Erosion

Understanding the local and regional environment is critical for assessing a road removal project. The section below will help you understand how water flows through watersheds, how streams are classified, and how the land's slope is described. In addition, it will help you understand the erosion process and help you recognize different types of erosion, which is important since roads greatly accelerate natural erosion rates.

Water Flow

Subsurface flow is water flowing below the soil surface. It is the dominant water movement mechanism in many undisturbed watersheds, since rainfall rate rarely exceeds infiltration capacity of undisturbed soils (except in arid regions). Infiltration capacity is the maximum rate at which water can enter soil. Surface runoff, also called overland flow, occurs from areas that are impervious, locally saturated, or where rainfall rate exceeds infiltration capacity. Subsurface flow is slow relative to overland flow. In addition to subsurface flow and overland flow, which directly increase in response to precipitation or snowmelt, some water percolates to the groundwater. In many areas, groundwater sustains streamflow between periods of precipitation or snowmelt.

Subsurface water flows downhill until it reaches a stream or swale. A swale is a concave (u- or v-shaped) feature on a slope that begins to concentrate water during runoff events, although a distinct channel is not apparent. Swales are generally found in headwaters, upslope from well-defined stream channels.

Established stream channels may flow perennially, intermittently, or ephemerally. Perennial streams flow continuously throughout the year. Intermittent streams flow during the wet season, but dry up during the drier portion of the year. Ephemeral streams flow only in direct response to precipitation or snowmelt.

Stream Orders

A stream segment is classified as an order. Low-order streams are smaller and found closer to the headwaters, while high-order streams are larger, and form as low-order streams converge. First-order streams develop as swales gather sufficient water from uphill areas. First-order streams are tributaries of second-order streams. However, a first-order stream joining a second-order stream does not alter the rank of the second-order stream; two second-order streams must converge for the stream to be considered third-order (two third-order streams must converge to form a fourth-order stream, etc.). A watershed is sometimes referred to by the order of the stream at its outlet; for example, a watershed with a third-order stream flowing from it is a "third-order watershed."

Stream ordering is highly dependant on the scale of observation. For example, lower resolution maps may underrepresent the channel network. A third order stream on a lower resolution map may be a fifth order stream on a higher resolution map.

Slope

The land's slope is described in a variety of ways, including percent, ratio, and degree. Percent slope describes the rise over run. For instance, a rise in slope of one foot per ten feet of horizontal distance indicates a 10% slope. Slope ratios are calculated just the opposite of percent slope, so are based on the run to rise ratio (a 10% slope corresponds to a 10:1 slope ratio). Expressing slope in degrees is less common, but possibly the most intuitive to understand. Think back to high school geometry: a perfectly vertical line is 90° and a perfectly flat surface is 0°. Halfway between flat ground and a vertical rock face is a 45° slope.

Soil

Soil is a habitat for a diversity of organisms, a processing system for breaking down plant and animal detritus, and a symbiotic macroorganism that lives in direct symbiosis with the plant community (DeLuca 1998). Roads change many soil characteristics by increasing exposure, compaction, and erosion. Exposure, the removal of the protective layer of organic material (ex. decaying leaves), changes both the physical and chemical nature of a soil. Compaction, the compression of soil, reduces porosity, which is important for water and air movement through soil. Erosion, the process of physically detaching and transporting soil particles, can be accelerated by a decrease in infiltration capacity (Satterlund and Adams 1992).

Erodibility describes a soil's susceptibility to erosion, and is influenced by properties such as texture, structure, organic matter content, and chemical make-up (Lal and Elliot 1994). Soil texture, the relative proportion of sand, silt, and clay particles, often provides the clearest measure of erodibility. Silt soils tend to be the most erodible because the particles are easily detached and transported (Lal and Elliot 1994). Clay soils, while not easily detached, have lower infiltration rates, so may be more susceptible to greater runoff and increased erosion from concentrated runoff. Sandy soils have high infiltration rates, but are more easily detached; however, the larger particle sizes are less easily transported. In reality, most soils are made up of a combination of different sizes of soil particles and rock fragments. Soils with an even mix of sand, silt, clay, and coarse rock fragments tend to have the greatest strength, and hence, are the least susceptible to erosion (DeLuca 1998). Rock fragments affect soil erodibility when they are on the soil surface by acting as a protective mulch. Subsurface rock fragments, however, can reduce the soil void space, reducing the conductivity of water through the soil. This can reduce infiltration of water into the soil and effectively increase runoff.

Erosivity describes the ability of erosive agents (water, wind, and gravity) to cause soil erosion. Substrates (soil and rock) are erodible, while energy-possessing agents are erosive. For instance, a high intensity downpour is much more erosive than a light rain, and fast-moving concentrated water is much more erosive than slow-moving dispersed water.

Surface Erosion

Surface erosion occurs when soil particles are dislodged by raindrop impact, flowing water, blowing wind, and cycles of freezing/thawing and wetting/drying of the soil surface. The particles are then transported by water, wind, or the force of gravity.

Wind Erosion

Surface erosion by wind is common in arid regions, but may also occur in wetter regions where soils are exposed. The force of wind along the ground surface dislodges small soil particles and carries them in the air as dust. Wind also moves larger soil particles through a process called saltation. Saltation occurs when wind dislodges and moves the larger soil particles, which then jump along the ground and dislodge other soil particles as they hit the ground. As the length of unobstructed terrain (fetch) increases, wind gains momentum and increases its erosive power (Brooks et al. 1991). Compared to water, wind is a minor factor causing road-related soil erosion. Wind becomes a problem, however, when vehicles using roads cause dust to be carried into the air and deposited on nearby vegetation.

Freeze-Thaw Cycles

Freeze-thaw cycles (soil frost) cause surface erosion when soils are bare or sparsely vegetated, as is common for road prisms. Though not common in areas receiving significant snowpack (snow insulates the soil surface), soil frost is a significant erosive factor where bare or sparsely vegetated soils are rarely covered by snow and freezing temperatures are common. These conditions occur together in much of the central and southeastern United States (Satterlund and Adams 1992). Soil frost influences surface erosion in three different ways:

- expanding water overcomes the cohesive forces holding soil together, causing soil particles to detach from the surface
- frozen soils prevent infiltration, resulting in greater surface runoff
- as soil frost melts, it can become a source of surface runoff, even without rain or snowmelt

Water Erosion

Most erosion associated with roads is caused by water, either in a concentrated flowing form or by the impact of water falling as raindrops on the soil surface. Different types of water erosion include inter-rill erosion, rill erosion, and gully erosion.

Inter-Rill Erosion

Inter-rill erosion (also called sheet erosion) occurs when soil particles are detached by raindrop impact and transported by broad, shallow surface water flow. Raindrops can break surface soil aggregates, causing fine particles to wash into surface pores. Blocked soil pores impede infiltration, causing additional runoff and erosion. Rocks or pieces of wood sitting atop soil pedestals provide evidence of sheet erosion. The soil under the rocks or wood is protected from raindrop impact, so it is not eroded (Figure 8a in Appendix C).

Rill Erosion

As surface runoff deepens and concentrates, the erosive energy of moving water and the energy from rainfall impact combine to cause rill erosion. A rill is an erosion channel that varies in size from a rivulet up to one square foot (one foot deep and one foot across).

Road prisms experience significant sheet and rill erosion due to the lack of vegetative cover and relatively impermeable surfaces (Figure 8b in Appendix C). Road maintenance activities such as grading erase evidence of rilling, but new rills can often be found after rain storms. As a rill continues to grow or a series of rills converge, a gully may develop.

Gully Erosion

A gully is a relatively deep, recently formed channel where no well-defined channel previously existed (Brooks, et al. 1991). Gullies usually only carry water during or just after rainstorms or snowmelt events. Gully erosion is often caused by a combination of concentrated surface runoff, elevation change, and a lack of protective vegetative cover (Figure 8c in Appendix C). In addition to carrying surface runoff, deep gullies can intercept subsurface flow, allowing water to seep from the gully walls.

Gully formation generally occurs when surface runoff concentrates, allowing the erosive force for water to "eat away" at the soil. The gully then erodes upslope (headcutting) and migrates downslope due to vertical lowering of the gully bottom (downcutting). If the conditions conducive to gully formation are not reversed, the gully will deepen, widen, and lengthen until a new equilibrium is reached. At this point, extensive erosion and sedimentation is likely to have already occurred.

Look for road-related gully erosion in the following places:

- below unprotected culvert outlets
- in inboard ditches, on road surfaces, and on adjacent natural slopes where streams are diverted out of natural channels
- in inboard ditches with no or infrequent ditch relief culverts
- on road surfaces and adjacent natural slopes where cutslope material sloughs into and blocks inboard ditches
- downslope of waterbars and rolling dips
- in wheel ruts in road surface

Mass Failure

Mass failure, also called mass movement and mass wasting, is a gravity-driven process that occurs when the strength of a soil mass is overcome by the stresses acting against it (Satterlund and Adams 1992) (Figure 8d in Appendix C). Table 1 summarizes natural factors that impede or contribute to mass failure.

Table 1: Natural Factors in Mass Failure

Natural factors that resist mass failure	Natural factors that contribute to mass failure
• root binding of the soil mass • cohesive properties of the soil • fracturing of the sliding surface (bedrock)	• slope steepness that equals or exceeds the angle of internal friction (averages 35°) • wet soils • geology and soil types susceptible to failure, such as decomposed granite.

Soil type, which is related to the characteristics of the parent material that forms a soil, determines the strength of a soil mass. Soils formed from granite and sandstone, for example, tend to be shallow, coarse-textured, and cohesionless (Satterlund and Adams 1992). The presence of clay in soils increases their stength because of the cohesive nature of clay. For example, a soil developed from granitoid material that has a high clay content will have greater strength than a granitoid soil without a significant amount of clay (Burroughs et al. 1976). Without clay, the frictional resistance between particles provides strength to the sandy granitoid material relies on for its strength; with large amounts of clay, additional strength is provided by the binding together of particles due to the "stickiness" of clay. Soil moisture may add additional strength by contributing to soil cohesion, but generally increases stress by adding weight to a soil mass. In fact, while a dry clay has considerable resistance to failure, its strength decreases substantially when saturated because water films tend to separate the particles (Burroughs et al. 1976). A straightforward generalization regarding mass failures is that slopes become less stable as slope gradients increase and water content increases, regardless of the geologic material or the soil type (Burroughs et al. 1976).

Vegetation removal (logging and fire) also influences mass failure because the root binding strength decreases as roots die and decay; soils remain wetter longer because of decreased evapotranspiration (water use by plants). Wind can play a role in failures when the swaying of trees causes root mass disturbance.

Mass failures occur as relatively coherent masses of soil materials (slides) or as flowing bodies of materials that incorporate water, rocks, and large woody debris as they move downhill (debris flows and torrents). Some failures begin as slides of relatively small amounts of materials, then become debris flows or torrents when water content increases. For example, a slide of 250 cubic yards of material in the Coast Range of Oregon evolved into a 250,000 cubic yard flow by incorporating water from a stream and scouring debris from valley sides and the valley floor (Dunne and Leopold 1978). During the New Year's storm of 1997, a road failure in a small headwater swale in Whiskeytown National Recreation Area (California) evolved into a debris torrent that deposited at least 200,000 cubic yards of sediment into a creek (McCullah and Ring 1998).

Some common causes of road-related mass failures include:

- very steep slope gradients
- saturated fill materials
- decayed organic material buried in and beneath fill materials
- slopes overloaded with sidecast fill materials
- removal of slope support (cutting into slope)
- diverted and concentrated water
- improper fill placement and construction

- inadequate maintenance
- insufficient culvert sizes

Road-Related Erosion

Sediment from roads reaches a stream channel by one of two principle pathways: mass failure or surface erosion of the road prism. Mass failure is generally the more significant cause of sedimentation in areas of steep slopes and unstable soils, while the erosion of road surfaces, cutslopes, and fillslopes is more significant in areas with more stable soils and slopes (Bilby et al.1989). Road-caused surface erosion (especially gully erosion) also occurs on natural slopes when concentrated water is diverted downhill of roads or when stream water is diverted out of natural channels.

Road-related surface erosion is highest immediately following construction, decreasing with time to a relatively constant rate, as less erodible subsoils are exposed. Erosion from mass failures, however, is less predictable and initiates "pulses" in the overall rate of erosion. Mass failures due to decaying organic material in fill materials may increase with road age.

Chapter 3: Understanding Road Removal

As described in previous chapters, roads cause a variety of impacts to the hydrologic system and aquatic and terrestrial habitat. Removing roads, therefore, can help reduce or even reverse these impacts, moving ecosystems toward recovery. This chapter provides information on the different aspects of road removal, including road removal treatments; types of road removal; necessary equipment; and costs associated with removing wildland roads.

Basic Road Removal Treatments

Specific road removal treatments include removing stream crossings, constructing cross road drains, ripping, recontouring, and outsloping. Each treatment is summarized below.

Removing Stream Crossings

Stream crossing removal is a fundamental treatment for removing roads. When done correctly, stream crossings are removed by excavating ALL fill materials and restoring the original channel and valley shape (Figure 9a in Appendix C). Simply removing culverts is not enough, because any remaining road fill will erode into the channel. Materials excavated from stream crossings can be used to recontour road segments to their approximate natural slope, essentially returning fill to the location from which it was cut. Endhauling is necessary when the amount of fill removed is greater than that needed for recontouring. Any road removal project that does not remove stream crossings (or does not remove ALL fill materials) is not effective and may cause more ecological damage by causing additional sedimentation.

Constructing Cross Road Drains

Cross road drains are deep ditches excavated across road surfaces (similar to waterbars, but more substantial) to facilitate drainage on closed roads (Figure 9b in Appendix C). They are too deep and steep to be cleared by motor vehicles. Unless spaced frequently enough to disperse concentrated water, cross road drains may cause erosion downslope. They must be constructed more frequently on roads with steep grades, but are not necessary if roads are fully recontoured or outsloped steeply.

Ripping

Ripping involves decompacting road surfaces and fill sites to a depth of two to three feet. The goal is to enhance subsurface water flow by reducing soil density and increasing porosity, infiltration, and percolation. Ripping fill sites increases their permeability, reducing the chance of fill saturation and failure. Some soil settling occurs since organic matter is generally limited in road soils compared to adjacent soils that are less disturbed. Therefore, adding organic matter to the ripped soil can greatly accelerate the recovery of hydrologic function, including both infiltration and percolation (Luce 1997). Ripping also increases revegetation success.

Recontouring

Recontouring involves placing all fill materials back into locations where fill was removed during road construction (Figure 9c in Appendix C). Recontouring restores the original slope as much as possible, dispersing concentrated water and greatly enhancing slope stability. Full recontouring is sometimes impossible, especially on very steep slopes, since the sidecast material may have slid downhill out of reach. In some cases, cutslopes will be so high and road cuts so narrow, that replaced fill material will not blend with the original undisturbed slope. Even so, slope recontouring to the extent possible generally results in the most stable landform shape, restores natural surface runoff patterns, and deters motorized access.

Outsloping

Outsloping involves filling inboard ditches with sidecast fill material and sloping the road surface to disperse water to the downhill side of the road (Figure 9c in Appendix C). Some sidecast fill materials remain, but saturation and potential failure is reduced because water cannot concentrate in inboard ditches or on the road surface. The remaining fill slope materials may still cause stability problems, especially on steep slopes.

General Approaches to Removing Roads

Removing a road from an agency's transportation system on paper or computer (for example, taking it out of the forest transportation system) without removing it from the ground does not address the road's ecological impacts. When an agency states intentions to remove a road, it is critical to determine the extent of its planned activities. Permanent removal to one person may mean "storing" the road for future use to another.

Approaches to removing roads may be divided into six categories: closure, abandonment, reclassification as trail, decommissioning, conversion to trail, and obliteration.

Closure

Some agencies close roads with gates, berms, or deep ditches (tank traps) as an approach to road removal. On-the-ground surveys indicate that conventional closure devices are ineffective at stopping road use by people intent on accessing restricted areas (Hammer 1995). With an effective device that prohibits motorized access, however, closure may reduce a road's terrestrial impacts by providing wildlife security. Even so, closure is an ineffective approach to removing a road, because the road may continue to disrupt natural drainage patterns, cause soil erosion, and potentially initiate mass failures; in short, a closed road continues to impact aquatic ecosystems.

Abandonment

When a road is "abandoned," it is no longer maintained and may or may not be driveable based on physical conditions or the presence of vegetation. The Forest Service considers road abandonment a "no-action treatment" (Moll 1996). Like a closed road with an effective closure device, abandoned roads that no longer receive motorized use may reduce a road's terrestrial impacts by providing wildlife security. Simply discontinuing maintenance and abandoning a road, however, rarely prevents continuing and potential hydrologic problems. The presence of vegetation may provide the false idea that the road is recovering and is no longer problematic. Culverts can become plugged, and roads may continue to function as surface flow paths for water. Road fills may remain unstable and susceptible to failure. Because an abandoned road continues to impact aquatic ecosystems, abandonment is an ineffective approach to removing a road.

Reclassification as trail

Reclassifying a road as a trail without restoring drainage patterns and stabilizing fill materials is not an effective approach to removing a road, especially if motorized use continues. Even if wildlife security is improved by stopping motorized use, simply reclassifying a road as a trail does not address a road's aquatic impacts; this type of approach is basically the same as abandonment. If a road is changed to a trail, it must be actively converted (see "Conversion to trail" below) by first stabilizing fill materials and dispersing concentrated water.

Decommissioning

Decommissioning is carried out to minimize short-term sediment production, while "storing" a road for future use. Major treatments include removing stream crossings and stabilizing sidecast fill material. Site-specific drainage treatments such as constructing cross road drains, removing inboard ditches, and/or outsloping also help disperse concentrated water. Road surfaces may be mechanically scarified to facilitate revegetation. The goal of decommissioning is to leave much of the road prism intact so the road can be recontructed in the future with only minimal effort. Decommissioning preserves most of the original construction investment, while reducing road-caused erosion and avoiding maintenance and/or repair costs. Other common terms used to indicate road removal with plans for future reconstruction include storm-proofing, flood-proofing, erosion-proofing, putting-to-bed, deactivation, reclamation, hydrologic closure, hydrologic obliteration, and storage for future use.

Planning for reconstruction and leaving much of the road prism intact may result in treating a road too lightly during removal. Future plans may change; post-decommissioning is too late to further treat the road for the long-term. Even if decommissioning stops road-related erosion in the short-term, it is not the same as obliterating a road because the road is expected to be reconstructed. Even if roads may be reconstructed in the future, they should be removed as if reconstruction will not occur.

Conversion to trail

Converting a road to a modest walking trail can be an effective approach to removing a road if all fill materials are stabilized before the trail is constructed. Some road-to-trail conversions are implemented by only partially recontouring a road, which may not stabilize all fill materials. Conversion is ineffective when ORVs are allowed because impacts associated with motorized use continue. Although trails are less intrusive and damaging than roads, they can cause similar impacts, such as stream sedimentation and facilitation of non-native species invasions.

Obliteration

Obliteration involves removing a road with no plans for future reconstruction. To be most effective, obliteration restores the original landform to the greatest extent possible. Stream crossings are removed and slopes are recontoured. Road surfaces and fill sites are ripped to improve subsurface water flow. Coarse woody debris placed on the recontoured road surface provides erosion protection, long-term nutrient sources, and wildlife habitat. Revegetation is also actively carried out with native species collected near the site. Fully obliterating roads speeds the restoration and recovery of hydrologic function, as well as ecological and evolutionary processes. If implemented appropriately, obliteration is the most effective approach to road removal since it addresses both terrestrial and aquatic impacts caused by roads.

Road Removal Equipment

Effectively removing roads using the treatments described above requires the same machinery used in road construction. Past experience shows that tracked excavators and bulldozers with ripper/winged subsoiler implements are the most effective combination of heavy equipment for removing roads (Spreiter 1992) (Figure 10a in Appendix C). Dump trucks are used when necessary for endhauling fill materials. Table 2 summarizes the characteristics of the major equipment types used to remove roads.

Equipment Production

A number of factors affect equipment production rates, including (Spreiter 1992):

- distance the excavated material must be moved
- whether material is pushed downhill or uphill
- ground moisture conditions
- amount of large organic debris buried in fill
- age of the equipment

To maximize efficiency and keep costs down, ensure that road removal projects:

- employ skilled, cooperative operators
- use equipment with compatible capacities and production rates
- minimize the number of times fill is handled

Table 2: Summary of Road Removal Equipment

Primary uses:	Features:	Advantages:	Limitation:
Tracked excavators			
• lifting fill materials on steep slopes • reshaping stream channels following excavation • placing large organic debris on finished surface	• bucket digs and moves fill materials • hydraulic "thumb" on bucket grabs materials not readily lifted or carried by bucket alone • "tracks" provide stability and traction in varied conditions • rippers can be mounted on bucket for decompaction	• work well in tight locations • can work on slopes up to 55% with a skilled operator • rotate a full 360 degrees (material can be readily placed for movement by other machinery) • work well in combination with other machinery • can retreive materials on steep slopes with long reach of excavator arm • can load materials into dump trucks for endhauling	• moves relatively small amounts of materials
Bulldozers			
• performing preliminary excavation of stream crossings • completing final shaping of outsloped road surfaces • ripping road surfaces and fill sites (with ripper attached) • pushing materials to fill sites	• hydraulically-controlled blades move material (U-shaped blades have more capacity than straight) • winches can be attached for moving large materials and pulling out stuck equipment • "tracks" provide stability and traction in varied conditions	• can quickly move large quantities of materials • can work on slopes up to 55% with a skilled operator	• unable to load materials into dump trucks
Winged subsoiler			
• decompacting soil to depth of two to three feet	• angled wings on shanks are mounted on tool bar to lift and shatter dry soil	• mounted on bulldozer (can be interchanged with other implements)	• do not decompact moist soil effectively • do not mix soil or organic matter • additional weight affects machine balance on steep ground when not in use

Road Removal Costs

Road removal is a necessary undertaking to prevent further ecological degradation caused by existing roads and allow quicker ecological recovery. Investing in road removal saves money because preventing erosion and sedimentation is less expensive than fixing damaged waterways, restoring habitat, and/or recovering threatened and endangered species. Remember two points regarding road removal costs:

First, the majority of road removal cost is associated with heavy equipment work. Equipment purchase costs are well over $100,000 and rental costs are generally over $100 per hour. Second, road removal costs are extremely variable, and depend mostly on the amount of fill and the distance it must be moved. The number and size of stream crossings that must be removed plays heavily into cost where stream crossings are large and/or frequent.

Road removal costs vary depending on treatment and terrain. In Redwood National Park, for example, road removal costs vary from $10,000 to over $250,000 per mile. Removing a small road in gentle terrain with few stream crossings may cost as little as $10,000 to $20,000 per mile, while a major low-slope road in unstable terrain with frequent large stream crossings may cost $100,000 to $250,000 per mile (Spreiter 1992). Ripping alone averages $800 per mile and recontouring alone averages $10,000 per mile. A combination of treatments, however, is required for completion of any given project. The roads in Redwood National Park were constructed on steep unstable terrain to haul old growth redwood logs on oversized off-highway logging trucks (roads are often 30 to 40 feet wide, with pull-outs 50 to 60 feet wide).

Removing roads, including stream crossing removal and recontouring, in the Clearwater National Forest in Idaho varies in cost from $5,000 to $13,000 per mile and ripping alone averages $2,000 per mile (Conner 1997). Removing roads in the Lolo National Forest in Montana costs approximately $5,000 per mile (calculations indicate a cost of $1 per linear foot; Hegman 1997).

Though it may seem easier to consider costs on a *per mile* basis, the complexity and variability of site-specific needs along any one mile of road make it easier to compare costs on a *per cubic yard* basis (one cubic yard is about one pickup truck load). This is especially true when describing stream crossing removal. Excavating stream crossings in Redwood National Park and private lands in northern California averages between $1.00 and $3.50 per cubic yard. This cost doubles if materials must be endhauled (Spreiter 1992; Pacific Watershed Associates 1996).

Costs of Not Removing Roads

Removing sediment from streams, rivers, and lakes is much less economically efficient than preventing it from eroding in the first place. In the Trinity River watershed in northern California, collecting ponds were constructed as a last-ditch effort to stop sediment from entering the river. Removing the accumulated sediment from these ponds costs approximately $10 per cubic yard (McCullah 1997). A dam in the same area constructed specifically to trap sediment (up to one million cubic yards) cost $19.6 million dollars (McCullah 1997). This is equivalent to $19.60 per cubic yard of sediment removed. Compared to the cost of preventing sedimentation by stabilizing fill materials at a cost of usually less than $5 per cubic yard, managing sediment after it has entered streams and other water bodies does not make economic sense (McCullah 1994; McCullah and Conrad 1994). Not removing roads may also result in damage to infrastructure (in addition to the road itself) such as bridges (McCullah and Ring 1998). In addition to the measurable economic costs of not removing roads, the contribution that roads play in degrading ecosystems is often not measurable in economic terms.

Chapter 4: Ensuring Road Removal Success

In addition to understanding the different treatments of road removal, you need to consider these treatments in context. To effectively assess road removal projects, consider the primary rationale for treatment (i.e. to benefit aquatic or terrestrial habitat, or both). While a single threatened or endangered species may drive restoration funding or priorities, it is still important to consider the whole ecosystem. Once you know the rationale, you can measure whether or not priorities have been set appropriately and if the proposed project will effectively remove the road. This chapter explains this process, from setting priorities and understanding revegetation to evaluating and monitoring road removal projects.

Setting Road Removal Priorities

Because roads are so pervasive, priorities must be set to ensure that the most damaging roads are removed first. Roads need to be evaluated and prioritized for removal based on their relative ecological and hydrologic impacts. The section below provides guidelines to help determine which watersheds in your region are most in need of road removal. Once you have selected a watershed, the next step, also described below, is to perform a road inventory to determine which specific roads will be most detrimental if left untreated.

Prioritizing Watersheds

Prioritizing road removal is straightforward when done within the context of a regional wildland recovery plan. A regional wildland recovery plan considers the status of aquatic and terrestrial habitat, a step which is necessary for prioritizing watersheds in your region that are most in need of road removal. Using ecological criteria to select watersheds (within which to prioritize roads for removal) is the best approach to ensuring that road removal helps in recovering ecosystems, rather than being a haphazard activity motivated by social and political forces alone.

Just as roads were built into wildlands in an incremental fashion, so too can they be removed. Give first priority to watersheds where habitat is unimpaired and where the full complement of native aquatic and terrestrial species are flourishing. However, many areas are missing a few species, but have habitat of high quality that could be used if the area was accessible to those missing species. For example, a dam may impede access for anadromous fish to reach quality habitat upstream, or a terrestrial species may not be able to migrate through a developed valley to reach potential habitat. These areas are also high priorities for restoration. On a relative scale of watershed integrity, give priority to those with the greatest integrity (least degraded), followed in succession by those watersheds with lower degrees of integrity (most degraded). For instance, watersheds with very poor quality habitat where most native species have been extirpated are of lowest priority. From a temporal perspective, give first priority to those areas requiring immediate short-term protection and restoration, then focus on those that are so degraded that the return of viable populations of native flora and fauna can only occur in geologic time. Several additional key points are helpful in prioritizing watersheds:

1. Protecting and restoring the healthiest, most intact watersheds provides a better chance that source populations of wildlife will survive to colonize the more disturbed watersheds as they recover. These watersheds are the "anchors" of recovery efforts.

2. Some watersheds may have been heavily roaded since the last large storm or snowmelt event, and so far have retained healthy populations of aquatic species. Removing roads from these watersheds before an extreme event causes road-related mass failures will ensure that the aquatic ecosystems remain healthy and intact.

3. While some watersheds may be naturally devoid of certain native species, they may provide other ecological benefits. For instance, even if anadromous fish do not have access to a watershed because of an impassable waterfall, the watershed may still provide cool, clean water, large woody debris, and nutrients for aquatic species. Removing roads from these watersheds restores or maintains water quality.

4. Some watersheds may have roads that are particularly detrimental to terrestrial species, but have relatively little impact on aquatic species. For example, removing ridge roads can greatly benefit migratory terrestrial species, but may only marginally reduce aquatic impacts.

Prioritizing Road Removal within a Watershed

Even before venturing into the field to determine which roads in your selected watershed are the most detrimental, you can learn a substantial amount of information about a road by simply looking at a map. This section highlights some fundamental factors that influence a road's potential impact, including slope position, adjacent logging, and soil and bedrock characteristics. In addition, this section describes how to perform a field inventory of the roads in a selected watershed.

Slope Position

A road's location within a watershed provides useful information to consider when prioritizing road removal. Slope position defines the location of a road on a hillside or mountainside, with ridgetop having the highest slope position, and valley-bottom having the lowest.

The slope position will directly influence:

- the amount of sediment produced from stream crossing failure
- the amount of subsurface water intercepted and converted to surface runoff
- the potential for gullies to form due to concentrated surface runoff
- overall slope stability

Sediment production from stream crossing failure

Roads higher on a slope have more stream and swale crossings, so may be more problematic because of the greater number of drainage structures that could fail. The amount of fill per crossing, however, increases as roads are placed lower on a slope since stream size increases downstream. Single crossing failures of lower-positioned roads, therefore, have a greater potential for introducing large amounts of sediment to the stream system. In addition, lower-positioned roads are closer to channels, so sediment from road-related failures is more readily deposited into channels.

Another important point to remember: although higher-positioned roads may produce less direct sediment, they can cause significant downstream damage if they fail. Small failures can incorporate water and debris to produce debris flows that cause much more sedimentation and scouring of stream channels. Sediment from a small high-positioned stream crossing failure can plug a culvert at a lower stream crossing, causing additional failure and sedimentation.

Subsurface water intercepted and converted to surface runoff

The amount of upslope area for moisture accumulation largely determines the amount of subsurface water interception. Because valley-bottom roads have the most upslope area, they can potentially intercept more subsurface water compared to roads on slopes. However, because valley-bottom roads are usually adjacent to stream channels, the intercepted subsurface water is quickly discharged into the stream. Hence, valley-bottom roads are less problematic in terms of causing surface runoff due to intercepting subsurface flow (Wemple 1994).

Roads positioned in the middle of a slope are the most problematic in terms of converting subsurface water to surface runoff because they have sufficient upslope area to accumulate moisture, and are further from established stream channels. Two main consequences are related to subsurface flow interception by mid-positioned roads. First, intercepted subsurface water flows for a longer time as erosive surface runoff. Second, water arrives at a channel faster when it is converted to surface runoff.

High-positioned and ridgetop roads also allow water to flow faster through a watershed, but most of the surface runoff is associated with precipitation that does not infiltrate into the compacted road surfaces, rather than intercepted subsurface flow.

Potential for gullies to form due to surface runoff

Because they concentrate water, all roads have the potential to cause gully erosion, whether it be in the inboard ditch, in wheel ruts, or below culvert outlets or waterbars. Gullying in inboard ditches or wheel ruts is more likely to occur due to steep road grades (not related to slope position). Gullying below culvert outlets, however, is more often associated with ridgetop and high-positioned roads. There, concentrated surface runoff from roads is diverted onto natural slopes where such volumes of water have not historically occurred and channels are not formed (Montgomery 1994).

Slope stability

In general, steeper slopes are less stable. Certain landforms produce characteristic slope profiles. For instance, concave slopes in U-shaped valleys carved by glaciers are steeper in higher positions. Therefore, high-positioned roads in U-shaped valleys are likely to be less stable. In landforms with convex slope profiles, low-positioned roads are on the steeper slopes.

Logging Adjacent to Roads

In addition to slope position, logging adjacent to roads can exacerbate road impacts. Because logging reduces evapotranspiration and increases snow accumulation and melting rate, soil moisture is increased in harvested areas. Thus, more water is available for subsurface flow, which in turn may increase the amount of water intercepted by a road located below a harvested area (Wemple 1994).

Soil and Bedrock

Roads constructed where shallow soil overlies impermeable bedrock (or relatively impermeable subsoils) are particularly effective at intercepting subsurface flow (Wemple 1994). In addition to the physical structure of bedrock, the type of bedrock and soil directly influence road soil erodibility and potential for mass failure. Although broad generalizations provide a first step in understanding the importance of using soil and bedrock characteristics to help guide road removal priorities, considering sites on a case by case basis provides a more complete understanding.

Regional and local information sources are available to help prioritize roads based on soil and bedrock characteristics. The Natural Resource Conservation Service (NRCS; formerly Soil Conservation Service) has conducted soil surveys for each county in the United States that provide useful information for determining the relative erodibilities of soils in a given area. Detailed maps, divided into "map units," allow users to investigate how site conditions in the field relate to published information regarding soil erodibility.

Soil surveys discuss potential problems associated with roads based on the following:

- potential erosion of the roadbed resulting from concentrated water
- soil strength, which influences rutting, drainage, and trafficability during wet periods
- shrink-swell potential (constant shrinking and swelling due to wetting and drying can damage road surfaces and drainage structures)

County soil surveys also provide a ranking of soil erodibility. An erosion factor, "K," indicates a soil's susceptibility to sheet and rill erosion. Values range from 0.02 to 0.69, with higher values indicating higher erodibility. County soil surveys are available (for free) from NRCS offices. Libraries also make soil surveys available to the public.

Some land management agencies have published soil surveys that are available to the public. For example, some National Forests have soil surveys that are especially helpful for setting road removal priorities. Information is presented in user-friendly charts that compare the relative erodibility of soils.

Some chart components include:

- "susceptibility of the soil to erosion" (a rating of different soils based on relative susceptibility to erosion when exposed)
- "sediment delivery efficiency" (a rating of relative probability that eroded soil will reach a stream channel and become sediment; based on landform type, slope, and distance between drainageways)
- "risk of landslides" (rating of probability of downslope movement of masses of soil and rock material under natural conditions; based on slope, geologic properities, and landform)

- "sediment hazard on roads" (rating of risk of sediments entering channels as a result of erosion or landslides caused by road construction)
- "maintenance of cut and fill areas" (provides information regarding tendency for cutbank slough and erosion)

In addition to soil surveys, road buildling manuals are also helpful because they provide similar information regarding a site's potential for causing soil erosion and mass failure problems. Any published information should be supplemented with discussions with knowledgeable agency and university staff to gain a thorough understanding of how road impacts (and hence relative priority for removal) are related to soil characteristics.

Performing a Field Inventory

After you have considered Table 3, "What to Look for when Prioritizing Roads for Removal," to help get a general idea of the potential impacts of roads in your selected watershed, the next step is to put on your hiking boots and observe the road network first-hand. Use the road removal inventory form in Appendix A to perform an inventory to determine each road's impacts on aquatic conditions in the selected watershed. Then use the data you collect to decide which roads should be removed first.

When performing inventories, be on the lookout for evidence that roads and their drainage features are not functioning as planned; this is most apparent during or just after runoff events. Look for poorly designed roads. The suggestions in the table are in no particular order, but you can set priorities based on the number of problematic factors you find (more problems = higher priority).

As an overall approach, assign special priority to:

- Roads in the most unstable part of the watershed
- Roads in highly erodible soils
- Roads with diversion potential at crossings
- Insloped roads with inboard ditches
- Roads with organic material used in the fill
- Roads with sidecast fill perched on steep slopes

Table 3: What to look for when prioritizing roads for removal

Problem	Significance of problem
Streams diverted out of natural channels and crossings with diversion potential	Water diverted out of a stream channel causes extensive damage to the road and adjacent natural slopes. All stream crossings can potentially fail if culverts plug, but crossings with diversion potential are likely to cause more damage when they fail. A plugged culvert at a crossing without diversion potential still results in failure, but the water stays in the stream channel.
Inboard ditches discharging water directly into streams.	Inboard ditches can transport significant amounts of sediments to streams.
Concentrated water running down the road surface (or evidence of past concentrated water)	Concentrated water on the road surface can be caused by a number of factors, including outsloped roads that are not angled steeply enough to facilitate dispersed drainage, depressions caused by wheel ruts, and steep road grades.
Cracks and slumps in the road	Cut-and-fill road construction results in sidecast fill, which often overloads slopes and initiates mass failures. Failures do not necessarily occur all at one time; cracks and slumps may occur in fill materials before failures occur.
Sagging of the outside road edge	Sagging may indicate that cracks and slumps were graded away in the past
Leaning trees growing in road fill	Leaning trees indicate instability and potential future failure.
Holes in road surfaces and fill slopes	Large woody debris such as stumps and logs were used in the past as fill materials. When these organic materials decompose, they often form voids in the fill that may produce holes when they collapse. Voids cause fill instability, so are a sign of possible future failure.
Insloped roads with few or no ditch relief culverts	Even though culverts are prone to failure, too few culverts do not allow water to drain from the inboard ditch and return to subsurface flow. This can cause erosion of the ditch. Water can also move from one subwatershed to another if water is not relieved from an inboard ditch by a culvert.
Inboard ditches blocked by debris	Accumulated debris in inboard ditches can divert water onto the road surface.

Inboard ditches with evidence of past erosion	Ditches with insufficient drainage may enlarge into gullies.
Culverts with crushed inlets and/or outlets	Small debris can readily plug damaged culverts and cause failure.
Culverts with rusted inlets and/or outlets	Rust indicates deterioration, so rusted inlets and/or outlets may reflect the condition of the entire culvert. Rusting culverts do not function as designed, so failure is likely to occur as they age.
Culverts with deteriorated bottoms	Don't assume that culverts appearing in good condition at the inlets and outlets are also in good condition inside. Water can seep through deteriorated culvert bottoms and saturate fill, causing failure. Look inside.
Erosion around culvert inlets	Erosion around culvert inlets indicates that water may be seeping around culverts and could saturate fill materials, causing failure. In addition, erosion around a culvert inlet may indicate that the culvert is too small to accomodate the water it is expected to pass.
Gullies below culvert outlets	Gullies below culvert outlets often form when the ground below them is not armored to dissipate the energy of flowing water, or where culverts discharge water onto slopes where there was no natural stream channel.
Shotgun culverts	Shotgun culverts are culverts that are not placed upon the natural channel bed; rather, they stick out above the ground, resulting in a large vertical drop for the discharged water. This causes accelerated erosion.
Crossings without drainage structures	Crossings in ephemeral streams or headwater swales may only contain fill, without culverts to pass water under the road. Even small crossings can cause extensive downslope damage.
Log crossings	Log crossings are quickly plugged by debris and sediment, and can cause similar problems as crossings without drainage structures or with plugged culverts. Problems worsen as logs decay and collapse.

Removing a Road

Even though many site-specific factors affect how road removal projects are implemented, several characteristics are common to all effective and efficient projects. When assessing a road removal project, make sure the following principles are followed:

• The project should be implemented when the potential to cause additional erosion and sedimentation is minimal–during the dry season. Planning and field assessment is more flexible than on-the-ground work. While equipment work is usually limited to the drier periods of the year, field assessment may be more effective if it occurs during the wet season in order to identify sites needing special considerations. In addition to climatic constraints, work should be timed based on biological phenomena such as spawning fish or breeding birds. A project should be adaptable and designed so work can stop if conditions warrant. The long-term success of many species depends on the short-term impact of removing roads.

• Revegetation should be planned well in advance. See the "Revegetation" section later in this chapter.

• Pre-project monitoring should be conducted prior to heavy equipment work. See the "Monitoring" section later in this chapter.

• Heavy equipment should be cleaned before it is brought to the site to ensure that exotic species are not introduced.

• All revegetation materials (seed, mulch, woody debris, etc.) should be placed at strategic points along the intact road alignment before removal work begins to ensure materials are available when needed. Labor-intensive revegetation can proceed as equipment work is completed.

• Useful materials (topsoil, woody debris, rocks) encountered during heavy equipment work should be salvaged and stockpiled for later use.

• Surplus fill materials and structures such as culverts should be endhauled to appropriate locations.

• Surfacing material such as gravel should be salvaged and endhauled for other uses.

• Suitable fill sites should be decompacted before burying beneath recontoured fill.

• All stream crossing fill material should be removed down to the original valley form and channel bed. Indicators such as rocks similar to those above and below the crossing help identify the channel. Flared-out tree stumps and a decomposed organic layer help identify original landforms. Small amounts of water may also be seeping through gravels of the original channel. Simply removing culverts is not enough, since they may not have been aligned with the natural channel. Some crossings are constructed by placing fill material in the stream before installing the culvert. In all cases, ALL fill materials must be removed from stream channels. It is also important not to disturb the buried natural channel armor during excavation.

• Topsoil buried beneath sidecast fill materials should be uncovered whenever possible. Topsoil is usually the first material that is sidecast downslope during road construction, so it can generally be recovered by excavating the fill materials covering it. Topsoil is rich in nutrients and organic matter, and may contain viable native plant seeds and algal and microbial propagules. Topsoil on the finished surface greatly speeds the recovery of native vegetation. Flared roots on stumps and decayed remnants of original vegetation (generally darker in color) help identify original topsoil.

• Water should be diverted or pumped around excavation sites until all fill is removed (if water is present). This is especially important if a culvert is not aligned with the natural channel.

• Stream bottoms should be armored by placing rocks and large woody debris if the original channel cannot be located.

• Rocks and large woody debris should be placed along the surface of the entire recontoured alignment to provide microsites for vegetation germination, protection against erosion, and a long-term nutrient source (woody debris). Woody debris also provides immediate habitat for some wildlife.

• Post-project monitoring should be performed. See "Monitoring" section later in this chapter.

Revegetation

The revegetation phase of a road removal project is especially important in healing the disturbance caused by heavy equipment. Avoiding cookbook approaches and giving special consideration to the local abiotic and biotic conditions will maximize revegetation success (VanderMeer 1996). The section below will help you recognize effective and deficient revegetation activities associated with road removal.

A successful revegetation project should:

- Consider site-specific requirements (soil moisture, nutrients, etc.)
- Establish physical stability prior to revegetation
- Use local native plant materials
- Recover topsoil when possible
- Be planned well in advance

Benefits of Revegetation

Revegetation speeds recovery of disturbed sites and prevents further off-site degradation for a number of reasons:

<u>Vegetation controls surface erosion:</u>

Controlling surface erosion is the most important short-term benefit of revegetation. Raindrop impact and surface runoff energies are dissipated by vegetation and organic litter. Plant stems further reduce surface runoff by providing avenues for water to "funnel" into the soil (infiltration). Root channels facilitate water percolation through the soil, allowing more water to be absorbed at the surface.

Vegetation enhances soil structure:

Plant roots and substances released by soil organisms bind the soil together, improving soil structure. Soil organic matter and an organic debris layer on the soil surface increase resistance to erosion and improve soil development.

Vegetation enhances slope stability:

Vegetation enhances slope stability primarily by reducing soil moisture due to increased evapotranspiration. In addition, plant roots bind the soil, preventing some small slope failures.

Vegetation enhances biological activity:

Vegetation and organic matter provide an energy source for soil organisms.

Impediments to Revegetation

A number of common problems impede revegetation, including insufficient topsoil, organic matter, and plant nutrients such as nitrogen and phosphorus. Topsoil is integral to plants since it is the major zone of root development, contains many available nutrients, and holds and supplies much of the water available to plants (Brady 1990). Recovered topsoil is likely to contain viable plant propagules including seeds and plant fragments that can establish in suitable conditions. Therefore, recovering topsoil during road removal greatly improves the revegetation potential of a disturbed site. Organic matter is an important component of soil because it binds soil particles together, increases water holding capacity, and provides an energy source for soil organisms (Brady 1990). In addition, organic matter increases porosity and water infiltration, and makes nutrients more readily available to plants. To be successful, any revegetation project must account for these impediments.

Options for Revegetation

Approaches to revegetation include relying on natural plant colonization, using exotic/non-native species, using native species, or using a combination of exotic and native species. Each approach has its benefits, but using native species collected near the disturbed site ensures the best chance of long-term revegetation success. An overview of each approach is provided below.

No action

A no action approach is based on the assumption that the adjacent plant community will provide a sufficient seed source for vegetative recovery. Most road removal projects in Redwood National Park, for example, do not include a revegetation component. Instead, the road removal staff focuses on moving unstable soil to prevent it from entering the aquatic system. In general, this approach is not as effective as active revegetation, especially where road-related sedimentation is primarily caused by surface erosion rather than mass failure.

Exotic plant species

Exotic (non-native) plant species are commonly used in revegetation projects because they provide a quick cover to protect the soil surface. In addition, they are often readily available and relatively inexpensive. Some exotic species also allow slower developing native perennials to establish strong root systems. Though exotic species often require less effort to establish, they have many disadvantages that can be avoided by using local native plants.

Potential problems with exotic plant species used in revegetation:

- Exotics may persist for long periods, inhibiting establishment of native perennials.

• Exotics may invade and outcompete adjacent native plant communities.

• Proper and timely planning generally negates the need to use exotic species. However, if exotics are used for revegetation, they should only be non-invasive, non-persistent "temporary stabilizing species" that allow native plants from the surrounding area to establish.

Native plant species

Native plant species are more appropriate for revegetation because they are associated with dependent wildlife species and are naturally occurring components of affected ecosystems (USFS 1995). However, a revegetation project labeled "native" may not be what it first appears. Distinguishing between *local* and *non-local* native species is important to maximize adaptability of plants to site conditions and to minimize possible negative genetic influences on native plant populations adjacent to the revegetation site (Shelly 1997).

"Local" native plant material originates from genetically local sources. Genetic locality is formally determined by plant movement guidelines set up to increase the probability that reproductive materials (seeds, cuttings, etc.) will survive, grow to maturity, and reproduce on disturbed sites (USFS 1995). Local native plant material may be planted 500 feet higher or 1000 feet lower than the elevation at which it was collected.

Non-local native plants

Most non-local native species used in revegetation are wide-ranging and genetically diverse. They may include a number of different ecotypes, which are locally-adapted variations within a species that differ genetically from one another, but maintain the basic characteristics of the species. Using maladapted native plants could jeopardize revegetation success. Non-local native individuals may establish well, but the extremes of the site can reduce long-term success. Using non-invasive exotic species or sterile annuals and non-persistent perennials is generally more appropriate than using non-local native plant materials, until true local native plant materials are available (Huber 1993).

Key points about non-local native plants used in revegetation:

• Non-local native plants may not be adapted to environmental conditions of the site.

• Non-local native plants may contaminate the genetic make-up of the local population of the same species.

Local native plants

Locally adapted native individuals may initially establish and grow less dramatically than non-local native individuals. However, they are more likely to survive the extremes of the site, since they are adapted to local environmental conditions (temperature, soil, nutrients, etc.). Using local native plants maximizes revegetation success by avoiding negative genetic influences on local plant populations. Using local native plants requires more planning and forethought, as well as more funding and personnel.

Key points about local native plants used in revegetation:

• Local native plants are adapted to environmental conditions of the specific site.

• Local native plants maximize long-term revegetation success.

• Local native plant collection may disturb ecosystems (and increase their susceptibility to invasion by exotic plants)

Using Local Native Plant Seeds in Revegetation

Collecting seed from local sources in advance allows seed to be stored until needed for revegetation. This can be accomplished by direct seeding or increased seeding (Huber 1993). Both approaches require concise documentation to ensure that the collection site matches the revegetation location. Commercial production during increased seeding uses fertilizers and irrigation to maximize yield, which can result in selecting for individuals that thrive under such conditions (often not characteristic of the revegetation site). Since revegetation sites are commonly low in nutrients and moisture, the duration of seed increase should not be long enough to change the genetic make-up of the increased seed. Revegetation success could be compromised by selecting for individuals not adapted to low nutrients and moisture, even though they were from plants collected at the revegetation site.

Planting Techniques

Several appropriate planting techniques exist, including seeding, transplanting from the adjacent plant community, and/or transplanting nursery grown seedlings. Each technique is described below.

- **Seeding**

Broadcasting seed over the disturbed soil surface is a typical planting technique, especially on steep slopes. Ensuring seed/soil contact greatly improves germination success, so seeds from some species need to be placed at a certain depth below the soil surface. Flat or gently sloping sites can be seeded with drill implements, which automatically place the seeds at a pre-determined depth. Seeds can also be collected during revegetation from the adjacent plant community and spread over the disturbed site.

- **Transplanting from the adjacent plant community**

Transplanting whole plants, cuttings, or vegetation mats from adjacent areas ensures that individual plants are adapted to the local environment. Transplanting also introduces soil organisms that improve growing conditions for plants. The small amount of additional disturbance is a trade-off for assisting overall site recovery.

• **Using nursery-propagated seedlings**

Bareroot and containerized seedlings propagated from locally-collected materials can be planted on the disturbed site. Developing a strong root system before planting greatly improves revegetation success. Planting seedlings is much easier directly following soil disturbance, since the soil is not compacted.

Mulching

Once an area has been seeded and planted, mulches are then applied. Mulches are organic materials applied to the soil surface after seeding and planting. They are primarily used to protect the soil surface, reduce erosion, ameliorate temperature extremes, and reduce moisture stress. Typical mulching material includes straw, native hay, and wood residues (wood chips, sawdust, and bark fragments). Erosion control mats are also used for locations within a site that are particularly susceptible to erosion. Some studies report no differences in soil erosion and plant establishment success between mulched and non-mulched sites (Redente 1993).

Sites that generally do require mulching include (Redente 1993):

- steep slopes
- highly erodible soils
- sites where low moisture limits plant establishment
- sites where high winds are common
- soils that readily form a surface crust

Ensure that any mulching material is certified weed-free so exotic invasive species are not introduced to the site.

Monitoring

Road removal is a relatively new land management activity. Many road removal projects are carried out by personnel more familiar with building than removing roads. Monitoring the success of projects is extremely important for identifying current, and avoiding future, mistakes. Evaluating overall watershed recovery should be part of larger monitoring programs, while site-specific monitoring should be planned as part of individual road removal projects.

Site-Specific Recovery

Monitoring activities to evaluate site-specific recovery include establishing permanent photo points and conducting qualitative and quantitative surveys. A combination of activities provides the best idea of how a site is recovering following active road removal. This section describes each component of an effective monitoring program.

• Establish permanent photo points

Taking pictures is a simple and common technique for monitoring site recovery through time. Photographs qualitatively indicate vegetation changes, erosion problems, and stream channel adjustments following excavation. Established photo points may be obscured in the shorter term as vegetation becomes thicker and lusher. Recovery will be more noticeable, however, as trees grow and shade out brushy vegetation.

• Conduct qualitative surveys

Periodic visits help identify erosion problems, non-native species problems, and vegetation recovery. Annual visits should be appropriate for monitoring vegetation. Erosion problems should be monitored following major snowmelt and rainfall runoff events when possible. Erosion problems can also be identified on portions of roads not treated as part of a project (for instance, along road segments between crossings, if stream crossing removal is the only treatment carried out). Treatments can be adjusted as monitoring information becomes available. Some treatment adjustments may include: adding rocks to armor stream crossings, moving soil with hand tools to disperse runoff, and planting vegetative cuttings in unanticipated wet areas.

• Conduct quantitative measurements

Following stream crossing removal, a stream adjusts its channel as more natural hydrologic patterns return. Channel adjustments may include downcutting, widening, armoring, and development of "steps." Adjustments will occur even with careful handwork following heavy equipment excavations because post-removal channel structure depends on the energy of flowing water. The amount of adjustment depends on the success of the excavation at locating the original channel; unanticipated meanders and abrupt changes in channel slope sometimes make this difficult. If large amounts of fill are left behind and channels are not excavated widely enough, the fill will erode into the aquatic system. Establishing permanent stream channel cross-sections after excavation and monitoring them through time allows channel adjustment erosion to be quantified. Measuring the size characteristics of rocks and other "armoring" materials also allows channel adjustments to be quantified (Klein 1984, 1987). In addition to erosion, sedimentation monitoring should also be carried out (this can be part of a larger scale monitoring program).

Video footage can also be used to observe site recovery through time, as well as to document a project as it is implemented. Though not necessarily used to monitor a project's effectiveness, video can help improve future projects by acting as a learning tool for project designers and heavy equipment operators. The staff at Redwood National Park use time-lapse photography to document heavy equipment techniques. Using a camera that shoots one frame every five seconds, they can later view a workday in five minutes.

Monitoring the Big Picture: Overall Watershed Recovery

Removing roads is a major component of wildland ecosystem recovery. While short-term site-specific monitoring is important, the primary long-term concern is how watersheds and their components are recovering following road removal and restoration. For instance, how are native aquatic species responding to reduced road-caused sedimentation? Are all native species, including wide-ranging carnivores, utilizing the formerly roaded area? Are ecological and evolutionary processes recovering to near pre-disturbance conditions? Is the landscape *functionally* more connected?

Methods originally designed to detect the damaging influences of management activities can also be used to evaluate habitat recovery due to restoration activities (Madej 1996). Monitoring is critical to ensure that road removal improves, rather than damages, ecosystems. A detailed explanation of monitoring is beyond the scope of this guide, but many sources provide useful monitoring information, including MacDonald et al. 1991; Madaj 1996; Noss 1990; and Noss and Cooperrider 1994.

Assessing Agency-Designed Road Removal Projects

Agencies often design road removal projects using standard engineering techniques. They place numbered stakes or fluorescent flags along the road every 100 feet and at locations where work is planned. Each stake and flag is considered a "station." For example, the station 500 feet from the beginning of the road is labelled "5+00," and the station 2345 feet from the beginning is labelled "23+45." They use abbreviations to describe road components and treatment instructions for contractors, and develop contract plan sheets that detail the work required for contract completion. You can acquire all of this information from the agency in charge of the contract. Developing a working relationship with agency road removal personnel will increase your success in ensuring projects are implemented appropriately.

Some projects are implemented without developing detailed contracts. In cases where a contract is not developed, the agency rents equipment and hires operators on an hourly basis. The road removal personnel direct the operator as the work proceeds. This arrangement, while allowing greater flexibility for the project, makes assessing a project more difficult. Meeting with road removal personnel and discussing project plans are especially important in these cases.

Carry out the following steps to effectively assess a pre-designed project:

1. Develop a working relationship with agency road removal personnel.

2. Request a copy of the contract plan sheets (if developed) and review contract design procedures.

3. Visit the road removal site and note any project deficiencies by comparing on-the-ground conditions with contract plans. When a contract plan is not developed, compare the information provided by agency personnel to on-the-ground conditions. Use the information presented in this guide to recognize inadequate plans.

4. Organize your findings using the project design assessment form in this guide.

5. Write a report, detailing your findings and suggestions.

6. Submit your report to the appropriate agency personnel and arrange a meeting to discuss necessary changes to the contract before it is awarded.

7. Follow up. Arrange to visit the site during work to insure goals are being met.

Reminders

Two goals guide all road removal activities. First, **STABILIZE ALL FILL MATERIALS** (especially stream crossing fill and sidecast fill). Most catastrophic fill failures are initiated by "extreme" climatic events, such as a long, soaking rain followed by an intense storm, or a rapid snowmelt event.

Second, **DISPERSE CONCENTRATED WATER**. Concentrated water is much more erosive than dispersed water.

In addition, several actions will ensure that the two basic road removal goals are accomplished.

• Stream crossings should be excavated down to the original channel bed and valley shape.

• Inboard ditches should be obliterated.

• Insloped roads should be outsloped (at least).

• When outsloping, roads should be outsloped at a steep enough angle to disperse water to the downhill side of the road, rather than down the road surface.

- Fill sites should be decompacted.

- Equipment should be cleaned prior to and after on-site work.

- An appropriate revegetation plan should be developed and implemented.

- An appropriate monitoring plan should be developed and implemented.

Last words

Securing terrestrial habitat through road closure is only a step towards wildland recovery. Closing a road without alleviating its hydrologic impacts will not stop road-caused aquatic habitat degradation. Actively removing roads ensures that overall road-related ecological degradation is reversed.

Appendix A: Performing road inventories

Using the Road Inventory Form

Overall road information

By completing this section, you will gain a general understanding of the road prior to performing a more in-depth field inventory. **Road type** and **access** will tell you what the road is used for. **Road history** will reveal much about the potential and real impacts associated with a road. Knowing the **year of construction** will help you determine, for example, whether organic materials were incorporated into a road's fill (initiating failure as it decomposes). Knowing **maintenance history** will help you determine the perennial problems associated with a road. For example, there may be sections of a road that have washed out on a regular basis, soaking up large amounts of maintenance money. Some roads may have surface drainage problems, requiring grading on a regular basis to stop rills from developing into gullies. Use the appropriate agency publications or ask agency staff in order to find general information about a road, as noted above.

Determine a road's **hillslope position** either by looking at the contour lines on a topographic map, or by estimating it in the field based on your sense of the surroundings. Refer back to the "Prioritizing road removal within a selected watershed" section in Chapter 4 to review the significance of hillslope position in determining a road's relative hydrologic impact.

Sites and Segments

Refer back to Chart 3 in Chapter 4, which summarizes many of the potential problems to look for when surveying a road to document its impacts. Use the chart in the field to help you recall the subtleties of a road that can cause big problems. Once in the field, take plenty of photographs to document your findings.

As you progress along a road, assign a number to each site and segment, and note this on the form in the appropriate location. Label each site on a topographic map for later reference.

Sites

Determine the type of **drainage structure**, if one exists. If necessary, refer back to the "What is a road?" section in Chapter 2 to review drainage structures. Note culvert sizes for additional information. Determine the **condition** of culverts, the ground around the culvert inlet, the ground below culverts, and fill materials by observing them up close.

Segments

Surface shape refers to the direction water will flow from a road's surface. Refer back to the "What is a road?" section in Chapter 2 to review road surface shapes. Don't forget that insloped road segments concentrate water in an inboard ditch (allowing water to become more erosive than if it was dispersed).

The **condition** of the road surface, road fill, inboard ditch, and cutslope should be obvious by observing each portion of the road prism. Refer back to the "Understanding watersheds and soil erosion" section in Chapter 2 to review rill and gully erosion.

Understanding diversion potential

Diversion potential refers to the likelihood that backed up water behind a plugged culvert will be diverted down the inboard ditch or road surface, or onto the adjacent natural slope, rather than back into the stream channel. You can determine whether a stream crossing has diversion potential by standing near the stream on the uphill side of the road. Stand so that the road surface is at your eye level, then determine where backed up water will flow if it reaches the elevation of the road surface. If the road grade slopes to either side of the stream crossing, there is potential for diversion. If there is a broad dip in the surface of the crossing, the backed up water will flow back into the stream on the downhill side of the road. Hence, a stream crossing with a dip in the road surface has no diversion potential.

Road Inventory Form

Overall road information

Road name/number	
Date	
Location	
Agency	
Road type (service, haul, spur, etc.)	
Access (car, 4wd, ORV, walk only) Will portions of the road need to be reconsructed due to past failures?	
Road history (year of construction, maintenance history)	
Hillslope position (valley bottom, low/mid/high slope, ridgetop)	
Comments	

Road Inventory Form

Sites

Site number	
Type of site (stream crossing, swale crossing, seep, ditch relief culvert)	
Drainage structure (culvert, log crossing, bridge, ford, fill only)	
Culvert condition (good, plugged, inlet/outlet rusted, inlet/outlet crushed, inside rusted)	
Ground condition around culvert inlet (eroded, good/armored)	
Ground condition below culvert (gully, good/water reinfiltrates)	
Fill condition (rilling, cracking, slumping, sagging, holes)	
Crossing history (now diverted, past diversion, no diversion, washed out)	
Diversion potential? (Y/N)	
Comments	

Segments

Segment number	
Surface shape (outsloped, insloped, crowned, flat)	
Surface condition (rilling, gullying, ponded water, holes)	
Fill condition (rilling, cracking, slumping, sagging, holes)	
Cutslope condition (rilling, slumping)	
Inboard ditch condition (good, converted to gully, blocked by debris)	
Does inboard ditch discharge directly into a stream? (Y/N)	
Comments	

Appendix B: Performing assessments

Using the Project Design Assessment Form

Overall project:

Use the "Overall Project" section to organize what you know about factors that are relevant to the entire project (type of removal project, revegetation plans, monitoring and documentation plans, etc.). The easiest way to complete the Overall Project section is to meet with or call the agency road removal personnel and ask questions. Also use the project plans to gleen information relevant to the entire project. You can use the answers to these basic questions to make suggestions for changes to the project.

Specific locations

After documenting the plans relevant to the entire project, use the "Specific Locations" section of the form to organize your findings while you are assessing the road in the field.

Sites:

Sites include stream crossings, swale crossings, seeps, and ditch relief culverts. **The overall concern when assessing a site is whether the treatment will remove all fill materials.**

Segments:

Segments are road sections between sites. **The overall concern when assessing a road segment is whether the treatment (or lack of treatment) will disperse concentrate surface runoff.** Stabilizing fill materials is also important, especially in steep, unstable watersheds. Though a segment is defined as a road section between sites, you can break up segments into subsegments if one road segment has different characteristics.

Project Design Assessment Form

Overall project

Road name/number	
Date	
Location	
Agency	
Describe the type of removal. Will the road be re-opened in the future? Will motorized access be effectively limited?	
What is the funding source?	
What type of equipment will be used?	
When will the project be implemented?	
Will the equipment work be supervised/directed? If no, why not?	
Is there a revegetation plan in place? Describe. (origin of plant materials, mulching materials)	
Is there a monitoring plan in place? Describe. (photos, qualitative/quantitative surveys) Is monitoring directly associated with the road removal project? Is funding appropriated specifically for monitoring?	
Will fill sites be ripped?	
Will equipment be cleaned prior to and after work?	

Project Design Assessment Form

Specific locations

Road name and/or number: ________________ **Date:** ________________

Sites: stream and swale crossings, seeps, ditch relief culverts Questions to address: Will all fill materials be removed? Will culverts be removed? Will stream bottoms be armored if original channel is not located?	Segments: road sections between sites Questions to address: Segment ripped? Inboard ditch obliterated? Will perched fill be left if not recontoured? Will outsloping be steep enough to disperse water downhill of road, rather than allow it to concentrate on the road surface?

Station number and/or location description	Notes and suggestions
Site or Segment	
Site or Segment	
Site or Segment	
Site or Segment	
Site or Segment	
Site or Segment	
Site or Segment	
Site or Segment	

Appendix C: Illustrations

Figure 1. Basic components of a road.

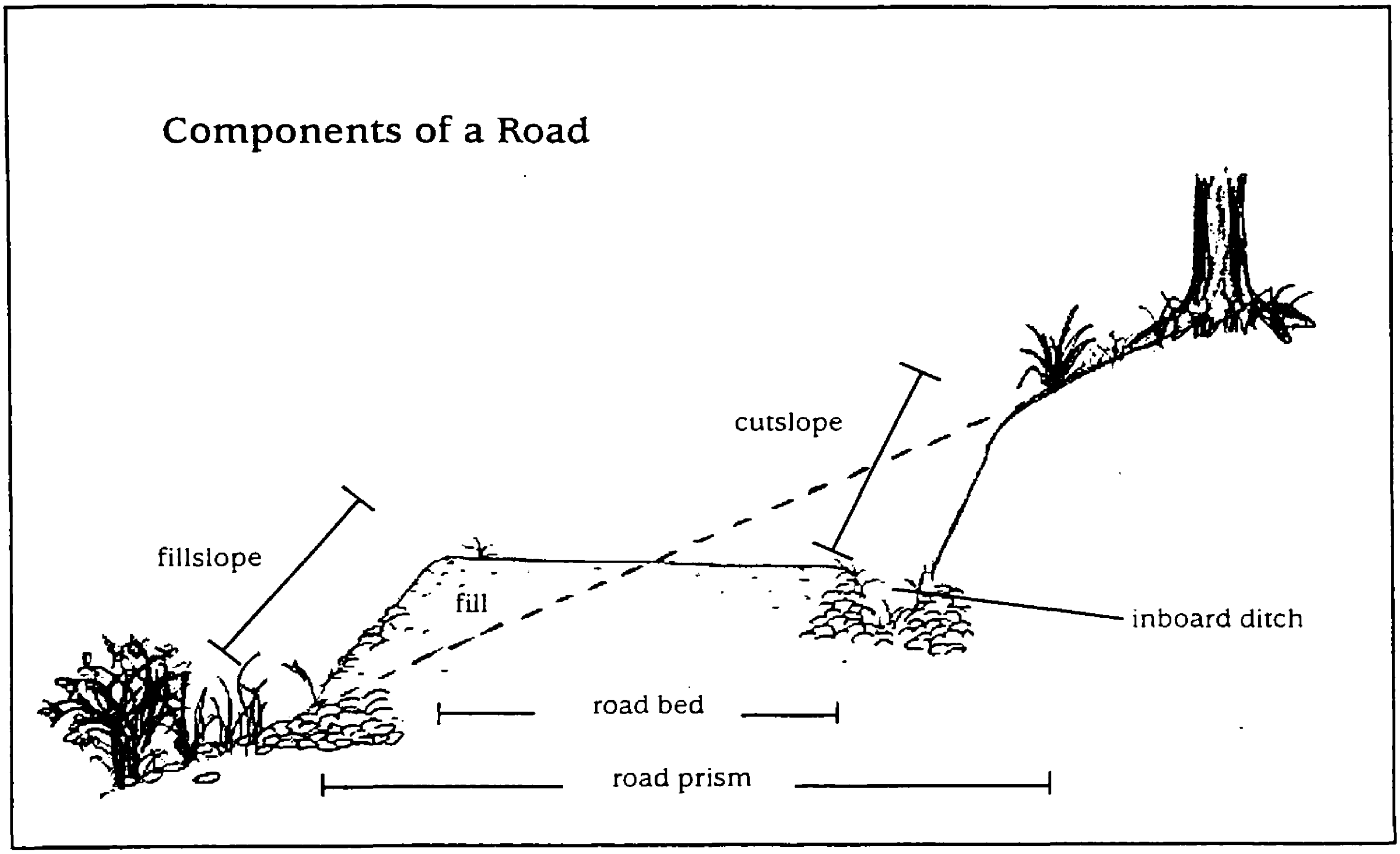


Figure 2. Types of road construction.

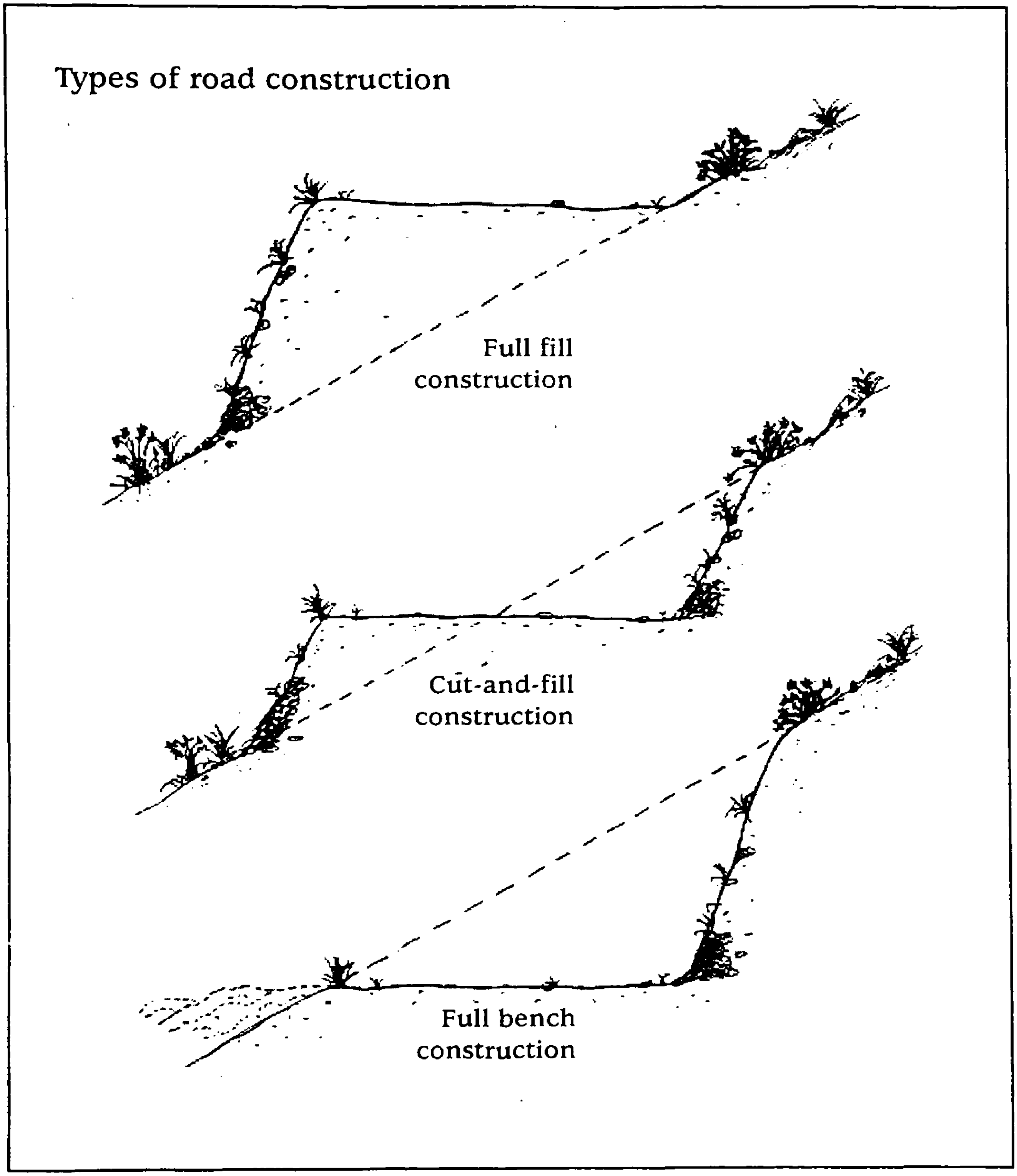


Figure 3. Road surface shapes.

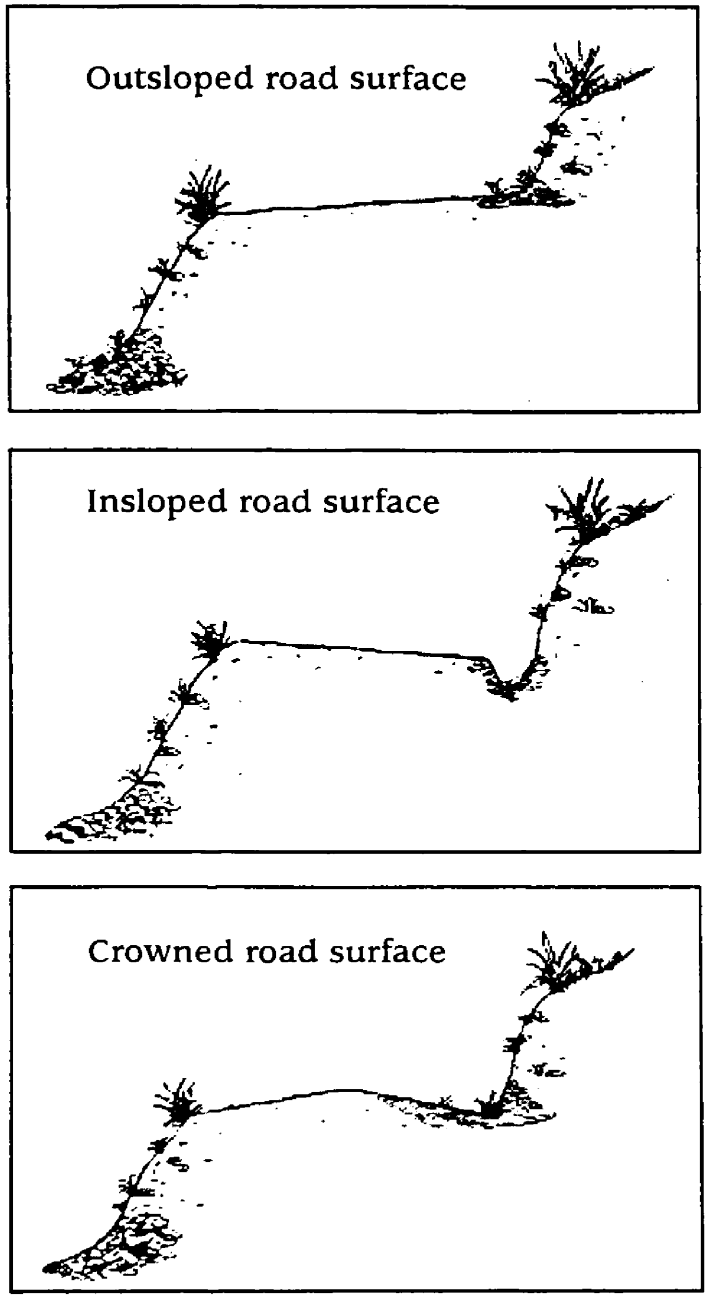
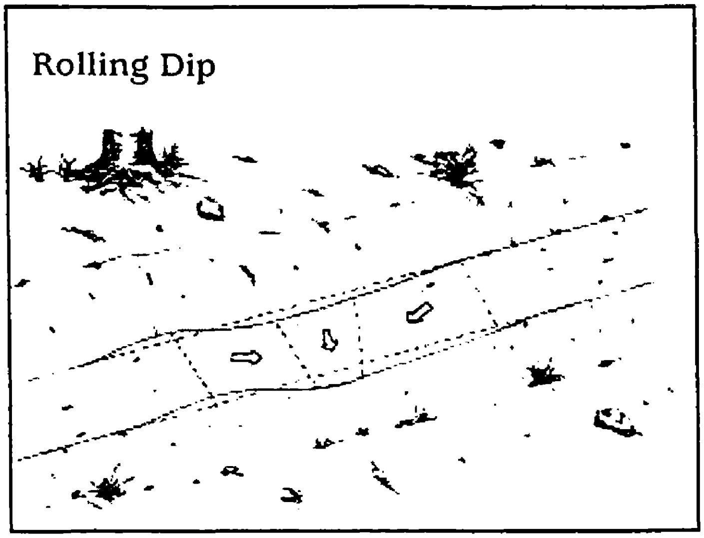


Figure 4. Road surface drainage features.

A. Rolling dip



B. Waterbar

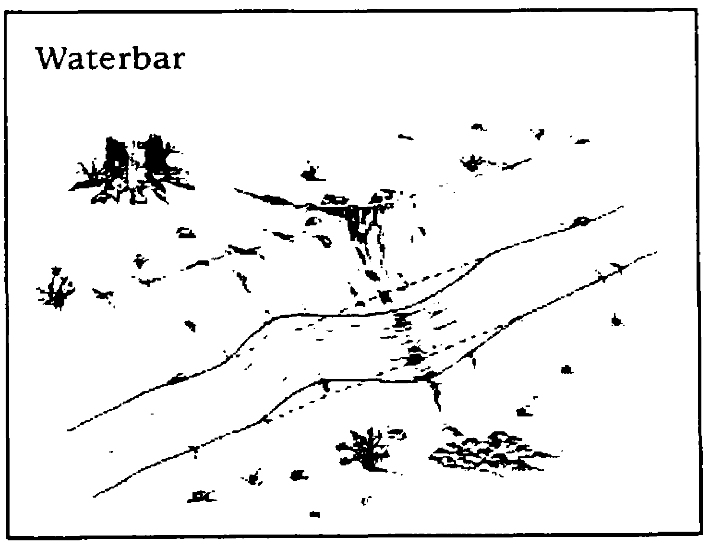


Figure 5. Ditch relief culvert.

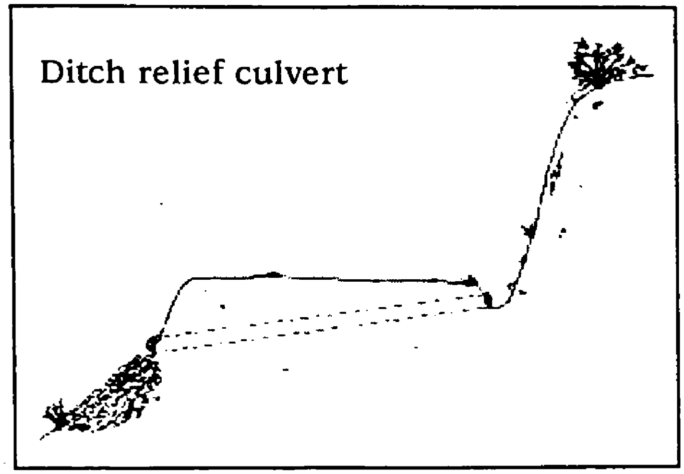
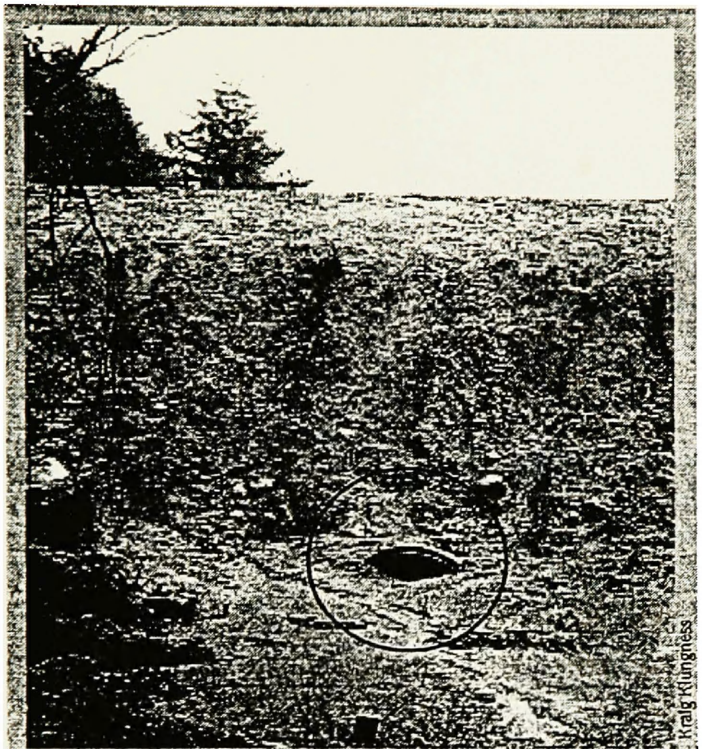


Figure 6. Disfunctional culvert.



Plugged culverts like this one can lead to road failures and stream diversions.

Figure 7. Stream crossing without diversion potential.

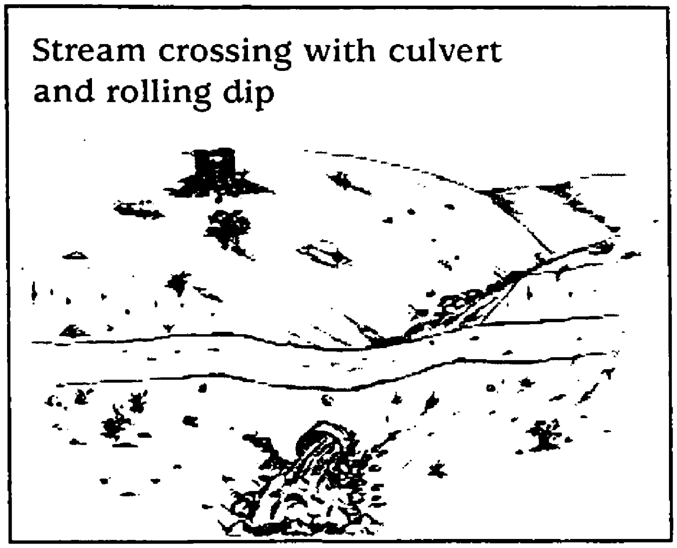
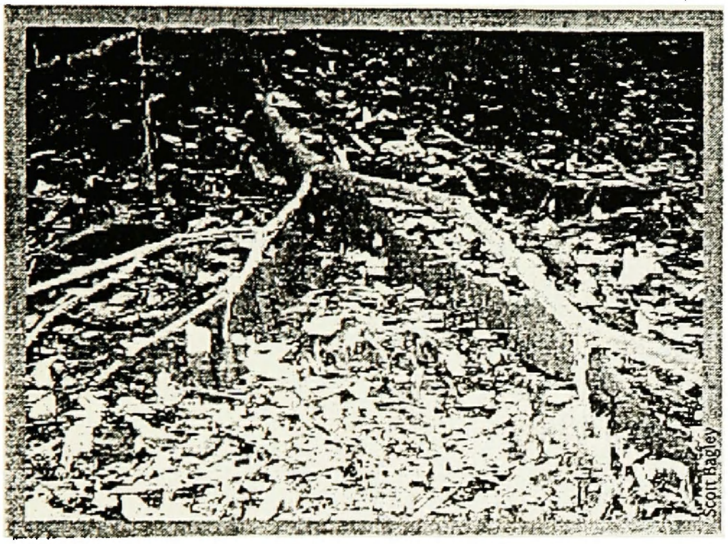


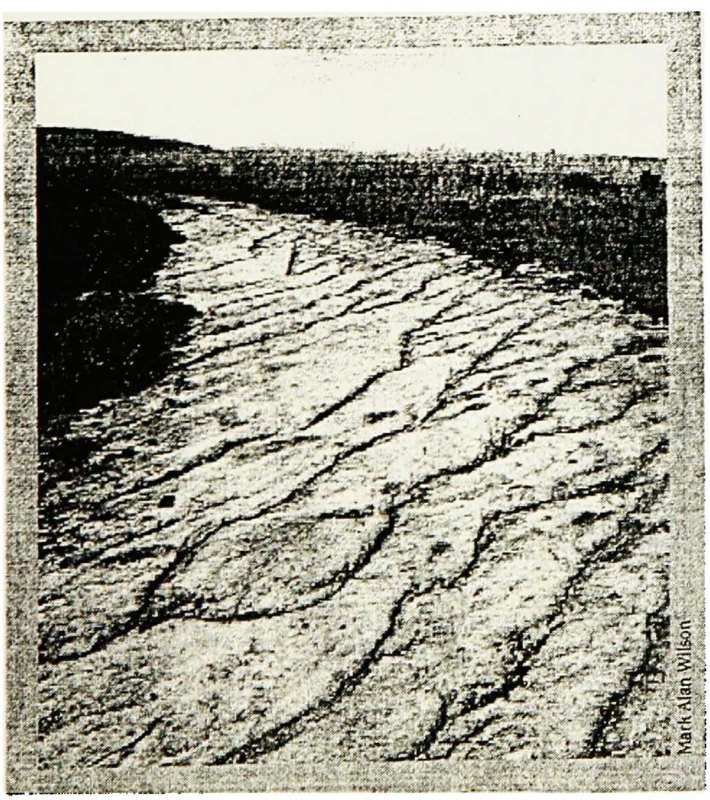
Figure 8. Types of erosion.

A. Inter-rill erosion



C. Gully erosion

B. Rill erosion



D. Mass failure

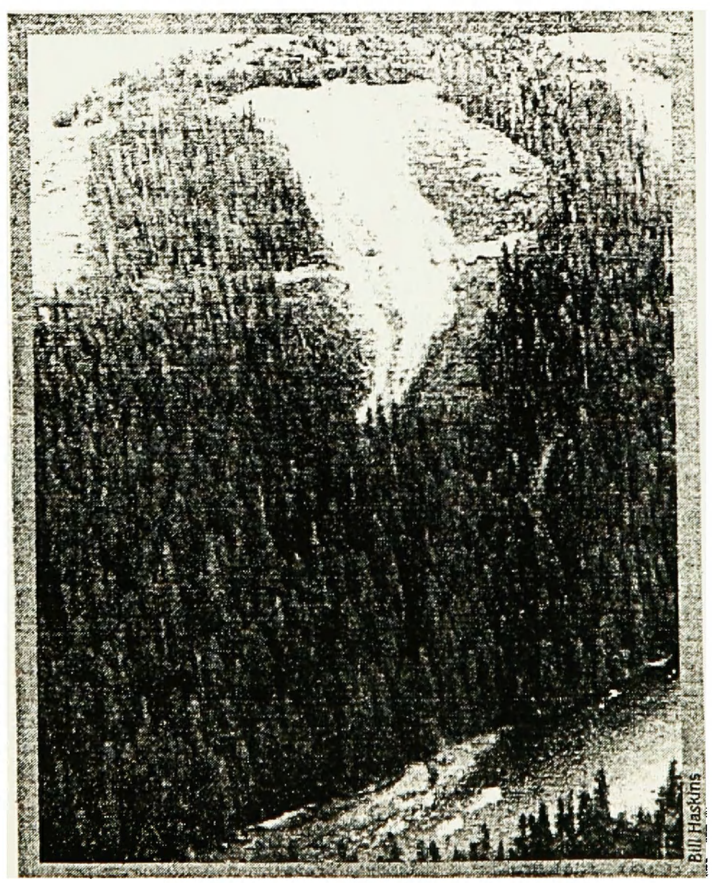
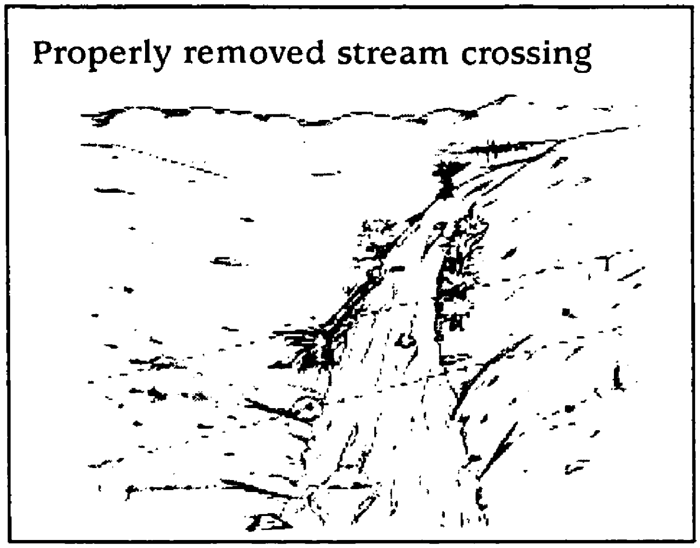
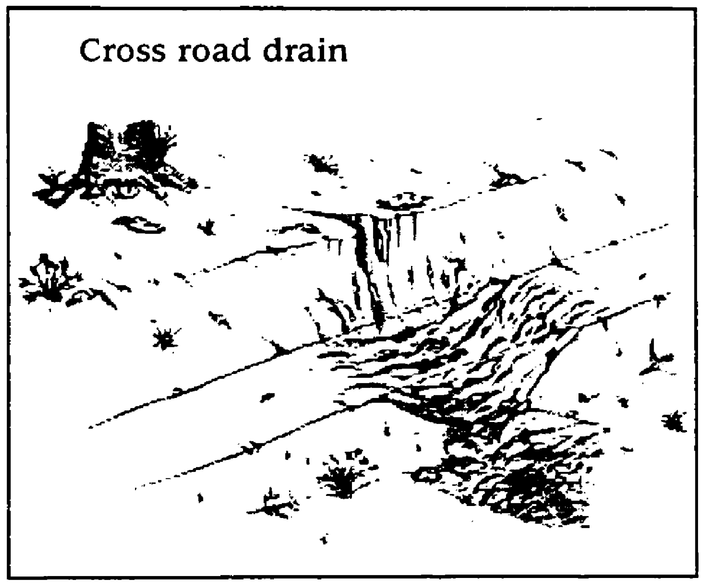


Figure 9. Basic road removal treatments

A. Stream crossing removal



B. Cross road drain



C. Recontouring and outsloping

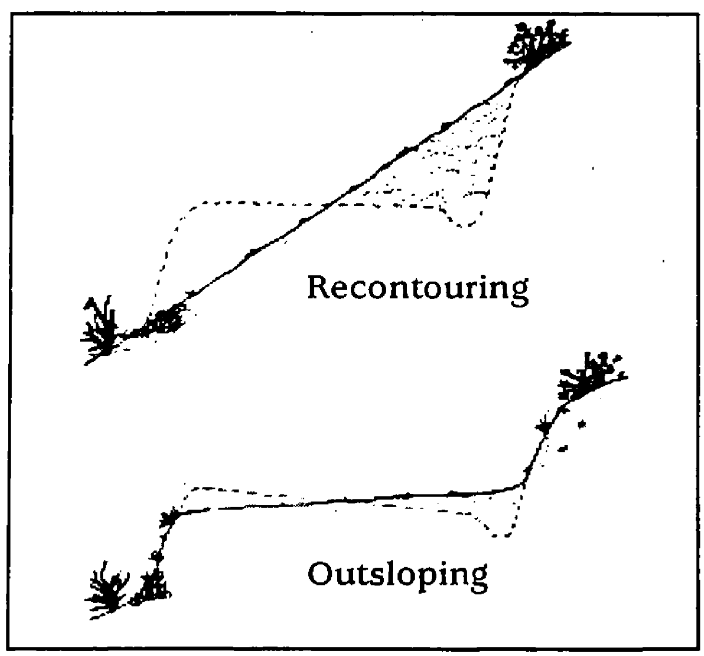
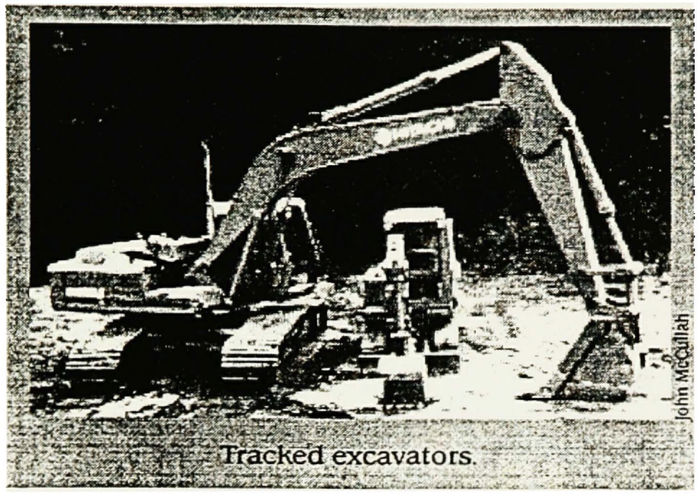
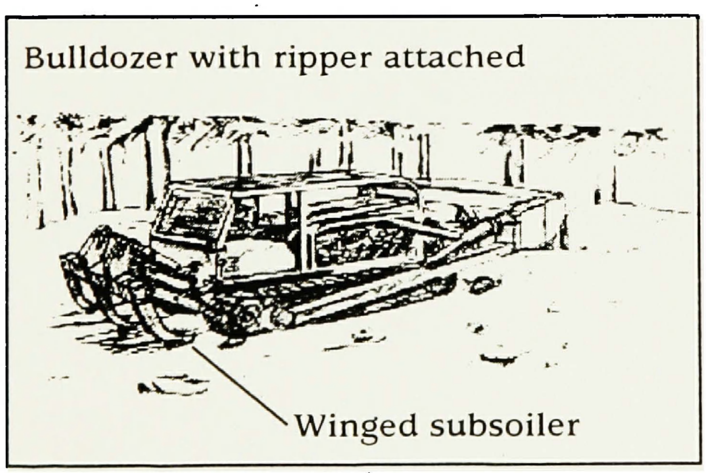


Figure 10. Road removal equipment

A. Tracked excavators



B. Bulldozer and winged subsoiler



Bibliography

Adams, P.W. 1991. Maintaining woodland roads. The Woodland Workbook. Oregon State University Extension Service.

Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. The generation and fate of road-surface sediment in forested watersheds in southwestern Washington. *Forest Science* 35(2): 453-468.

Brady, N.C. 1990. The Nature and Properties of Soil. 10th edition. MacMillan Publishing Company, New York, NY.

Brooks, K.N., P.F. Ffolliot, H.M. Gregersen, and J.L. Thames. 1991. Hydrology and the Management of Watersheds. Iowa State University Press, Ames, IA.

Burroughs, E.B., G.R. Chalfant, and M.A. Townsend. 1976. Slope Stability in Road Construction: A Guide to the Construction of Stable Roads in Western Oregon and Northern California. United States Department of Interior Bureau of Land Management. Oregon State Office. Portland, OR.

Conner, A. 1997. Personal communication. United States Forest Service Engineer. Clearwater National Forest.

DeLuca, T. 1998. Personal communication. University of Montana School of Forestry, Missoula, MT.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Company, San Francisco, CA.

Furniss, M.J., T.D. Roelofs, and C.S. Yee. 1991. Road construction and maintenance. Chapter 8 in: Influences of Forest and Rangeland Management on Salmonid Fishes and their Habitats. American Fisheries Society Special Publication 19: 297-323.

Hammer, K.J. 1995. The Road Ripper's Guide to the National Forests. Road Removal Implementation Project, Missoula, MT.

Harr, R.D. and R.A. Nichols. 1993. Stabilizing forest roads to help restore fish habitats: a Northwest Washington example. *Fisheries* 18(4): 18-22.

Hegman, S. 1997. Personal communication. United States Forest Service Engineer. Lolo National Forest.

Hobbs, R.J. and D.A. Norton. 1996. Toward a conceptual framework for restoration ecology. *Restoration Ecology* 4(2): 93-110.

Huber, L.S. 1993. Native Seed Collection Guide for Ecosystem Restoration. Wallowa-Whitman National Forest, August 1993.

Klein, R.D. 1984. Channel adjustments following logging road removal in small steepland drainages. Pages 187-195 in: Proceedings, Symposium on Effects of Forest Land Use on Erosion and Slope Stability, 7-11 May, 1984, Honolulu, Hawaii. International Union of Forestry Research Organizations. Published by the Forest Research Institute, New Zealand Forest Service. Christchurch, New Zealand.

Klein, R.D. 1987. Stream channel adjustments following logging road removal in Redwood National Park. Redwood National Park Technical Report 23. National Park Service. Arcata, CA. 38 pages.

Lal, R. and W. Eliot. 1994. Erodibility and erosivity. In Lal, R. (ed.). 1994. Soil Erosion Research Methods. St. Lucie Press, Delray Beach, FL.

Luce, C.H. 1997. Effectiveness of ripping in restoring infiltration capacity of forest roads. *Restoration Ecology* 5(3): 265-270.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. (EPA/910/9-91-001) USEPA Region 10 in cooperation with the Center for Streamside Studies, University of Washington, Seattle, WA. 176 pages.

Madaj, M.A. 1996. Measures of stream recovery after watershed restoration. In McDonnel, J.J. et al. 1996 (eds.). Proceedings of the AWRA Annual Symposium, Watershed Restoration Management: Physical, Chemical, and Biological Considerations. American Water Resources Association, Herndon, Virginia, TPS-96-1, 524 pages.

McCullah, J. 1994. Restoration work in a granite watershed. *Land and Water*: May/June 1994.

McCullah, J. 1997. Personal communication. Consultant, Salix Applied Earthcare, Redding, CA.

McCullah, J., and G. Ring. 1998. Watershed Restoration in Whiskeytown National Recreation Area. Paper presented at the International Erosion Control Association Conference in Reno, NV.

Moll, J.E. 1996. A Guide for Road Closure and Obliteration in the Forest Service. United States Department of Agriculture. Forest Service. San Dimas Technology and Development Center. # 4E41L03.

Montgomery, D.R. 1994. Road surface drainage, channel initiation, and slope instability. *Water Resources Research* 30(6): 1925-1932.

Noss, R. 1996. The ecological effects of roads. Road Ripper's Handbook. Road Removal Implementation Project, Missoula, MT.

Noss, R.F. 1990. Indicators for monitoring biodiversity: a hierarchical approach. *Conservation Biology* 4: 355-364.

Noss, R.F. and A.Y. Cooperrider. 1994. Saving Nature's Legacy: Protecting and Restoring Biodiversity. Island Press, Washington, D.C.

Pacific Watershed Associates. 1996. Removing Roads...Restoring Wildlands: Training Manual and Source Materials for Inventories of Watershed Road Systems. Arcata, CA.

Redente, E.F. 1993. Revegetation and reclamation training workshop. In: United States Forest Service. 1995. Northern Region Native Plant Handbook: a Guide to Revegetation with Native Species.

Satterlund, D.R. and P.W. Adams. 1992. Wildland Watershed Management. 2nd edition. John Wiley and Sons, Inc. New York.

Shelly, S. 1997. The influence of life history traits on patterns of genetic variation - implications for revegetation with native species. Unpublished manuscript presented at United States Forest Service, Region 1, 1997 Regional Training Academy, The Role of Genetics in Ecosystem Management.

Spreiter, T. 1992. Redwood National Park Watershed Restoration Manual. Redwood National Park, Orick, CA.

Stotter, D. 1996. The Road Ripper's Guide to the Bureau of Land Management. Road Removal Implementation Project, Missoula, MT.

United States Forest Service. 1995. Northern Region Native Plant Handbook: A Guide to Revegetation with Native Species.

VanderMeer, M. 1996. Disturbed Site Assessment and How to Choose your Revegetation Technique. VanderMeer's Wildland Conservation Services.

Weaver, W.E. and D.K. Hagans. 1996. Sediment treatments and road restoration: protecting and restoring watersheds from sediment-related impacts. Chapter 4 in: Healing the Watershed: A Guide to the Restoration of Watersheds and Native Fish in the West, The Pacific Rivers Council, Inc., Eugene, OR.

Weaver, W.E. and D.K. Hagans. 1994. Handbook for Forest and Ranch Roads: A Guide for Planning, Designing, Constructing, Reconstructing, Maintaining, and Closing Wildland Roads. Mendocino County Resource Conservation District; in cooperation with the California Department of Forestry and Fire Protection and the USDA Soil Conservation Service. Ukiah, CA.

Wemple, B.C. 1994. Hydrologic Integration of Forest Roads with Stream Networks in Two Basins, Western Cascades, Oregon. M.S. Thesis, Oregon State University, Corvallis, Oregon.

Wemple, B.C., J.A. Jones, and G.E. Grant. 1996. Channel network extension by logging roads in two basins, Western Cascades, Oregon. *Water Resouces Bulletin* 32(6): 1195-1207.