

Chapter 4

Low-Volume Roads Engineering

"You get what you Inspect, not what you Expect."

A **LOW VOLUME ROAD** is considered a road that has relatively low use (an Average Daily Traffic of less than 400 vehicles per day), low design speeds (typically less than 80 kph), and corresponding geometry. Most roads in rural areas are low-volume roads. A well planned, located, designed, constructed, and maintained low-volume road system is essential for community development, flow of goods and services between communities, and resource management activities. However roads, and particularly road construction, can create more soil erosion than most other activities that occur in rural areas. Proper planning and design of the road system will minimize adverse impacts to water quality. Poorly planned road systems can have high maintenance and repair costs, contribute to excessive erosion, and fail to meet the needs of the users.

It is very important from the outset to locate roads on stable ground, on moderate slopes, in dry areas away from drainages, and away from other problematic and difficult areas. Avoiding problem areas can save major design, construction, and maintenance costs and can minimize many undesirable impacts.

For a road project to be successful, each step of the road management process must be performed.

The basic steps are:

Planning
Location
Survey
Design
Construction
Maintenance

If any one of these steps is omitted, a road may perform poorly, not meet its expectations, fail prematurely, require unnecessarily high maintenance, or cause environmental impacts. Without planning and good location, a road may not adequately serve its users or may be in a problematic area. Survey and design are needed to fit the road to the ground and have it function properly. Good construction insures that the design is implemented and built with some degree of quality control. Maintenance is needed to keep the surface drivable and the drainages functioning. Finally, a bad road may need to be reconstructed or closed (decommissioned) to eliminate unacceptable problems.

Road Planning

Road planning and analysis are key to ensuring that a road meets the current needs of the users, that it is not overbuilt, that it minimizes impacts to the environment and to the people along the road, and that it considers future needs of an area. Road Management Objectives (RMOs) help define and document the road purpose,

BEST MANAGEMENT PRACTICES

Some key Best Management Practices for road design and construction include the following:

- Minimizing road width and area of disturbance;
- Avoiding alteration of natural drainage patterns;
- Providing adequate surface drainage;
- Avoiding steep ground with slopes over 60 percent;
- Avoiding problems such as wet and unstable areas;
- Maintaining an adequate distance or separation from creeks and minimizing the number of drainage crossings;
- Minimizing the number of “connections” between roads and water courses, and minimizing “diversion potential”;
- Designing creek and river crossings with adequate capacity and bank erosion protection and allowing for fish passage at all stages of life;
- Avoiding constriction of the active (bankfull width) stream channel;
- Having a stable, structurally sound road surface;
- Installing subsurface drainage where needed;
- Reducing erosion by providing vegetative or physical ground cover on cuts, fills, drainage outlets, and any exposed or disturbed areas;
- Using stable cut and fill slope angles;
- Using slope stabilization measures, structures, and drainage as needed;
- Applying special techniques when crossing meadows, riparian areas, and when controlling gullies;
- Providing thorough, periodic road maintenance; and
- Closing or obliterating roads when not in use or when they are no longer needed.

standards, and how a road will be used, managed, maintained, and funded, as well as applicable BMPs for the road.

RECOMMENDED PRACTICES

Planning

- Do road transportation analysis to determine the optimum road system for an area, user needs, and to evaluate future options.
- Keep minimum road standards consistent with user demands, needs, Road Management Objectives, and public safety.
- Use an Interdisciplinary Team approach to road planning, and coordinate development with local landowners.
- Use topographic maps, aerial photos, and soils information for planning the optimum route.
- Consider both short-term and long-term access needs of the road users.
- Limit the total area disturbed by minimizing the number, width, and length of roads.
- Use existing roads only if they serve the long-term needs of the area and can be reconstructed to provide adequate drainage and safety.
- Minimize the number of stream crossings.

Road Location

Road location is key to ensuring that a road is placed in a desirable area, that it avoids problematic features or areas where construction is very expensive, that it best accesses areas where the road is needed, and that it minimizes the driving distance between destinations. Flag or mark the proposed road location **on the ground** to ensure that it meets the road design criteria (*Photo 4.1*).

It is much better to have a bad road in a good location than it is to have a good road in a bad location. A bad road can be fixed. A bad location cannot. Most of the investment in the bad road can be recovered, but little, if any, can be recovered from a bad location!

Road Survey, Design, and Construction

Road survey, design, and construction are the steps in the process where road user needs are combined with geometric factors and terrain features, and the road is built on the ground. A road or site survey is needed to identify the terrain features, such as drainages, outcrops, and ground slopes, and to add some level of geometric control to a project. A survey may be very simple and accomplished with compass and cloth tape for a rural road, or it may be very detailed using instruments and a high level of precision in difficult terrain or for a high standard road.



Photo 4.1 Plan and locate roads using topographic control points and natural ground features. Verify road location and alignment on the ground!

RECOMMENDED PRACTICES

Location

- Use topographic control points and physical features to control or dictate the ideal location of a road. Use saddles in the terrain, follow ridges, and avoid rock outcrops, steep slopes, stream crossings, etc.
- Locate roads to avoid or minimize adverse affects on water quality and outside of riparian areas and SMZs except at stream crossings. Approach stream crossings at the least gradient possible.
- Locate roads high on the topography to avoid steep inner canyon slopes and provide for more distance between the road and streams.
- Locate roads on well-drained soils and slopes where drainage will move away from the road.
- Locate roads to follow the natural terrain by conforming to the ground, rolling the grade, and minimizing cuts and fills (*Figure 2.1* and *Figure 4.1, Photo 4.2*).
- Locate roads, switchbacks and landings on bench areas and relatively flat terrain.
- Avoid problematic locations such as springs, wet areas, landslides, steep slopes, massive rock outcrops, flood plains, and highly erosive soils.
- Avoid very steep terrain (over 60%) and very flat terrain where drainage is difficult to control.

Elements of design include roadway geometry, design speed, drainage, stream crossing structures, slope stabilization needs, structural sections (materials type, use, and thickness), and road grades (*Table 4.1*). Construction involves all aspects of implementation of the design and fitting the project to the ground. A key link between design and construction are the use of **standard plans and drawings** that show how the work should look, and **specifications** that describe how the work is to be done. Another key part of construction is **quality control and inspection** to ensure that the work is done in

accordance with the plans and specifications. Some amount of **sampling and testing** is typically specified to ensure that the materials used in construction meet specifications.

**Remember --
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not what you Expect.**

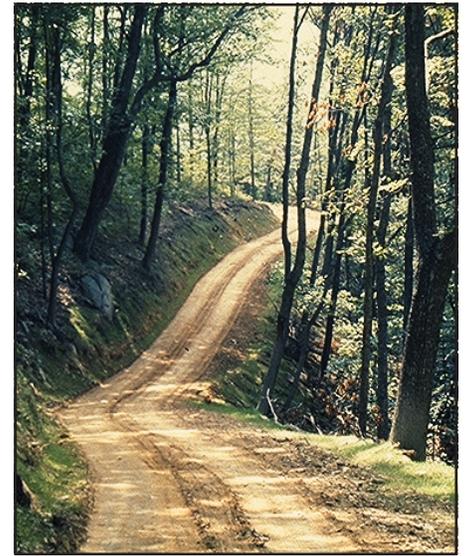
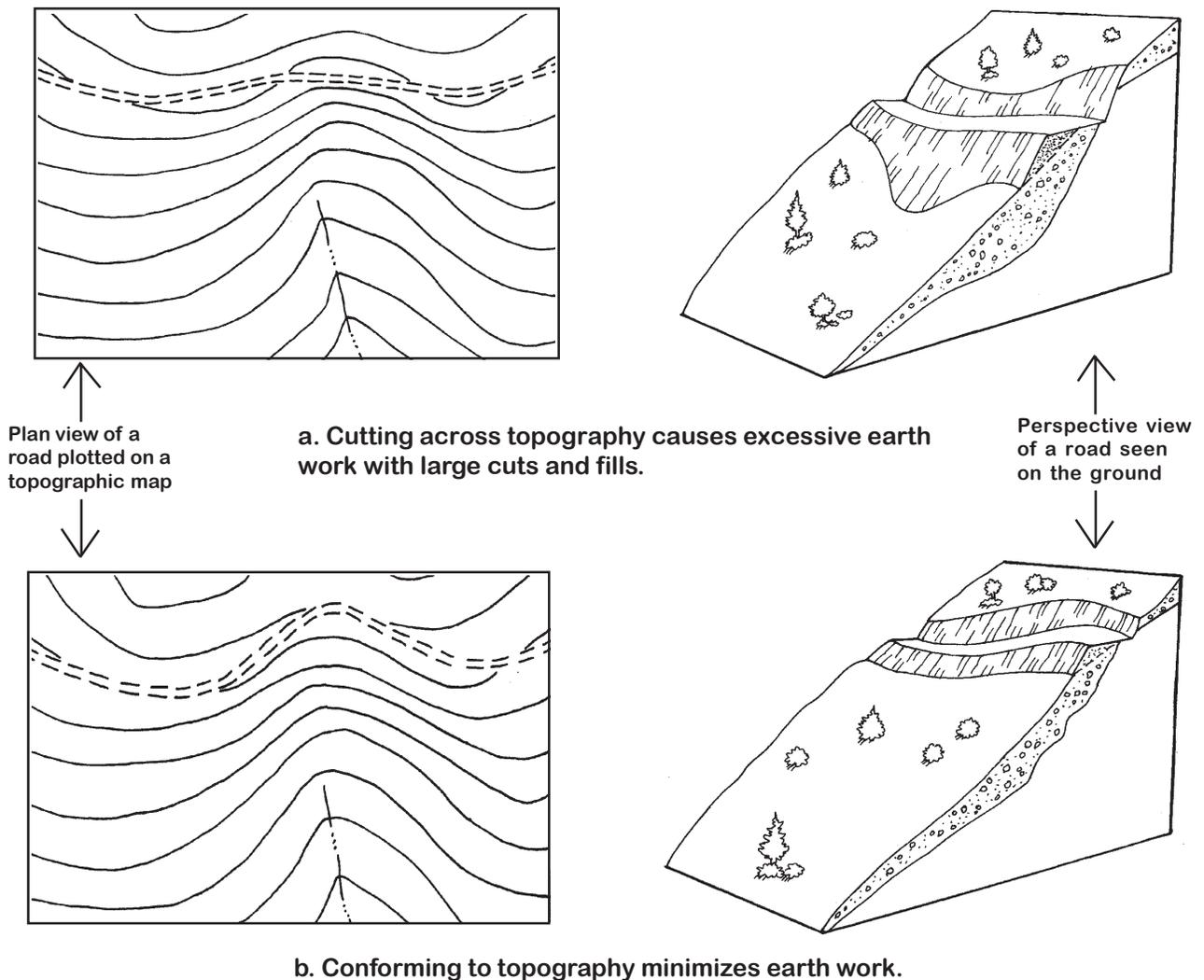


Photo 4.2 Locate roads to conform to the natural terrain and roll the road grades to disperse surface water frequently.

Figure 4.1 The affects of road alignment across topography.



RECOMMENDED PRACTICES

General Design

- Use minimum Road Standards needed for safety and traffic use (*Table 4.1*).
- Use Standard Plans and Specifications, with Standard Drawings, for most typical construction work. Develop Special Project Specifications and Drawings for unique types of work.
- Remove merchantable timber from the road right-of-way before excavation. Deck the material in a designated area.
- In community and urban areas, build footpaths along the road for the safety of people walking along the road. Use roadway surfacing and speed bumps to control dust and traffic speed.
- Construct roads with grades of 12% or less, using short sections of 15% where necessary. On steep roads, drainage is difficult to control (*Photo 4.3*)!
- Construct the road only wide enough to safely pass the traffic, normally 3.5 to 4.5 meters wide for single-lane roads and 5 to 7 meters for double-lane roads. Add turnouts as needed. Minimize the area of clearing.

- Locate roads with a minimum curve radius of 15 meters.

Materials

- Compact the road embankments, subgrade material, and surfacing materials, particularly in sensitive areas (*Photo 4.4*), or allow new roads to “settle” for several weeks before using the road. In wet climates a longer period of time is desirable.
- Use road surface stabilization measures, like aggregate or pavements, where needed and as often as possible (*Photo 4.5*). Utilize durable materials that will not degrade to fine sediments under traffic.
- Dispose of unsuitable or excess excavation material in locations that will minimize water quality or other adverse resource impacts.
- Establish minimum sampling and testing requirements and schedule for quality control of materials.

Slopes

- Typically construct cut slopes on a 3/4:1 or flatter slope. Build fill slopes on a 1½:1 or flatter slope. Revegetate the slopes.
- Typically use balanced cut-and-fill construction in gentle terrain. Use full-bench

construction on slopes over 65 % and end haul the excavated material to a suitable disposal site.

- In very steep terrain build narrow roads (3-4 meters wide) with turnouts, or use retaining walls as needed. End-haul most excavated material to stable disposal sites. Avoid side-casting.

Drainage

- Outslope road surface 3-5% for road grades less than 10% on stable soils, using rolling dips for cross-drainage structures. In slippery soils, either inslope the road or add aggregate surfacing to the road.
- Construct ditches only when necessary. An outsloped road without ditches disturbs less ground and is less expensive to construct.
- Inslope road surface 3-5% with a ditch section for road grades in excess of 10% or in areas with steep natural slopes, erodible or slippery soils, or on sharp turns. Provide cross drainage with culvert pipes or rolling dips.
- Use a crown road section on a wide road with gentle slopes or flat ground to prevent water from standing on the road surface (see *Figure 7.1*).

RECOMMENDED PRACTICES (cont.)

Drainage (cont.)

- Construct roads with rolling grades to minimize concentration of water.
- Provide filter strips or infiltration areas to trap sediment between drain outlets and waterways. Keep roads and streams disconnected!
- Use appropriate type and adequately sized drainage structures for natural stream crossings. Design bridges and culverts that are large enough to span the ordinary high water width of flow (bankfull width). Use armoring, headwalls, and trash racks as necessary to protect the structure (*Photo 4.6*).
- Divert water and stream flows around construction areas as needed to keep the construction site dry and avoid water quality degradation. Restore natural channels as soon as possible after construction.

Erosion Control

- Remove windrow slash, tops, tree trunks and stumps

from the right-of-way at the toe of the fill slope before excavation for erosion control (*Figure 4.2*). The quantity of material may be limited for fire hazard.

- Require a final Erosion Control Plan and interim erosion control measures during seasonal shutdowns. Stabilize all disturbed areas, work areas, and temporary roads. Include typical drawings for sediment traps, brush barriers, silt fences, biotechnical structures, and so on.

Miscellaneous

- Develop dependable local water sources for project construction and maintenance needs where possible. Construct a well located, durable, stabilized site that will protect water quality and aquatic life. The timing and amount of water withdrawal may require control.
- Use construction techniques that are the most appropriate and cost effective for the project and geographic area, using either equipment or hand labor (*Photo 4.7*).

- Use best available appropriate technologies, such as Global Positioning Systems (GPS), personal computer programs, geotextiles, biotechnical erosion control measures, Mechanically Stabilized Earth (MSE) retaining structures, and soil stabilization materials where applicable.
- Minimize earthwork activities when soils are very wet or very dry or before oncoming storms. Time road construction activity and road use for the milder, drier seasons where possible (*Photo 4.8*).
- Use traffic control devices as necessary to provide safety for construction personnel and road users.
- Visit the field during both the design and construction phases of a project. Ensure that you have adequate inspectors, vehicles and quality control testing to **see that the job is built correctly.**

Road Costs

Road construction costs are most influenced by the standard of road built, particularly road width and type of surfacing, and the steepness of the terrain. Placing a

road with cuts and fills on steep cross slopes greatly increases the time of construction, the amount of excavation and earthwork, the areas of clearing and needed revegetation, and adds length to

cross-drains and other drainage structures. *Figure 4.3* shows the difference in quantities for road construction on a 10 percent side slope versus a 50 percent slope. *Table 4.2* presents those typical

Table 4.1

TYPICAL LOW-VOLUME ROAD DESIGN STANDARDS

Design Element	Rural Access Road	Collector Road
Design Speed	25-35 kph	45-60 kph
Road Width	3.5-4.5 m	4-5.5 m
Road Grade	15% max.	12% max.
Curve Radius	15 m min.	25 m min.
Crown/Shape	outslope/inslope (5%)	in/outslope or crown (5%)
Surfacing Type	native or gravel	gravel, cobble-stone or pavement



Photo 4.3 Avoid constructing roads with steep grades or on steep side slopes. It is difficult to control drainage with steep road grades.



Photo 4.4 Compact the roadway surface and fill material when the road is located near streams or in areas with erosive soils.

quantities for the major road work items. Ideal construction is in terrain with cross-slopes in the range of 25 to 35 percent.

Road cost estimates are important in both the planning process and the overall project budgets to ensure that adequate funds are available to properly build the road. Good design and construction techniques require relatively high initial costs but can greatly reduce future maintenance needs and avoid costly failures, repairs, and adverse environmental impacts.

KEY COST FACTORS

- Steep side slopes (particularly with wide roads) rapidly increase the quantities of work, including the area involved for clearing and revegetation, and the amount of excavated material. Thus, steep slopes greatly increase the cost of construction (see *Figure 4.3* and *Table 4.2*)!
- High standard surfacing materials (aggregate, asphalt, etc.) greatly increase road cost -- but also greatly improve user comfort and reduce road surface erosion.
- Frequent or large numbers of drainage (stream) crossings greatly increase road costs -- but must be used as needed, particularly in dissected terrain.
- Steep grades increase long-term maintenance costs of the road.



Photo 4.5 A stable logging road with aggregate surfacing. Use road surfacing materials as frequently as possible to reduce erosion and improve the roadbed structural support and rider comfort.



Photo 4.6 A well designed and installed culvert with head walls for efficiency and fill protection.

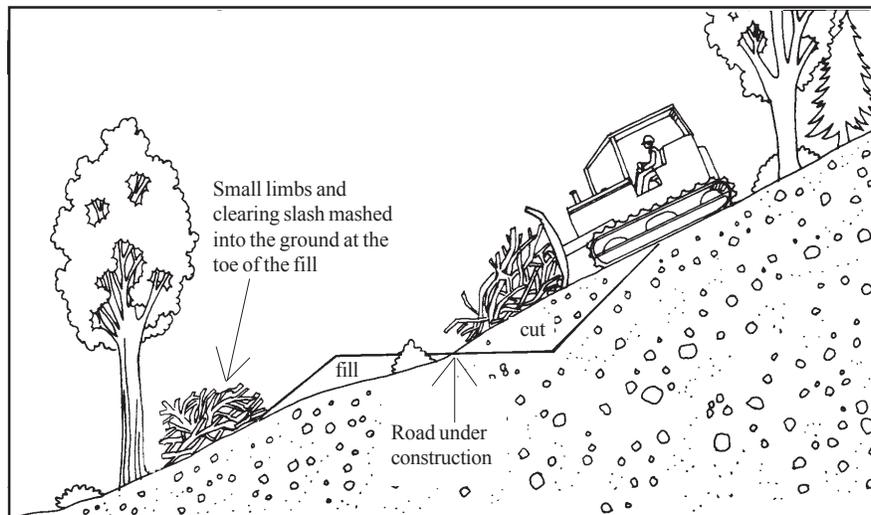


Figure 4.2 Windrow construction slash at the toe of the fill slope for erosion control. Place the slash before excavation begins. **Do not** bury the slash in the fill.



Photo 4.7 Use the road construction techniques that are most appropriate and cost-effective for the job and geographic area. Hand labor versus equipment depends on labor costs, equipment availability, and production rates.

PRACTICES TO AVOID

General Design

- Road construction on steep side slopes.
- Side-casting material on cross-slopes steeper than 50 to 60 %.
- Burying stumps, logs, slash, or organic debris in the fill material or in the road prism.
- Construction and resource extraction activities during periods of wet weather (see *Photo 4.8*).
- Steep road grades (over 12-15%). Water becomes very difficult to control.
- Vertical cut slopes, particularly on roads with inside ditches.
- Very flat areas (where drainage cannot be controlled).
- Locating roads within flood plains, riparian areas, wetlands, or the SMZ (except at crossings).
- Wet and spring areas, landslide areas, and large rock outcrops.
- Construction projects with **insufficient funds** for proper design, construction, inspection, and future maintenance. Consider building fewer kilometers of road, and building them well.

Figure 4.3 Road quantity variation with ground slope.

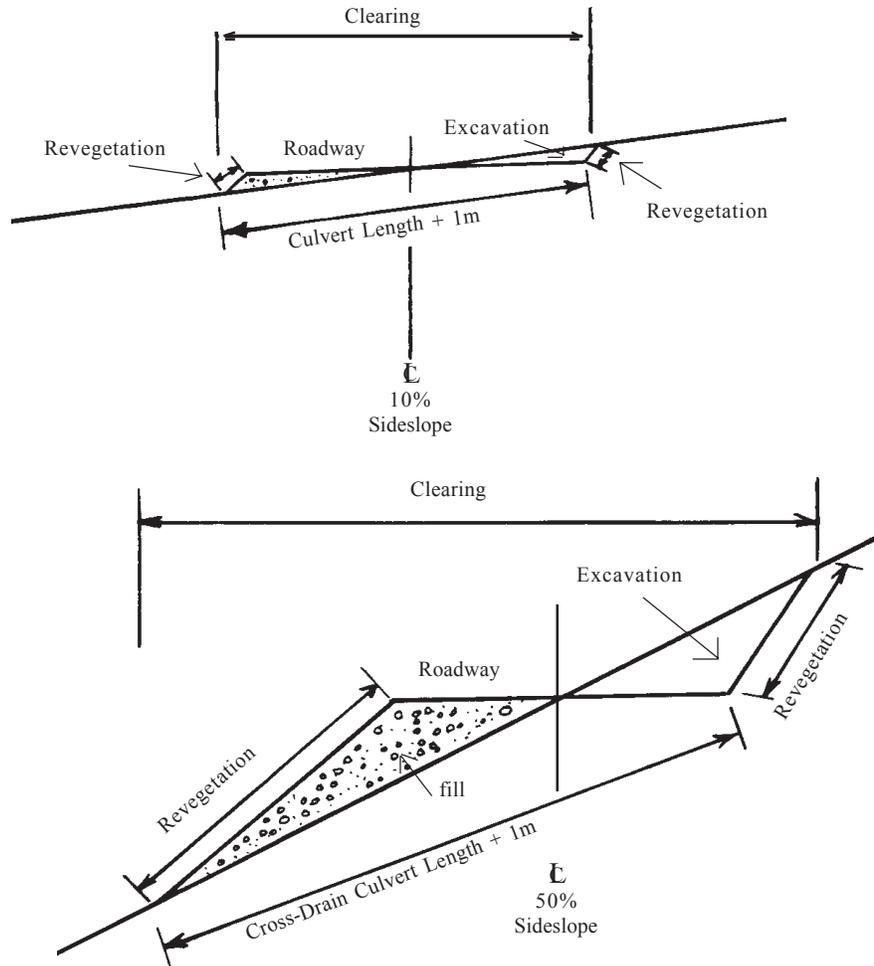


Table 4.2

TYPICAL QUANTITIES OF WORK & MATERIALS FOR ROAD CONSTRUCTION IN TERRAIN WITH GENTLE AND STEEP SLOPES (FOR A 4.5 M WIDE ROAD)

Work Item	10% Side Slope	50% Side Slope
Clearing	0.62 ha/km	0.95 ha/km
Excavation	237 m ³ /km	2220 m ³ /km
Revegetation (cut & fill slopes)	0.10 ha/km	0.89 ha/km
Culvert length (natural channel)	8 m	22 m
Culvert length (ditch relief crossdrain)	6 m	11 m

Road Maintenance

Rural roads must be maintained during active use, after periodic operations have been completed, and after major storm events, to ensure that the drainage structures are functioning properly. Heavy rainstorms will cause cut slope failures that block ditches, cause water flow on the road surface, and erode the surface and fill slopes (see *Figure 4.4*). Debris moves down natural channels during heavy rains and blocks drainage structures, causing water to overtop the road and erode the fill. Ruts, washboards, and potholes in the road surface will pond water, weaken the roadway structural section, accelerate surface damage, and make driving difficult, as shown in *Figure 4.5*. Routine maintenance is needed on any road to keep the road serviceable and its drainage system working properly. A well-maintained road will reduce road user costs, prevent road damage, and minimize sediment production.

How road maintenance will be accomplished should be resolved **before** the road is built or reconstructed. Maintenance work can be accomplished either by state or local agency personnel, by contractors, or by local community groups. Funding for maintenance may be allocated directly from agency funds, from local or gas taxes, from road user fees, or from donated local labor by interested road users.



Photo 4.8 Avoid construction and other road activities during wet periods when possible. Alternatively, add drainage and surface stabilization to the roadway in weak soil areas for all-weather use.

Key Road Maintenance Items

Maintenance items that should be performed routinely include:

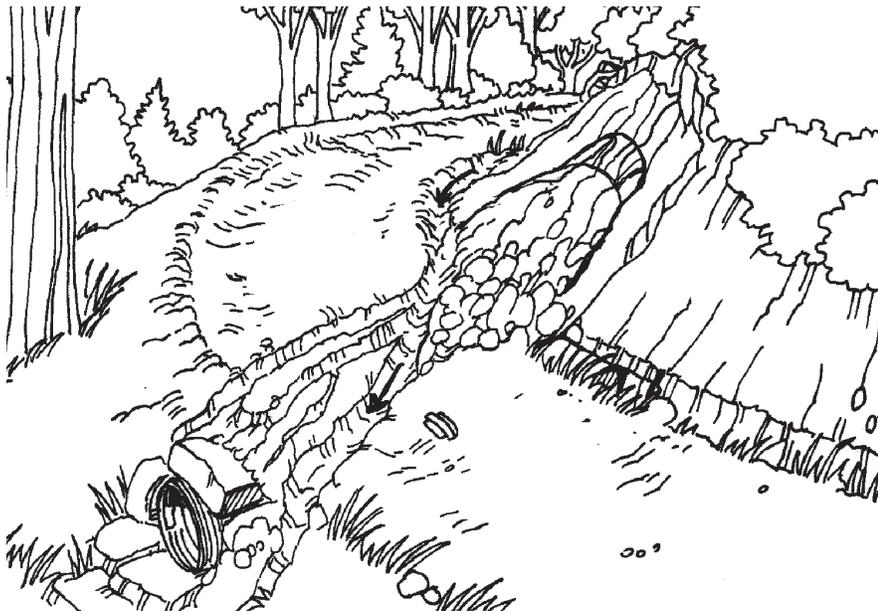
- Grading and shaping the roadway surface to maintain a distinct insloped, outsloped, or crown shape to move water rapidly off the road surface.
- Compacting the graded roadway surface to keep a hard driving surface and prevent the loss of fines. Replace surfacing material when needed. Keep the road surface moist!
- Removing ruts through rolling dips and water bars. Reshape the structures to function properly.
- Cleaning ditches and reshaping them when necessary to have adequate flow capacity. Do not grade ditches that do not need it!
- Removing debris from the entrance of culverts to prevent plugging and overtopping. Check for damage and signs of piping or scour.
- Replacing/repairing rock armor, concrete, or vegetation used for slope protection, scour protection, or energy dissipation.
- Trimming roadside vegetation (brushing) adequately, but not excessively, for sight distance and traffic safety.
- Replacing missing or damaged road information, safety, and regulatory signs.

RECOMMENDED PRACTICES

Maintenance

- Perform maintenance when needed. **DO NOT WAIT!** The longer you wait, the more damage will occur and repairs will be more costly.
- Keep ditches and culverts free from debris, but maintain an erosion resistant surfacing such as grass or rock in the ditches. Remove debris during inspections (*Figure 4.4, Photo 4.9*). Also keep overflow channels clean.
- Regrade and shape the road surface periodically to maintain proper surface drainage (*Photo 4.10*). Keep the road surface moist during grading. Fill in ruts and potholes with gravel or compacted fill as frequently as possible (see *Figure 4.5*). Keep rolling dips shaped and graded. Ideally, compact the final graded road surface.
- Keep the downhill side of the road free from a berm except where a berm is intentionally constructed to control water or traffic.
- Apply a surface stabilization material, such as aggregate, cobblestone, or pavement, to the road surface to protect the roadbed from damage and reduce the frequency of maintenance needed.
- Avoid disturbing soil and vegetation if not necessary. Leave as much vegetation (grasses) in ditches, on road shoulder areas, and on cut or fill slopes (especially grasses and low growing brush) as possible. However, ensure sight distance and that the drainage systems still function properly.
- Remove slide material from the roadway or inside ditches where the material will block normal roadway surface drainage (*Photo 4.11*).
- Avoid widening the road or oversteepening the fill slopes formed by blading surface material off the road.
- Close the road during very wet conditions or periods of inactivity.
- Inspect the road at regular intervals, especially following periods of heavy rains.

Figure 4.4 Road maintenance is needed to maintain roadway surface drainage patterns and remove slides that block ditches and culvert inlets.



Road Closure

A road may be closed because it is no longer needed, such as if a resource is depleted, if a community has moved, if it will not be used for some period of time, or if the road is causing unacceptably high maintenance costs or environmental damage. Road closure often involves input from the public and other affected road users. Basic road closure options include the following: **temporary closure** or blockage with gates, barricades or berms; **permanent closure, or decommissioning**, where the road surface is stabilized and drainage structures are removed, yet the road template is left on the terrain; or **road obliteration** where the roadway and drainage features are totally removed and the area is reshaped to its natural, pre-road condition. *Figure 4.6* shows the range of options commonly considered in road closure.

If interim road use has been completed, such as after logging or mining operations, roads should be temporarily closed or decommissioned in order to protect them from erosion during the period that they are not being used. **Temporarily closed roads** should be blocked with a gate, barricade or berm to keep traffic off the road but drainage crossing structures should be maintained. The road surface should be reshaped for good drainage and stabilized with water bars and possibly scarified, seeded and mulched. Permanent drainage structures such as culverts and ditches will require periodic cleaning. Use of road closure techniques and routine



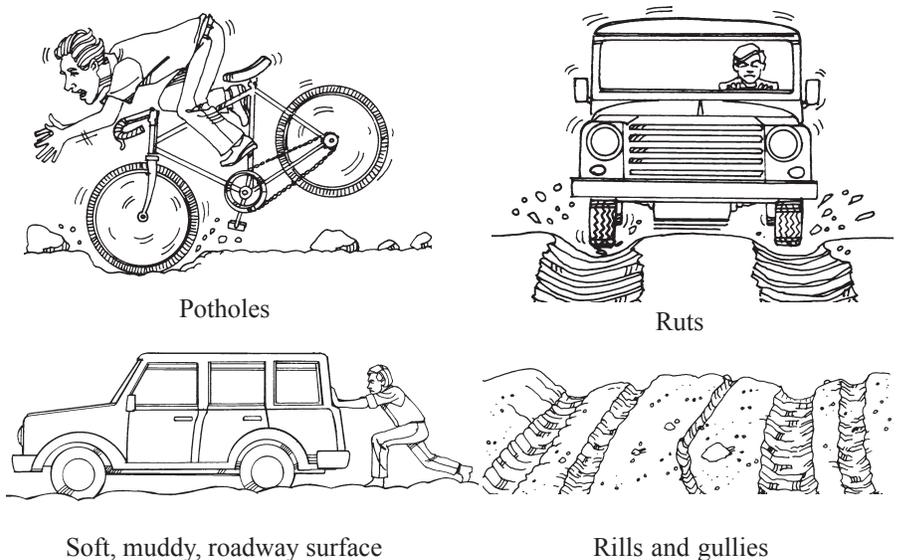
Photo 4.9 Perform road maintenance, either with equipment or by hand, to keep the roadway shaped and drainage structures functioning. Keep ditches clean but do not remove the layer of vegetative (grass) stabilization.



Photo 4.10 Use grader maintenance to keep the road surface properly shaped and drained.

Figure 4.5 Signs of need for road maintenance. (Adapted from *PIARC Road Maintenance Handbook*)

*Implement road maintenance
before significant surface damage occurs!*



maintenance after operations are completed will protect the road investment until it is needed in the future.

Permanent road closure (decommissioning) involves blocking the road, removing all drainage crossing structures and fill material, and stabilizing the road surface. This is commonly accomplished by breaking up the road surface (scarification), then seeding and mulching, so that the road will naturally be revegetated over time (*Photo 4.12*). The cost of this work is relatively inexpensive, most environmental damage from the road is eliminated, and the basic roadbed shape is still in place in case the road is ever reopened in the future.

Road closure by **obliteration** is where the roadbed is totally eliminated and the ground is restored



Photo 4.11 Remove slide material that blocks the drainage ditches and narrows the road.

to its natural terrain shape. All drainage crossing materials are removed, the ground is reshaped, natural drainage patterns are restored, ideally including subsurface groundwater flow patterns, and the area is revegetated. It is particularly important to remove all fill

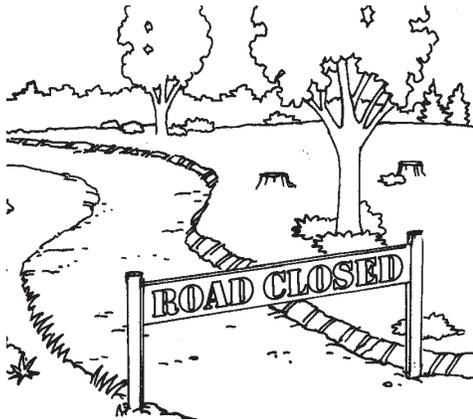
material that has been placed into drainages, such as the culvert backfill material. These relatively expensive measures are ideally used in sensitive areas such as parks or reserves, near recreation areas, or near streams and lakes. These measures are very effective to remove all traces of a road and

eventually restore the area to a pre-road natural condition. However, because of high cost, simple decommissioning is typically most cost-effective for road closure, and thus is the most commonly used closure option.

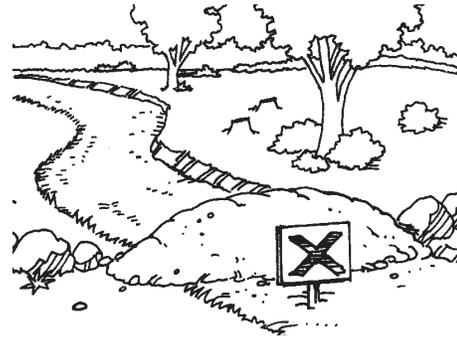


Photo 4.12 Close roads that are not needed. Stabilize the surface with water bars, berms, and ground cover such as grass seed and mulch.

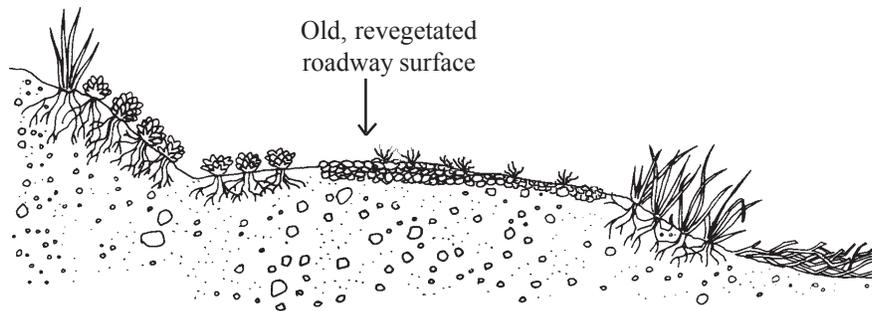
Figure 4.6 Road closure options, including temporary closure (a,b), decommissioning (c), and full road obliteration (d).



a. Gate Closure (Temporary)

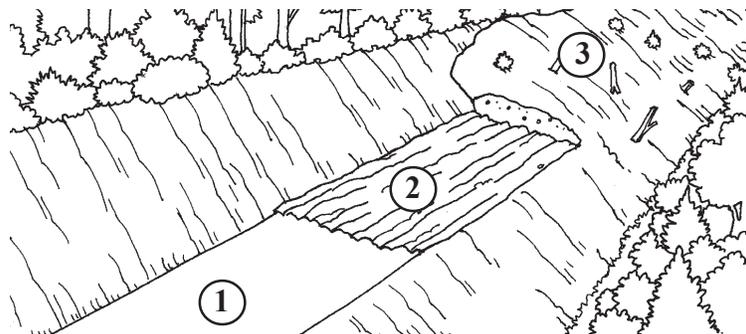


b. Earth Mound or Berm Closure (Temporary)



c. Decommissioning - Permanent Road Closure with Surface Scarification and Seeding for Revegetation, but Keeping Most of Road Template (Shape).

- (1) Road template before obliteration.
- (2) During obliteration, old road is scarified and refilled.
- (3) Final obliteration, with filling and recontouring to the original natural topography, followed by revegetation.



d. Road Obliteration

RECOMMENDED PRACTICES

Road Closure

- Involve the affected population or road users in decisions regarding road closure, typically using an interdisciplinary process.
- Temporarily close roads using gates, barricades, or large berms.
- Install water bars (See Chapter 7, Drainage) on closed roads to divert water off the road surface.
- Remove all drainage and stream crossing structures in permanently closed roads.
- Close roads by reshaping the roadbed to maintain natural surface drainage patterns and avoid concentration of water.
- Revegetate exposed soil on closed roads. A common treatment includes scarification, seeding, and a mulch application to promote grass and brush growth. Trees may be planted. On grades, waterbars should be added.
- Remove berms that may impede surface drainage on closed roads.
- Decommission roads with closure structures, drainage control, and erosion protection, but without recontouring the road template, if future use of the road is likely.
- Obliterate unneeded roads whenever possible and where cost-effective to provide the highest degree of road removal and land reclamation.

PRACTICES TO AVOID

- Leaving drainage structures on closed (decommissioned or obliterated) roads.
- Neglecting temporarily closed roads.



The paved road (above) and gravel road (below) are relatively well located and designed low-impact roads since their surfaces are armored and they conform to the terrain, thus dispersing water effectively and avoiding heavy earthwork.

