Road Drainage Alternatives

By

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“Three of the most important aspects of road design – drainage, drainage, and drainage!”

Keller and Sherar, 2003

Impacts

Roads can alter both drainage patterns and runoff generation, resulting in:

- Destabilization of side-cast material downslope hillsides;
- Gullying and channel network expansion;
- Increased downstream sediment loads;
- Altered stream flow and channel adjustments;
- Standing water (pothole, sag, rut, wet area) can weaken the subgrade and accelerate erosion and damage to the road.

See Drew Coe's and Mike Wopat's presentations under Series 1

Photo: Matt Boone, RWQCB

Photo: USDA Forest Service

Photo: USDA Forest Service

Photo: Gordon Keller

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Primary Objective

Design, construct and maintain roads so they are hydraulically invisible (i.e., water intercepted by roads is returned to natural flow processes as quickly as practical).

Remember!

Successfully treating road drainage (hydraulically invisible)

=

Protecting natural resources

+

Ensuring full use of road and reduced maintenance and repair costs

Outline

- Types of road prism shapes
- Drainage structures
  - Types
  - Spacing
  - Location
- Ditch and outlet scour protection

Road Prism Shapes

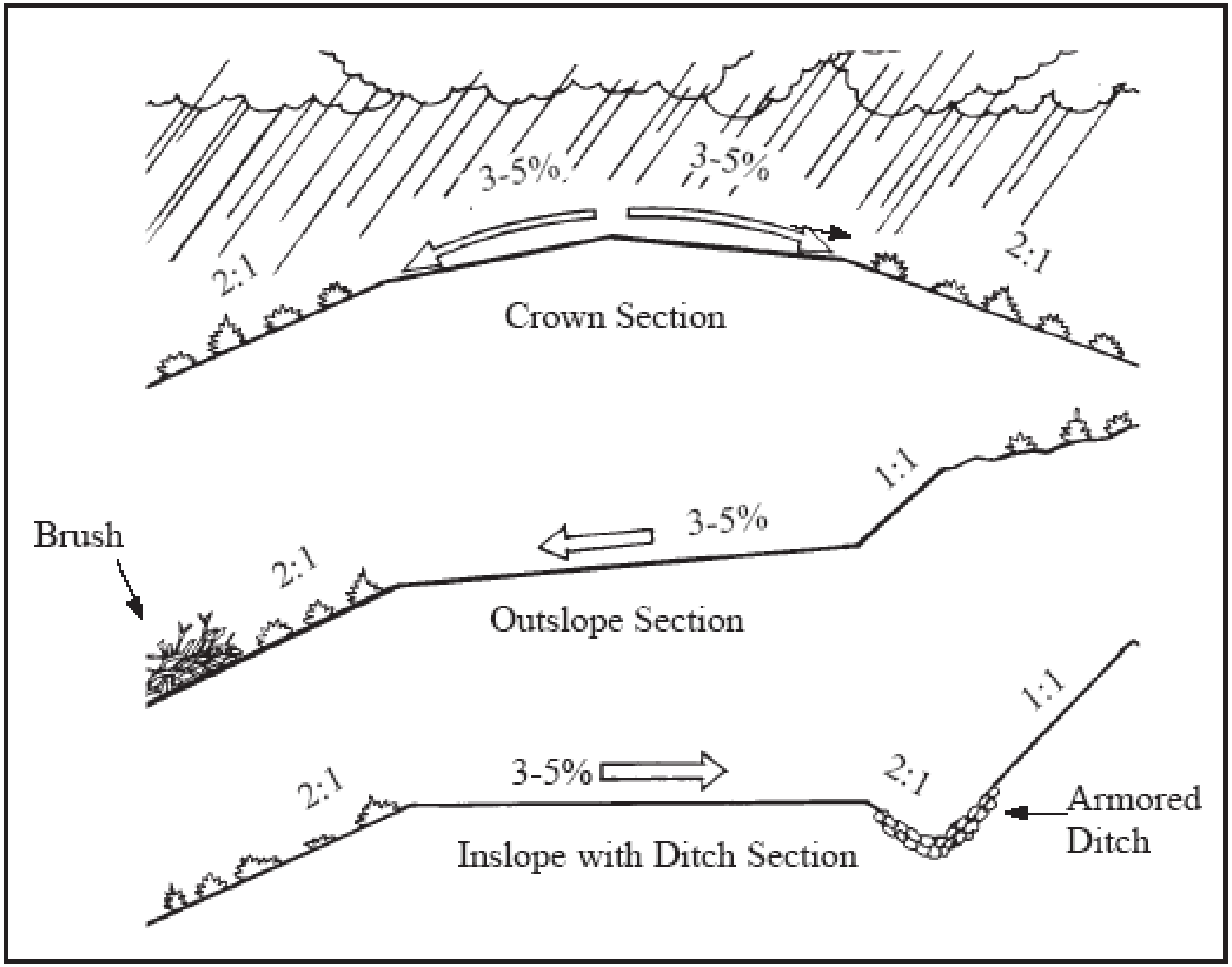
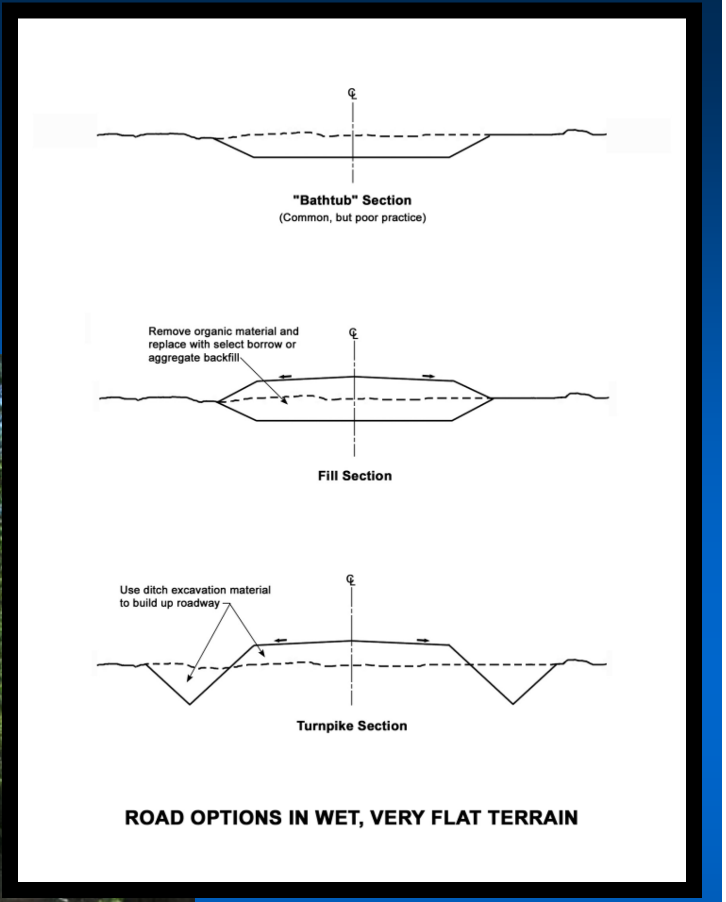


Figure 7.1 Typical road surface drainage options.

Keller and Sherar, 2003

Photo: Gordon Keller

Photo: Gordon Keller



"Bathtub" Section
(Common, but poor practice)

Fill Section

Turnpike Section

ROAD OPTIONS IN WET, VERY FLAT TERRAIN

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Photo: Matt Boone, RWQCB

Photo: Matt Boone, RWQCB

Drainage Structure

- Inboard Ditches
- Culverts (Cross-drains)
- Rolling Dips
- Waterbars
- Over-side drains/flumes
- Leadouts/ditchouts
- Subdrains
    - Intercept
    - Blanket
- Others
    - Rubber water diverters
    - Open-topped channels
    - Grade Reversals and Rolls

Ditch Structures

Photo: USDA Forest Service

Ditch Structures

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Ditch Structures

Photo: Gordon Keller

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Pipe Structures

Figure 7.4 Culvert cross-drains.

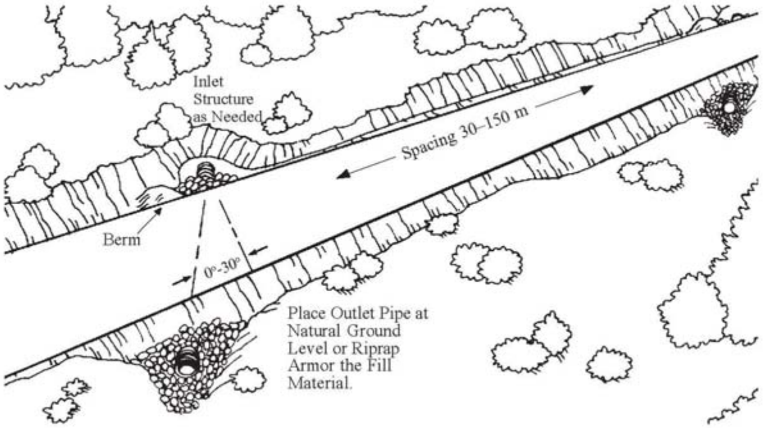
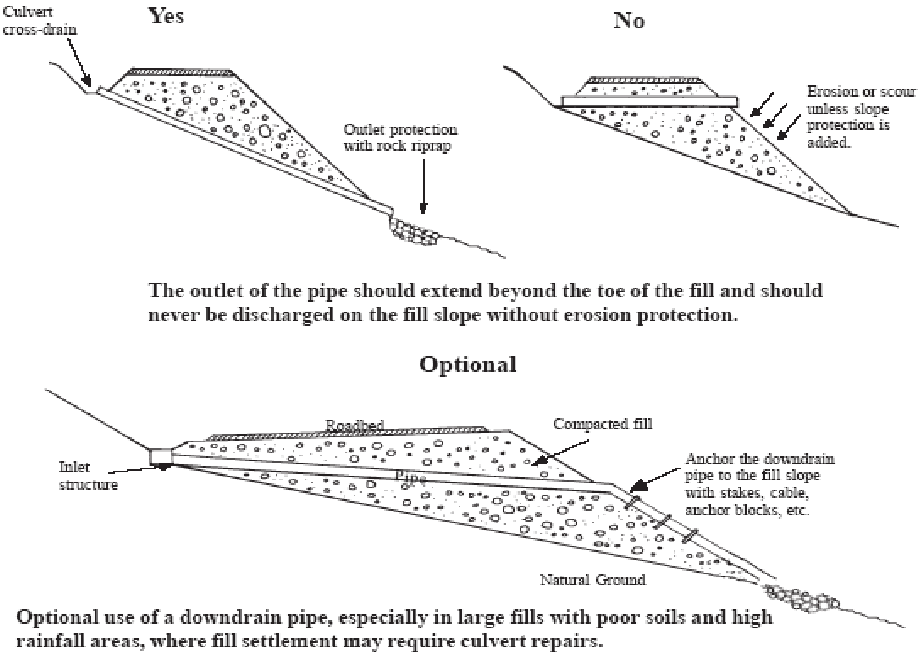


Figure 8.1 Culvert cross-drain installation options in a fill.



The outlet of the pipe should extend beyond the toe of the fill and should never be discharged on the fill slope without erosion protection.

Optional use of a downdrain pipe, especially in large fills with poor soils and high rainfall areas, where fill settlement may require culvert repairs.

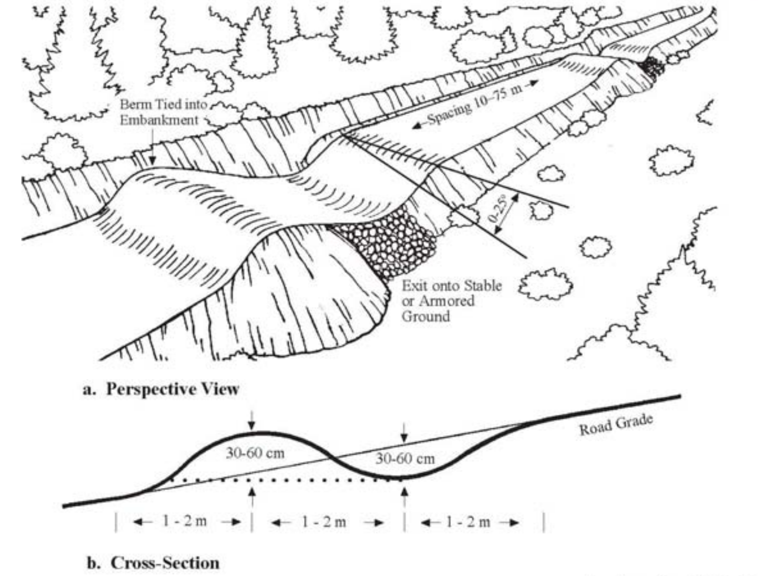
Keller and Sherar, 2003

Pipe Structures

Pipe Structures

Waterbars

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)*



Keller and Sherar, 2003

Rolling Dips

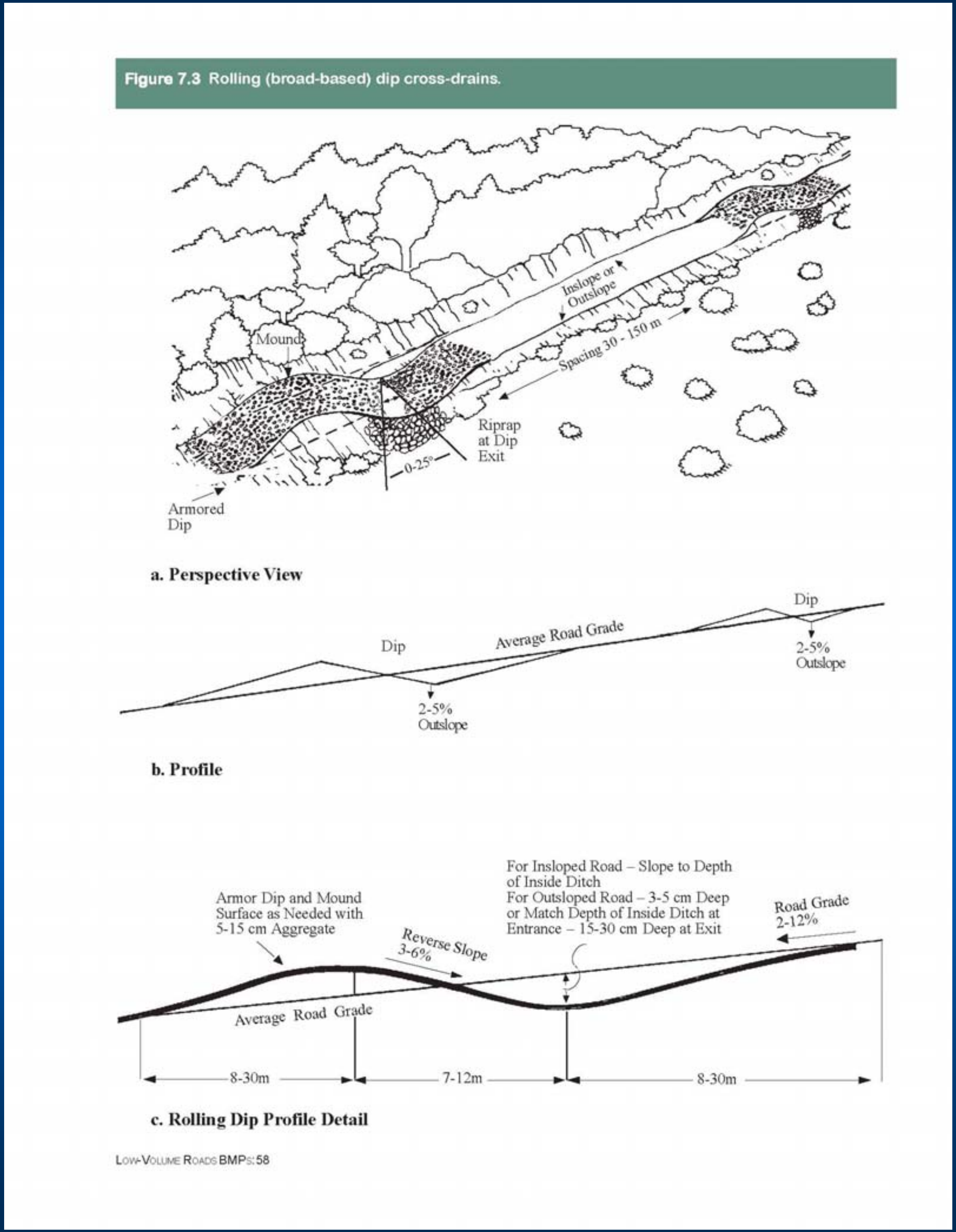


Figure 7.3 Rolling (broad-based) dip cross-drains.

a. Perspective View

b. Profile

c. Rolling Dip Profile Detail

Keller and Sherar, 2003

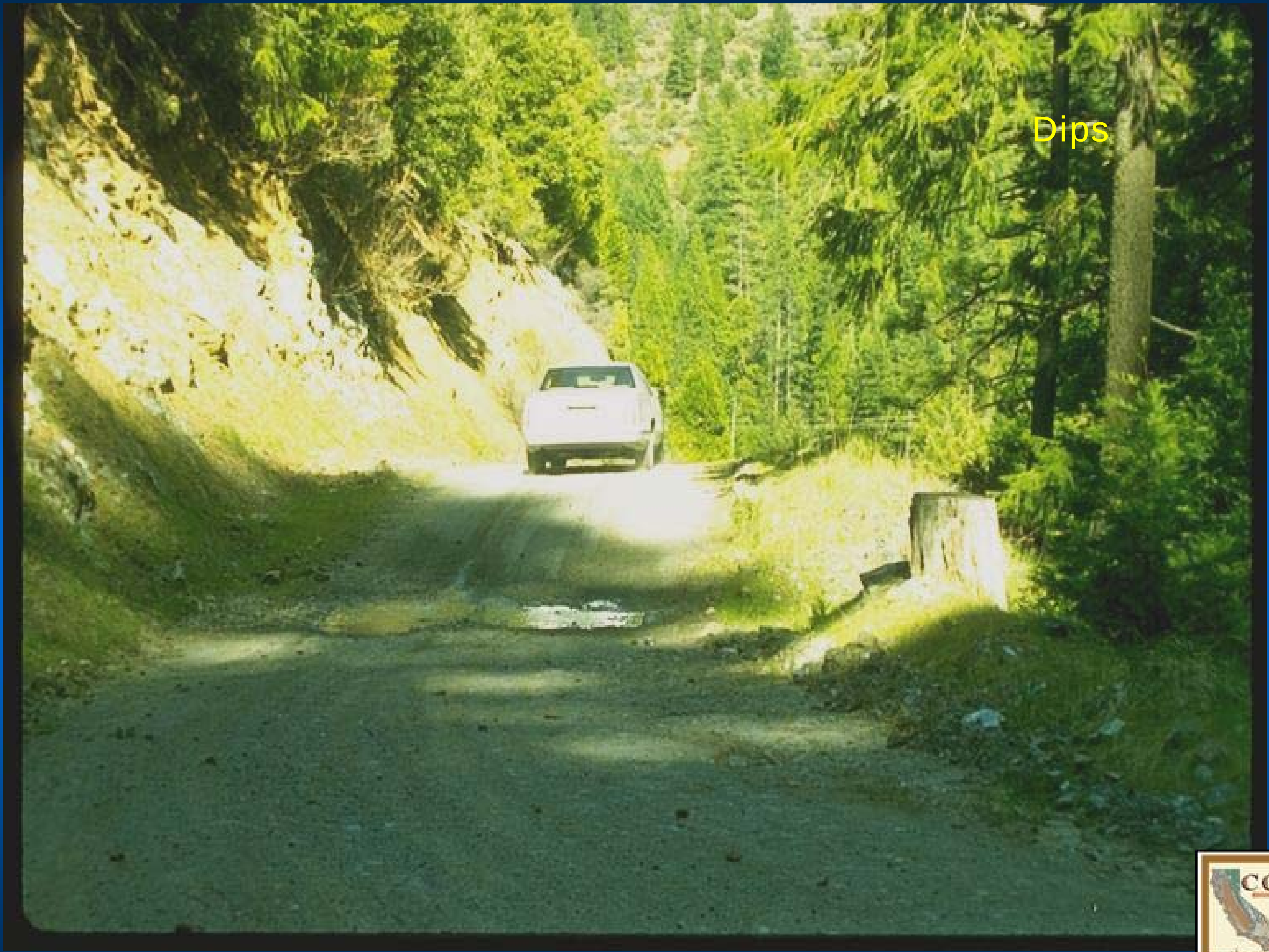


Photo: Gordon Keller

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Over-side drains

Photo: Gordon Keller

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Over-side drains

Photo: Matt Boone, RWQCB

Over-side drains

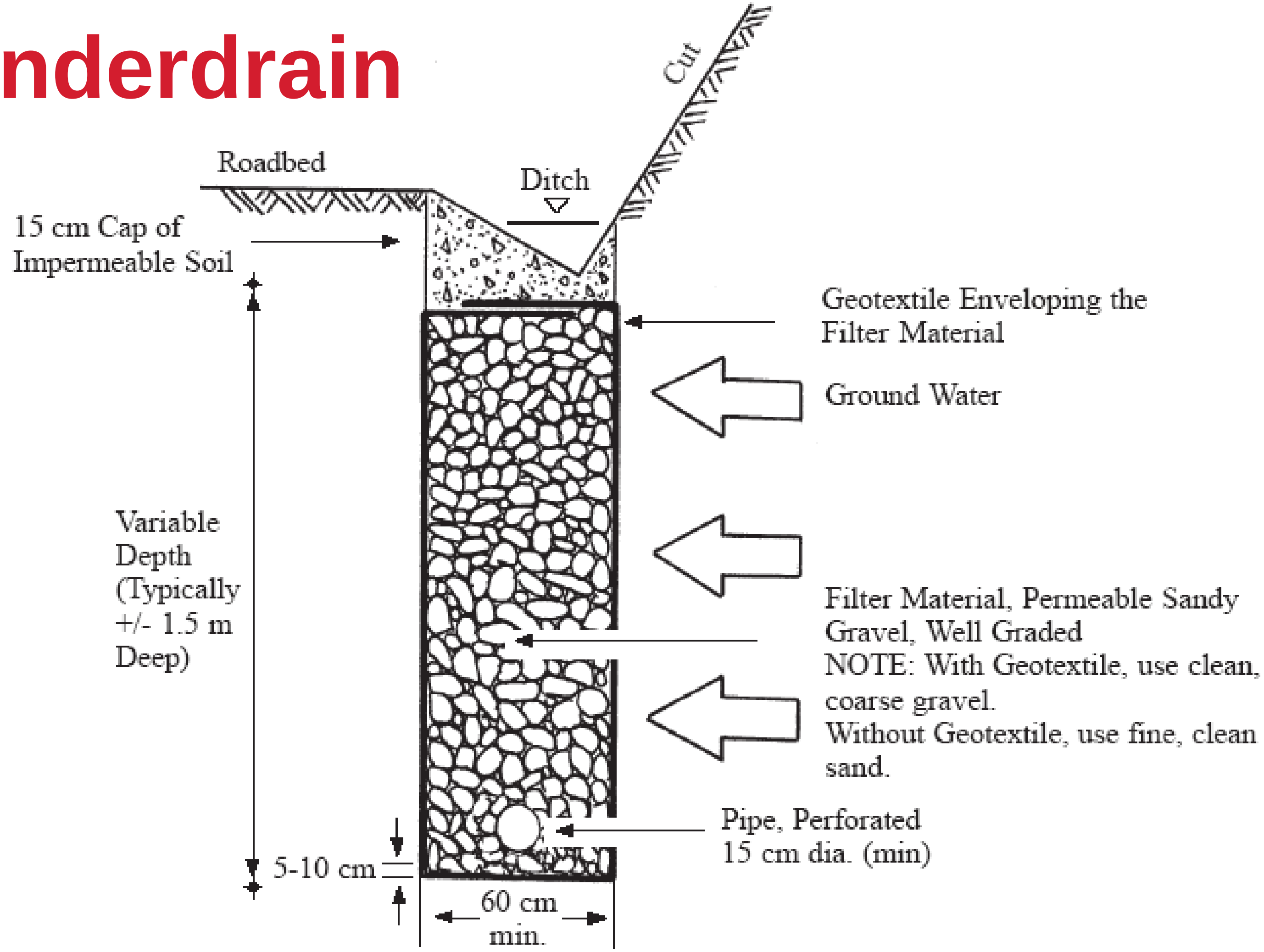

Leadouts

Subdrains

Photo: Gordon Keller

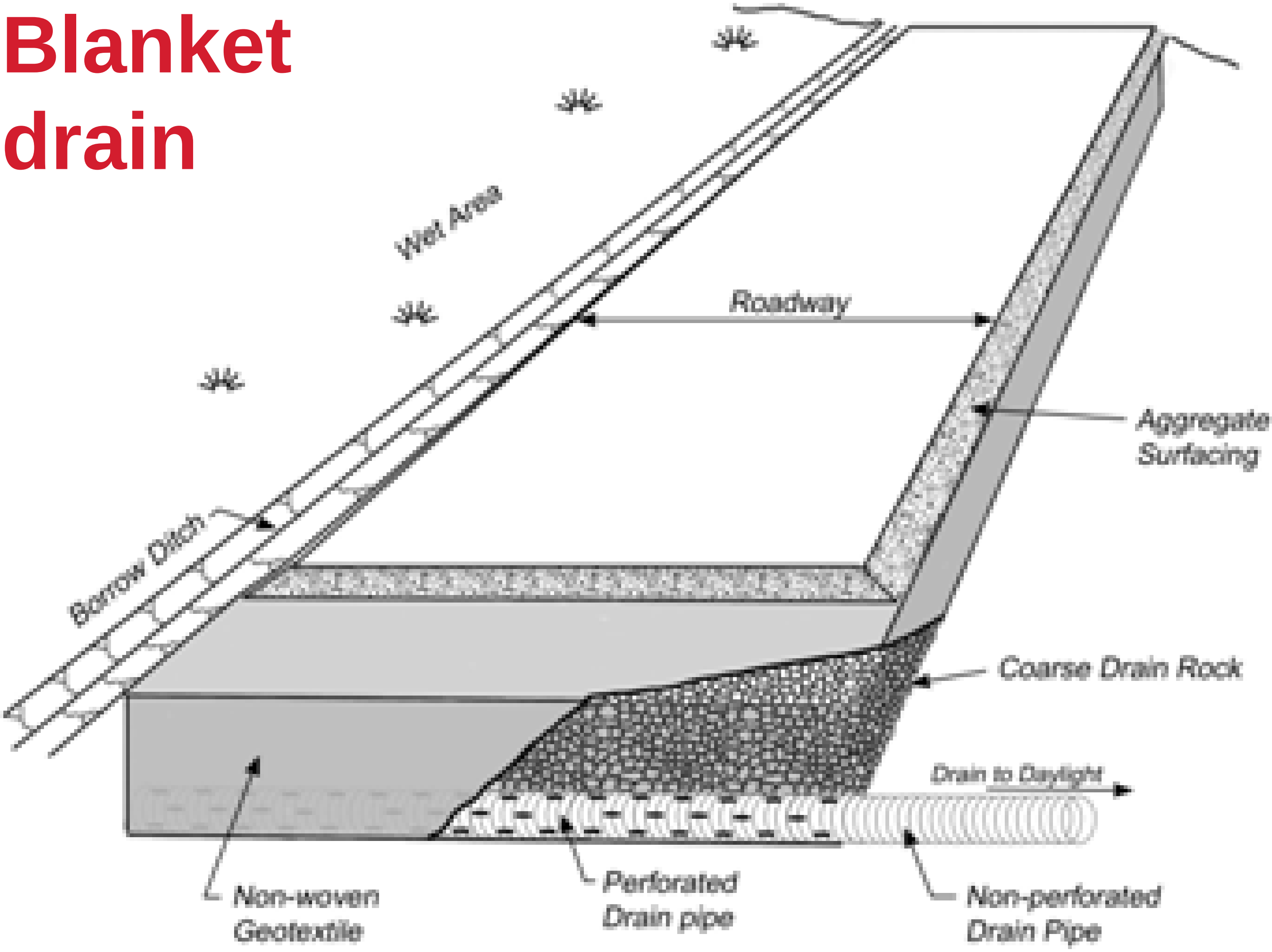
underdrain

Figure 7.16 Typical road underdrain used to remove subsurface water.



Keller and Sherar, 2003

Blanket drain



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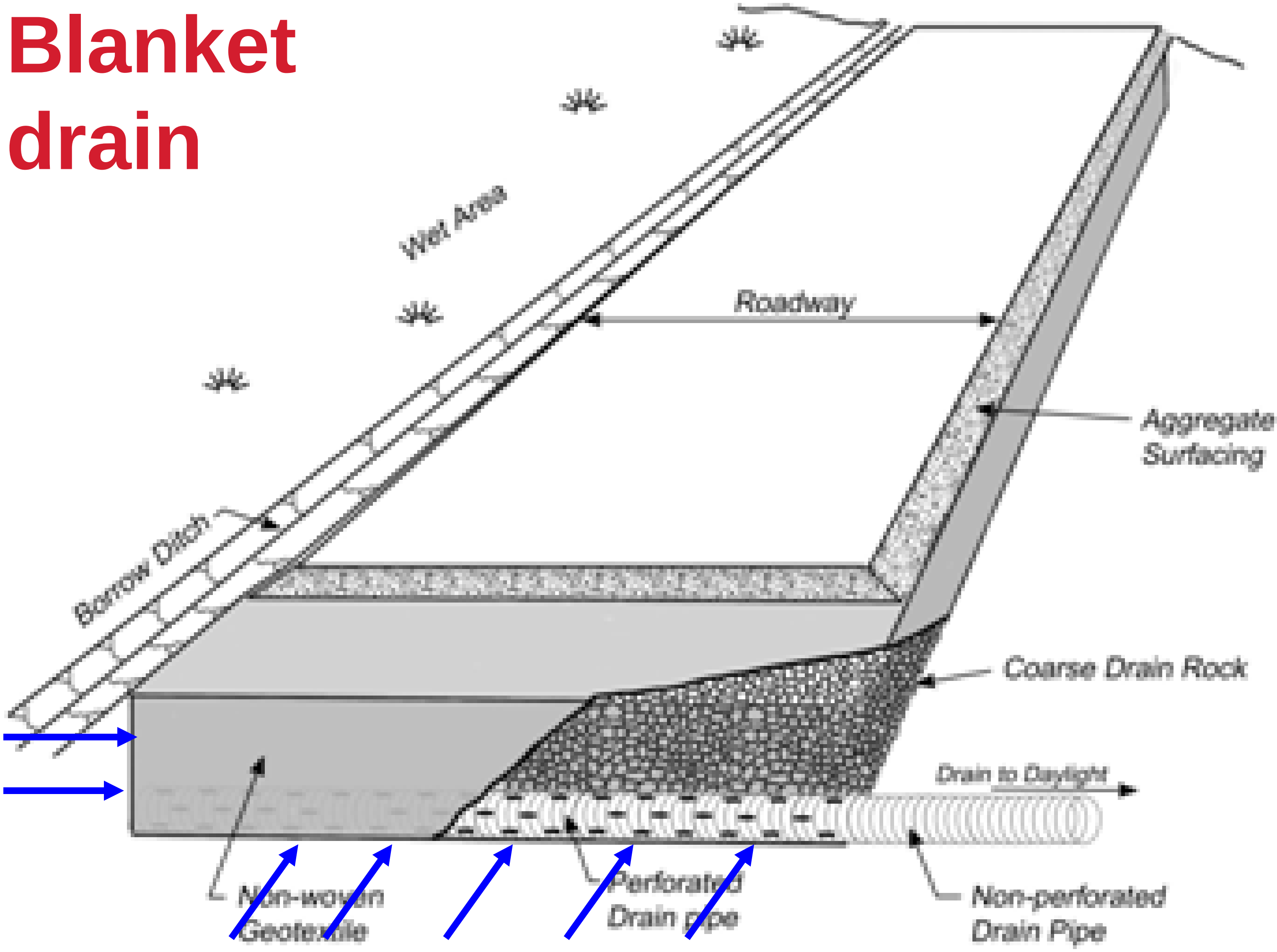
Blanket drain



Keller and Sherar, 2003

Geofabric

<u>NONWOVEN</u> ★	🚫 <u>WOVEN</u>
High porosity + High permeability = High flow for longer.	High permeability but percent open area (POA) is more prone to clogging.

Rubber diverters

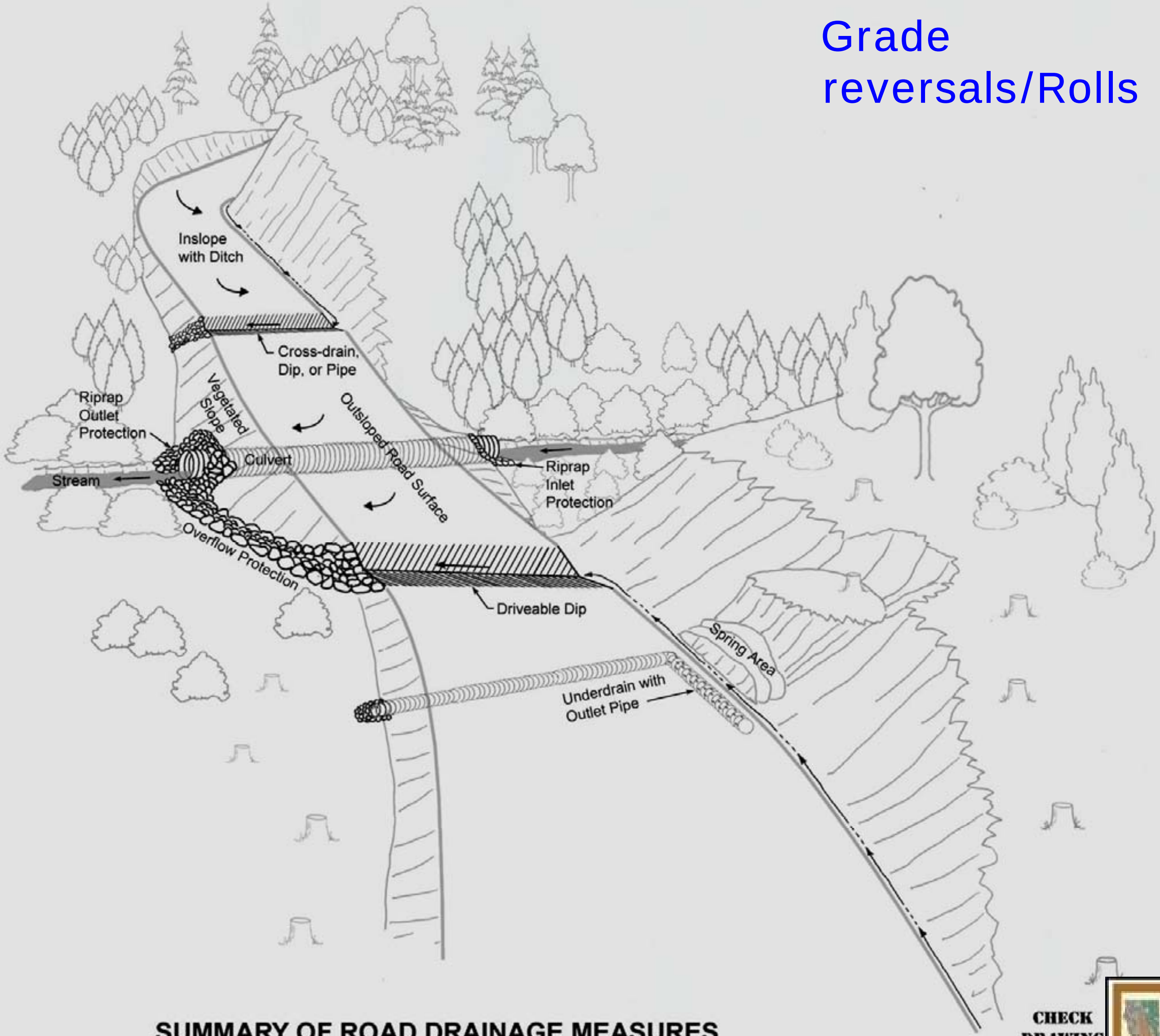
Photo: Gordon Keller


Open-topped channels

7. 25. 2003

Photo: Gordon Keller

Grade reversals/Rolls



SUMMARY OF ROAD DRAINAGE MEASURES

CHECK DRAWING
07-05-06

Source: Gordon Keller

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Questions?

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Drainage Structure Spacing

- Drainage structures should be constructed at a spacing that would prevent excessive erosion either in the inboard ditch, along the road surface, or downslope of the road.
- Spacing is a function of:
  - Road grade
  - Hydrology
  - Soil type
  - Surfacing
- Modify Structure locations to account for landscape features as necessary (topography, wet areas, landslides, etc).

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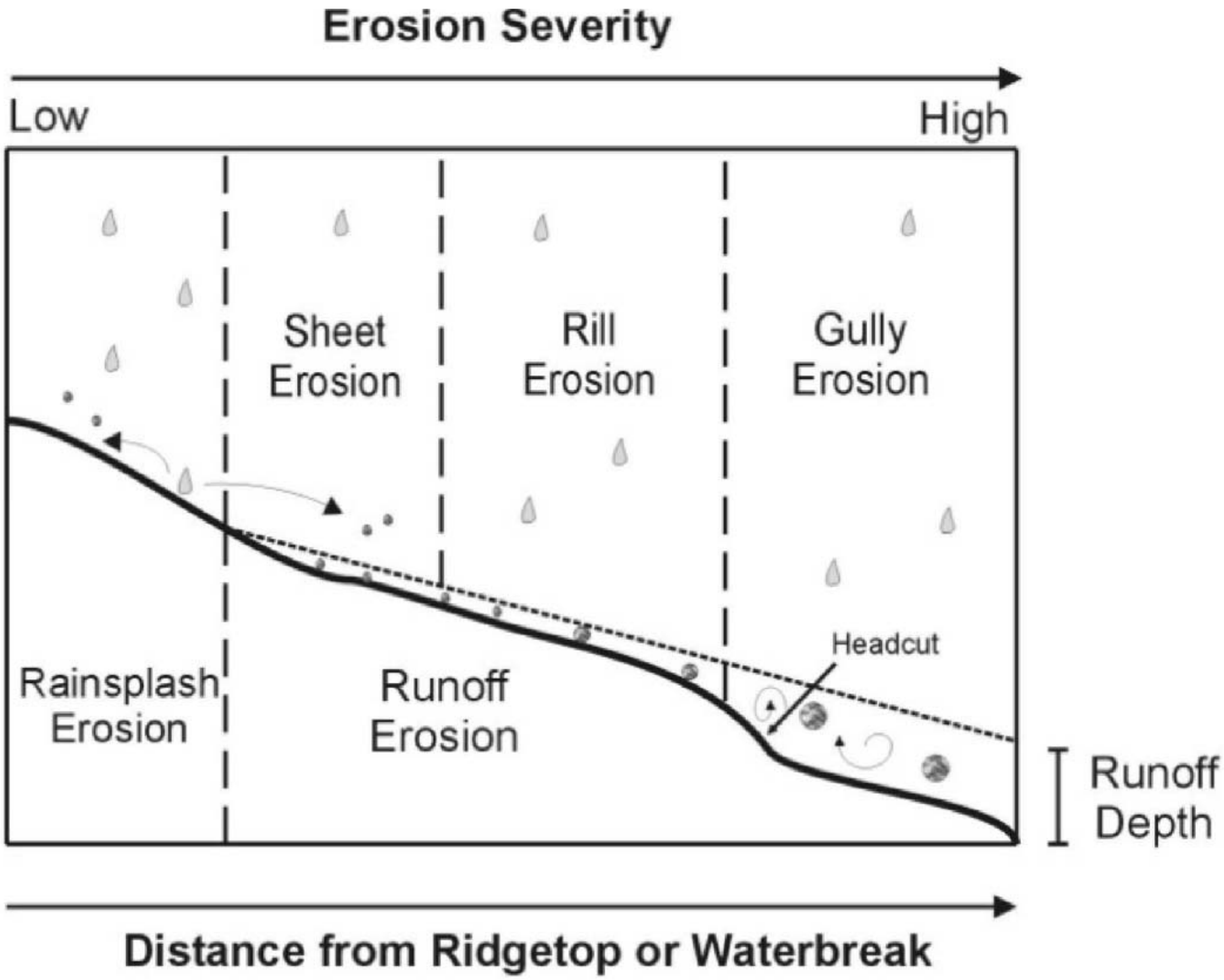
Erosion power = Kinetic energy = $0.5(mv^2)$



Spacing is a function of:

- Road grade
- Hydrology
- Soil type
- Surfacing

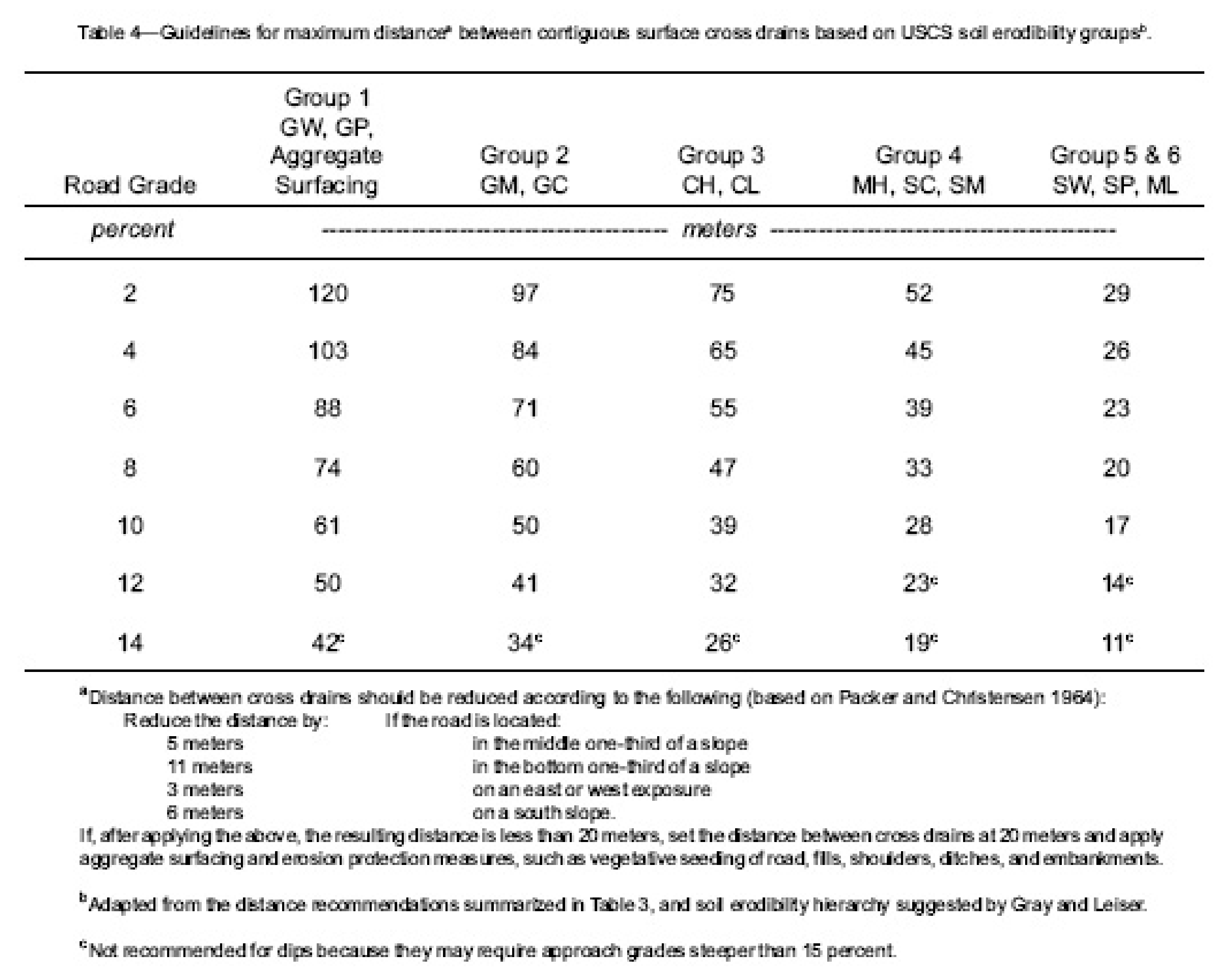


Table 4—Guidelines for maximum distance[a] between contiguous surface cross drains based on USCS soil erodibility groups[b].

Road Grade	Group 1 GW, GP, Aggregate Surfacing	Group 2 GM, GC	Group 3 CH, CL	Group 4 MH, SC, SM	Group 5 & 6 SW, SP, ML
percent	----------	----------	*meters*	----------	----------
2	120	97	75	52	29
4	103	84	65	45	26
6	88	71	55	39	23
8	74	60	47	33	20
10	61	50	39	28	17
12	50	41	32	23[c]	14[c]
14	42[c]	34[c]	26[c]	19[c]	11[c]

[a] Distance between cross drains should be reduced according to the following (based on Packer and Christensen 1964):

Reduce the distance by:	If the road is located:
5 meters	in the middle one-third of a slope
11 meters	in the bottom one-third of a slope
3 meters	on an east or west exposure
6 meters	on a south slope.

If, after applying the above, the resulting distance is less than 20 meters, set the distance between cross drains at 20 meters and apply aggregate surfacing and erosion protection measures, such as vegetative seeding of road, fills, shoulders, ditches, and embankments.

[b] Adapted from the distance recommendations summarized in Table 3, and soil erodibility hierarchy suggested by Gray and Leiser.

[c] Not recommended for dips because they may require approach grades steeper than 15 percent.

Copstead, R. L., et al. (1998)

Drainage Structure Location

1. Spaced close enough to avoid excessive rilling and gullying.
2. Located sufficiently upgrade of watercourse crossings to allow filtering of sediment-rich runoff by the buffer strip between the road and stream.
3. Direct discharge away from unstable or potentially unstable areas.
4. Upgradient of drainage divides to keep water from one catchment basin mixing with, and potentially impacting, another catchment basin not conditioned to the additional flows.
5. Discharge onto divergent (convex) to planar slopes, where possible, to promote better dispersion and infiltration.
6. Drain saturated soils of the road prism.
7. Upgrade of breaks in the road grade that transition from low-gradient to high-gradient.

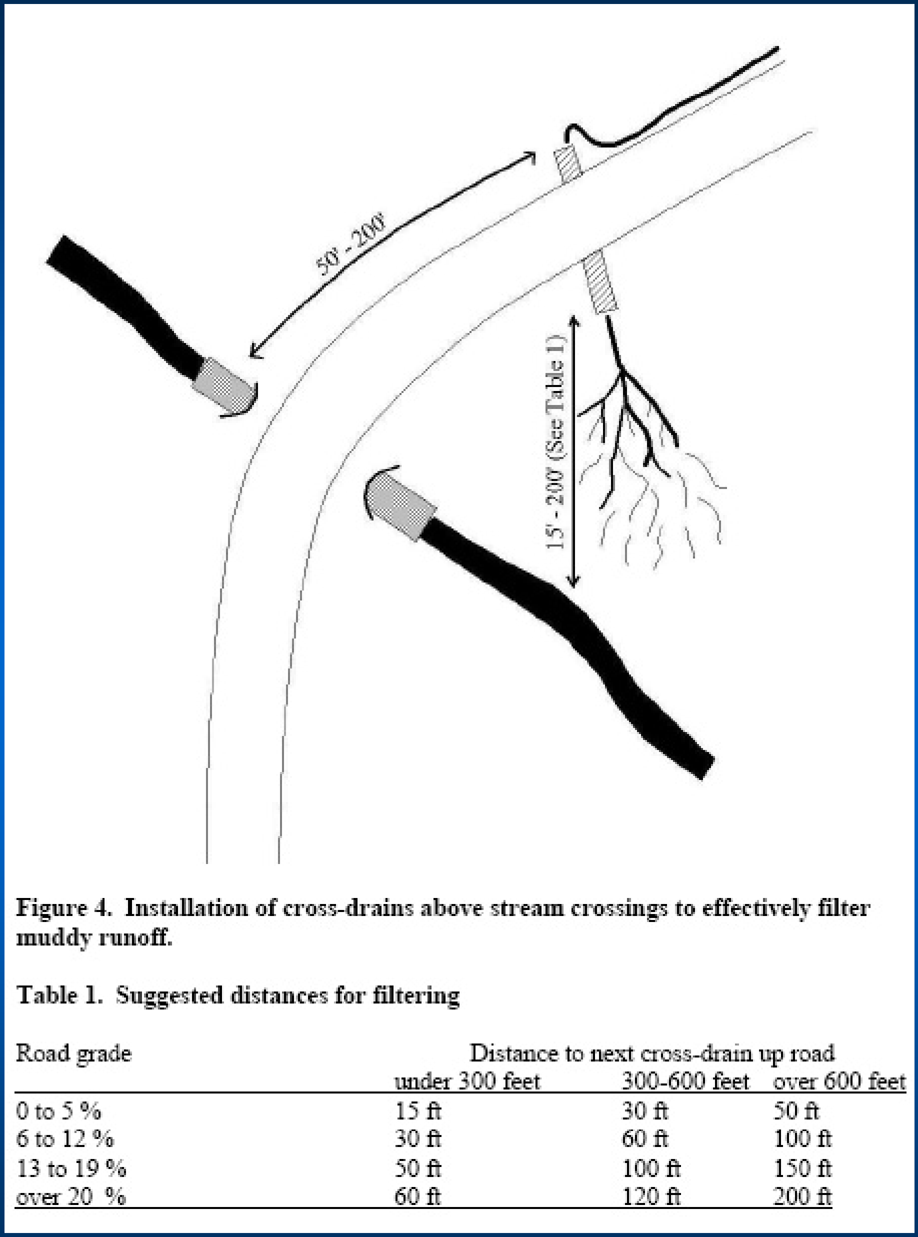


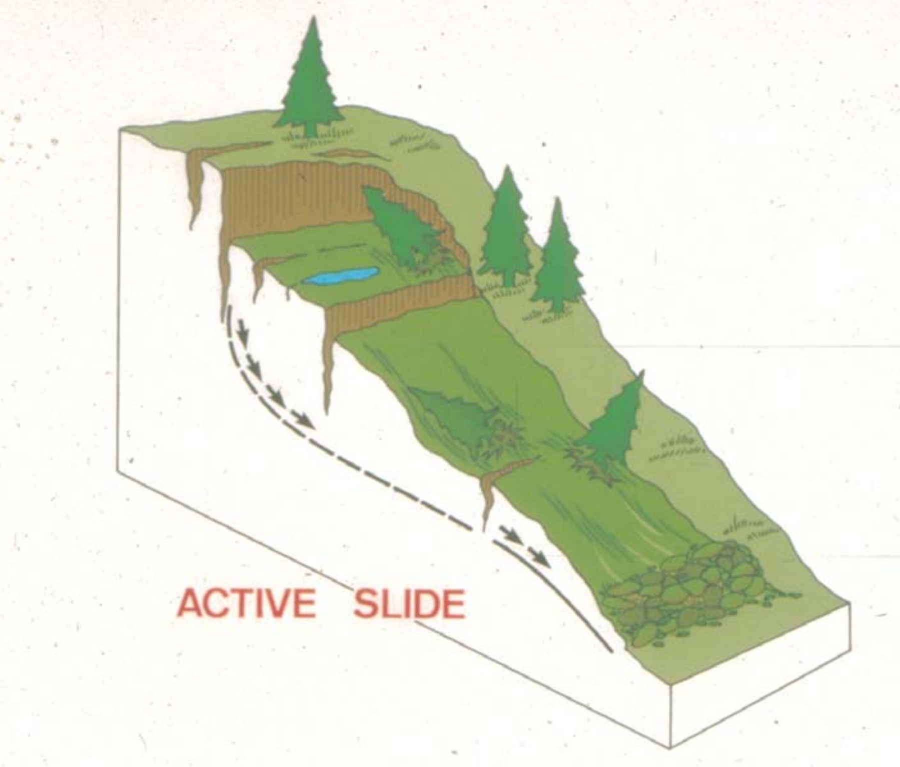
Figure 4. Installation of cross-drains above stream crossings to effectively filter muddy runoff.

Table 1. Suggested distances for filtering

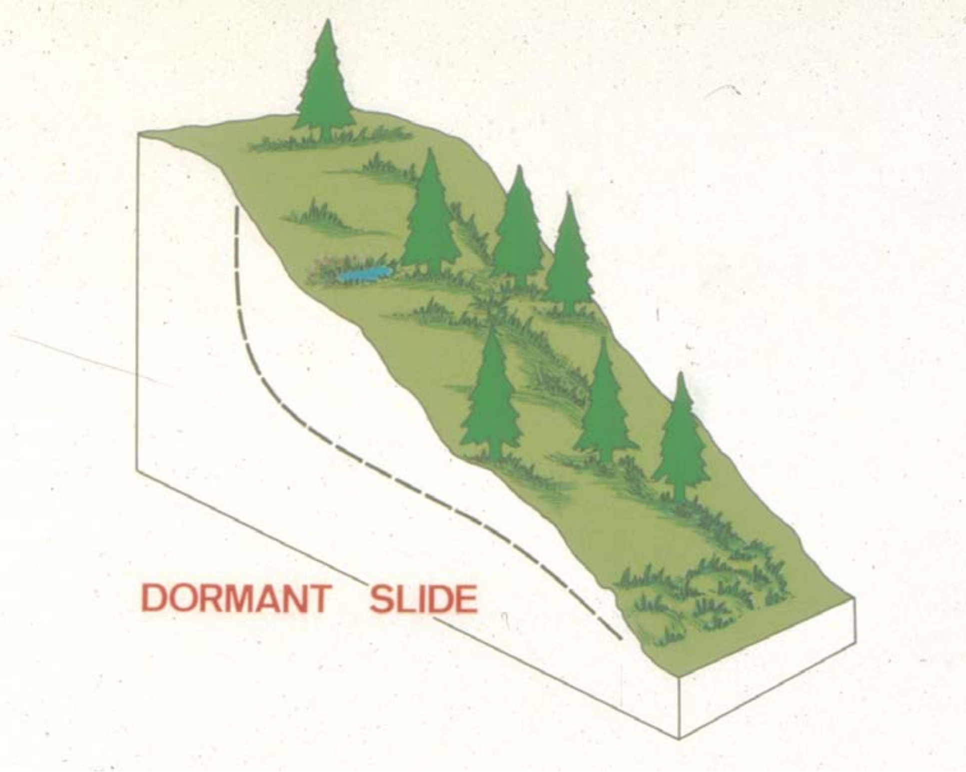
Road grade	Distance to next cross-drain up road		
	under 300 feet	300-600 feet	over 600 feet
0 to 5 %	15 ft	30 ft	50 ft
6 to 12 %	30 ft	60 ft	100 ft
13 to 19 %	50 ft	100 ft	150 ft
over 20 %	60 ft	120 ft	200 ft

Place upgrade of stream crossings to allow for filtering of sediment-rich runoff prior to entering the stream.

Oregon Department of Forestry



Place to discharge away from unstable or potentially unstable areas.



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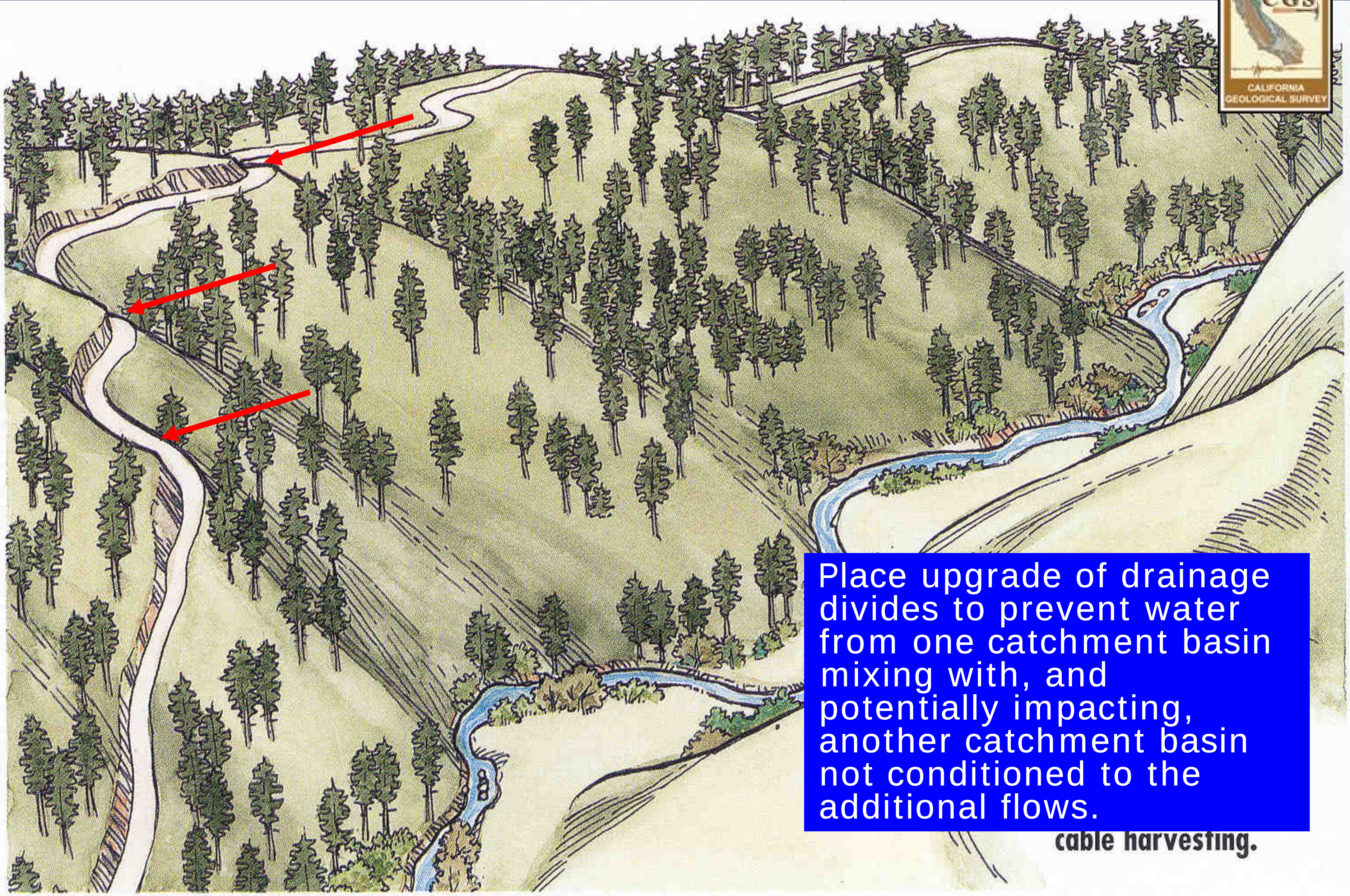
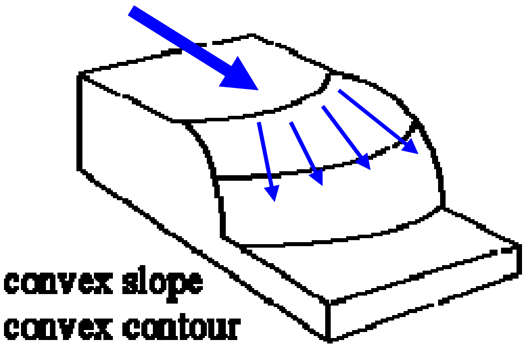
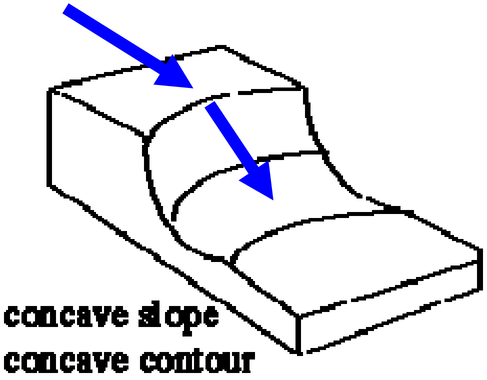


Place upgrade of drainage divides to prevent water from one catchment basin mixing with, and potentially impacting, another catchment basin not conditioned to the additional flows.

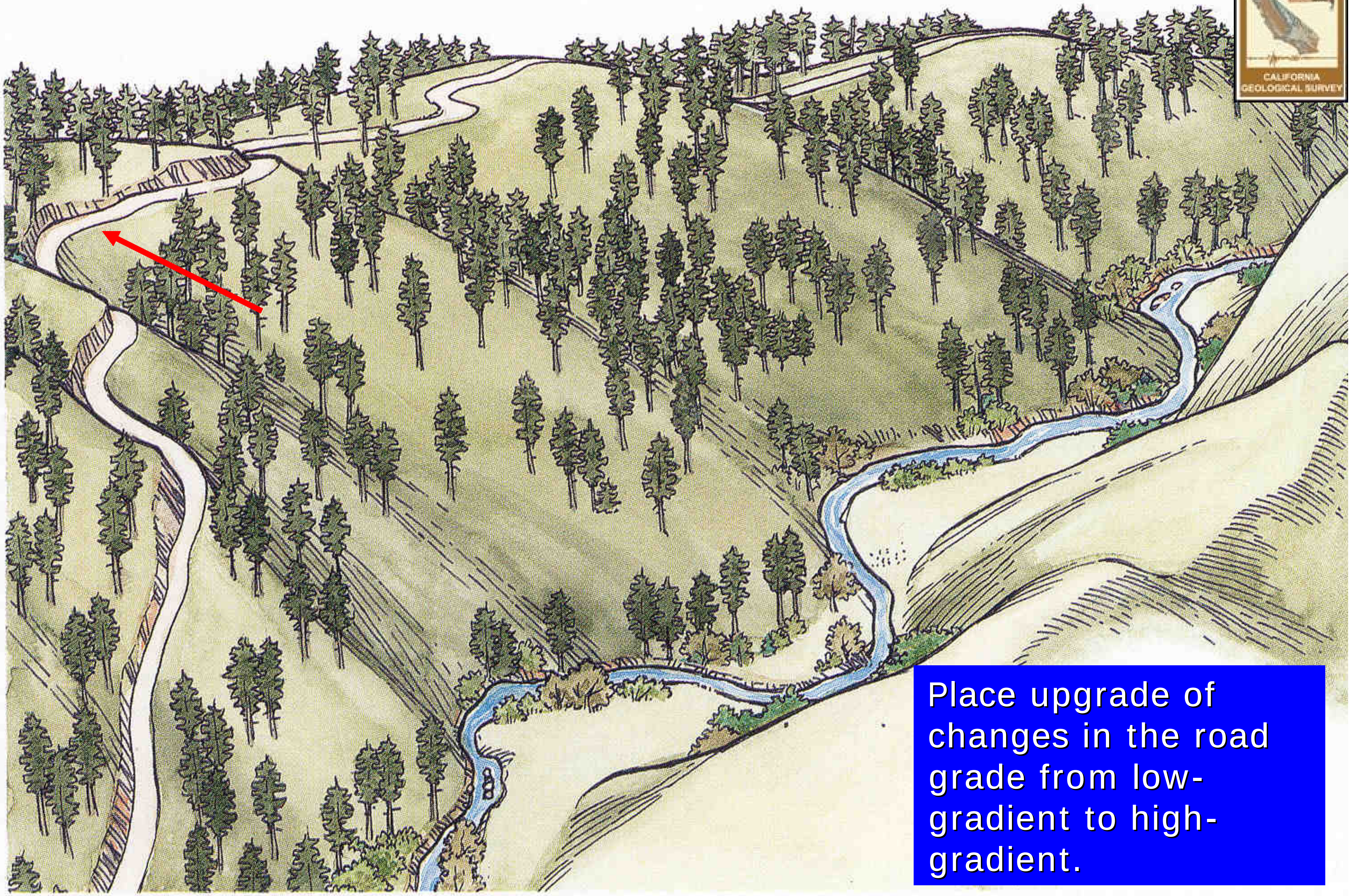
Oregon Forest Resources Institute, 2002





Place to discharge onto divergent (convex) to planar slopes, where possible, to promote better dispersion and infiltration.

Place to drain saturated soils present in the road prism.



Place upgrade of changes in the road grade from low-gradient to high-gradient.

Oregon Forest Resources Institute, 2002

Energy Dissipators

The use and selection of an appropriate energy dissipator should be based on in-field conditions that include:

- Flow
- Soil erodibility
- Slope gradient, and
- Slope roughness and cover

Ditches

Photo: Gordon Keller

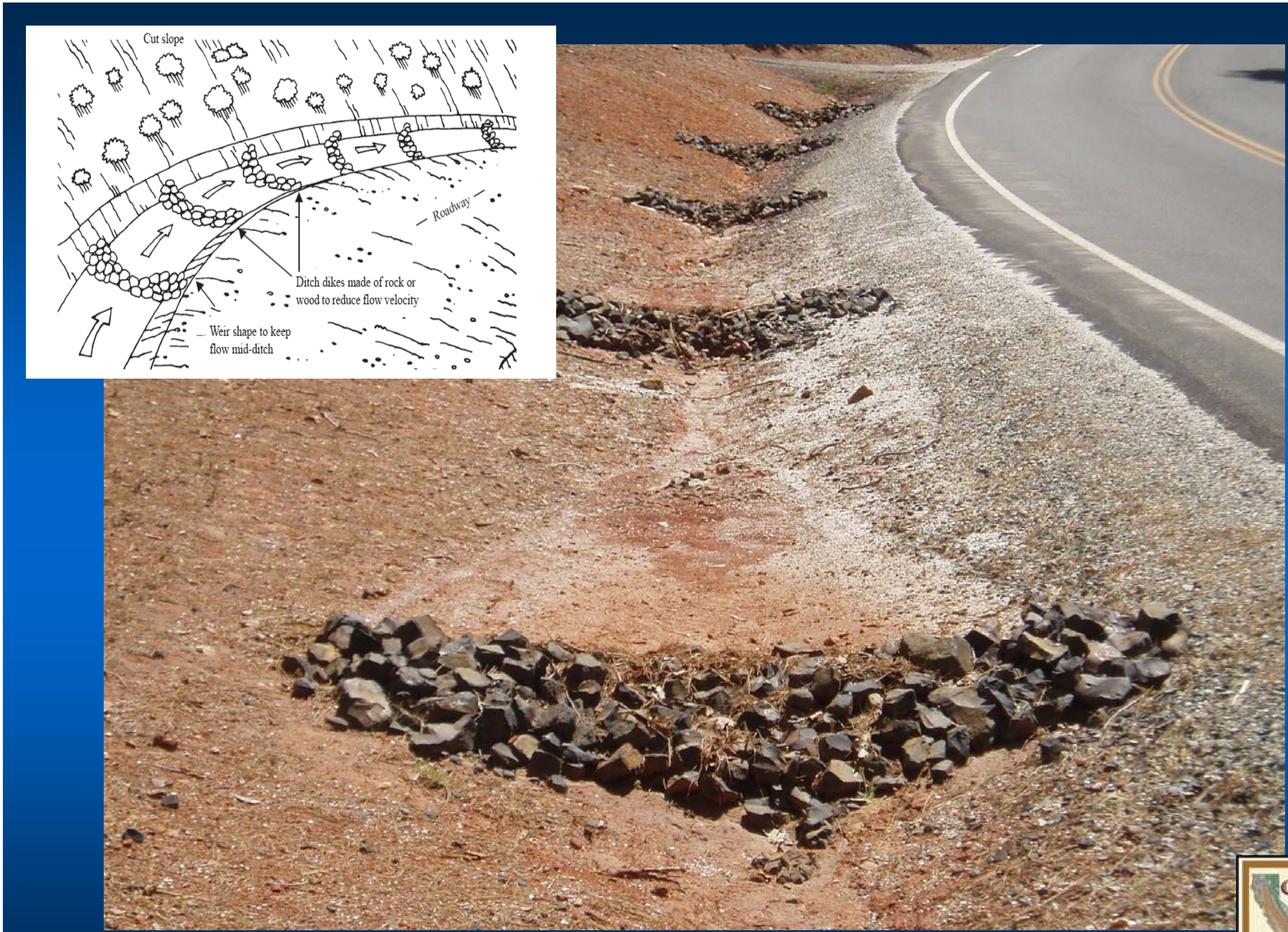


Photo: Gordon Keller

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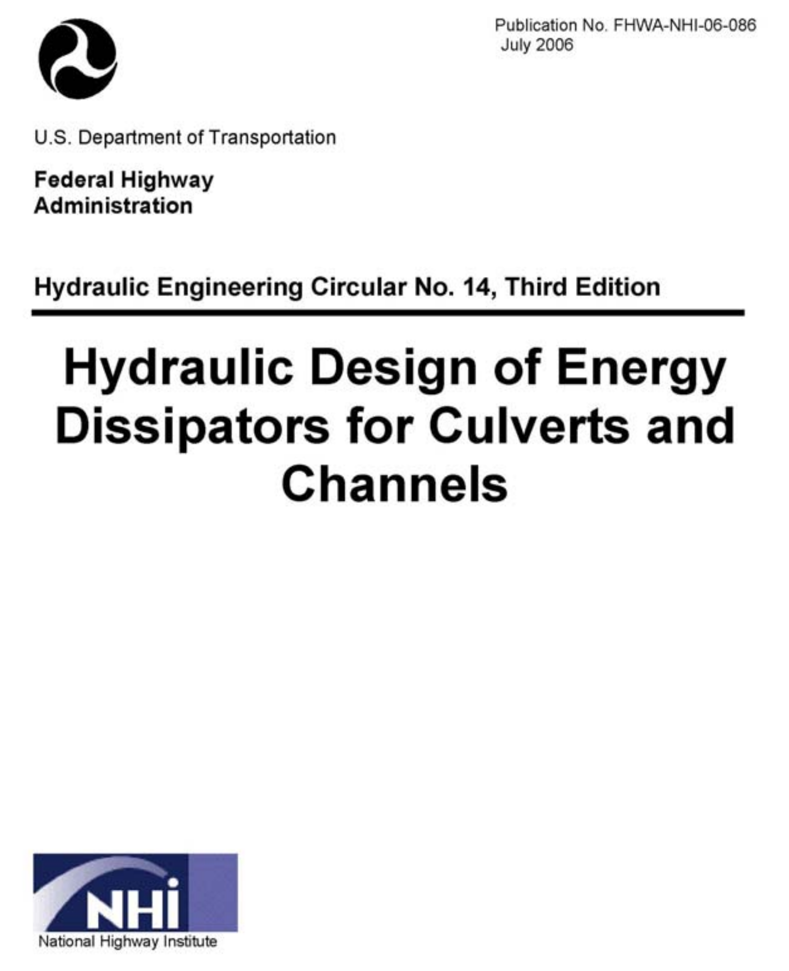

Publication No. FHWA-NHI-06-086
July 2006

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**Federal Highway
Administration**

Hydraulic Engineering Circular No. 14, Third Edition

Hydraulic Design of Energy Dissipators for Culverts and Channels

NHI
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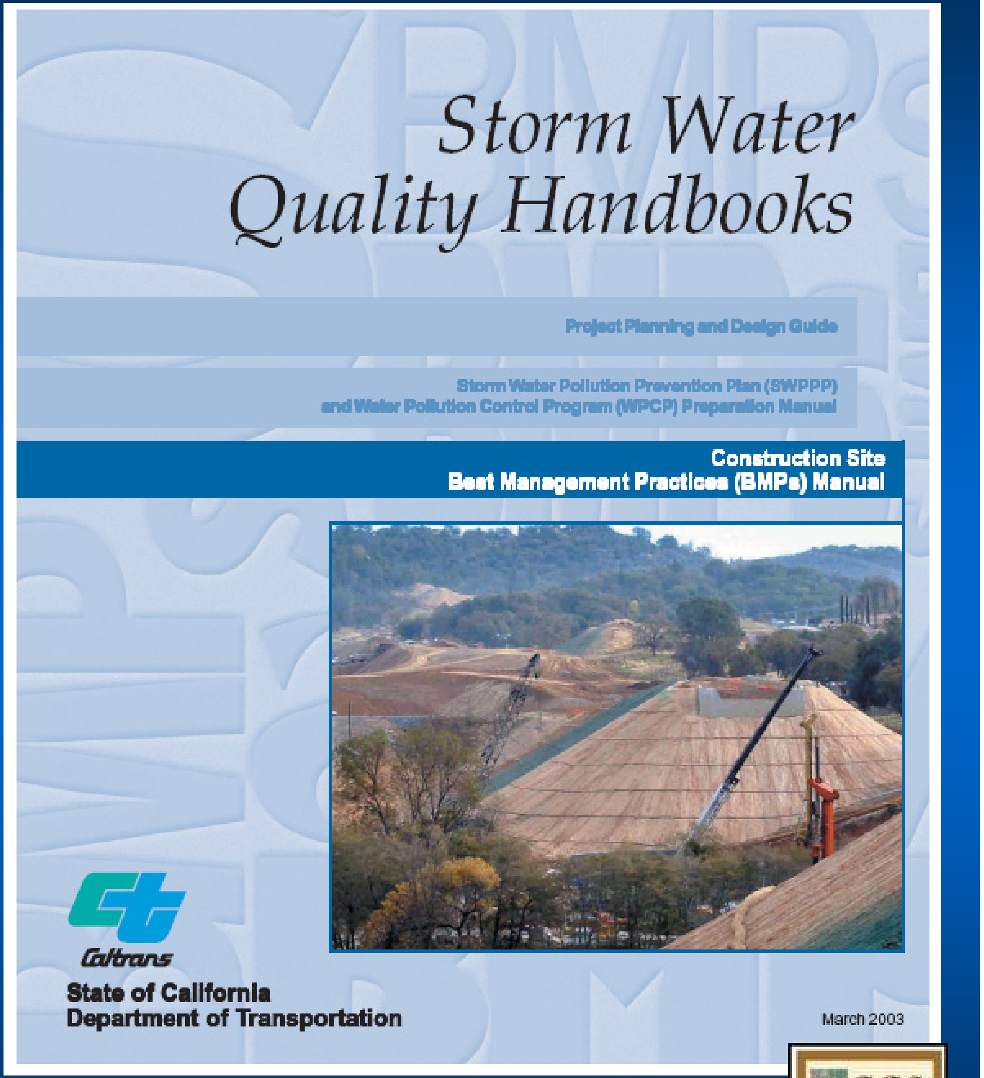

Storm Water Quality Handbooks

Project Planning and Design Guide

Storm Water Pollution Prevention Plan (SWPPP)
and Water Pollution Control Program (WPCP) Preparation Manual

**Construction Site
Best Management Practices (BMPs) Manual**

Caltrans

**State of California
Department of Transportation**

March 2003

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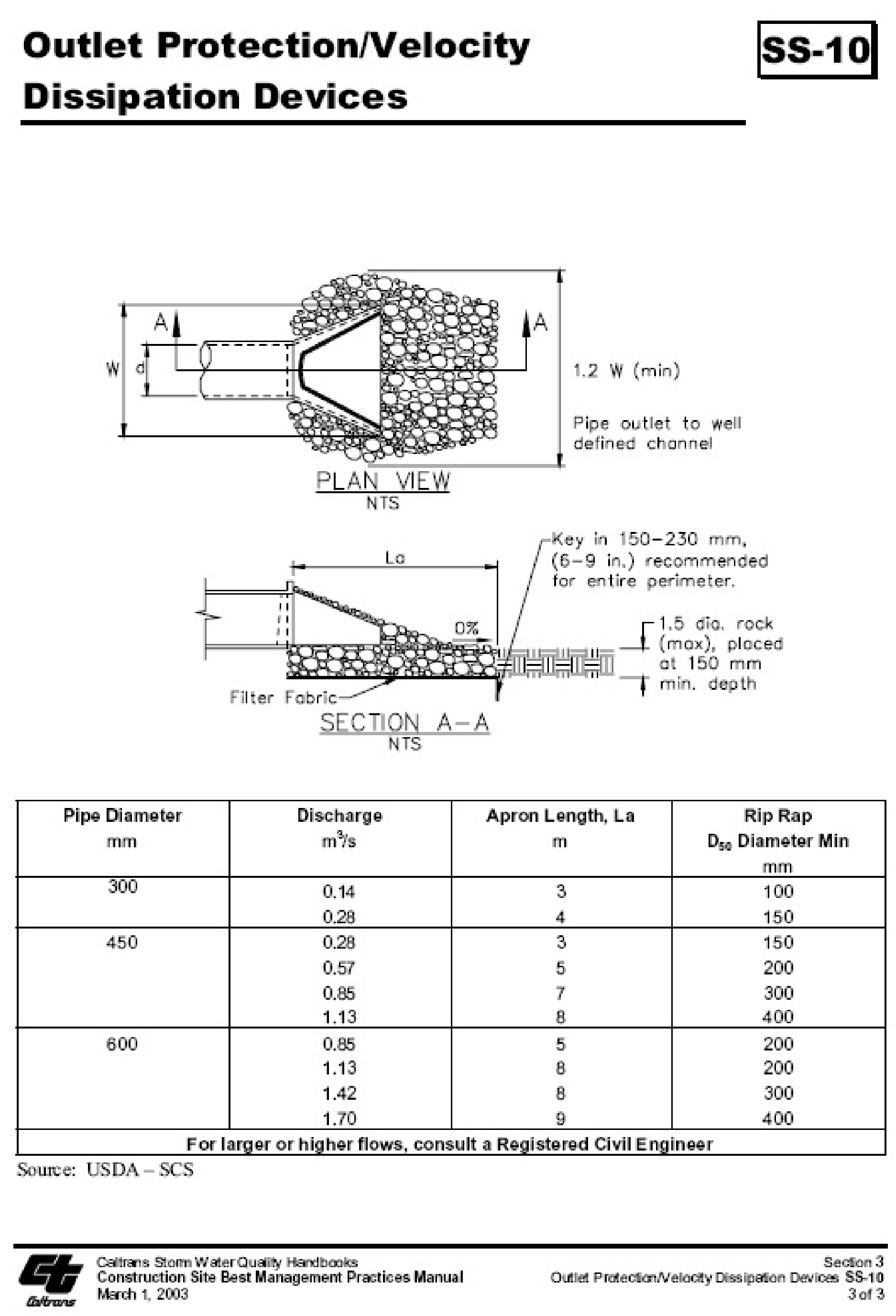
Outlets

Photo: Gordon Keller



Outlet Protection/Velocity Dissipation Devices

SS-10

Pipe Diameter mm	Discharge m^3/s	Apron Length, La m	Rip Rap D_{50} Diameter Min mm
300	0.14	3	100
	0.28	4	150
450	0.28	3	150
	0.57	5	200
	0.85	7	300
	1.13	8	400
600	0.85	5	200
	1.13	8	200
	1.42	8	300
	1.70	9	400
For larger or higher flows, consult a Registered Civil Engineer			

Source: USDA – SCS

Stilling basin / tailwater

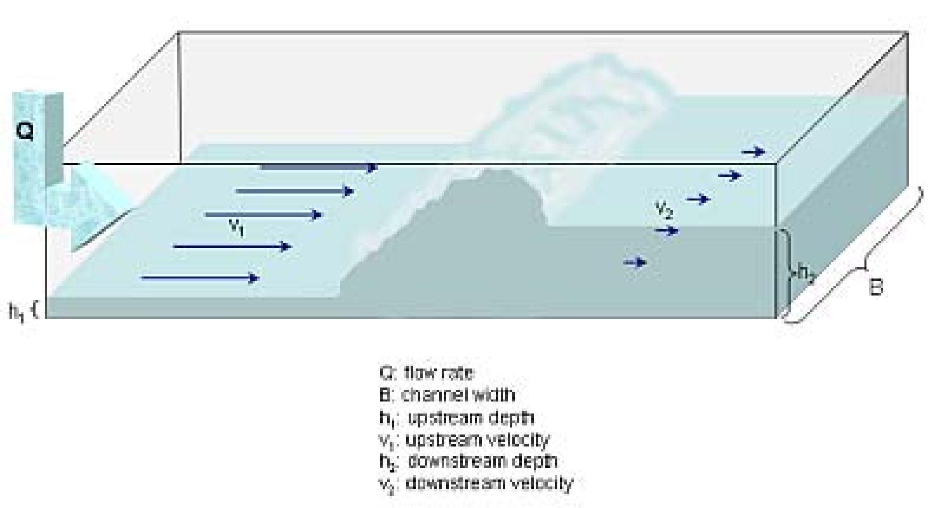


Figure: Brian McNoldy

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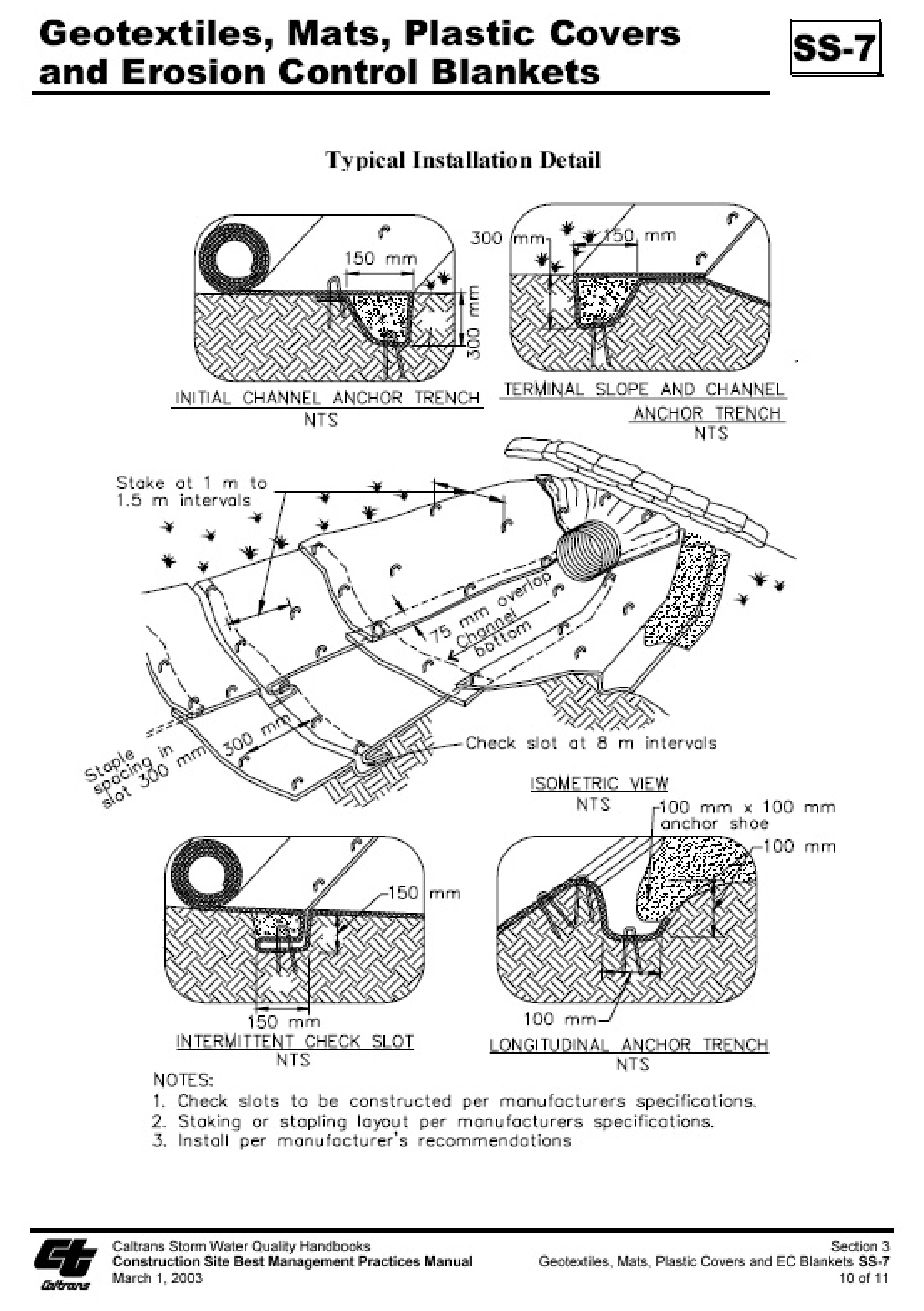


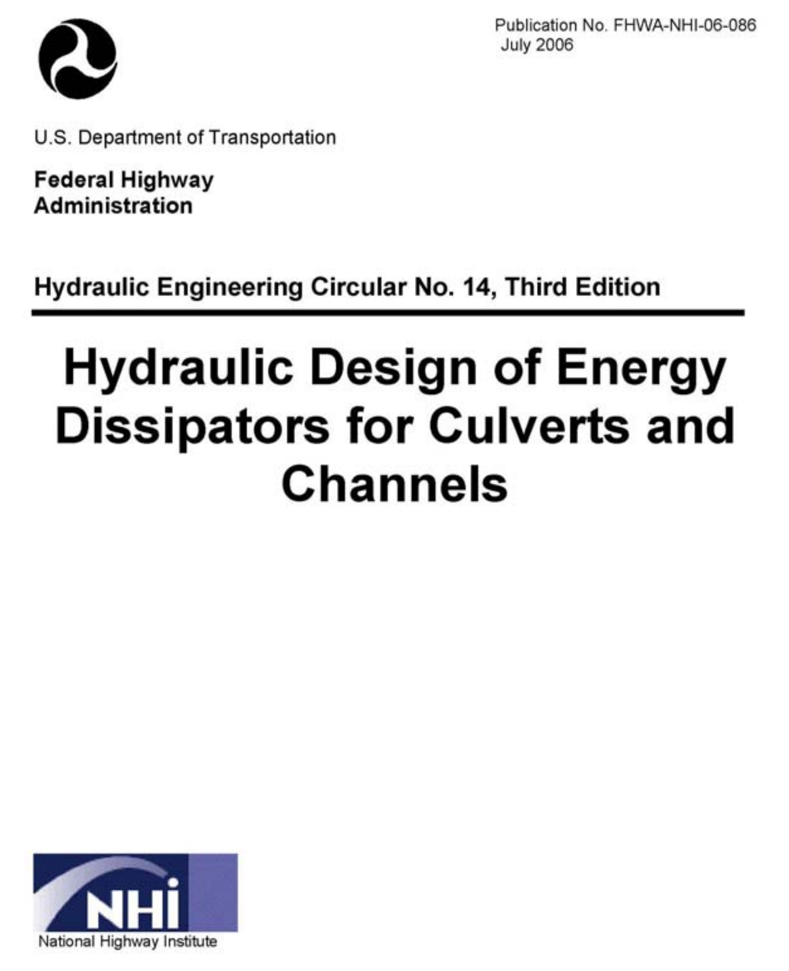
Geotextiles, Mats, Plastic Covers and Erosion Control Blankets

SS-7

Typical Installation Detail

NOTES:

1. Check slots to be constructed per manufacturers specifications.
2. Staking or stapling layout per manufacturers specifications.
3. Install per manufacturer's recommendations



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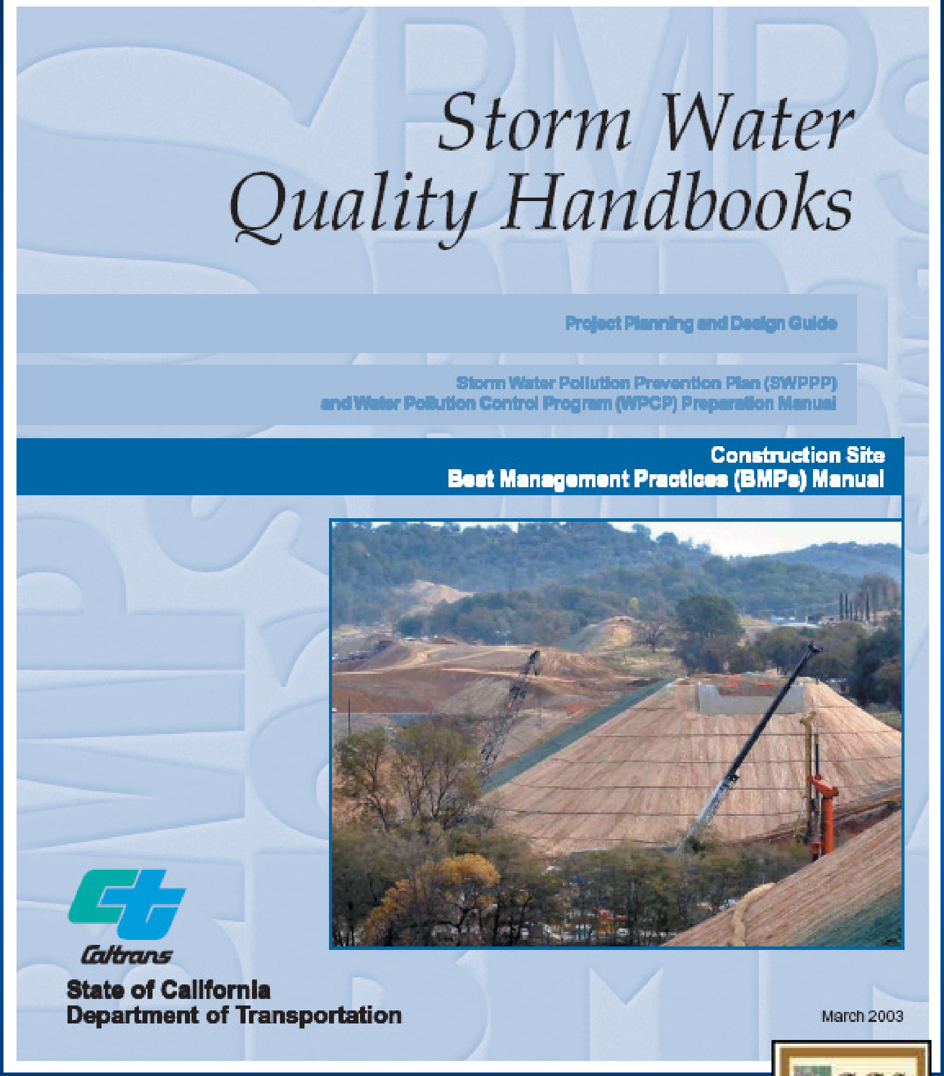

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Best Management Practices (BMPs) Manual

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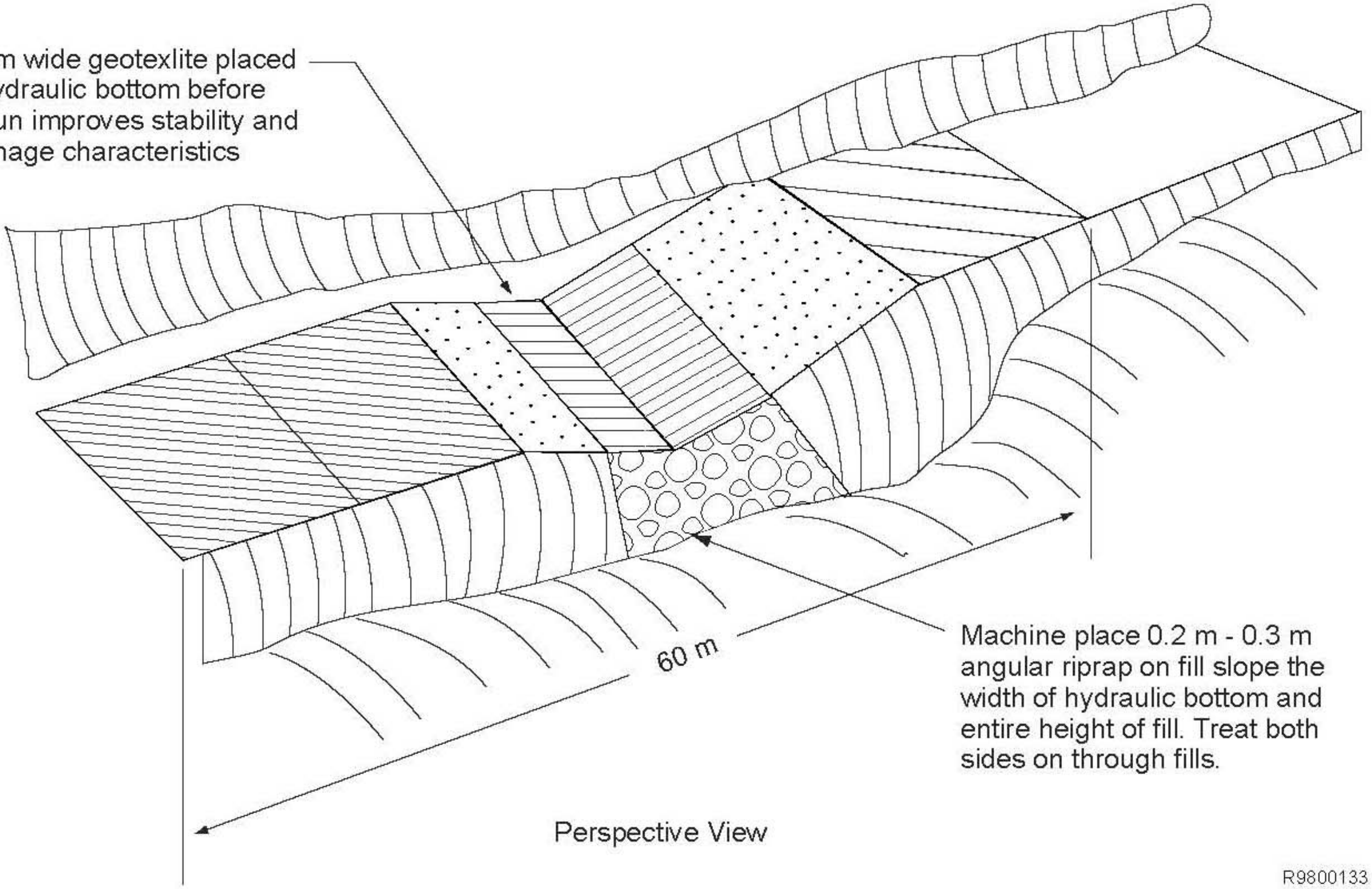
Dip outlets

Photo: Matt Boone, RWQCB

Photo: Matt Boone, RWQCB

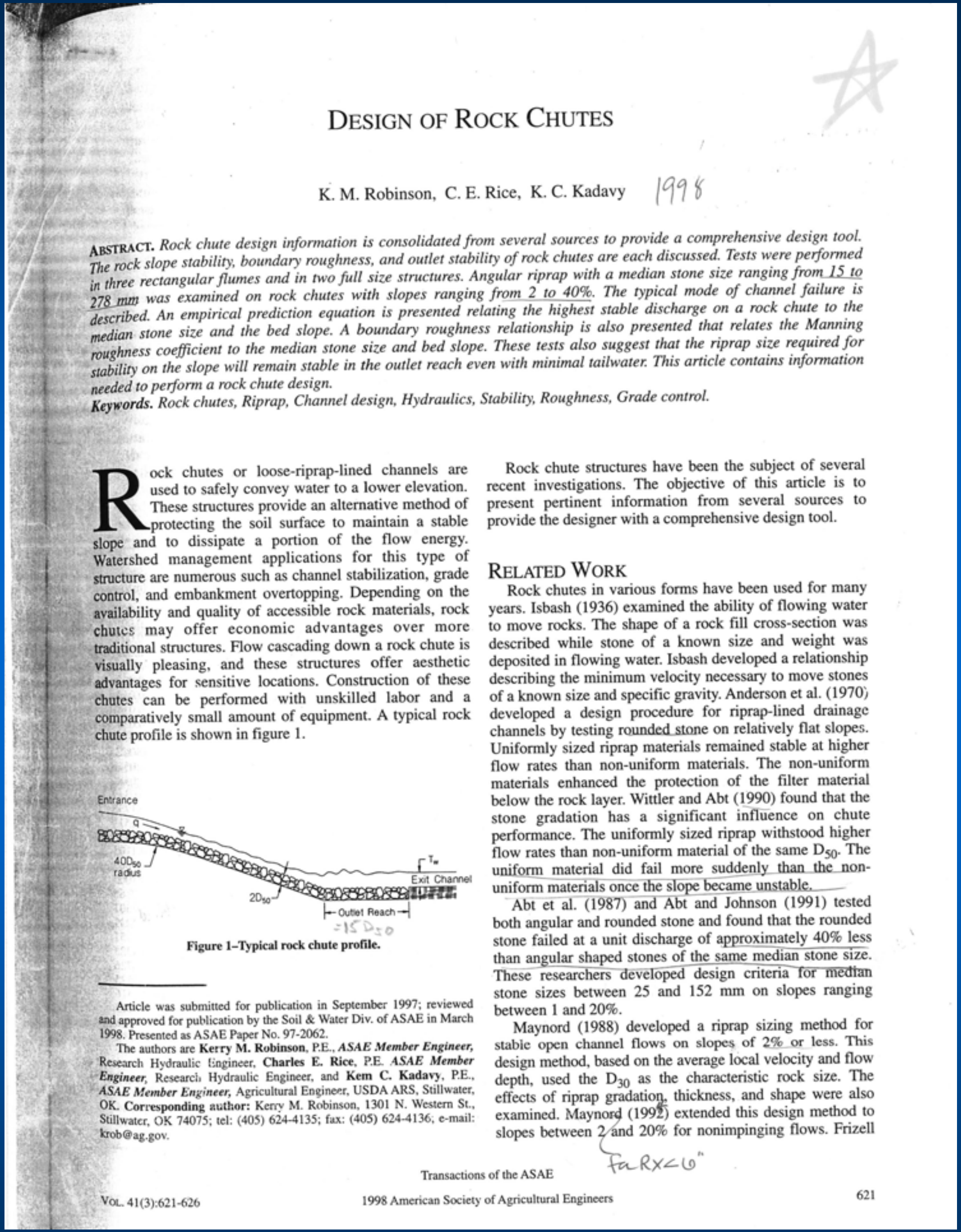


2.7 m wide geotexlite placed in hydraulic bottom before pit run improves stability and drainage characteristics

Machine place 0.2 m - 0.3 m angular riprap on fill slope the width of hydraulic bottom and entire height of fill. Treat both sides on through fills.

Perspective View

Copstead, R. L., et al. (1998)



DESIGN OF ROCK CHUTES

K. M. Robinson, C. E. Rice, K. C. Kadavy 1998

ABSTRACT. *Rock chute design information is consolidated from several sources to provide a comprehensive design tool. The rock slope stability, boundary roughness, and outlet stability of rock chutes are each discussed. Tests were performed in three rectangular flumes and in two full size structures. Angular riprap with a median stone size ranging from 15 to 278 mm was examined on rock chutes with slopes ranging from 2 to 40%. The typical mode of channel failure is described. An empirical prediction equation is presented relating the highest stable discharge on a rock chute to the median stone size and the bed slope. A boundary roughness relationship is also presented that relates the Manning roughness coefficient to the median stone size and bed slope. These tests also suggest that the riprap size required for stability on the slope will remain stable in the outlet reach even with minimal tailwater. This article contains information needed to perform a rock chute design.*

Keywords. *Rock chutes, Riprap, Channel design, Hydraulics, Stability, Roughness, Grade control.*

Rock chutes or loose-riprap-lined channels are used to safely convey water to a lower elevation. These structures provide an alternative method of protecting the soil surface to maintain a stable slope and to dissipate a portion of the flow energy. Watershed management applications for this type of structure are numerous such as channel stabilization, grade control, and embankment overtopping. Depending on the availability and quality of accessible rock materials, rock chutes may offer economic advantages over more traditional structures. Flow cascading down a rock chute is visually pleasing, and these structures offer aesthetic advantages for sensitive locations. Construction of these chutes can be performed with unskilled labor and a comparatively small amount of equipment. A typical rock chute profile is shown in figure 1.

Figure 1–Typical rock chute profile.

Rock chute structures have been the subject of several recent investigations. The objective of this article is to present pertinent information from several sources to provide the designer with a comprehensive design tool.

RELATED WORK

Rock chutes in various forms have been used for many years. Isbash (1936) examined the ability of flowing water to move rocks. The shape of a rock fill cross-section was described while stone of a known size and weight was deposited in flowing water. Isbash developed a relationship describing the minimum velocity necessary to move stones of a known size and specific gravity. Anderson et al. (1970) developed a design procedure for riprap-lined drainage channels by testing rounded stone on relatively flat slopes. Uniformly sized riprap materials remained stable at higher flow rates than non-uniform materials. The non-uniform materials enhanced the protection of the filter material below the rock layer. Wittler and Abt (1990) found that the stone gradation has a significant influence on chute performance. The uniformly sized riprap withstood higher flow rates than non-uniform material of the same D_{50}. The uniform material did fail more suddenly than the non-uniform materials once the slope became unstable.

Abt et al. (1987) and Abt and Johnson (1991) tested both angular and rounded stone and found that the rounded stone failed at a unit discharge of approximately 40% less than angular shaped stones of the same median stone size. These researchers developed design criteria for median stone sizes between 25 and 152 mm on slopes ranging between 1 and 20%.

Maynord (1988) developed a riprap sizing method for stable open channel flows on slopes of 2% or less. This design method, based on the average local velocity and flow depth, used the D_{30} as the characteristic rock size. The effects of riprap gradation, thickness, and shape were also examined. Maynord (1992) extended this design method to slopes between 2 and 20% for nonimpinging flows. Frizell

for Rx<6"

Article was submitted for publication in September 1997; reviewed and approved for publication by the Soil & Water Div. of ASAE in March 1998. Presented as ASAE Paper No. 97-2062.

The authors are **Kerry M. Robinson**, P.E., ***ASAE Member Engineer,*** Research Hydraulic Engineer, **Charles E. Rice**, P.E. ***ASAE Member Engineer***, Research Hydraulic Engineer, and **Kem C. Kadavy**, P.E., ***ASAE Member Engineer,*** Agricultural Engineer, USDA ARS, Stillwater, OK. **Corresponding author:** Kerry M. Robinson, 1301 N. Western St., Stillwater, OK 74075; tel: (405) 624-4135; fax: (405) 624-4136; e-mail: krob@ag.gov.

Robinson, K.M., Rice, C.E., and Kadavy, K.C., 1998, Design of Rock Chutes, Transactions of the ASAE, Vol. 41(3): 621-626

Remember!

Successfully treating road drainage = Protecting natural resources + Ensuring full use of road and reduced maintenance and repair costs

Questions?

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United States
Department of
Agriculture

Forest Service

Technology &
Development
Program

7700—Transportation Systems
2500—Watershed and Air Management
September 1998
9877 1806—SDTDC

Water/Road Interaction:
Introduction to Surface
Cross Drains

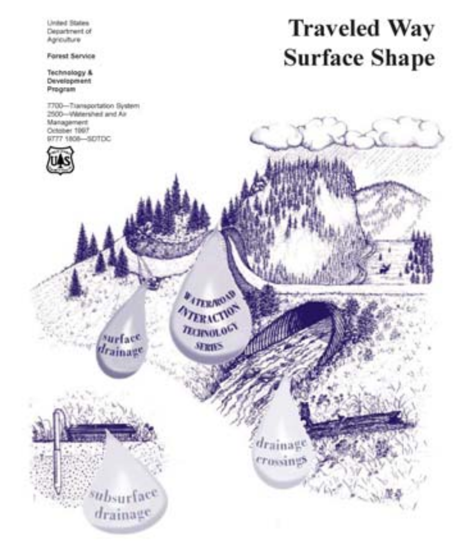
United States
Department of
Agriculture

Forest Service

Technology &
Development
Program

7700—Transportation System
2500—Watershed and Air
Management
October 1997
9777 1812—SDTDC

Relief Culverts



United States
Department of
Agriculture

Forest Service

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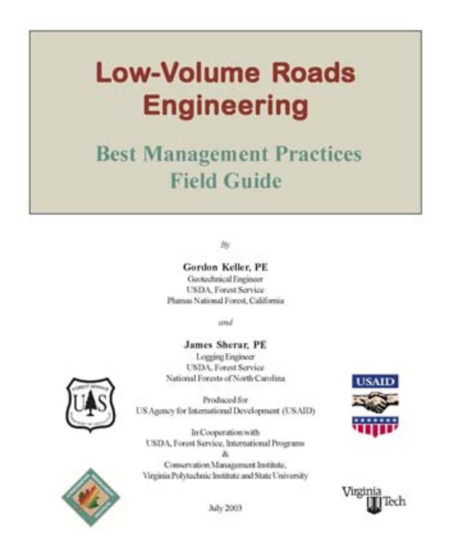
Development
Program

7700—Transportation System
2500—Watershed and Air
Management
October 1997
9777 1808—SDTDC

Traveled Way
Surface Shape



Low-Volume Roads
Engineering

Best Management Practices
Field Guide

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In Cooperation with
USDA, Forest Service, International Programs
&
Conservation Management Institute,
Virginia Polytechnic Institute and State University

July 2003

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