Chapter 7

Drainage of Low-Volume Roads

"Three of the most important aspects of road design -- drainage, drainage, and drainage"

Road location and drainage of roads, construction areas, and other areas of activity are the most significant factors that can affect water quality, erosion, and road costs. Drainage includes controlling surface water and adequately passing water under roads in natural channels. Drainage issues that must be addressed in road design and construction include roadway surface drainage; control of water in ditches and at pipe inlets/outlets; crossings of natural channels and streams; wet area crossings; subsurface drainage; and selection and design of culverts (Chapter 8), low water crossings (Chapter 9), and bridges (Chapter 10). Three of the most important aspects of road design are **drainage, drainage, and drainage!**

Adequate road drainage requires careful **attention to detail.** Drainage conditions and patterns must be studied on the ground. Drainage should be observed during rainy periods to see how the water is actually moving, where it is concentrated, what damage it may cause, and what measures are needed to prevent damage and keep the drainage systems functioning properly.

Roadway Surface Drainage Control

The roadway surface needs to be shaped to disperse water and move it off the road quickly and as

Photo 7.1 Design roads that move water rapidly off the surface of the road and minimize water concentration with the use of rolling grades and outsloped, insloped, or crowned roads.

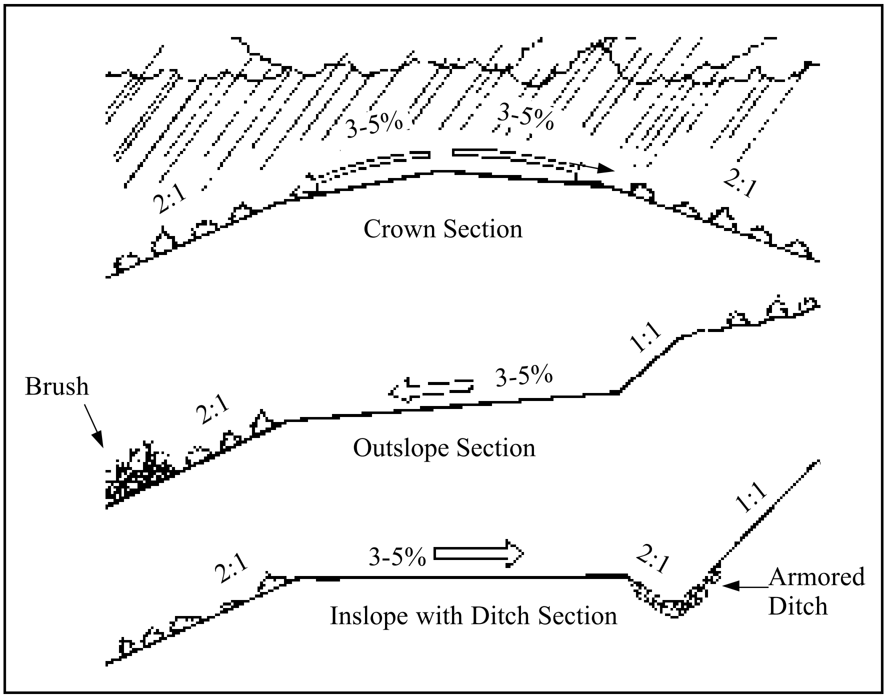


Figure 7.1 Typical road surface drainage options.

frequently as possible (*Photo 7.1*). Water standing in potholes, ruts and sags will weaken the subgrade and accelerate damage. Water concentrated in ruts or kept on the road surface for long distances can accelerate erosion as well as wash off the surface material. Steep road grades cause surface and ditch water to move rapidly, and make surface drainage difficult to control. Steep grades accelerate erosion unless surfaces are armored or water is dispersed or removed frequently.

Roadway surface water should be controlled with positive drainage measures using **outsloped**, **insloped**, or **crown** sections of road, as shown in *Figure 7.1*. **Outsloped** roads best disperse water and minimize road width, but may require roadway surface and fill slope stabilization. An outsloped road minimizes concentration of water, minimizes needed road width, avoids the need for an inside ditch, and minimizes costs. Outsloped roads with clay rich, slippery road surface materials often require rock surface stabilization or limited use during rainy periods to assure traffic safety. On road grades over 10 to 12 percent and on steep hill slope areas, outsloped roads are difficult to drain and can feel unsafe.

Insloped roads best control the road surface water but concentrate water and thus require a system of ditches, cross-drains, and extra road width for the ditch. Cross-drains, using either rolling dips (broad-based dips) or culvert pipes, must be spaced frequently enough to remove all the expected road surface water before erosion occurs. The maximum recommended distances (listed in *Table 7.1*) should be used for guidance on spacing of cross-drains and ditch relief structures. Specific locations should be determined in the field based upon actual water flow patterns, rainfall intensity, road surface erosion characteristics, and available erosion resistant outlet areas.

Crown section roads are appropriate for higher standard, two lane roads on gentle grades. They also require a system of inside

Photo 7.2 Use rolling dip (broad-based dip) cross-drains to move water off the road surface efficiently and economically, without the use of culvert pipes. Rolling dip cross-drains are not susceptible to plugging.

Table 7.1

Recommended Maximum Distance Between Rolling Dip or Culvert Cross-Drains (meters)

Road Grade %	Low to Non-Erosive soils (1)	Erosive Soils (2)
0-3	120	75
4-6	90	50
7-9	75	40
10-12	60	35
12+	50	30

Table 7.2

Recommended Water Bar Spacing (meters)

Road/Trail Grade %	Low to Non-Erosive soils (1)	Erosive Soils (2)
0-5	75	40
6-10	60	30
11-15	45	20
16-20	35	15
21-30	30	12
30+	15	10

Note: (1) **Low Erosion Soils** = Coarse Rocky Soils, Gravel, and Some Clay
(2) **High Erosion Soils** = Fine, Friable Soils, Silt, Fine Sands

Adapted from Packer and Christensen (1964) & Copstead, Johansen, and Moll (1998)

ditches and cross drains. It is difficult to create and maintain a crown on a narrow road, so generally insloped or outsloped road drainage is more effective for rural roads.

Culvert cross-drains are used to move ditch water across the road. They are the most common type of road surface drainage, and are most appropriate for high-standard roads where a smooth road surface profile is desired. However the pipes are expensive, and the relatively small culvert pipes used for cross-drains are suseptible to plugging and require cleaning.

Rolling dip cross-drains (**broad-based dips**) are designed to pass slow traffic, while also dispersing surface water (*Photo 7.2*). Rolling dips usually cost less, require less maintenance, and are less likely to plug and fail than culvert pipes. Rolling dips are ideal on low volume, low to moderate speed roads (20-50 kph). Spacing is a function of road grade and soil type, as seen in *Table 7.1*. Other types of roadway surface cross-drain structures occasionally used include open top wood or metal flumes, and rubber water deflectors.

Steep road grades are undesirable and problematic, but occasionally necessary. On grades up to 10%, cross-drains with culverts or rolling dips are easy to use. Between 10 and 15%, frequently spaced culvert cross-drains work, often in conjunction with armored ditches. On grades over 15%, it is difficult to slow down the wa-

RECOMMENDED PRACTICES

Roadway Surface Drainage Control

- Design and construct roads so that they will move water rapidly off the road surface to keep the surface drained and structurally sound.

- Avoid steep road grades in excess of 12 to 18%. It is very difficult and expensive to properly control drainage on steep grades.

- Maintain positive surface drainage with an outsloped, insloped, or crown roadway section using 3 - 5 % cross slopes (up to 5% is best) (*Figure 7.1*).

- Roll grades or undulate the road profile frequently to disperse water, particularly into and out of stream crossings (*Figure 7.2a, Photo 7.1*).

- Use frequently spaced leadoff ditches (*Figure 7.2b* and *Figure 7.8*) to prevent accumulation of excessive water in the roadway ditches.

- Use roadway cross-drain structures (either rolling dips, pipe culverts, or open top culverts (flumes)) to move water across the road from the inside ditch to the slope below the road. Space the cross-drain structures frequently enough to remove all surface water. *Table 7.1* gives recommended cross-drain spacing.

- **Protect cross-drain outlets** with rock (riprap), brush, or logging slash to dissipate energy and prevent erosion, or locate the outlet of cross drains on stable, non-erosive soils, rock, or in well vegetated areas (*Figure 7.2b*).

- Construct **rolling dips** rather than culvert cross-drains for typical, low-volume, low speed roads with grades less than 12%. Construct rolling dips deep enough to provide adequate drainage, angled 0-25 degrees from perpendicular to the road, with a 3-5% outslope, and long enough (15 to 60 meters) to pass vehicles and equipment (*See Photo 7.2*). In soft soils, armor the mound and dip with gravel or rock, as well as the outlet of the dip (*Figure 7.3*).

- Install **culvert cross-drains** with an angle of 0-30 degrees perpendicular to the road, using an outslope of 2% greater than the ditch grade to prevent plugging. (*Figure 7.4*). (See Chapter 8 for more information on culverts). Use culvert cross-drains on roads with an inside ditch and moderately fast vehicle speeds.

- Construct **water bars** on infrequently used roads or closed roads to control surface runoff. Construct frequently spaced waterbars angled at 0-25 degrees with an outslope of 3-5% and a depth of 0.3 to 0.6 meters. Install water bars as shown in *Figure 7.5*. Spacing of waterbars is shown in *Table 7.2*.

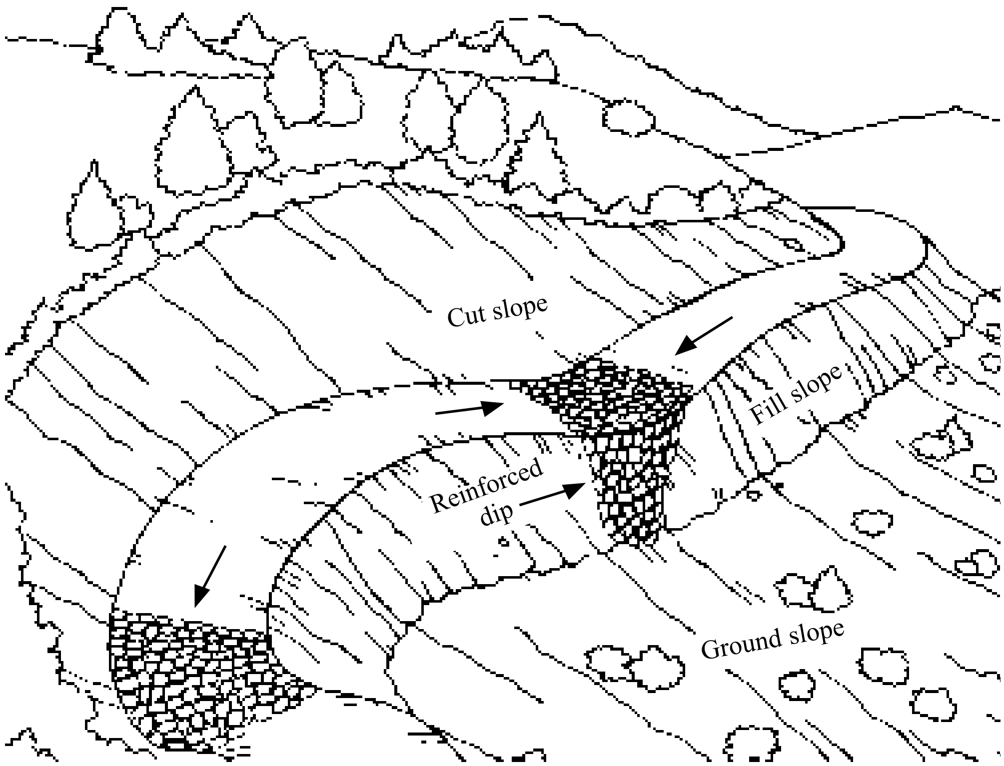
- Use **catch water ditches** (intercept ditches) across the natural ground above a cut slope only in areas with high intensity rainfall and overland flow. These ditches are useful to capture overland sheet flow before it pours over the cut slope and erodes or destabilizes the cut. However, be aware that catch water ditches are that are not properly maintained can become a counter-productive pool for water above the slope, increasing the probability of a slope failure.

- Avoid the use of **outside ditches**, along the outside edge of the road, except in specific areas that must be protected from sheet flow off the road surface. Preferably, use berms. Note that an outside ditch or berm necessitates additional road width.

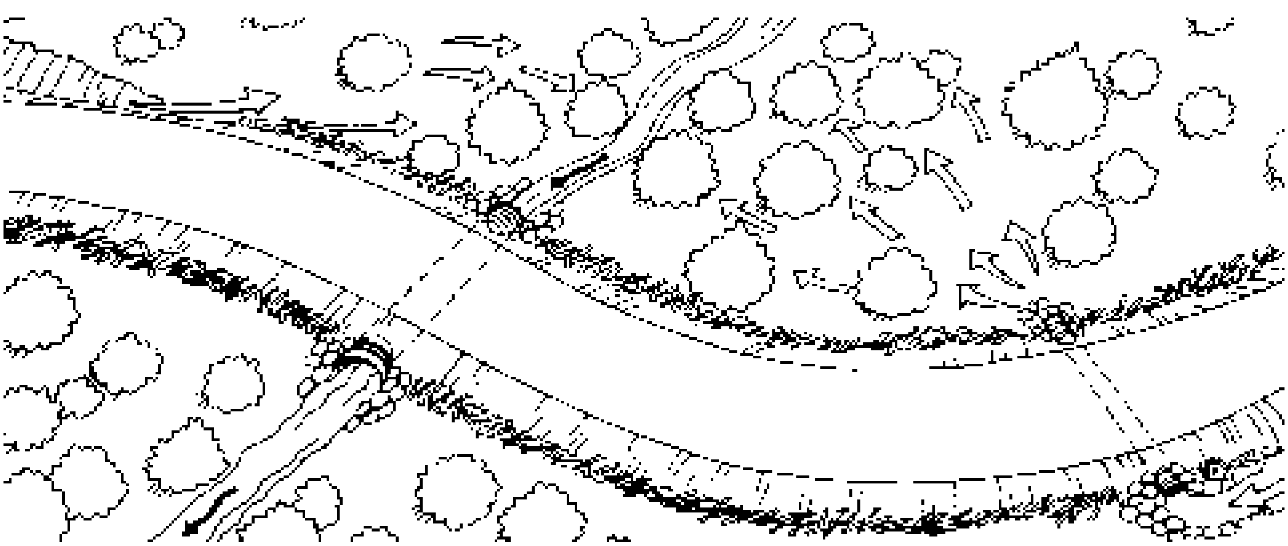
PRACTICES TO AVOID

- Long sustained road grades that concentrate flows.
- Discharging water onto erosive, unprotected soils.
- "Eyeballing" grades in flat terrain. Use a clinometer, abney level, or survey equipment to ensure that you have proper slopes or grades.

Figure 7.2

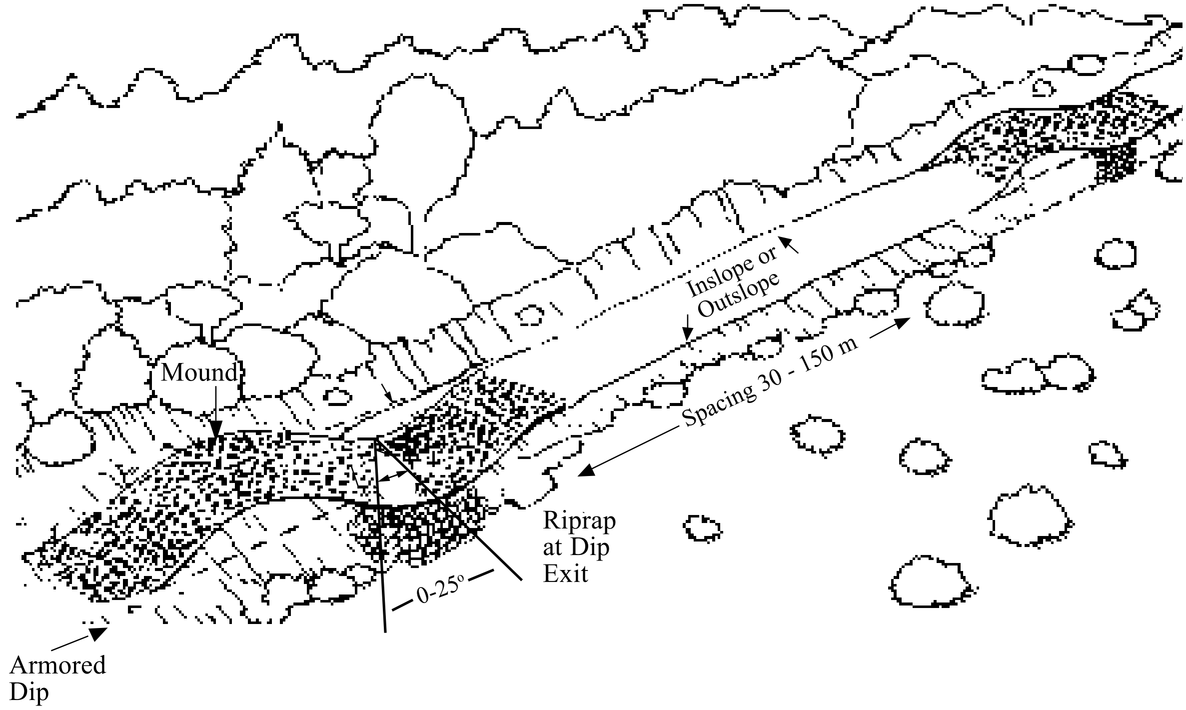


a. **Basic road surface drainage with outsloping, rolling grades, and reinforced dips.**

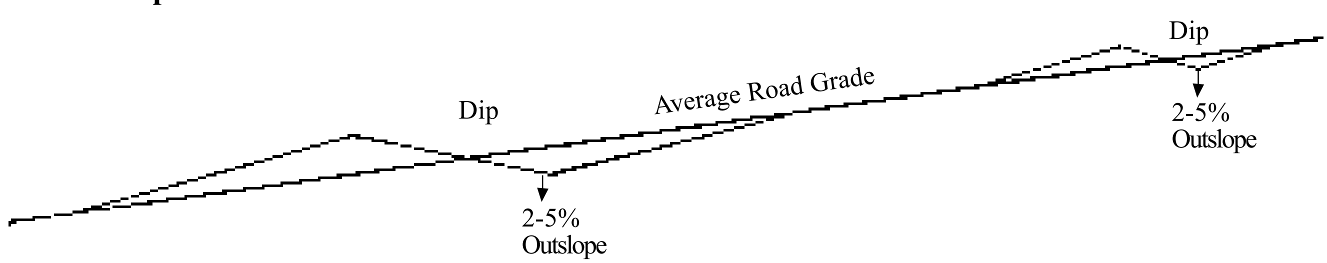


b. Basic road surface drainage with leadoff ditches and culvert cross-drains exiting into vegetation or a streamside buffer area. ***(Adapted from Montana State Univ. 1991)***

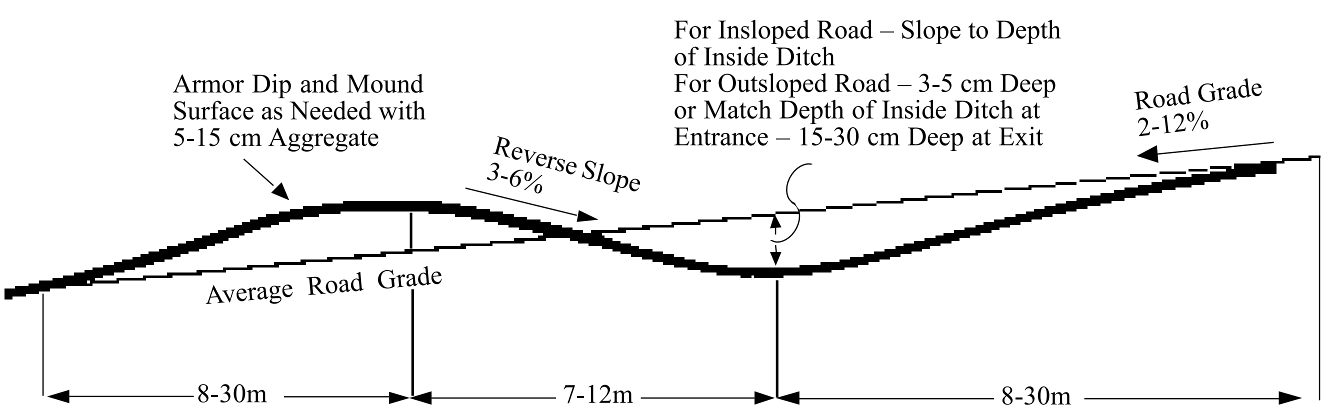
Figure 7.3 Rolling (broad-based) dip cross-drains.



a. Perspective View



b. Profile



c. Rolling Dip Profile Detail

Figure 7.4 Culvert cross-drains.

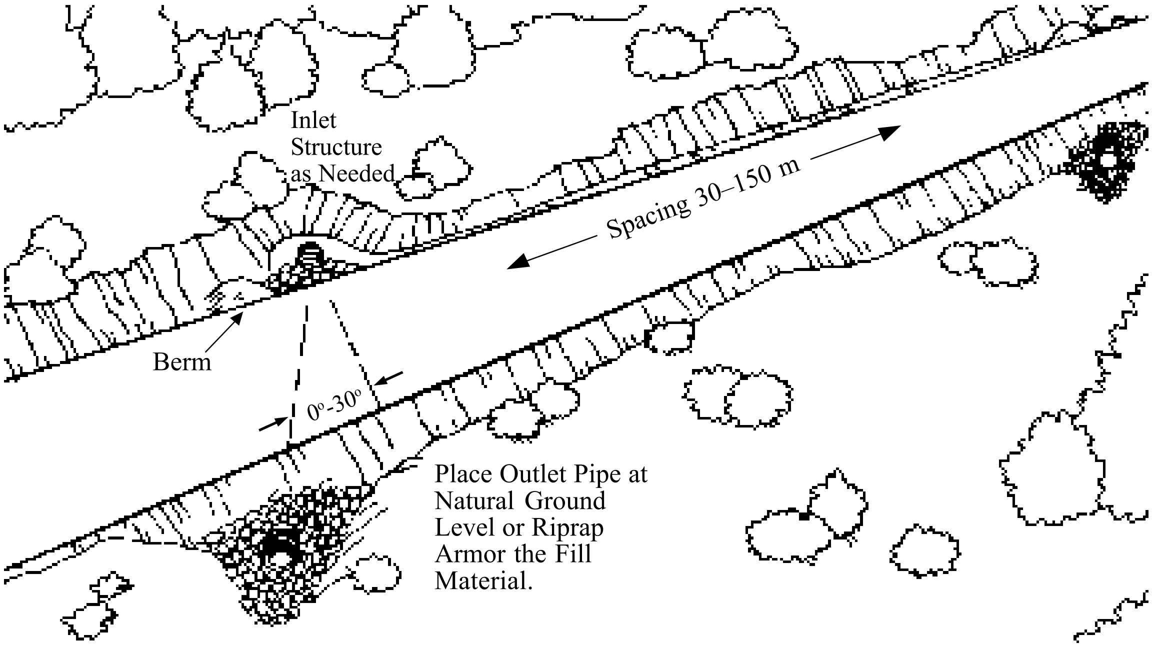
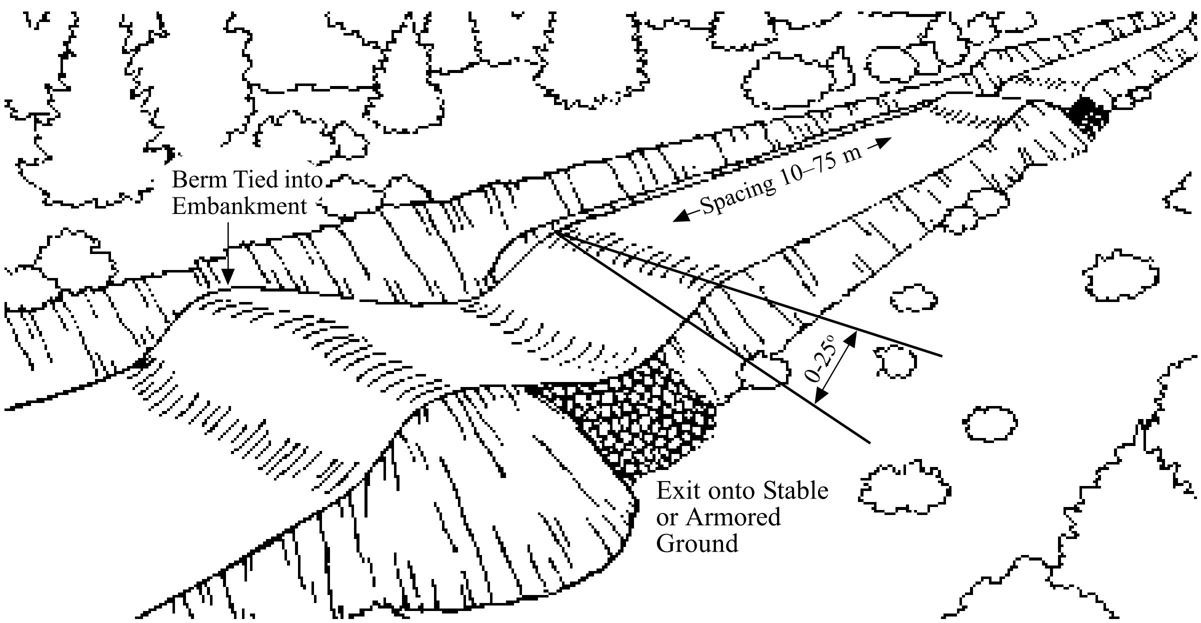
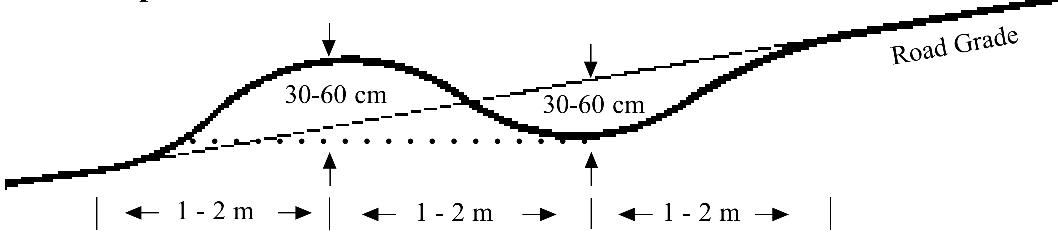


Figure 7.5 Water bar construction. *(Adapted from Wisonsin's Forestry Best Management Practices for Water Quality. 1995, Publication FR093, Wisconsin Department of Natural Resources)*



a. Perspective View



b. Cross-Section

Photo 7.3 Use masonry, concrete, or metal inlet structures to control water in the ditch, direct the water into the cross-drain pipe, and prevent ditch down-cutting.

ter or remove it from the road surface rapidly. On such steep grades, it is best to use frequently spaced cross-drain culverts, with armored ditches. Also, the road surface will need armoring or surfacing with some form of pavement to resist erosion. For seasonal or low use roads, interim drivable waterbars could also be constructed.

Water bars are used to control drainage on closed or inactive roads, 4-wheel drive roads, skid roads, and skid trails. Water bars are frequently spaced (see *Table 7.2*) for maximum erosion control and can be shaped to pass high clearance vehicles or to block traffic.

Photo 7.4 Add outlet protection and/or energy dissipators to prevent erosion and the formation of gullies.

Control at Inlets and Outlets of Cross-Drains and Ditches

Water should be controlled, directed, or have energy dissipated at the inlet and outlet of culverts, rolling dips, or other cross-drainage structures. This can ensure that water and debris enters the cross-drain efficiently without plugging, and that it exits the cross-drain without damaging the structure or causing erosion at the outlet.

Culvert inlet structures (drop inlets) are usually placed in the inside ditchline at the location of a culvert cross-drain. They are commonly constructed of concrete, masonry (*Photo 7.3*), or from round metal pipe, as seen in *Figure 7.6*. They are typically used where the ditch is eroding and downcutting, so that the structure controls the ditch elevation. Inlet structures are also useful to change the direction of water flowing in the ditch, particularly on steep grades, and they can help stabilize the cut bank behind the pipe inlet.

The outlet of pipes and dips are ideally located in a stable, non-erosive soil area or in a well-vegetated or rocky area. The accelerated velocity of water leaving a roadway can cause severe erosion or gullying if discharged directly onto erosive soils (*Photo 7.4*). The pipe, dip, or drain outlet area can be stabilized, and the energy of the water dissipated, by discharging the water onto 1-2 cubic meters of a graded rock riprap, as seen in *Figure 7.7*. Other energy dissipation measures include the use of stilling basins, rein-

Photo 7.5 Protect the outlet of culvert pipe and rolling dip cross-drains with riprap or a masonry splash apron, or choose areas of bedrock or dense vegetation.

forced splash aprons, or use of dense vegetation or bedrock (*Photo 7.5*).

Ditches on steep road grades, in erosive soils, and with flow velocities over one meter per second may require armoring or the use of small ditch dike or dam structures placed in the ditch to slow down the velocity of water, as shown in *Figure 7.8*. Ditches are commonly armored with grass, erosion control matting, rock, or masonry /concrete paving (*Photo 7.6*). Grasses can resist flow velocities to 1-2 meters per second. A durable armoring such as graded rock riprap or concrete is recommended on grades over 5 percent in erosive soils or for velocities over a few meters per second.

Ditch dikes will prevent ditch erosion, and dikes can serve to catch sediment, but they require maintenanceneed in that they need to be periodically cleaned out. Common ditch dike construction materials include loose rock, masonry, concrete, bamboo, and wooden posts. Each dike structure should be keyed into the banks of the ditch and a notch is needed over each structure to keep the flow in the middle of the ditch.

RECOMMENDED PRACTICES

Control at Inlets & Outlets

- When ditch grade control is needed, use drop inlet structures with culvert cross-drains to prevent ditch down-cutting or where space is limited against the cut bank (*Figure 7.6*). Alternately, use catch basins excavated into firm soil.

- Discharge culverts and cross-drain dips at natural ground level, on firm, non-erosive soil or in rocky or brushy areas. If discharged on the fill slopes, armor outlets with riprap or logging slash, or use down-drain structures. (*Figures 7.3, 7.4, 7.7* and *Figure 8.1*). Extend the pipe 0.5 to 1.0 meters beyond the toe of the fill slope to prevent erosion of the fill material.

- In erosive soils, armor roadway ditches and leadoff ditches with rock riprap (*Photo 7.7*), masonry, concrete lining or, at a minimum, grasses. Ditch dike structures can also be used to dissipate energy and control ditch erosion. (*Figure 7.8*).

- Discharge roadway drains in an area with infiltration capability or into filter strips to trap sediment before it reaches a waterway. Keep the road and streams hydrologically “disconnected.”

PRACTICES TO AVOID

- Discharging a cross-drain pipe or dip onto any unprotected fill slope or barren, erosive soil.

- Discharging cross-drain pipes mid-height on a fill slope.

- Discharging cross-drain pipes or dips onto unstable natural slopes.

Photo 7.6 **Armor ditches with vegetation, rock, masonry, or concrete to resist ditch erosion and carry the water to a stable exit point.**

Figure 7.6 **Typical drop inlet structure types (with culvert cross-drains).**

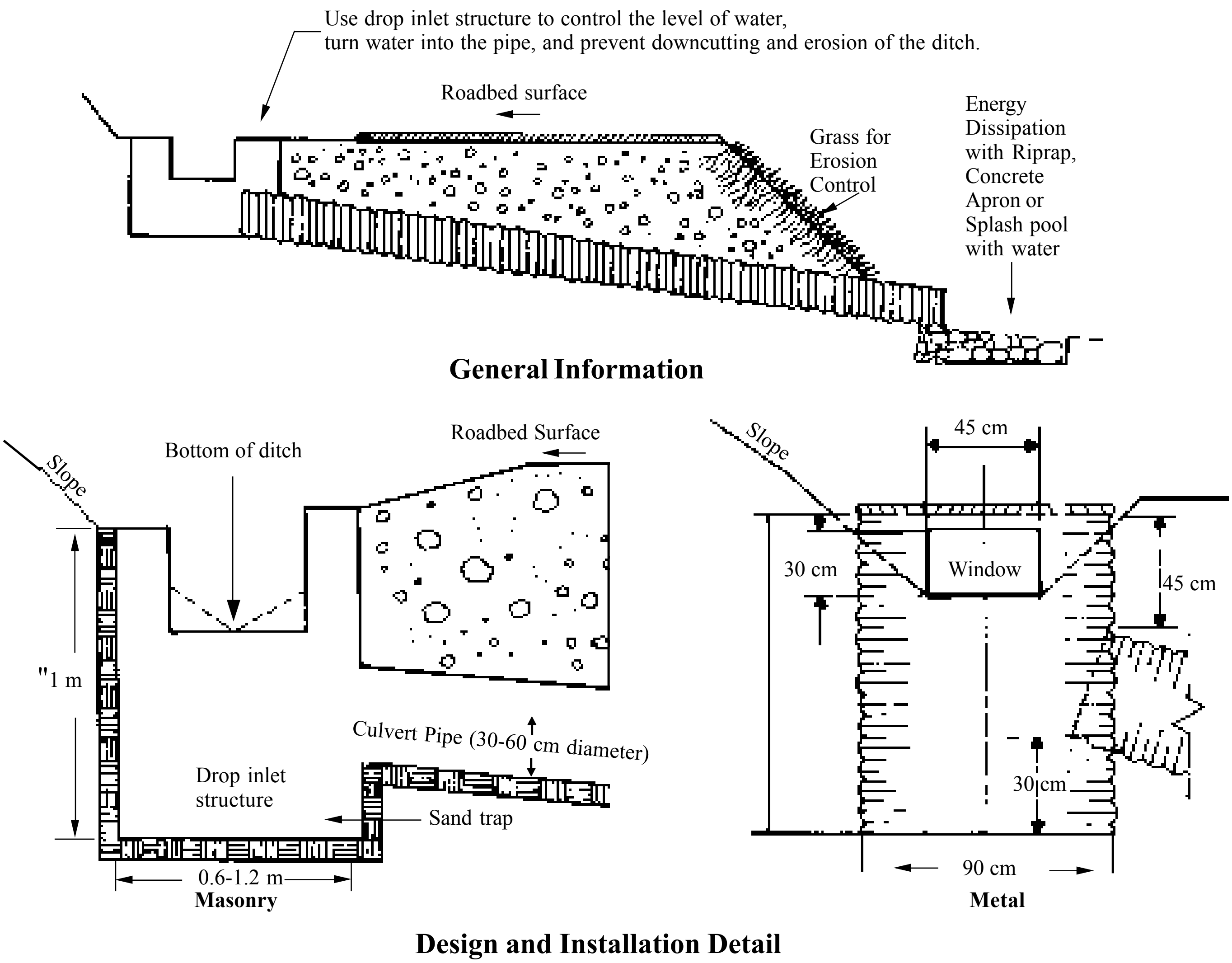


Figure 7.7 Culvert outlet protection.

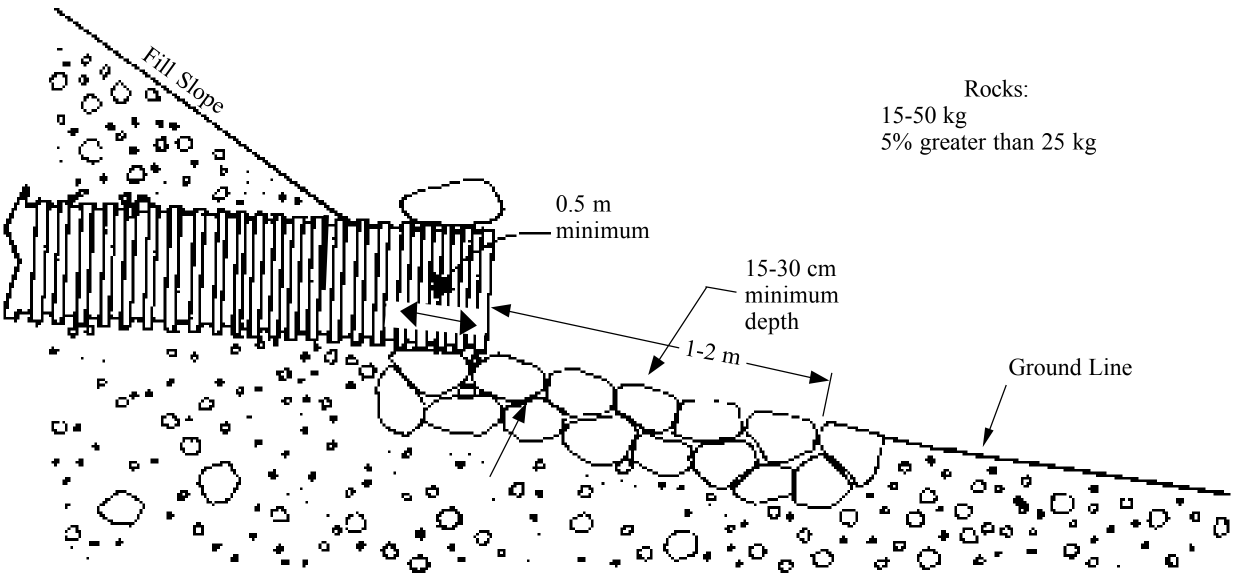
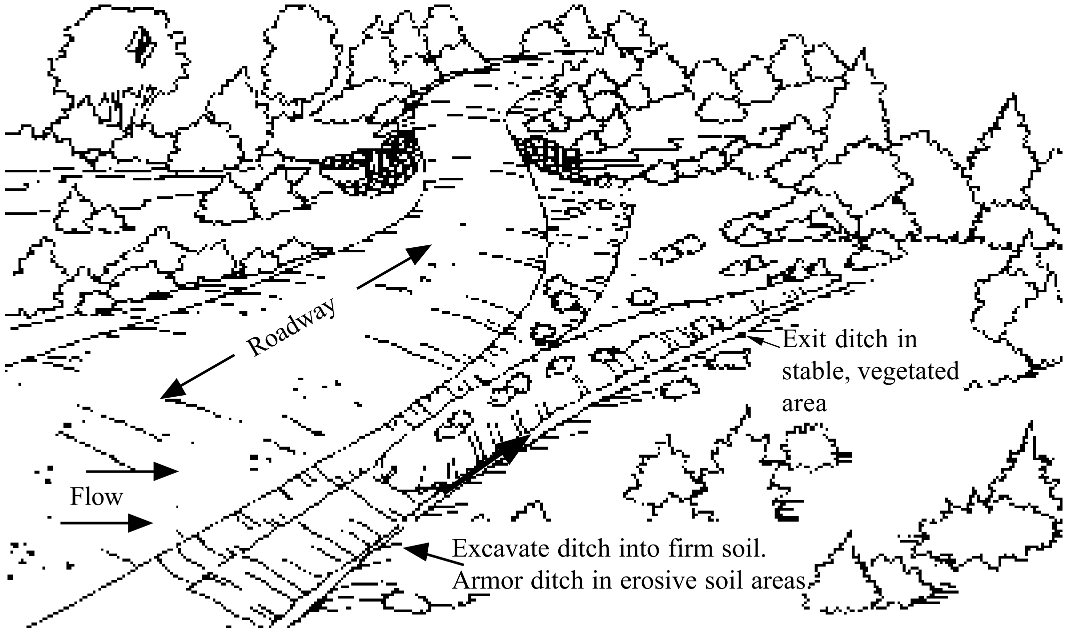
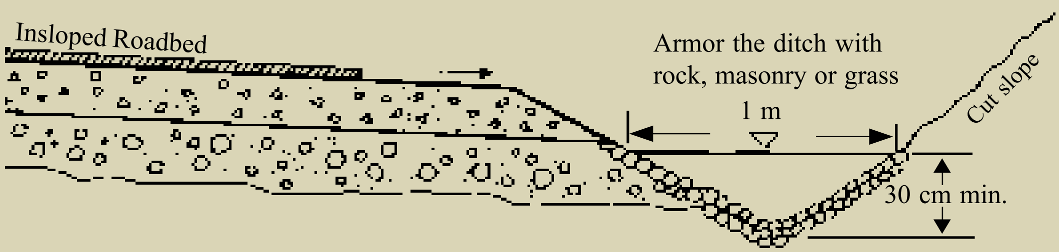


Photo 7.7 **A rock armored ditch and metal drop inlet to control the water and prevent down-cutting of the ditch.**

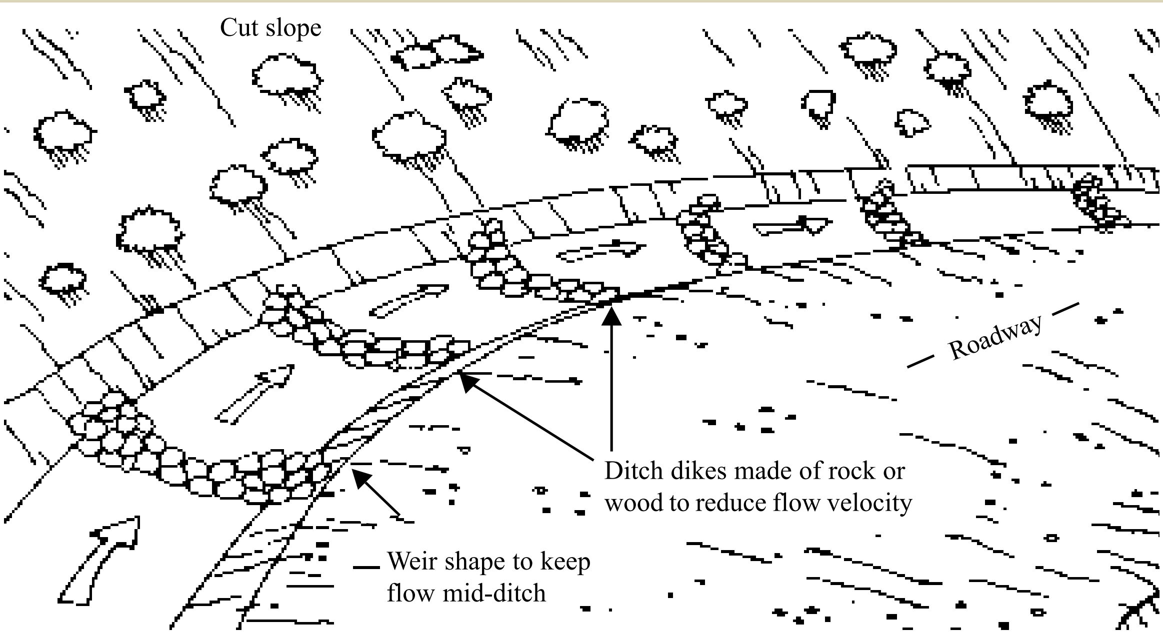
Figure 7.8 Ditches and ditch armoring.



a. Ditch Layout and Leadoff (Adapted from *Wisconsin's Forestry Best Management Practices for Water Quality, 1995)*



b. Typical Ditch Armoring and Shape



c. Use of Ditch Dikes

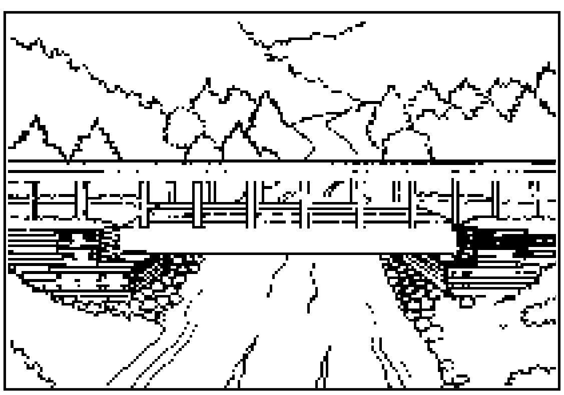
Natural Stream Crossings

Road crossings of natural drainage channels and streams require hydrologic and hydraulic design expertise to determine the proper size and type of structure, as discussed in Chapters 5 and 6. Structures for small drainages can be sized using *Table 8.1*. The choice of structure includes culvert pipes, arch or box culverts, low water fords, or bridges, as shown in *Figure 7.9*.

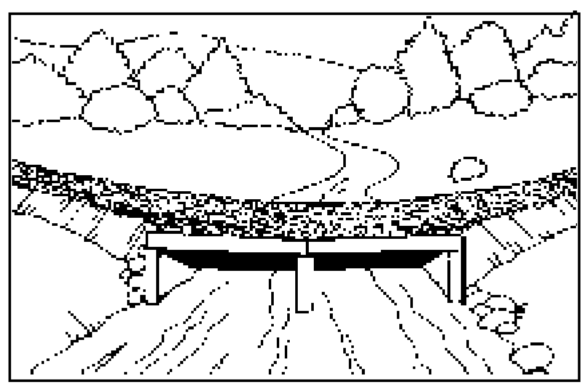
Because drainage crossings are at areas of running water, they can be costly to construct and can have major negative impacts on water quality. Impacts from improper design or installation of structures can include degraded water quality, bank erosion, channel scour, traffic delays, and costly repairs if a structure fails. Also, structures can greatly impact fish, as well as other aquatic species, at all stages of life. Stream crossings should be as short as possible and cross perpendicular to the channel (*Photo 7.8*). The road and ditches should be armored, ditches should divert surface water before it reaches the stream channel, and construction should minimize the area of disturbance, as shown in *Figure 7.10*. Large drainage crossings should receive site-specific analysis and design input, ideally by an experienced hydraulic engineer and other specialists.

In drainages with uncertain flow values, large quantities of debris in the channel, or on sites with existing undersized pipes, there is a high risk of a culvert pipe plugging and the site washing out or failing. In such areas, or in particularly sensitive watersheds, overflow protection is desirable. A low point in the fill and an armored overflow "spillway," as shown in *Figures 7.11a & b*, will protect the fill and keep the flow in the same drainage, thus reducing diversion potential and usually preventing a failure. A plugged pipe that diverts the stream water down the road can cause a great deal of off-site damage or gullying or cause landslides, as seen in *Figures 7.11c & d*. Overflow structures should not be used as a substitute for good hydraulic design, but they can offer "cheap insurance" against failure at culvert crossings.

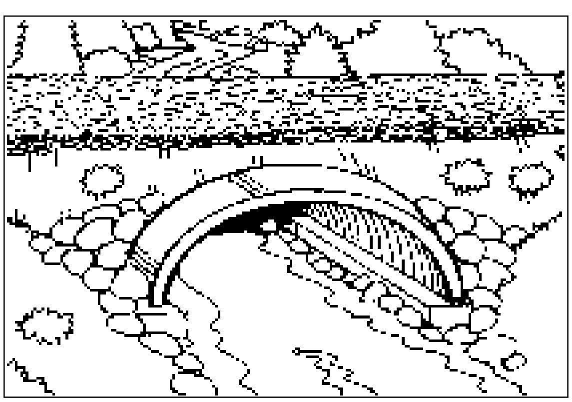
Figure 7.9 Structural options for crossing natural streams. ***(Adapted from Ontario Ministry of Natural Resources, 1988)***



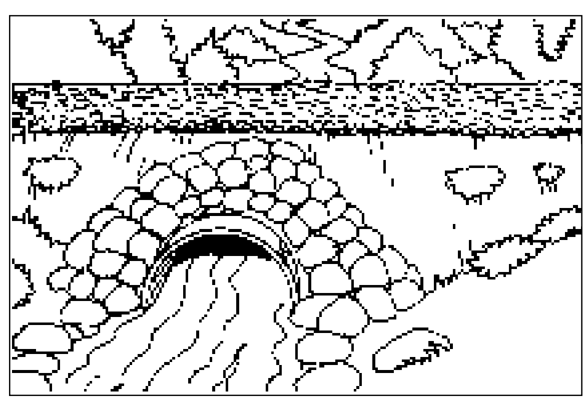
a. Bridge



b. Low-Water Crossing



c. Arch Pipe



d. Culvert with Single or Multiple Pipes

RECOMMENDED PRACTICES

Natural Stream Crossings

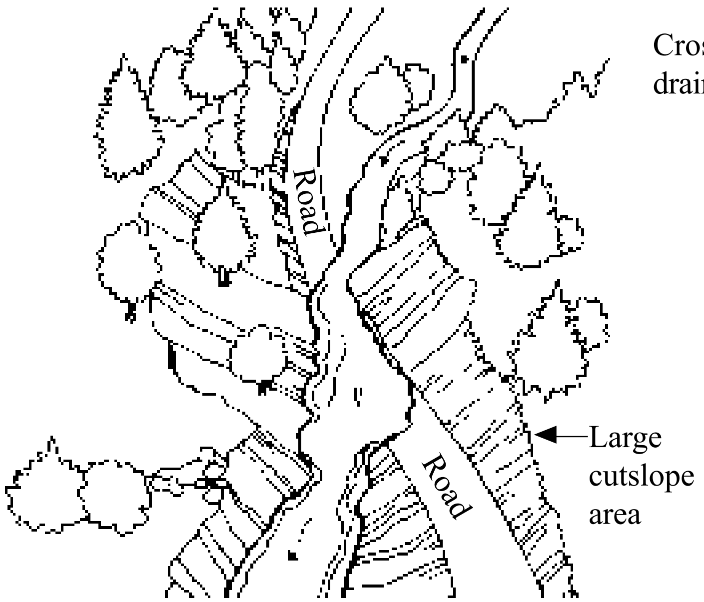
- Use drainage structures that best conform to the natural channel and that are as wide as the active stream channel (bankfull width). Minimize natural channel changes and the amount of excavation or fill in the channel.
- Limit construction activity to periods of low flow in live streams. Minimize use of equipment in the stream. Stay out of the stream!
- Design structures and use construction practices that minimize impacts on fish and other aquatic species or that can enhance fish passage.
- Cross drainage channels as infrequently as possible. When necessary, cross streams at right angles except where prevented by terrain features (*Figure 7.10*).
- Keep approaches to stream crossings to as gentle a grade as practical. Roll grades into and out of the crossing to disperse water.
- Stabilize disturbed soil around crossings soon after construction. Remove or protect fill material placed in the channel and floodplain.
- Use bridges, low-water fords or improved fords, and large arch pipes with natural stream bottoms wherever possible to maximize flow capacity, minimize the possibility of a plugged pipe, and minimize impacts on aquatic species.
- Locate crossings where the stream channel is straight, stable, and not changing shape. Bedrock locations are desirable for concrete structures.
- For overflow protection, construct fills over culverts with an armored low point near the pipe in low fills or add an armored rolling dip on native ground just beyond a large fill to return water to the drainage and prevent off-site damage (*Figure 7.11*).
- Stabilize roadway approaches to bridges, fords, or culvert crossings with gravel, rock, or other suitable material to reduce road surface sediment from entering the stream (*Figure 7.12*). Install cross-drains on both sides of a crossing to prevent road and ditch runoff from entering the drainage channel.
- Construct bridges and culvert fills higher than the road approach to prevent road surface runoff from draining directly into the stream -- but ONLY if likelihood of culvert failure is VERY small. (*Figure 7.13*). Typically, the crossing should be designed to minimize the amount of fill.

PRACTICES TO AVOID

- Working with equipment in an unprotected natural streambed.
- Locating stream crossings in sinuous or unstable channels.
- Adversely impacting fisheries with a stream crossing structure.
- Allowing runoff from roadside ditches to flow directly into streams.

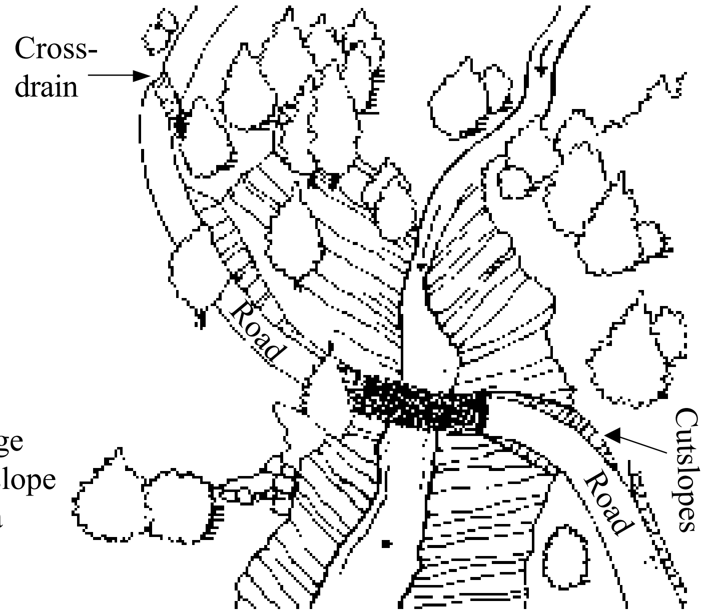
Figure 7.10 Natural drainage crossings. Minimize the area of disturbance with a perpendicular stream crossing alignment, and armor the roadway surface.

Poor Stream Crossing



Crossings near parallel to the drainage cause a large disturbed area in the channel, streambank, and approach cuts.

Better Stream Crossing

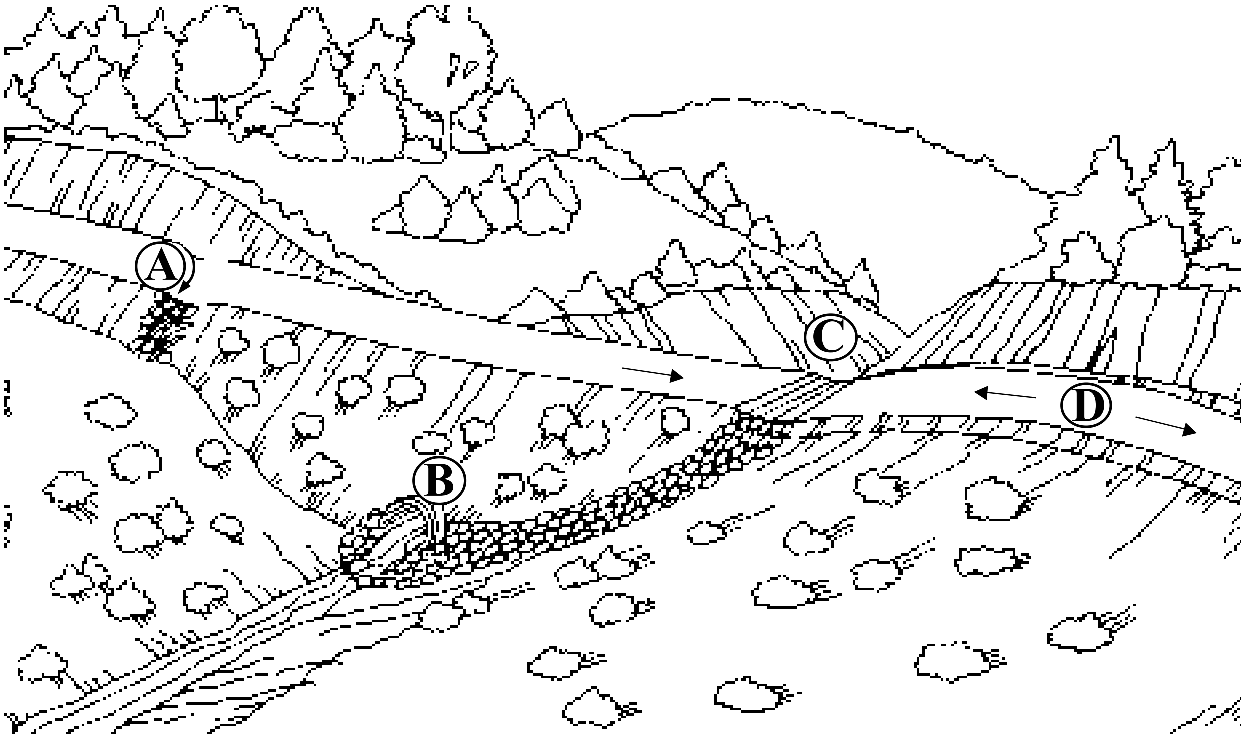


Drainage crossings perpendicular to the creek minimize the area of disturbance. Armor the stream crossing and roadway surface.

Photo 7.8 Avoid natural drainage crossings that are broad and that are not perpendicular to the drainage. Stay out of the stream! This broad channel is a good site for a vented ford.

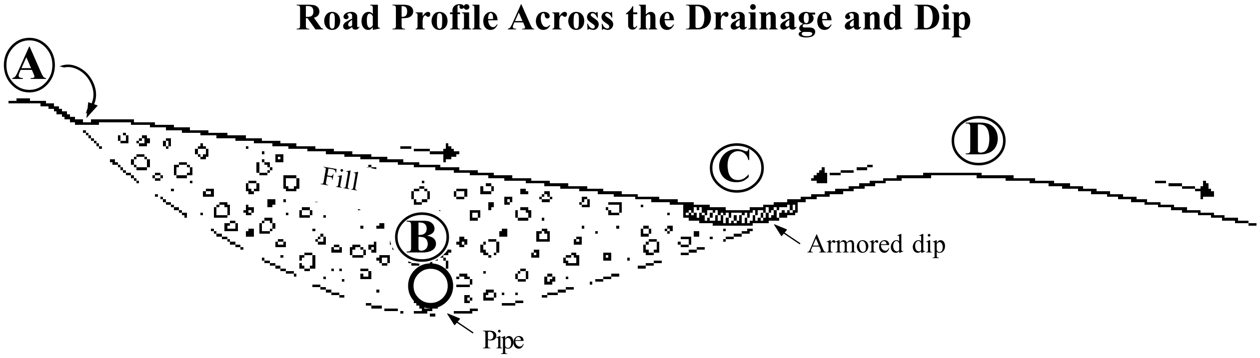
Figure 7.11

Culvert Installed with Protection using an Armored Overflow Dip to Prevent Washout and Fill Failure



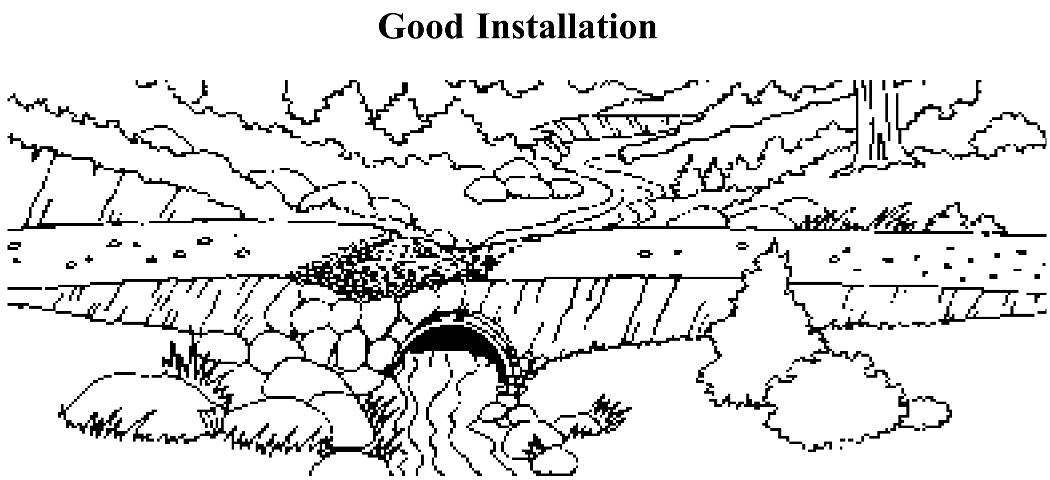
(A) Roadway Cross Drain (Dip)
(B) Culvert
(C) Overflow Protection Dip
(D) High point in the road profile

Road Profile Across the Drainage and Dip

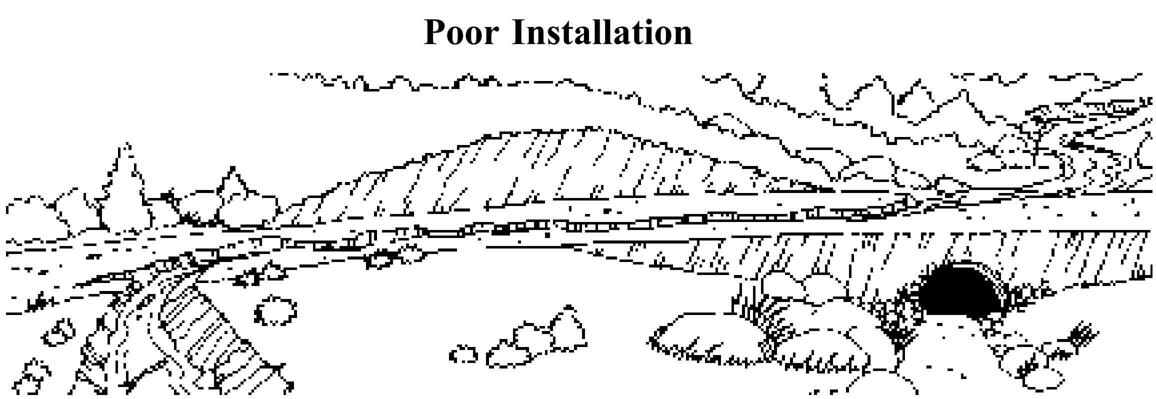


a. Overflow dip protection at a fill stream crossing. ***(Adapted from Weaver and Hagans, 1994)***

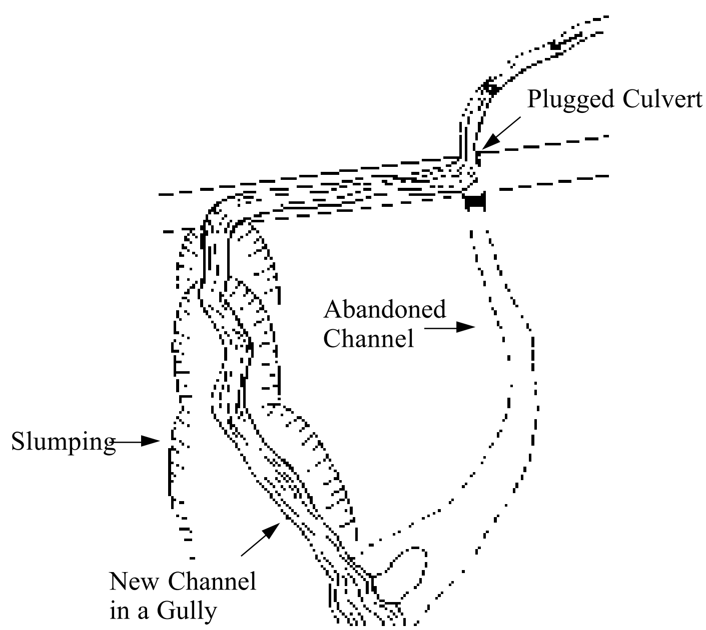
Figure 7.11 (continued)



b. Armored dip over a low fill to prevent stream diversion.

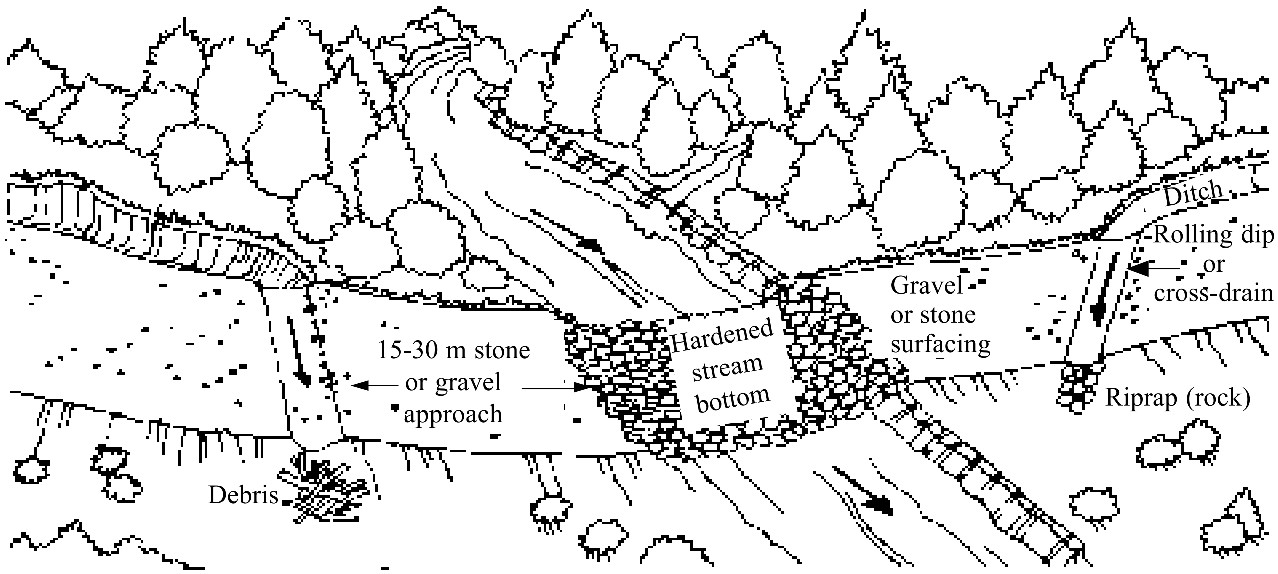


c. Sketch of a stream diverted down the road, forming a new channel.



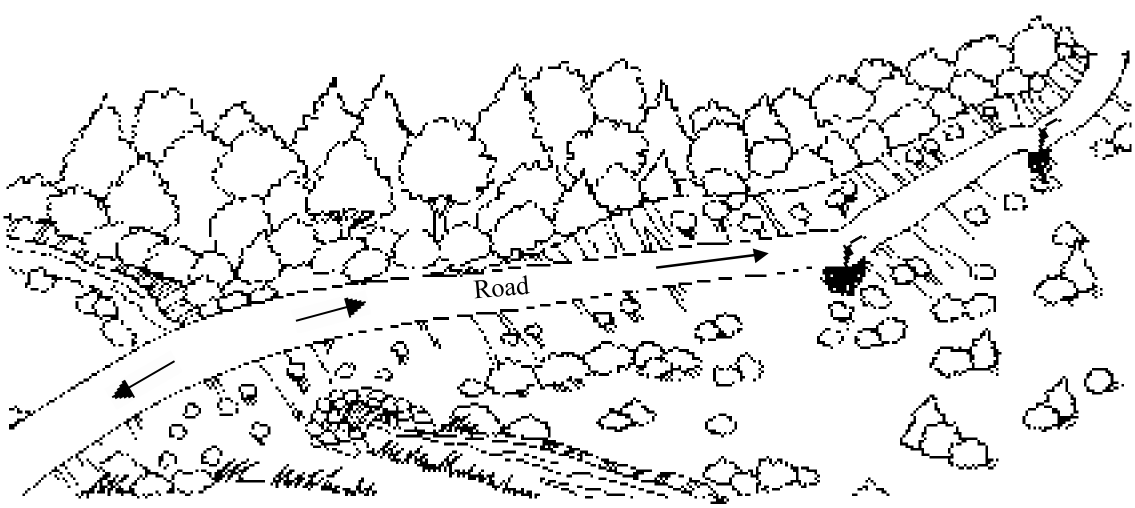
d. Consequence of stream diversion out of its natural channel. ***(Adapted from M. Furniss, 1997)***

Figure 7.12 Protection measures at stream crossings.



Armor or stabilize the actual stream crossing (ford), add surfacing to the roadbed, and drain water off the road surface before reaching the crossing. Set stream channel armoring at the elevation of the natural stream bottom.

Figure 7.13 High point over the crossing. ***(Adapted from Wisconsin's Forestry Best Management Practices for Water Quality, 1995)***



If a plugging failure is **unlikely** to occur, place fill directly over a culvert higher than the road approach to prevent surface road runoff from draining toward the crossing structure and into the stream.

Wet Areas and Meadow Crossings, Use of Underdrains

Road crossings in wet areas, including damp meadows, swamps, high groundwater areas, and spring sources are problematic and undesirable. Wet areas are ecologically valuable and difficult for road building, logging, or other operations. Soils in these areas are often weak and require considerable subgrade reinforcement. Drainage measures are expensive and may have limited effectiveness. **Wet areas should be avoided**!

If wet areas must be crossed and **cannot** be avoided, special drainage or construction methods should be used to reduce impacts from the crossing. They include multiple drainage pipes (*Photo 7.9*) or coarse permeable rock fill to keep the flow dispersed, subgrade reinforcement with coarse permeable rock, grade control, and the use of filter layers and geotextiles, as shown in *Figure 7.14*. The objective is to maintain the natural groundwater level and flow patterns dispersed across the meadow and, at the same time, provide for a stable, dry roadway surface.

Local wet areas can be temporarily crossed, or "bridged" over, using logs, landing mats, tires, aggregate, and so on. (see *Figure 7.15*). Ideally, the temporary structure will be separated from the wet area with a layer of geotextile. The geotextile helps facilitate removal of the temporary material and minimizes damage to the site. Also, a layer of geotextile can provide some reinforcement strength as well as provide separation to keep aggregate or other materials from punching into the weak subgrade.

Subsurface drainage, through use of underdrains or aggregate filter blankets, is commonly used along a road in localized wet or spring areas, such as a wet cut bank with seepage, to **specifically remove** the groundwater and keep the roadway subgrade dry. A typical underdrain design uses an interceptor trench 1-2 meters deep and backfilled with drain rock, as shown in *Figure 7.16*. Subsurface drainage is typically needed in local wet areas and is much more cost-effective than adding a thick structural section to the road or making frequent road repairs. Design and filtration requirements for underdrains are discussed in Chapter 6 and other references.

In extensive swamp or wet areas, subsurface drainage will often not be effective. Here, either the roadway platform needs to be raised well above the water table, such as with a turnpike roadway section, or the surfacing thickness design may be based upon wet, weak subgrade conditions that will require a relatively thick structural section. A thick aggregate layer is commonly used, with the thickness based upon the strength of the soil and anticipated traffic loads.

PRACTICES TO AVOID

- Crossing wet areas unnecessarily.
- Concentrating water flow in meadows or changing the natural surface and subsurface flow patterns.
- Placing culverts below the meadow surface elevation.

Photo 7.9 Avoid crossing wet meadow areas. When necessary to cross, use multiple drainage pipes to keep water flow dispersed across the meadow.

Figure 7.14 Wet meadow road crossing options. *(From Managing Roads for Wet Meadow Ecostream Recovery by Wm. Zeedyk, 1996)*

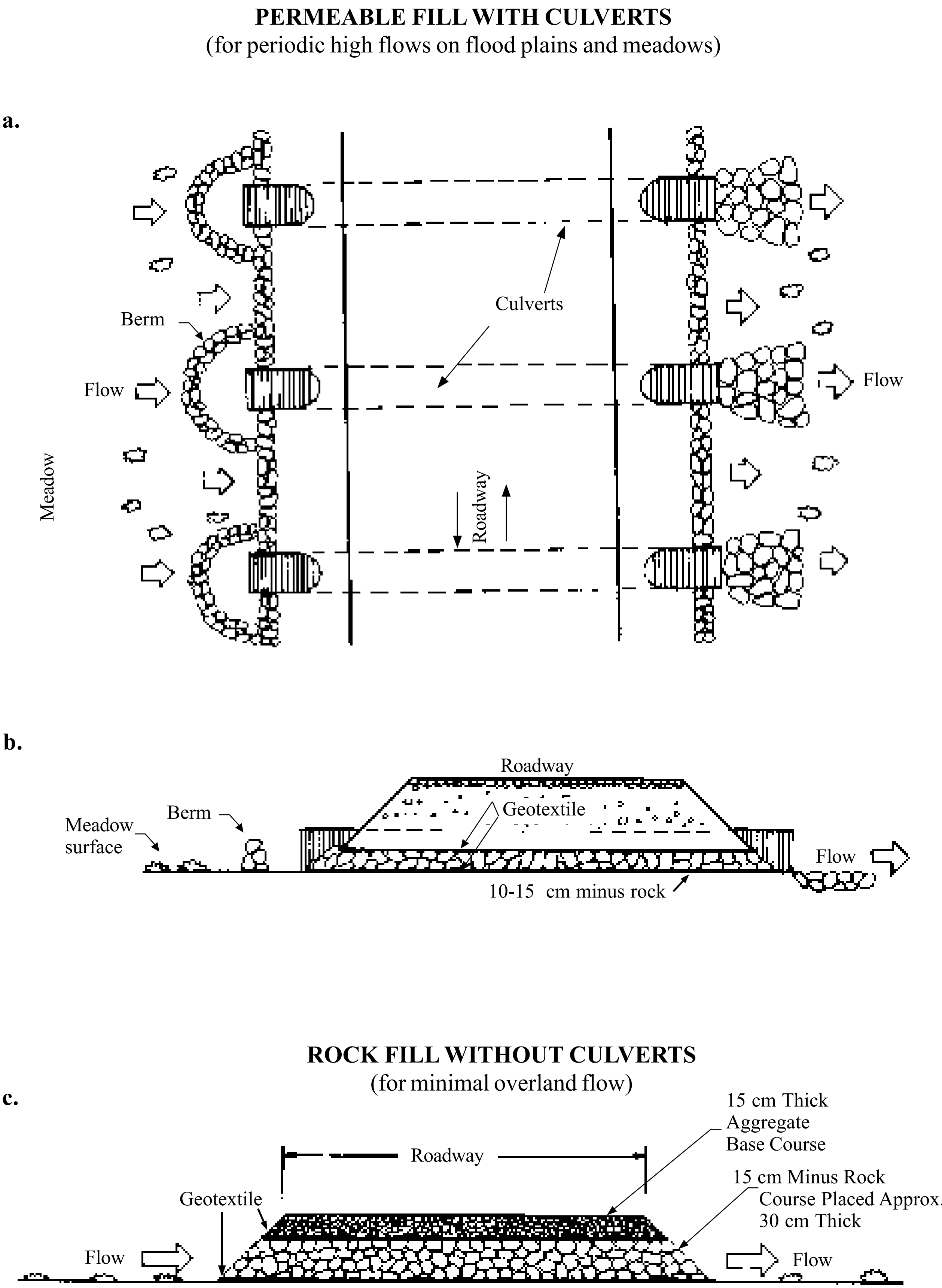
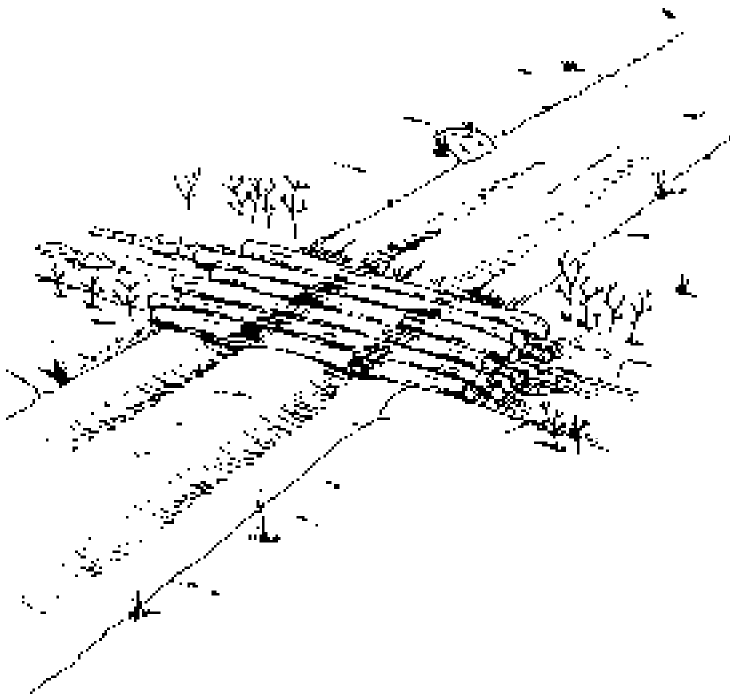


Figure 7.15 Pole or plastic pipe fords for wet area and bog crossings. Pole fords must be removed immediately after use or before the upstream end becomes clogged with debris and impedes stream flow. ***(Adapted from Vermont Department of Forests, Parks and Recreation, 1987)***



RECOMMENDED PRACTICES

Wet Areas and Meadow Crossings, Underdrains

- For permanent road crossings of meadows and wetlands, maintain the natural groundwater flow patterns by the use of multiple pipes set at meadow level to spread out any overland flow (See *Photo 7.9*). Alternatively, a coarse, permeable rock fill can be used where overland (surface) flow is minimal (see *Figure 7.14*).

- In areas with local wet spots and limited road use, reinforce the roadway with at least 10-30 cm of coarse graded rock or a very coarse granular soil. Ideally, separate the coarse rock and wet soil with a filter layer of geotextile or gravel.

- For temporary crossing of small, wet drainages or swamps, "corduroy" the road with layers of logs placed perpendicular to the road and capped with a soil or gravel driving surface. PVC pipe, landing mats, wood planks, tire mats and other materials have also been used (see *Figure 7.15*). Place a layer of geotextile between the saturated soil and logs or other material for additional support and to separate the materials. Remove logs from any natural drainage channel before the rainy season (see *Photo 8.8*). A layer of chain-link fencing or wire under the logs can help facilitate removal of the logs.

- In spring areas, use drainage measures such as underdrains or filter blankets to remove local groundwater and keep the road subgrade dry (*Figure 7.16*, *Photo 7.10*).

- Use underdrains behind retaining structures to prevent saturation of the backfill. Use underdrains or filter blankets behind fills (embankments) placed over springs or wet areas to isolate the fill material and prevent saturation and possible subsequent fill failure.

Figure 7.16 Typical road underdrain used to remove subsurface water.

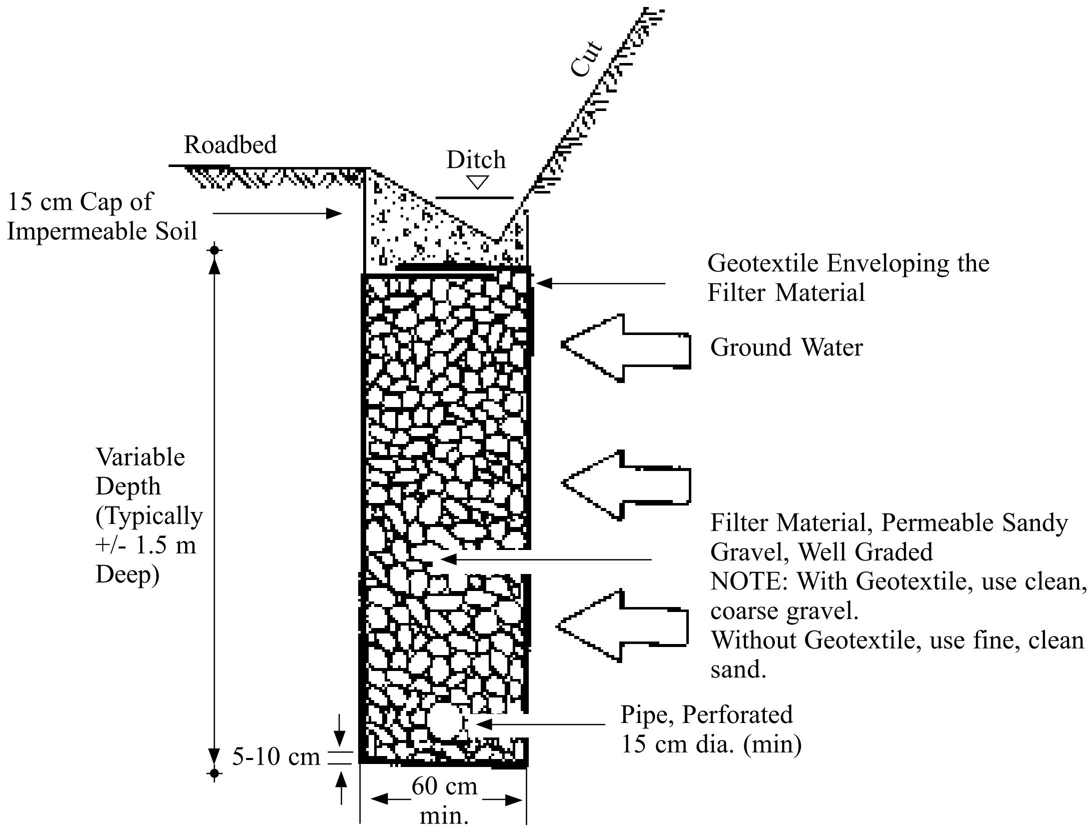


Photo 7.10 **Use subdrains or filter blankets when necessary to remove groundwater from the roadway subgrade in local wet or spring areas. Note that this design needs a second layer of geotextile between the soft subgrade soil and the coarse filter rock to keep the rock clean.**