Rural Roads Educational Webinar Series
UC Cooperative Extension/ Society of American Foresters

Treatment of Wet Sites

Gordon R. Keller, PE, GE
Geotechnical Engineer
grkeller@fs.fed.us
or
gordonrkeller@gmail.com

DRAINAGE ISSUES

- Surface Drainage (Last week)
- Culverts, Fords, Bridges

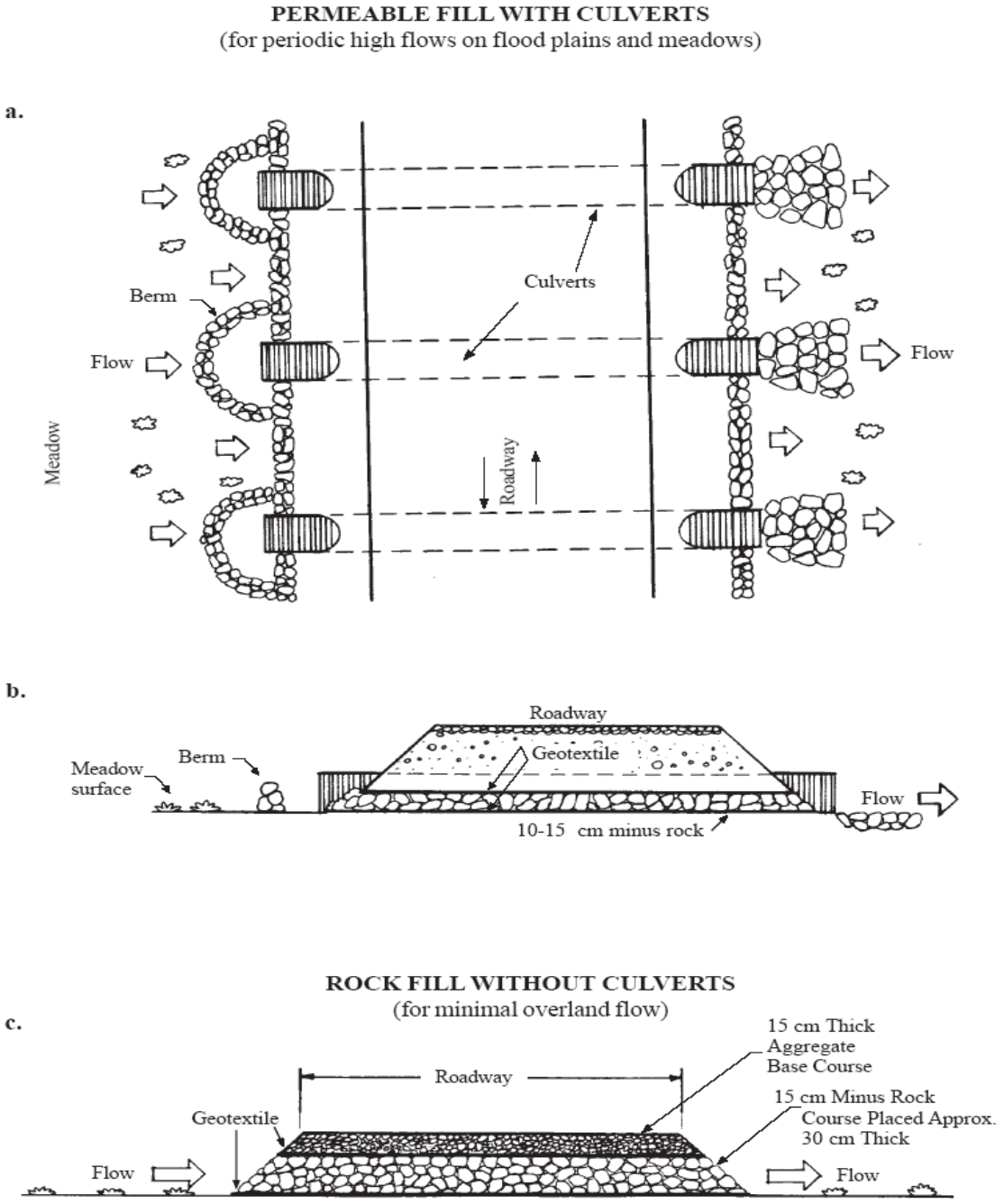
- Meadow Crossings (Maintain the flow-Bridge over the water)

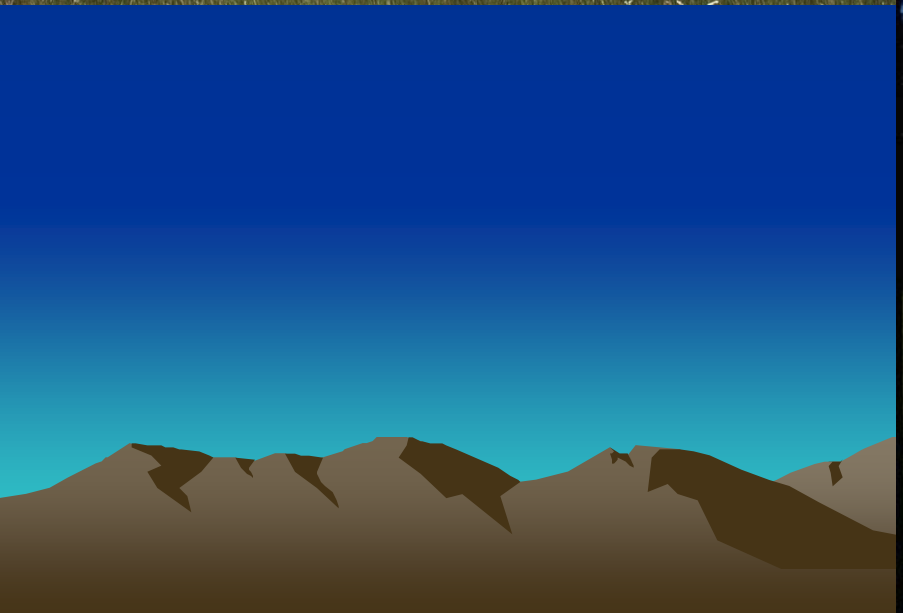
- Sub-Surface Drainage (Remove the water)

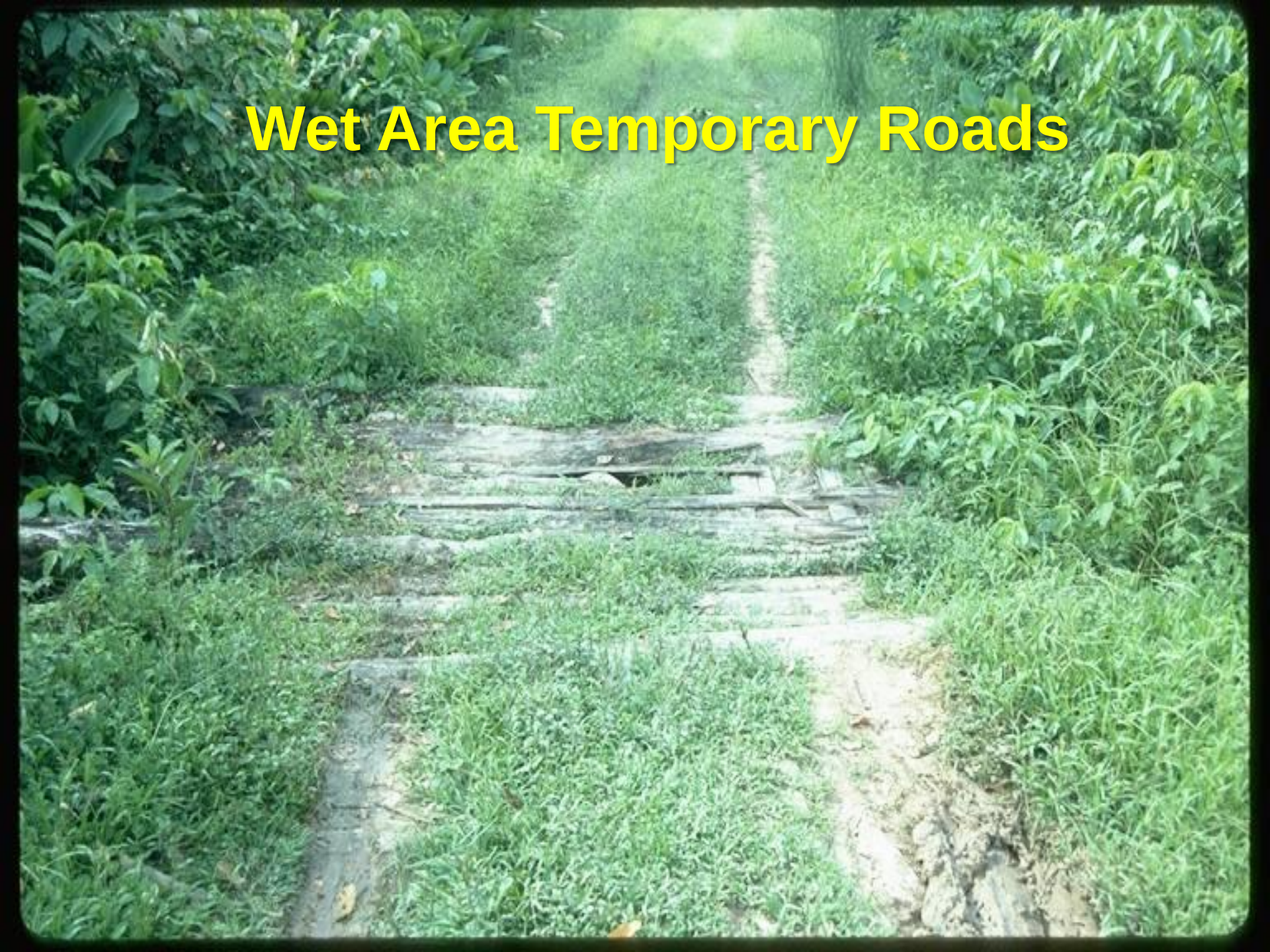

Subsurface Drainage


Wet/Meadow Area Crossings

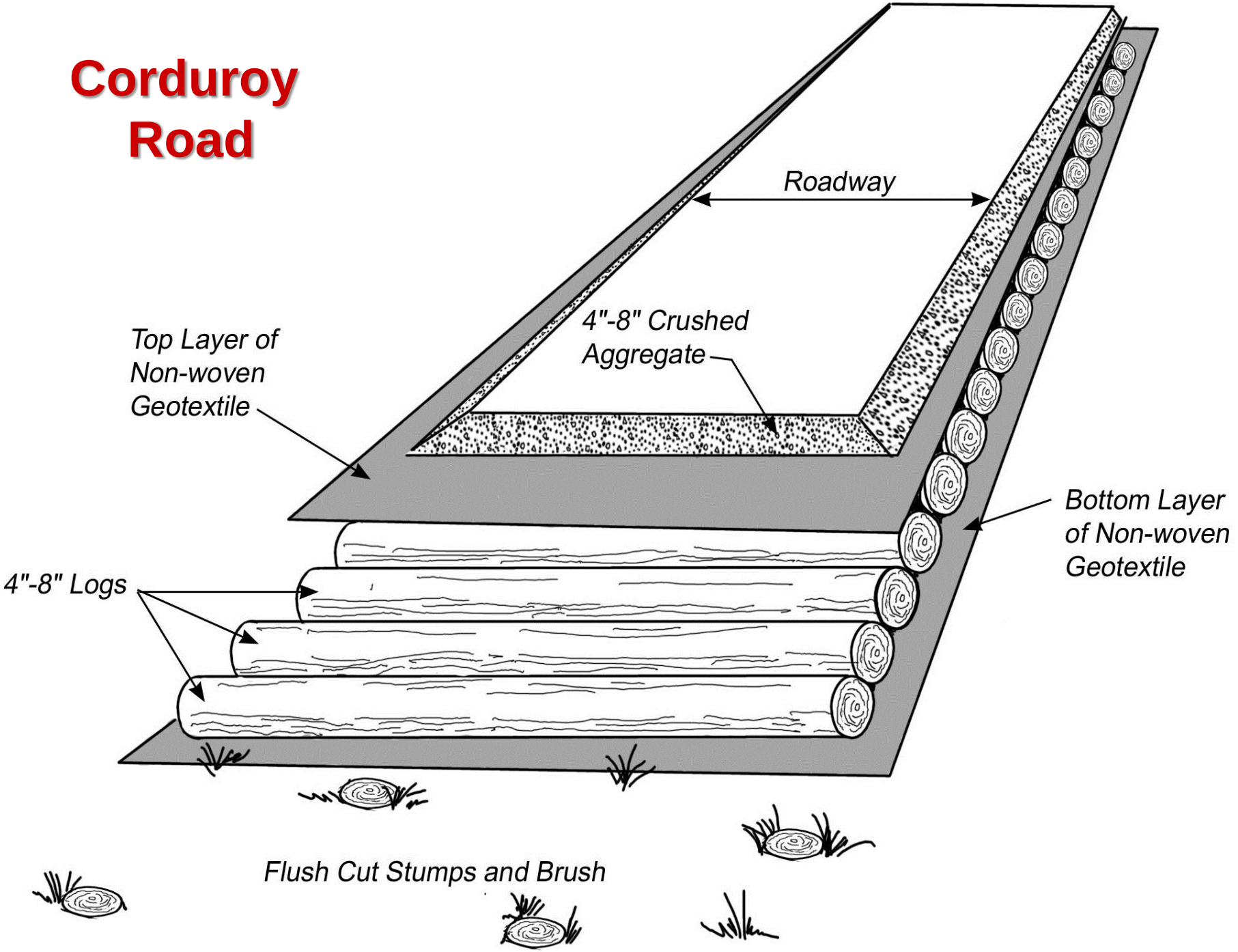
Figure 7.14 Wet meadow road crossing options. *(From Managing Roads for Wet Meadow Ecostream Recovery by Wm. Zeedyk, 1996)*






Wet Area Temporary Roads

Corduroy Road



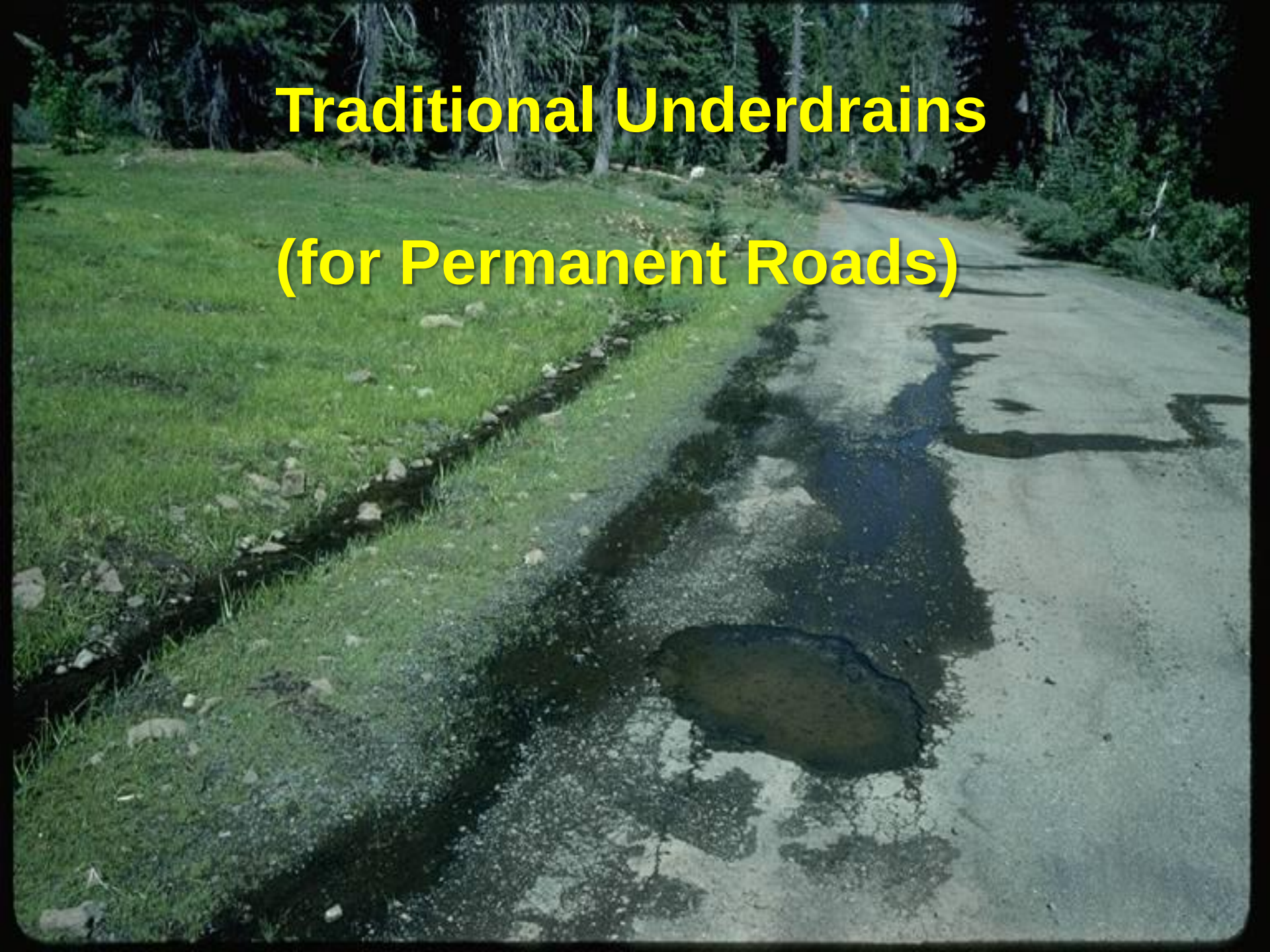
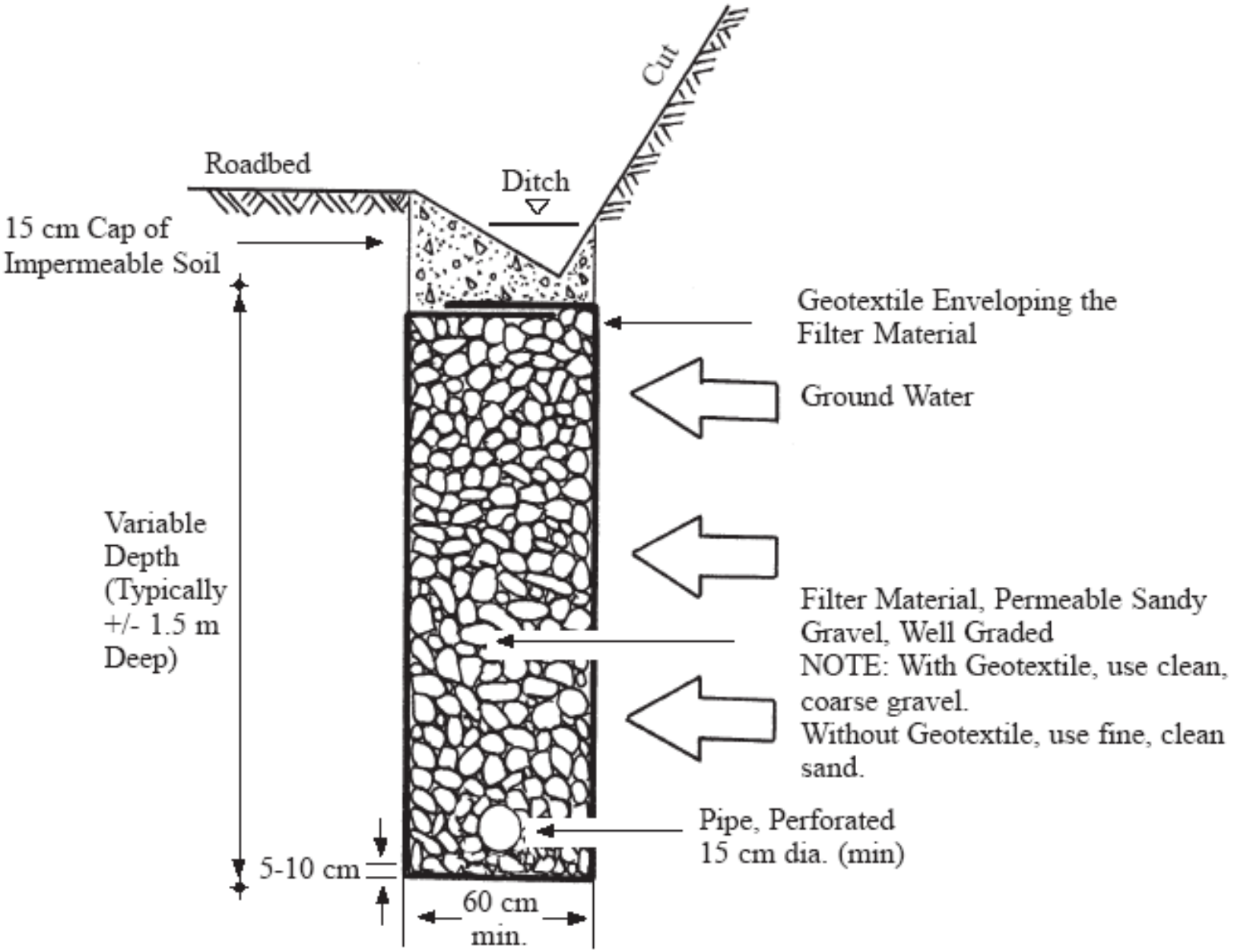
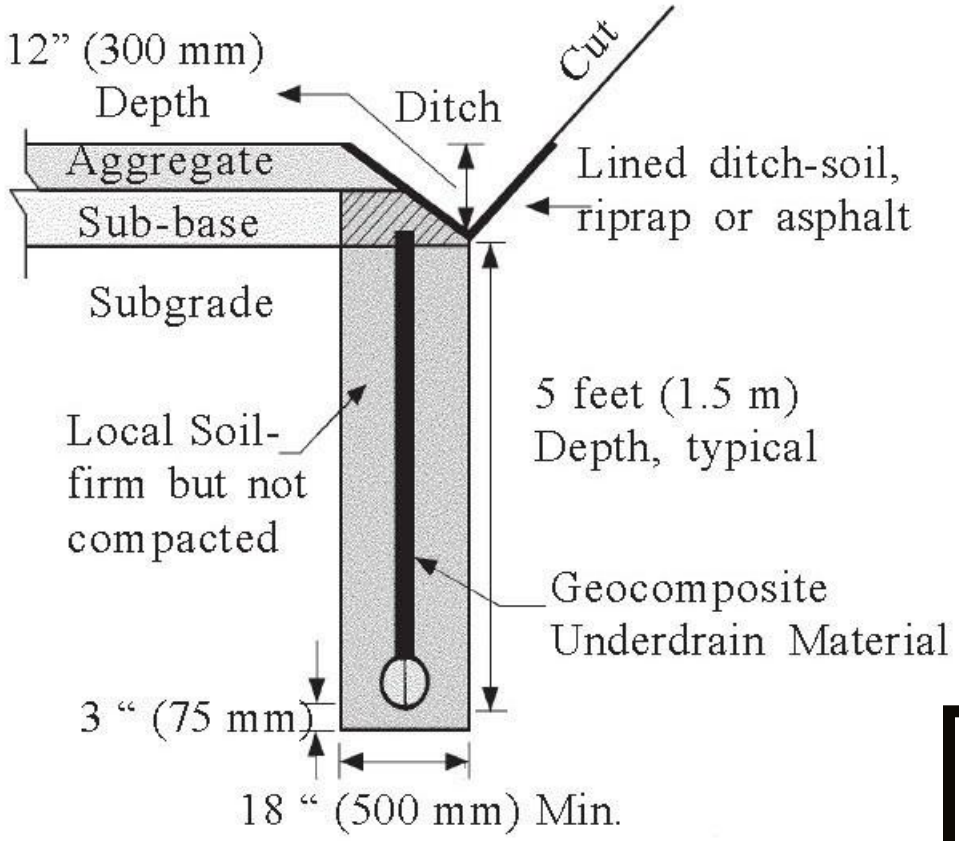
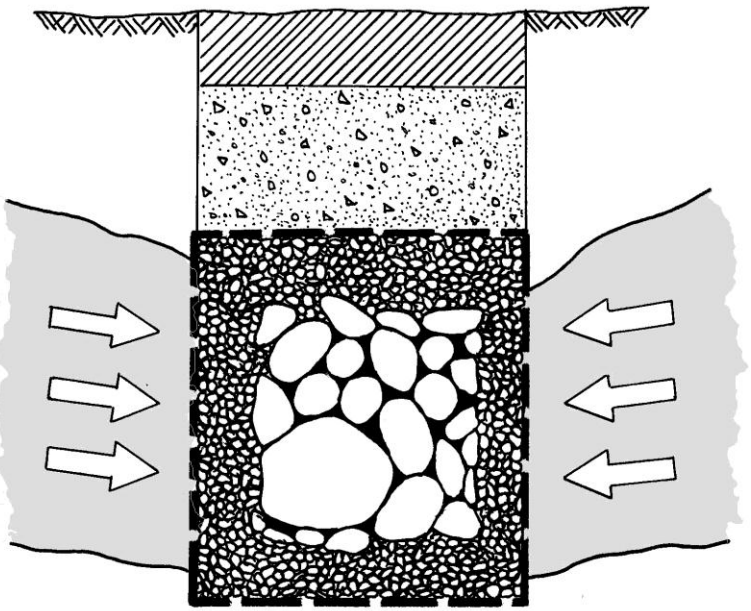

Traditional Underdrains
(for Permanent Roads)

Figure 7.16 Typical road underdrain used to remove subsurface water.





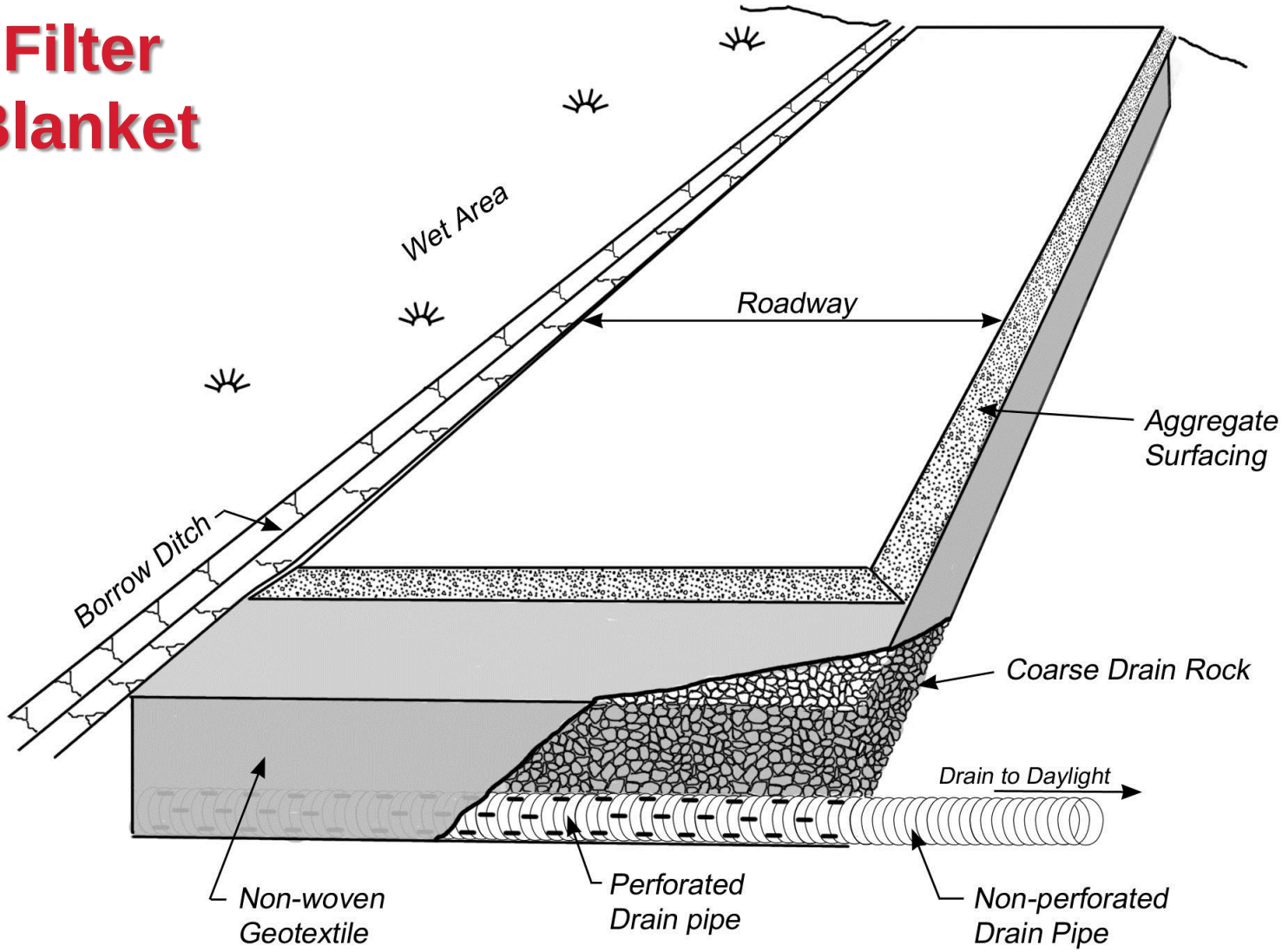
Geocomposite Underdrain



French Drain


Filter Blankets

Filter Blanket



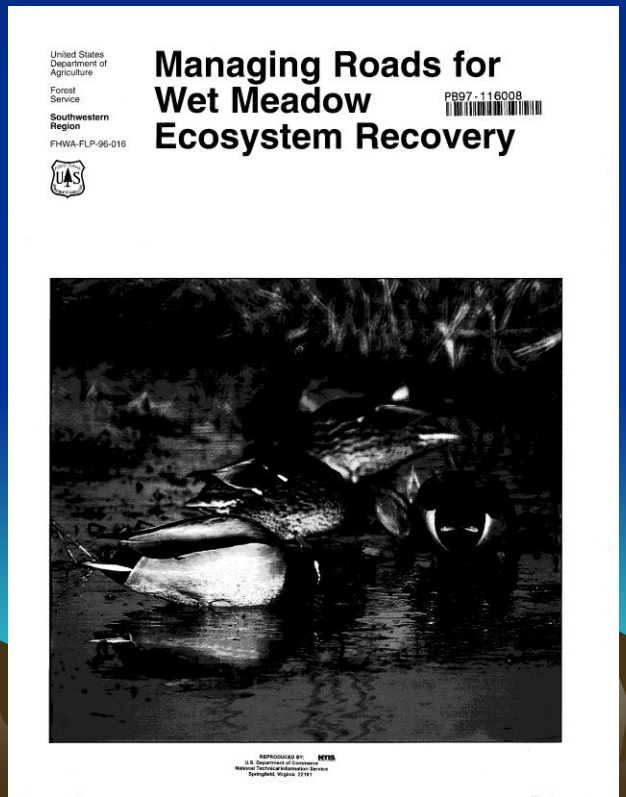
Horizontal Drains for Slide Stabilization


DRAINAGE
DRAINAGE
DRAINAGE


Pay Attention to
Drainage Details

Cedergren, H. 1989. Seepage, drainage, and flow nets, John Wiley and Sons.

Orr, D. 1998 (Update 2003). Roadway and roadside drainage. Cornell Local Roads Program and New York LTAP Center, Ithaca. NY.



W. Zeedyk

USE OF GEOSYNTHETICS

AASHTO M 288-06-
Geotextile Specification
for Highway Applications

DOD Publications

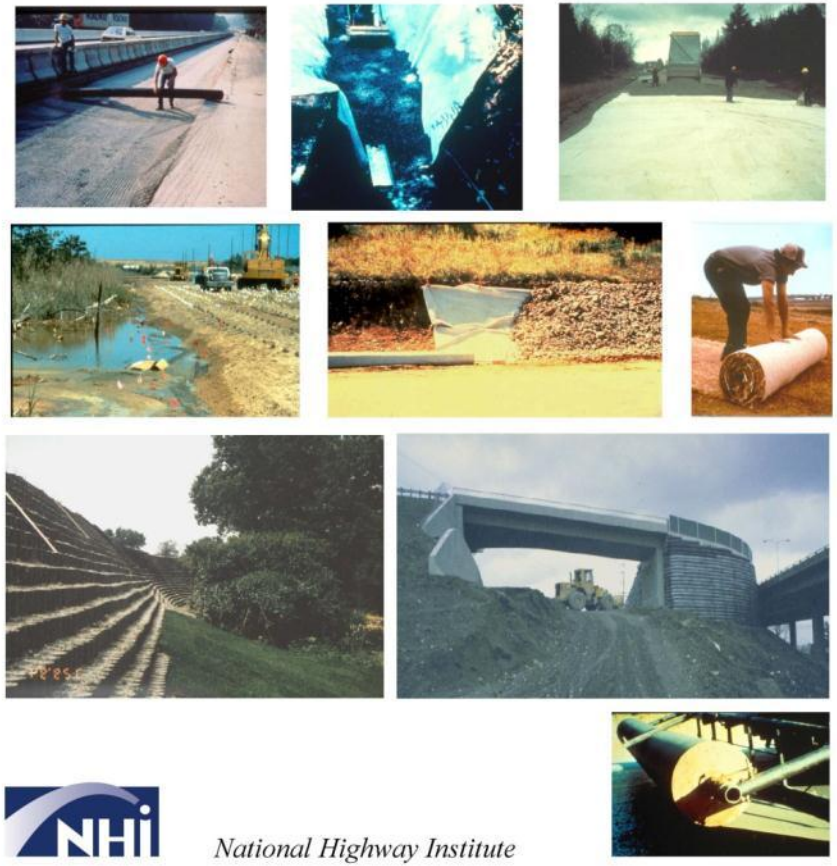
U.S. Department of Transportation
Federal Highway Administration

Publication No. FHWA NHI-07-092
August 2008

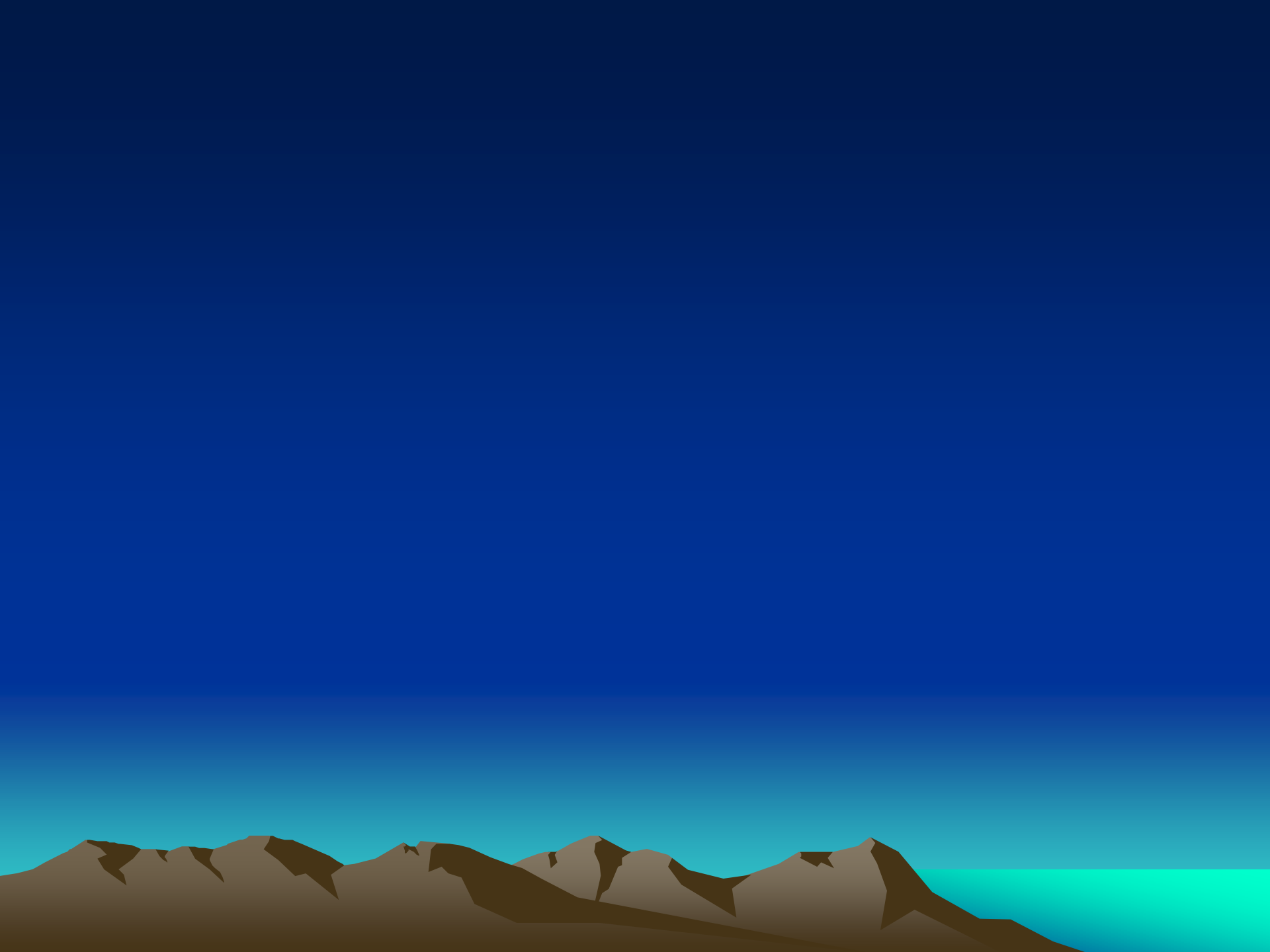
NHI Course No. 132013

Geosynthetic Design & Construction Guidelines

Reference Manual

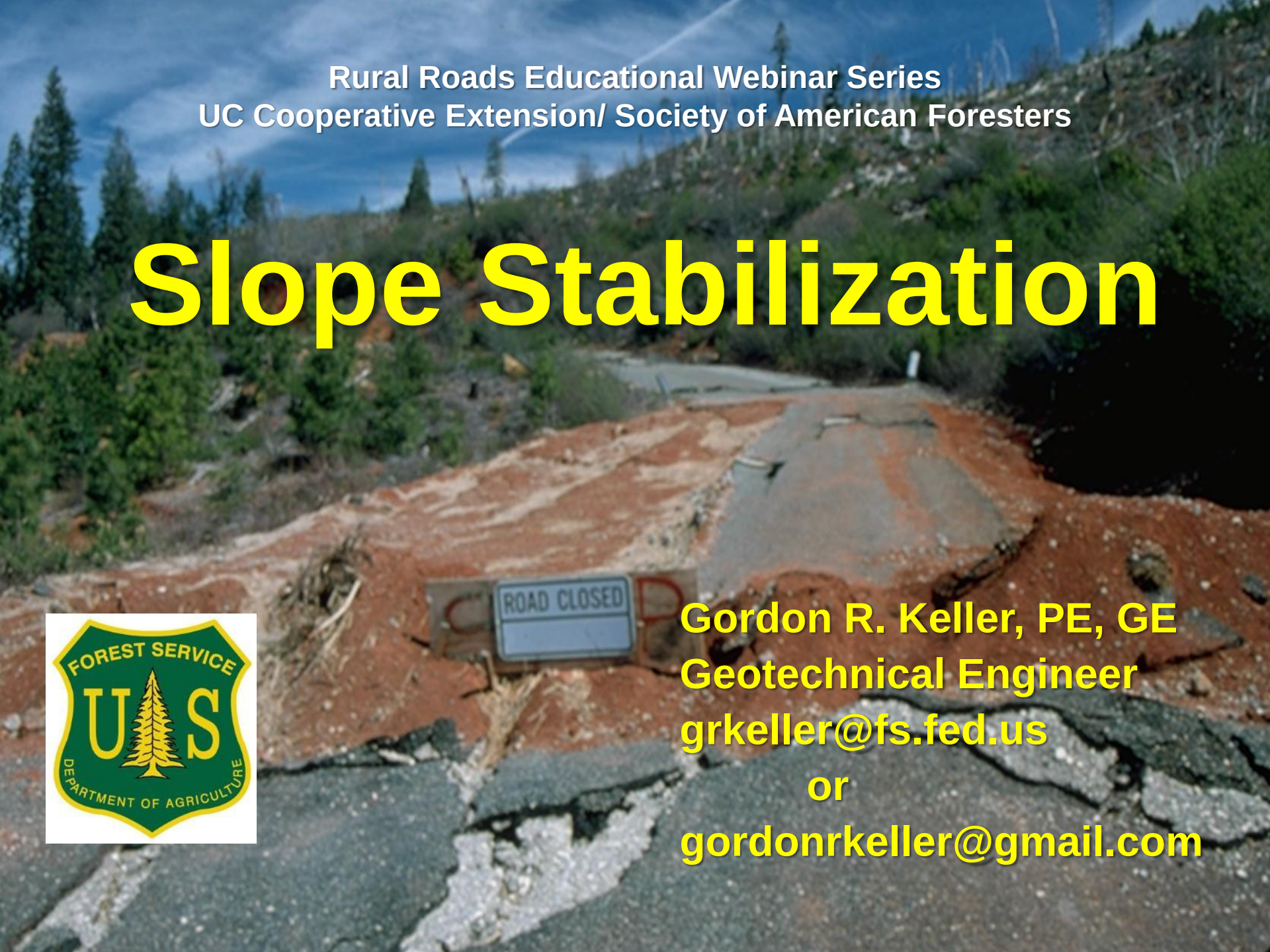


National Highway Institute



Rural Roads Educational Webinar Series
UC Cooperative Extension/ Society of American Foresters

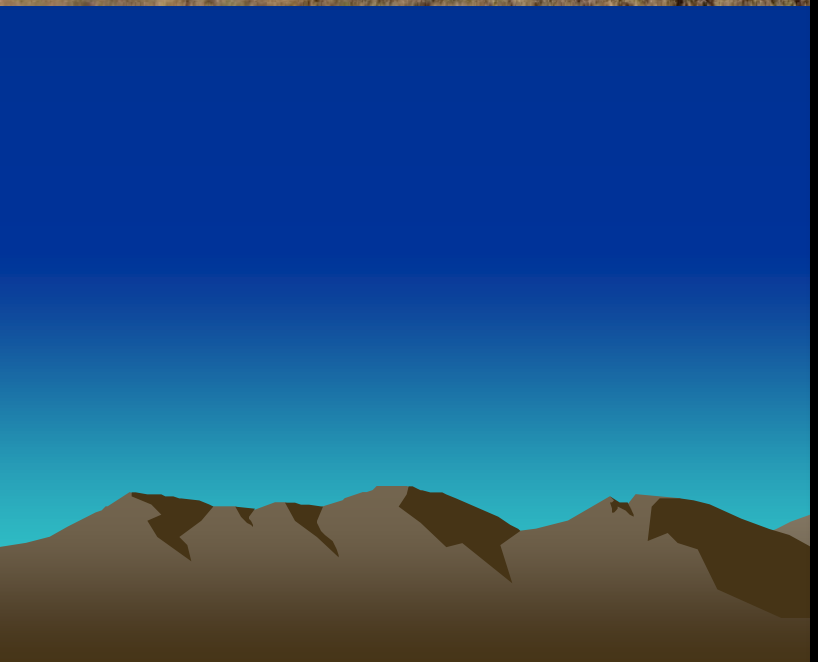
Slope Stabilization



Gordon R. Keller, PE, GE
Geotechnical Engineer
grkeller@fs.fed.us
or
gordonrkeller@gmail.com

Slopes and Slope Instability

- Avoiding Unstable Areas
- Preventing Instability
- Stabilizing Slides
  - Stabilization Alternatives

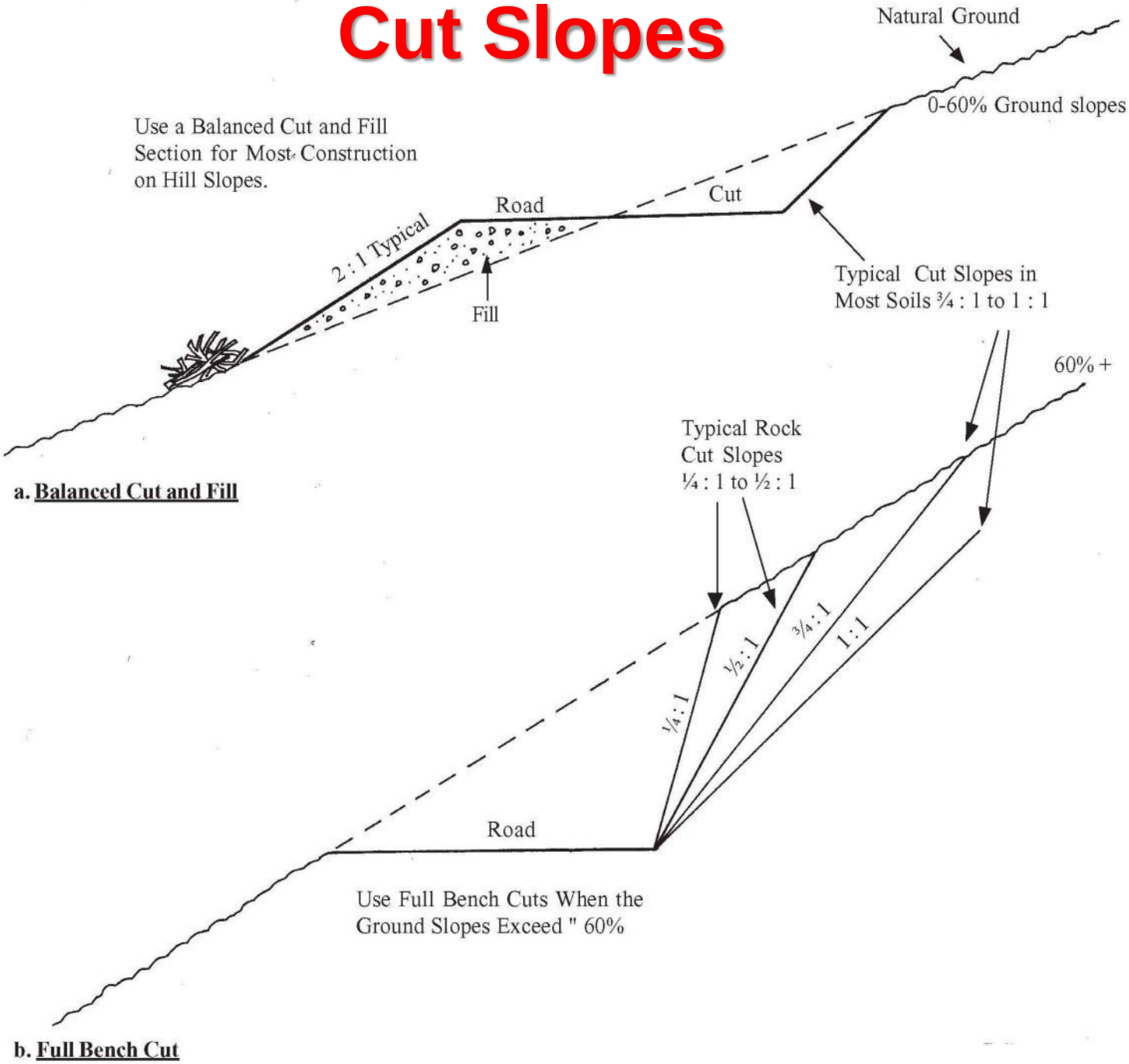



8% GRADE

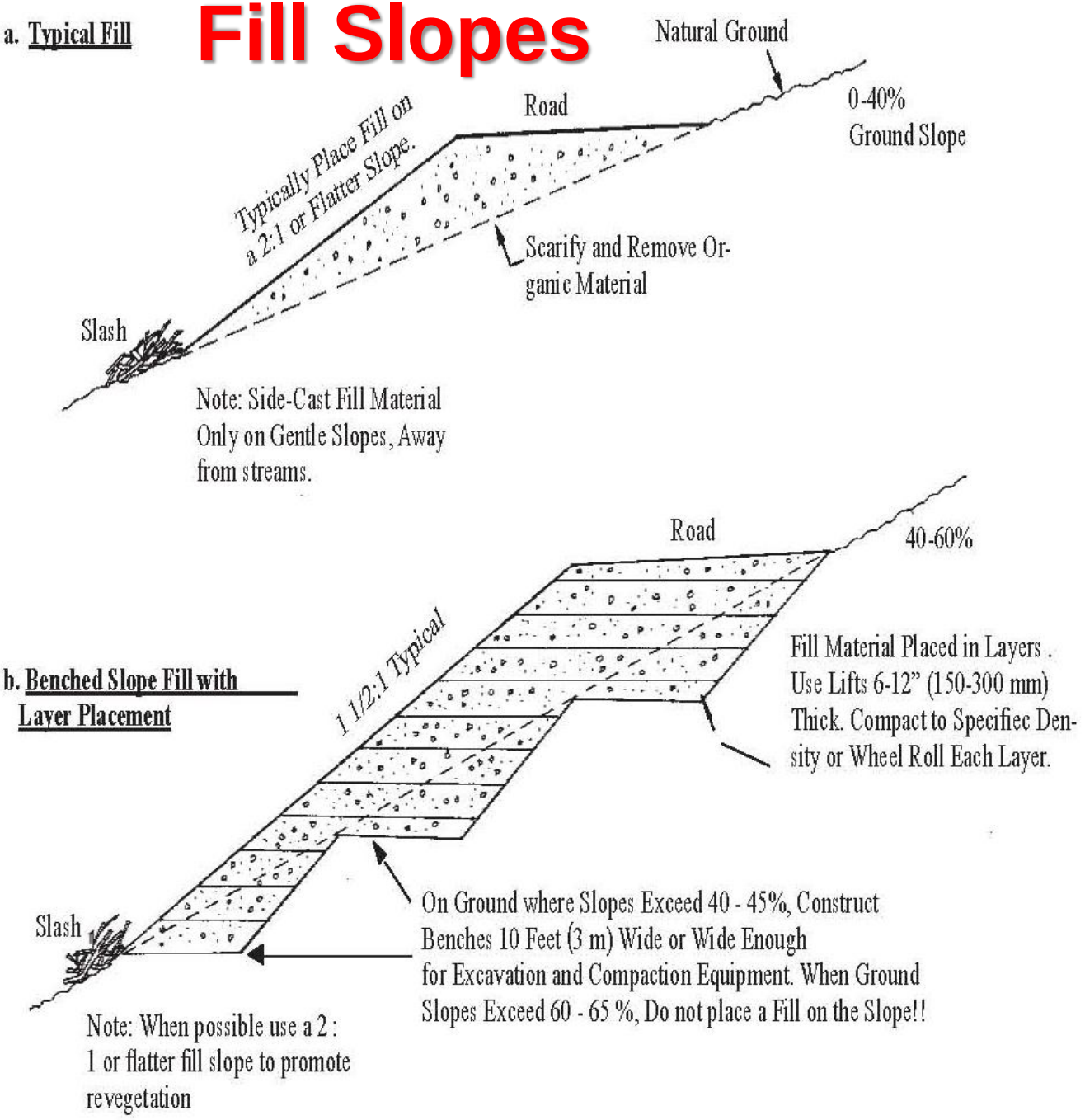
Slide Recognition and Avoidance


Slide Prevention

Cut Slopes


Natural Ground
0-60% Ground slopes
Use a Balanced Cut and Fill Section for Most Construction on Hill Slopes.
Road
Cut
2 : 1 Typical
Fill
Typical Cut Slopes in Most Soils ¾ : 1 to 1 : 1
60% +
Typical Rock Cut Slopes ¼ : 1 to ½ : 1
a. Balanced Cut and Fill
¼ : 1
½ : 1
¾ : 1
1 : 1
Road
Use Full Bench Cuts When the Ground Slopes Exceed " 60%
b. Full Bench Cut

Fill Slopes


a. Typical Fill
Natural Ground
Road
0-40%
Ground Slope
Typically Place Fill on a 2:1 or Flatter Slope.
Scarify and Remove Organic Material
Slash
Note: Side-Cast Fill Material Only on Gentle Slopes, Away from streams.
Road
40-60%
b. Benched Slope Fill with Layer Placement
1 1/2:1 Typical
Fill Material Placed in Layers . Use Lifts 6-12" (150-300 mm) Thick. Compact to Specifiec Density or Wheel Roll Each Layer.
On Ground where Slopes Exceed 40 - 45%, Construct Benches 10 Feet (3 m) Wide or Wide Enough for Excavation and Compaction Equipment. When Ground Slopes Exceed 60 - 65 %, Do not place a Fill on the Slope!!
Slash
Note: When possible use a 2 : 1 or flatter fill slope to promote revegetation

COMMON STABLE SLOPE RATIOS FOR VARYING SOIL/ROCK CONDITIONS

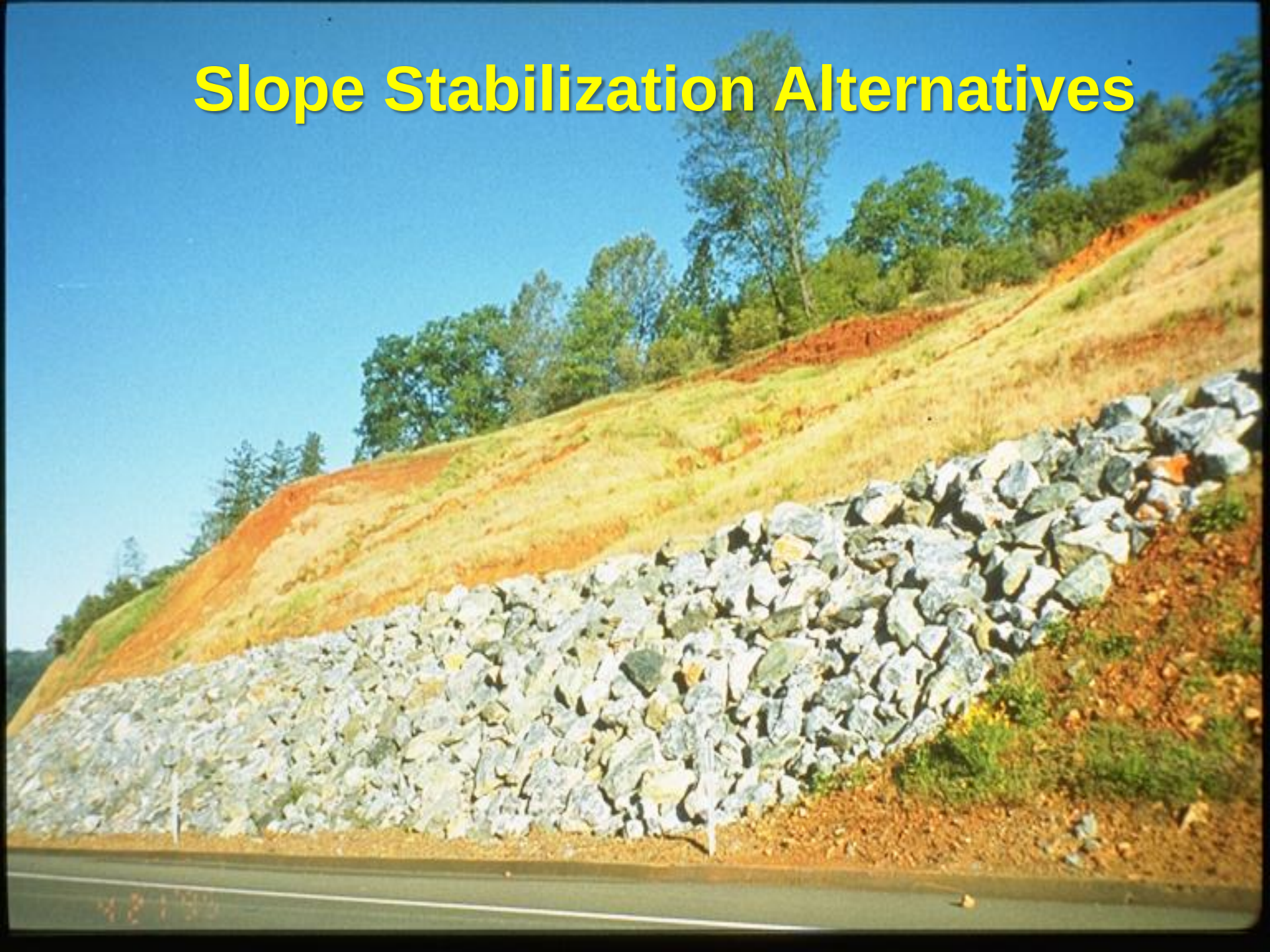
Soil/Rock Condition	Slope Ratio (Hor:Vert)
Most rock	¼:1 to ½:1
Very well cemented soils	¼:1 to ½:1
Most in-place soils	¾:1 to 1:1
Very fractured rock	1:1 to 1 ½:1
Loose coarse granular soils	1 ½:1
Heavy clay soils	2:1 to 3:1
Soft clay rich zones or wet seepage areas	2:1 to 3:1
Fills of most soils	1 ½:1 to 2:1
Fills of hard, angular rock	1 1/3:1
Low cuts and fills (<2-3 m. high)	2:1 or flatter (for revegetation)


Nearly Vertical Cuts
TOYOTA


20t


22 7 03

Slope Stabilization Alternatives



Assessment of Risks Involved

- Hazard, or Likelihood of Failure
- Consequences of Failure/Values at Risk (Infrastructure and Environment)

Range of Management Options

- Do Nothing or Adapting to Slide
- Move Facilities, Protection Measures
- Stabilization Measures

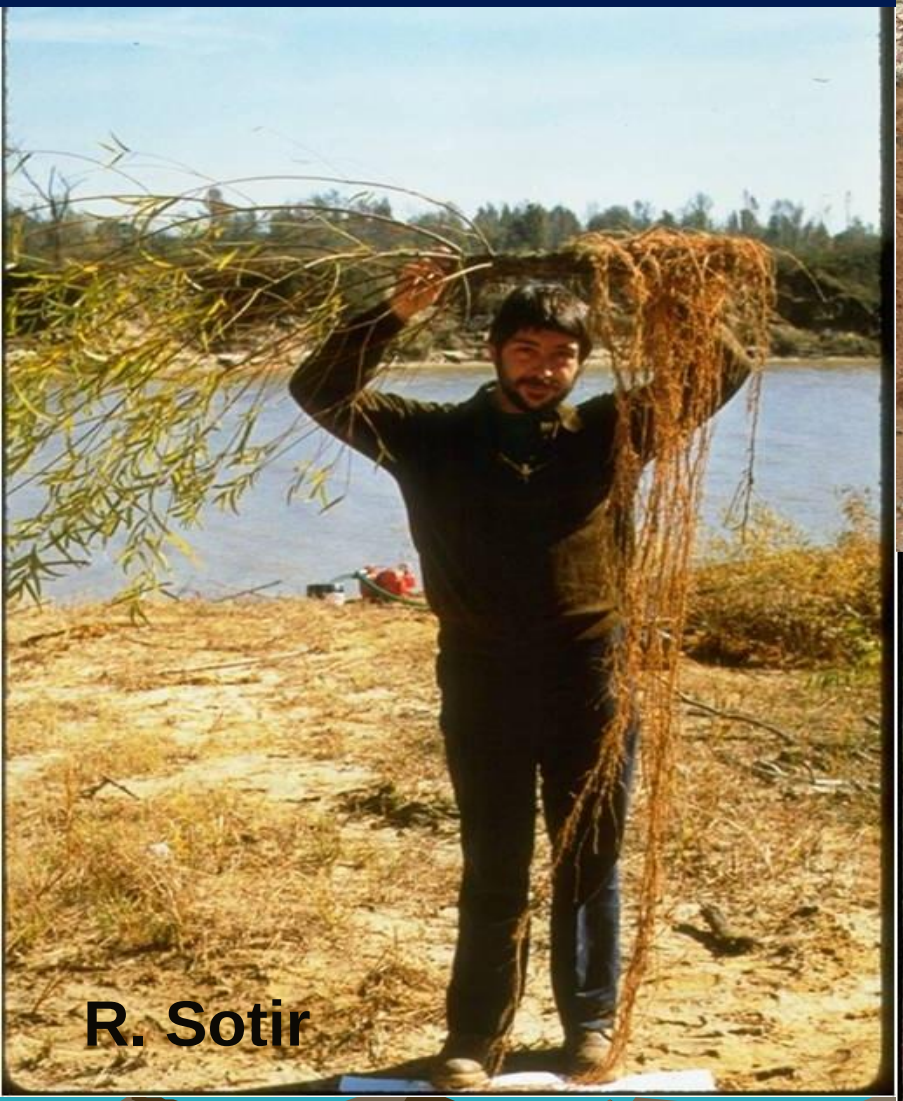
Stabilization Measures

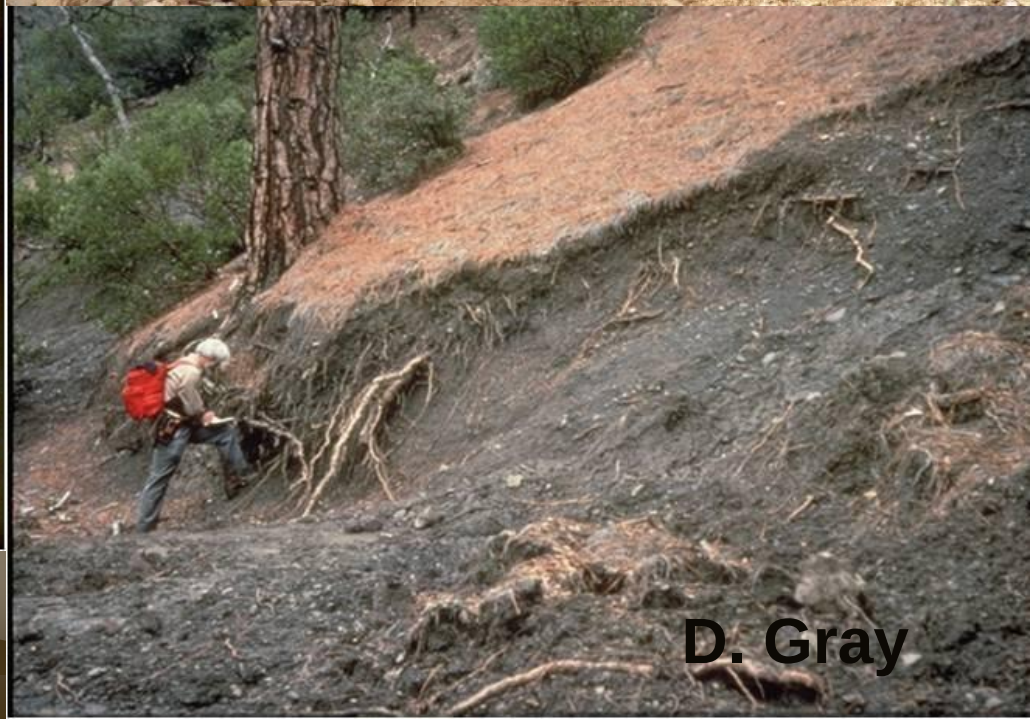
(What is adequate and cost-effective)

- Maintenance--Slide Removal
- Use of Vegetation, Drainage
- Slope Modification
- Gabions, Small Walls, Buttresses
- Reinforced Fills, Deep Patch Repairs
- Designed Retaining Structures
- Piles, Anchors, Soil Nails, Etc.


690E LC


Use of Vegetation for Slide Prevention
and Slope Stabilization

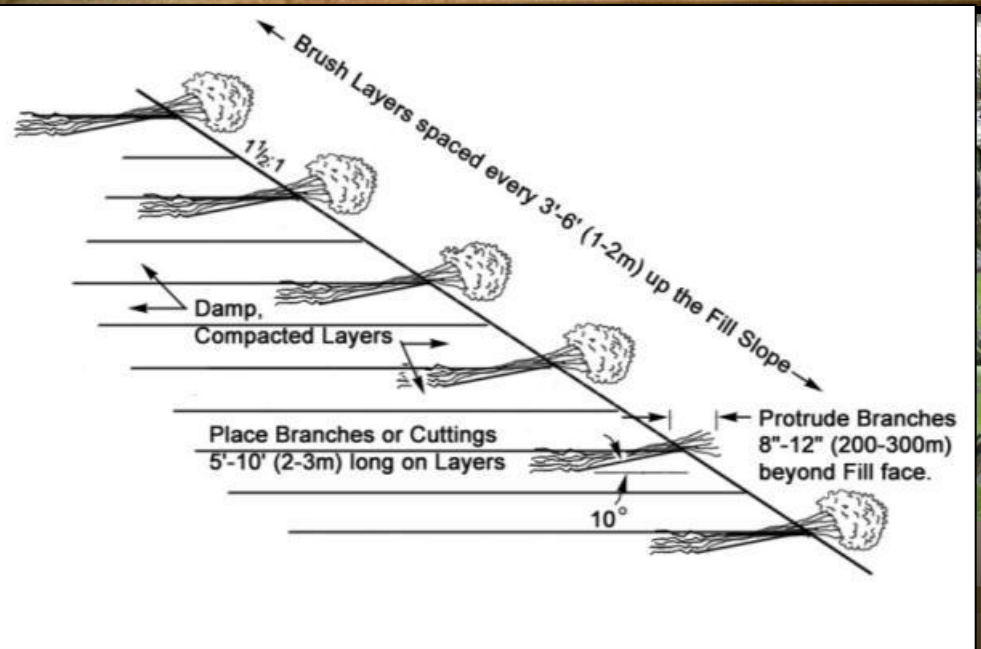

R. Sotir


D. Gray

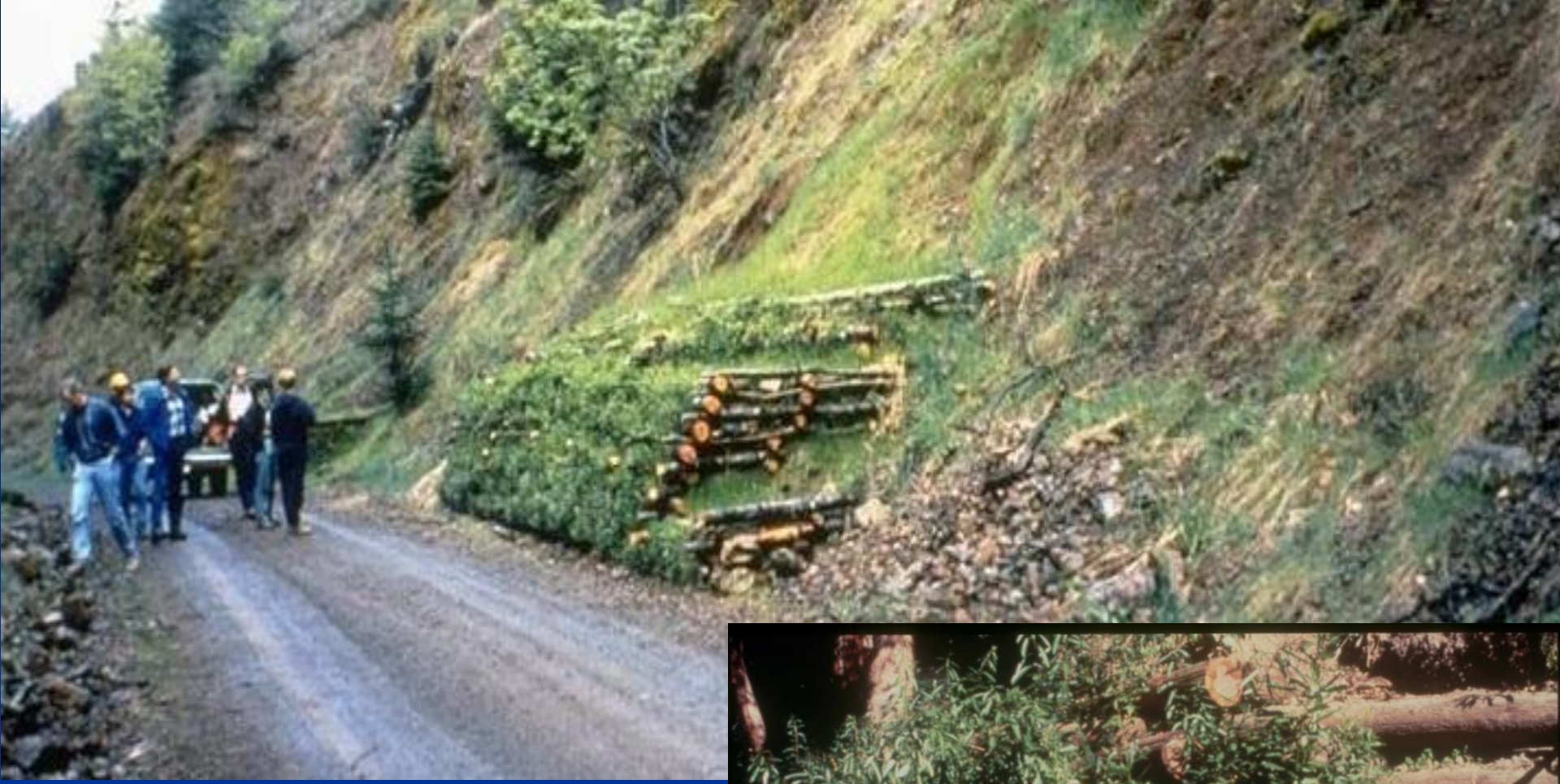
Soil bioengineering and biotechnical slope stabilization

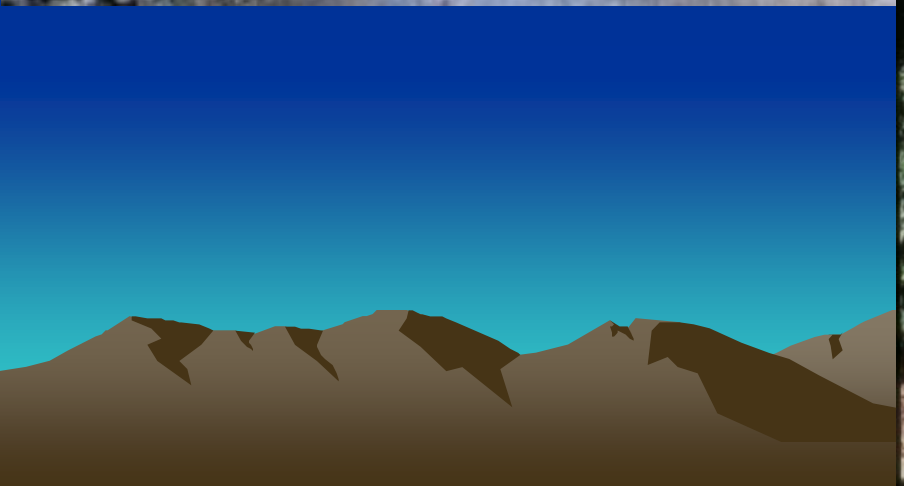
R. Sotir


R. Sotir

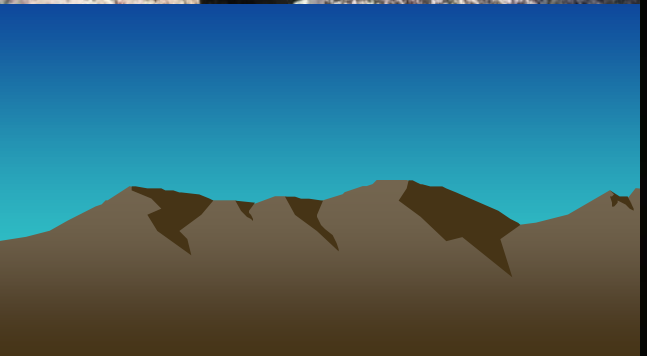

Brush Layers spaced every 3'-6' (1-2m) up the Fill Slope
1½:1
Damp, Compacted Layers
Place Branches or Cuttings 5'-10' (2-3m) long on Layers
Protrude Branches 8"-12" (200-300m) beyond Fill face.
10°

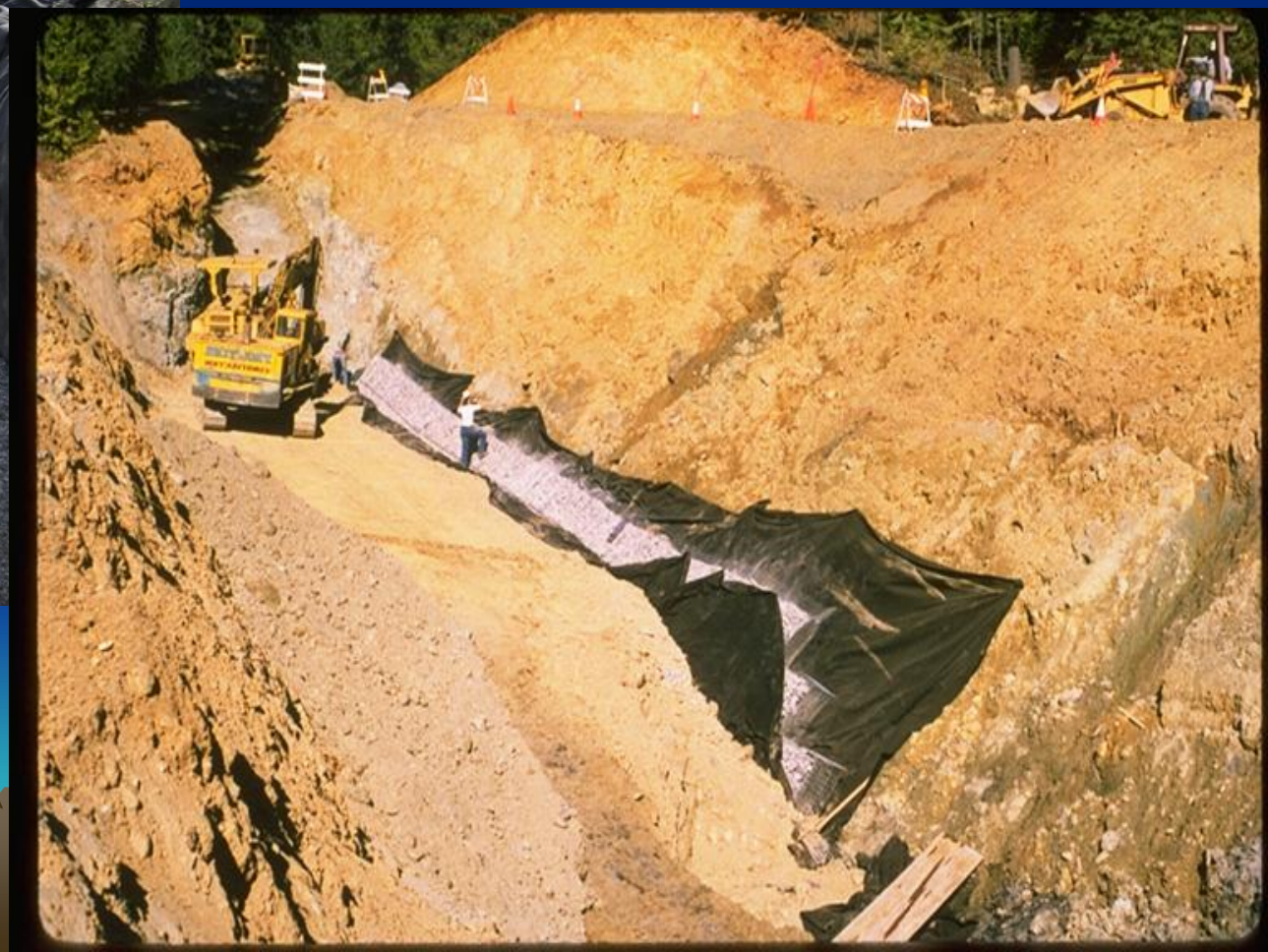

J. McCullah

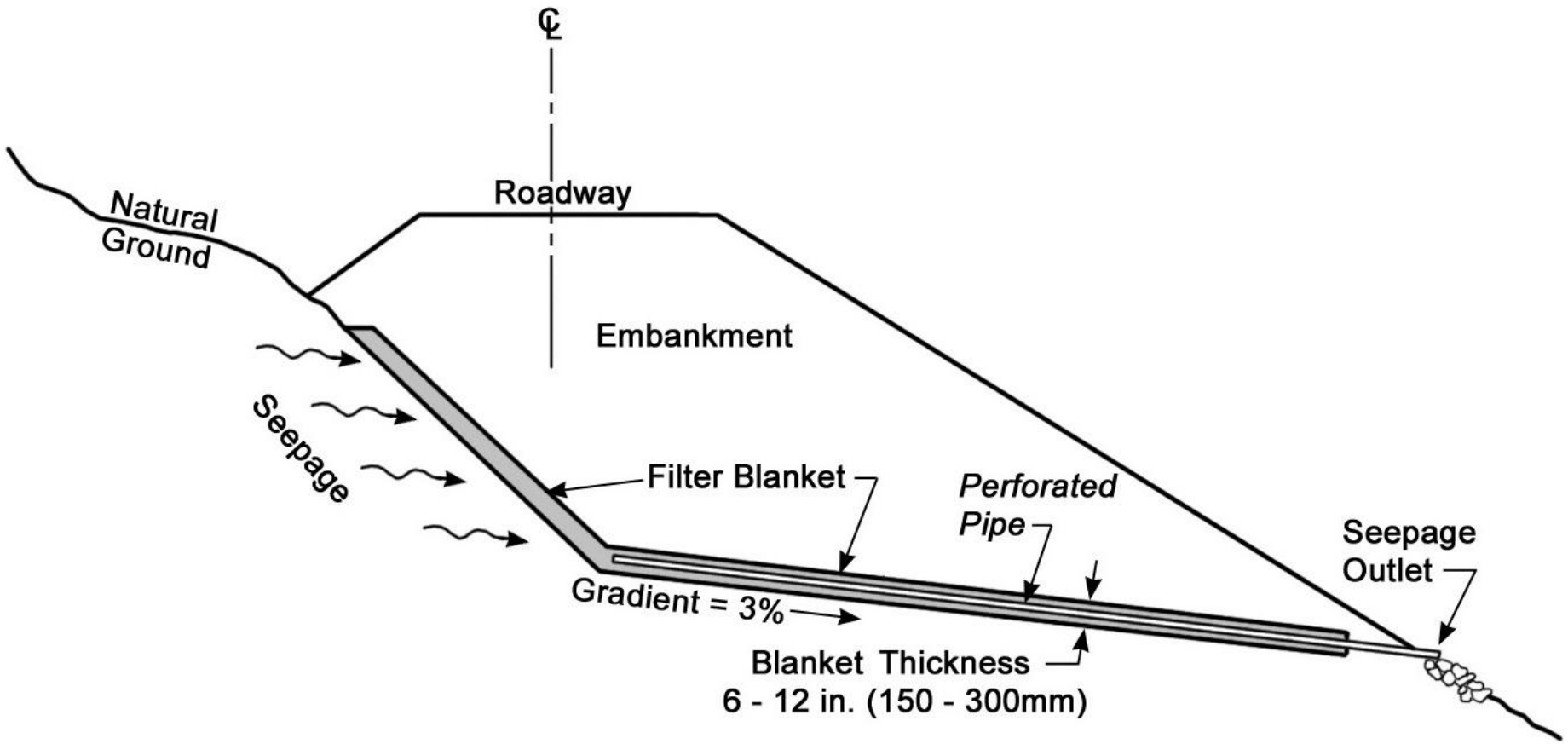




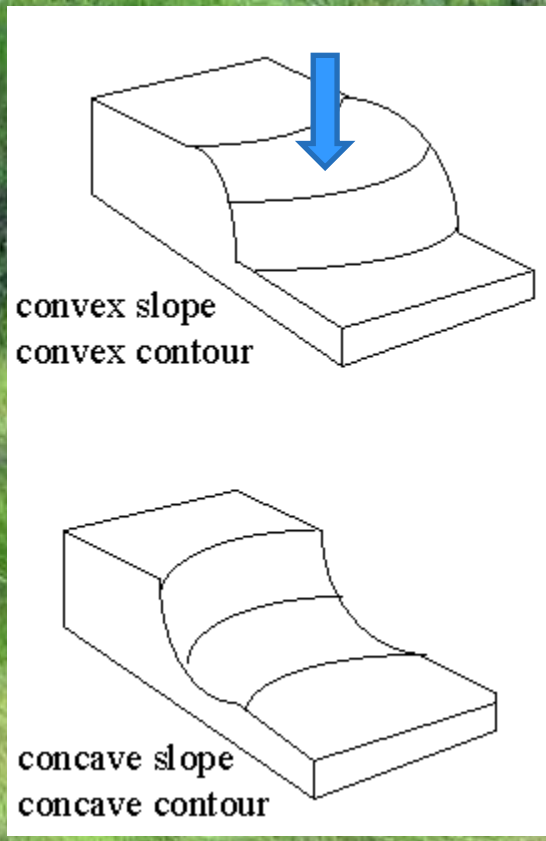
Surface and subsurface drainage






℄
Roadway
Natural
Ground
Embankment
Seepage
Filter Blanket
Perforated
Pipe
Seepage
Outlet
Gradient = 3%
Blanket Thickness
6 - 12 in. (150 - 300mm)

Don’t Forget Surface Drainage!!

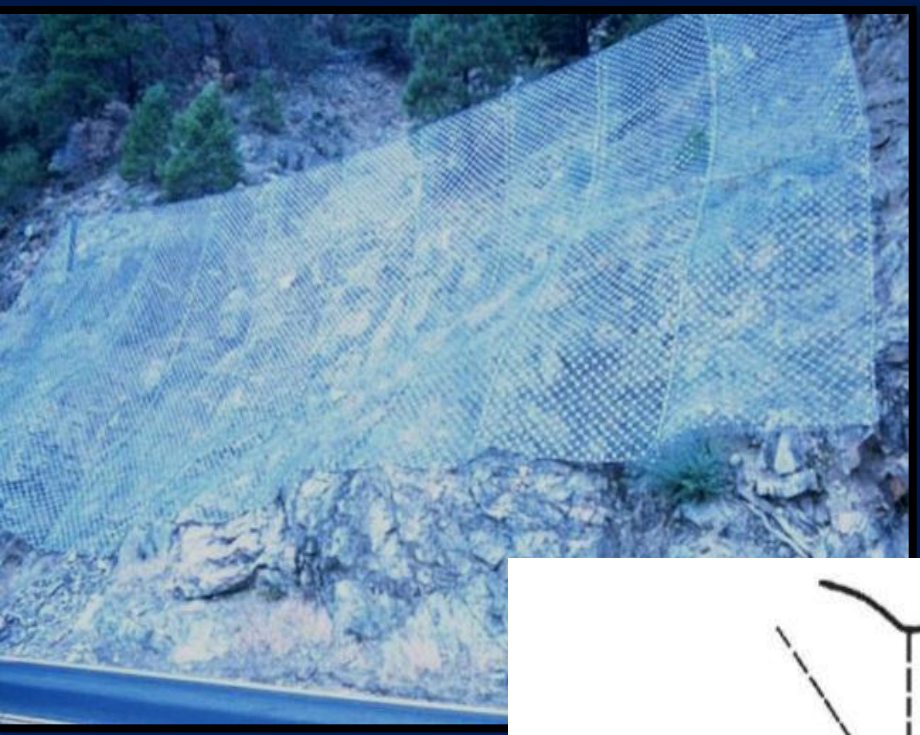


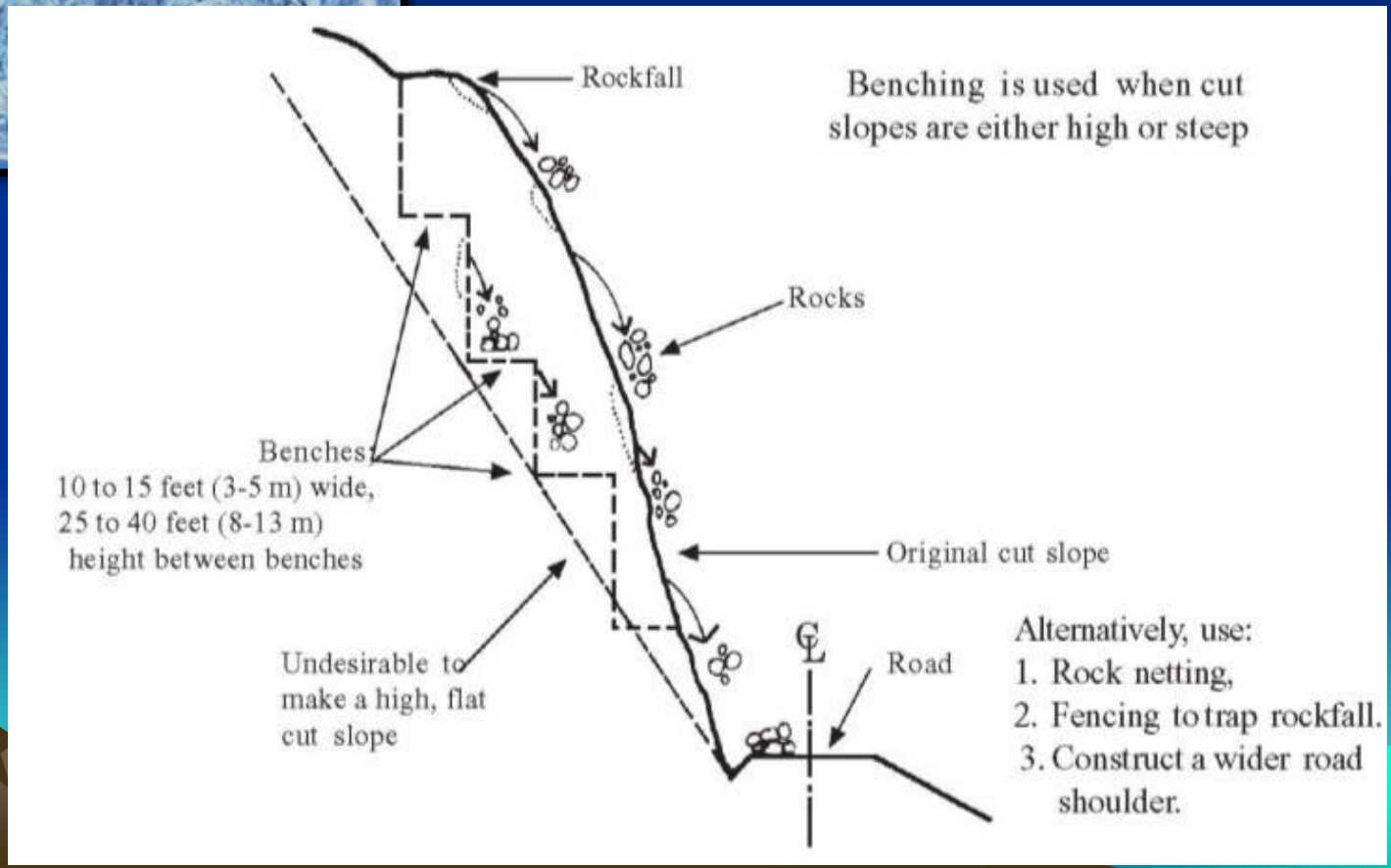
C. Gillies

Don Lindsay, CGS

Rock Cuts & Rock Fall Problems

CDOT

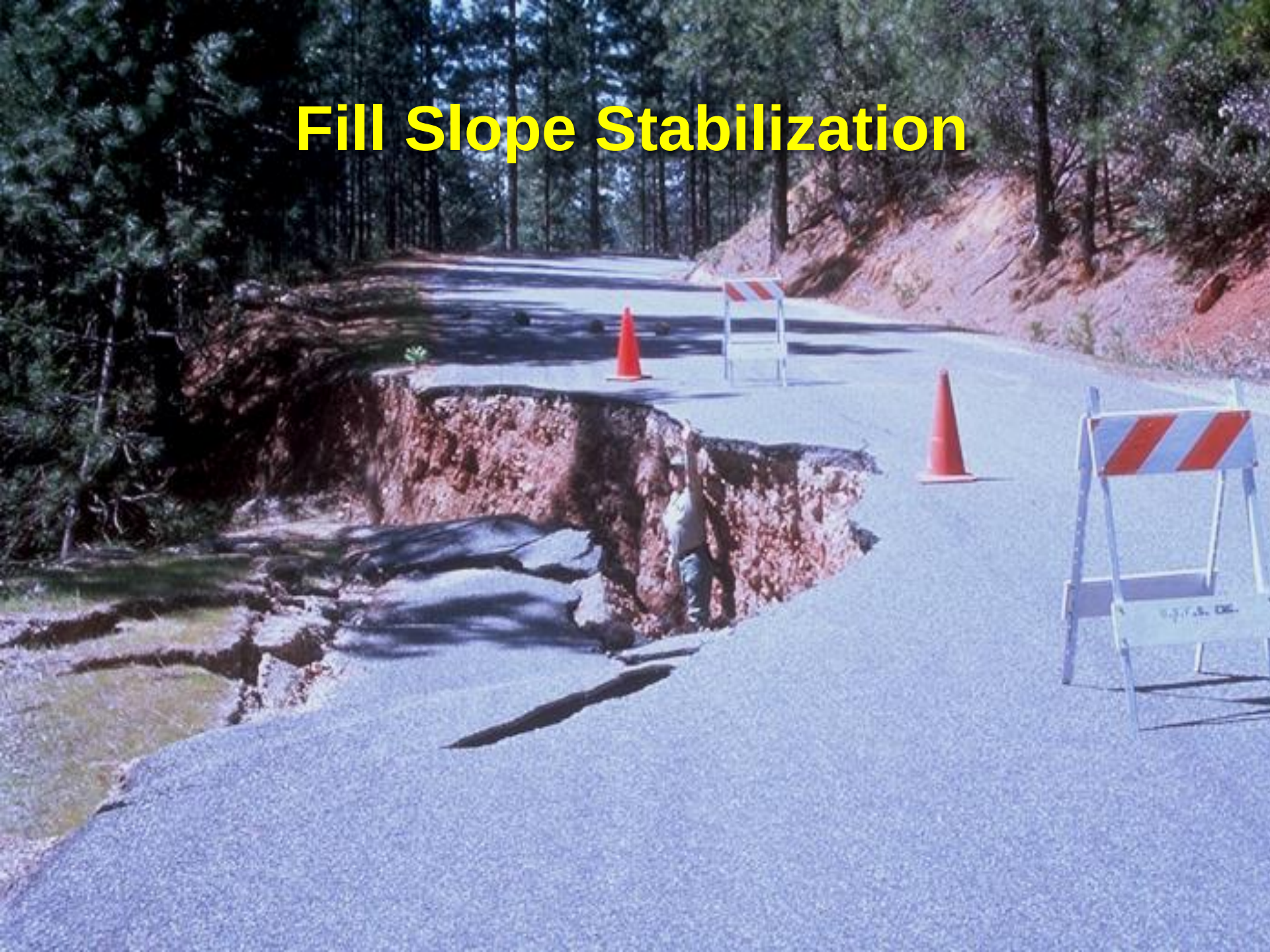



Rockfall
Benching is used when cut slopes are either high or steep
Rocks
Benches
10 to 15 feet (3-5 m) wide,
25 to 40 feet (8-13 m)
height between benches
Original cut slope
Undesirable to make a high, flat cut slope
℄
Road
Alternatively, use:
1. Rock netting,
2. Fencing to trap rockfall.
3. Construct a wider road shoulder.


5/31/2007

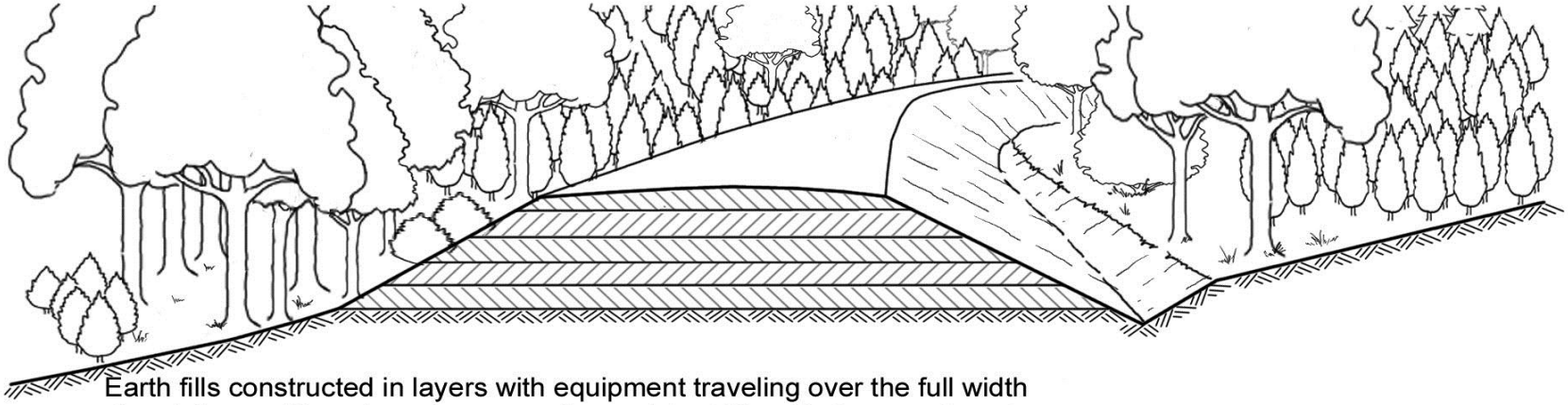
Flattening or reshaping over-steep failing slopes;

Fill Slope Stabilization

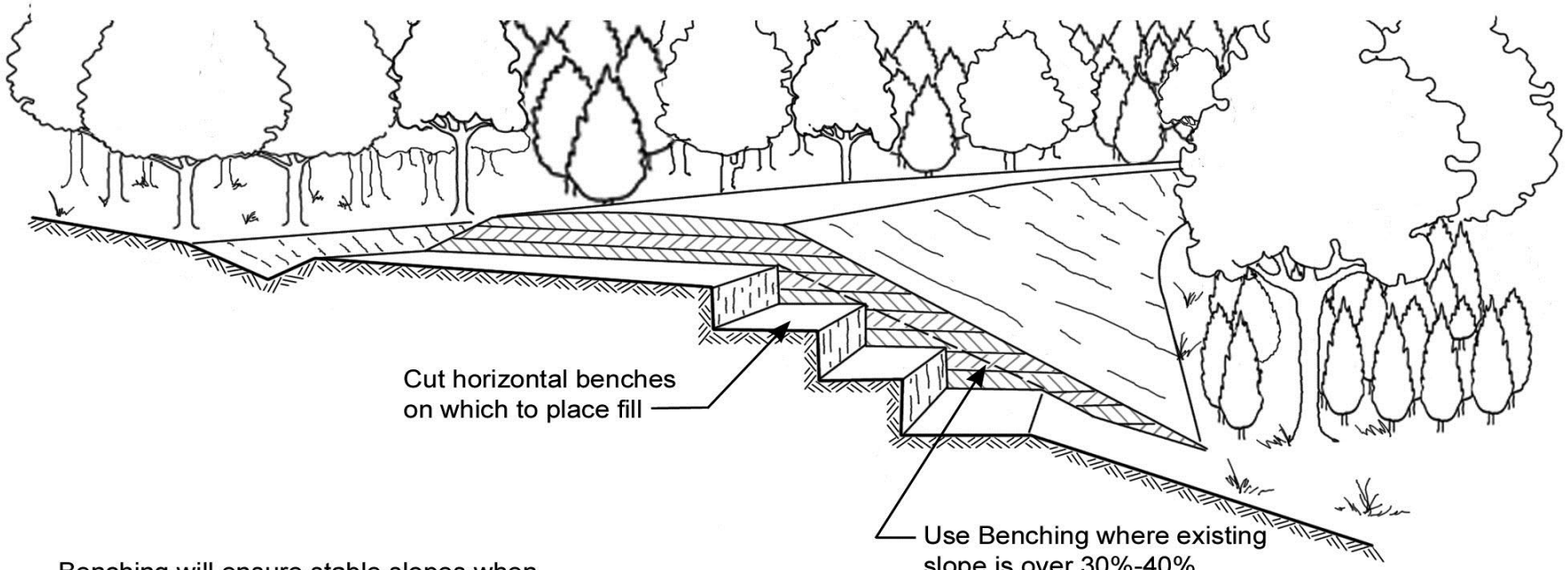



8%
GRADE


CAT



Earth fills constructed in layers with equipment traveling over the full width of each layer will produce dense erosion resistant fills with fewer soft spots.



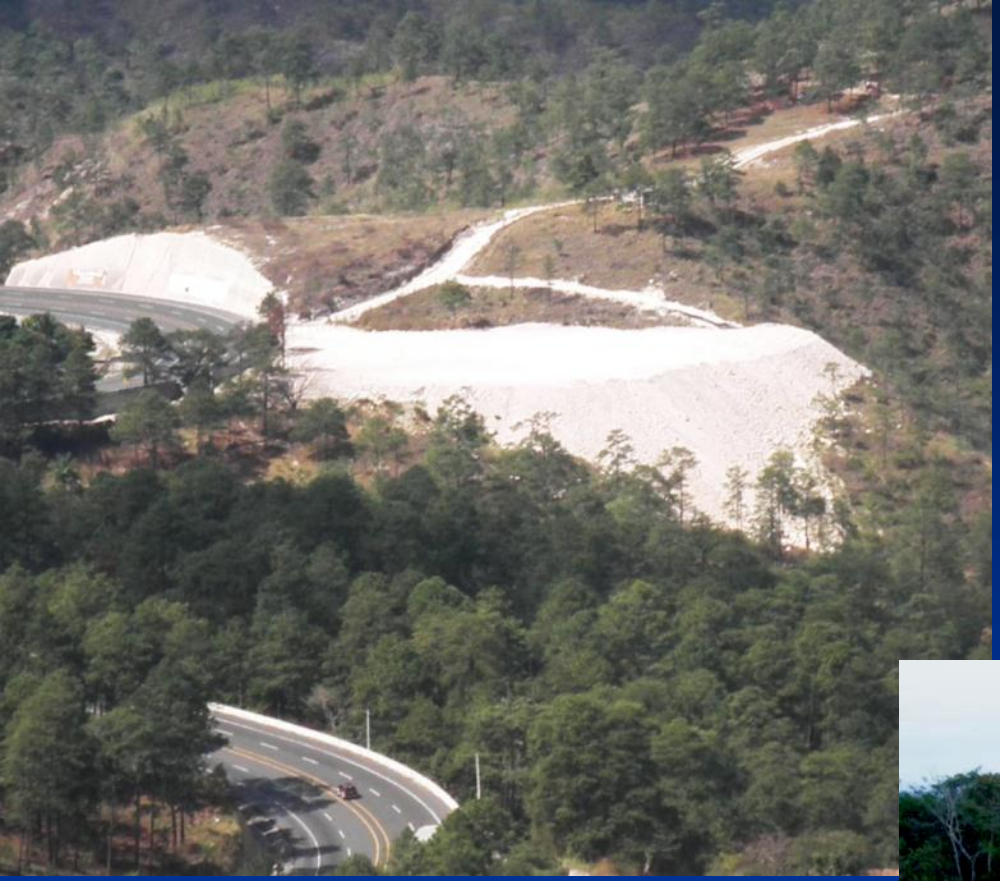
Benching will ensure stable slopes when constructing fills on steep side hills

Source: Nova Scota Construction Specs June 200?

Figure 11.3.2b **FILL CONSTRUCTION OPTIONS**

CHECK DRAWING
07-05-06

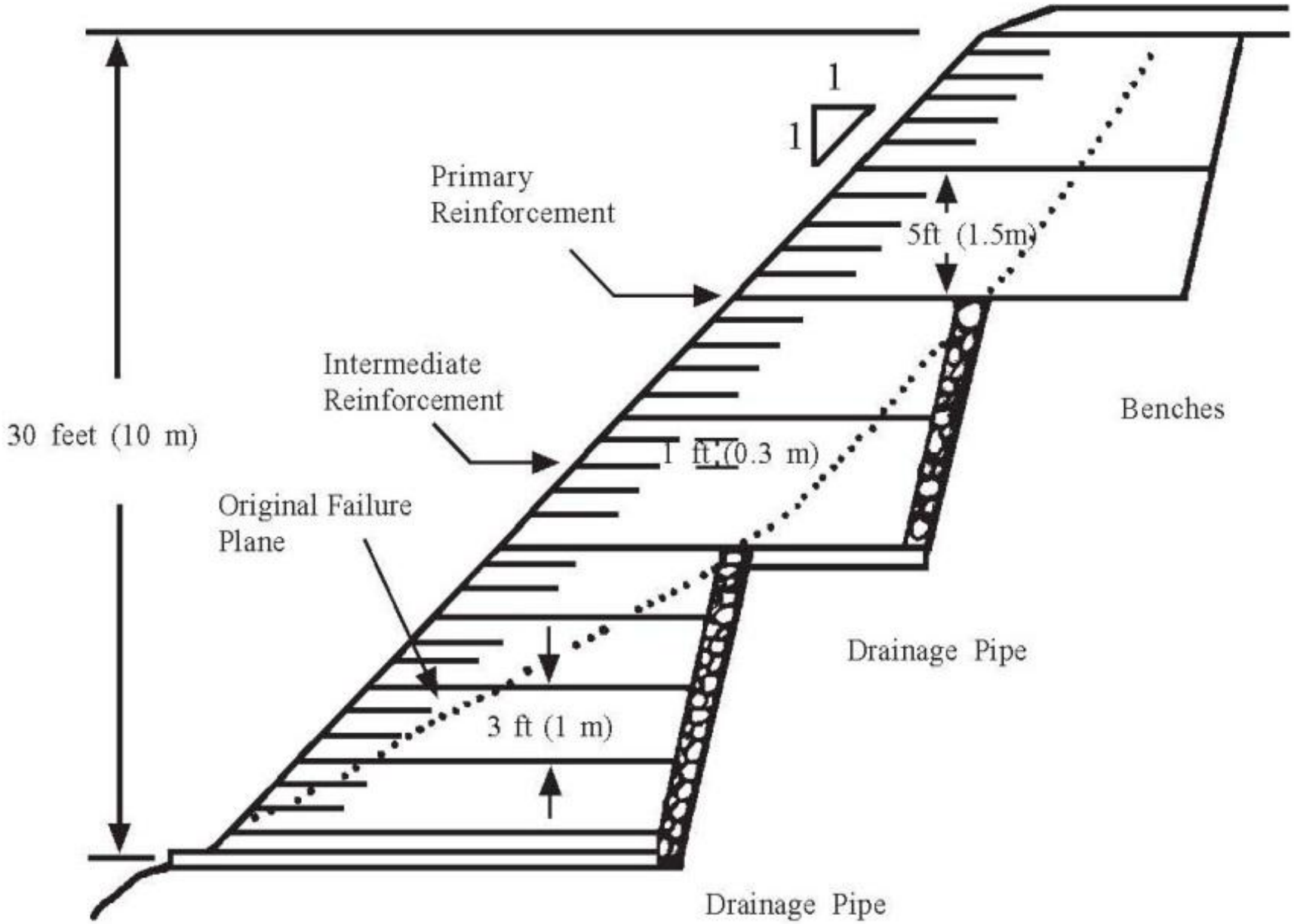
Bad Disposal Sites



OK Disposal Areas-

Designate Disposal Sites!!

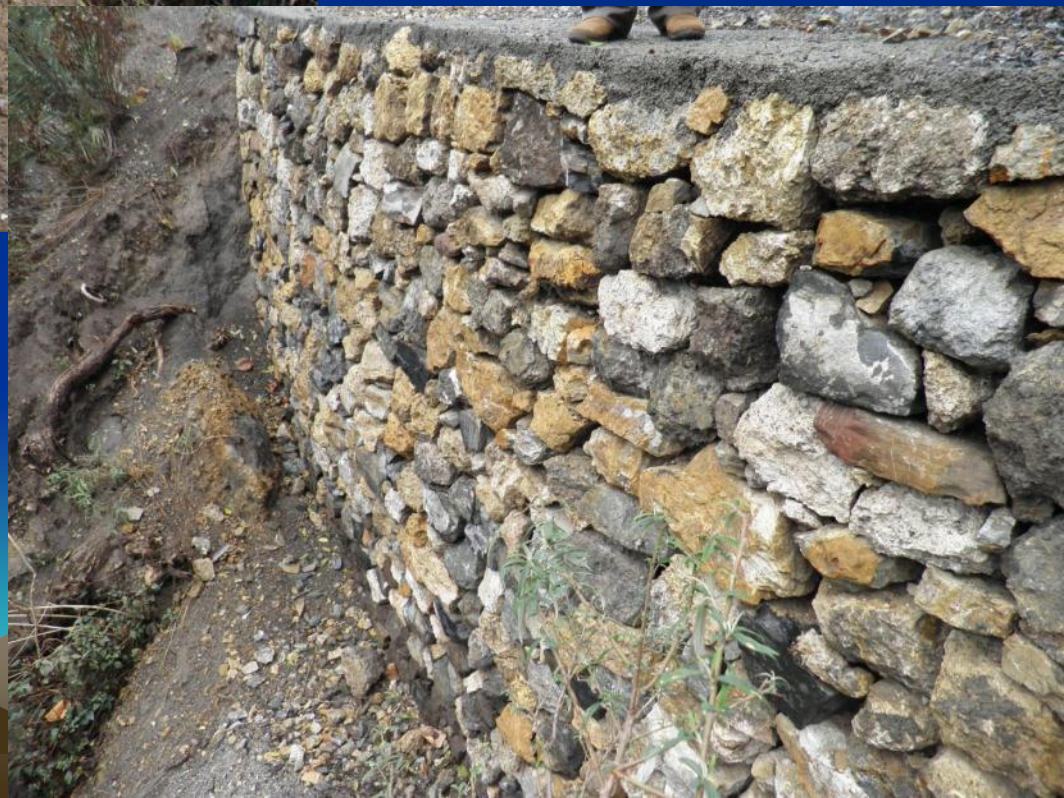

Reinforced
Fills

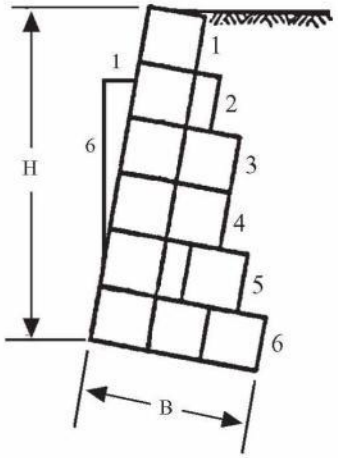

1
1
Primary
Reinforcement
5ft (1.5m)
Intermediate
Reinforcement
Benches
30 feet (10 m)
1 ft (0.3 m)
Original Failure
Plane
Drainage Pipe
3 ft (1 m)
Drainage Pipe

Deep Patch

CROSS-SECTION OF TYPICAL DEEP PATCH
ROAD EMBANKMENT REPAIR

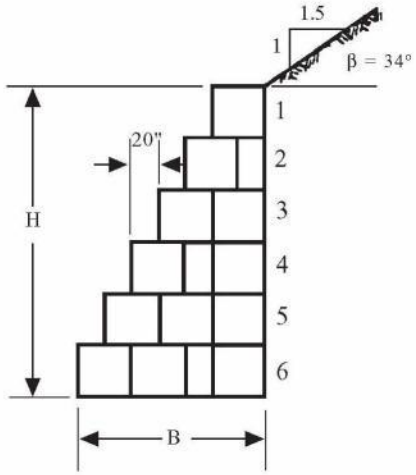
Retaining Walls





No of levels	H	B	No. of gabions (per width)
1	3' 3"	3' 3"	1
2	6' 6"	4' 3"	1 1/2
3	9' 9"	5' 3"	2
4	13' 1"	6' 6"	2
5	16' 4"	8' 2"	2 1/2
6	19' 7"	9' 9"	3

Figure A. - Flat Backfill (smooth face)



No. of levels	H	B	No. of gabions (per width)
1	3' 3"	3' 3"	1
2	6' 6"	4' 11"	1 1/2
3	9' 9"	6' 6"	2
4	13' 1"	8' 2"	2 1/2
5	16' 4"	9' 9"	3
6	19' 7"	11' 5"	3 1/2

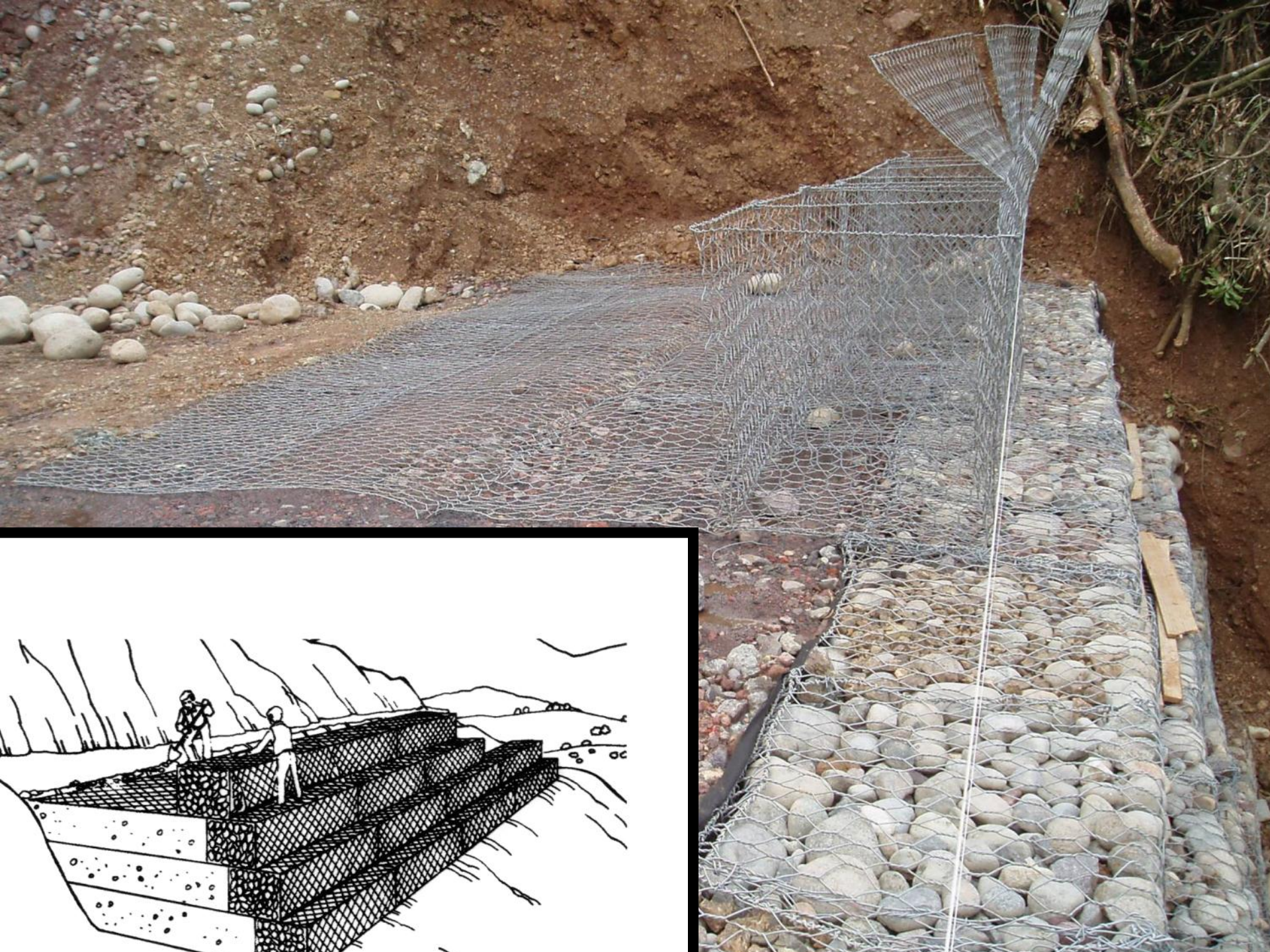
Figure B. - Fill at 1 1/2:1 (face with steps)

Note: Loading conditions are for silty sand to sand and gravel back fill. For finer or clay rich soils, earth pressure on the wall will increase and the wall base width (B) will have to increase for each height. Backfill weight = 110 pcf. (1.8 Tons/m^3)

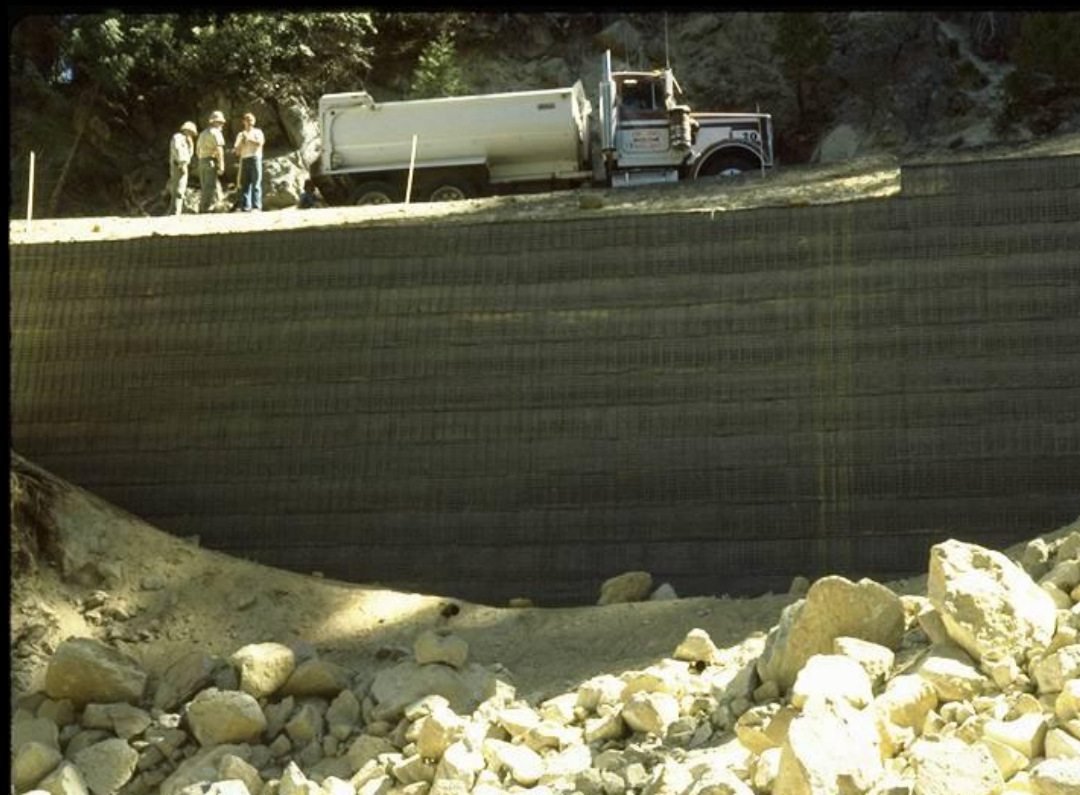
- Safe against overturning for soils with a minimum bearing capacity of 2 Tons/$foot^2$
- For flat or sloping backfills, either a flat or stepped face may be used.

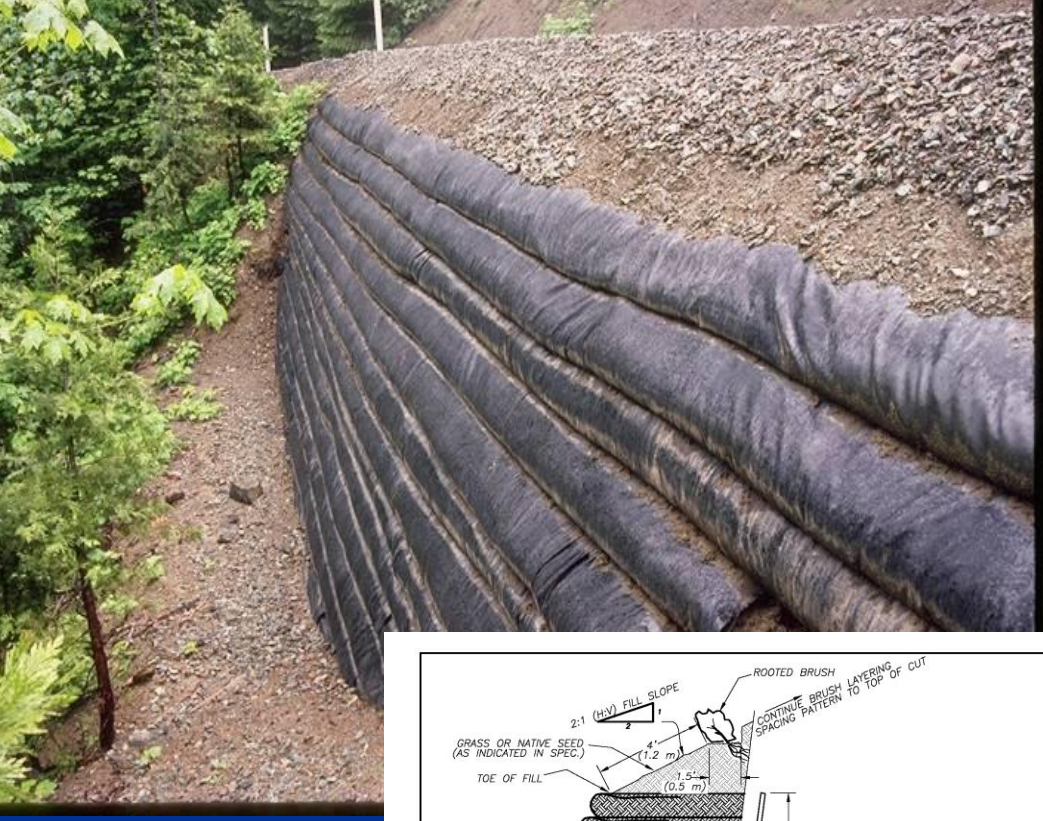
Standard design for Gabion Retaining Structures to 20 feet high (6 meters) with flat or sloping backfill.

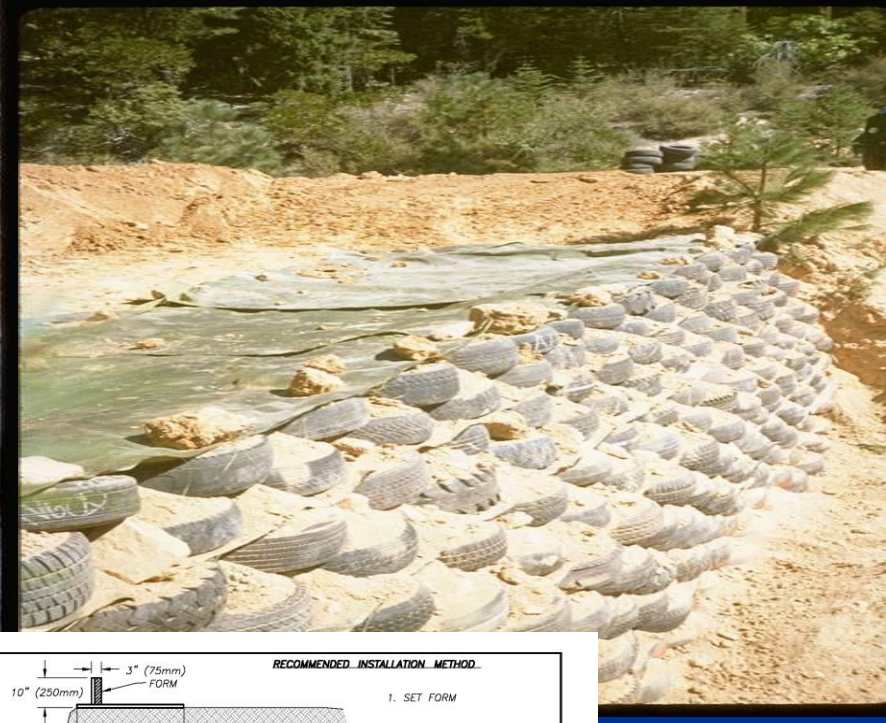
Source: Adapted from Gray y Leiser, 1982.

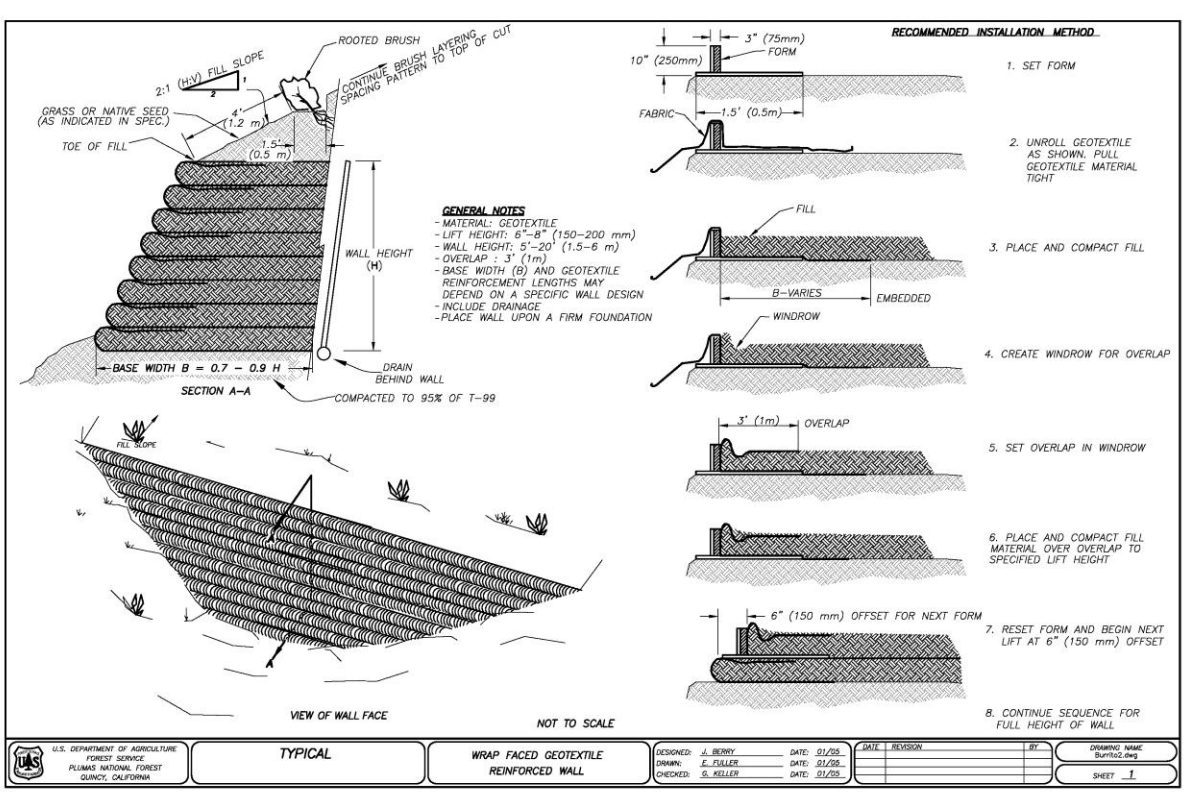


MSE Walls
(MechanicallyStabilized Earth)

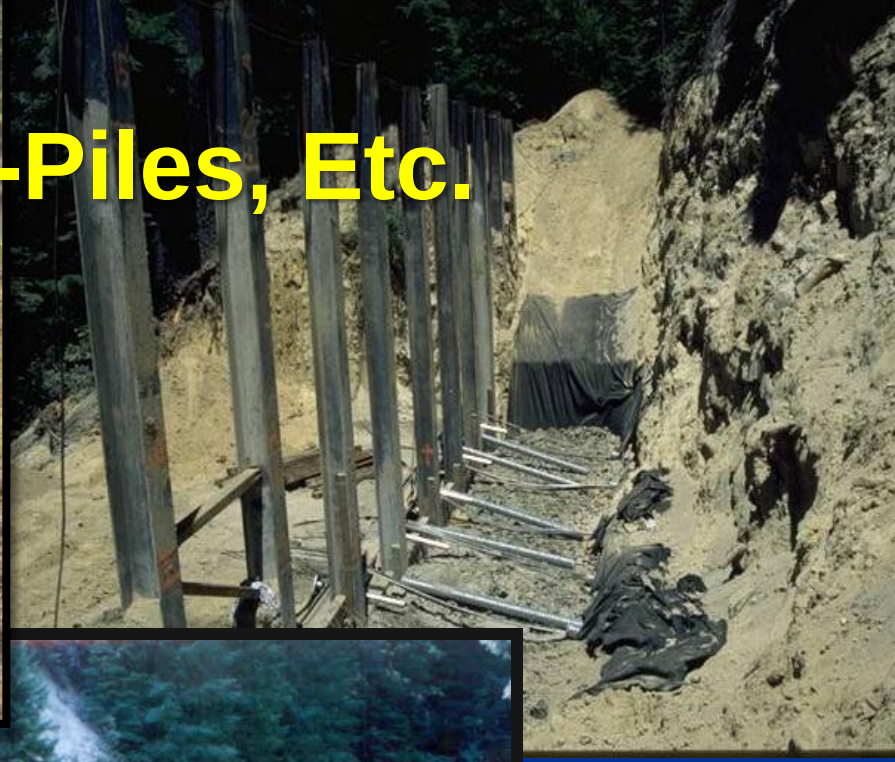







ROOTED BRUSH
CONTINUE BRUSH LAYERING SPACING PATTERN TO TOP OF CUT
2:1 (H:V) FILL SLOPE
GRASS OR NATIVE SEED (AS INDICATED IN SPEC.)
4' (1.2 m)
1.5' (0.5 m)
TOE OF FILL
WALL HEIGHT (H)
BASE WIDTH B = 0.7 – 0.9 H
DRAIN BEHIND WALL
COMPACTED TO 95% OF T-99
SECTION A–A
GENERAL NOTES
- MATERIAL: GEOTEXTILE
- LIFT HEIGHT: 6"–8" (150–200 mm)
- WALL HEIGHT: 5'–20' (1.5–6 m)
- OVERLAP : 3' (1m)
- BASE WIDTH (B) AND GEOTEXTILE REINFORCEMENT LENGTHS MAY DEPEND ON A SPECIFIC WALL DESIGN
- INCLUDE DRAINAGE
- PLACE WALL UPON A FIRM FOUNDATION
FILL SLOPE
VIEW OF WALL FACE
NOT TO SCALE
RECOMMENDED INSTALLATION METHOD
3" (75mm) FORM
10" (250mm)
FABRIC
1.5' (0.5m)
1. SET FORM
2. UNROLL GEOTEXTILE AS SHOWN, PULL GEOTEXTILE MATERIAL TIGHT
FILL
B–VARIES
EMBEDDED
3. PLACE AND COMPACT FILL
WINDROW
4. CREATE WINDROW FOR OVERLAP
3' (1m) OVERLAP
5. SET OVERLAP IN WINDROW
6. PLACE AND COMPACT FILL MATERIAL OVER OVERLAP TO SPECIFIED LIFT HEIGHT
6" (150 mm) OFFSET FOR NEXT FORM
7. RESET FORM AND BEGIN NEXT LIFT AT 6" (150 mm) OFFSET
8. CONTINUE SEQUENCE FOR FULL HEIGHT OF WALL
U.S. DEPARTMENT OF AGRICULTURE
FOREST SERVICE
PLUMAS NATIONAL FOREST
QUINCY, CALIFORNIA
TYPICAL
WRAP FACED GEOTEXTILE REINFORCED WALL
DESIGNED: J. BERRY DATE: 01/05
DRAWN: E. FULLER DATE: 01/05
CHECKED: G. KELLER DATE: 01/05
DATE REVISION BY
DRAWING NAME: Burrito2.dwg
SHEET 1

Tiebacks, H-Piles, Etc.



Soil Nail Launcher

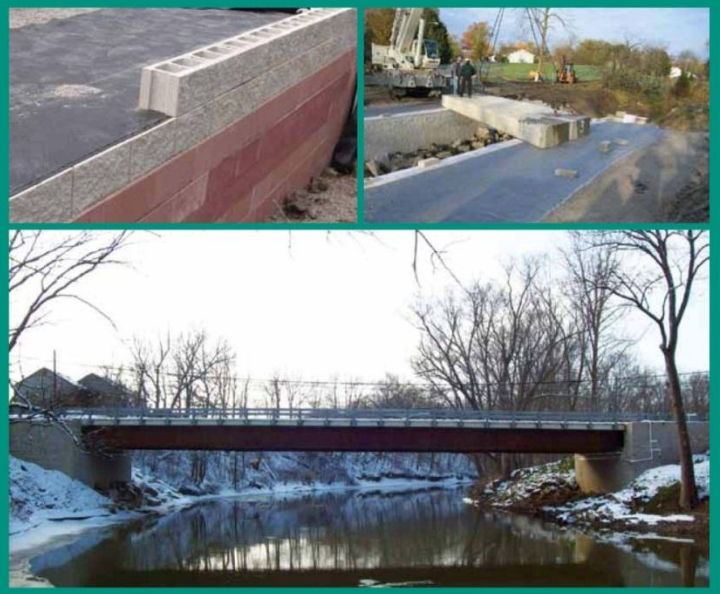
Geosynthetic Reinforced Soil (GRS) Bridge Abutments

FHWA, Defiance Co. Ohio

Geosynthetic Reinforced Soil Integrated Bridge System Synthesis Report

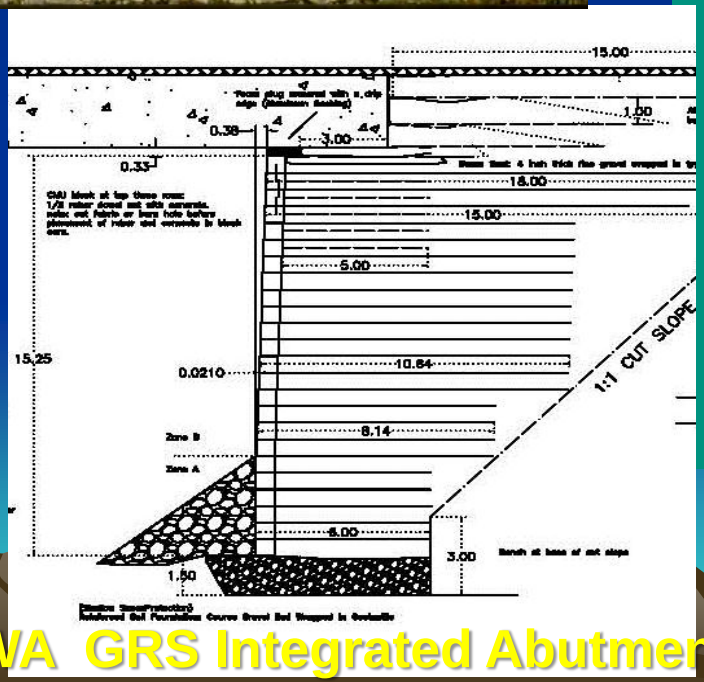
PUBLICATION NO. FHWA-HRT-11-027

JANUARY 2011



U.S. Department of Transportation
Federal Highway Administration

Research, Development, and Technology
Turner-Fairbank Highway Research Center
6300 Georgetown Pike
McLean, VA 22101-2296



FHWA GRS Integrated Abutment Design

NCHRP
SYNTHESIS 430

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Cost-Effective and Sustainable Road Slope Stabilization and Erosion Control

A Synthesis of Highway Practice

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

-USFS- Slope Stability Reference Guide

-TRB SR 247- Landslides- Investigation and Mitigation

U. S. Department of Transportation
Federal Highway Administration

Publication No. FHWA-NHI-10-024
FHWA GEC 011 – Volume I
November 2009

NHI Courses No. 132042 and 132043

Design and Construction of Mechanically Stabilized Earth Walls and Reinforced Soil Slopes – Volume I

Developed following:
AASHTO LRFD Bridge Design Specifications, 4th Edition, 2007, with 2008 and 2009 Interims. and *AASHTO LRFD Bridge Construction Specifications, 2nd Edition, 2004, with 2006, 2007, 2008, and 2009 Interims.*

NHI
NATIONAL HIGHWAY INSTITUTE


Walls Need Good Foundations!!

Ed Rose

Ed Rose

Summary

- Use commonly stable cut and fill slope angles
- For failures, assess why a site failed
- Find the least expensive, effective stabilization measure
- Consider use of drainage and vegetation
- Use structures where necessary. Analyze and design significant structures!
- Place structures on a solid foundation

Gordon Keller, PE, GE
Geotechnical Engineer
grkeller@fs.fed.us

Thank You!