Environmental Issues and Best Practices for Rural Roads

Brief Description of the Sector

USAID support for rural roads is generally confined to the development or rehabilitation of unpaved one- or two-lane roads. These may be constructed to provide farmers with access to markets or increase community access to services such as healthcare or education. In some cases USAID may also improve roads for tourism in or around protected areas. Under USAID's Environmental Procedures, all road construction and rehabilitation activities require a full environmental assessment. The reader is advised to consult with the Bureau Environmental Officer regarding specific protocols for roads related to environmental assessments.

Road improvements can bring substantial economic and social benefits to rural communities and national economies. They may also have significant adverse, long-term environmental impacts. This section briefly summarizes major effects and outlines key mitigation measures to familiarize project developers and mangers with these issues.

Potential Environmental Impacts

Many adverse impacts of road projects can be avoided or minimized by applying environmentally sound design, construction, and operation and maintenance practices (Table 3.1). Some of the most significant adverse impacts of road activities include:

Soil erosion. Adverse impacts from soil erosion can occur when water is not kept off road surfaces. Roads that cross hilly or steep terrain without following contours or minimizing grades are especially susceptible to erosion, as are roads that concentrate water without adequate side drainage to handle heavy rain or flooding. Roads that develop multiple tracks to avoid water and ruts may also contribute to soil erosion problems. Multiple tracks occur wherever inadequate attention is paid to keeping standing water off the road surface. These effects can be particularly pronounced where roads pass through "black cotton" heavy clay soils (vertisols) or across wetlands. Abandoned roads, if not properly decommissioned, can also become gullies with severe erosion impacts. Other barren

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areas associated with roads can contribute to soil erosion, including material sources, work areas, temporary routes, excessively wide shoulders, and turnout or parking areas.

Effects from indirect siltation are primarily caused by agricultural development.

Degraded water quality. Detrimental effects on water quality may be associated with soil erosion and the siltation of nearby bodies of water—rivers, streams, lakes, wetlands. Effects from indirect siltation are primarily caused by agricultural development, which tends to increase significantly when new roads expand into previously inaccessible areas and when existing roads are rehabilitated, improved, or upgraded. Water quality may be adversely affected when fuel and lubricants at road camps, vehicle maintenance depots, and fueling areas are poorly managed.

Reduced water quantity. Large quantities of water are needed for the preparation and compaction process of road construction and maintenance. Temporary impacts on water quantity may be significant where road improvements pass through arid or semi-arid areas, with potential to significantly affect fish and farm production—particularly if the water used for the improvements is withdrawn during dry seasons. Roads and quarries ("borrow pits") may also create craters that breed mosquitoes or harbor waterborne diseases. On the other hand, the pits can be managed to supplement dry season water supplies.

Altered hydrology. Roads that pass through areas with high water tables or wetlands may create a dam-like effect on surface and subsurface water flows. These effects are especially prominent where large quantities of initial material must be added to raise the road above the land surface, where new material must be added annually to keep the road elevated, or where there are water crossings. Under these circumstances, land on one side of the road can become much wetter than before the improvement, land on the opposite side drier. This may adversely effect crop production, ecosystem species composition, and road stability. Alternatively, poorly installed culverts in wet areas or meadows may concentrate water and then form gullies both up-slope or down-slope of the road. These gullies can subsequently drain the area and contribute to drying up the wetland.

Deforestation and uncontrolled settlements. Opening new roads to support and promote agricultural development puts adjacent forests at risk, especially where no effective forest management systems are in place. The most significant impacts result from land cleared for agriculture. Once a road is in place, it provides access to urban or semi-urban charcoal and fuel wood markets.

Ecosystem and habitat damage. International concern is growing for the maintenance and protection of biodiversity. Inadequate attention to biodiversity

issues in road improvement can lead to the loss of local species—even in relatively undegraded forests—and to significant adverse effects on threatened species. Building new roads or rehabilitating existing roads may disrupt the integrity of plant and animal populations and permanently alter sensitive ecosystems. New roads may also introduce exotic or non-indigenous flora and fauna that may be highly detrimental to the stability of existing plant and animal communities. Road access can also contribute to poaching and trapping of exotic species, and high-speed roads can significantly contribute to animal mortality.

For more information…
Practitioners are also referred to *Low-Volume Road Engineering: Best Management Practices Field Guide* (Keller and Sherar 2001) developed for USAID and the USDA Forest Service International Programs. Many other excellent resources listed in the reference section offer technical guidance on best practices for road improvements. Almost all of these are drawn from Keller and Sherar's bibliography.

Declines in scenic quality. Constructing new roads or realigning existing roads may adversely affect scenic and aesthetic values, which under some circumstances can lead to lost tourism revenues. The cumulative effects of poorly located and managed quarries and borrow pits over time may also cause significant losses in scenic values.

Health and safety concerns.

- *Dust and noise.* Depending on local conditions and the vicinity of houses and communities, dust and noise may be detrimental to health during construction and once the road is in use.
- *Communicable diseases.* Road improvements increase communication among rural and urban populations—which in turn increases the potential for exposure to sexually transmitted and other communicable diseases, including HIV/AIDS and tuberculosis.
- *Water-borne diseases.* Where poor road design and maintenance results in poor drainage and areas of standing water, the risk of water-borne diseases such as cholera and malaria increases. The same is true for standing water found in open quarries and borrow pits.
- *Traffic hazards.* Road improvements, especially those that lead to increased vehicular speed, can increase accident rates for both humans and animals.
- *Roadwork hazards.* The operation of roadwork machinery can pose a threat to the safety of workers during road construction and maintenance. In addition, the creation of borrow pits and quarries for roadwork, if not well planned, can pose threats ranging from drowning in quarry pits to falling from quarry faces or less serious injuries.

Changed local culture and society. Developing new roads or rehabilitating existing roads often improve personal well-being. Access to educational opportunities and social services, including healthcare, is often a rationale for road

improvements. But socio-cultural values may also be altered and the stability of communities adversely affected by rapid exposure to social change. Road construction and maintenance may also provide income for road workers and farmers, but under some circumstances it may compete with farm labor during harvest and planting seasons. A sample environmental impact matrix for road improvement activities can be found in Attachment 1 of this chapter.

Program Design—Some Specific Guidance

When planning to undertake rural road improvement activities, ecological and social science expertise should be engaged and the references listed at the end of this section should be reviewed in depth. Many impacts can be avoided or minimized through careful attention in the initial planning and design stage. Specifications can be incorporated into construction contracts or roadwork procedures for governments or communities and mitigation training provided during construction, operation, and maintenance.

It is particularly important to evaluate the initial goal of providing transport by assessing the need for the road and the purpose it will serve.

Planning and Design

It is particularly important to evaluate the initial goal of providing transport by assessing the need for the road and the purpose it will serve. If the primary purpose is to transport produce from farm to market, seasonal tonnage and transport patterns need to be identified. Then, costs and benefits of potential alternatives should be weighed. In some cases, transport by water, rail, bicycle, or footpath may be more desirable, economically and environmentally. Similarly, if the primary purpose is tourism, then road construction or rehabilitation should be weighed in the overall transportation network planning. Tourist roads can often be rerouted to improve scenic views—following contours, avoiding straight highly visible stretches, creating more pleasing meandering tracks through woodlands. In other cases, substituting walking trails for roads can improve visitor experience and provide greater protection to resources and ecosystems in sensitive protected areas.

During planning and design:

- ***Estimate future demand to decide the type and size of road.*** It is important to decide how many vehicles can be expected on the road and the approximate tonnage they will carry seasonally. This information will help planners design a road that will last and balance environmental sustainability with human needs.

- ***Assess the long-term impact on the road against the "no action" alternative.*** Since road improvements have many direct and indirect effects on the environment, over 20 or 30 years they may accumulate and become highly significant, resulting in agricultural expansion or deforestation. Ancillary developments can be expected—gas stations, restaurants, hotels, markets, shops, retail stores, and bars. Road improvements around protected areas can result in an increase in revenues for the area's management systems. However, these considerations must be balanced against potential damage to sensitive ecosystems and biodiversity.
- ***Look ahead when siting roads.*** Ensure that professional hydrologic and engineering studies are completed first to avoid potentially adverse impacts on soils, to minimize effects on water resources, to ensure correct design of drainage systems, and to reduce the potential for damage from rains and floods. Avoid problematic areas such as springs and wetlands, steep canyon areas, floodplains, and large rock outcrops. Involve hydraulic and geo-technical specialists for expensive and high-risk structures such as bridges, retaining walls, and slide stabilization structures.
- ***Require that road design follows contours and minimizes negative impacts on scenic values.*** Use specifications for design and maintenance that keep water off road surfaces, such as the use of turnout drains. Keep clearing on vegetation along roadside to a minimum.
- ***Assess the quantity of road construction material needed and where it can be found.*** Based on the quantity and quality of material at alternative sites, prepare quarry, borrow pit, and stream mining management plans that identify locations, quantity to be removed from each site, and provide specific instructions for reclamation at each site. Quarries, pits, and access roads are often left unclosed because the extent of the resource was never determined, and no plan for phased closure was prepared. Develop these plans in consultation with stakeholders. Consider that maintaining an unpaved rural road for 20 years or more can require extensive use of road material, and unplanned use of quarries and borrow pits can have significant adverse cumulative effects.
- ***Train equipment operators and road crews*** in environmentally sound road construction and maintenance.
- ***Develop a project erosion control plan*** for every construction or reconstruction project.
- ***Identify recurring costs*** for operation and maintenance, as well as potential funding sources, and build these into annual budgets or user fee charges.

Implementation of environmental mitigation measures during construction is key to avoiding and reducing short- and long-term environmental impacts.

Construction[1]

Many negative impacts may be avoided by taking preventive measures when setting up a work site.

Implementation of environmental mitigation measures during construction is key to avoiding and reducing short- and long-term environmental impacts. Once conditions or mitigation measures have been defined in the environmental review process, they should be included in technical specifications in all contract documents related to the road construction or rehabilitation activities. Environmental clauses should be prescriptive and specify: what needs to be done, where it needs to be done, when and how the actions will take place, who is responsible, what monitoring and reporting requirements there are, and what sanctions or legal recourse are available for work that does not meet the required specifications. Table 3.1 provides detailed environmental impacts and mitigative measures for each phase of road construction and rehabilitation.

Preparing the construction site. Many negative impacts may be avoided by taking preventive measures when setting up a work site. Careful siting of borrow pits, stock-piling areas, work depots, and work camps can preserve sensitive areas, reduce air and noise pollution, minimize visual intrusion, and alleviate local traffic congestion. Confining the handling and use of hazardous materials at the construction site can go a long way in reducing the risks of accidental spills.

Managing the construction activity and work force. Construction activities that can contribute to serious environmental degradation include accidental spills, compaction of the area, poor waste treatment or management, and inadequate local services (such as law enforcement) to support the influx of construction workers. Well thought-out environmental construction guidelines (see Table 3.1), usually contained in an environmental management plan, can prevent these impacts. Measures to prevent erosion are of major importance during the work phase, and can include:

- Planting on cleared areas and slopes immediately after equipment belonging to a specific site has been moved, and reusing stripped topsoil.
- Temporarily covering soil with mulch or fast-growing vegetation.
- Intercepting and slowing water runoff.
- Protecting slopes by using reshaping techniques, rock fill, and other methods.

[1] This section is taken from Tsunokawa and Hoban 1997.

Dust problems can be avoided by watering the site on a predetermined schedule and as required. Construction noise problems can be minimized by using well-maintained and "silenced" equipment, operating within existing noise control regulations, and limiting work hours near residential areas. Traffic control for construction vehicles and diverted routes should minimize impacts across the entire affected area. Pollution from chemical products can be limited by following recommended procedures for containing and confining their use (such as bitumen production) and by not using them during extreme meteorological events such as high winds or rainstorms.

Construction site rehabilitation. Site rehabilitation requires a well-designed planting program that uses native vegetation where possible, with follow-up maintenance and repairs as required. Quarries and large borrow sites can be landscaped and developed for a variety of natural, economic, or recreational uses. Work site facilities, such as wells, water storage, sewer systems, and buildings, are sometimes converted for local use on completion of a project.

Road rehabilitation. Perhaps the most important mitigation measure for rehabilitation projects is to ensure that maintenance, included in the road design, operates effectively. Protection of the biophysical environment can be assisted by regular drain clearing, upkeep of vegetation on slopes and exposed surfaces, maintenance of flow reduction devices in drains, removal of waste arising from road works, and avoiding the use of herbicides and other polluting substances.

Impacts on the community and social environment can be mitigated by designing good traffic management plans, using quiet equipment, operating during daily periods of high ambient noise, and focusing attention on improvements in the quality of signs, guard rails, footpaths, and other features that contribute to safety and local accessibility.

Environmental "hot spots" or problem locations, such as easily eroded sites or notoriously unstable slopes, can be identified during the planning and design process and during the execution of rehabilitation and maintenance works.

Experts in roadside vegetation, traffic management, and transportation safety should monitor maintenance activities to ensure that work practices meet environmental objectives. Understanding the functions and techniques of roadside planting, signs, and guard rails is important for their proper functioning. Training road crews in these issues can help them considerably in executing and managing road maintenance.

The most significant effects from unpaved rural roads are generally brought on by a lack of regular maintenance, which generally results from a lack of funding, inadequately trained road personnel, and poor operation and maintenance of road equipment.

Operation and Maintenance

The most significant effects from unpaved rural roads are generally brought on by a lack of regular maintenance, which generally results from a lack of funding, inadequately trained road personnel, and poor operation and maintenance of road equipment. Well-trained grader operators are key to shaping road surfaces that direct water away from vehicle tracks and keep it from accumulating on road surfaces. Proper management plans and well-trained road personnel are needed to ensure that work is completed satisfactorily, following specified maintenance schedules. The same is true for maintaining heavy equipment and training mechanics. Often even simple maintenance procedures may not be followed—routine equipment servicing may not occur because odometers are broken or no one maintains log books on equipment use. If the equipment is not available when needed, the adverse impacts on roads can be highly detrimental and very costly to correct. Anticipate recurring costs and build these costs into annual budgets or user fee charges.

Annual environmental management plans with well-defined responsibilities and timetables for meeting those responsibilities are critical.

Training must be provided regularly for road crews on using environmentally sound design principles to ensure that drainage structures are cleaned, water accumulation on roads is dealt with in a timely way, road camps are well-maintained, and worker health and safety plans are being implemented.

Annual environmental management plans with well-defined responsibilities and timetables for meeting those responsibilities are critical to all efforts to bring about more environmentally sound road improvement programs. By incorporating mitigation and monitoring needs into the annual workplan, provisions for funding them can be made a part of the yearly budget preparation process. When feasible, annual environmental management plans should be subjected to independent evaluation to determine if mitigation and monitoring results are being achieved and to suggest corrective actions when necessary.

Decommissioning

Re-aligning existing roads is common in rural road improvement programs. When this occurs, old roads may need to blocked off with stones, mounds of earth, or other devices to prevent use. In some cases the old surface must be scraped for drainage or "ripped" to encourage re-vegetation.

Environmental Mitigation and Monitoring Issues

Table 3.1 Environmental Mitigation and Monitoring Issues for Rural Roads

Situation or Activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
General Planning and Design—New and Existing Roads		
Identifying and weighing alternatives		• Along possible routes identify known and potential areas of ecological, archeological, paleontological, historic, religious, or cultural significance and ecologically sensitive areas such as tropical forests, wetlands, and other areas of high biodiversity or threatened species (P&D)
Establishing design standards	• Damage valuable ecosystems and habitats • Damage valuable historic, religious, cultural, and paleontological resources • Change local culture and society • Cause soil erosion • Degrade water quality, alter hydrology • Mar scenic views • Lead to injury, disease, or death of workers and local residents	• Chose or develop design standards for each facet of construction and related activities—road bed, road surface, drainage, erosion control, re-vegetation, stream crossing, sensitive areas, steep slopes, material extraction, transport and storage, construction camps, decommissioning (P&D) • Provide plans to identify, protect, and use sensitive habitats (P&D) • Take into account problems in soil and slope stability and local weather and natural phenomena—fog, flooding, earthquakes, heavy rain, mudslides, drought (P&D) • Develop an erosion control plan for all projects (P&D)
Road surface	• Increase or decrease sedimentation • Help or be adverse to road user comfort	• Stabilize the road surface with gravel, murram, and other rocky surfacing material (P&D) (C) • Elevate road surface (measure from base of wheel tracks) above side channel water) (P&D) (C) • Clearly define the type of road surface shape and drainage method—in-sloped, out-sloped, or cambered/crown roadway—to be used for each section of roadway (P&D) (C)
Perennial and intermittent rivers and streams	• Destruction of bridge by 50- or 100-year flood • Damming and resultant meandering of stream that destroys neighboring sections of roadway, dwellings, and native flora and fauna	• Construct fords rather than bridges where feasible and cost effective. Periodic replacement or reconstruction of damaged bridges and culverts can be costly. Involve hydraulic engineers in bridge designs (P&D) (C) • When constructing a bridge, consider a design, such as Bailey Bridges, that can be erected and dismantled—if the waterway meanders, the structure can be moved to another site (P&D) (C) • "Train" rivers and streams to follow desired channels by selectively removing debris. But channel changes should be minimized. Use a combination of hand labor and small machinery. Careful and selective bulldozing may be feasible in some cases, but consider that dozer tracks can easily expose soil to erosion and do more harm than good (P&D) (C)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Route planning	• Damage valuable ecosystems and habitats • Damage valuable historic, religious, cultural, and paleontological resources • Change local culture and society • Cause soil erosion • Degrade water quality • Alter hydrology • Contribute to deforestation • Mar scenic views	• In planning new routes, involve a multidisciplinary team, including (ideally) an ecologist, geo-technical and road engineer, soil scientist, hydrologist, and other relevant professionals such as archaeologists or tourism specialists (P&D) • Avoid routing road through sites of known paleontological, archeological, historic, religious, or cultural significance (P&D) • Avoid routing across agriculturally productive soils • Take into account problems in soil and slope stability and local weather and natural phenomena—fog, flooding, earthquakes, heavy rain, mudslides, drought (P&D) • Whenever possible site roads to follow hill contours and avoid creating slopes greater than 10 degrees • Avoid gradients greater than 10 percent and long straight downhill stretches (P&D) (C) • Identify sites for temporary and permanent storage of excavated material and construction materials. Where excavated material will not be reused decide how it will be disposed of or shaped (P&D) (C) • Avoid environmentally sensitive areas, such as wetlands, and sites near protected areas or relatively undegraded forests. Explore possible compromise alternatives—a narrow, improved trail across protected area lands that provides access to foot, bicycle, or motorcycle traffic while constructing main access roads around these areas (P&D) (C) • Avoid constructing roads through forest areas, especially tropical forest, if possible. If clearing is unavoidable, protect or restore forests elsewhere in the drainage basin as close as possible to those lost (P&D) • Minimize aesthetic and scenic impacts by avoiding roads that cut long straight paths across valleys and plains. Instead, hide roads beneath forest cover to minimize adverse aesthetic effects, and provide meanders where feasible (P&D) • Avoid siting roads where they may disturb animal behavior or migration patterns (P&D) • If sensitive areas cannot be avoided, involve ecologists and engineers in designing road, construction camp, quarries, and other areas (P&D) (C)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Drainage	• Cause soil erosion • Degrade water quality • Alter hydrology • Damage valuable ecosystems and habitats	• Install drainage structures during rather than after construction. Most erosion associated with roads occurs in the first year after construction. Delaying installation of drainage features greatly increases the extent of erosion and damage during the first year (P&D) (C) • Clearly define the type of road surface shape and drainage method—in-sloped, out-sloped, or crown roadway—to be used for each section of roadway. Use outside ditches control surface water when necessary, but keep in mind that they concentrate water flow and require the road to be at least a meter wider. Install structures, such as berms or ditches, to divert water off the road before it directly reaches live stream channels (P&D) (C) • Install diversion structures, such as cross drains, drivable, rolling dips, or water bars, to move water off the road frequently and minimize concentration of water (P&D) (C) • Install drainage crossings to pass water from uphill to downhill. If using culvert pipes, at least roughly design them using the Rational Formula or back-calculate using Manning's Formula and high-water mark before or during construction to determine the anticipated flow, and select the correct size of pipe. Where flows are difficult to determine, use structures—such as fords, rolling dips, and overflow dips—that can accommodate any flow volume and are not susceptible to plugging (P&D) (C) • Stabilize outlet ditches (inside and outside) with small stone riprap or vegetative barriers placed on contour to dissipate energy and to prevent the creation or enlargement of gullies (P&D) (C) • Extend runout drains far enough to allow water to dissipate evenly into the ground (P&D) (C) • Visually spot check for drainage problems, such as accumulation of water on road surfaces, immediately after first heavy rains and at the end of the rainy season. Institute appropriate corrective measures (C)
Wetlands	• Degrade wetland damaging the valuable ecosystems and habitats • Alter hydrology	• Avoid routing through these areas (see "Route planning" above for additional guidance) (P&D) • Minimize cuts and fills and compensate for impact by protecting other wetlands (P&D) (C) • Take special precautions to prevent dumping of debris, oil, fuel, sand cement, and similar harmful materials (C) • Use elevated porous fills (rockfills) or multiple pipes to maintain natural groundwater and near-surface flow patterns (C)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Sloped areas and raised roads	• Cause soil erosion • Degrade water quality • Alter hydrology • Damage valuable ecosystems and habitats	• Stabilize slopes by planting vegetation. Work with agronomists to identify native species with the best erosion control properties, root strength, site adaptability, and other socially useful properties. Set up nurseries in project areas to supply necessary plants. Do not use non-native plants. Use soil stabilizing chemicals or geo-textiles (fabrics) where feasible and appropriate (P&D) (C) • Minimize use of vertical road cuts even though they are easier to construct and require less space than flatter slopes. The majority of road cuts should have no more than a 0.75:1 or 1:1 slope to promote plant growth. Vertical cuts are acceptable in rocky landscapes and in well-cemented soils (P&D) (C) • Install drainage ditches or berms on uphill slopes to divert water away from roads and into streams (P&D) (C) • Install drainage turnouts at more frequent intervals and check dams to reduce ditch erosion (P&D) (C) • If possible, use higher grade gravel that is much less prone to erosion (P&D) (C) • If very steep sections cannot be avoided, provide soil stabilizers or surface with asphalt or concrete (P&D) (C)
Construction contracts		• Select or develop guidelines and procedures to be applied to each facet of road construction and incorporate them into contracts with construction companies—site clearing, bed and surface construction, drainage, fuel and material usage, quarry site management, construction camp and work site operating procedures, including worker safety • Include incentives for adhering to guidelines and penalties for violating them
Maintenance agreements		• Finalize maintenance agreements with local communities before beginning construction. All parties must clearly understand and be committed to terms of the agreement, such as who will do what work, when, how frequently, for what compensation, and within what limits
Planning and Design—Existing Roads		
All projects		• Use a "clean slate" approach: consider realigning all minimal or informal roads to follow contours and avoid sensitive areas (P&D)
Road surface is below grade of surrounding road	• Cause soil erosion • Degrade water quality • Alter hydrology	• Raise road surface with stable fill material. Grade with in-slope, out-slope, or cambered shape. Install sufficient cross-drains, ditches, and settling ponds (P&D) (C) (O&M)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Road is steeply sloped and eroding	• Cause soil erosion • Degrade water quality • Alter hydrology	• Consider realigning the road section so that it conforms to preferred design parameters described above. Decommission original road sections after realignment (see "Decommissioning" below) (P&D) (C) (O&M)
Deteriorated road surface	• Cause erosion • Damage vehicles	• Determine cause of deterioration. If heavily used, find a means of reducing traffic or upgrade road to more durable surface—gravel, asphalt, or concrete (P&D) (C) (O&M)
High-speed driving	• Cause injury and death of people and animals	• Realign road sections to meander; curving roads deter speeding (P&D) • Add speed bumps in villages or populated areas (C)
Sections have multiple tracks/off-road driving	• Cause soil erosion • Degrade water quality • Alter hydrology • Damage ecosystems and habitats	• Generally caused by either muddy/flooded roadway or highly deteriorated roadway. Maintain or upgrade road so section no longer floods or becomes muddy (P&D) (O&M) • Raise the road bed or define the roadway with rocks. Realign the road to a better area. Avoid very flat terrain (P&D) (O&M)
Road section must be realigned		• Remove surface and loosen soil of previous track to accelerate regeneration of vegetation. Block access with rocks, branches, roadblocks, and signs. Narrow tracks usually re-vegetate naturally with no noticeable scars. Wider roads may require planting and reseeding (C) (O&M)
Construction		
Use of heavy equipment and hazardous materials	• Cause erosion due to machinery tracks, damage to roads, stream banks • Compact soil, change surface and groundwater flows, and adversely affect future use for agriculture • Contaminate ground or surface water when hydraulic oil, motor oil or other harmful mechanical fluids are spilled or dumped • Put workers at risk from exposure to hazardous materials	• Minimize use of heavy machinery (P&D) (C) • Set protocols for vehicle maintenance, such as requiring that repairs and fueling occur elsewhere or over impervious surface such as plastic sheeting. Prevent dumping of hazardous materials, and capture leaks or spills with drop cloths or wood shavings. Burn waste oil that is not reusable or readily recyclable and does not contain heavy metals and are flammable. Prohibit use of waste oil as cooking fuel (P&D) (C) • Investigate and use less toxic alternative products (P&D) (C) • Prevent fuel tank leaks by a) monitoring and cross-checking fuel level deliveries and use, b) checking pipes and joints for leaks, c) tightening generator fuel lines, d) preventing over-filling of main storage and vehicle tanks (Also consult Chapter 4: Activities with Micro and Small Enterprises in this manual) (C)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Construction camp and crew	• Damage local habitat, compact soil, and create erosion via building and occupation of construction camp • Contaminate surface water and spread disease via solid waste and feces generated by camp • Spread communicable diseases including malaria, tuberculosis, and HIV/AIDS via construction crew who come from outside the region • Introduce alcohol or other socially destructive substances via construction crew • Adversely effect local flora and fauna (especially game and fuelwood) via poaching and collection by construction crews • Generate trash due to lack of solid waste management	• Explore off-site accommodations for crew. Avoid wet, muddy sites (P&D) (C) • Keep camp size to a minimum. Require that crew preserve as much vegetation as possible, for example, by creating defined foot paths. Define areas of use (with rocks or fencing) (P&D) (C) • Provide potable water for crew • Provide temporary sanitation on site, such as a ventilated improved pit latrine, assuming the water table is low enough and soil and geology of appropriate composition. Where this is not possible instruct road crews to employ soil mining—digging a pit for waste and covering immediately after use (P&D) (C) • Use local or regional labor, if possible. Provide hygiene and public health training to road crews, including on transmission and prevention of HIV/AIDS and other sexually transmitted diseases (P&D) (C) • Collect all solid waste (metal, glass, and burnable materials) from all work and living areas and dispose of waste in local dump or landfill. If this is not possible, sell recyclables for reuse or recycling, place organic wastes in well-screened waste pits, covering with soil weekly, and bury the remainder, excluding toxic materials. (Also consult Chapter 5: Management of Solid Waste in this volume) • Set guidelines prohibiting poaching and collection of plants/wood with meaningful consequences for violations, such as termination of employment. Provide adequate quantities and good quality food and cooking fuel (C) • Restore site through re-vegetation and similar measures after camp is broken down (C) • Test grade driver's ability to follow grade, slope, and contour design standards; train if necessary (P&D) (C) • Test bulldozer and other equipment operators' ability to properly maintain drainage structures, and train if necessary (P&D) (C) • Test road crew's ability to keep roads clear of vegetation with least adverse environmental impacts, and train if necessary (P&D) (C) • Provide workers with appropriate safety equipment—ear plugs or head gear to mute noise from very loud equipment, masks for workers exposed to large amounts of dust, safety glasses for workers doing jobs that may generate sharp projectiles

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Storing materials	• Deplete water resources Damage valuable ecosystems and habitats	• Pre-wet gravel when water is more available—not during the dry season—and store gravel in a way that will keep it wet, for instance, covered with plastic sheeting (P&D) (C) • Avoid using sensitive areas or sites that drain directly into a sensitive area for storage (P&D) (C)
Material extraction: quarrying, logging	• Damage aquatic ecosystems through erosion and siltation • Harm terrestrial ecosystems via harvesting of timber or other natural products • Spread vector-borne diseases when stagnant water accumulates in active or abandoned quarries or borrow pits and breeds insect vectors • Take land out of other useful production • Make quarry a safety hazard • Cause erosion and siltation in streams mined for gravel	• Identify the most environmentally sound source of materials that is within budget (P&D) (O&M) • Use material from local road cuts first, but only if it produces a suitable, durable aggregate for embankment fill or surface stabilization material. Local borrow material can be very cost effective. On removal of material, the area should be restored and be treated with erosion control measures (P&D) (C) • Develop logging, quarrying, and borrowing plans that take into account cumulative effects (P&D) • Take photos of site before initiating excavation so restoration can match original site characteristics as much as possible (C) (O&M) Site quarries and gravel pits so that they are not visible to travelers on the roads (P&D) (C) (O&M) • Monitor adherence to plans and impacts of extraction and modify as necessary (C) (O&M) • Restore area so it is suitable for sustainable use after extraction is completed (C) • Install drainage structures to direct water away from pit (C) (O&M) Implement safety protocols to minimize risks from falling rock or debris, collapsing quarry walls, or accidental falls from cliffs (P&D) (C) (O&M) • Develop specific procedures for storing topsoil and for phased closure, reshaping, and restoration when extraction has been completed. Include plans for segregating gravel and quarry materials by quality and grade for possible future uses. Where appropriate, reseed or re-vegetate to reduce soil erosion, prevent gulleying, and minimize visual impacts (P&D) (C) (O&M) • Discuss with local community the option of retaining quarry pits as water collection ponds for cattle, crops, or similar uses. Issues of disease transmission and prohibiting use for drinking, bathing, and clothes washing should be highlighted (Also consult Chapter 8: Agriculture and Watershed Management, Section B—Stream Bank Protection and Restoration) (P&D) (C) (O&M)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Site clearing or leveling	• Damage or destroy sensitive terrestrial ecosystems • Produce areas of bare soil that cause erosion, siltation, changes in natural water flow, and damage to aquatic ecosystems	• Minimize disturbance of native flora during construction. Minimize the amount of clearing. Clear small areas for active work one at a time (P&D) (C) • Avoid use of herbicides. Any use should follow health and safety procedures to protect people and the environment. Herbicides should be used according to manufacturer specifications (C) • Clear without destroying large plants and turf where possible and preserve for replanting in temporary nurseries (P&D) (C) • Move earth and vegetation only during dry periods. Store topsoil for re-spreading. If vegetation must be removed during wet periods, disturb ground only just before actual construction (P&D) (C) • Install temporary erosion control features when permanent ones will be delayed. Use erosion control measures such as hay bales, berms, straw, or fabric barriers (C) • Re-vegetate with recovered plants and other appropriate local flora immediately after equipment is removed from a section of the site (C)
Excavation, cutting, and filling	• Cause erosion, siltation, changes in natural water flow, and damage to aquatic ecosystems when excavated soil is piled inappropriately • Expose inhabitants and crew to risk of falls and injuries in excavation pits • Block water courses when fill is inappropriately placed • Destroy valuable ecosystems when fill is inappropriately placed • Cause land subsidence or landslides when fill is inappropriately placed, causing injuries and damages • Degrade water quality • Alter hydrology	• Cover pile with plastic sheeting, prevent run-off with hay bales, or use similar measures (P&D) (C) • Place fence around excavation (P&D) (C) • Investigate shallower excavation and no excavation alternatives (P&D) • Have construction crews and supervisors be alert for buried historic, religious, and cultural objects and provide them with procedures to follow if such objects are discovered. Provide incentives for recovery of objects and disincentives for their destruction (P&D) (C) • Ensure excavation is accompanied by well engineered drainage (P&D) (C) • Do not fill the flow-line of a watershed. Even in arid areas, occasional rains may create strong water flows in channels. A culvert may not supply adequate capacity for rare high volume events (P&D) • Design so that filling will not be necessary. Transplant as much vegetation and turf as possible (P&D) (C) • Use good engineering practices. For instance, do not use soil alone; first lay a bed of rock and gravel (P&D) (C) • Balance the cuts and fills whenever possible to minimize earthwork movement • Test grade driver's ability to follow grade, slope, and contour design standards. Train if necessary (P&D) (C)

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Compacting	• Deplete freshwater resources • Improve road material performance	• Water the road immediately before compacting to strengthen the road surface, otherwise traffic will soon beat back the road surface to pre-bladed condition (P&D) (C) • When possible, delay compacting until the beginning of the wet season or when water becomes more available (P&D) (C)
Blasting	• Cause soil erosion • Degrade water quality • Alter hydrology • Damage valuable ecosystems and habitats	• Minimize blasting (P&D) (C) • Take safety precautions to protect workers and others from being injured by flying or falling rock and avalanches (P&D) (C)
Design verification and quality control		• Conduct periodic independent inspection of work to see that it conforms to original plan and design specifications. Provide incentives and disincentives to ensure conformance (C) • Drive roads after moderate rains to identify areas that collect or gully water. Mark and redesign/rehabilitate as necessary (C)
Operation and Maintenance		
Road maintenance	• Create gullies and standing pools • Create mud holes, potholes • Breed disease vectors in settling basins and retention ponds • Remove ruts, potholes, washboarding, and standing water	• Monitor and maintain drainage structures and ditches including culverts. Clean out culverts and side channels and runouts when they begin to fill with sediment and lose their effectiveness (O&M) • Fill mud holes and potholes with good quality gravel; remove downed trees and limbs obscuring roadways (O&M) • Use water from settling basins and retention ponds for road maintenance (O&M)
Construction camp and crew	• (See "Construction camp and crew" above)	
Use and maintenance of equipment	• (See "Use of heavy equipment and hazardous materials" above)	• Install concrete pads, drains, and oil/water separators in areas where vehicle and equipment maintenance and fueling will occur regularly

Issue or aspect of activity	Impact *The activity may …*	Mitigation *Note: Mitigations apply to specified project phase—planning and design (P&D), construction (C), or operation and maintenance (O&M)*
Decommissioning		
Decom-missioning	• Cause soil erosion • Degrade water quality • Damage valuable ecosystems and habitats	• Break up old road surface and soil. Remove and dispose of surfacing material if necessary and loosen soil of previous track to accelerate regeneration of vegetation • Reshape eroded or culled surfaces with out-sloping, or add cross drains or water bars so water will no longer follow the course of the roadway • Re-vegetate as needed. Narrow tracks will usually re-vegetate naturally with no noticeable scars or impact on the environment, but wider roads may require active planting and reseeding (O&M) • Block access with rocks, branches, roadblocks, and signs.

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This manual is currently being rewritten in English and is not yet available electronically. For a copy, contact Gordon Keller at the USDA Forest Service, Sierra Cascade Province, Plumas National Forest, 159 Lawrence Street, Quincy, CA 95971, United States, Tel: 1-530-283-2050, Fax: 1-530-283-7746, Email: gkeller@fs.fed.us.

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Provides useful information for those in developing countries who have direct responsibility for low-cost water crossings.

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The Roads and Highways Group offers links to tools and literature covering many dimensions of road construction, including planning, finance, institutional management, safety, construction and maintenance, environment, and tolls. Online: www.worldbank.org/transport/publicat/reh/toc.htm.