INFLUENCES ROADS CAN HAVE ON HYDROLOGY & WATER QUALITY IN RURAL WATERSHEDS

In rural watersheds roads are perhaps the most significant and easily controlled sources of modification to the stream systems. Road systems can have three major impacts on stream systems in the watersheds: **episodic** sediment delivery, **chronic** sediment
delivery, and **hydromodification**.

When looking at rural road systems to improve water quality 4 factors should be taken into account 1) Episodic erosion sources, 2) Chronic erosion sources, 3) Hydromodification, and 4) Treatment prioritization.

<u>Episodic erosion</u> occurs when soils fail in response to storm events or other triggers. These erosion volumes are a **potential** volumes that may or may not occur during a given storm event. The erosion may occur once, or in pulses over an indeterminate time period. Stream crossing washouts, road-related landslides, and gullying are examples of episodic erosional features.

<u>Chronic erosion</u> is sediment production from hydrologically connected road surfaces and cutbanks that collect flow and deliver it to the stream system. This erosional process is termed chronic because it occurs **annually** during any storm events that produces runoff.
Focusing treatments on chronic sediment sources can significantly reduce future sediment delivery as well as normalize the hydrology of the watershed.

<u>Hydromodification:</u> Poorly constructed roads tend to collect surface flow from the landscape and concentrate that runoff into discrete discharge points thereby increasing the flow volumes that the stream channel would normally experience during the storm event. Increasing the volume of water to a stream channel causes stream to incise and erode its banks to accommodate the larger flows. Channel incision and bank failures are yet another erosional concern identified in the TMDL for the Napa River.

Along with channel incision and bank failures, concentrating surface runoff into stream channels can cause higher stream flows during the wet season and less stream flow during the dry season. If surface runoff is allowed to percolate into surrounding soils then the groundwater system can be recharged, allowing for sustained flows during summer months. These summertime flows are necessary to various aquatic species to live until the following years rains bring the much need flows to the watershed.

<u>Treatment priority</u> Treatment priority is a professional evaluation of how important it is to quickly perform erosion control or erosion prevention work at a site. It is an integral part of an assessment because it is the basis for prioritizing treatment sites prior to implementation. Treatment priority is designated as “high,” “moderate,” or “low,” indicating the relative degree of urgency to treat the site before it erodes or fails. Sites that require further engineering to determine capacity will not be given a treatment priority until such work has been done. Criteria for evaluating treatment priority include:

1) Erosion potential, or whether there is a low, moderate, or high likelihood for future episodic erosion at a site. Remember that only the episodic erosion volume has an erosion potential whereas the chronic erosion volume is assumed to be occurring on an annual basis.

2) Sediment delivery volume, which is an estimate of the sediment volume projected to be eroded from the site and the associated road lengths. It is entirely possible to have large episodic erosion volumes but because it has a low erosion potential, the site may be classified with a low (L), moderate-low (ML) or moderate (M) treatment priority.

3) Diversion potential at culverted stream crossings. These sites should be given a higher treatment priority than sites with similar characteristics but without diversion potential.

4) Stream crossing capacity, weather it us undersized or not for a given storm event (example the 100-year peak storm flow). This should be looked at on a magnitude basis, i.e. ‘how much is the crossing undersized for a given

storm event. Crossing sizing not only determines its capacity to carry water during peak flows but also influences plug potential.

5) Evaluation of the sites for fish passage on anadromous streams. If the site poses a barrier to salmonid fish migration then the site should receive a "High" treatment priority regardless of its erosion volume or potential. Also take into consideration the amount and quality of habitat that would be made available.

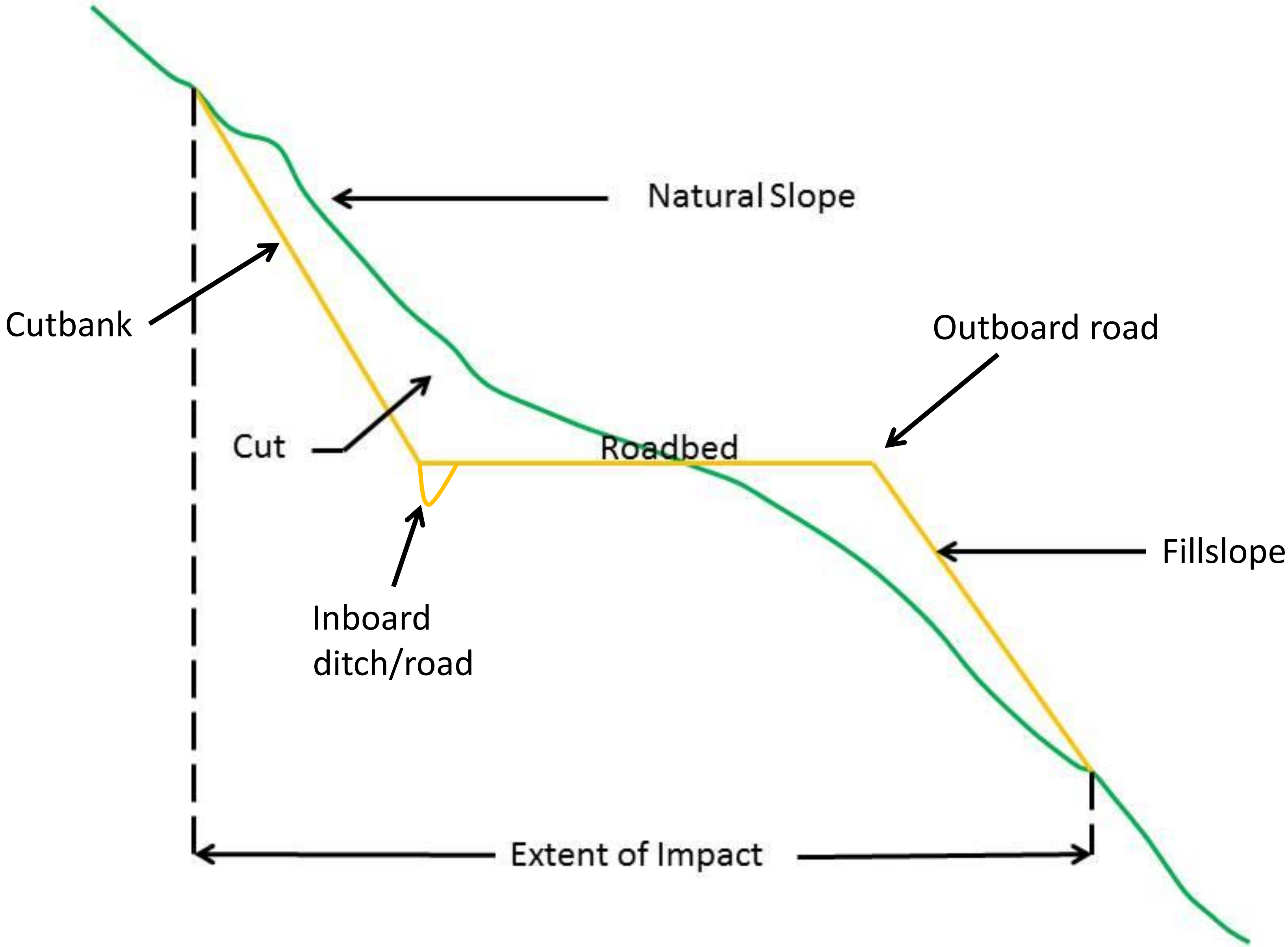
6) The value or sensitivity of downstream resources being protected. In general, all sites located up stream of an instream pond or reservoir are identified as 'disconnected' and should be given a Low treatment priority. These sites are deemed 'disconnected' from the anadromous portions of the watershed because these instream structures act as sediment basins for upstream erosional process and are barriers to anadromous fish species.

7) Cost effectiveness may be analyzed, along with transportation needs, to prioritize treatment sites or locations for implementation. Cost effectiveness is not only a necessary consideration for environmental protection and restoration projects for which funding may be limited, but is also an accepted and well-documented tool for prioritizing potential treatment sites in an area. A quantitative estimate for cost effectiveness is determined by dividing the cost of accessing and treating a site by the volume of sediment prevented from being delivered to local stream channels (the sediment savings). The resulting value provides a comparison of cost-effectiveness among sites, and an average for the entire project area. For example, if the cost to develop access and treat an eroding stream crossing is projected to be $5,000, and the treatment will potentially prevent 500 yd3 of sediment from reaching the stream channel, the predicted cost effectiveness for that site would be $5,000/500yd3, or $10/yd3. At sites that pose barriers to anadromous fish passage, cost effectiveness could be look at from the standpoint of amount and quality of upstream habitats that would be made available to the species.

<u>Road lengths draining down to the site:</u> Standing on the road surface, above the stream crossing and looking down stream, record the total distance of road length(s) draining down to the site. Left road length and Right road length are relative to looking down stream. Include road intersections and spur road lengths. If the road continues downhill through the site then cut-off your road length at the site and count the road length draining away as 0ft. Road surface drainage features that effectively end the road length include functional waterbars, rolling dips, and natural drainage break (divides and dips). If a culverted stream crossing has 0 Left or Right road length s draining to the site then the crossing has Diversion potential.

<u>Road drainage ends at:</u> (functional) Waterbar, Rolling dip, Critical dip, or Drainage break.

ROAD SURFACE TERMINOLOGY



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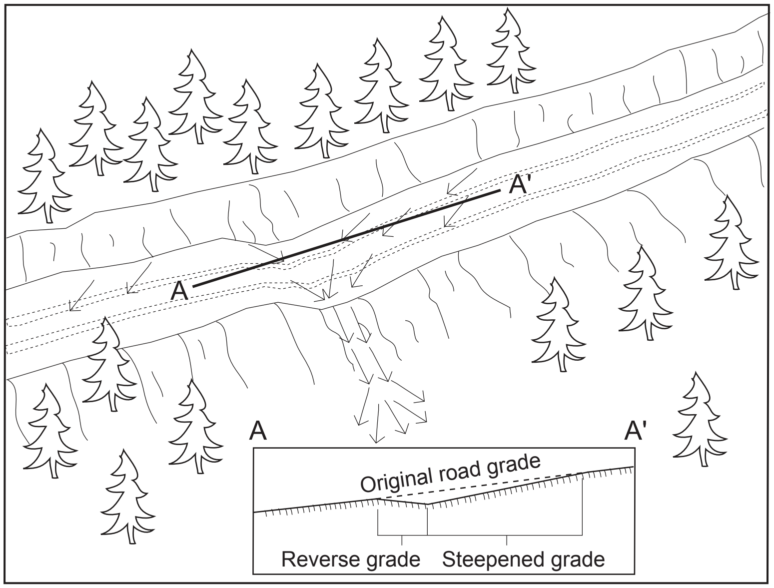
Typical Road Surface Drainage by Rolling Dips



Rolling dip installation:

1. Rolling dips will be installed in the roadbed as needed to drain the road surface.
2. Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3. Rolling dips are usually built at 30 to 45 degree angles to the road alignment with cross road grade of at least 1% greater than the grade of the road.
4. Excavation for the dips will be done with a medium-size bulldozer or similar equipment.
5. Excavation of the dips will begin 50 to 100 feet up road from where the axis of the dip is planned as per guidelines established in the rolling dip dimensions table.
6. Material will be progressively excavated from the roadbed, steepening the grade unitl the axis is reached.
7. The depth of the dip will be determined by the grade of the road (see table below).
8. On the down road side of the rolling dip axis, a grade change will be installed to prevent the runoff from continuing down the road (see figure above).
9. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to the original slope.
10. The transition from axis to bottom, through rising grade to falling grade, will be in a road distance of at least 15 to 30 feet.

Table of rolling dip dimensions by road grade

Road grade %	**Upslope approach distance** (from up road start to trough) ft	**Reverse grade distance** (from trough to crest) ft	**Depth at trough outlet** (below average road grade) ft	**Depth at trough inlet** (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20 - 25	1.2	0.01
>12	100	20 - 25	1.3	0.01

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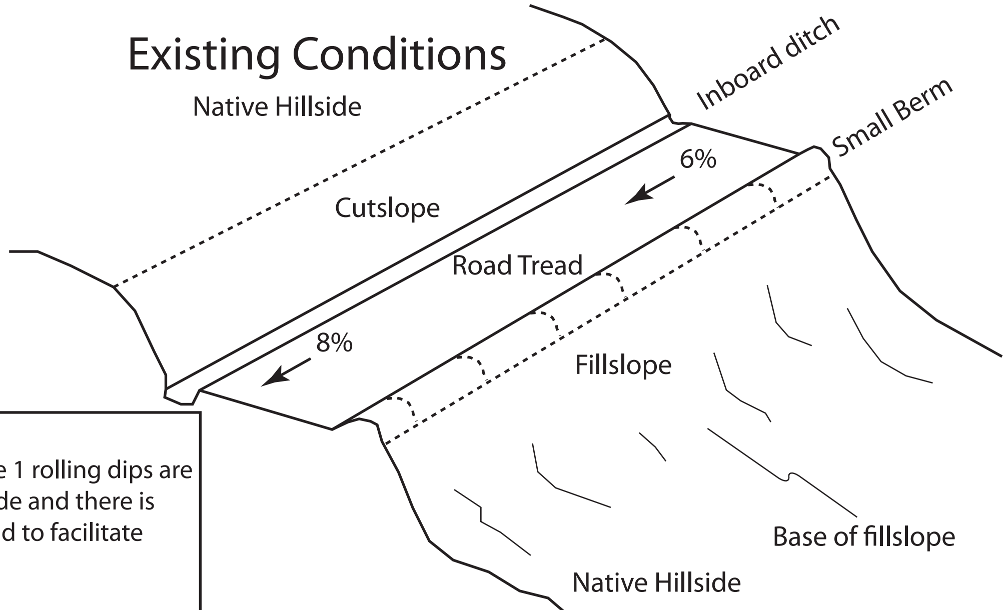
Standard (Type 1) Rolling Dip Construction

Existing Conditions



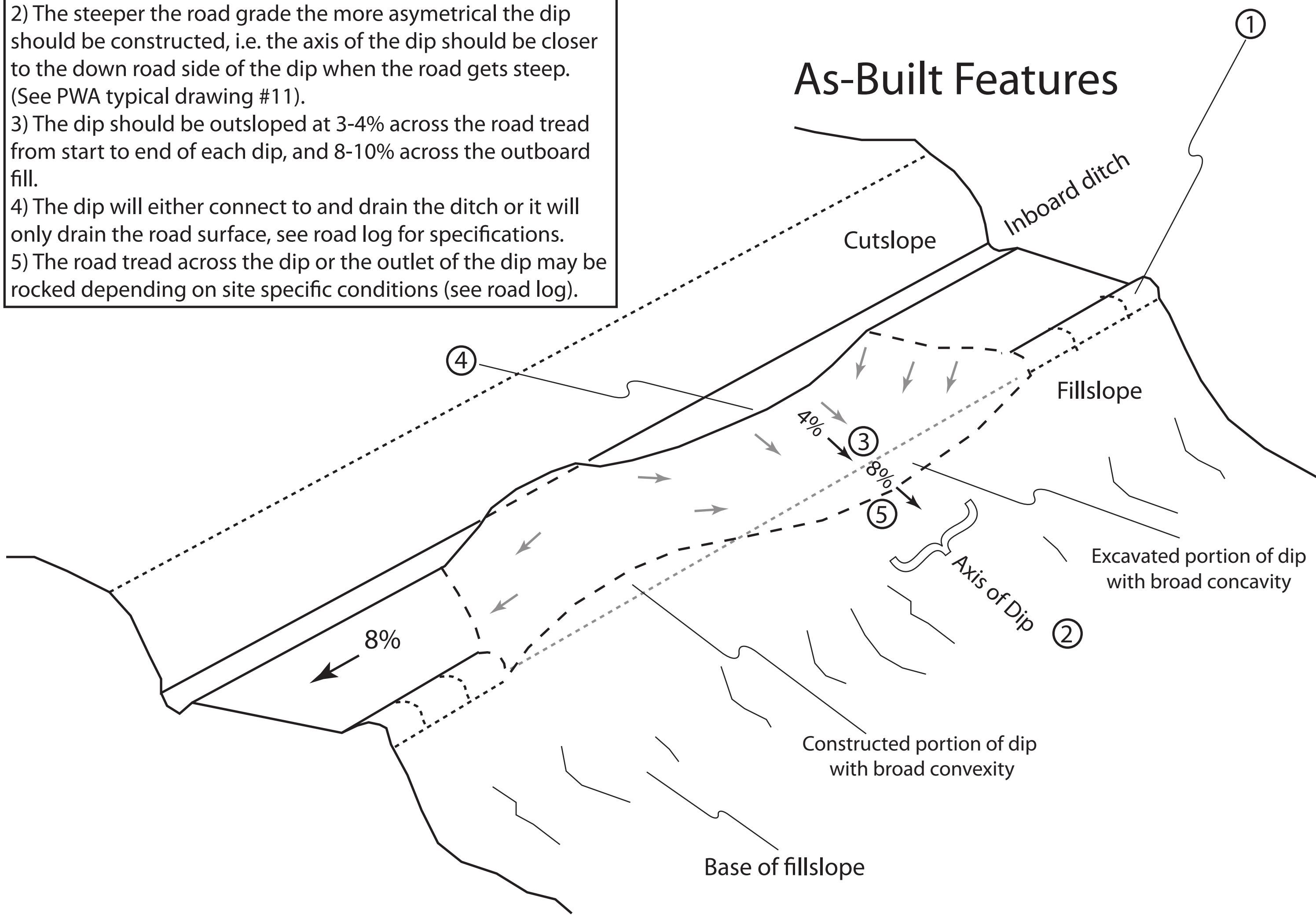
Notes

Rolling dip type 1 existing conditions: Type 1 rolling dips are utilized when roads are less than 12-14% grade and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread from start to end of each dip, and 8-10% across the outboard fill.
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-Built Features



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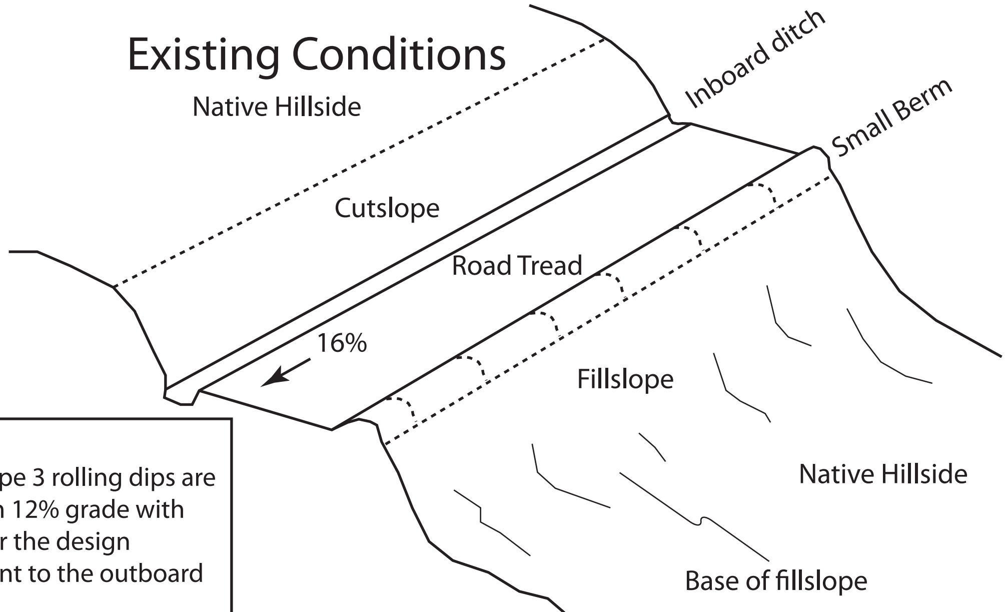
Type 3 Rolling Dip Construction
(steep slope outslope)

Existing Conditions

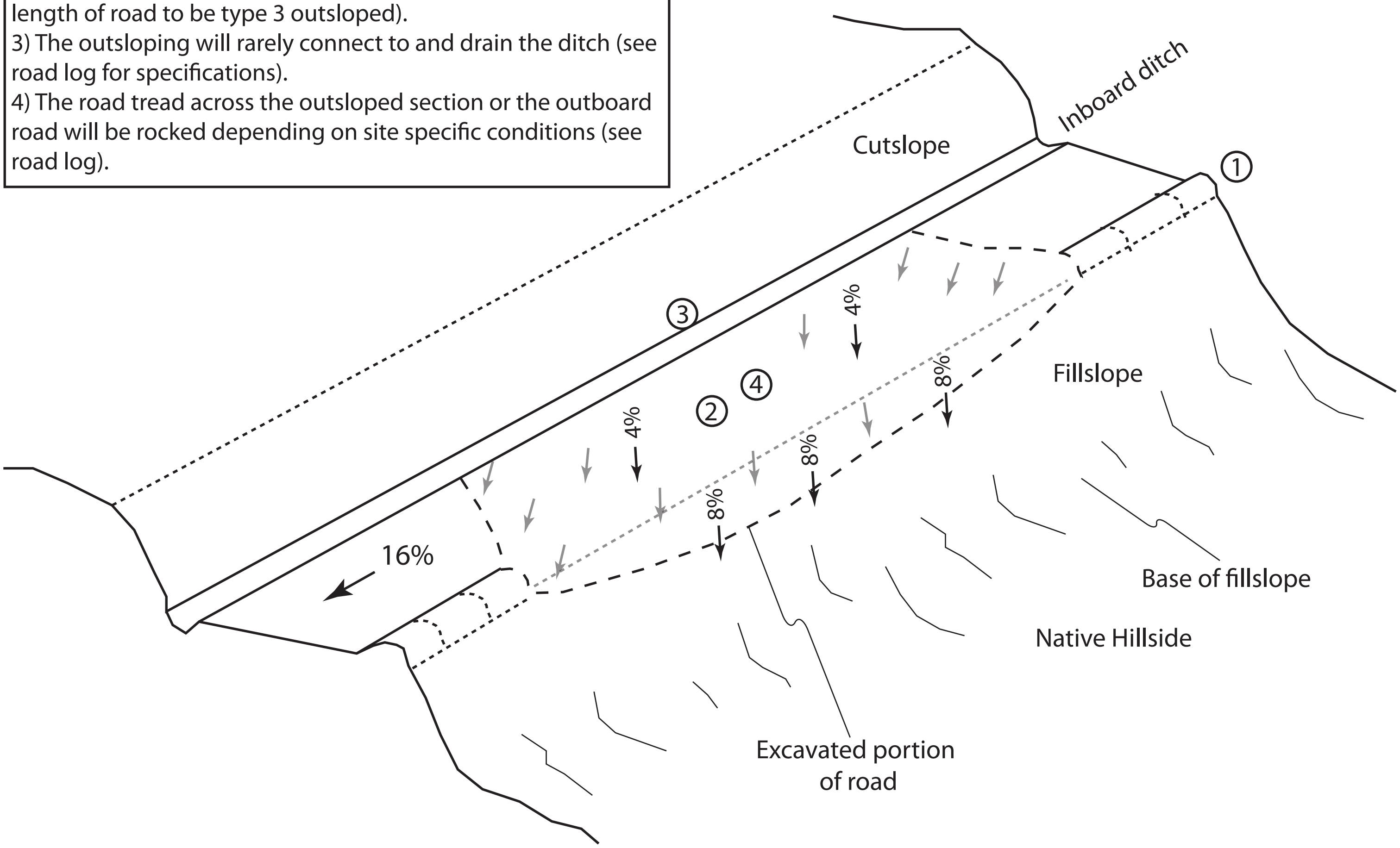


Notes

Rolling dip type 3 existing conditions: Type 3 rolling dips are utilized when roads grades are steeper than 12% grade with little opportunity to create reverse grade for the design vehicle, and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the outsloped section.
2) The dip should be outsloped at 2-4% across the road tread and 4-8% across the outboard fill. (The road log will specify the length of road to be type 3 outsloped).
3) The outsloping will rarely connect to and drain the ditch (see road log for specifications).
4) The road tread across the outsloped section or the outboard road will be rocked depending on site specific conditions (see road log).



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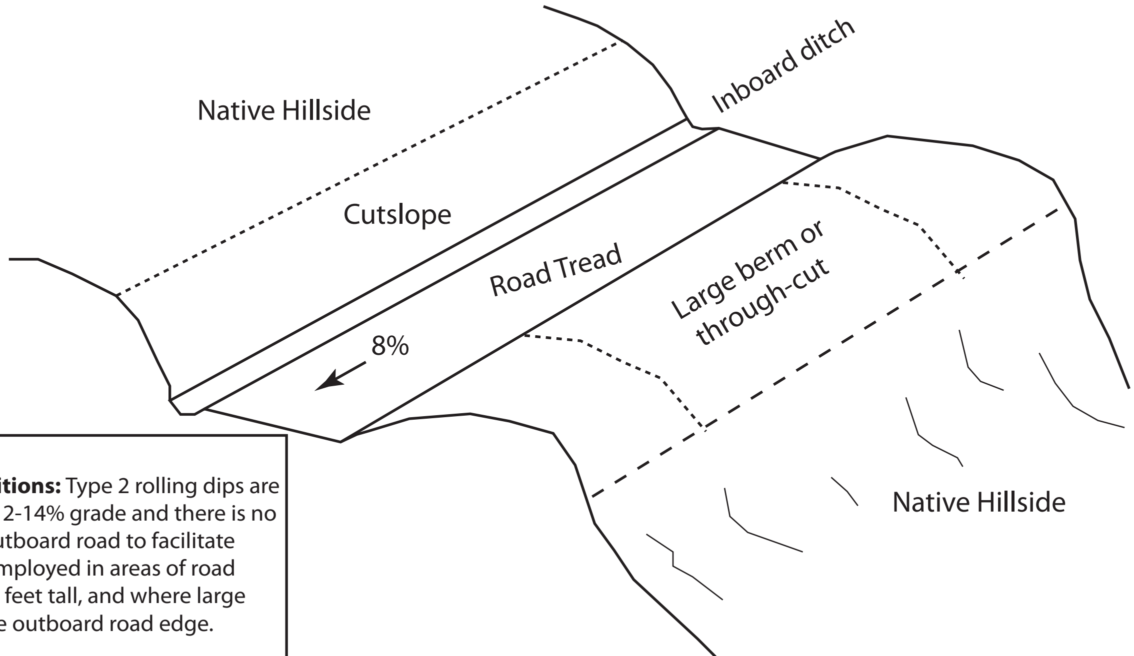
PWA Typical Drawing #19c

Type 2 Rolling Dip Construction
(Through-cut or thick berm road reaches)



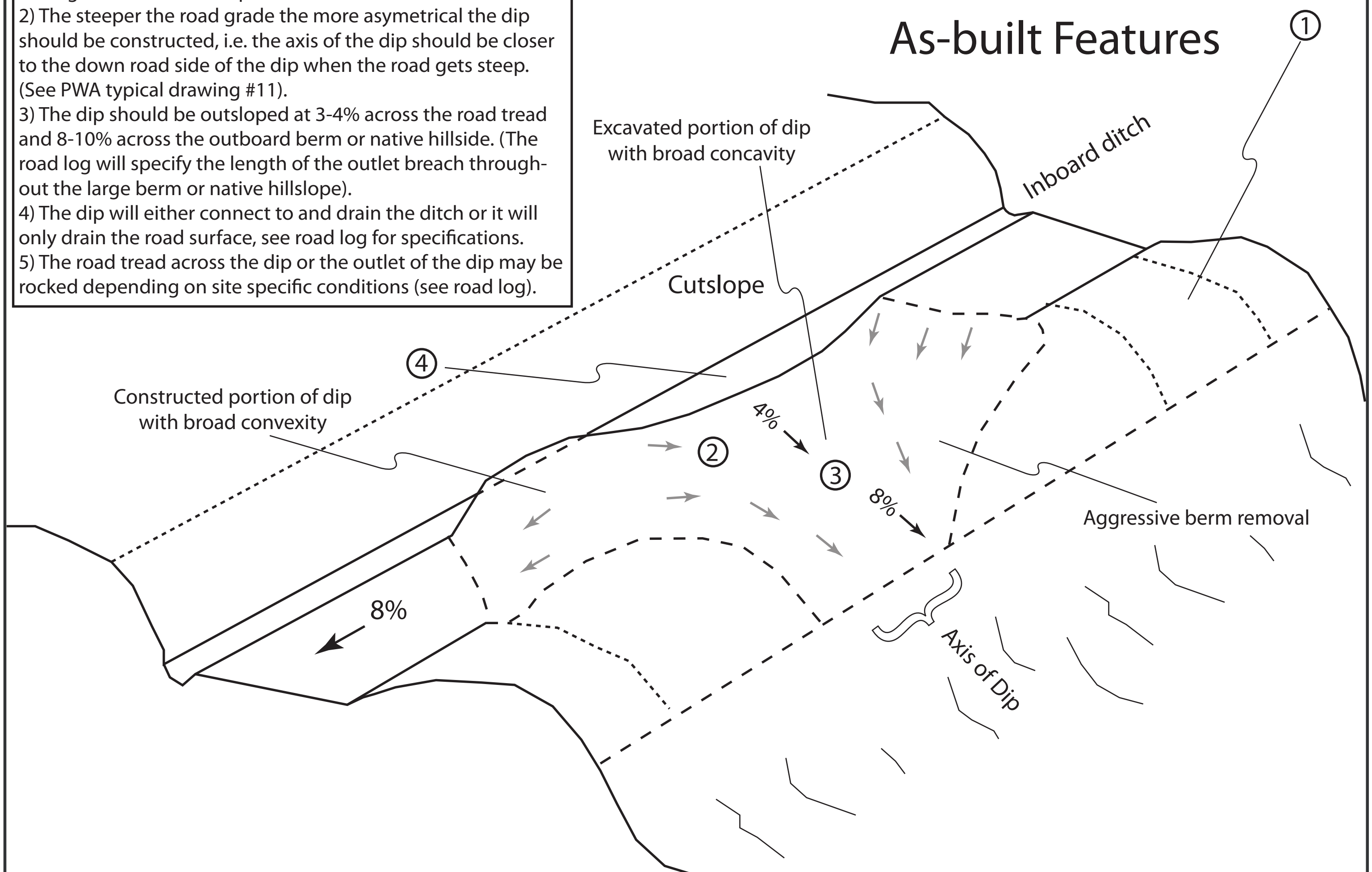
Notes

Rolling dip type 2 existing conditions: Type 2 rolling dips are utilized when roads are less than 12-14% grade and there is no proximal outfall adjacent to the outboard road to facilitate road drainage. These should be employed in areas of road through-cuts generally less than 3 feet tall, and where large wide and/or tall berms exist on the outboard road edge.

Design Notes:

1) The berm or native hillside should be removed for the entire length of the excavated portion of the dip, or, at a minimuim through the axis of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread and 8-10% across the outboard berm or native hillside. (The road log will specify the length of the outlet breach through-out the large berm or native hillslope).
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-built Features



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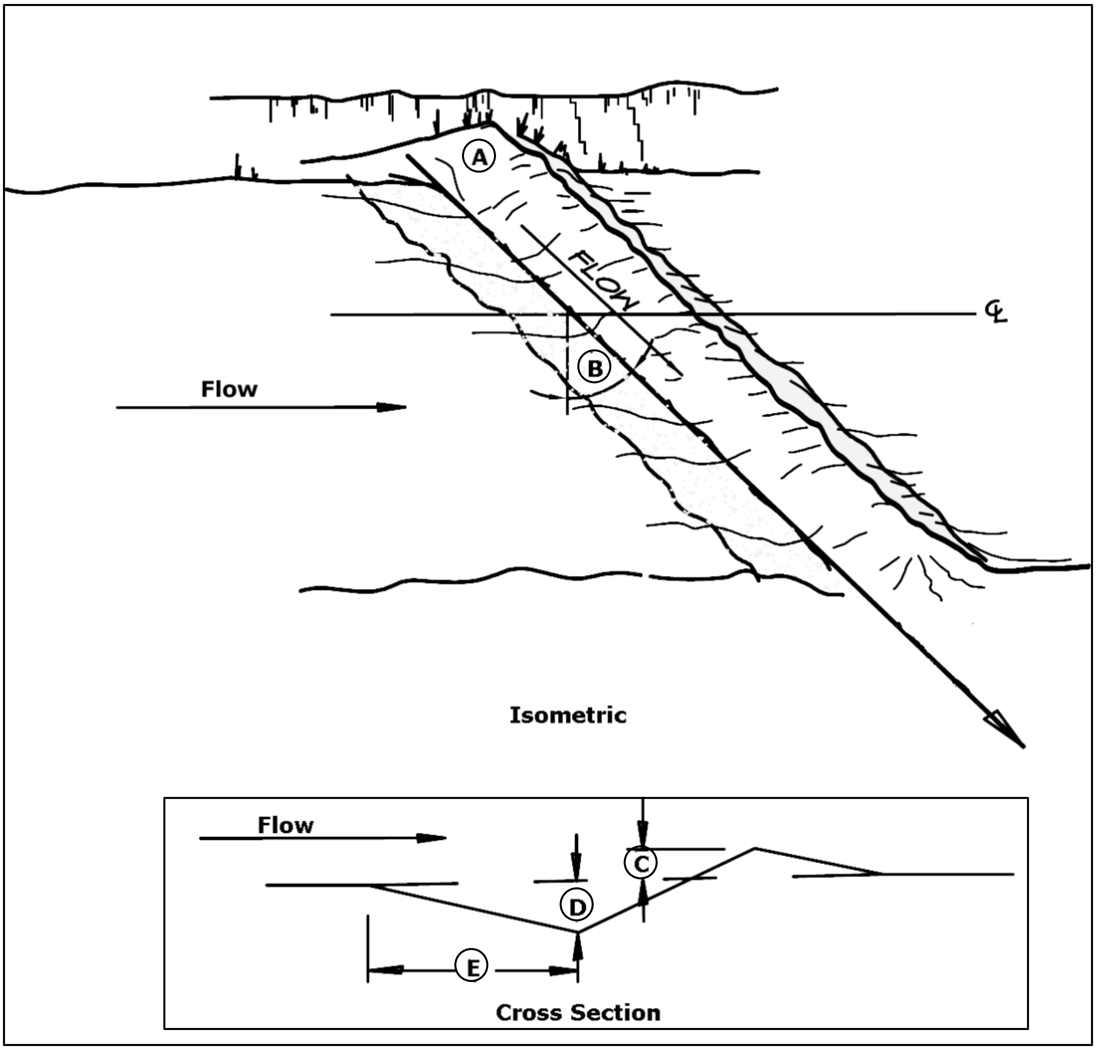
Typical Road Surface Drainage by Waterbars

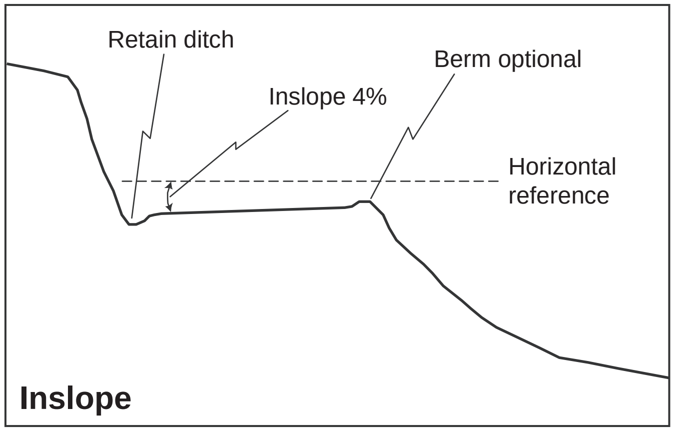


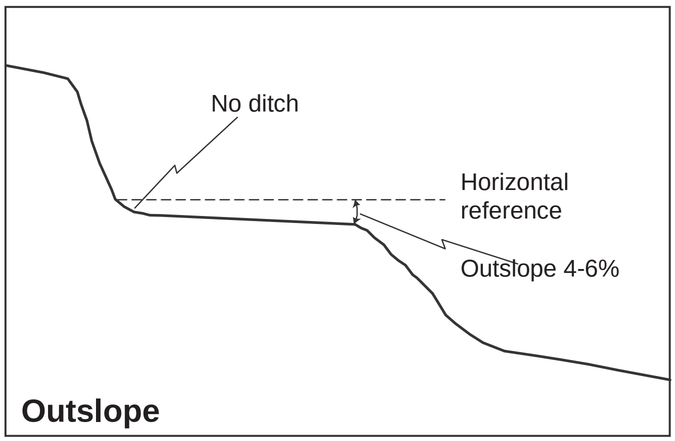
Waterbar installation:

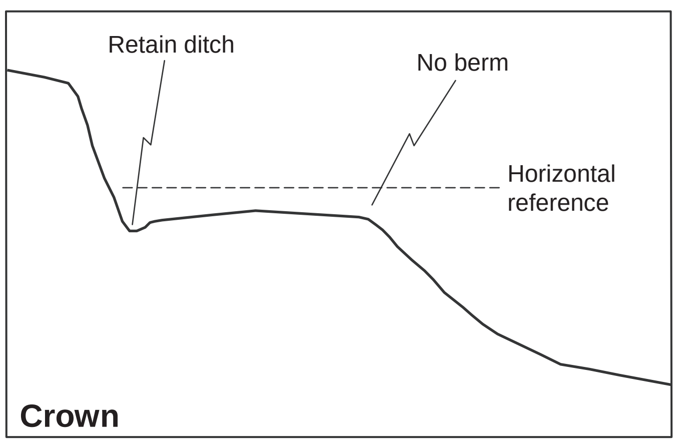
1. Waterbar construction for seasonal use roads. Specifications are average and may be adjusted to conditions.
2. Ⓐ tie-in cut and berm to cutbank.
3. Ⓑ angle waterbar 30^0-40^0 downgrade with road centerline.
4. Ⓒ berm height should be 4”-6” above the roadbed.
5. Ⓓ cut depth should be 4”-6” into roadbed.
6. Ⓔ approach should be 3’-4’ length.

Waterbar spacing: 1,000/slope gradient
Example: @20% slope waterbar spacing =1,000/20=***50 feet***

Typical Designs for Using Road Shape to Control Road Runoff







Outsloping Pitch for Roads Up to 8% Grade		
Road grade	**Unsurfaced roads**	**Surfaced roads**
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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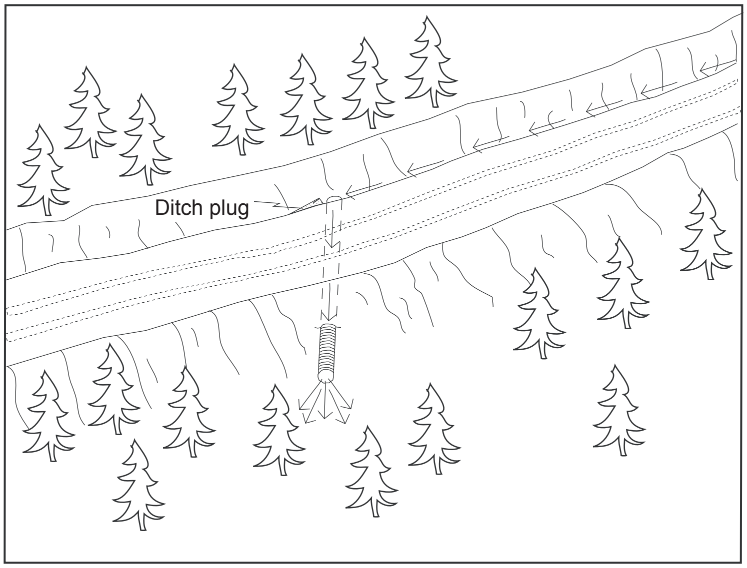
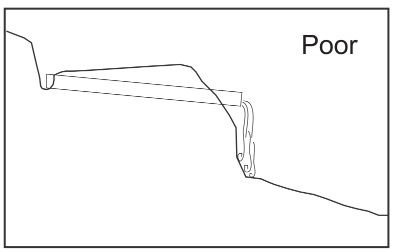
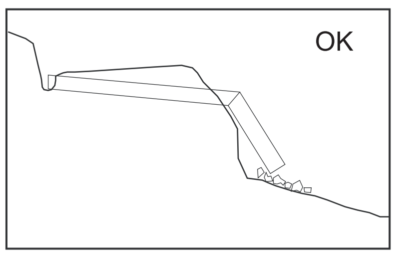
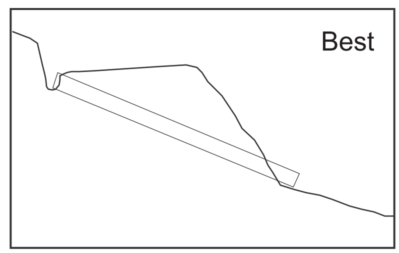
Typical Ditch Relief Culvert Installation









Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum, culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, which ever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used). 7Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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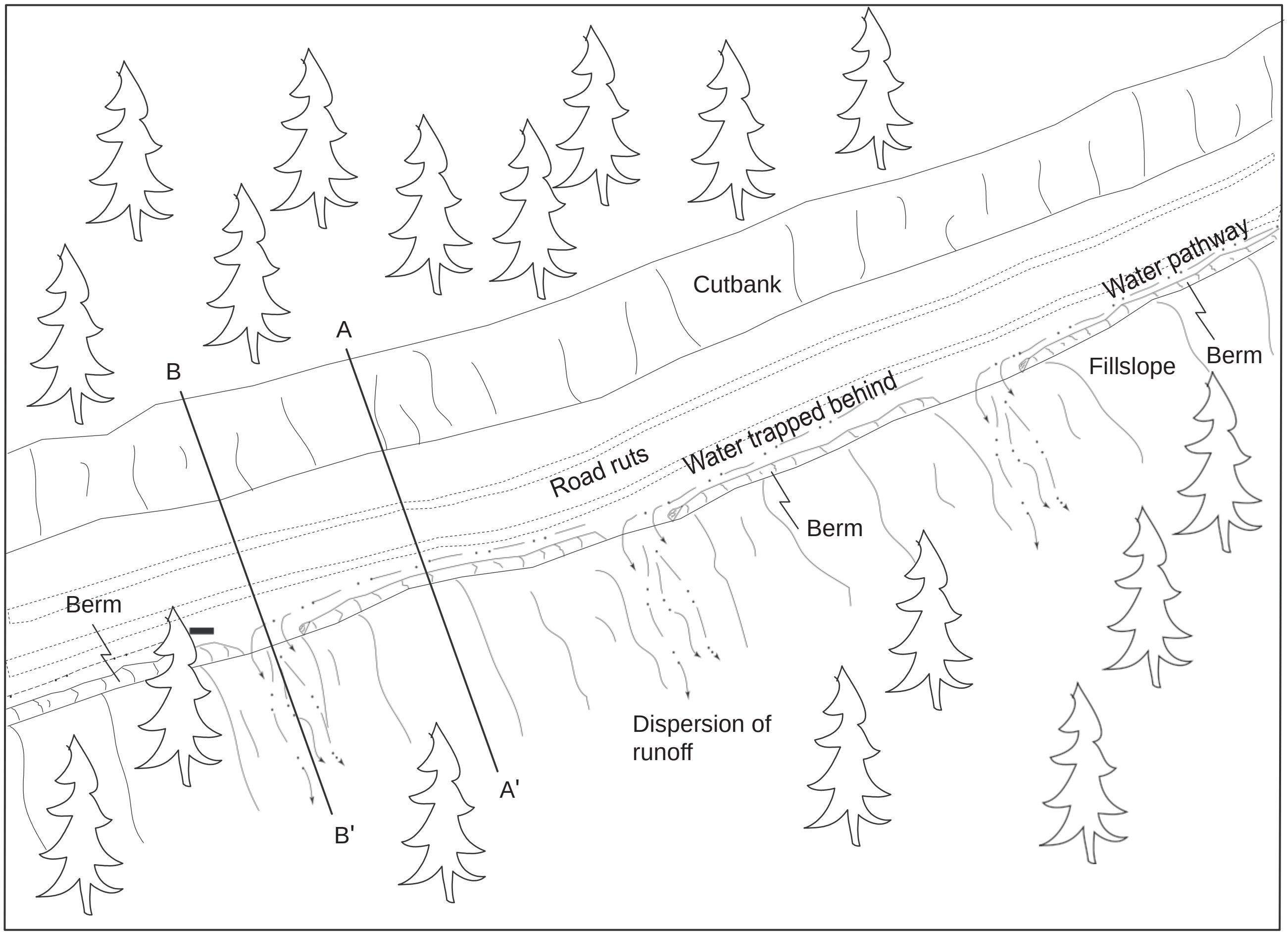
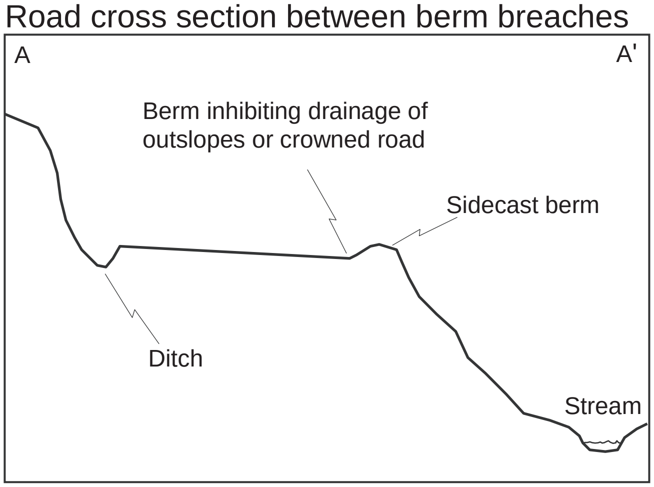
Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

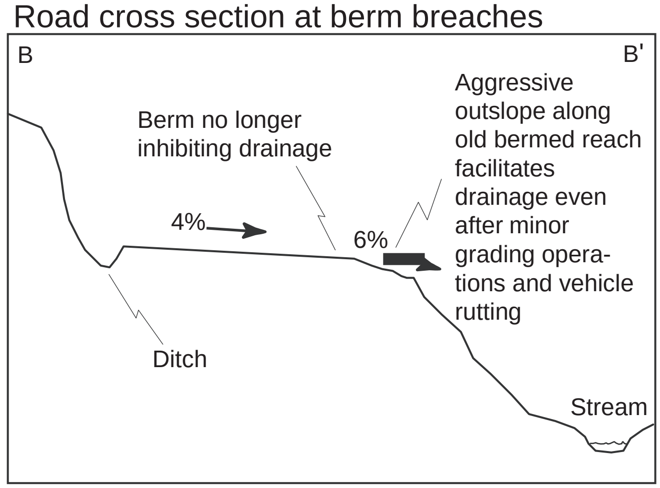
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B') Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a semi-continuous berm for vehicle safety.



Road cross section between berm breaches



Road cross section at berm breaches



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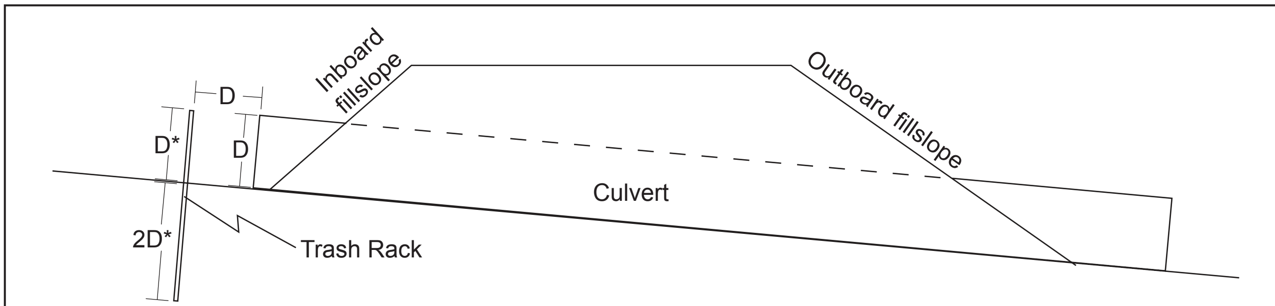
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



D - Culvert diameter

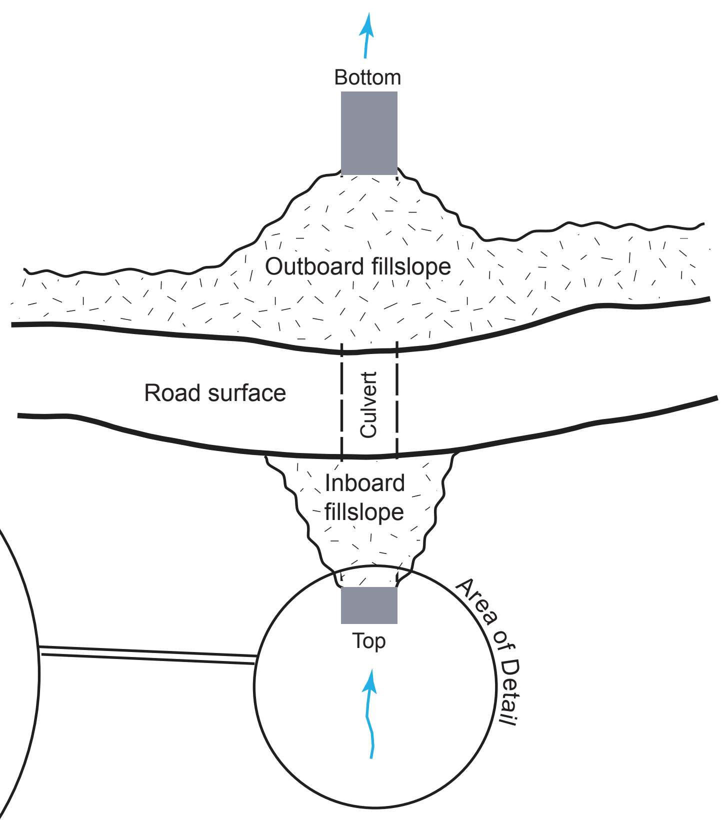
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

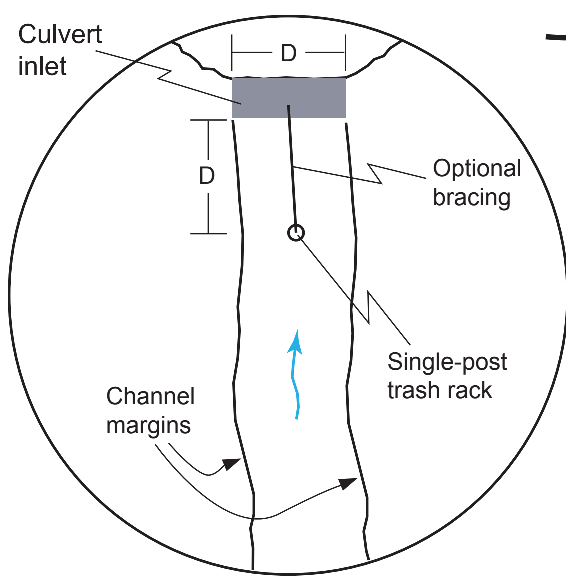
Plan view

Notes:

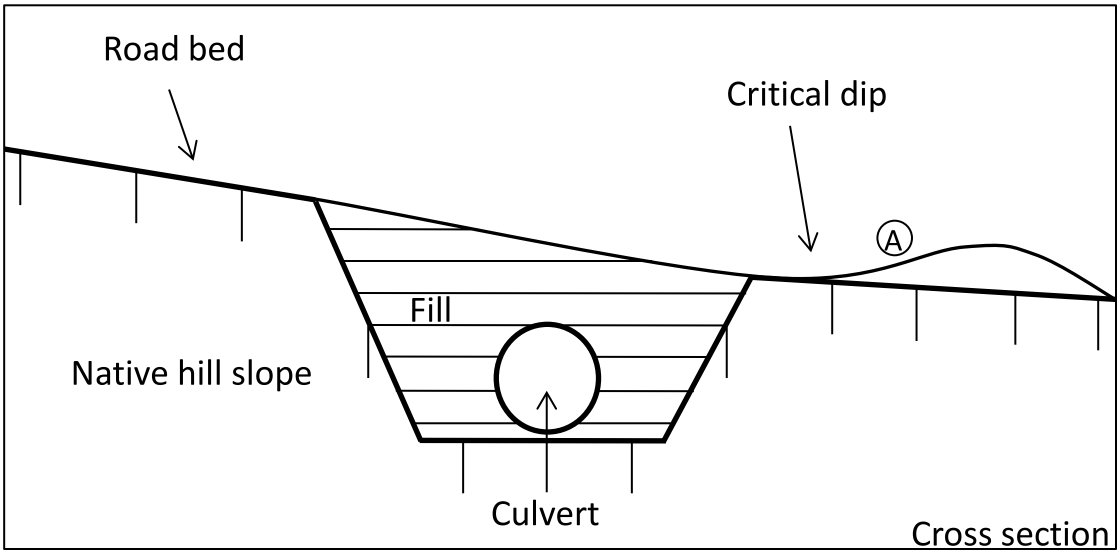
1. Many materials can be used for a single-post trash rack including old railroad track, galvanized pipe, and fence posts.

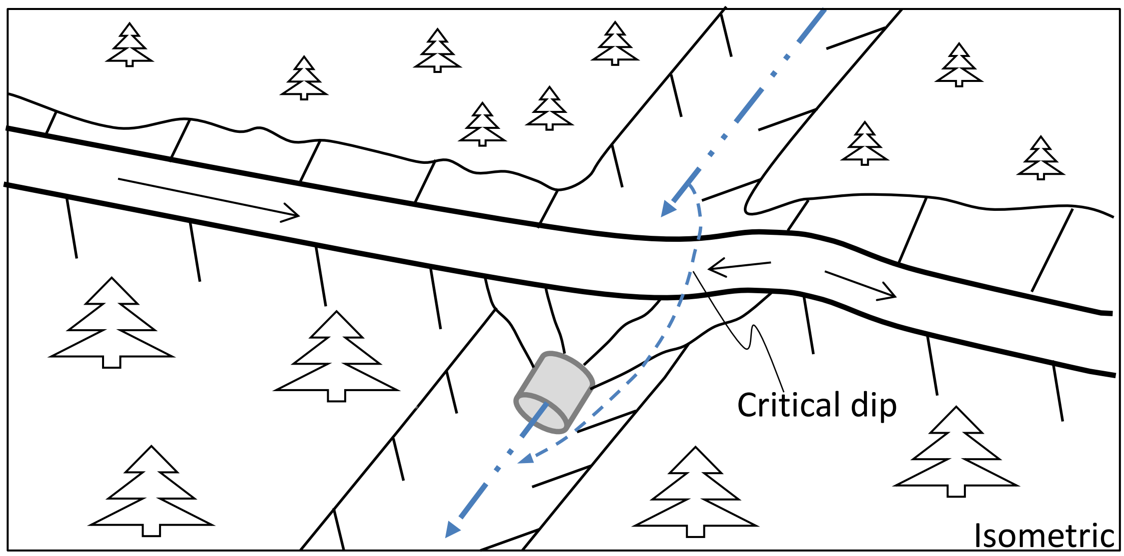
2. The diameter of single-post trash racks should be sized based on the size of expected woody debris. As a basic rule of thumb, the diameter of the trash rack should be equal to the diameter of the expected woody debris up to 4 inches.





Typical Critical Dip Design for Stream Crossings with Diversion Potential





Critical Dip Construction:

1. Critical dip will be constructed on the lower side of crossing.
2. Critical dip will extend from the cutbank to the outside edge of the road surface. Be sure to fill inboard ditch, if present.
3. Critical dip will have a reverse grade Ⓐ from cutbank to outside edge of road to ensure flow will not divert outside of crossing.
4. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to original slope.
5. The transition from axis of bottom, through rising grade, to falling grade, will be in the road distance of at least 15 to 30 feet.
6. Critical dips are usually built perpendicular to the road surface to ensure that flow is directed back into the stream channel.

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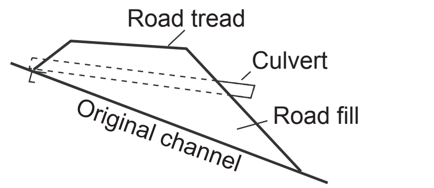
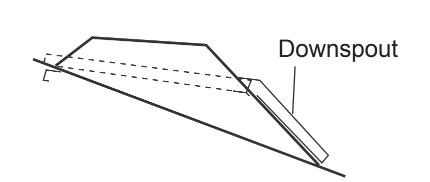
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing



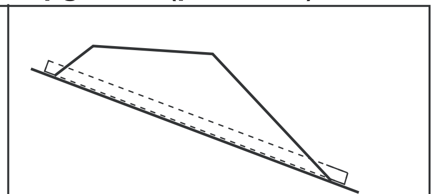
1. Culvert not placed at channel grade.
2. culvert does not extend past base of fill.

Upgraded



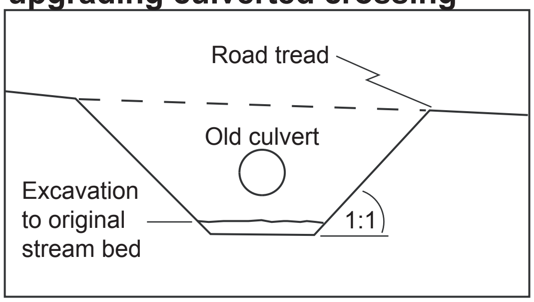
1. Culvert not placed at channel grade.
2. Downspout added to extend outlet past road fill.

Upgraded (preferred)

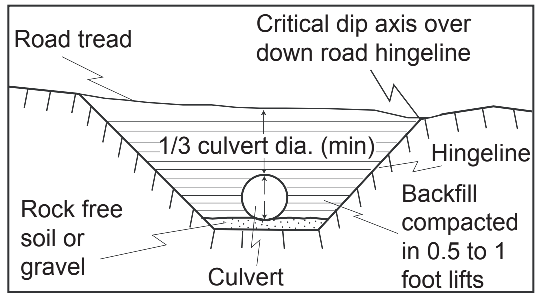


1. Culvert placed at channel grade.
2. Culvert inlet and outlet rest on, or partially in, the originial streambed.

Excavation in preparation for upgrading culverted crossing



Upgraded stream crossing culvert installation



Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calulations using a procedure such as the Rational Formula.

Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed, or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - Backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures implemented will be evaluated on a site by site basis. Erosion control measures include but are not limited to:

1. Minimizing soil exposure by limiting excavation areas and heavy equipment distrubance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as “anchor” for the fill and filter windrows.
4. Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first rains.
5. Excess or unusable soil will be stored in long term spoil disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential, or proximity to a watercourse.
6. On running streams, water will be pumped or diverted past the crossing and into the downstream channel during the construction process.
7. Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.

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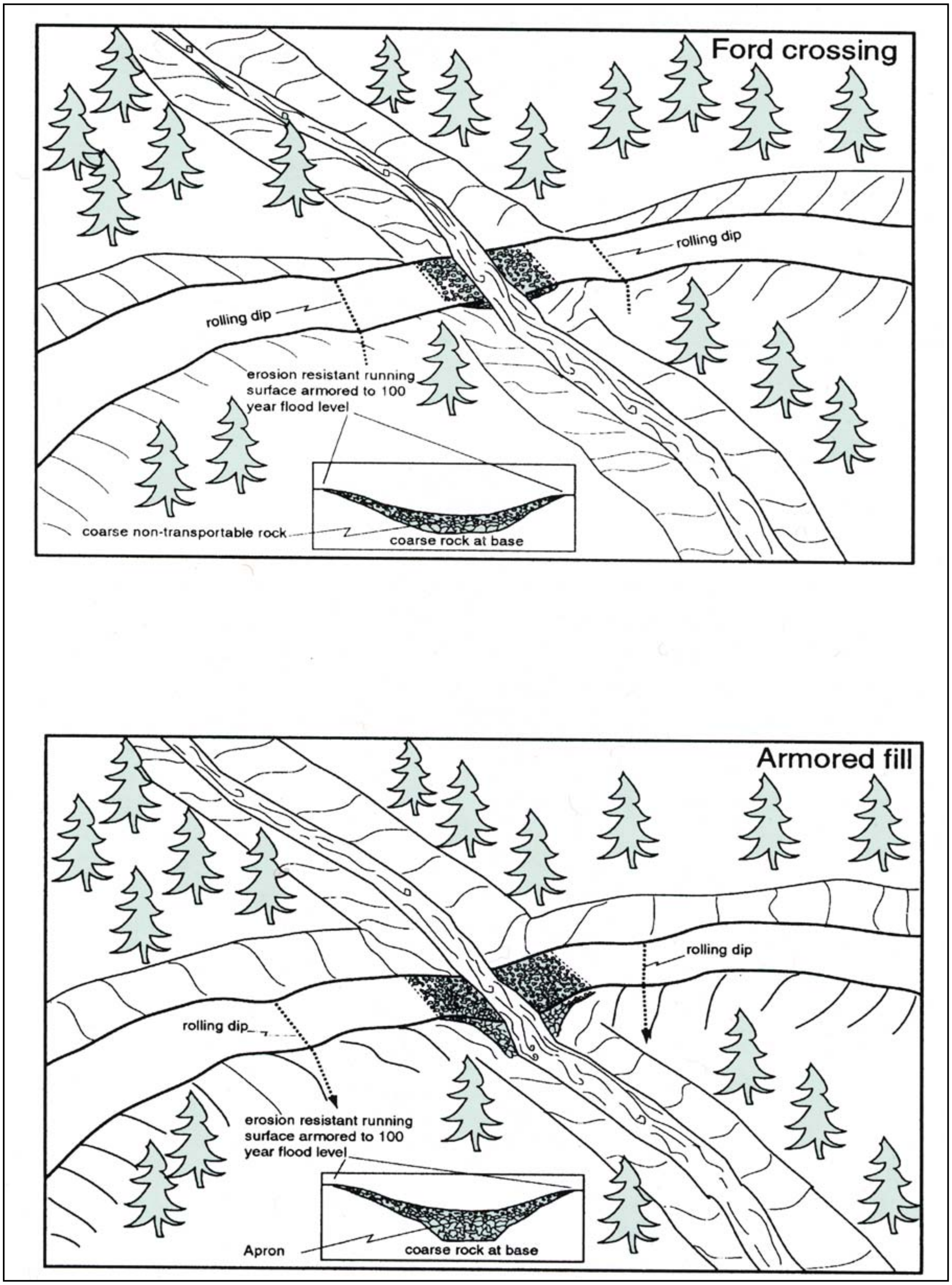
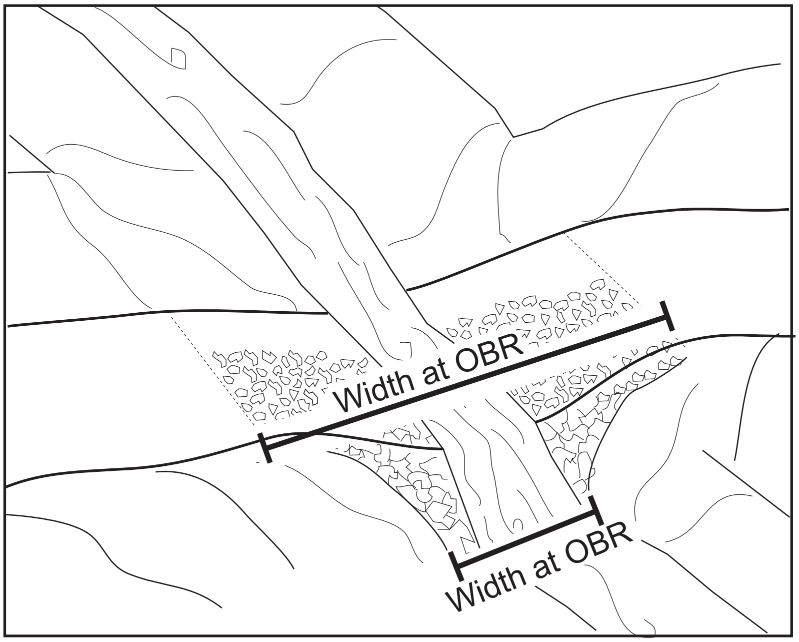


Figure X-15. Typical ford and armored fill stream crossings.

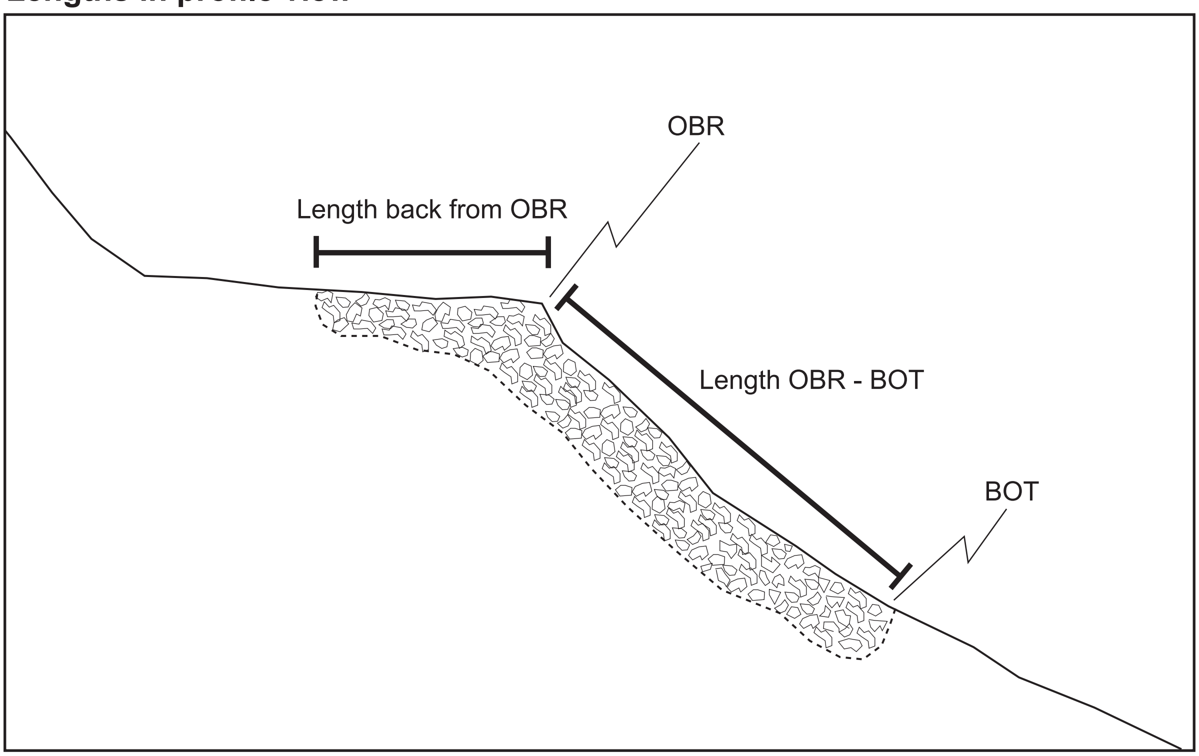
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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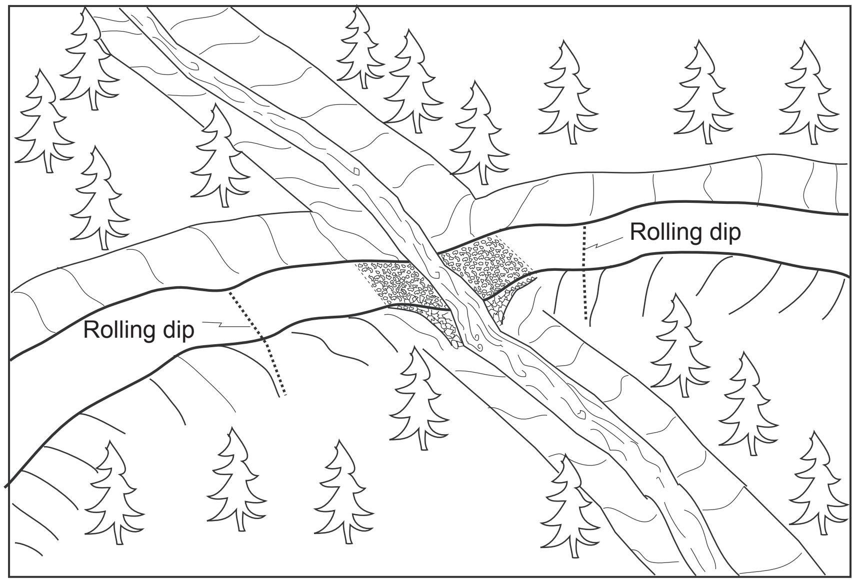
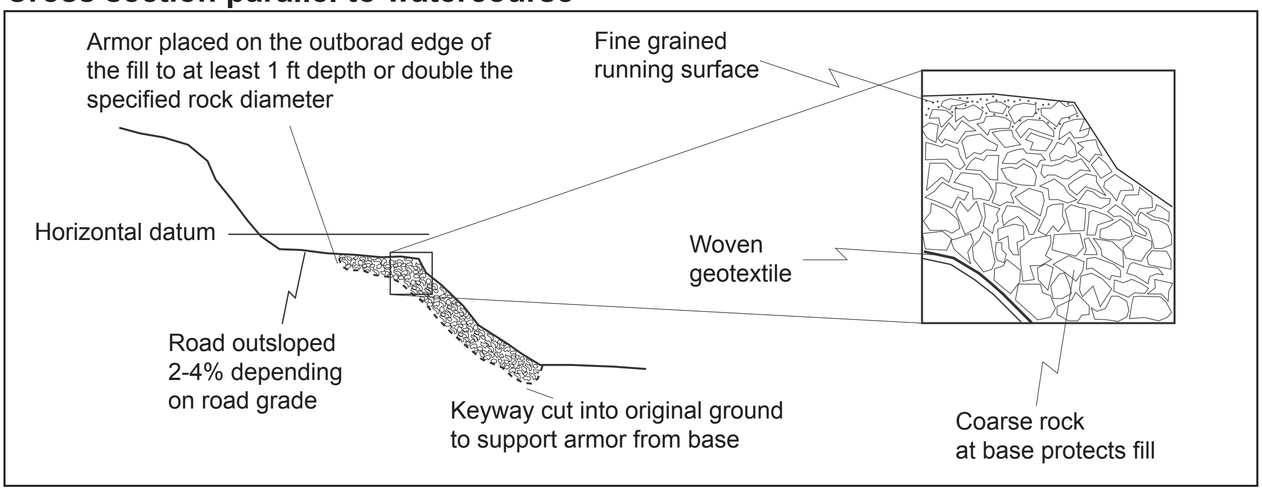
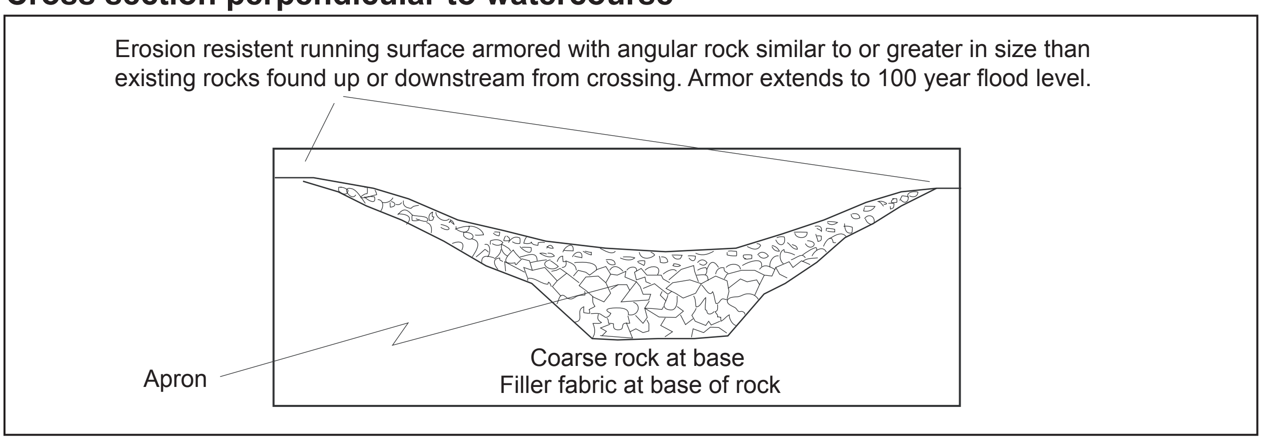
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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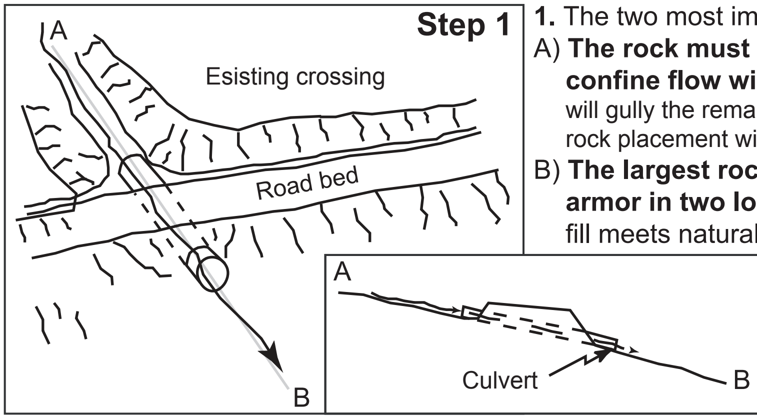
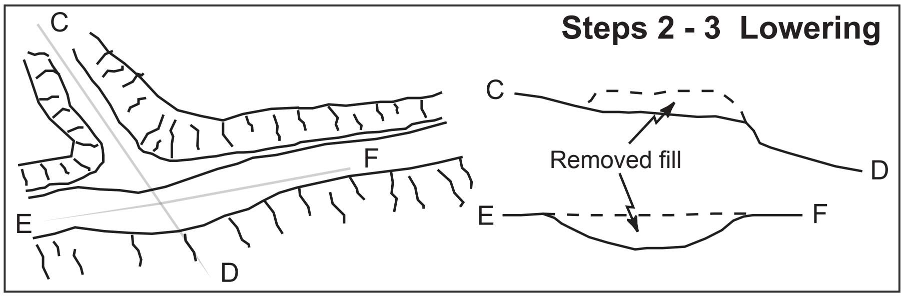
Ten Steps for Constructing a Typical Armored Fill Stream Crossing



1. The two most important points are:

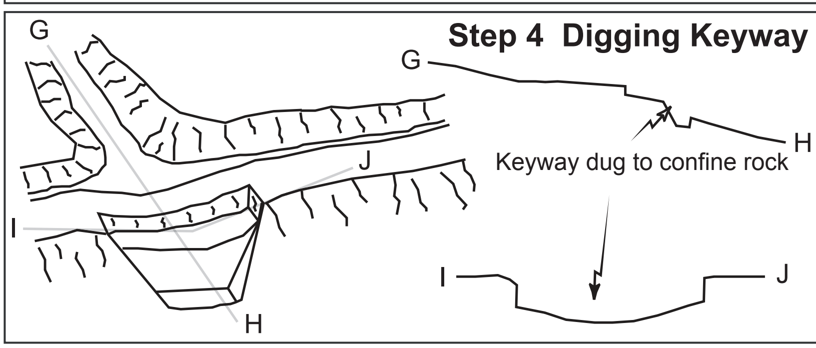
A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

B) **The largest rocks must be used to buttress the rest of the armor in two locations:** (i) The base of the armored fill where the fill meets natural channel. (This will butress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). (ii) The break in slope from the road tread to the outer fill face. (This will butress the fill placed on the outer road tread and will determine the "base level" of the creek as it crosses the road surface).



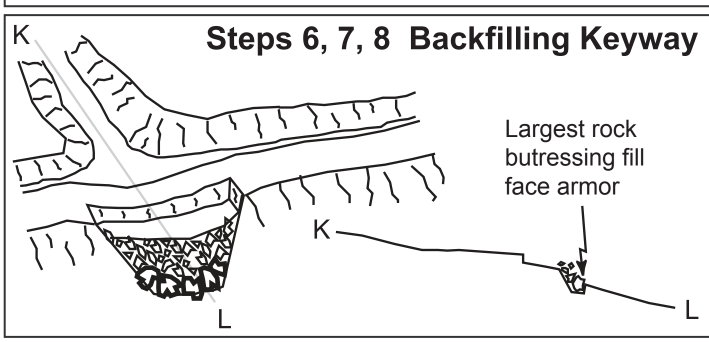
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year peak storm flow and prevent diversion (C-D, E-F).



4. Dig a keyway (to place rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to the point where outbaord fill meets natural channel (up to 3 feet into the channel bed depending on site specifics) (G-H, I-J).

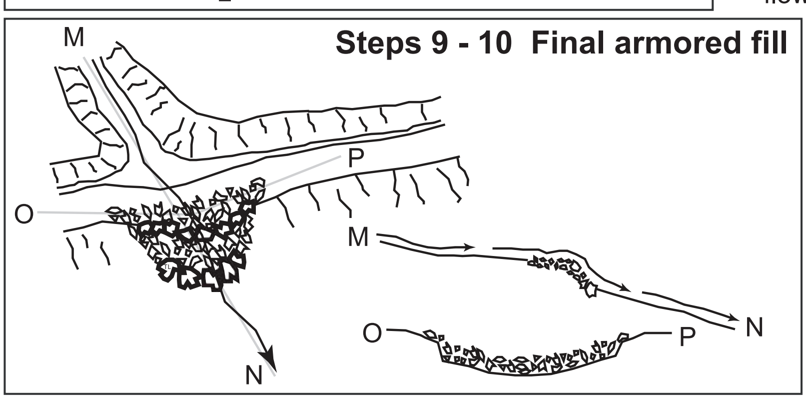
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



6. Put aside the largest rock armoring to create 2 buttresses in the next step.

7. Create a buttress using the largest rock (as described in the site treatments specifications) at the base of fill. (This should have a "U" shape to it and will define the outlet of the armored fill.)

8. Backfill the fill face with remaining rock armor making sure the final armored area has "U" shape that will accomodate the largest expected flow (K-L).



9. Install a second buttress at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction). (M-N)

10. Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a "U" shape that will accommodate the largest expected flow (O-P).

Typical Drawing #7

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Characteristics of Storm Proofed Roads

The following abbreviated criteria identify common characteristics of storm-proofed roads. Roads are storm-proofed when delivery to streams is strictly minimized. This is accomplished by dispersing road surface drainage, preventing road erosion from entering streams, protecting stream crossings from failure or diversion, and preventing failure of unstable fills from delivering sediment to a stream. All bare soils with potential to deliver sediment to streams should be seeded and straw mulched before any rain events occur.

Storm-proofed stream crossings

- All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris).
- Culverts are set in at base of fill and at channel grade.
- Culvert inlet, outlet, and bottom are open and in sound condition.
- Stream crossings have no diversion potential (functional critical dips are in place).
- Stream crossing inlets have low plug potential (trash barriers installed).
- Stream crossing outlets are protected from erosion (extended beyond the base of fill and/or dissipated with rock armor).
- Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow.
- Stream crossings on fish bearing streams meet CDFW and NMFS fish passage criteria.
- Decommissioned stream crossings have been completely excavated to original grade and side slopes are laid back to 2:1 where possible.

Storm-proofed fills

- Unstable and potentially unstable stream crossing and road fills are excavated or structurally stabilized.
- Excavated spoil is placed in locations where it will not enter a stream.
- Excavated spoil is placed where it will not cause a slope failure or landslide.

Road surface drainage

- Year round use roads are either paved or rocked well enough so that none of the native surface is visible and raindrop impact is absorbed by the applied surface.
- Un-surfaced roads are either closed during rainy periods of the year or are not used when the road surface is wet.
- All road surfaces are disconnected from streams by implementing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping, or crowning) and installing rolling dips, ditch relief culverts, and /or waterbars.
- Ditches and cutbanks are disconnected from streams by frequently draining them with rolling dips &/or ditch relief culverts.
- Outflow from rolling dips and ditch relief culverts do not discharge to streams or onto active (or potentially active) landslides.
- Gullies (including those below ditch relief culverts) are dewatered to the extent possible.
- Decommissioned roads have been de-compacted (ripped) and have frequently installed permanent drainage structures (cross road drain) to prevent runoff contribution to streams.

Equipment Hours Assumptions

Excavator/backhoe use

It is recommended that excavator/backhoe come equipped with a thumb. An excavator/backhoe is used at all stream crossing sites, fill slope excavations, rock armor/rip-rap locations, ditch relief culvert installations, to generate fill material for road shaping, and to pull outboard berm from in-between trees.

Roller use

Un-rocked roads: Could decline to use roller if landowner is OK with track-walked road surface, though this should only be done on roads that will be closed for the winter or receive very light use. Otherwise road should use roller after all shaping has been done.

Rocked roads: use roller after re-rocking road surface.

Water truck use

Use water truck when doing all road shaping, re-rocking road surface, and back filling of ditch relief culverts. Less water will be needed if road shaping is done just after the rainy season, when soils are moist. Some road shaping could be done without a water truck but only if road can be closed for an entire wet season following construction.

Bulldozer use

A bulldozer should be used for all road shaping and rock spreading. A dozer is usually always accompanying an excavator at all stream crossing sites and fill slope excavations (upgrade or decomm), unless fills are small enough that excavator/backhoe can manage spoil pile without inhibiting productivity.

Dump truck use

Dump trucks are used to export fill materials to offsite locations (spoil exceeds local storage capacity, paved/rocked road surface), import clean fills for upgraded stream crossings, and may be needed for rolling dip construction. The distance material needs to be endhauled will influence excavator production rate. The amount of dump trucks to be uses is based upon volume of material needed to be endhauled and whether or not dump trucks can pass each other between locations. If materials are being endhauled then you can assume the dozer will be managing the spoils away from the site.

Road Shaping equipment and labor hours. *These production rates do not include time for moving between treatment areas and assumes a 12-15 foot road width. Assume lower productivity is traffic control need to be managed. Water truck will most likely be used for only half the time that the dozer are doing road shaping and Ditch relief culvert installation.*

Outslope remove ditch: 500'/hr dozer & water truck
Outslope retain ditch/Inslope/Crown: 300'/hr dozer & water truck
Remove ditch: 500'/hr dozer & water truck
Remove berm with dozer: 1,000'/hr. Include water truck hrs when shaping is being done
Remove berm with excavator/backhoe: 500'/hr . Include water truck hrs when shaping is being done.
Clean/cut ditch: 1,000'/hr dozer
Rock road surface (12' wide by 0.25' depth): 1,500'/hr dozer and water truck to spread the rock. 1,500'/hr roller and water truck to compact road rock.
Rolling dip: 1.5hr dozer & water truck. Some dips may require importing soil to build up reverse grade. Add an additional 0.5hr for dozer, roller, and water truck if road needs to be rocked.
Critical dip: 1hr dozer & water truck. Add an additional 0.5hr for dozer, roller, and water truck if road needs to be rocked.
Ditch relief culvert: 3hrs backhoe/excavator, water truck, & Labor. Add an additional 0.5hr for dozer, roller, and water truck if road needs to be rocked. Backfill material shall be free of limbs or other large organics that could decompose over time. Be sure to prevent rocks from denting culverts. Backfill compacting will be done with water in 0.5-1 foot lifts. Compaction can be done using a gas powered tamper, sheepsfoot roller, or excavator/backhoe bucket.
Cross road drain: 0.25hr dozer
Ripping road surface: 1,000'/hr dozer. Usually requires at least two passes with the rippers to de-compact entire road width.
Rock armor placement with excavator/backhoe: 10yd^3/hr on fill slopes at stream crossings. 5yd^3/hr at armored fill stream crossings
Stream crossing excavation and backfill: Rate an excavator/backhoe can excavate a crossing you should consider; traffic control needs, depth of crossing (reach of equipment/ does equipment need to ramp down), and how clean the fill is (large wood decreases production), and if excavated material has to be enhauled. Backfill productivity is assumed to be 100yd^3/hr unless material has to be imported to site.
Road fill excavation: : Rate an excavator/backhoe can excavate unstable road fills is usually higher (120 yd^3/hr) than stream crossing excavations because road fills are easily accessible and don't extend too far down slope from the roadbed.

Estimated heavy equipment and labor hours for road surface treatments					
Treatment type	Backhoe	Dozer	Water Truck	Roller	Labor
Rolling dip*	0	1.5	1.5	0.5	0
Ditch relief culvert	3	0	0.5	0.25	3
Critical dip	0	1	1	0.5	0
Outlsope road fill ditch	0	500 ft/hr	500 ft/hr	1,500 ft/hr	0
Outslope road keep ditch	0	300 ft/hr	300 ft/hr	1,500 ft/hr	0
Inslope road	0	300 ft/hr	300 ft/hr	1,500 ft/hr	0
Crown Road	0	300 ft/hr	300 ft/hr	1,000 ft/hr	0
Remove berm	500 ft/hr	1,000 ft/hr	1,000 ft/hr	0	0
Rock road surface	0	1,500 ft/hr	1,500 ft/hr	1,500 ft/hr	0

** These production rates do not include time for moving between treatment areas and assumes a 12-15 foot road width. Assume lower productivity if underground utilities exist and/or traffic control needs to be managed. Water truck will most likely be used for only half the time that the dozer are doing road shaping and Ditch relief culvert installation.*

Back filling

Backfill material shall be free of limbs or other large organics that could decompose over time. Be sure to prevent rocks from denting culverts. Backfill compacting will be done with water in 0.5-1 foot lifts. Compaction can be done using a gas powered tamper, sheepsfoot roller, excavator/backhoe bucket, and/or by track walking.

Rock

Base rock for road surface is 1.5”minus Class ll aggregate base should be calculated at 2 tons per cubic yard. Road rock is applies 12’ wide by 0.25’ (3”) depth.

Rip-rap (light class 1’-2’) should be calculated at 1.6 tons per cubic yards.

Develop a low impact road system based upon transportation needs and physical constraints

By implementing these road surface drainage practices should dramatically reduce annual maintenance cost because dispersing runoff decrease the ability of water to erode your roads.

Cost effective treatments doing road shaping along should drastically reduce the amount of permitting needed for implementation. Consult with your local county planning department for grading permit requirements, most (if not all) of this work should fall under 'general road maintenance'.

Transportation needs

- Road upgrade; year round vs. seasonal, vehicle usage, road user
- Legacy road network? Road decommissioning (long term winterization) can be a very cost effective way to reduce road maintenance
- Road to trail conversion; quad use, horse use, hiking trail use.

Physical constraints

- Adjacent landowners
- Unstable hill slopes
- Public safety issues
- Existing infrastructure
- Underground utilities

When to use DRC's and Rock road surface

- Seasonal vs. Year-round use
- Year round use roads, grassland setting = disconnect the ditch from road. Drain ditch with DRCs and drain road with Rolling dips. Stagger DRC and Rollings Dips.
- Grassland setting with seasonal use roads = fill in inboard ditch, drain road surface and cutbank with Rolling dips.
- On the whole roads in forested settings don't have active ditches. Fill in inboard ditch and drain road surface and cutbank with Rolling dips.
- Keep an eye out for springy sections of cutbanks. If year round use road then drain springs with ditch and DRC. If seasonal use the construct Rolling dip just downhill from spring.
- Rock year round use roads only.
- North facing slopes = prune canopy to allow for greater air flow and exposure to sunlight.
- Rolling dips up to 15% grade then crown road with DRCs

Napa County Resource Conservation District, Low Impact Roads References:

BMPs

1) “Handbook for Forest and Ranch Roads” = seen as **BMPs** by DFW, CDF, and USDA Soils Conservation Svc. A Mendocino County RCD publications, sells for $22.00. Publication is old but it is supposed to be updated Oct. 2013. Contact the Mendocino RCD for more information. Click on the link below to get a free pdf copy of the manual.
http://www.krisweb.com/biblio/gen_mcrcd_weaveretal_1994_handbook.pdf

2) CA DFW California Salmonid Stream Habitat Restoration Manual Ch IX & X. Chapter IX discusses stream crossings for fish passage. Ch X discusses **BMPs** for rural roads maintenance and design. Click on the link below to get a free pdf copy of the manual.
http://www.dfg.ca.gov/fish/resources/habitatmanual.asp

3) Fish Net 4C Roads **BMPs** manual. This manual was developed for the 4 counties project (Counties of Mendocino, Sonoma, Marin, San Mateo, Santa Cruz and Monterey). Click on the link below to get a free pdf copy of the manual.
http://www.marinwatersheds.org/documents/RoadsManual.pdf

NOAA Fisheries 2001, Guidelines for Salmonid Passage at Stream Crossings.
http://www.westcoast.fisheries.noaa.gov/publications/hydropower/fish_passage_at_stream_crossings_guidance.pdf

Cal Fire, 2004. Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood and Sediment. http://www.calfire.ca.gov/resource_mgt/downloads/reports/ForestryReport1.pdf

TYPICAL DRAWINGS

Pacific Watershed Associates **typical drawings** pdf (www.pacificwatershed.com). There are typical drawings in the ‘Handbook for Forest and Ranch Roads’ as well, but the link below provides more up to date drawings. Click on the link below to get a free pdf copy of the typicals.
http://www.co.sanmateo.ca.us/vgn/images/portal/cit_609/23704076appendix_b.pdf
http://www.naparcd.org/GeologyResources.html

EDUCATIONAL MATERIALS

1) Video link that discusses roads and how they influence the watershed. 5counties website – (Del Norte, Humboldt, Mendocino, Siskiyou & Trinity) road related sediment source video (www.5counties.org/ Document Library/ Roads Manual)

1. Roads video http://www.5counties.org/video1.htm
2. LITH Road Standards (pdf)
3. “DIRT” Direct Inventory of Roads and Treatment (database)

2) Forest and Ranch roads DVD $17.00. DVD discusses the influences road have on the watershed, very similar to the 5counties video. Contact the Mendocino County RCD (www.mcrcd.org) to purchase the video.

MISC. REFERENCE MATERIALS

CA DFW Fish Passage Assessment Database: http://nrm.dfg.ca.gov/PAD/Default.aspx

USFS Stream crossing response to flood events
http://www.fs.fed.us/t-d/pubs/html/wr_p/98771807/98771807.htm

CDF Designing Watercourse Crossings for Passage of 100-year Flood Flows, Wood, and Sediment.
http://www.fire.ca.gov/resourcemanagement/PDF/100yr32links.pdf

USFS Fish Xing: http://stream.fs.fed.us/fishxing/

1. Online software intended to assist individuals in the evaluation and design of culverts for fish passage. Comes with tutorial.

Monitoring the Effectiveness of Road System Upgrading and Decommissioning at the Watershed Scale DFG
http://forestry.berkeley.edu/reports/Monitoring%20the%20Effectiveness%20of%20Road%20System%20Upgrading%20March%20.pdf

Monitoring the Effectiveness of Upland Restoration DFG:
http://forestry.berkeley.edu/reports/Monitoring%20the%20Effectiveness%20of%20Upland%20Restoration%20March%20200.pdf