Appendix 1. Ecological, Social, and Economic Considerations

Below are some primary example questions that might be used for roads analysis for both the existing and a potential road system. Not all of these questions will be relevant in all places, but these types of questions are expected to be relevant in many of the analysis areas. Some of the questions will be best addressed at the local scale; others will be more appropriate at a regional or multiforest scale. In addition, some of the questions require consideration at the regional, forest, watershed, and individual road scales. The questions and associated information are not intended to be prescriptive, but to assist analysis teams in developing questions and approaches appropriate to each analysis area.

Notes

For additional information on each of these topics see also: USDA Forest Service. (In press) Forest Service Roads: A Synthesis of Scientific Information. A draft of this document may be found at *www.fs.fed.us/news/roads/science.pdf.*

All references listed in this section have been assembled for easy access. Check for access information and updates at *www.fs.fed.us/news/roads.*

Acknowledgments

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Ecosystem Functions and Processes (EF)

EF (1): What ecological attributes, particularly those unique to the region, would be affected by roading of currently unroaded areas?

Background

Unroaded areas may differ from roaded areas in many ways related to ecological integrity. The presence of roads can be associated with distribution and spread of exotic plants, changes in forest composition and structure including the loss of old-forest characteristics, changes in fuel loading, and increased probability of human-caused ignitions (Hann and others 1997). There can also be both direct and indirect effects on aquatic and terrestrial species and habitats, and effects on management activities including fire suppression and law enforcement. Road density, road class, road location, and types of habitats traversed by roads may influence the severity of those effects. The presence of a road in a previously unroaded area will likely accelerate access for a variety of forest management activities, including timber harvest, that will change the amount, pattern, and composition of forest cover, and that may in turn lead to changes in terrestrial wildlife ecological processes.

Scale

Each of the questions requires information gathered at the ranger district and subbasin scales, and comparison to information gathered at the regional scale.

Information needs

Identify the ecotypes present in the area and their extent. Describe their ecological integrity in terms of intact communities of native aquatic and terrestrial plants and animals. Describe their scarcity relative to the distribution of that ecotype on a larger scale and relative to other areas where the same type is maintained through some type of nondestructive allocation.

Determine the role the area plays in a larger landscape context given its location, size, composition, and spatial relation to other important sites (for example, key habitat areas, key buffers to exotic invasion, areas that facilitate animal movements, concentration areas for important pollinators, uncommon area free from human disturbance).

Determine how the species richness for the area compares to richness in neighboring areas of similar size and to other unroaded areas with similar ecotype representation.

What other unique populations or communities live in the area (for example, disjunct populations of a more broadly distributed species, distinct subspecies or ecotypes, unique assemblages of plant or animal species, exceptionally old or large plant specimens, pockets of species endemism)?

What other unique or special features are found in the area (caves, cliffs, springs, other geological features)?

Lists of threatened and endangered, sensitive, and scarce species living in the unroaded area, based on heritage data, GAP data, and Forest Service data bases

Range maps for all these species

Historical range maps for species that may have been extirpated from the area

Information sources

Maps of ecotypes (Bailey and others 1994, Bailey 1995) and land uses and allocations for all ownerships in the region

Existing vegetation map for the unroaded area

Data on disturbance regimes (such as fire-history maps), non-native species (such as map of exotic weeds, information on stocking of exotic fishes in lakes), and human-caused disturbances (such as grazing history for the area)

Map of habitats to be used in determining important areas of habitat types unique or rare in the larger landscape

Maps that display risk of invasion by exotic species

Maps of road density in the whole landscape to identify scarce combinations of habitat types and low road density

Other information needs as identified, based on local conditions

GAP data and actual-occurrence data for vertebrates in the unroaded area, surrounding areas of similar size, and other unroaded areas with similar ecotype representation

Various data needed here, including heritage data, Forest Service inventory data, GAP data

Geographic Information System (GIS)-based maps of caves, cliffs, talus, abandoned mines, springs and wetland features for the unroaded area under consideration

Overlay of these features on maps of vegetative and aquatic habitats

Survey information of special features at the province scale

Survey information of special features overlain on habitats at the province scale

Analytical tools and information sources

Determine what threatened and endangered, sensitive, and locally scarce species are found in or could be reintroduced into the area.

Determine whether these populations or potential populations are important to maintaining the species at a larger scale.

See Quigley and others (1996) for an example rating system for ecological integrity.

See Holthausen and others (in press) for a summary of tools available to look at species persistence.

Recommended references

Bailey, R.G. 1995. Description of the ecoregions of the United States. Misc. Publ. 1391. Washington, DC: U.S. Department of Agriculture, Forest Service. 108 p.

Bailey, R.G.; Avers, P.E.; King, T. [and others] (eds). 1994. Ecoregions and subregions of the United States [map]. Reston, VA: U.S. Geological Survey. 1 p.

Cowardin, L. M.; Carter, V.: Golet, F. C.; La Roe, E. T. 1979. Classification of wetland and deepwater habitats in the United States. FWS/OBS-79/31. Washington DC: U.S. Department of the Interior, Fish and Wildlife Service. 103 p. (Also see National Wetlands Inventory website at *www.nwi.fws.gov*)

Hann, W.J.; Jones, J.L.; Karl, M.G. [and others]. 1997. Landscape dynamics of the basin. Vol. II, Chapter 3. Pages 338-1055 *in* Quigley, T.M.; Arbelbide, S.J. (tech. eds.). An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Holthausen, R.S.; Raphael, M.G.; Samson, F.B.; Ebert, D.; Hiebert, R.; Menasco, K. In press. Population viability in ecosystem management. *In* Johnson, N.C.; Malk, A.J.; Sexton,W.T.; Szaro, R. (eds.) Ecological stewardship: a common reference for ecosystem management. Oxford: Elsevier.

Quigley, T.M.; Haynes, R.W.; Graham, R.T. (tech. eds.). 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p.

EF (2): To what degree do the presence, type, and location of roads increase the introduction and spread of exotic plant and animal species, insects, diseases, and parasites? What are the potential effects of such introductions to plant and animal species and ecosystem function in the area?

Background

Roads may influence the spread of exotic organisms through the direct effects of vehicles transporting organisms or through the indirect effect of habitat alteration and creation of early-seral substrates that favor weedy species. The organisms may in turn have undesirable effects on native species and ecosystems.

Scale

Wildlife populations occupy large land areas, so watershed scale is probably the smallest effective unit. Disease and pest environment should also be considered in a larger context, at least the subbasin scale.

Information needs

Catalog of diseases, predators, parasites (for example, the brown-headed cowbird), that affect wildlife and whose rates of transmission may be affected by road density or placement

Distribution of disease-carrying species, predators, and parasites in the planning area

Maps of those species likely to be influenced by roads overlaid on a map of the road network

Estimate of risk of direct effects on populations through changes in disease rates or severity

Location of known strongholds of plants and animals that may be put at risk by the introduction of new pathogens and parasites

Analytical tools and information sources

See Hann and others (1997) for an example of developing a risk rating for exotic invasion

Inventories of exotic species directly associated with road disturbances (for example, road cuts)

Inventories of exotic species associated with human activities facilitated by roads (for example, introducing exotic seed in hay for recreational stock)

Map of road network

Condition of the vegetation along the roads and around associated structures

Distribution maps of exotic plant and animal species in the planning area and in the larger context (subbasin)

Survey State veterinary data bases

Review local reports and literature

Use GIS maps to describe known strongholds of species of concern and zones of risk for new diseases, insect pests, parasites, or predators

Map species ranges for those wildlife species at risk to any of these interspecific interactions

Overlay forest road maps to identify coincidence of roads and disease risk

Recommended references

Baker, H.G. 1986. Patterns of plant invasion in North America. Pages 44-57 *in* Mooney, H.A.; Drake, J.A. (eds.). Ecology of biological invasions of North America and Hawaii. New York: Springer-Verlag.

Forcella, F.; Harvey, S.J. 1983. Eurasian weed infestation in western Montana in relation to vegetation and disturbance. Madroño: 30:102-109.

Hann, W.J.; Jones, J.L.; Karl, M.G. [and others]. 1997. Landscape dynamics of the basin. Vol. II, Chapter 3. Pages 338-1055 *in* Quigley, T.M.; Arbelbide, S.J. (tech. eds.). An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Zobel, D.B.; Roth, L.F.; Hawk, G.M. 1985. Ecology, pathology, and management of Port-Orford-cedar (*Chamaecyparus lawsoniana*). General Technical Report. PNW-184. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 161 p.

EF (3): To what degree do the presence, type, and location of roads contribute to the control of insects, diseases, and parasites?

Background

Roads provide a transportation network that may be important in managing pathogens, including plant diseases and pest insects. Transportation plans should evaluate the role of roads in maintaining these management functions in light of the risks present in the area of interest.

Scale

The most appropriate scales are the forest or province scale and the ranger district or watershed. Roads can provide needed access to allow the efficient use of various management activities to control the spread of insects, diseases, and parasites, especially during outbreaks. In addition, the spread of some organisms, such as root diseases or mistletoe, is deterred when roads act as a barrier to their movement.

Information needs

Potential treatments

Density of forest roads

Locations of forest roads relative to populations of harmful organisms and their host vegetation

Vegetation inventories

Inventories or surveys of insect, disease, or parasite species and their related host species

Analytical tools and information sources

Insect, disease, or parasite population projection models

Vegetation growth projection models

Road maps and aerial photos

GIS

Recommended references

See EF (1)

EF (4): How does the road system affect ecological disturbance regimes in the area?

Background

Roads can affect the rates of flow of various disturbance processes, especially fire. Fire frequency and severity can be affected by the fragmentation of forest caused by roading by creating fuel breaks. Unroaded areas may be subject to fires of greater extent and severity, which in turn may influence the representation of plant communities in relation to their adaptation to fire.

Scale

Disturbance regimes must be evaluated at the broad scale, at least watershed to subbasin.

Information needs

Fire frequency and severity by major cover type or vegetation series

Analytical tools and information sources

Vegetation maps, including cover types and seral stages

Digital Elevation Models (DEMs)

Fire models

Vegetation models (such as Hann et al. 1997)

Recommended references

Hann, W.J.; Jones, J.L.; Karl, M.G. [and others]. 1997. Landscape dynamics of the basin. Vol. II, Chapter 3. Pages 338-1055 *in* Quigley, T.M.; Arbelbide, S.J. (tech. eds.). An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

USDA Forest Service. (In press). Forest Service roads: A synthesis of scientific information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

EF (5): What are the adverse effects of noise caused by developing, using, and maintaining roads?

Background

Traffic on roads can be a disturbance both to people (in campgrounds or at recreational sites) and to sensitive wildlife (nesting birds). An evaluation of these potential disturbances will rely on information about the types of vehicles using the existing or proposed road and the timing and frequency of use. This information should be coupled with reviews of the potential effects of disturbance on people and the organisms of concern.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Artificial and natural barriers

Type of road equipment and length of project

Type of public (user, resident, neighbor)

Public health and safety risk

Distance from road to public

Analytical tools and information sources

Engineering reports, maintenance schedules, traffic counters

Appropriate Federal, State, and local fish and wildlife agencies, conservation organizations

Health and safety code

Road maps, plans and surveys, air photos, topographic maps

Recommended references

Bowles, A.E. 1995. Response of wildlife to noise.Pages 109-156 *in* Knight, R.L.; Gutzwiller, K.J. (eds.). Wildlife recreationists. Washington, DC: Island Press.

Dooling, R.J. 1980. Behavior and psychophysics of hearing in birds. Pages 261-288 *in* Popper, A.N.; Fay, R.R. (eds.). Comparative studies of hearing in vertebrates. New York: Springer-Verlag.

Dorrance, M.J.; Savage, P.J.; Huff, D.E. 1975. Effects of snowmobiles on white-tailed deer. Journal of Wildlife Management 39(3): 563-569.

Fay, R.R. 1988. Hearing in vertebrates: A psychophysics handbook. Winnetka, IL: Hill-Fay Associates. 621 p.

Forest Ecosystem Management Assessment Team (FEMAT). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. Portland, OR: U.S. Department of Agriculture, Forest Service.

Kuck, L.; Hompland, G.L.; Merrill, E.H. 1985. Elk calf response to simulated mine disturbance in southeast Idaho. Journal of Wildlife Management 49(3): 751-757.

Quigley, T.M.; Haynes, R.W.; Graham, R.T. (tech. eds.). 1996. Integrated scientific assessment for ecosystem management in the interior Columbia basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p.

Stockwell, C.A.; Bateman, G.C.; Berger, J. 1991. Conflicts in national parks: A case study of helicopters and bighorn sheep time budgets at the Grand Canyon. Biological Conservation 56(3): 317-328.

Aquatic, Riparian Zone, and Water Quality (AQ)

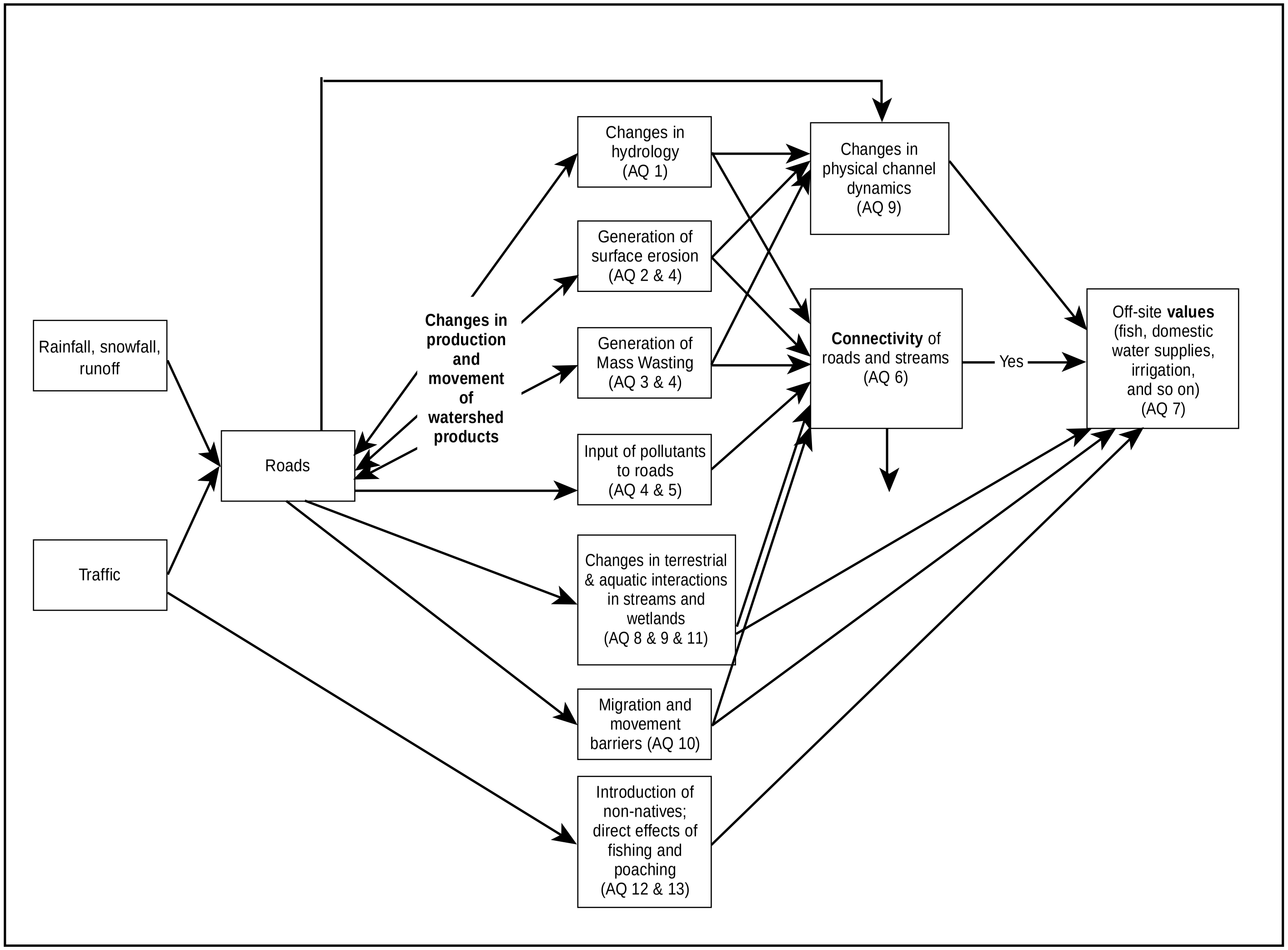

Figure 1-1. The questions in this section are organized according to the following simplified model of watershed process

Note: An annotated bibliography on water-road interactions can be found at *fsweb.sdtdc.wo.fs.fed.us/water-road* (FS intranet) or at *www.stream.fs.fed.us/water-road*.

A collection of water-road interaction papers has recently been prepared and distributed to all Forest Service units by the San Dimas Technology and Development Center. It is a large blue and white binder and should be available on all national forests and ranger districts. Contact the San Dimas T&D Center (909-599-1267) if you cannot find a copy of this valuable reference collection.

A note on indicators: For each question in this section, a listing of potential indicators is given. The term 'indicator' is used to refer to a measure or characterization of natural or human-made features that may be interpretable in terms of the effects of roads on watershed processes and values, and that may aid in addressing the questions posed. Indicators are given that can be developed at intermediate and large scales. Recognizing that indicators usually do not directly answer the questions is important, as is interpreting indicators in terms of watershed processes, functions, and interactions. A detailed discussion of indicators is given in appendix 2.

The AQ section refers to a hierarchy of scales that is coming into wide use:

Table 1-1. Aquatic ecosystem scale hierarchy

Scale	Size (mi^2)
Region	>10,000
Province (used in some places)	~3,000-5,000
Basin (3rd field HUC)	500-5,000
Sub-Basin (4th field HUC)	200-1,000
Watershed (5th field HUC)	10-200
Sub-watershed (6th field HUC)	1-10
Site	<1

Based on: Maxwell, J.R.; Edwards, C.J.; Jensen, M.E.; Paustian, S.J.; Parrott, H.; Hill, D.M. 1995. A hierarchical framework of aquatic ecological units in North America (Nearctic Zone). Gen. Tech. Rep. GTR NC-176.) St. Paul, MN: USDA Forest Service, North Central Forest Experiment Station 72 p.

The AQ section also refers to forest (national forest) and ranger district scales, as these are sometimes the most appropriate or practical scales of consideration.

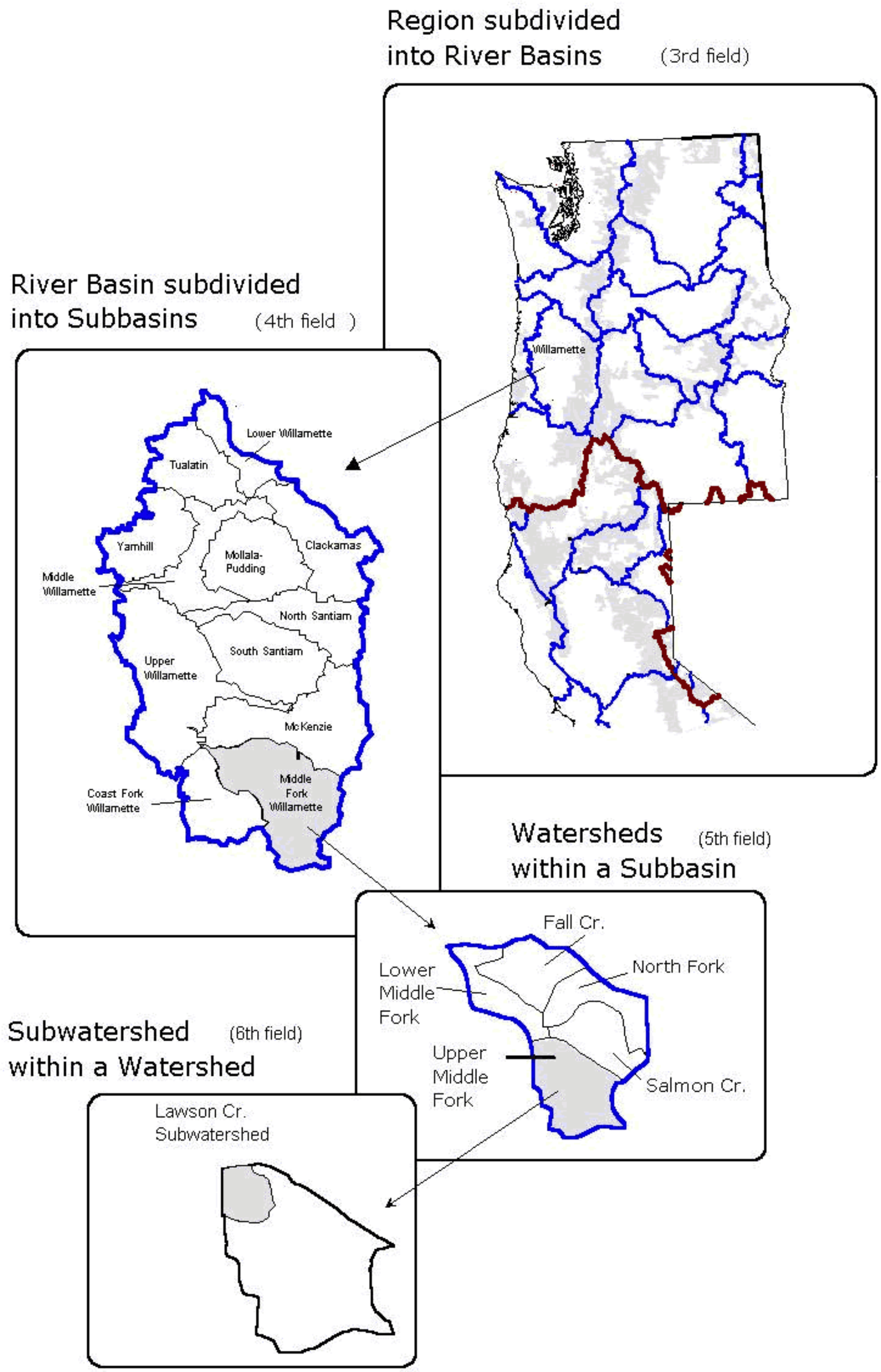

Figure 1-2. The aquatic scales hierarchy.

AQ (1): How and where does the road system modify the surface and subsurface hydrology of the area?

Background

Roads can affect the routing of water through a watershed by intercepting, concentrating, and diverting flows from their natural flowpaths. These changes in routing can result in increases in peak flows by both a volumetric increase in quickflow and changes in the timing of storm runoff to streams (Wemple et al. 1996).

Scale

Subsurface water movements are strongly influenced by local topography and geology, which are best addressed at the ranger district or watershed scale.

Information needs and sources

Location of known groundwater interception in the existing road network

Location of roads relative to groundwater-controlled ecosystem components, such as wet meadows, marshes, swamps, bogs, and fens; subirrigated patches of riparian vegetation; and other wet slope and lentic environments

Location of areas with high spring and seep densities

Road cut heights relative to soil depth.

Hydrologic connectivity of roads (See appendix 2, stream channel proximity indicator)

Drainage rerouting: Estimate of number of points where road drainage is routed from one catchment to another

Susceptibility of nearby channels to peak flow increases

Ground truthing and sampling

Potential indicators

Slope class

Slope position

Road-stream proximity

Road-stream crossings, predicted or actual

Soil depth and hydrologic properties (hydrologic soil group)

Road density

Channel stability

Recommended references

Harr, R.D. 1976. Forest practices and streamflow in western Oregon. Gen. Tech. Rep. PNW-49. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment. 18 p.

Hartman, G.F.; Scrivener, J.C. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223. Ottawa, ON: Canadian Department of Fisheries and Oceans. 148 p.

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

Ziemer, R.R. (ed.). 1998. Proceedings of the conference on coastal watersheds: the Caspar Creek story. 1998 May 6, Ukiah, CA. U.S. Department of Agriculture, Forest Service Gen. Tech. Rep. PSW GTR-168. Albany, CA: Pacific Southwest Research Station, Forest Service, 149 p. Available at *www.psw.fs.fed.us/Tech Pub/Documents/gtr-168/gtr168-toc.html*.

AQ (2): How and where does the road system generate surface erosion?

Background

Surface erosion occurs on most wildland roads because their surfaces, cutslopes, fillslopes and associated drainage structures are usually composed of erodible material and are exposed to rainfall and concentrated surface runoff. Surface erosion differs greatly depending on many factors, the most influential of which are usually: the erodibility of the exposed surface; the slope of the exposed surface; and the area of exposed surface that generates and concentrates runoff. Surface erosion and associated sedimentation are highly sensitive to road maintenance practices. Small changes in road drainage configuration can result in large changes in erosion and the routing of eroded sediments.

Scale

For this question, the forest or province scales and the ranger district or watershed scales are the most appropriate, but larger scales may be appropriate as well. Fine sediments tend to stay in suspension in streamflow until encountering slow water, a lake or estuary, or when streamflow drops to low levels. Thus, fine sediments are readily transported long distances from the site of generation, and the effects of fine sediment can appear many miles from the point of origin, necessitating an assessment of the potential effects on receiving waters, regardless of how far downstream they might be.

Information needs

Fine sediment delivery to streams is a product of erosion from road features and transport of the eroded fines to streams. Therefore, estimating two components is necessary.

Expected erosion rates from road features, including surface, cutslope, fillslope, and ditch, if present. Road surface erosion is most sensitive to drainage area (amount of road that concentrates runoff) and slope (of surface, ditch, cuts, and fills).

Expected delivery of eroded material to the stream network. This value can be expressed as the amount of road that is 'hydrologically connected' to the stream network (See AQ 6).

Expected erosion rates may require information about:

Traffic use

Road characteristics

Surface type and resistance to pulverizing;

Cut height, fillslope length;

Distribution of drainage areas on road surfaces and fillslopes;

Cross-drain spacing,

Drainage density, topographic complexity of terrain,

Number of road-stream crossings,

Road gradients;

Density of forest roads

Density of skid trails and landings (which can have the same hydrologic function and effects as roads, but are usually not inventoried)

Road maintenance records.

Expected delivery of eroded material to the stream network may require information about:

(These are components of hydrologic connectivity, (See AQ 6), and the hydrologic connectivity indicator in appendix 2.)

Road-stream proximity;

Density of road-stream crossings;

Density of road cross-drain features that connect to streams via sediment plumes, gullies, or both;

Slope position (as an indicator of slope wetness and subsurface flow interception);

Slope steepness; and

Proximity of cross-drain features to stream.

Tallying the proportion of road by each surface drainage template may allow an estimate of the amount of road with functioning (those that move sediment) ditchlines.

Sampling to determine those factors that influence or control delivery and connectivity.

Potential Indicators

- Bedrock geology
- Surficial geology
- Geomorphology
- Soil survey
- Landtype associations
- Slope position
- Slope class
- Road density
- Road gradient
- Road surface type
- Road type
- Road sediment delivery
- Maintenance level
- Traffic intensity
- Construction type
- Road-stream proximity
- Stream density
- Sediment risk index
- Road surface type + road gradient
- Road surface type + road gradient + traffic intensity
- Road surface type + road gradient + traffic intensity + bedrock geology
- Road density + slope position
- Road density + slope position + stream density
- Slope position + slope class
- Slope position + riparian area + road mileage
- Slope class + surficial geology
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

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

Everest, F.H.; Beschta, R.L.; Scrivener, J.C. [and others]. 1987. Fine sediment and salmonid production a paradox. Pages 98-142 *in* Salo, E.O.; Cundy, T.W. (eds.). Streamside management forestry and fishery interactions, proceedings of a symposium held at the University of Washington, February 12-14, 1986. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources

Furniss, M.J.; Roelofs, T.D.; Yee, C.S. 1991. Road construction and maintenance. Pages 297-323 *in* Meehan, W.R.(ed). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society.

Water Erosion Prediction Program (WEPP). *forest.moscowfsl.wsu.edu/4702/road0.html*. A WEPP bibliography can be found at *soils.ecn.purdue.edu/~wepp/wepppubs/list.html*.

AQ (3): How and where does the road system affect mass wasting?

Background

Many forest roads, especially those on steeper slopes, are subject to failure through mass wasting processes. The mechanisms for road-related mass wasting failures include removing slope support in roadcuts, increasing the weight on fillslopes, groundwater saturation of the road prism, intercepting subsurface flow, hillslope drainage rerouting, and initiating debris flows at failed stream crossings. Some mass wasting road failures extend long distances downhill from the failure site. If the failure track extends to a stream channel, the initial failure and subsequent chronic surface erosion of the slide will deliver sediment directly to the channel. These types of failures are typical where unstable road or landing fill is placed on steep slopes. Road construction on unstable slopes can increase the frequency of mass wasting failures by an order of magnitude. Debris flows and debris torrents often severely affect road-stream crossing fills and transport fill and channel materials to higher order channels. The factors that may influence the potential for road-related mass-wasting failures are hillslope gradient, slope position, soil type, bedrock geology, geologic structure, type of road construction, road drainage, and groundwater characteristics. Some of these factors can be used in a GIS to rate the relative susceptibility of road segments to mass wasting failures. If a stream channel layer and a road system layer are present, which road segments are likely to deliver materials to the streams can be estimated. An approximation of risk can be obtained by combining the probability of road-related mass wasting failures with the potential effects to the resource of interest. The risk analysis can then be used in determining which roads will receive treatment. Many roads appear relatively stable under normal climatic and geologic conditions but may fail during high intensity precipitation events or in major earthquakes.

Scale

The most appropriate scales for addressing this question are probably the watershed and subbasin scales. The scale of areas that exhibit instability when roaded may indicate the appropriate scales of analysis. The effects of road-related mass wasting materials that enter stream channels can be significant for long distances downstream, especially for suspended sediment, requiring large-scale assessment.

Information needs and sources

Geologic and engineering geologic assessments (FSM 2883; Hall et al. 1994) are sources of essential information for addressing the effects of roads on mass wasting. The roads analysis would obtain this information, and then integrate it with other relevant resource information or assessments in an interdisciplinary process to address issues related to mass wasting.

Geologic assessment of mass wasting under natural conditions.

The starting point for an analysis of mass wasting in roaded areas is a geologic analysis of mass wasting that is characteristic of the area in a natural, unroaded condition. Mass wasting or landslides are part of natural disturbance regimes in many terrestrial and aquatic ecosystems. The type, frequency, magnitude, and distribution of landslides differ significantly in different geologic settings.

For example, northwestern California is one of the most landslide-prone terrains in the world. Landslide activity is frequent and widespread. In contrast, in the geologic setting of western Virginia, landslides are important components in ecosystems, but landslide activity is less frequent and less widespread.

A geologic assessment can provide an understanding of the various natural factors affecting mass wasting under natural conditions in the analysis area. The geologic assessment can characterize the natural range of variability of mass wasting over time, and can include such topics as:

- The type, frequency, volume, and distribution of landslides.
- Evaluation of natural slope stability.
- Landslide hazard assessment and risk assessment.
- The effects of landslides on erosion, sedimentation, streams, and riparian areas.
- The past, present, and potential future state of landslide activity.

The geologic assessment of mass wasting under natural conditions is a baseline for assessing the effects of roads on mass wasting.

Engineering geologic assessment of mass wasting associated with existing roads.

An engineering geologic assessment is conducted to assess the effects of existing and proposed roads on mass wasting. Engineering geology investigates mass wasting associated with roads and with other human-induced changes in the landscape, and evaluates methods to avoid, mitigate, stabilize, control, and reclaim areas of mass wasting.

The engineering geologic assessment can provide information and analysis for such questions as:

- How much of the mass wasting associated with a road is caused by natural processes, by the road, by other human-induced causes, or by some combination of natural and human-induced causes?
- Is road-associated mass wasting likely to increase or decrease in the future?
- What effects will this increase or decrease in mass wasting have on road maintenance costs?
- Are practical, cost-effective measures available to control the mass wasting, or is the type and magnitude of mass wasting beyond practical control?
- What are the mass wasting hazards and risks to resources from different roads and road segments?
- What effects would new roads have on mass wasting?
- For road decommissioning, what methods of treatment of mass wasting are likely to have the best success in a particular geologic setting?
- Will road decommissioning reduce mass wasting associated with the road?

Considerable information about road mass wasting hazard can be obtained from a digital elevation model (DEM) in combination with the road system coverage.

These sources can be used to attach slope position and hillslope gradient to road segments. Many watersheds and subwatersheds will have a unique combination of factors that will best address where mass wasting is more likely. Acquiring the best available information for an area is important, and it may require some compilation of data such as the locations of known road mass wasting failure sites and discussions with personnel familiar with the road system. Useful information may be found in geologic maps, geomorphic maps, soils maps, landslide inventories, landslide hazard maps, aerial photographs, topographic maps, road logs, and road damage-site reports. If these data are digital or can readily be made digital, the analysis will be expedited. If the information is readily accessible, the next major step is to determine which of the variables can be used to assign hazard ratings to the road system. Determining variables and assigning hazard values are probably best done by compiling the attributes of known road-related mass wasting failure sites. If this compilation is not possible, the best anecdotal information should be obtained from personnel familiar with existing road-related mass wasting failure sites.

Potential indicators

- Slope class
- Slope position
- Bedrock geology
- Surficial geology
- Geomorphology
- Quaternary landslides
- Soil type
- Construction type
- Slope position + slope class
- Slope class + surficial geology
- Road-stream proximity

Recommended references

Costa, J.E.; Baker, V.R. 1981. Exogenetic geologic hazard: Landslides. Pages 242-283 *in* Surficial geology: Building with the Earth. New York: John Wiley & Sons.

Dietrich, W.E.; Wilson, C.J.; Reneau, S.L. 1986. Hollows, colluvium and landslides in soil-mantled landscapes. Pages 361-388 *in* Abrahams, A.D. (ed.). Hillslope processes. Boston, MA: Allen and Unwin.

Furniss, M.J.; Roelofs, T.D.; Yee, C.S. 1991. Road construction and maintenance. Pages 297-323 *in* Meehan, W.R.(ed). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society.

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Swanson, F.J.; Benda, L.E.; Duncan, S.H. [and others]. 1987. Mass failures and other processes of sediment production in Pacific Northwest forest landscapes. Pages 9-38 *in* Salo, E.O.; Cundy, T.W. (eds.). Streamside management forestry and fishery interactions, proceedings of a symposium held at the University of Washington, February 12-14, 1986. Contribution 57. Seattle, WA: University of Washington, Institute of Forest Resources

AQ (4): How and where do road-stream crossings influence local stream channels and water quality?

Background

Culverted road-stream crossings can cause large inputs of sediment to streams when culvert hydraulic capacity is exceeded, or the culvert inlet is plugged and streamflow overtops the road fill. The result is often erosion of the crossing fill, diversion of streamflow onto the road surface or inboard ditch, or both. An inventory of all the road-stream crossings (and cross-drains, if needed) in a watershed allows assessing the distribution and severity of risks to beneficial uses from this important potential source area; screening of crossings to determine the most crucial and cost-effective ones to upgrade; and allows estimating the cost of road upgrading or decommissioning, because these costs are very sensitive to the configuration of road-stream crossings. A complete inventory of all crossings in a watershed for these purposes need not gather detailed and highly accurate data, as might be required for a contract, but can be accomplished quickly and inexpensively if methods are adjusted to the desired analytical objectives.

Scale

The watershed scale is ideal for defining the cumulative risk of road-stream crossings, for summarizing the ‘hotspots’ (those crossing with the greatest potential and likelihood to cause damage), and for setting priorities to reduce risks most efficiently.

Information needs

The road drainage network (road-stream crossings, and, if desired, cross drains), can be inventoried at various intensities, depending on objectives of the inventory, time, and financial constraints. A baseline inventory will, at a minimum, provide the locations of the installed drainage system. Near the other end of the spectrum is a complete road-stream crossing risk assessment that defines all aspects of environmental risk.

Three levels of inventory and assessment can be conducted:

Consequences inventory – This approach is designed to locate the installed system and identify those crossings with stream diversion potential over the area of inventory. This inventory technique is the quickest. Because remediation of diversion potential is often inexpensive and straightforward, the technique is meant to identify sites where large erosional consequences can be easily and cost-effectively minimized.

Hazard assessment – This approach addresses the likelihood and potential erosional volume of crossing failure, based on more extensive data collection.

Risk assessment – Building on the results from a hazard assessment, resources of concern (endpoints) are incorporated to locate sites with the greatest overall risk.

Analytical methods and information sources

Flanagan et al. (1998) provides an extensive guide to designing inventory and risk analysis systems for road drainage structures.

Potential Indicators

- Bedrock geology
- Surficial geology
- Geomorphology
- Quaternary landslides
- Slope position
- Slope class
- Road density
- Road-stream proximity
- Stream density
- Road density + slope position
- Road density + slope position + stream density
- Slope position + slope class
- Slope position + riparian area + road mileage
- Fish presence in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Braudrick, C.A.; Grant, G.E.; Ishikawa,Y; Ikeda, H. 1997. Dynamics of wood transport in streams: A flume experiment. Earth Surface Processes and Landforms 22(7): 669-683.

Chatwin, S.C., Howes, D.E.; Schwab, J.W.; Swanston, D.N. 1994. A guide for management of landslide-prone terrain in the Pacific Northwest. Victoria, BC:.British Columbia Ministry of Forests. 220 p.

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Furniss, M.J.; Ledwith, T.S.; Love, M.A.; McFadin, B.C.; Flanagan, S.A. 1998. Response of road-stream crossings to large storm events in Washington, Oregon and northern California. Water/Road Interaction Technology Series No. 9877 1806-SDTDC. San Dimas CA: U.S. Department of

Agriculture, Forest Service, Technology and Development Program. 18 p. Available at *www.stream.fs.fed.us/water-road/floodresponse.pdf*.

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Mt. Baker-Snoqualmie National Forest. 1997. Road decommissioning and closure treatment on the Mt. Baker-Snoqualmie National Forest. White Paper. Mountlake Terrace, WA: USDA Forest Service. Mt. Baker-Snoqualmie National Forest. 16 p.

Normann, J.L.; Houghtalen, R.J.; Johnston, W.J. 1985. Hydraulic design of highway culverts. Hydraulic Design Series 5. Washington, D.C.: U.S. Department of Transportation, Federal Highway Administration, 272 p.

Piehl, B.T.; Beschta, R.L.; Pyles, M.R. 1988. Ditch-relief culverts and low-volume forest roads in the Oregon Coast Range. Northwest Science 62(3): 91-98.

Piehl, B.T.; Pyles, M.R.; Beschta, R.L. 1988. Flow capacity of culverts on Oregon coast range forest roads. Water Resources Bulletin 24: 631-637.

Tsihrintzis, V.A. 1983. Necessity of sediment transport calculations in culvert design. 2PAL0401. 21 p.

Wemple, B.C. 1994. Hydrologic integration of forest roads with stream networks in two basins, western Cascades, Oregon. M.S. Thesis. Corvallis, OR: Oregon State University, Department of Geosciences. 88 p.

AQ (5): How and where does the road system create potential for pollutants, such as chemical spills, oils, de-icing salts, or herbicides, to enter surface waters?

Background

Roads may create potential pollutants in several way. Chemicals such as surfacing oils, de-icing salts, herbicides, and fertilizers may be applied to roads for maintenance, safety, or other improvement. Roads may also become contaminated by material from vehicles, including accumulation of small spills, such as crankcase oil, brake pad linings, and hydraulic fluid; or from accidental spills of hazardous or harmful materials being transported over roads. Applied or spilled materials may have access to waterbodies, depending on road drainage systems and runoff patterns. The severity of damage depends on what organisms might be exposed, their susceptibility to the material, and the degree, duration, and timing of their exposure.

Scale

Province and forest are appropriate scales for analysis; watersheds are appropriate for data preparation.

Information needs

For all segments of the road system,information needed includes: the nature and frequency of hazardous material transport at stream-proximal roads and stream crossings; road conditions that could result in spills; frequency of application of road and forest chemicals; and location of downstream aquatic resources and public water supplies that could be affected by a spill or road-chemical runoff.

Acute and chronic toxicity of each type of chemical to aquatic life and public water supplies

Spill containment and emergency treatment procedures

Distribution of hydrologically connected roads [see AQ (6)]

Stream-discharge information, with estimated water-flow times (based on slope and length of stream network between point of entry and exposure)

Presence of susceptible organisms and populations (for example, people, fishes).

Analytical tools and information sources

Water-chemistry sampling

Bioassay of tolerance of aquatic organisms to short- and long-term exposure to road and forest chemicals

Computer-Aided Management of Emergency Operations software (CAMEO) (*www.nsc.org/ehc/cameo.htm*)

Potential Indicators

- Soil survey
- Land-type associations
- Slope position
- Slope class
- Road density
- Road surface type
- Road type
- Maintenance level
- Traffic intensity
- Road-stream proximity
- Stream density
- Fish presence in streams
- Road density + slope position
- Road density + slope position + stream density
- Slope position + riparian area + road mileage
- Fish presence in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Bisson, P.A.; Ice, G.G.; Perrin, C.J.; Bilby, R.E. 1992. Effects of forest fertilization on water quality and aquatic resources in the Douglas-fir region. Pages 179-193 *in* Chappell, H.N.; Weetman, G.F.; Miller, R.E. (eds.). Forest fertilization: Sustaining and improving nutrition and growth of western forests. Institute of Forest Resources, Contribution 73, Seattle, WA: University of Washington.

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Norris, L.A.; Lorz, H.W.; Gregory, S.V. 1991. Forest chemicals. Pages 207-296 *In* Meehan, W.R. (ed.). Influences of forest and rangeland management on salmonid fishes and their habitats. Special Publication 19. Bethesda, MD: American Fisheries Society.

Tiedemann, A.R. 1973. Stream chemistry following a forest fire and urea fertilization in north-central Washington. Research Note PNW-203, Portland, OR: USDA Forest Service, Pacific Northwest Forest and Range Experiment Station. 20 p.

AQ (6): How and where is the road system "hydrologically connected" to the stream system? How do the connections affect water quality and quantity (such as, the delivery of sediments and chemicals, thermal increases, elevated peak flows)?

Background

To assess the potential for roads to affect water quality and aquatic habitats, a simple parameter—the extent of roads hydrologically connected to the stream network—can be used to indicate the potential for several important adverse effects:

- Hydrologic changes associated with increased drainage density and extension of the stream network [see AQ(1)];
- Delivery of road-derived sediments to streams [see AQ(2),(3),& (4)]; and
- The potential for road-associated spills and chemicals applied to roads to enter streams [see AQ(5)].

This parameter can help to distinguish between roads that have these effects or the potential for them (that is, those that are connected to streams), and roads that do not have these effects or potential (unconnected roads).

What is the hydrologic connectivity of roads?

Roads frequently generate Horton overland flow resulting from relatively impermeable running surfaces and cutslopes. In addition, the interception of interflow at cutslopes can generate substantial amounts of runoff, converting subsurface flows to surface flows. Where these surface flows are continuous between roads and streams, such as where inboard ditches convey road runoff to stream channels, the road generating or receiving the runoff is considered hydrologically connected to the stream network. Wherever a hydrologic connection exists, rapid runoff, sediments, and road-associated chemicals (for example, spills, oils) generated on the road surface and cutslope are provided an efficient route into the natural channel network.

This indicator can be referred to as: **hydrologically connected road**; expressed as length and, if desired, as a proportion of a particular road network. Equivalent terms include "hydrologic integration of roads and streams," "stream-connected road," or "stream network extension by roads."

A working definition of **hydrologically connected road** is:

Any road segment that, during a design runoff event, has a continuous surface flowpath between any part of the road prism and a natural stream channel (any declivity in the land that exhibits a defined channel and evidence of scour and deposition).

[**Note:** Hydrologic connection will tend to increase with increasing intensity and duration of precipitation or snowmelt, and with increasing antecedent soil moisture content. A suitable design runoff event for many purposes might be the 1-year, 6-hour storm, with antecedent moisture conditions corresponding to the wettest month of the year, or similar expression of precipitation depth, statistical frequency, duration, and antecedent soil moisture status.]

The parameter should be expressed as the total length of road in a watershed or other analysis unit that is 'connected,' and may also be expressed as the proportion of the total road length in a watershed or analysis unit that is connected.

Water, sediment, and chemical runoff generated on the road prism can enter the natural stream channel network in a variety of ways:

Inboard ditches delivering to a road-stream crossing;

Inboard ditches delivering to a cross-drain where sufficient discharge is available to create a gully, sediment plume, or both that extends to a stream channel;

Other cross-drainage features, such as waterbars or dips, that discharge sufficient water to create a gully, sediment plume, or both that extends to a stream channel;

Where roads are so close to streams that the fillslope encroaches on the stream (as at road-stream crossings); or

Landslide scars or rock outcrops that create a surface flow path from the road to an adjacent channel.

Any specific road segment is either hydrologically connected or not. Partial connectivity can be defined, but is unnecessary for intermediate and large-scale effects analysis. When remediation is considered at the site scale, characterizing the degree of connection may be useful.

Scale

The forest or province, and the ranger district or watershed are the most appropriate scales. Water quality changes caused by forest roads are typically a watershed-scale issue, but larger-scale depiction of connectivity may help to reveal risks and develop restoration priorities.

Information needs

Road inventory that includes either census or valid sampling of features that contribute to connectivity.

The length of road that is hydrologically connected to the stream system.

Assessment of connectivity at various scales

Watershed and larger scales

As a first approximation, road-stream proximity and the number of road-stream crossings can be used to indicate connectivity. Using road-stream proximity involves field observations, sampling, or both to provide an indication of how close roads must be to streams to have a high likelihood of being connected. For example, field sampling may reveal that roads within 100 meters of streams (any stream) are typically mostly connected, while those more distant from streams are much less likely to be connected. (See the road-stream proximity indicator in appendix 2).

Each road-stream crossing provides a point of hydrologic connectivity, though the length of road connected at each crossing may differ widely. A field-sampling-based assumption of the average length of road connected at each crossing can be used. The number of crossings, multiplied by the average length connected per crossing, provides a value for this mode of connection. Then, simple road-stream proximity (see appendix 2) can be used to account for other modes of connection (adjusting for connected length already accounted for by road-stream crossings). Because of high variability in conditions and the variety of mechanisms that can connect roads and streams, the combination of the road-stream crossing tally and road-stream proximity as a surrogate for connectivity may be quite inaccurate, but, for large-scale comparisons among watersheds, for example, it may be sufficient. More detailed sampling, based on stratifying watershed, road and geomorphic features believed to control connectivity, could greatly improve the relation between proximity and connectivity.

A 20 percent sample of road miles in a watershed for actual observed connectivity may provide an indication of the degree of connectivity.

How is connectivity assessed in the field, at the site scale?

Delineating hydrologically connected road segments is relatively straightforward. For cross-drain structures, inspect the outlet for a gully or plume and determine if it enters a channel. The same procedure is applied to waterbars, other cross-drainage structures, rock outcrops, and landslide scars, where the presence or absence of evidence of surface flowpaths is noted. Connectivity also occurs where ditches (or the road surface) deliver directly to the stream at road-stream crossings.

The contributing road length should be noted for each site. Often, this variable can be expressed as contributing ditch length. If total road length is known, the proportion of hydrologically connected road can be determined. Further, if gully or plume lengths are recorded below cross drains and landslides, increases in drainage density can be quantified.

A sampling approach may be used for efficiency, although the considerations and constraints for this type of survey are not yet fully developed. We expect that a relation between soil type, road grade, ditch length, and discharge slope steepness can predict gully or sediment plume lengths, and together with stream proximity, predict connectivity via cross-drain gullies and sediment plumes. We expect that WEPP can be used to approximate this relation. This approach is currently being studied, and a subsequent paper will detail possible methods and the reliability of various intensities of sampling in determining this important indicator.

Data collected for a connectivity inventory are

Drainage feature: road-stream crossing, cross-drain culvert, rolling dip, waterbar, landslide scar;

Connected? Yes or no. If yes, then:

Contributing ditch and road length;

Gully or plume length below outlet to stream channel;

Road-stream proximity (See appendix 2. Road-stream proximity indicator); and

Total road length.

Analytical tools and information sources

Road logs (for cross-drain location and spacing)

WEPP software to predict gully or sediment plume length below cross-drains

The X-Drain program provides a lookup interface to a wide array of WEPP runs that may be useful in this effort as well. (*forest.moscowfsl.wsu.edu/4702/ road0.html*)

Road-stream crossing inventory

Road maintenance records

Road logs (for location of cross-drains and estimate of cross-drain spacing)

Potential Indicators

- Bedrock geology
- Surficial geology
- Geomorphology
- Soil survey
- Landtype associations
- Slope position
- Slope class
- Road density
- Road gradient
- Road surface type
- Road type
- Road sediment delivery
- Construction type
- Road-stream proximity
- Stream density
- Road surface type + road gradient
- Road density + slope position
- Road density + slope position + stream density
- Slope position + slope class
- Slope position + riparian area + road mileage
- Slope class + surficial geology
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Brownlee, M.J.; Shepherd, B.G.; Bustard, D.R. 1988. Some effects of forest harvesting on water quality in the Slim Creek watershed in the central interior of British Columbia. Canadian Technical Report of Fisheries and Aquatic Sciences 1613, Ottawa, ON: Department of Fisheries and Oceans. 41 p.

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Wemple, B.C. 1994; Hydrologic integration of forest roads with stream networks in two basins, western Cascades, Oregon. M.S. Thesis . Corvallis, OR: Oregon State University, Department of Geosciences. 88 p.

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

Water Erosion Prediction Program (WEPP) *forest.moscowfsl.wsu.edu/4702/road0html.* A WEPP bibliography can be found at *www.soils.ecn.purdue.edu/~wepp/wepppubs/list.html.*

AQ (7): What downstream beneficial uses of water exist in the area? What changes in uses and demand are expected over time? How are they affected or put at risk by road-derived pollutants?

Background

Water and waterbodies have a great many potential uses and benefits, and the distribution, value, and sensitivity of the beneficial uses often differs greatly from area to area. Identifying what values can be affected and making an assessment of the degree to which they are affected by roads is crucial. Some potential beneficial uses include

- Fish habitat,
- Aquatic organisms other than fish,
- Domestic water supplies,
- Municipal water supplies,
- Irrigation water supplies,
- Recreational use,
- Reservoirs,
- Recreational areas,
- Water supplies for industry and hatcheries,
- Visual values,
- Ecosystem interactions value,
- Use by wildlife associated with riparian and aquatic habitats (both obligate and facultative),
- Freshwater supplies to estuarine environments,
- Freshwater recharge to prevent saltwater intrusion into groundwater supplies,
- And so on.

Scale

Usually best discerned and displayed at watershed, subbasin, and basin scales.

Information needs

Distribution of beneficial use

Proximity of roads to beneficial uses

Road density or other interpretation in upstream watershed

Stream miles between road or road feature and point(s) of beneficial uses

Sensitivity of beneficial uses to pollutant of concern

Analytical tools and information sources

Cumulative effects assessments

Spatial relation between interpreted road risk locations and locations of beneficial uses

Steam surveys

Water rights record

Basin plans

Forest plans

Potential indicators

Road-stream proximity

Distribution of fish habitat, domestic water-supply diversions, and other sensitive beneficial uses in the area under analysis

AQ (8): How and where does the road system affect wetlands?

Background

Roads can affect wetlands by direct encroachment or through changes in hydrology. Roads can modify both surface and subsurface drainage in wetlands, causing changes in wetland moisture regimes. Where roads cross or are near wetlands, the effect on wetland form, process, and function is evaluated by examining the degree to which the local hydrology is modified, in terms of flow quantity, timing, routing, and water quality.

Scale

District or watershed scale is the most appropriate.

Information needs

Location of wetlands (such as lakes, ponds, bogs, fens, marshes, wet meadows, sub-irrigated riparian zones)

Locations where roads cross or encroach directly on wetlands or are close to wetlands.

Nature of encroachment

Severity of effects of encroachment

Presence of susceptible organisms

Analytical tools

Field sampling and evaluation of road segments that encroach on wet environments

Groundwater hydrology analysis of sampled areas

Potential indicators

- Geomorphology
- Soil survey
- Land-type associations
- Slope position
- Slope class
- Road sediment delivery
- Road-stream proximity
- Stream density
- Slope position + riparian area + road mileage
- Slope class + surficial geology
- Road-wetland proximity
- Road-stream intersections
- Road-stream intersection density
- Road-stream intersections by channel order

Recommended references

DeBano, L.F., Schmidt, L.J. 1989. Improving southwestern riparian areas through watershed management. Fort Collins, CO. Gen. Tech. Rep. RM-182. USDA Forest Service. Rocky Mountain Forest and Range Experiment Station. 33 p

LaFayette, R.A.; Pruitt, J.R.; Zeedyk, W.D. 1992. Riparian area enhancement through road management. Indianapolis, IN. Proceedings of the International Erosion Control Association, 24th conference. Pages 353-368

Oakley, A.L.; Collins, J.A.; Everson, L.B. [and others]. 1985. Riparian zones and freshwater wetlands. Pages 58-79 *in* Brown, E.R. (ed.). Management of wildlife and fish habitats in forests of western Oregon and Washington. Part 1. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Stanford, J.A.; Ward, J.V. 1992. Management of aquatic resources in large catchments: Recognizing interactions between ecosystem connectivity and environmental disturbance. Pages 91-124 *in* Naiman, R.B. (ed.). Watershed management: Balancing sustainability and environmental change. New York: Springer-Verlag.

USDA Forest Service. 1996. Managing roads for wet meadow ecosystem recovery. Albuquerque, NM. FHWA-FLP-96-016. Southwestern Region. 80 p.

AQ (9): How does the road system alter physical channel dynamics, including isolation of floodplains; constraints on channel migration; and the movement of large wood, fine organic matter, and sediment?

Background

Stream channels are dynamic. They migrate within historic flood plains, eroding the bed and banks in one place while aggrading the bed and building new banks in other places. Streams also transport and deposit large pieces of woody debris and fine organic matter, providing physical structure and diverse aquatic habitat to the channel. When roads encroach directly on stream channels, these processes can be modified. Wood and sediment can be trapped behind stream crossings, reducing downstream transport and increasing the risk of crossing failure. Road alignment and road fills can isolate floodplains, constrict the channel, constrain channel migration, and simplify riparian and aquatic habitat. In some places, road encroachment can divert streamflows to the opposite bank, thereby destabilizing the hillslope and resulting in increased landsliding.

Scale

The ranger district or watershed scale is most appropriate.

Information needs

Locations where roads encroach directly on stream channels or are proximate to streams

Nature of encroachment (for example, fill in channel, channel constriction, riprap, road-stream crossing, floodplain isolation, route through channel)

Extent of encroachment relative to the total drainage network

Presence of susceptible organisms adjacent to or downstream from the encroachment

Location of woody-debris dams, sediment terraces, or both upstream from road crossings

Distribution of channel types, woody-debris abundance, and alluvial reaches downstream from road crossings

Analytical tools and information sources

GIS for screening (roads, streams, proximity) query

Field evaluation of encroaching road segments

Channel geomorphic analysis

Fish population and other aquatic organism surveys

Stream surveys and inventories of existing road crossings

Debris movement studies (tagging experiments)

Potential Indicators

- Bedrock geology
- Surficial geology
- Geomorphology
- Soil survey
- Landtype associations
- Slope position
- Slope class
- Road-stream proximity
- Stream density
- Road density + slope position
- Road density + slope position + stream density
- Slope position + slope class
- Slope position + riparian area + road mileage
- Slope class + surficial geology
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Gregory, S.V.; Swanson, F.J.; McKee, W.A; Cummins, K. W. 1991. An ecosystem perspective of riparian zones. BioScience 40(8): 540-551.

Hartman, G.F.; Scrivener, J.C. 1990. Impacts of forestry practices on a coastal stream ecosystem, Carnation Creek, British Columbia. Canadian Bulletin of Fisheries and Aquatic Sciences 223. Ottawa, ON: Canadian Department of Fisheries and Oceans. 148 p.

Sedell, J.R.; Beschta, R.L. 1991. Bringing back the "bio" in bioengineering. Pages 160-175 *in* American Fisheries Society Symposium 10. Bethesda, MD: AFS.

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AQ (10): How and where does the road system restrict the migration and movement of aquatic organisms? What aquatic species are affected and to what extent?

Background

Culverted road-stream crossings can sometimes block the migration of fishes and other organisms in streams, which can have serious consequences on fish life histories and populations. Sometimes maintaining barriers at road crossings is desirable where such barriers prevent invasions by unwanted aquatic species. Most culvert migration blockages prevent or restrict upstream migration, though sometimes downstream migration through a culvert can pose hazards to the fish from poor outlet conditions (for example, high perch with no outlet pool). Blockages at the crossing may be partial or total, they can affect adult spawners, migrating juvenile fish, or both. A variety of factors affect the nature of culvert migration barriers. Determining the extent of the problems and a feasible and effective range of solutions requires analysis with an interdisciplinary approach, drawing from fisheries biology, hydraulics, engineering, geomorphology, and hydrology.

Scale

Problems and remediation options can only be thoroughly analyzed and designed at the site scale, but fish populations and hydrology must be defined at watershed and subbasin scales. Summaries of the distribution of problems and priorities of remediation are best summarized at the watershed and larger scales. Where fish must negotiate more than one culvert to reach spawning or rearing habitat, the culverts must be considered as a system, along with migration timing and hydrology, to understand the nature and scope of the problem.

Information needs

Four categories of data are needed at the site scale: species life histories, culvert characteristics, stream characteristics, and hydrology. For intermediate and larger scales, summaries of findings at the site scale are appropriate.

At the site scale, the following information is needed to assess fish passage through culverts (table 1-2):

Table 1-2. Information needed to assess fish passage through culverts. The second column shows the data class, and the third column elaborates on specific needed details.

Species life histories		
Data required	Migration timing	Juvenile migration timing Adult migration timing
	Swimming abilities	Species Juvenile, by age class Adult Prolonged (red muscle)and burst (white muscle) speeds relative to water temps Design fish length
Output	For each species and age class: Season(s) and duration(s) of concern Minimum depth of flow required Maximum allowable water velocity, for burst and prolonged swimming speeds	
Stream characteristics		
Data required	Channel cross-sections	At outlet At a typical reach without influence from the culvert
	Channel and bank characterization	Substrate size and distribution Large wood distribution Vegetation type, size, and location Ordinary high-water marks
	Channel geometry	Bed width, active channel and bankfull Rate of meandering Gradient, up- and down-stream Outlet pool characteristics
Output	Channel roughness coefficient Pool or tailwater stage-discharge relations Cross-check for theoretical design discharge Perch height and horizontal jump distance at various discharges	
Culvert Characteristics		
Data required	Culvert length Rise and span Shape (arch, circular, etc.) Type of material Corrugation size Inlet and outlet configuration and type Installation type (on grade, embedded below streambed) Appurtenances, such as baffles, weirs, tailwater controls Culvert gradient Substrate size and distribution Description of blockage or damage in the culvert	
Output	Culvert hydraulics	Velocity Depth at various discharges Backwater elevations in the culvert Composite roughness coefficient Percent channel constriction
	Allowable travel distance, by discharge or max and min passable flows	Burst (white muscle) Prolonged (red muscle) inlet, outlet, and barrel zones

Hydrology		
Data required	Local gage data or best estimate	Mean daily, mean monthly, mean annual peak
	Stream temperature regime during migration period (vs. swimming ability)	
	Basin characteristics above the culvert	Area, slope, length
	Regional and local regression equations for design flows	
Output	Flow duration curves for	Whole year Migration periods, Monthly,
	Flow at bankfull and active channel	
	Design flow hydrographs	
	Fish passage design flows	Minimum and maximum

Potential Indicators for intermediate and larger scales

Watershed scale

- Distribution of barriers, arranged by
  - Partial or total (or other expression of the nature and severity of the blockage)
  - Adult or juvenile blockage, or both, by species of interest
  - Amount of habitat blocked
    - Totally blocked or partially blocked
    - Quality and type of habitat blocked
  - Cost to remediate

In the absence of site-scale analysis

Intersection of:

1. Road-stream crossings: actual inventory or predicted crossings (road-stream intersections on GIS.) N.B. This can be grossly in error if the road layer, stream layer, or both are inaccurate.
2. Distribution of fish-bearing streams, based on
   - Actual habitat assessment
   - Channel gradient—fish-habitat associations

- Estimated number of sites that need site-scale investigation

Subbasin and larger scales

- Stream systems affected by blockages
- Adults, juveniles, or both
- Most severely affected watersheds
- Total area of habitat affected
- Area affected by channel type, species, or population type
- Cost-benefit analysis to inform the setting of priorities for remediation

Recommended references

Barber, M.E.; Downs, R.C. 1996. Investigation of culvert hydraulics related to juvenile fish passage. Final Report. WA-RD-388.1. Pullman, WA: Washington State University, Washington State Transportation Center (TRAC). 54 p.

Bates, K. 1999. Fish passage design at road culverts. Olympia WA: Washington State Department of Fish and Wildlife. *www.wa.gov/wdfw/hab/engineer/cm/toc.htm*

Behlke C.; Kane, D.; McLean, R.F.; Travis, M.D. 1991. Fundamentals of culvert design for passage of weak-swimming fish. FHWA-AK-RD-90-10. 2301 Peger Road, Fairbanks, AK 99709. Alaska DOT & PF Research Station. 203 p

Evans, W.A.; Johnson, F.B. 1972. Fish migration and fish passage: A practical guide to solving fish passage problems. San Francisco, CA: USDA Forest Service, Pacific Southwest Region. 1 v.

Gebhards, S; Fisher, J. 1972. Fish passage and culvert installations. Boise, ID: Idaho Fish and Game Department.12 p.

Moore, K.; Furniss, M.J.; Ory, J.; Love, M. 1998. Fish passage through culverts: an annotated bibliography. Unpublished report. Eureka, CA: USDA Forest Service, Six Rivers National Forest. 36 p. Available at *www.stream.fs.fed.us/fishxing*.

AQ (11): How does the road system affect shading, litterfall, and riparian plant communities?

Background

When roads are constructed adjacent to streams, riparian vegetation is often removed to accommodate the road right-of-way, improve visibility, and reduce the hazard of trees falling on the roadway. This action can reduce shading of the stream, however, causing increased stream temperatures, reduced potential for recruiting large woody debris in the stream, reduced leaf fall and riparian invertebrates, and loss of habitat for aquatic and riparian species.

Scale

The forest or province and ranger district or watershed scales are appropriate. The question can be recast as how roads affect the delivery of water, organic materials (such as, large wood, small wood, litter, invertebrates), heat, and sediment to streams and other water bodies from adjacent riparian zones. The watershed will usually be the most critical landscape unit.

Information needs

Survey of plant communities in riparian areas (to help establish riparian boundaries, especially on alluvial landforms)

Location of roads relative to riparian boundaries, and intersection with influential riparian vegetation communities.

Assessment of the risk of the road system substantially altering riparian stand age, patch continuity and composition, understory vegetation and canopy, as well as access by aquatic organisms to floodplain habitats, overflow channels, springbrooks, riverine ponds, and wetlands

Analytical tools and information sources

Biological surveys; appropriate Federal, State, and local fish and wildlife agencies, conservation organizations

GIS with riparian and road layers; but riparian vegetation is rarely mapped into GIS (zones are too narrow to resolve)

Some form of site-specific biological assessment will be needed; it will need to balance the “damage” done by roads in riparian zones with the potential “benefits” derived from allowing the riparian zone to be actively managed.

Potential Indicators

- Bedrock geology
- Surficial geology
- Geomorphology
- Soil survey
- Landtype associations
- Slope position
- Slope class
- Riparian vegetation
- Road density
- Road-stream proximity
- Stream drainage density
- Fish presence in streams
- Sediment risk index
- Road density + slope position
- Road density + slope position + stream density
- Slope position + slope class
- Slope position + riparian area + road mileage
- Slope class + surficial geology
- Fish presence in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Gregory, S.V.; Swanson, F.J.; McKee, W.A.; Cummings, K. W. 1991. An ecosystem perspective of riparian zones. BioScience 40(8):540-551.

Naiman, R.J.; Beechie, T.J.; Benda, L.E. [and others]. 1992. Fundamental elements of ecologically healthy watersheds in the Pacific Northwest Coastal Ecoregion. Pages 127-188 *in* Naiman, R.J. (ed.). Watershed management: Balancing sustainability and environmental change. New York: Springer-Verlag.

AQ (12): How and where does the road system contribute to fishing, poaching, or direct habitat loss for at-risk aquatic species?

Background

Recreational use of aquatic resources, if improperly managed, can contribute significantly to declines in rare or unique native vertebrate populations or to damage to important habitats. The presence of the road system facilitates access to streams, lakes, and wetlands where at-risk species may live.

Scale

The forest or province and ranger district or watershed scales are appropriate, depending on the species at risk.

Information needs

Distribution of at-risk species

Assessment of the risk of species' extirpation with increasing public access

Analytical tools and information sources

Biological surveys; appropriate fish and wildlife agencies, conservation organizations

Potential Indicators

- Road density
- Maintenance level

- Traffic intensity
- Fish presence by species in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

AQ (13): How and where does the road system facilitate the introduction of non-native aquatic species?

Background

Introductions of non-native sport fishes, whether authorized or unauthorized, have the potential to affect the distribution and abundance of native fishes, amphibians, and other aquatic organisms. Exotic aquatic plants may also be introduced to lakes and streams from boats and boat trailers. Unauthorized releases of aquarium fishes, bait fishes, exotic amphibians and reptiles, and non-native plants to streams and lakes are strongly influenced by road access.

Scale

The ranger district or watershed scales are most appropriate. In part, the scale will depend on the species of concern and whether it (they) are perceived to be a substantial ecological problem.

Information needs

Survey of plants and animals associated with road cuts and roadside ditches

Location of fish stocking sites and State and local stocking policies

Analysis of the risk of accidental release of non-native species, such as non-native aquarium fishes, sport and bait fishes, amphibians and reptiles, aquatic and riparian plants

Analytical tools and information sources

Biological surveys; information from appropriate Federal, State, and local fish and wildlife agencies, and conservation organizations

Potential indicators

- Maintenance level
- Traffic intensity
- Road-stream proximity
- Stream density
- Fish presence in streams
- Slope position + riparian area + road mileage
- Fish presence in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Miller, R.R.; Williams, J.D.; Williams, J.E. 1989. Extinctions of North American fishes during the past century. Fisheries 14(6):22-38.

AQ (14): To what extent does the road system overlap with areas of exceptionally high aquatic diversity or productivity, or areas containing rare or unique aquatic species or species of interest?

Background

Not all areas have the same biological values. Areas where diversity or productivity are especially high, or where other special conditions are particularly valued, may suggest that the degree of acceptable risk is lower and restoration priority is higher than in other areas. The spatial coincidence of roads with such areas is a first step in determining if roads are affecting them. Roads in these areas may be a high priority for the detailed examination and analysis needed to determine the extent of actual effects.

Scale

Appropriate scales are watershed, subbasin, and basin. This summary question is intended to aid in showing the interaction of road-related risk to biological refugia or special areas for production or diversity at larger scales.

Information needs

Location of known areas of diversity

Location of areas of high productivity

Location of known or designated population refugia

Road density by hazard zone in the watersheds or larger units with special biological attributes

Analytical tools and information sources

Fish habitat typing and summaries

INFRA–Travel Routes software

Interpretations of road-water-aquatic-habitat influences, relative to spatial distribution of habitats

Biologists opinion as to the most valuable areas

Potential indicators

- Road-stream proximity
- Stream density
- Fish populations in streams
- Road density + slope position
- Road density + slope position + stream density
- Slope position + riparian area + road mileage
- Fish presence in streams + road-stream proximity
- Road-stream intersections
- Road-stream intersections by channel order
- Road-stream intersection density

Recommended references

Lee, D.C.; Sedell, J.R.; Rieman, B.E.; Thurow, R.F.; Williams, J.E. 1997. Broadscale assessment of aquatic species and habitats. Pages 1057-1496 *in* Quigley, T.M.; Arbelbeide, S.J. (tech. eds.). An assessment of ecosystem components in the Interior Columbia Basin and portions of the Klamath and Great Basins: Volume 3. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

Terrestrial Wildlife (TW)

TW (1): What are the direct effects of the road system on terrestrial species habitat?

Background

The presence of roads directly affects habitat for many species. Direct effects include habitat loss and fragmentation, and edge effects (Table 1-3). The magnitude of these effects depends on road density, intensity of road use, road location, types of habitats traversed by roads, and the status of populations in the surrounding area.

Table 1-3. Road-associated factors that have a direct negative effect on habitat for terrestrial vertebrates, a generalized description of each factor's effect in relation to roads, and example citations linking roads as a facilitator of the factors and effects. (adapted from Wisdom and others, in press)

Road-associated factor	Effect of factor in relation to roads	Example Citations
Habitat loss and fragmentation	Loss and resulting fragmentation of habitat from establishing and maintaining of road and road-right-of-way	Forman and others (1997) Reed and others (1996)
Negative edge effects	Specific case of fragmentation for species that respond negatively to openings or linear edges created by roads (such as "habitat-interior" species [Marcot and others 1994])	Forman and others (1997) Mader (1984) Reed and others (1996)

Scale

Fragmentation should be measured at the subwatershed or larger scale.

Other habitat effects are initially analyzed at the site scale, but their significance must be evaluated at larger scales, at least at the watershed scale.

Information needs

Map of existing road network and proposed changes

GIS map of vegetation structural stages and cover types, including vegetation conditions adjacent to roads

List of species associated with interior habitat (defined as amount of core habitat within a patch greater than a specified distance from the edge of that patch)

Tally of acres of early-seral vegetation created or maintained by the road network

Tally of openings associated with roads and estimated longevity of these openings

Identification of wildlife species associated with early-seral vegetation and affected by creating openings and edges

Analytical tools and information sources

Use landscape-pattern software to analyze patch conditions before and after proposed changes (for example, FRAGSTATS, UTOOLS).

Survey the literature and use WHR tools to identify interior and other species that respond to road-related vegetation changes.

Develop estimates of width of road-related vegetation effects for each class of road (separating effects of slope), and map the zone of influence by road class.

Overlay road (and associated influence zone) with species distributions. Assess change in habitat for each species.

Calculate influence of roads by defining geographic areas in classes of road density, expressed as miles of road per square mile.

Assess risk to persistence of species and investigate which risks are substantially increased or decreased with proposed changes to the road system. Use habitat capability models to judge changes in carrying capacity for those species at risk.

Recommended references

Forman, R.T.T.; Friedman, D.S.; Fitzhenry, D.; [and others]. 1997. Ecological effects of roads: Toward summary indices and an overview of North America. Canters, K.; Piepers, A.; Hendriks-Heersma, D. (eds). Proceeding of the international conference "Habitat fragmentation, infrastructure, and the role of ecological engineering," 17-21 September 1995, Maastricht—The Hague.Delft: The Netherlands: Ministry of Transport, Public Works, and Water.

Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29: 81-96.

Marcot, B.G.; Wisdom, M.J.; Li, H.W.; Castillo, G.C. 1994. Managing for featured, threatened, endangered, and sensitive species and unique habitats for ecosystem sustainability. Gen. Tech. Rep. PNW-GTR-329. Portland, OR: USDA Forest Service, Pacific Northwest Research Station. 89 p.

USDA Forest Service. (In press) Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Wisdom, M.J.; Holthausen, R.S.; Wales, B.K. [and others]. In press. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broad-scale trends and management implications. Portland, OR: Gen. Tech. Rep. PNW-GTR-xxx. USDA Forest Service, Pacific Northwest Research Station.

TW (2): How does the road system facilitate human activities that affect habitat?

Background

Roads may facilitate human activities that result in habitat disturbances. Disturbances may include removing structures (snags and logs), losing habitat to fires resulting from human ignitions, and destroying habitat by trampling (Table 1-4).

Table 1-4. Mechanisms of habitat loss from human activities facilitated by roads. (adapted from Wisdom and others, in press)

Road-associated factor	Effect of factor in relation to roads	Example Citations
Snag reduction	Reduction in density of snags and/or area where snags are present due to removal near roads, as facilitated by road access	Hann and others (1997) Quigley and others (1996)
Down log reduction	Reduction in density of logs and/or area where logs are present due to removal near roads, as facilitated by road access	Hann and others (1997) Quigley and others (1996)
Direct loss	Habitat loss from trampling in campgrounds and other direct disturbances	
Loss to fire	Habitat lost to fire resulting from increased incidence of human-caused ignitions	Hann and others (1997)

Scale

Effects are seen at the site and road scales but should be evaluated at the watershed scale.

Information needs

Determine if otherwise suitable habitat would be made less valuable by changes in road-related disturbance.

Determine effects of habitat disturbances, including burning, removing structures (snags, logs), or directly destroying habitat (such as camping in riparian zones).

Recommended references

Hann, W.J.; Jones, J.L.; Karl, M.G. [and others]. 1997. Landscape dynamics of the basin. Vol. II, Chapter 3. Pages 338-1055 *in* Quigley, T.M.; Arbelbide, S.J. (tech. eds.). An assessment of ecosystem components in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-405. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Quigley, T.M.; Haynes, R.W.; Graham, R.T. (tech. eds.). 1996. Integrated scientific assessment for ecosystem management in the interior Columbia Basin and portions of the Klamath and Great Basins. Gen. Tech. Rep. PNW-GTR-382. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 303 p. (Quigley, T.M. (ed.). The Interior Columbia Basin Ecosystem Management Project: Scientific Assessment).

USDA Forest Service. (In press) Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Wisdom, M.J.; Holthausen, R.S.; Wales, B.K. [and others]. In press. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broad-scale trends and management implications. Portland, OR: Gen. Tech. Rep. PNW-GTR-xxx. USDA Forest Service, Pacific Northwest Research Station.

TW (3): How does the road system affect legal and illegal human activities (including trapping, hunting, poaching, harassment, road kill, or illegal kill levels)? What are the effects on wildlife species?

Background

Roads allow both legal and illegal impacts on species through hunting, trapping, poaching, collecting, harassing, road kill, disruption of dispersal, displacement, and other negative interactions with people (Table 1-5). The magnitude of these effects depends on road density, intensity of road use, road location, types of habitats traversed by roads, and the status of populations in the surrounding area.

Table 1-5. Human activities facilitated by roads that directly affect species populations (adapted from Wisdom and others, in press)

Road-associated factor	Effect of factor in relation to roads	Example Citations
Over-trapping	Nonsustainable or nondesirable legal harvest by trapping, facilitated by road access	Bailey and others (1986) Hodgman and others (1994)
Poaching	Increased illegal take (shooting or trapping) of animals, facilitated by road access	Cole and others (1998) McLellan and Shackleton (1988)
Collecting	Collection of live animals for human uses (such as collecting amphibians and reptiles for pets), facilitated by the physical characteristics of roads or by road access	Nussbaum and others (1983)
Harassing or disturbing at specific use sites	Direct interference of life functions at specific use sites due sto human or motorized activities, as facilitated by road access (such as increased disturbance of nest sites, breeding leks, or communal roost sites)	Forman (1995); White (1974)
Collisions	Death or injury resulting from a motorized vehicle running over or hitting an animal on a road	Blumton (1989) Boarman and Sazaki (1996) Vestjens (1973)
Movement barrier	Preclusion of dispersal, migration, or other movements as posed by a road itself or by human activities on or near a road or road network	Bennett (1991) Mader (1984)
Displacement or Avoidance	Spatial shifts in populations or individual animals away from a road or road network in relation to human activities on or near a road or road network	Forman and Hersperger (1996) Mech and others (1988)
Chronic, negative interactions with people	Increased mortality of animals (e.g., euthanasia or shooting of gray wolves or grizzly bears) from increased contact with people, facilitated by road access	Mace and others (1996) Thiel (1985)

Scale

Effects are seen at the site and road scales, but they should be evaluated at the watershed scale.

Information needs

Map of road system showing traffic volume

General map of forest cover types

List of species affected by road-related activities in the planning area

Estimated density of each species in each cover type

Probability of road kill for species in the area

Analytical tools and information sources

Determine how roads affect rates of trapping, hunting, poaching, or illegal kill and what effect such changes have on populations in the area.

Identify effects of road-related harassment.

Based on acres of habitat and density of populations by cover type, estimate population size of each species in the planning area affected by road-related activities.

Estimate potential yearly loss of individuals from existing records or judgments.

Evaluate yearly losses against estimated population size.

Evaluate whether losses pose enough risk to a population's persistence to suggest changes in the road system are warranted.

Recommended references

Bailey, T.N.; Bangs, E.E.; Portner, M.F. [and others]. 1986. An apparent overexploited lynx population on the Kenai Peninsula, Alaska. Journal of Wildlife Management 50: 279-290.

Bennett, A.F. 1991. Roads, roadsides and wildlife conservation: a review. Pages 99-118 *in:* Saunders, D.A.; Hobbs, R.J. (eds.). Nature conservation 2: The role of corridors. Surrey, Beatty and Sons, Victoria, Australia.

Blumton, A.K. 1989. Factors affecting loggerhead shrike mortality in Virginia. M.S. Thesis. Blacksburg, VA: Virginia Polytechnical Institute and State University. 85 p.

Boarman, W.I.; Sazaki, M. 1996. Highway mortality in desert tortoises and small vertebrates: Success of barrier fences and culverts. Pages 169-173 *in:* Evink, G; Garrett, P.; Berry, J., (eds.). Proceedings, Transportation and wildlife: Reducing wildlife mortality and improving wildlife passageways across transportation corridors. Florida Department of Transportation/ Federal Highway Administration transportation-related wildlife mortality seminar, April 3 - May 2, 1996, Orlando, FL

Cole, E.K.; Pope, M.D.; Anthony, R.G. 1998. Effects of road management on movement and survival of Roosevelt elk. Journal of Wildlife Management 61: 1115-1126.

Forman, R.T.T. 1995. Land mosaics: The ecology of landscapes and regions. Cambridge: Cambridge University Press 632 p.

Forman, R.T.T.; Hersperger, A.M. 1996. Road ecology and road density in different landscapes, with international planning and mitigation solutions. Pages 1-23 *in:* Evink, G.; Garrett, P.; Berry, J. (eds.). Proceedings, Transportation and wildlife: reducing wildlife mortality and improving wildlife passageways across transportation corridors. Florida Department of Transportation/Federal Highway Administration transportation-related wildlife mortality seminar, April 3 - May 2, 1996, Orlando, Florida.

Hodgman, T.P.; Harrison, D.J.; Katnik, D.D.; Elowe, K.D. 1994. Survival in an intensively trapped marten population in Maine. Journal of Wildlife Management. 58(4): 593-600.

Mace, R.D.; Waller, J.S.; Manley, T.L. [and others]. 1996. Relationships among grizzly bears, roads and habitat in the Swan Mountains, Montana. Journal of Applied Ecology 33: 1395-1404.

Mader, H.J. 1984. Animal habitat isolation by roads and agricultural fields. Biological Conservation 29: 81-96.

McLellan, B.N.; Shackleton, D.M. 1988. Grizzly bears and resource-extraction industries: Effects of roads on behaviour, habitat use, and demography. Journal of Applied Ecology 25(2): 451-460.

Mech, L.D.; Fritts, S.H.; Radde, G.L.; Paul, W.J. 1988. Wolf distribution and road density in Minnesota. Wildlife Society Bulletin 16: 85-87.

Nussbaum, R.A.; Brodie, E.D., Jr.; Storm, R.M. 1983. Amphibians and reptiles of the Pacific Northwest. Moscow, ID: University of Idaho Press. 332 p.

Thiel, R.P. 1985. Relationship between road densities and wolf habitat suitability in Wisconsin. American Midland Naturalist 113: 404-407.

USDA Forest Service. (In press) Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Vestjens, W.J.M. 1973. Wildlife mortality on a road in New South Wales. Emu 73:107-112.

White, C.E. 1974. Current problems and techniques in raptor management and conservation. Transactions, North American Wildlife Conference 39: 301-312.

Wisdom, M.J.; Holthausen, R.S.; Wales, B.K. [and others]. In press. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broad-scale trends and management implications. Portland, OR: Gen. Tech. Rep. PNW-GTR-xxx. USDA Forest Service, Pacific Northwest Research Station.

TW (4): How does the road system directly affect unique communities or special features in the area?

Background

In addition to effects on species, roads may have both direct and indirect effects on rare communities and special habitat features. Rare communities are unique assemblages of species that are not in themselves rare. Rare plant communities have been identified in State Heritage Programs. Special habitat features that may be directly or indirectly affected by roads include talus slopes and other rock formations, cliffs, caves, and wetlands.

Scale

Effects are seen at the site and road-segment scales but should be evaluated at the watershed scale.

Information needs

Maps of caves, cliffs, talus, abandoned mines, wetland features, and unique communities.

Analytical tools and information sources

Heritage data for occurrence of rare species

GAP data for lower resolution evaluation of distributions of cover types or plant communities

Overlays of special features on maps of vegetative and aquatic habitats

Recommended references

USDA Forest Service. (In press) Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Wisdom, M.J.; Holthausen, R.S.; Wales, B.K. [and others]. In press. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broad-scale trends and management implications. Portland, OR: Gen. Tech. Rep. PNW-GTR-xxx. USDA Forest Service, Pacific Northwest Research Station.

Economics (EC)

The following economic questions address the broader concepts of efficiency and distribution analysis. More focused information and analytic needs are identified in the Commodity Production, General Public Transportation, Administrative Use, Protection, Recreation, Social Issues, and Civil Rights and Environmental Justice sections that follow.

Analysis of the existing road system and planned modifications should address

- Financial efficiency from the agency point of view,
- Economic efficiency from a societal point of view, and
- Economic distribution analysis.

EC (1): How does the road system affect the agency's direct costs and revenues? What, if any, changes in the road system will increase net revenue to the agency by reducing cost, increasing revenue, or both?

Background

Financial efficiency analysis calculates the net revenue to the agency generated by the program or project under review. Gross revenue is the money received by the agency from the goods or services produced by national forest lands. Net revenue is determined by subtracting from gross revenue all payments (costs) made by the agency to generate the revenue.

Financial efficiency analysis asks whether a project or program generates more revenue than it consumes. It also asks whether a proposed change in the status quo increases net revenue. If it does increase net revenue, it is more efficient than the status quo. If the question is one of choice among several proposed changes, the change that produces the greatest increase in net revenue is the most financially efficient alternative.

National forests and the policies, management activities, and agency facilities related thereto produce costs and benefits that do not appear in agency financial accounts either because they are not readily measured or measurable in dollars or because they are external to agency accounts (that is, they accrue to someone other than the agency). Such costs and benefits are included in economic efficiency analysis as discussed in EC(2).

Scale

The scales are those where costs and revenues affected by the existing and planned road system are measurable and relevant to address issues concerned with financial efficiency to the agency. The scale must be that at which significant effects occur. A scale that is too small fails to capture significant costs, benefits, or impacts. If increasing the scale of analysis changes the conclusion, the scale is too small. If differences in choices are not measurable at a specific scale, the scale is too large. The sensitivity of conclusions to changes in scale should be examined.

Information needs

New roads

Costs include planning, constructing, maintaining, and decommissioning roads—if the road is temporary—and mitigating unacceptable environmental effects.

Revenues include receipts from commodities (timber, grazing, and minerals), recreation fees, and other services such as special-use permits. Reduced management costs are also included.

Maintain existing roads

This "maintain existing roads" category includes current maintenance levels, planned changes to them, and suspension of maintenance because of unplanned reductions in funding.

Costs include planning, reconstructing, maintaining roads, and mitigating unacceptable environmental effects.

Revenues include receipts from commodities (timber, grazing, minerals), recreation fees, and other services such as special-use permits.

Close existing roads

Costs include planning, closure costs, maintaining, and enforcing, and mitigating unacceptable environmental effects. Some closures may increase management costs. Decreases in revenues from commodities (timber, grazing, minerals), recreation fees, and other services such as special-use permits are also considered a cost.

Revenues can include reduced maintenance costs and reductions in costs to mitigate unacceptable environmental effects.

Decommission existing roads

Costs include planning, executing the plan, and monitoring. Decreases in revenues from commodities (timber, grazing, and minerals), recreation fees, and other services such as special-use permits are also considered a cost where applicable.

Revenues can include reduced maintenance and reductions in costs to mitigate unacceptable environmental effects.

Analytical tools and information sources

Cost and revenue accounting records for various years such as the annual Timber Sale Program Information Reporting System (TSPIRS) reports. Forest and project environmental assessment documents; cost-benefit analysis tools

USDA Forest Service Manual and Handbook direction

Descriptions of analysis methods, tools, and their sources are available at the USDA Forest Service Inventory and Monitoring Institute website, *fsweb.ftcol.wo.fs.fed.us/imi*.

Recommended references

Federal Budget Consulting Group, and Price Waterhouse. 1997. Financing roads on the national forests. Washington, DC. 37 p.

Gardner, R.B. 1979. Some environmental and economic effects of alternate forest road designs. American Society of Agricultural Engineers 22(1):63-68.

Mater, C.M. 1997. Consumer trends, market opportunities, and new approaches to sustainable development of special forest products.Pages 8-25 *in* Vance, N.C.; Thomas, J., (eds.) Special forest products; Biodiversity meets the marketplace. Gen. Tech. Rep. GTR-WO-63. Washington D.C: USDA Forest Service.

Schlosser, W.E.; Blatner, K.A.; Chapman, R.C. 1991. Economic and marketing implications of special forest products harvest in the coastal Pacific Northwest. Western Journal of Applied Forestry 6:67-72.

Sessions, J.; Sessions, J.B. 1997. Scheduling and network analysis program: SNAP II+ and III. Corvallis, OR: Oregon State University, Forest Engineering Department.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Weintraub, A.; Jones, G.; Magendzo, A.; Meacham, M.; Kirby, M. 1994. A heuristic system to solve mixed integer forest planning models. Operations Research 42(6):1010- 1024.

Zuuring, H.R.; Wood, W.L.; Jones, J.G. 1995. Overview of MAGIS: A multi-resource analysis and geographic information system. Res. Note INT-427.Ogden, UT: USDA Forest Service, Intermountain Research Station. 6 p.

EC (2): How does the road system affect the priced and non-priced consequences included in economic efficiency analysis used to assess net benefits to society?

Background

Economic efficiency goes beyond financial efficiency. Economic efficiency analysis measures net economic benefit to society in aggregate, including non-marketed and external costs and benefits, without regard for who gains and who loses. The economic efficiency question asks whether a specific investment produces more aggregate economic value than it costs at the scale in question. Economic efficiency analysis may include consequences that cannot be expressed in dollars. Examples of benefits included in economic efficiency analysis are the value of recreation experiences provided free-of-charge and passive-use values. Examples of costs include decreased quality and value of water flowing from the national forests, sedimentation of fish habitat, and fragmentation of species habitat resulting from management activities. Economic distribution effects such as employment, income, who benefits, and who pays are not included. They are the focus of distribution analysis as covered under EC(3).

Although passive-use value is a component of economic efficiency analysis, it is addressed in more detail after the recreation section below. This added emphasis is due to the potential long-term loss of unique unroaded values in areas planned for road entry. Passive-use value, however, in areas currently roaded can be lost with planned road decommissioning.

Scale

The appropriate scales are those where the road system generates measurable consequences identified by the issues. These effects must be relevant to address economic-efficiency analysis questions to society at large. These effects may require larger scales than required for the financial efficiency determination for the agency. The scale must be that at which significant effects occur. A scale that is too small fails to capture significant costs, benefits, or impacts. If increasing the scale of analysis changes the conclusion, the scale is too small. If differences in choices are not measurable at a specific scale, the scale is too large. The sensitivity of conclusions to changes in scale should be examined.

Information needs

The following list of potential information items useful to address economic efficiency analyses includes consequences identified under the biophysical, management, and social questions elsewhere in this appendix. They are repeated here to emphasize the all-inclusive nature of economic efficiency considerations whether or not the consequence can be monetarily quantified. These consequences may be positive, neutral, or negative depending on the geographic and temporal scale and individual viewpoints.

New roads

Timber harvest revenues and costs
Commercial recreation revenues and costs
Non-priced benefits and costs to recreationists
Less cost for research that requires access
Less cost for inventory and monitoring
Fragmentation of habitat
Hillslope erosion and landsliding
Sedimentation of streams
Increased hazards of water contamination
Decreased value of affected water and water-based habitats
Loss of soil productivity

Introduction of exotic species
Increased risk of fire
Litter and other adverse human effects
Wildlife stress
Modification of ecological processes
Noise
Loss of solitude
Air and water pollution
Road kill
Loss of scenic beauty
Loss of existence and bequest value in unroaded areas

Maintain existing roads

Timber harvest revenues and costs
Commercial recreation revenues and costs
Non-priced benefits and costs to recreationists
Less cost for research that requires access
Less cost for inventory and monitoring requiring access
Road management costs
Other management costs
Fragmentation of habitat
Hillslope erosion and landsliding
Sedimentation of streams
Increased hazards of water contamination
Decreased value of affected water and water-based habitats
Introduction of exotic species
Risk of fire
Litter and other adverse human effects
Wildlife stress
Modifying of ecological processes
Noise
Air and water pollution
Road kill
Excluded uses and users

Close existing roads

Less fragmentation of habitat
Less erosion, landsliding, and sedimentation of streams
Less hazard of water contamination
Improved water quality and water value
Less introduction of exotic species
Less risk of fire
Less litter and other adverse human effects
Less wildlife stress
Less modification of ecological processes
Less noise
Increasing soil productivity
Increased solitude
Less pollution
Less road kill
Potential increase in unroaded area
Loss for excluded uses and users
Increased management cost
Increased cost for research that requires access
Increased inventory and monitoring cost

Decommission existing roads

Less fragmentation of habitat
Less erosion, landsliding, and sedimentation of streams
Less hazard of water contamination
Increased water value
Increased soil productivity
Fewer introductions of exotic species
Less risk of fire
Less litter and other adverse human effects
Less wildlife stress
Fewer modifications of ecological processes
Less noise
Increased solitude
Less pollution
Fewer road kills
Increase in unroaded area
Loss for excluded uses and users
Increased management cost
Increased cost for research that requires access
Increased inventory and monitoring cost
Less potential for confrontation between perceived incompatible uses

Analytical tools and information sources

Cost and revenue accounting records for various years such as the annual TSPIRS reports; forest and project environmental assessment documents; Economic analysis methods include engineering economics, cost-benefit analysis, cost-effectiveness analysis, risk assessment, uncertainty analysis, and mathematical optimization methods.

Non-market monetary valuation methods include contingent valuation, conjoint analysis, travel cost analysis, and hedonic pricing. Non-monetary methods for measuring values, preferences, and priorities include psychometric methods, judgment methods, juries, focus groups, public meetings, and questionnaires.

Use only those methods that are appropriate and cost-effective for the question(s) and scale(s) at issue, and do not use methods for which the required skills are not available.

USDA Forest Service Manual and Handbook direction.

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Inventory and Monitoring Institute website *fsweb.ftcol.wo.fs.fed.us/imi*.

Recommended references

Brown, T.C. 1993. Measuring nonuse value: A comparison of recent contingent valuation studies. Pages 163-203 *in* Bergstrom, J.C. (comp.), W-133: Benefits and costs transfer in natural resource planning. Athens, GA: Univ. of Georgia.

Brown, T.C.; Champ, P.A.; Bishop, R.C.; McCollum, D.W. 1996. Which response format reveals the truth about donations to a public good? Land Economics 72(2): 152- 166.

Champ, P.A.; Bishop, R.C.; Brown, T.C.; McCollum, D.W. 1997. A comparison of contingent values and actual willingness to pay using a donation provision mechanism with implications for calibration. Journal of Environmental Economics and Management 33(2): 151-162.

Fight, R.D.; Johnson, K.N.; Connaughton, K.P.; Sassaman, R.W. 1979. Can intensive management make up the harvest lost when roadless areas are left undeveloped? Journal of Forestry 77(3): 148-151.

Jones, J.G; Hyde, J.F.C. III; Meacham, M.L. 1986. Four analytical approaches for integrating land management and transportation planning on forest lands. Res. Pap. INT-361. Ogden UT: USDA Forest Service, Intermountain Research Station, 33p.

Kirby, M.W.; Hager, W.A.; Wong, P. 1986. Simultaneous planning of wildland management and transportation alternatives. TIMS Studies in the Management Sciences 21: 371-387.

Miller, S.M.; Miller, S.D.; McCollum, D.W. 1997. Attitudes toward and relative value of Alaskan brown bears to resident voters, resident hunters, and nonresident hunters. International Conference on Bear Research and Management, volume 10.

Molina, R.; Vance, N.C.; Weigand, J.; Pilz,D.; Amaranthus, M. 1997. Special forest products: Integrating social, economic, and biological considerations into adaptive ecosystem management. Pages 315-336 *in*: Kohm, K.; Franklin, J. (eds). Creating a forestry for the 21st century: the science of ecosystem management. Washington, DC: Island Press.

Nelson, J.; Brodie, J.D. 1990. Comparison of a random search algorithm and mixed integer programming for solving area-based forest plans. Canadian Journal of Forest Research 20(7):934-942.

Peterson, G.L.; Sorg, C.F. 1987. Toward the measurement of total economic value. Gen. Tech. Rep. RM-148. Ft. Collins CO:. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 44 p.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Walsh, R.G.; Bjonback, R.D.; Aiken, R.; Rosenthal, D. 1990. Estimating the public benefits of protecting forest quality. Journal of Environmental Management 30(2): 175-189.

See also EC(1) Recommended references.

EC (3): How does the road system affect the distribution of benefits and costs among affected people?

Background

Economic efficiency by itself is an important but not sufficient criterion by which to evaluate programs. Equity, often an important concern, considers the distribution of costs and benefits among the people, but equity must be decided by policy negotiation and not by technical calculation. An important function of economic analysis is to describe the distribution of costs and benefits among geographical, political, social, ethnic, and economic sectors of society. Knowledge of this distribution allows the political and legal processes that judge equity to proceed fully informed.

Economic distribution analysis identifies where benefits and costs are distributed in society. Distribution analysis can be either financial or economic. Financial distribution analysis includes only direct cash flows. Examples include job and income gains or losses by different sectors of the economy. Economic distribution analysis adds non-market and external values and costs. Examples of this type of distribution consequences include who incurs the negative effects of air or water pollution and who benefits from enhanced scenic beauty or solitude. Realizing that any dollar value estimates derived in economic distribution analysis cannot be added to financial or economic efficiency analyses is very important.

Scale

The appropriate scales are those for which the distribution consequences identified by the issues are affected by the existing and planned road system. These effects must be measurable and relevant to address economic distribution analysis questions. This analysis may require larger or smaller scales than those required for the financial or economic efficiency determinations. The scale must be that at which significant effects occur. A scale that is too small fails to capture significant costs, benefits, or impacts. If increasing the scale of analysis changes the conclusion, the scale is too small. If differences in choices are not measurable at a specific scale, the scale is too large. The sensitivity of conclusions to changes in scale should be examined.

Information needs

The following list of potential information items useful to address economic distribution analyses includes consequences identified under the biophysical, management, and social questions elsewhere in this appendix. They are repeated here to emphasize the all-inclusive nature of economic efficiency and equity considerations whether or not the consequences can be measured in dollars. These consequences may be positive, neutral, or negative depending on the geographical and temporal scale and individual viewpoints.

New roads

Temporary planning and construction employment and income
Change in timber-related employment and income
Change in recreation-related employment and income
Noise
Air and water pollution
Loss of soil productivity
Changes in scenic beauty
Loss of existence and bequest value in unroaded areas

Maintain existing roads

Timber-related employment and income
Recreation-related employment and income
Noise
Air and water pollution
Loss of existence and bequest value in unroaded areas

Close existing roads

Change in timber-related employment and income
Change in recreation-related employment and income
Change in existence value and distribution of effects among public sectors
Noise
Less air and water pollution
Loss for excluded uses and users
Increase in solitude

Decommission existing roads

Change in timber-related employment and income
Change in recreation-related employment and income
Less noise
Decrease in air and water pollution
Loss for excluded uses and users
Increase in existence and bequest value in unroaded areas

Analytical tools and information sources

Forest and project environmental assessment documents. Economic distribution analysis methods include input-output analysis, engineering economics, risk assessment, uncertainty analysis, and other mathematical models.

Non-market distribution analysis methods that measure values, preferences, and priorities include psychometric methods, judgment methods, juries, focus groups, public meetings, and questionnaires.

Use only those methods that are appropriate and cost-effective for the question and scale at issue, and do not use methods for which the required skills are not available.

USDA Forest Service Manual and Handbook direction.

Descriptions of analysis methods, tools and their sources are available at the USDA Forest Service Inventory and Monitoring Institute website: *fsweb.ftcol.wo.fs.fed.us/imi*.

Recommended references

Archer, B. 1996. Economic impact analysis. Annals of Tourism Research 23(3): 704-707.

Berechman, J. 1994. Urban and regional economic impacts of transportation investment: A critical assessment and proposed methodology. Transportation Research-A, 28A(4): 351-362.

Bergstrom, J.C.; Cordell, H.K.; Ashley, G.A.; Watson, A.E. 1990. Economic impacts of recreational spending on rural areas: A case study. Economic Development Quarterly 4(1): 29-39.

Broder, J.M.; Taylor,T.D.; McNamara, K.T. 1992. Quasi-experimental designs for measuring impacts of developmental highways in rural areas. Southern Journal of Agricultural Economics 24(1): 199-207.

McCollum, D.W.; Miller, S.M. 1994. Alaska voters, Alaska hunters, and Alaska nonresident hunters: Their wildlife related trip characteristics and economics. Anchorage: Alaska Dept. of Fish and Game, Division of Wildlife Conservation.

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Rephann, T.J. 1993. Highway investment and regional economic development: Decision methods and empirical foundations. Urban Studies 30(2): 437-450.

Rietveld, P. 1994. Spatial economic impacts of transport infrastructure supply. Transportation Research-A. 28A(4): 329-341.

Thomas, M.G.; Schumann, D.R. 1993. Income opportunities in special forest products, self help suggestions for rural entrepreneurs. Agriculture Information Bulletin 666. Washington, DC: USDA Forest Service. 206 p.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Commodity Production

Timber Management (TM)

TM (1): How does road spacing and location affect logging system feasibility?

Background

Road spacing has direct effects on yarding costs of wood fiber. As the road spacing increases, so does the average yarding distance for a given harvest unit. This increase affects turn speeds and production rates, which affect yarding costs. Frequently, the edge of a harvest unit farthest from the road reflects the maximum external yarding distance. External yarding distance dictates the size class of the yarding equipment needed to retrieve the material, which in turn determines the road width needed for that size equipment. Generally, wider road spacing means longer yarding distances, which require larger yarders and wider roads.

The location of a road is particularly important in a area planned for cable logging. Roads located at the "break" (where the side slope changes from gentle to steep) provide better cable deflection, which allows larger payloads and less ground disturbance.

Scale

The watershed or finer scale is most appropriate.

Information needs

Existing road system

Slope class

Slope deflection

Anchor, tail hold, and lift-tree identification

Average log size

Number of pieces per turn

Logging system

Landing locations and design

Roads surplus to timber management needs

Analytical tools and information sources

GIS data bases, aerial photos, DEM's, and ground truthing

Terrain profiles

Logging and road system cost curves

Logging and transportation system software

Skyline analysis software "LOGGERPC"

Helicopter analysis software "HELIPACE"

Log forwarder analysis software "FORWARDER"

Harvest unit scheduling and network analysis software "SNAP III"

A multiple-resource tactical planning tool like "MAGIS" (Multi-Resource Analysis Geographic Information System)

Harvest area plans including silvicultural prescriptions, road systems, logging systems, fuels treatments, and method of regeneration

Road management objectives

Recommended references

Brooks, E.J. 1992. Optimal road spacing for forwarding equipment. Corvallis, OR: Oregon State University.

Matthews, D.M. 1942. Cost control in the logging industry. New York: McGraw-Hill.374 p.

Wenger, K. F. (ed) 1984. Forestry handbook. 2nd ed. New York: John Wiley. 1335 p

McGonagill, K. L. 1978. Logging systems guide. Series no. R10-21. Juneau, AK: USDA Forest Service, Alaska Region. 257 p.

O'Brien, S.; Brooks, E.J. 1996. A coarse filter method for determining the economic feasibility of helicopter yarding. Engineering Field Notes, 28: 5-16. Washington, DC: USDA Forest Service.

TM (2): How does the road system affect managing the suitable timber base and other lands?

Background

Road systems provide for faster and less expensive access to national forest lands for resource inventory data collection, for monitoring activities and conditions, law enforcement, fire suppression, watershed restoration, site preparation and tree planting, treating noxious weeds, thinning operations, and numerous other forest management activities.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Land allocations

Where other resources can be improved by harvesting timber

Conflicts between timber management and other resources

Mitigation measures

Existing road system

Frequency of entry for all timber management purposes

Other projected traffic

Service life of roads (temporary vs. permanent)

Roads planned for extension in future activities

Maximum feasible yarding distance assuming an average product value, an average yield per acre, and state-of-the-art logging technology

Areas unavailable or unsuited for harvest because of physical or economic limitations

Roads surplus to timber management needs

Analytical tools and information sources

Forest plans

Consultation agreements

GIS data bases, aerial photos, DEM's, and ground truthing

Ecosystem assessment at the watershed scale for vegetative and other ecological objectives

Silvicultural priorities

Riparian management objectives

Logging and road system cost curves

Harvest area plans including silvicultural prescriptions, road systems, logging systems, fuels treatments, and method of regeneration.

Road management objectives

TM (3): How does the road system affect access to timber stands needing silvicultural treatment?

Background

The emphasis in silvicultural practices is shifting from even-aged management to managing for uneven-aged stands. These multistory stands require treatments with greater frequency, thus needing road access more often.

Overstocked timber stands can generally be economically thinned only if adjacent to existing forest roads. Likewise, mechanical restoration projects to remove excessive fuels or treat diseased trees are usually only feasible if road access is present.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Timber stand silvicultural schedule

Track condition of current vegetation in stands to determine treatment necessary to achieve desired condition

Potential vegetation; stand capabilities

Wildlife species condition

Analytical tools and information sources

Silvicultural models (SILVA, CVS, CDS, FVS, RMSTAND, SRS, CISC, SIS, DFSIM)

Forest plan documents, other NEPA decisions

Basin-scale assessments (such as in the Interior Columbia Basin)

Species habitat capability models (HABCAP, HEIWEST, HEICALC)

State Best Management Practices (BMP's)

Species tracking data bases (RCWDB, WILDOBS, STRIX)

GIS/satellite imagery (PMR, POLYVEG data base)

Minerals Management (MM)

MM (1): How does the road system affect access to locatable, leasable, and salable minerals?

Background

Road access for locatable minerals tends to be limited to access for trucks and equipment for mapping and prospecting, unless a significant deposit is located. If a large ore body is found, mining operations frequently require a high-standard access road to the mine site.

Road access for leasable minerals (oil and gas) is generally planned and developed based on a large grid. High production oil or gas fields may require high standard haul roads unless a pipeline can be built from the field to the refinery.

The value of salable minerals (crushed rock, sand, gravel, or building stone) is sensitive to the transportation costs of moving the materials to a market.

Scale

Access to individual claims and sources depend on the arterial and collector roads. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Land allocations

Existing road system

Type and location of deposit

Feasible road corridors

Mitigation measures

Service life of roads (temporary vs. permanent)

Traffic estimates

State-required well-spacing pattern

Areas of “no surface occupancy” lease requirements

Isolated areas without access to mineral leases

Analytical tools and information sources

Forest plans

GIS data base, aerial photos, and ground truthing

Riparian management objectives

Mining operations and reclamation plans

Oil and gas lease conditions

Mining operations and reclamation plans

Design standards

Type and location of material source

Demand location for the materials

Demand quantities needed

Least-cost source for building materials

Mitigation measures

Commercial road use permits

Pit development plans

Manual network analysis methods

Network analysis software “NETWORK II” or “AV ROUTES”

Range Management (RM)

RM (1): How does the road system affect access to range allotments?

Background

Range allotments generally need only limited road access for maintaining constructed features like fence or water systems. Access needs for hauling feed or shipping animals require a permanent road system however.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Land allocations

Existing road system

Location of constructed improvements

Roads surplus to management needs

Analytical tools and information sources

Range allotment plans

Consultation agreements

GIS data base, aerial photos, and ground truthing

Ecosystem assessment at the watershed scale for vegetative and other ecological objectives

Riparian management objectives

Road management objectives

Water Production (WP)

WP (1): How does the road system affect access, constructing, maintaining, monitoring, and operating water diversions, impoundments, and distribution canals or pipes?

Background

Water uses on the national forests may include diversions, impoundments, and distribution systems. Road access is usually needed to move in the equipment used to build and maintain these structures. Road access also facilitates the monitoring and operation of these water systems.

Scale

The most appropriate scale is watershed or finer.

Information needs

Claimed water rights

Priority of water users

Existing road system

Location of constructed improvements

Roads surplus to management needs

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

State water-rights data base

Road management objectives

WP (2): How does road development and use affect water quality in municipal watersheds?

Background

Road development and use in watersheds used to supply domestic water may affect the water quality. Watersheds in the national forest that provide domestic water to a municipality may be set aside from all forms of location, entry, or appropriation. (Domestic Water Supply Act of May 28, 1940 - revised by the Federal Land Policy and Management Act of 1976)

Scale

Analysis of the effects of roads on water quality must consider processes and conditions across scales; water quality is identified typically at subbasin scales, while effects are usually best determined at the watershed scale or finer.

Information needs

See questions AQ (1) through AQ (9) in previous section

Water treatment systems, capacity to remove turbidity, potential contaminants

Existing road system

Access restrictions by statute or policy

Location of constructed improvements

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

State water rights data base

Travel plan map

Water quality testing results

See Aquatic, Riparian Zone, and Water Quality section

WP (3): How does the road system affect access to hydroelectric power generation?

Background

The need for road access to hydroelectric power generation sites are similar to the needs for water distribution systems. Access for heavy equipment and construction materials is needed for developing and maintaining sites. Then, frequent access is needed to the site for operations and monitoring of the facilities.

Scale

The most appropriate scale is watershed or finer.

Information needs

Claimed water rights

Priority of water users

Existing road system

Type of power-generation license

Location of power-generation structures and transmission lines

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

State water rights data base

Special Forest Products (SP)

SP (1): How does the road system affect access for collecting special forest products?

Background

Collecting special forest products often depends on using existing forest roads. These activities provide employment opportunities, but typically do not support developing or maintaining roads.

Scale

The most appropriate scale is watershed or finer.

Information needs

Land allocations

Existing road system

Access restrictions

Identifying collectors

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

Travel-plan map

Collection-permit area maps

Social assessments

Special-Use Permits (SU)

SU (1): How does the road system affect managing special-use permit sites (concessionaires, communications sites, utility corridors, and so on)?

Background

Many of the special-use sites on national forest lands are by permit, for profit. Safe and efficient access to those sites directly affect either the number of potential customers or the operations and maintenance costs.

Scale

The most appropriate scale is the watershed or finer.

Information needs

Land allocations

Existing road system

Type of special-use permit

Location of sites

Critical design vehicle

Travel restrictions

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

Travel-plan map

Collection-permit area maps

General Public Transportation (GT)

GT (1): How does the road system connect to public roads and provide primary access to communities?

Background

Many of the arterial and collector roads in the national forests have evolved into de facto “public roads,” providing the primary access to rural communities and creating major network connections between the State highways and County roads. These routes may be important to the economic survival of these communities by providing access for commercial traffic, mail delivery, school bus service, emergency vehicle response, farm-to-market shipments, and enhanced tourism.

Scale

Access to individual watersheds depends on arterial and collector roads. The appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Community size and location

Route and termini

Identifying connecting routes into the national forest

Traffic measurements and commuting patterns

Classifying traffic by type and vehicle

Feature and condition information (road-condition survey)

Analytical tools and information sources

GIS road coverage

Road-condition survey data (see protocols)

Origin-destination studies for traffic patterns

Recommended references

AASHTO. 1994. A policy on geometric design of highways and streets.

Wenger, K.F. (ed). 1984. Forestry Handbook. 2nd ed. New York: John Wiley. 1335 p.

USDA Forest Service. Transportation System Manual. Forest Service Manual 7700. Washington DC: USDA Forest Service. Available at: *fsweb.wo.fs.fed.us/directives/fsm/7700*.

GT (2): How does the road system connect large blocks of land in other ownership to public roads (ad hoc communities, subdivisions, inholdings, and so on)?

Background

Land ownership patterns on the national forests are sometimes so intermixed that large blocks of private land or lands under other ownership are accessed by Forest Development Roads or by roads under cost-share agreements. A long-standing goal of planners has been to share a single road with other land owners wherever feasible rather than constructing parallel road systems.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Community size and location

Traffic measurements

Ongoing road-condition assessment

Community profile including community resources and opportunities

Community-preference assessment

List of potential public road authorities

Identifying public road funding that can be applied to these routes

Determine persons needing access to land holdings and adjacent to agency lands

Plan and coordinate rights-of-way across agency lands

Analytical tools and information sources

GIS road coverage

Network analysis programs

AV Routes (in ArcInfo)

NETWORK II

Community-profile information

Community plans and projections of future activities and growth

Collaborative stewardship relations with the community and community leadership

Analysis of alternative public-road-authority opportunities

Automated Land Project status system

Right-of-way plats and agreements

Interagency memorandums of understanding

GT (3): How does the road system affect managing roads with shared ownership or with limited jurisdiction? (RS 2477, cost-share, prescriptive rights, FLPMA easements, FRTA easements, DOT easements)?

Background

Many of the roads that cross national forest lands are owned and operated privately or by other public agencies. Some roads are owned jointly with the Forest Service and others carry valid rights-of-way. While the responsibility for environmental stewardship remains with the Forest Service, the Forests Service's discretion to manage specific roads may be limited.

Scale

Access to individual watersheds depends on arterial and collector roads. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Terms and conditions of the easements that reflect limits of jurisdiction

Traffic measurements

Limitations on the Forest Service's ability to close or restrict use.

Analytical tools and information sources

GIS road coverage

Land-ownership GIS layer

Network analysis programs

AV routes (in ArcInfo)

NETWORK II

Copies of easement documents

GT (4): How does the road system address the safety of road users?

Background

Driving on any road poses hazards. Road managers should provide for road safety conditions consistent with road maintenance levels, and expected uses and users. Roads should be configured and signed to reduce safety hazards to the extent practicable, within the context of financial, topographic, and other constraints. Traffic control may be used to restrict traffic during exceptional conditions.

Scale

Access to individual watersheds depends on the arterial and collector road system. The appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Accident frequency locations

Law enforcement accident reports

Hazardous site locations

Traffic measurements

Feature and condition information (road-condition survey)

Season of use and traffic rules

Analytical tools and information sources

GIS road coverage

Road condition survey information

Traffic engineering studies

Administrative Use (AU)

AU (1): How does the road system affect access needed for research, inventory, and monitoring?

Background

Road access affects research, inventories, and field monitoring. Limited or no road access increases time and costs for field observations.

Scale

Access to individual watersheds depends on the arterial and collector roads. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Status of long-term ecological studies

Amount of recovery and seral stage

Location of research, inventory, and monitoring sites

Area of influence of roads on variables being monitored or studied

Analytical tools and information sources

Problem analyses

Research plans

Inventory and monitoring plans

AU (2): How does the road system affect investigative or enforcement activities?

Background

Forest Service law-enforcement agents are faced with a growing work load paralleling the growth in forest recreation users. This new work load is adds to the traditional work related to natural resource theft or trespass. Expanded road access, particularly near towns, can add to problems with garbage dumping, vandalism and other criminal activities.

Scale

Because law enforcement use of roads most often applies to local access, it is best addressed at the watershed scale or finer.

Information needs

Traffic-accident investigative information; roadway condition, direction of travel, accident evidence

Federal-violation investigative information; evidence of timber theft

Analytical tools and information sources

Investigative photographs

Issued Code of Federal Regulations closures or restrictions

Law-enforcement information data bases (LEMAR, LECMS)

Protection (PT)

PT (1): How does the road system affect fuels management?

Background

Many areas requiring fuels treatments need to have the fuels reduced through mechanical methods before prescribed burning. Mechanical fuels treatments are depend on existing road access.

Scale

Access to individual watersheds depends on arterial and collector roads. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Existing road system

Priority areas for underburning

Priority areas for mechanical fuels treatments (that is, precommercial or commercial thinning or slashing)

Areas requiring mechanical treatments before underburning

Predicted fire frequency and intensity

Road-use restrictions

Analytical tools and information sources

Ecosystem assessments at the watershed scale for vegetative and other ecological objectives

GIS data base, aerial photos, and ground truthing

Regional or local fire data bases

Prescribed fire prescriptions

Travel-plan map

Road management objectives

Recommended references

Wenger, K.F. (ed). 1984. Forestry Handbook. 2nd ed. New York: John Wiley. 1335 p.

Western Forestry and Conservation Assn. Western Fire Fighters Manual. Portland, OR.

PT (2): How does the road system affect the capacity of the Forest Service and cooperators to suppress wildfires?

Background

The firefighting organizations fielded by responsible agencies and entities comprises a broad mix of aerial and ground resources. The foundation for delivering firefighters and resources is provided by the network of roads, created for and funded by other purposes. To a large extent, the existing road system has molded the intensity and extent of fire suppression activity, and the agencies ability to fight fires has grown during this century along with the expanding network of roads. In fact, the availability and siting of roads have affected the approaches to fire suppression, with mixed effects, inasmuch as fires in road-accessible areas have been more intensively managed than those in more remote locations.

Roads have proved useful during actual fire suppression, limiting fire spread under low and moderate conditions. However, the more intense, rapidly spreading fires, or those accompanied by spotting are usually beyond the capacity of roads to check. Roads have often been used as foundations for fuelbreaks and considered as having some value in isolating and breaking up the continuity of fuelbeds.

The effects of organized and effective suppression (initial attack is successful in 97 percent of wildland fire ignitions) on fire regimes are widely acknowledged, particularly in the inland West, where the amounts of available fuel have significantly increased over historic amounts and where fuels that now occupy extensive contiguous tracts of land support larger and more intense fires. Partly in recognition of this trend, the new national wildland fire policy aims to substantially increase the number of acres where fuels are managed and wildland fire is used to accomplish program goals to restore ecosystems and to reduce deleterious fire effects and suppression costs.

The need for access to conduct these management activities will lead practitioners to argue for maintaining a maximum network of roads, but the associated costs of doing so as a specific and attendant project expense have not been widely assessed. In efforts to reduce available road networks, those responsible for fire and fuel management are expected to favor gating and placing barriers on road segments rather than decommissioning.

All roads are not of equal value for fire suppression. For example, ridgetop roads tend to be most useful for firebreaks and defensible firelines while midslope roads are of least value. Road location and slope position, relative to fuel hazards and values at risk, could form the basis for assigning incremental values to specific roads for fire suppression.

One fact that warrants consideration is that budget, organization, staffing, and resource placement are largely determined in the context of the existing transportation system. National Fire Management Analysis System (NFMAS), the use of which is appropriate to planning for administrative units, blends actual fire history, suppression policy, firefighter unit productions rates, cost, and net value change (the positive and negative effects of fires of various intensities, expressed in dollars) into an economic efficiency model, the output of which is a description of the optimum fire organization for the unit. This optimum organization (most efficient level, or MEL) is one that minimizes the sum of the funded fire organization, suppression costs, and net value change. Funding appropriated for fire preparedness and presuppression is directly connected to the outputs of this analysis and is thus predicated on the access provided by the existing road system, any sizable reduction of which should prompt appropriate reanalyses. The cost of maintaining the road system must also be considered, as well as the identifying benefiting function and assigning financial responsibility.

Public and commercial road access are known to lead to increased ignitions, but this effect is highly variable in incidence and effects from place to place. The evidence is strong but anecdotal, and should be quantified to enable better analysis of the associated risks.

Scale

Access to individual watersheds depends on the arterial and collector road system. The most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Existing road system

Predicted fire frequency and intensity

Road-use restrictions

Topographic features

Net effect of ignitions attributable to public road access

Costs/benefits of road use in fire suppression

Trade-off analyses on firefighter/firefighting resource delivery: ground and aerial

Analytical tools and information sources:

NFMAS and enhancement software, currently being beta tested, will automatically determine response/arrival times based upon a management unit's specific fire history and transportation system.

Networked road systems for arrival times and alternate access routes

FARSITE represents fire spatially on a landscape and may be used to analyze changes in fire behavior based on road barriers or backfiring from roads

PT (3): How does the road system affect risk to firefighters and to public safety?

Background

The greatest fire safety concern associated with road access is at the interface of urban and forest lands. Home owners sometimes build access roads that will not accommodate large emergency vehicles. Forest Service firefighters must sometimes attempt to protect privately owned structures from wildfire without the benefit of reasonable access.

Scale

Access to individual watersheds depends on arterial and collector roads; the most appropriate scale is the forest or province. Minor collector and local roads needed for detailed access planning should be addressed at the watershed scale or finer.

Information needs

Existing road system

Travel restrictions

Location of fire-risk hazards

Type of firefighting equipment to be used

Location of wildland/urban interface areas

Critical design of vehicles for roads

Maximum bridge loading

Analytical tools and information sources

GIS data base, aerial photos, and ground truthing

Risk assessment

Regional and local fire data bases

Prescribed fire prescriptions

Travel plan map

INFRA travel routes data base

PT (4): How does the road system contribute to airborne dust emissions resulting in reduced visibility and human health concerns?

Background

Vehicular road traffic generates dust. Traffic on native or aggregate surfaced roads can be a significant source of airborne dust (particulate matter) and has been investigated extensively by U.S. EPA and others. Airborne dust can reduce visibility causing a driving hazard, and it is a human health concern.

Scale

The issue is examined in terms of vehicle miles traveled (VMT) in the spatial domain being considered. Once airborne, dust can remain suspended and be transported great distances by the wind. Under these conditions management concerns relate to effects on regional and urban air pollution.

Information needs

The equation to calculate dust emissions from unpaved road surfaces is

$$E = (k\, (s/12)^{a} (W/3)^{b}) / (M/0.2)^{c}$$

Where E is the size specific emission factor in lbs/VMT (lbs/VMT = 281.9 g/VKT, VKT is vehicle kilometers traveled), s is surface material silt content (%), W is mean vehicle weight (tons), and M is surface-material moisture content (%).

Silt is defined here as particles smaller than 75 micrometers in diameter. Thus, dust from roads contributes to the three regulatory categories of airborne particulate: <2.5 micrometers in diameter (PM2.5), airborne particulate matter < 10 micrometers in diameter (PM10), and total suspended particulate (TSP). The empirical coefficients in the equation (a,b,c) are defined separately for each of these regulatory categories. Note that, if the road surface contains significant amounts of a contaminant, the road dust could contribute to dispersion of that contaminate and environmental loading.

Airborne dust is also generated from paved surfaces, though a different equation is used and the total airborne material generated is much less.

Analytical tools and information sources

U.S. EPA has developed a guide to calculating emission factors from most significant human sources. This document is known as AP-42. Chapter 13 is on 'Miscellaneous sources' and both unpaved (Section 13.2.2) and paved (Section 13.2.1) roads are discussed in great detail, along with mitigation measures. Tables of the equation coefficients shown above and other guidance on calculating road dust emissions are given. This document is available to be downloaded as individual chapter sections at *www.epa.gov/ttnchie1/ap42c13.html*.

Other tools include:

Fugitive Dust Models (FDM1 and FDM2) to calculate atmospheric transport and dispersion of airborne dust from roads and other sources, available at *www.epa.gov/scram001/*.

Recreation

The recreation component is divided into two sections. The first discusses the issue of entry into unroaded areas and the second identifies existing road management. Although these components are discussed separately, they are linked. Decommissioning roads may create new unroaded recreation opportunities while decreasing roaded recreation opportunities. Roading unroaded areas will have the opposite effect. Balancing the trade-off between unroaded areas and roaded recreation is a policy question. The responsibility of technical analysis is to inform line officers about the effects of the road system on unroaded areas, and on roaded and unroaded recreation.

Unroaded Recreation (UR)

Background

The unroaded entry issue concerns areas where forest plans direct constructing or decommissioning roads and other management activities that may change an area's character. Road entry into unroaded areas may decrease the quantity or quality of unroaded recreation opportunities. Decommissioning of existing roads may add unroaded recreation opportunities. Changes in the road system may have cumulative as well as local effects. Piecemeal or project-by-project analyses may identify only minor local effects that, in total, combine to produce important cumulative effects at a broader scale. The significance of local as well as cumulative effect depends on the supply of unroaded recreation opportunities relative to demand. With excess supply, a small increment or decrement in supply will have no important effect. If demand exceeds supply, any change in supply is likely to have an effect.

Questions

UR (1): Is there now or will there be in the future excess supply or excess demand for unroaded recreation opportunities?

UR (2): Is developing new roads into unroaded areas, decommissioning of existing roads, or changing the maintenance of existing roads causing substantial changes in the quantity, quality, or type of unroaded recreation opportunities?

UR (3): What are the adverse effects of noise and other disturbances caused by developing, using, and maintaining roads, on the quantity, quality, and type of unroaded recreation opportunities?

UR (4): Who participates in unroaded recreation in the areas affected by constructing, maintaining, and decommissioning roads?

UR (5): What are these participants' attachments to the area, how strong are their feelings, and are alternative opportunities and locations available?

Scale

The most appropriate scale is the forest or province. The contribution of the unroaded areas to the supply of unroaded and roaded recreation opportunities compared with existing and future demand is best assessed at larger landscape scales. The larger scale will also help identify the comparative uniqueness of the area as well as cumulative effects. Areas with highly valued unique features may need to be considered at the national scale.

Information needs

Inventory of the existing supply of unroaded recreation opportunity by capacity, type, quantity, quality, location, unique characteristics, and accessibility

Assessment of the unroaded recreation demand and participation by type, quantity, quality, location, and unique characteristics

Assessment of people's needs and wants for roads, potential road closures and decommissioning, and constructing new roads

Assessment of the magnitude of the present and estimated future gap, if any, between supply of and demand for unroaded recreation opportunities by type, quantity, quality, location, and unique characteristics

Estimation of the effects of road constructing, decommissioning, and maintaining existing roads on the type, quantity, quality, location, and accessibility of unroaded recreation opportunities.

Identification of issues of concern, strength of concern, and likely responses

Analytical tools and information sources

Reports on demand, supply, and participation inventory and analysis such as State Comprehensive Outdoor Recreation Plans (SCORP).

Forest recreation use survey and measurement methods such as Customer Survey and Public Area Recreation Visitor Survey (PARVS) reports.

Focus groups and public participation processes

Sociological, psychological, and anthropological measurement and observational methods

RPA Program and Assessment documents

USF&WS survey of hunting and fishing

FEMAT and ICBEMP assessments

Roadless area analyses from forest plan EIS documents

Recommended references

Cordell, H.K.; Bergstrom, J.C. 1991. A methodology for assessing national outdoor recreation demand and supply trends. Leisure Sciences 13(1): 1-20.

Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G. (eds). 1996. Nature and the human spirit: Toward an expanded land management ethic. State College, PA: Venture Publishing. 467 p.

Driver, B.L.; Nash, R.; Haas, G. 1987. Wilderness benefits: A state-of-knowledge review. Pages 294-319 *in* Lucas, R.C. (comp). Proceedings–National Wilderness Research Conference: Issues, state-of-knowledge, future directions: Gen. Tech. Rep. INT-220. Ogden UT: USDA Forest Service, Intermountain Research Station.

Fan, D.; Bengston, D. 1997. Attitudes toward roads on the national forests: An analysis of the news media. Washington, DC: USDA Forest Service, Office of Communications. (*www.ncfes.umn.edu/epubs/pdf/roads.pdf*)

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team. USDA Forest Service, Portland, OR.

Payne, C.; Bowker, J.M.; Reed, P.C. (comps). 1992. The economic value of wilderness: proceedings of the conference, Jackson, Wyoming, May 8-11, 1991. Gen. Tech. Rep. SE-78. Ashville, NC: USDA Forest Service, Southeastern Forest Experiment Station. 330 p.

Shelby, B.; Heberlein, T.A. 1986. Carrying capacity in recreation settings. Corvallis, OR: Oregon State University Press.. 164 p.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Road-Related Recreation (RR)

Background

Road constructing, maintaining, and decommissioning can change the type, quantity, quality, and accessibility of roaded recreation opportunities. Changing the maintenance level on existing roads, including closing roads and maintaining for high-clearance vehicles only, may have major effects on public access to recreation sites and the on-road recreation opportunities provided by the road itself. The presence of roads and their maintenance levels also help determine which members of the public can or will want to have access to the opportunities served by the roads. Issues of concern also include the realities of limited budgets, congestion, user conflict, and other quantitative and qualitative effects.

Questions

RR (1): Is there now or will there be in the future excess supply or excess demand for roaded recreation opportunities?

RR (2): Is developing new roads into unroaded areas, decommissioning of existing roads, or changing maintenance of existing roads causing substantial changes in the quantity, quality, or type of roaded recreation opportunities?

RR (3): What are the adverse effects of noise and other disturbances caused by constructing, using, and maintaining roads on the quantity, quality, or type of roaded recreation opportunities?

RR (4): Who participates in roaded recreation in the areas affected by road constructing, changes in road maintenance, or road decommissioning?

RR (5): What are these participants' attachments to the area, how strong are their feelings, and are alternative opportunities and locations available?

Scale

The most appropriate scales are the forest or province and watershed scales. The forest/province scale places the road(s) within the broader recreation objectives of the national forest and other landowners. The watershed scale helps to identify the site-specific needs of the roads such as for reaching sites like developed and undeveloped campgrounds and accessing trails. These two scales will also help to address the supply and demand question for specific areas and in aggregate. Crowding may be identified for specific road links or destinations, but forest- or province-wide excess supply or excess demand may indicate a distribution problem.

Information needs

Inventory of the existing supply of roaded recreation opportunity by capacity, type, quantity, quality, location, and accessibility

Assessment of roaded recreation demand and participation by type, quantity, quality, location, and unique characteristics

Assessment of people's needs and wants for roads, potential road closures and decommissioning, and constructing new roads

Assessment of the size of the present and estimated future gap, if any, between supply of and demand for roaded recreation opportunity by type, quantity, quality, location, and unique characteristics

Analytical tools and information sources

Forest road design-capacity and inventory and use surveys

Reports on demand, supply, and participation inventory and analysis such as State Comprehensive Outdoor Recreation Plans (SCORP).

Forest recreation-use survey and measurement methods such as Customer Survey and Public Area Recreation Visitor Survey (PARVS) reports.

Focus groups and public participation processes.

Sociological, psychological, and anthropological measurement and observational methods.

RPA Program and Assessment documents.

USF&WS survey of hunting and fishing.

FEMAT and ICBEMP assessments

Roadless area analyses from forest plan Environmental Impact Statement documents

Recommended references

Cordell, H.K.; Bergstrom, J.C. 1991. A methodology for assessing national outdoor recreation demand and supply trends. Leisure Sciences 13(1): 1-20.

Fan, D.; Bengston, D. 1997. Attitudes toward roads on the national forests: An analysis of the news media. Washington, DC: USDA Forest Service, Office of Communications. (*www.ncfes.umn.edu/epubs/pdf/roads.pdf*)

FEMAT 1993. Forest ecosystem management: an ecological, economic, and social assessment. Report of the Forest Ecosystem Management Assessment Team, Portland, OR: USDA Forest Service.

Shelby, B.; Heberlein, T.A. 1986. Carrying capacity in recreation settings. Corvallis, OR: Oregon State University Press. 164 p.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Passive-Use Value (PV)

Background

Passive-use value is a value or benefit people receive from the existence of a specific place, condition, or thing, independent of any intention, hope, or expectation of active use. Recreation activity, such as fishing, hunting, camping, wildlife viewing, hiking, boating, picnicking, and viewing pictures or movies, or reading books about outdoor recreation, are examples of active use of recreation-related resources. Such activity requires direct or indirect use of specific recreation sites, facilities, or opportunities. Passive-use value is divided into two components, existence value and bequest value. Existence value is value or benefit people receive from the existence of a specific place, condition, or thing, independent of any intention, hope, or expectation of their active use by the person receiving the passive-use benefit. Bequest value is value or benefit received because a place, condition, or thing is available for active or passive use by others.

When the affected resources are unique or rare, such as threatened or endangered species, spectacular scenic views, pristine wilderness, unusual geological or natural conditions, or unique cultural heritage resources, passive-use value can be greater than the value produced from the same place by active recreational use or commodity production.

Questions

PV (1): Do areas planned for road construction, closure, or decommissioning have unique physical or biological characteristics, such as unique natural features and threatened or endangered species?

PV (2): Do areas planned for road construction, closure, or decommissioning have unique cultural, traditional, symbolic, sacred, spiritual, or religious significance?

PV (3): What, if any, groups of people (ethnic groups, subcultures, and so on) hold cultural, symbolic, spiritual, sacred, traditional, or religious values for areas planned for road entry or road closure?

PV (4): Will constructing, closing, or decommissioning roads substantially affect passive-use value?

Scale

The most appropriate scales are the national and ecoregion assessment, and forest or province scales. The contribution of the unroaded area to the total supply of unroaded areas should be assessed at each of these scales. The larger scales establish value from a national perspective; the forest or province scale will help to identify value and uniqueness from a local perspective.

Information needs

Inventory of extent and unique characteristics of unroaded areas

Estimate of the size and significance of changes in unroaded areas and their unique characteristics, relative to the existing supply, that planned changes in the road system will cause

Estimate of the difference in existence and bequest value of unroaded areas with and without the planned changes in the road system

Identification of cultural, symbolic, spiritual, sacred, traditional, or religious values affected by the road system

Identification of concerned individuals or groups and the issues of concern

Analytical tools and information sources

Contingent valuation and related methods for measuring passive-use values
Benefit transfer and meta-analysis methods
Expert judgment and consultation
Passive-use value, benefit-transfer, and expert-judgment studies
Focus groups, customer surveys, and public participation processes

Recommended references

Brown, T.C. 1993. Measuring nonuse value: A comparison of recent contingent valuation studies. Pages 163-203 *in* Bergstrom, J.C. (comp.), W-133: Benefits and costs transfer in natural resource planning. Athens, GA: University of Georgia.

Brown, T.C.; Champ, P.A.; Bishop, R.C.; McCollum, D.W. 1996. Which response format reveals the truth about donations to a public good? Land Economics 72(2): 152- 166.

Driver, B.L.; Dustin, D.; Baltic, T.; Elsner, G.; Peterson, G. (eds). 1996. Nature and the human spirit: Toward an expanded land management ethic. State College, PA: Venture Publishing. 467 p.

Driver, B.L.; Nash, R.; Haas, G. 1987. Wilderness benefits: A state-of-knowledge review. Pages 294-319 *in* Lucas, R.C. (comp). Proceedings–National Wilderness Research Conference: Issues, State-of-Knowledge, Future Directions. Gen. Tech. Rep. INT-220. Ogden UT: USDA Forest Service, Intermountain Research Station.

Fan, D.; Bengston, D. 1997. Attitudes toward roads on the national forests: An analysis of the news media. Washington, DC: USDA Forest Service, Office of Communications. (*www.ncfes.umn.edu/epubs/pdf/roads.pdf*)

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Kiester, A.R. 1997. Aesthetics of biological diversity (with commentaries by R.Ribe and S.Z. Levine and a response by Kiester). Human Ecology Review 3(2): 151-163.

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Randall, A. 1992. A total value framework for benefit estimation. Pages 87-111 *in* Peterson, G.L.; Swanson, C.S.; McCollum, D.W.; Thomas, M.H. Valuing Wildlife Resources in Alaska. Boulder, CO: Westview Press.

USDA Forest Service. (In press). Forest Service Roads: A Synthesis of Scientific Information. (draft available at *www.fs.fed.us/news/roads/science.pdf*)

Walsh, R.G.; Loomis, J.B.; Gillman, R.A. 1984. Valuing option, existence, and bequest demands for wilderness. Land Economics 60(1): 14-29.

Social Issues (SI)

SI (1): What are people's perceived needs and values for roads? How does road management affect people's dependence on, need for, and desire for roads?

Background

Peoples perceived needs and dependence on roads can be viewed separately from the access they provide. As travel ways, roads provide social, cultural and economic benefits and costs. These costs and benefits are determined by road placement, management and use and are independent of the costs and benefits of road existence and the access afforded.

Scale

The appropriate scales are forest or ranger district.

Information needs

Information about road uses, people's perceptions of what roads they believe to be particularly important, and the reason or reasons for this designation

Analytical tools and information sources

Constituent analysis, social assessment, or both

Road surveys and traffic counts

Maps delineating roads regarded as having high priority roads

Descriptions of analysis methods, tools, and their sources; available at the Forest Service Human Dimensions websites: *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Oregon State University data-sharing center website *govinfo.kerr.orst.edu*.

Recommended references

Interorganizational Committee on Guidelines and Principles. 1994. Guidelines and principles for social impact assessment. Journal of Impact Assessment 12 (2): 107-152.

SI (2): What are people's perceived needs and values for access? How does road management affect people's dependence on, need for, and desire for access?

Background

Forest roads represent more than just a travelway to many people. Various sources, particularly public response to the "Proposed Rulemaking on Administration of the Forest Development Transportation System," showed great concern and notably disparate views regarding roads and their management. Comments about the proposed rulemaking went well beyond the actual proposal, into discussion regarding the functions that roads and access have and the values that people hold toward them. Some people perceive roads to be the means to access forest resources, on which they may be economically and culturally dependent. Some people perceive roads to be a deterrent to healthy wildlife habitat, or unacceptable contributors to stream sedimentation. Certain types of recreation may be road-dependent, and people express interest in wanting the roads maintained. Other types of recreation may be negatively affected by roads and road use, and people thus express interest in wanting roads closed or decommissioned. Sometimes people value a road and the access it provides. Conversely, sometimes they value the fact that roads do not exist, as in unroaded or wilderness areas, and believe these areas are critical to their individual and community lifestyle and economic base.

Scale

Most scales would be relevant.

Information needs

Assessment of values held and needs for access

Analytical tools and information sources

Social assessment, constituent analysis, or both

Descriptions of analysis methods, tools and their sources are available at the Forest Service human dimensions website *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Oregon State University data-sharing center website *govinfo.kerr.orst.edu*.

Recommended references

Interorganizational Committee on Guidelines and Principles. 1994. Guidelines and principles for social impact assessment. Journal of Impact Assessment 12 (2): 107-152.

SI (3): How does the road system affect access to paleontological, archaeological, and historical sites?

Background

Access to paleontological, archaeological, and historical sites provides opportunities for studying, learning about, and enjoying our natural history and cultural heritage. Access to these sites also poses increased risks of unintended physical damage, crowding-out other users and uses of the sites, and vandalism.

Scale

The scale is forest or ranger district.

Information needs

Location of paleontological, archaeological, and historical sites and location of roads accessing them

Whether people want access to these sites and why, and whether the road facilitates undesirable access

Analytical tools and information sources

Heritage survey atlases and heritage overviews

Descriptions of analysis methods, tools and their sources are available at the Forest Service human dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

SI (4): How does the road system affect cultural and traditional uses (such as plant gathering, and access to traditional and cultural sites) and American Indian treaty rights?

Background

Cultural and traditional uses, and American Indian treaty rights, can be affected by changes in the management of roads. Closing a road that accesses an area where reserved treaty rights or other uses have been traditionally exercised (gathering, hunting, fishing) might hinder these activities. Likewise, increased access to an area can increase conflicts between competing users.

Scale

The forest or ranger district scale is appropriate because of the need to look at specific areas.

Information needs

If possible, locations of traditional collecting areas, practices, and access to these locations

Analytical tools and information sources

Constituent analysis, social assessment, or both

Heritage survey atlases and heritage overviews

Coordination and collaboration with affected tribes and interest groups

Appropriate treaties

American Indian Religious Freedom Act (1978)

National Register Bulletin 38: 1991. "Guidelines for evaluating and documenting traditional cultural properties", Washington, DC: US Department of the Interior, National Park Service, Interagency Resources Division.

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Human Dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

SI (5): How are roads that constitute historic sites affected by road management?

Background

Some roads constitute historic sites under the National Historic Preservation Act (1966). Management opportunities being developed for these roads must address compliance with this act.

Scale

The forest or ranger district is appropriate because of the need to look at specific roads.

Information needs

Historic background of a road (date of original construction, modifications over time, purpose for constructing road)

Analytical tools and information sources

National Register of Historic Places eligibility criteria

Heritage sites atlas and historic overviews

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Human Dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Recommended references

US Government. National Historic Preservation Act of 1966. 16 USC 470.

US Government. National Register of Historic Places. Available at *www.cr.nps.gov/nr*.

US Government. Protection of historic and cultural properties. 36 CFR 800. Available at *www.access.gpo.gov/nara/cfr/*.

SI (6): How is community social and economic health affected by road management (for example, lifestyles, businesses, tourism industry, infrastructure maintenance)?

Background

Communities have social and economic dependencies on roads and resources provided by the access. Changes to a road system may affect commuting patterns; lifestyles, businesses such as tourism, special forest products and timber; school bus routes; firefighting access needs in the urban-wildland interface; and access to municipal water supplies.

Scale

Community, county, tribal governments

Information needs

Descriptions of lifestyles (including traditional ones) and the role of access and roads in those lifestyles

Economic composition of community

Direct wildland dependency

Timber dependency

Recreation dependency

Employment diversity index

Assessment of how a community can withstand change

How roads contribute to economic composition of a community

Analytical tools and information sources (also see economics section)

Economic assessment

Social assessment

State highway department's data

REIS data

County budget records

PRIZM data

Descriptions of analysis methods, tools and their sources are available at the Forest Service human dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Oregon State University data-sharing center website *govinfo.kerr.orst.edu*.

Recommended references

Interorganizational Committee on Guidelines and Principles. 1994. Guidelines and principles for social impact assessment. Journal of Impact Assessment 12 (2): 107-152.

Creighton, J.; Harwood, R. C. 1996. A way of life: Great Plains citizens talk about ecosystems. The Harwood Group. 30 p. Available at *greatplains.org/resource/citizen/waylife/waylife.htm*.

SI (7): What is the perceived social and economic dependency of a community on an unroaded area versus the value of that unroaded area for its intrinsic existence and symbolic values?

Background

Unroaded areas within national forests have a variety of societal values. Some people value natural resources existing in unroaded areas for the economic contribution afforded by their extraction such as timber, minerals, and roaded access. Other people value roadless areas for the contributions they provide in an undeveloped state such as increased solitude, quiet, and refugia for plants and animals.

Scale

Most scales would be relevant.

Information needs

Employment diversity index

Direct wildland dependency (also timber and recreation dependency)

Assessment of held existence value, or symbolic values, or both

Assessment of community lifestyle

Analytical tools and information sources

See also the Economic, Recreation, and Passive Use sections

Census data

U.S. Bureau of Economic Analysis data

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Human Dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Oregon State University data-sharing center website *govinfo.kerr.orst.edu*.

Recommended references

Interorganizational Committee on Guidelines and Principles. 1994. Guidelines and principles for social impact assessment. Journal of Impact Assessment 12 (2): 107-152.

USDA Forest Service. 1998. National roads policy preliminary public comment content analysis (March 1998). Washington, DC. USDA Forest Service

SI (8): How does road management affect wilderness attributes, including natural integrity, natural appearance, opportunities for solitude, and opportunities for primitive recreation?

Background

Road management affects wilderness attributes and primitive recreation opportunities in many ways. The closure, presence, or addition of new roads and their management in proximity to wilderness areas can change the natural integrity and opportunities for solitude because of differences in vistas, amounts of noise and dust, and crowding. Roading unroaded areas also affects consideration of these areas as additions to the National Wilderness Preservation System.

Scale

Most scales would be relevant.

Information needs

Assessing effects of road management options on:

Natural integrity

Natural appearance

Opportunities for solitude

Opportunities for primitive recreation

Analytical tools and information sources

Recreation opportunity spectrum

EIS's for forest plans, appendix C

Wilderness plans

USDA-FS Region One "Roadless Area Protocol"

USDA-FS Region Four "Roadless Area Protocol"

Descriptions of analysis methods, tools and their sources are available at the Forest Service Human Dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Recommended references

Leopold, A. 1925. Wilderness as a form of land use. Journal of Land and Public Utility Economics 14: 398-404.

Leopold, A. 1949. A Sand County Almanac. Oxford: Oxford Univ. Press, Inc. 295 p.

Marshall, R. 1930. The problem of the wilderness. Science Monthly 30: 141-148.

Marshall, R. 1933. The forest for recreation and a program for forest recreation. *In* A National Plan for American Forestry. 73rd Cong., 1st sess., Senate Document 12. Washington, DC: US Government Printing Office.2 v.

Marshall, R. 1937. The universe of the wilderness is vanishing. Nature: April edition.

Nash, R. 1982. Wilderness and the American mind. 3rd rev. ed. New Haven, CN: Yale Univ. Press. 380 p.

Vickery, J.D. 1994. Wilderness visionaries. Rev. ed. Minnetonka, MN: Creative Pub. Intl. 280 p.

SI (9): What are traditional uses of animal and plant species in the area of analysis?

Background

People individually, communities, and tribes can depend socially, culturally, and economically on certain plant and animal species. Identifying these species of concern is important because changes to the road system can affect access to and use of these species as well as their populations and viability.

Scale

This assessment could be done at any scale, although generally the resolution of information is related to the scale; the finer the scale, the more specific the information that can be incorporated.

Information needs

Assessment of the traditional uses

Analytical tools and information sources

Social assessment, constituent analysis, or both

Data from State or Federal fish and wildlife agencies

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Human Dimensions websites at *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Oregon State University datasharing center website *govinfo.kerr.orst.edu*.

Recommended references

Interorganizational Committee on Guidelines and Principles. 1994. Guidelines and principles for social impact assessment. Journal of Impact Assessment 12 (2): 107-152.

SI (10): How does road management affect people's sense of place?

Background

"Sense of place" describes the character of an area and the meaning people attach to it. It integrates the interpretations of a geographic place, considering the biophysical setting, psychological influences (memory, choice, perception, imagination, emotion), and social and cultural influences. Changes in road management can affect access to these places or change the biophysical setting, affecting what people value.

Scale

Most scales would be relevant.

Information needs

Assessment of people's sense of place

Assessment of how roads and access affect people's sense of place

Analytical tools and information sources

USDA-FS Region One "Sense of Place Protocol"

Descriptions of analysis methods, tools, and their sources are available at the Forest Service Human Dimensions websites *128.192.104.16/hdf* and *www.srs.fs.fed.us/athens/index.htm*.

Recommended references

Galliano, S.J.; Loeffler, G.M. 1995. Place assessment: How people define ecosystems: A background report of the scientific assessment for the Interior Columbia Basin Ecosystem Management Project. USDA Forest Service. Walla Walla, WA: The Project. 42 p.

Kemmis, D. 1990. Community and the Politics of Place. Norman, OK: University of Oklahoma Press.

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Roberts, E. 1996. Place and spirit in public land management. Pages 61-80 *in* Driver et al. (eds.). Nature and the human spirit: toward an expanded land management ethic. State College, PA: Venture Publishing.

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Williams, D.R.; Carr, D. 1993. The sociocultural meanings of outdoor recreation places. Pages 209-219 i*n* Ewert, A.W.; Chavez, D.J.; Magill, A.W. (eds.). Culture, conflict and communication in the wildland-urban interface. Boulder, CO: Westview Press.

Civil Rights and Environmental Justice (CR)

CR (1): How does the road system, or its management, affect certain groups of people (minority, ethnic, cultural, racial, disabled, and low-income groups)?

Background

People are affected by changes in road management and the access afforded by roads. Executive Order 12898, Federal Actions to Address Environmental Justice in Minority Population and Low-Income Populations, orders Federal agencies to identify and address "disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations…." Department of Agriculture agencies are required, per the Secretary of Agriculture's 1978 decision, to identify and address the civil rights implications of proposed agency actions in their management decisions.

Scale

The forest or ranger district scale is appropriate.

Information needs

Who is using the roads?

What are the road being used for?

What role do the roads serve for these pursuits?

Analytical tools and information sources

Public involvement and working collaboratively with people who might be affected.

Social assessment

Civil rights impact analysis

Recommended references

US Government. Americans with Disabilities Act of 1990. PL 101-336, 42 USC 12101.

US Executive Office of the President. 1994 Feb. 11. Federal actions to address environmental justice in minority populations and low-income populations, Executive Order 12898, Washington, DC: The Office.

USDA Forest Service 1988. Economic and social analysis handbook. Forest Service Handbook 1909.17. Washington, DC: USDA Forest Service. *fsweb.wo.fs.fed.us/directives/fsh/1909.17*