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4. WHAT DO WE NEED TO KNOW ABOUT ROADS?

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Abstract

Roads facilitate forest management activities, recreational access, and fire suppression. At the same time, they damage wildlife habitat, destroy the remoteness many seek in wildland recreation, produce sediment, alter aquatic ecosystems, and abet the dispersal of noxious weeds. Design of appropriate road networks is thus a controversial task for land managers, and no such design is free of value-laden decisions between conflicting needs. Because of changing silvicultural practices, fewer roads will be needed in the future in many forest lands, and decisions must be made about which roads to preserve, which to control access on, and which to obliterate. Each action has environmental costs and benefits, but the nature of these effects is usually not fully understood. The types of information provided by basin assessment, watershed analysis, and project-level analysis can be used to clarify the trade-offs for various options, and thus can provide a credible basis for management decisions.

Introduction

The road network is considered by many to be the most important, the most costly, and the most damaging component of forest land use. Roads are associated with high sediment inputs and altered hydrology, both of which can strongly influence downstream channel habitats. Roads are also important as a source of indirect human impacts and as an agent of vegetation change and wildlife disturbance. Each issue requires a different type of information about roads if the issue is to be adequately addressed.

The fundamental message of the Record of Decision for Amendments to Forest Service and Bureau of Land Management Planning Documents Within the Range of the Northern Spotted Owl (USDA and USDI 1994; the Record of Decision and the accompanying Standards and Guidelines are referred to here as the "ROD") is that future land-management decisions on federal lands in the range of the northern spotted owl will be based on information about how the land-use activity in question relates to the full variety of relevant ecosystem and social needs at the site, in the watershed, in the larger river basin, and within the region. The ROD establishes watershed analysis and basin assessment as the mechanisms through which the necessary contextual information is identified. This mandate is particularly important for the road network. The ROD recognizes roads as an important tool for land management and as an important contributor to past land-use impacts. Roads are thus presented as a major target for restoration. Existing problems are to be repaired, sites of potential future problems are to be upgraded, and some roads are to be decommissioned. Each road segment eventually will be evaluated to determine how it fits with the aquatic conservation strategy objectives presented by the ROD. Future road planning will thus require an evaluation of how a road relates to the rest of the road network (whether "system" roads or not), future transportation requirements, and its environmental context.

The need for comprehensive transportation planning throughout western federal lands has been evident for a long time, but budgets, workloads, day-to-day crises, and lack of interagency communication have conspired to give this objective a low priority. Some advances have been made already, however. In the Forest Service Pacific

Northwest Region, 15,000 miles (one-sixth the total mileage) of important interforest and cross-forest roads of all standards have been identified as the "backbone" of the road network. Although many of these roads will remain unimproved, all will be managed and maintained as the major access routes through the forests. This type of planning effort will be facilitated by the requirement for watershed and basin analysis; these tasks can now be used to provide the information, motivation, and interagency cooperation needed for comprehensive transportation planning.

Interagency cooperation is particularly important because roads strongly affect communities and land management outside of federal lands. Many state and federal highways and county roads cross federal lands, and agencies with responsibility for these roads are concerned about how the requirements of the ROD will affect them. The federal agencies, in turn, are concerned about how to ensure that maintenance and management of these routes is compatible with federal land management goals. The Commerce Department, state agencies, and counties did not participate in preparation of the Forest Ecosystem Management Assessment Team report (FEMAT 1993), so mechanisms for interacting with these agencies are still being explored.

In addition, different agencies have different needs and opportunities for their road systems. The Forest Service will continue to require an extensive road system for timber management and resource use and protection. In contrast, National Parks and the BLM in California will be concerned primarily with the network necessary for management of late seral reserves and recreation. These agencies will be using watershed analysis to prioritize roads for rehabilitation and decommissioning, and for weighing the tradeoffs between decommissioning, maintenance, and the environmental damage these options incur. Different agencies have different areas of expertise in road management, and the ROD is likely to facilitate sharing of expertise between agencies.

In addition to these "government" roads, many roads are built across federal lands to access private inholdings or adjacent private lands. And, within any given watershed or river basin, there are many roads that lie exclusively on private lands upon which government agencies have little or no influence. However, these private roads also affect social, biological, and physical concerns and must be included in any watershed analysis or basin assessment.

The societal context for forest roads

Almost everyone who uses federal lands uses the road system, and almost everyone has an opinion about the roads. Most commercial users want safer roads with improved trafficability. Non-commercial users range from those who want a paved road for a Sunday drive to those who want to preserve the feelings of remoteness and isolation that road construction and improvement would imperil. All, however, want a level of roading that allows them to use the area as they are accustomed to, and few want to see increased traffic in "their" watersheds. Even hunters and anglers, who need roads for access, usually judge the success of a trip by the quality of the wilderness or social experience rather than by the trophies bagged. Improved roads would give these users better access during the hunting or fishing season, yet would detract from their experience by increasing the use level and decreasing the feeling of wildness and isolation.

Even if there were no change in road density, use levels would continue to increase in federal wildlands. As population centers grow, more people turn to the woods for recreational opportunities. At the same time, changing technology changes the types of activities going on there. Off-highway vehicles, trail bikes, and mountain bikes are now common on unimproved roads and trails, and recreational vehicles have turned pull-outs into summer homes. Both activities are carried out in remote areas to lessen the possibility of conflict with other users, but their presence itself makes the areas "unremote" to other users with conflicting values. In addition, the amount of leisure time and the activity of retirees is growing, so isolation seekers tend to stay in wildlands for longer than they have in the past, increasing the probability of an encounter with a conflicting use. Long-time wildland users report that new users seem to have little attachment to the land and little ethic for preserving its wildland values (Kathy Hefner-McClellan, Six Rivers National Forest, personal communication). Long-time users and land owners cite increased litter and vandalism as evidence of the change, and suggest that if access had not been improved, the new users would not have come. Roads thus are seen as a mechanism for increasing conflict over wildland uses and values. Because modern vehicular technology allows almost any road to be driven, the sociological effects of a rural road do not depend strongly on its construction standards.

Roads also have a considerable image problem among environmentalists. On Forest Service and BLM land, a new road is seen as the first step along a route that leads inevitably to horizontal trees. Roads are also recognized as a major contributor to erosion, degraded water quality, and hydrologic change. The environmentally oriented public has little appreciation for the role of roads in carrying out ecosystem management. This reputation will be a major hurdle for cooperation between land management agencies and environmental organizations in establishing a transportation policy that serves ecosystem management.

In the past, agencies did not adequately consider the cultural values and needs associated with roads when new roads were planned or old ones abandoned. The result has been a long history of conflict between agencies and local communities. The philosophy outlined by the FEMAT report (1993), on which the ROD is based, is a strong indication that this approach will change. As rural communities begin to work with the agencies to diversify the economic base, federal agencies increasingly have the opportunity to be seen as a partner in development. In the Mad River area, for example, 75 percent of the land is managed by Six Rivers National Forest, and this land will be the basis for an ecotourism industry being planned by the community. It is now the responsibility of the Forest Service to work with the Mad River community to identify the types of forest uses appropriate for the area, the type of transportation system needed, and its maintenance requirements. The agency must also work with the smaller interest groups, whose needs may not be evident at early stages but who have the power to block development later. Above all, we must remember that roads are just a tool for managing other things. The ideal road system is one that allows efficient management to the desired objectives and that does not impact other components of the social, physical, and biological systems. Unfortunately, any road causes impacts. The challenge thus is to strike an appropriate balance between transport efficiency and the level of detrimental effects.

Road problems and problem roads

Roads directly or indirectly affect all components of the watershed and the ecosystems it supports. Some of these influences are widely understood, while others are just beginning to be recognized. Physical influences have been the most carefully studied so far, but increasing efforts are being devoted to understanding the impacts of roads on biological systems and to identifying the types of influences exerted by different types of roads.

Physical effects

Any ground disturbance increases the potential for erosion and hydrologic change, and roads are a major source of ground disturbance in wildlands. Compacted road surfaces generate overland flow, and much of this flow often enters the channel system, locally increasing peak flows. Localized peak flows are also increased where roads divert flow from one swale into another, and where roadcuts intercept subsurface flows. Such altered peaks are rarely detectable in larger channels. However, overland flow from the road surface is a very effective transport medium for the abundant fine sediments that usually are generated on road surfaces. Road drainage also can excavate gullies and cause landslides downslope in swales. Cut- and fill-slopes are often susceptible to landsliding, and road-related landsliding is the most visible forestry-related erosional impact in many areas.

Most erosional and hydrological problems result from poor road location or design. The harder the running surface, the less likely it is to erode, so paved surfaces are usually preferred over graveled surfaces. Unsurfaced roads are almost always a problem, creating dust in dry weather and erosion in wet weather. Ridge-top roads have the least hydrological impact because they do not modify natural flow-lines, and they usually have less erosional impact than mid-slope roads, which often cut across the most unstable part of the hillslope. Valley-bottom roads are generally stable, unless they impinge on "inner gorges," but eroded sediment from their surfaces usually has a direct route to mainstem channels. Many stability problems are caused by altered drainage. Careful control of location and road drainage can prevent most erosional and hydrological impacts, but occasional problems occur even on well-sited, well-designed roads. Control of road use during wet weather can help reduce road-surface erosion.

The types of problems encountered vary with the age of the road. In many areas most failures occur within the first decade of road construction (e.g. Reid and Dunne, in press), while road-surface erosion persists as long as traffic continues to use the road. However, some failures are caused by the decay of organic materials in road

fills, and these may not be triggered until 20 to 50 years after construction. Some abandoned roads become particularly susceptible to failure because designed drainage modifications are no longer maintained. Continued erosion of old roadcuts can fill ditches, divert flows, and trigger failure. The propensity for problems also varies through time as the style of road construction changes. More recently built roads tend to be better located and more resistant to drainage problems. However, decreased funding for road construction and maintenance during the past decade led to increased use of unsurfaced roads, and this has caused increased road-surface erosion. The reduction of funding and the decreased emphasis on road maintenance is increasing the risk of accelerated erosion and road-related landslides.

Generally, a few large problems account for most of the maintenance effort, and a very high proportion of the sediment loosed by road-related landslides usually comes from the few largest slides (e.g. Reid 1981). The sites that cause maintenance problems on a road usually correspond to those that cause erosional problems, so maintenance workers are good sources of information about erosion problems. Unfortunately, maintenance records for roads are rarely accessible, and most of this information exists only in people's memories. With the present budget outlook and new directions for forestry, many of the people who know this information are retiring or are being reassigned, and it is important that their knowledge be recorded before they leave.

Wildlife

Roads permit more careful management of second-growth stands and contribute to fire suppression efforts; both of these activities benefit wildlife. Roads also make wildlife surveys easier. However, most other effects of roads are detrimental to wildlife.

The most pervasive impacts are associated with the fragmentation of wildlife habitat. A road produces a cleared swath through previously continuous vegetation. The presence of the cleared edge modifies the temperature, light, and wind in the remaining stands, and allows access by predators. The effects of such changes on vegetation composition have been measured as far as 2 to 3 tree-heights from the edge of a clearcut (Chen et al. 1992). The native forest fauna is less well adapted to these altered margin habitats. If the microclimate and vegetation response is similar along the linear clearcuts associated with road construction, prime habitat may be decreased by 50 percent in an area with a road density of 3 km/km².

Roads are also important because of the disturbances that drive along them. Traffic increases noise levels, causes road kill, and increases the vulnerability of game species by providing access for hunting and poaching. Roads present a physical barrier to migration and dispersal. Amphibians and other animals with short legs find a 16-foot width of gravel to be a very long way indeed, and fishers are reported to avoid roads (Ken Hoffman, US Fish and Wildlife Service, personal communication). Problems arise in some areas because amphibians seasonally return to wetlands to spawn. Where roads separate living areas from spawning areas, seasonal mortality from traffic may be high enough to prompt road closures, such as occurs annually in Tilden Park near San Francisco, California.

Although road closure addresses some of the impacts on wildlife, the major problems arise simply because the roads are there. Rehabilitation of habitat for some wildlife species thus requires the obliteration of roads. Where road design actually has considered wildlife, the wildlife considered was usually the "charismatic megafauna," the large animals important to hunters and sightseers. New directives of the ROD include the need to plan for less visible and less mobile species, such as amphibians. New types of information are thus needed, including information on how different designs affect different species. Any road design will benefit some species while impacting others, and we need to understand what the trade-offs will be.

Aquatic biota

The aquatic biota of greatest immediate concern in the Pacific Northwest is anadromous salmonids, but all trophic levels are important to the fish. Direct influences of roads include impacts on migration, spawning, incubation, and rearing, and these are described in detail by Furniss et al. (1991). In the past, migration routes often have been blocked where roads cross small channels. Either culverts produce water velocities too high for upstream passage or the height to the culvert mouth is too great. This effect is important not just for migrating

spawners, but also for young fish in search of rearing or refuge habitat and for invertebrates. Movement is also blocked where road-related channel aggradation widens and shallows flows or forces streamflow to percolate underground through the gravels. Such changes benefit the predators that feed on stranded fish.

Anadromous salmonids require clean gravel for spawning, incubation, and emergence. Deposition of fine sediments can seal off redds and suffocate eggs and young. Such deposition also fills the intergravel crannies that young fish, amphibians, and many invertebrates use for cover from predators. Other species, such as the Sacramento pike (*Ptychocheilus grandis*) and California roach (*Hesperoleucus symmetricus*), may benefit from the change in substrate. Many important species have particular requirements for rearing habitat that include deep pools and cool water. Erosion from roads often results in channel aggradation and in-filling of pools, and sedimentation can smother benthic macroinvertebrates that are important food sources for young fish.

The effects of a particular road-related change depends on what species are present, when they use the stream, and what type of competition they are subject to. In addition, the same type of road-related change, such as an increase in erosion, can have very different effects in different channel systems. The severity of such a change may depend strongly on the channel gradient and history of flood events at a site.

Vegetation and silviculture

Roads are recognized as a major vector for contamination of natural plant communities by exotic species. In Redwood National Park, for example, 90 percent of the 181 exotic species present are found along roads (Sue Fritzke, Redwood National Park, personal communication). Roads can also affect vegetation by facilitating the spread of pathogens. For example, spores of the root-rot fungus (*Phytophthora lateralis*) that attacks Port-Orford-cedar (*Chamaecyparis lawsoniana*) can be spread by contaminated moist soil, such as mud on vehicles (Zobel et al. 1985). On the other hand, roads also provide the access needed during programs to eradicate exotic vegetation and are crucial for environmentally sound management of second-growth stands.

Roadsides provide disturbed soil and high light inputs that are ideal for many weedy exotic species. Many of these are carried in inadvertently in or on visitors' cars; others arrive in road construction material. Scotch broom (*Cytisus spp.*) seeds, for example, may remain viable in surfacing gravels for decades and germinate when exposed by grading or erosion.

Control of exotic species will require several types of effort. First, visitors to public lands must be educated about their role in introducing plants. For example, visitors to Redwood National Park are occasionally seen with pampas grass (*Cortaderia jubata*) plumes tied to their antennas, apparently unaware that they are dispersing this serious pest throughout the park. Special measures must also be taken by the land management agencies, such as washing mud from agency vehicles before entering areas closed to public access that have sensitive natural vegetation. Finally, there must be increased levels of communication and cooperation between road designers, road maintenance personnel, and botanists. Such cooperation could result in management plans for roadsides that will help reduce the spread of exotic plants.

Substrate conditions are unnatural as long as a road bed exists, and some exotic species will be able to persist. For these, it will be necessary to obliterate the road to restore the natural vegetation community. The types of heavy equipment used to rip road surfaces and remove fills can also grub out exotic shrubs. Other species, such as Scotch broom and pampas grass, eventually disappear as the disturbance level decreases after a road is abandoned and shading increases.

Occasionally the altered conditions created by roads creates habitat for threatened or endangered plants. Modification of these conditions then requires permitting from the U.S. Fish and Wildlife Service. If the road is to be obliterated, it may be necessary to transplant the affected plants to suitable sites after consultation with the appropriate regulatory agencies.

Because of constraints caused by the mosaic of land uses in the region, maintenance of natural vegetation patterns and ecosystems would require some active management even if logging and grazing of public lands were to be discontinued, and active management requires roads. What we consider to be "natural" vegetation in

many areas was the result of periodic wildfires or was managed by Native Americans through controlled burning. However, land management practices were changed with the European incursion. It is becoming increasingly apparent that fire must be reintroduced to many ecosystems, and this can be done safely only if roads are present to help control the fires. In addition, much federal land is covered by young, second-growth forest, which will need selective thinning or "roughening" to hasten its attainment of late-seral-stage character. This activity also requires roads if it is to be carried out efficiently on the scale required.

In the past, yarding and silvicultural systems largely determined the road pattern in forest lands. Cable yarding required a low density of primarily ridge-top roads, while tractor yarding required a high density of roads extending upslope from the valley bottoms. At this point, the road system is pervasive, with the pattern in any area reflecting the transportation needs of the era during which it was logged. Even though these patterns are not ideal for the present silvicultural systems, it is unlikely that many new roads will be built or that old ones will be rerouted. Where the existing network is unworkable for modern practices, it is likely that either helicopter yarding or temporary roads will be used.

Fire management

Fire management is important both for public safety and for vegetation management. A dense road network abets fire suppression by facilitating access, providing fire breaks, and promoting early fire detection. However, roads also provide access for the casual users and arsonists often implicated in starting wildland fires, and roadside vegetation is often particularly flammable. Closing roads to public access is thus one of the first measures taken when fire danger becomes especially high.

High road densities and heavy use have provided such efficient fire detection in southern California that fire lookout stations are no longer needed. Road locations that provide expansive views are particularly important for this function. Once a fire is sighted, high densities of high-standard roads are the most important factor in controlling the fire at an early stage. The road situation largely determines the level of staffing for a fire, the control methods and equipment used, and the control strategy. Roads are also important tactically, creating barriers to fire expansion and providing lines from which back-fires can be set. Fire management personnel thus require extensive information on road types, bridge strengths, and access speeds. Almost all decisions about logistical support are based on the status of the road network.

The level of roading also determines the methods of fire prevention that can be used. High road densities allow wider use of controlled burning, for example, because they make the prescribed burns easier to control. The ecosystem's requirements for prescribed burning thus need to be considered when deciding what the basic road network should be. In essence, the ecosystem impact of less fire suppression needs to be balanced against the ecosystem impact of more roads. In the past, managers have compartmentalized cost-benefit calculations by discipline, and costs to the ecosystem of reduced fire frequencies have not been considered. Watershed analysis can provide a mechanism for determining the implication of different levels of fire suppression for the variety of biological, social, and physical concerns in a watershed.

Options for existing roads

Examination of the needs of various components of the ecosystem demonstrate that although roads markedly impact each component, some level of roading is required for appropriate management of each component. The consensus seems to be that the present density of roads is greater than required, and that we currently are unable to adequately maintain the existing network. Parts of the existing road system will thus need to be decommissioned or closed, but these options also entail some environmental trade-offs.

Restricting road use

Some types of impacts can be avoided simply by keeping people off the roads during part of the year. This approach has been taken to decrease road-surface erosion rates during wet weather. Temporary road closure has been used to enhance salamander survival during their annual migration in Tilden Park. This approach is only as effective as the barriers are for keeping people off the roads. Gates are the most commonly used method for

controlling access, but some users perceive a gate as a challenge rather than a barrier. No gate is capable of keeping a motivated user out. Most motivated users also have the means of getting through felled trees and ditches.

Barriers are more effective if they are accompanied by explanations of why they are needed and of the length of time the road will remain closed. It is particularly important to provide early warning of closures on routes that might be used as through roads. Even the most law-abiding citizen is tempted to adopt anti-social behaviors if they are required to backtrack for an hour because of an unexpected gate. Problems can often be avoided if the land managers understand who is using what roads for what purposes during what seasons, and then plan closures to avoid conflicting with those needs. In general, if people need a road, they will continue to use it irrespective of the measures used to try to keep them out.

Decommissioning roads

Much of the existing road network on federal lands of northwest California was built to support early tractor logging operations, which required a high road density. Modern yarding practices need fewer roads in different locations, so many of the old roads are unlikely to be used in the future. Methods for managing the abandoned roads range from simply blocking them to obliterating the road bed using heavy equipment.

Redwood National Park has had considerable experience in decommissioning roads, with the goals of reducing erosion and of restoring the lands to a more park-like condition. Because of the latter requirement, the Park has emphasized the complete obliteration of roads, and has dealt with about half of their 175 miles of roads during the past 15 years. Their 15 years of data on cost and effectiveness demonstrate that use of the largest earth-moving equipment is most cost-effective, but that the per-mile cost depends heavily on the terrain. Highly engraved terrain has larger volumes of fill that must be moved, and it must be hauled a longer distance for disposal. In the engraved terrain of Redwood National Park, the erosion control work (digging out stream crossings, pulling back fills) accounts for 85 to 90% of the total cost of obliteration, and this would need to be done even if obliteration were not the objective. If the parts of the road-bed between stream crossings were left intact, they would require continued maintenance at about 15-year intervals because revegetation would obstruct water bars and contribute to future instability. With the crossings removed, such maintenance would be difficult, at best. The cost of obliteration was approximately the same as that required to upgrade roads to a standard at which they could be safely maintained, since undersized culverts and road fills containing woody debris would need to be removed and replaced.

Managing the road network

Decisions on road closures and removal will require careful analysis of how the roads are currently being used and how they are likely to be used in the future. In addition, methods must be developed to weigh the advantages posed by the roads' presence against the environmental risks they pose, and against the potential environmental damage caused by removing the roads. A rational approach to road closures and removal will require completion of a general transportation plan for the watershed. Such a plan would include an analysis of long-term management goals and reentry needs for different parts of the watershed, and evaluation of the size of the network that can reasonably be maintained, given the requirements of the ROD and likely future budget levels. Most existing roads on agency lands will probably continue to be maintained to allow recreational access, forest management, and fire management.

Redwood National Park is developing a new approach to long-term road management that has three distinct emphasis areas: road maintenance, road obliteration, and non-Park roads. In the past, the Park was concerned primarily with maintaining and obliterating roads on Park lands. First, a network was identified that allows appropriate vegetation management and visitor access; then, excess roads were prioritized for repair or obliteration based on the risk they posed for sediment production. Priorities were based on an on-the-ground inventory of fluvial and landslide erosion sites, diversion potential of crossings, and slope stability. Future prioritization will also take into account the effects of the roads on fish, vegetation, and wildlife. Because Park lands are to be managed to return them to their pristine state, all non-essential roads will eventually be obliterated.

There is an increasing realization that roads in the privately held upper two-thirds of the Redwood Creek basin will strongly influence environmental conditions within the Park. This has led to increased involvement of Park personnel with road management in the upper basin. Over 1000 miles of road are present on privately owned land upstream of the Park, and Park personnel have no guaranteed access to these lands. Roads in this area were inventoried using aerial photographs. The upper basin will then be stratified by geology and gradient to determine which types of sites have the highest road densities and the highest risk of sediment production. Abandoned roads are of particular concern because their drainage structures are no longer maintained. The ultimate goal is to work with the land-owners to identify the major problems and target the areas where public erosion control funds can be most effectively spent. Cooperation with landowners is needed to plan road treatments based on long-term future use, rotation age, and fire-road access. The Park hopes that this cooperation will grow as the land-owners see the utility of information that the Park can provide, and that they will begin to see the Park as an ally in efforts to procure public funding for erosion control on private land.

In the Butter Creek watershed on the Shasta-Trinity National Forest, watershed analysis is being used to help develop a transportation plan. Analysis discloses the basic, long-term transportation system needs and identifies the short-term uses required by the present land-use distribution. Information on long-term needs will be used to select existing roads to incorporate into a permanent road network that is appropriate for the future distribution of land uses, while the short-term needs will be used to establish a schedule for decommissioning the excess roads.

Another approach is to design the "ideal" road system from scratch using information about the current and likely future land-use distribution and ecosystem needs. The ideal system can then be overlaid on a map of the existing road network to identify what parts of the existing system should be upgraded, maintained, closed, or decommissioned, and what additional roads should be built.

What we need to know

Descriptions of the influence of roads on various components of the ecosystem indicate that a tremendous amount of information is needed for a particular road segment to determine its significance for the ecosystem and watershed processes (Table 4-1). Clearly, not all of this information can be gathered for any given area. There are many decisions to be made about what information is necessary, what precision and areal coverage is useful, and what methods can be used. Most important, however, is to develop an approach for making those decisions. Road inventories have already been identified as an important tool for general land-management planning. Such inventories will contribute useful information to watershed analyses, so analysis will be facilitated if appropriate inventories have been carried out before analysis begins.

Table 4-1. Road attributes of importance to ecosystem and watershed concerns

Attribute	physical	wildlife	aquatic.biota	social	fire	vegetation	timber management
construction history	x					x	
recurrent maintenance problems	x						
maintenance level and history	x			x	x		x
how road fits transportation plan				x			
how road fits land-use plan				x	x		x
how road fits safety needs				x	x		
what the road accesses				x	x	x	x
who uses road for what		x		x	x	x	x
traffic level and type by season	x	x		x	x		x
likely changes in use	x	x		x	x	x	x
land-use context in area		x		x	x		
views to and from road				x	x		x
topographic position	x	x			x	x	x
geologic substrate	x						
storm history	x						
sideslope gradient	x						x
road gradient	x				x		x

road and right-of-way width	x	x		x	x	x	x
load bearing capacity				x	x		x
travel speed				x	x		x
fill character and condition	x						
roadcut character and condition	x						
ditch character and condition	x						
surface character and condition	x				x		x
failure history	x						
likely failure mode	x						
cost and impacts of likely failure	x		x	x			x
future erosion potential	x		x				
sediment delivery to channel	x		x	x			
proximity to channel	x	x	x	x	x	x	
drainage structure type, condition	x						
stream crossing type, flow capacity	x		x				
modification of natural drainage	x		x			x	
diversion potential	x		x				
ditchline length	x						
surface drainage design	x						x
flow length on bearing surface	x						
drainage delivery to stream	x		x				
surrounding vegetation	x	x		x	x	x	x
patch size resulting		x			x	x	x
relation to wildlife migration routes		x					
in-channel barriers			x				
location with respect to wetlands	x	x	x		x	x	

Inventory methods

A variety of methods are already in use for inventorying roads in different areas. Most agencies have some record of their road network, if only in the form of maps. Even these, however, are difficult to keep up-to-date. Some data are usually available concerning road widths, standards, and maintenance levels, although details are usually available only in people's memories. Even where formal inventory procedures are used, each administrative unit usually has its own inventory methods, lists of attributes to be described, and schedule for updating inventories. In the context of watershed analysis, the problem of data consistency is even greater because federal workers have no guaranteed access to private lands in the watershed. Thus, not only are existing data likely to be uneven in quality and coverage, but there will be no opportunity to upgrade data sets to a standard level of consistency.

There is an effort now to standardize road inventory procedures within the Pacific Southwest Region of the Forest Service with the intent of developing a consistent information set to be entered into a standardized database on the Forest Service computer system. The first stage will be to standardize information for infrastructure and recreation; standardization for other disciplines will follow later. Most the existing road inventory information is in computer data bases or on paper maps. Converting it to GIS will be expensive and time-consuming, and may be a low priority in this era of flat or declining budgets. It is thus important that future inventory efforts be designed to address the full range of questions needed, and that it be done at useful and efficient levels of precision. Interagency and interdisciplinary cooperation is needed to select appropriate attributes, scales, and procedures.

Information requirements for various analysis scales

The question of what information is required at what level of precision is particularly relevant for meeting the challenges posed by the ROD. The ROD requires analyses on scales that we have not often considered in the past: we must now consider problems on the scale of 50- to 500-km² watersheds, and of river basins that may be hundreds of thousands of square kilometers. The river basin sets the context for the watershed analyses, which,

in turn, sets the environmental context for specific projects. These three different scales of analysis require different types of information, but in each case, the information needs are driven primarily by the issues to be considered in the analysis. At each scale, all issues cannot be addressed at the same intensity everywhere, and issues thus must be prioritized to allocate the available effort efficiently. In addition, because of the variations between existing data sets, a different level of detail is possible in different areas. It is important to keep the distinction in goals of the three analysis scales in mind to avoid inappropriate allocations of effort.

Basin assessments

River basin assessments are to be carried out for entire drainage basins, from headwaters to estuary. Basins may be as large as the Klamath-Trinity system, or as small as the Smith River drainage. The original objective of basin assessments was to identify the issues of concern on the scale of a river basin to ensure that watershed analyses within that basin would address those issues. This is particularly important in northwest California because the large population centers are located far downstream of the watersheds to be evaluated during watershed analysis.

Basin assessments might identify issues such as estuary sedimentation, water quality at a municipal water supply intake, particular threatened fish stocks, or gravel recharge for mining. Using a broad understanding of general patterns of land use, geomorphic processes, and ecosystem distribution in the basin, a basin assessment could then identify the parts of the basin likely to be particularly influential for each of the issues. This information would then provide guidance for watershed analyses in those areas. For example, a basin assessment might identify which watersheds are important for coho production and which are not, and subsequent watershed analyses would use this information to prioritize efforts during the analyses. In essence, the basin assessment is insurance that the watershed analysis will not be blind-sided by large-scale issues that were not evident at a watershed scale. The initial basin assessment is expected to require a few weeks to a month, with most effort devoted to obtaining public input for issue identification.

Basin assessments, like watershed analyses, will be iterative. As information from watershed analyses within the basin becomes available, basin assessments can be revisited in greater detail. At this point, it will be the responsibility of the basin assessment to integrate results from multiple watershed analyses to re-evaluate the relative importance of various processes and interactions for the basin-scale issues that the earlier assessments had identified. Thus, the basin assessment would use evaluations of sediment input trends from multiple watersheds to estimate basin-wide trends in water quality or estuary sedimentation. These issues are likely to be of greatest concern to the largest number of people, but they could not be evaluated during any individual watershed analysis.

Table 4-2. Data useful for evaluating roads at different analysis scales

Basin assessment

1:500,000 road map

population centers

tourist routes and season of use

general land-use distribution

general land ownership pattern

seasonal road closures

large-scale road-use trends

large-scale land-use trends

recurring maintenance problems on the major roads (e.g. highway segments susceptible to sliding)

Watershed analysis

Forest or District road map or USGS 7.5-minute quadrangle (1:24,000)

road characteristics by silvicultural method

watershed development trends
site types for road-related impacts
general wildlife migration patterns
use patterns on major roads

Project analysis

Site diagram

whatever information from Table 4-1 is relevant to the particular project

Clearly, a comprehensive road inventory is inconceivable in a river basin the size of the Klamath-Trinity. The area is too large, ownership is too varied, and by the time an inventory were completed it would be outdated. On the other hand, it is also clear that some information about the road network is essential for understanding the socio-economic setting of the river basin. We must understand where the major roads are, what their regional significance is, and how they relate to the general patterns of land use in the area. For example, identifying which state highways and county roads are used seasonally by tourists is important for predicting future recreational use patterns for individual watersheds within a river basin. At a basin scale, the level of detail useful for a road "inventory" might simply be the information present on the 1:500,000 regional maps put out by state automobile associations (e.g. the "Northwest California" map published by the California State Automobile Association). The basin scale is particularly important for evaluating the socio-economic context for an area, since these concerns are rarely interpretable on the scale of individual, 50- to 500-km² watersheds (Table 4-2).

Watershed analyses

A watershed analysis is intended to identify the issues of importance in the watershed and to describe the biological, social, and physical processes that affect those issues. The concept of watershed analysis was developed because land managers have rarely stood back far enough to look at large-scale issues, interdisciplinary relationships, and the context for environmental problems. The watershed analysis is an opportunity to compile and evaluate existing data sets and identify their implications for the critical issues, and to identify the types of information that will allow better understanding of these relations. Analysis will deal primarily with patterns rather than locations, and will make use primarily of existing information. At the watershed scale it may be important to know that tractor-yarded clearcuts in this topography have road densities that range from 3 to 6 km/km², but it is not important at this scale to know the location of each road (Table 4-2).

Watershed analysis is not intended to provide all the information needed to justify any particular project or solve any specific site-level problem. Instead, it will provide information to establish the broader context for the site-specific problem. For example, the analysis will not provide a cumulative effects analysis for a particular project. Instead, it will provide information about how different types of impacts are generated in the watershed, and this information can then be used to help evaluate cumulative effects, help plan particular projects, help design monitoring plans, help plan rehabilitation work, or help with any of a number of other site-specific tasks. Watershed analysis is an opportunity to step back from the project-level view that has been emphasized in the past and develop a broad interdisciplinary view of the landscape. In a sense, it gives us an opportunity to establish a proactive approach to project design. In the past, we designed a project and then did the cumulative effects analysis to see how the project would affect the environment. Watershed analysis now will give us an understanding of how different impacts are generated, and what features are likely to be affected by what types of changes in what parts of a watershed. This information will then help us to design projects that will avoid those effects.

However, many agency management objectives require detailed information about the road network. For example, the California Department of Forestry and Fire Protection would benefit from a detailed map of all roads within each watershed to support their fire management planning and timber harvest plan review. The Forest Service, BLM, and Redwood National Park all require careful inventories of road drainage conditions to prioritize rehabilitation efforts. Although these types of inventories may be useful for carrying out a watershed

analysis, they certainly are not essential. On the other hand, a watershed analysis could provide information about the types of road characteristics that are important for particular reasons in different parts of the watershed, and this information could then be used to design inventory protocols that better address the needs in the watershed.

Although detailed road inventories would be useful for a watershed analysis, they are simply not possible given the available levels of staffing and time. For example, Redwood National Park carried out an inventory of haul roads in a 440-km² watershed using only aerial photographs. Even without field checking, the task required 6 person-months of full-time work, and this did not include entering the data into a computer. To achieve consistency, such inventories must be carried out by only a few people, so time commitments cannot be reduced by higher staffing levels. Watershed analyses are expected to be completed over about a 2-month period, and hundreds of watershed analyses need to be completed, so methods other than inventory must be used to describe the road system.

The level of detail actually used in a watershed analysis depends primarily on the level of detail of the available information, and secondarily on the level of detail required to address the high priority issues in the watershed. As a result, the current pilot watershed analyses exhibit a wide range of levels of detail. Some make use of existing road inventories, while others do not quantify the road system at all. For most applications, existing road maps held by the agencies are expected to be adequate, even though they may not be up-to-date. This information can be used along with sampling of non-recorded roads, such as skid trails, at representative sites in the field or on air photos to characterize road types in different parts of a watershed according to stability, erosion, design, drainage, and use. Road densities may be important in some watersheds for particular issues, but these can be determined easily by sampling subareas on aerial photographs. More generally, we need only an idea of what types of roads are in what areas, what they are used for, and the types of risks associated with them.

Project analysis

Analysis is also required at a project or site level, as it always has been. Such an analysis would be carried out as the project is designed, and would include delineation of Riparian Reserves, biological assessments, cumulative effects assessments, and whatever other types of analysis are required by NEPA and other regulatory legislation. This is the scale at which the details listed in Table 4-1 become important (Table 4-2). Agencies are already required to do this level of analysis, and this burden is not being shifted to the aegis of watershed analysis. However, results of the watershed analysis will aid in project analysis by showing what issues need to be addressed and what processes and interactions need to be understood. The watershed analysis provides information on the physical, biological, and social context within which the project must fit. Results from site-level analyses, in turn, can be used to provide more detailed information about local conditions and interactions for later iterations of the watershed analysis.

Transportation management: balancing road needs and hazards under the ROD

The ROD introduces a philosophical change from past approaches to transportation planning. Land management decisions are now expected to consider a wider variety of environmental issues and social concerns than in the past, and the transportation system in some areas will serve primarily to support non-timber-related values. Operationally, this will require considerable effort to identify the broad range of issues and concerns likely to be important in an area, to understand the social, biological, and physical processes that interact to influence these issues and concerns, and to forge cooperation between federal land management agencies and the public, other land-management agencies, and regulatory agencies. This change in emphasis requires a shift in organizational structure and attitude if the necessary information and cooperation is going to be obtained.

The socio-economic context

Of particular importance to transportation planning is the need to understand the public's use patterns of wildland roads. Before decisions can be made about road closures or maintenance levels, we need to know who is using what roads for what purposes, and during what seasons. This task requires expertise in social science methods. Unfortunately, federal land-management agencies do not yet have enough of the trained personnel

needed for such work. Some of this work would be carried out on a basin scale, as it relates to interregional transportation, tourism, and most economic issues. At a watershed scale, analysis would consider specific information about the main roads, and generic information about lower-standard roads of different classes in different parts of the watershed.

In addition, analysis of the socio-economic context for the transportation network must take into account likely future uses and needs. Ideally, decisions made now about roads would foster the desired future uses, aid the management of the unavoidable future uses, and discourage the undesired future uses. These projections of future use require information about land-use trends on the scale of a river basin or a province because of the overriding importance of shifting regional economic patterns and growing urban centers. At a watershed scale, it is important to identify those resource attributes that would attract road users.

Making value-based decisions

Because roads benefit some land uses and ecosystem functions and damage others, no decision about the "ideal" road network is free from controversy. We must develop ways to balance socio-economic needs and the environmental advantages for a road against the environmental damage it might cause. Even with a perfect understanding of the social and environmental effects of roads, we would not have a consensus on what should be done because people weight their own personal values highest. For example, obliterating a section of road may result in enhanced water quality and decreased ability to control wildfire. There is no objective method of comparing the "values" of these two effects.

In the past, some decisions have been made strictly for budgetary reasons. For example, roads in one area were undermaintained with the full realization that landsliding rates would increase as a result. The budget for road maintenance in this area was low, while the emergency road repair budget was well-funded. The management agency simply shifted the burden from maintenance to repair, without regard for the difference in ultimate cost to the agency, the public, or the environment. Politically, it is easier to obtain funding for emergency repairs than for routine preventive maintenance. The change in approach represented by the ROD is intended to display these trade-offs and prevent this type of decision in the future. Instead, the ROD is likely to encourage construction of higher standard roads since they are required to meet Aquatic Conservation Strategy objectives, and this is likely to result in lower maintenance costs in the future.

Planning decisions are often based on cost-benefit analyses, but this becomes very difficult when intangible values weigh heavily in the equation. Many methods have been developed to assign dollar values to intangibles to make them comparable to commercial values, but all are controversial. In addition, these intangible values partially depend on context. An isolated 1-hectare stand of old-growth redwoods has considerably higher perceived existence value in some settings than in others. If such a stand existed in downtown San Francisco, for example, its destruction would be unthinkable. There thus is no inherent value that can be assigned to a particular feature.

No method for assigning dollar values to intangibles has been accepted widely. However, several procedures have been developed for considering intangible values when making decisions. It may thus be possible to standardize decision-making procedures without requiring a particular method for valuation. For example, the Kepner-Traegoe procedure incorporates steps of issue identification, prioritization, distinction between what is absolutely necessary and what is simply preferred, and weighting the importance of different considerations. Most of the other decision procedures involve similar steps. Consensus approaches to land-management decisions are also being explored by the Timber-Fisheries-Wildlife effort of Washington State and by several community groups in the Pacific Northwest. All methods require a good information base, a good representation of the variety of interest groups involved, a desire on the part of all participants to reach a mutually tolerable decision, and a willingness on all sides to recognize other points of view. So far, federal agencies have not been as effective as they could be in incorporating the public into planning and decision making, and the result has been costly mistakes such as the attempt to open the Gasquet-Orleans road (the "GO Road") in northwest California.

Incorporating the other players

President Clinton made it clear during the Forest Summit on 2 April 1993 that future land management decisions will incorporate a greater sensitivity to community concerns, and that federal agencies will establish a more consistent approach to management and a greater level of cooperation than has existed in the past. These changes require a change in federal agencies' relations with the public, with other agencies, and with each other. In this case, too, the changes have obvious implications for transportation planning, both because roads connect lands of several agencies as well as agency and private lands, and because the public has a strong interest in agency roads.

Interviews with interested citizens suggest that the types of public outreach the agencies have used in the past will not be sufficient for obtaining the types of information and public cooperation that the ROD requires. Advertised public meetings have not been effective in disclosing the variety of issues that have later plagued agency management plans, and most of the public still seem to feel alienated from the decision-making process. In addition, interviews suggest that much of the public does not understand the variety of issues that must be weighed before making decisions about land-management options. Several reasons have been put forward for these problems. First, public meetings are often not well publicized, so many of the interested parties do not hear about them until too late. Second, there are so many meetings going on that small interest groups and volunteers cannot go to all that may be relevant. Third, many consider it poor use of their time to waste an entire evening in exchange for being allowed to give only a short statement. Fourth, some well-informed resource professionals avoid public meetings because they cannot risk appearing to be biased on environmental issues. Fifth, many have the impression that their concerns will be ignored at this stage, so they might as well wait until later when they can halt the project with an appeal or a lawsuit (Reid, in review).

Public meetings will continue to be an important part of the NEPA process. However, other methods of soliciting public input may be more useful for other purposes. An approach that has proven useful for watershed analysis and issue definition is to identify individuals who are locally recognized as experts on particular topics and to interview them directly. This procedure has provided a wealth of information that the 60-second public meeting "sound-bites" cannot equal, and has had the serendipitous benefit of making those interviewed--and their communities--feel like a valued part of the planning process (Kathy Hefner-McClellan, Six Rivers National Forest, personal communication). In any case, federal land-management planning will need to incorporate some methods for educating the local communities about the broad range of issues and needs in the watersheds around them. In any case, it is important to keep the communities informed of the planning processes that will be going on in their watersheds. Establishment of formal Coordinated Resource Management Plans with other land-owners in the watersheds can also make analysis, planning, and management easier.

Outreach must also extend to other agencies. Federal agencies need to work with county, state, and federal transportation authorities and with private land owners to develop management plans for non-agency roads on agency-managed lands, and on other lands where roads affect the agency lands. This type of planning will require cooperation among agencies that are not obviously affected by the ROD. It will also require a realization among the land-management agencies that their concerns extend far beyond the boundaries of the lands they manage. Federal agency representatives may need to become more active in reviewing management plans for adjacent lands. In some cases, for example, it may be environmentally advantageous to permit construction of a low-risk road across federal lands to allow an adjacent land-owner to avoid construction of a high-risk road across their own land. Provisions of the California Environmental Quality Act that would regulate the private road cannot prevent such a road from being built; they can only attach conditions for its design and use.

Analysis support for decision making

A good information base has repeatedly been shown to be the key to enlightened decision-making. The ROD has established a procedure for analysis that is intended to complement and guide the existing information-gathering efforts of federal land-management agencies. From the point of view of roads, as described above, basin assessment compiles information on the regional socio-economic context for road use in a river basin, and identifies road-related issues in different parts of the river basin that will require further examination at a watershed scale. Watershed analysis then uses existing data to examine the social, biological, and physical interactions and needs that influence the value and hazard presented by different types of roads in different parts of the watershed. Both analyses also identify the types of information that will be needed to better understand

the problems. Information from these analyses, and from the later work they suggest, will be used to guide general planning in the watershed and to develop rehabilitation strategies.

Management planning will identify particular projects to be carried out in the watershed. These may include rehabilitation work (e.g. road obliteration, relocation), resource extraction (e.g. logging, mining), infrastructure improvements (e.g. road construction, surfacing), and resource management activities (e.g. thinning of second-growth stands, fire prevention). The ROD requires that each road segment involved in a project be evaluated for its effect on the Aquatic Conservation Strategy Objectives, and information from watershed analysis is used to provide the context for this evaluation. How the road segments will be evaluated depends on the types of issues that roads influence in the watershed. Many of the projects to be carried out over the next several years will involve watershed restoration, and the ROD directs much of this restoration work toward the road network. Information from watershed analysis will be used to identify the types of sites and road conditions that most affect issues of concern, and thus are in most need of treatment. This information will be a primary tool in prioritizing restoration efforts. The project analysis will then provide the information needed to plan the restoration work at particular sites. In effect, watershed analysis provides the information required to develop a restoration strategy, while project analysis allows planning of restoration tactics.

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