# Geological Constraints on Road Design and Use:

## *Building Roads that Fit the Landscape*

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# Primary Environmental Constraints on Road Design and Use

- Topography
- Water
- Geology

# Road Design can be Adjusted for Environmental Constraints

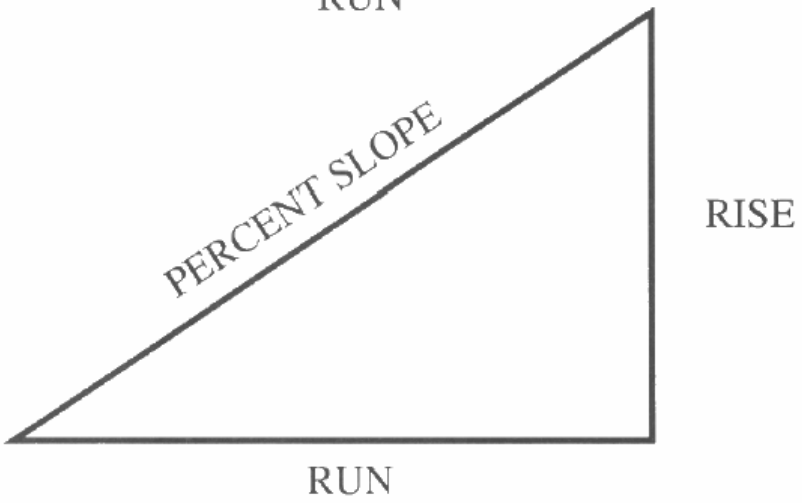
- Good Design can mitigate difficult environmental conditions.
- Poor Design can negate favorable environment conditions.

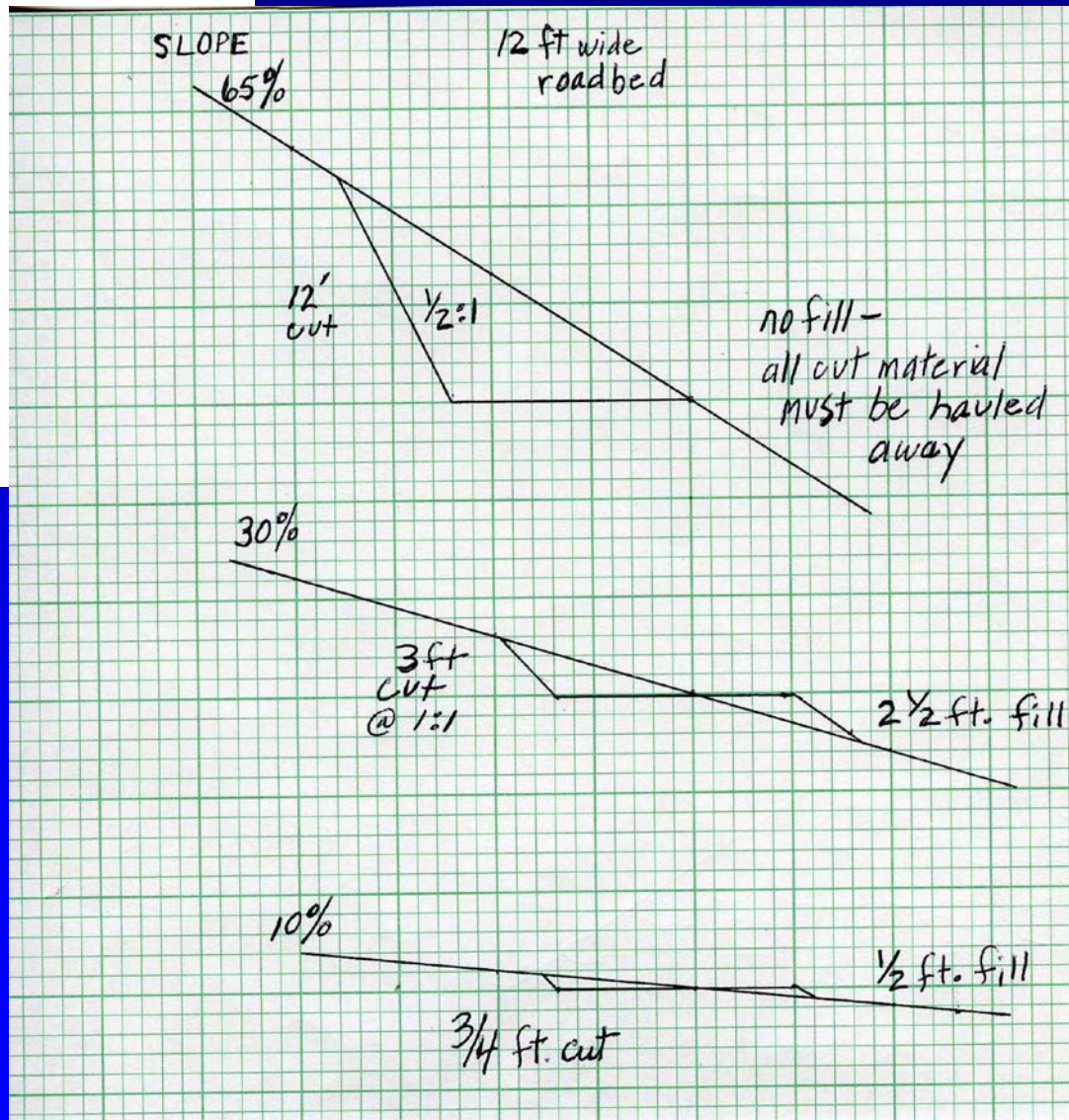
# Good Road Design

- Gentle Road Grades less than 10% are much easier to use and maintain, and are much more forgiving if something goes wrong.
- "Hydrologically Invisible" is the goal. Get water across the road as soon as possible. Less inside ditch; more cross drains, more outsloping

**Figure 2 – Calculation of Percent (%) Slope**

$$\% \text{ Slope} = \frac{\text{RISE}}{\text{RUN}} \times 100$$



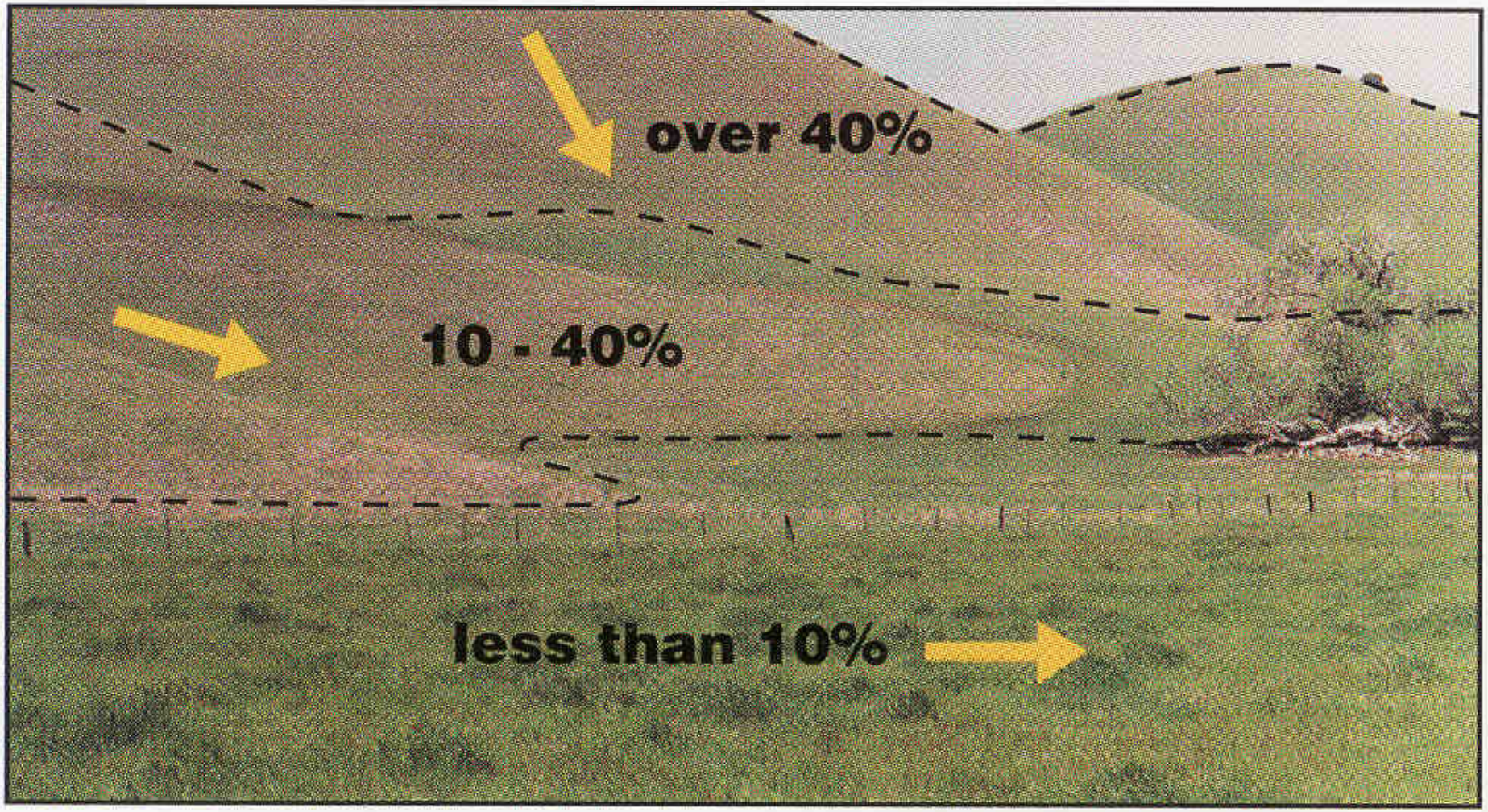



# Topography

- Steep slopes (> 40 %) and low-lying flat (<10%) areas are difficult
- Gentle slopes (10 to 40 % are preferable –

  Gentle slopes minimize:
  - Road grade (road steepness)
  - Excavation and fill volumes

  Examples of gentle slopes
  - Toe slopes
  - Topographic benches
  - Ridge and hill tops



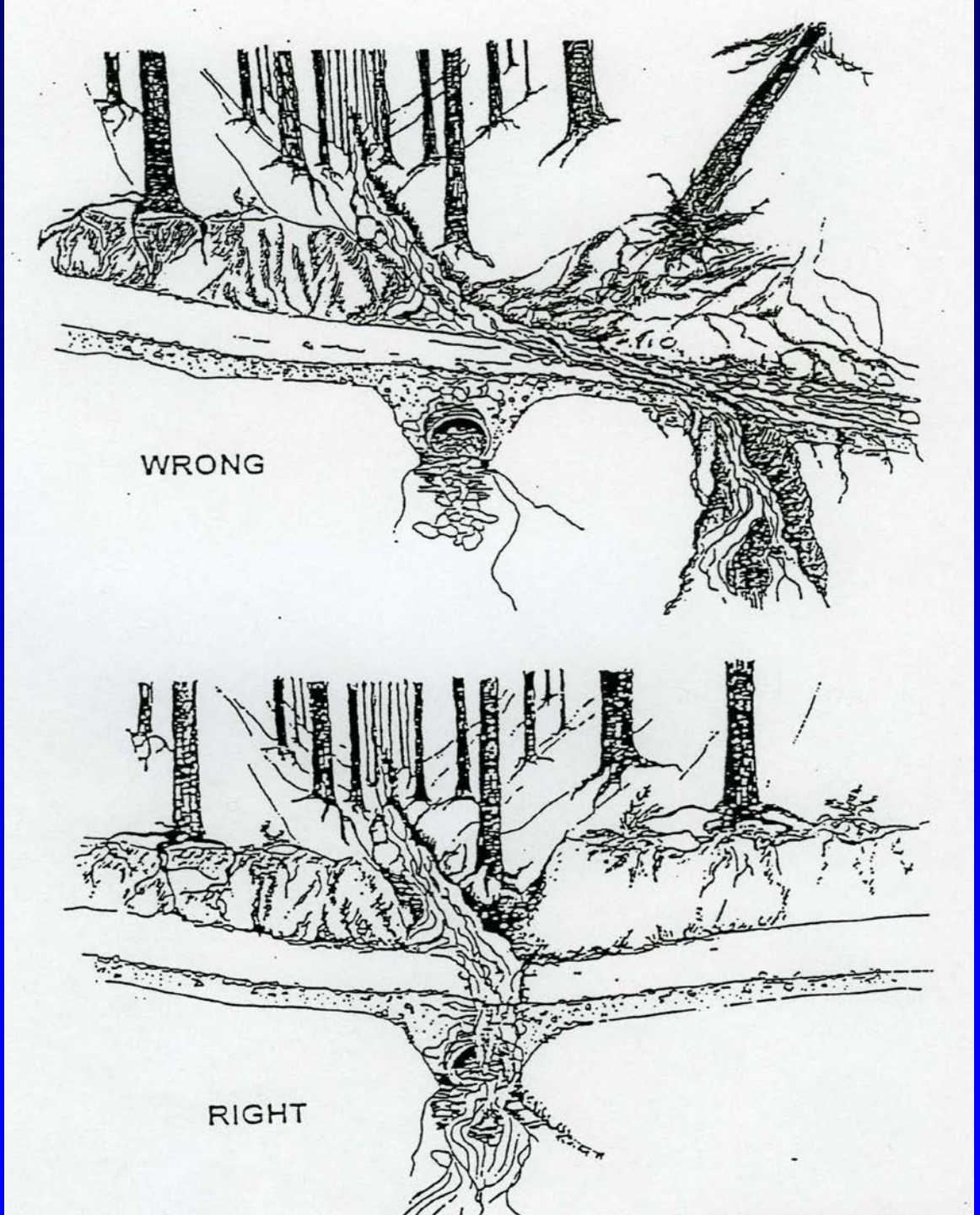

*Wildland Solutions, 1999*

# Topography

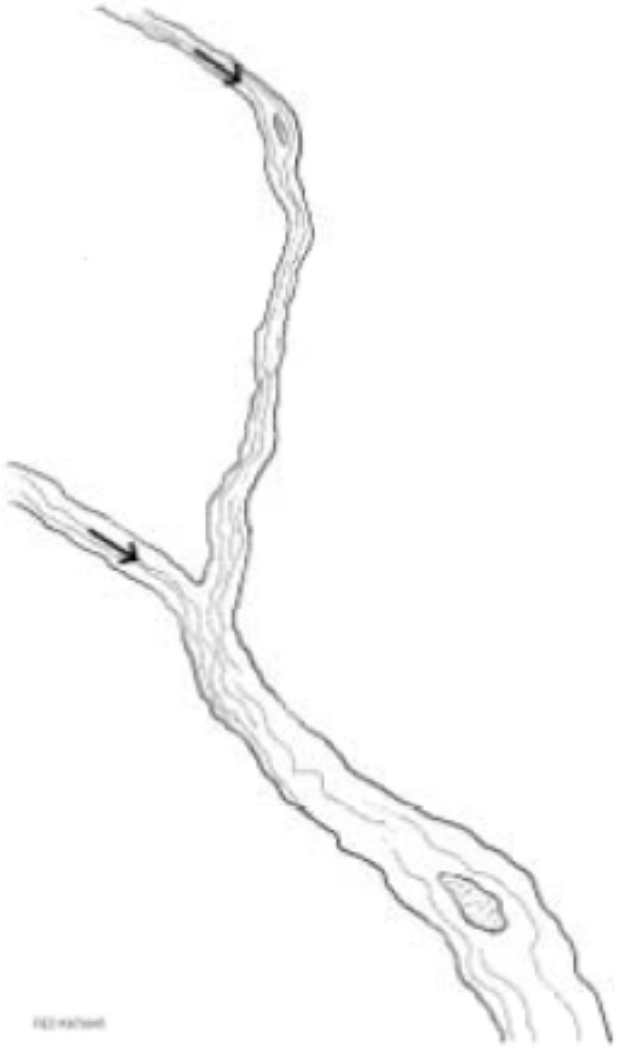
- Gentle slopes:
  - Minimize road grade (steepness)
    - Reduces potential for
      - Erosion of roadbed
      - Stream diversion at watercourse crossings
    - While allowing road surface to drain downslope

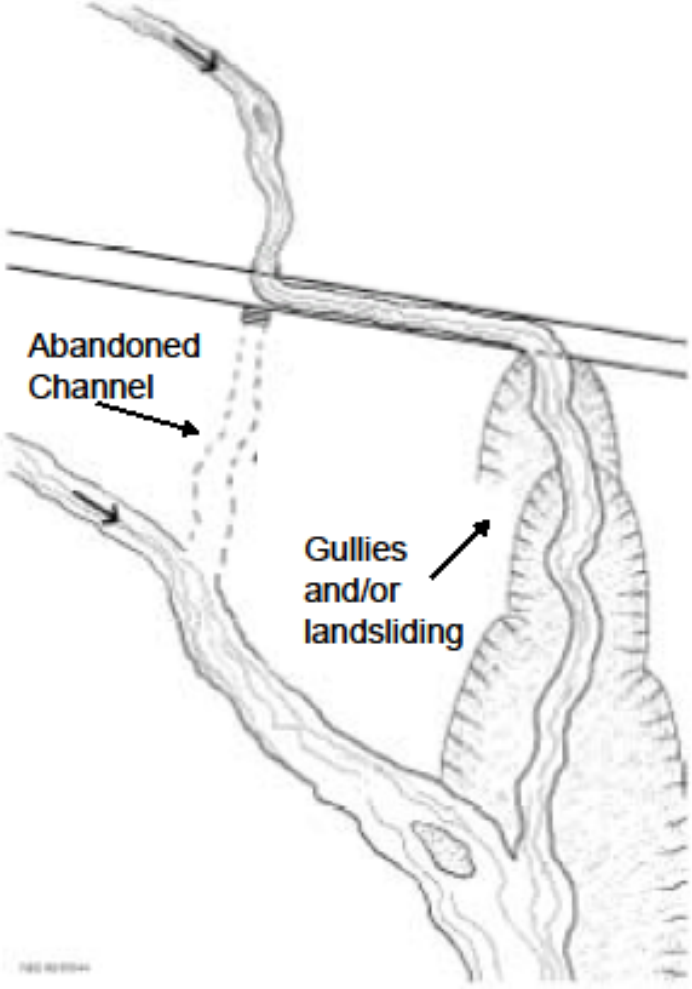
Steep road grades
+
surface water
=
EROSION

Steep road grades + watercourse crossing = high stream-diversion potential



# Road Segment Hydrology – Stream Diversion






(Furniss et al., 1997)

Low-lying horizontal grades (hard to drain)

+

surface water

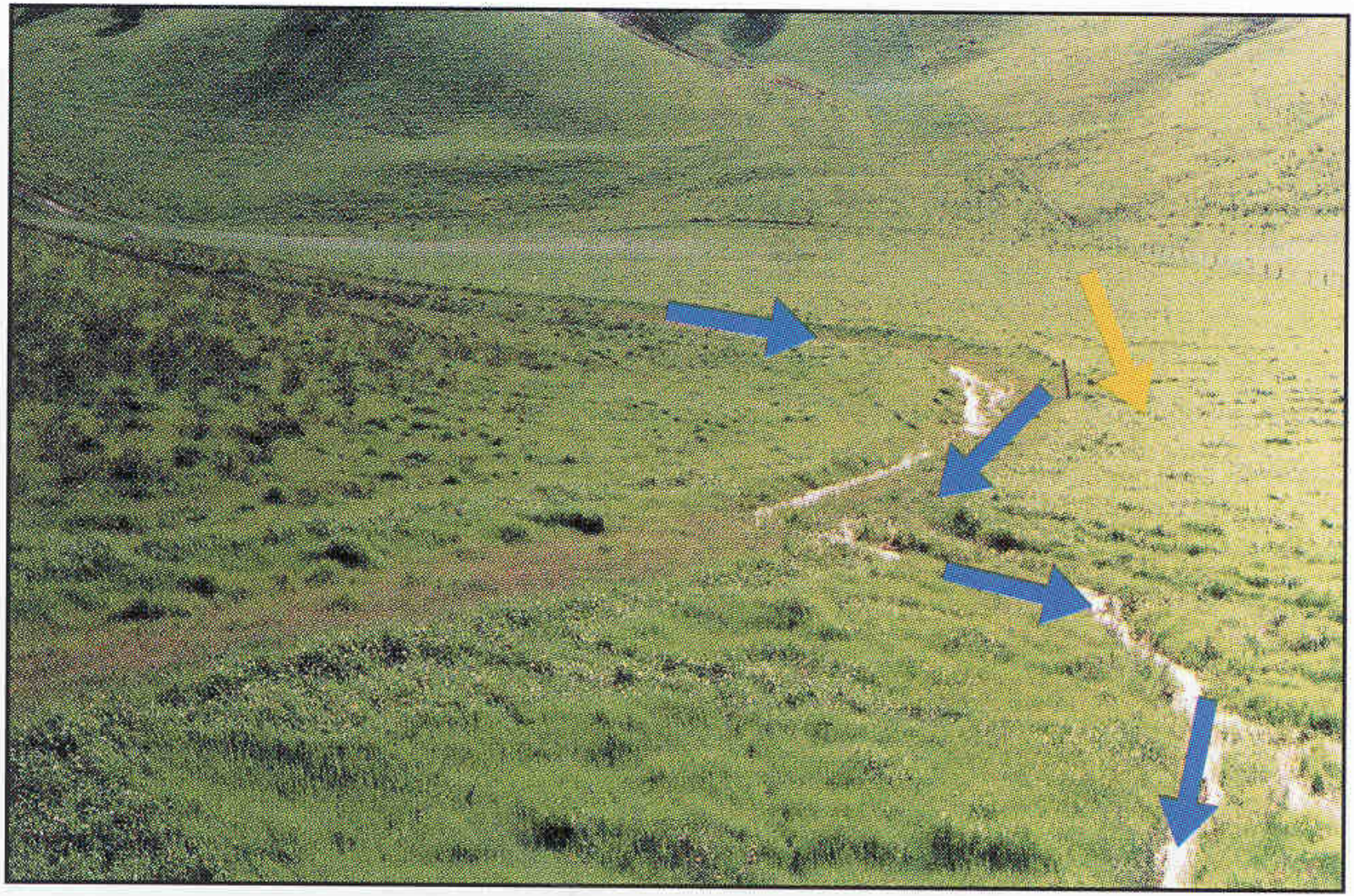
=

<u>WET</u>

road prism

**Problem**

# *Road in drainage bottom – cannot drain*



***Wildland Solutions, 1999***

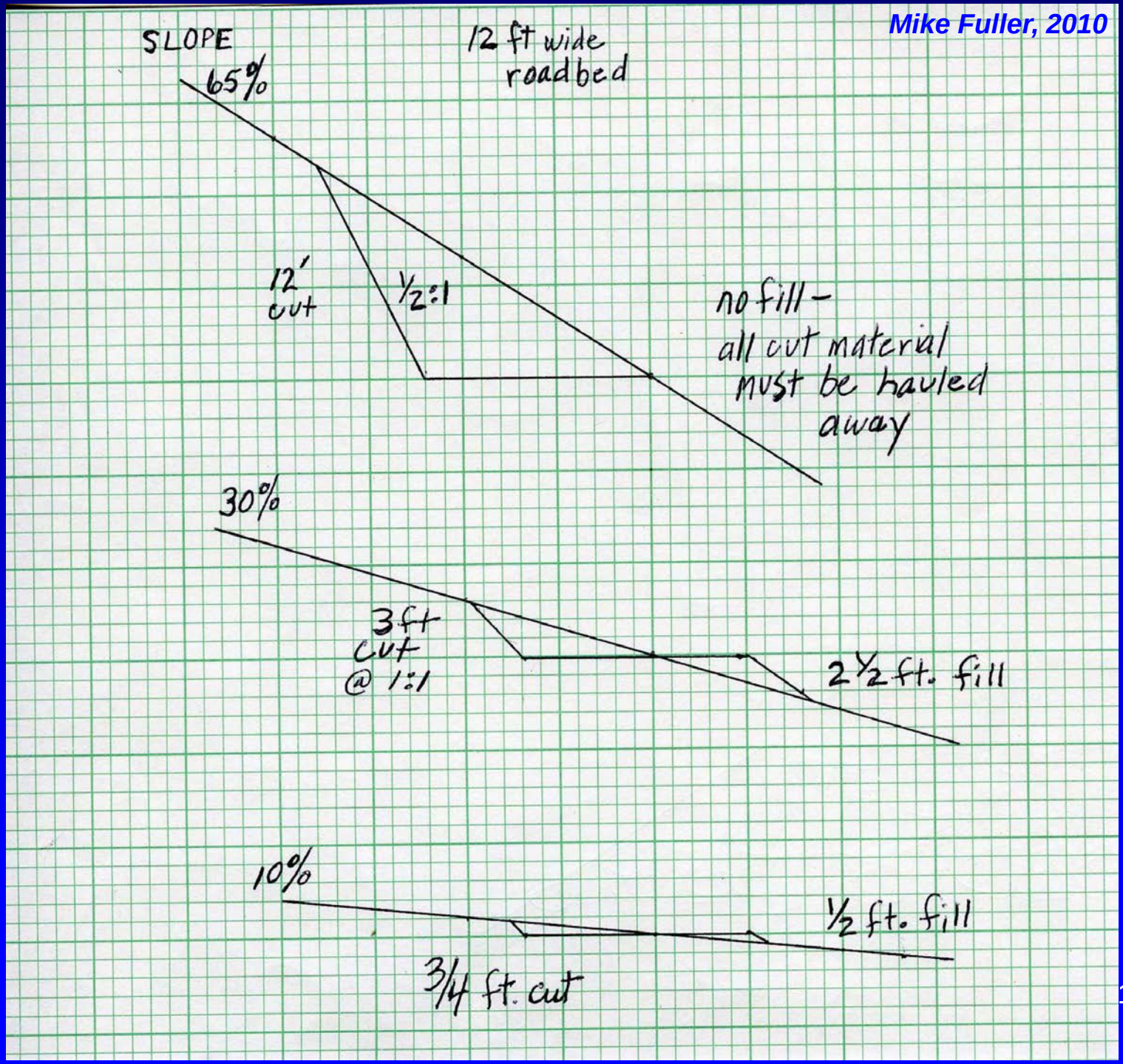
# **Solution**: *Reroute road to adjacent low-angle toe slope and outslope road*


*Wildland Solutions, 1999*

# Topography

- Gentle side slopes minimize:
  - Excavation and fill
    - Shorter and less steep
      - Cutslopes
      - Fillslopes
    - Less likelihood of
      - Cutslope failure
      - Fillslope failure

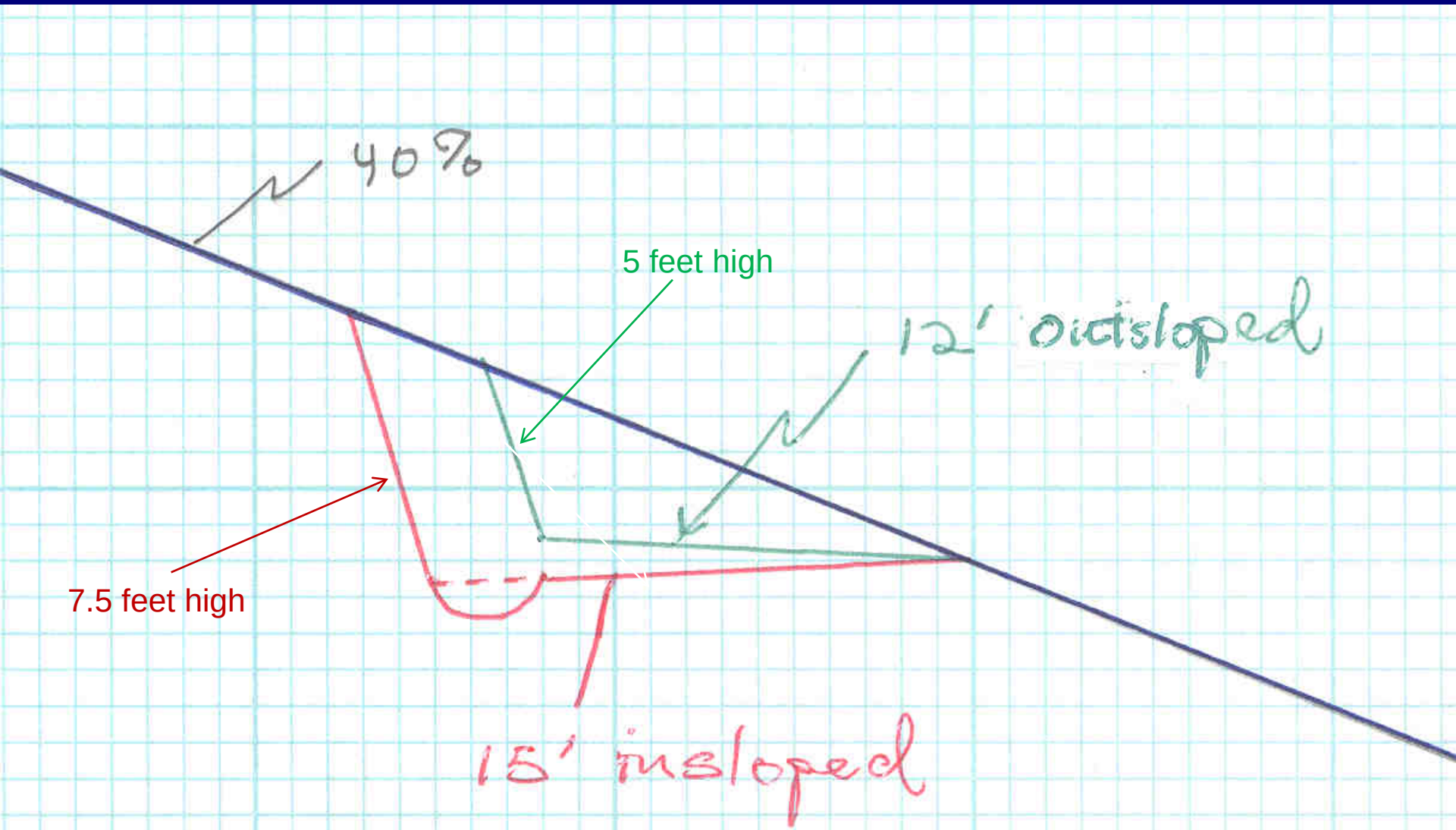
Mike Fuller, 2010




Oversteep (near vertical) cutslope
Cut failure
Uncontrolled water
Fill failure in oversteep or uncompacted fill material
Loose sidecast fill on a steep slope

# Road Design

- Outsloped roads (versus insloped w ditches):
  - Drain better
  - Shorter cutslope (≈1/3 shorter)
  - Less spoils from excavation (>50% less)


40%
5 feet high
12' outsloped
7.5 feet high
15' insloped

# Water

- Streams
- Wet areas

# Water

- Streams

  Stay away from except to cross

  - Road effects on streams
  - Stream effects on roads

# Road Effects on Streams

- Can Increase Sediment Discharge to Streams
- Can Increase Stream Peak Flow – Flood Crest
- Road effects reduced by increasing distance between road and stream (buffer effects)

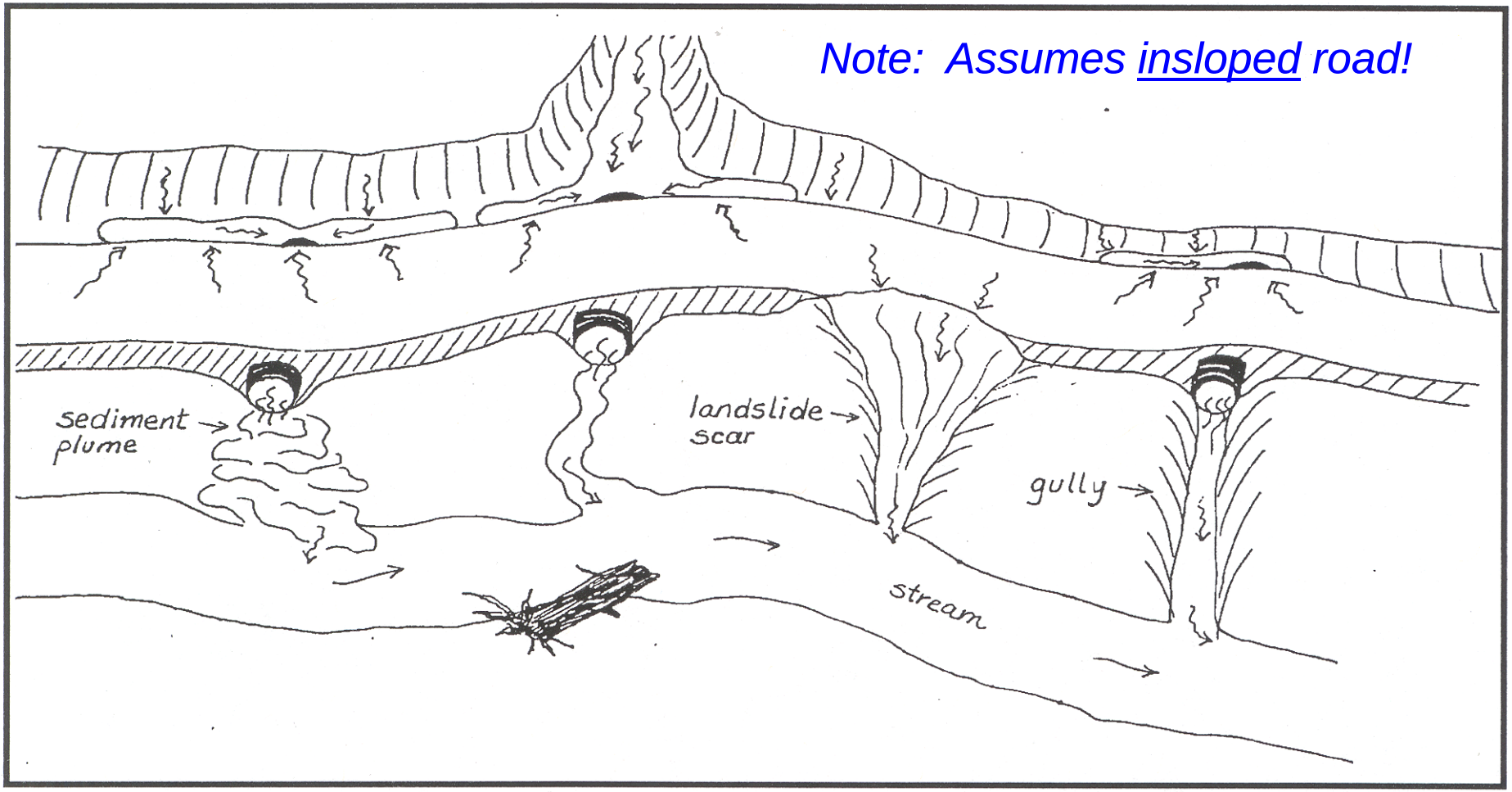
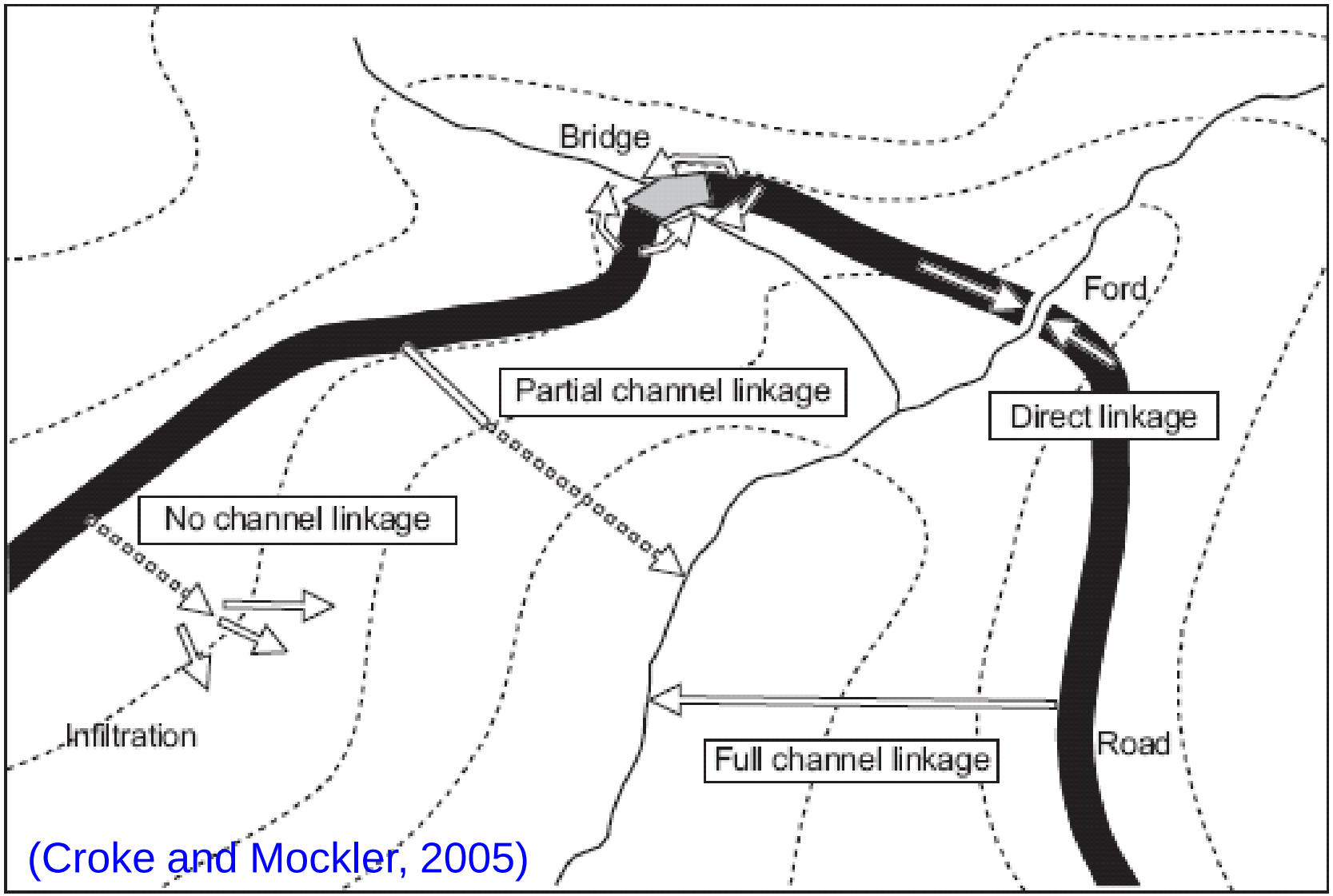



**Figure 1-2. How roads can be connected to streams.**

# Road Segment Hydrology – Connectivity to Surface Water




(Croke and Mockler, 2005)

# Road Effects on Streams

Stream peak flows increased by

- *Runoff from compacted road surface, cutslope, fillslope.*
- *Interception of shallow groundwater by cutslope.*

# *How subsurface water comes off hillslopes***

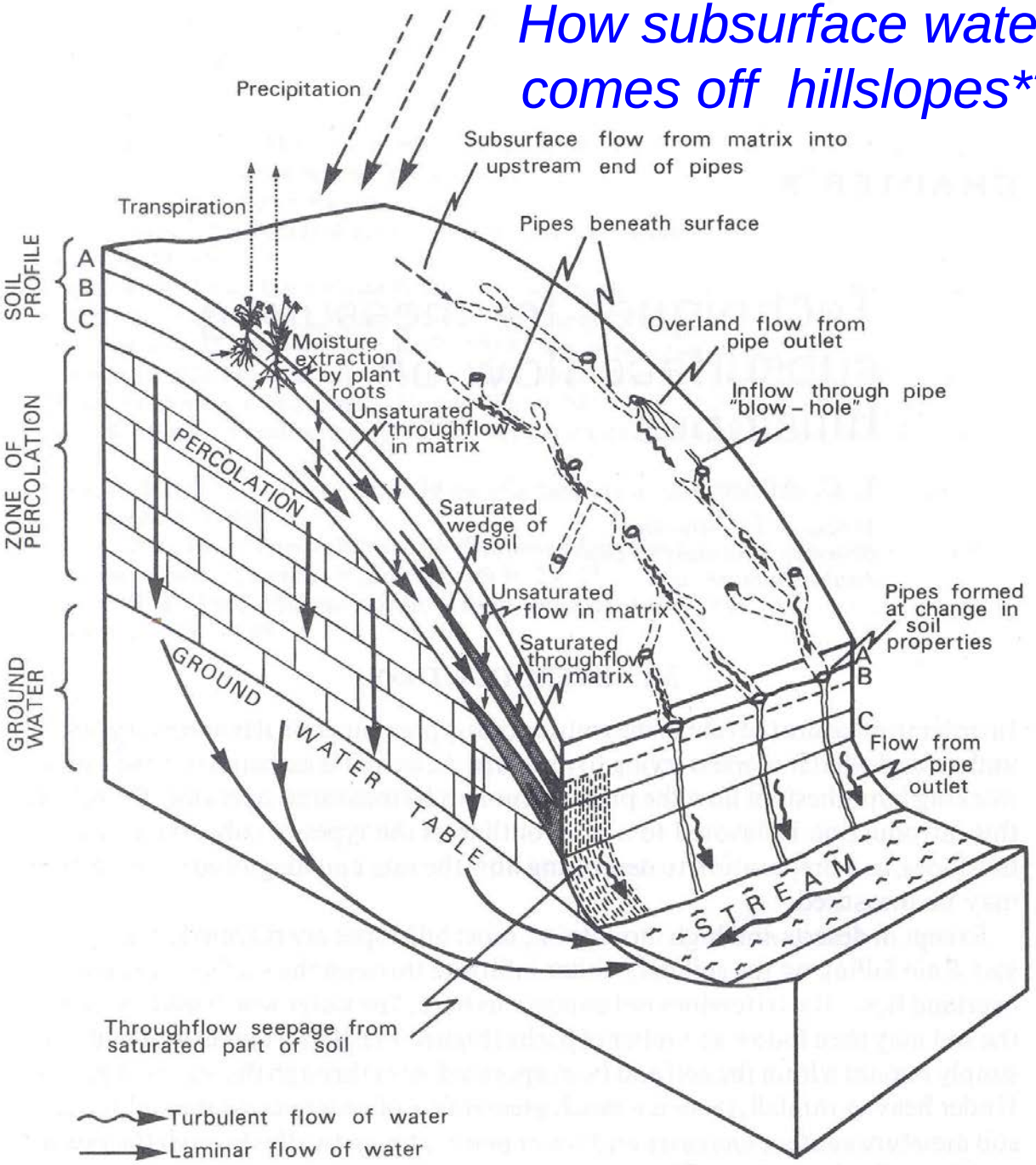



Figure 3.1 Flow routes followed by subsurface runoff on hillslopes

*Atkinson, 1978*

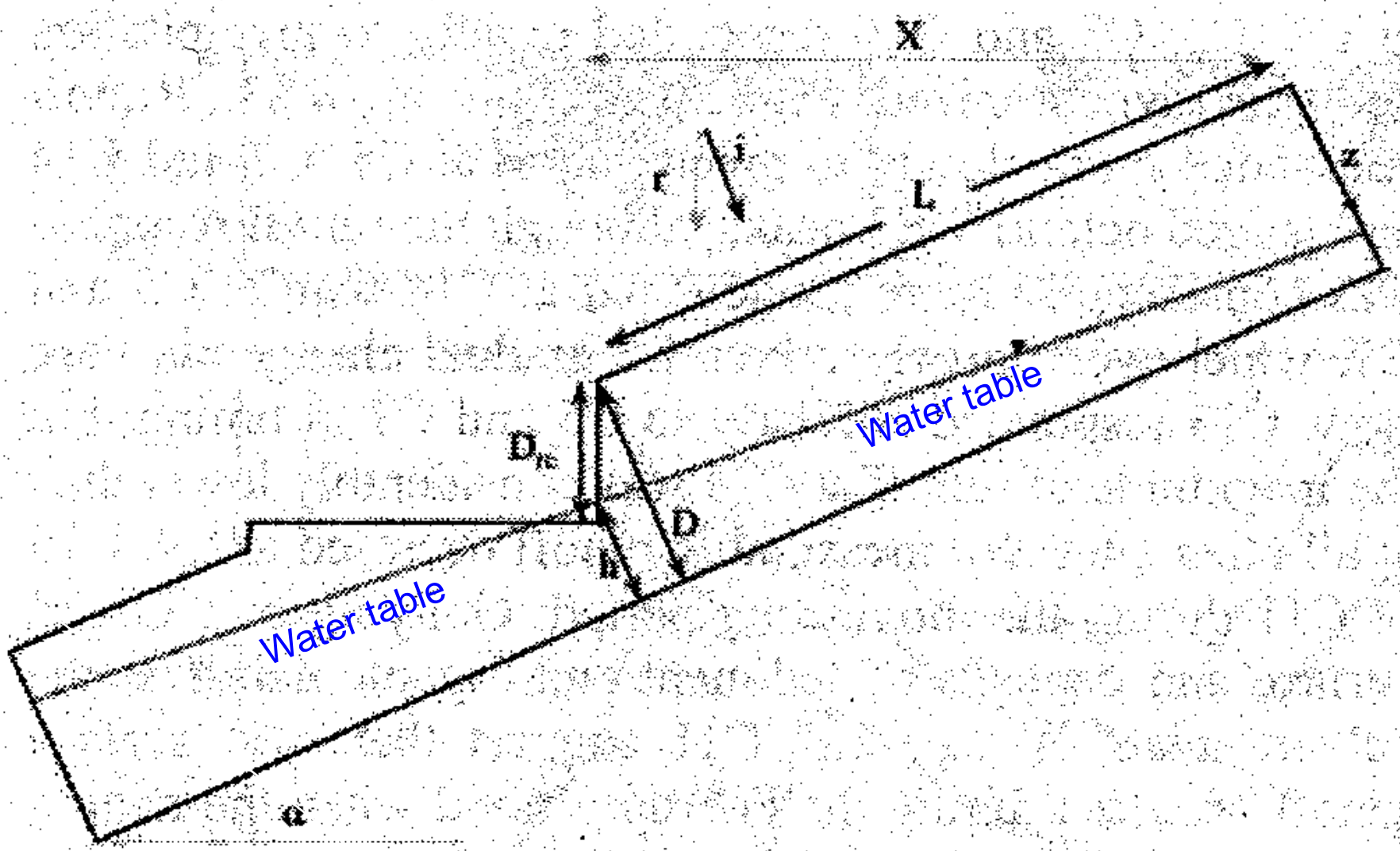
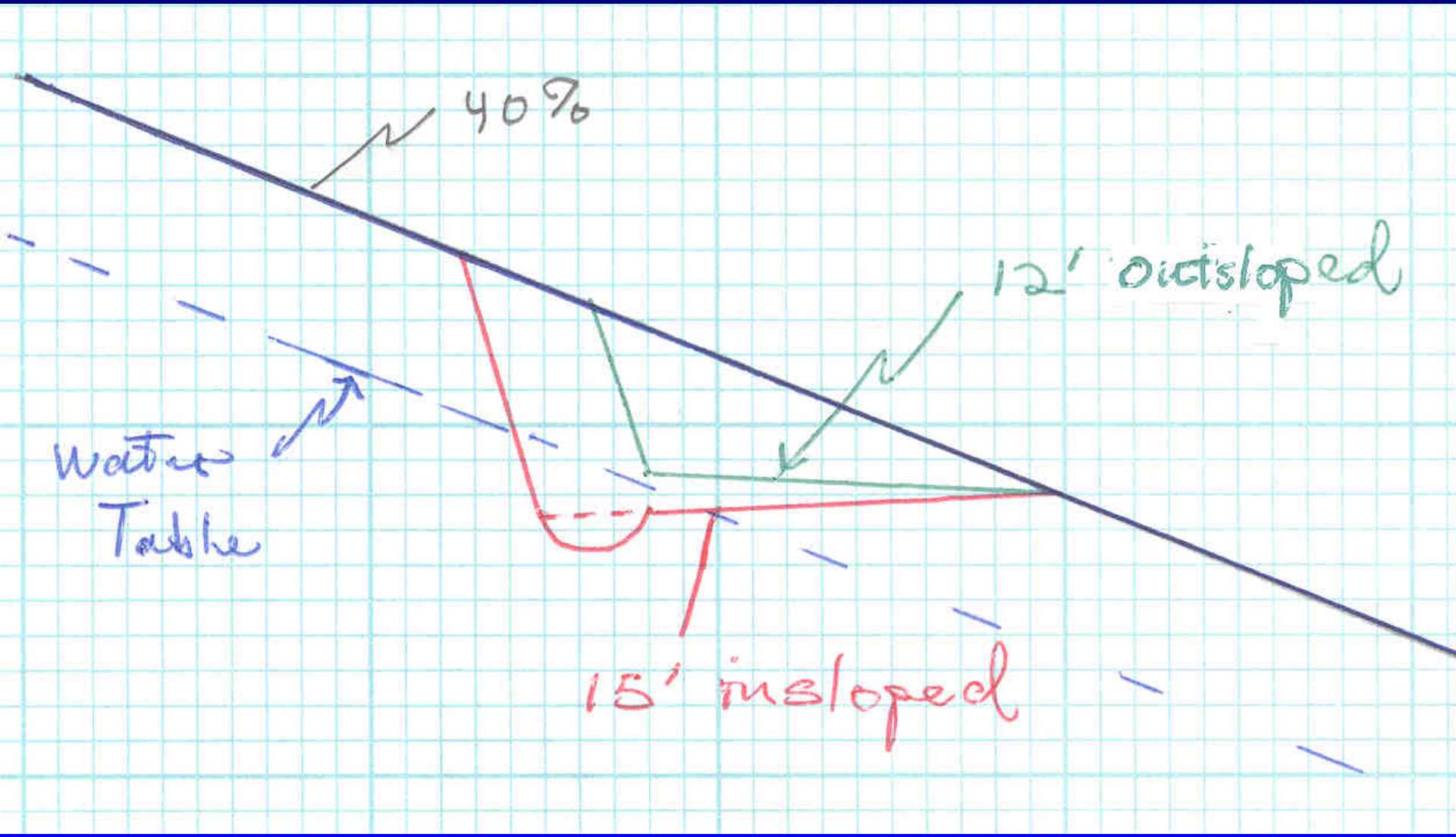



**Figure 3.** Schematic diagram illustrating the interaction of the hillslope water table with the road cut and parameters used in calculations.

# Road Effects on Streams

- Interception of shallow groundwater minimized by:
  - Smaller road width
  - Outsloping
    - Eliminates inner ditch,
    - Narrows the road width
    - Raises inside edge of road


40%
12' outsloped
Water Table
15' insloped

# Stream Effects on Roads

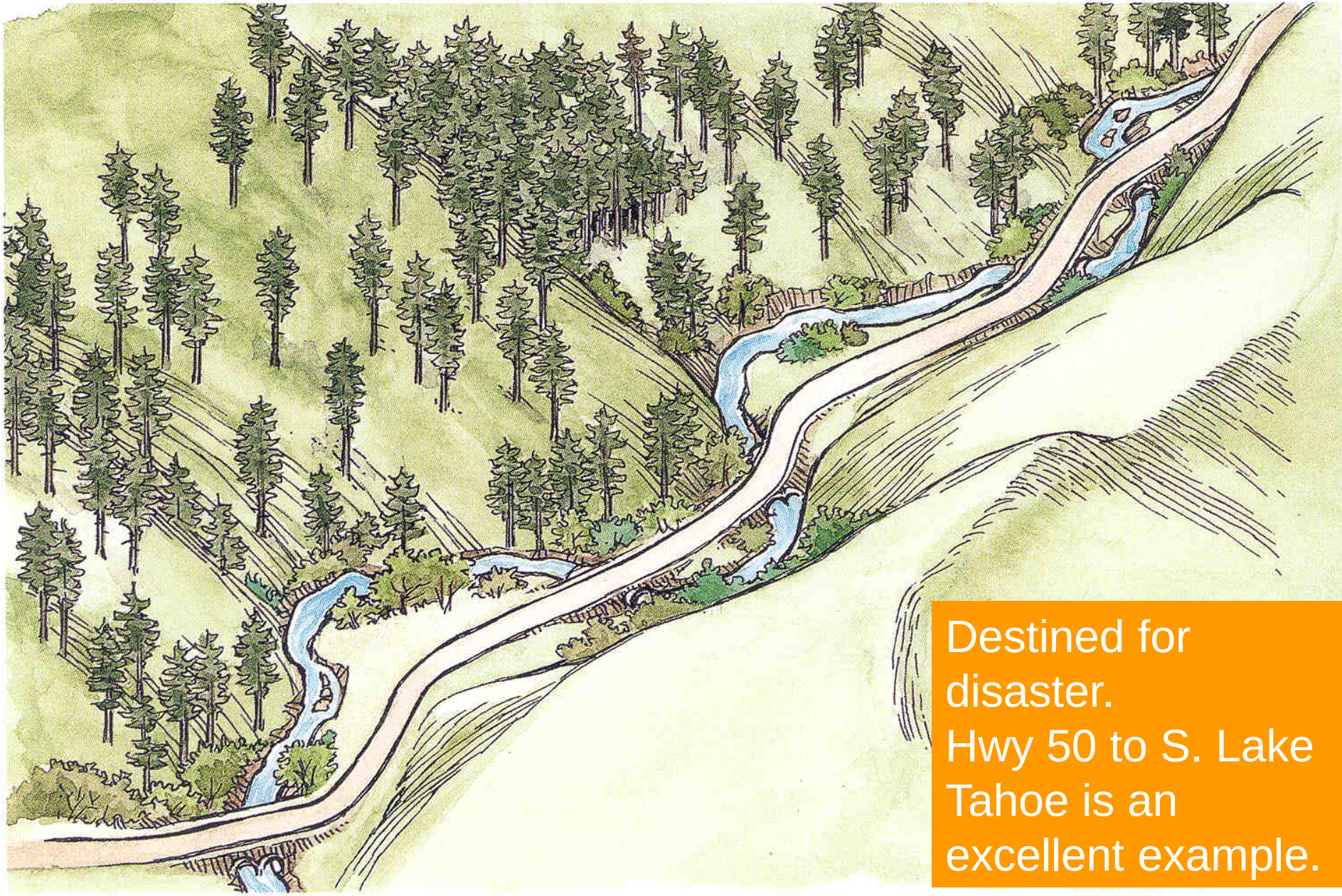
- Inner gorges along streams
  - Unstable
  - Poor location for roads (unstable, too close to stream)

- Road located near valley bottom must cross tributary streams.

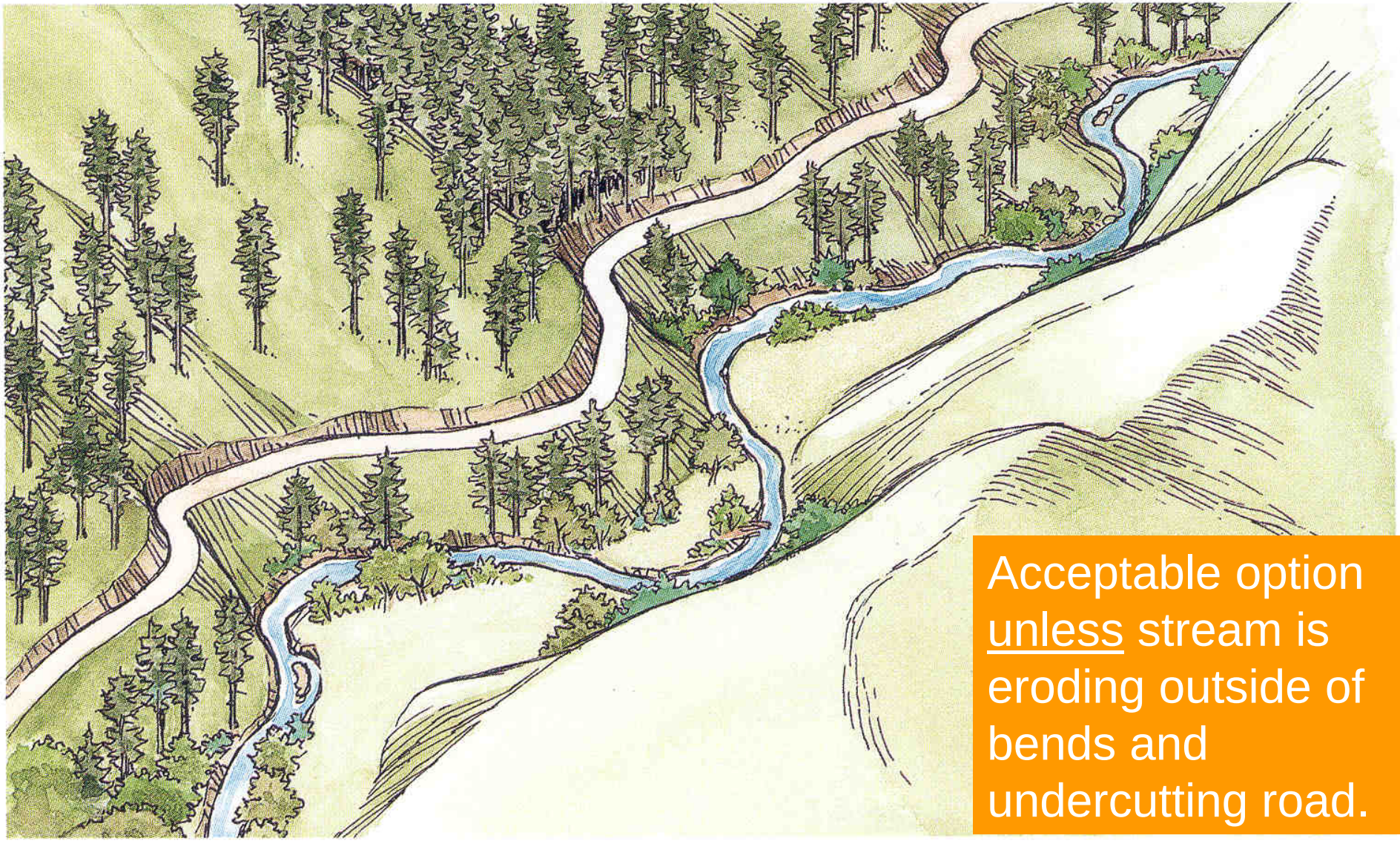
- Lateral erosion may erode roadway if located close to stream.

*Keep roads away from streams!*


Inner Gorge



Destined for disaster.
Hwy 50 to S. Lake Tahoe is an excellent example.

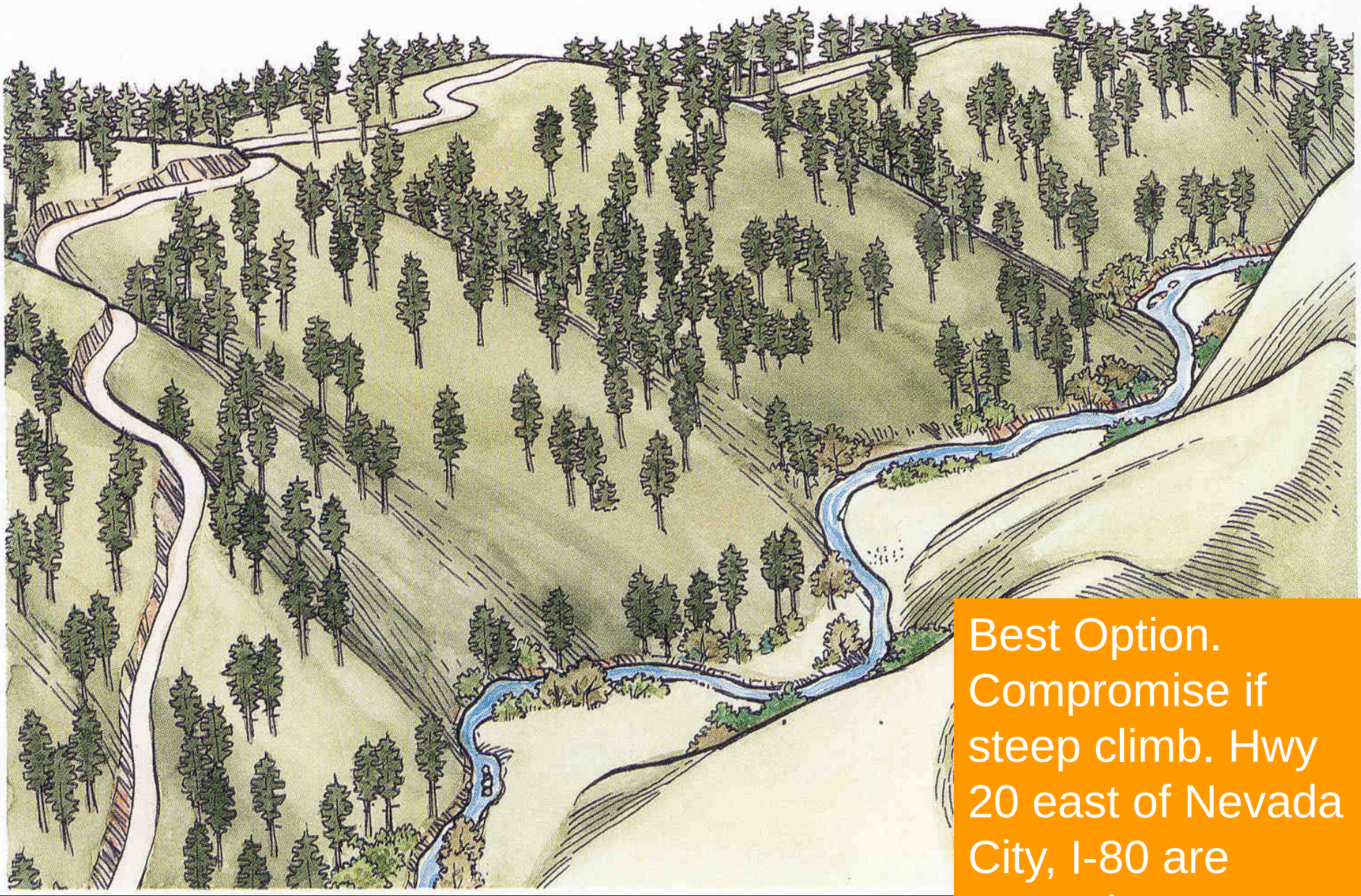


Acceptable option <u>unless</u> stream is eroding outside of bends and undercutting road.

*Road failure caused by stream undercutting*

# Stream Effects on Roads

- Best to locate roads up on ridge tops if possible – away from potential adverse effects of the stream.



Best Option. Compromise if steep climb. Hwy 20 east of Nevada City, I-80 are examples.

*Oregon Forest Resources Institute, 2002*

# Stream Effects on Roads

- Crossings
  - Expensive to install, maintain
  - Failure potential

Best to avoid stream crossings if possible!

# Wet Areas

How to Identify –

- Water present on ground surface
- Water-loving plants (horsetail, maple, dogwood, etc.) = hydrophytes
- Green areas when all else is dried up

# Wet Areas

Problems –

- Possible surface drainage across road and sediment to streams
- Seepage into road prism

*(Don Lindsay will address road drainage next)*

- Soft soils and road substrate

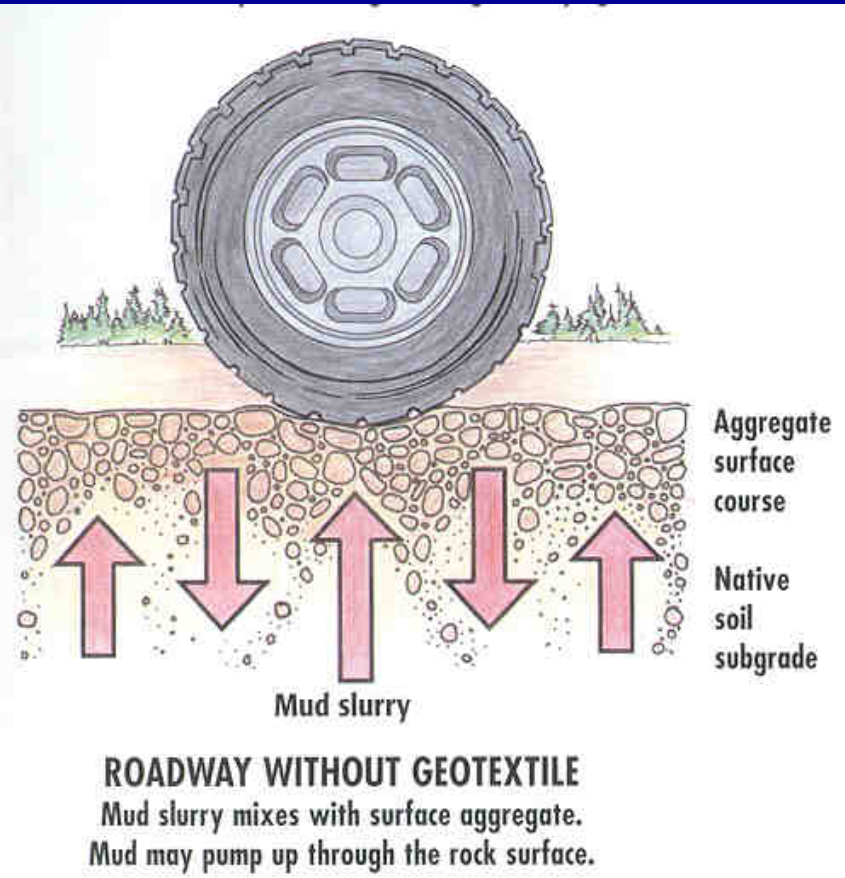
*Results in rutting*

# Wet Areas

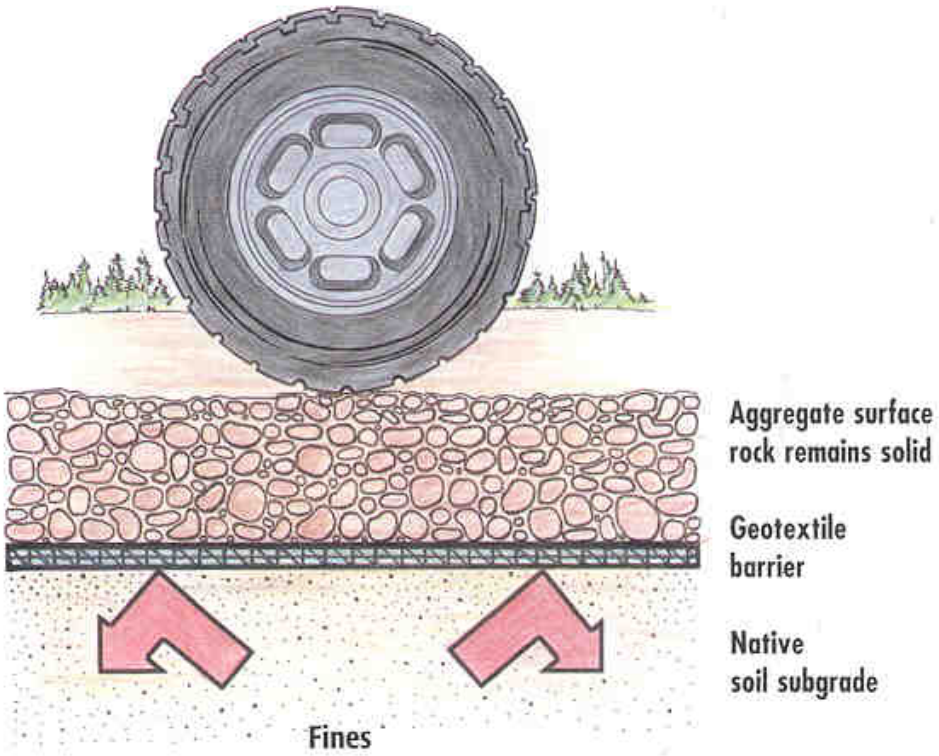
Mitigations –

- Avoid wet areas if possible
- Drain wet areas *(Don Lindsay will address)*
- Use Geotextile as a separator on soft soils

# Use Geotextile as a separator




**ROADWAY WITHOUT GEOTEXTILE**
Mud slurry mixes with surface aggregate.
Mud may pump up through the rock surface.

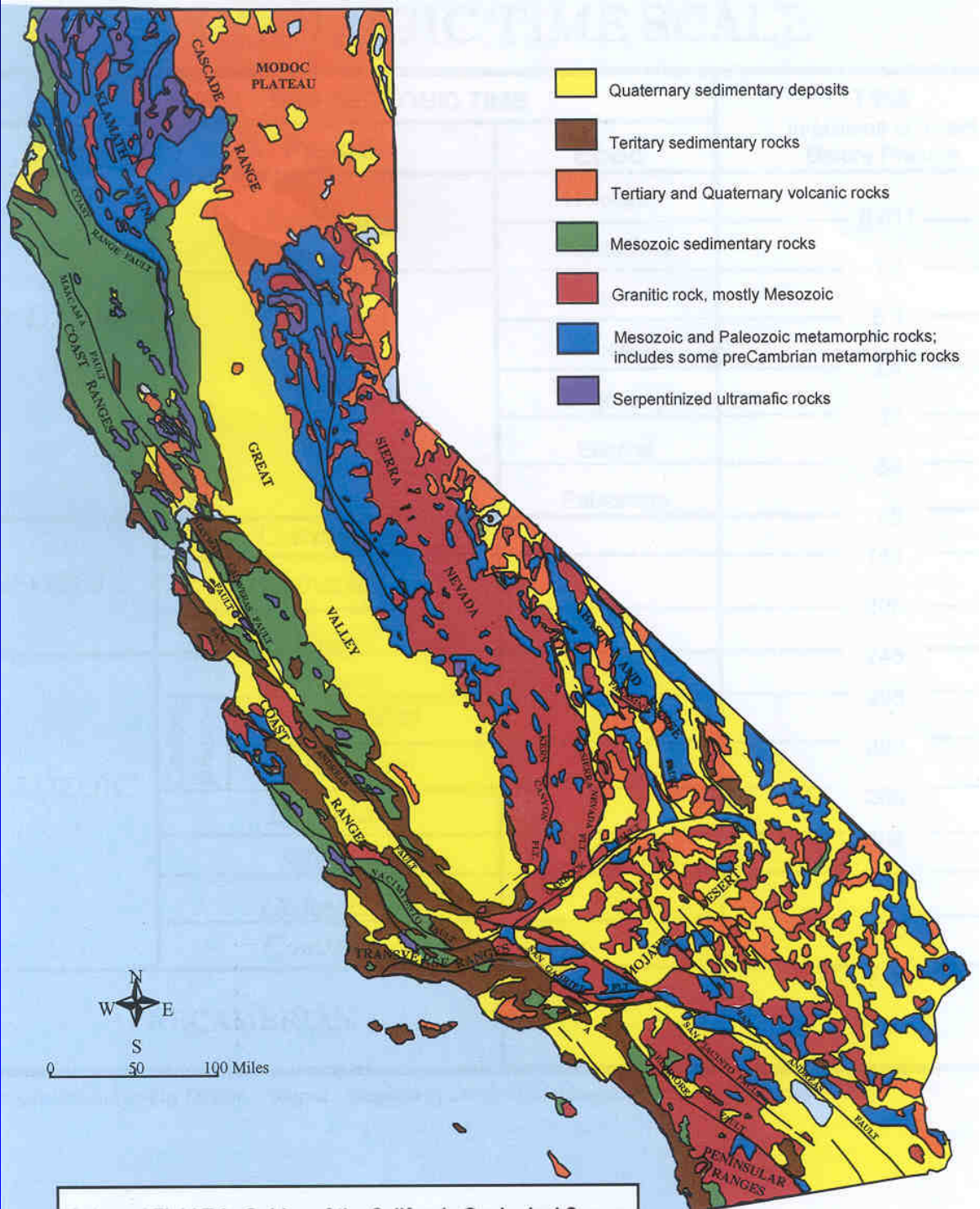



**ROADWAY WITH GEOTEXTILE**
Fines are stopped by geotextile

Geotextiles are used to reinforce subgrades by spreading the load over a larger area. This reduces the chance of settling and failure. It also allows road construction over wet areas, reducing the need to remove unsuitable roadbed material.

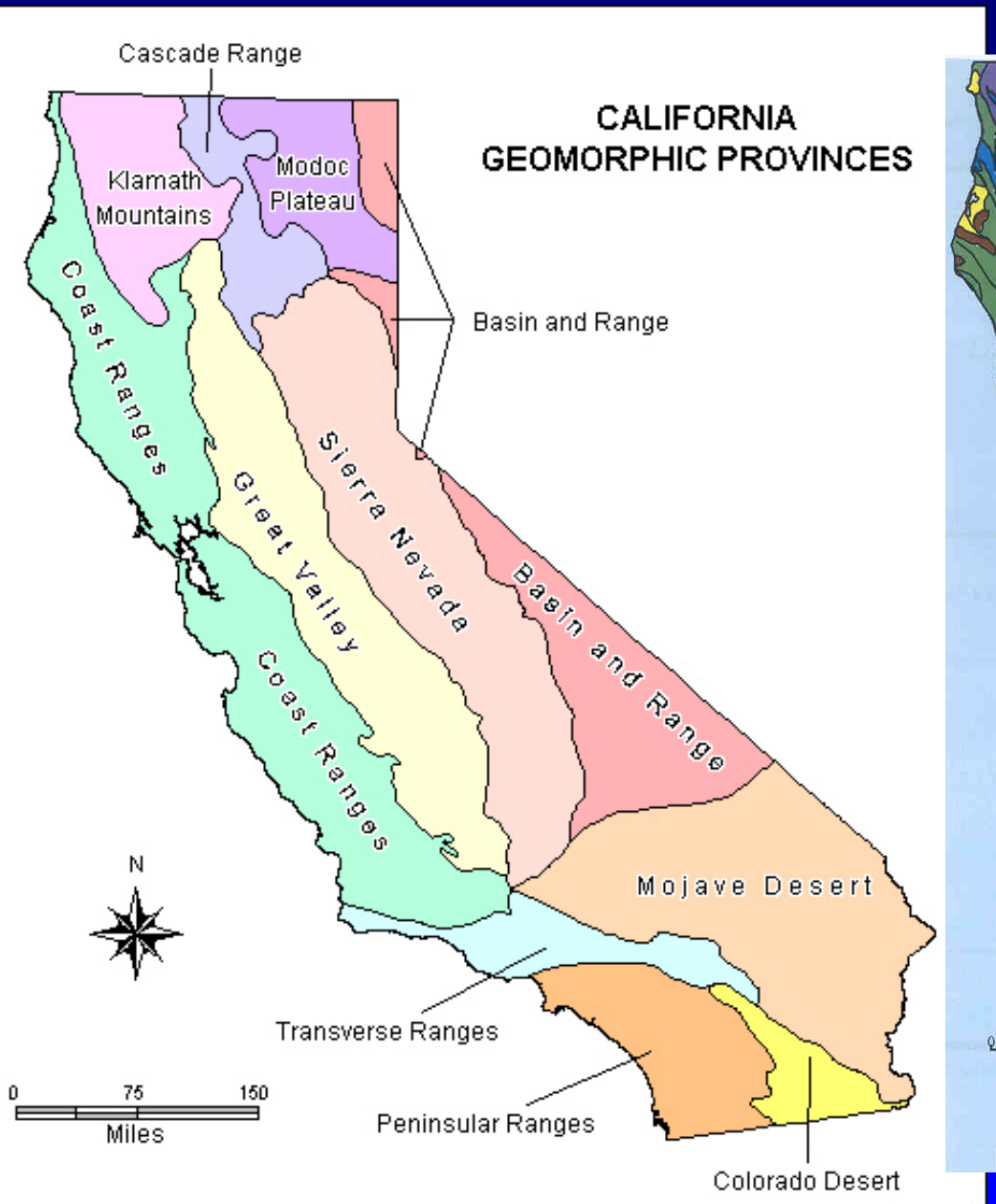
# Geology

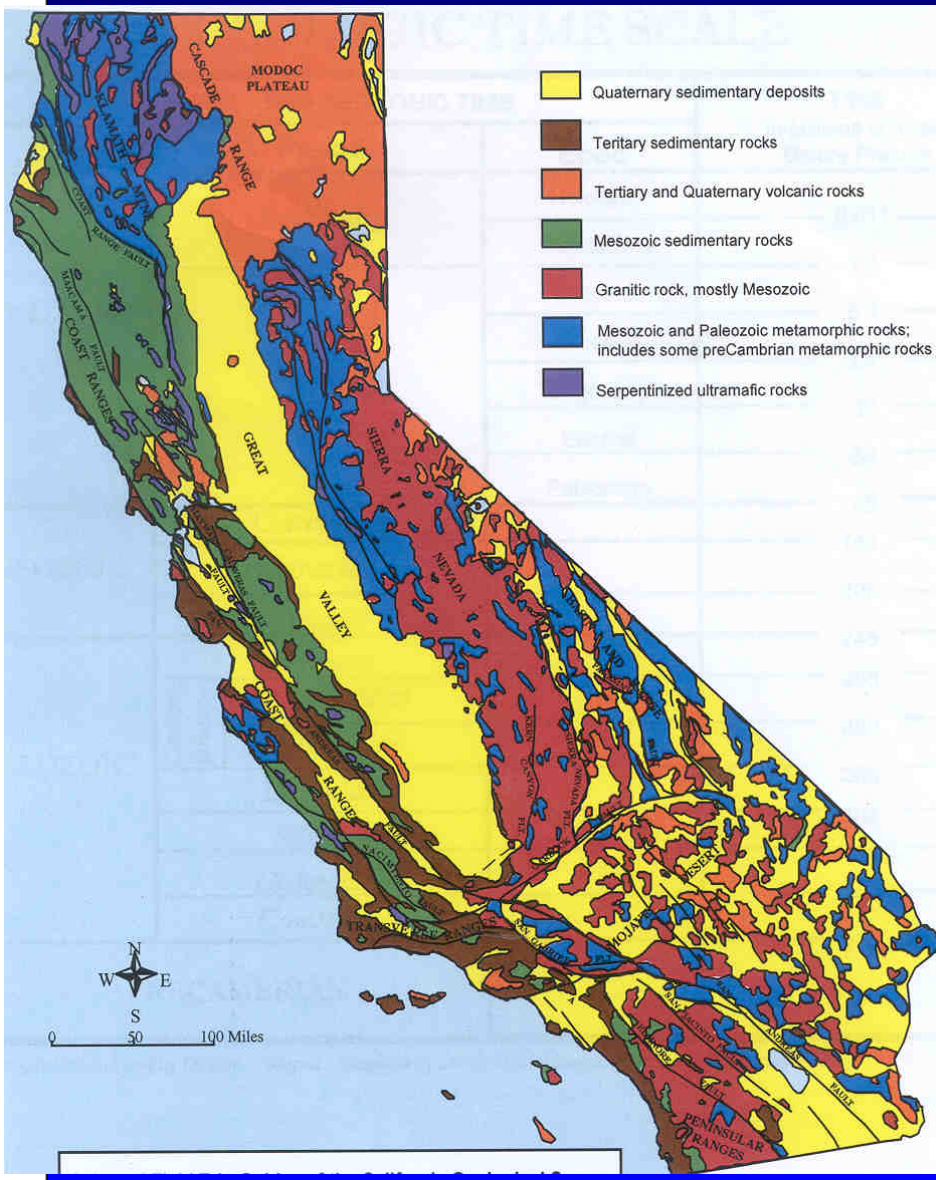
- Geology of California
- Road problems resulting from geology

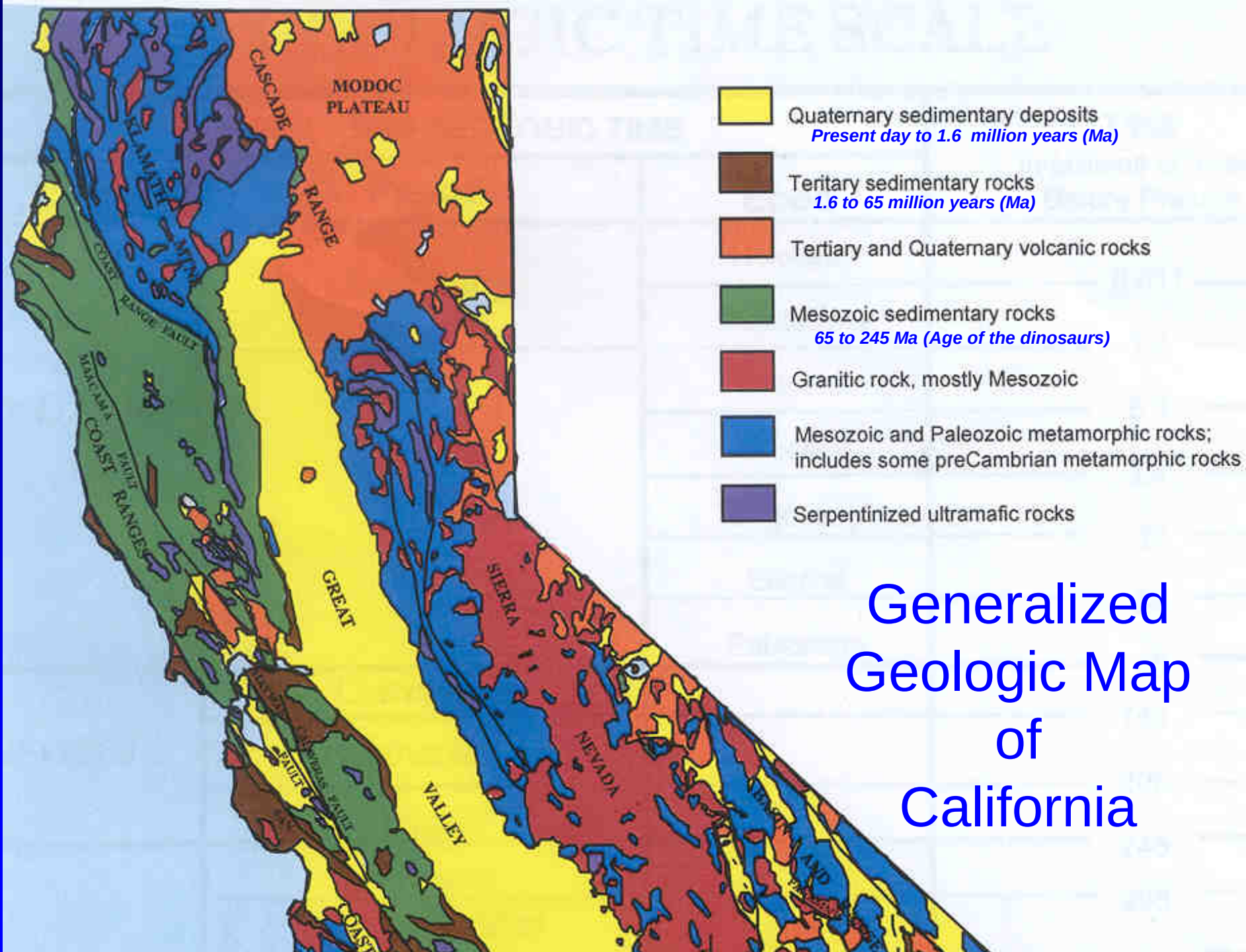



| Geologic Time Scale | |
|---|---|
| **Era or Period** | **Age** *(Millions of Years Before Present (Ma))* |
| Quaternary | Present day to 1.6 Ma |
| Tertiary | 1.6 Ma to 65 Ma |
| Mesozoic | 65 Ma to 245 Ma |
| Paleozoic | 245 to 570 Ma |
| Precambrian | Older than 570 Ma |

# Generalized Geologic Map of California


Cascade Range
CALIFORNIA
GEOMORPHIC PROVINCES
Klamath Mountains
Modoc Plateau
Basin and Range
Coast Ranges
Great Valley
Sierra Nevada
Basin and Range
Coast Ranges
Mojave Desert
N
Transverse Ranges
0 75 150
Miles
Peninsular Ranges
Colorado Desert


Quaternary sedimentary deposits
Teritary sedimentary rocks
Tertiary and Quaternary volcanic rocks
Mesozoic sedimentary rocks
Granitic rock, mostly Mesozoic
Mesozoic and Paleozoic metamorphic rocks; includes some preCambrian metamorphic rocks
Serpentinized ultramafic rocks
MODOC PLATEAU
CASCADE RANGE
GREAT VALLEY
SIERRA NEVADA
PENINSULAR RANGES
N
W E
S
0 50 100 Miles




# Generalized Geologic Map of California

# Geology

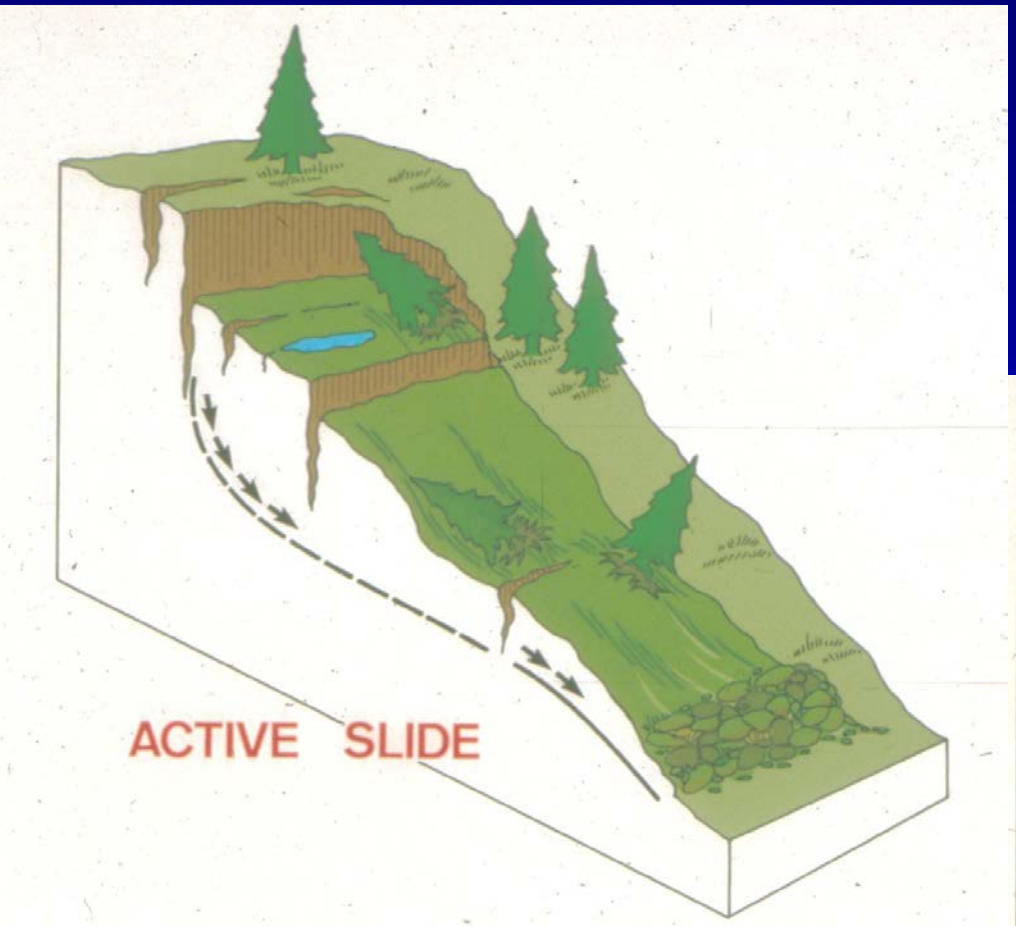
- California geologic information available through California Geological Survey (CGS)

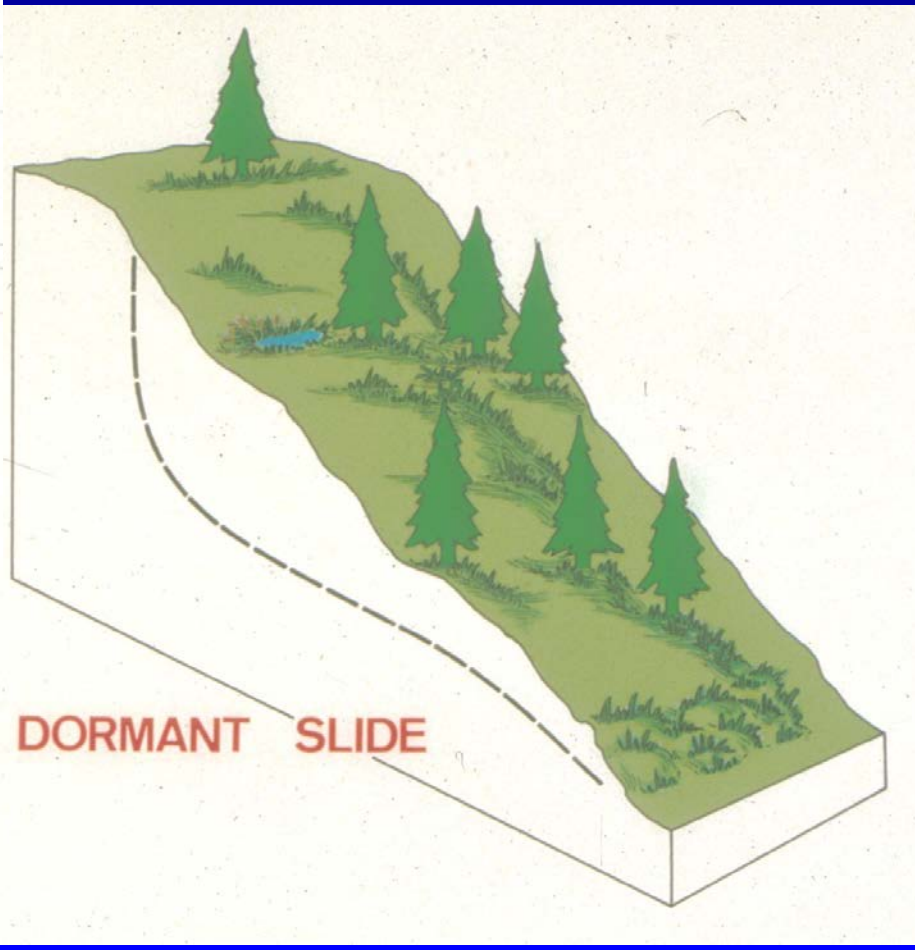
# Geology

- Problems resulting from geology
  - Unstable soils (landslides)
  - Rockslides, rock fall
  - Erodible soils (esp. DG soils)
  - Asbestos-bearing rock units

# Unstable area characteristics

- Tension cracks and headwall scarps
- Leaning, jackstrawed, or split trees are common
- Trees with excessive sweep
- Evidence of impaired groundwater movement
  - Sag ponds, springs, patches of wet ground, hydrophytic (water-loving) vegetation
- Short irregular surface drainages begin and end on the slope
- Hummocky topography
  - Rolling bumpy ground
  - Frequent topographic benches
  - Frequent closed depressions


ACTIVE SLIDE


DORMANT SLIDE

*Arc-shaped cracks in sidecast fill are evidence of a landslide starting to move*

# Geology

- Unstable areas
  - Types of slides
    - Deep-seated (rotational) *(cohesive, clay-rich soils)*

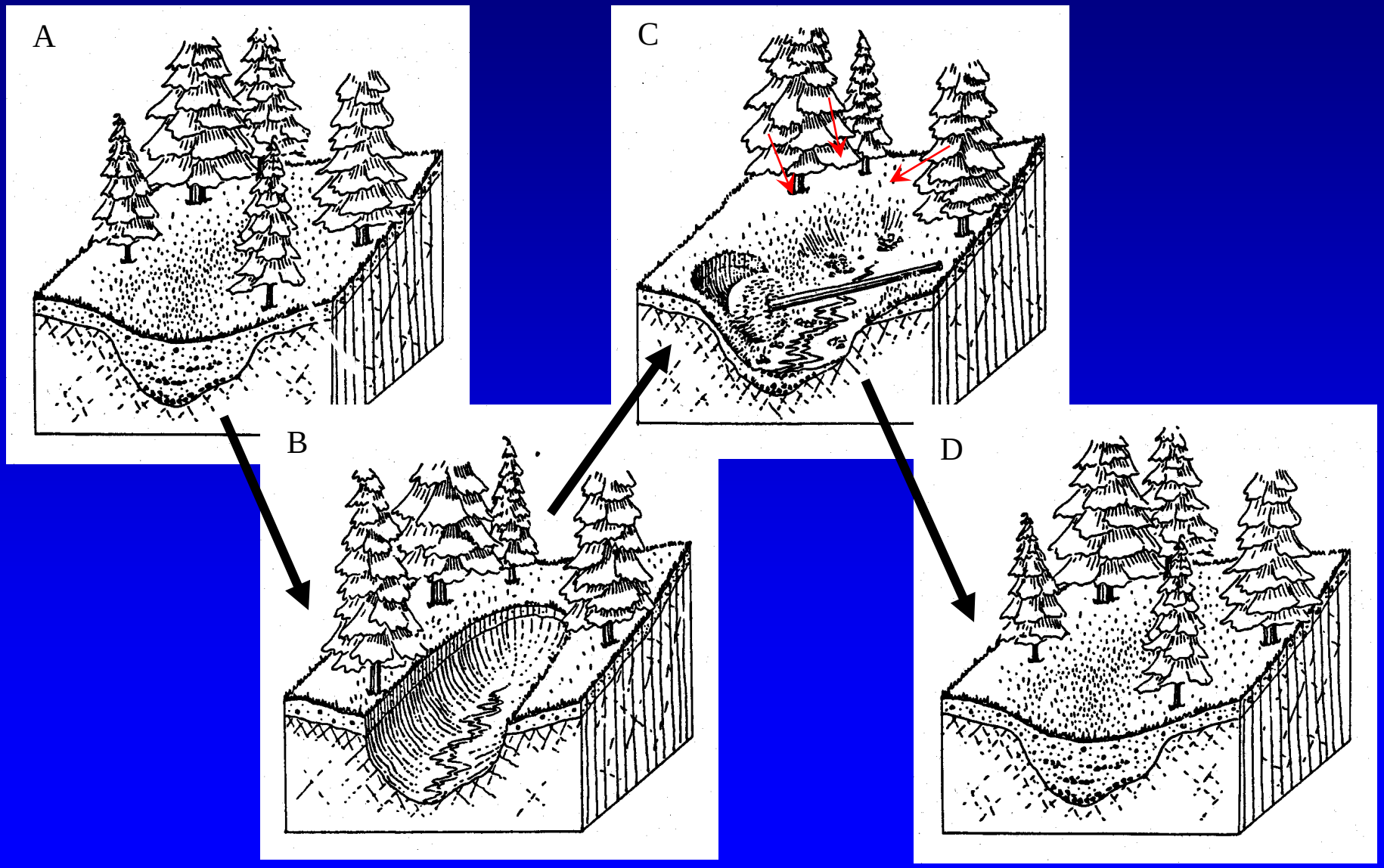
      *Relatively thick slide body (often includes bedrock)*
    - Shallow-seated (debris slides, flows, torrents) *(non-cohesive, clay-poor soils)*

      *Relatively thin slide body (usually only regolith over bedrock)*

# Deep-Seated Landslide

# Shallow-Seated Landslide

# Colluvial Hollows



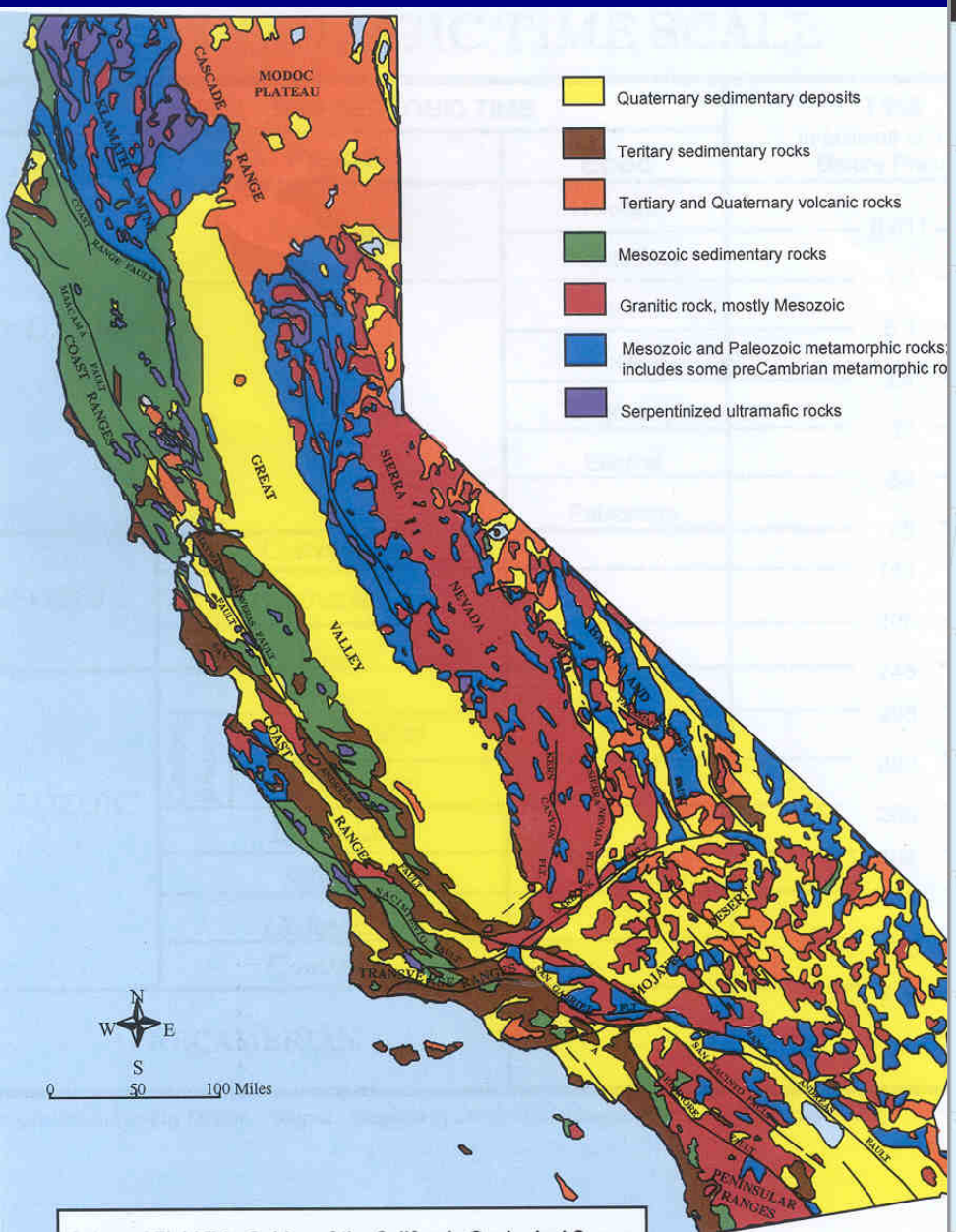
# Geology

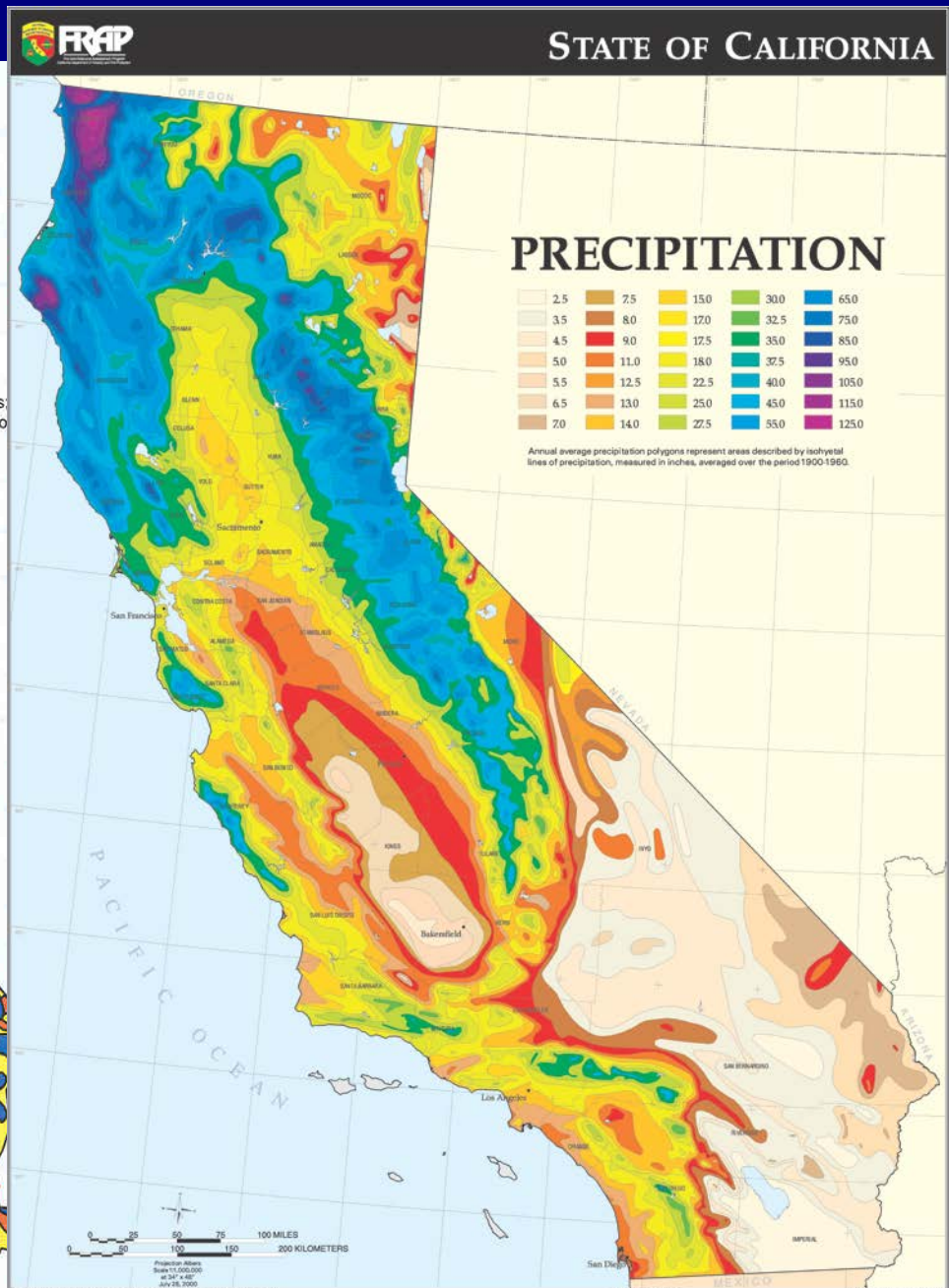
- Unstable areas – typically associated with:
  - Steep slopes – result from
    - Tectonic uplift (mountain-building),
    - Subsequent erosion and valley incision
  - Water
    - weakens substrate
    - reduces slide-resisting forces thru buoyancy effects

# Geology

- Unstable areas associated with:
  - Certain Rock types and associations:
    - Clays, and rocks that weather to clay
    - Colluvium in hollows; poorly consolidated rocks
    - Slippery rocks (phyllites, mica schists, serpentinite)
    - High-permeability rocks over low-permeability rocks
    - Fault zones (weak, sheared, often clay-like rocks, permeability difference)
  - Bad areas
    - Areas of groundwater convergence (bottom of swales)
    - Areas of groundwater discharge, esp. at toes of slopes (e.g., inner gorges of streams)

# Water is important!!



# Geology

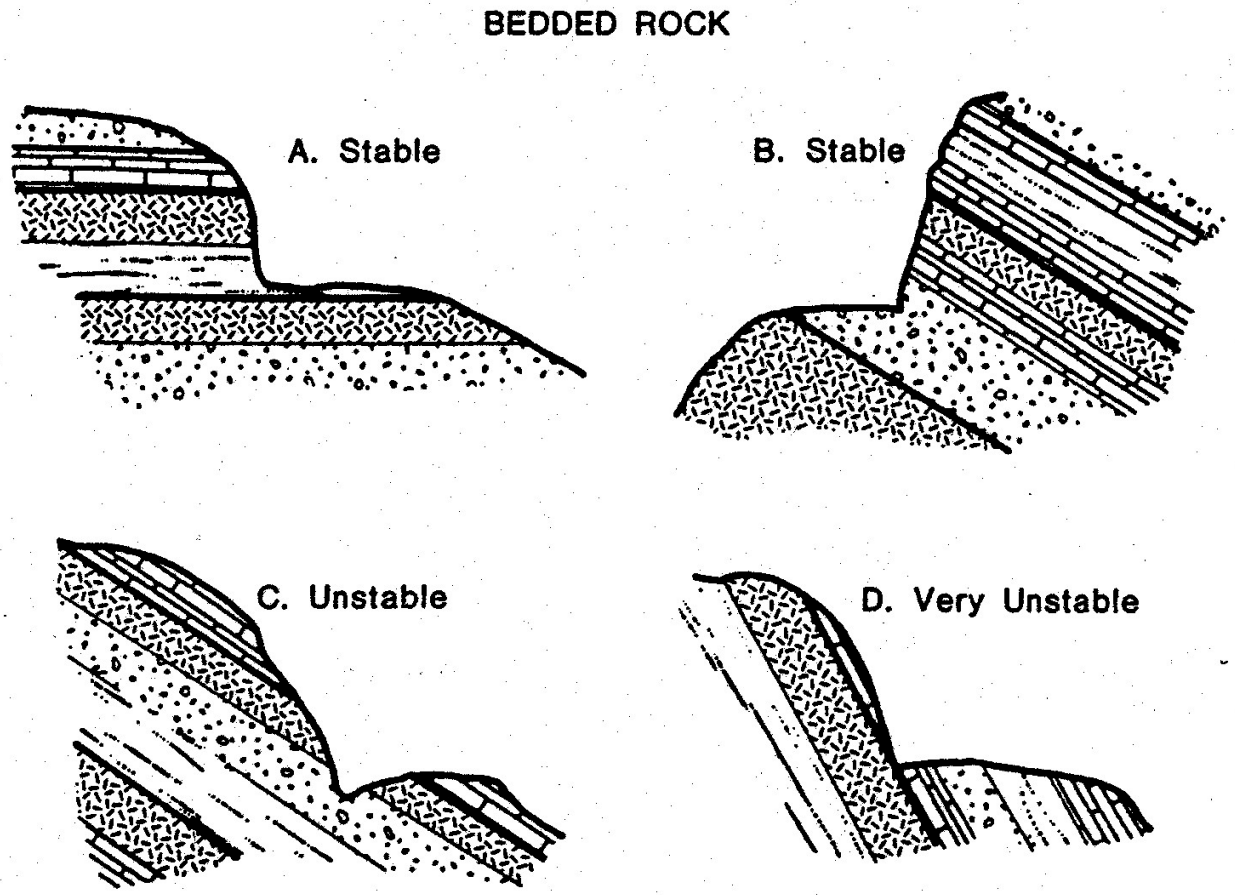
- Examples of rocks in California associated w unstable areas
  - Young, relatively unconsolidated rocks
    - Colluvium *(esp. in hollows)*
    - Young sedimentary rocks on steep slopes
  - Melange rocks *(melange = French for "mixture")*
    - Franciscan Formation in Coast Ranges
    - Rattlesnake Creek Terrane in Klamath Mountains
  - Ultramafic rocks (typically serpentinized) and serpentinite *(purple on geologic map)*
  - Mica schists (Klamath Mtns)
  - Volcanic mudflow cap over less permeable granitic and metamorphic bedrock in Sierra

# Geology

- Unstable-area mitigation
  - **Avoid if at all possible**
  - Do not:
    - Excavate toe *(reduces slide-resisting forces)*
    - Load head *(increases slide-driving forces)*
    - Concentrate water onto or into the slide

# Rock Slides

- Tilted planar features in bedrock
  - Tilted beds
  - Tilted foliation
  - Tilted rock-jointing




Source: Washington State DOE Report # 82-5, Handbook for Forest Roads, November 1982

# Geology

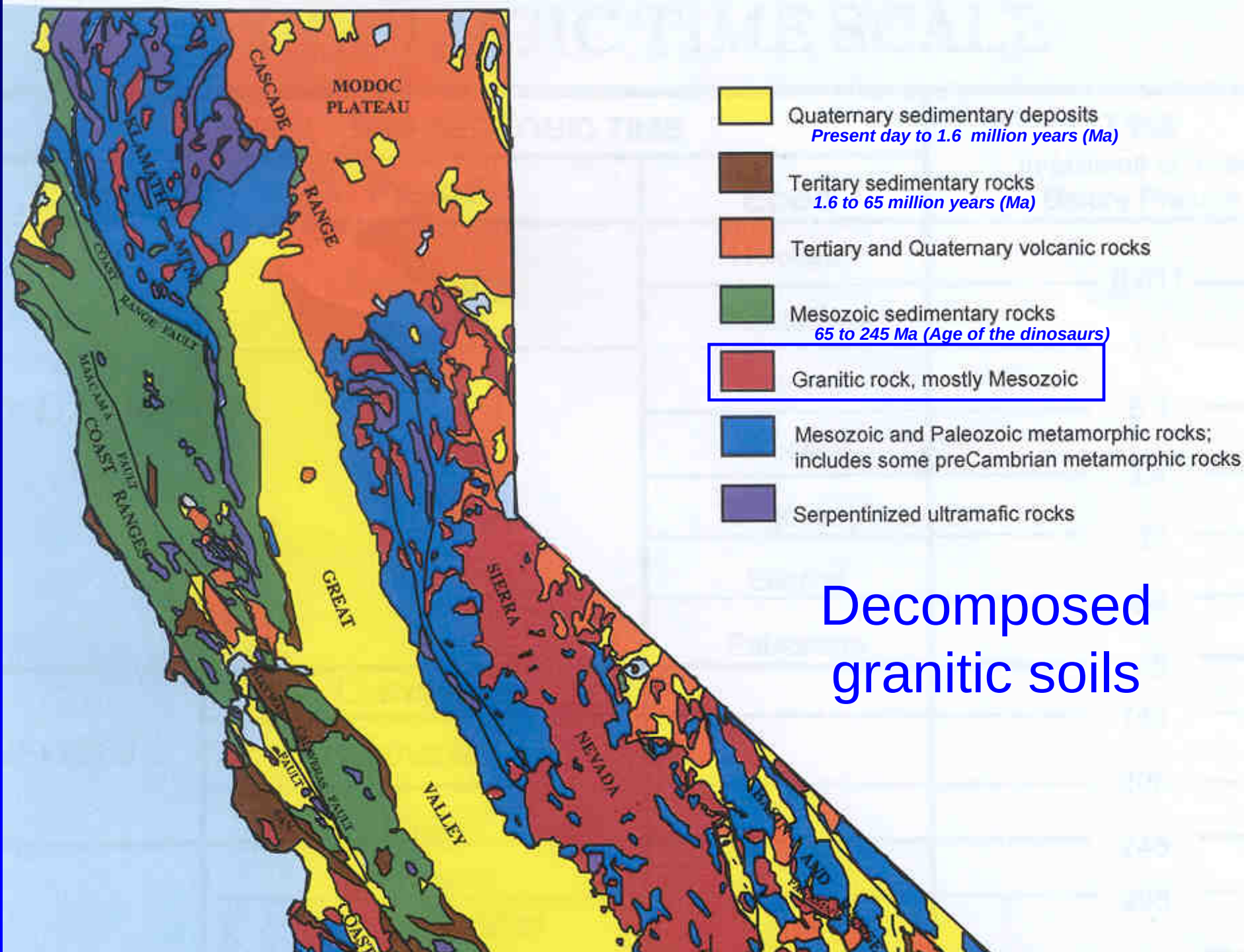
- Erodible soils
  - Sandy and silty soils
    *(<u>especially</u> decomposed granite [DG] soils)*
  - How to identify
    - Field test
    - Soil Survey—available from
      - NRCS—Soil Surveys on the Internet at USDA's
        Soil Data Mart

# Decomposed granite soils

C. The interior of the granite outcrop consists of hard igneous rock, with light-colored feldspar and quartz, and dark biotite.

D. The outer part of the outcrop is crumbly granite, notably browner than the interior sample and with less biotite.

E. Fragments that accumulated at the base of the outcrop are almost entirely quartz and feldspar, coated in fine brown dust.




# Decomposed granitic soils

# Geology

- Erodible soils
  - Sandy and silty soils *(especially decomposed granite [DG] soils of the Shasta Bally batholith and associated intrusions)*
  - How to identify
    - Field tests for soil textures
    - Soil Survey – available from
      - NRCS – soil surveys on the Internet at: *(http://websoilsurvey.nrcs.usda.gov/app/)*
      - USFS Forest Service

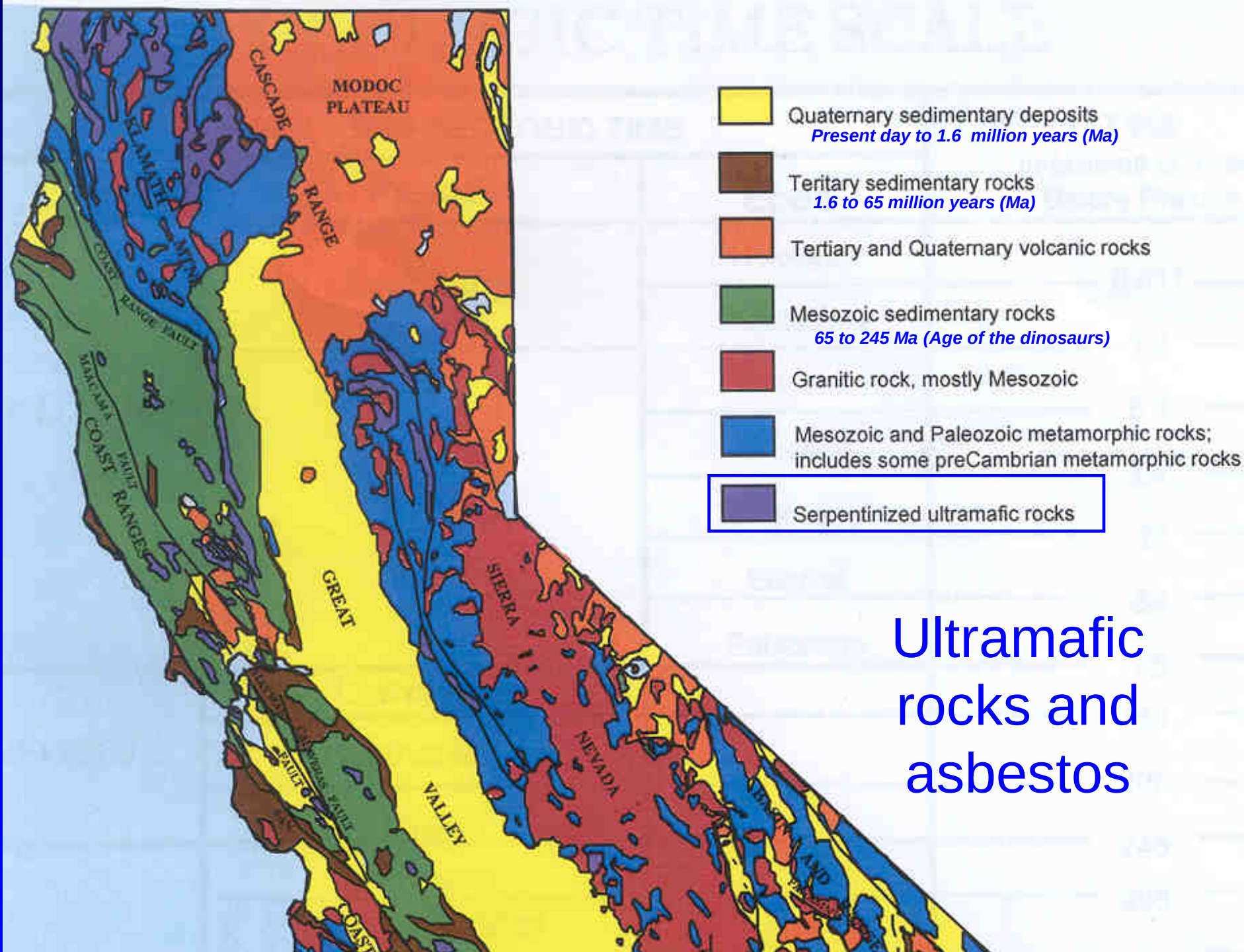
# Geology

- Mitigating erodible soils
  - Keep road gradient gentle
  - **Get water off the road!**
    - Outslope the road
    - Frequent water breaks *(Rolling dips, Waterbars)*
  - **Rock or pave the road!**
  - Avoid draining water over unvegetated cutslopes
  - For DG soils, see CAL FIRE guidance document: ***Recommended Mitigation Measures for Timber Operations in Decomposed Granite Soils***

    *Available on the Internet at:*
    *http://www.fire.ca.gov/resource_mgt/downloads/DGSoilsMits.pdf*

# Hazardous asbestos dust

- Asbestos-bearing rock units
  *(Contain naturally occurring asbestos [NOA])*
  - Occur in ultramafic rocks and soils
  - Concerns and effects
  - How to identify
    - Geology maps
    - Rock descriptions
    - See CGS site (*http://www.conservation.ca.gov/cgs/minerals/hazardous_minerals/asbestos/Pages/Index.aspx*)
  - Mitigation
    - Keep soil damp to avoid dust during construction




# Ultramafic rocks and asbestos

# The End

# Questions?

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