



**XXIVth World
Road Congress
Mexico 2011**
Mexico City 2011.

VULNERABILITY REDUCTION (STORMPROOFING) AND DAMAGE REPAIRS USING BEST PRACTICES ON LOW-VOLUME ROADS

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What Natural Events Impact Roads?

- **Hurricanes/Floods**
- Earthquakes
- **Landslides**
- Fires
- Volcanoes
- Tsunamis
- Wind
- Tornadoes











“MITCH”

1998



“VERMONT”

2011



CARRETERA A PAVENCUL
MOTOZINTLA, CHIAPAS
REGION XI, FRONTERA SUR

COORD.
6588452
1676691

**MOVIMIENTO MASIVO DE SUELO
SIN MEDIDAS DE CONSERVACION**

Camino (peligro antrópico)

Vulnerabilidad

**HURRICANE
STAN**

18 10 2005

Roads Storm Damage Risk Reduction

What Can We Do to Reduce our Vulnerability to Natural Disasters?

- **Planning/Preparation**
- **Risk Assessment**
- **Preventative Maintenance**
- **Key Preventative Mitigation Measures**
- **Apply Best Management Practices**



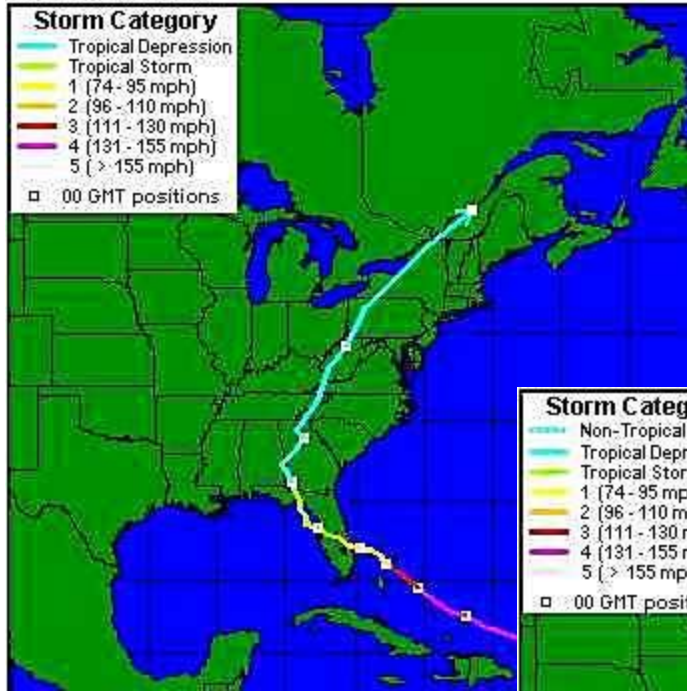
Roads Storm Damage Risk Reduction

Storms Will Happen!

- **The Question is....**
- **Where?**
- **When?**
- **How Big?**



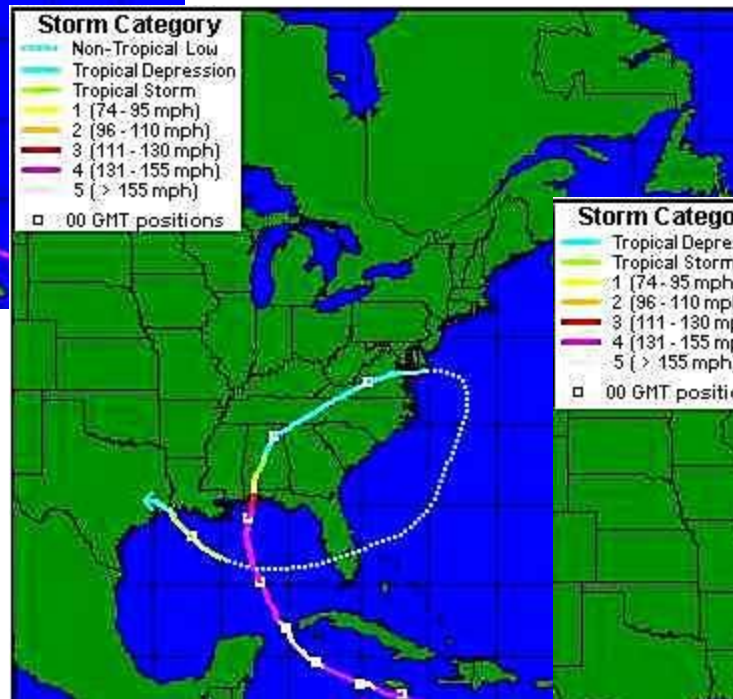
Tracking Map



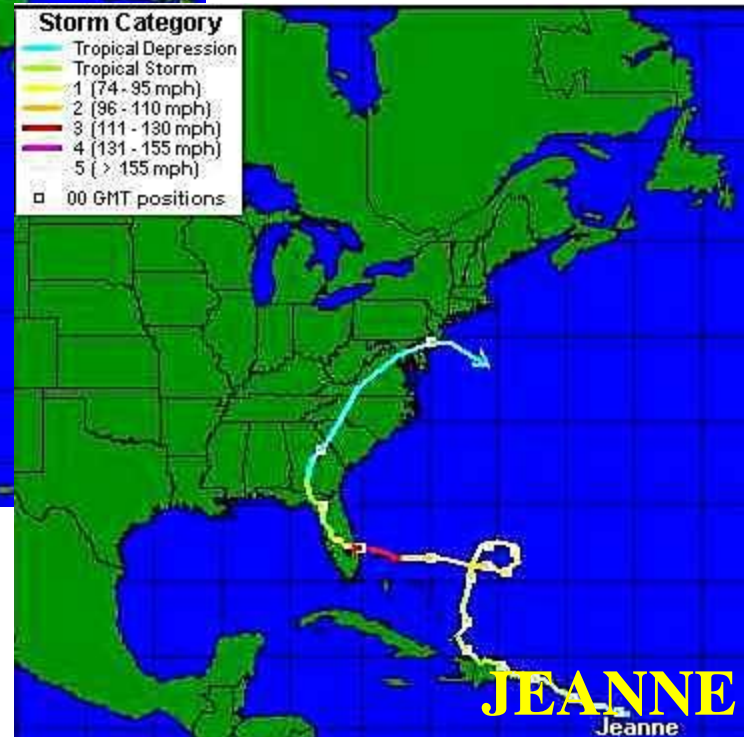
FRANCES

HURRICANES, NORTH CAROLINA,

2004



IVAN



JEANNE
Jeanne

Roads Storm Damage Risk Reduction

Pre-Disaster Risk Assessment

- **Local Knowledge**
- **Site location, geomorphology, soils, watershed condition, slope, road standard, etc.**
- **Risk of Failure**
- **Values at Risk**
- **Consequences of Failure**





Crowds panic as flooding threatens Ireland...







Roads Storm Damage Risk Reduction Risk Assessment

- ***Upslope Erosion Inventory and Sediment Control Guidance***, Part X of California Salmonid Stream Habitat Restoration Manual (Weaver et. al. 2006)
- ***Geomorphic Roads Analysis and Inventory Package (GRAIP)***

<http://www.fs.fed.us/GRAIP/index.shtml>

- ***Soil and Water Road-Condition Index-Field Guide*** [http://www.fs.fed.us/td/php/library card.php?p_num=0877%201806P](http://www.fs.fed.us/td/php/library/card.php?p_num=0877%201806P)



Roads Storm Damage Risk Reduction Preventative Maintenance

- **Clean Ditches and Culverts**
- **Cleaning and Stabilization of Channels**
- **Shaping Road Surfaces to Drain**
- **Clearing Bridge Waterways**
- **Replacing Riprap**
- **Maintaining Vegetative Cover**









Roads Storm Damage Risk Reduction

Key Mitigation Measures

- 1. Surface Drainage Improvements**
- 2. Stream Crossing Structure Improvements**
- 3. Bridge Protection and Improvements**
- 4. Local Slope Stabilization Measures**
- 5. Erosion Protection/Deep-Rooted Vegetation**

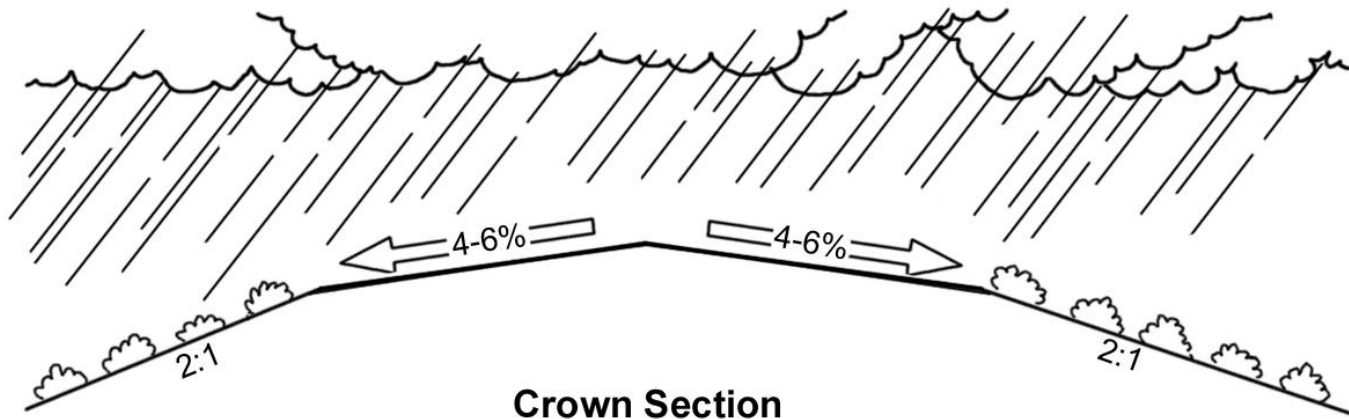


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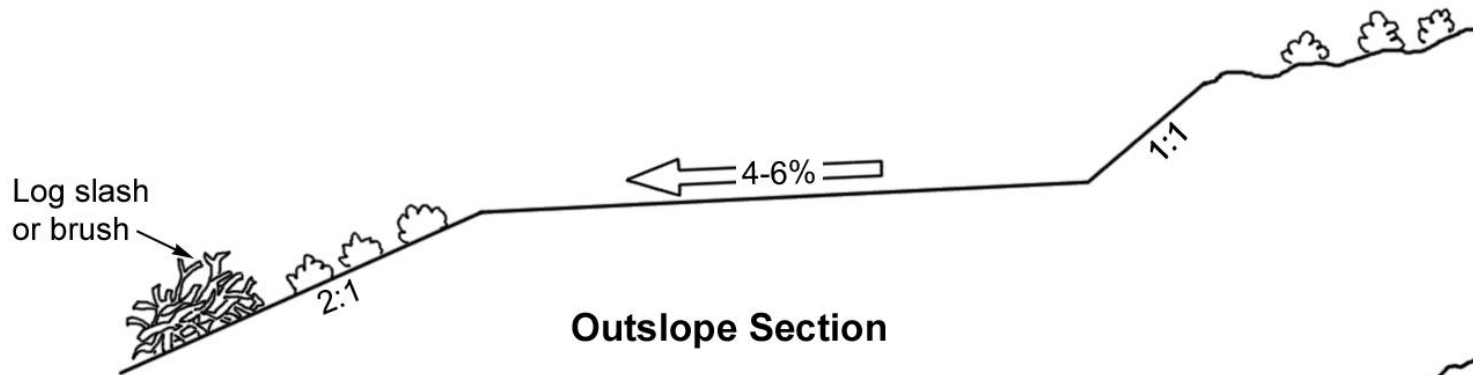
Surface Drainage Improvements

- **Rebuild Inslope, Outslope, Crown**
- **Add Cross-drain Structures**
- **Use Rolling Dips Where Possible**
- **Add Lead-off Ditches**
- **Armor Ditches in Erosive Soils**
- **Protect Cross-drain Outlets**
- **Add Drop Inlets on Cross-drain Pipes**

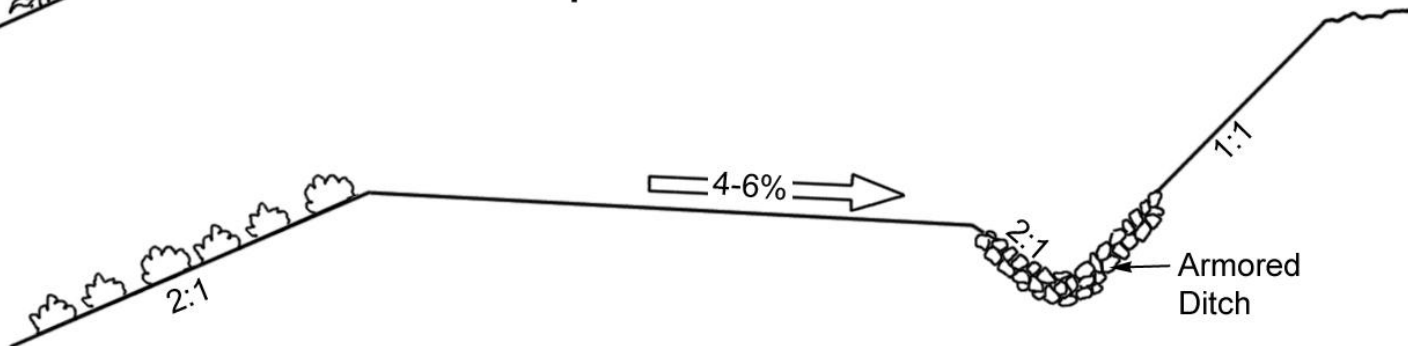




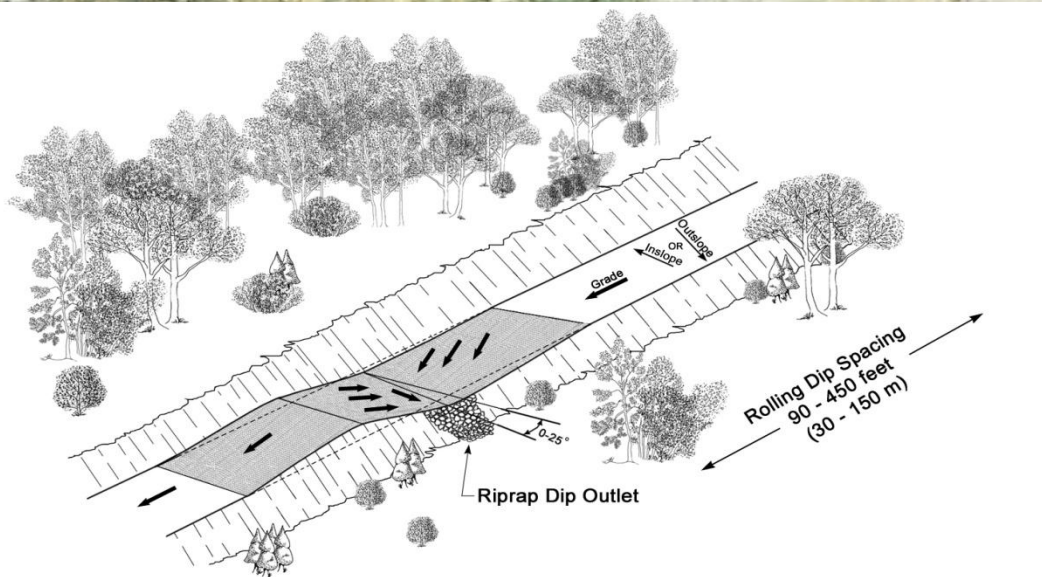
Crown Section



Outslope Section



Inslope with Ditch Section



PERSPECTIVE VIEW





Roads Storm Damage Risk Reduction

Stream Crossing Structure Improvements

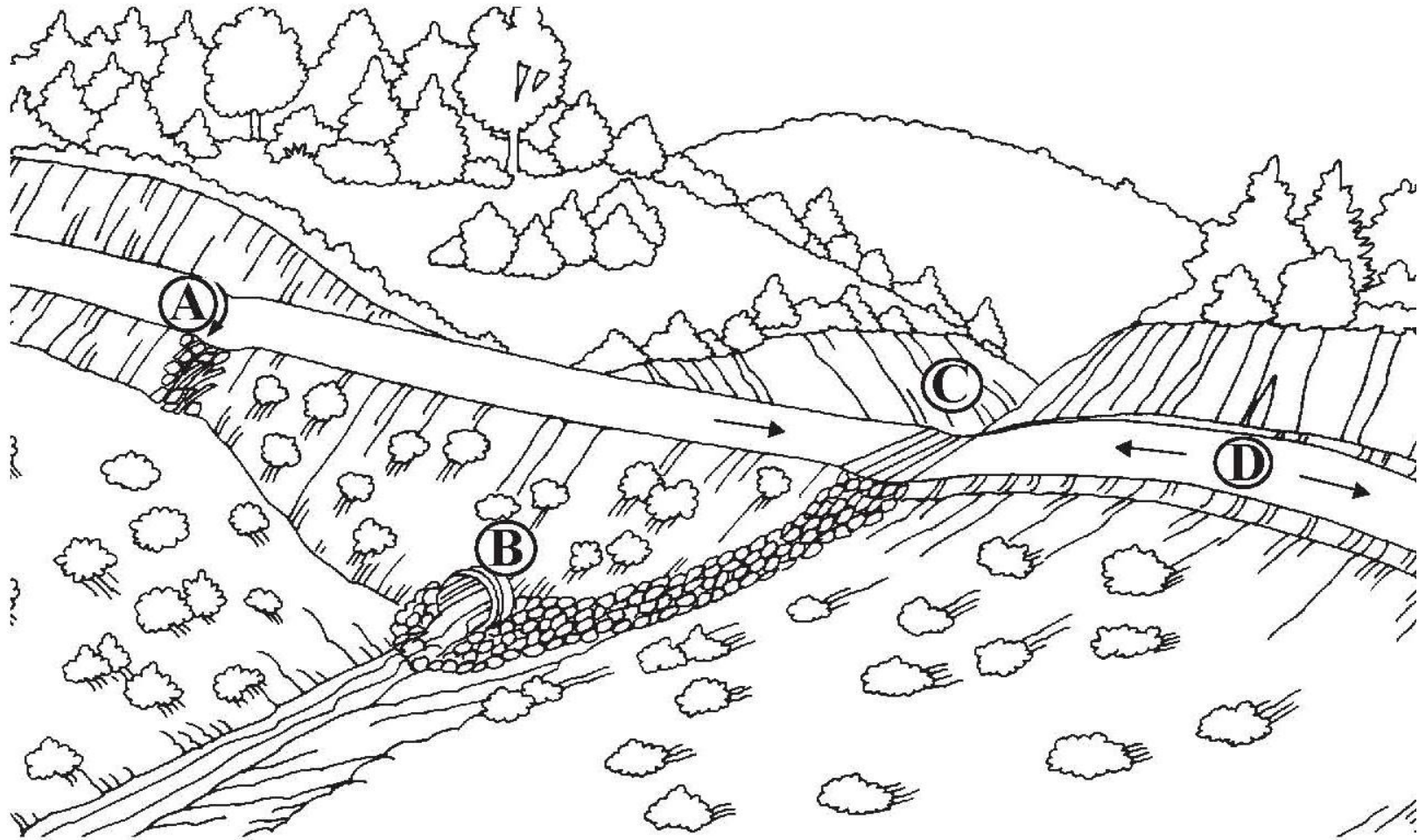
- **Improve Culvert Inlets with Headwalls**
- **Increase Capacity with Larger/Multiple Pipes**
- **Add Overflow Protection/Diversion
Prevention**
- **Add Trash Racks for Debris/Prevent Plugging**
- **Add Streambank Stabilization as Needed**
- **Convert Culvert Pipes to Low-Water Xngs**







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



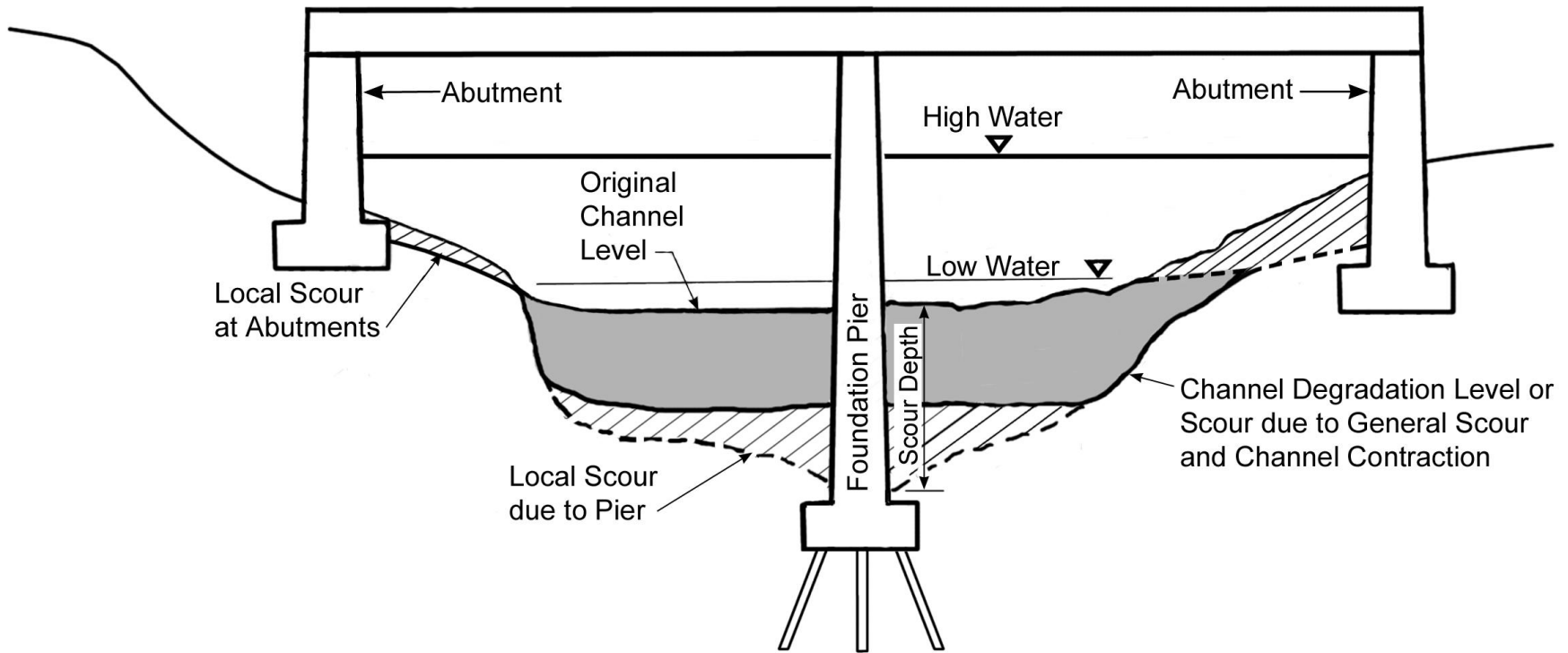
Roads Storm Damage Risk Reduction

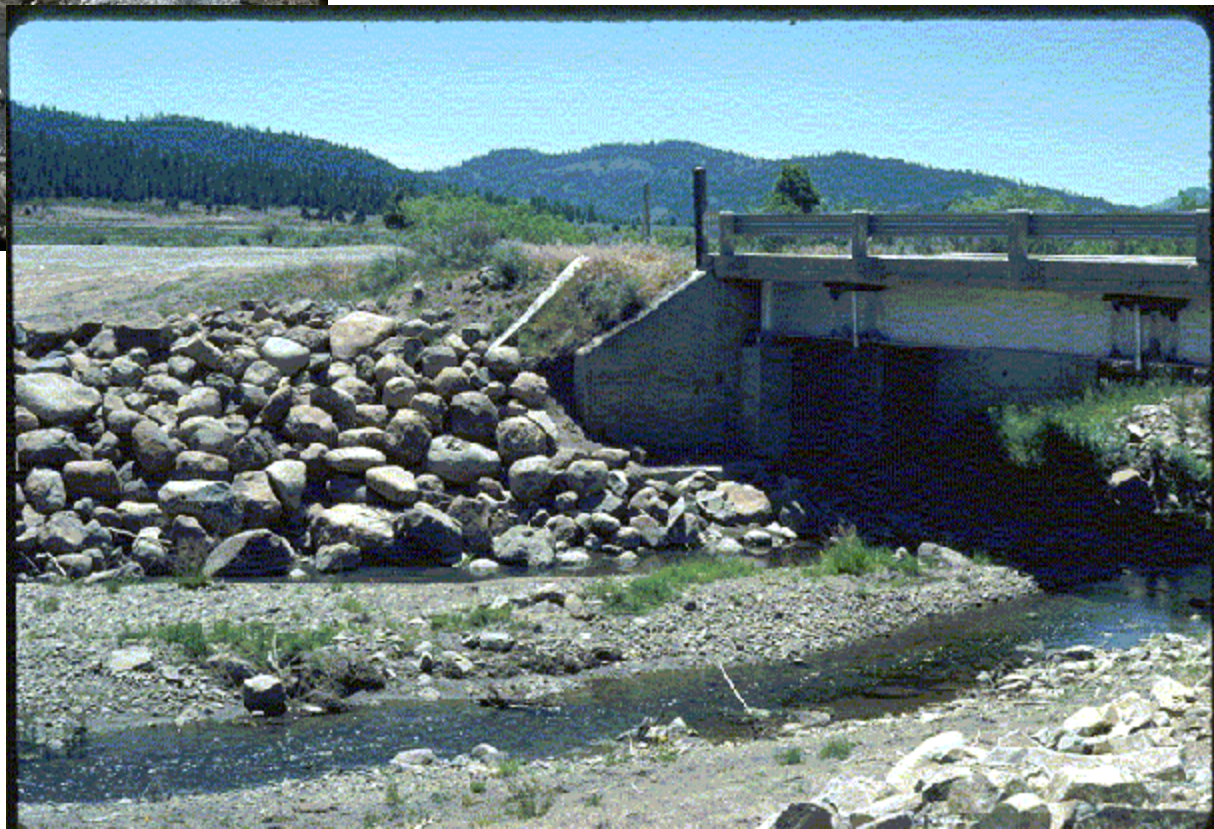
Bridge Protection and Improvements

- **Add Scour Countermeasures**
- **Add Riprap/Vegetation Bank Protection**
- **Clear Channel Debris and Vegetation**
- **Redirect Channel Flow with Barbs/Jetties**
- **Add Overflow Dip in Approach Fill**
- **Raise Superstructure**

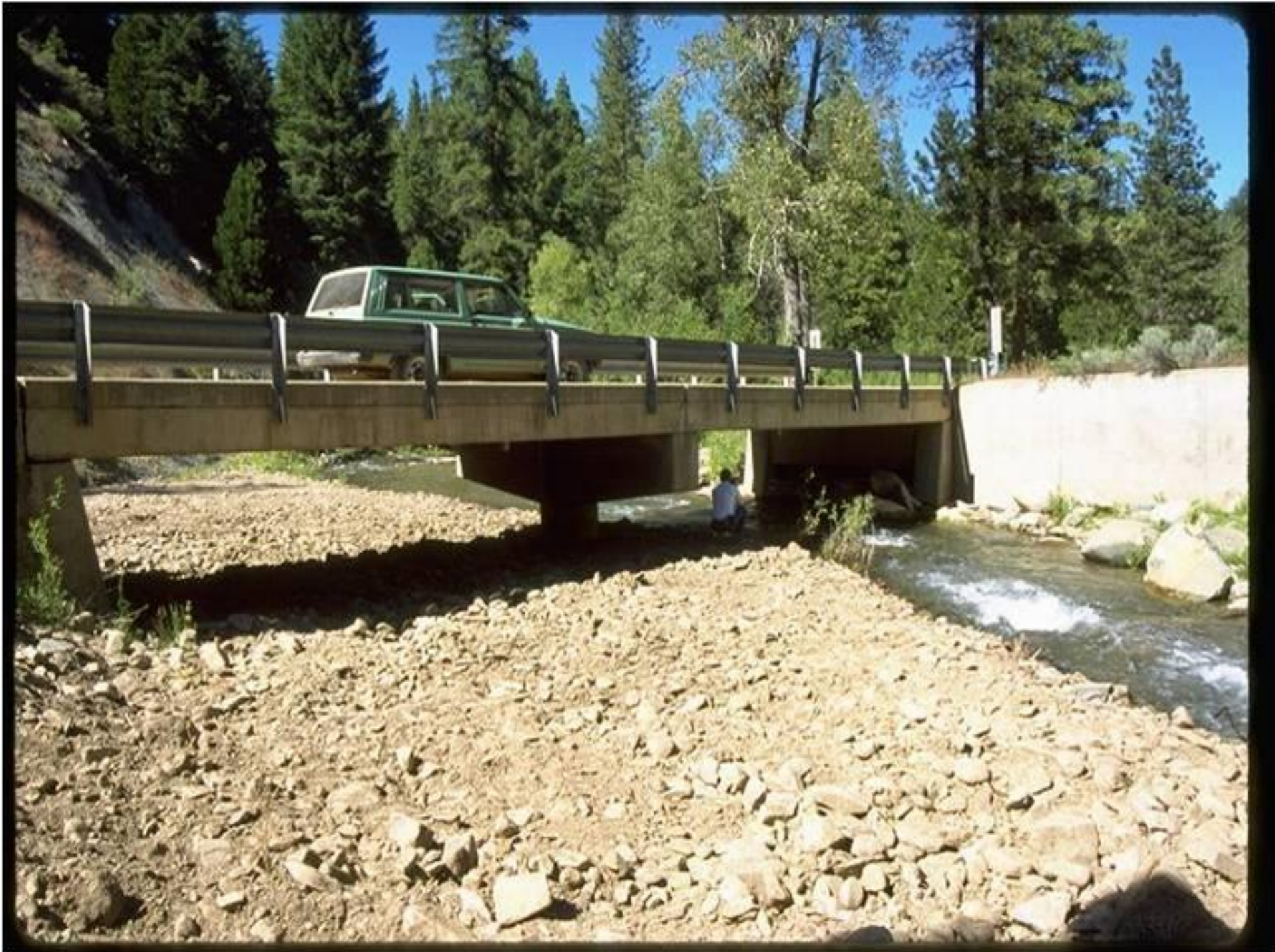












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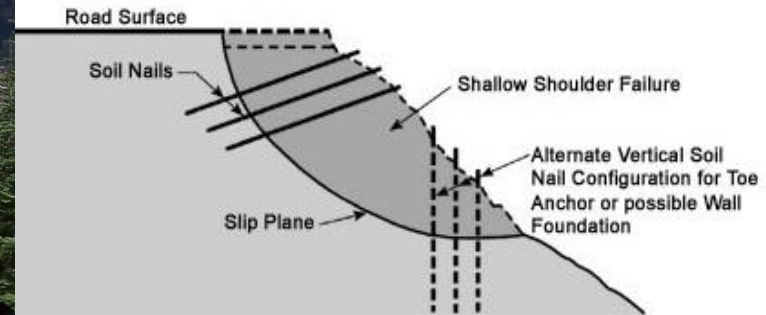
Slope Stabilization Measures

- **Flatten Oversteep/Marginal Slopes**
- **Improve Slope Drainage**
- **Add Buttress/Retaining Structure**
- **Pull Back Failing Fill Slopes**
- **Use “Deep Patch” Stabilization**
- **Biotechnical Slope Stabilization**
- **Adding Rockfall Protection**



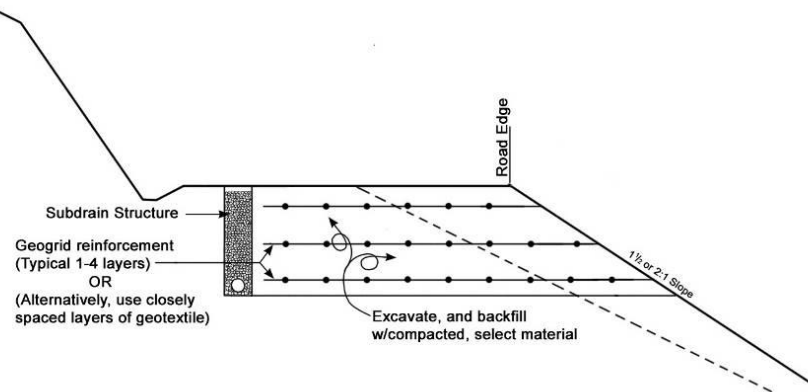




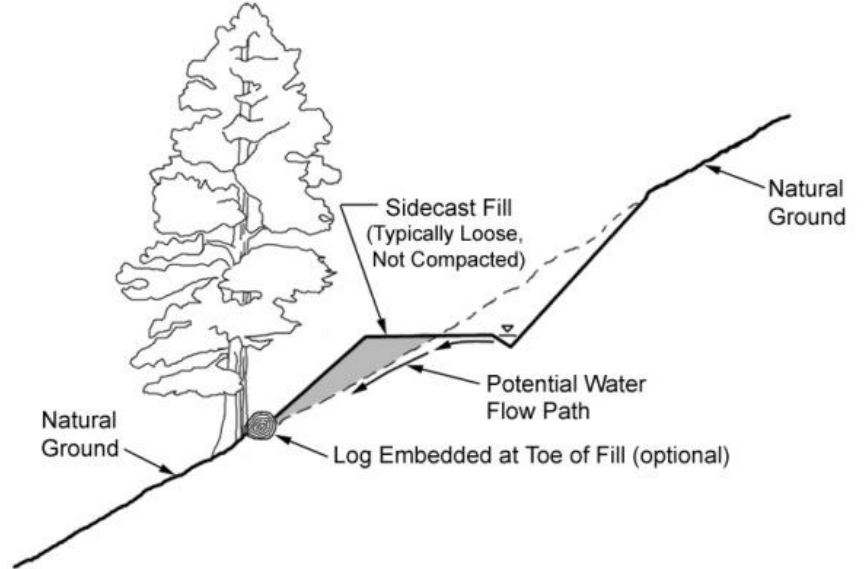


Source: Bob Barrett

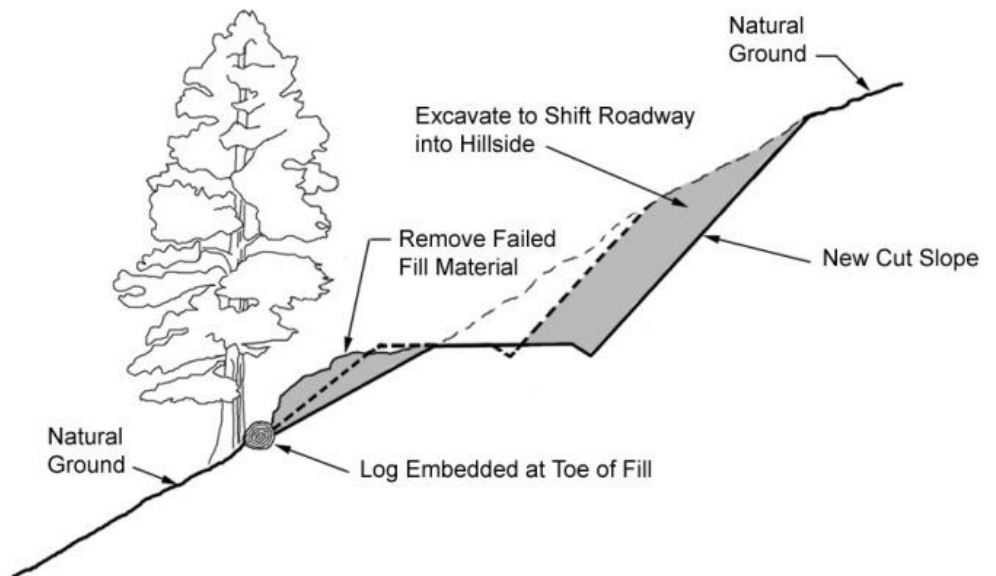
LAUNCHED SOIL NAILS







TYPICAL VIEW OF A SIDECAST FILL PRIOR TO FAILURE



**FAILED FILL REPAIR ALTERNATIVE 1-
MOVING INTO THE HILLSIDE**



Roads Storm Damage Risk Reduction

Erosion Protection

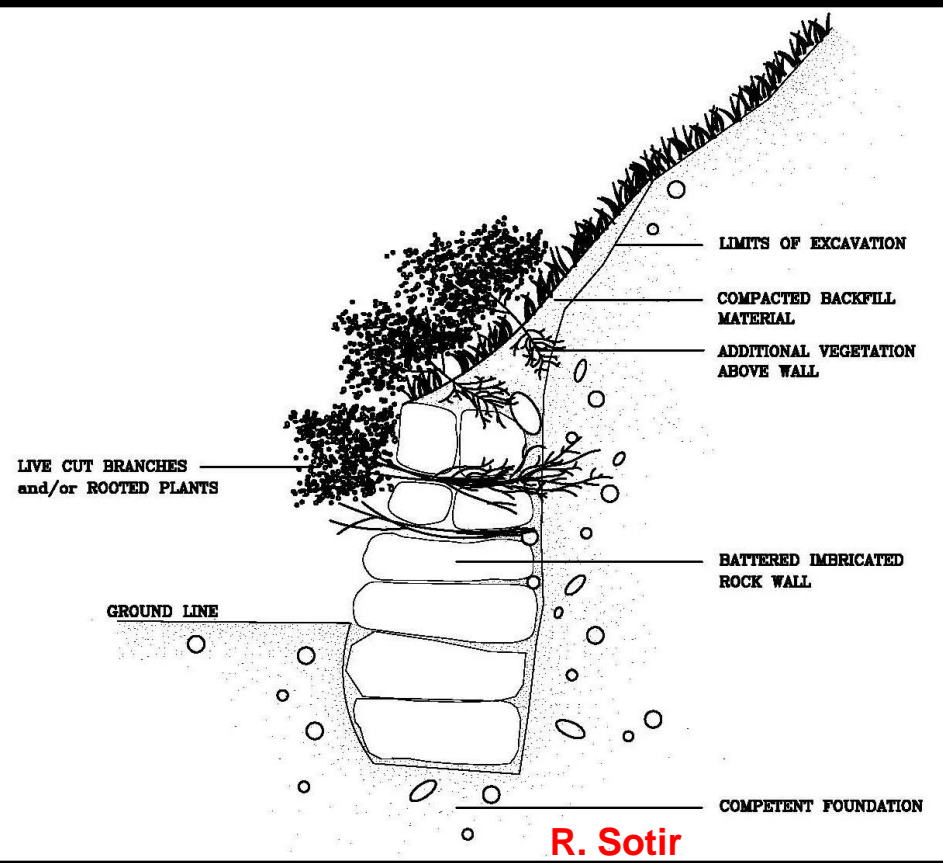
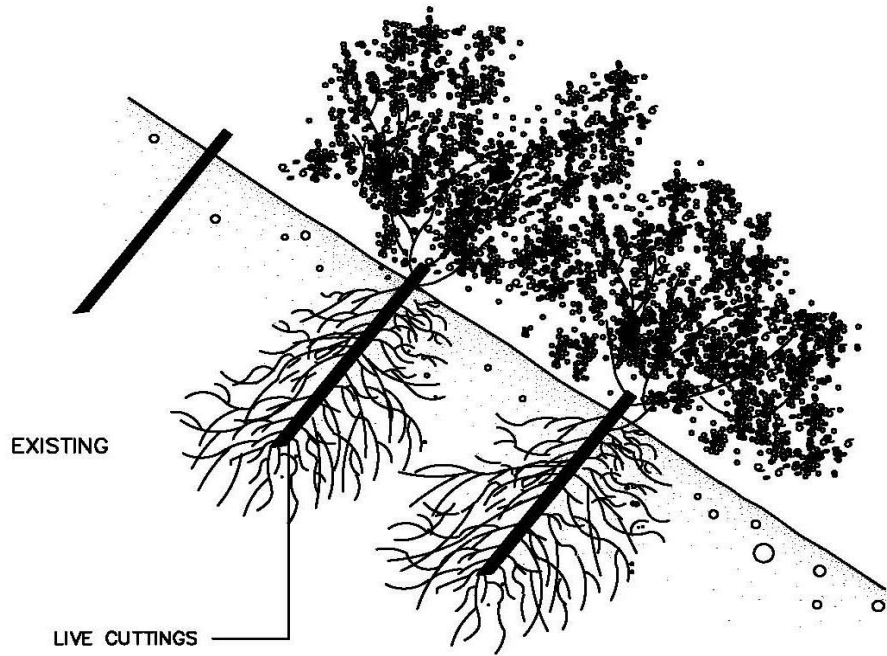
- **Control Drainage**
- **Provide Ground Cover**
- **Use Physical and Vegetative Methods**
- **Thorough Vegetative Cover on Slope**
- **Use Deep Rooted Vegetation**
- **Apply Soil Bioengineering**
- **Provide Gully Control**











Roads Storm Damage Risk Reduction

Web Sites

- www.zietlow.com
- www.desastre.org
- www.dot.ca.gov/hq/esc/techpubs
- www.pubs.asce.org
- www.fhwa.dot.gov/bridge
- www.piarc.org



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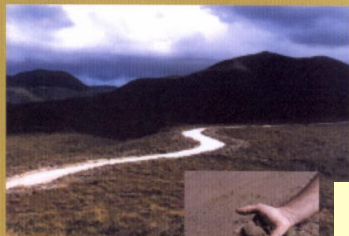
Local Roads Manuals

UNSEALED ROADS MANUAL

Guidelines to Good Practice

Revised July 2000

Unsealed roads
Unsealed roads
Unsealed roads
Unsealed roads



Department
Defence - A



Commonwealth Depa
Transport and Region

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Environmentally Sensitive Maintenance for Dirt and Gravel Roads

- Better Roads
- Better Environment
- Better Community
- Less Maintenance



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March 2006

LOW-VOLUME ROADS ENGINEERING



Best Management Practices Field Guide



Gordon Keller
&
James Sherar



Roads Storm Damage Risk Reduction

References

- **FHWA HEC 18-Scour and HEC 23-Scour Countermeasures**
- **TRB 247-Landslides**
- **ASCE/ FAO-Debris Flows**
- **ASCE-Flood Resistent Design**
- **CALTRANS-Seismic Bridge Retrofits**
- **PIARC-Road Vulnerability**
- **OAS-Disaster Vulnerability**
- **FS-SDTDC-Culvert/Drainage/LWXs**



Thank You!!!

