Environmental Constraints on Road Design and Use

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The Main Environmental Constraints on Road Design and Use

- Topography
- Water
- Geology (soils)
  - Fire effects

In addition to Environmental Constraints - Road Design is a Major Factor

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

Good Road Design – Two Main Components

- 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 quickly as possible. Less inside ditch; more cross drains, more outsloping

Topography

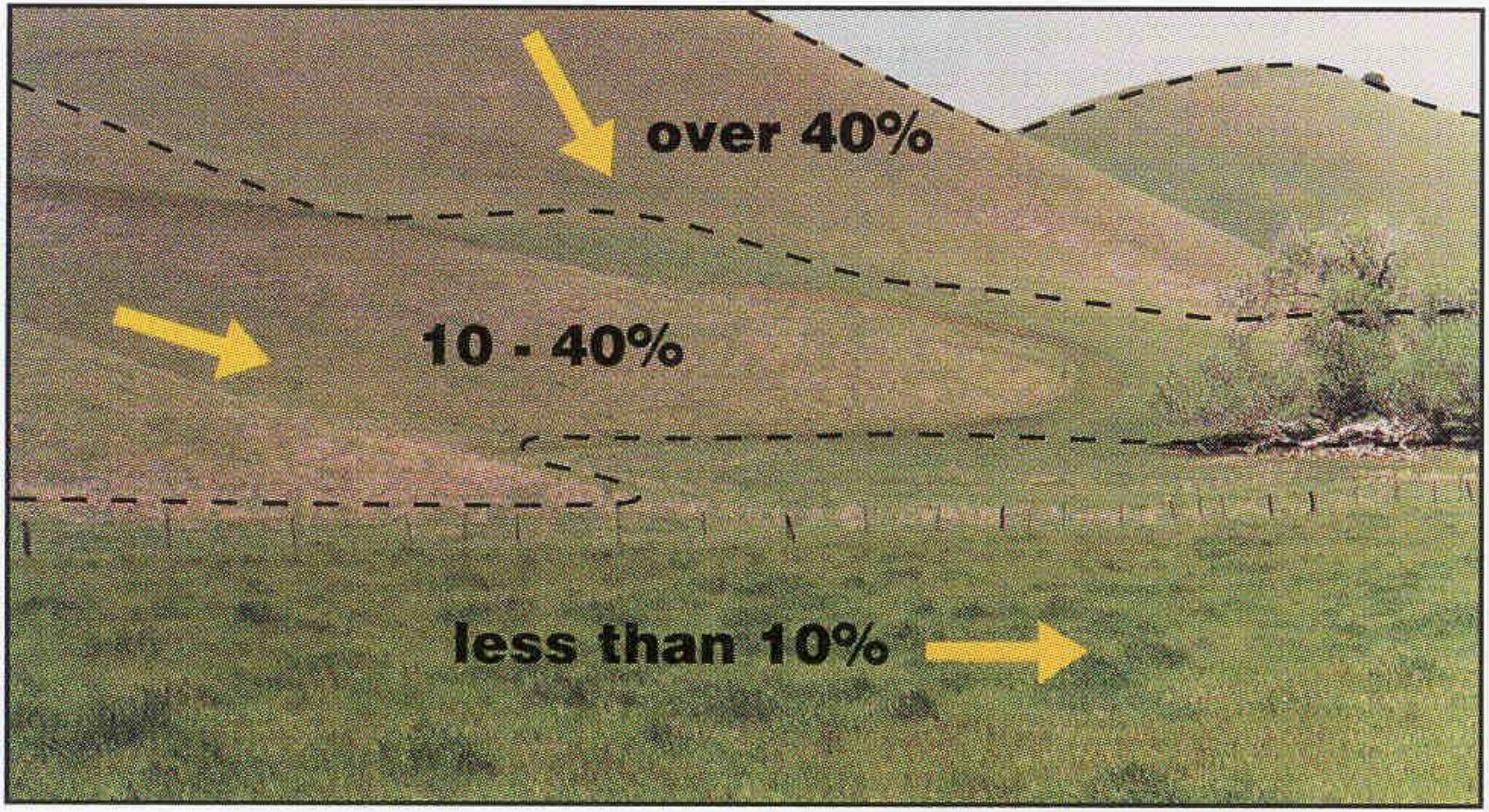
- Steep slopes (> 40 %) and flat low-level areas (<10%) are more difficult
- Gentle slopes (10 to 40 % are preferred)

Gentle slopes minimize:

- Road grade (steepness)
- Excavation and fill volumes

Examples of gentle slopes

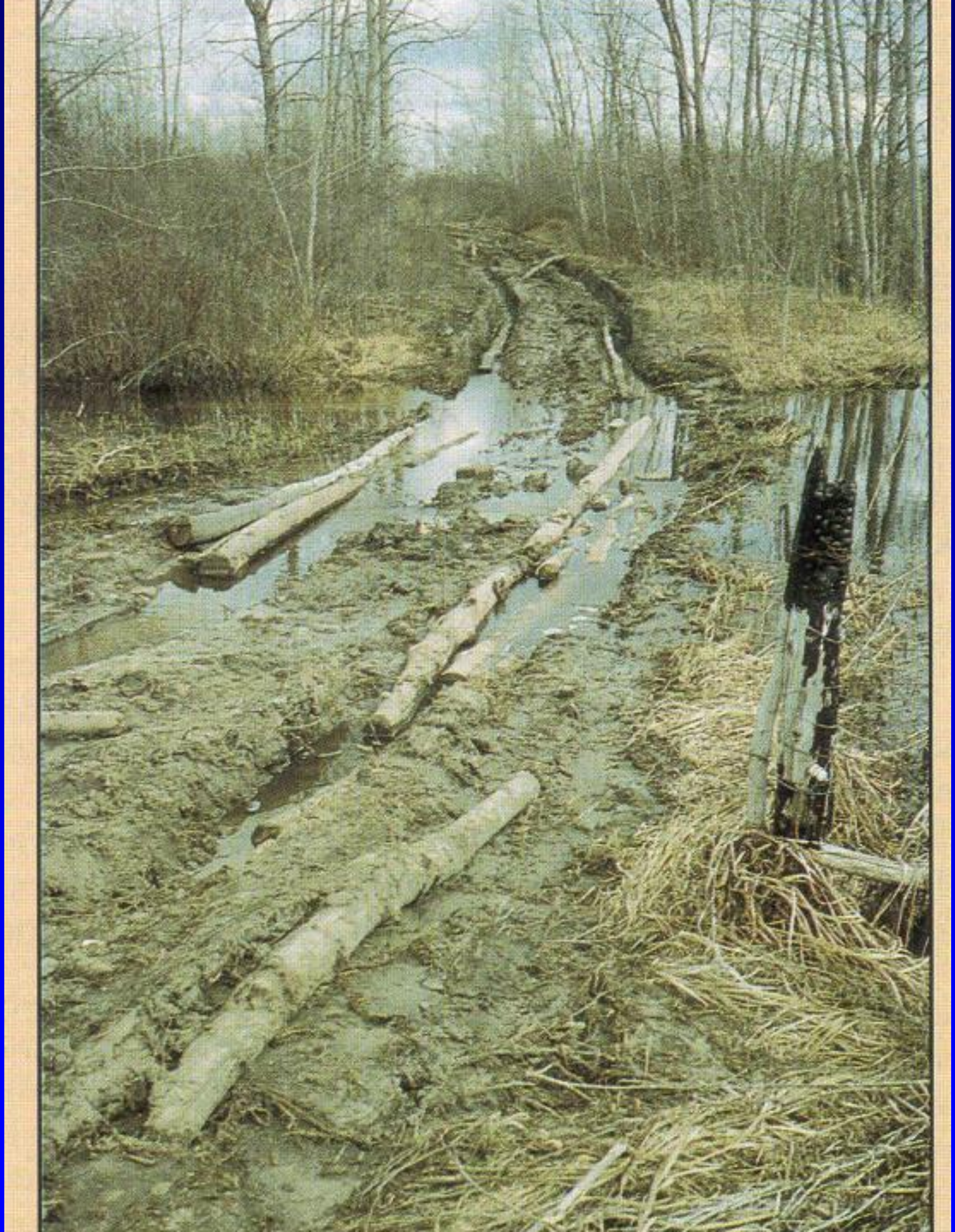
- Toe slopes
- Topographic benches
- Ridges


over 40%
10 - 40%
less than 10%

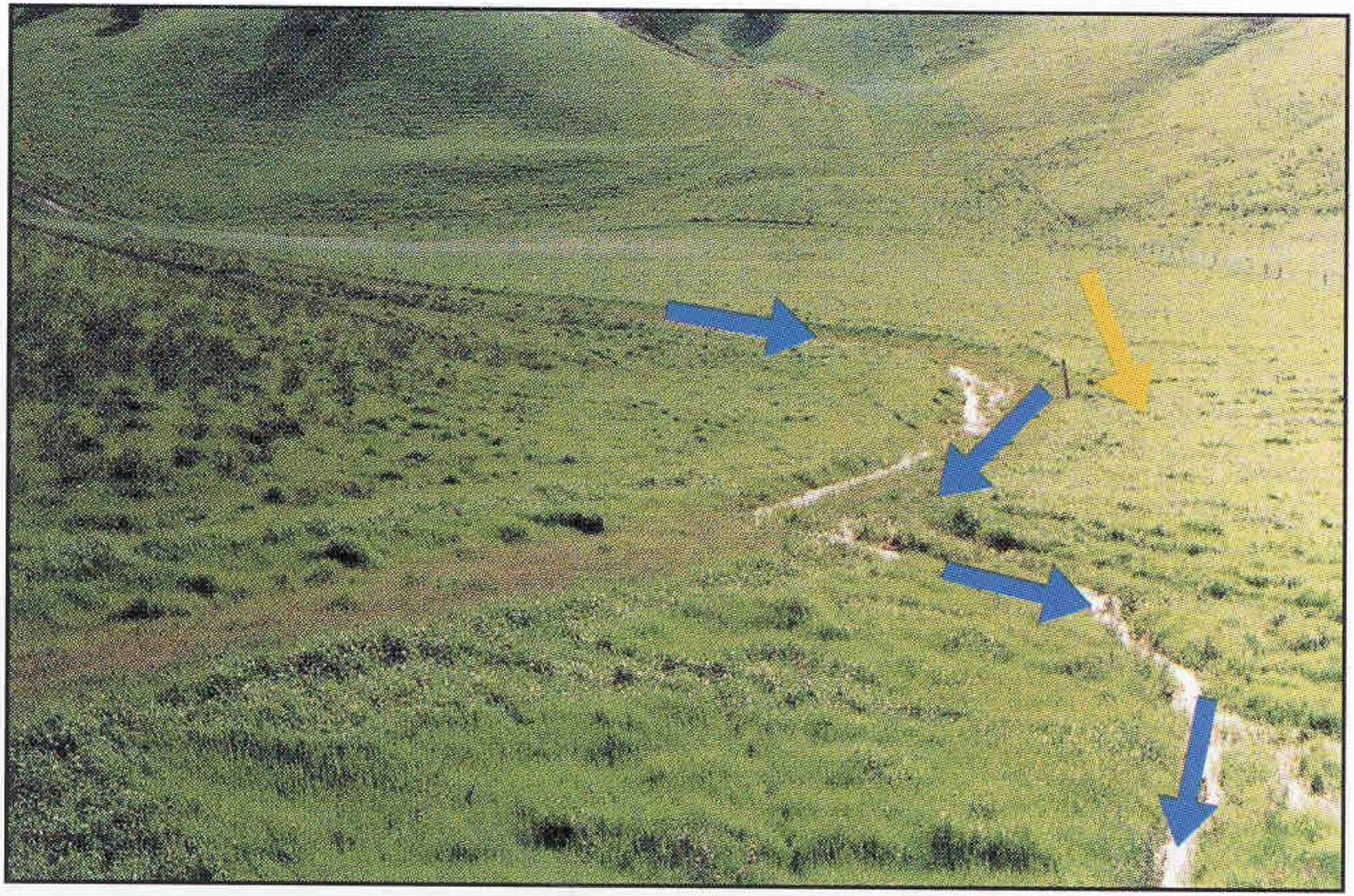
Roads on flat ground

• can be hard to drain

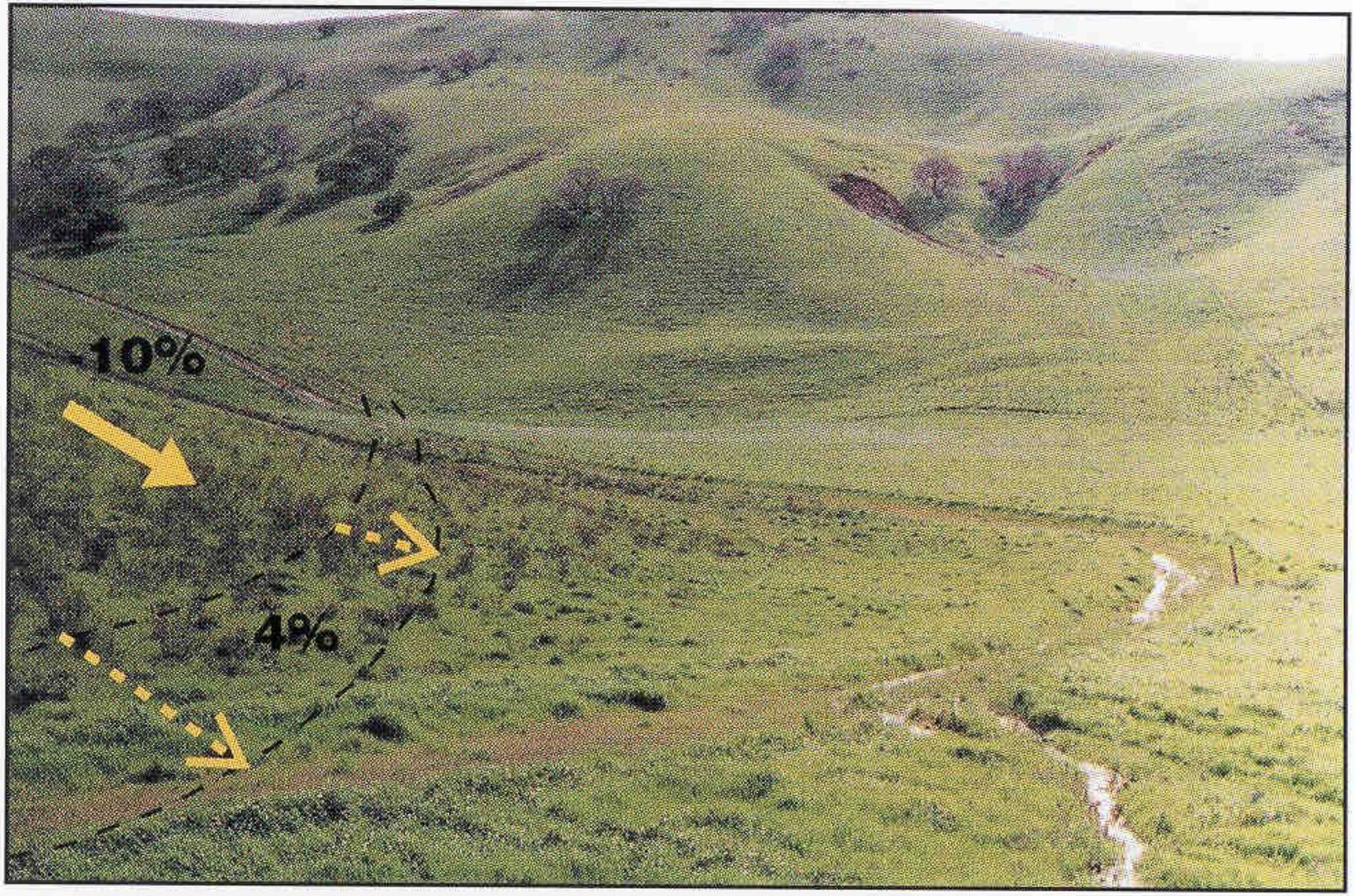
• can become entrenched by repeated grading



Problem



Solution

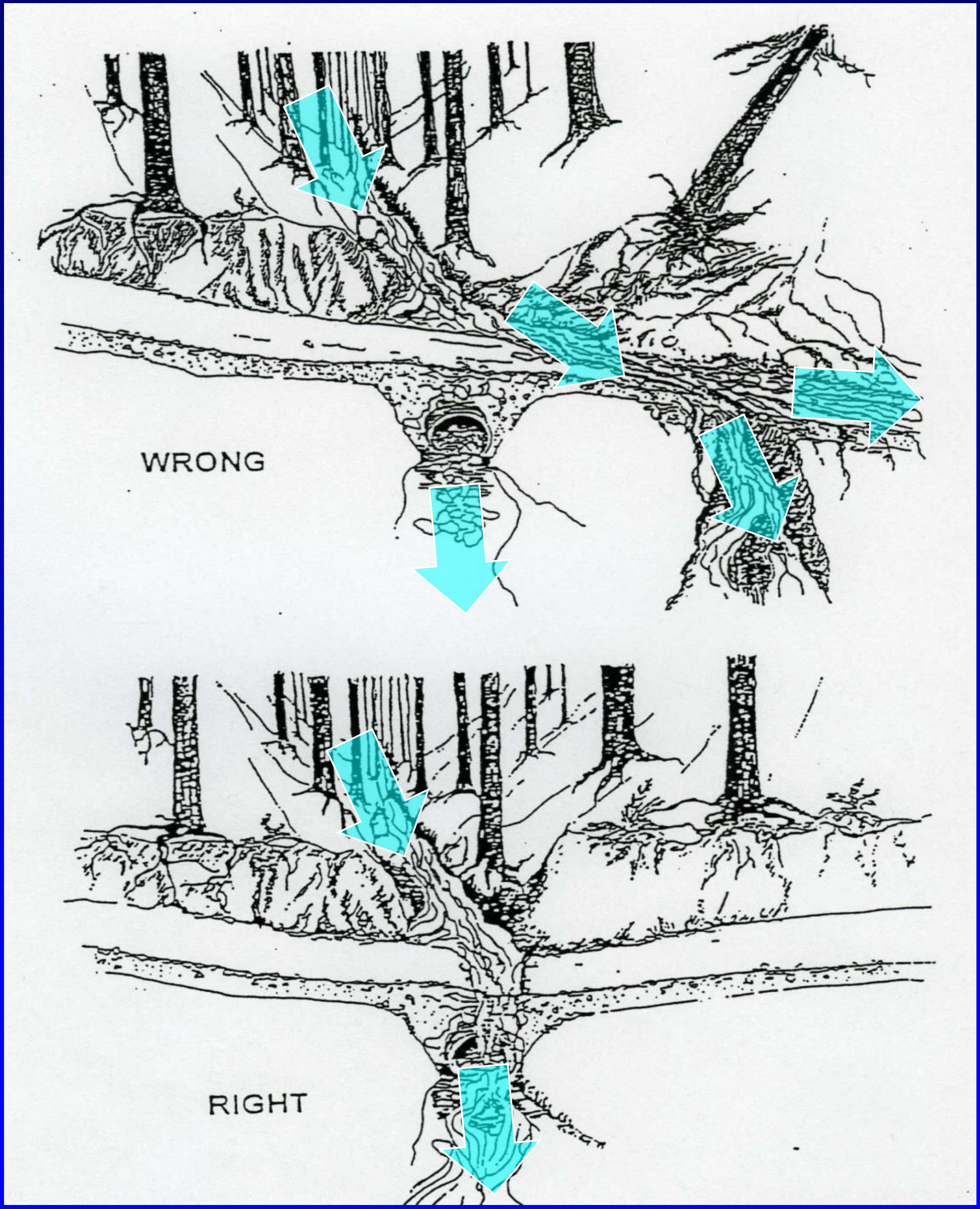


Topography

- Gentle slopes (10% - 40%):
  - Minimize road grade (steepness)
    - Reduces potential for
      - Erosion of roadbed
      - Stream diversion at watercourse crossings
    - While allowing road surface to drain downslope

Road Grade Effects

Stream Diversion Potential



Topography

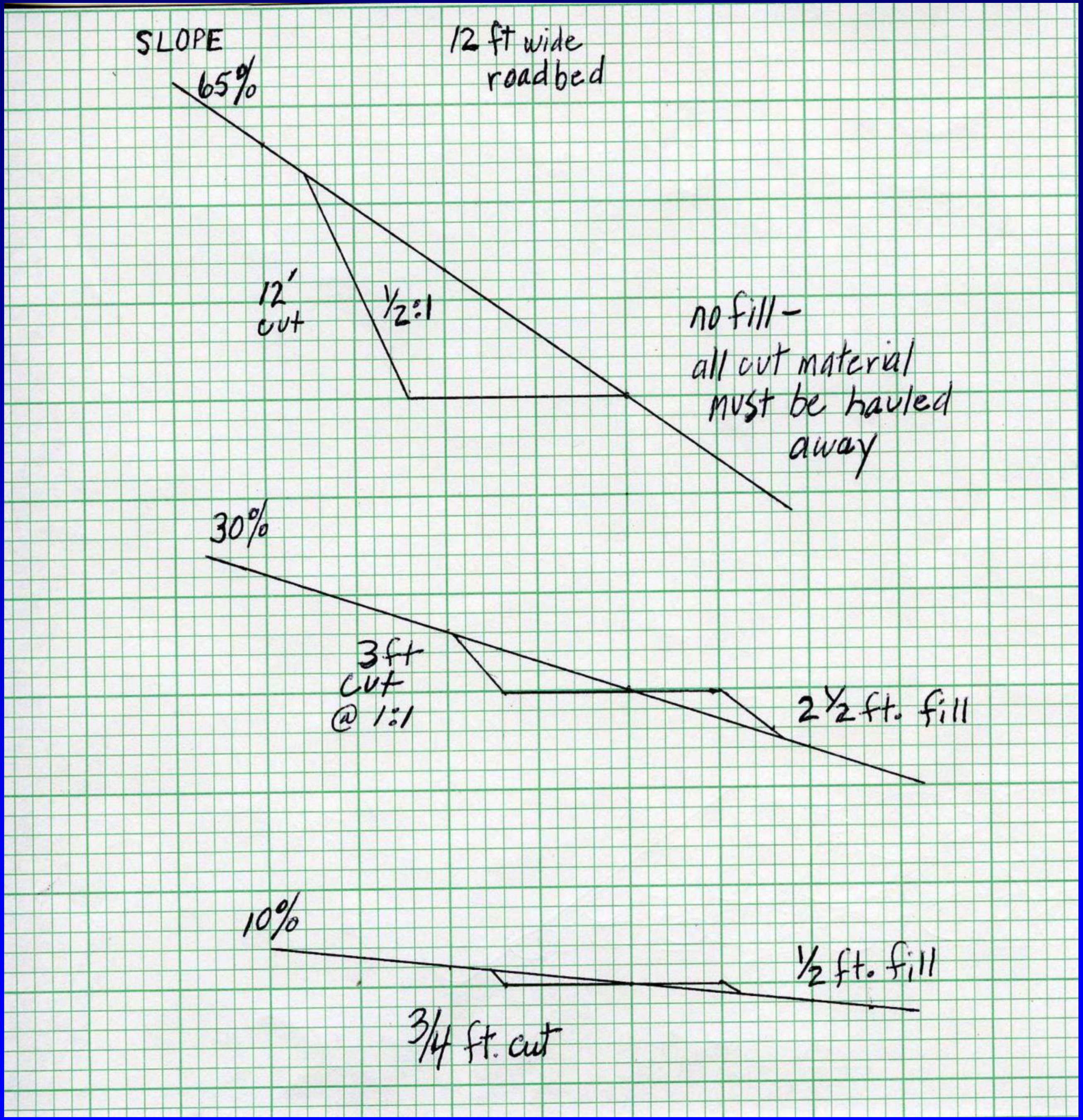
- Gentle slopes <u>minimize</u>:

  – Excavation and fill
    - Shorter and less steep
      – Cutslopes
      – Fillslopes
    - Less likelihood of
      – Cutslope failure
      – Fillslope failure

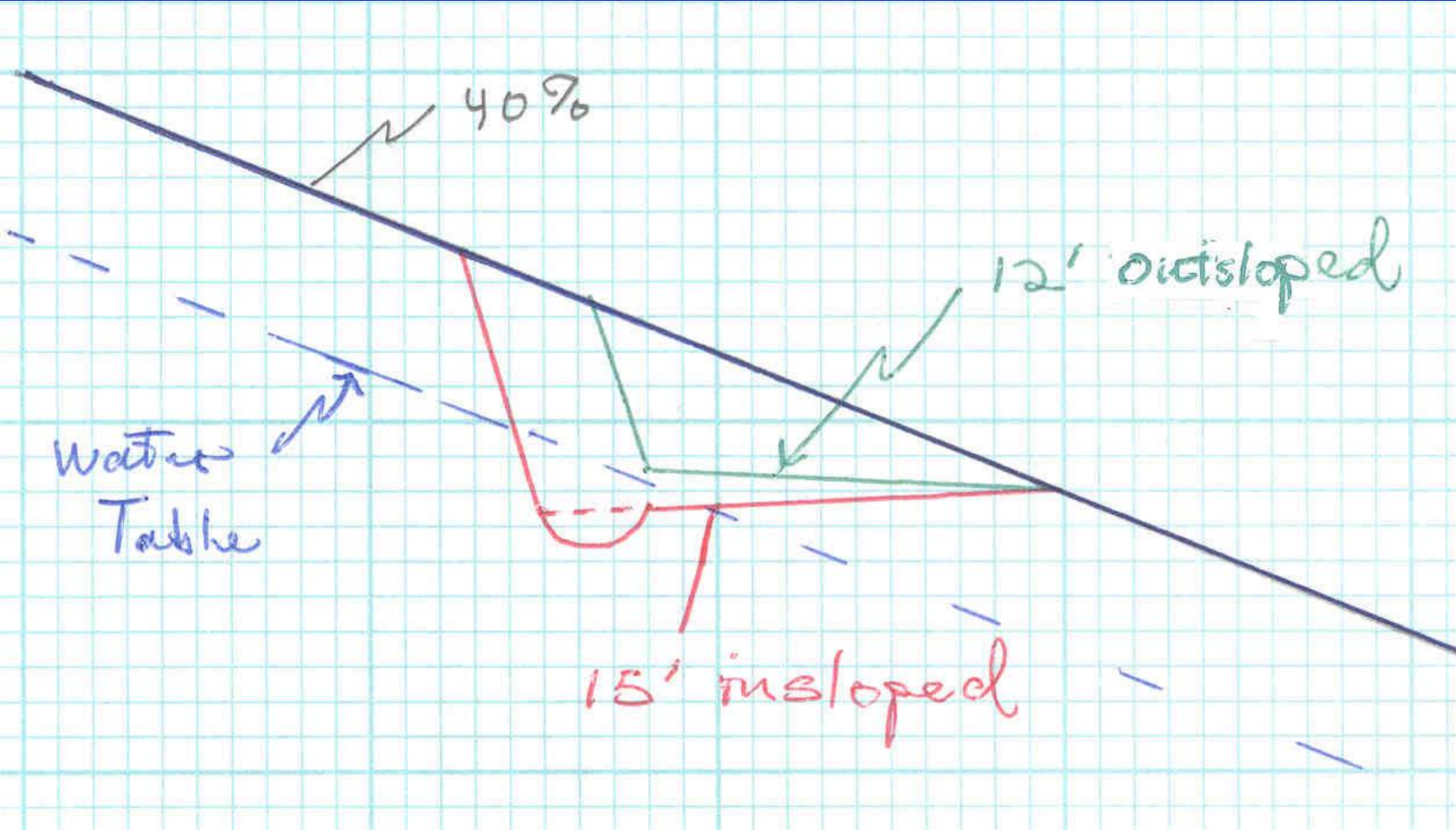
Slope Effects

Cut and Fill

Volumes



Insloped vs outsloped also affects cut volumes



Cutbank Heights

Road width	12' with outslope		15' with inside ditch	
Side slope		Cut height		Cut height
40%		4 ¾ ft		7 ¼ ft
65%		7 ¾ ft		11 ¾ ft
80%		9 ½ ft		14 ½ ft

Spoils Volumes

Road width	12' with outslope		15' with inside ditch	
Side slope		Spoils volume		Spoils volume
40%		1 yd^3/ft		2 1/3 yd^3/ft
65%		1 2/3 yd^3/ft		4 yd^3/ft
80%		2 yd^3/ft		5 yd^3/ft

Water

- Streams
- Wet areas
- Groundwater

Water

- Streams

  Stay away from except to cross

  (Pete Cafferata will discuss crossings)

- 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)

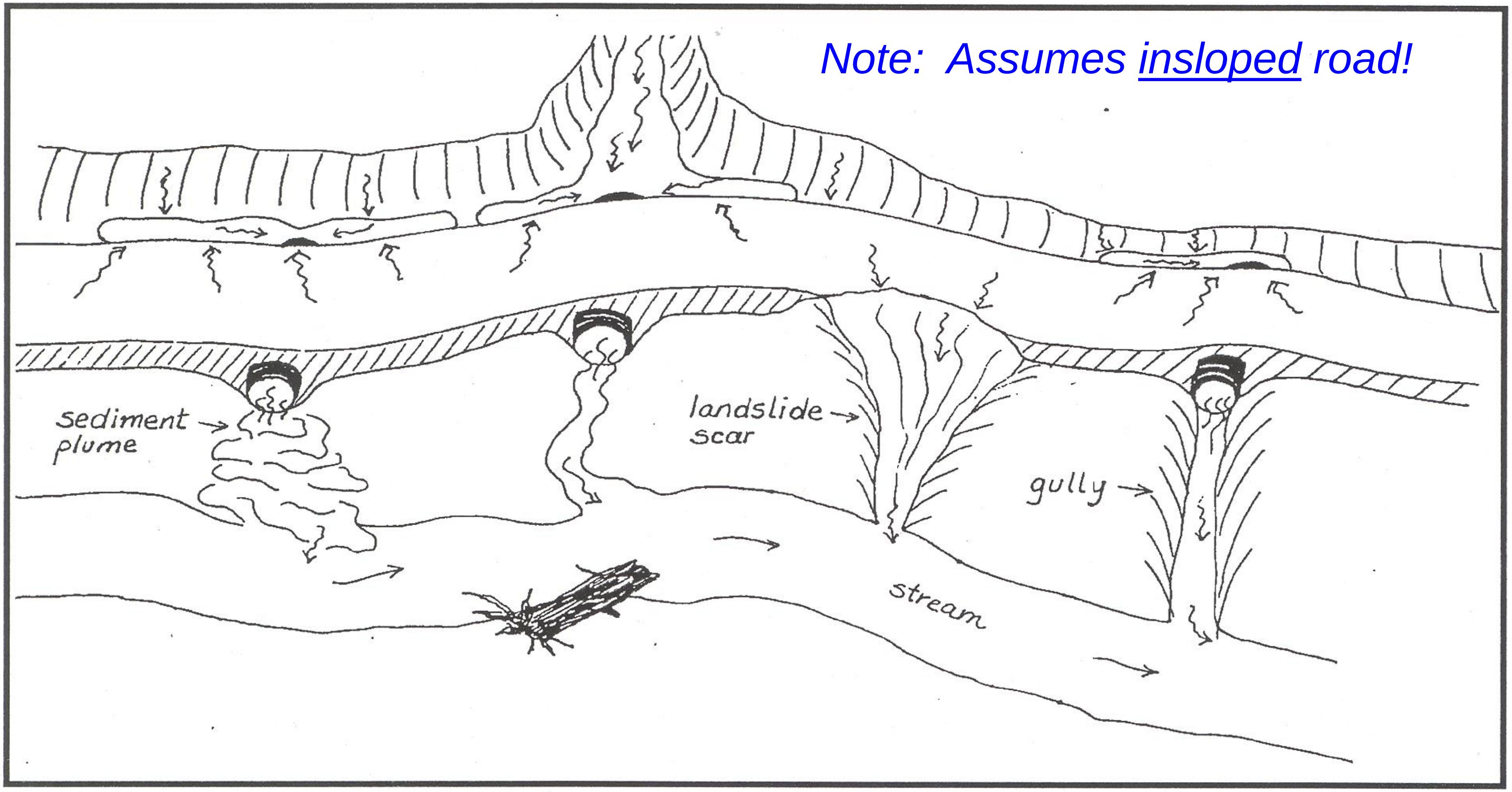


Figure 1-2. How roads can be connected to streams.

Road Effects on Streams

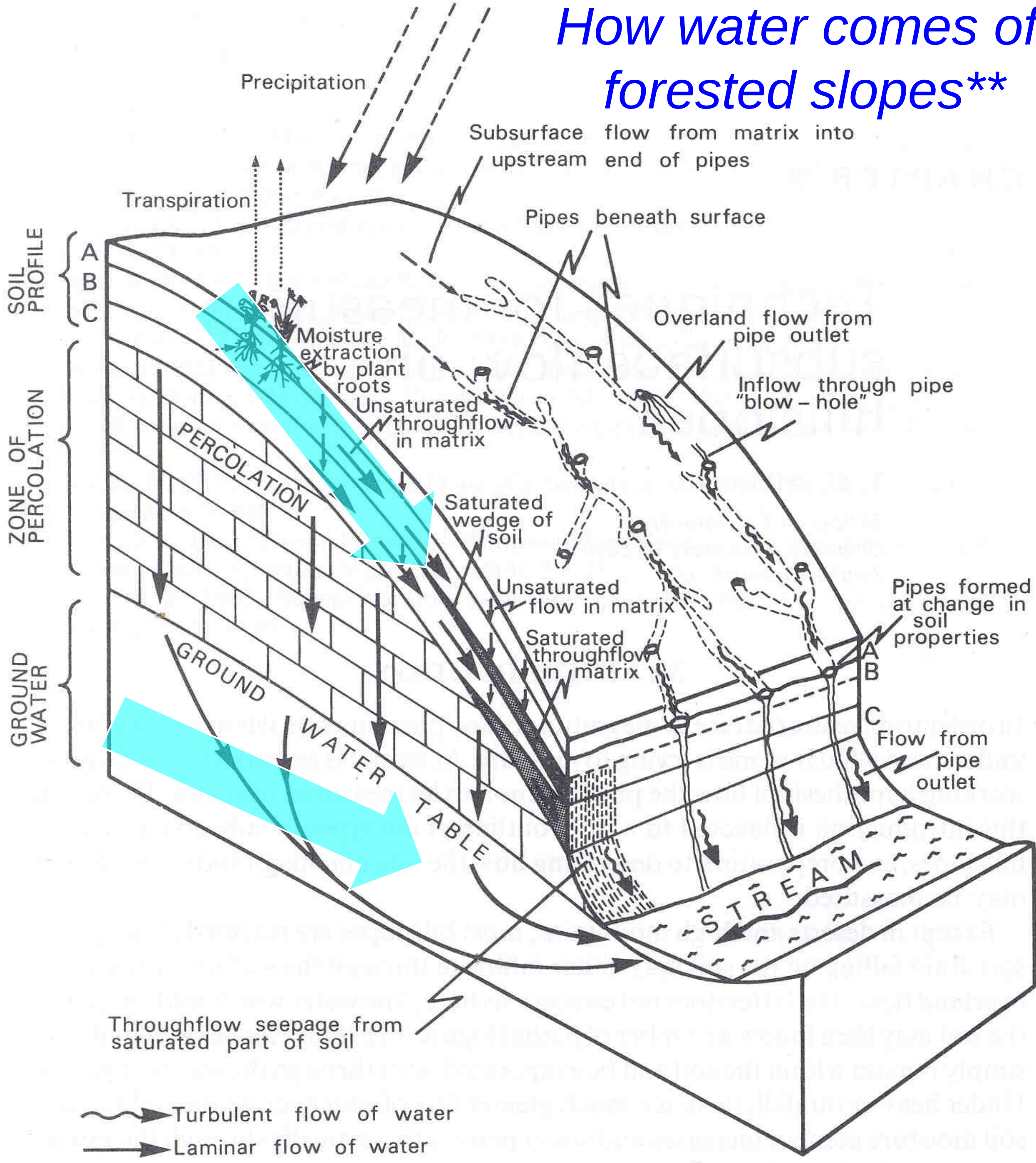
<u>Sediment discharge</u> to streams

- *Affects the form and texture of the channel as well as the organisms that live in the stream*

Sediment derived from erosion of

- *Road running surface (if near stream / insloped)*
- *Inside Ditch (if flows connect with a stream)*
- *Cutslopes (if there is an inside ditch)*
- *Fillslopes (if close to a stream)*

*How water comes off forested slopes***



Atkinson, 1978

Road Effects on Streams

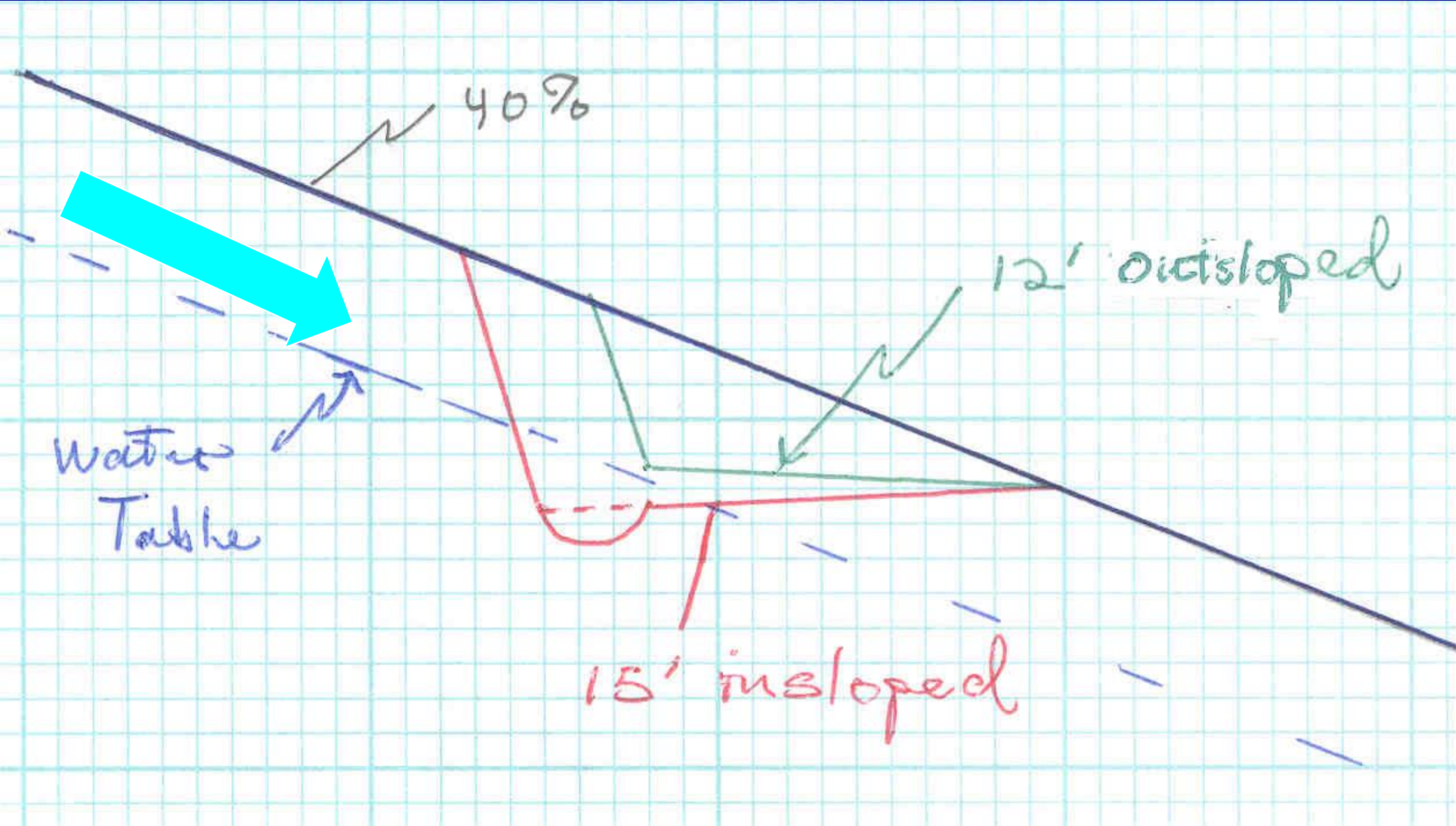
<u>Stream peak flows increased by</u>

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

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

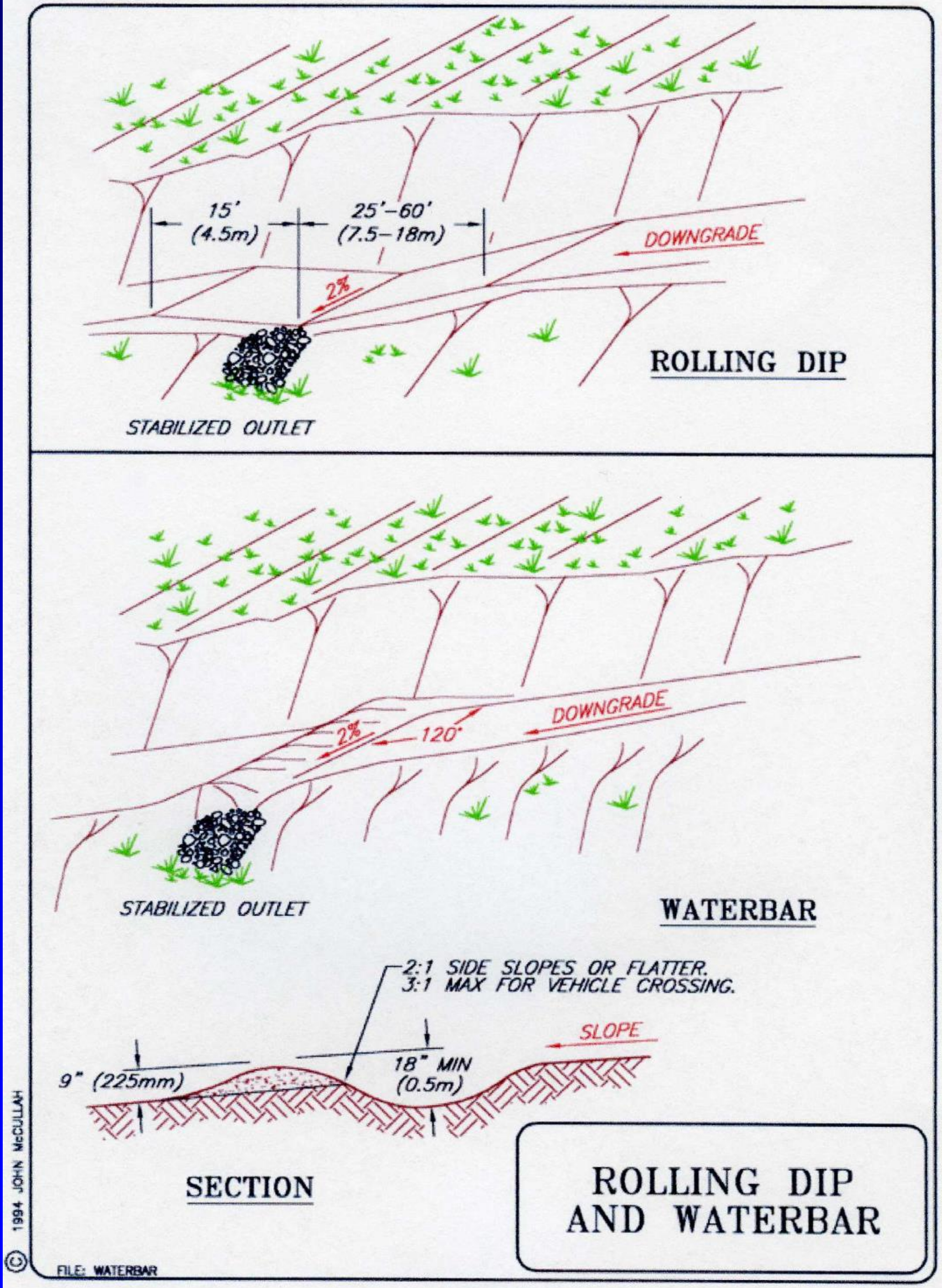
Insloped vs outsloped affect on intercepting ground water



Road Drainage Designs

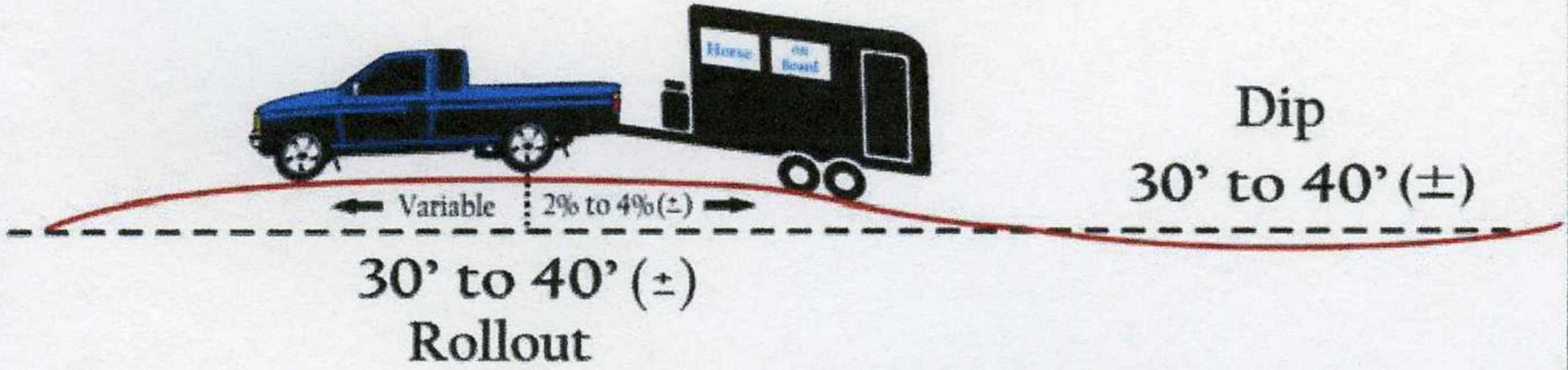
- Outsloped road is best (not practical at times)
- Rolling dips – good (not >10% grade)
- Insloped with inside ditch
- cross-drain spacing for ditch relief culverts - closer spacing the better.

Rolling Dip

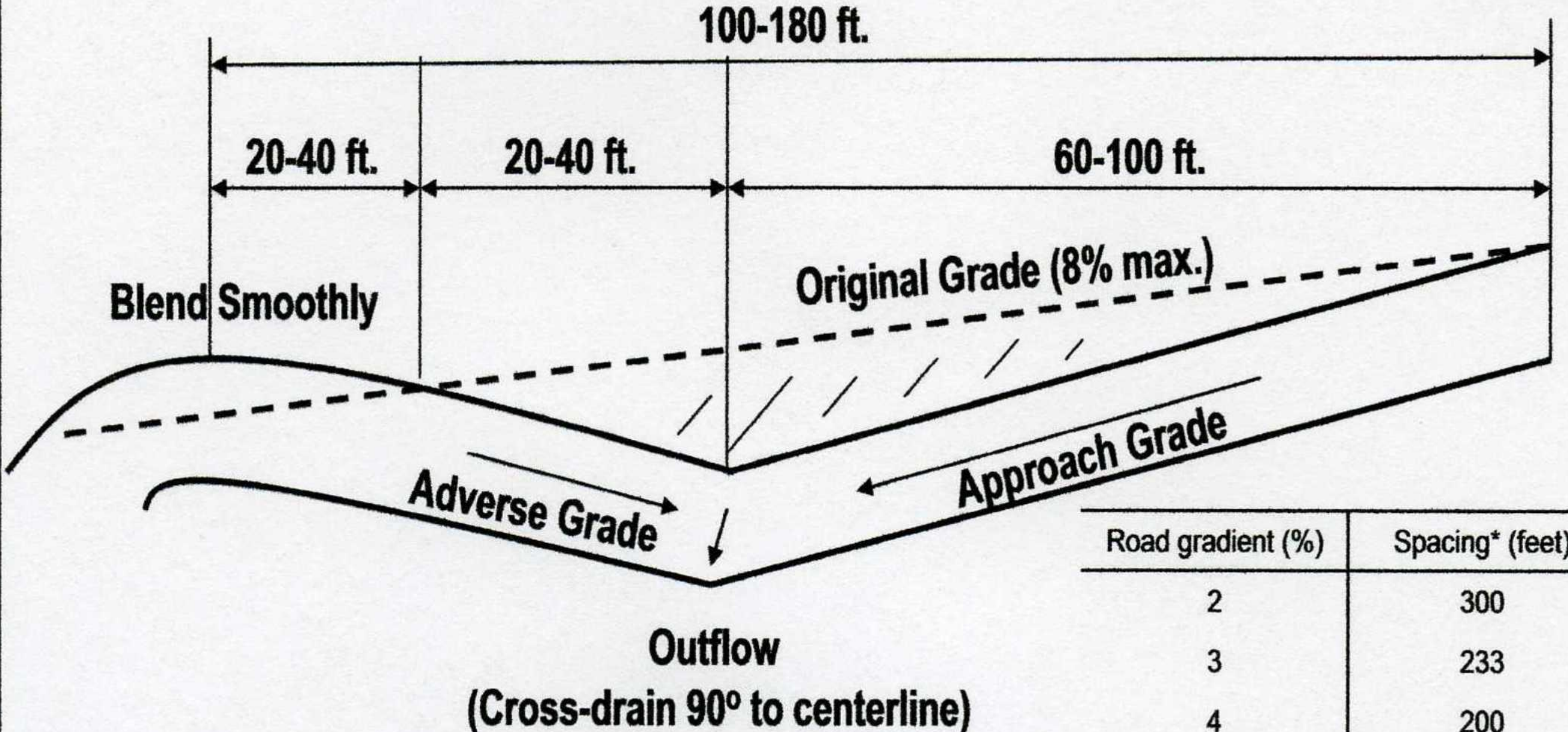

15'
(4.5m)
25'-60'
(7.5-18m)
DOWNGRADE
2%
ROLLING DIP
STABILIZED OUTLET
2%
120°
DOWNGRADE
STABILIZED OUTLET
WATERBAR
2:1 SIDE SLOPES OR FLATTER.
3:1 MAX FOR VEHICLE CROSSING.
SLOPE
18" MIN
(0.5m)
9" (225mm)
SECTION
ROLLING DIP
AND WATERBAR
© 1994 JOHN McCULLAH
FILE: WATERBAR

Rolling Dip for Pick-up with Trailer

(Longitudinal Profile)



Length of dip and length of rollout each approximately equal to total length of truck and trailer.



Road gradient (%)	Spacing* (feet)
2	300
3	233
4	200
5	180
6	167
7	157
8	150

* For low to moderate erosion hazard soils, in high erosion hazard soils these distances should be reduced by 20 to 30 percent.

Note: Not to Scale

Water Bar Spacing

Road Grade (%)	Spacing in feet based on Soil Erodibility Rating		
	High (sandy)	Med (loam)	Low(Clay or gravel)
2 to 10	150	200	300
11 – 25	100	150	200
26 – 50	75	100	150

Rolling Dip Spacing

2 – 4	160 to 400	200 to 500	200 to 600
5 – 8	120 to 300	150 to 400	150 to 500
9 – 10	less than 200	less than 250	less th 300

Ditch Relief Culvert Spacing

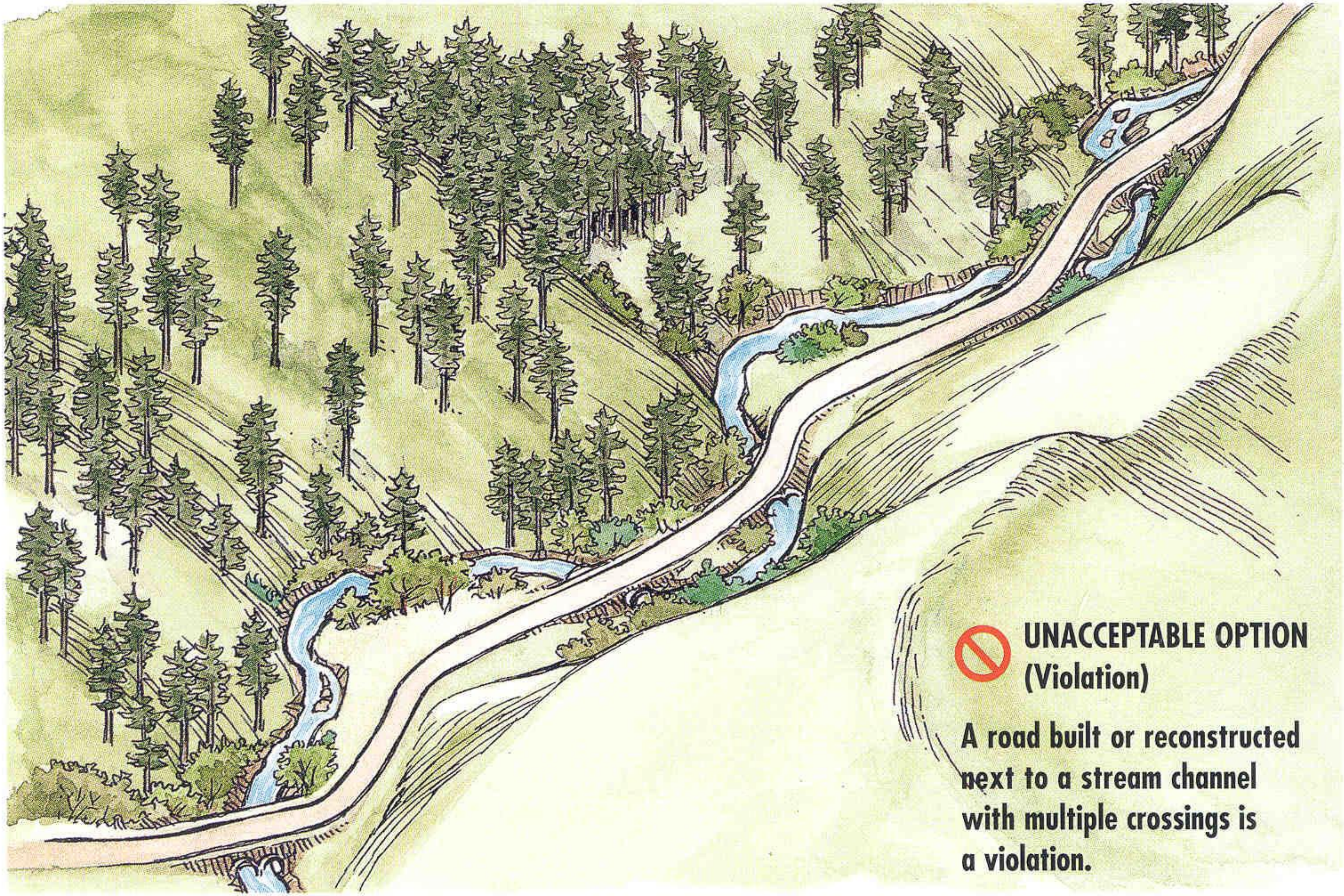
2 - 4	530 to 900	800 to 1000	1000
5 – 8	265 to 600	525 to 800	600 to 800
9 – 12	180 to 340	350 to 420	460 to 550
13 – 18	115 to 245	240 to 300	310 to 365

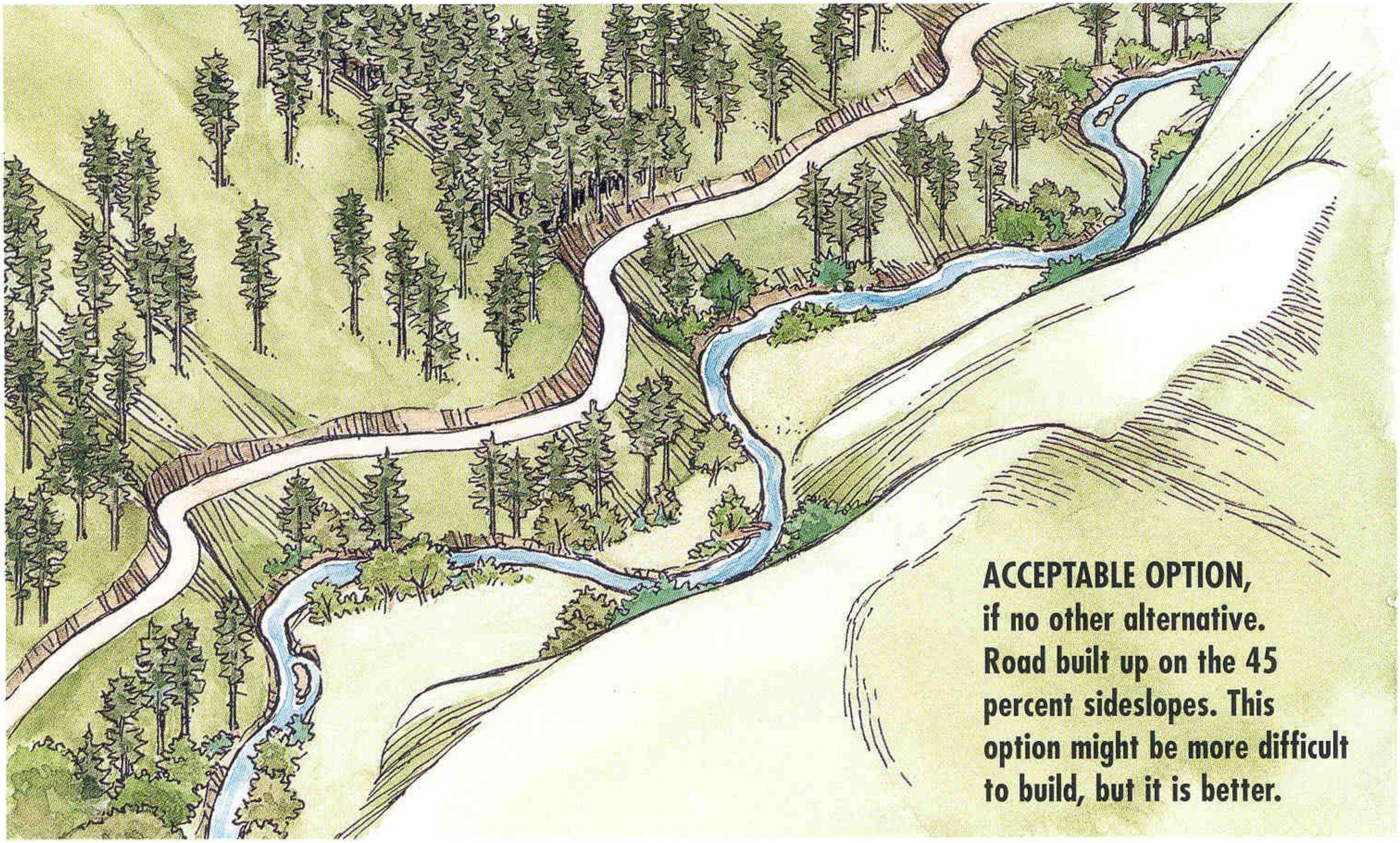
Stream Effects on Roads

- Inner gorges
  - Unstable
  - Poor location for roads (unstable, too close to stream)
- Lateral erosion may erode roadway if located close to stream.
- Road located near valley bottom must cross tributary streams.


Inner Gorge

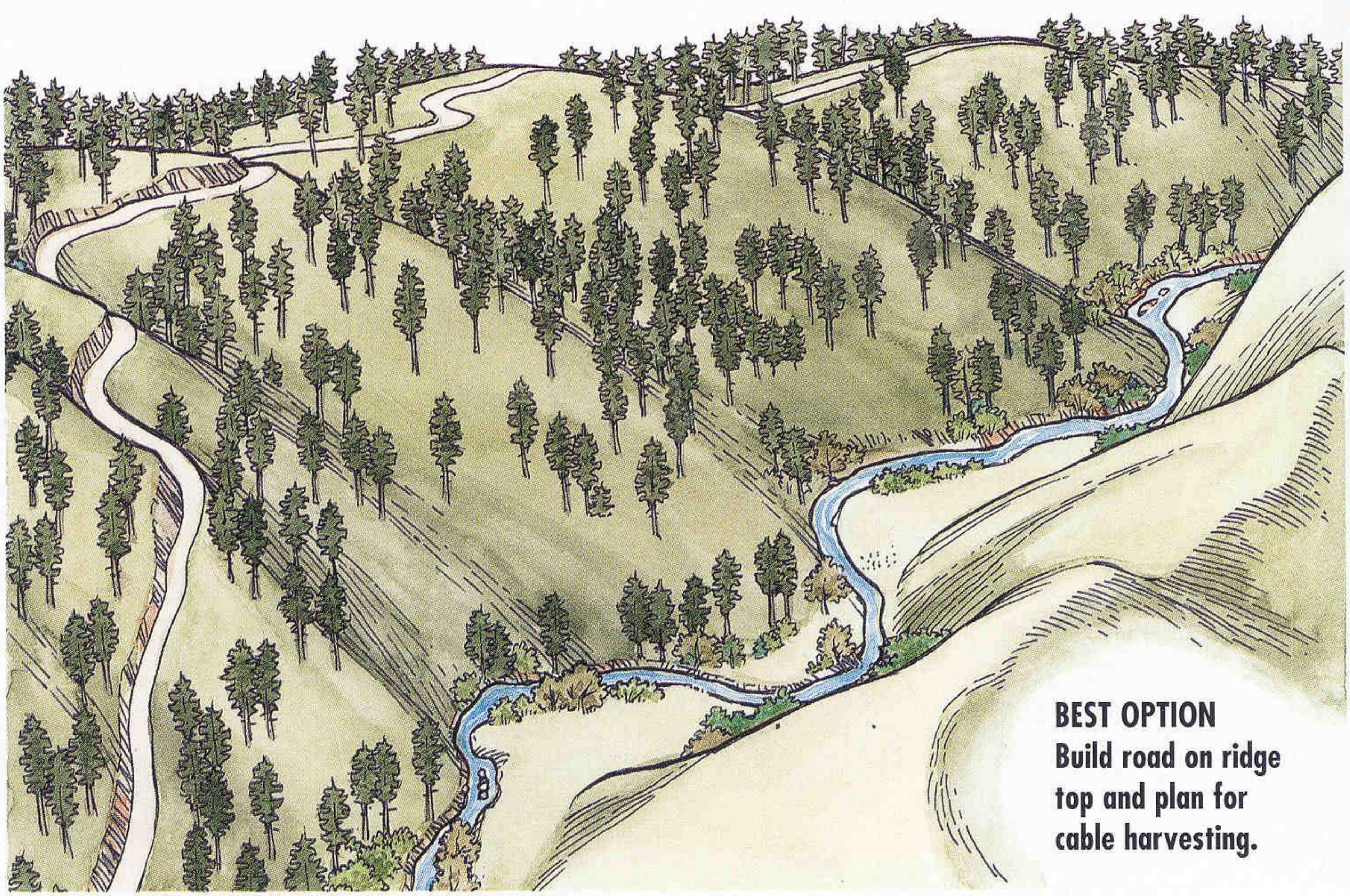
Road failure caused by stream undercutting


UNACCEPTABLE OPTION
(Violation)
A road built or reconstructed next to a stream channel with multiple crossings is a violation.


ACCEPTABLE OPTION,
if no other alternative.
Road built up on the 45 percent sideslopes. This option might be more difficult to build, but it is better.

Stream Effects on Roads

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


BEST OPTION
Build road on ridge top and plan for cable harvesting.

Stream Effects on Roads

- Crossings *(Pete Cafferata will discuss)*
  - ➢ Expensive to install, maintain
  - ➢ Failure potential – need to consider
    - – Cost of re-installing crossing
    - – Stream diversion, subsequent road erosion, and road reconstruction costs
- <u>Best to avoid stream crossings if possible!</u>

Wet Areas (seeps, wet ground)

- How to ID?
- Problems
- Mitigations

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 –

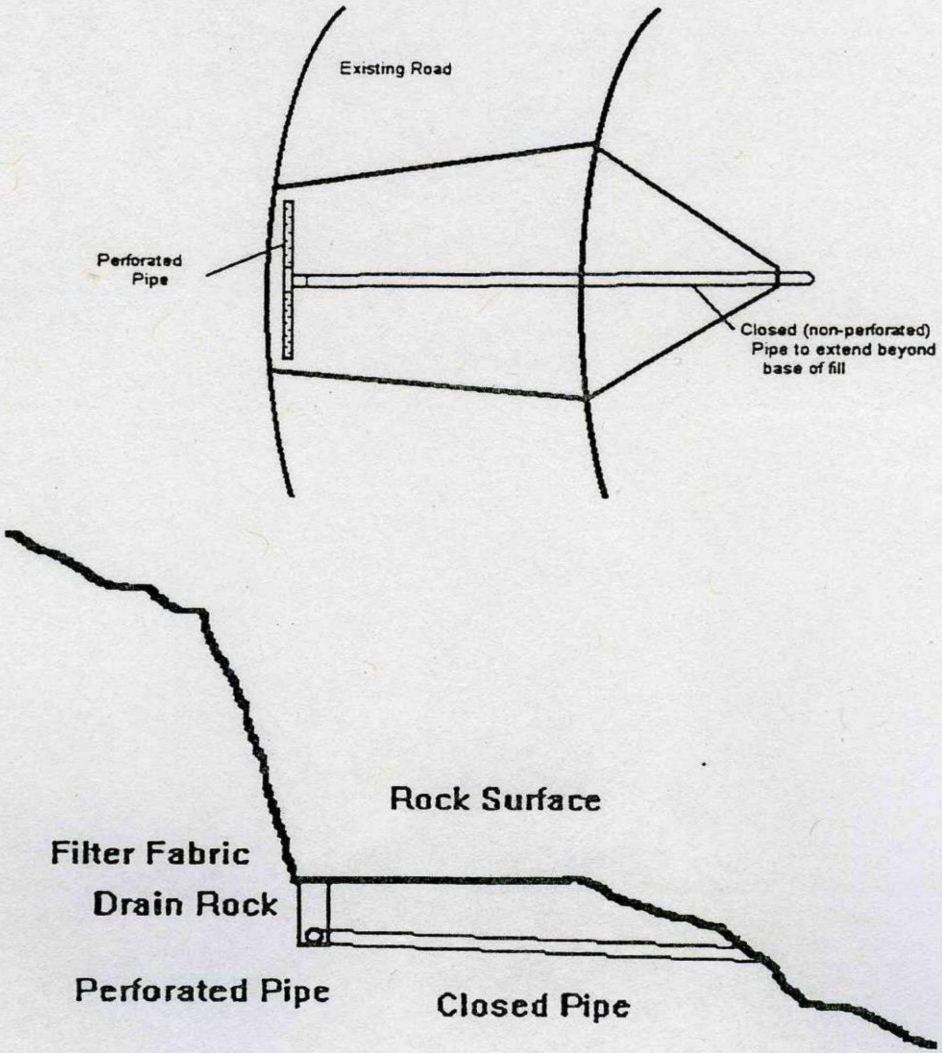
- Soft soils and road substrate
- Possible surface drainage across road and sediment to streams

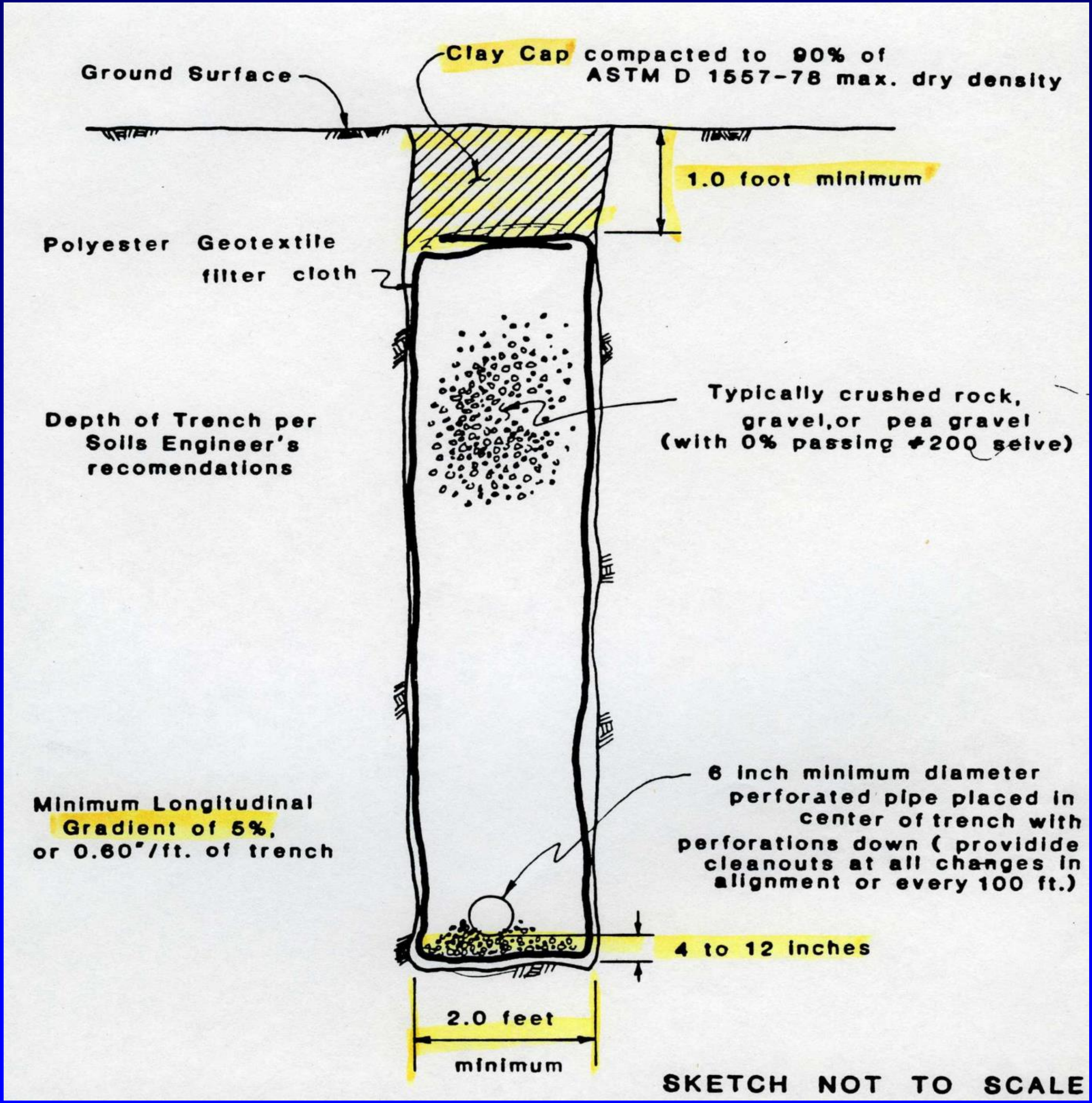
Wet Areas

Mitigations –

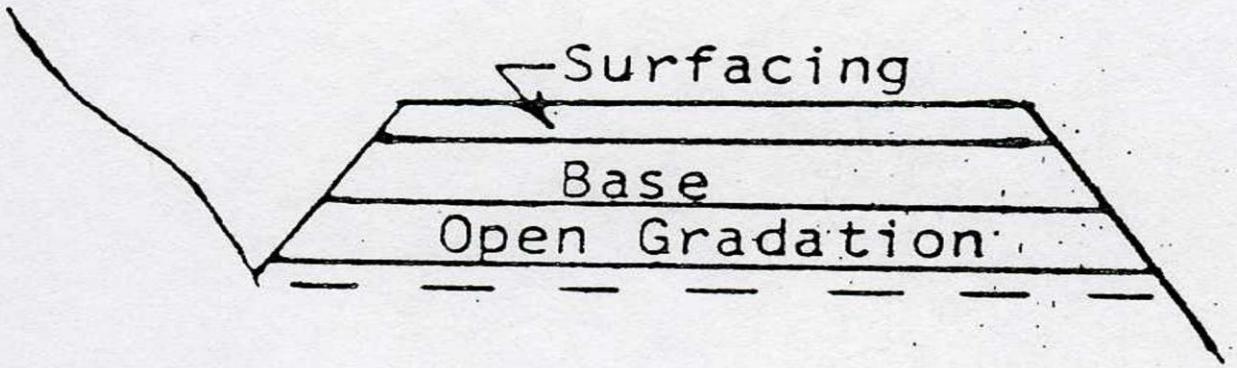
- Avoid wet areas if possible
- French drain
- Engineered road substrate, Geofabric

French Drain details




Clay Cap compacted to 90% of
ASTM D 1557-78 max. dry density
Ground Surface
1.0 foot minimum
Polyester Geotextile
filter cloth
Typically crushed rock,
gravel,or pea gravel
(with 0% passing #200 seive)
Depth of Trench per
Soils Engineer's
recomendations
6 inch minimum diameter
perforated pipe placed in
center of trench with
perforations down (providide
cleanouts at all changes in
alignment or every 100 ft.)
Minimum Longitudinal
Gradient of 5%,
or 0.60"/ft. of trench
4 to 12 inches
2.0 feet
minimum
SKETCH NOT TO SCALE

Fabric – drain rock – fabric sandwich with soil/rock road prism over it



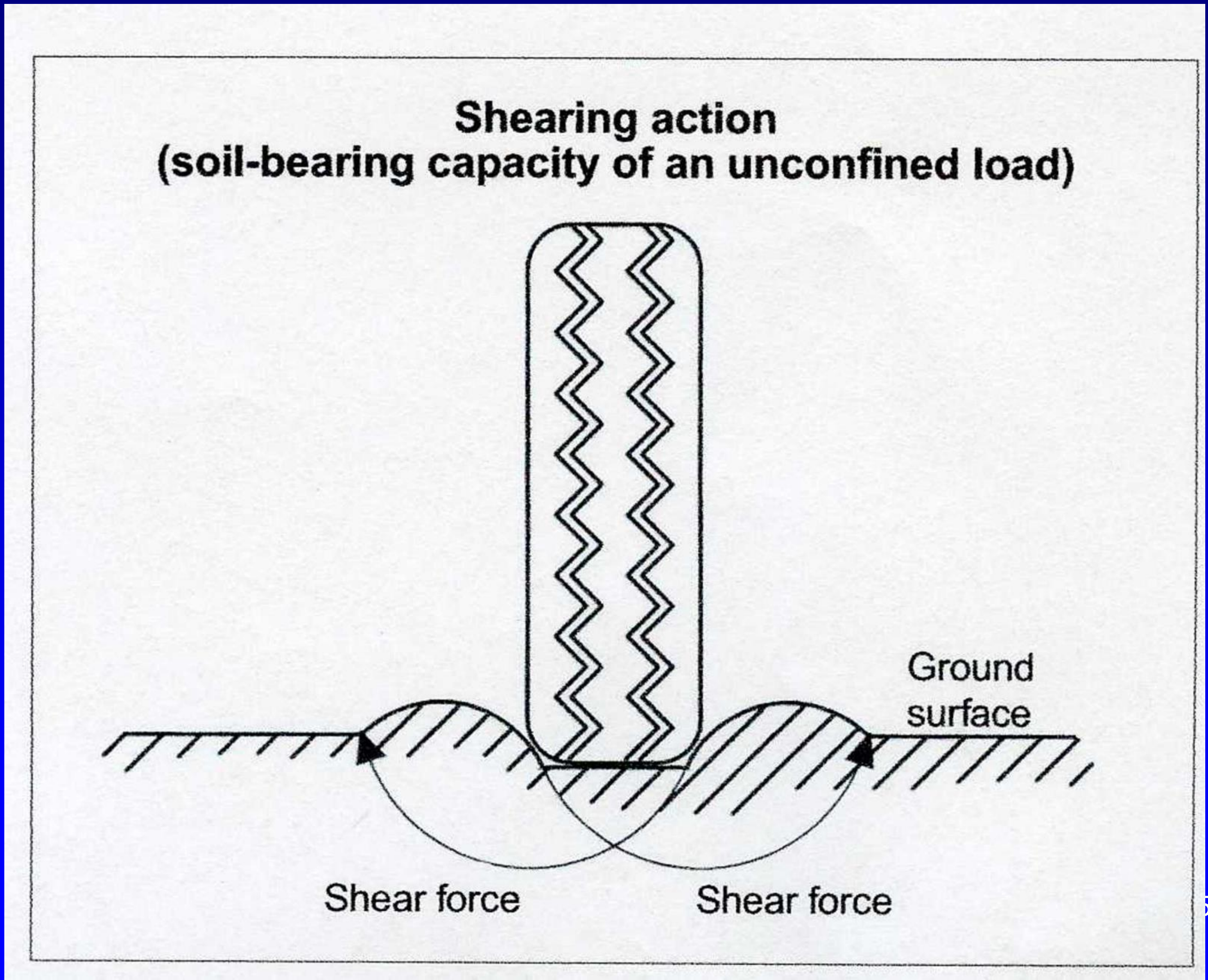
e. Subgrade Seepage

Wet Areas

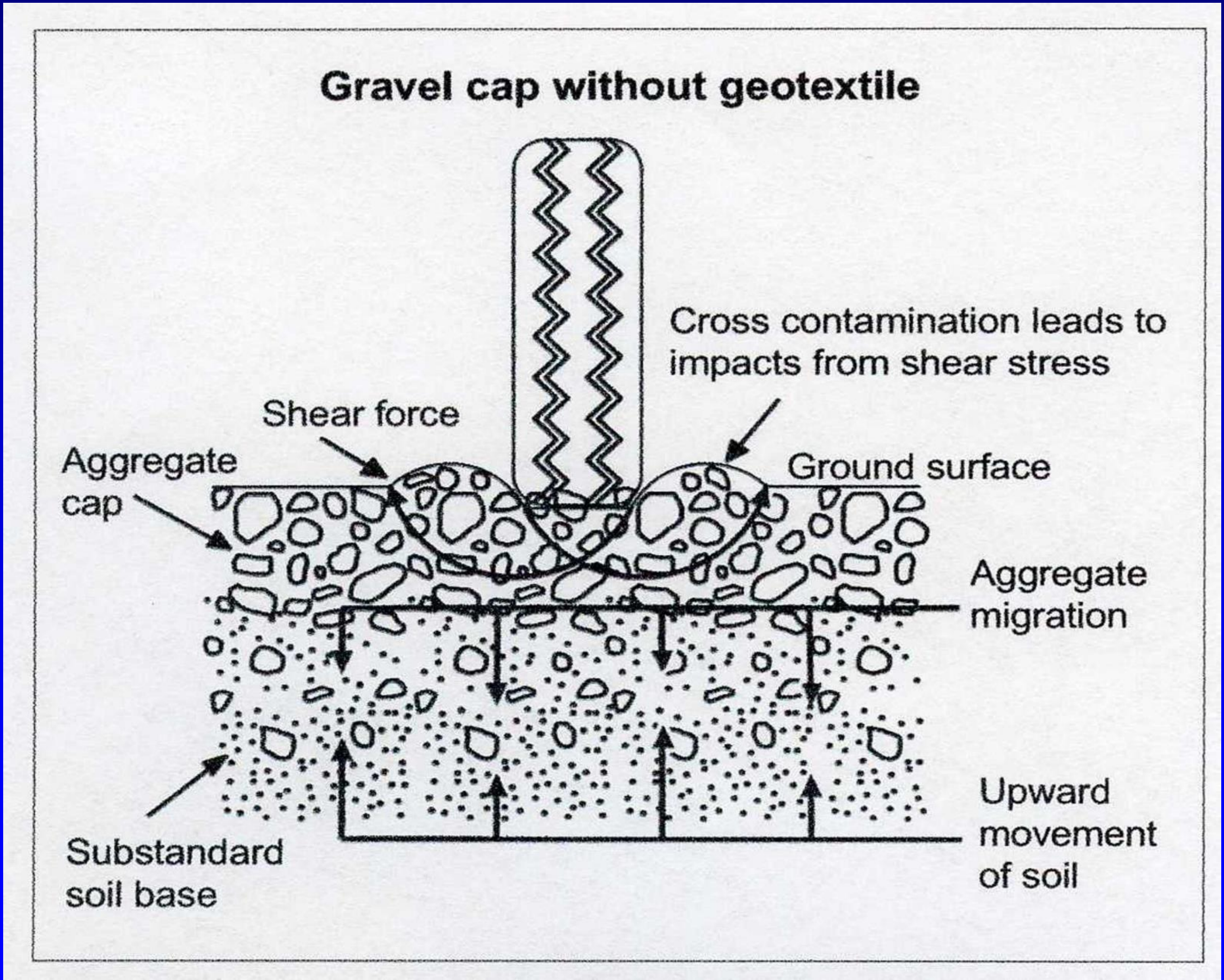
With saturated soft soils underlying the roadway –

can be fixed with geotextile and road rock

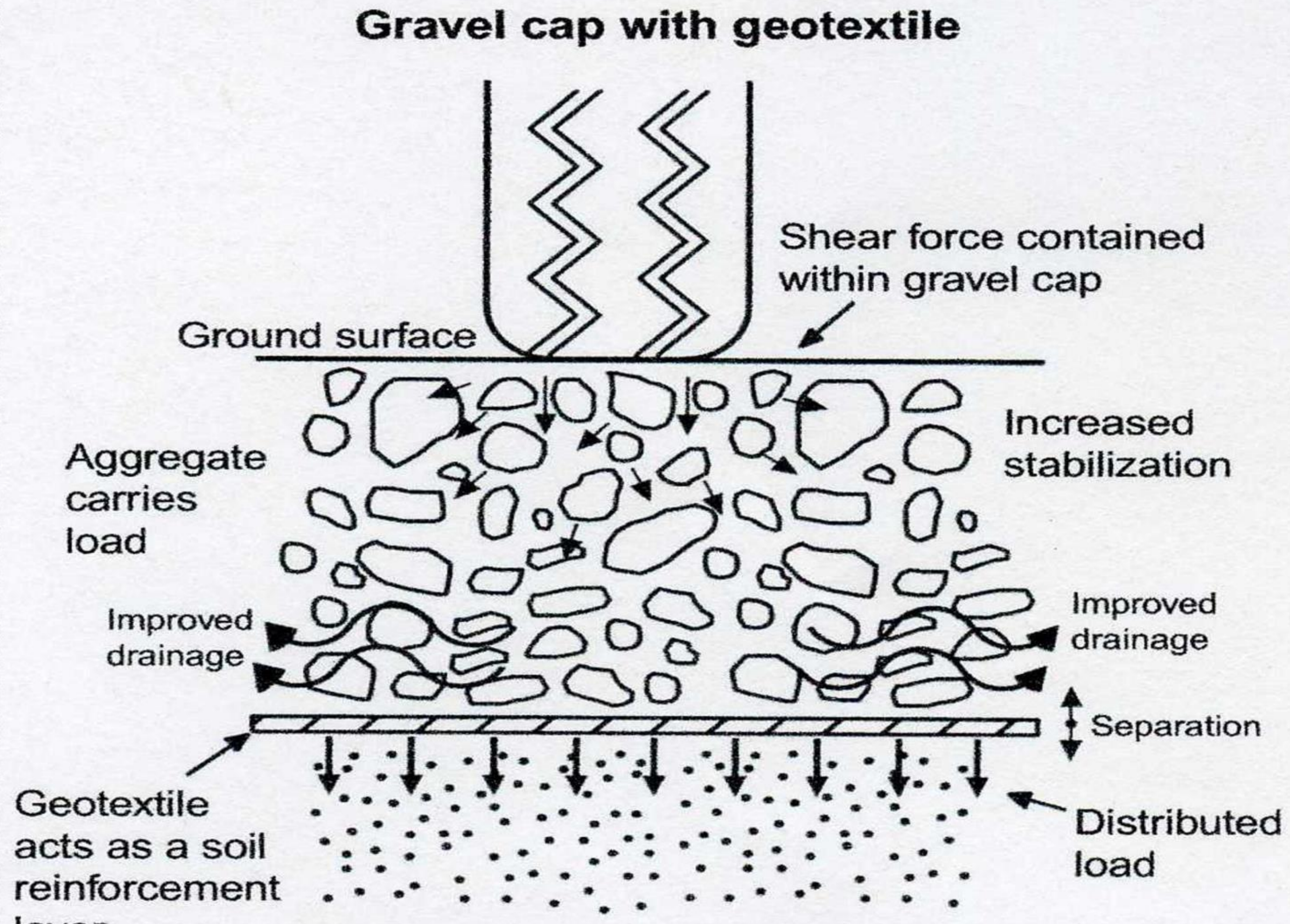
Soft Soil Road Surface



Soft Soil – Gravel Cap – No Geotextile



Gravel Cap with Geotextile

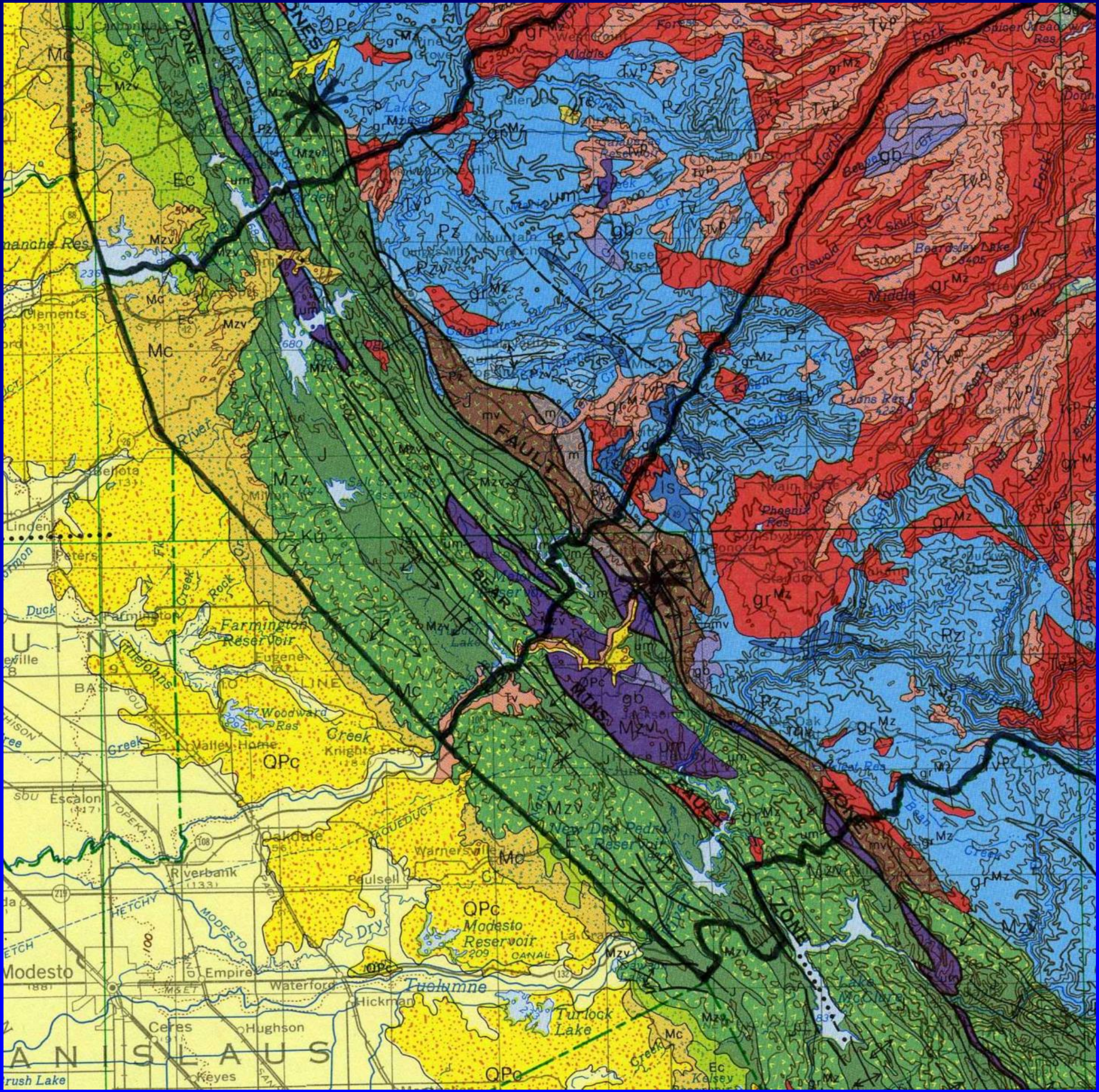


The addition of a geotextile creates a broad base that distributes the load, increasing bearing strength and reducing pumping action.

Geology

- The Geology of the Sierra Foothills in Tuolumne, Calaveras, and Mariposa Counties is typical of the Central Sierras.

- Consists of belts of volcanic and sedimentary rocks that have been metamorphosed to predominantly greenstone, slate, schist, and limestone.



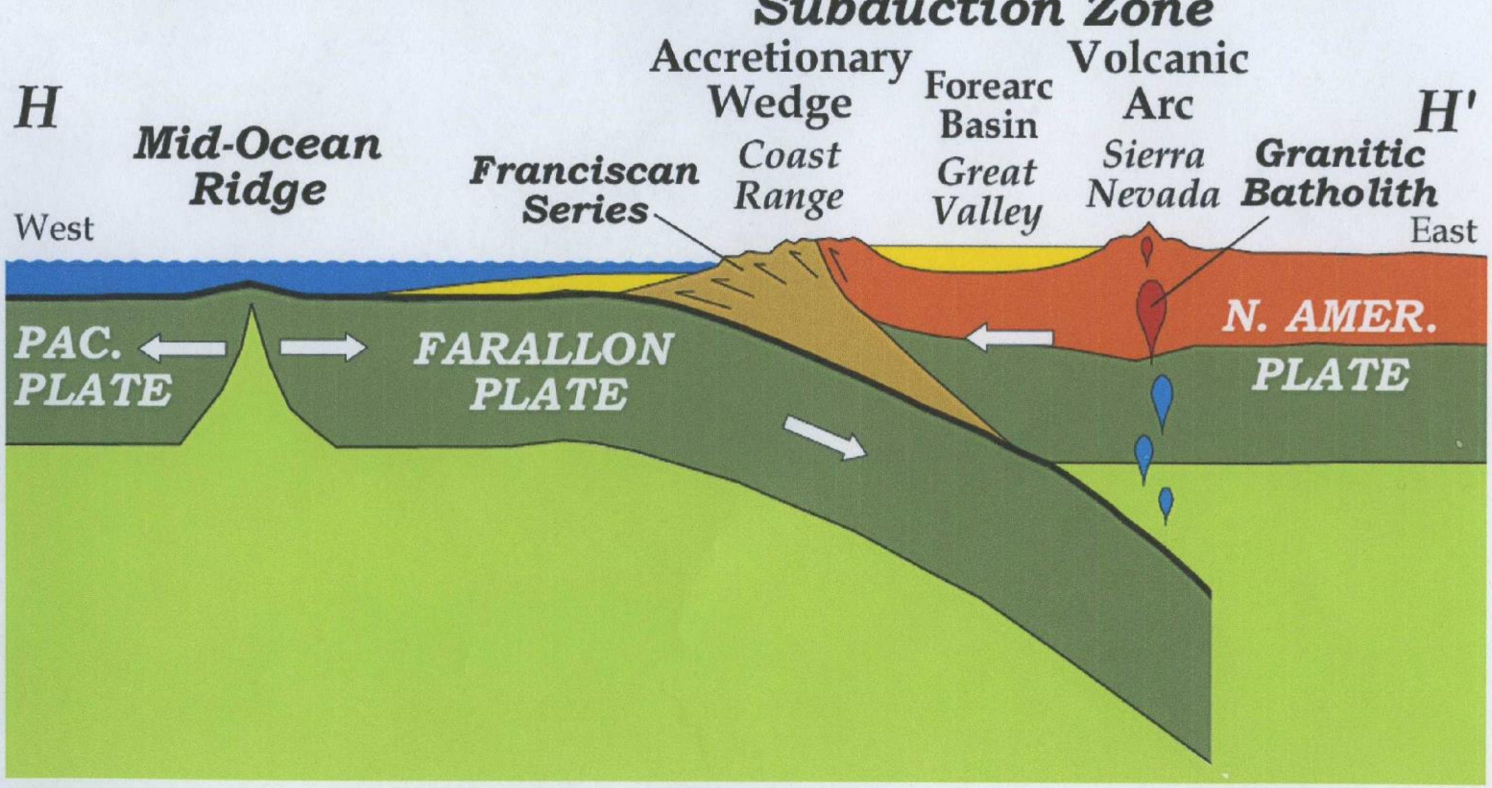
FAULT
BEAR
MTNS
ZONE
Farmington Reservoir
Woodward Res
Valley Home
Knights Ferry
Oakdale
Riverbank
Escalon
Modesto
Empire
Waterford
Hickman
Ceres
Hughson
Keyes
Turlock Lake
Tuolumne
Modesto Reservoir
New Don Pedro Reservoir
Lake McClure
Lyons Res
Phoenix Res
Linden
Peters
Bellota
Clements
Farmington
Eugene
Paulsell
Warnersville
Kelsey
STANISLAUS
QPc
Mzv
Mc
Ec
Pz
grMz
Tvp
gb
um
Ku
Tv

Geology

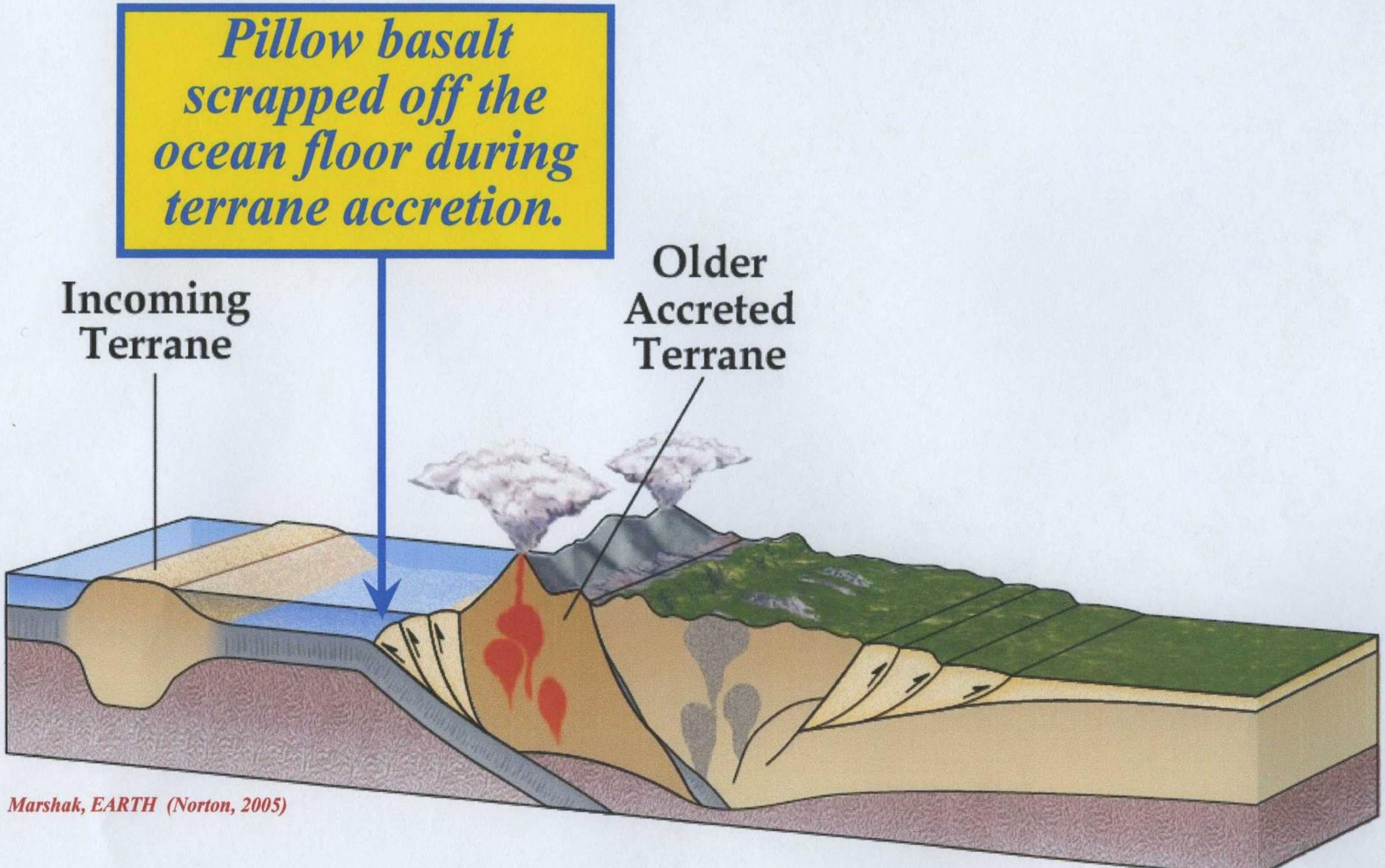
- For many millions of years the west coast of North America has been the site of subduction, where oceanic crust from the west has been thrust underneath the continental crust of North America.

ORIGIN OF ROCKS OF WESTERN CALIFORNIA

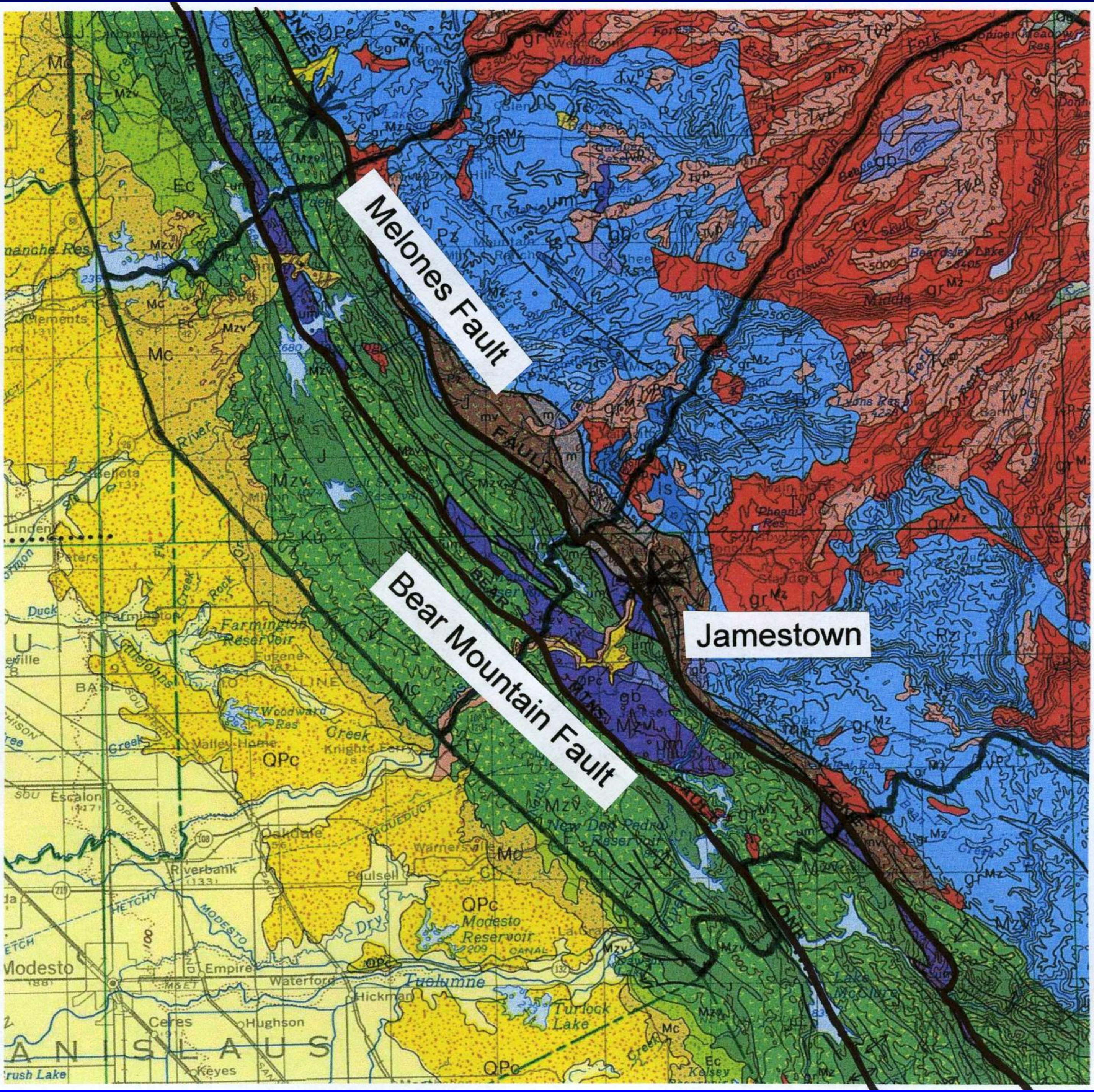
GRANITE BATHOLITHS ***are the remains of the magma chambers formed beneath the volcanoes.***



Terrane Accretion



Parks and Plates

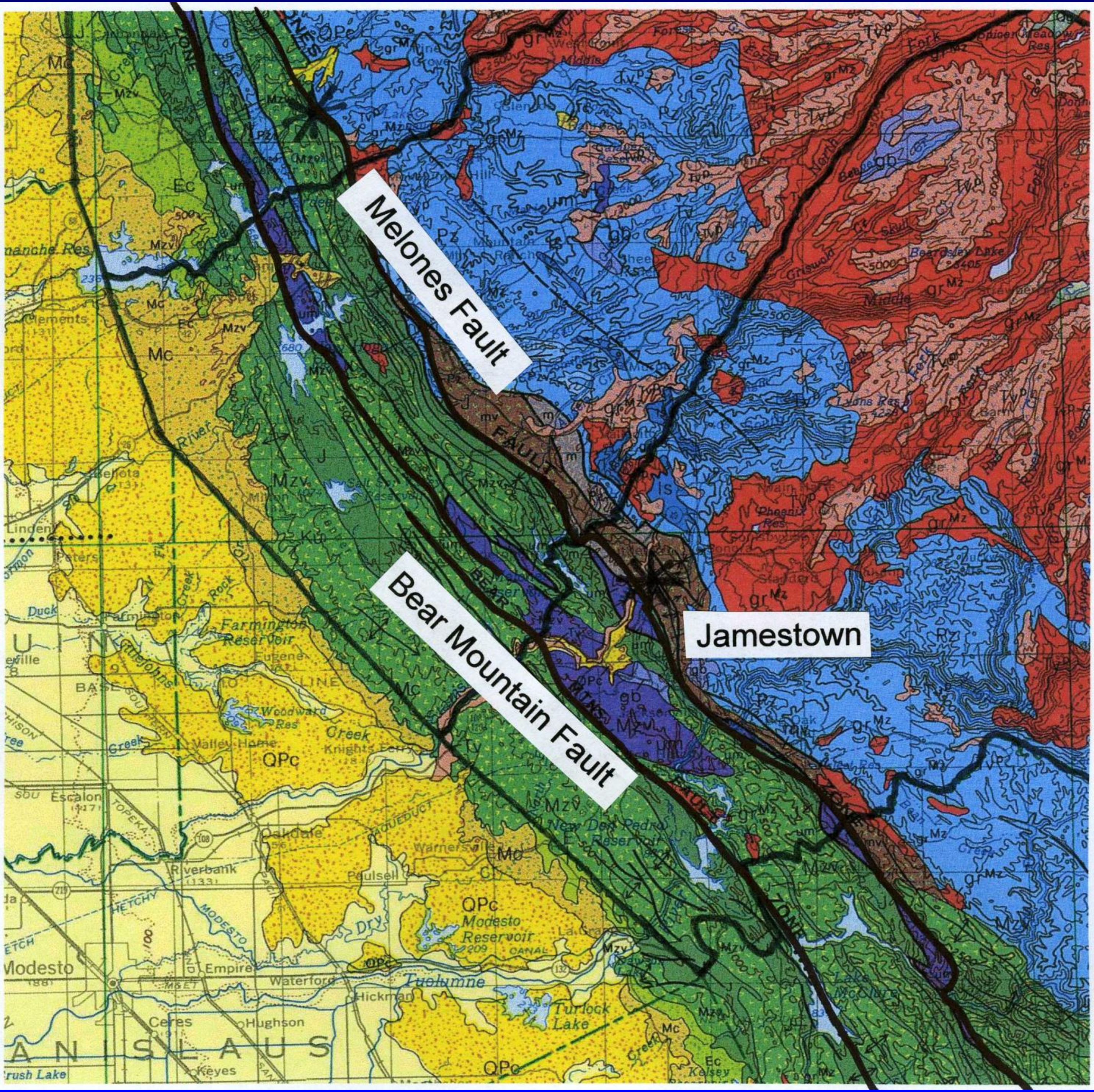

Melones Fault
Bear Mountain Fault
Jamestown

Geology map

- Yellow – younger sediments in the Central Valley and lower foothills
- Green and Brown – younger (Jurassic) metamorphic rocks
- Purple – serpentine (along fault zones)
- Blue – older (Paleozoic) metamorphic rocks
- Red – Granite
- Pink – cover of volcanic mudflow (Mehrten Formation)

Geology

– Metamorphic belts from west to east :
  - Western Jurassic Belt ,west of Bear Mountain Fault Zone
  - Central Jurassic Belt ,between Bear Mountain and Melones Fault Zones
  - Eastern Jurassic Belt, east of Melones Fault Zone
  - Paleozoic Belt, between Eastern Jurasic Belt and the granitic plutons


Melones Fault
Bear Mountain Fault
Jamestown

Landslides

- Generally the Foothills of the Sierras do not have a lot of landslides.
- You run across them occasionally so want to briefly review the types of landslides, and how to identify them.

Landslides

- Unstable area characteristics:
  - Hummocky topography
    - Rolling bumpy ground
    - Frequent topographic benches
    - Frequent closed depressions
  - Tension cracks and headwall scarps

Landslides

- Unstable area characteristics:
  - Evidence of impaired groundwater movement
    - Sag ponds, springs, patches of wet ground, hydrophytic vegetation
  - Short irregular surface drainages begin and end on the slope
  - Leaning, jackstrawed, or split trees are common
  - Trees with excessive sweep

Landslide evidence

- Leaning trees
- Scarps with freshly exposed dirt

Landslide evidence

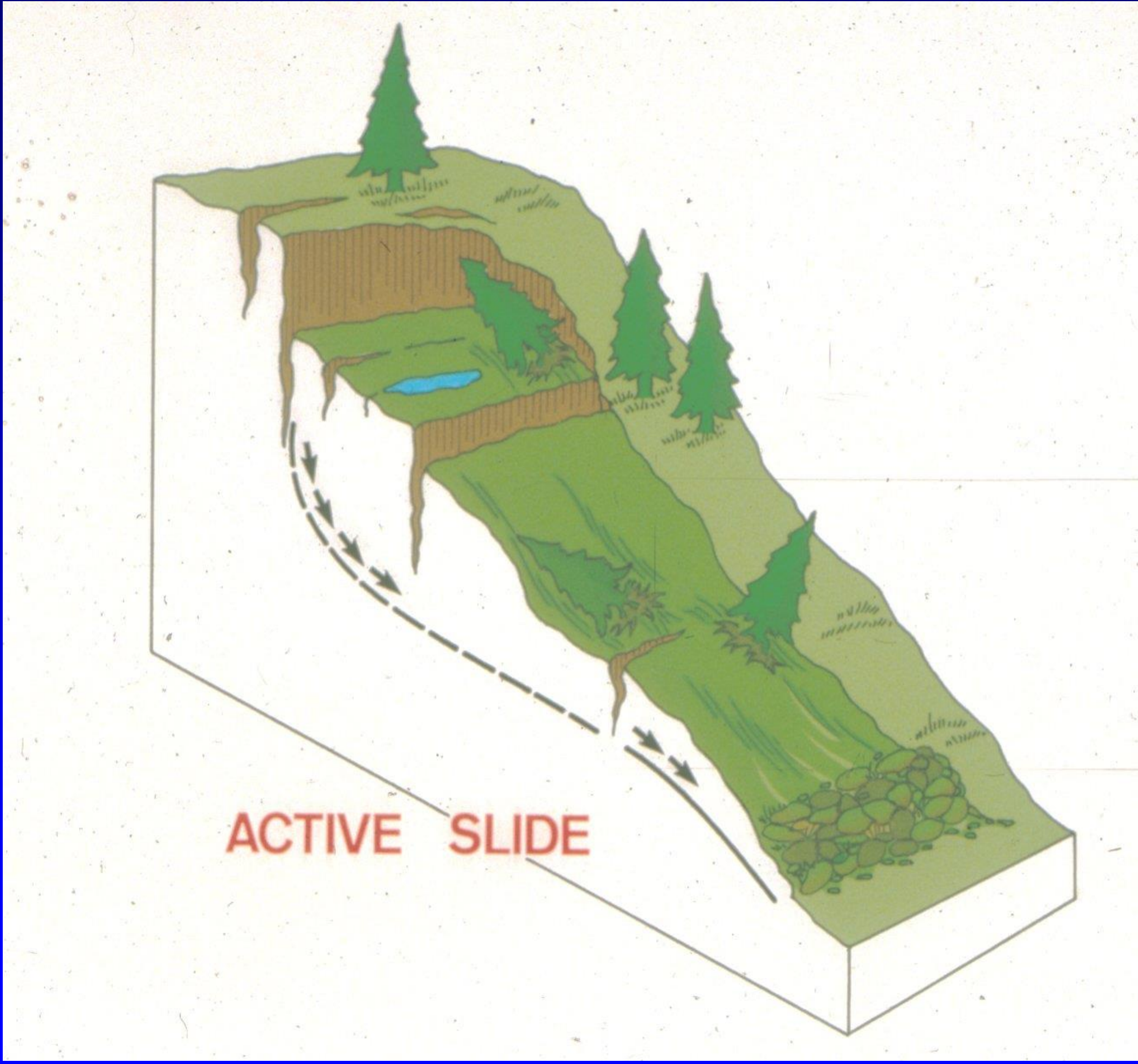
Scarps

Benches

Leaning Trees

Ponded Water

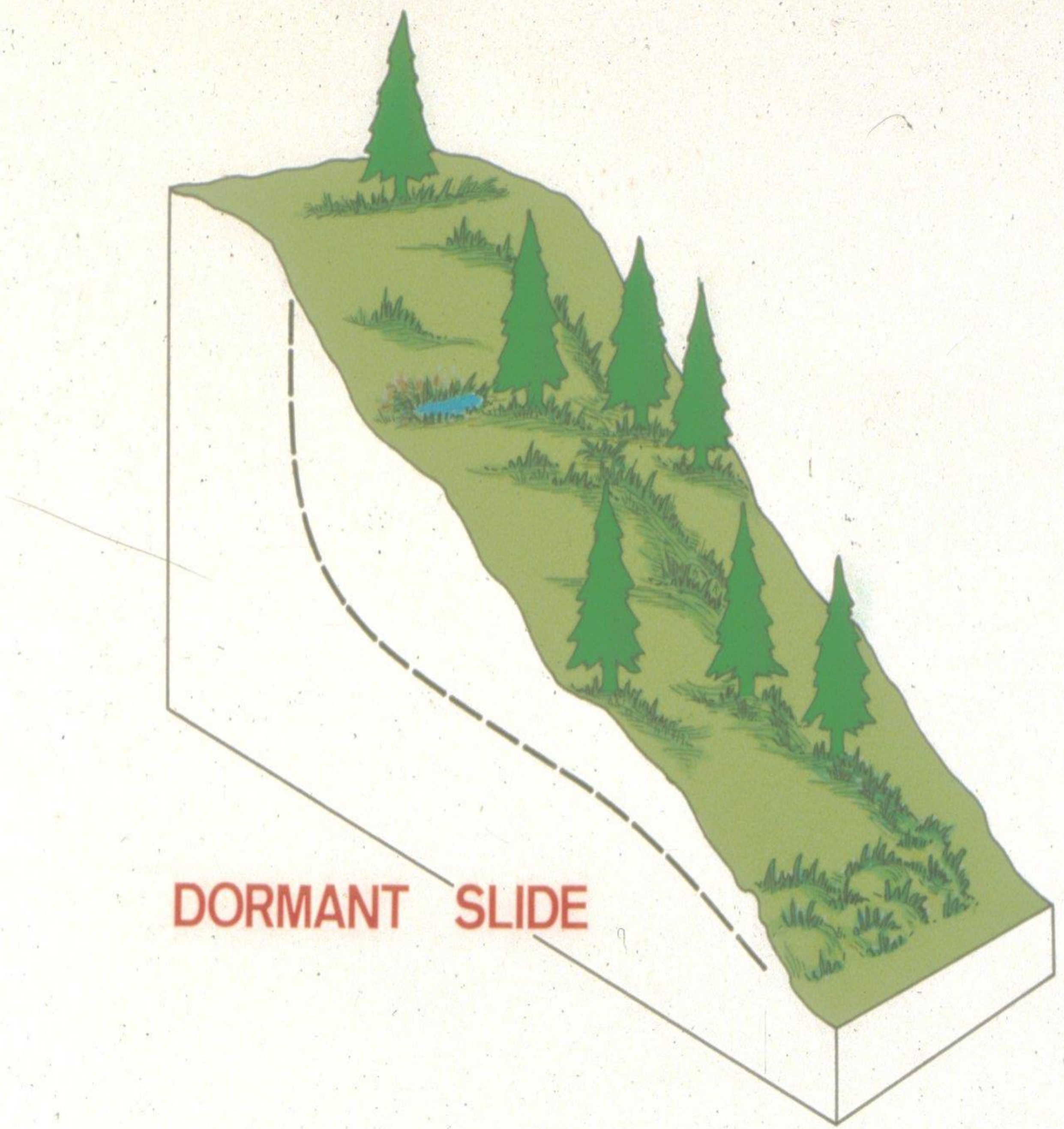
Hummocky Ground



Old Landslide evidence

Scarps and Benches are rounded and smoothed; revegetated.

Trees are straight

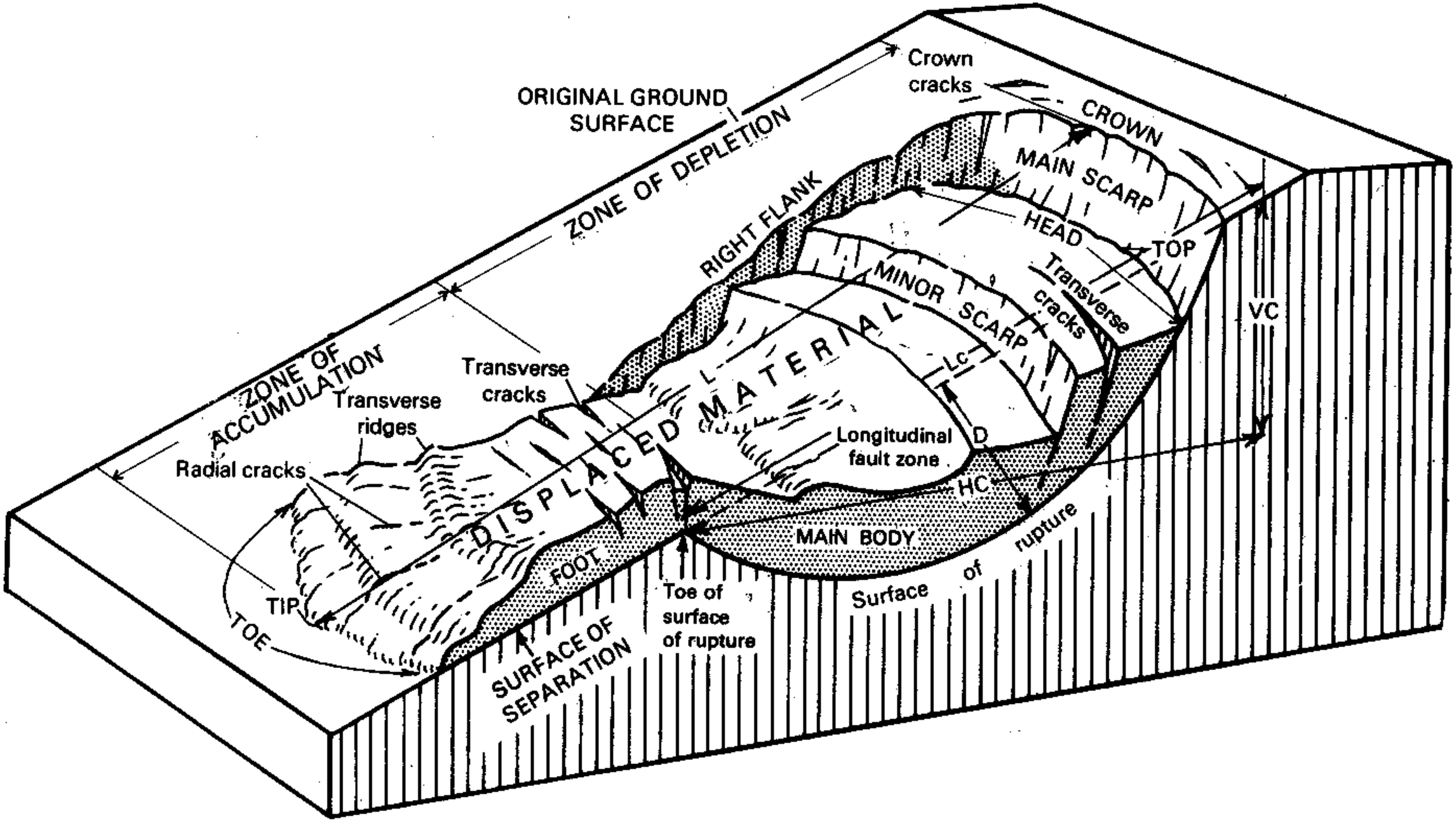


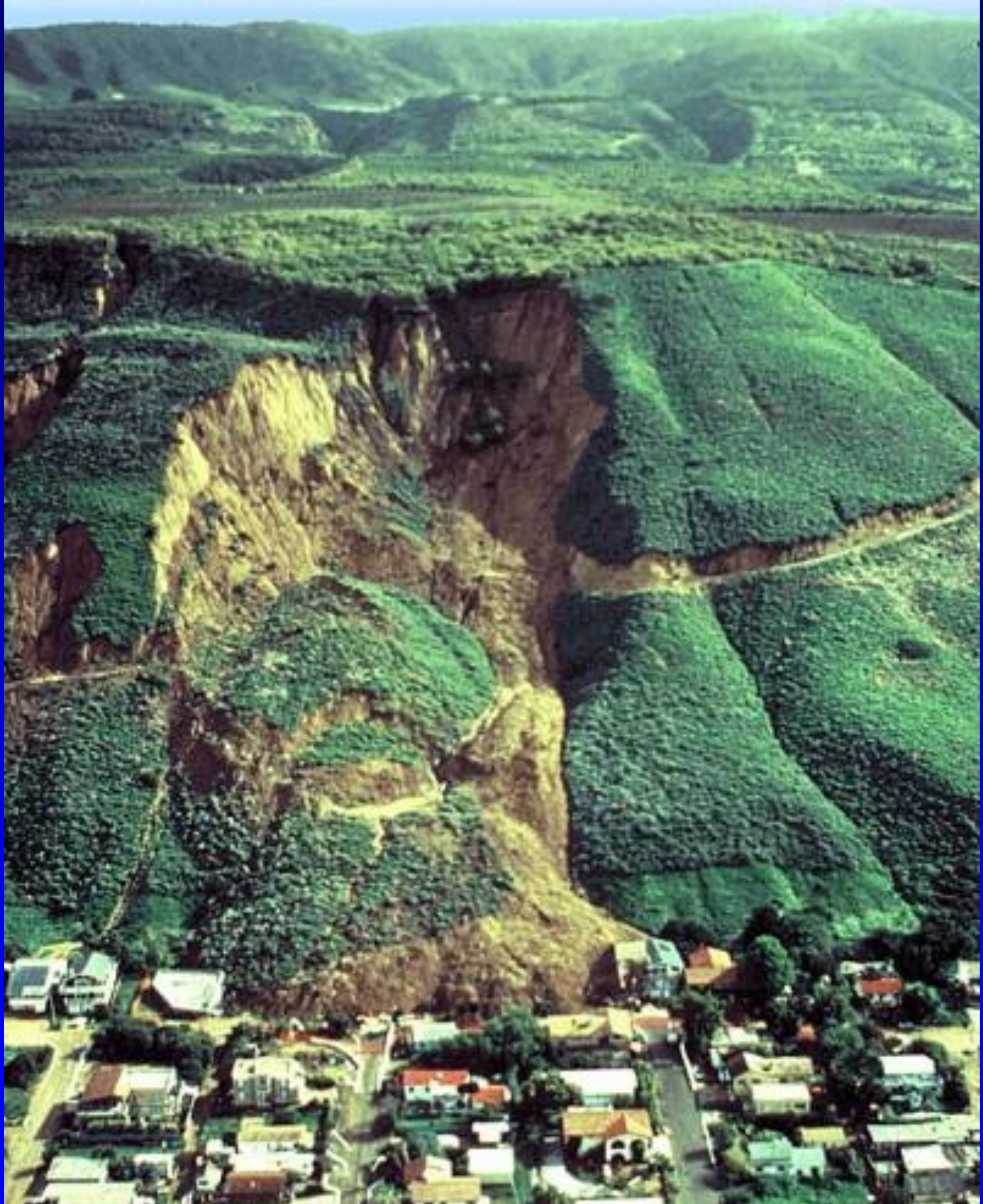
Arc-shaped cracks in sidecast fill are evidence of a landslide starting to move

Geology

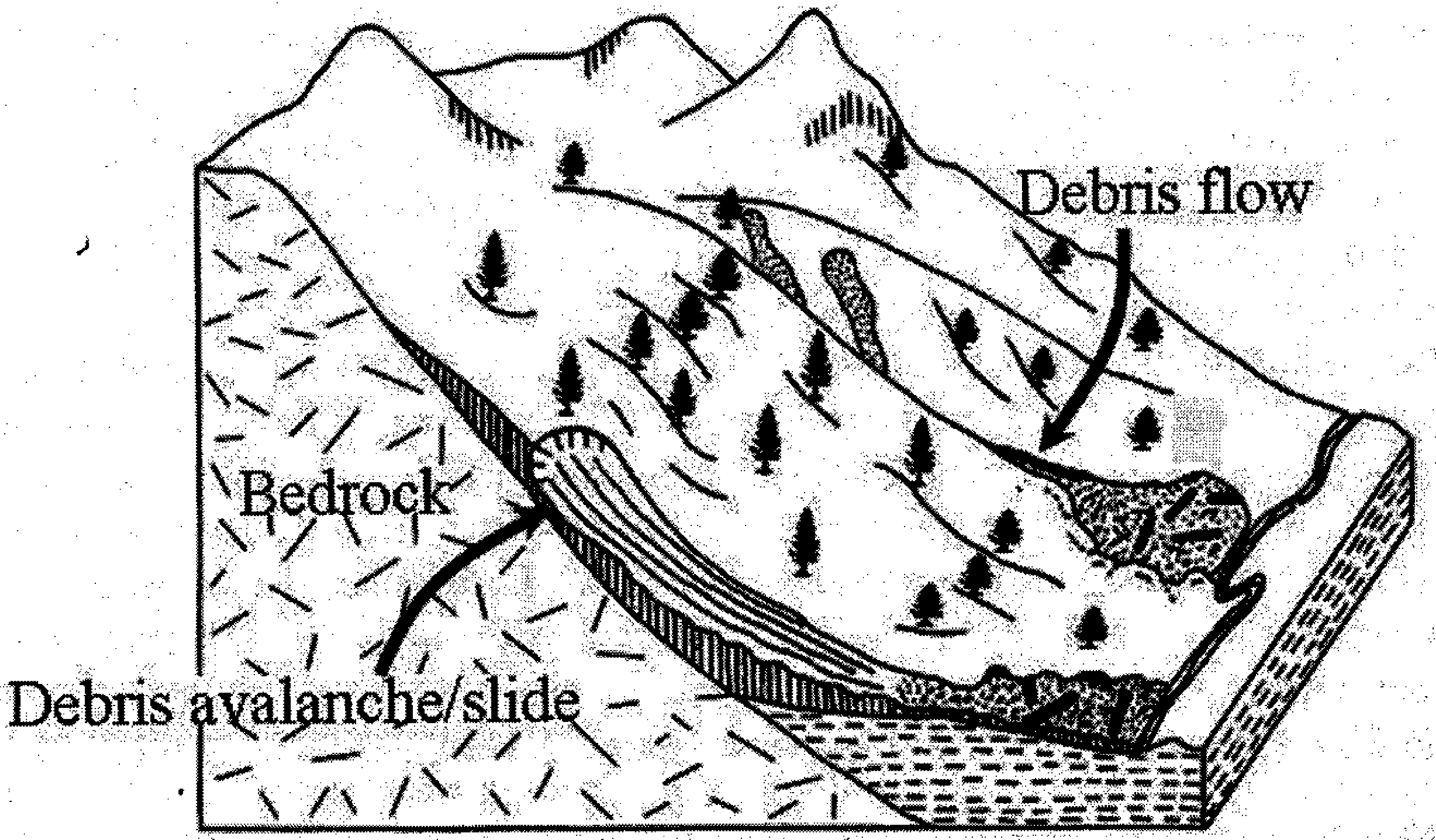
- Unstable areas
  - Types of slides
    - Deep-seated (rotational) *(cohesive, clay-rich soils)*
    - Shallow-seated (debris slides, flows, torrents) *(non-cohesive, clay-poor soils)*

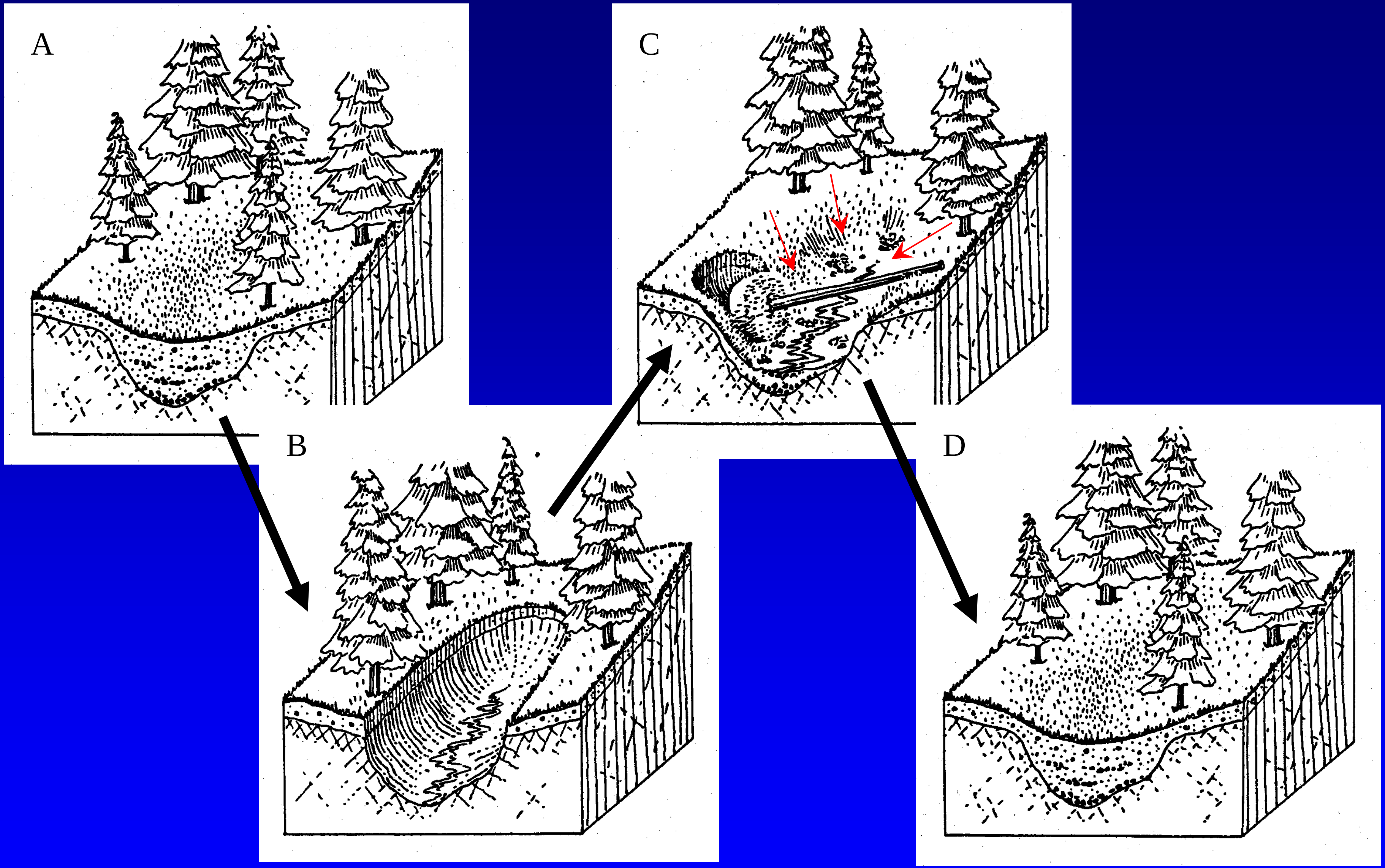
Deep-Seated landslide





Shallow-Seated landslides



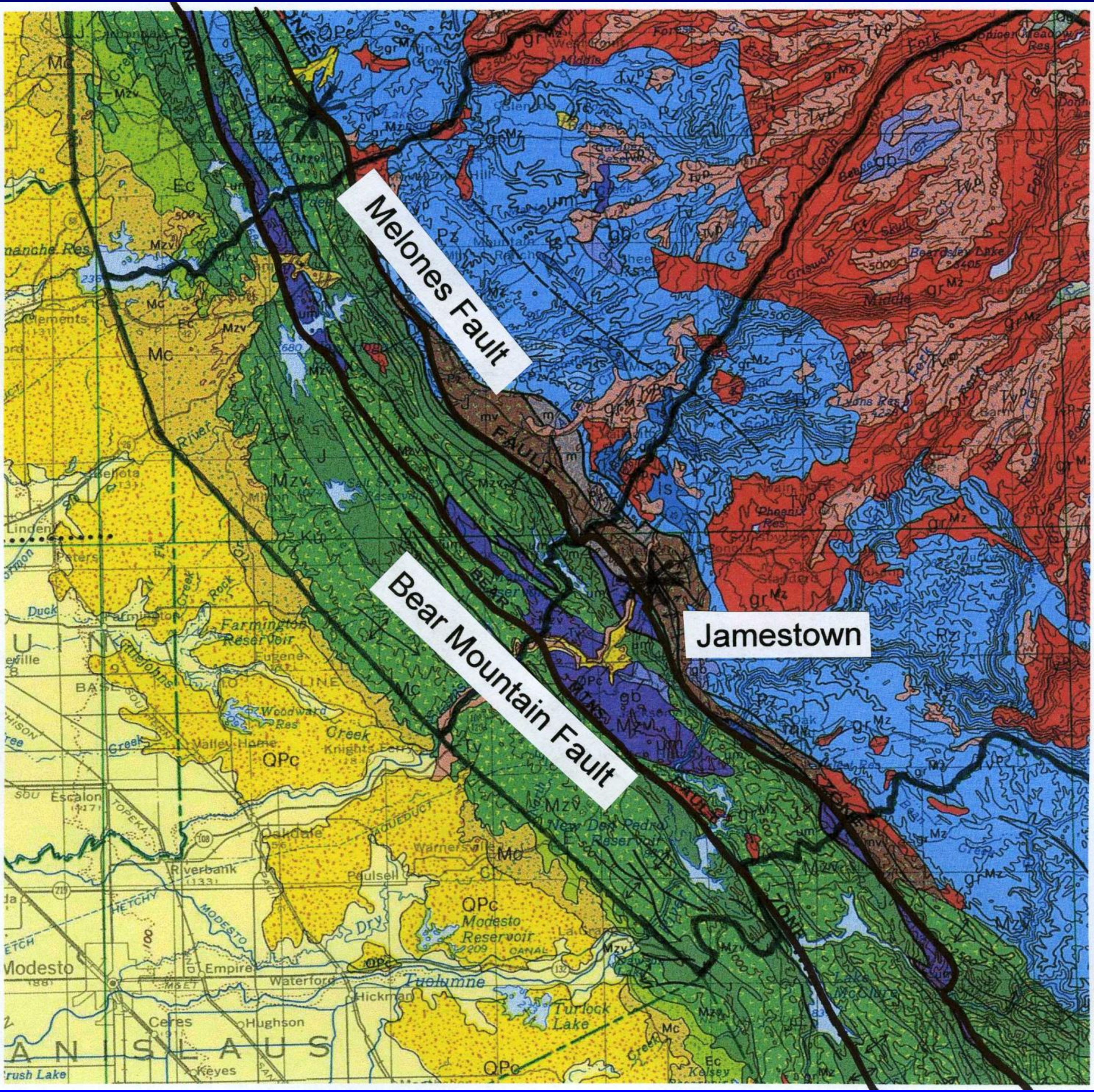

A
B
C
D

Roads and Landslides

- Unstable areas
  - **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

Geology

- Highly Erodible soils
  - Sandy soils with little or no cohesive binder
  - "Decomposed Granite" type of soil, found in some areas underlain by granite bedrock.
  - Not all granitic plutons weather to sandy cohesionless soil, some weather to a red sandy clay type of soil that is much less erodible.


Melones Fault
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Jamestown

Erodible Soils

- How to identify
  - ➢Field test
  - ➢Soil Survey – available from
    - – NRCS – soil surveys on the Internet at: (*http://websoilsurvey.nrcs.usda.gov/app/*)
    - – USFS Forest Service

Erodible Soils

– For DG (decomposed granite) 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

Fire Effects

- Loss of vegetation due to fire can result in temporary increases in both runoff and groundwater.

General Fire Effects

- Loss of vegetation due to fire can result in temporary increases in both runoff and groundwater.
- The above condition plus the loss of root support can result in increased occurrences of rock fall, ravel, rills, and perhaps gullies.

Predicted Rim Fire Effects

- Increased storm runoff erosion damage to roads;
  - while reduced control of storm water;
- Destabilized rock slopes, falling trees, etc.

» -Rim Fire Baer Engineer's Report

Predicted Rim Fire Effects

- 37% of area had moderate soil burn severity;
- 7% of area had high soil burn severity;
- 5-10X increase in sediment for a 2yr event
  - 15-40X for a 5yr event
  - 25-60X for a 10yr event

» -Rim Fire Baer Soils Specialist Report

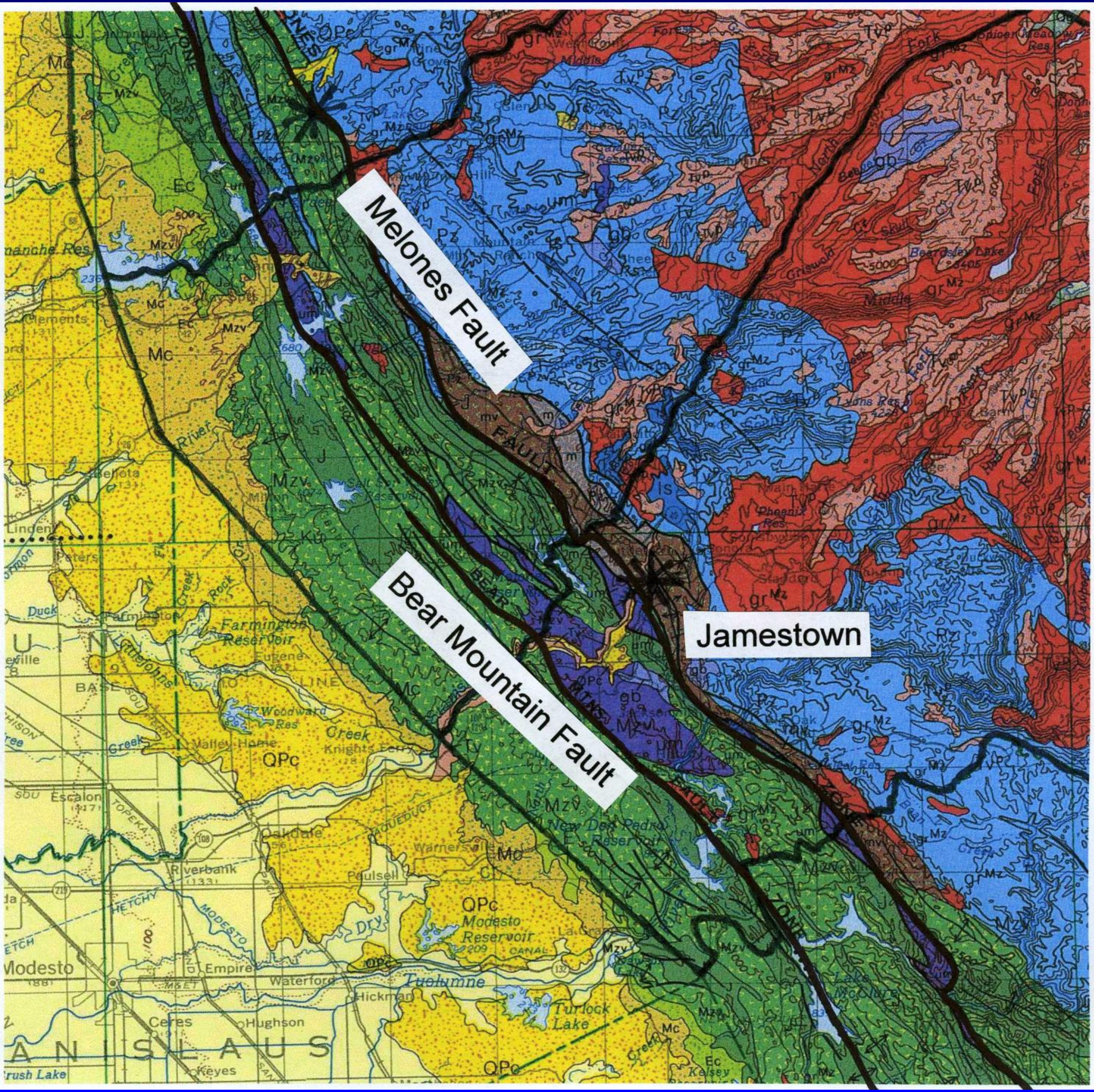
Predicted Rim Fire Effects

- Debris flows and rock falls are imminent.
- 40-60% chance of a debris flow within the Granite Creek watershed for a 10-yr event
  - Probability decreases to 16% after 3 years

» -Rim Fire Baer Geologist Report

Health Hazard Soils

- Asbestos-bearing rock units
  (Contain naturally occurring asbestos [NOA])
  - Occur in ultramafic rocks such as serpentine
  - Concerns and How to identify
    - See CGS site (*http://www.conservation.ca.gov/cgs/minerals/hazardous_minerals/asbestos/Pages/Index.aspx*)
  - Mitigations
    - Keep soil damp to avoid dust during construction
    - Cover serpentine soils with non-asbestos bearing soils (import soil)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The End

Questions??