SECTOR ENVIRONMENTAL GUIDELINES

RURAL ROADS

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Cover Photo: USAID/Afghanistan's Infrastructure Project: Road Construction in Ghazni, Afghanistan. USAID/Afghanistan funded the construction of this road connecting two provinces: Ghazni (Central Afghanistan) and Sharan (South – West). Project implemented by LBG. Photo dated 27 August 2005. Massoud Hossaini.

About this document and the *Sector Environmental Guidelines*

This document presents one sector of the *Sector Environmental Guidelines* prepared for USAID under the Agency's Global Environmental Management Support Project (GEMS). All sectors are accessible at www.usaidgems.org/bestPractice.htm.

Purpose. The purpose of this document and the *Sector Environmental Guidelines* overall is to support environmentally sound design and management (ESDM) of common USAID sectoral development activities by providing concise, plain-language information regarding:

- the typical, potential adverse impacts of activities in these sectors;
- how to prevent or otherwise mitigate these impacts, both in the form of general activity design guidance and specific design, construction and operating measures;
- how to minimize vulnerability of activities to climate change; and
- more detailed resources for further exploration of these issues.

Environmental Compliance Applications. USAID's mandatory life-of-project environmental procedures require that an environmental analysis be conducted to identify the potential adverse impacts of USAID-funded and managed activities prior to their implementation according to USAID Environmental Procedures 22 CFR 216 or Reg. 216. They also require that the environmental management or mitigation measures ("conditions") identified by this analysis be written into award documents, implemented over life of project, and monitored for compliance and sufficiency.

The procedures are USAID's principal mechanism to assure ESDM of USAID-funded activities—and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. They strengthen development outcomes and help safeguard the good name and reputation of USAID.

The Sector Environmental Guidelines directly support environmental compliance by providing: information essential to assessing the potential impacts of activities, and to the identification and detailed design of appropriate mitigation and monitoring measures. When an activity receives a "Negative Determination with Conditions" these guidelines should be used to help establish which conditions are appropriate to the particular activity.

However, the Sector Environmental Guidelines *are **not** specific to USAID's environmental procedures. They are generally written, and are intended to support ESDM of these activities by all actors, regardless of the specific environmental requirements, regulations, or processes that apply, if any.*

Region-Specific Guidelines Superseded. The *Sector Environmental Guidelines* replace the following region-specific guidance: (1) *Environmental Guidelines for Small Scale Activities in Africa* ; (2) *Environmental Guidelines for Development Activities in Latin America and the Caribbean*; and (3) Asia/Middle East: *Sectoral Environmental Guidelines*. With the exception of some more recent Africa sectors, all were developed over 1999–2004.

Development Process & Limitations. In developing this chapter, regional-specific content in these predecessor guidelines has been retained. Statistics have been updated, and references verified and some new references added. However, this chapter is not the result of a comprehensive technical update.

Further, The *Guidelines* are not a substitute for detailed sources of technical information or design manuals. Users are expected to refer to the accompanying list of references for additional information.

Comments and corrections. Each sector of these guidelines is a work in progress. Comments, corrections, and suggested additions are welcome. Email: gems@cadmusgroup.com.

Advisory. *The Guidelines are advisory only. They are not official USAID regulatory guidance or policy. Following the practices and approaches outlined in the Guidelines does not necessarily assure compliance with USAID Environmental Procedures or host country environmental requirements*

CONTENTS

RURAL ROADS

Road improvements can bring substantial economic and social benefits to both rural communities and national economies. But they may also lead to significant and long-lasting environmental damage.

BRIEF DESCRIPTION OF THE SECTOR

USAID support for rural roads is generally confined to the development or rehabilitation of one- or two-lane roads. These may be constructed to provide farmers access to markets or to increase community access to services, such as health care or schools. In some cases USAID may also provide support to improve roads leading to or into protected areas in order to encourage tourism.

Road improvements can bring substantial economic and social benefits to both communities and national economies, including access to education, employment, and health care. But they may also lead to significant and long-lasting environmental damage. That is why USAID's environmental procedures typically require an Environmental Assessment before any new road construction. However, a Negative Determination with Conditions is relatively limited in scope and is often recommended for the rehabilitation of existing rural roads. This section can be used to identify significant environmental issues associated with new roads, as well as to develop a mitigation and monitoring plan for a small-scale rehabilitation of rural roads. The reader is advised to consult with the Bureau Environmental Officer regarding specific protocols for Environmental Assessments related to road activities. This section briefly summarizes a few of the major impacts and outlines key mitigation measures, in order to familiarize project developers and mangers with these issues.

Practitioners are also referred to Low-Volume Roads Engineering Best Management Practices Field Guide (Keller and Sherar 2003), developed for the USDA Forest Service's International Programs and USAID. Many other excellent references are listed in the Resources and Useful References section of this briefing; these offer technical guidance on best practices for road improvements. Many of these are drawn from Keller and Sherar's bibliography.

In this guideline, you will learn about:

- Common types of environmental damage from road projects.
- Proper planning of road projects to avoid environmental degradation and loss of ecosystem services.
- Putting operation and maintenance programs into effect to prevent and mitigate environmental impacts.
- Best means of decommissioning roads to prevent erosion and loss of resources.

CLIMATE CHANGE

Global climate change is resulting in changes in temperatures, rainfall patterns, sea levels, and extreme weather events that are putting stress on many communities and challenging development efforts. It is becoming more difficult to predict future climate based on historical baseline conditions or trends. This uncertainty is increasing project design risks and community vulnerabilities. In response, project designers should now include a focus on climate change adaptation — defined as adjustment to natural or human systems in response to actual or expected climate change effects. Successful road projects should include efforts to moderate climate-related risks and vulnerabilities and to take advantage of potential benefits to improve the likelihood of long-term project success. At the same time, project design should assess the potential contribution of a proposed project to greenhouse gas emissions, and implement cost-effective strategies and actions that minimize these emissions. Taken individually, impacts of small activities may appear minimal, but collectively, their scale and magnitude can have far reaching effects on human health and life-sustaining natural systems. This *Guideline* provides information on the relationship between climate change and road development activities.

By implementing an adaptive risk management system, the implications and uncertainties of climate change scenarios can be better understood, and used to inform planning, investment and operation decisions.

POTENTIAL ENVIRONMENTAL IMPACTS OF DEVELOPMENT PROGRAMS IN THE SECTOR AND THEIR CAUSES

Many adverse impacts of road projects can be avoided or minimized by applying environmentally sound design, construction, and operation and maintenance practices. Some of the most common adverse environmental impacts associated with road improvements are summarized in Annex A, "Sample Road Improvements Environmental Impact Matrix." Of these, some of the most significant may include:

Loss of Ecosystem Services

Ecosystem services, or the benefits that ecosystems provide, are impacted by both road construction and road use. Impacts to ecosystem services include many of the environmental impacts discussed below (i.e., soil erosion, degradation of water quality, deforestation, loss of habitat and biodiversity, etc.). Evaluating these impacts holistically, via an Ecosystem Services Valuation (ESV) as part of the Planning and Development phase, can provide insight how road construction may damage those ecosystems that are most valuable to human well-being. An ESV can help communities realize the trade-offs associated with development and management of rural roads. It can also inform decisions that minimize and mitigate the most harmful environmental and social impacts. For more information about applying an ecosystem services framework to the Environmental Impact Assessment process, see the Environmental Compliance Factsheet: Ecosystem Services in the Environmental Impact Process.

SOIL EROSION

Soil erosion is often caused by failing to keep water 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 collect water and do not have enough side drainage to handle heavy precipitation or abnormal flooding.

Roads may also contribute to soil erosion through the development of multiple tracks, as travelers try to avoid standing water and ruts. Multiple track development occurs wherever inadequate attention is paid to keeping standing water off the road surface. These effects may 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 gulleys, with severe erosion impacts. Other barren areas associated with roads can contribute to soil erosion, including building material sources, work areas, temporary routes, excessively wide shoulders, and turnout or parking areas.

Potential environmental impacts

Some impacts of road projects are:

- Loss of ecosystem services
- Soil erosion
- Degradation of water quality
- Adverse effects on quantities of water
- Altered hydrology and flooding
- Deforestation
- Damage to valuable ecosystems and habitat diversity
- Damage to scenic quality and tourism
- Adverse impacts on human health and safety
- Changes to local culture and society

DEGRADATION OF WATER QUALITY

Water quality may be damaged by soil erosion and the siltation of nearby rivers, streams, lakes and 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. Siltation also occurs as a secondary effect of soil erosion resulting from road improvements.

Adverse impacts on water quality may also be associated with poor management of fuel and lubricants at road camps, vehicle maintenance depots and fueling areas.

Borrow pits associated with road construction and maintenance fill with water during rains, creating safety hazards and standing water that attracts mosquitoes and other disease vectors.

ADVERSE EFFECTS ON WATER QUANTITY

Large quantities of water are needed to help prepare and compact the road surface during road construction and maintenance. Although this demand for water is temporary, it may significantly affect local water supplies. In arid and semi-arid areas, drawing water for road improvements may decrease the amount of water available for aquatic species and farm production, especially if the water is taken during dry seasons.

Roads and quarries or “borrow pits” may also create artificial ponds and lakes (impoundments) that may inadvertently breed mosquitoes or harbor water-borne diseases. Without appropriate planning, road builders may create such ponds by damming gullies or other small catchment areas or streams. However, with appropriate foresight, pits can minimize erosion and sedimentation by constructing retention basins and settling ponds. When managed effectively, they may also be used to supplement water supplies during dry seasons. or be managed to supplement dry season water supplies.

ALTERED HYDROLOGY

Roads crossing areas with high water tables or wetlands may act like dams that block surface and sub-surface water flows. This is especially true where large quantities of material must be added to raise the road above the land surface, and where new material must be added annually to keep the road elevated. Under these circumstances, land on one side of the road can become much wetter than it was before the improvement, while land on the opposite side may be drier. This may adversely affect crop production, the composition of species in the local ecosystem, and road stability.

Alternatively, poorly installed culverts in wet or meadow areas may concentrate water and then form gullies upslope and/or downslope of the road. Subsequently, these gullies can potentially drain the wetland area, generally on of the most valuable land types in terms of the value of the ecosystem services it provides, and contribute to dry conditions.

DEFORESTATION

Opening up new roads for expanded agricultural development puts adjacent forests at risk, especially where no effective forest management systems are in place. Typically, the most significant impact on forests results from the clearing of land for farms. However, once a road is in place, it also provides access to people wanting to supply urban markets with wood products such as charcoal, fuelwood, bush meat, or construction materials, contributing further to deforestation, carbon emissions, and a loss of carbon sinks. On the one hand new opportunities for income generation will be welcomed but at the same time it could result in conflict or ill feelings depending on how resource extraction activity takes place.

DAMAGE TO VALUABLE ECOSYSTEMS AND HABITATS

International concern over the protection of biodiversity continues to grow. Inadequate attention to biodiversity issues in road improvement projects can threaten or endanger local species. Especially in tropical regions, constructing new roads, or rehabilitating existing roads, may disrupt the integrity of plant and animal populations due to hunting, road kill, or alteration of sensitive ecosystems. Roads can separate an otherwise fully functioning and integrated ecosystem by impeding animal movement, migration, and habitat accessibility, permanently segregating members of the same species.

The construction of new roads may also introduce exotic or non-indigenous flora and fauna that may severely destabilize local plant and animal communities. Road access can also contribute to poaching and the trapping of endangered species or species with international trade value. High-speed roads can significantly raise animal mortality (road kill).

DECLINES IN SCENIC QUALITY

Ecosystems can provide nonmaterial benefits, such as the aesthetic value of an area, to local residents and visitors. Construction of new roads or the realignment of existing roads may adversely affect scenic vistas. Under some circumstances, such damage can lower tourism revenues. The cumulative effects of poorly located and poorly managed quarries and borrow pits supplying building materials for road projects may also cause significant loss in scenic value.

ADVERSE IMPACTS ON HUMAN HEALTH AND SAFETY

Potential concerns include:

Dust and noise. Depending on local conditions and the vicinity of houses and communities, dust and noise may damage human health during construction and, especially, once the road is in use. The health of road construction and maintenance staff may also be adversely affected by noise and dust produced from construction, road rehabilitation and maintenance.

Adverse impacts through greater contact with outside communities. Road improvements increase interactions amongst populations. The construction of rural roads serve as an entry point for new products and services and in most cases this is a positive development. However, the construction of a road does raise the specter of unwanted influences and impacts as communities become more open and accessible entities. This may include exposure to communicable diseases and unwanted social patterns such as increased alcohol consumption.

Spread of water-borne diseases. Where poor road design and maintenance result in poor drainage and areas of standing water, the risk of water-borne diseases such as cholera or malaria increases. The same is true for standing water found in open quarries and borrow pits.

Traffic hazards. As the number of motor vehicles on roads continues to increase, road improvements, especially those that allow increased vehicular speed, can lead to increases in accident rates for both human and animal populations. Safe infrastructure for pedestrians and cyclists is lacking in most developing countries.

Road works hazards. The operation of road works machinery often endangers both operators and laborers during construction and road maintenance. Poorly planned borrow pits and quarries for road work can also pose threats, ranging from falls from quarry faces to drowning in quarry pits that have become standing water reservoirs.

CHANGE LOCAL CULTURE AND SOCIETY

The development of new roads, or rehabilitation of existing ones, often improves personal livelihoods. Access to educational opportunities and to social services, including health care, is often a key rationale for road improvements. However, socio-cultural values may also be altered and the stability of communities adversely affected by exposure to social change. New road access can change how a place is used or valued. For example, increased hunting or fishing access may impact the food supply of local communities.

CLIMATE CHANGE

PLANNING FOR A CHANGING CLIMATE

Sea level rise, shifting temperatures and precipitation patterns are climatic changes to baseline conditions that affect rural roads. These changes can lead to more frequent or more severe droughts, floods, and tropical storms and storm surge; climate change should be considered in design, construction, and operation. Considering the life expectancy of a road project (decades or more), projects must be designed to be resilient to anticipated medium- and long-term climate change effects. Specifically, the road materials selected, and aspects of road design and improvement, will affect the sensitivity of the road and its users to climate variability and change, warranting greater attention to risk analysis and climate change information to ensure the long-term viability of the road and its ability to provide services even during extreme weather events.

ADAPTING TO CLIMATE CHANGE BY MINIMIZING VULNERABILITY THROUGH PROJECT DESIGN

Adaption to climate change through planning, design, and project execution involves ensuring that road infrastructure is able to withstand changes and variations in climatic conditions and extreme weather events such as heavy storms and heat waves. This involves incorporating within design the potential climate change effects on both the function and the purpose of the road (e.g., primary destinations), as well as the types of vehicles that will use it and the vulnerability of users (e.g., drivers and pedestrians).

Designers and project managers should incorporate information on climate change, looking at past baseline trends as well as mid-term projection scenarios (e.g., the next 25-50 years, where feasible). In many cases, managing for greater uncertainty and risk associated with potential extreme conditions rather than past historical trends emphasizes the **"no regrets" principle** over "**business as usual.**" This type of focus on risk analysis and management is commonly applied by the financial and insurance industries and can also be used in assessing proposed development activities.

Direct Impacts	Indirect Impacts	Possible Adaptation Responses
• Higher intensity heat waves make pavement soften and expand. • Heavy storms and flooding increase erosion, make the road impassible, increase maintenance costs, and reduce the life expectancy of the road	• Reduced access to transportation services • Poor quality road leads to more accidents	• Choose sites for new roads that are at lower risk of flooding • Design roads with increased drainage capacity; or, leave more room on the shoulder to increase drainage capacity later as needed • Choose materials that are less likely to be damaged by heat, or permeable pavement to reduce water pooling and flooding

From a **risk management** perspective, it is less costly to design for the potential direct and indirect impacts of climate change on roads and people now than to have the users risk paying the full cost of damages or face the loss of service in the future. For example, design and siting plans for roads near the sea or floodplains, rivers, and wetlands should take into account projected sea level rise and exposure to flooding from storm surge. Bridges and roads designed to withstand 100 year floods may now be at risk, as floods of that severity start to happen more frequently, especially in watersheds where rainfall patterns have shifted and soil erosion and deforestation are accelerating. Water (from rain and runoff) stresses roads, requiring more frequent maintenance and shortening the road's expected lifespan. In locations where annual average temperatures are rising, heat may cause pavement to soften, giving way to ruts and potholes, which worsen with increased traffic.

MINIMIZING GREENHOUSE GAS EMISSIONS AND MAXIMIZING SEQUESTRATION

Road construction contributes to greenhouse gas emissions from equipment use, the transport of materials and labor, and the production of materials. Removing vegetation that would otherwise act as a carbon sink also affects the stock of greenhouse gas in the atmosphere, and mechanical disturbance of soil or draining wetlands can release greenhouse gasses. Establishing new roads can also increase traffic and vehicle emissions, and lead to increased deforestation as people have more access to forested areas.

Greenhouse gas emissions from road construction can be reduced by taking steps to improve project energy efficiency. Emissions reductions can be achieved by requiring practices under contract that include procurement and sourcing of energy efficient equipment and materials; conserving electricity, fuel and renewable energy sources during construction and during operation and maintenance. Operations and maintenance specifications can require reducing equipment fuel use and idling times, applying regular equipment maintenance, training drivers, utilizing properly sized equipment, replacing or repowering equipment, switching to renewable fuel sources, and using alternatives to diesel generators.

In the practice of EIA, mitigation is the implementation of measures designed to eliminate, reduce or offset the potential adverse impacts of a proposed action on the environment.

In the practice of climate change, mitigation is an intervention to reduce GHG sources and emissions or to enhance the sequestration of GHG's by natural means (e.g., uptake by trees, vegetative cover, algae) or the use of technology (e.g., underground carbon storage) to limit the magnitude and/or rate of climate change.

Tree and ground cover removal for road construction or improvements can be addressed through compensatory tree-planting to replace vegetation lost from road-building activities. Road routing should consider land cover and soil types and the greenhouse gas emissions that would result from their removal and disturbance, including land cover change that may result from increased access. Limiting road access to undisturbed forest land and protected areas also helps maintain the benefits of natural atmospheric carbon sequestration by tress and other natural cover.

SECTOR PROGRAM DESIGN—SOME SPECIFIC GUIDANCE

When planning rural road improvement activities, engineering, ecological and social science expertise should be engaged at a minimum 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 can be provided during construction, operation, and maintenance.

One important aspect of road building is anticipating future development consequences. Here a road was built in a forested area, leading to in-migration and indiscriminant cutting for charcoal production.

Planning and design elements

It is particularly important to assess the need for, and purposes of, a new road. Some ways of accomplishing this are to:

- Estimate future demand for transport and road use
- Assess the long term impact of limiting building or reconstruction of a road
- Use professional hydrologists, engineers and social scientists in planning and assessing a project
- Follow land contours in road building
- Provide specifications for designing and maintaining drains
- Properly assess the need for construction and road-building materials from quarries, forests and "borrow pits"
- Train equipment operators and maintenance personnel
- Develop an erosion control plan for every project

PLANNING AND DESIGN

It is particularly important to evaluate the **need** for the road by assessing the **purposes** it will serve. For example, if the primary purpose is to transport produce from farm to market, approximate tonnages and seasonal transport patterns need to be identified. Then the costs and benefits of **potential alternatives** should be weighed. In some cases, transport by water, rail, bicycle or footpath may prove more practicable and desirable from an economic and environmental standpoint. Similarly, if the primary purpose is tourism, then road construction or rehabilitation should be weighed within the context of overall plans for the transportation network. In some cases, tourist roads can be re-routed to improve effects on scenic vistas (for example, by following contours, avoiding straight, highly visible stretches, creating more pleasing meandering tracks through woodlands, etc.). In other cases, building walking trails instead of roads can improve visitors' experiences and also provide greater protection to sensitive and valuable resources and ecosystems in protected areas.

Planning and design suggestions include:

- **Estimate future demand in order to decide on the type and size of road to be provided.** It is important to decide how many vehicles can be expected to move on the road and the approximate tonnage they will carry seasonally. This information is needed both to design the road to last and to balance environmental sustainability with human needs. Since roads also provide opportunity for people to move into an area, limiting the size of a road may be desirable for communities that desire to remain small or that have limited capacity to support a higher volume of people. Depending on the circumstances, this may be the most important design variable.

- **Conduct an ecosystem service valuation (ESV),** to estimate current ecosystem services and how different road development scenarios will impact those ecosystem services in the long term. Assessing the value of current and projected ecosystem services allows a holistic view of potential social and environmental impacts. Over a 20 or 30-year period, these impacts, such as decreased agricultural land or increased deforestation, may prove cumulative and highly significant. Estimating the impacts of different development scenarios on ecosystem services will help reveal the most harmful effects to be avoided or mitigated.

- **In the context of the above costs, assess the long-term impact of the road against the "no-action" alternative**, since road improvements can have many direct and indirect effects on the environment. Over a 20- or 30-year period, these impacts, such as increased agricultural expansion or deforestation, may prove cumulative and highly significant. Ancillary developments can be expected, including gas stations, restaurants, hotels, markets, shops, retail stores and bars. In the case of road improvements associated with protected areas, a long-term benefit can be an increase in revenues for the protected area management systems from consumptive uses (e.g., getting food and shelter) and non-consumptive ones (e.g., sightseeing). However, these must be balanced against the potential damage to sensitive ecosystems and biodiversity.

- **Ensure that professional hydrologic and engineering studies are done first**, to avoid potentially adverse impacts on soils, to minimize possible effects on surface or sub-surface water resources, to ensure correct design of drainage structures and systems, and to reduce the potential for damage from unusually heavy rains and floods, including the rare but catastrophic kind known as "100-year floods." These studies should take into account anticipated changes in the climate, which can increase weather variability and the frequency and intensity of extreme rainfall. Avoid problematic areas such as springs, wetlands, landslides, steep canyons, flood plains and large rock outcrops. Be sure to involve hydraulic and geotechnical specialists in planning expensive and high-risk structures such as bridges, retaining walls and slide stabilization structures.

- **Require that road designs follow contours** and minimize harm to scenic vistas where feasible.

- **Write construction specifications that will reduce maintenance needs.** Provide specifications for road design that will keep water off road surfaces, such as use of camber and turnout drains. Also, ensure that specifications cover the quantity of road construction material needed and its potential sources, based on the quantity and quality of material at various sites. Prepare quarry and borrow pit management plans that identify locations, specify amounts to be removed from each site, and provide specific instructions for reclamation at each site. Quarries and pits are often left unclosed because the planners never decided how much of each resource should be used and thus never prepared a plan for phased closure. Develop these plans in consultation with affected stakeholders. (**Note:** The maintenance of a rural unpaved road for 20 years or more can require extensive use of road material, and unplanned use of quarries and borrow pits can cause very significant harm over time.)

- **Provide for training of equipment operators and road works 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.
- **Ensure that road designs protect vulnerable road users** such as cyclists; disabled, senior, and injured citizens; and pedestrians in general. Implement "low speed zones" and non-interrupted walkways or refuge medians where necessary or feasible.

Upgrading this rural road in Zambia will require elevating the roadbed across a wetland area, adversely affecting local water flow. Could USAID funds still be used for this project?

CONSTRUCTION[1]

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.

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, 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.

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,

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

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, or areas that are expected to be inundated in the future by sea level rise, 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.

OPERATION AND MAINTENANCE

The main goal of environmentally sound road maintenance is to keep the road in working condition and minimize environmental damage. Good road maintenance practices that keep the road usable and durable, such as clearing drainage structures and restoring camber, will minimize much of the environmental damage the road might cause. Other practices, such as proper management of petrol and oil from equipment, are also necessary for optimal environmental protection.

Special areas for consideration

Maintenance and operation are the areas where the most adverse impacts of road projects occur. Be sure to train all equipment operators in the environmentally sound operation of their machinery. Maintenance personnel should be? trained to maintain the roadway in a manner that prevents erosion and damage to water and natural resources.

Decommissioning is also an important aspect of a road project. Old roads should be blocked to prevent their continued use, or "ripped" to encourage re-vegetation.

The day-to-day work of road maintenance involves adjusting road surface and drainage structures to control the flow of water over and alongside the road, clearing vegetation, maintaining vehicles, and managing road use and user behavior.

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.

Accomplishing these tasks effectively requires a good management plan and well-trained and equipped road works personnel. *When adequately funded,* these elements together can ensure that roads remain in good condition and minimize environmental damage.

POOR OR INADEQUATE MAINTENANCE—A PRIMARY CAUSE OF ENVIRONMENTAL DAMAGE FROM UNPAVED ROADS

Environmental damage from unpaved rural road construction is frequently the effect of insufficient or poor quality maintenance. These in turn stem from poorly or incompletely trained maintenance personnel, broken or incorrect equipment, or lack of regular maintenance schedules. To succeed, a maintenance program for rural unpaved road must therefore:

Provide timely, comprehensive, regular training to equipment operators. Operators should be given good training and frequent refresher courses on correct and environmentally sound use of their equipment.

Purchase appropriate, maintainable equipment, apply preventive maintenance, and keep mechanics trained and equipped; consider using manual labor as an alternative. Too often in road maintenance operations, projects are underfunded and go over the time initially budgeted for the project, and most heavy road equipment is broken. If equipment is not available when needed, roads may incur heavy, costly damage. To keep equipment in working order:

- Only purchase equipment in good condition and suited to the types of tasks it will be used for. It should be of the correct size, purpose and durability and of a brand and model for which replacement parts are readily available and can be afforded by the maintenance budget.
- Carry out regular preventive maintenance by keeping records on use, stocking a full array of tools, hoists, spare parts, etc., and hire mechanics who can read and understand foreign technical equipment manuals. Alternatively, if possible, contract with a private firm to perform preventive maintenance.
- Provide sufficient funding for operation and repair. Account for recurring costs and assign funds to cover them in the annual budget.
- An alternative approach is to use local manual labor and hand tools for road maintenance instead of heavy equipment. In some cases this may be both practical and economical, and it avoids the problems associated with heavy equipment. Hand labor–based methods also create employment opportunities, often enhance workers' skills, and can improve economic conditions in their home towns and nearby communities. Building local capacity in this way may make sustained maintenance of the road truly achievable.

Develop and follow a good management plan. A good management plan, and the annual work plans derived from it, should encompass a number of elements and specific timetables. The issues covered by the management plan should include timelines for maintaining sections of the road network; a schedule for introductory and refresher training for equipment operators and mechanics, as well as a list of topics to be covered in the training; and, possibly, a schedule and instructions for routine maintenance of equipment. These timelines should consider whether changes will be needed in maintenance practices or timing based on changes in climate over the road's intended lifetime.

OTHER SOURCES OF ENVIRONMENTAL DAMAGE

The overall management plan must also address other sources of environmental damage associated with building and maintaining rural roads. This can include but is not limited to:

Maintaining vehicles. Dumping and spillage of hazardous fluids generated during vehicle maintenance, such as used oil, petrol and solvents, is a common problem. It can be avoided by training staff in sound practices and installing correctly designed maintenance structures such as concrete pads for vehicle servicing. Equipment operators and mechanics should receive training in the safe storage, use and disposal of fuel, lubricants, solvents and other chemicals.

Off-road driving and out-of-season road use. A great deal of off-road driving near existing roads results from drivers' attempts to avoid deep ruts and flooding in the official roadway. Regular, correct maintenance of the road surface and drainage system will minimize this problem by preventing the flooding and the expansion of ruts. Wet-season traffic on roads designed only for dry-season use can severely damage the road surface and promote erosion. Closure and enforcement are the recommended management measures, but they often provoke off-road driving. The best solution, if there is a significant demand during rainy seasons, is to upgrade the road for wet use.

Invasive plants. When planning new roadways local experts should be consulted regarding the restoration of construction areas and plantings on road shoulders to prevent the introduction of non-native species. Attention also needs to be paid to ensuring that crews are trained in the early removal of exotic plant species that have been accidentally (e.g., transported on road machinery) or otherwise introduced, and preservation of native plants, especially when roads pass near or within protected areas.

Quarries and borrow pits. Extraction of road materials from quarries and borrow pits must be closely supervised, and procedures for reclamation, which should have been prepared during the planning and design stage, must be carefully followed

HIV/AIDS and other diseases. Road crew members from other geographic areas can spread various health problems, especially HIV/AIDS and other sexually transmitted infections (STIs), to local populations. To protect both employees and local residents, road maintenance projects should implement HIV-prevention programs that focus on changing risky behaviors and the parts of organizational culture that encourage them, by encouraging condom use, teaching how HIV is spread and how to reduce STIs, promoting tolerance of HIV-infected individuals, and encouraging voluntary testing. Three common and relatively inexpensive first steps are to provide regular HIV/STD awareness training, condom use education, and easily accessible free condoms. Sources of more detailed guidance can be found in this guide's References and Useful Resources section.

DECOMMISSIONING

Re-alignment of an existing road is not uncommon 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 continuing use. In some cases the old surface must be scraped for drainage or "ripped" to encourage revegetation.

A well-designed decommissioning plan helped a Zambian landowner and a road construction company convert a construction camp into a hotel complex.

ENVIRONMENTAL MITIGATION AND MONITORING ISSUES FOR RURAL ROADS PROJECTS

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)*
PLANNING AND DESIGN IN GENERAL (NEW AND EXISTING ROADS)		
Identification and weighing of alternatives		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, threatened species, or along possible routes. Conducting an ESV can help identify areas of ecological and social value that will be impacted by different development scenarios (P&D).
Establishing design standards	Damage valuable ecosystems, their services, and habitats. Damage valuable historic, religious, cultural, and paleontological resources Change local culture and society Cause soil erosion Degrade water quality and/or alter hydrology Mar scenic views Lead to injury, disease, or death of workers, and local residents	Choose or develop design standards for each facet of construction and related activities, e.g., road bed, road surface drainage, culvert installation, erosion control, re-vegetation, stream crossing, sensitive areas, steep slopes, material extraction, transport and storage, construction camps, decommissioning, etc. (P&D) Provide plans to identify and protect sensitive habitats as well as ecosystem services (P&D) Take patterns of local weather and natural phenomena into account, e.g., fog, flooding, earthquakes, heavy rain, mudslides, drought, etc. (P&D) Take predicted climate changes into account, e.g. intensification of extreme events, sea level rise, higher temperatures, etc. Develop an Erosion Control Plan for all projects (P&D)
Planning route	Damage valuable ecosystems and habitats Damage valuable historic, religious, cultural, and paleontological resources	Have a multidisciplinary team involved in planning new routes. Ideally the team will include an ecologist, geotechnical and road engineer, soil scientist, hydrologist and other relevant professionals, such as an archeologist or tourism specialist (P&D) Conducting an ESV can help identify areas of ecological and social value that will be impacted by different routes (P&D)

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)*
	Change local culture and society Cause soil erosion Degrade water quality Alter hydrology Contribute to deforestation and eliminate carbon sinks Mar scenic views	Avoid routing road through sites of known paleontological, archeological, historic, religious or cultural significance as well as sites with potential to damage ecosystem services and sensitive habitats (P&D) Avoid routing across agriculturally productive soils (P&D) Avoid routing road through places that currently experience or are predicted to experience intensive degradation (through heavy heat waves, flooding, sea level rise) due to climate changes Take problem areas involving soil and slope stability into account. Note seasonal and long-term (50- and 100-year) flooding patterns (P&D) Whenever possible, site roads to follow hill contours (P&D, C) Avoid creating road grades of greater than 10% as well as long straight downhill stretches (P&D) (C) Identify sites for temporary/permanent storage of excavated material and construction materials. If excavated material will not be reused, decide how it will be disposed of or shaped (P&D) (C) Keep the route a safe distance from river and stream banks (P&D) Avoid environmentally sensitive areas, such as wetlands, and places near protected areas or relatively pristine forests. Explore possible “compromise” alternatives such as building a narrow, improved trail across protected area lands to provide access on foot, bicycle or motorcycle, with construction of main access roads around these areas (P&D) (C) Avoid constructing roads through forest areas, especially primary or intact forest. If clearing is unavoidable, protect or restore forests elsewhere within the drainage basin as close as possible to those that were lost (P&D) Minimize impacts on viewsheds (scenic landscapes) by avoiding planning roads that cut long straight paths across valleys and plains. Instead, hide roads beneath forest cover to minimize aesthetic damage, and provide meanders where feasible (P&D) Avoid siting roads that may disturb animal behavior such as feeding, mating, and migration patterns (P&D)

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)*
		If sensitive areas cannot be avoided, involve ecologists and engineers in designing road, construction camp, quarries and other areas. (P&D) (C)
Constructing road surface	Increase sedimentation Cause discomfort to road users	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 (see figure 3-1.2) (P&D) (C) Clearly define the type of road surface shape and drainage method—insloped, outsloped, or cambered/crown roadway—to be used for each section of roadway (see figures 3-1.2 - 3-1.5 for examples of cambered roadway) (P&D) (C)
Drainage	Cause soil erosion Degrade water quality Alter hydrology Damage valuable ecosystems and habitats	Install drainage structures during construction rather than after construction. Most erosion associated with roads occurs in the first year after construction. Delaying installation of the drainage features greatly increases the extent of erosion and damage during the first year (P&D) (C) Factor climate change scenarios into the analysis of the drainage capacity that will be needed Clearly define the type of road surface shape and drainage method—insloped, outsloped, or crown roadway—to be used for each section of roadway. Use outside ditches to control surface water when necessary, but avoid general use, as they concentrate water flow and require the road to be at least a meter wider. Install frequent structures, such as berms or ditches , to divert water off the road before it directly reaches live stream channels (see figure 3-1.2 and 3-1.4) (P&D) (C) Install frequent 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 the uphill to the downhill side. If using culvert pipes, at least roughly design them before or during construction. Use either the Rational Formula or back-calculation using Manning's Formula and high-water mark data to determine the anticipated flow. This will allow you to roughly determine the

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)*
		correct pipe sizes. Where flows are difficult to determine, use structures such as fords, rolling dips, and overflow dips that can accommodate any volume of flow and are not susceptible to plugging (P&D) (C) Stabilize outlet ditches (inside and outside) with small stone riprap and/ 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 by looking for accumulation of water on road surfaces. Do this immediately after first heavy rains and again at the end of the rainy season. Institute appropriate corrective measures as necessary (C)
Perennial and intermittent rivers and streams	Risk destruction of bridge by 50-or 100-year flood Cause damming and resultant meandering of stream which destroys neighboring sections of roadway, dwellings and/or native flora and fauna	Construct drifts rather than bridges, where feasible and cost-effective. Since 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 using a design, such as a Bailey Bridge, that can be erected and dismantled so if the waterway meanders, the structure can be moved to another site (P&D) (C) Try “training” rivers and streams to follow desired channels by selectively removing debris. However, any channel changes should be minimized. Use a combination of hand labor and small machinery. Careful and selective bulldozing may be feasible in some cases. However, bulldozer tracks can easily expose soil to erosion and do more harm than good (P&D) (C)
Wetlands	Degrade wetland, damaging the valuable ecosystems and habitats Alter hydrology	Avoid routing through these areas (see “Planning route” above for additional guidance) (P&D) Minimize cuts and/or fills and compensate for impact by protecting other wetlands (P&D) (C) Take special precautions to prevent release or dumping of debris, oil, fuel, sand cement

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)*
		and similar harmful materials (C) Use elevated porous fills (rockfills) and/or multiple pipes to maintain natural flow patterns of groundwater and near-surface water (C)
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 geotextiles (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 ¾:1 to 1:1 slope to promote plant growth. Vertical cuts are acceptable in rocky material and in well-cemented soils (P&D) (C) Install drainage ditches or berms on up-hill slope to divert water away from road and into streams (see figure 3-1.4) (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, which is much less prone to erosion (P&D) (C) If very steep sections cannot be avoided, provide soil stabilizers or surface with asphalt/concrete (P&D) (C)
Construction contracts	Cause all types of damage mentioned	Select or develop guidelines and procedures to be applied to each facet of road construction, and incorporate them into contracts with construction companies. These will apply, for example, to site clearing; bed and surface construction; drainage; fuel and materials usage; quarry site management; and procedures for operating construction camp and work site, including procedures addressing worker safety Include incentives for adhering to guidelines and penalties for violating them

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)*
Maintenance agreements	Cause all types of damage mentioned	Finalize maintenance agreements with local communities **before** beginning construction. All parties must clearly understand and be committed to the 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 (RECONSTRUCTION/REPAIR/REALIGNMENT)		
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 and/or alter hydrology Mar scenic views Lead to injury, disease, or death of workers, and local residents	Choose or develop design standards for each facet of construction and related activities, e.g., road bed, road surface drainage, culvert installation, erosion control, revegetation, stream crossing, sensitive areas, steep slopes, material extraction, transport and storage, construction camps, decommissioning, etc. (P&D) Conducting an ESV can help identify areas of ecological and social value that will be impacted by different routes (P&D) Provide plans to identify and protect sensitive habitats (P&D) Take patterns of local weather and natural phenomena into account, e.g., fog, flooding, earthquakes, heavy rain, mudslides, drought, etc. (P&D) Develop an Erosion Control Plan for all projects (P&D)
Planning route	Damage valuable ecosystems and habitats Damage valuable historic, religious, cultural, and paleontological resources Change local culture and society	Have a multidisciplinary team involved in planning new routes. Ideally the team will include an ecologist, geotechnical and road engineer, soil scientist, hydrologist and other relevant professionals, such as an archeologist or tourism specialist (P&D) Avoid routing road through sites of known paleontological, archeological, historic, religious or cultural significance (P&D) Avoid routing across agriculturally productive soils (P&D) Take problem areas involving soil and slope stability into account. Note seasonal and

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)*
	Cause soil erosion Degrade water quality Alter hydrology Contribute to deforestation and greenhouse gas emissions Mar scenic views	long-term (50- and 100-year) flooding patterns (P&D) Whenever possible, site roads to follow hill contours (P&D, C) Avoid creating road grades of greater than 10% as well as long straight downhill stretches (P&D) (C) Identify sites for temporary/permanent storage of excavated material and construction materials. If excavated material will not be reused, decide how it will be disposed of or shaped (P&D) (C) Keep the route a safe distance from river and stream banks (P&D) Avoid environmentally sensitive areas, such as wetlands, and places near protected areas or relatively pristine forests. Explore possible “compromise” alternatives such as building a narrow, improved trail across protected area lands to provide access on foot, bicycle or motorcycle, with construction of main access roads around these areas (P&D) (C) Avoid constructing roads through forest areas, especially primary and intact forest, if possible. If clearing is unavoidable, protect or restore forests elsewhere within the drainage basin as close as possible to those that were lost (P&D) Minimize impacts on viewsheds (scenic landscapes) by avoiding planning roads that cut long straight paths across valleys and plains. Instead, hide roads beneath forest cover to minimize aesthetic damage, and provide meanders where feasible (P&D) Avoid siting roads where they may disturb animal behavior such as feeding, mating, and 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)
Constructing road surface	Increase sedimentation Cause discomfort to road users	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 (see figure 3-1.2) (P&D) (C) Clearly define the type of road surface shape and drainage method—insloped,

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)*
		outsloped, or cambered/crown roadway—to be used for each section of roadway (see figures 3-1.2 - 3-1.5 for examples of cambered roadway) (P&D) (C)
Drainage	Cause soil erosion Degrade water quality Alter hydrology Damage valuable ecosystems and habitats	Install drainage structures during construction instead of after construction. Most erosion associated with roads occurs in the first year after construction. Delaying installation of the drainage features greatly increases the extent of erosion and damage during the first year (P&D) (C) Factor climate change scenarios into the analysis of the drainage capacity that will be needed Clearly define the type of road surface shape and drainage method—insloped, outsloped, or crown roadway—to be used for each section of roadway. Use outside ditches to control surface water when necessary, but avoid general use, as they concentrate water flow and require the road to be at least a meter wider. Install frequent structures, such as berms or ditches , to divert water off the road before it directly reaches live stream channels (see figure 3-1.2 and 3-1.4) (P&D) (C) Install frequent 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 the uphill to the downhill side. If using culvert pipes, at least roughly design them before or during construction. Use either the Rational Formula or back-calculation using Manning's Formula and high-water mark data to determine the anticipated flow. This will allow you to roughly determine the correct pipe sizes. Where flows are difficult to determine, use structures such as fords, rolling dips, and overflow dips that can accommodate any volume of flow and are not susceptible to plugging (P&D) (C) Stabilize outlet ditches (inside and outside) with small stone riprap and/ 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)

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)*
		Visually spot-check for drainage problems by looking for accumulation of water on road surfaces. Do this immediately after first heavy rains and again at the end of the rainy season. Institute appropriate corrective measures as necessary (C)
Perennial and intermittent rivers and streams	Risk destruction of bridge by 50-or 100-year flood Cause damming and resultant meandering of stream which destroys neighboring sections of roadway, dwellings and/or native flora and fauna	Construct drifts rather than bridges, where feasible and cost-effective. Since periodic replacement or reconstruction of damaged bridges and culverts can be costly, involve hydraulic engineers in bridge designs (P&D) (C) Factor climate change scenarios into the analysis of severity of 50-or 100-year floods. When constructing a bridge, consider using a design, such as a Bailey Bridge, that can be erected and dismantled so if the waterway meanders, the structure can be moved to another site (P&D) (C) Try “training” rivers and streams to follow desired channels by selectively removing debris. However, any channel changes should be minimized. Use a combination of hand labor and small machinery. Careful and selective bulldozing may be feasible in some cases. However, bulldozer tracks can easily expose soil to erosion and do more harm than good (P&D) (C)
Wetlands	Degrade wetland, damaging the valuable ecosystems and habitats Alter hydrology	Avoid routing through these areas (see “Planning route” above for additional guidance) (P&D) Minimize cuts and/or fills and compensate for impact by protecting other wetlands (P&D) (C) Take special precautions to prevent release or dumping of debris, oil, fuel, sand cement and similar harmful materials (C) Use elevated porous fills (rockfills) and/or multiple pipes to maintain natural flow patterns of groundwater and near-surface water (C)
Sloped areas and raised roads	Cause soil erosion Degrade water quality Alter hydrology Damage valuable	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 geotextiles (fabrics) where feasible and appropriate (P&D) (C)

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)*
	ecosystems and habitats	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 ¾:1 to 1:1 slope to promote plant growth. Vertical cuts are acceptable in rocky material and in well-cemented soils (P&D) (C) Install drainage ditches or berms on up-hill slope to divert water away from road and into streams (see figure 3-1.4) (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, which is much less prone to erosion (P&D) (C) If very steep sections cannot be avoided, provide soil stabilizers or surface with asphalt/concrete (P&D) (C)
Construction contracts	Cause all types of damage mentioned	Select or develop guidelines and procedures to be applied to each facet of road construction, and incorporate them into contracts with construction companies. These will apply, for example, to site clearing; bed and surface construction; drainage; fuel and materials usage; quarry site management; and procedures for operating construction camp and work site, including procedures addressing worker safety Include incentives for adhering to guidelines and penalties for violating them
Maintenance agreements	Cause all types of damage mentioned	Finalize maintenance agreements with local communities **before** beginning construction. All parties must clearly understand and be committed to the 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 (RECONSTRUCTION/REPAIR/REALIGNMENT)		
All projects		Use a "clean slate" approach, i.e., consider realigning all existing minimal/informal roads to follow contours and avoid sensitive areas (P&D) Ensure that designs incorporate near-term projections for climate, or at a minimum, factor in greater climate uncertainty about the timing and frequency of extreme events (P&D)

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 surface is below grade of surrounding road	Cause soil erosion Degrade water quality Alter hydrology	Raise road surface with stable fill material. Grade with inslope, outslope or cambered shape. Install sufficient cross-drains, ditches and settling ponds (Figure 3-1.1 and 3-1.2) (P&D) (C) (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 the cause is heavy use, either find a means of reducing traffic or upgrade road to a more durable surface (gravel, asphalt, or concrete) (Figure 3-1.6) (P&D) (C) (O&M)
Drivers drive at excessively high speeds	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 valuable ecosystems and habitats	Generally caused by either muddy/flooded roadway or highly deteriorated roadway. Maintain or upgrade road so road 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 or relocated	Prevent vegetation from regenerating at or near location of former road surface	Remove surface if necessary and loosen soil of previous track (to accelerate regeneration of vegetation). Block access with rocks, branches, roadblocks and signs. Narrow tracks will usually revegetate naturally with no noticeable scars or impact on the environment. Wider roads may require active planting and reseeding (C) (O&M)
CONSTRUCTION		
Construction camp and crew	Damage local habitat, compact soil and create erosion via building and occupation of construction camp	Explore off-site accommodation for crew. Avoid wet, muddy sites (P&D) (C) Keep camp size to a minimum. Require that crew preserve as much vegetation as possible, e.g., by creating defined foot paths. Define areas of use (with rocks or fencing) (P&D) (C)

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)*
	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 members who come from outside the region Introduce alcohol or other socially destructive substances via construction crew Generate trash due to lack of solid waste management Adversely affect local fauna and flora (especially game and fuelwood) via poaching and collection by construction crews	Provide potable water for crew (O&M) Provide temporary sanitation on site, e.g., VIP latrine (assuming the water table is low enough and soil and geology is of appropriate composition) (also consult "Water Supply and Sanitation" in this volume). Where this is not possible, instruct road crews to employ soil mining (digging a pit for human waste and covering with soil immediately after use) (P&D) (C) Use local or regional labor, if possible. Provide hygiene and public health training to road crews, including information about transmission 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. Dispose of waste in local dump or landfill. If this is not possible, sell recyclables for reuse/recycling, place organic wastes in well-screened waste pits, covering with soil weekly, bury the remainder (excluding toxic materials). (Also consult "Management of solid waste from residential, commercial and industrial facilities" in this volume) Set guidelines prohibiting the poaching and collection of plants/wood, with meaningful consequences for violation, such as termination of employment. Provide enough food and cooking fuel; both should be of good quality (C) Restore site through revegetation and similar measures after camp is broken down (C) Test grade drivers' ability to follow grade, slope, and contour design standards. Train if necessary (P&D) (C) Test the ability of bulldozer drivers and other equipment operators to properly maintain drainage structures. Train if necessary (P&D) (C) Test road crew's ability to keep roads clear of vegetation with least adverse environmental impacts. Train if necessary (P&D) (C) Provide workers with appropriate safety equipment, e.g., earplugs or headgear 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

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)*
Use of heavy equipment and hazardous materials	Cause erosion due to machinery tracks, damage to roads, stream banks, etc. Compact soil, changing surface and groundwater flows and adversely affecting future use for agriculture Contaminate ground or surface water when (1) machinery repairs result in spill or dumping of hydraulic oil, motor oil or other harmful mechanical fluids; and (2) hazardous construction materials 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 an impervious surface such as plastic sheeting. Prevent dumping of hazardous materials. Capture leaks or spills with drop cloths or wood shavings. Burn waste oil **if** it is not reusable/readily recyclable, does not contain heavy metals and is 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 levels deliveries and use, (b) checking pipes and joints for leaks, (c) tightening generator fuel lines, and (d) preventing over-filling of main storage and vehicle tanks (C) (Also consult "Activities with Micro and Small Enterprises (MSEs)" in this volume)
Materials 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	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 fairly suitable, durable aggregate for either embankment fill or surface stabilization material. Local borrow material can be very cost-effective. Upon removal of material, the area should be restored and receive erosion control measures (P&D) (C) Develop logging, quarrying and borrowing plans that take into account cumulative effects (P&D) If possible, avoid extracting from or damaging areas that provide valuable ecosystem

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)*
	active or abandoned quarries or borrow pits and breeds insect vectors Take land out of other useful production The quarry may become a safety hazard	services, as revealed by an ESV (P&D). Take photos of site before initiating excavation, so that 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 practices. Modify as necessary (C) (O&M) Decommission/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, as well as 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, include reseeding or revegetation 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 watering cattle, irrigating crops or similar uses. Highlight issues of disease transmission and the need to prohibit its use for drinking, bathing, and clothes washing (P&D) (C) (O&M)
Storing materials	Deplete water resources Damage valuable ecosystems and habitats	Pre-wet gravel when water is more available (i.e., not during dry season) and store gravel in a way that will keep it wet, e.g., covered with plastic sheeting (P&D) (C) When siting storage areas, avoid using sensitive areas or sites that drain directly into a sensitive area (P&D) (C)

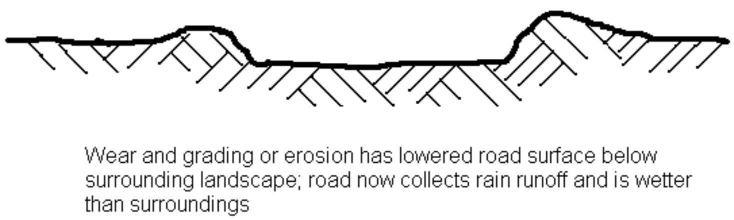
ACTIVITY	IMPACT *The activity may. . .*	MITIGATION *Note: Mitigations apply to specified project phase: Planning and Design (P&D), Construction (C), or Operation and Maintenance (O&M)*
Site clearing and/or leveling	Damage or destroy sensitive terrestrial ecosystems Produce areas of bare soil which cause erosion, siltation, changes in natural water flow, and/or damage to aquatic ecosystems	Minimize disturbance of native flora (vegetation) during construction. Minimize the amount of clearing. Clear small areas for active work one at a time (P&D) (C) Avoid damaging areas that provide valuable ecosystem services, as revealed by an ESV (P&D). Avoid use of herbicides. Any use should follow health and safety procedures to protect people and the environment. At a minimum, herbicides should be used according to manufacturer's specifications (C) Where possible, remove large plants and turf without destroying them, and preserve them for replanting in temporary nurseries (P&D) (C) Move earth and remove vegetation only during dry periods. Store topsoil for respreading. 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) Revegetate with recovered plants and other appropriate local flora immediately after equipment is removed from a section of the site (C)
Excavation	Cause erosion, siltation, changes in natural water flow, and/or damage to aquatic ecosystems when excavated soil is piled inappropriately Expose inhabitants and crew to risk of falls and injuries in excavation pits Deprive down-gradient populations and ecosystems of water if upper regions of aquifer	Cover pile with plastic sheeting; prevent run off with hay bales or similar measures (P&D) (C) Place fence around excavation (P&D) (C) Investigate alternatives, such as shallower excavation and no excavation (P&D) "Avoid excavating areas that provide valuable ecosystem services, as revealed by an ESV (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 or theft.(P&D) (C) Ensure that excavation is accompanied by well-engineered drainage (P&D) (C)

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)*
	are blocked	
Filling	Block water courses when fill is inappropriately placed Destroy valuable ecosystems when fill is inappropriately placed Cause later land subsidence or landslides when fill is inappropriately placed, causing injuries and damages.	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) Avoid filling areas that provide valuable ecosystem services, as revealed by an ESV (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 example, do not use soil alone; first lay a bed of rock and gravel (P&D) (C) Balance the cuts and fills (to minimize earthwork movement) whenever possible.
Cutting and filling	Cause soil erosion Degrade water quality Alter hydrology Damage valuable ecosystems and habitats	Test grade driver’s ability to follow design standards for grades, slopes, and contours. Train if necessary (P&D) (C)
Compacting to improve road materials performance	Deplete freshwater resources	Water the road immediately before compacting it to strengthen the road surface. (Otherwise, traffic will soon beat back the road surface to pre-bladed condition) (P&D) (C) When possible, delay compaction activities until the beginning of the wet season or when water becomes more available (P&D) (C)

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)*
Blasting	Cause soil erosion Degrade water quality Alter hydrology Damage valuable ecosystems and habitats	Minimize blasting (P&D) (C) Avoid blasting in areas that provide valuable ecosystem services, as revealed by an ESV (P&D) Take safety precautions to protect workers and others from being injured by flying or falling rock and avalanches (P&D) (C)
Design verification Quality control		Conduct independent inspections of work periodically 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 to remove ruts, potholes, washboarding, standing water and materials blocking road	Create gulleys and standing pools Create mud holes, potholes Breed disease vectors in settling basins and retention ponds	Monitor and maintain drainage structures and ditches, including culverts. Clean out culverts and side channels/runout (leadoff ditches) 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)	(See "Construction camp and crew" above)
Use and maintenance of equipment	(See "Use of heavy equipment and hazardous materials" above)	(See "Use of heavy equipment and hazardous materials" above) Install concrete pads, drains and oil/water separators in areas where vehicle and

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)*
		equipment maintenance and fueling will occur regularly
DECOMMISSIONING		
Decommissioning	Cause soil erosion Degrade water quality Damage valuable ecosystems and habitats	Break up old road surface and soil. Remove and dispose of surfacing material (e.g., asphalt) if necessary, and loosen soil of previous track (to accelerate regeneration of vegetation) Reshape eroded or culled surfaces with outsloping, or add cross-drains or water bars so that water will no longer follow the course of the roadway (See fig. 3-1.1) Revegetate as needed. Narrow tracks will usually revegetate naturally with no noticeable scars or impact on the environment. Wider roads may require active planting and reseeding (O&M) Block access with rocks, branches, roadblocks, waterbars and signs.

Typical Existing Road Section



Typical Proposed Road Cross Section

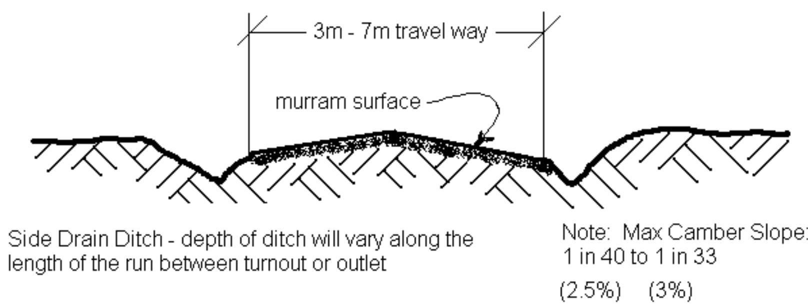
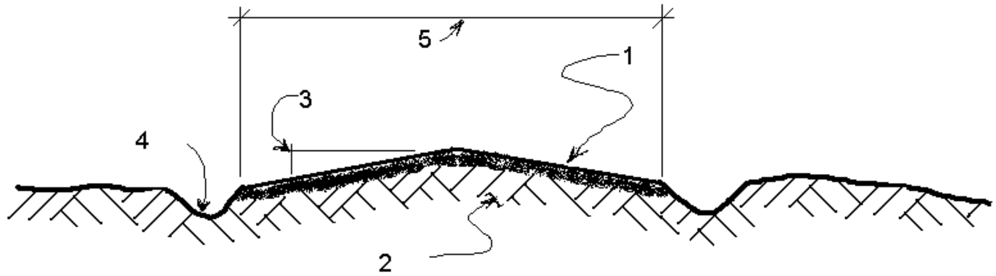


Figure 3-1.1 and 3-1.2

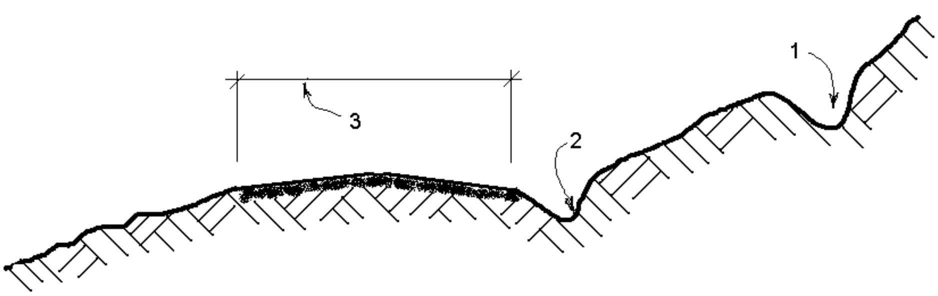
Cross Section of a Gravel Road



KEY
1 - Layer of murram; thickness of murram layer depends on soil type at site
2 - Subgrade
3 - Cross-slope 1 in 33 to 1 in 40
(3%) (2.5%)
4 - Side drain ditches
5 - Traveled way; width depends on the class of road

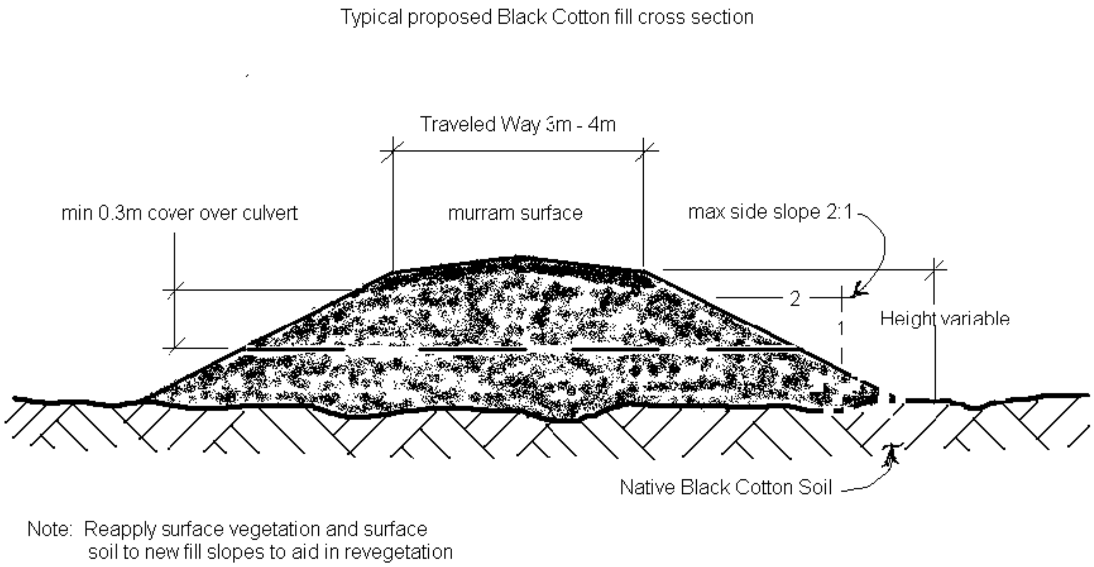
Drainage in Hilly Roads Cross Section

Key
1 - Water catchment ditches/drains
2 - Side ditch drain
3 - Traveled way

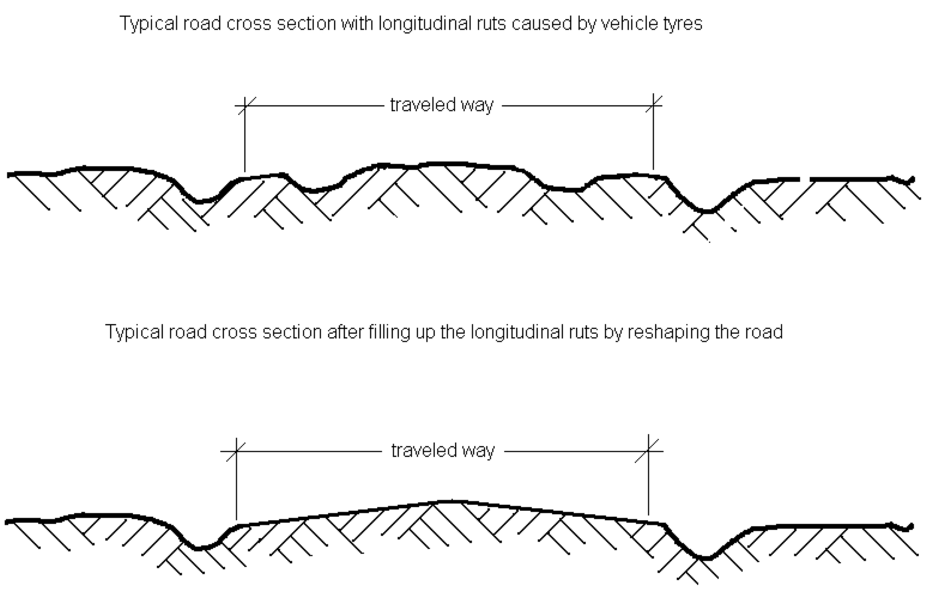


Figures 3-1.3 and 3-1.4

Raised Road Embankment



Longitudinal Ruts Correction



Figures 3-1.5 and 3-1.6

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  The guide also has an extended bibliography for readers in need of more depth or detail regarding specific issues and applications. In addition to the topics listed below, the extended bibliography offers references for hydrology for drainage crossing design; tools for hydraulic and road design including Manning's Formula, riprap, filters, and the use of geosynthetics; general considerations for drainage of low-volume roads; fords and low-water crossings; physical, vegetative and biotechnical methods of erosion control; and stabilization of gullies. The extended bibliography can be found at http://ntl.bts.gov/lib/24000/24600/24650/Chapters/Q_Selected_References.pdf.

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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.

- Oregon Department of Forestry (2000). *Forest Roads Manual*. Forest Engineering Coordinator, State Forests Program, Oregon Dept. of Forestry, Salem, OR (503-945-7371). http://www.oregon.gov/ODF/STATE_FORESTS/Roads_Manual.shtml

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- Australian Road Research Board Limited (2009). *Unsealed Roads Manual: Guidelines to Good Practice*. Vermont, South Victoria, Australia. 3rd Edition. Available to order at http://www.arrb.com.au/Information-services/Publications/Reports-Manuals/Pavements.aspx

  A useful manual for gravel road design and maintenance, particularly in semi-arid regions.

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  A useful field guide to road closure and obliteration, with great photos and figures.

- Lesbarreres, D. and L. Fahrig (2012). *Measures to reduce population fragmentation by roads: what has worked and how to we know?* Trends in Ecology & Evolution. Vo.. 27. Issue 7. P. 374-380 http://www.sciencedirect.com/science/article/pii/S0169534712000341

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- Normann, J.M., R.J. Houghtalen and W.J. Johnston (1985) (Reprinted 1998). Hydraulic Design of Highway Culverts. Hydraulic Design Series No. 5. Tech. Rep. No. FHWA-IP-86-15 HDS 5. September. McLean, VA: Department of Transportation, Federal Highway Administration, Office of Implementation. 265 p. http://www.fhwa.dot.gov/engineering/hydraulics/pubs/hds5si.pdf

  Includes a comprehensive design for both conventional culverts and culverts with inlet improvements.

BRIDGE LOCATION AND DESIGN FACTORS

- American Association of State Highway and Transportation Officials (2002). Standard Specifications for Highway Bridges (17th Edition). ISBN Number: 1-56051-171-0 Available for purchase at: https://bookstore.transportation.org/item_details.aspx?ID=51

  Covers the design of wood, steel, and concrete bridges, as well as structural plate structures.

- Larcher, P. Low Cost Structures for Rural Roads: A Review of Existing Books, Manuals, and Design Guides.

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  Covers the analysis and design of a wide variety of retaining walls.

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  Covers the products available, how they work, selecting the product, and the product's environmental impacts.

HIV/AIDS PREVENTION

- HEARD - Health Economics and HIV/AIDS Research Division, University of Natal, Durban, RSA. http://www.heard.org.za/

  Provides toolkits, presentations, publications, links, statistics and more.

- Rau, B. 2002. Workplace HIV/AIDS Programs: An Action Guide for Managers. Family Health International. 85 p. http://www.fhi.org/en/HIVAIDS/pub/guide/Workplace_HIV_program_guide.htm

CLIMATE CHANGE RESOURCES

Note: USAID's Global Climate Change (GCC) Office can provide support on the climate change aspects of this Guideline. To contact the GCC office, please email: climatechange@usaid.gov

- USAID. 2007. Adapting to Climate Variability and Change: A Guidance Manual for Development Planning. http://pdf.usaid.gov/pdf_docs/PNADJ990.pdf

- USAID. 2009. Adapting to Coastal Climate Change: A Guidebook for Development Planners. http://pdf.usaid.gov/pdf_docs/PNADO614.pdf

  The guidances provide information to assist planners and stakeholders as they cope with a changing climate throughout the project cycle.

- USAID. 2013. Addressing Climate Change Impacts on Infrastructure. (Especially “Transportation”, pages 7-10). https://dec.usaid.gov/dec/GetDoc.axd?ctID=ODVhZjk4NWQtM2YyMi00YjRmLTkxNjktZTcxMjM2NDBmY2Uy&rID=MzM2Njkx&pID=NTYw&attchmnt=VHJ1ZQ==&uSesDM=False&rIdx=NDM2MzY4&rCFU=

- **National Communications** are submitted by countries to the UNFCCC and include information on country context, broad priority development and climate objectives, overviews of key sectors, historic climate conditions, projected changes in the climate and impacts on key sectors, potential priority adaptation measures, limitations, challenges and needs. http://unfccc.int/national_reports/non-annex_i_natcom/items/2979.php

- **The World Bank's Climate Change Knowledge Portal** is intended to provide quick and readily accessible climate and climate-related data to policy makers and development practitioners. The site also includes a mapping visualization tool (webGIS) that displays key climate variables and climate-related data. http://sdwebx.worldbank.org/climateportal/

- **National climate change policies and plans.** Many countries have policies and plans for addressing climate change adaptation.

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- Ingeniería de Caminos Rurales: Guía de Campo para las Mejores Prácticas de Gestión de Caminos Rurales por Gordon Keller, PE y James Sherar, PE USDA, Forest Service. Producido por US Agency for International Development (USAID (2008).
  http://www.fs.fed.us/global/topic/sfm/roads_manual_espagnol_012908.pdf

- Guía Básica para el Manejo Ambiental de Carreteras. Programa nacional de competividad. Esta Guía es parte del proyecto Paz con la Naturaleza con alcances dirigidos hacia los conceptos PML (Producción Más Limpia) y una primera aproximación del país al concepto 0-E (Cero Emisiones); complementado con aportes de factores y efectos minimizadores con influencia dentro de los fenómenos relacionados con los cambios climáticos y el calentamiento global (Sin Fecha).
  http://www.competitividad.go.cr/Apoyo%20Medio%20Ambiente/Lineamientos/Guias/3.%20Gu%C3%ADa%20Ambiental%20-%20Carreteras.pdf

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ANNEX A: SAMPLE ROAD IMPROVEMENTS ENVIRONMENTAL IMPACT MATRIX

Legend

Adverse Impact Level		Beneficial Impact Level
λ	Low	μ
λ	Medium	μ
λ	High	μ

Impact Category ⇒ / Activities ⇓	Physical Resources: Soil Erosion	Debris Deposition	Siltation	Soil Compaction	Surface Runoff	Hydrology	Topography	Drainage	Wetlands	Surface Water Quantity	Surface Water Quality	Ground Water Quantity	Ground Water Quality	Ecological Systems: Habitat Change	Species Diversity	Alien Species	Vegetation	Poaching	Wildlife Movement	Animal Harassment	Ecological Function	Exceptional Resources	Tropical Forest	Landscape: Scenic Quality	Wilderness Quality	Viewshed	Carrying Capacity	Visitor Experience	Socio-Economic: Human Settlement	Compatibility w/ Policies	Cost to Agency	Benefit to Agency	Costs to Communities	Benefits to Communities	Health	Disease Vectors	Noise Levels	Dust Levels	Risks/Hazards	Employment	Local Economy	Tourist Industry
Construction																																										
Vegetation clearing	λ	λ	λ	λ	λ				λ	λ	λ	λ		λ	λ		λ		λ		λ	λ	λ	λ	λ	λ		λ						μ				λ	λ	μ	μ	
Construction camp	λ		λ	λ	λ				λ	λ	λ		λ	λ	λ	λ	λ	μ	λ	λ	λ	λ	λ	λ	λ	λ		λ	λ	λ		μ			λ	λ	λ		λ			
Quarry management	λ		λ	λ	λ	λ	λ	λ	λ	λ	λ	λ	λ	λ	λ	λ	λ		λ	λ	λ	λ	λ	λ	λ	λ		λ		λ	λ	μ	λ	μ	λ	λ	λ	λ	λ	μ	μ	
Trucking gravel	λ		λ	λ	λ						λ				λ	λ			λ	λ			λ	λ	λ	λ	λ	λ			λ			μ	λ		λ	λ	λ	μ	μ	
Cutting & filling	λ		λ	λ	λ	λ	λ	λ	λ	λ	λ	λ		λ	λ		λ		λ	λ	λ	λ	λ	λ	λ	λ		λ									λ	λ	λ	μ		

Impact Category ⇒ / **Activities ⇓**

Physical Resources

Activities	Soil Erosion	Debris Deposition	Siltation	Soil Compaction	Surface Runoff	Hydrology	Topography	Drainage	Wetlands	Surface Water Quantity	Surface Water Quality	Ground Water Quantity	Ground Water Quality
Blasting	≿	≿	≿	≿	≿	≿	≿	≿		≿	≿	≿	
Construction material use	≿		≿						≿		≿		
Management of spoil	**≿**		**≿**	≿	**≿**			**≿**	≿		**≿**		
Storage of diesel/oils									**≿**		**≿**		**≿**
Waste management									**≿**		≿		≿
Water use	π		π		≿				**≿**	**≿**	≿	≿	≿
Operation													
Vehicle Traffic Movement	**≿**		**≿**	**≿**	**≿**			≿	≿	≿	≿		≿
Road maintenance	**≿**		**≿**	≿	**≿**	≿		**≿**	≿	≿	≿		
Maintenance of machinery									≿		≿		≿
Tourist activities	**≿**		**≿**	**≿**	**≿**			≿	≿		≿		
Waste management									**≿**		**≿**		≿
Off-road driving	**≿**		**≿**	**≿**	**≿**	≿		**≿**	≿		≿		
De-commissioning													
Ripping old road	≿		≿		π			π	≿	π	≿	π	
Shaping	**π**		**π**	≿	**π**		π	π	π	π	≿		
Revegetation	**π**		**π**		**π**	π		π	π	π	π	π	

Ecological Systems

Activities	Habitat Change	Species Diversity	Alien Species	Vegetation	Poaching	Wildlife Movement	Animal Harassment	Ecological Function	Exceptional Resources	Tropical Forest
Blasting		≿		≿		≿	≿	≿	**≿**	**≿**
Construction material use		≿	≿							
Management of spoil	≿	≿						≿		**≿**
Storage of diesel/oils	≿	≿		≿				≿	≿	≿
Waste management	≿	≿		≿				≿	≿	≿
Water use	**≿**	**≿**		≿		≿	≿	≿		**≿**
Operation										
Vehicle Traffic Movement	≿	≿	≿	≿	**π**	≿	**≿**	≿	**≿**	≿
Road maintenance	≿	≿	≿	≿	**π**	≿	≿	≿	≿	≿
Maintenance of machinery		≿						≿		
Tourist activities	**≿**	**≿**	≿	≿	**π**	≿	**≿**	**≿**	**≿**	**≿**
Waste management	≿	≿	≿	≿				≿		
Off-road driving	**≿**	**≿**		≿	π	≿	**≿**	**≿**	**≿**	≿
De-commissioning										
Ripping old road		≿						≿		
Shaping	π	≿		π				≿		π
Revegetation	π	≿		π				≿		π

Landscape

Activities	Scenic Quality	Wilderness Quality	Viewshed	Carrying Capacity	Visitor Experience
Blasting	≿	**≿**	≿		≿
Construction material use	**≿**	≿			**≿**
Management of spoil	**≿**	≿	**≿**		**≿**
Storage of diesel/oils					
Waste management	**≿**	≿	**≿**		≿
Water use					
Operation					
Vehicle Traffic Movement	**≿**	**≿**	**≿**	**≿**	**≿**
Road maintenance	≿	≿	≿	≿	≿
Maintenance of machinery	**≿**		**≿**		π
Tourist activities	**≿**	**≿**	**≿**	**≿**	**≿**
Waste management	**≿**	≿	**≿**		**≿**
Off-road driving	**≿**	**≿**	**≿**		**≿**
De-commissioning					
Ripping old road	π	≿	≿		
Shaping	**π**	π	**π**		π
Revegetation	**π**	π	**π**		π

Socio-Economic

Activities	Human Settlement	Compatibility w/ Policies	Cost to Agency	Benefit to Agency	Costs to Communities	Benefits to Communities	Health	Disease Vectors	Noise Levels	Dust Levels	Risks/Hazards	Employment	Local Economy	Tourist Industry
Blasting							≿		≿	≿	≿			
Construction material use						π				**≿**	≿		**π**	
Management of spoil										≿		π		
Storage of diesel/oils	≿	**≿**			≿		≿				**≿**			
Waste management	≿	**≿**	**≿**	**π**	**≿**		≿	**≿**		≿	≿			
Water use	≿	**≿**			≿					π			π	≿
Operation														
Vehicle Traffic Movement		**≿**	**≿**	**π**	**≿**	**π**	**≿**		≿	**≿**	**≿**			**≿**
Road maintenance	≿	**≿**	**≿**	**π**		π	≿		≿	≿	**≿**	**π**	π	**π**
Maintenance of machinery			**≿**	**π**		π					**≿**	π	π	**≿**
Tourist activities			**≿**	**π**	**≿**	**π**	**≿**	**≿**	≿		≿	**π**	**π**	**π**
Waste management		**≿**	**≿**	**π**		π	**≿**	**≿**	≿		**≿**	π		≿
Off-road driving		**≿**	**≿**	π						**≿**	≿			**≿**
De-commissioning														
Ripping old road			≿	π										
Shaping			≿	π					π		≿	π		
Revegetation			≿	π					π			π		