Environmentally Sensitive Maintenance for Dirt and Gravel Roads

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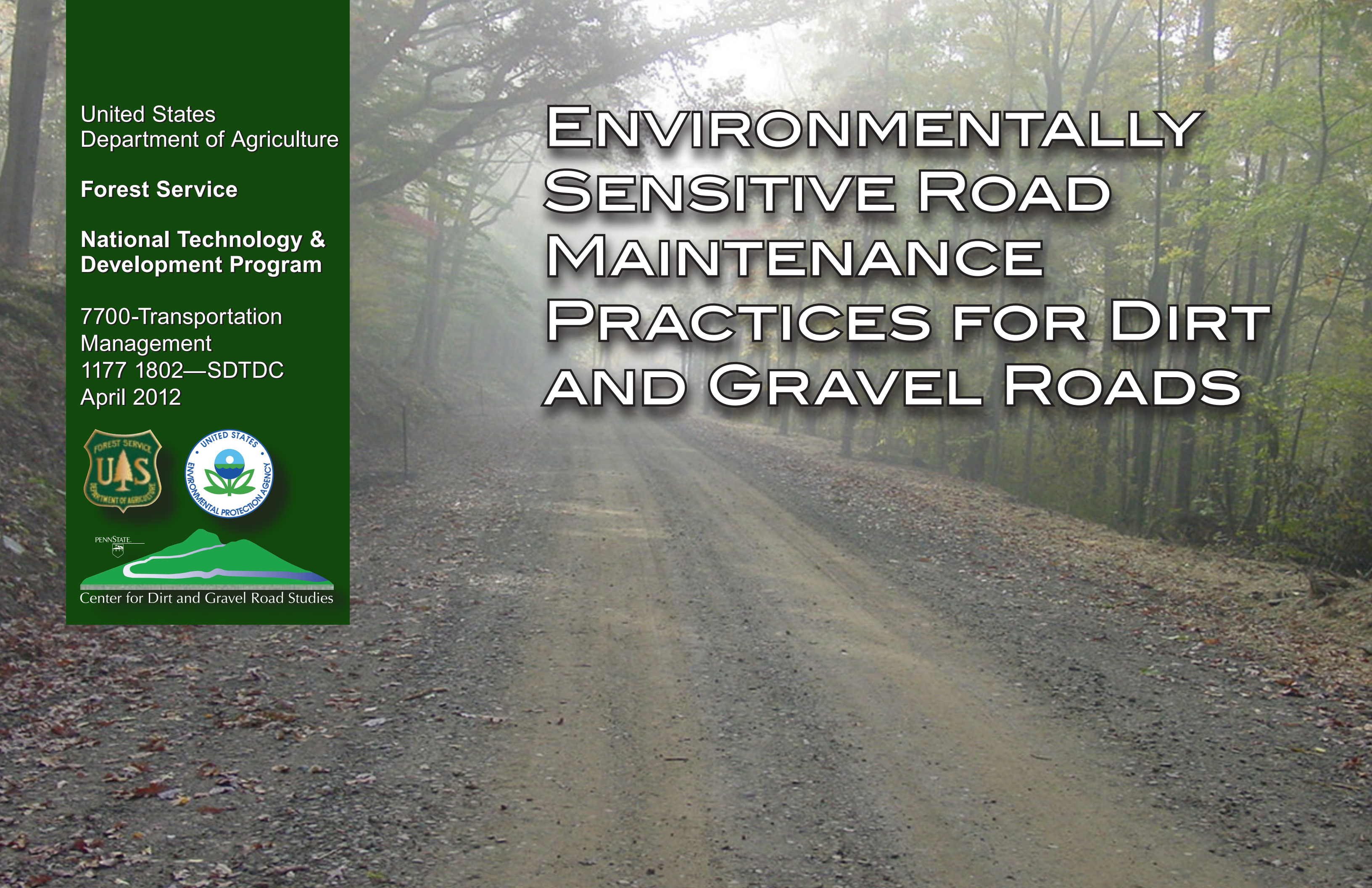

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Environmentally Sensitive Maintenance Practices for Dirt and Gravel Roads

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INTRODUCTION

Over 1.6 million miles of dirt and gravel roads exist within the United States providing a vital part of the nation's transportation system. Roads crisscross mountains, flat lands, and valleys intercepting streams, meadows, and riparian areas. The ecological effect a road has on the surrounding environment varies greatly depending on location, design, and maintenance. Roads can adversely affect the surrounding environment through erosion, and increased sediment delivery to streams, meadows, and riparian areas. Roads can intercept subsurface flows; increase hillslope drainage density through ditch lines and relief culverts; and create diversion potential at stream crossings. An environmentally sensitive road maintenance practice is a practice that when implemented reduces the adverse effect of a road on the environment by treating the cause of the problem and is in keeping with the natural landscape. The goal of this field guide is to provide examples of environmentally sensitive maintenance practices, which if implemented reduce erosion and sediment, maintain subsurface hydrologic connectivity, restore drainage density to more natural conditions, and eliminate diversion potential. Additionally environmentally sensitive maintenance practices reduce long term maintenance costs and lengthen maintenance cycles. To achieve this goal, the Forest Service, U.S. Department of Agriculture, and Pennsylvania State University's Center for Dirt and Gravel Roads, have established a simple protocol to help road managers and maintenance practitioners to: carefully assess road conditions; identify problems; determine cause; and select the appropriate environmentally sensitive practices that fit the site conditions.

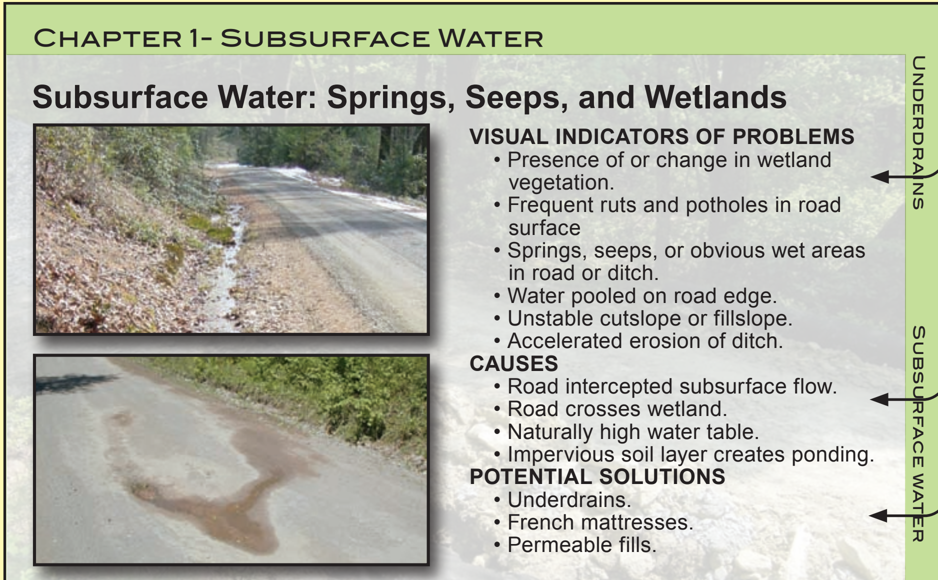
ORGANIZATION

This field guide is organized to identify visual signs of problems associated with CAUSES and SOLUTIONS for the most commonly encountered road problems. The Keys Section guides the users to specific practices with the guide that is grouped according to the type of problem (road surface, ditch, cutbank, etc). Additional references and links to other useful guides are included in chapter 10.

Keys To Using the Guide

Don't address symptoms. Address the problem by identifying the cause of the symptoms.

The following keys help identify indicators, determine the cause, and provide potential solutions.


Chapter 1- Subsurface Water

Subsurface Water: Springs, Seeps, and Wetlands

VISUAL INDICATORS OF PROBLEMS
- Presence of or change in wetland vegetation.
- Frequent ruts and potholes in road surface
- Springs, seeps, or obvious wet areas in road or ditch.
- Water pooled on road edge.
- Unstable cutslope or fillslope.
- Accelerated erosion of ditch.

CAUSES
- Road intercepted subsurface flow.
- Road crosses wetland.
- Naturally high water table.
- Impervious soil layer creates ponding.

POTENTIAL SOLUTIONS
- Underdrains.
- French mattresses.
- Permeable fills.

UNDERDRAINS

SUBSURFACE WATER

Figure 1.1—Subsurface water key.

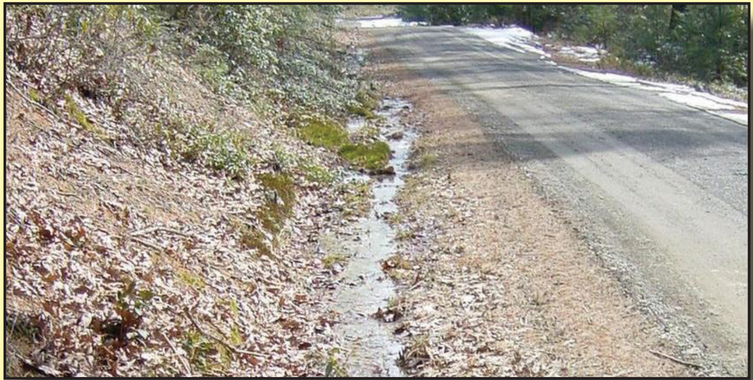
Example key

Visual Indicators of Problems: Use this section to identify problems that you see on the road.

Causes: These are common causes of the symptoms listed above.

Potential Solutions: The environmentally sensitive road maintenance practices identified address the causes of the problem.

Chapter 1 - Keys to Diagnosing Road Problems -Subsurface Water: Springs, Seeps, and Wetlands



Visual Indicators of Problems

- Presence of or change in wetland vegetation.
- Frequent ruts and potholes in road surface.
- Springs, seeps, or obvious wet areas in road.
- Water pooled on road edge.
- Unstable cutslope or fillslope.
- Accelerated erosion of ditch.

Causes

- Road intercepts subsurface flow.
- Road crosses wetland.
- Water table naturally high.
- Soils poorly drained.

Potential Solutions

- Underdrains..pg 12
- French drains ....pg 14
- French mattresses ....pg 17
- Permeable fills ....pg 22

Visual Indicators of Problems

- Rutting and potholes in road surface.
- Washboarding.
- Flowing or ponding water on road.

Causes

- Loss of road-surface shape (template).
- Inadequate drainage features (frequency and design).
- Inconsistent drainage design with topography and or use.
- Changes or increase in traffic use.
- Infrequent maintenance.

Potential Solutions

- Crown, outslope, inslope road-surface shapes ....pg 30
- Grade breaks ....pg 35
- Broad-based-dips ....pg 38
- Conveyor belt diversions....................pg 41

Visual Indicators of Problems

- Flowing or ponding water in ditch.
- Erosion, scour, or downcutting of ditch.
- Ditches drain directly to streams or wetlands (hydrologic connectivity).

Causes

- Excessive water volume for ditch capacity.
- Insufficient or ineffective ditch relief outlets.
- Run-on from another source (hillslope, driveway, outside the right-of-way).
- Entrenched road template.

Potential Solutions

- Outsloping ....pg 32
- Reading the ditch ....pg 48
- Raising the road profile.....................................pg 52
- Berm removal..pg 58
- Low-maintenance ditches ....pg 60
- Disconnecting ditches from streams ....pg 63

Ditch Outlets

Visual Indicators of Problems

- Erosion at ditch outlet.
- Sediment delivered to stream (hydrologic connectivity).
- Long trenches cut for outlet.
- Disconnected turnouts (lead-out).
- Ponding of water in ditch.

Causes

- Too much water volume for ditch capacity (insufficient outlets).
- Cross pipes (ditch relief) installed too deep.
- Poor road-surface shape.
- Entrenched roads.
- Lack of pipe inlet and outlet protection.
- Road and stream are hydrologically connected.

Potential Solutions

- Outslope..pg 32
- Reading the ditch ....pg 48
- Raising the road profile..pg 52
- Shallow cross pipes ....pg 68
- Through-the-bank pipes ....pg 72
- Headwalls and endwalls ....pg 75

Road-Stream Crossings

Visual Indicators of Problems

- Frequent flooding.
- Culvert plugging with debris.
- Gravel bar deposition at culvert inlet.
- Downcutting at culvert outlet.

Causes

- Insufficient crossing capacity for flows and associated bedload.
- Poor crossing alignment.

Potential Solutions

- High-water bypass ....pg 82
- Improved fords and low-water crossings ....pg 86
- Improved stream crossings................................pg 90

Visual Indicators of Problems

- Rill or gully erosion on cutslope.
- Unstable or unvegetated banks.
- Sloughing bank material blocking ditches and plugging pipes.

Causes

- Excessive waterflow over bank, or from seeps coming out of bank.
- Unfertile subsoil as growing medium.
- Loss of topsoil during road construction.
- Oversteepened cutslope – not at a stable angle of repose.
- Undermining of cutslope through road design or maintenance.

Potential Solutions

- Underdrains ....pg 12
- Raising the road profile..pg 52
- Naturalize cutbanks/fillslopes...............................pg 95
- Rock buttressing..pg 98
- Benches and interceptor swales...........................pg 99
- Off right-of-way issues...pg 103

Surface Aggregrate

Visual Indicators of Problems
- Loss of fine materials.
- Increased sediment and erosion.
- Potholes in travelway.
- Washboard road surface.
- Berms formed from loose aggregate.
- Need for frequent maintenance.

Causes
- Inadequate road-surface drainage.
- Poor aggregate quality.
- Lack of adequate gradation of aggregates.
- Loss of road-surface shape from vehicle traffic or infrequent grading.

Potential Solutions
- Quality aggregate with appropriate gradation of aggregates...pg 108

Figure 2.1—Permeable fill provides for subsurface flows.

Subsurface Water

Roads often must cross wet areas and can intercept subsurface flows. The degree to which a road intercepts subsurface flow and subsequently redirects it varies from location to location. Wetlands, springs, and seeps can become problem areas if not addressed properly. Left untreated, perpetually wet conditions can expedite road degradation, which requires more frequent maintenance and often times creates hazardous driving conditions.

Most subsurface water is clean, meaning free of sediment (unlike overland flow). Redirecting subsurface water away from the traveled way will dry the road surface and reduce erosion and maintenance costs.

It is important to identify the SOURCE of any water on the road. The environmentally sensitive maintenance practices discussed in this chapter apply to subsurface water only.

Figure 2.2—Road intercepts subsurface flows and redirects it down the road as surface runoff.

Figure 2.3—Road crosses meadow without adverse impacts to subsurface flows.

Underdrains

An underdrain is a drainage system installed under a road or road ditch to collect and transport subsurface water. These buried conduits come in a variety of shapes and sizes and are usually wrapped in geotextile fabric, which allows water to enter the conduit while keeping sediment out.

Criteria for Underdrain Use

- Locations with spring flow discharge onto the road.
- Roads with seeps appear on the surface of the road.
- Road shoulders that are continually wet and rutting.
- Road ditches with standing water or active flow due to springs and seeps.
- Cutslopes that are unstable and failing due to excess moisture.
- Areas with clayey soils that collect subsurface flows.

Important Underdrain Considerations

- Never use underdrains to handle surface flows; sediment will clog drain.
- Install all underdrains with at least a 1 percent slope to carry water to the outlet.
- Always cover underdrains with at least 8 inches of fill.
- Outlet underdrains separately from ditch drainage when possible.
- Consider animal guards on outlets to prevent clogging.
- Outlet underdrains in natural swales or stable filter areas.

Figure 2.4—Road ditch with standing water.

Figure 2.5—This drain collects water from springs and seeps under the road ditch.

Benefits of Underdrains

- Inexpensive and easily installed.
- Decreases volume of water on road surface.
- Allows the road cutbank, ditch, and base to dry out and become more stable.
- Separates subsurface water from road runoff.
- Saves money by reducing maintenance time and costs associated with perennially wet roadsides.
- Maintains vegetative communities and habitat.

Types of underdrains. There are two types of underdrain, prefabricated and constructed. A prefabricated underdrain can be purchased in a variety of shapes and sizes. While it is usually less expensive and easier to install, it will not collect as much water as a constructed underdrain or French drain. French drains, like those used around home foundations, provide greater surface area for water collection.

French Drains

Figure 2.6—Perforated plastic pipe.

Prefabricated underdrains

- Consist of perforated plastic pipe wrapped in fabric.
- Available in a variety of sizes and shapes.
- Less expensive and easier than French drains.
- Best for use in well-drained soils (rocky and sandy areas).
- Unsuitable for clay soils.

Figure 2.7—Free draining stone.

French drains

- Consist of a bed of free-draining stone wrapped in geotextile fabric.
- Usually includes a perforated pipe for more flow capacity.
- Provide more surface area for collection of flows coming from various directions and depths.
- Provide flexibility in shape and size.
- Best for fine soils (silt and clay), because it provides more surface area to collect water.

Figures 2.8a through 2.8d—French drain construction sequence.

French drain construction sequence. The underdrain shown here collects water from several spring seeps along the cutslope bank and conveys it to the woods in the background.

1. Excavate trench. Place fabric in trench. Leave enough fabric on sides to cover top. Overlap all fabric seams by at least 12 inches (figure 2.8a).
2. Place thin layer of stone on fabric in trench. Place perforated pipe on stone (figure 2.8b).
3. Cover pipe with stone. Continue filling trench, allowing enough room over top of underdrain for minimum cover of 8 inches. Overlap fabric over top of trench (figure 2.8c).
4. Place and compact a minimum 8-inch cover over top of underdrain. Avoid using fine soils, such as clay for cover as it will "seal" the underdrain from above (figure 2.8d).

Materials required for French drains

- ***Geotextile fabric*** *(Class 1 or 2 nonwoven)*. Fabric around the underdrains is intended to prevent clogging. The fabric allows water to pass through while blocking fine silt and clay, which would eventually clog the underdrain.
- ***Clean stone (rock).*** Use clean stone. Clean stone is relatively uniform in size with no fine material. Typically, 2- to 4-inch-diameter stone is used. Larger stones will increase the flow capacity of the underdrain.
- ***Perforated pipe.*** A perforated pipe (typically 4 inch) buried in the stone will greatly increase flow capacity.
- ***Animal guard.*** The outlet of the perforated plastic pipe can be fitted into a more durable piece of solid pipe. Install a commercial or homemade animal guard to prevent clogging.

Equipment required for French drains

- ***Excavator/backhoe.*** The minimum width of the underdrain will be limited by the width of the bucket.
- ***Trucks.*** Needed to import clean stone and haul away excavated material.
- ***Hand tools.*** Use rakes and shovels to move stone in trench.
- ***Trench compaction.*** Use a tamper or vibratory plate to compact fill over the underdrain.
- ***Transit or laser level.*** Use to ensure continuous minimum 1 percent slope in trench.

Figure 2.9—Prefabricated wrapped underdrain is inexpensive and easy to use in rocky and sandy soils.

Figure 2.10—This homemade guard will prevent animals from entering the underdrain outlet.

French Mattresses
A structure under a road consisting of clean coarse rock wrapped in geotextile fabric through which water can pass freely. French mattresses are used in extremely wet areas, such as wetlands, to support the roadbed while allowing unrestricted water movement.

Figure 2.11—Side view of a large French mattress.

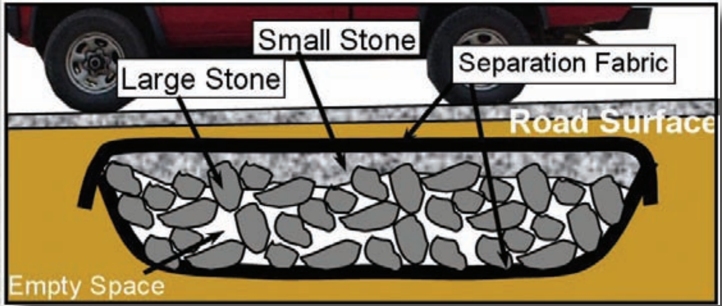


Figure 2.12—Graphical side view of the mattress components.

Criteria for French mattress use

- Areas where concentrated outlet flow through a pipe is undesirable, impractical, or regulated.
- Low-lying areas near streams or wetlands where installing cross drains would be difficult due to lack of grade or vegetation.
- Areas where the road acts as a dam by cutting off the natural flow of subsurface water.
- Areas with a high water table.

Benefits of French mattresses

- Stabilizes the road base in areas where the road is weakened by water saturation.
- Allows for bidirectional free flow of water through road base.
- Maintains dispersed flows and prevents gully erosion above or below the structure.
- Can be used in wetland situations where a traditional pipe may unintentionally lower the wetland water level.
- Requires no maintenance and has a long service life.
- Are extremely difficult for beavers to plug.
- Maintains natural vegetative communities and habitat.

Figure 2.13—This small mattress was built to accommodate several springs and seeps that saturate the road each spring.

Figure 2.14—This is the same mattress outlet after completion. Notice the water flowing out of the mattress below the road.

Important mattress considerations

- Mattresses are **NOT** pipe replacements. Mattresses should **NOT** be used for concentrated overland flow, such as small stream channels or stormwater from ditches. These flows naturally carry sediment, which will clog the mattress over time.
- Mattress size is very flexible. In the example above, three small mattresses were used to drain several springs and seeps. In the example on pages 20 and 21, a large mattress was used to allow wetland flow through during high flows. The width, depth, and size of stone used will all affect the flow capacity of the mattress.
- The finished mattress should be covered by at least 8 inches of compacted fill material.
- French mattresses should be installed to match the slope of the land. In some wetland situations, this slope may be minimal. In sloped areas a 1- to 2-percent slope should be used to aid drainage.

Figure 2.15a—Small mattresses installed to drain several springs and seep.

Figure 2.15b—Large mattress allows wetland flow.

French mattress construction sequence

This is a large mattress using large stone to accommodate a wide wetland.

1. Excavate the mattress to desired depth, allowing for a minimum 8 inches of cover over the mattress. Place geotextile fabric in the trench, leaving enough fabric on the sides to overlap on the top of the finished mattress (figure 2.16a).
2. Place porous stone on top of the fabric and spread out into a uniform bed (figure 2.16b).
3. Wrap ends of fabric over top of structure. Place a piece of fabric on the top if existing fabric does not completely cover mattress. Overlap all fabric joints by at least 12 inches (figure 2.16c).
4. Compact fill over top of finished mattress (figure 2.16d).

Figures 2.16a through 2.16d—Frecnch mattress construction sequence.

Materials required for a French mattress

- ***Geotextile fabric*** *(Class 2 woven)**.*** The fabric around the mattress allows water to pass through while blocking fine silt and clay, which would eventually clog the structure. In situations where water flowing into the mattress may contain sediment (farm fields, etc.), the ends of the mattress should also be wrapped in fabric.
- ***Clean stone.*** Use clean stone. Clean stone is relatively uniform in size with no fine material. Typically 3- to 4-inch-diameter stone is used. Larger stones will increase the flow capacity of the mattress.

Equipment required for a French mattress

- ***Excavator/backhoe.*** Needed to excavate trench; helps to spread stone after dumping.
- ***Trucks.*** Needed to import clean stone (rock) and haul away excavated material.
- ***Hand tools.*** Use rakes and shovels to move and level stone in mattress.
- ***Compaction.*** A tamper or vibratory plate can be used to compact fill over small mattresses. A roller is needed for large mattresses.

Figure 2.17 and 2.18—This roadway cuts across a flood plain wetland. A 300-foot-long French mattress was used to provide relief for wetland flows while providing a stable road base and preventing beavers from damming the nearby stream pipe.

Permeable Fills
Install a permeable fill as part of the road to promote the passage of subsurface and surface flows with minimum flow concentration and maximum spreading across meadows and wetlands. The road fill is permeable because of its construction with relatively large, preferably angular, uniformly graded rock sandwiched between layers of geotextile fabric that preserves voids in the structure and promotes the uninterrupted ground water flow. The permeable fill is similar to the French mattress, but differs in its ability to spread surface flows with culvert placement.

Criteria for permeable fill use

- Use in wet meadow sites where there is no defined channel.
- Use where subsurface flows need to be maintained.
- Use where road access is needed in meadow or wetland crossings.
- Use where spreading of surface flow is important to channel and meadow function.
- Use at springs (cienegas) and seeps where ground water discharges are relatively constant and the need to maintain well dispersed surface flows is critical to site preservation or recovery.

Figure 2.19—Permeable fill with culverts spreads surface flows.

Important permeable fill considerations

- Keep fill heights low to reduce consolidation pressures on underlying soils.
- Incorporate multiple culverts in an array to enable spreading of flood flows and to imitate the natural flooding event in meadows.
- Consider designing culverts or the stream crossing to accommodate 100-year storm events.
- Install culverts at meadow elevations to disperse flows.
- Culverts may require outlet energy dissipators.

Benefits of permeable fills

- Maintains and/or restores natural wet meadow hydrology.
- Maintains and enhances wildlife habitat, vegetation diversity, and water storage.
- Helps culvert arrays maintain stream access to flood plain.
- Prevents formation of a single channel.

***Kinds of permeable fills*.** Permeable fills can be used alone or in combination with culvert arrays. Place multiple culverts in an array to enable spreading of flood flows and imitate the natural flooding event in the meadow. Culverts may require outlet energy dissipators. In meadows without any surface flow or a small contributing area above the structure can often function well without additional culverts.

Permeable Fills

Figure 2.20—Permeable fill with culverts.

Permeable fill with culverts

- Best for areas of concentrated runoff.
- Size and number of culverts depends on site characteristics.
- Include an overtopping structure in areas with large woody debris.
- Design culverts for all life stages of amphibians, fish, or small wildlife.

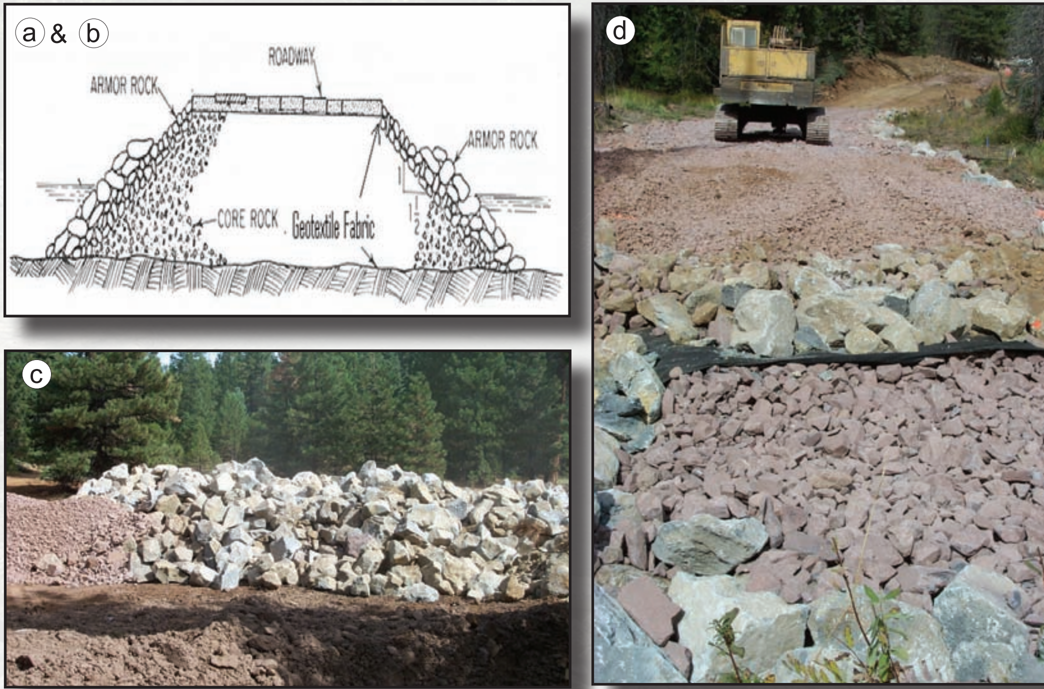
Figure 2.21—Permeable fill without culverts.

Permeable fill without culverts

- Use to facilitate ground water movement through structure.
- Consider traffic and road width needed.
- Best for small watersheds with minimal flash flows.

Permeable fill construction sequence

1. Prepare a subgrade at the meadow elevation that slopes slightly downhill (figure 2.22a).
2. Place the geotextile fabric on the prepared subgrade (figure 2.22b).
3. Spread relatively large, angular, uniformly graded rock to a minimum of 1-foot across the fabric and cover with another layer of geotextile fabric (figure 2.22c).
4. Construct an earthen embankment on the rock fill bringing the entire structure to grade (figure 2.22d).



Figures 2.22a through 2.22d—Permeable fill construction sequence.

Materials required for permeable fills

- ***Geotextile fabric.*** Fabric around the rock is intended to prevent clogging. The fabric allows water to pass through while blocking fine silt and clay. The fabric also provides surface strength and prevents the structure from sinking into the meadow.
- ***Clean rock.*** A good gradation of clean rock is important so that the structure is well knitted together for strength yet provides the necessary voids for water movement. Any fines within the rocks could reduce the permeability of the structure.
- ***Aggregate base.*** A good driving surface of surface aggregate is placed to complete the structure.
- ***Culverts.*** Number and dimensions of culverts will vary depending on the length of the structure, distribution of overland flow across the flood plain, and the type and habitat needs to accommodate unrestricted passage of all life stages of amphibians, fish, or small wildlife.
- ***Energy dissipators.*** Dissipators are constructed from rock and placed at the outlet of any culverts to prevent scouring and erosion of meadow soils.

Figure 2.23—Geotextile fabric provides support for permeable fill.

Equipment required for permeable fills

- ***Track-laying excavator.*** Working in sensitive meadow environments requires equipment with low ground pressure.
- ***Trucks.*** Needed to import clean rock.
- ***Trench compaction.*** A tamper or vibratory plate is needed to compact fill over culverts.
- ***Roller.*** To compact each lift of aggregate base.
- ***Water truck.*** In some locations water may be needed to ensure proper compaction of base material.

Figure 2.24—Track-laying excavator operates in a sensitive meadow environment with little adverse impact.

Figure 2.25—Roller compacts each of lift aggregate.

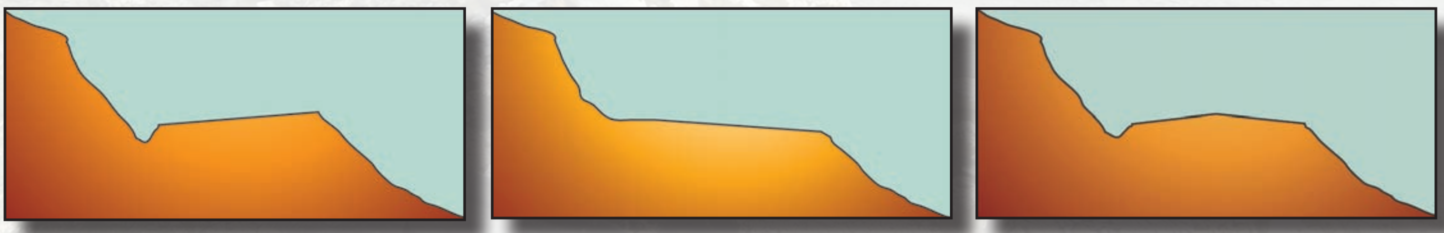
Figure 3.1—The road cross-section should be designed to shed water from the road surface.

Road Surface Drainage

Surface drainage provides for the interception, collection, and removal of water from the surface of roads (traveled way). One can minimize erosion from road surfaces with proper road building and maintenance practices. The road surface should be shaped to shed water and keep it from accumulating. Standing water and flowing water will weaken the subgrade and result in rutted, potholed, and washboarded roads that generate more sediment and require more frequent maintenance.

The road's template (cross section) whether crown, insloped, or outsloped, is the first line of defense against erosion. The road-surface shape may vary with changes in topography, hillslope position, road gradient, and surface and subsurface drainage features. The road-surface shape criteria includes environmental and resource considerations, safety, traffic requirements, and traffic-service levels.

There are several environmentally sensitive road maintenance practices that ensure the road surface quickly sheds the water and avoids concentrating drainage, which reduces erosion, restores hillslope hydrology, and lowers long-term maintenance costs.



Insloped *Outsloped* *Crown*

Figures 3.2—Road surface templates.

Importance of Road-Surface Shape

The road-surface shape (template) dictates the necessity for certain road drainage design elements and structures including ditches, cross-drain culverts, rolling dips, grade breaks, as well as the road's ability to intercept, collect, and remove water from the road surface. It is important to identify the road-surface shape and assess that design elements are in place and functioning as designed. If any of the visual indicators identified earlier are apparent, the road surface may need maintenance or an environmentally sensitive practice, such as modifying the road-surface shape or the installation of surface-drainage structures.

Crown, insloped, and outsloped road shapes are slowly lost over time due to traffic, erosion, and maintenance activities. Prior to maintaining a road, drive the segment and identify the road-surface shape. For example an insloped road generally has cross-drain relief culverts and an inside ditch. An outsloped road has no ditches or cross-drain culverts, and a crowned road often has ditches on the sides and cross-drain relief culverts. The effectiveness of a crown, inslope, or outslope in shedding water should be one of the major factors in determining when to grade a road.

Proper Road-Surface Shape

- **Crowned.** Shaping the road with an elevated centerline and continuous fall towards the shoulders.
- **Insloped.** Shaping the road to drain all water toward the backslope (uphill or cutslope side) and away from the fillslope. An inslope road-surface shape concentrates runoff against the backslope or inside ditch.
- **Outsloped.** Shaping the road to drain all surface water to the downhill or fillslope side allowing sheet flow off of the road.

Crowned

- Has highest point in middle of road.
- Drains in either direction and divides runoff.
- Is common on double-lane roads.
- Is effective on road gradients 8 percent or more.

Crowned road considerations

- Use on double-lane roads since wider surface areas generate more surface runoff. Less cumulative surface erosion may occur if the drainage is split.
- Use where slippery, icy, or snowy conditions may occur since drivers tend to drive in the center of the road.
- Avoid crowned surface shape on single-lane roads prone to rutting. Remove berms from the road shoulder that may trap water and prevent it from reaching the ditch or leaving the road area.

Figure 3.3—Crowned road.

Road-Surface Shape

Outsloped
- Has highest point on uphill side.
- Eliminates ditches and disperses flows.
- Drains to downhill side.
- Use on road slopes less than 8 percent.
- Avoid outsloped road where unsafe dropoff exists below roadway.

Outsloped road considerations
- Use where it is important to maintain distributed surface runoff for ecological reasons.
- Use on less steep roads without large downslope drop offs.
- Use where insloping could cause excessive erosion of the toe of an unstable backslope or ditch.

Figure 3.4a—Outsloped road disperses flow.

3.4b—Outsloped roads eliminates ditches.

Figure 3.5—Insloped road.

Insloped

- Has highest point on downhill side.
- Drains to inside (uphill) side.
- Concentrates road drainage into one ditch.
- Is commonly used for steep sideslopes to ensure driver safety.
- Is effective in highly erodible or unstable soils to direct flow away from fillslope.

Insloped road considerations

- Use on roads traversing steep hillslopes.
- Use on roads with slick traveled way surfaces.
- Use where outsloping could cause excessive erosion of the fillslope.
- Use more frequent ditch-relief culverts since the entire road drains to the ditch.
- Use on roads receiving frequent maintenance.
- Combine with ditch-to-dip drainage features to prevent cascading culvert failure.

How much crown or cross slope?
Unpaved roads require more sideslope than asphalt roads because the road surface is permeable and the roughness slows runoff. Steeper roads require a more pronounced crown to ensure that water flows off to the side instead of down the road surface. As a general rule, there should be at least 1/2 inch to 3/4 inch of fall per foot across the road (4 to 6 percent).

Figure 3.6—A road's sideslope can be measured using a level and tape measure. The road should drop 2 to 3 inches over the 4-foot length of the level used in the picture above.

Scaled figure of 5% slope

Grade Break
A grade break is an intentional increase in road elevation or change in road grade to create an undulating road profile (rolling grade). It is designed to shorten the contributing area and force water off the road surface into stabilized ditches or outlets on either side of the road. Grade breaks shed water toward the shoulders and are not meant to carry concentrated flow across the traveled way.

Benefits of grade break

- Is a reliable treatment that is inexpensive and easy to install and maintain.
- Reduces potential road-surface erosion by shortening the contributing area and forcing water off the road at designated locations.
- Provides necessary fill for cross-drain pipes.
- Continues to shed water even after road-surface shape is lost (longevity).

Criteria for grade break use

- Use on infrequently maintained roads.
- Use before stream crossings to direct water into vegetative filters and reduce hydrologic connectivity.
- Use on gentle-to-moderate sloped roads (less than 10 percent).
- Use on low-volume or low-speed roads.
- Use just before road gradient changes in order to shed water off of surface before it enters a steep section of road.

Grade Break

Figure 3.7—The two grade breaks pictured here prevent water from flowing down the road, even if the road's crown were to be lost.

Materials required for a grade break

- Requires 40 to 60 tons of material to create a grade break.
- Requires more fill to ease the transitions into and out of the grade break on steeper roads and roads with longer vehicles use.

Equipment required for a grade break

- Use trucks to transport material.
- Use bulldozer if available. If not, use other earthmoving equipment, such as excavators and graders.

Grade break considerations

- Consider using signs after installation to notify road users of the grade breaks.
- Educate your entire road crew about the grade break. An uninformed operator can remove it in a single grading.
- Consider marking the ends of the grade break to alert maintenance crews to where the grade break is located.
- Use longer transitions on steeper slopes to tie the grade break into the existing road elevation.
- Use grade breaks in conjunction with cross pipes. They can be located to direct water into the pipe inlet while providing necessary pipe cover.

Figure 3.8—A grade break, such as the one pictured in the distance, should be big enough to shed water, but gentle enough to allow traffic passage.

Broad-based Dip (rolling dip)
Dips are designed and constructed to divert water off the road surface, disperse surface water flows, and reduce erosion. The road profile (vertical alignment) is changed by simultaneously constructing a dip and raising the grade by placing fill material in the road below the dip. The slightly skewed dip turns surface flows and disperses runoff away from the road surface. Broad-based dips have an intended flow channel are meant to carry water across the road surface on low-traffic roadways.

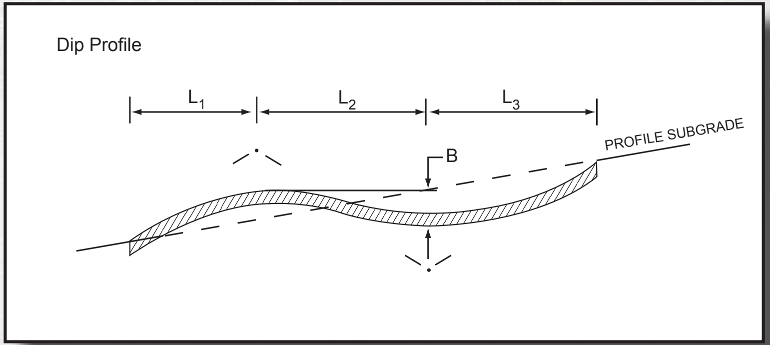


Figure 3.9—Diagram of dip.

Benefits of broad-based dips

- Can replace or supplement cross-drain culverts.
- Can reduce erosion and are inexpensive and easy to install.
- Reduce maintenance costs associated with cross-drain culverts.
- Can prevent stream diversion if natural channel culverts overtop.
- Can shed water for years with little maintenance when properly located and installed.

Criteria for broad-based-dip use

- Use dips on road grades up to 10 percent.
- Use on roads with infrequent surface maintenance.
- Use where traditional cross-drain pipes are not applicable or desired.
- Use before stream crossings to direct water into vegetative filters and reduce hydrologic connectivity.
- Use to divert road drainage only, not for springs or small streams.
- Use on low-volume roads where traffic speed is not a concern.

Broad-based dip versus grade break

- **Broad-based dips** have an intended flow channel and are meant to carry water across the road surface on low-traffic roadways.
- **Grade breaks** shed water toward the shoulders and are not meant to carry concentrated flow across the traveled way.

Materials required for a broad-based dip

- Use 20 to 40 tons of material to create a broad-based dip.
- Recommend 3- to 4-inch stone to reinforce the bottom of the dip where water will flow.

Equipment required for a broad-based dip

- Use a truck to transport material.
- Use a bulldozer due to its maneuverability and efficiency in shaping. The broad-based dip can be maintained later by a good grader operator.
- Use a vibratory roller or tamper to compact bottom and top of dip.

Broad-based dip considerations

- ***Spacing.*** Multiple broad based dips can be used in sequence, similar to cross pipes.

Figure 3.10—The broad-based dip pictured here conveys water from the road surface and upslope ditch into a vegetative filter area on the right.

- ***Size and shape.*** Dip design and construction vary according to road maintenance objectives. Consider traffic limitations and install the proper length of dip to accommodate the design vehicle (logging truck, horse trailer, or pickup truck).
- ***Angle.*** Broad-based dips should be angled across the road at approximately 20 to 40 degrees.
- ***Slope.*** Since a broad-based dip conveys water similar to cross pipes (ditch relief), an elevation drop towards the outlet end of at least 3 percent is recommended.
- ***Dip reinforcement.*** Because a broad-based dip is designed to carry concentrated flow, reinforcement of the dip bottom is recommended. Hard stone and geosynthetic materials can be used to reinforce the bottom of the dip to resist erosion.

Figure 3.11—Broad-based dip breaks up contributing area and reduces maintenance frequency.

- ***Outlet reinforcement.*** Rock armor may be required on the fillslope as outlet protection and energy dissipation.

Belt Diversions
A belt diversion is a structure used on low-volume roads to divert water off the road surface. The diversion consists of a piece of used conveyor belt bolted to treated lumber and buried in the road.

Benefits of belt diversions

- Forces water off the road to reduce surface erosion.
- Functions after road crown or sideslope are lost.
- Will not deform or crush under heavy hauling as can be the case with earthen and aggregate structures.
- Is inexpensive, easy to install, long lasting, and requires low maintenance.

Criteria for belt-diversion use

- Use on low-volume (traffic) roads and access roads (driveways, farm lanes, gated roads, and camp lanes). They are NOT suitable for roads that have heavy traffic, fast traffic, frequent grading, or plowing.
- Install on sloping sections of low-volume roads with long, continuous grades and evidence of rills, gullies, and loss of road-surface fines.

Figure 3.12—Low-volume access roads, such as the one pictured here, are ideal candidates for diversions.

Figure 3.13—Conveyor-belt diversion on a farm lane (road).

Belt Diversions

Figure 3.14—On most roads a completed diversion should leave no more than 4 inches of belt exposed.

Figure 3.15—A completed diversion directs surface drainage off the roadway and into a field.

Materials required for belt diversions

- Use a conveyor belt approximately ½-inch wide by approximately 15 inches high by the necessary length.
- Use treated 2-by 6-inch lumber. Length and number depends on road width. Overlap any lumber joints with 4-foot length of board.
- Use bolts and nuts 3/8-inch-diameter. (Length varies with belt).
- Use wide-diameter washers.
- Use a utility knife, drill, hammer, and adjustable wrenches.

Equipment required for belt diversions

- Use a backhoe, excavator, or trenching machine.
- Use an upright tamper (jumping jack), shovel, and rake.

Belt-diversion considerations

- Determine the spacing of belt diversions by road gradient, surface-material stability, and road-surface runoff.
- Be sure that the belt diversion is long enough to (1) be angled across roadway (a minimum of 30 degrees) and (2) ensure that water does not flow back to the roadway around the end of the diversion.
- Obtain free or low-cost used conveyor belts from any facility that uses conveyor belts (mines, mills, etc). Belts typically come in 26- to 30-inch widths and can be cut with a utility knife or a reciprocating saw.
- For longer diversions, consider constructing the belt offsite and then removing the 4-foot joint board. The diversion can then be folded in half for transport and reassembled onsite.

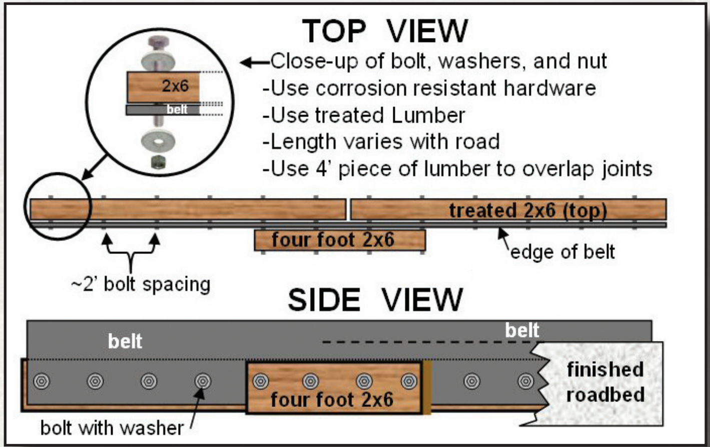


Figure 3.16—Schematic view of conveyor belt diversion. This schematic assumes the diversion is long enough that two separate pieces of lumber need to be joined end to end to span the road. On narrow roads, the diversion may be constructed using a single piece of 2-by 6-inch material.

Figure 3.17—Construction of a 24-foot-length diversion. Note that the belt has been cut in half lengthwise. A 4-foot board on top of the belt spans the lumber joint of two 12-foot boards.

Figures 3.18a through 3.18d—Belt diversion construction sequence.

Belt diversion construction sequence

1. Excavate a trench diagonally across the road (figure 3.18a).
    a. Dig trench at a minimum 30-percent angle.
    b. Have a minimum of 1 percent of continuous fall toward the outlet.
    c. Dig trench wide enough to allow for compaction equipment beside the belt diversion.
    d. Dig trench deep enough to provide 3- to 4-inch of cover over the top of the supporting 2- by 6-inch board.

2. Place the diversion against bottom edge of the trench, leaving approximately 4 inches of the belt exposed above the final road surface (figure 3.18b).
3. Backfill the trench and compact with a tamper (figure 3.18c).
4. Place large stones at the end of the diversion to control erosion if a lot of flow is expected.
5. Mark the ends of the conveyor belt diversion with reflective posts to avoid damage during future maintenance (figure 3.18d).

Figure 4.1—Eroded ditch caused by excessive volume and velocity of water.

Roadside Ditches

Ditches collect and carry road-surface water, water from springs or seeps, and water from run-on sources to designated discharge locations. Criteria for using a roadside ditch include (1) water expressed in the cutbank needs to be prevented from reaching the traveled way; (2) safety concerns dictate an insloped road with a berm on roads traversing steep sideslopes; and (3) high-standard roads require a road template shape that is super-elevated to accommodate higher speeds. All other roads should be outsloped or crown to reduce the road-drainage density, to restore natural surface-drainage patterns, and to reduce maintenance costs.

Roads that do require a ditch often have downcut and degraded ditch lines. Too often, traditional practices designed to fix ditches address only the symptom (erosion) rather than the problem (water volume and steep road gradient), which causes increased water power. Many low-volume roads are modeled after urban storm sewers, collecting water and transporting it to the nearest stream, which can adversely affect water quality and aquatic habitat. A change in philosophy, away from collecting water, and towards dispersing water, is what is desired to reduce environmental impacts and simplify road maintenance.

This chapter focuses on managing ditches to reduce the volume of water in the road drainage system and to allow it to infiltrate naturally. Environmentally sensitive road maintenance practices that eliminate ditches or maximize the number of ditch outlets are effective techniques to disperse road drainage and reduce long-term maintenance costs.

Reading the Ditch

The practice of reading the ditch is an art that requires looking at historical evidence and paying special attention to the cause of ditch problems. To properly read the ditch requires training your eyes to detect subtle changes in the landscape and road. Reading the ditch involves determining when and where to use an environmentally sensitive maintenance practice, such as raising the road profile or installing rolling dips. Road drainage can be designed and/or modified to allow for more infiltration and dispersion of flows by observing how the road lies across the landscape and intercepts natural drainages. Instead of relying on standard tables or guides, reading the ditch requires observation to determine when and where to use environmentally sensitive maintenance practices based on your knowledge, experience, and site-specific conditions.

Benefits of reading the road ditch

- Standards exist for cross-pipe spacing based solely on road slope. This one-size-fits-all methodology does not take into account site-specific hydrologic conditions.
- Reading the road ditch is a process that allows you to address the cause of many drainage problems instead of the symptoms.
- Unlike drainage standards, reading the road ditch is a methodology that can be applied to any landscape.

Criteria for reading the road ditch

- Applicable to all roads with a ditch.

Factors affecting ditch stability

- **Water volume**
  - Run-on from offsite water sources (lanes, field drains, trails, forest thinning projects, etc).
  - Length of ditch run or size of contributing area.
  - Subsurface water interception from springs and seeps.
  - Road surface drainage design and effectiveness.
  - Increase in impervious surfaces.

- **Road geometry.** Slope, grade changes, curves.
- **Soil type and texture.**
- **Available ditch outlets.** (It is not always possible to lead water away from the road when you want to.)

Figure 4.2—This photograph is taken only 300 feet from the top of the hill, yet the road ditch is over 5 feet deep. Further investigation of the site revealed a large amount of water emptying out of a meadow and into the road ditch. This water should be either diverted before it reaches the road or handled as quickly as possible and not allowed to flow down the road ditch.

Figure 4.3—Length of ditch and contributing area must be evaluated.

How do you read the ditch?

- Start at the top of the hill to identify problems in the ditch line as soon as they begin.
- Walk downhill following the ditch and look for the current frequency of ditch outlets. Identify any signs of erosion or downcutting in the ditch, and note where it begins.
- In drier climates, look for signs of debris and scour from high runoff events, such as flash floods and spring melt, that may have occurred much earlier in the year.
- Look for signs of erosion. Typically, the ditches will begin to show signs of erosion depending on road gradient, soil stability, and water volume.
- Look for opportunities to create a new drainage outlet ABOVE the point where the ditch starts to erode.
- Estimate how long the ditch can remain stable. If the road grade (slope) is continuous and there are no other contributing sources of water (run-on from driveways, springs, lanes), then the distance from the top of the hill to your sign of erosion will give you a good estimate of how long the ditch can remain stable before an additional outlet is needed. Use this strategy as you progress down the hill to place new drainage structures.
- Make note of any water entering the road and ditch from offsite sources (springs, driveways, trails, etc.), and plan to address this flow as quickly as possible to avoid carrying more water volume in the roadside ditch.
- If possible, outlet ditches before curves or steeper sections of road since this will help reduce ditch erosion. Try to install additional outlets before the ditch empties into a stream or intermittent channel to keep road drainage separate from natural flows.
- Look at the condition of the road ditch, and outlets as well. If the ditch outlet is eroded or plugged, consider installing a new outlet above the existing one to further disperse the drainage and reduce erosion and sediment.

Figure 4.4—This eroded ditch is a symptom. The problem is excessive water volume for this road gradient and soil, and must be managed upslope.

Figure 4.5—Near the top of a hill, this ditch is starting to erode. The team looks for drainage options.

Figure 4.6—Eroded ditches are a common problem.

Raising the Road Profile
The process of raising the road profile starts with filling the road cross section to an elevation that more closely resembles the natural topography, allowing for sheet flow from the downslope side of the road, and additional culverts to drain the upslope side of the road.

Understanding the Entrenched Road Problem

Many low-volume roads have become entrenched, or lower than the surrounding terrain on either side, over time due to traffic, maintenance, and erosion. Entrenched roads collect drainage from the surrounding area and trap it in the road corridor. This can lead to a host of drainage problems on the road. Raising the road profile is an environmentally sensitive practice that addresses the problem (the road is lower than the surrounding topography and concentrates runoff) instead of the symptoms (eroded ditches, cutbanks, and road surfaces).

Problems Stemming from Entrenched Roads

Because entrenched roads collect and trap water, many problems can result including:

- Continual erosion of ditches and banks.
- Inability to install cross pipes and drainage turnouts.
- Excessive runoff volumes due to lack of available outlets.
- Increased sediment transport to stream crossings.
- Difficulty performing snow removal.

Figure 4.7—Example of an entrenched roadway.

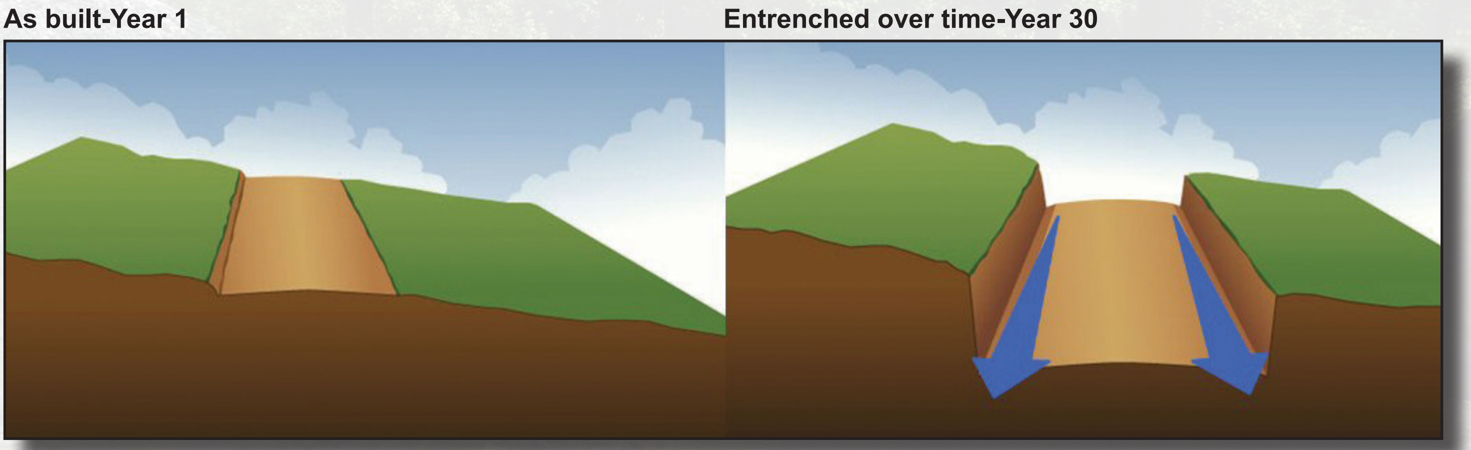


Figure 4.8—Over time, the elevation of many roads, especially unpaved roads, is lowered due to traffic, maintenance, and erosion. When roads become lower than the surrounding terrain, they are referred to as entrenched, and water often is trapped in the road traveled way.

How does raising the road profile work?
Raising the road profile uses imported fill material to build up the entrenched road. Ideally, the final road elevation will be high enough to restore natural drainage patterns by eliminating the downslope ditch and providing cover for cross-drain pipes to effectively drain the uphill ditch. Raising the road profile is sometimes the only long-term solution to many entrenched road problems.

Raising the Road Profile

Raising the road profile considerations

- Fill material can come from a variety of sources including environmentally safe recycled waste material and traditional earthen fill.
- Each lift of fill material (maximum 8 inches uncompacted lifts) should be well compacted and placed to reflect the desired final road shape of crown, inslope, or outslope.
- The final elevation of the road should allow sheet flow from the downslope side of the road.
- If possible, consider waiting a season prior to placing the final road surface as fill material will often settle, especially for deep fill sections.
- When raising the road profile stay within the existing road prism and do not expand the footprint of the road.

Figures 4.9 and 4.10—This entrenched roadway was a constant source of maintenance and pollution. The road was filled over 6 feet in places to eliminate the ditch on the left and provide elevation and cover for cross pipe to drain the ditch on the right.

Benefits of raising the road profile

- Provides a long-term solution to many drainage problems.
- Eliminates at least one parallel ditch.
- Provides cover for needed pipes to drain uphill ditch.
- Restores a more natural drainage pattern, similar to what existed before the road was in place.
- Reduces concentrated flow and allows for infiltration.
- Provides a shoulder area on the road (road width increases as it is filled).
- Allows space for snow removal in cold climates.
- Alleviates bank stability problems by reducing bank height and angle.

Criteria for raising the road profile

- Use on roads that are entrenched.
- Use in areas where suitable fill material is available.
- Use for roads that cannot be relocated along a more suitable alignment.

Figures 4.11 and 4.12—This entrenched roadway trapped runoff in the ditches and emptied into a small headwater stream. The road was elevated up to 5 feet in places in order to eliminate the ditch on the left and provide elevation and cover for several cross pipes.

Materials required for raising the road profile

- Use suitable fill material.
- Use new surface material; old surface will be buried.
- Use new cross pipes (potentially) to drain the upslope ditch and underdrains to capture spring seeps.

Equipment required for raising the road profile

- Use trucks to move fill material.
- Use earthmoving equipment to spread fill material.
- Use vibratory roller to compact fill material.
- Use equipment and materials to install new cross pipes (potentially).

Figures 4.13a through 4.13d—Raising the road profile construction sequence.

Raising the road profile construction sequence

1. Begin filling entire road cross section, bank to bank, including ditches. Local shale was used on this site.
2. After initial 8 inches of fill is in place, compact fill material with a vibratory roller.
3. Continue to fill road, compacting again after every 8-inch lift of material.
4. Road has reached the ideal final elevation when it drains to natural ground on the downslope side. Be sure to reflect desired crown or cross slope in final fill grade.
5. Place cross pipes as needed to drain uphill ditch.
6. Place new surface aggregate if desired. Consider allowing a year for fill to settle, then regrade before placing final surface-wearing course.

Berm Removal

Berm Removal: The process of removing an unnecessary berm, windrow, or false shoulder on the downslope side of the road provides dispersed sheet flow off the road surface.

Figure 4.14—Berms can range from several feet high to only a few inches high as pictured here. The small partially vegetated berm on the left is preventing runoff from exiting the road surface. A stable vegetated buffer exists to the left, but the berm is causing an unnecessary ditch to form at the road edge.

What Is a Road Berm?

A berm is a mound of soil material, parallel to the roadway on the downslope side that has been placed or accumulated over time due to road traffic or maintenance activities (grader can windrow material). Road berms may be several inches or several feet high, but once a berm forms, it traps runoff on the road surface causing accelerated erosion of the road surface.

Removing the Berm

Berm removal is a straightforward process. Many berms can be eliminated using small earthmoving equipment. A truck may be needed to take excess berm material to a suitable location. Depending on the size and composition of the berm, the material generated from removal may even be used to as road fill or surface material.

Benefits of berm removal

- Is inexpensive and cost effective.
- Eliminates the downslope parallel ditch and associated ditch maintenance.
- Reduces concentrated flow and provides infiltration.
- Reduces road surface erosion by removing water from the road corridor.

Criteria for berm removal

- Use on outsloped and crowned roads.
- Use anywhere there is a berm or windrow if material exists that prevents drainage from entering the ditch or leaving the road area.

Materials and equipment required for berm removal

- Does not use materials. Berm removal actually generates material!
- Use earthmoving equipment, such as a bulldozer or backhoe and possibly a truck to haul berm material away.

Berm removal considerations

- Beware that long-established berms may be hard to recognize. They may be large and well vegetated.
- Create as many turnouts, or notches, in the berm as possible to allow drainage to exit if entire berm cannot be removed.
- Berms may be used for safety concerns when there is a steep slope along the fill slope. If the entire berm cannot be removed, look for opportunities to pull the berm and roll the road grade with a broad-based dip.
- Avoid creating new berms during standard maintenance practices, such as grading or plowing.

Figure 4.15—The berm was created by recent grading. Removing the berm and crowning the road allows sheet flow into the vegetation to the left.

Low-maintenance Ditches. There are several strategies and guidelines outlined below for reducing maintenance needs and erosion problems associated with roadside ditches.

Characteristics of low-maintenance ditches

- A wide, parabolic shape (not "V" shaped).
- Shallow relative to the road surface (no large drop-off; can be safely driven into by vehicles).
- Vegetated when possible.
- Lacks signs of excessive erosion. Adequate drainage outlets exist to minimize flow volume and velocity. (See reading the ditch section.)

Strategies for low-maintenace ditches

Using the side of the bucket to determine ditch shape

As viewed from the side, the back and bottom of a typical backhoe bucket is an ideal shape for a wide, shallow ditch line. The bucket can be dragged along small sections of ditch to achieve the proper shape. The required size of the ditch is dependent upon the volume of water it must manage. More frequent ditch outlets reduces the need for large ditches.

Pulling Ditches

Cleaning ditches while grading, or pulling ditches, often leads to deep ditches that are "V" shaped and unstable. Consider alternative methods or equipment to clean the ditch other than a grader, such as the one pictured here. Also consider using a separate piece of equipment to clean the ditches after grading.

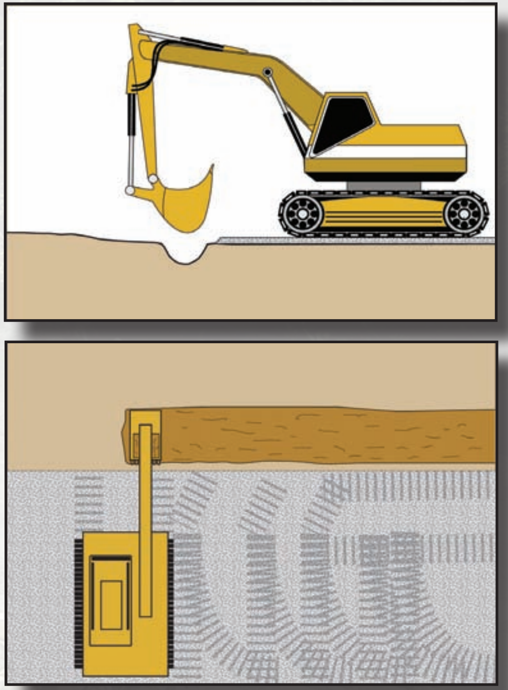


Figure 4.16—This bucket is a good parabolic shape for ditch construction.

Leaf Blowers and Vacuums

In locations with deciduous vegetation, graders are often used to remove fallen leaves from the ditch in order to prevent plugging of cross-drain culverts. However, it is difficult to remove leaves with a grader without disturbing the soil in the ditchline. Pull-behind or three-point-hitch leaf blowers are inexpensive and multiuse tools that remove dead vegetation without disturbing the soil. Leaf blowers can be attached to a small tractor and are easy to operate. If ditch cleaning, not reshaping, is the issue, then a leaf blower can accomplish the task faster, cheaper, and with less soil disturbance than a grader. Leaf vacuums have the added advantage of not blowing leaves up onto the uphill bank that could return to the road ditch.

Figure 4.17—A leaf blower clears dead vegetation without disturbing the soil.

Figure 4.18—Homemade ditch cleaner for a grader.

Reprofiling Ditches

When the entire length of a ditch is cleaned or reshaped at once, it creates an easy source and pathway for sediment to get into waterways. An alternative is to clean or reshape ditches in sections, skipping every other section each year. The unmaintained section will have residual vegetation and a rougher shape. These unmaintained sections can function as a filter area, slowing the water flowing in the ditch before it enters the cleaned, less stable section of ditch. This strategy can be employed in locations where ditch discharge to the stream cannot be avoided.

Disconnecting Ditches and Streams. Ditch lines that drain directly to the stream are hydrologically connected to the stream and become efficient conduits of sediment to the stream channel. Environmentally sensitive maintenance practices identify opportunities to reduce sediment delivery and restore more natural hydrologic conditions by decreasing ditch connectivity and encouraging infiltration.

Criteria for disconnecting ditches and streams

- Roads with through cuts at the approach to stream crossing.
- Insloped roads on gentle or rolling ground with no signs of intercepting subsurface flows.
- Ditch lines with a large contributing area.

How to disconnect ditches from streams

- Eliminate ditches where possible through berm removal and filling the road profile.
- Locate drainage outlets away from streams and into vegetation when possible.
- Regrade ditches in wide flood plains to drain away from stream crossings.
- Construct broad-based dips to disperse surface and ditch flows before stream crossings.
- Outslope the road before stream crossings to disperse surface flows.

Benefits of disconnecting ditches and streams

- Reduces discharge of sediment to the stream.
- Reduces pulse flow of stormwater to stream system (lessens flood flows).
- Encourages infiltration and sediment filtration.
- Simple, effective, and inexpensive.

Figure 4.19—Unstable ditch. This ditch presents a safety, maintenance, and environmental concern. It is too deep, too wide, unvegetated, and can route sediment to the stream.

Figure 4.20—Traditional urban stormwater approaches collect and convey ditches directly to streams, as pictured above. Modern rural stormwater management should disconnect the road and stream by avoiding concentrated discharges to streams and encourage drainage dispersal.

Reprofiling Ditches at Stream Crossings

In broader valleys or relatively flat landscapes, it is often possible to make road ditches flow away from the stream crossing. To accomplish this, fill material is added to the area around the crossing to raise the grade. The ditch is regraded to force water to flow away from the stream crossing into stable vegetated outlets.

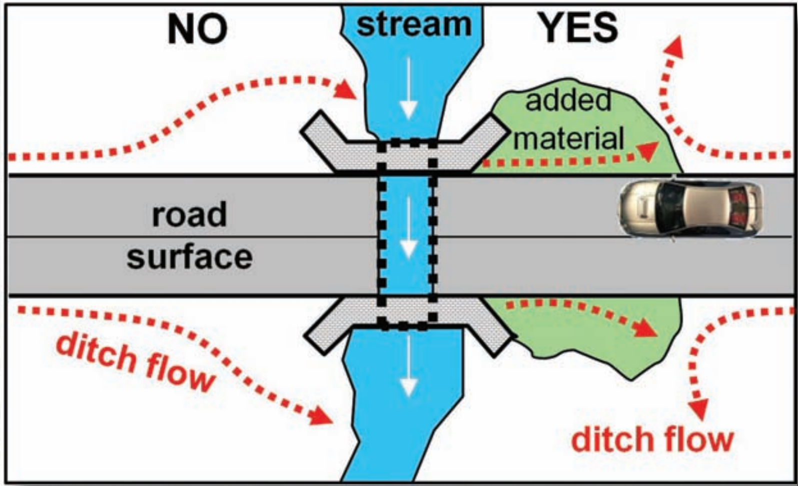


Figure 4.21—Aerial depiction of road-stream crossing. The left side of the diagram shows the traditional practice of discharging water to the stream. The right side of the diagram shows material added to redirect ditch flow and outlet water away from the stream.

*Figure 4.22a—**Before:** A typical crossing with ditches armored with rock and draining directly into the stream.*

*Figure 4.22b—**After:** Material has been added and the ditch has been reprofiled to drain away from the stream through a new cross pipe and into the woods.*

Figure 5.1—Culvert placed below the natural elevation requires frequent maintenance and long ditch outlets.

Ditch Outlets

Roads with cross-drain culverts or lead-out ditches can show signs of accelerated erosion at the outlet. Accelerated erosion at the outlet is a symptom of excess volume or velocity of water being discharged as well as the soil type that the concentrated flow is placed on. The location and condition of the ditch outlets can be an indicator of how much erosion and sediment reaches nearby streams. Whenever possible, ditch and culvert outlets should be strategically located to disperse road runoff and sediment into well-vegetated buffer areas away from streams. Unfortunately many roads are located in areas immediately adjacent to streams and lack adequate buffers, or exist on steep hillslopes where concentrated discharge scours the fillslope causing accelerated erosion. Environmentally sensitive road maintenance practices are designed to first identify the cause of the problem and then implement practices to reduce the adverse effects of ditch and culvert outlet drainage as it leaves the road. The overall intent is a well-designed, low-maintenance road that has minimal impact to soil, water, and aquatic resources.

Figure 5.2—Shotgun culverts causes accelerated errosion.

Figure 5.3—Culvert outlet is well armoured.

Shallow Cross Pipes (ditch-relief culverts). A ditch-relief culvert installed at the natural ground elevation, avoids the need for an excavated outlet trench or tail ditch.

Deep: Traditional deep culvert where pipe cover is obtained by digging a trench and backfilling with compacted fill to the original road-grade elevation.

Shallow: The shallow culvert is placed at the natural ground elevation and fill is imported to provide pipe cover above the original road-grade elevation.

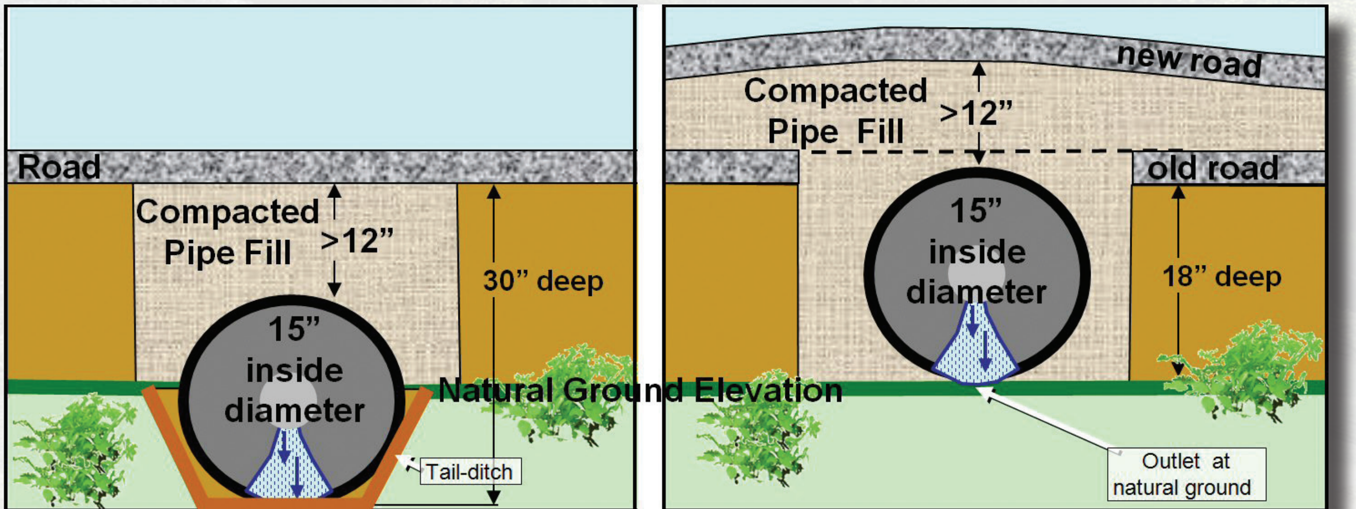


Figure 5.4—Side-view schematic, looking through cross pipe from the outlet, compares the deep and shallow pipe placements on the road. The deep pipes are bedded below the natural ground elevation line and require outlet trenches to function. The shallow pipe placement is at natural ground elevation and uses imported fill to achieve pipe cover.

Problems Associated with Traditional Deep Pipes

When a pipe outlet is placed below ground surface, it often creates the need for continual maintenance of a tail ditch to keep water flowing away from the road. Problems with tail ditches include:

- Constant cleaning is required to maintain function, which costs money and generates large amounts of sediment.
- Unmaintained tail ditches are prone to plugging, resulting in standing water at the outlet that can breed mosquitoes, saturate the road base, and lead to culvert failure.
- Tail-ditch channels increase the overall drainage density of the watershed and concentrate rather than disperse runoff and sediment making stream and wetland pollution more likely.
- Deep-pipe installation also can create head cutting, where the upstream channel will erode to the elevation of the pipe inlet.

Figure 5.5—Traditional deep pipe. It has a long outlet trench requiring continual maintenance.

Shallow Cross Pipes

A shallow cross-pipe installation uses the natural ground elevation at the pipe outlet to determine the cross-pipe elevation. Any additional pipe cover is obtained by importing fill over the pipe, rather than by digging deeper into the road base.

Figure 5.6—Shallow pipe. Placing the outlet at the natural ground elevation reduces maintenance and helps disperse flows.

In contrast, typical deep cross pipes use the existing road elevation to determine pipe installation depth.

Benefits of S*hallow Cross Pipes*

- Eliminates tail-ditch maintenance; saves time and money.
- Lowers risk to the road from standing water or culvert plugging.
- Reduces runoff and potential erosion through increased infiltration.
- Disperses runoff with added grade break caused by fill over pipe.
- Decreases the spread of invasive species.

Criteria for use of shallow cross pipes

- When possible, ALL cross pipes should be outletted at natural ground elevation to avoid tail ditches at pipe outlet.
- Cross pipes should be placed in areas of flat topography or areas with limited topographic relief.
- Cross pipes may be helpful in areas of shallow bedrock.

Figure 5.7—A shallow cross pipe being installed: The cross pipe shown is partially installed. Notice that the pipe outlet is at the elevation of the existing ground, no outlet trench or tail ditch is required. The top of the pipe is ABOVE the existing road surface. The required pipe cover is obtained by importing fill. When completed, the fill will create a grade break over the pipe.

Procedure for installing a shallow cross pipe

1. Determine preferred cross-pipe location by reading the ditch and looking for available outlets away from streams.
2. Determine proper outlet elevation. The pipe should outlet onto natural ground. The elevation of the ground, not the elevation of the road surface, establishes the depth of the entire cross pipe.
3. Excavate a shallow trench. The trench depth is based on outlet elevation. Ideally, the pipe inlet is placed in existing ditch line. Ensure there is a minimum fall of ¼ inch per foot (2 percent) across trench.
4. If necessary, spread pipe bedding in trench to support pipe evenly.
5. Compact fill around and over pipe (8-inch maximum lifts). Proper compaction is critical to avoid settling and pipe strain.
6. Shallow pipe installations typically require 30 to 60 tons of fill to obtain necessary pipe cover. Most pipes require a minimum of 12 inches of compacted material (not including surface aggregate) before allowing traffic on the road. Taper the fill into the existing road elevation on either side of the pipe. The amount of fill and length of taper depends on site conditions, such as road slope and pipe depth. Ensure that transitions are sufficiently long to accommodate the expected design vehicle.

Figure 5.8—The same pipe is shown here covered with fill, before final compaction. Arrow denotes headwall or pipe inlet.

Through-the-bank pipes

Through-the-bank pipes. A pipe placed in the downslope ditch to carry drainage through the downslope bank and away from the road.

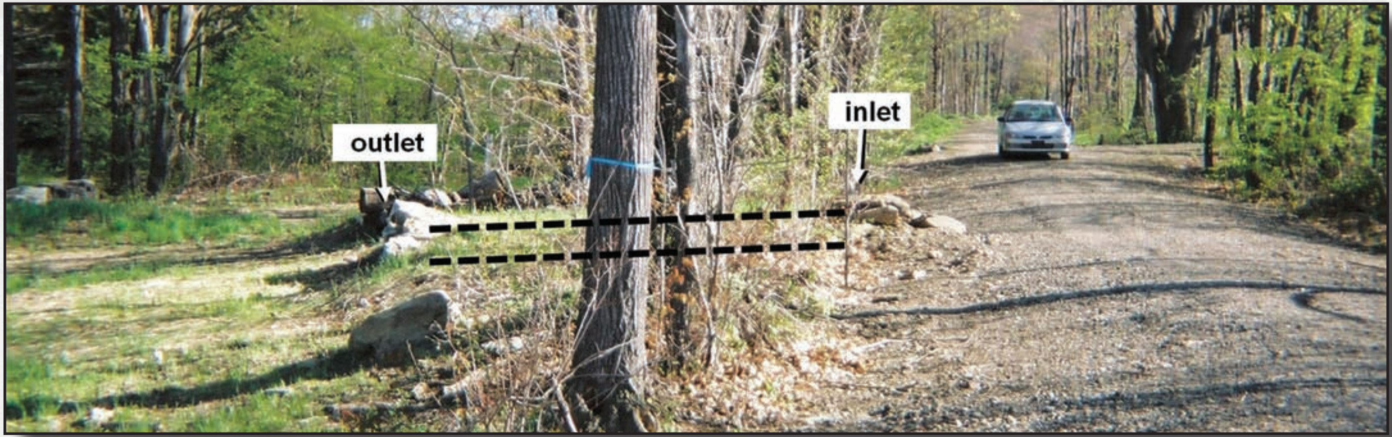


Figure 5.9—The through-the-bank pipe provides an outlet for road drainage that is trapped in the road corridor by road banks. The pipe inlet is located in the road ditch, and the outlet is at the natural ground elevation where the water can drain away from the road.

Benefits of through-the-bank pipes

- Provides additional outlets for road drainage that otherwise is trapped in the road corridor.
- Reduces contributing area of road drainage, which reduces the water velocity and erosion potential.
- Offers a good alternative to open turnout trenches (lead-out ditches) that disturb the bank and require constant maintenance.
- Establishes a solution that may be more aesthetically pleasing that open turnout trenches.

Criteria for using through-the-bank pipes

- Use on entrenched roads where raising the road elevation to a level above the surrounding road bank is impossible or impractical.
- Use on roads with large berms that trap drainage on the road surface where berm removal is not possible.
- Use where an appropriate drainage area exists within reach of a pipe, but is obscured by a downslope road bank or berm.
- Use on entrenched roads with large cut banks where opening up the area is unfeasible due to scope, cost, or aesthetics.
- Use in locations where building a traditional “turn out/lead out” would destabilize the road and contribute more sediment.

Materials required for a though-the-bank pipe

- Use culvert pipe. Determine the appropriate length and size of pipe needed for location.
- Use headwall stone or metal end section to prevent bypassing of road run-off.
- Use stone for energy dissipation at pipe outlet if high flows are expected.

Equipment required for a through-the-bank pipe

- Use an excavator/backhoe to dig the pipe trench from the roadway.
- Use a dump truck to remove excess soils if needed.

Through-the-bank pipe installation

- Identify desired pipe inlet location in downslope road ditch based on contributing area and road gradient.
- Use a level to locate an outlet on natural ground maintaining a 1-percent slope from the inlet. Flatter topography requires longer pipes. Ensure that water will not flow back to the road from the outlet.
- Excavate the pipe trench, ensuring at least a 1-percent continuous slope.
- Place pipe in trench, cover with excavated material, seed, and mulch.
- Build the headwall and plug the ditch below the inlet to force ditch flow into pipe.

Through-the-bank-pipe considerations

- Compaction and quality of fill material is not an issue since the pipe does not go under the road and/or carry loads.
- Block the road ditch immediately below the pipe inlet to prevent drainage from bypassing the pipe and flowing down the road.
- Outlet the pipe at natural ground elevation to reduce erosion.
- Install a cross pipe or broad-based dip just above the through-the-bank pipe to drain the upslope road ditch as well.
- Use a level to determine if these structures are feasible. Often times the level will show that there is sufficient fall in locations where the naked eye thinks the pipe is actually going up hill.

Figure 5.10—The inlet of a through-the-bank pipe shown during installation before the pipe is covered.

Headwalls and Endwalls. A wall built around a pipe opening to support the road and protect the road from erosion caused by excessive velocities and turbulence. A wall at a pipe inlet is a headwall and the wall at a pipe outlet is an endwall. Headwalls vary depending on the physical conditions at each installation site and may include wingwalls, debris fins, and aprons.

Figure 5.11—Headwalls come in various shapes, sizes, and materials, based on the situation and material available.

Benefits of headwalls and endwalls

- Provides a low cost, long lasting solution to retain fill material and reduce erosion of the embankment.
- Increases hydraulic efficiency on inlet-controlled pipes by directing flow and reducing turbulence around the pipe inlet.
- Reduces sediment delivery to stream and can reduce streambed and streambank scour at the pipe outlet.
- Prevents culvert plugging with debris if design includes wingwalls.
- Provides structural support to the culvert ends to offset uplift forces.
- Inhibits piping (water working through the fill around the outside of the pipe).

Criteria for headwall endwall use

- Use on culverts that show signs of inlet erosion, bank sloughing, and scour.
- Use on crossings with high stream velocities and turbulence.
- Use on streams that carry debris, which can plug the culvert entrance.
- Use for outlet protection where turbulence can damage the structure or streambank.

Headwall materials

- Use locally obtained stone or stone that may be available onsite. It is the easiest and cheapest headwall rock source if available and suitable.
- Purchase angular rock or riprap material (where natural stone is round or nonexistent).
- Purchase preformed headwalls including concrete, plastic, and metal.

Headwall and Endwall Considerations

- Be aware that the size and shape of headwalls will vary based on pipe size, road layout, stream or ditch layout, and approach velocities.
- Coordinate with design engineers to determine the design-storm discharge to identify the appropriate headwall configuration for stream pipes based on local requirements.
- Reinforce headwalls by placing fabric between layers of rock, and tying the fabric into the backfill (a process known as creating a deadman).
- Build headwalls and endwalls before or after backfilling the pipe.

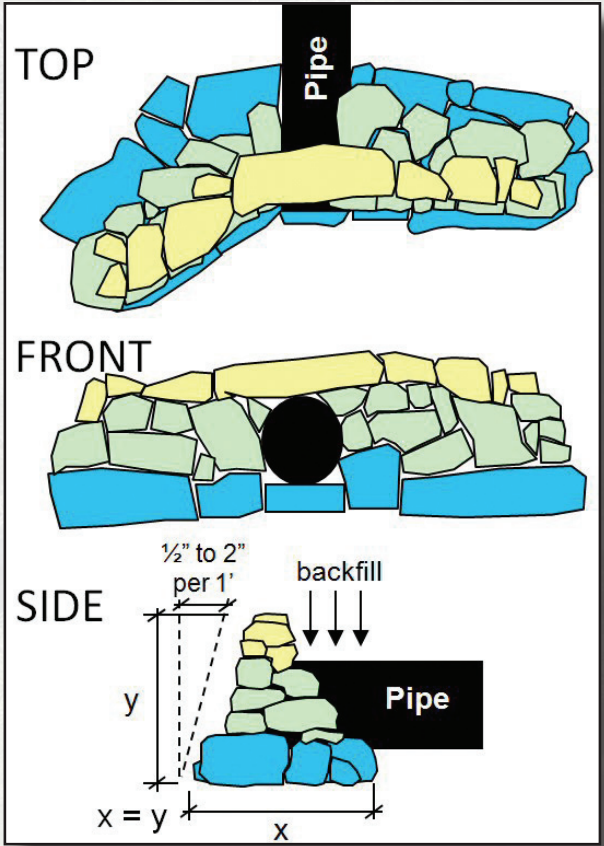


Figure 5.12—Plan views of a stone headwall. Note that the base width should be equal to the height, the face should be sloped or canted back, seams should be overlapped like bricks, and stone should be placed under the pipe.

Figure 5.13—A properly constructed natural stone headwall can last for decades.

Figure 5.14—Headwall with wingwalls.

Figure 6.1—Consequence of poor road location results in loss of road and increases sediment delivery.

Road-Stream Crossings

The road-stream crossing is a critical area to assess for opportunities to reduce erosion and sediment delivery. Roads often are hydrologically connected to streams and contribute sediment from the ditch and the road surface. This direct road-stream connection causes deteriorated water quality and adverse impacts to aquatic species, animals, and humans. Chapter 6 provides environmentally sensitive practices for reducing sediment and maintenance costs associated with stream crossings of all forms including bridges, pipes, and low-water crossings. The type of crossing at a given location depends on many factors, such as stream type, road use, and available funding.

This chapter does not cover the sizing and installation procedures for bridges or pipes. Many sources exist to provide more in-depth guidance on designing, selecting, and installing bridges and major culverts. This chapter addresses alternative maintenance practices, especially designed for use on low-volume roads, which can reduce sediment and erosion at stream crossings and lower maintenance frequency.

Figure 6.3—This direct road-stream connection causes deteriorated water quality and adverse impacts to aquatic species, animals, and humans.

High-Water Bypass. An intentionally designed flat, low-lying section of reinforced road that serves as an emergency spillway to allow water to flow over the road with minimal damage during high, but anticipated, flow events.

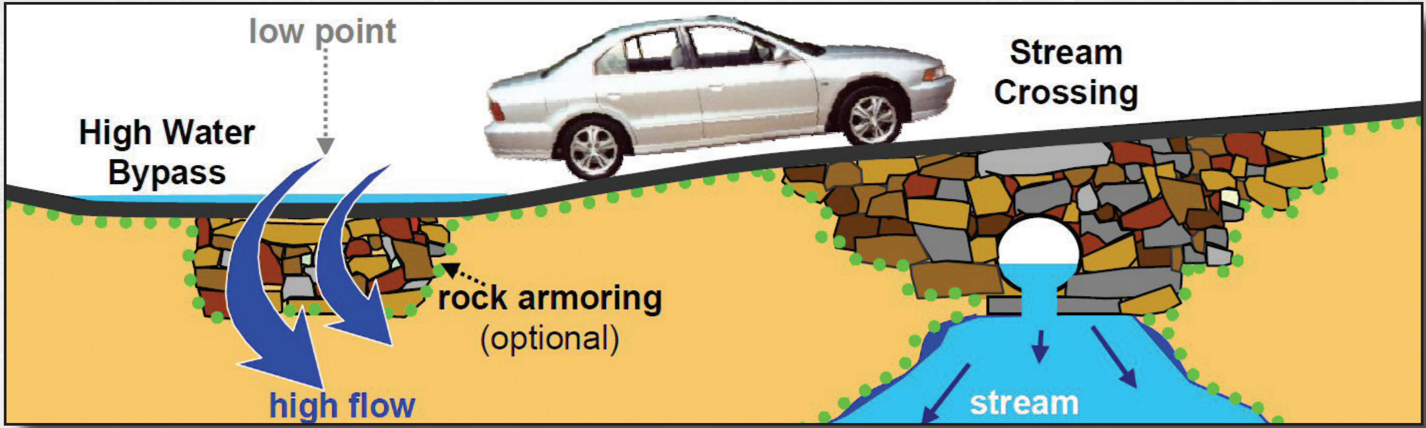


Figure 6.3—The road illustrated here will allow water from extreme events to flow over the reinforced bypass.

Benefits of High-Water Bypass

- Reduces risk of failures at stream crossings by directing high flows to a stable road crossing.
- Minimizes erosion of costly road material and damage to drainage structures.
- Reduces emergency maintenance needed to make roads passable after damage by high water flow.
- Allows for effective management of storm flows beyond the design capacity of bridges and culverts.
- Connects flood plains bisected by a road.

Criteria for Use

- Use on crossings where flow historically overtops an inadequately sized bridge or culvert.
- Use on lower volume roads where occasional waterflow over the road is acceptable.
- Use on broad flood plains or meadow complexes where it is desirable to connect the flood plains on either side of the road instead of concentrating all of the stream's flow at the crossing structure.

Considerations

- The bypass should be wide and flat to encourage sheet flow.
- The bypass should be constructed directly over a stream crossing in areas where space is limited.
- The bypass should be used for high flow events, not as regular flow channels for frequent events (fords).
- For road reinforcement, the bypass should be reinforced to resist erosion when high flows occur. In the example on the following page, 3-dimesional geogrid adds additional strength and helps to tie the surface together AASHTO #1 (2-to 6-inch stone) provide traffic support while resisting erosion.
- For bank reinforcement, it also may be necessary to armor the downslope bank as well (if a steep or unstable fillslope exists). The bypass is armored with R7 (12-to 30-inch stone) rip-rap.

Construction Sequence

1. Excavate the road to create room for surface reinforcement. Depth will depend on size of geogrid, stone (rock), and elevation of road. A 10-inch excavation depth is shown in the example *(figure 6.4a).*
2. Place geotextile fabric and geogrid in excavated area. Geogrid is secured with pins *(figure 6.4b).*
3. Fill geogrid with rock, AASHTO #1 (2-inch to 6-inch stone) as shown *(figure 6.4c).*
4. Place an additional rock over bypass as driving surface. Ensure that the bypass remains the lowest point on the road to direct flow safely over roadway *(figure 6.4d)*.

a


b


Figures 6.4a through 6.4d—Construction sequence for high-water-bypass.

Construction Considerations

- Size. Bypass sizes vary greatly depending on available space and stream morphology. Make the bypass as wide as possible to spread the force of the water out and encourage sheet flow.
- Elevation. Use leveling equipment to ensure that the finished surface of the bypass is level and will be the lowest section of road in the flood plain.
- Shape. Flat and wide. The finished bypass surface should be as flat and wide as possible to ensure even sheet flow and minimize erosive forces.

Improved Fords and Low-Water Crossings. A stream crossing at or near streambed elevation can be shaped and surfaced with many types of materials (rock, concrete, etc.). A small channel or slot may be included in the structure's low point to pass very low flows and aquatic animals. The downstream roadway edge may be stabilized and buttressed with boulders, gabions, or concrete jersey barriers (K-rails).

Criteria for Low-Water-Crossing Use

- Ephemeral or low baseflow channel at time of use.
- Alternate access to the area is available.
- Low traffic use.
- Where traffic can be interrupted for periods of flooding.
- Channel is broad and shallow.
- Watershed has large flow fluctuations or flashy response.

Figure 6.5—Concrete ford crossing.

Figure 6.6— Low-water crossing.

Important Low-Water-Crossing Considerations

- Soft and erodible channel bottoms can require a hardened driving surface.
- Traffic volume and timing.
- User safety.
- Use vented fords or low bridges where fisheries and/or water quality requirements do not allow vehicles to enter the stream.

Figure 6.7—Vented ford or low-water bridge.

Low-Water-Crossing Types. Low-water crossings fall into two general categories: (1) simple, unimproved or improved unvented fords with a natural or hardened bottom, and (2) vented fords with culverts or vents to bypass very low flows. Ideally these two types match the natural channel shape. Occasionally low-water bridges are used for broad streams or rivers with extreme flow fluctuations.

Benefits of Low-Water Crossings

- Structure can provide needed grade control to prevent headcuts.
- Costs and maintenance are low.
- Failure in large storm events is low.
- Damage from debris or vegetation plugging is less than culverts.
- Risk to riparian and aquatic resources associated with road fills and culverts is eliminated.

Figure 6.8—Gabion ford crossing.

Simple Boulder Fords or Concrete Jersey Barriers

- Use large boulders with a smaller rock matrix.
- Bury large boulders at base of structure as footer rocks.
- Use for appropriate grade control and/or steep gradient transport channels.
- Can be designed for narrow as well as wide channel crossings.
- Are inexpensive and easy to construct.
- Are appropriate for large wide channels (Jersey barriers).
- Can be constructed in stair-step fashion to reduce scour.
- Use boulders as energy dissipaters at base (Jersey barriers).

Construction Sequence for a Boulder Ford

1. Dewater site by routing flows around stream crossing.
2. Reshape drainage crossing and approaches to desired grade with a grader or dozer. Be sure to provide a 2- to 4-percent outslope to the crossing so bedload and debris move through the crossing.
3. Key in large boulders at base of structure so no more than 4 to 6 inches of each boulder is visible.
4. Begin placing boulders and smaller rock, building up to the desired road crossing elevation. Use smaller rocks to fill voids and create a tight cohesive matrix.
5. Place smaller drain rock to stabilize approaches and reduce sediment delivery to stream.
6. Construct grade break or rolling dip on these approaches to reduce the hydrologic connectivity of the approaches.

Figure 6.9—Boulder ford on Stanislaus National Forest in California has had no maintenance since construction in 1997.

Figure 6.10—Jersey barrier in Arizona provides safe, low maintenance access to forest roads.

Construction Sequence for a Jersey-Barrier Ford

1. Dewater site by routing flows around stream crossing.
2. Reshape drainage crossing and approaches to desired grade with a grader or dozer. Be sure to provide a 2-to 4-percent outslope to the crossing so bedload and debris moves through the crossing.
3. Key in energy dissipating boulders at base of Jersey barrier.
4. Place barrier, being sure to extend the structure so high flows do not go around the end.
5. Backfill barriers with accumulated bedload to desired height.
6. Place second row of Jersey barriers if needed due to steep channel gradient.
7. Backfill with bedload.
8. Place smaller drain rock on approaches to reduce sediment delivery to stream.
9. Construct grade break or rolling dip on these approaches to reduce the hydrologic connectivity of the approaches.

Improved Stream Crossings. This section identifies practices to improve existing stream crossings in order to reduce erosion and sediment delivery to the stream. Often erosion and sediment delivery to streams is due to undersized culverts. Culvert sizing is part of road design and generally requires several disciplines and resource objectives prior to designing a stream crossing. This guide focuses on road maintenance practices that can be implemented easily by road crews. Therefore, only brief summaries are presented here with links for additional resources.

Better Pipe Alignment

Pipes are often placed perpendicular to the road in order to save on pipe lengths. However, this can cause streambank erosion if the stream is forced to turn at hard angles as it enters and exits the pipe. When this is the case, a better strategy is to use a longer section of pipe to create a better alignment of the crossing with the natural stream channel.

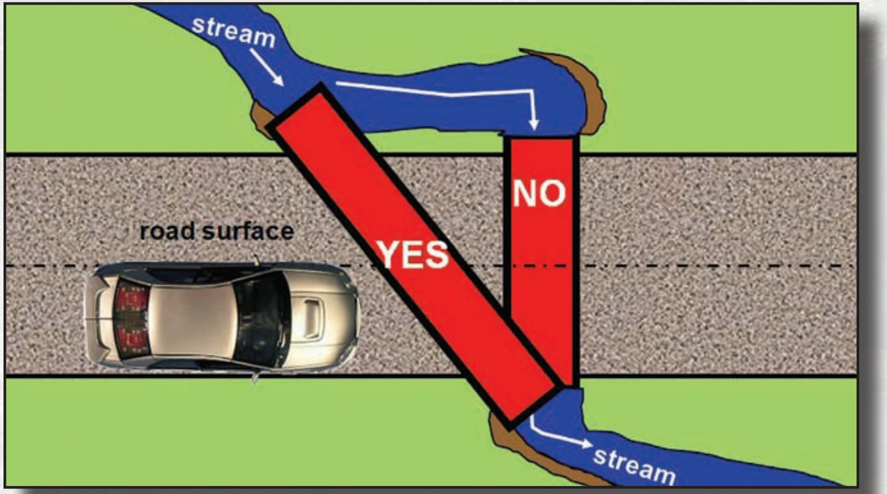


Figure 6.11—Better pipe alignment.

Figure 6.12—A bottomless arch pipe has just been installed over a currently dry stream channel.

Bottomless-Arch Pipes

Arch pipes are bolted to concrete footers that run along each side of the stream channel. They can be purchased already assembled, or in plates that can be assembled onsite.

Benefits of Bottomless-Arch Pipes

- Retains natural steam bottom through the structure.
- Requires less fill height than equivalent sized round pipes.
- Spans larger sized compared to round pipes.
- Costs much less than a typical bridge.

Paving Bridge Approaches

Road aggregate should never be graded onto, or allowed to sit on, bridge decks. In addition to falling easily into the stream, the aggregate holds water, impedes drainage, and reduces the bridge load limit. Another solution is to pave the bridge approaches to reduce sediment delivery to the bridge and stream. Carefully review the sediment contributing area and extend the pavement to the break in slope.

Figure 6.13—Paved bridge approach reduces sediment delivery to the stream.

Figure 6.14—This road is constantly being eroded and flooded. Relocating the road away from the stream, while initially costly, will pay for itself in a few years of reduced flooding and repair costs.

Road Relocation

Sometimes the best solution for the road and the stream is to relocate the road out of the stream corridor. The forest road shown here was relocated because it frequently flooded and eroded the road. The new road was located away from the stream. Road relocation can restore the natural hillslope hydrology and allow for recovery of native and riparian vegetation.

Figure 7.1—Unvegetated cutslopes are a source of sediment.

Cutslopes/Fillslopes

This chapter addresses stability problems associated with road cutslopes (backslope) and fillslopes. Unstable road cutslopes can disrupt road drainage, adversely impact water quality, create safety hazards, and increase maintenance frequency and cost. Addressing unstable cutslopes involves correctly identifying the source of the problem. Common cutslope problems originate from several sources; undermining of the cutslope, intercepting subsurface flows, and run-on from offsite sources.

Naturalize Bank Shapes

Naturalize Bank Shape. A simple practice designed to mimic the natural landscape and create a stable roughened cutslope or fillslope.

Why naturalize the bank shape?

Traditionally, equipment operators try to create roadbanks that are smooth and uniform. The banks are often composed of subsoil or rock, which is seeded with grass. In the natural world, slopes are rarely uniform. By incorporating features to roughen the slope, erosion is reduced and an environment rich in diversity of plant species is created.

Criteria for Use:

- Use on cutbanks with surface run-on from upland areas.
- Use on steep cutslopes where surface runoff causes rills and gullies.
- Use on new road construction or redesign of an existing road.

Bank Roughening. When building or maintaining road cutslopes and fillslopes, allow for surface roughness by leaving grade imperfections and debris in place. These imperfections reduce erosion, create tortuous flow paths, increase infiltration, and provide small niches for different types of plants to grow. Heavy equipment grousers (cleats) run perpendicular to the slope to provide additional surface roughness. Their tracks help to trap water and provide seed niches for a variety of vegetation.

Vegetation. Use a variety of plants, shrubs, and trees that are native to the area and require little maintenance. Identify plants that have deep roots that will stabilize the slopes. Avoid shallow rooted grasses and weak colonizer tree species. Hardy trees can permanently stabilize roadbanks and are especially beneficial on steep slopes.

Figure 7.2—Trying to grow grass on a smooth bank made of subsoil and rock is not a good strategy.

Figure 7.3—Tree roots are Mother Nature's rebar.

Woody Debris. Downed wood and stumps are often removed from the site and burned or chipped. A better use is to place woody debris perpendicular to the slope of the bank to disrupt flow paths and foster diverse bank habitat. Naturalize slopes by embedding stumps and snags into cutslopes (figures 7.4 and 7.5). Stumps bring their own seed base that adds to the diversity of vegetation on the bank.

Figure 7.4—All of the woody debris and stumps in this picture were placed there to naturalize the bank shape.

Figure 7.5—The same bank as pictured in figure 7.4, 4 years later.

Topsoil. The soil in cutslopes often is unfertile subsoil that cannot support vegetation. During new road construction, stockpile topsoil and reapply it over the newly constructed cutslope. In areas where cutslopes are reshaped to establish a more stable angle, import topsoil and spread on sites without topsoil to help reestablish vegetation.

Compost Berms. Use compost berms or socks (a mesh tube stuffed with compost) to control run-on from upland areas. A compost berm reduces erosion, retains soil moisture, and increases site fertility. Compost berms are trenchless and stake free. Place compost berms on the hillslope contour at varying intervals depending on the hillslope gradient.

Retaining Walls and Rock Buttress

Retaining walls are used for unstable cutslopes and come in many sizes and shapes. Retaining walls are designed to prevent sloughing material (soil and rocks) from entering the traveled way and disrupting the road drainage design.

Criteria for Use

- Use on steep, eroding cutslopes that cannot establish and maintain vegetative cover.
- Use on roadways where diversion potential exists from sloughing material (diversion of water out of the ditch).
- Install on areas where the consequence of sediment delivery are immediate and acute (near vicinity of perennial stream with anadromous fish).

Benefits of Retaining Walls and Rock Buttress

- Allows flattening and revegetation of the top portion of the cutslope by steepening the bottom with a retaining wall structure.
- Promotes the establishment of vegetative cover to stabilize soil and reduce erosion.
- Armors the bottom of the slope and provides resistance to slumps and slides.
- Provides aesthetic (rock buttress), and safety benefits (reducing rockfall onto highways from unstable slopes).

Figure 7.6—Crib wall stabilizes this steep cutslope ensuring appropriate road width and drainage function.

Figure 7.7—Retaining walls come in an assortment of materials and can often be constructed from large boulders onsite.

Benches and Interceptor Swales

Bench. A bench is a step or terrace built into the cutslope to slow and divert runoff before reaching the road.

Interceptor Swale. An interceptor swale is a drainage channel built parallel above a roadway and above the cutslope to intercept overland flow and direct it to a stable outlet.

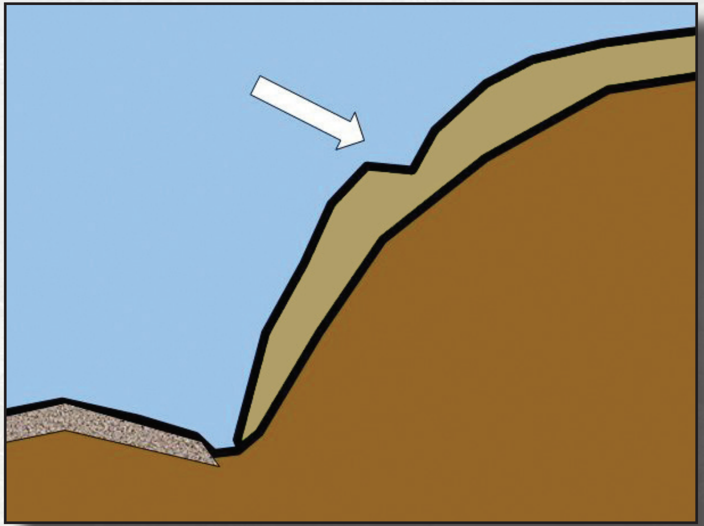


Figure 7.8—A bank bench has a flatter profile than an interceptor swale, similar to an insloped terrace.

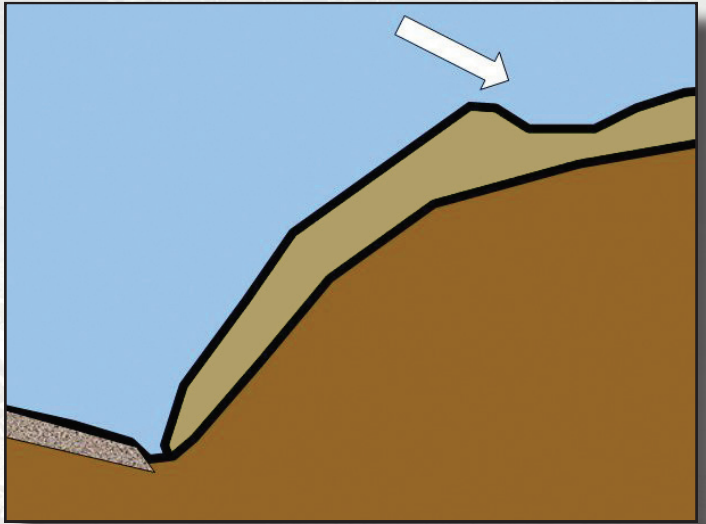


Figure 7.9—An interceptor swale is designed to carry more water than a bank bench.

Benches and Interceptor Swales

While benches and interceptor swales are similar in form and function, there are subtle differences. Benches are slightly insloped steps designed to slow water down and carry minimal flow. They are especially useful on steeper slopes and often can be built within existing road right-of-ways. Interceptor swales usually are used above banks with larger flow volumes, and require landowner approval if located outside the road right-of-way. These structures should outlet water into a stable filter area.

Bank Benches Criteria for Use

- Use on steeper slopes.
- Use on cutslopes subject to relatively low surface flows.
- Use if stable filter area exists nearby to drain bank bench.
- Use if evidence of rill erosion exists on the bank.

Interceptor Swale Criteria for Use

- Use on gentler slopes.
- Use on cutslopes with excessive overland flow.
- Use if stable outlet area exists nearby to drain interceptor swale.
- Use with landowner's approval if located outside the right-of-way.
- Use when the longitudinal slope is gentle enough to prevent erosion in the swale.

Benefits of Benches and Interceptor Swales

- Prevents run-on water from adding to the road drainage system.
- Protects roadbanks and ditches from erosive impact of run-on.
- Allows road managers to direct surface flows to a desirable location before it reaches the road.
- Can increase soil moisture to promote plant diversity on bank.

Bank Bench Considerations

- Built from the roadway.
- Use material only if the outlet requires stabilization.
- Use to reduce the erosion potential if the longitudinal slope of the bench should be minimal, less than 5 percent.
- Use on site conditions, that can accomodate a bank bench 3 to 7 feet in width.
- Use where the cross-sectional shape of a bank bench can be flat, or slightly parabolic, with a slight slope towards the cutslope bank.
- Use an interceptor swale instead of a bank bench in areas of excessive runoff.

Interceptor Swale Considerations

- Interceptor swales can be built from the road; however, landowner permissions may be required for swales off the road right-of-way.
- Use like bank benches; longitudinal slope should be minimal.
- Use outside the right-of-way must consider upslope land use.
- Use stone reinforcement if required to stabilize the outlet.
- Use on site conditions, that can accomodate a swale 6 to 12 feet wide (bank-to-bank). More gentle sites allow for wider swales to reduce erosion.
- Use if the cross-sectional shape of a swale should be shallow and parabolic.

Benches and Interceptor Swales

Figure 7.10—The slightly insloped bench in this image takes water around the hill and away from the road.

Figure 7.11—The interceptor swale pictured here catches the runoff from a large field before it enters the road.

Off Right-of-Way Issues

Off Right-of-Way (ROW) Issues. There are several strategies for addressing impacts to the road from off right-of-way or offsite sources. Practices can be used to lower traffic impacts as well as reduce the volume of water managed in the road drainage system at locations where driveways, lanes, trails, etc, intersect the roadway.

Off-ROW refers to anywhere roadside accesses either intersect or send water to the road. Farm lanes, driveways, utility ROWs, trails, developments are all potential off-ROW impacts to public roads. These access points act as tributaries to the public road drainage system, reaching out into the landscape and funneling water to the road area. The key to handling this water is to address it on the access road, BEFORE it ever reaches the public road.

Benefits of Addressing Off-ROW Issues:

- Reduces road damage due to outside water sources.
- Reduces the amount of runoff the roadside drainage system must handle.
- Creates smooth transitions for traffic to enter/exit the road.
- Improves landowner access while improving the road.
- Encourages drainage disconnection and stormwater infiltration.

Figure 7-12—Unchecked off-ROW accesses, such as this logging road, lead to increased runoff, erosion, and maintenance cost to the receiving road.

Strategy 1

Ordinances or Permits. Ordinances and permits can effectively control the way a new driveway or access road handles water, giving the road manager a tool to directly oversee the installation of the new interface. Simply creating an access permit that allows encroachment is not enough. The permit or ordinance must address the way access roads bring water to the public road, and the effectiveness of vehicle transitions at the intersections. This process will allow involvement in the planning and layout phase before the road is cut, instead of retrofitting solutions.

Access interface and drainage. Many practices in this guide can be applied effectively to new off-ROW interfaces; broad-based dips, grade brakes, and conveyor-belt diversions work well in redirecting surface flow from a driveway or lane. A change in the elevation of the access road can prevent surface water from flowing on to the public road. Smooth surface transitions at the access road interface will reduce traffic impacts on the road. The increase in elevation also will improve driver visibility.

Strategy 2

Mixed Road Ownership Road Drainage Solutions. Run-on from a permanent or temporary road access can be disconnected using different practices.

- Install drainage culverts under the access road (driveway) to maintain the ditch function and capture the additional run-on.
- Use prefabricated or constructed open-top culverts to maintain drainage function for temporary access roads for heavy equipment. Culverts can be moved from site to site and reused, allowing more permanent drainage structures to be installed upon road retirement.
- Construct a hardened ditch with a drivable cross section or install a cattle grate to allow road ditch water to cross the access.

Figure 7.13—This conveyor-belt diversion on a farm access lane prevents drainage from flowing on to the public road at the bottom of the hill.

Figure 7.14—The broad-based-dip on this driveway provides a good transition and keeps water off the public road.

Figure 8.1—Proper gradation of aggregate can prevent the raveling and pumping in this picture.

Surface Aggregate

Surface aggregate is often the most visible and expensive component of unpaved road maintenance. Aggregates used for gravel road surfacing vary a great deal around the nation based on climate and available material.

Poor quality aggregates, or poor gradation of aggregates, will lead to excessive road surface erosion and degradation. This will lead to increased sediment runoff, increased maintenance costs, and poor traffic support.

The ideal surface aggregate should be designed with a range of particle sizes in order to achieve the highest possible dry density after compaction. This chapter is presented as an introduction to some important concepts in choosing a surface aggregate.

Figure 8.2—Rutting due to excess clay content.

Figure 8.3—3-year-old dense packed surface aggregate after 40,000 vehicles.

Surface Aggregate. Surface aggregate is the unbound layer of graded rock and other material used as a driving surface for a roadway.

About Surface Aggregates

In many locations, the surface aggregate of choice is whatever is cheapest. Many road managers assume the gravel will erode away, and the road surface will need to be regraveled in a relatively short timeframe. However, some entities see a benefit from putting in a higher quality aggregate to resist erosion and stretch the life cycle of the road surface before regraveling is needed. There are two major factors that determine surface aggregate quality: material and gradation (size distribution).

What Qualities Make a Good Surface Aggregate?

Space Material Properties

- **Shape.** Should be equal dimensional or blocky (avoid elongated or flat/platy shapes).
- **Angularity.** Should be angular, preferably with at least two crushed surfaces (not rounded like river gravel).
- **Abrasion resistance.** A hard stone with a Los Angeles abrasion value of 40 or less is recommended to resist breakdown.
- **Debris Free.** Good aggregate should be free from soil, organics, and even clay in wet or cold climates.

Figure 8.4—Loose aggregate will unravel and form windrows of material along the road center and edge.

Quality Gradation

- **Maximum size.** Nominal maximum particle size should be adjusted based on the expected traffic. A 1.5-inch nominal maximum size is desirable for most aggregates where passenger vehicle traffic is expected.

- **Well-graded size distribution.** Even the best material will fail if it is not properly sized. Well graded means that a broad spectrum of particle sizes is present throughout the range of the aggregate. This includes at least 10 percent minus #200 fine material for most aggregates. A mixture of aggregate sizes, especially including fine material, is necessary in order to achieve maximum compacted dry density to resist erosion and wear.

Aggregate Placement Considerations

Base Preparation. It is important that a stable road base exists on which to place aggregate. Any failures in road base will be reflected in the new surface aggregate. Surface aggregate will also reflect any imperfections in the road base. Ensure that any ruts or potholes are graded out prior to placing aggregate. It is also important to establish adequate (4 to 6 percent) crown or cross slope in the existing road. Then place aggregate in a uniform layer to maintain this crown. When placing aggregate deeper than 4 inches, consider cutting a key along the edge of the road to support the edge of the aggregate. Otherwise, the noncompacted aggregate edge may create a traffic hazard and unravel more quickly than a supported edge.

Figure 8.5—A well-graded aggregate is being placed through a paver at a noncompacted depth of 8 inches, and compacted to 6 inches. Notice the roller in the background for compaction.

Moisture. Optimum moisture is critical when placing a well-graded aggregate. A dry aggregate will segregate by size and will never achieve maximum compaction. The range of optimum moisture will depend on the aggregate type and gradation. Optimum moisture should be determined by a lab before ordering, and verified in the field when possible.

Compaction. Maximum dry density must be achieved through compaction equipment, such as a vibratory roller. Maximum compaction has been achieved when the road surface no longer compacts under the roller, or when larger stones on the road surface begin to break apart. The exact degree of compaction can be measured in the field using a nuclear density meter.

Depth. Aggregate must be placed at a sufficient depth to allow for compaction. As a general rule, the depth of compacted aggregate should be three times the largest stone diameter. For example, an aggregate with a 1.5-inch maximum stone size should be placed 3x1.5 inches = 4.5 inches deep. Thinner so-called skim coats of aggregate are often ineffective because the material cannot form a cohesive layer and is quickly raveled off by traffic.

Placement Method. A well-graded aggregate should be placed using methods that cause the least amount of size segregation. A motor paver, like those used to place asphalt, is the best way to ensure uniform aggregate distribution and coverage. Other devices, such as spreader boxes can be used to place aggregate. Tailgating (dump and spread) aggregate makes it much more difficult to avoid segregation and create a uniform surface. Every time the aggregate is handled or graded, it begins to segregate by size and becomes more likely to fail.

Should a Surface Aggregate Include Clay?

NO CLAY. In regions with abundant precipitation, ground moisture, or freeze-thaw cycles, clay-laden aggregate can cause problems. In these regions, clay in surface aggregate can retain excessive moisture and cause rutting, especially during thaw cycles. The clay also will tend to pump to the surface of the aggregate in wet conditions, increasing the amount of sediment runoff during rain events, and increasing the amount of dust generated during dry conditions. Clay particles are more likely to become mobilized by traffic than crushed rock, and are more likely to travel long distances before settling out of the air because of their fine size and platy shape

YES CLAY. In arid regions where dust is not a major concern, a small amount of clay may be desirable in surface aggregates. The clay will retain moisture and help to bind the aggregate together during excessive dry periods. The amount of clay in the aggregate (approximated by the plasticity index) will vary depending on local climate and material being used.

Table 8.1

Other “Surface Aggregate” Specifications from around the United States:

This table shows the variation in aggregates designated for an unbound wearing course from around the country.

Passing Sieve Size	mm	50	38	25	19	4.75	2.36	1.18	0.600	0.075	Plasticity Index
	in	2	1.5	1	0.75	#4	#8	#16	#30	#200	
PA Driving Surface Aggrgate			100		65-75	30-65		15-30		10-15	minimal
S. Dakota “General Surfacing” spec (2)					100	50-78	37-67		13-35	4-15	4-12
“Grading D” (3)				100	60-90	30-55	40-60		11-27	6-15	
Surface Coarse Aggregate (4)				100	86-100	50-76		32-50	22-36	9-21	2-10
“Surface Coarse Gradation” (5)				100	97-100	41-71			12-18	4-12	
Ohio “411” spec (6)			100	75-100	60-100	30-60			7-30	3-15	<6 on -#40
Maine Surface Aggregate (7)		100								7-12	
AASHTO Class A&B, 4120.04, 4120.05 (8)				100	95-100	30-55	15-40			6-16	4-9
AASHTO Class C 4120.03 (8)					100	50-80	25-60			>6	4-9
“Close Graded Surface Course” (9)					100			15-30		3-8	4-9

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3 Foltz, R.B. and M. Truebe. 2003. Locally Available Aggregate and Sediment Production.. In Low-Volume Roads 8 proceedings. TRB, Washington, D.C. (http://www.fs.fed.us/rm/pubs_other/rmrs_2003_foltz_r001.pdf. Pg 118)

4 Keller, G., and J. Sherar. 2003. Low-volume Roads Engineering Best Management Practices Field Guide. USDA Forest Service (http://ntl.bts.gov/lib/24000/24600/24650/Chapters/N_Ch12_Roadway_Materials.pdf. Pg 120)

5 1996 FHWA Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects (FP-96) (http://www.efl.fhwa.dot.gov/design/manual/Fp96.pdf. Pg 686)

6 Ohio Dot Specification (http://www.dot.state.oh.us/Divisions/ConstructionMgt/OnlineDocs/Specifications/2005CMS/700/703.htm#a_703_18__Materials_for_Items_410_411)

7 http://www.maine.gov/dep/blwq/docstand/escbmps/escsectionh1.pdf

8 Iowa DOT: http://www.iowadot.gov/erl/archives/Apr_2005/GS/common/english_gradations.htm

9 http://www.highwaysmaintenance.com/Aggtext.htm

CASE STUDY: Driving Surface Aggregate (DSA): DSA is an aggregate specification from Pennsylvania Department of Transportation that was designed as a wearing course for unpaved roads. It was designed to achieve maximum packing density in order to resist wear and erosion.

Key Facts about DSA

- Developed in 1997 as an alternative to sub-base aggregates being used on road surfaces in Pennsylvania.
- Used to surface over 500 miles of road to date.

Table 8.2

Passing sieve	Lower %	High %
1 1/2 inches	100	
3/4 inches	65	95
#4	30	65
#16	15	30
#200	10	15

DSA size gradation.

- Derived of crushed rock. No soil or clay fines may be added. (Pennsylvania has approximately 40 inches annual rainfall, and more than 70 freeze-thaw days annually.)
- Placed at optimum moisture, preferably through a motor paver at a noncompacted depth of 6 to 8 inches.
- When placed properly, the surface should be maintenance free for roughly 3 to 5 years with average daily traffic below 150. DSA can be graded easily under moist conditions with a carbide-toothed grader blade.
- Experience has shown that DSA produces less dust than other aggregates and native surfaces in Pennsylvania.
- Studies have proven that DSA reduces sediment runoff from the road surface by over 90 percent in locations where it has been placed over existing mixed-surface roads in Pennsylvania.
- It is important that any surface aggregate be easy to make. In Pennsylvania, DSA can be made using common existing aggregates (8 parts PENNDOT 2A, 1 to 1.5 parts PENNDOT #57, and 1 part #200 fines).

Figure 9.1—Road Assesment and monitoring.

Road Assessment and Monitoring

Assessing road condition and monitoring post-treatment installation requires a systematic process to evaluate if treatments implemented have corrected the problem. The soil water road condition index serves as an assessment and monitoring tool, which is used to identify road condition relative to soil and water resource concerns. The form can be used on a single road or every road of concern. The index is a systematic process that first characterizes the road or road segment by identifying surface shape, location, road gradient, hillslope gradient, and surface material. Once the segment is characterized, the road is evaluated using the following eight key indicators.

1. Road surface drainage.
2. Stream crossing condition.
3. Road subsurface drainage.
4. Diversion potential at crossings.
5. Road-stream connectivity.
6. Road surface condition.
7. Cutslope condition.
8. Fillslope condition.

For each of the eight indicators the reviewers identify if the road design, structure, or stream crossing is functioning. If the structure and design is operating in the proper or expected manner the road condition evaluation for that indicator is functional. If the structure or design is not operating as expected and is blocked, eroded, or has the chance of damaging resources (soil and water) in its present condition, the road condition evaluation is at-risk.

To determine the overall condition index for a road or segment, the reviewers evaluate each indicator for functionality and track each score to determine the percentage. Road segments with greater than 25 percent of the surface drainage structures at-risk receive an overall impaired condition rating. If less than 25 percent of the segment's surface drainage is not operating or functioning in the proper or expected manner, the overall rating is at-risk. The sample form and rule set shows how the tool is used.

Steps to determine overall condition index:

1. Drive the entire road or road segment to review the road and identify potential road segments. Road segments can be delineated from U.S. Geological Survey quadrangles or routed linear Arc/Info coverage. Without any preidentified segment breaks, look for the following when segmenting a road:
    a. Changes in surface shape (insloped to outsloped).
    b. Location (road within stream zone, climbing segment, upper one third).
    c. Surface material (gravel, native, paved), or surface drainage type.

The amount of segmentation may vary depending on resource objectives.

2. Characterize each segment by closely examining the indicators on the form. Return to the first road segment and before driving the segment; identify the road surface shape, location, gradient, hillslope gradient, and surface material. Together with a coworker identify the following:
    a. What type of surface drainage is used? Is it functioning?
    b. Are there stream crossings within the segment, are they open and functional?
    c. Does the road intercept subsurface drainage? Is it a point or linear feature throughout the segment?
    d. Is the ditch eroded? What type of vegetation is growing on either side of the road?
    e. Is there diversion potential with insloped roads, ditch-relief culverts, or at natural stream crossings? If a structure fails, where will the water flow?

f. Is the road segment connected to the stream at natural stream crossings or from gullies delivering sediment to the stream?
g. Are there rills or ruts on the road surface?
h. Are the cutslopes and fillslopes well vegetated and stable? Or are there rills, sparse vegetation, and indications of mass wasting?

3. Drive the remainder of the segment. Identify the number of drainage structures that are functional. Often if one culvert is plugged, many culverts on the road also will be plugged. The record keeper tracks the ratings to determine the overall road segment rating.

4. Complete a form for each segment. Circle functional, at-risk, or N/A for each of the eight indicators. Add the circled rating for each category. Determine the percentage of functioning indicators for each indicator. Follow the rule set to obtain an overall rating. Turn the form over and answer the questions on the back related to maintenance or improvement considerations, potential causes of sediment, and site-specific concerns.

5. Repeat the process and drive to a typical location within the next segment. Identify the segment (2) of FS road (x) and complete the form. Identify the segment breaks on quadrangle maps or with a global positioning system waypoint. Photograph a representative segment of the road.

Soil and Water Road Condition Index

Road #
Segment Length__________________ Total road length_________________
Reviewed by:____________________

STEP 1	***Road Characterization (circle each to characterize segment)***			
Road Surface shape	***Hillslope Position***	***Road Gradient***	***Hillslope Gradient***	***Road Surface Material***
Inslope	upper 1/3	0-8%	0-15%	Native
Outslope	middle 1/3	9-15%	16-35%	Aggregate
Crown	lower 1/3	>15%	>35%	Paved
Entrenched	climbing segment			
Turnpiked	within SMZ			
User Created				

STEP 2	**Road Condition Evaluation**			
1. Road Surface Drainage (Identify surface drainage on road segment from list below)	**N/A**	**Functional**	**At-Risk**	**Impaired**
Ditch (linear feature)		No signs of erosion or scour	Eroded ditch with signs of downcutting or scour	>25 percent of segment "at-risk"
Lead-off or winged ditch		Open / no deposition/ no scour	Partially blocked or blocked, scour at outlet	>25 percent of segment "at-risk"
Ditch relief culverts (point)		Open / no deposition/ no scour	Partially blocked or blocked, scour at outlet	>25 percent of segment "at-risk"
Drainage dips / broad-based dips(point)		Open / no deposition/ no scour	Deposition, scour, erosion at outlet	>25 percent of segment "at-risk"
Overside drains (point)		Open / no deposition/ no scour	Blocked or scour at outlet	>25 percent of segment "at-risk"
Diffuse Drainage feature (outslope) linear		Equal distribution of runoff, no signs of erosion or concentrated flows.	Concentrated flowpaths on fill slopes, erosion present	>25 percent of segment "at-risk"
Non-engineered (user-created)		No signs of erosion.	Surface has erosion from concentrated flowpaths	>25 percent of segment "at-risk"

2. Condition of Stream Crossing (point)		Open & Functional	Reduced capacity at inlet, development of terrace at inlet	>25 percent of segment "at-risk"
3. Road Subsurface Drainage (Pt or linear)		Intercepts subsurface flows with no adverse effect to vegetation & no ditch scour	Eroded ditch, evidence of vegetation change	>25 percent of segment "at-risk"
4.Diversion Potential at Crossings (point)		No diversion	Diversion potential present at stream crossing	>25 percent of segment "at-risk"
5. Road-stream Connectivity (point)				
Road connected to stream crossing		No flowpaths from road prism to stream	Direct flowpaths present from road surface or ditch to stream	>25 percent of segment "at-risk"
Road connected thru gully formation to stream		No signs of gully or sediment entering stream	Gullies present	>25 percent of segment "at-risk"
6. Road Surface Condition (linear)		No rilling/rutting	Rills and ruts prevalent	>25 percent of segment "at-risk"
7. Cutslope Condition (linear)		Vegetated/stable	Unvegetated and unstable	>25 percent of segment "at-risk"
8. Fillslope Condition (linear)		Vegetated/stable	Unvegetated and unstable	>25 percent of segment "at-risk"
Add together the numbers for 1-8 at the base of each column				
Select SWRCI for segment from criteria on back of sheet		Functional	At- Risk	Impaired

Comments:

Figure 9.2—Road assessment and monitoring form.

STEP 3				
Maintenance or Improvement Considerations				
Operational Maintenance Level (Level 1-5)				
Season of Use for road		Seasonal	Year long	
Traffic Level		High	Low	Closed
Design Storm (Circle dominant storm type for which road and structures are designed)	Snow	Short duration/high intensity	Rain	Rain on Snow
Dominant Soil Texture		Sandy loam	Silt Loam	Clay loam

If sediment transport is occurring what is the cause?

Inappropriate time of use of road with respect to soil and weather conditions.		
Inappropriate location/design of road.		
No maintenance of structures or road prism		
Inadequate drainage features		
Natural events (large storm event)		
Unknown		
Will sedimentation continue?	Yes	No
Are downstream beneficial uses at risk?	Yes	No

Site specific concern on road requiring immediate attention?

GPS location:
Photo numbers:
Describe problem:

Additional comments

Definitions:
Functional: To operate in the proper or expected manner.
At-risk: The chance of damage to resources (water or soil quality) are present in the current condition.
Impaired: Not functioning as designed or maintained.

Rule set for determining an **overall at- risk condition rating** for the segment any of the following must be true:
1. Any road surface drainage is evaluated as at-risk.
2. Diversion potetial is identified at road stream crossings.
3. If road stream connectivity is present.
4. The combination of road stream connectivity and unvegetated or unstable cutslopes.
5. A road segment with ONLY an-at risk surface condition rating and no other indicators even if >25% is still at-risk.

Rule set for determining an **overall impaired condition rating** for the segment any of the following must be true:
1. A road segment with greater than 25% of the surface drainage structures at risk.
2. A road segment with greater than 25% of the stream crossing structures at risk.
3. A road segment with greater than 25% with at subsurface drainage at risk.
4. A road segment with greater than 25% of the crossings with diversion potential
5. A road segment with greater than 25% road stream connectivity.
6. A road segment with a combination of at-risk ratings for road surface drainage, diversion potential, road-stream connectivity, road surface conditon, and cutslope or fillslope condition.

Figure 9.2—Road assessment and monitoring form (cont'd).

Chapter 10

References and Additional Resources

Subsurface Water

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Road Surface Drainage

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Ditches

1. *Water Roads Interaction: Introduction to Surface Cross Drains* <http://www.fs.fed.us/eng/php/library_card.php?p_num=9877%201806P>.

Road-Stream Crossings

1. *Low-Water Crossings: Geomorphic, Biological and Engineering Design Considerations* <http://www.fs.fed.us/eng/php/library_card.php?p_num=0625%201808P>.
2. *Stream Simulation: An Ecological Approach to Providing Passage to Aquatic Organism at Road-stream Crossings.* <http://www.fs.fed.us/eng/php/library_card.php?p_num=0877%201801P>.
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Fillslopes and Cutslopes

1. *Soil Bioengineering: An Alternative to Roadside Management* <http://www.fs.fed.us/eng/php/library_card.php?p_num=0077%201801>.
2. *Roadside Revegetation. An Integrated Approach To Establishing Native Plants* <http://www.wfl.fhwa.dot.gov/td/>.

Surface Aggregate

1. *Driving Surface Aggregate* <www.dirtandgravelroads.org>.
2. *Stabilization Selection Guide for Aggregate and Native-Surfaced Low-Volume Roads* <http://www.fs.fed.us/eng/php/library_card.php?p_num=0877%201805P>.

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